D. Vapor Cycle Systems

1. Subcooler (Figure 1-24)

Some vapor cycle systems use a subcooler to reduce the temperature in the liquid refrigerant after it leaves the receiver. By cooling the refrigerant premature vaporization (flash-off) can be prevented. Maximum cooling takes place when the refrigerant changes from a liquid to a gaseous state. For efficient system operation this must occur in the evaporator. If the refrigerant vaporizes before it reaches the evaporator the cooling efficiency of the system is reduced.

The subcooler is a heat exchanger containing passages for liquid freon from the receiver on its way to the evaporator and cold freon gas leaving the evaporator on its way to the compressor. The liquid on the way to the evaporator is relatively warm in comparison to the cold gas leaving the evaporator. Although the gas leaving the evaporator has absorbed heat from the air being circulated through the evaporator, its temperature is still in the vicinity of 40°F. This cool gas is fed through the subcooler where it picks up additional heat from the relatively warm liquid freon that is flowing from

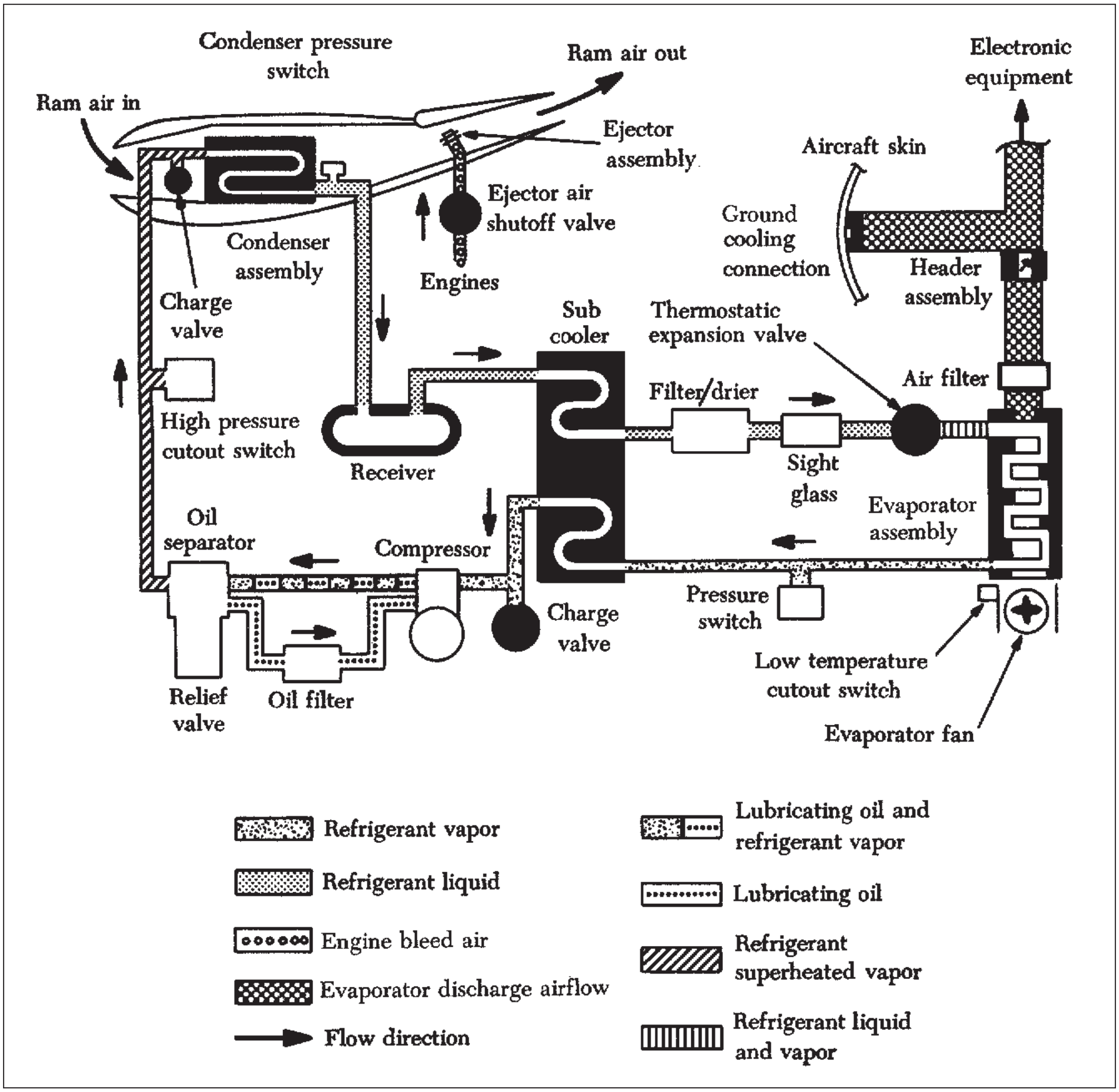

Figure 1-24 Vapor cycle system flow schematic.

the receiver. This heat exchange subcools the liquid freon to a level that ensures little or no flash-off (premature vaporization) on its way to the evaporator.

Subcooling is a term used to describe the cooling of a liquid refrigerant at constant pressure to a point below the temperature at which it was condensed. at 117 p.s.i.g., freon vapor condenses at a temperature of 100°F. If, after the vapor has been completely condensed, the liquid is cooled still further to a temperature of 76°F., it will have been subcooled 24°. Through subcooling, the liquid delivered to the expansion valve is cool enough to prevent most of the flash-off that would normally result, thereby making the system more efficient.

2. Major Components, Large Aircraft Vapor Cycle Systems

Since the vapor cycle system used in Boeing aircraft models 707 and 720 are typical of most large vapor cycle systems, they are used here to describe the operation of such systems.

The major components of the vapor cycle air conditioning system are the: (1) air turbine centrifugal compressors, (2) primary heat exchangers, (3) refrigeration units, (4) heaters, and (5) necessary valves to control the airflow.

The vapor cycle system shown schematically in figure 1-25 is divided into a left-hand and a right-hand installation. Both installations are functionally identical.

a. Air Turbine Compressor

