Aircraft Pressurization

An Environmental Control System

AEM 617
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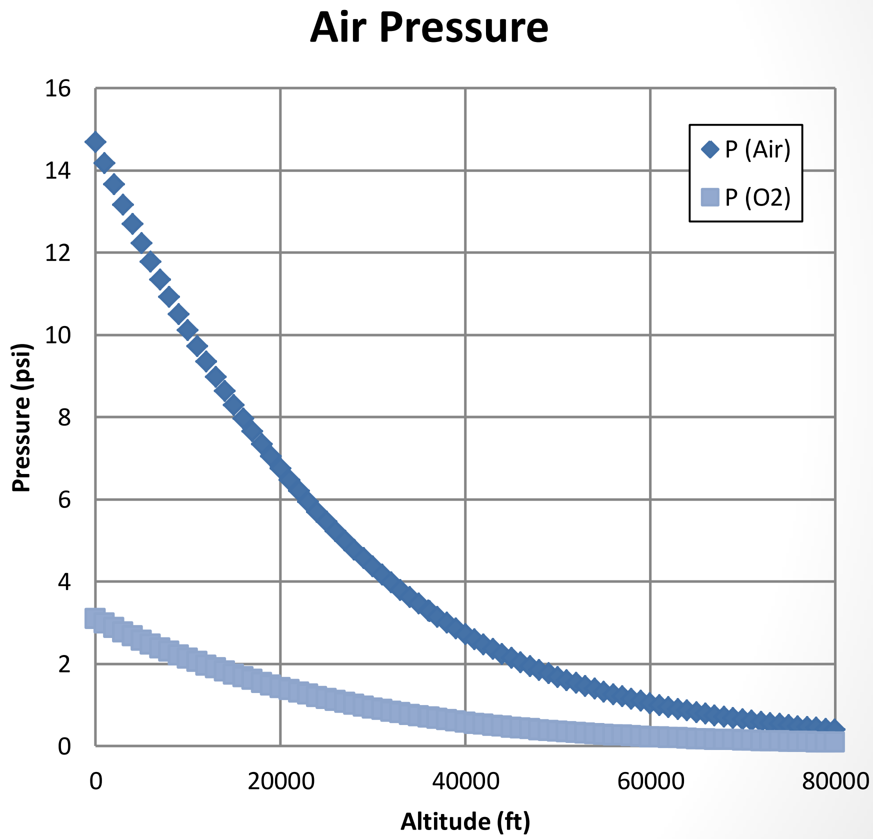
Role

- Adequate passenger comfort and safety
- Maintaining 8000’ pressure at cruise
- Prevent rapid changes in cabin pressure
- Permit exchange of air from inside cabin to outside (eliminate odors and stale air)

Need for Aircraft Pressurization

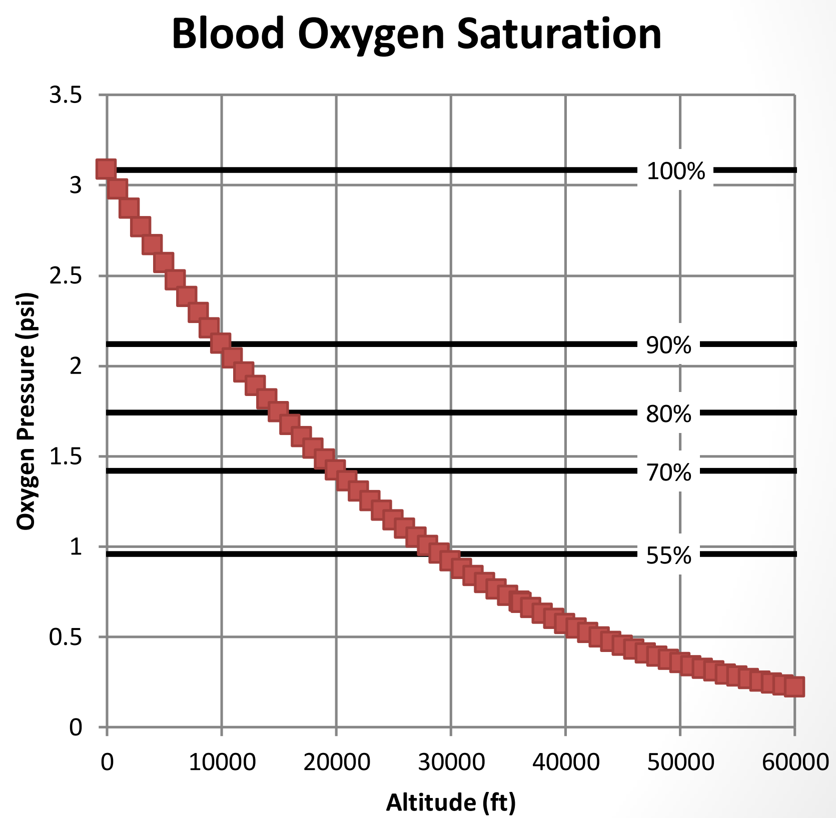
- Pressure decreases as altitude increases
- Oxygen makes up 21% of air, so less O_2 as altitude increases
- Recreate lower cabin altitude for more oxygen



Need for Aircraft Pressurization

- SL to 7,000': enough O_2 for full saturation

- 90% O_2 results in headache and fatigue for long exposure
- 80% O_2: sleepiness, impaired vision and judgment
- 70% O_2: convulsions
- 55% O_2: unconsciousness



Code of Federal Regulations Title14 25.841

a) Pressurized Cabins: not more than 8,000 ft pressurization, normal conditions
   1) Operation above 25,000 ft, max 15,000 ft altitude pressure if failure in pressurization system
   2) Decompression Limits
      i. 25,000 ft pressurization - no more than 2 minutes
      ii. 40,000 ft pressurization - not to occur
   3) Fuselage structure, engine, and systems failure considered in evaluating decompression

CFR Title14 25.841, continued

b) Valves, Controls, and Indicators
   1) Two pressure relief valves
   2) Two reverse pressure differential relief valves
   3) System to equalize pressure differential rapidly
   4) Regulator to control inflow/outflow
   5) Instruments that show pressure differential, cabin pressure, rate of change of pressure altitude
   6) Warning indication when safe/preset pressure differential and cabin altitude exceeded
   7) Warning placard if structure not designed for pressure differentials up to max relief valve settings
   8) Pressure sensors necessary to meet 5 and 6 and Oxygen Dispensing System located so that hazards from decompression will not be increased

