8 Hydraulic Power (ATA 29)

8.1 Definition

Those units and components which furnish hydraulic fluid under pressure (includes pumps, regulators, lines, valves, etc.) to a common point (manifold) for redistribution to other defined systems. (**ATA 100**)

8.2 Purpose

The **purpose of the hydraulic system** is to assist the pilot in accomplishing mechanical task that would otherwise be impractical or impossible because of the level of force, work, or power required. On smaller aircraft the flight control surfaces are moved by pilot force. On larger and faster aircraft this becomes impossible and so hydraulic power is applied. A total failure of the flight control system evidently has a catastrophic effect. Consequently, a failure of the hydraulic power supply of large aircraft has to be extremely improbable. This required level of safety is achieved with redundancy through three or even four independent hydraulic subsystems.

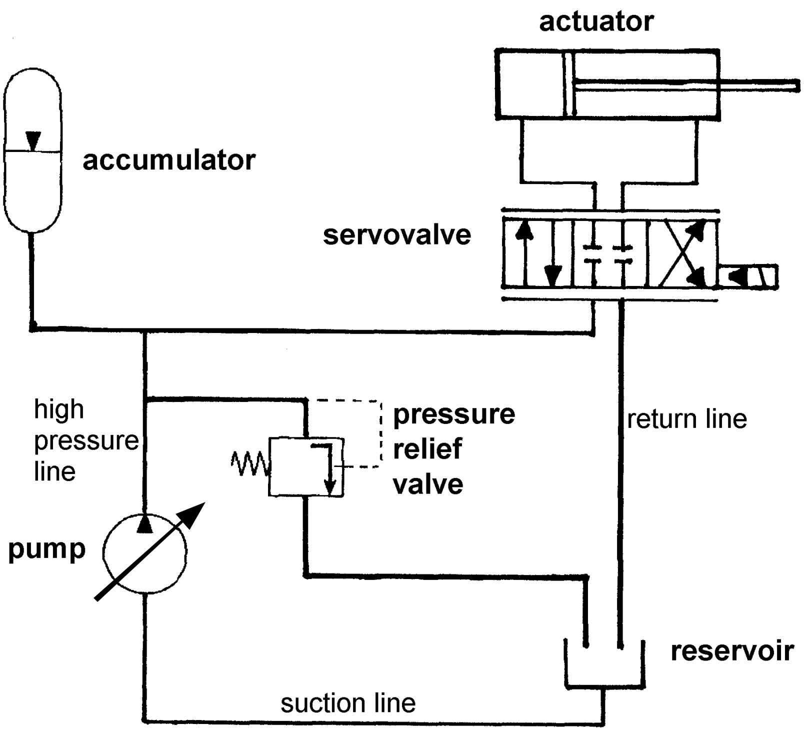


Figure 8.1 A basic hydraulic system

8.3 Principle

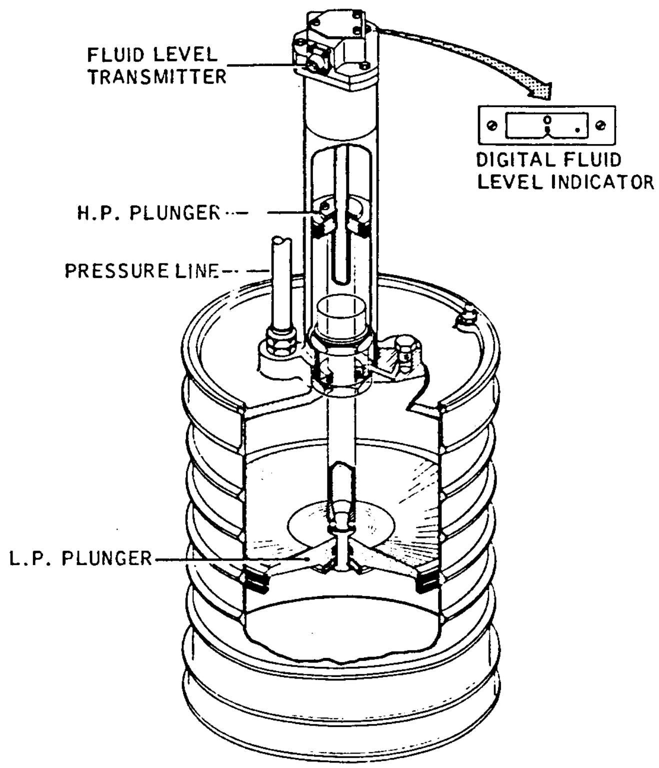
Figure 8.1 shows the **principle of a hydraulic system**. Hydraulic fluid is contained in a *reservoir*. Through a suction line the *pump* draws fluid from the reservoir and puts is at a higher pressure. Today aircraft hydraulic systems are typically designed to a nominal pressure of 206 bar (3000 psi). The trend is toward higher system pressure: 345 bar (5000 psi). An *accumulator* serves as temporary energy storage and is able to store or redistribute surplus high-pressure fluid. A *pressure-relief valve* is able to shortcut the high-pressure line to the reservoir in case of a system malfunction leading to higher pressure than specified. The pressure differential supplied by the pump is used by hydraulic consumers. The example shows a typical consumer in the flight control system. An actuator piston rod has to move in and out in order to deflect a control surface (not shown). The actuator piston is moved through hydraulic fluid that enters the left actuator chamber and fluid that leaves the right actuator chamber (or vice versa). A valve schedules the required fluid flow. Shown is a *servo valve*. The valve has four connections to hydraulic tubes: one connection to each of the two actuator chambers, one connection to the high-pressure line, and one connection to the return line. The valve may be moved into one of three positions that lead to piston rod extension, piston rod retraction, or no piston rod movement. In the case of a flight control consumer, it is necessary that the valve moves gradually from one position into the other to allow a proportional control of the surface. In case the of landing gear extension and retraction, a *selector valve* would be used. The selector valve allows three distinct valve positions without any intermediate positions.

