



SURFACE VEHICLE INFORMATION REPORT

J169™

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(R) Design Guidelines for Air-Conditioning Systems
for Off-Road Operator Enclosures

RATIONALE

This document has been substantially revised to increase the scope and the information contained within to make it more comprehensive. It has also changed to comply with the new SAE Technical Standards Board format.

The experience gained from automobile air conditioning is very important, but it must be remembered that operating conditions for automobiles and off-road equipment are vastly different. Off-road equipment shall be designed to meet severe conditions of heat, dust, vibration, and general rough usage.

1. SCOPE

The purpose of this document is to establish air-conditioning design guidelines that will apply to most systems rather than the specific design of any particular system. Operating conditions and characteristics of the equipment will determine the design of any successful system; since these characteristics and conditions vary greatly from one application to another, the designer shall determine the goals expected to be reached under the conditions encountered. To determine the capacity of such items as blowers, condenser fans, condenser coils, evaporator coils, filters, compressors, etc., will require the adherence to several guidelines, some of which are outlined in the following paragraphs.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publication

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1503	Performance Test for Air-Conditioned, Heated, and Ventilated Off-Road, Self-Propelled Work Machines
SAE J2064	Coupled Automotive Refrigerant Air-Conditioning Hose Assemblies
SAE J3078/1	Off-Road Self-Propelled Work Machines Operator Enclosure Environment, Part 1: Terms and Definitions

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Documents
Document Sharing Hub

SAE J3078/2	Off-Road Self-Propelled Work Machines Operator Enclosure Environment, Part 2: Air Filter Element Test Method
SAE J3078/3	Off-Road Self-Propelled Work Machines Operator Enclosure Environment, Part 3: Operator Enclosure Pressurization System Test Procedure
SAE J3078/5	Performance Test for Windshield Defrosting Systems for Off-Road, Self-Propelled Work Machines
SAE J3078/6	Off-Road Self-Propelled Work Machines Operator Enclosure Environment, Part 6: Determination of Effect of Solar Heating

Eischen, F., "Producing a Quiet and Comfortable Cab," SAE Technical Paper 680587, 1968, <https://doi.org/10.4271/680587>.

2.1.2 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ISO 6682	Zones of Comfort and Reach for Controls
ISO 10263	Earth Moving Machinery Operator Enclosure Environment
ISO 14269	Tractors And Self-Propelled Machines for Agriculture and Forestry - Operator Enclosure

2.1.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D380	Standard Test Methods for Rubber Hose
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2.1.4 ASHRAE Publications

Available from ASHRAE Headquarters, 1791 Tullie Circle, NE, Atlanta GA 30329, Tel: 800-527-4723 (U.S. and Canada only) or 404-636-8400, www.ashrae.org.

ASHRAE Guide and Data Book, Vol. 1, Fundamentals and Equipment.

2.1.5 Other Publications

AS 2823	Agricultural Tractors and Self-Propelled Machines - Test Procedure for Performance of Air-Conditioning Systems - Australian Government
ASABE-S613 1-3	Air Quality Systems for Cabs
EEC/78/317	Defrost Test
SMS 2864	Test Procedure for the Performance of Defroster Systems for the Windscreen in Cabs
SMS 2865	Test Procedure for HVAC Cabs

Vogelaar, B.F., "Engineering and Operational Characteristics of Air Conditioning Cab." Paper 59-639 presented at ASAE meeting, December 1959.

3. DEFINITIONS

3.1 EFFECTIVE TEMPERATURE

Combination of relative humidity and temperature which can indicate the level of comfort perceived by the human body.

3.2 AIR FLOW

The direction, velocity, and volume of air moved to and around the occupant space.

3.3 OPERATOR ENCLOSURE

Part of the machine which surrounds the operator, preventing the free passage of external air, dust, or other substances into the area around the operator.

3.4 AIR CONDITIONING SYSTEM

System which lowers the effective temperature of the air within the operator enclosure.

3.5 EXTERNAL AIR

Controlled air entering the system or opening from outdoors before any air treatment.

3.6 RECIRCULATED AIR

Air within the operator enclosure which passes through the air-conditioning system.

3.7 COOLING

A decrease in the temperature of the air inside the operator enclosure.

3.8 HEATING

An increase in the temperature of the air inside the operator enclosure.

3.9 VENTILATION

A system or means of providing fresh air into an operator enclosure.

3.10 VENTILATION SYSTEM

System which provides external air to, and maintains air circulation within, the operator enclosure.