Typical Pressurization System

- Cabin, flight compartment, and baggage compartment incorporated in sealed unit
- Contains air under higher pressure than outside atmosphere
- Pressurized air enters through superchargers, compressors, or bleed air
- Air released through pressure regulator and outflow valve
- Constant air entering due to supercharges so major controlling element is outflow valve

Design Factors

- Fuselage strength for differential pressure (ratio of internal to external pressure)
- Capacity of superchargers to maintain constant volume airflow (higher altitude, less external air pressure)

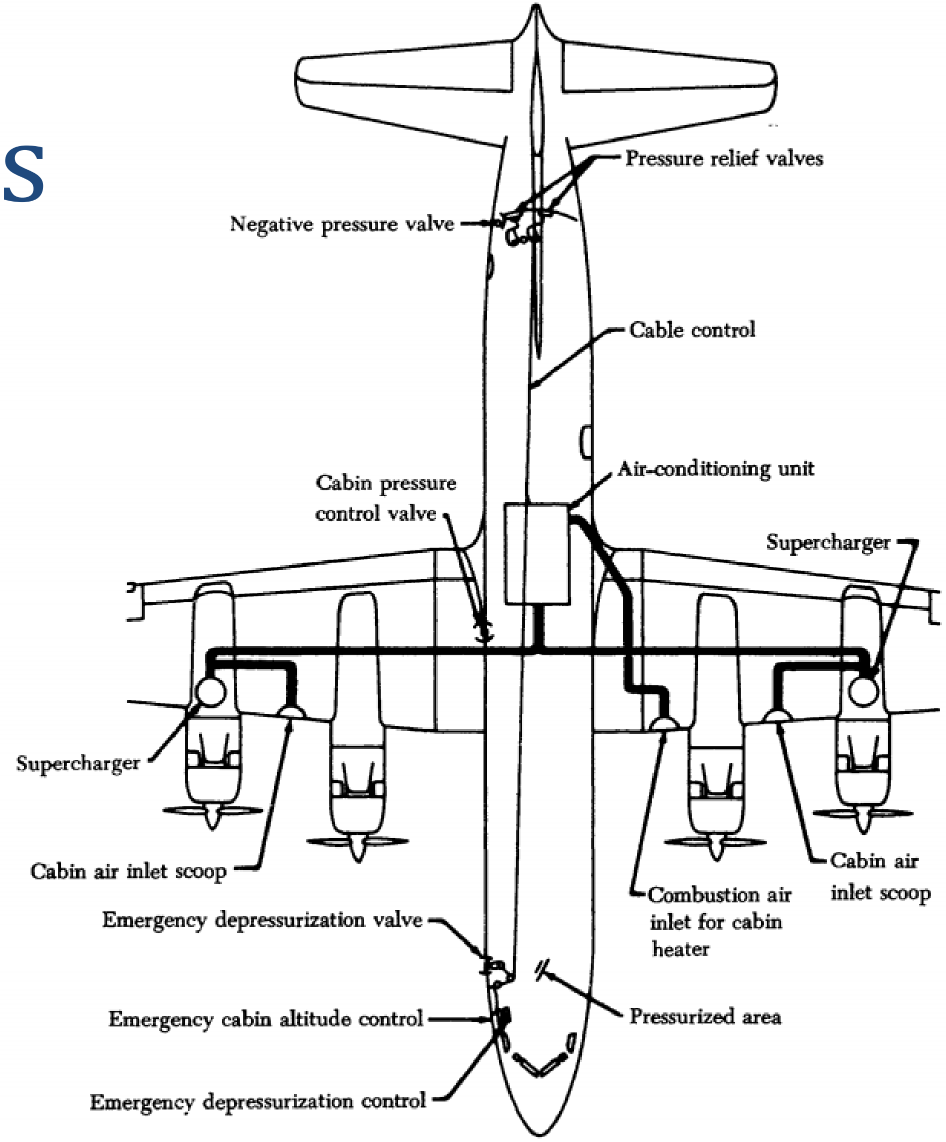


FIGURE 14-3. Basic pressurization system.

Pressurization Example 1

- Selection of materials to withstand the greatest differential pressure (Weight)

The atmospheric pressure at 8,000 ft. is approximately 10.92 p.s.i., and at 40,000 ft. it is nearly 2.72 p.s.i. If a cabin altitude of 8,000 ft. is maintained in an aircraft flying at 40,000 ft. the differential pressure which the structure will have to withstand is 8.20 p.s.i. (10.92 p.s.i. minus 2.72 p.s.i.). If the pressurized area of this aircraft contains 10,000 sq. in., the structure will be subjected to a bursting force of 82,000 lbs., or approximately 41 tons. In addition to designing the fuselage to withstand this force, a safety factor of 1.33 must be added. The pressurized portion of the fuselage will have to be constructed to have an ultimate strength of 109,060 lbs. (82,000 times 1.33), or 54.5 tons.

