DESIGN PHILOSOPHIES

The aircraft manufacturer will attempt to design an aircraft to take into account all the loads that it may experience in flight. There are various guidelines, formulae and experience to guide them in the design of a good fail safe/damage tolerant structure.

Safe Life
The safe life of an aircraft structure is defined as the minimum life during which it is known that no catastrophic damage will occur. Life-counts for components of assemblies may be recorded as number of flying hours, cycles of landing or pressurization events or even on a calendar basis. After the elapsed life-count or fatigue cycle (typically pressurisations or landings has been reached, the item is replaced or overhauled. In the interim (operational life) of the Aircraft, and to minimise the chances of failure due to fatigue, aircraft designers apply the principle of **Fail safe** construction or **Damage tolerance.**

Fail Safe or Damage Tolerant Structure
Large modern Aircraft are designed with a **Fail-safe** or **Damage-tolerant** structure. This can be described as a structure in which a failure of a particular part is compensated for by an alternative load-path provided by an adjacent part that is able to carry the loads for a **limited time period.** Typically this is a structure which, after any single failure or crack in any one structural member can **safely** carry the normal operating loads until the **next periodic inspection**. True dualling of load-paths in common practice could be found in wing attachments and also in vertical stabiliser and horizontal stabiliser attachment points.

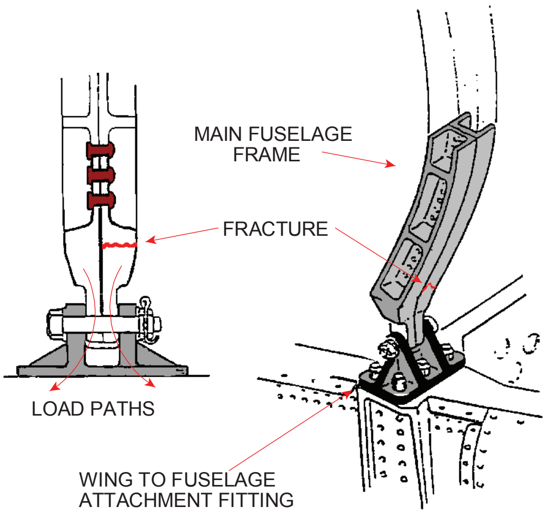

Figure 1.4

Detection of faults is reliant upon a planned inspection programme capable of finding such failures. In order to gain access to the vulnerable areas a certain amount of dismantling is necessary although the use of non-destructive testing (NDT) may be employed in less critical areas. The disadvantage of true dualling of load-paths is that it is fundamentally very heavy.

Modern concepts of construction employ the **'Stressed-Skin'** or **'Semi-Monococque'** style of construction where each piece of the Aircraft has its part to play in spreading loads throughout the Airframe and is tolerant to certain amount of damage. The programmed inspection cycle periodicy is determined on the basis that if a crack of detectable length has been missed at the first inspection, the structure will allow this crack to develop until a subsequent inspection before it becomes critical. The criteria of inspection cycles, Design Limit Loads, and Design Ultimate Loads are agreed at the time of certification.

Damage Tolerant Structure

Fail safe structures are rather heavy due to the extra structural members required to protect the integrity of the structure. Damage tolerant structure eliminates the extra structural members by spreading the loading of a particular structure over a larger area. This means that the structure is designed so that damage can be detected during the normal inspection cycles before a failure occurs.