The cabin and flight compartments are pressurized by using two air turbine centrifugal compressors (turbo-compressors). Each compressor consists of a turbine section and a compressor section as shown in figure 1-26.

The turbine section inlet duct is connected to the sixteenth stage compressed air from the engine bleed air manifold. The bleed air is under a pressure of approximately 170 p.s.i. This high-pressure, high-velocity air is reduced to approximately 76 p.s.i. by a differential pressure regulator located in the air duct leading to the turbine inlet. This regulated air pressure turns the turbine at about 49,000 r.p.m.

Since the compressor is connected directly to the turbine, it also turns at the same r.p.m. The compressor output is approximately 1,070 cu. ft. of air per minute at a maximum of 50 p.s.i. The compressor section inlet is connected to a ram-air scoop and the outlet is connected through ducts into the air conditioning system.

Air flows through the ducts, through a wing isolation valve, past the shutoff valve, and through the primary heat exchanger.

b. Primary Heat Exchangers

The two primary (air-to-air) heat exchangers are located in the left- and right-handed installation of the vapor cycle system as shown in figure 1-25.

Each primary heat exchanger consists of a duct assembly, a core assembly, and a pan assembly. The welded duct assembly contains both the inlet and outlet passages. The tube-type core assembly forms the center portion of the unit. The pan assembly completes the enclosure of the tubes. Cabin ventilating air flows through the inside of the tubes of the core assembly. Ram air is forced around and between the outside of the tubes. Figure 1-27 shows a schematic diagram of the primary heat exchanger.

The primary heat exchangers remove about 10% of the heat of compression from the cabin ventilating air as it comes from the turbo-compressors, thus cooling the air to about 10° to 25° above outside air temperature.

c. Refrigeration Units

From the primary heat exchangers the ventilating air is ducted to the refrigeration units. The two refrigeration units are located in the left- and right-hand installation of the vapor cycle system as shown in figure 1-25. Each refrigeration unit consists of an electric motor driven freon compressor, an air-cooled refrigerant condenser, a receiver (freon container), an evaporator heat exchanger, a dual control valve, a heat exchanger (liquid-to-gas), and the necessary electrical components to assure proper operation of the unit. The refrigerant used in the system is freon 114. Lubricating oil is added to the freon each time the refrigeration unit is charged to provide lubrication for the compressor bearings.