During system design the complete circuit, including hydraulic power generation, distribution, and consumption, has to be analyzed. According to the ATA breakdown, the consumers with their valves are allocated to their respective system. ATA 29 deals only with power generation and distribution.

Three types of **hydraulic fluids** exist: *vegetable based*, *mineral based*, and synthetic or *phosphate ester-based*. Transport category aircraft use the purple-colored phosphate ester-based fluid – most commonly Skydrol® LD. Skydrol® shows good performance even at low temperatures, excellent flammability characteristics, and minimal effects on most common aircraft metals, but does react with certain types of paint and can be an eye and respiratory irritant.

8.4 Components

The **reservoir** acts as a storage tank for the system's fluid. Reservoirs can be broken down into two basic types, *in-line* and *integral*, and these can be further classified as *pressurized* and *unpressurized*. Integral reservoirs, found on small aircraft, are combined with the pump. Aircraft that operate at low altitudes could use unpressurized reservoirs that vent the reservoir to the atmosphere. Other aircraft positively pressurize the reservoir with air from the pneumatic system, hydraulic pressure (bootstrap reservoir) (Figure 8.2), or a spring. In a bootstrap reservoir, high pressure (HP) fluid acts on a small plunger that is coupled with a large plunger that in turn acts on the low pressure (LP) fluid in the reservoir. Commonly, air pressure is used for reservoir pressurization. The air pressure usually needs to be reduced by a



pressure regulator. It then enters the airspace above the fluid in the reservoir.

Figure 8.2 Hydraulically pressured reservoir known as bootstrap reservoir (VFW 614)

Commonly used are axial multiple-piston **pumps**. The two principles applied are *constant displacement* and *variable displacement*. The shaft can be driven by the aircraft engine, by an electric motor, or through a device powered by the pneumatic system. The shaft turns the cylinder block with the pistons. Whenever an elevated piston is pushed into the cylinder block, fluid is ejected into an out port. Accordingly, during the other half of the revolution on its way back to the elevated position, the piston draws fluid from an in port into the cylinder block. Constant displacement pumps deliver exactly the same amount of fluid every revolution and must incorporate a pressure regulator. Most widely used, however, are *variable* *displacement axial multiple-piston pumps* (Figure 8.3). The variable displacement is achieved by a swashplate. The angle of the swashplate is adjusted by a pressure controller. At highest swashplate angle, the pump achieves its maximum flow rate, and at zero angle there is no fluid flow.

