

HYDRAULIC AND PNEUMATIC SYSTEMS

Introduction

1. The following definitions should be understood before reading the remainder of the chapter :—

(a) *Intensity of Pressure.* Intensity of pressure is the force per unit area exerted by a fluid on the surface of a container. It is generally measured in pounds per square inch. Throughout this chapter the term *pressure* is used to indicate *intensity of pressure* expressed as pounds per square inch.

(b) *Total Effective Pressure.* This is the total force exerted on a particular surface of a container. It is calculated from the following formula :—

$$\text{Total effective pressure} = \text{Pressure (lb./sq. in.)} \times \text{surface area (sq. in.)}$$

Throughout this chapter the term *force* is used to indicate *total effective pressure* expressed in pounds.

(c) *A Fluid.* All liquids and gases which change shape to suit the shape of the vessel which contains them are fluids.

Operating Principles of Hydraulic and Pneumatic Systems

2. Hydraulic and pneumatic systems are used to transmit power for the operation of services which require considerable power for short periods at infrequent intervals, e.g. retractable undercarriages, flaps, bomb doors, air brakes, wheel brakes.

3. The hydraulic or pneumatic pumps used to generate the necessary pressure, and pipeline systems which transmit this pressure to remote points in the airframe, weigh less than purely mechanical or electrical systems designed for the same purpose.

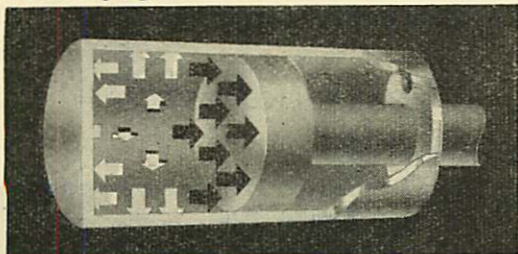


Fig. 1.
Principle of a Simple Hydraulic or Pneumatic Jack.

4. In hydraulic and pneumatic systems, power is transmitted as fluid pressure to the mechanism which converts this power into mechanical work. If fluid is confined under pressure in any container, the pressure per unit area is the same on all surfaces of the container. Fig. 1 shows a cylinder with a piston and a piston-rod. If the fluid in the cylinder is at a pressure (P) of, say, 10 lb./sq. in. and the area (A) of the face of the piston is 10 sq. in., the total force acting on the piston and transmitted by the rod to any mechanism to which it may be connected is $P \times A = 10 \times 10 = 100 \text{ lb.}$

5. Figs. 2 and 3 illustrate the application of the principle of fluid pressure in a simple hydraulic machine. Two cylinders are shown connected by a pipe fitted with a pressure gauge. The small cylinder is fitted with a piston of 10 sq. in. area (A_1), the large cylinder has a piston of 100 sq. in. area (A_2). Application of a weight or force (F_1) of 100 lb. to the rod of the small piston produces throughout the fluid a pressure (P) of $\frac{W_1}{A_1} = \frac{100}{10} = 10 \text{ lb./sq. in.}$, as indicated by the pressure gauge. This pressure acting on the face of the large piston produces a force of $P \times A_2 = 10 \times 100 = 1,000 \text{ lb.}$, thus supporting the weight W_2 .

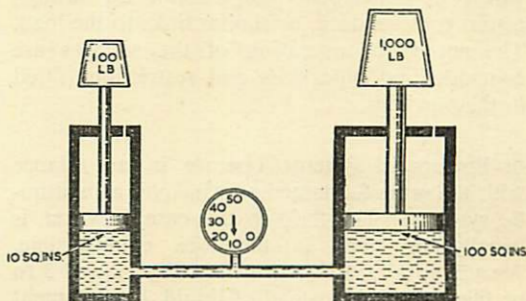


Fig. 2. Transfer of Force.

