13 Pneumatic (ATA 36)

13.1 Definition

> *Those units and components (ducts and valves) which deliver large volumes of compressed air from a power source to connecting points for such other systems as air conditioning, pressurization, deicing, etc.* (**ATA 100**)

13.2 High-pressure Pneumatic Systems

High-pressure pneumatic systems must be differentiated from *low-pressure pneumatic systems.* High-pressure pneumatic systems, much like hydraulic systems, may apply a nominal system pressure of 20.7 MPa (3000 psi). In contrast, low-pressure pneumatic systems may operate at only 0.3 MPa (44 psi).

High-pressure pneumatic systems work very similarly to hydraulic systems. The difference is that in pneumatic systems compressible air is used instead of incompressible hydraulic fluid. Pneumatic systems do not need a reservoir because air is directly available from the operating environment. The air is put to high pressure in a *compressor*. The pneumatic pressure is stored in an *air storage bottle*. The bottle can provide a short-burst reserve flow for heavy operations, or limited emergency flow in case of compressor failure. The compressed air is routed through *tubes*, *filters*, *moisture separators*, and *valves* to the consumer. After having done its duty at the consumer, the air is simply released. In a high-pressure system it is of the utmost importance that the air in the system be completely dry. Moisture in the system can cause freezing of units and thus interfere with normal operation. High-pressure pneumatics have been applied, e.g., for landing gear extension and retraction, nose wheel steering, as well as to wheel and propeller braking. The Fairchild Hiller FH-227 is equipped with such a high-pressure pneumatic system.

High-pressure pneumatics shows advantages and disadvantages *compared to hydraulics* in aircraft operation:

Advantages:

- Air is a readily available, nonaggressive, clean, and lightweight fluid.
- There is no need for return lines.

Disadvantages:

- Due to compressibility of the air, pneumatic systems lack the instant response that hydraulic systems provide.
- The rate of movement of pneumatic actuators is highly load-dependent.
- An actuator position cannot easily be controlled since even when the flow has stopped, the actuator will move in response to load variations.

- Pneumatic systems are inefficient in transmitting power because energy is lost in compressing the air.

The many more disadvantages than advantages explain why high-pressure pneumatic systems are rarely used. This is much different to the low-pressure pneumatics that is used extensively on most aircraft.

13.3 Low-pressure Pneumatic Systems

Low-pressure consumers are the
- air conditioning (including cabin pressurization)
- wing and engine anti icing
- engine starting
- hydraulic reservoir pressurization
- potable water pressurization
- air-driven hydraulic pumps.

One aircraft type will not necessarily use all these pneumatic functions.

Pressurized air is generated and used in aircraft ranging from light single-engine aircraft up to big turbine-powered transport aircraft. The simplest **source of pressurized air** is *ram air*. Reciprocating engines can supply pressure from a *supercharger* (driven by the engine primarily used to produce compressed air for the combustion process), a *turbocharger* (similar to a supercharger but driven by exhaust gases), or an *engine-driven compressor*. Turbine-powered aircraft usually use *bleed air* as a source for compressed air. The bleed air system will now be explained in more detail.

The engine **bleed air system** extracts pressurized air from one or more bleed ports at different stages of the engine compressor of each engine on the aircraft. The system controls the pressure and temperature of the air and delivers it to a distribution manifold. The pressure is controlled by a *pressure-regulating valve*, and the temperature is lowered in a *precooler* with fan air or ram air. Bleed air form alternate sources such as the auxiliary power unit (APU) or a ground cart is also connected to the distribution manifold. The consumers are supplied from the distribution manifold. Additional bleed air from each engine may be taken directly off the engine (independent from the pneumatic system) for engine demands such as engine intake antiice. *Isolation valves* and a *crossbleed valve* are required in the distribution manifold to maintain essential functions in the event of a failure in the supply or in a consumer. *Check valves* are required to prevent reverse flow. The Airbus A321 (Figure 13.1) shows all those elements that are typical for a conventional bleed air system.

Pressure control is set to the lowest level acceptable to all consumers. Engine bleed port switching is designed to use intermediate pressure (IP) bleed air during cruise. When intermediate stage bleed pressure is not adequate, the system switches automatically to off-takes from the high-pressure (HP) stage. A check valve prevents air from flowing back to the IP port. Pressure control may be pneumatic or computer controlled electro-pneumatic.