After the air is cooled to the desired temperature, it is ducted into the cabin and flight deck.

E. Types of Aircraft Heaters

1. Electric Heaters

The main cabin ventilating air and the flight compartment ventilating air are heated separately and independently by two electric heaters, one heater for each.

The flight compartment heater consists of a core which is made up of nine electrical heater elements mounted in a rectangular aluminum shell assembly,

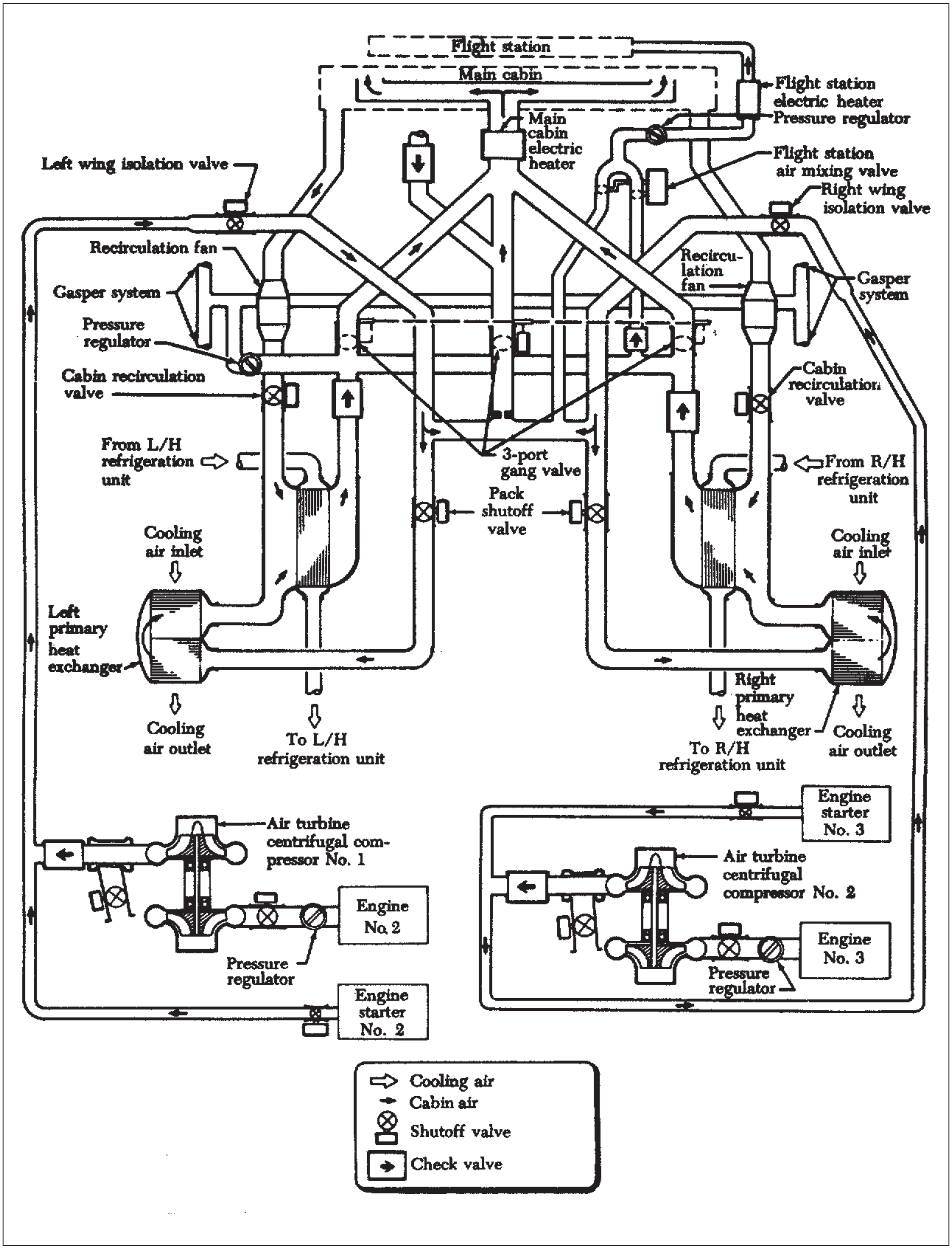

Figure 1-25 Schematic of vapor cycle air conditioning system on Boeing 707 and 720 airplanes.

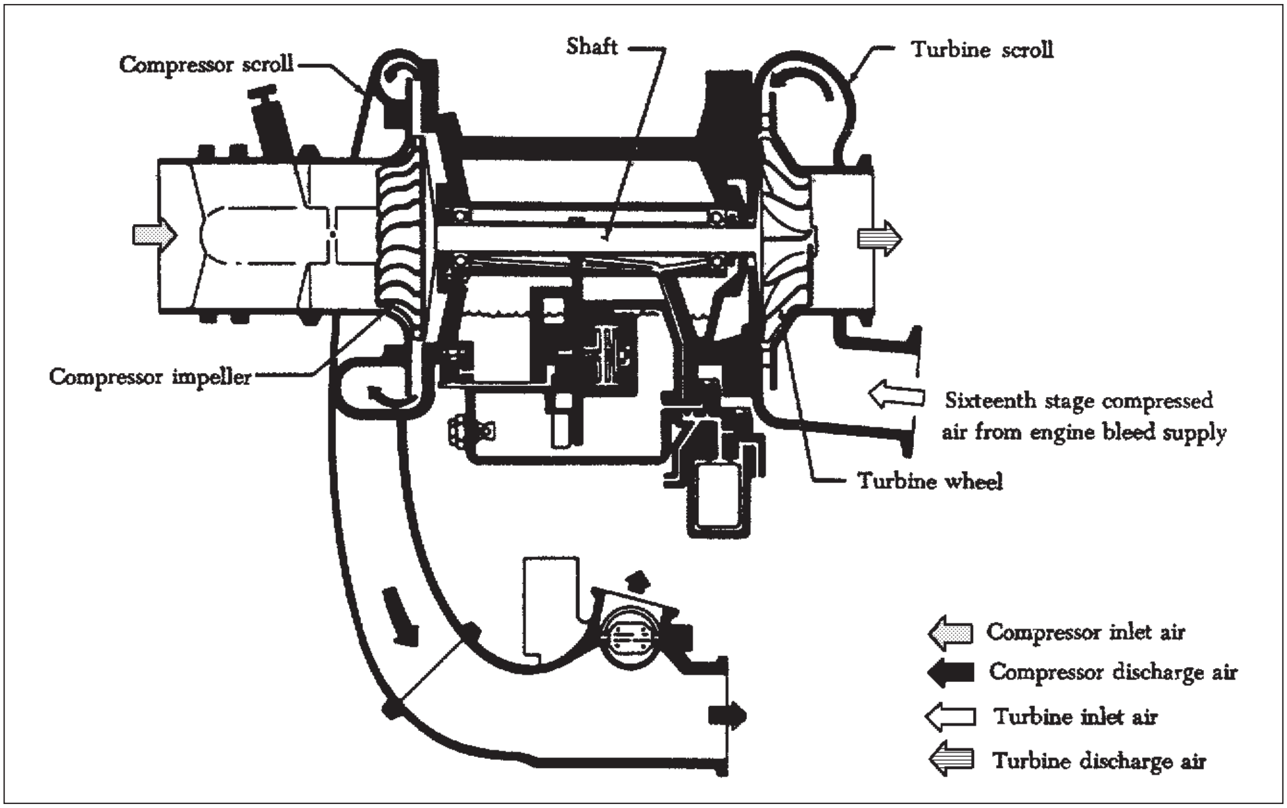

Figure 1-26 Schematic of air turbine centrifugal compressor.

three protectors, a.c. power connection to the elements, and a control circuit to the thermal protectors.

