

Appendix A
FLIGHT REFUELLING

APPENDIX A

Flight Refuelling

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APPENDIX A

Flight Refuelling

1 Introduction

(a) Either B(K)1 or BK(PR)1 aircraft may be equipped for refuelling in flight. The aircraft are of two types referred to in these Notes as Tanker or Receiver aircraft. Tanker aircraft are equipped for transferring fuel and also for receiving fuel, but Receiver aircraft are equipped only for receiving fuel.

(b) It is recommended that pilots and operators of either Tanker or Receiver aircraft should be familiar with the handling of, and operation of equipment in, the other aircraft.

2 General

(a) The probe and drogue system of flight refuelling is used, fuel being transferred from the Tanker to the Receiver through a flexible hose trailing from the bomb bay of the Tanker, and a probe in the nose of the Receiver. A full load of fuel can be transferred in about 15 minutes; if the main pump in the Tanker fails, successful transfer is still possible, but will take about twice as long. Radio silence can be maintained throughout the operation if desired, as all necessary signals to the Receiver are given by duplicated coloured lights.

(b) The tanks used for transferable fuel have a total capacity of 46,248 lb, but 1,160 lb of this is not transferable (see para. 15(c)). This gives a total of 45,088 lb of fuel which can be transferred from the Tanker to the Receiver.

3 Limitations

(a) The Tanker and Receiver aircraft are subject to the normal aircraft limitations (see Part II) except, for the Tanker aircraft, when streaming the hose.

(b) The following limitations apply specifically to the operation of refuelling in flight:

Maximum speed for streaming the hose and flying with it streamed. Gentle manoeuvres only;	300 knots or 0·8 M
Maximum indicated G	1·5
Maximum speed for making contact	250 knots or 0·76 M
Maximum altitude	No limit

(c) *Duration of trail.* The maximum period during which the hose may be trailed without fuel flow depends on the ambient air temperature. The limitations are shown in Fig. 1.

(d) *Auto-pilot and auto-stabiliser.* During the whole of a flight refuelling operation, both for Tanker and Receiver, the auto-pilot must be off. The auto-stabiliser (if fitted), however, will be a help to steady flying, and it is recommended that it should be in use.

(e) *Hose jettison.* The hose can be jettisoned at any speed, but it is recommended that where possible the speed should be 180 knots with 20° of flap selected.

4 Receiver equipment description

(a) The receiver aircraft is fitted with a refuelling probe in the nose which feeds into a "ring main" fuel system serving all fuel tanks. The probe incorporates a shut-off valve which is automatically opened when contact is established with the Tanker hose coupling, a vent valve, and a de-icing valve. All tanks can be filled in the air simultaneously.

(b) All controls for air-to-air fuel reception are on the starboard coaming panel. They consist of a refuelling valve selector switch (G11 to 21) for each tank or cell, a probe de-icing switch (G22), and a tank indicator below the rear of the panel. A fuel gallery pressure gauge is on the starboard quarter panel.