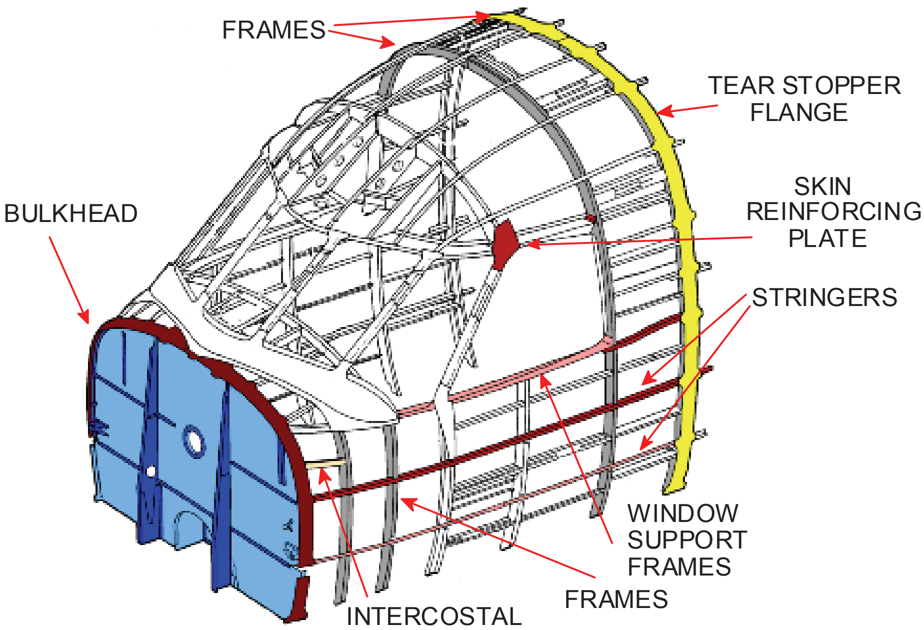

Figure 1.5: Damage tolerant structure.

Fatigue
A structure which is subjected to continual reversals of loading will fail at a load of less than would be the case for a steadily applied load. This is known as **Fatigue.** The failing load will depend on the number of reversals experienced. It can be seen in the example below that if the applied stress was 80% of the ultimate stress, the specimen could expect to fail after 100 applications but if the applied stress was reduced to 20% the failure would not occur until 10 million applications.

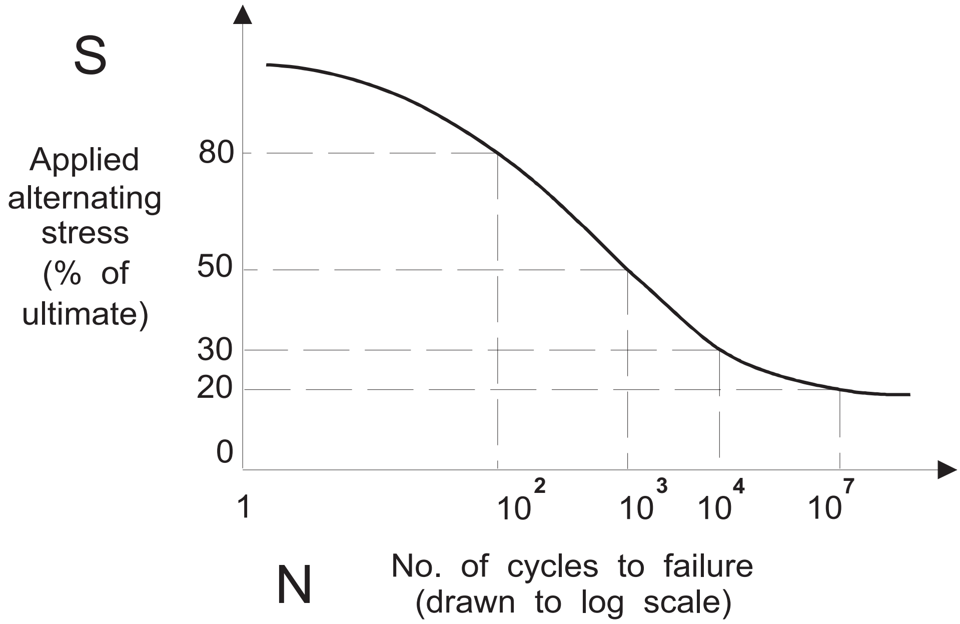

Figure 1.6: Fatigue.

Station Numbers
A method of locating components on the aircraft must be established in order that maintenance and repairs can be carried out. This is achieved by identifying reference lines and **station numbers** for fuselage, wings, empennage, etc. Fuselage station lines are determined by reference to a **zero datum line (fuselage station 0.00)** at or near the forward portion of the aircraft as defined by the manufacturer. Station numbers are given in inches forward (negative and given a - sign) or aft (positive and with a +sign) of the zero datum. Wing stations are measured from the centre line of the aircraft and are also given in inches left or right of the centre line. Vertical position from a ground line or horizontal datum can be known as a **Water Line (WL) or Buttock Line**, given as a dimension in inches from the horizontal datum.

