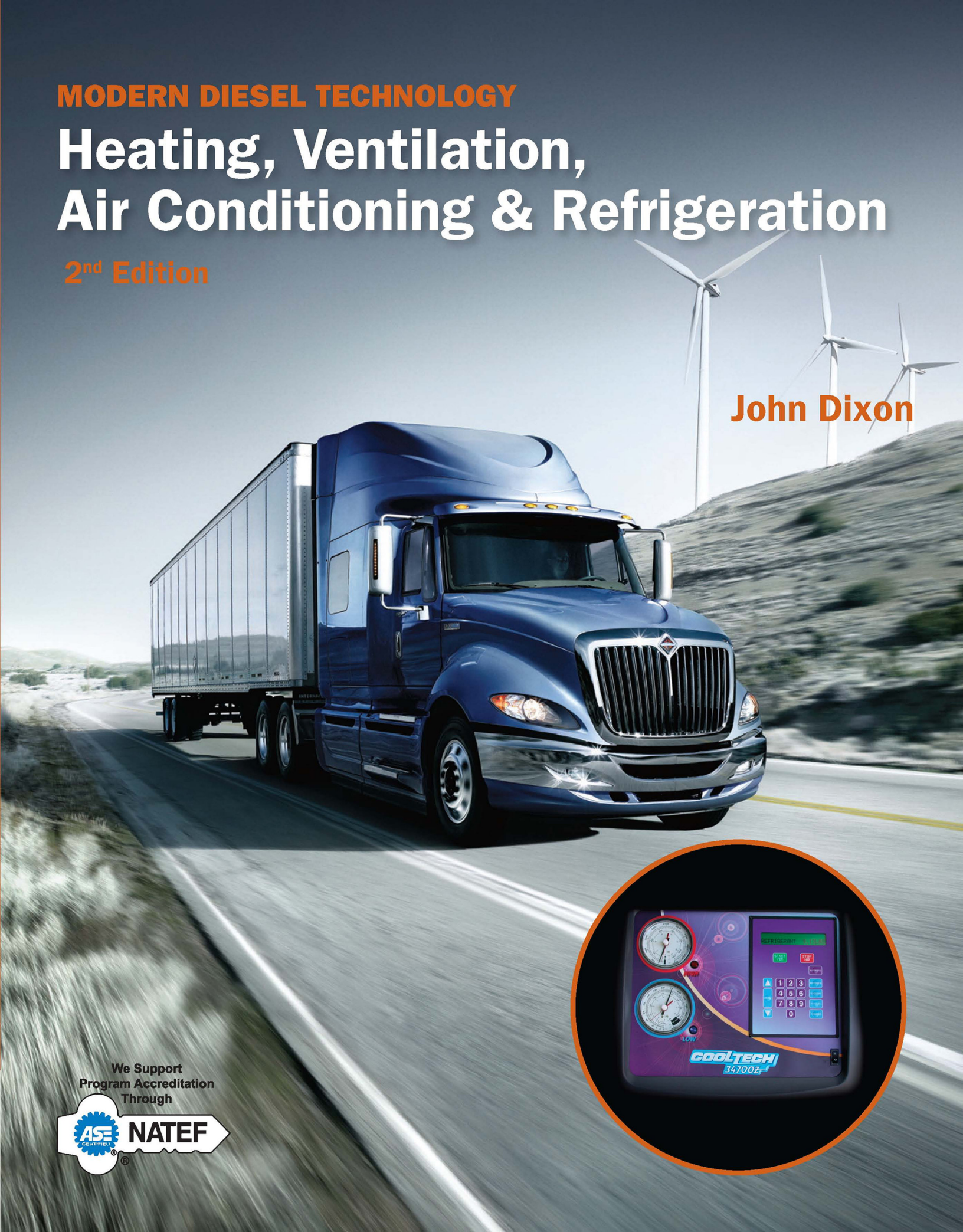
MODERN DIESEL TECHNOLOGY

Heating, Ventilation, Air Conditioning & Refrigeration

2nd Edition

John Dixon



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Modern Diesel Technology: Heating, Ventilation, Air Conditioning & Refrigeration

2nd Edition

John Dixon

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Modern Diesel Technology: Heating, Ventilation, Air Conditioning & Refrigeration, 2nd Edition
John Dixon

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Preface for Series

The Modern Diesel Technology (MDT) series of textbooks debuted in 2007 as a means of addressing the learning requirements of schools and colleges whose syllabi used a modular approach to curricula. The initial intent was to provide comprehensive coverage of the subject matter of each title using ASE/NATEF learning outcomes and thus provide educators in programs that directly target a single certification field with a little more flexibility. In some cases, an MDT textbook exceeds the certification competency standards. An example would be Joe Bell's *MDT: Electricity and Electronics* in which the approach is to challenge the student to attain a higher level of understanding than that required by the general service technician but suited to one specializing in the key areas of chassis electrical and electronics systems.