NOTE: BOMB BAY TEMPERATURE BEFORE HOSE TRAIL
MUST BE ABOVE $+10^{\circ}\text{C}$

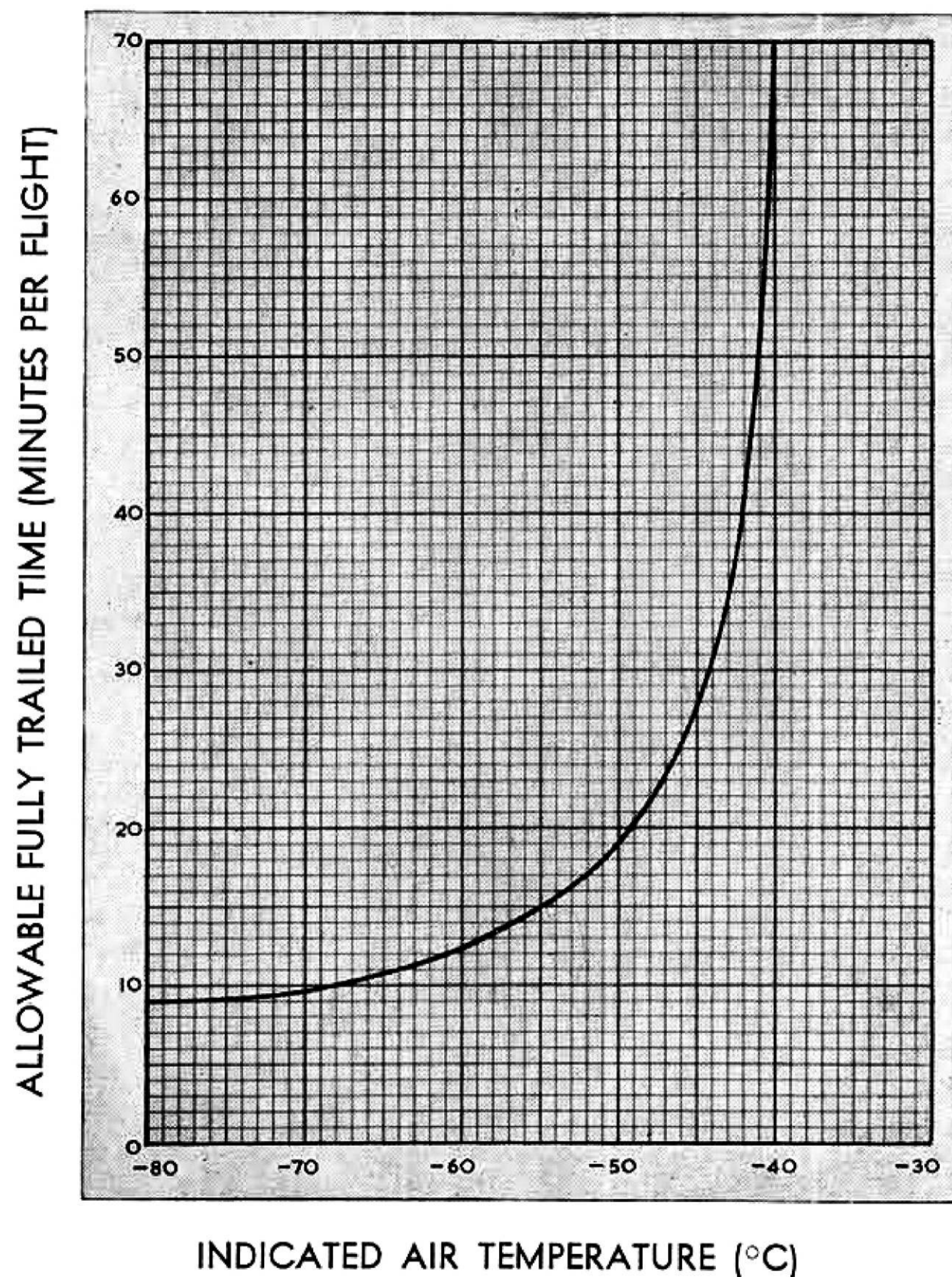


Fig. 1 Maximum hose trail time

(i) *Tank indicator.* The tank indicator comprises a circular dial on which is inscribed an outline of the aircraft. The approximate position of each tank is shown by a number and by a light, with the exception of the bomb bay and fuselage transfer tanks which have one common light. A visor is provided to shield the indicator from glare, and a ring round the indicator enables the brightness of the lights to be adjusted for day or night operation.

(ii) *Refuelling valve selector switches.* Each tank or cell contains a refuelling valve which is controlled by its relevant selector switch and also by a float switch in the tank or cell. When any refuelling valve selector switch is set ON, the refuelling valve in the selected tank is opened and the relevant light on the tank indicator comes on. When the tank is full, the float switch closes the refuelling valve and the light on the tank indicator will go out. When a tank is full, the selector switch will not open the refuelling valve, nor will the light come on. The refuelling valve can be shut at any time by setting the selector switch to OFF, when the lights will go out.

NOTE 1: The reserve and/or No. 1 fuselage cell lights will come on when the bomb bay and transfer tanks are selected at any time. The wing tank lights will come on when the underwing tanks are selected.

NOTE 2: The selector switches are only used for flight refuelling; it is essential that they are all OFF for ground refuelling.

(iii) *Fuel gallery pressure gauge.* The fuel gallery pressure gauge indicates the pressure of fuel delivery from the Tanker, and together with the fuel gauges, provides the only indication that fuel is being transferred. The pressures indicated on this gauge are:

Full flow rate, all tanks receiving—approx. 21 PSI.

Emergency transfer, all tanks receiving—approx. 10 PSI.

NOTE: As individual tanks reach their maximum capacity, the pressure may rise to a maximum of 60 PSI.

(iv) *Probe de-icing switch.* The PROBE DE-ICING switch, when set to ON, closes the vent valve and feeds fluid to de-ice the probe. The system is not yet operative, and must not be used.

(c) *Probe lighting.* The tip of the probe is illuminated by two lamps in the nose of the aircraft. The lamps have independent supplies, each being controlled by one of two dimmer switches (G9 and 10) at the rear of

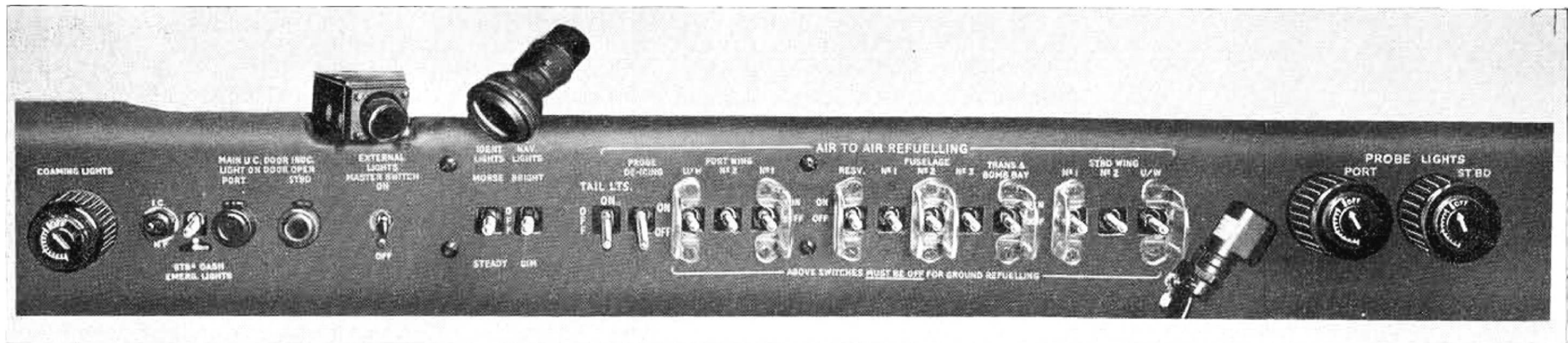


FIG. 2—Starboard coaming panel

the starboard coaming panel. The lamps may be used singly or together, according to the intensity of light required.

5. Signalling system

In order that radio silence may be maintained if necessary, all signals are made by the Tanker with coloured lights. Above the hose drum unit in the Tanker's bomb bay is a row of six coloured lights; two red, two amber and two green. The duplication is simply a safeguard against failure; a single signal light has exactly the same meaning as a pair. The lights have the following meanings:

- (i) *Red lights.* Do not attempt contact *or* Break contact immediately.
- (ii) *Amber lights.* Contact may be made, or if in contact, Tanker main fuel valve closed.
- (iii) *Green lights.* Tanker main fuel valve open.

Refuelling in Flight—Receiver

6. Checks before making contact

Prior to making contact, make the following checks:

Auto-pilot OFF.

Auto-stabiliser ON (if fitted).

Probe lighting as required.

Refuelling valve selector switches, of tanks to be refuelled, ON.

Tank indicator lights, of tanks selected, ON.

NOTE: 1. If a tank light does not come on, the reason may be that the tank is full, the refuelling valve has failed, or the light has failed. In any event the tank should remain selected ON.

NOTE: 2. The above drill applies even if only dry contacts for practice purposes are made. For dry contacts at least one refuelling valve *must* be selected ON.

7. Initial approach

WARNING. If red or green lights are showing, or if no lights are showing, on the hose drum unit in the Tanker bomb bay, a contact *must not* be attempted. If, when in contact, a red light comes on or all signal lights go out, contact must be broken off *immediately*.

A contact may only be attempted when only amber lights are showing.