For minor tasks, *hand pumps* may be applied. A *ram air turbine* (RAT) (Figure 8.8) may be turned into the free stream of air to power a hydraulic pump. This is done in the event of an engine failure or a major electrical system failure.

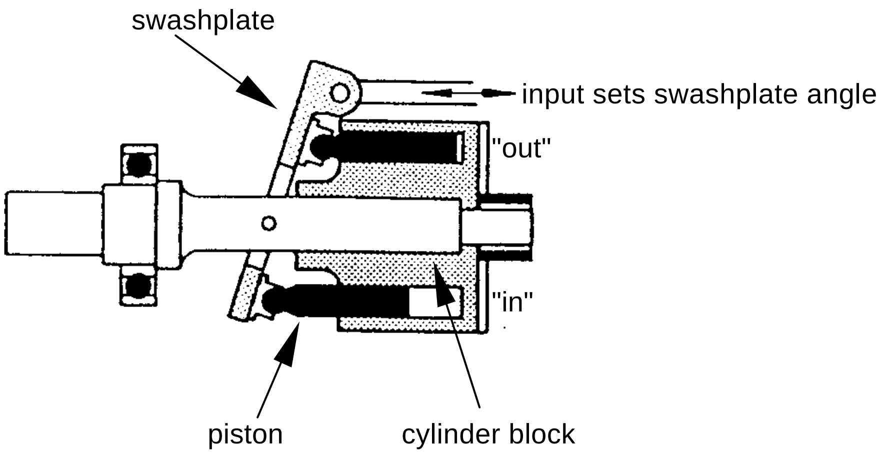


Figure 8.3 Variable displacement axial multiple-piston pump

Three types of **accumulators** are known: The *diaphragm-type accumulator*, the *bladder type accumulator*, and the *piston type accumulator* (Figure 8.4). Diaphragm, bladder, or piston divide the fluid chamber from the nitrogen chamber of the accumulator. Hydraulic fluid is allowed to flow freely into and out of the fluid chamber of the accumulator. The compressible nitrogen acts like a spring against the hydraulic fluid. The accumulator acts as a high-pressure and fluid storage and eliminates shock waves from the system.

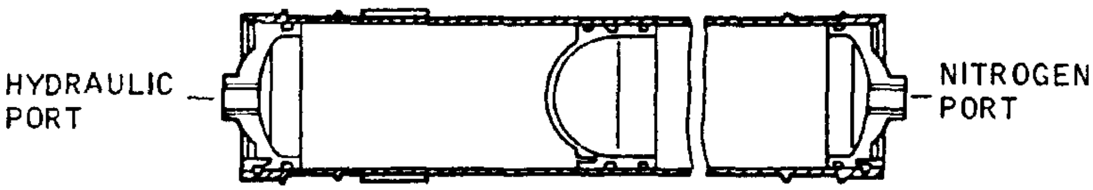


Figure 8.4 Piston type accumulator (VFW 614)

Filters are installed in the high-pressure and the return line. Three filter types are in use: micron, porous metal, and magnetic. *Micron filters* contain a treated paper element to trap particles as the fluid flows through the element. *Porous metal filters* are composed of metal particles joined together by a sintering process. *Magnetic filters* attract metal particles. Filters consist of a head assembly that contains the fluid line connections and a bypass valve to prevent the system from becoming inoperative should the filter become clogged, a bowl assembly, and the filter element. Fluid enters through the head into the bowl and leaves through the filter element and out of the head (Figure 8.5).