Pressurization Example 2

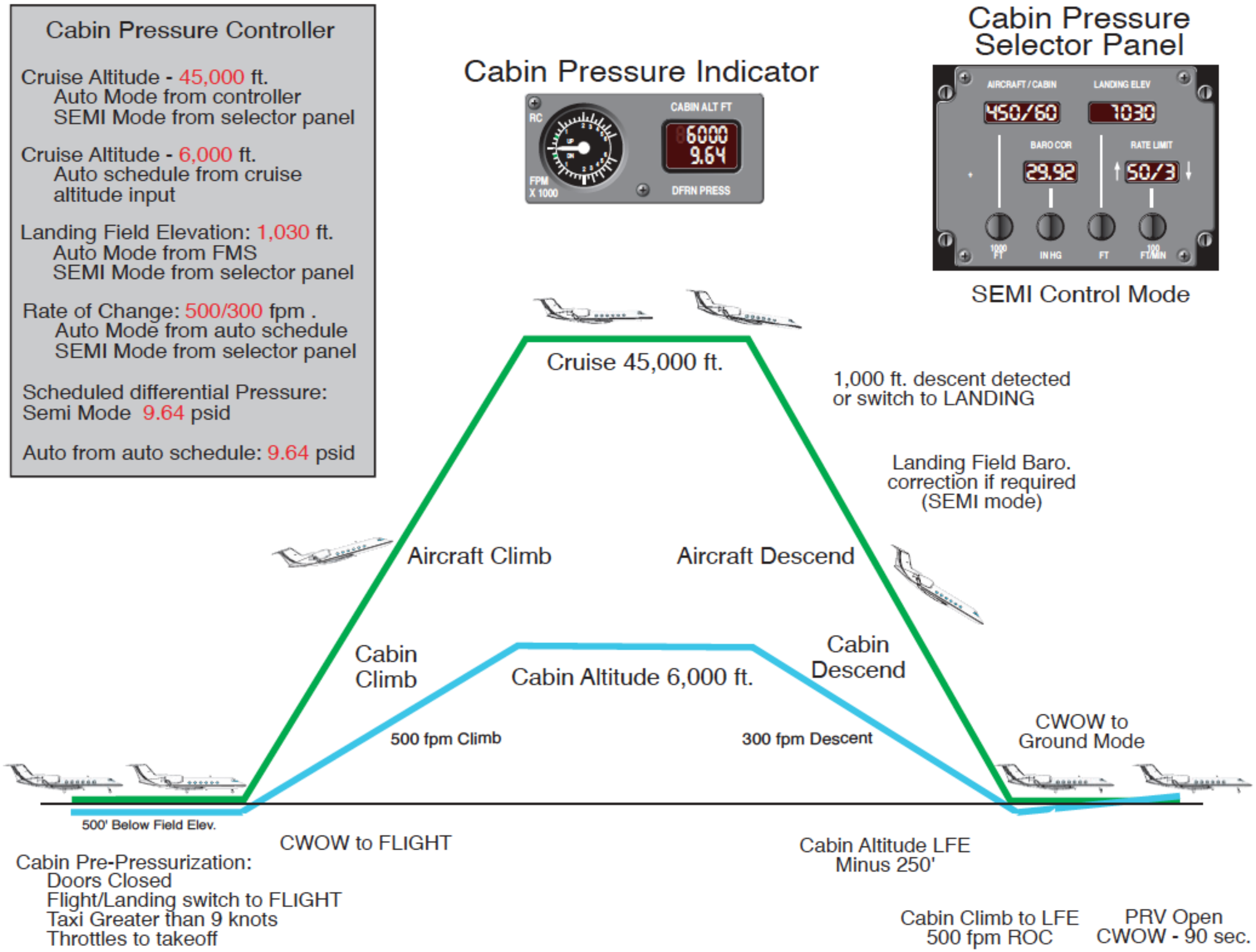


Figure: Pressurization control flight profile, from FlightSafety G450 Maintenance Training Manual, figure 21-81.

Methods for Pressurization

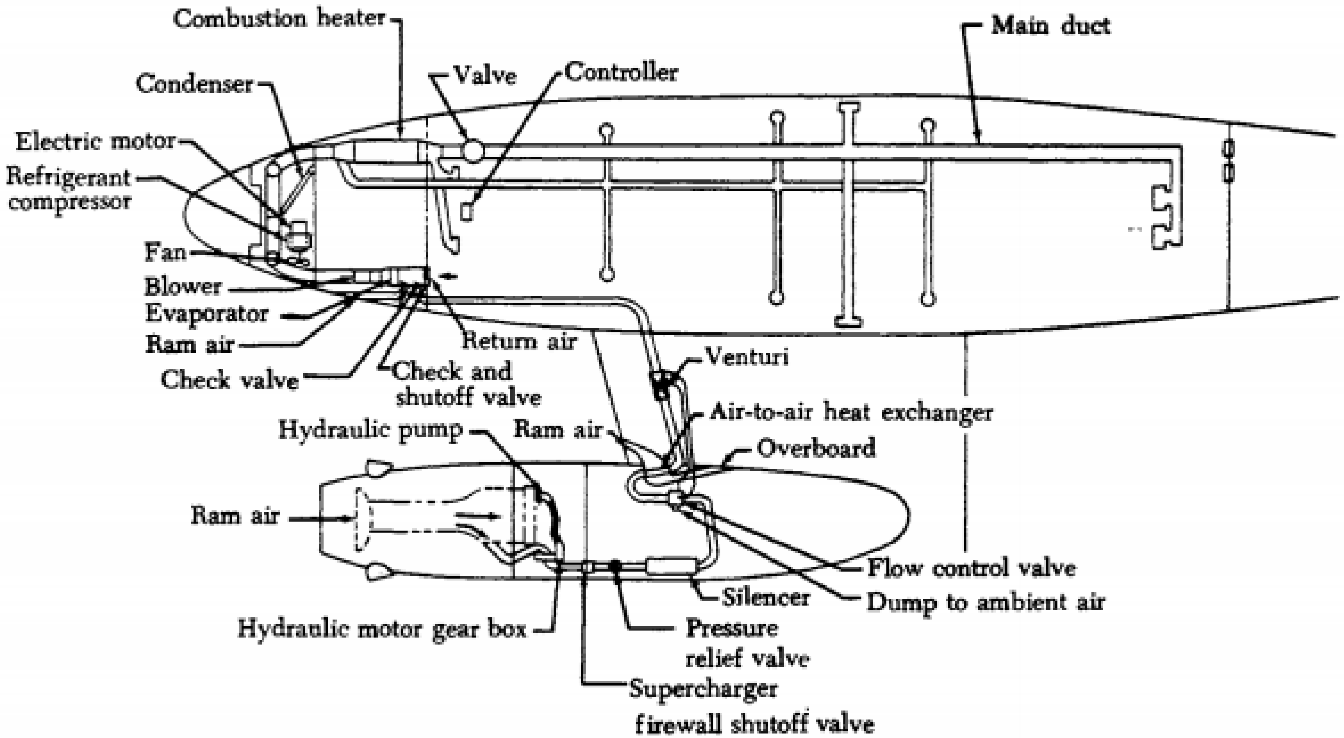
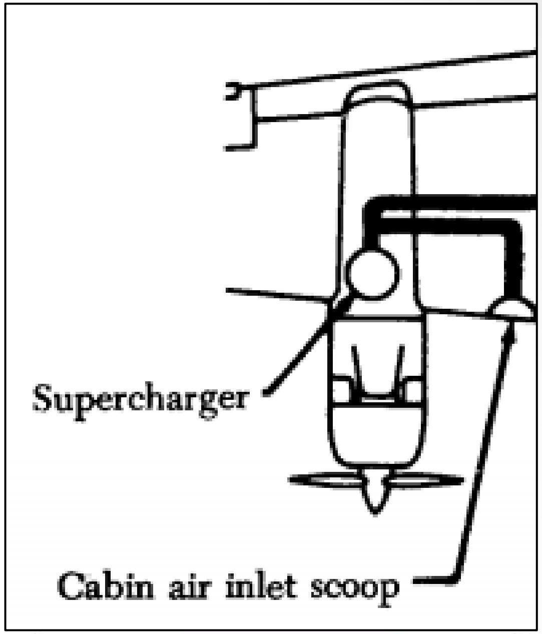


FIGURE 14–16. Typical air distribution system.