With modern high-bypass-ratio engines the **fuel burn penalty** of a given amount of engine bleed air has been decreased. However, high-bypass-ratio engines also show decreased total compressor airflow relative to engine thrust. Hence, less bleed air is available form these engines. The economic impact of the bleed air system is by no means negligible. An overall economically optimum solution has to take into account all aspects that were named in Subsection 1.8. These design details could be considered:

- Use of lowest acceptable compressor stage bleed port.
- Strict control of leakage from pneumatic systems.
- Optimized precooler design with a trade-off among weight, price, and coolant air usage.
- Optimum proportioning of bleed flows from multiengine installations.
- Use of multiple bleed ports, i.e., tapping at more than the typical two compressor stages.
- Consideration of alternate sources of compressed air (APU, mixing ejector, auxiliary compressor: engine driven, pneumatic, hydraulic, or electric driven).

At the airport, an external supply with pressurized air (in contrast to an APU supply) is environmentally more friendly and can also be more economical.

13.4 Example: Airbus A321

The A321 pneumatic system supplies high-pressure hot air to these **consumers**:

- air conditioning
- engine starting
- wing anti icing
- hydraulic reservoir pressurization
- potable water pressurization.

There are two **engine bleed systems** (Figure 13.1): the left side (engine 1) (Figure 13.2 and 13.3) and the right side (engine 2). A crossbleed duct connects both engine bleed systems. A *crossbleed valve* mounted on the crossbleed duct, allows the left and the right side to be either interconnected or separated. During normal operation, the crossbleed valve is closed and the systems are separated. There are two interconnected *bleed monitoring computers* (BMC 1 and BMC 2). BMC 1 is used primarily for engine 1 bleed system, BMC 2 is used primarily for engine 2 bleed system.

