

Fig. 2 . . . . Basic Evaporative Air-Cycle Refrigeration System

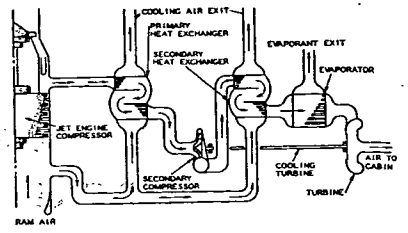


Fig. 4 . . . . Bootstrap Evaporative Air-Cycle Refrigeration System

exchanger and then cooled further in the cooling turbine by the process of expansion with work extraction. The heat sink for this system is *ram air* (the ambient air rammed into an airplane through a scoop, such as an engine scoop, as the airplane moves through the air).

The basic evaporative air-cycle refrigeration system, shown in Fig. 2, is the same as the basic system except for the addition of an evaporative cooler in the high-pressure air duct between the air-to-air heat exchanger and the cooling turbine. An expendable evaporant such as water, alcohol, or ammonia may be used as a heat sink for the evaporative cooler.

Bootstrap and Bootstrap-Evaporative Types

The term bootstrap, as used in air-cycle refrigeration systems, indicates a system in which the pressure of the working fluid (high-pressure air) is raised to a higher level in the compressor section of the cooling turbine unit before expanding in the turbine section (See Fig. 3).

The bootstrap air-cycle refrigeration system, shown in Fig. 3, consists of a primary heat exchanger, a secondary heat exchanger, and a cooling turbine. High-pressure air is cooled first in the primary heat exchanger. The air is then compressed to a higher pressure and temperature in the compressor of the cooling turbine. A substantial amount of the heat of compression is removed in the secondary heat exchanger, and the air is cooled further as it expands through the turbine section of the cooling turbine. Ram air is used as a heat sink in the primary and secondary heat exchangers.

The bootstrap evaporative air-cycle refrigeration system, shown in Fig. 4, utilizes the same equipment as the bootstrap system and, in addition, an evaporative cooler located in the high-pressure air duct between the secondary heat exchanger and the turbine. Any suitable expendable evaporant may be used as a heat sink for the evaporative cooler.

The bootstrap air-cycle refrigeration system is used most frequently in transport type aircraft. A typical one which could be used on a jet transport airplane is shown schematically in Fig. 5. Two turbocompressors, driven by bleed air from the main engines, compress ram air and deliver it through two identical bootstrap refrigeration units and water separators to the flight deck and the cabin. The gas turbine compressor power unit may be utilized to furnish high-pressure air for operation of the air-conditioning system during ground operation, when the main engines are not running. However, to obtain any significant amount of cooling from the air-cycle conditioning system, it must be specifically designed to match the gas turbine air source.

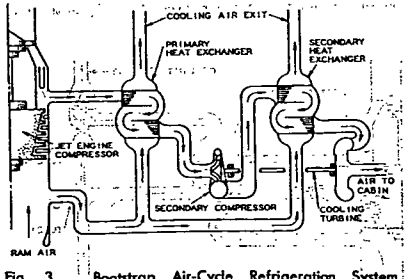


Fig. 3 . . . . Bootstrap Air-Cycle Refrigeration System

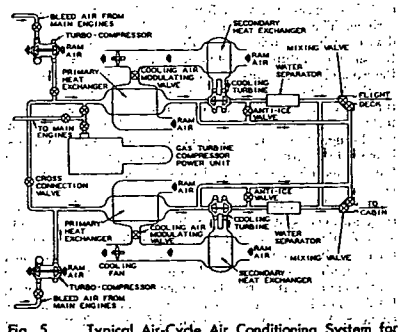


Fig. 5 . . . . Typical Air-Cycle Air Conditioning System for a Jet Transport Airplane

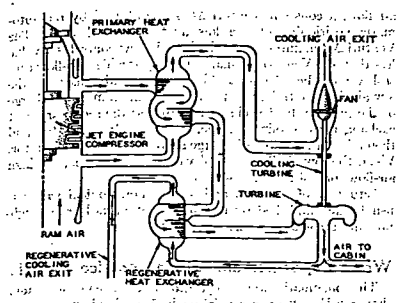


Fig. 6 . . . . Regenerative Air-Cycle Refrigeration System

Regenerative Type

The regenerative air-cycle refrigeration system, shown in Fig. 6, consists of a primary air-to-air heat exchanger, a regenerative air-to-air heat exchanger, and a cooling turbine. High-pressure, high-temperature air is cooled first in the primary heat exchanger, then in the regenerative heat exchanger, and finally in the cooling turbine. Ram air is used as the heat sink in the primary heat exchanger, and part of the cold air from the turbine discharge is used as the heat sink in the regenerative heat exchanger.

Reduced Ambient Type

The reduced ambient air-cycle refrigeration system, shown in Fig. 7, is composed of an air-to-air heat exchanger and two expansion turbines supplying power through appropriate gearing to a single fan. High-pressure, high-temperature air is cooled first as it passes through the heat exchanger and again as it expands through the turbine mounted downstream from the heat exchanger. The heat sink for the heat exchanger is ram air cooled by expansion across the turbine mounted in the ram-air circuit upstream from the heat exchanger.

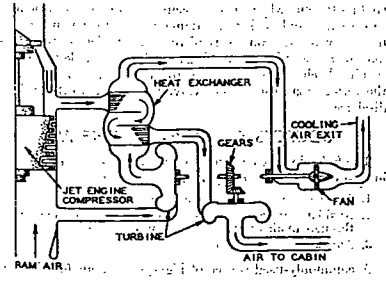


Fig. 7 . . . . Reduced Ambient Air-Cycle Refrigeration System

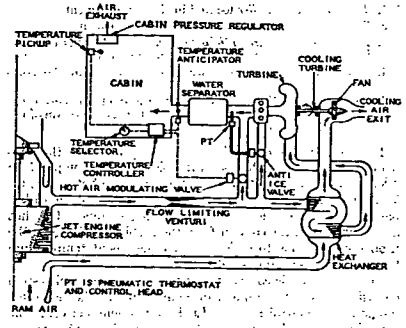


Fig. 8 . . . . Basic Air-Cycle Air Conditioning System

CONTROL SYSTEMS

Typical control systems for air-cycle air-conditioning systems using water separators (see Fig. 5) are those which will provide: (1) automatic temperature control of the compartment being cooled, (2) automatic protection against the supply of too much or too little air to the compartment, and (3) automatic protection against ice collection in the water separator.

Figs. 8 and 9 show schematically the control systems for a basic air-cycle air-conditioning system and for a bootstrap air-cycle air-conditioning system, respectively.

Compartment Air Temperature Control

The electronic system for compartment air temperature control consists of the following items:

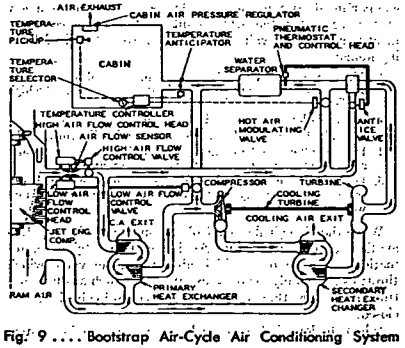


Fig. 9 . . . . Bootstrap Air-Cycle Air Conditioning System