Superchargers

- Reciprocating engines
- Ducting air from a manifold which supplies compressed air to the pistons
- Only used when carburetor downstream of supercharger (no fuel in air)
- Disadvantages
  - Contaminated air
  - Harder at higher altitudes
  - Decreases engine performance → air loss for pressurization



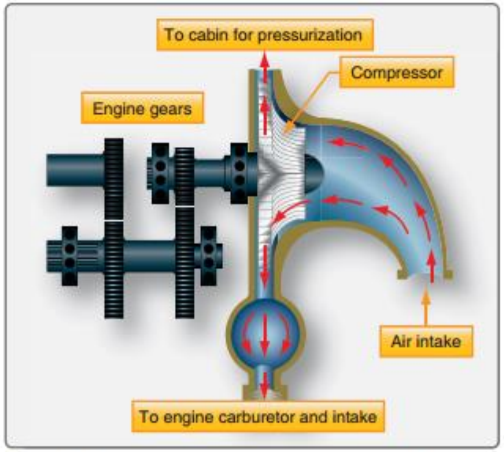


Figure 16-42. *A reciprocating engine supercharger can be used as a source of pressurization if it is upstream of carburetion.*

Supercharger Control

- Maintain fairly constant volume of air output from supercharger
  - Reciprocating engine→ vary drive ratio
- Airflow gauge: measure pressure differential of supercharger

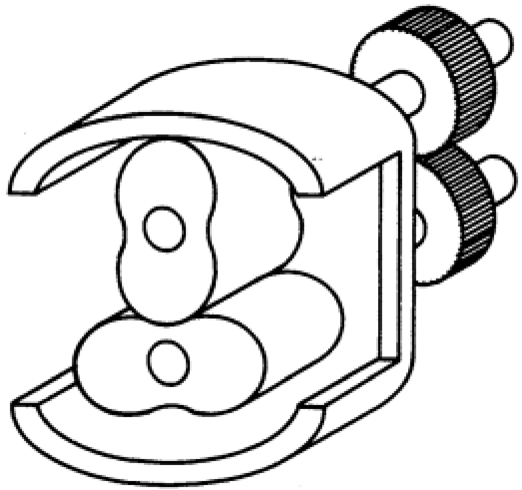
Gas Turbine Engines

- Bleed air from engine compressor
- Disadvantages
  - Possible contaminated air
  - Dependence on air for engine performance

- Independent cabin compressors
  - Driven through accessory drive or bleed air
  - Types:
    - Positive-displacement compressor
    - Centrifugal compressor

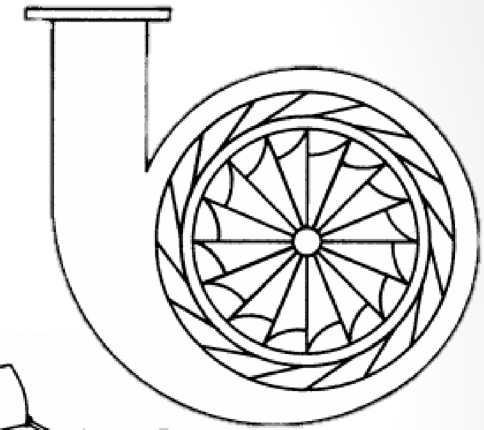
Positive-Displacement Compressor

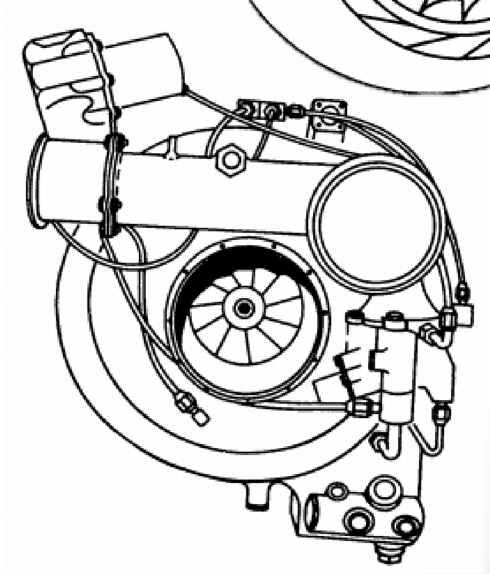
- Intakes air which is compressed and delivered to cabin
- Bearing in separate chamber to achieve oil-free air
- Requires silencers to reduce noise caused by air pulsations from the rotors



Centrifugal Compressors

- Increases kinetic energy of air passing through impeller
- Air accelerated and compressed
- Limited by impeller speed and back pressure