3.11 PRESSURIZATION

Positive pressure differential between the static pressure inside and outside of the operator enclosure.

3.12 PRESSURIZATION SYSTEM

Means used to create a state of positive pressure within the operator enclosure including any components which influence the performance of the system.

3.13 FILTRATION

Removal of contamination particles from the air forced or drawn into the operator enclosure by mechanical means.

3.14 FILTRATION SYSTEM

Means for removing contamination particles from air entering or being recirculated in the operator enclosure.

3.15 SOLAR HEATING

Heating factor from the sun to be considered in determining air circulation and cooling requirements necessary to maintain a comfortable temperature inside the operator enclosure.

3.16 SOLAR RADIANT ENERGY

Process by which solar heating is generated.

3.17 LATENT HEAT

Amount of energy in the form of heat released or absorbed by a substance during a change of phase state.

3.18 SENSIBLE HEAT

The heat required to change the temperature of a substance.

3.19 HVAC SYSTEM

Heating, ventilating, and air-conditioning system.

3.20 HVAC MODULE

The evaporator, heater, and blower that is contained in an enclosure and designed to operate as a system.

4. AMBIENTS AND OPERATING CONDITIONS

4.1 Ambient Temperature

The ambient air temperature at which the equipment will normally operate is one of the most significant factors to be considered in determining the capacity required for proper heating or cooling of the operator enclosure.

4.2 Solar Heating

Solar heating shall be considered carefully when designing the system. Solar radiant energy causes a heating effect to be considered in determining cooling capacity and insulating requirements. Also, direct radiation on the operator can cause discomfort not easily overcome by the system.

4.3 Mechanical Load

The mechanical load is heat transferred to the operator enclosure from the engine, transmission, hydraulics, etc. This load shall be considered when locating system components and may require special insulation.

4.4 Dirt and Dust

Contamination particles shall be considered when designing the filtration system and when locating components, particularly—but not limited to—those outside the operator enclosure, such as the external air inlet.

4.5 Global Factors

Ambient conditions of the various markets that the vehicle will operate in shall be considered (consider North American versus European average ambient conditions). For example, environments with high heat and humidity will need higher AC capacity as condensing water vapor from the air requires removing significant energy as heat. Environments with extremely low temperatures will require a higher heating capacity to keep the occupants comfortable and defrost windows.

4.5.1 Durability

4.5.1.1 Normal Duty

Off-road equipment normally encounters shock and vibration conditions requiring more robust design than automobiles and trucks. However, unless the operating conditions are severe, normal manufacturing techniques used for off-road equipment are usually adequate.

4.5.1.2 Severe Duty

Equipment such as track mounted off-road equipment and accessories for such equipment are often subjected to greater shock and vibration than usually encountered in other off-road equipment. Therefore, provisions should be made in the air-conditioning system to withstand such conditions. This may require shock mounting of some components. Sheet metal parts may have to be fastened together with more robust methods. Additional vibration testing may be required.

5. SYSTEM BASICS OF OPERATION

The HVAC system consists of the following parts: refrigeration loop, heater circuit, air circulation system, and control system. The refrigeration loop and heater circuit remove and add heat to the air through the evaporator and heater cores which act as heat exchangers.