The MDT series now boasts nine textbooks. As the series has evolved, it has expanded in scope with the introduction of books addressing a much broader spectrum of commercial vehicles. Titles now include *Heavy Equipment Systems; Mobile Equipment Hydraulics;* and *Heating, Ventilation, Air Conditioning & Refrigeration,* with the latter including a detailed examination of trailer reefer technology, subject matter that falls outside of the learning objectives of a general textbook. While technicians specializing in all three areas are in demand in most areas of the country, there are as yet no national certification standards in place.

In addition, the series now includes two books that are ideal for students beginning their study of commercial vehicle technology. MDT's titles *Preventive Maintenance and Inspection* and *Diesel Engines* are written so that they can be used in high school programs. Each uses simple language and a no-nonsense approach suited for either classroom or self-directed study. That some high schools now offer programs specializing in commercial vehicle technology is an enormous progression from the more general secondary school ''shop class,'' which tended to lack focus. It is also a testament to the job potential of careers in the commercial vehicle technology field in a general employment climate that has stagnated for several years. Some forward-thinking high schools have developed transitional programs partnering with both colleges and industry to introduce motive power technology as early as grade 10, an age at which many students make crucial career decisions. When a high school student graduates with credits in ''Diesel Technology'' or ''Preventive Maintenance Practice,'' it can accelerate progression through college programs as well as make those responsible for hiring future technicians for commercial fleets and dealerships take notice.

Because each textbook in the MDT series focuses exclusively on the competencies identified by its title, each book can be used as a review and study guide for technicians prepping for specific certification examinations. Common to all of the titles in the MDT series, the objective is to develop hands-on competency without omitting any of the conceptual building blocks that enable an expert understanding of the subject matter from the technician's perspective. The second editions of these titles not only integrate the changes in technology that have taken place over the past five years but also blend in a wide range of instructor feedback based on actual classroom proofing. Both should combine to make these second editions more pedagogically effective.

Sean Bennett 2012

Preface

The reason for writing this textbook is to give truck technicians a solid foundation in the area of current HVAC systems. The book starts with an introduction to the system as well as to environmental and safety practices. The chapter on thermodynamics is a key building block for students to comprehend. All other chapters of this book build on the principles that are learned in that chapter. My belief is that if technicians understand how something is supposed to function, they will have a greater ability to diagnose and make the necessary repairs to the system than technicians who arbitrarily change parts until the system operates correctly and/or the complaint goes away. The text is written in a step-by-step format for the entry-level technician, in appropriate language so as to not leave new technicians behind. Once the fundamentals of air conditioning have been discussed, the text continues on to the air-conditioning components, types of systems, service procedures, air-conditioning protection units (ACPU), and troubleshooting.

The second part of the text deals with truck-trailer refrigeration equipment. Skilled technicians in this area of the trucking industry are in great demand. Again, this section of the text builds on the earlier chapter on thermodynamics and goes forward from there to an introduction of the mobile refrigeration unit (reefer), then takes the technician through the components, refrigerant flow, electrical components, and system preventive maintenance. A secondary objective of this book is to cover some of the ASE T7 and NATEF task objectives. This section is included in the instructor's manual. The learning outcome objectives are designed to meet or exceed ASE T7 and NATEF task objectives. Included in learning objectives are HVAC system service and repair; A/C system and component diagnosis, service, and repair; heating and engine cooling systems diagnosis service and repair; and refrigerant recovery, recycling, and handling.

Heating, Ventilation, Air Conditioning & Refrigeration, 2nd Edition is unique to today's market because there is currently no competitive textbook that combines truck HVAC and truck-trailer refrigeration systems. This book should be a very usable study resource for entry-level as well as experienced technicians working on HVAC systems. In addition, mobile refrigeration technicians get an overview of refrigeration systems and maintenance tasks required in the industry.

New to this edition:

- **Chapter 12** is a completely new chapter on coach air conditioning. This chapter takes the technician through Carrier large bus system refrigerant flow schematics, system controls, performance testing, and service procedures.

I would like to thank Stuart Bottrell, corporate trainer at Freightliner Canada, LLC, for all of his help and technical expertise in the production of this textbook; Index Sensors & Controls, which provided technical information, art, and troubleshooting charts for this text; and Carrier Refrigeration Operations for its excellent training and service procedures in bus air conditioning.

John Dixon, August 2012

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I feel it is important to thank my apprenticeship students for their feedback over the years. While developing this text, I was able to teach from it a sort of field test run, if you will. This allowed my students to be my greatest critics, and I was able to make any changes as required. My rationale is that if my students didn't understand a concept, I would try another explanation until they did. Many of my students have been working in the trade for five years or more on the front line of new technology. Their feedback was and is paramount to me.

I would also like to thank my wife, Connie, and our three daughters, Alyzza, Jaymee, and Olyvia for giving me the time to work on this text. They sacrificed much of their time spent with me, allowing me to pursue my goals.