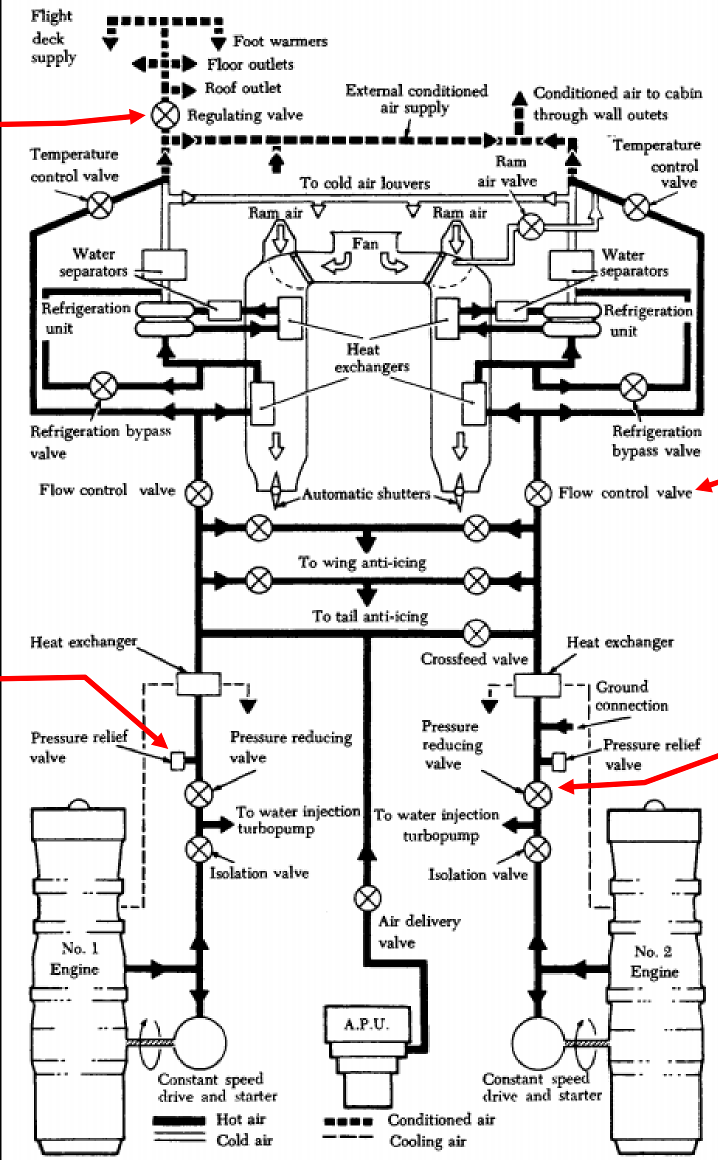


FIGURE 14-4. Typical pressurization and air conditioning system.

Regulating Valve

Flow Control Valve

Pressure Relief Valve

Pressure Reducing Valve

Note: APU air delivery as well

Pressure Valves

- Flow determined by degree of opening
- Controlled by automatic system set by crew
- In event of malfunction, manual controls provided
- Butterfly valve to pneumatic valve

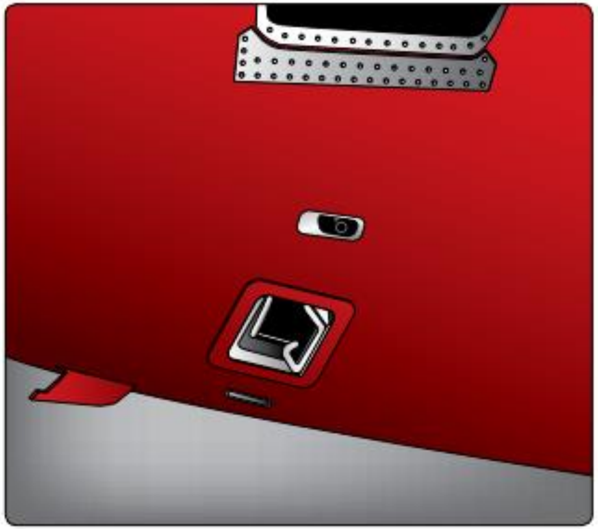


Figure 16-55. *This outflow valve on a transport category aircraft is normally operated by an ac motor controlled by a pressure controller in the electronics equipment bay. A second ac motor on the valve is use when in standby mode. A dc motor also on the valve is used for manual operation.*

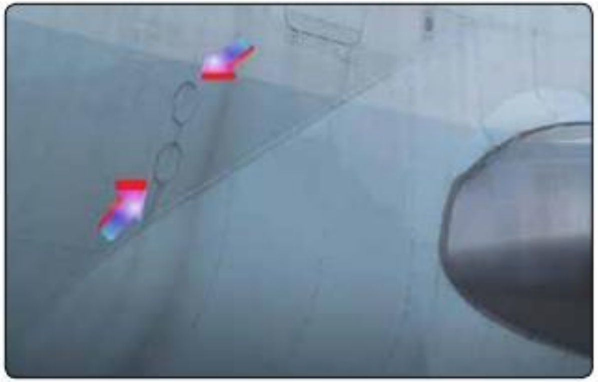


Figure 16-56. *Two pressurization safety valves are shown on a Boeing 747.*

Pressure Valves, continued

- Principal outflow valve usually placed underneath airplane
- Held fully open on ground by landing gear switch
- Closes gradually as altitude is gained
- Pressure relief valve: opens when preset differential pressure reached
- Negative pressure valve: opens when internal pressure greater