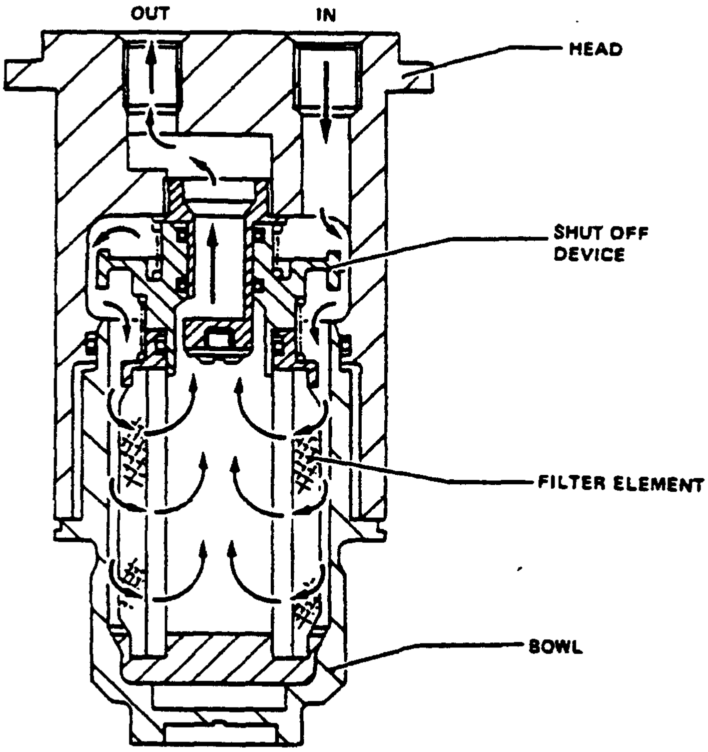


Figure 8.5 Low pressure filter (A321)

Two principle types of **valves** are used in the hydraulic system: Flow control valves and pressure control valves. *Flow control valves* route the fluid through the system. Examples are s*elector valves,* which permit the user to channel the fluid selectively and *servo valves,* as explained above. *Check valves* permit flow only in one direction. A *hydraulic fuse* is a safety valve that prevents fluid flow in the event of a serious system leak. Examples of *pressure-control valves* are the *pressure-relief valve* and the *pressure regulator*. A *priority valve* is mechanically identical to a pressure relief valve, set to an opening pressure below nominal pressure. The priority valve is closed at low pressure and allows flow to secondary consumers only if a minimum system pressure has been reached. In this way it gives priority to primary consumers located upstream of the priority valve.

Hydraulic **fluid lines** are classified as rigid or flexible. *Rigid lines* are made of either aluminum for return and suction lines or of stainless steel for high-pressure lines. *Flexible lines* are hoses typically wrapped with stainless steel braid. *Fittings* are used to connect fluid lines with other hydraulic components.

"The **power transfer unit** (PTU) is a device which uses some of the hydraulic power in one hydraulic system to supplement the hydraulic power in a second system without interchange of fluid between the systems" (**ARP 1280**).

PTUs can be designed either to transfer power from one system to a second system in one direction only (*unidirectional PTU*) or to transfer power in either direction between two systems (*bidirectional PTU*) (Figure 8.6). The basic concept consists of a hydraulic motor driving a pump, mounted back-to-back. The displacement of each of these may be the same or different. Accordingly, PTUs can be used as pressure reducers, as pressure intensifiers, or to maintain the same pressure in both systems. If bidirectional operation is required, both the pump and the motor reverse their functions. That unit which was previously the pump will operate as motor and vice versa. If the pressure relationship between the two systems must remain the same in both directions of operation, at least one of the units must be of a variable displacement design.