During the initial approach to the Tanker, the Receiver captain should check that the signal lights are amber before closing for

contact. The recommended Tanker speed for refuelling is 230 knots. An initial closing speed of not more than 5 knots T.A.S. relative to the Tanker speed should be established, approaching from dead astern, keeping the signal lights visible at all times.

8. Final approach to establish contact

(a) The last thirty to forty feet prior to contact must be made with the Receiver flying level, dead behind the drogue, when buffet will be felt, accompanied by a marked noise. From this point, accurate and steady flying is required. The ideal to be aimed at is a steady approach, keeping the probe in line with the centre of the drogue at a closing speed of not more than 5 knots T.A.S. When absolutely certain that a clean contact can be made with the centre of the drogue it will be necessary to apply power to counteract drag from the drogue and maintain the correct closing speed. Immediately a successful contact has been made, and the probe is observed to be positively coupled to the drogue, a definite reduction in closing speed should be made by slightly closing the throttles before moving up to the refuelling position.

(b) The Receiver pilot's attention should then be transferred to the signal lights and the hose markings. When the aircraft is steady, a small amount of power should be applied and the aircraft flown gradually up the line of the hose, keeping the signal lights just in view below the Tanker's bomb bay deflector, until the refuelling position is reached. This is indicated when the 10-foot long yellow band on the hose (30 to 40 feet from Tanker end of the hose) is just visible out of the hose drum unit. In addition to this yellow band there is a white band on the hose at 10 foot intervals. The first five feet are marked with red and white stripes. Seven feet of hose will have to be wound in before the fuel valve can be opened. The Tanker panel operator will open the fuel valve when approximately 25 feet of hose has been wound in. This is indicated by the lights changing from amber to green. The fuel gallery pressure gauge will then indicate the pressure of the fuel transfer (see Para. 4 (b) (iii)).

9. In contact

(a) Once in contact small control and throttle movements should be made to hold station; any tendency to over-correct must be guarded against. When fuel is being transferred at high altitudes (above 34,000 feet) and at high aircraft weights, it is important to anticipate as early as possible the changes of power necessary to hold station. Small movements of the Receiver relative to the Tanker can be detected by careful observation of the hose. It is essential for the Receiver to avoid flying too low relative to the Tanker. The ideal refuelling position is with the distinctive yellow mark on the hose just half way into the H.D.U., and with the signal lights just in view below the Tanker's bomb bay deflector.

(b) When fuel is flowing, cross reference should be made to the fuel contents gauges to ensure that the tanks are filling. If a tank is not filling, the C.G. may rapidly move outside the limits, and action must be taken quickly to counteract this condition (see para. 21). As tanks become full, the float switches will close the refuelling valves, and the relevant tank indicator lights will go out; as this happens the refuelling valve selector switch for the appropriate tanks should be put OFF. When all the fuel that is required has been transferred, the Tanker operator will close the fuel valve. This will be indicated by the lights changing from GREEN to AMBER. If it is only required partially to fill a tank, the appropriate selector switch should be put OFF when the fuel contents gauge shows the required level. All refuelling valves should be closed before contact is broken.

10. Breaking contact

(a) *Normal procedure.* To break contact, the throttles should be closed slightly and the Receiver allowed to fall back gently. The rate at which the hose is unwinding off the drum should be controlled by the throttles to keep it to a gradual movement. When the last 7 feet of hose is coming off the drum, the lights will change to amber, if the fuel valve in the Tanker has not already been closed. The aim should be to allow the drogue to part gently from the probe at its natural trailing position, when it will draw away in line with the

probe where it can be watched all the time. If contact is broken higher or lower than the natural trailing position of the drogue, it will move rapidly to that position and will oscillate widely about it.

(b) *Emergency procedure.* If a red signal light comes on, or if all signal lights go out, or if due to any other emergency it is necessary to break contact as quickly as possible, the throttles should be closed fully. The Receiver will then decelerate rapidly, and when the hose reaches a speed of 5 ft./sec. the brake will be applied automatically and contact will be broken immediately. Such rapid disconnections should only be made in emergency conditions. The air brakes should never be used to make an emergency disconnect.

(c) *Clearing away.* When contact is broken, some fuel splash will occur. This splash, which is normally small, will be greater following an emergency disconnect. After breaking contact, the Receiver should clear downwards and to starboard, so that the Tanker can be held in view all the time.

11. Checks after breaking contact

The following checks should be made after breaking contact:

- Refuelling valve switches all OFF.
- Tank indicator lights all out.
- Probe lighting off.

12. Flying techniques

It is important that the procedures detailed in para. 6 to 11 are adhered to in order to complete successful air-to-air refuelling. To achieve maximum success, the following common faults should be fully understood and avoided.

(a) Contacts in excess of a closing speed of 5 knots T.A.S. must be avoided, as the hose drum unit is only capable of taking up a closing speed of 7 knots before hose whip occurs. In this event it is unlikely that there will be sufficient time for the Receiver pilot to take corrective action to prevent the hose whip breaking off the probe nozzle.

It is equally important that downward approaches on to the drogue are avoided, as this technique will result in hose whip. Similarly, after contact with the drogue the Receiver should be flown in line with the hose, and carrying the hose excessively downward or sideways must be avoided. In the event of the probe nozzle being broken off, all refuelling valves must be closed to prevent the tanks being pressurised by ram air. The Receiver should be moved clear of the Tanker immediately, as cockpit visibility is likely to be reduced by fuel spillage. The residual fuel in the probe tube will also spray back over the windscreen for some time afterwards. Aircraft handling with the probe nozzle broken off is not affected, but speeds in excess of normal cruising speeds should be avoided.

(b) The engagement of the probe with the drogue demands accurate flying, and any tendency to over-correct must be avoided. Pilots are strongly advised to guard against becoming impatient and making attempts at contact by chasing the drogue on the off chance of making a lucky connection. If it is thought at any time that the drogue is unsteady due to erratic Tanker flying, turbulence or bow wave effects, check by observing the drogue in relation to the Tanker. If the Tanker and the drogue appear to move together, then it is the Receiver which is unsteady. If, due to unsteadiness on the part of the drogue or the Receiver, smooth contact cannot be achieved, pause some thirty to forty feet behind the drogue, allow everything to become settled and then make a further attempt at contact. It is essential that hovering a few feet behind the drogue be avoided.

(c) If rough air is encountered the chances of making contact are reduced. If turbulence is making contact difficult, less time will be wasted if the altitude is changed.