Pressure Valves, continued

- Cabin air regulator

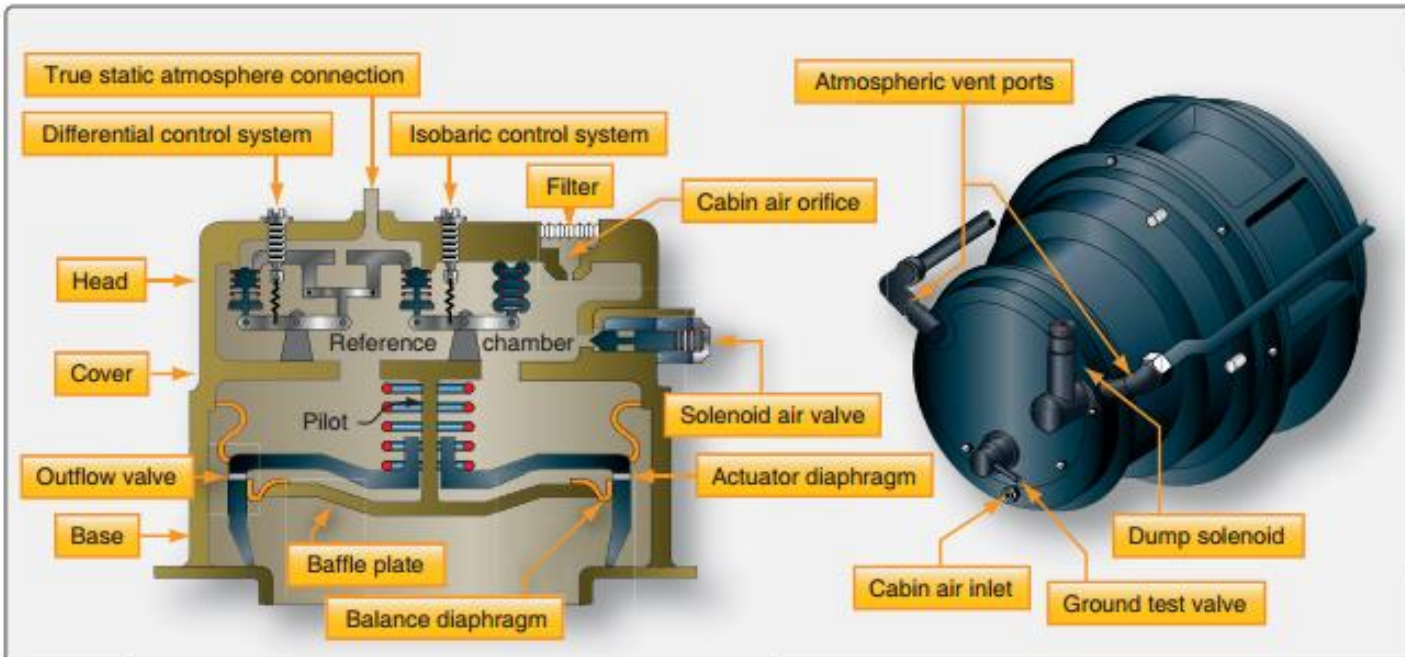


Figure 16-54. *An all-pneumatic cabin pressure regulator and outflow valve.*

Pressure Instrumentation

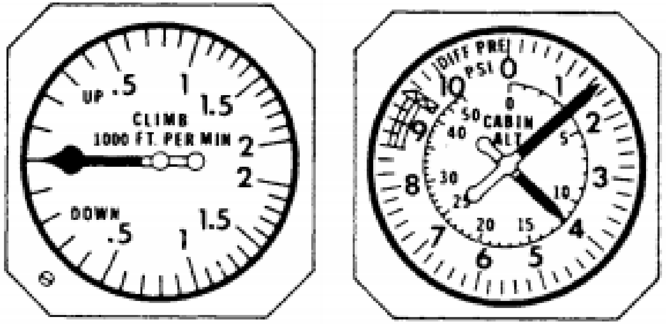


FIGURE 14–11. Instruments for pressurization control.

Figure 16-53. *This pressurization panel from an 800 series Boeing 737 has input selections of flight altitude and landing altitude.*

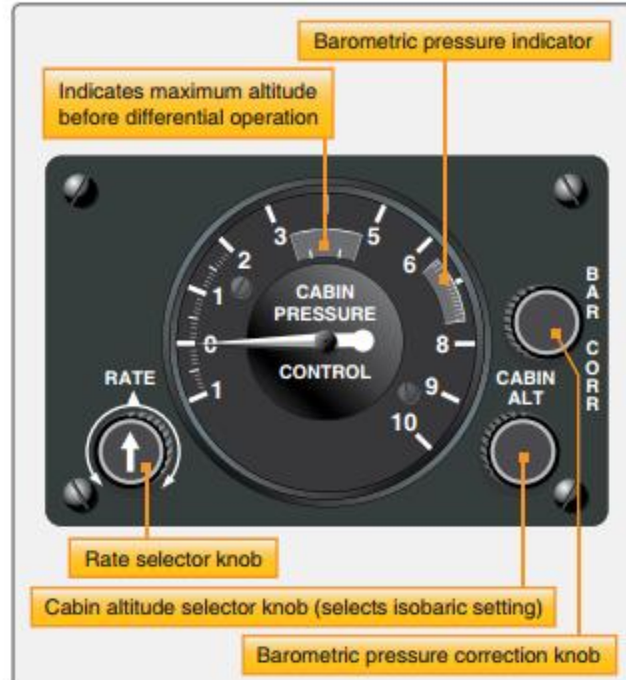
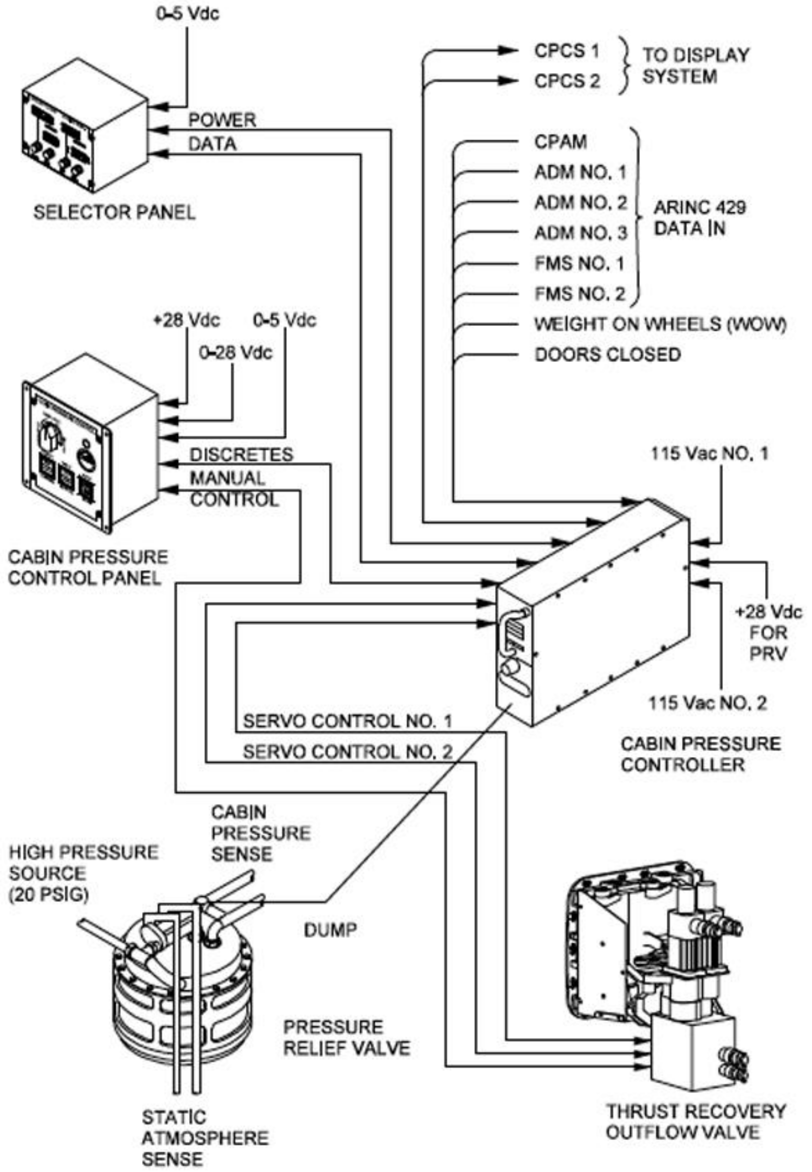