6. In a hydraulic (as distinct from pneumatic) machine, the cylinders and pipes are filled with a liquid (usually oil) which for all practical purposes may be considered as being incompressible. It follows that if the small piston is

RESTRICTED

A.P. 129, VOL. 1, PART 1, SECT. 6, CHAP. 3

pushed downwards in the cylinder through a distance of 5 inches, as shown in Fig. 3, the large piston will move upwards in its cylinder through a distance inversely proportional to the areas of the two pistons, *i.e.* through $\frac{10 \times 5}{100} = \frac{1}{2}$ inch, thus raising the weight of 1,000 lb. through this distance. The work done by the small weight (*i.e.* weight \times distance through which it acts) is transmitted hydraulically and equals the work expended in producing the greater force through a smaller distance. This illustrates the principle of any hydraulic power transmission.

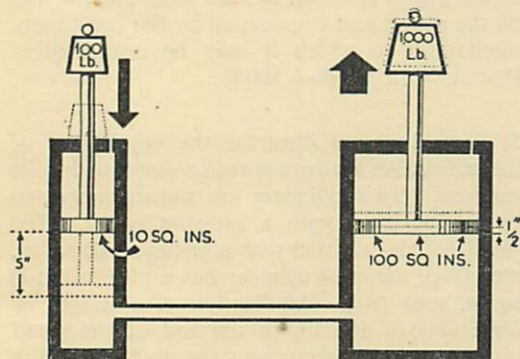


Fig. 3. Transfer of Movement.

7. Owing to the incompressibility of liquids, hydraulic systems are just as positive in operation as mechanical power transmission machines in which the power generator is connected through piston rods, gearing, or similar links to the load. The speeds of operation of the services are controlled by pipe sizes and restrictions fitted in the pipelines.

8. Pneumatic systems operate in accordance with the same fundamental principles as hydraulic systems. The fluid in this case, however, is usually air and is therefore compressible. Assuming the systems shown in Figs. 2 and 3 to be filled with air instead of liquid, displacement of the small piston under a load will not necessarily cause the large piston to move immediately. It will first compress the air, which may be considered as a spring, until the pressure rises to that required (in this case 10 lb./sq. in.) to overcome the resistance to movement of the larger piston. Thus, if a weight W (less than 100 lb.) is placed on the rod of the small piston, it will move downwards and compress the air to a

pressure of $\frac{W}{A_1}$ lb./sq. in. without causing the larger piston to move. As additional weight is added to the small piston, a point is reached at which the larger piston will move. Further compression of the air does not take place unless the load on the larger piston is increased, when the piston will continue its movement.

9. Thus, pneumatic systems are not as positive in their action as hydraulic systems, but this characteristic, or "springiness", of operation is of value in certain uses.

Electrical Control of Pneumatic and Hydraulic Systems

10. Most selector valves in aircraft pneumatic and hydraulic systems are fitted near the jacks which they control, thus reducing the length of pipelines. In such cases the valves are usually actuated by electrical solenoids, or small motor units, energized from the aircraft electrical system by the operation of switches. The switches are usually under manual control but may operate automatically, as in:—

(a) Pneumatically-operated coolant radiator shutter jacks, the control valves of which are electrically-operated by a thermostatic switch unit.

(b) The automatic supercharger gear-changing mechanism, in which valves controlling the pneumatic clutch-operating jacks are electrically actuated by switches responsive to barometric pressure. This mechanism engages high gear when a predetermined altitude is reached and re-engages low gear on the descent. In some installations a ram-air pressure element is embodied in the switch. This varies the height at which the gears change in accordance with the speed at which the aircraft is flying. When automatic gear changing is fitted, additional means are provided to override the pressure switch and engage high or low gear at any desired height.

HYDRAULIC SYSTEMS

Types of Systems

11. There are two types of hydraulic systems:—

(a) *Constant Delivery Type.* In this type the pump is always delivering fluid whether or not a service is being operated. Cut-out valves and an accumulator are used.