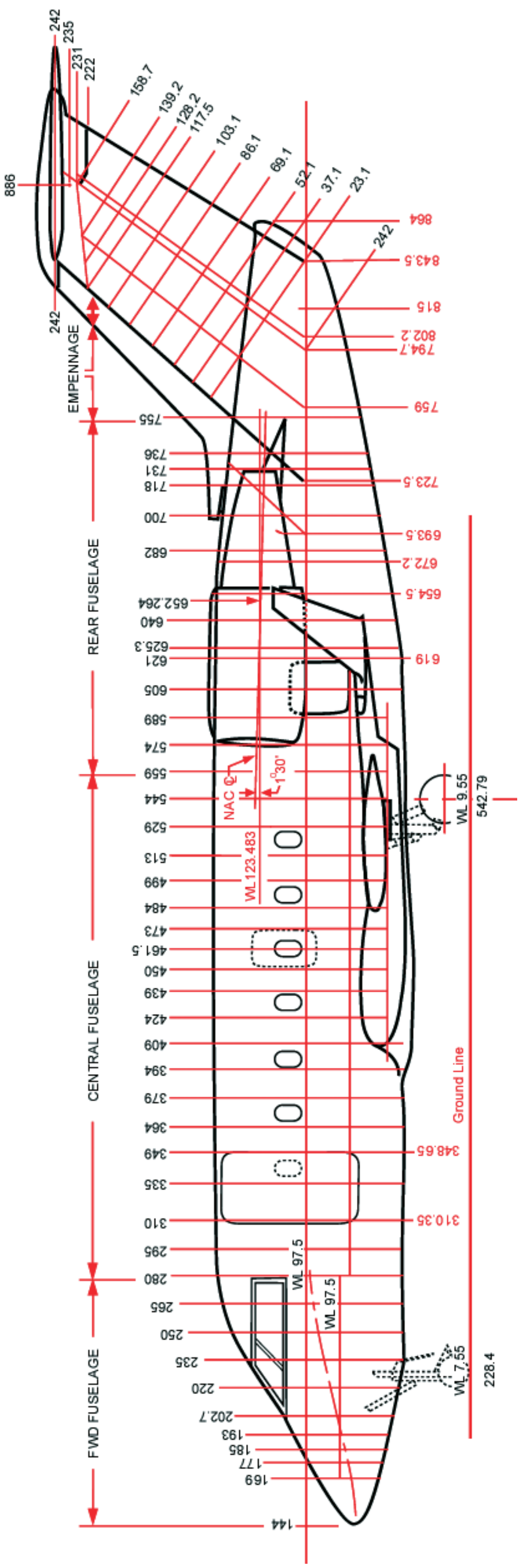

Figure 1.7: Various stations on a corporate jet aircraft.