5.1 Refrigeration Loop with TEV/TXV (Thermostatic Expansion Valve)

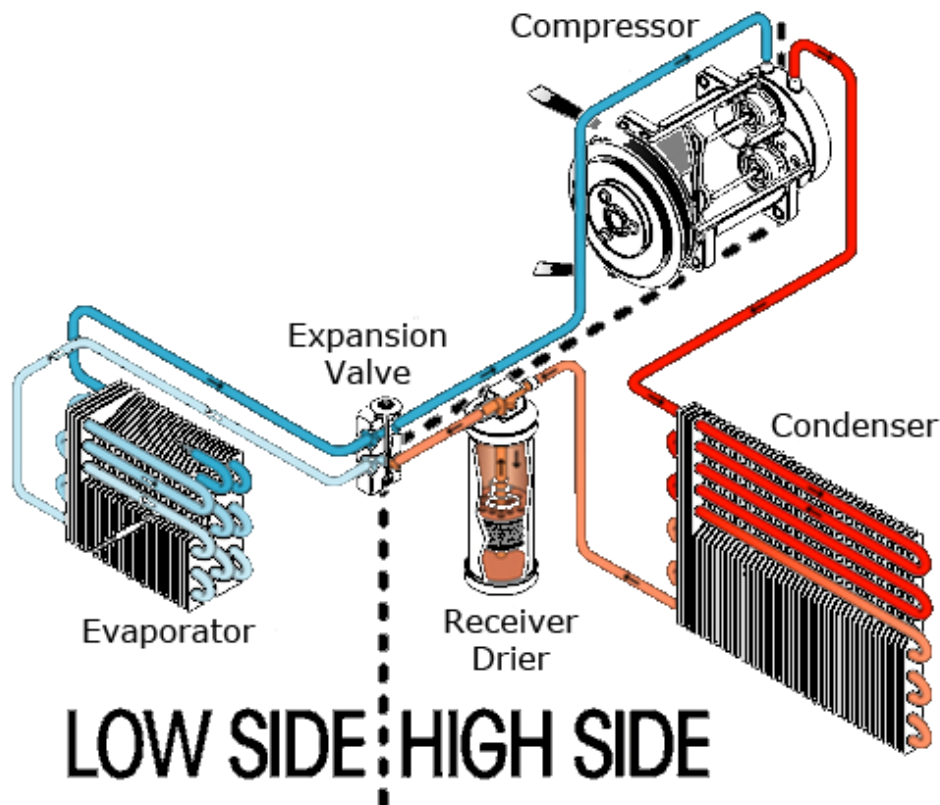


Figure 1

5.2 Refrigeration Loop with Orifice

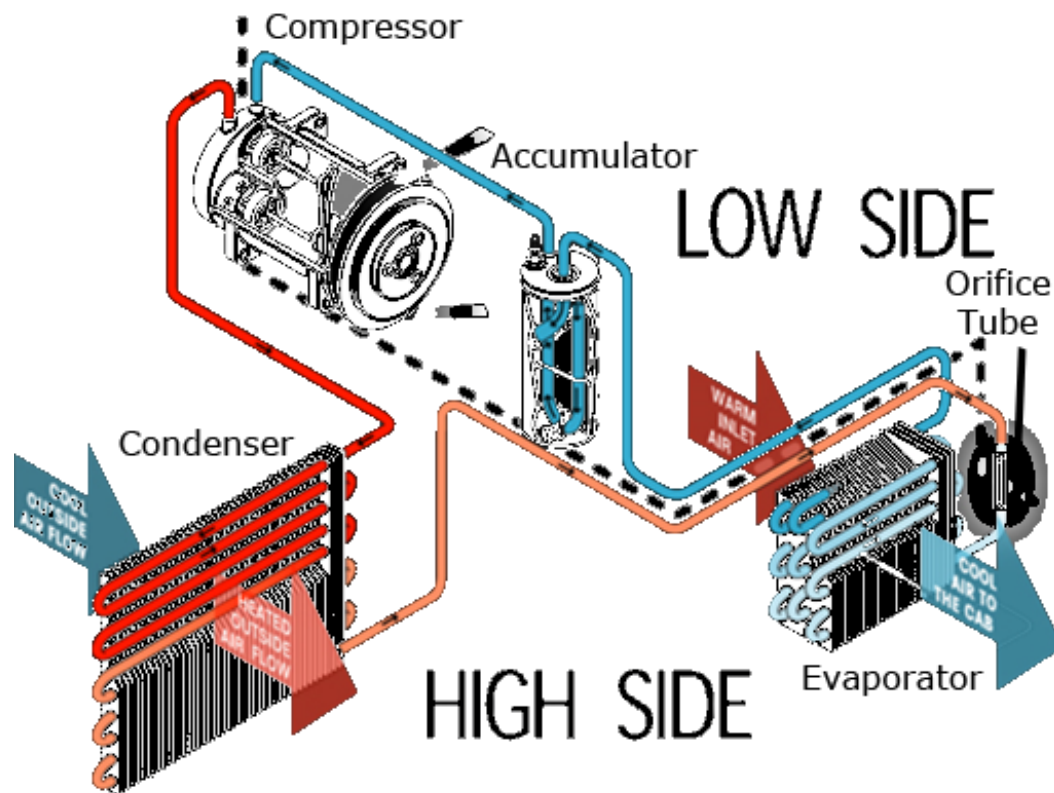


Figure 2

A compression refrigeration cycle consists of the following phases: compression, cooling and removing superheat, condensation subcooling, expansion, evaporation, and superheating. Compression is accomplished by means of an AC compressor where superheated vapor enters the compressor at low pressure and temperature and is compressed to a higher pressure and temperature. The high-pressure superheated vapor is carried to the condenser, where the refrigerant undergoes the following transformations utilizing outside ambient air; the heat is removed from the refrigerant vapor to bring its temperature to a condensing point, then gas is condensed to a liquid phase, and finally the liquid is subcooled to a specified level. The subcooled liquid refrigerant then undergoes expansion through an orifice device changing to a low temperature and pressure mixture of liquid and vapor. The mixture of liquid and vapor enters the evaporator where the latent and sensible heat from air passing through the evaporator core vaporizes and then superheats the refrigerant. The superheated vapor then flows back to the compressor and the cycle repeats. There are additional components in the refrigerant loop which perform non-refrigeration cycle roles. These are components such as receivers, filter-driers, accumulators, moisture indicators, sight glasses, etc.