(d) If a rim contact is made, or if the probe nozzle catches in the drogue spokes the hose will wind in. The correct action is for the Receiver to withdraw and allow the hose to be retracted. When an amber light is displayed, a further attempt at contact can be made. If contact is made too slowly, i.e. below about 2 knots T.A.S. the probe will not positively lock in the drogue coupling. The Receiver must then withdraw and allow the hose to be retracted.

13. Failure of a tank or tanks to fill

If one or more tanks fail to fill, the C.G. may rapidly move outside the limits and action must be taken quickly to counteract this condition and to maintain the aircraft in balance. The action to be taken depends on the tank position and the quantity of fuel in it. Information on this will be found in para. 21.

Tanker Equipment

14. General

The Tanker aircraft carries a hose drum unit (H.D.U.) in the aft end of the bomb bay, which consists of an electrically-driven drum carrying a 90-foot length of fuel hose, and also an air turbine-driven delivery pump. One end of the hose is connected to the transfer fuel system, the other end carries a conical drogue and refuelling coupling. A panel on the cabin starboard wall carries all the controls and indicators for the H.D.U. and the transferable fuel system.

15. Transferable fuel

(a) The fuel available for transfer is carried in the underwing tanks, the auxiliary (bomb bay) tank, the fuselage transfer tank and the fuselage tank No. 3 cells. Fuel from all except the underwing tanks is pumped by air turbine pumps to the H.D.U. delivery pump and then to the hose. Fuel from the fuselage No. 3 cells is isolated from the aircraft usable fuel by shut-off cocks between the cells and the fuselage pump housings (see para. 16 (a) (ii)). The electric booster pumps in the auxiliary tank and transfer tank are still connected to the pilot's normal controls, but on no account should these pumps be operated during flight refuelling. The transfer tank must contain not less than 800 lb. of fuel at any time that dry contact training is in progress, in order to keep the hose full of fuel.

(b) Fuel from the underwing tanks is transferred by the normal pump in each tank, in conjunction with the nitrogen pressure system and is fed to the H.D.U. delivery pump. When the underwing tanks are used by the pilot for his aircraft use, fuel is transferred in the

normal way to the wing tanks by the pump alone, with the nitrogen system as an emergency stand-by in case of pump failure. The control circuits for the underwing tanks are so arranged that the pilot can take over control at any time from the Tanker operator by using the normal underwing tank switches.

(c) When using the air turbine pumps for transferring fuel to the Receiver, the amount of untransferable fuel is greater than the normally unusable fuel when using the electric booster pumps or gravity feed for feeding the Tanker's own engines. The approximate amount of untransferable fuel (extra to the normal unusable fuel) is as follows:

Auxiliary tank	40 lb.
Fuselage No. 3 cell	240 lb. per side
Transfer tank	240 lb. per side
Underwing tanks	80 lb. each

NOTE: Due to variations in transfer rate, the figures may be exceeded, particularly by the transfer tank, which may be as much as 2,000 lb.

After a flight refuelling transfer this untransferable fuel may be used for the Tanker's engines by setting the PILOT/OPERATOR switches to PILOT and using the normal electric booster pumps.

16. Tanker panel

(a) *Transferable fuel controls.* Apart from the H.D.U. controls, the panel carries a MASTER SWITCH and, for each transferable fuel tank, a PILOT/OPERATOR switch, pump START and STOP pushbuttons, a fuel L.P. warning lamp and a fuel contents gauge. The panel also carries two circuit-breakers, one for the normal supply and one for an emergency supply.

(i) *Master switch.* None of the turbine pumps can be operated, nor can the hose be paid out, until the bomb doors are open and the MASTER SWITCH is ON. The bomb doors are further interlocked so that they cannot be closed until the hose is fully stowed.

(ii) *Pilot/operator switches and fuel contents gauges.* The PILOT/OPERATOR switches, when set to PILOT, further isolate the

(iv) *Brake warning light and switch.* The brake warning light comes on to indicate when the hose drum motor brake is applied. The switch can be used to apply the brake if necessary or to reset the brake to off if the brake has been applied by the overspeed governor.

(v) *Footage indicator.* This indicates the number of feet of hose wound on the drum.

(vi) *Main pump switch and warning light.* This switch, marked AUTO and OFF, controls the air turbine-driven delivery pump. When the switch is set to AUTO, the pump will run when the Receiver aircraft has made contact and when the operator puts the fuel valve switch to AUTO when approximately 25 feet have been wound in. The OFF position enables the pump to be stopped at any time. The warning light comes on when the pump is not running.

(vii) *Fuel valve switch.* This switch, marked AUTO, SHUT and OPEN controls the fuel valve in the fuel delivery line. When the switch is set to AUTO, the fuel valve will open, thus allowing fuel to flow, when the Receiver aircraft has made contact and 7 feet of hose have been wound in. The OPEN and SHUT positions of the switch enable the fuel valve to be opened or shut as required. An interference bar prevents OPEN being selected inadvertently.

(viii) *Fuel flow indicator.* This shows the fuel flow in pounds per minute and also in pounds gone.

(ix) *Fuel pressure gauge.* This shows the fuel delivery pressure at the drogue reception coupling.

(x) *Circuit selected indicator.* Shows which circuit has been selected and gives an indication of correct sequencing of circuits.

(xi) *Stand-by circuit selector.* This is a push-button which enables the next circuit to be selected if this has not been done automatically.

(xii) *Contact and refuel lights.* These are repeaters of the amber and green signal lights on the H.D.U.

(xiii) *Emergency signal switch and warning light.* This switch controls the red signal light on the H.D.U., and the warning light is a repeater of the signal light. The switch has two positions, AUTO

and STAND OFF. When the switch is set to STAND OFF, the red signal light will be on. When the switch is set to AUTO the red signal light will be off unless the hose is not fully trailed.

(xiv) *Hose jettison switch.* This is a guarded switch marked EMERGENCY TRAIL and HOSE JETTISON, and is spring-loaded to the central (off) position. When set, repeatedly if necessary, to EMERGENCY TRAIL, the hose will be fully trailed. Once the hose is fully trailed it is released from the drum and jettisoned by setting the switch to HOSE JETTISON.

17. Lighting

(a) *Panel lighting.* The warning and indicator lights on the face of the panel are controlled by a DIM - BRIGHT - TEST switch on the panel.