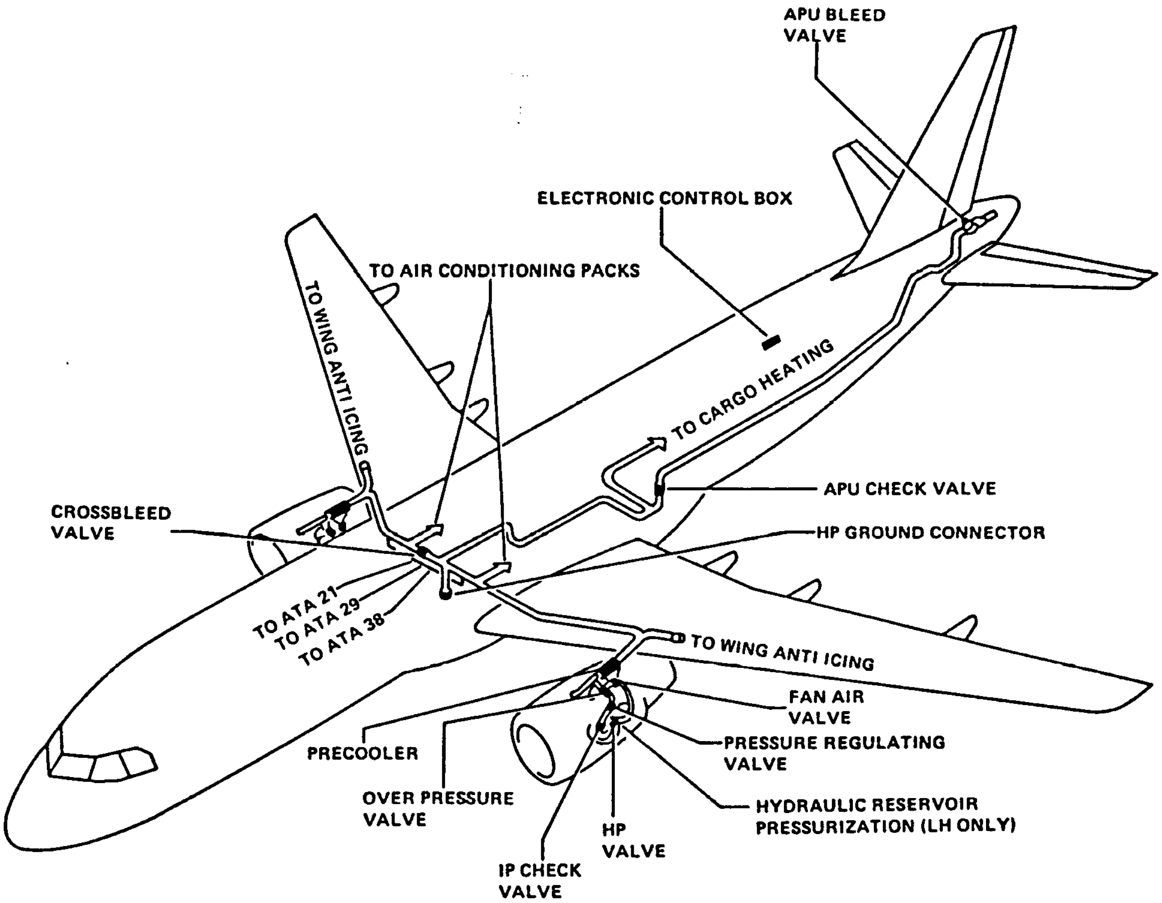

Figure 13.1 A321 pneumatic system overview

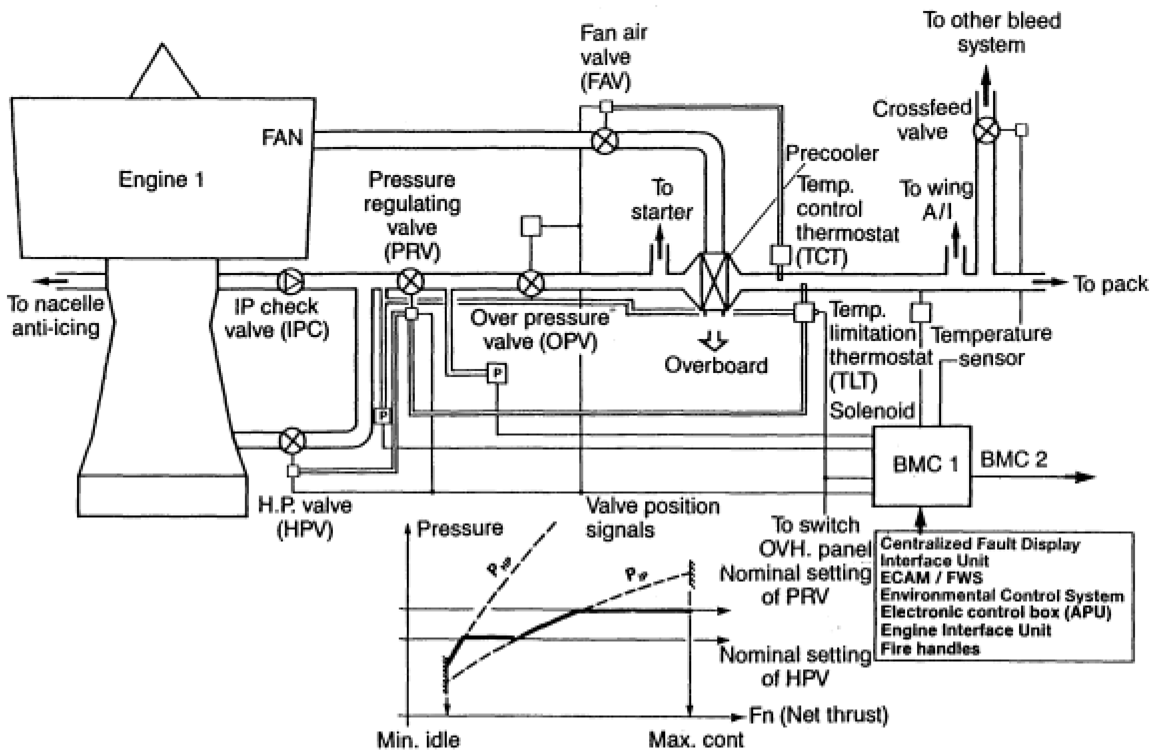

Figure 13.2 A321 schematic diagram of the pneumatic system

Air is normally bled from the *IP valve.* When IP pressure is not sufficient, the *HP valve* opens. This happens at low engine speeds, especially during descent, with engines at idle. **Pressure regulation** is done downstream of the junction of HP and IP ducting with the *pressure-regulating valve* **(**PRV), which acts as pressure regulator and shut-off valve. Delivery pressure is regulated to 0.3 MPa (44 psi). When pressure is excessive in a failure case, an *over-pressure valve* **(**OPV**)** closes.