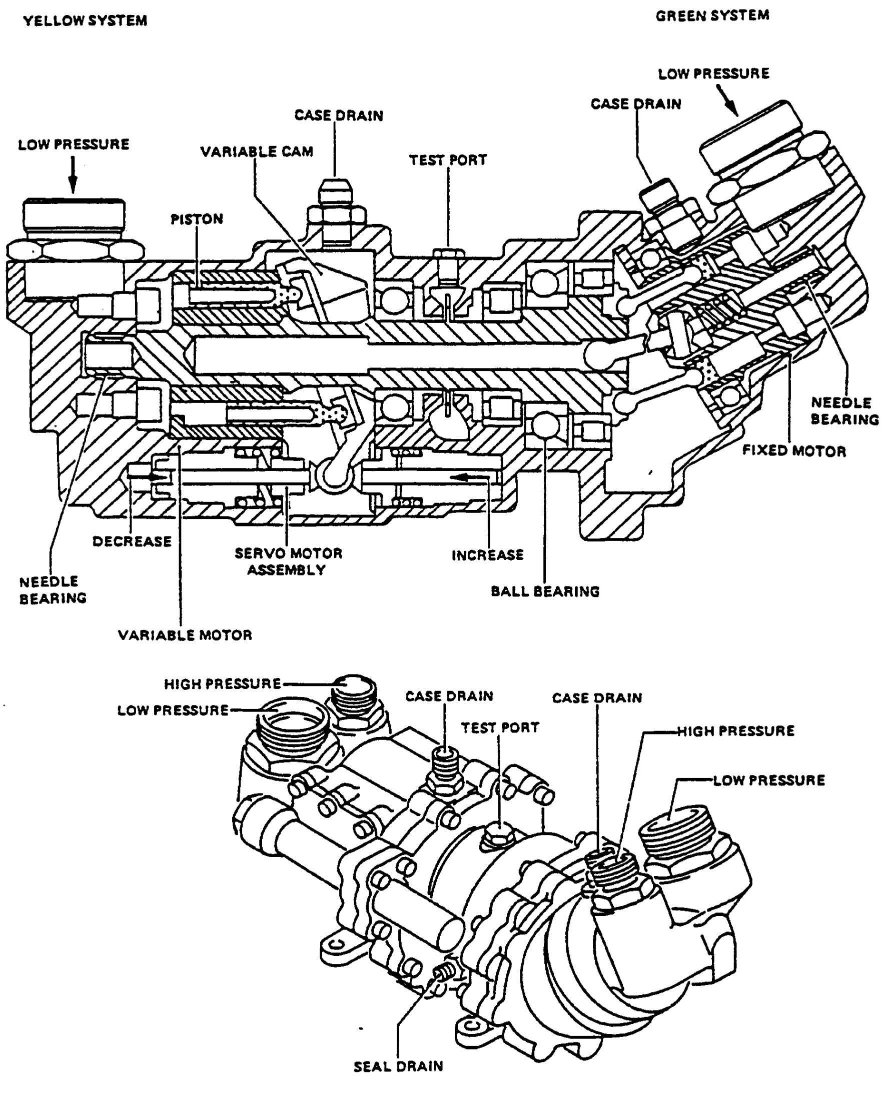


Figure 8.6 Bidirectional power transfer unit (PTU) (A321)

8.5 Example: Airbus A321

The Airbus A321 has **three main hydraulic (sub)systems** (Figure 8.7). They are identified as

- the Green system
- the Blue system
- the Yellow systems.

Together they supply hydraulic power at 20.7 MPa (3000 psi) to the **main power users**. These include:

- flight controls
- landing gear
- cargo doors
- brakes
- thrust reversers.

Main system pumps are the engine-driven pumps (EDPs) in the Green and Yellow system as well as the electric pump in the Blue system. The three main systems automatically supply hydraulic power when the engines operate. The two EDP are connected directly to their related engine (through the accessory gearbox), and the Blue electric pump operates when any one of the two engines starts. The three system main pumps are usually set to operate permanently. If necessary (because of a system fault, or for servicing), the pumps can be set to off from the flight compartment.

If the main pumps cannot be used, it is possible to pressurize each hydraulic system with one or more of the **auxiliary system pumps**.

- The Green system can also be pressurized by the power transfer unit (PTU).
- The Blue system can also be pressurized by the ram air turbine (RAT) (Figure 8.8).
- The Yellow system can also be pressurized by the Yellow electric pump or the power transfer unit (PTU).

Pressurization of the hydraulic systems on the ground is possible as follows:

- Yellow system – with the Yellow electric pump,
- Green system – with the Yellow electric pump (through the PTU),
- Blue main system – with the Blue electric pump.

For maintenance, all of the systems can be pressurized from a ground hydraulic supply. Connectors are installed on the ground service panels of the three systems. The cargo doors can also be operated with a hand pump in the Yellow system.