Figure 16-51. *A pressure controller for an all pneumatic cabin pressure control system.*

G450 Cabin Pressure Control



Boeing 737 Cabin Pressure Control

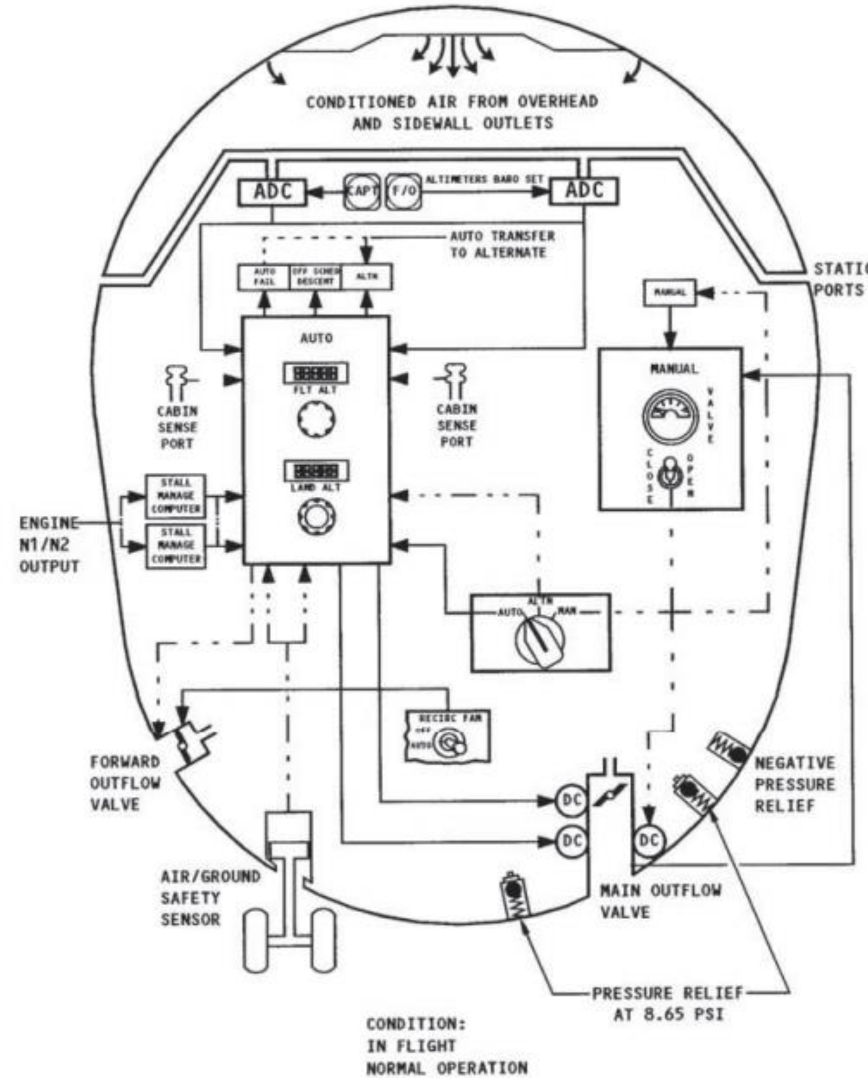


Diagram – Digital Cabin Pressure Control System Schematic

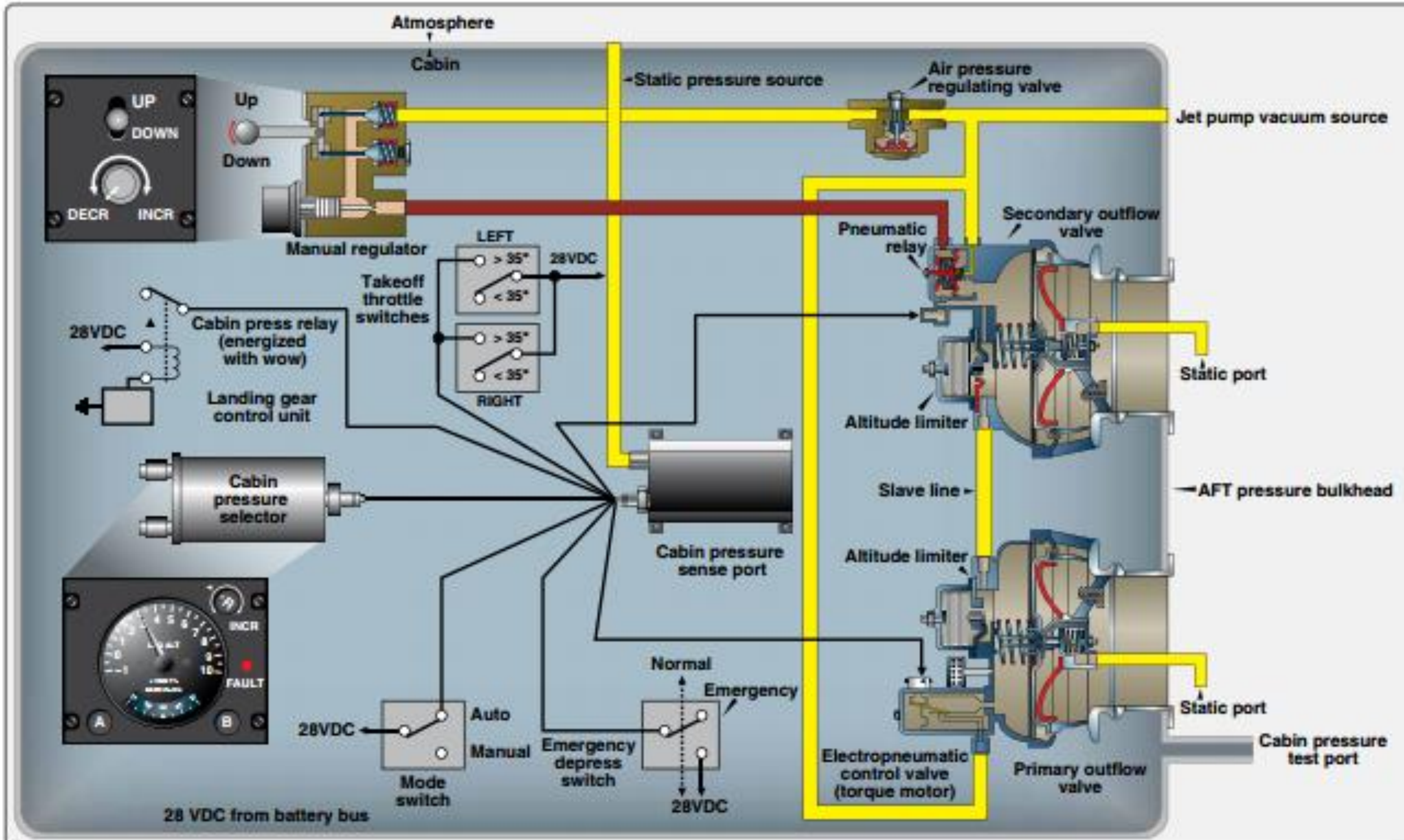


Figure 16-52. *The pressurization control system on many small transports and business jets utilizes a combination of electronic, electric, and pneumatic control elements.*

Case Studies

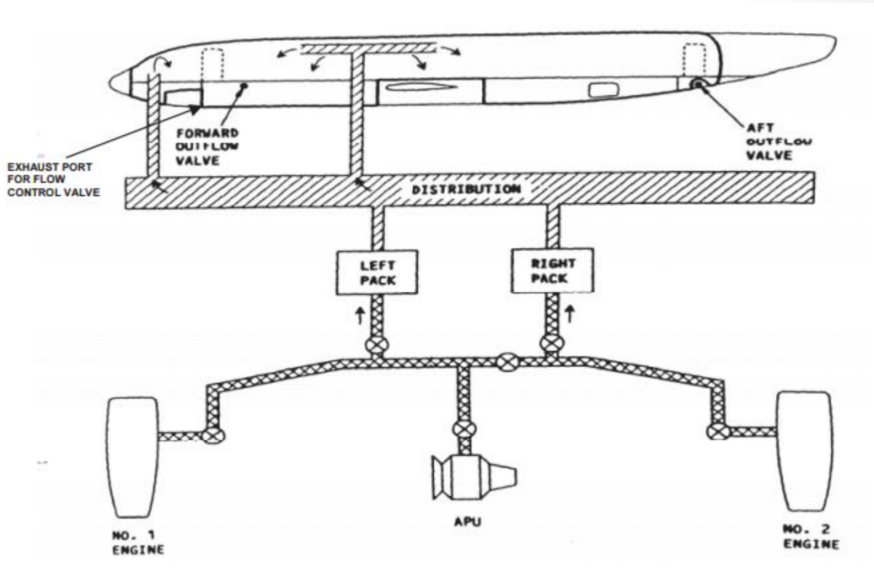
- Examples of aircraft for which the pressurization had some part in failure

Helios Airways Flight 552

- Boeing 737
- Maintenance set pressure control to manual for inspection and returned to service
- Through preflight checks crew did not return setting to auto
- Warnings of low pressure misread as “takeoff configuration”

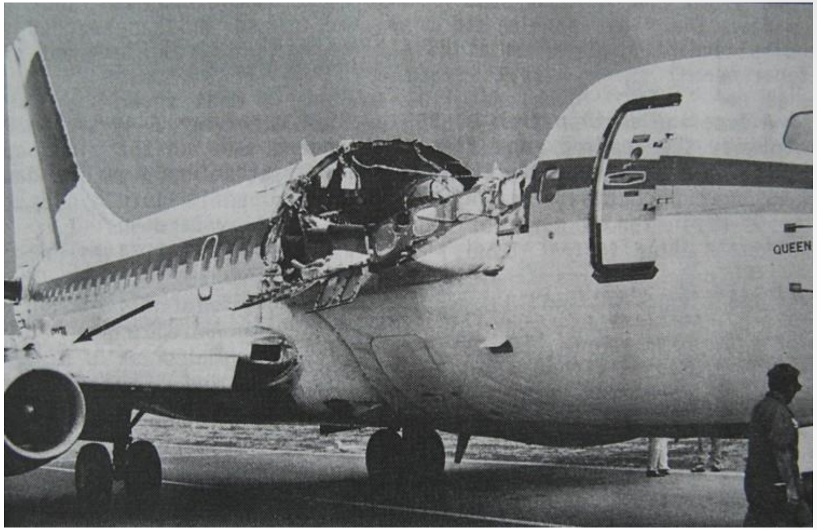