(b) *Signal lights.* A row of coloured lights, two red, two amber and two green, on the H.D.U. are used for signalling to the Receiver aircraft. The duplication is simply a safeguard against failure. The red lights warn the Receiver not to attempt contact, or to break away if in contact. They are controlled by an emergency signal switch (see para. 16 (b) (xiii)). The amber lights come on automatically when the hose is trailed and ready for contact to be made. When 7 feet of hose have been wound in, the fuel valve will open automatically when AUTO is selected, and it will be manually selected to AUTO at 25 feet when the MANUAL drill is being used. When the fuel valve is open, the lights will change from AMBER to GREEN. The GREEN lights will then remain on all the time that the fuel valve is open. The three pairs of signal lights each have a repeater on the Tanker panel, and their intensity is controlled by a DAY/NIGHT switch on the panel. This switch is marked REFUELLING LIGHTS.

(c) *Tanker aircraft floodlights.* The bomb bay and the underside of the wings, as well as the underwing tanks, are floodlit by four lamps. They are controlled by two dimmer switches on the top of the Tanker panel.

(d) *Tail beacon.* A flashing beacon is mounted on the tail of the Tanker. It is controlled by an on/off switch on the top of the Tanker panel.

(e) *Tail navigation light cut-out.* The tail navigation light causes some discomfort to the Receiver pilot when refuelling in the air at night, and a switch (G23) on the starboard coaming panel enables this light to be switched off while leaving the wing-tip navigation lights on.

Refuelling in Flight—Tanker

18 Aircraft handling

NOTE: Tanker pilots must refer to the Panel operators notes. In the air they should ensure that they are kept fully informed of the progress of the refuelling by the operator.

(a) The recommended contact speed for Valiant to Valiant refuelling is 230 knots, and in the refuelling configuration a light continuous airframe buffet will be felt. The Tanker should be trimmed out accurately before signalling "Ready for Contact." The auto-pilot must be disengaged, and the auto-stabiliser, if fitted, should be switched on. Use of the fine trimmer is recommended.

(b) When ready for contact, the Tanker speed of 230 knots should be accurately maintained so that the Receiver pilot can establish the correct closing speed of up to 5 knots TAS. Abrupt movements on the controls will cause the drogue to oscillate widely and will severely reduce the chances of making contact. Coarse use of the throttles must also be avoided. The aim must be to provide the steadiest platform possible to give the Receiver every chance of making a successful contact.

(c) When contact is made and the Receiver moves up into the refuelling position, a nose-down change of trim will be felt, and this must be countered by extremely careful use of the elevators. Also the speed will tend to increase unless power is reduced at this

point sufficiently to maintain 230 knots. Likewise when the receiver moves out to break contact, a nose-up change of trim will be felt and the speed will tend to decrease. Equal care should be taken in correcting for it.

(d) Power will have to be reduced progressively as fuel is transferred to the Receiver in order to maintain 230 knots and level flight. Care must be taken to ensure that a rate of climb is not sustained. This is especially important towards the end of the transfer, when if a rate of climb in excess of 200 ft./min. is allowed to develop, the Receiver will probably not have sufficient power to maintain station or, in the worst case, to prevent an inadvertent disconnect.

(e) Rough air should be avoided when positioning for a contact as the chances of success under these circumstances are slight.

18A Cross refuelling

The aircraft can be operated in the tanker role in conjunction with the following, using Mk. 8 equipment:

<i>Aircraft</i>	<i>Day/Night</i>	<i>Recommended contact speed</i>
Javelin 9 . . .	Day	230K
Lightning 1A, 2 and 3	Day*	250K
Scimitar . . .	Day/Night	—
Sea Vixen 1 and 2 .	Day/Night	—
Victor 1A . . .	Day/Night	240K
Vulcan 1A, 2 . . .	Day/Night	220-240K

* When Lightning Mods. 2162(1A) or 2101(2) are embodied night contacts are permitted.

NOTE: Limitations—See Part II and Appendix A, para. 3.

19 Equipment operation

The following tables give full details of the flight refuelling procedure:

(a) Pre-flight procedure

<i>Operator's action</i>	<i>Control panel indications</i>	<i>Circuit selected indicator</i>	<i>HDU response</i>
1 Ensure bomb doors closed, No. 3 inverter on, and instrument master switch selected on. Select PILOT/OPERATOR switches to OPERATOR for those tanks containing transferable fuel	Contents gauges read	Stowed	None
2 Ensure "Normal Supply" and "Emergency Supply" circuit-breakers are made	None	Stowed	None
3 Ensure main pump switch at AUTO and fuel valve switch at shut. Select signal lights day/night switch as appropriate	None	Stowed	None
4 Ensure wind/trail switch is at WIND	None	Stowed	None
5 Select master switch ON	None	Stowed	None
6 Select panel lights dimmer as required	As required	Stowed	None

(b) Normal procedure

Operator's action	Control panel indications	Circuit selected indicator	H.D.U. response
<p>PREPARATION FOR REFUELLING</p> <p><i>Note:</i> When refuelling is imminent, the pilot will open the bomb doors which will arm the H.D.U. and transfer pump circuits. If the underwing tanks are selected to OPERATOR the nitrogen bottles will charge them to 7 lb./sq. in.</p> <p><i>Warning:</i> The fuel valve must not be selected to AUTO prior to contact.</p> <ol style="list-style-type: none"> 1. Select motor switch to WARM. Turn hose tension control to maximum. When hose tension needle is steady (1 to 3 min.) place motor switch to OFF (central). 2. Press the required pump start buttons and hold until the lights go out. 3. Reset fuel flow indicator. 4. Select external lights as briefed; i.e. rotating beacon, underwing tank floodlights and H.D.U. floodlights. <p>TRAILING THE HOSE</p> <ol style="list-style-type: none"> 5. Select emergency signal switch to STAND OFF. 	<p>With the MASTER SWITCH on and bomb doors open the following indications will be observed: Transferable fuel pump warning lights as selected on. Fuel pressure gauge will read 7 to 10 lb./sq. in. if underwing tanks are selected. Main pump and brake warning lights on.</p> <p>Hose tension indicator will read a minimum of 270 knots.</p> <p>Fuel pressure gauge will read 50 lb./sq. in. if underwing tanks are selected, otherwise about 25 lb./sq. in.</p> <p>As required.</p> <p>Red stand off light on.</p>	<p>Stowed.</p> <p>Stowed.</p> <p>Stowed.</p> <p>Stowed.</p>	<p>Motor runs. Gear low. Brake on. Fuel valve closed.</p> <p>None.</p> <p>None.</p> <p>Red stand off lights on.</p>