CHAPTER TEN

AIRCRAFT PNEUMATIC SYSTEMS

Contents

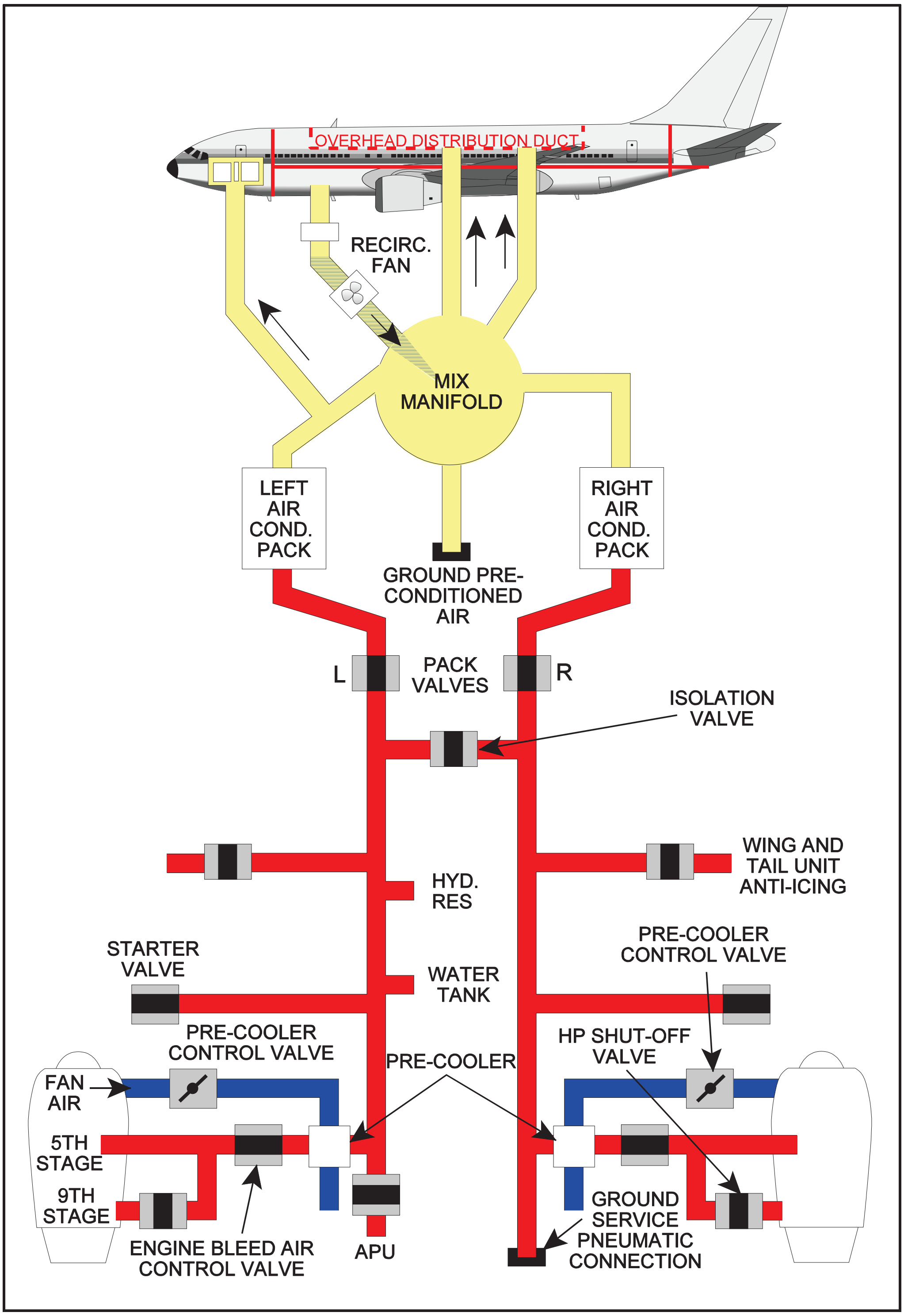

Figure 10.1a: Air sources and uses (schematic).

AIRCRAFT PNEUMATIC SYSTEMS

A pneumatic system is fitted in most modern aircraft to supply some or all of the following aircraft systems.

- Airconditioning
- Pressurisation
- Aerofoil and engine anti-icing
- Air turbine motors
    - Engine starting
    - Hydraulic power
    - Thrust reverse
    - Leading and trailing edge flap/slat operation
- Pneumatic rams, e.g. thrust reverser actuation
- Hydraulic reservoir and potable water tank pressurisation
- Cargo compartment heating

Most of these systems use high volume low pressure airflow bled from the compressor stages of a gas turbine engine, see *Figures 10.1a and 10.1b*. Other sources of supply are engine driven compressors or blowers, auxiliary power unit bleed air and ground power units.

Some older turbo-propeller and piston engined aircraft use high pressure pneumatic systems for the operation of landing gear, brakes, flaps etc. (Fokker F.27) but these aircraft are a minority and hydraulic power has become the normal method of operation for these systems.

ENGINE BLEED AIR SYSTEM

The engine bleed air system consists of the power source (the engine) and control devices for temperature and pressure regulation during operation. Because of the great variation of air output available from a gas turbine engine between idle and maximum rpm there is a need to maintain a reasonable supply of air during low rpm as well as restricting excessive pressure when the engine is at maximum rpm. It is usual to tap two pressure stages to maintain a reasonable pressure band at all engine speeds.