The main cabin heater is similar but has a greater output capacity since it provides heat for a larger compartment and a greater volume of air.

a. Air Routing/Valves

The solid black arrows in figure 1-25 indicate the flow route of the ventilating air from the turbo-compressor, through the air conditioning units to the cabin and flight compartment. The three-port gang valve regulates the flow of hot or cold air to the cabin in response to the selected temperature.

2. Exhaust Shroud Heaters

The most common type of heater for small single-engine aircraft is the exhaust shroud heater. A sheet metal shroud is installed around the muffler in the engine exhaust system, and cold air is taken into this shroud and held against the muffler so it can absorb some of the heat that is being wasted. This air is then routed into the cabin through a heater valve in the firewall. When the heater is not on, this air is directed overboard. This type of heater is quite economical for these small aircraft, as it requires no energy other than that which is otherwise wasted.

One of the problems with this type of heater is the possibility of carbon monoxide poisoning if there should be a crack in the exhaust system. For this reason, it is very important that the shrouds be removed and the exhaust pipes and mufflers carefully inspected on the schedule recommended by the aircraft manufacturer. Some leaks may be present but not large enough to show up clearly when the metal is cold, so many of these components should be tested with air pressure. It is possible to test some of them on the aircraft by connecting the output of a vacuum

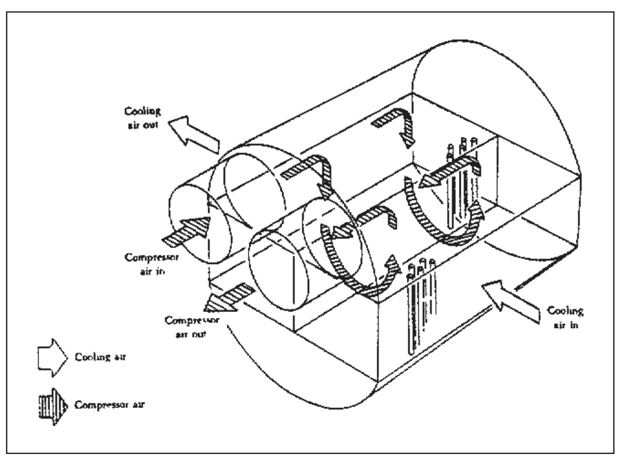

Figure 1-27a Schematic of primary heat exchanger.