Operator's action	Control panel indications	Circuit selected indicator	H.D.U. response
6. Select wind/trail switch to TRAIL and when, after 15 seconds, the hose tension gauge reads, turn hose tension control to the minimum setting. When hose starts to trail, increase hose tension until indicator reads trail setting.	(1) Brake warning light on. (2) Hose tension indicator reads. Brake warning light out.	Stowed. Trail.	(1) Brake on. Gear low. Then, after 15-second delay: (2) Motor on. Brake off. Gear low. Hose trails.
7. Observe hose movement on footage indicator.	Footage indicator shows hose movement to full trail. At full trail Brake warning light on, hose tension reads zero.	Gear high.	When hose is at full trail motor stops. Brake on. 15 seconds delay. Gear changes to high.
8. None.	Hose tension reads. Brake warning light out. Amber contact light on. Pump off warning light out.	Refuel.	Motor starts. Brake off. Amber contact lights on. Hot air gate valve open and air bleed valve closed.
9. Turn hose tension control to I.A.S. hose tension requirements.	Hose tension reading appropriate to I.A.S.	Refuel.	Fluid drive scoop tube moves as directed by hose tension control.
10. As directed by the Captain, select emergency signal switch to AUTO.	Red warning light out.	Refuel.	Red stand off lights out.
REFUELLING			
11. Before switching on the fuel the operator must first satisfy himself that a successful contact has been made. This can be done by: (i) Checking that approximately 25 ft. has been wound in on the drum. (ii) Checking that the brake light is OUT.			

Operator's action	Control panel indications	Circuit selected indicator	H.D.U. response
<p>The main fuel valve should then be put to AUTO and the amber light will go out and the green light come on. If a positive contact has in fact been made, the flow gauge should show that fuel is being transferred. If the flow gauge does not register a flow of fuel, put the RED stand off lights on, and the fuel valve to SHUT, wait 10 secs. and retrail as detailed in para. 3 of the stand by procedure.</p> <p>12. During fuel transfer, observations must be made of the footage indicator, fuel pressure and flow gauges. If any tank containing transferable fuel should empty, the warning light relevant to that tank will come on.</p> <p><i>Warning:</i> The hose tension indicator will be fluctuating considerably during this period, but under no circumstances should the hose tension control be touched.</p>	<p>Footage indicator will indicate the position of the receiver. When the fuel valve is put to AUTO the amber light will go out and the green light will come on. The fuel gauge will indicate rate and quantity of fuel flow.</p>	<p>Refuel.</p>	<p>Receiver establishes contact, the hose moves in and out as the distance from the Tanker is increased or decreased. When 25 ft. of hose has been wound on the drum the fuel valve will open, the green contact light comes on and the amber goes out. The air bleed valve will open and fuel will start to flow.</p>

Operator's action	Control panel indications	Circuit selected indicator	H.D.U. response
<p>13. (a) On completion of transfer of required amount of fuel, select the main fuel valve to OFF.</p> <p>(b) If no further refuelling operations are intended the pumps in those tanks still containing fuel will be stopped by pressing the stop buttons and holding them pressed until the warning lights come on. If further refuelling operations are intended, move interruptor bar on fuel valve switch and place switch to open for 30 seconds, to recharge hose with fuel.</p>	<p>Green light will go out and amber light come on. Flow rate will read ZERO.</p>	<p>Refuel.</p>	<p>Fuel valve closes green lights go out, amber lights come ON. The air bleed valve will open and the main pump will come off. The receiver will withdraw. Hose at Full Trail. Receiver clear.</p>
<p>WINDING IN THE HOSE</p>			
<p>14. Select wind/trail switch to WIND.</p>	<p>Brake warning light on. Hose tension reads zero. Red stand off and pump off lights on.</p>	<p>Gear low.</p>	<p>Motor off. Amber signal lights out. Red stand off lights on. Hot air gate valve closes. 15 seconds delay. Gear selected to low, and hose tension automatically adjusted.</p>
<p>15. Observe hose wind-in on footage indicator.</p>	<p>Hose tension reads. Brake light out, footage indicator shows hose winding in.</p>	<p>Wind.</p>	<p>Motor on. Brake off. Hose winds in.</p>
<p>16. Continue to observe footage indicator.</p>	<p>Hose tension reads. Brake light on when 80 ft. of hose wound on drum.</p>	<p>Pre-stow.</p>	<p>When approximately 80 ft. of hose has wound on the drum, the brake is applied.</p>
<p>17. None.</p>	<p>Brake light remains on when hose is fully stowed. Hose tension indicator then reads zero.</p>	<p>Stowed.</p>	<p>Motor off when hose fully stowed. Red stand off lights extinguished. Brake remains on.</p>

<i>Operator's action</i>	<i>Control panel indications</i>	<i>Circuit selected indicator</i>	<i>HDU response</i>
18 Select motor switch to WARM and hose tension control to maximum	Hose tension gauge indicates a minimum of 270 kts.	Stowed	Motor on. Hose is tightened on the drum
19 Ensure that stand off switch is at Auto and request Captain to close bomb doors	Transfer pump warning lights out. Instrument gauges read zero	Stowed	Motor off
20 Select PILOT/OPERATOR switches to PILOT	All fuel contents gauges read zero	Stowed	None
21 Place Motor Warm and master switch off, and trip normal and emergency supply circuit breakers. Report operation complete to Pilot, together with total weight of fuel transferred	Instruments read zero	Stowed	None

(c) "Stand by" procedure

<i>Control panel indications</i>	<i>Circuit selected indicator</i>	<i>HDU response</i>	<i>Operator's action</i>
EXCESSIVE TRAIL SPEED			
<i>Symptom:</i> Brake light on Footage indicator stationary	Trail	Speed control unit has applied the brake	Increase hose tension control slightly Press and release brake reset switch
Brake light out. Footage indicator shows hose trailing	Trail	Brake reset to Off. Hose moving to full trail	<i>Note:</i> If it is suspected that the Speed Control Unit is unserviceable the brake should be applied by pressing and holding the brake reset switch