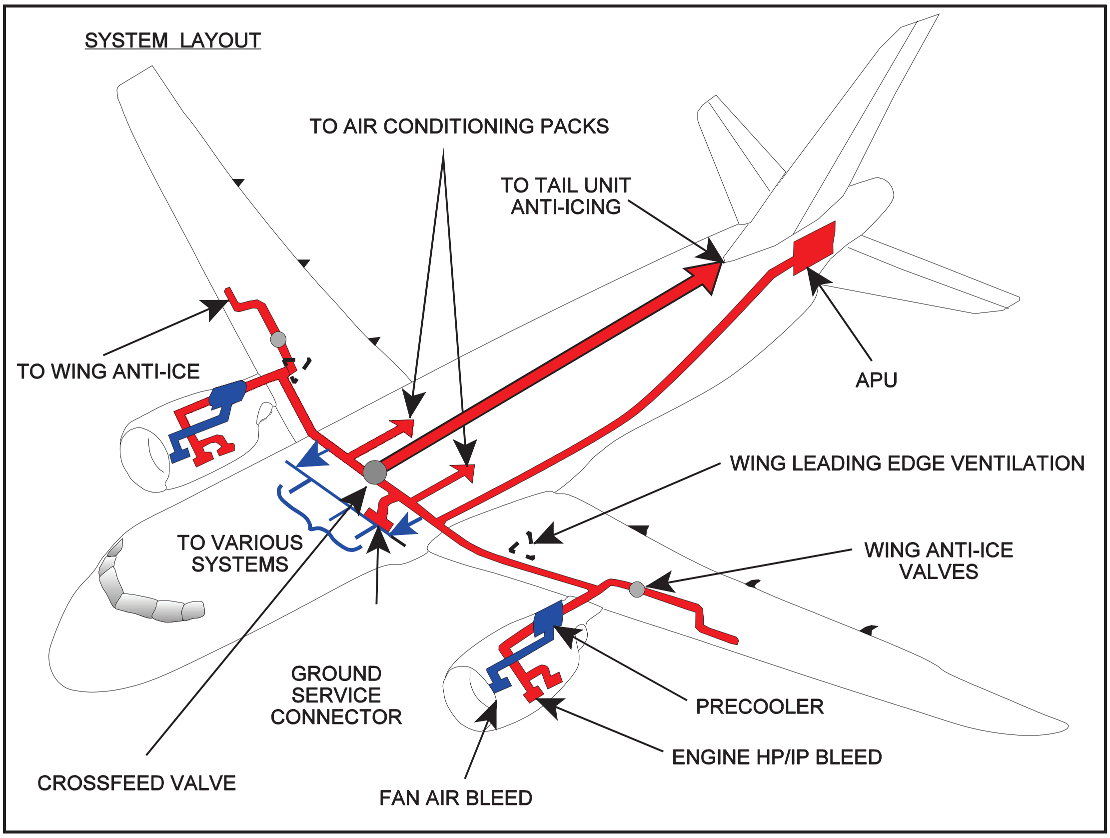

Figure 10.1b: Air sources and uses (pictorial).

Figure 10.1a shows a typical bleed air system with air being ducted from two stages of the compressor, a low pressure (LP) stage and a higher pressure (HP) stage. In this case the stages used are the 5th and 9th. The two sources are combined together at the High Pressure Shut-Off Valve (HPSOV). This valve is pressure sensitive and pneumatically operated and is open when there is insufficient air pressure from the LP system to maintain the required flow. As the engine speeds up the LP air pressure will increase until it closes the high pressure shut-off valve so that, in all normal stages of flight, bleed air will come from the LP stages. The high pressure shut-off valves are designed to open relatively slowly on engine start up or when airconditioning is selected to minimise the possibility of a surge of air pressure. They are also designed to close very quickly to prevent an ingress of fumes or fire to the cabin in the event of an engine fire.

The bleed air control valve is the separation point between the engine and the pneumatic system manifold and allows the bleed air to enter the pneumatic system and is controlled electrically from the flight deck. Non-return valves (NRV) are installed in the LP stage ducts to prevent HP air entering the LP stages of the engine when the high pressure shut-off valve is open.

Most multi-engined aircraft also keep the supplying engines or sides separate with each engine supplying its own user services. These are kept independent by **isolation valves** which are normally closed but which may be opened if an engine supply is lost to feed the other side's services.

The system will be fitted with a duct pressure gauge, valve position indicators and overheat sensors both inside and outside the supply ducts.