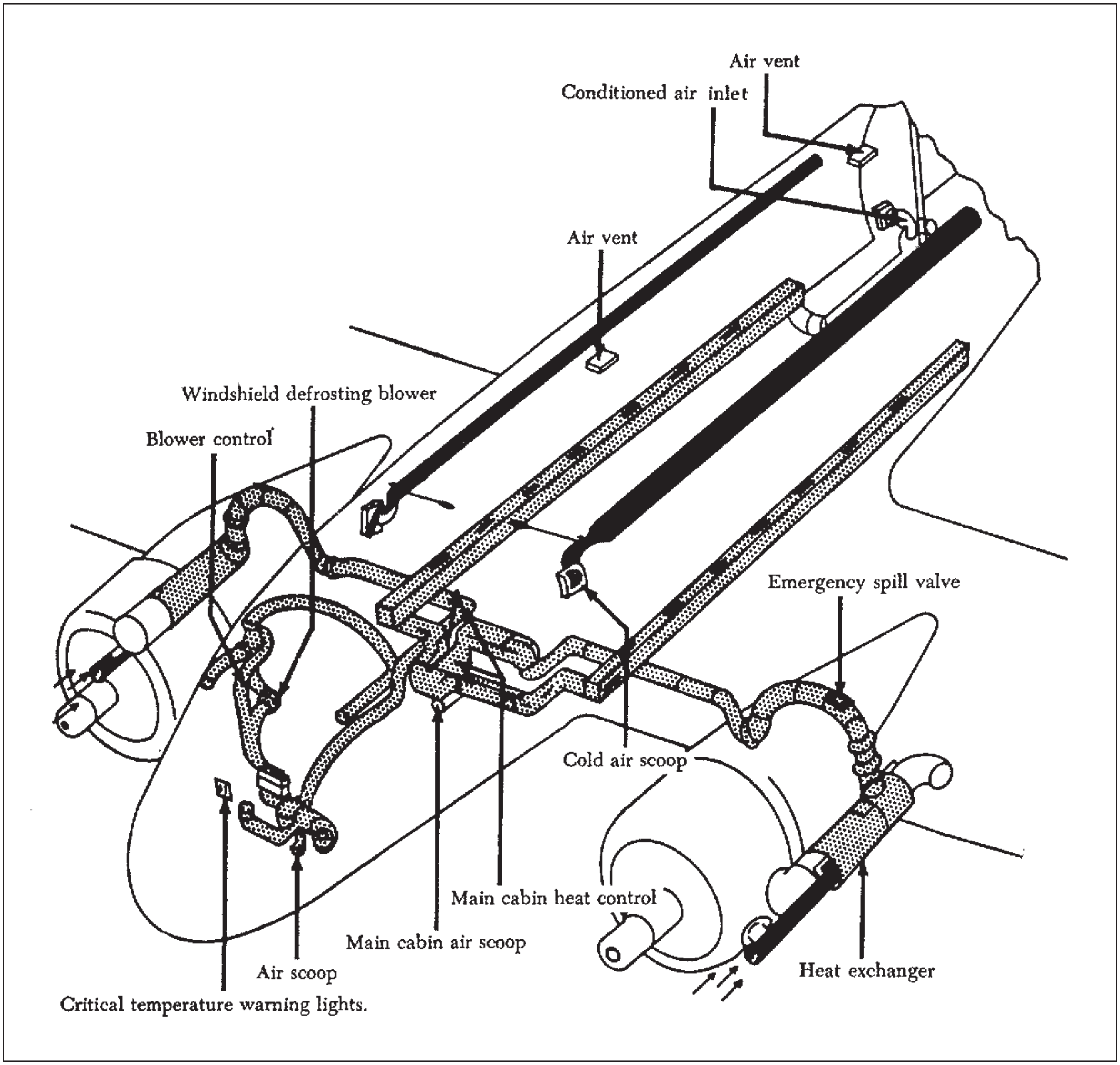

Figure 1-27b Engine exhaust heater system.

cleaner to the exhaust stack and covering the muffler with a soap solution and watching for bubbles. Some aircraft have Airworthiness Directives on the mufflers that require them to be removed and submerged in water and tested with air to search for leaks.

The amount of heat that is transferred to the air from the muffler is determined by the amount of the muffler's surface area. Some manufacturers have increased this area by using welded-on studs, as shown in figure 1-28a. This type of muffler is more efficient but it must be checked with special care as it is possible for minute cracks to start where the studs are welded on.

3. Electric Heating Systems

Electric heating on most aircraft is generally a supplemental heating source. The heaters use heating elements that create heat through electrical resistance. Some aircraft use this type of heat when the aircraft is on the ground and the engines are not running. A fan blows air over the heating coils in the heating elements which heats and circulates the air back into the cabin. Safety devices are installed in these systems to prevent them from overheating if the ventilating fan should become inoperative.

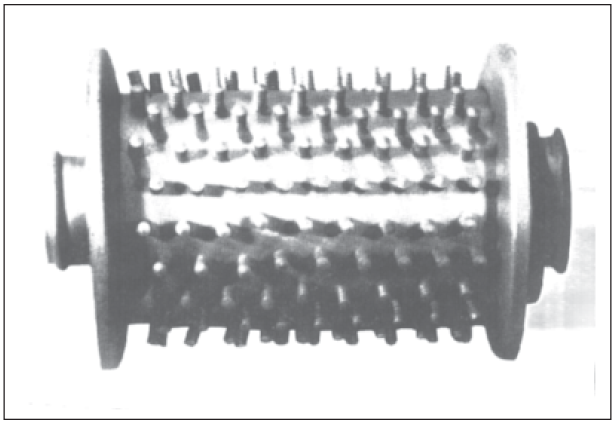

Figure 1-28a Engine muffler with studs welded on its surface to increase the amount of heat transfer.