<i>Control panel indications</i>	<i>Circuit selected indicator</i>	HDU response	<i>Operator's action</i>
FAILURE OF CIRCUIT SELECTOR TO PROCEED TO NEXT CIRCUIT AUTOMATICALLY			
<i>Symptom</i> : Failure of motor to restart following a gear change	As appropriate	Failure of an electrical item to signal Circuit Selector to next stage	Press and release standby circuit selector button <i>once only</i>
EXCESSIVE BREAKAWAY SPEED OR PREMATURE SEPARATION OF RECEIVER			
<i>Symptom</i> : Brake light on Footage indicator stationary Red stand off light on Flow indicator reads zero Reduction in pressure on fuel pressure gauge. Pump off warning light on	Refuel	Speed control unit has applied the brake. Fuel valve closed. Air bleed valve closed. Green lights off, amber lights on. Red stand off light on. Hot air gate valve closed	If the hose is not fully trailed select wind/trail switch to WIND and wind in the hose. Should further contacts be required by Receiver, retrail the hose
EXCESSIVE FUEL PRESSURE			
<i>Symptom</i> : Pressure gauge momentarily reads over 60 PSI Main pump warning light on	Refuel	Fuel and hot air valves closed. Air bleed valve closed	Set main pump switch to OFF then to AUTO. If main pump warning light comes on, place switch to OFF and allow a reduced fuel flow to Receiver
FAILURE OF MAIN FUEL VALVE TO OPEN WHEN AUTO SELECTED			
<i>Symptom</i> : (a) Brake light off (b) Footage indicator showing approx. 30-40 ft. on the drum and oscillating (c) Amber light on Green light OUT (d) No fuel flowing	Refuel	Receiver has successfully made contact, fuel valve closed, amber lights ON. Green light OUT No fuel flowing	Move interrupter bar on fuel valve switch and place to OPEN. Flow rate meter will indicate fuel flowing. Amber light will go out and green light come on

(d) Emergency procedure

Control panel indications	Circuit selected indicator	H.D.U. response	Operator's action
<p>HOSE BREAKAGE</p> <p>It is assumed that hose breakage may only occur should the Receiver move the hose to a critical point outside the refuelling envelope. The electrical circuits are arranged to close the fuel valve and switch off the motor should the hose break and the remaining hose wind in to the "Pre-Stow" position while in the refuel condition.</p> <p><i>Symptom:</i> Hose winding in rapidly. Hose tension reads lower than required I.A.S. setting. Fuel flow indicator reads maximum rate or Receiver pilot reports hose breakage.</p>	Refuel to Pre-Stow.	Hose parted.	Place Master Switch OFF. Trip circuit-breakers. Leave bomb doors open to dissipate fuel vapour.
<p>HOSE JETTISON</p> <p>Following an electrical or mechanical failure, applicable when hose has commenced to trail.</p> <p>1. <i>Electrical failure</i></p> <p>Hose Tension reads ZERO. No response on hose tension control. Brake warning light stays on. Red stand off light on.</p>	Trail, Refuel or wind.	Motor off. Brake on. Air bleed valve and fuel valve close if in refuel condition. Red stand off signal light on.	Select hose jettison switch to EMERGENCY TRAIL and hold. Brake light will go out and will come on again; release switch and repeat his action until brake light stays out. Then select HOSE JETTISON with pilot's permission. Switch OFF master switch.

Control panel indications	Circuit selected indicator	H.D.U. response	Operator's action
<p>2. <i>Mechanical failure</i> Hose Tension reads NO LOAD, no response on hose tension control. Brake light stays on, red stand off light on.</p>		<p>Mechanical failure of drive mechanism. Speed control unit has applied the brake.</p>	<p>As above.</p>

(e) *Dry contact procedure*

1. Ensure pilot/operator switches are at PILOT.
2. Main pump selected OFF.
3. Fuel valve as for normal refuelling.
4. Proceed as normal refuel.

Note: The transfer tank must contain not less than 800 lb. of fuel at any time that dry contact training is in progress, in order to keep the hose full of fuel.

(f) *In the event of unsuccessful contacts the following conditions may occur*

1. RIM CONTACT ON DROGUE

Symptom: Brake warning light on, hose not at full trail.

Action: Reset brake switch until hose at full trail, with red stand off light on.

2. DROGUE TOPPLE

Symptom: Brake warning light on, footage indicator stationary. Approximately 30 to 40 ft. wound on drum.

Action: Proceed as excessive breakaway speed.

20. Failure of a tank or tanks to feed (Tanker)*Air turbine pump failure*

In the event of failure of any of the air turbine pumps (i.e. in the fuselage No. 3 cells or the transfer or auxiliary tanks), the fuel in the affected tanks will not transfer. On completion of the flight refuelling operation, the equivalent weight of fuel which would have been transferred (if failure had not occurred) must be used from the fuselage tanks before using any further fuel from the wing tanks.

21. Failure of a tank or tanks to fill (Receiver)

(a) Figure 4 provides a ready indication of the action required to keep the C.G. within limits if a tank does not refuel correctly during flight refuelling. Provided that the C.G. position on completion of refuelling is known or computed, the chart enables the operator to decide at a glance if a C.G. problem exists, without the necessity of using the slide rule. The vectors represent the moment arms of the tanks for varying amounts of fuel. Two vectors are given for each tank, one at high weight and one at low weight. Interpolation is necessary for intermediate weights.

(b) Point o on the vectors represents the C.G. position which should be obtained when the predetermined flight refuelling is completed. Each vector shows the direction (away from point o) of the change of C.G. should any tank fail to refuel to the predetermined amount.

(c) Before commencing flight refuelling, calculate the C.G. and weight of the aircraft as it will be on completion of refuelling. The C.G. of the aircraft in relation to the C.G. limits of 46.93 and 47.97 feet aft of datum will then be known. For example, if the C.G. on completion of refuelling is calculated to be 47.7 feet aft of datum the aft limit is 0.27 feet aft of the C.G. and the forward limit is 0.77 feet forward of the C.G. Plot these two positions on the chart on each side of point o.

(d) By reference to the chart it can be seen that failure of any tank to refuel will not cause the C.G. to move outside the forward limit but if any of the reserve, fuselage No. 1, fuselage No. 2 or auxiliary tanks do not refuel beyond the point where the aft C.G. limit line crosses the vectors for the different tanks, the C.G. will be outside the aft limit.