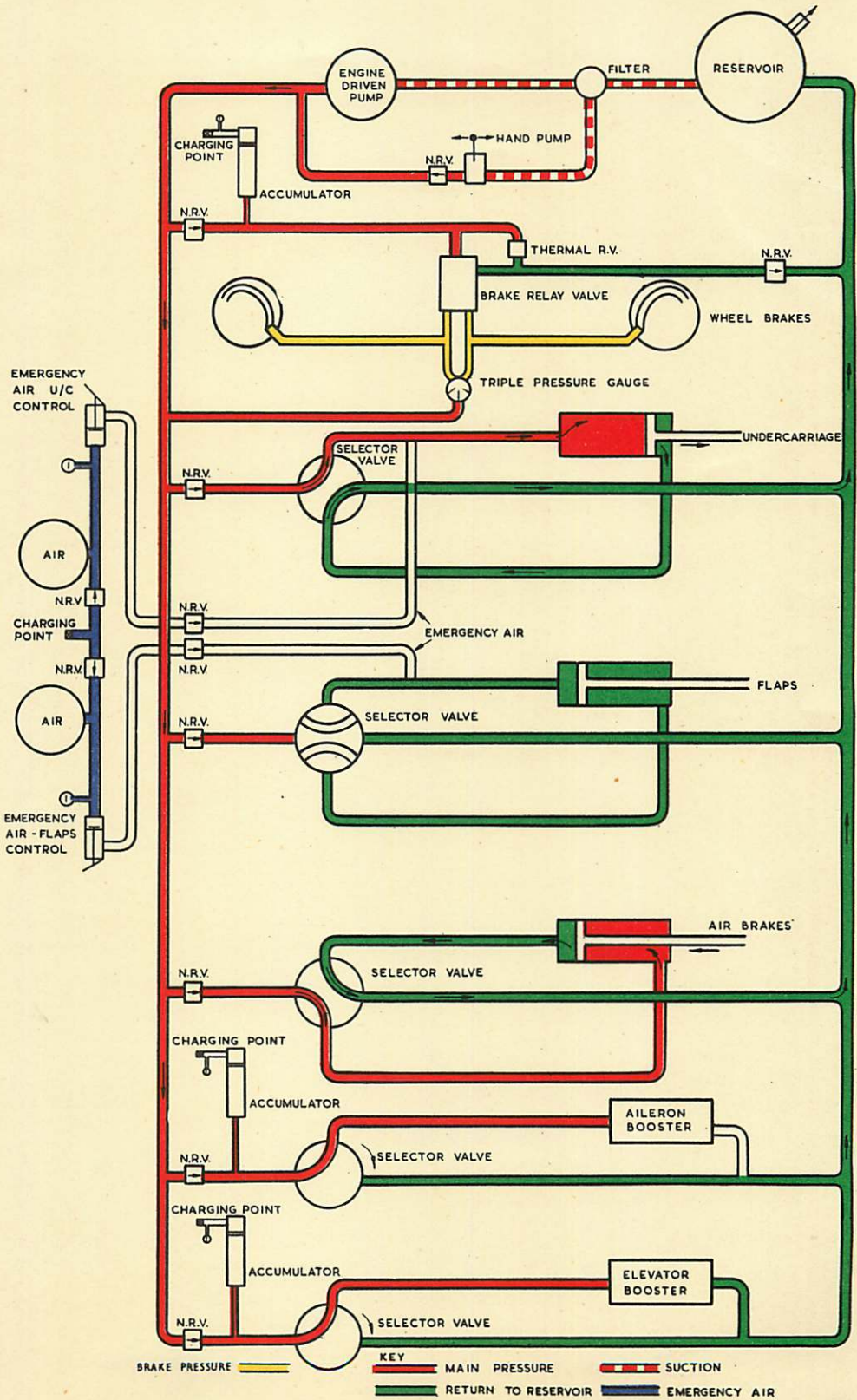


Fig. 4. Typical Hydraulic System

RESTRICTED

HYDRAULIC AND PNEUMATIC SYSTEMS

(b) *Constant Pressure Type (Live-Line Systems)*. In this application the pump incorporates a pressure-operated mechanism which causes the amount of fluid delivered by the pump to reduce when the system pressure approaches a set figure, until eventually the delivery ceases altogether, the pressure being stored in the lines. When a service is selected and the system pressure falls, the pump again starts to deliver fluid until the pressure is restored. No accumulator is necessary in this system, which is generally known as the *live-line* system.