4. Combustion Heaters

Exhaust shroud heaters are used for small single-engine aircraft, and compressor bleed air heating is primarily used on large turbine-powered aircraft. The light- and medium-twin engine aircraft are often heated with combustion heaters, as shown in figure 1-29.

These popular heaters consist of two stainless steel cylinders, one inside the other. Combustion air from outside the aircraft is forced into the inner cylinder, and aviation gasoline drawn from the fuel tank is sprayed over a spark plug that is continually sparking. This results in a very hot flame that heats the combustion chamber, and then the gases are exhausted overboard. Ventilating air flows through the outer cylinder around the combustion chamber and picks up the heat and distributes it through the cabin. This type of heater has a number of safety features that prevent it creating a fire hazard in the event of a malfunction. A complete schematic of a combustion heater system is illustrated in figure 1-30.

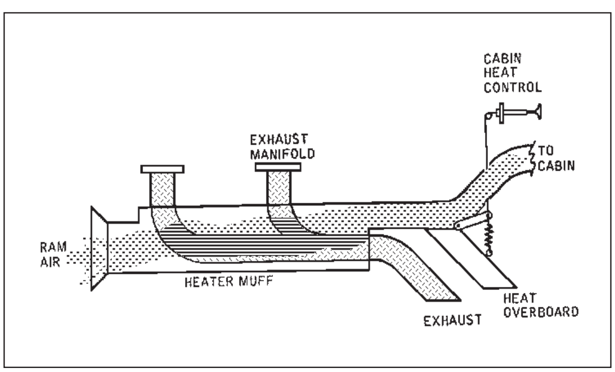

Figure 1-28b Exhaust heating system for a light airplane.

a. Combustion Air System

The air that is used in the combustion process is picked up from a scoop on the outside of the aircraft and is forced into the combustion chamber by the combustion air blower.

b. Fuel System

Fuel is taken from the aircraft fuel system and pressurized with a constant pressure pump, and after it passes through a fuel filter, it is controlled by a solenoid valve that may be turned off by the overheat switch, or by the pressure switch. There is a second solenoid valve in the fuel line that is controlled by the cabin thermostat. It shuts off the fuel just before it enters the combustion chamber.

c. Ventilation Air System

Ventilating air is normally taken into the heater from outside the aircraft, except for pressurized aircraft where air is taken from the cabin, and it flows over the outside of the combustion chamber, where it picks up heat and carries it inside the aircraft. There is a ventilating fan in the heater that operates when the aircraft is on the ground, but when the aircraft becomes airborne, a switch on the landing gear shuts off the ventilating fan. The ventilating air pressure is slightly higher than the pressure of the combustion air, so in the event of a crack in the combustion chamber, ventilating air will flow into the combustion chamber rather than allowing the combustion air that contains carbon monoxide to mix with the ventilating air.

d. Controls (Southwind 8240A)

The only action required by the pilot to start the combustion heater is to turn the cabin heater switch ON and adjust the cabin thermostat to the temperature wanted by the heater to maintain. When the cabin heater switch is turned on, the fuel pump starts, as well as both the ventilating air and the combustion air blowers. As soon as the combustion air blower moves the required amount of air, it trips a pressure switch which starts the ignition coil supplying sparks to the igniter plug. The fuel supply solenoid valve is opened and fuel can get to the heater. When the thermostat calls for heat, the second fuel solenoid valve opens and fuel sprays into the combustion chamber and burns. As soon as the temperature reaches the value for which the thermostat is set, the contacts inside the thermostat open and de-energize the fuel solenoid valve, shutting off the fuel to the heater, and the fire goes out. The ventilating air cools the combustion chamber, and the cool air causes the thermostat to call for more heat. The cycle then repeats itself.