(e) To compensate for the C.G. moving outside the limit it is necessary to reduce the contents of a tank whose moment arm is opposite to the faulty tank, by an amount which will move the C.G. to within the limits. As this involves a reduction in fuel capacity, further to that already lost by the failed tank, the C.G. should be compensated by a tank which provides the greatest change of moment for the least fuel capacity reduction. For aft C.G. compensation this is the transfer tank, and for forward C.G. compensation the reserve tank.

See overleaf for example

Example

Taking the calculated C.G. figures given in para. 21(c) plot the positions of the C.G. limits at 0.27 feet aft of point 0 and 0.77 feet forward of point 0. Let it be assumed that all tanks are to be completely filled and that the final all-up-weight will be 140,000 lb.

During refuelling it is noticed that the reserve tank does not refuel beyond 1,000 lb. The amount of C.G. compensation must now be determined.

From the reserve tank gauge reading scale for 1,000 lb. move horizontally to a point within the two reserve tank vectors, and interpolate for 140,000 lb. From this point move vertically upwards and obtain a reading of the distance aft from point 0, i.e. 0.37 feet. The amount by which the C.G. must be moved forward to come within the aft limit is therefore $0.37 - 0.27 = 0.1$ feet.

From point 0 move horizontally to 0.1 feet forward and then move downwards to the transfer tank vectors. At a point within these vectors, again interpolate for 140,000 lb. and then move horizontally to the transfer tank gauge reading scale. A reading of 4,850 lb. is thus obtained. This figure represents the *maximum* capacity to which the transfer tank should be filled to bring the C.G. the requisite distance forward so as to be within the aft limit. Any further reduction in transfer tank capacity will result in further forward C.G. movement.

The total fuel capacity lost, therefore, due to the failure of the reserve tank to refuel beyond 1,000 lb. is :

$$\text{Reserve tank, } 4,720 - 1,000 = 3,720 \text{ lb.}$$

$$\text{Transfer tank, } 5,680 - 4,850 = 830 \text{ lb.}$$

$$\underline{\underline{4,550 \text{ lb.}}}$$

NOTE - 1 THE MOMENT OF THE UNDERWING TANKS AT WEIGHTS ABOVE 40,000LB IS LESS THAN 0.2 FEET
 2 THE DOTTED LINES AND THE CG LIMITS SHOWN ON THE CHART REFER ONLY TO THE EXAMPLE IN THE TEXT

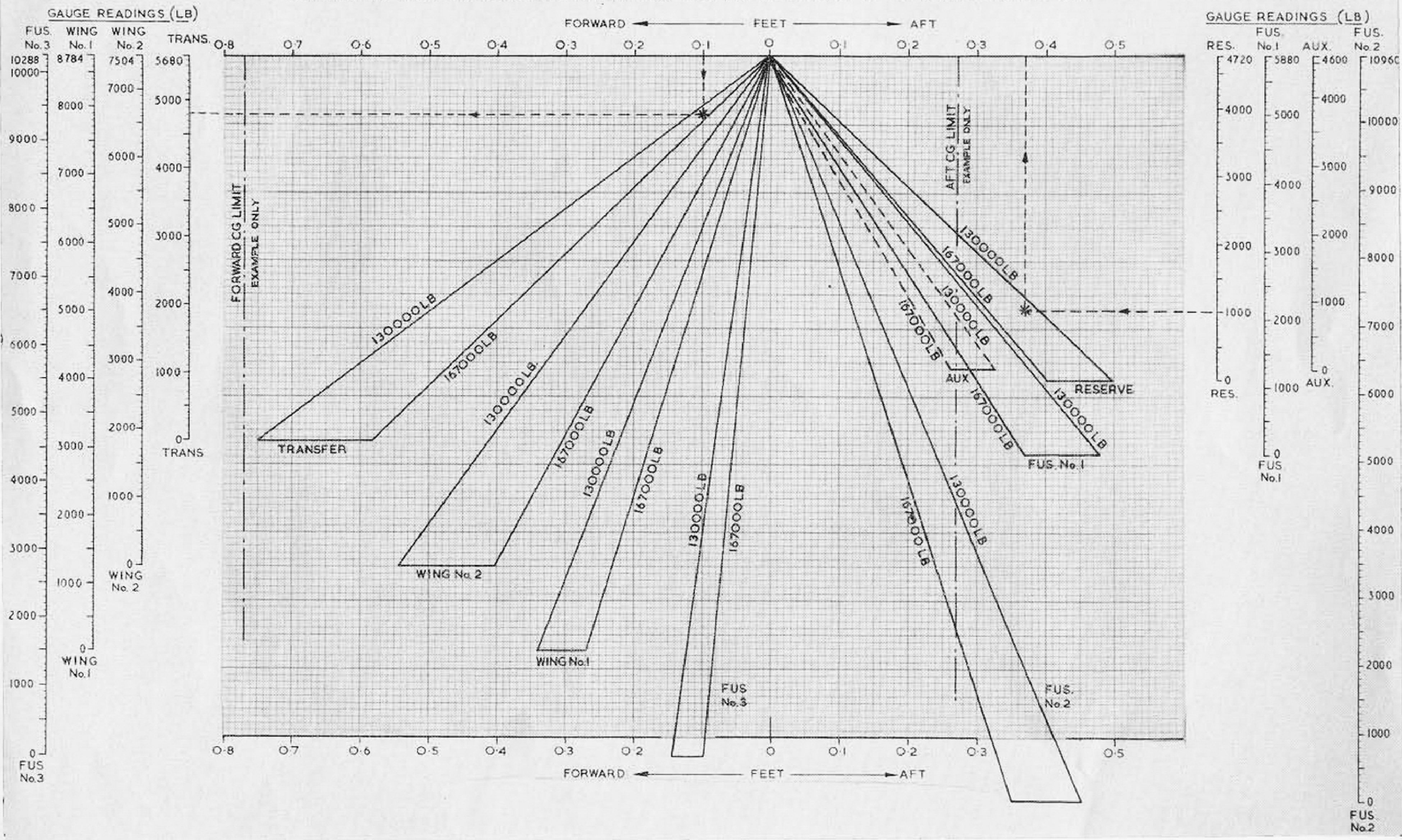


FIG. 4.—C. G. correction chart



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