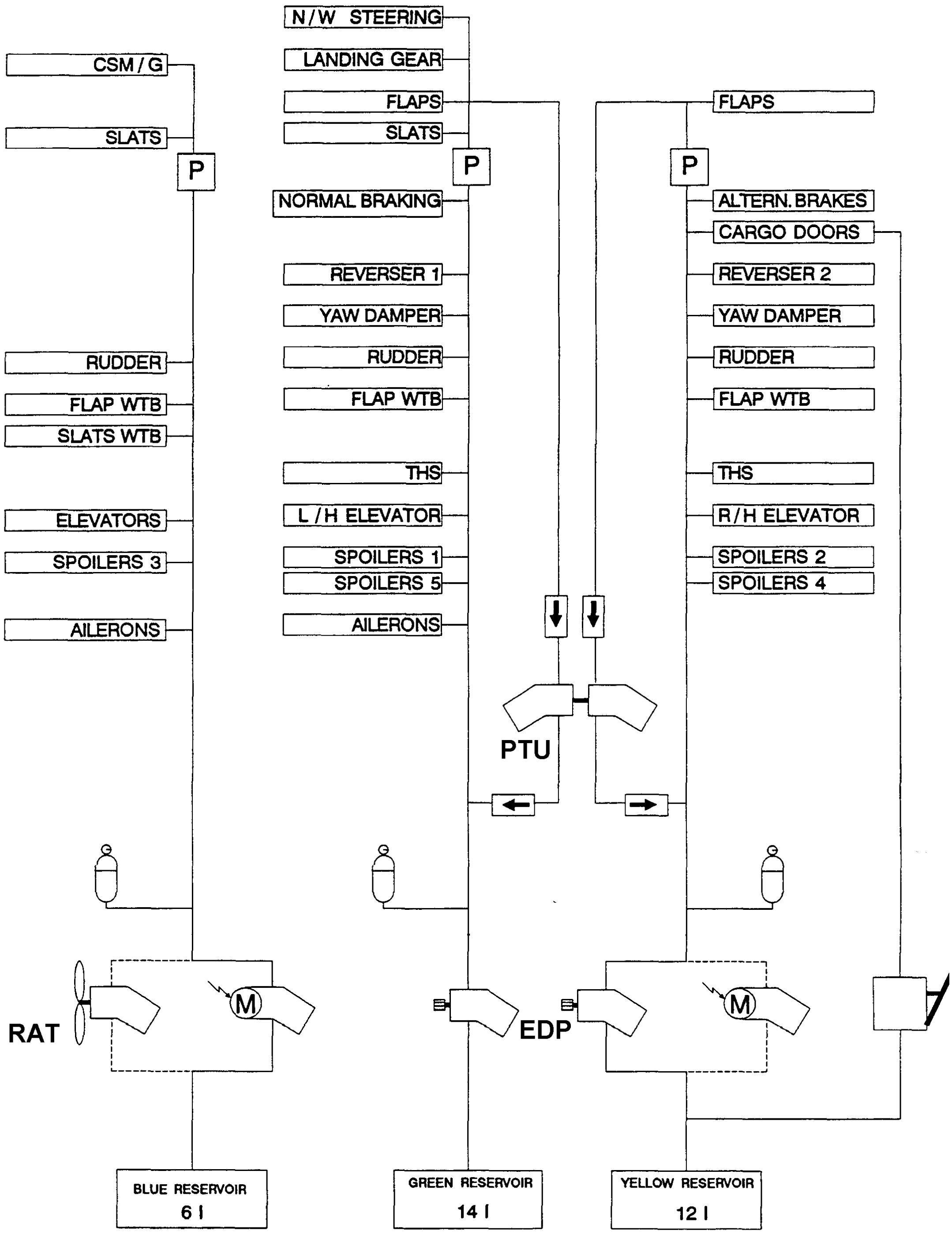


Figure 8.7 A321 hydraulic system schematic

EDP : Engine Driven Pump
M : Electric Pump
RAT : Ram Air Turbine
PTU : Power Transfer Unit
P : Priority Valve
→ : Check Valve (indicating flow direction)
CSM/G : Constant Speed Motor/Generator (emergency generator)
THS : Trimmable Horizontal Stabilizer (horizontal tail)
WTB : Wing Tip Brake (in high lift system)