Description of Components

12. **Cut-Out Valves.** When a selected service has completed its operation in the constant delivery system, the pressure in the line from the pump rises until the relief valve opens. This valve (which is frequently embodied in the pump, and is usually an automatic bypass valve known as a cut-out) diverts the fluid from the pump to the reservoir at low pressure, while locking the fluid to the jacks at high pressure. The cut-out valve in some early systems was incorporated in the control valves so that the selector lever automatically returned to a neutral position when the cut-out pressure was reached. In some cases a manually controlled cut-out was fitted.

13. **Accumulator.** When an automatic cut-out valve is fitted, an accumulator is used to maintain pressure in the system and compensate for leaks. This vessel is initially charged with air at about half the maximum hydraulic pressure, and when the delivery pressure from the pump exceeds the initial air pressure, oil enters the accumulator and further compresses the air. The compressed air acts as a spring, and even though there may be internal leaks in the jacks and valves the accumulator will compensate for them until the oil level falls to such an extent that the air expands and its pressure drops to what is termed *cut-in pressure*. The pump bypass valve then closes automatically and the pump replenishes the accumulator with oil. The accumulator sometimes serves the additional purpose of supplying power for a short period at a rate greater than the capacity of the pump. It also facilitates operation of certain services when the pump is not functioning and, in aircraft fitted with hydraulic brakes, is available as an emergency source of power for braking.

14. **Cut-In Pressure.** This is the pressure at which the cut-out valve closes and the pump resumes pumping against pressure (rather than merely circulating the fluid through the system).

15. **Hand-Pump.** The hand-pump is usually installed for ground servicing, but is sometimes used as an emergency power source when the engine-driven pump or engine fails, or when a leak occurs in the pipeline system. In these cases a reserve of fluid is ensured by connecting the engine-driven pump to a stand pipe in the reservoir and taking a hand-pump supply from the bottom of the reservoir.

16. **Selector Valve.** Each service has its own selector valve, although more than one jack within the service may be operated by the selector valve, e.g. two undercarriage jacks, a tail- or nose-wheel jack, and fairing door jacks may operate from a single selector valve.

17. **Brake-Relay Valve.** Hydraulically-operated wheel brakes may be controlled either by a lever on the control column, differential control being obtained by a relay valve interconnected with the rudder bar, or by twin toe-operated pedals, each moving a small piston in a cylinder and so controlling the relay valve hydraulically. From the hydraulic supply circuit, fluid passes through a non-return valve to the brake-relay control valve. For emergency operation of the brakes in the event of hydraulic failure, a hydraulic accumulator is fitted between the non-return valve and the brake-relay control valve. From the relay control valve two pipes convey fluid to the wheel brakes. From these two pipes, branch pipes lead to two pressure relays which are connected to a triple-pressure gauge in the cockpit. A third connection on the gauge shows the working pressure in the system.

18. **Aileron and Elevator Hydro-Booster Controls.** Where hydro-boosters are part of the aircraft control system (Fig. 4) they are brought into use by electrically-operated selector valves. Hydro-boosters reduce the stick forces required to operate the ailerons and elevator.

Emergency Operation of the Services

19. In some twin-engine aircraft a pump is mounted on each engine, thus reducing the risk of failure of the system due to pump or engine failure. The hand pump is frequently used as an alternative source, but its operation of the services, particularly the undercarriage, is usually slow. Owing to the limitations of the hand-pump, and to provide against total loss of fluid, additional means of lowering the undercarriage and flaps are usually provided. This generally consists of either a separate accumulator or a compressed air bottle, connected *via* an emergency control valve through independent pipelines to the *down*

RESTRICTED

A.P. 129, VOL. 1, PART 1, SECT. 6, CHAP. 3

side of the undercarriage and flap jacks. The services may be operated independently when provision is made for emergency operation of flaps and undercarriage. To permit fluid trapped in the *up* side of the jacks to escape, it is sometimes necessary for the undercarriage selector valve to be set to DOWN, but, since this is not always so, reference should be made to Pilots' Notes.