Temperature regulation of the bleed air is achieved with a *fan air valve* (FAV) and an air-to-air crossflow tubular heat exchanger called a *precooler*. The precooler uses cooling air bled form the engine fan to regulate the original bleed air with a temperature of up to 400 °C down to a delivery temperature of 200 °C.

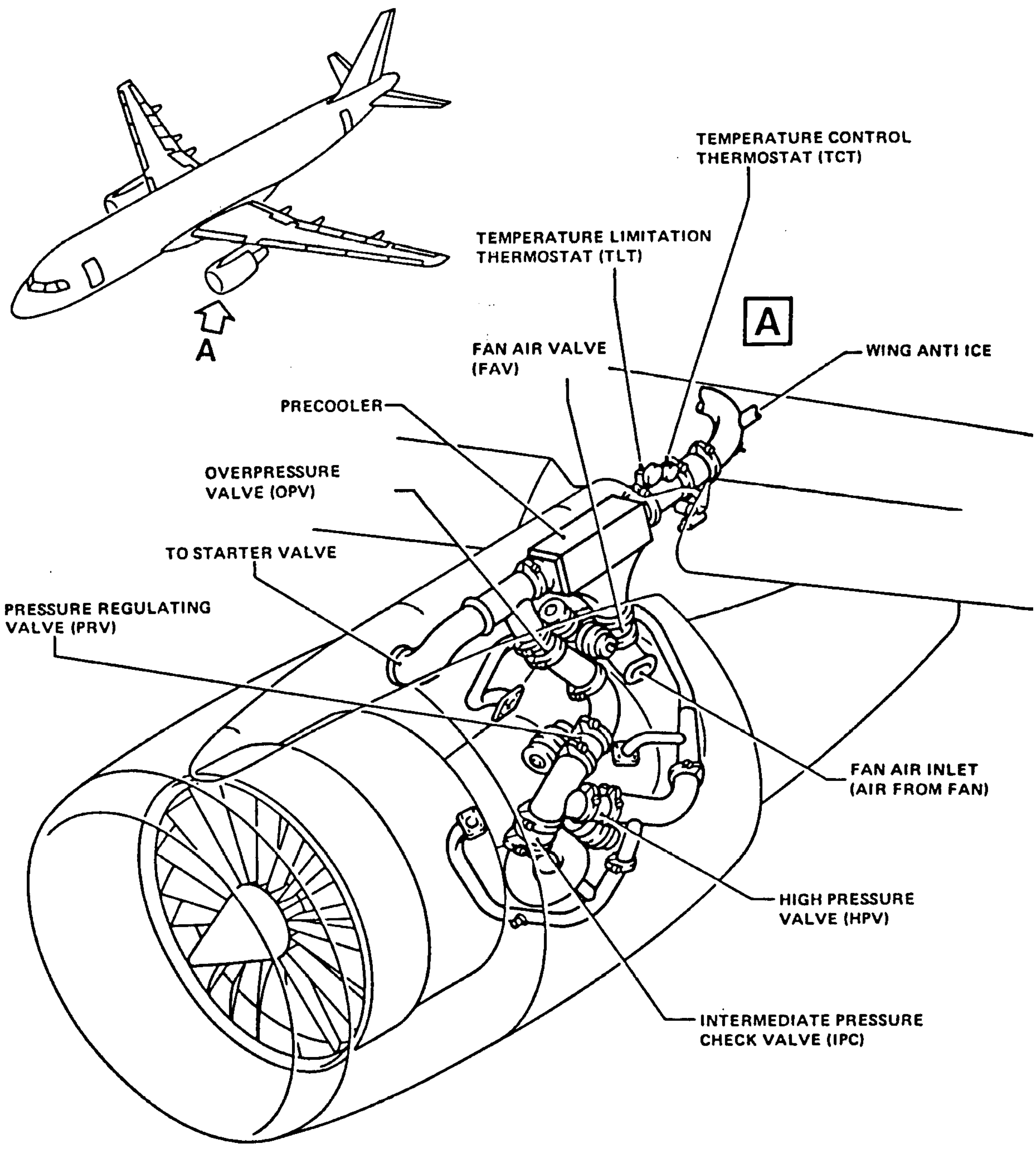

Figure 13.3 A321 engine bleed air supply components