5.3 Heater Circuit

The heater circuit usually taps into a high-pressure point on the engine cooling system to bring hot coolant into the heater core and then returns it to a low-pressure point on the engine or radiator. The amount of heat added by the heater circuit is controlled by regulating the amount of coolant flow through the heater core by means of a coolant valve or by controlling the amount of air going through the heater core.

5.4 Air Circuit

The air circuit has the following functions: bring and filter a specified amount of outside and inside air through the HVAC module and distribute it into the operator enclosure. The air distribution system needs to be able to meet the requirements of cooling, heating, dehumidification, defogging, and defrosting. The blower fan(s), which can be either an integral part of the HVAC module or of the operator enclosure, are utilized to bring the air through the air circuit. There are two major types of air circuit designs: reheat and blend.

5.4.1 Reheat Air Systems

In reheat systems, air first passes through the evaporator to remove heat and moisture and then flows through the heater core to adjust the temperature level. This approach allows for the active dehumidification of air by cooling and reheating. The heater valve is utilized to regulate the amount of heat added to the air by controlling coolant flow.

5.4.2 Blended Air Systems

In blended air systems all the air generally flows first through the evaporator core as well. However, in blend air systems, some or all air may bypass the heater core. The mode door position regulates the proportions of air flowing through the heater core and bypassing the heater core.

5.5 HVAC Control

There are two general approaches: manual temperature control and automatic temperature control (ATC). ATC uses a micro processor to maintain a constant operator enclosure temperature. Manual control relies on the operator to adjust controls to maintain cab comfort levels. Both manual and ATC systems utilize common methods to control cooling and heating output. The cooling output is controlled either by cycling the compressor clutch, varying compressor displacement (in case variable displacement compressor is used), or varying compressor speed. The amount of heat added is controlled by either varying the coolant or air flow through the heater core.

There are other control devices such as evaporator temperature sensors and high-pressure and low-pressure switches that are used to provide proper functionality, and protection of the system and its components.

6. HVAC SYSTEM DESIGN GUIDELINES - SYSTEM LEVEL

6.1 Location of Components

6.1.1 General

The type of equipment and location of the operator enclosure on the equipment will greatly affect the location of the system components. In general, refrigerant components should be isolated or insulated from high heat sources such as exhausts, engines, transmissions, etc. All components should be positioned in such a manner that they will not hamper the operator when entering or leaving the enclosure, or while operating the equipment. In many systems, it is practical and cost effective to locate the condenser upstream of the vehicle's radiator, which will yield good results if properly sized. Careful consideration shall be given to the problem of dust and dirt clogging the heat exchangers, which reduces their efficiency. An alternative is to mount the condenser in some other location and cool it with a motor (electric or hydraulic) driven fan(s). The advantage of cooling with motor-driven fans is that the condenser can be mounted in the best possible location relative to the rest of the system, minimizing exposure to dirt and dust.

6.1.2 HVAC Module Location within the Cab

The major HVAC system components can be located in multiple places within the cab. One of the key decisions is where to place the HVAC module. Several things impact this location.

6.1.2.1 Performance

6.1.2.1.1 In general, the closer the HVAC module to the louvers (vents), the closer the louver air temperatures will be to the air temperature leaving the heat exchangers. In other words, there will be less heat loss or gain as the air travels through the ducts.

6.1.2.1.2 In air-conditioning mode, operators usually put a priority on aiming the conditioned air to flow to the front of the upper body. Therefore, louvers that are facing the operator and close to the upper body are best for getting flow during air-conditioning mode. To reduce heat gain, the best location for the HVAC module is in the roof area or in the front console, to keep the duct length to a minimum.

6.1.2.1.3 During the heating mode, operators put a priority on aiming the conditioned air to flow to the lower body. In this case, louvers that are close to the lower body are best for getting flow during heating mode. To reduce heat loss, the best location for the HVAC module is around the floor area, or in the front console.