Servicing After Emergency Operation

20. After compressed air emergency systems have been operated, the jacks and pipelines must be bled of air and reprimed. Accumulator systems normally only require resetting.

Locking Devices

21. Normally jacks are retained in their selected positions by hydraulic pressure, but it is sometimes necessary to provide positive means of locking the mechanism when the pressure is off. This is always done with undercarriages to ensure that they do not collapse on the ground, or extend in flight under *g* loads, if the hydraulic pressure system should fail. Such locks may be mechanical latches or bolts, which, when engaged, prevent relative movement between certain members, *e.g.* the linkage in the undercarriage. The locks are engaged or disengaged automatically on completion or start of the operation of the service. In addition to the locking devices, the geometry of the undercarriage structure is designed to ensure that the load on the linkage, due to the weight of the aircraft, impedes the movement of one or more links in the direction of movement during retraction. Micro-switches connected to the undercarriage *up* and *down* locks control the circuits of the undercarriage position indicator.

Prevention of Inadvertent Retraction on the Ground

22. An additional automatic locking device is embodied in most aircraft to prevent inadvertent retraction of the undercarriage while on the ground. This consists of a bolt or catch device which prevents the undercarriage control lever from being moved out of the DOWN position until the oleo legs are fully extended. Many aircraft have push-button controls for undercarriage selection, and when the aircraft is on the ground, micro-switches operated by the compression of the oleo leg render the circuit inoperative. An override device is usually incorporated to enable the pilot to retract the undercarriage on the ground in an emergency.

Warning of Hydraulic Pressure Failure

23. Provision is made on some aircraft, fitted with powered or power-assisted controls, for warning the pilot when the hydraulic system has failed. This may be a warning light or an intermittent audio warning in the pilot's headphones. The purpose of this warning is to indicate that the main flying controls system has failed or is about to fail, and that the pilot must take the appropriate action.

Operation of a Typical Hydraulic System

24. Hydraulic fluid, which remains fluid at low temperatures, is drawn from the reservoir and pumped at high pressure through the pipelines to the selector-valves. Fig. 4 shows a typical live-line system. With the undercarriage selector-valve set as shown, *i.e.* at the DOWN position, the fluid is pumped through the selector valve into the undercarriage down line and thence to the jack. The second port in the valve provides a free passage for the return fluid from the jack to escape back into the tank through the return pipeline. If the cock is moved to raise the undercarriage, the high-pressure fluid from the pump is then fed to the undercarriage retraction line, and the other port is connected to the return pipeline to the tank; thus the direction of movement of the piston within the jack is reversed. When the control valve is in the intermediate position (as with the flap selector valve shown in Fig. 4) the fluid in both chambers of the jack cylinder is sealed off, no movement can take place, and the jack is said to be hydraulically locked. It should be noted that in some aircraft the hydraulic pumps are electrically driven only when a service is required. Otherwise the pumps are switched off and there is no pressure in the system.

Fire Risk from Hydraulic Fluid

25. Most hydraulic fluids used in aircraft systems are inflammable.

26. If a burst pipe releases hydraulic fluid as a stream, spray, or mist into the interior of the aircraft, immediate action should be taken to counter the risk of fire.

27. The aim is to rid the interior of inflammable vapour as quickly as possible. In an unpressurized aircraft, the windows and escape hatches should be opened to remove the fumes. Enclosed spaces such as radar scanner blisters, bomb bays, and cupboards should also be opened where possible. All galley equipment and cabin

RESTRICTED

heaters should be shut off. Switching electrical equipment, such as inverters, may be impracticable but the danger can be reduced by blocking off the ventilating air to these items (if they are supplied with air from inside the aircraft) by covering them with cockpit or engine covers or articles of clothing. Switching off any circuits that could cause sparking at contactor boxes etc. should be avoided.