Helios Airways Flight 552, continued

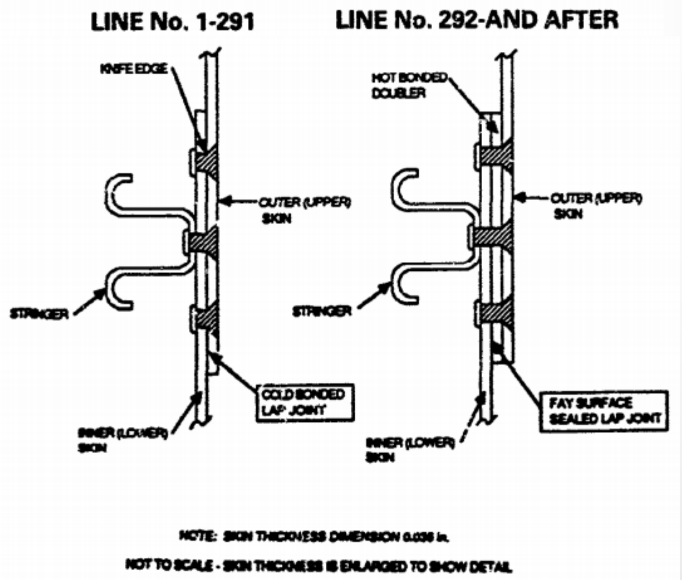
- Crew succumbed to effects of hypoxia and flight continued on autopilot until fuel ran out
- Crew did not recognize failure as pressurization
- Same alarm for low pressure and takeoff configuration
- Additional lights to be added on all 737s



Aloha Airlines Flight 243

- Boeing 737 (152)
- 35,496 flight hours (89,680 flight cycles)
- Explosive decompression at 24,000’ (ΔP=5.22 psi)
- Failure of maintenance program to identify disbonding and fatigue
- Additional plate added to strengthen skin at joints





Questions?

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Resources

- http://charles-oneill.com/aem617/docs/CFR-2015-title14-vol1.pdf
- http://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_65-15A.pdf
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