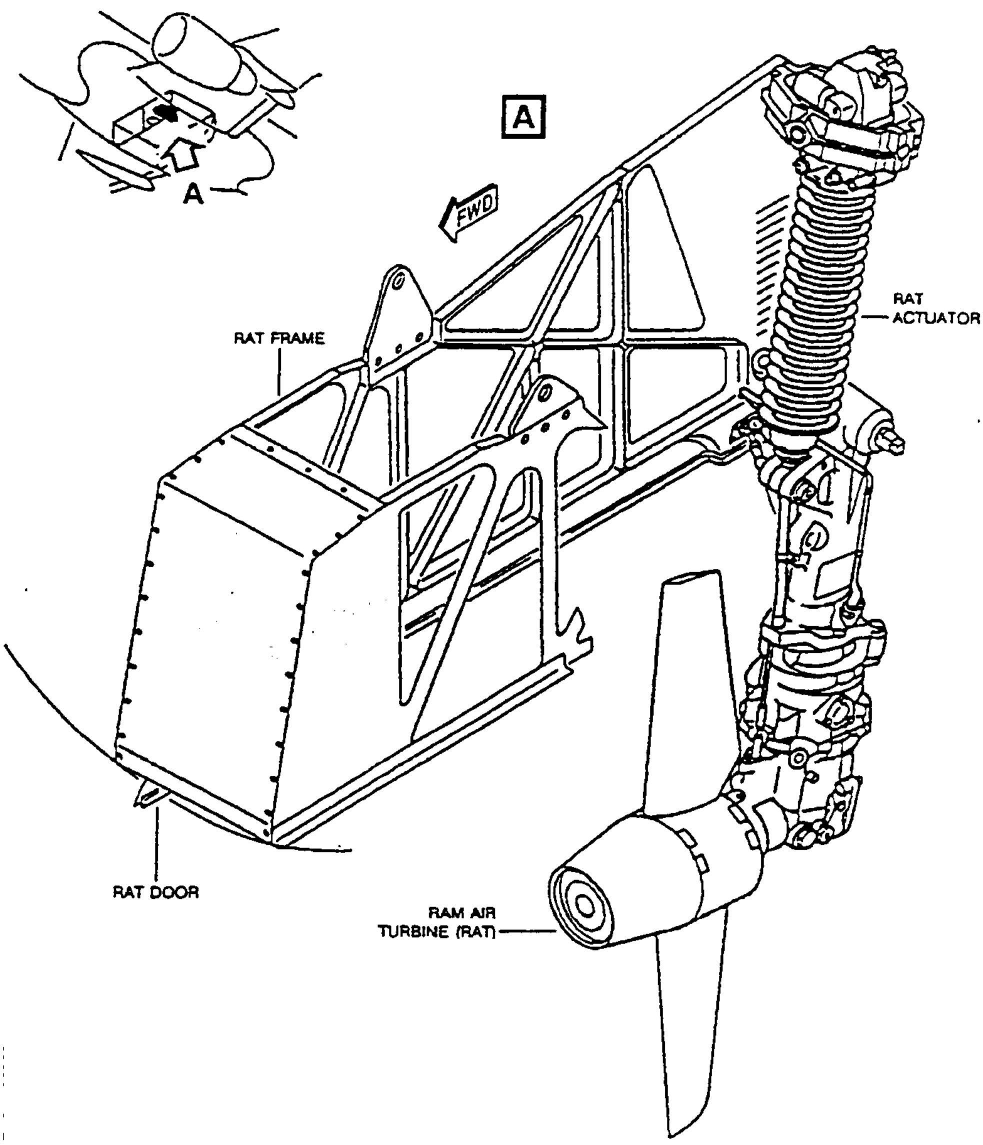


Figure 8.8 A321 ram air turbine (RAT)