28. The use of emergency air for flap and bomb door circuits may discharge more oil mist and this possibility should be remembered.

29. With pressurized aircraft, the opening of windows at high altitude is not possible. It is recommended therefore that the cabin ventilating system be set to flood flow to obtain the most rapid change of cabin air. The precautions concerning electrical sparking, described above, should be taken.

30. Oil in quantity or in large drops is unlikely to ignite through sparks but if allowed to lie on hot metal (*e.g.* combustion heaters) it may readily burn.

PNEUMATIC SYSTEMS

Introduction

31. Pneumatic systems are sometimes used to operate undercarriages, flaps, etc., but are more generally used to operate those services which require less power, such as radiator and oil cooler shutters, supercharger gear-changing mechanisms, gun firing and cocking mechanisms, wheel brakes, and windscreen wipers.

Simplified Pneumatic System

32. Fig. 5 shows the layout of a simplified pneumatic system as used in the Marathon aircraft. This system is similar in principle to the hydraulic system, power being transmitted by air at high pressure *via* selector valves to the jacks which operate the services. Certain additional components peculiar to pneumatic systems are incorporated.

33. **Components and their Functions.** The various components and their functions are described below:—

(a) *Storage Cylinders.* One or more storage cylinders charged to the working pressure of the system (450 lb./sq. in.) supply air for operating the services in low-pressure systems. In other systems the air is stored at 1,000 or

HYDRAULIC AND PNEUMATIC SYSTEMS

3,000 lb./sq. in. to reduce bottle size, but this pressure is decreased by reducing valves to that of the system.

(b) *Compressor.* An engine-driven compressor supplies air at high pressure to keep the storage cylinders fully charged.

(c) *Oil and Water Trap.* This is fitted to remove oil and water from the air supplied by the compressor.

(d) *Pressure Regulator.* A pressure regulator is installed to serve a similar purpose to the automatic cut-out in the hydraulic system.

(e) *Air Filter.* This is used to ensure that particles of solid matter are removed from the working air.

(f) *Pressure Relief Valve.* A pressure relief valve is fitted to ensure that a dangerous pressure build-up does not develop in the storage cylinders and supply pipelines from the compressor if the pressure regulator should fail. This valve is sometimes fitted on or near the compressor and may be part of the pressure regulator.

(g) *Pressure Reducing Valve.* A pressure reducing valve is incorporated in systems in which the storage cylinders are charged to a higher pressure than the system pressure. The function of the pressure reducing valve is to ensure that the pressure of air entering the *working system* is reduced to the correct value (usually between one-third and two-thirds of the full storage pressure).

(h) *Pressure Maintaining Valve.* A pressure maintaining valve is usually included if the system operates more than one service. This is arranged to isolate all but the most essential services should the storage pressure fall below a predetermined minimum, usually about 220 lb./sq. in. This ensures that sufficient air is conserved for the most important services, *i.e.* undercarriage and wheel brakes.

(j) *Selector Valves and Operating Jacks.* These serve a similar purpose to those in the hydraulic system except that the return air from the jacks is discharged to atmosphere.

(k) *Wheel Brake Control Unit.* This incorporates an additional pressure reducing valve which limits the maximum pressure for brake operation to between 80 and 150 lb./sq. in., depending on the installation. It also incorporates the brake control valve, operated by the brake lever. The wheel brake control unit admits air to the brake pipelines at a controlled pressure proportional to the degree of brake-lever movement.

RESTRICTED

A.P. 129, VOL. 1, PART 1, SECT. 6, CHAP. 3

(l) *Wheel Brake Differential Unit.* This is a valve frequently combined with the wheel brake control unit and connected to the rudder control. It varies the ratio between the pressure supplied to the port and starboard wheel brakes when the rudder bar is moved with the brakes applied. This enables directional control to be maintained during taxiing (when the rudder is ineffective).

(m) *Pneumatic Triple-Pressure Gauge.* This gauge combines three pressure indicating units, one of which indicates the main storage supply pressure, while the other two indicate the pressure at their respective wheels when the brakes are applied.

Locking Devices

34. Pneumatically operated undercarriages have mechanical up and down locks. If the pneumatic system fails the up-locks may be released manually by an emergency control.

Emergency Operation of the Services

35. In the system shown (Fig. 5) the undercarriage may be lowered by gravity in an emergency. However, some aircraft carry a reserve air bottle charged for emergency use, which is operated from a separate control. Similarly the flaps may be operated after selecting flaps down, by operating the emergency air control.

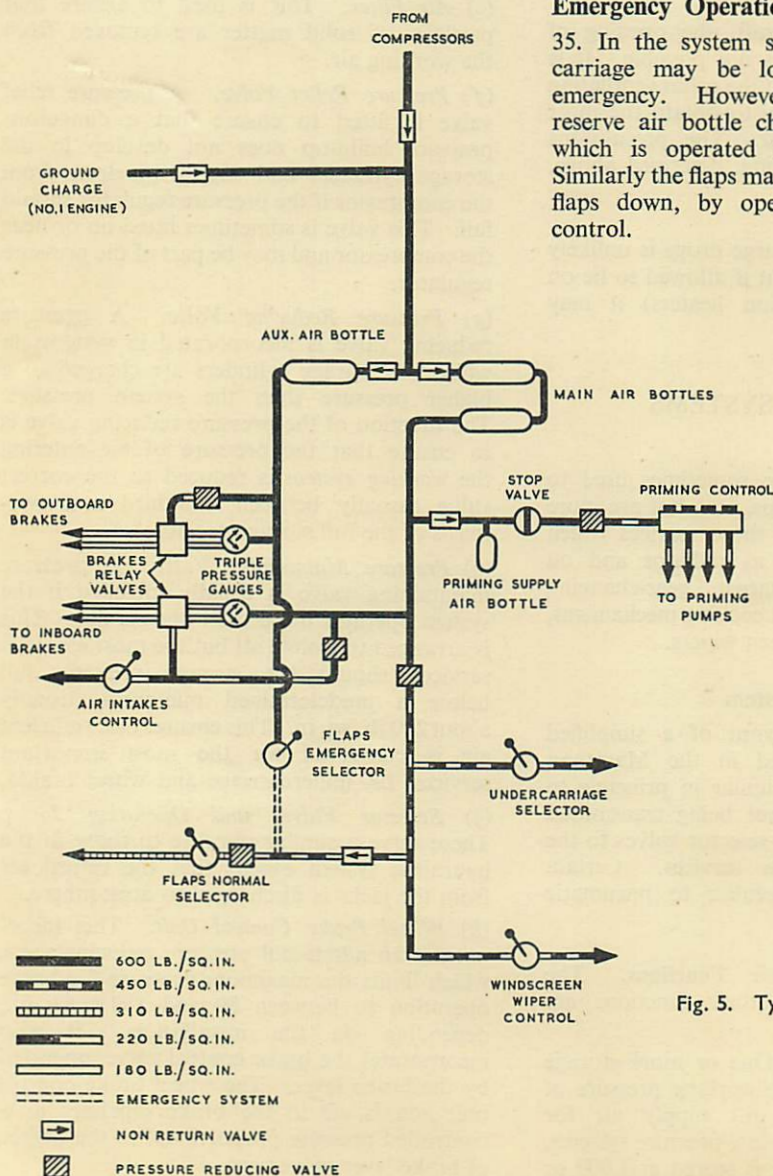


Fig. 5. Typical Pneumatic System.

This file was downloaded
from the RTFM Library.

Link: www.scottbouch.com/rtfm

Please see site for usage terms,
and more aircraft documents.