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INSTRUCTOR RESOURCES

Time-saving instructor resources are available at the Instructor Companion Website for the text or on CD. Either delivery option offers the following resources: PowerPoint chapter presentations with selected images, an ExamView test bank, an Image Gallery containing images from the book, an Instructor's Guide which includes an answer key to chapter review questions, Word documents containing the chapter review questions, a chart correlating NATEF tasks to text pages, and a set of job sheets for use in the shop.

CHAPTER

1 Heating, Ventilation, and Air Conditioning

Learning Objectives

Upon completion and review of this chapter, the student should be able to:

- Describe the evolution of the modern-day air-conditioning system.
- Explain the purpose of the compressor as used in an air-conditioning system.
- Describe the function of the condenser.
- Explain the key differences between an orifice tube and a thermostatic expansion valve.
- Explain the purpose of a drier as used in an air-conditioning system.
- Describe the function of the evaporator.
- Explain how the accumulator works and what its function is in an air-conditioning system.
- Describe the uses for the manifold gauge set.
- List the different types of leak detectors and explain the purpose of a leak detector.
- Explain the functions of a vacuum pump as used on an air-conditioning system.
- Outline the reasons for refrigerant recovery.
- Describe refrigerant recycling.
- Explain why antifreeze must be recycled.
- List the advantages of a ventilation system.
- Outline the advantages to a technician of having the use of a scan tool.
- Explain why a refrigerant identifier should be used before servicing an air-conditioning system.

Key Terms

accumulator
compressor
condenser
evacuation
evaporator
humidity
HVAC
leak detector
manifold gauge set
orifice tube
receiver-drier
recovery
recycle
refrigerant identifier
scan tool
thermometer
thermostatic expansion valve
vacuum pump
ventilation

INTRODUCTION

This is the first of many chapters intended for the technician in the **HVAC** (heating, ventilation, and air-conditioning) field. It is interesting to see just how far humanity has come in such a short time regarding the development of climate control systems in modern vehicles. A technician should understand what functions an HVAC system is intended to perform and how the system accomplishes these tasks. Next the technician will be introduced to the components that make up a modern HVAC system and the tools required to maintain these ever-evolving systems.

SYSTEM OVERVIEW

In this chapter, the technician will first be given a brief history of the modern HVAC system. The technician will then be introduced to the purpose of the heating, ventilation, and air-conditioning system and be given a brief description of the components making up modern HVAC systems. These components will be discussed in detail in later chapters. This chapter will finish with an introduction to some of the specialty tools used by technicians in the HVAC field.

HISTORY OF AIR CONDITIONING

People who lived as far back as the ancient pharaohs of Egypt were probably the first to actively try to control the temperature of their environment. Evidence shows that each night, thousands of workers were used to disassemble the inner walls of the pharaoh's palace, and the thousand-pound blocks were carried into the desert, where they were left to cool during the night. The next morning they were taken back to the pharaoh's palace and the inner walls were reassembled. This extreme amount of work allowed the palace to remain a relatively cool 80°F (27°C) when the temperatures outside the palace were as high as 120–130°F (49–54°C).

In 1884, the Englishman William Whiteley placed blocks of ice in a tray under a horse carriage and used a fan attached to a wheel to force air inside. Later, a bucket of ice in front of a floor vent became the automotive equivalent.

Railway passenger cars also used to have large blocks of ice loaded into containers built underneath the passenger compartment; a fan was used to blow air over the ice and circulate cool air through the rail car.

Automobiles were not very comfortable in the early years because the cabs were open. Passengers had to wear many layers of clothing in the winter, and in the summer the only ventilation was what could be brought in through the windows or open top of a vehicle that could cruise at a speed of 15 mph. Car companies then began closing up the cabins on cars; this required a change in temperature control systems. First, vents were put in the floors of cars, but this brought in more dirt and dust than it did cool air. In early attempts to cool the air, drivers placed buckets of water on the floor of their cars, thinking that air flowing over the surface of the water would cool the occupant compartment of the vehicle.

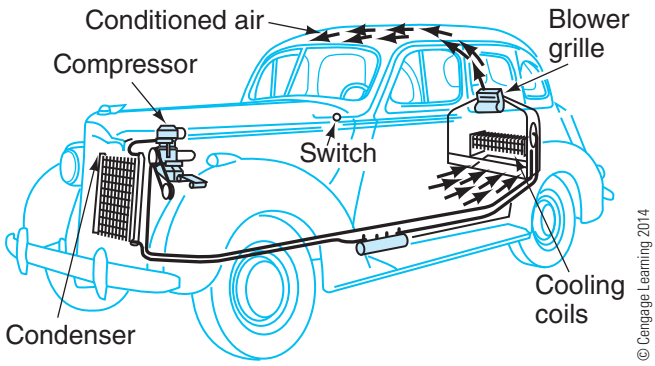


Figure 1-1 A 1939 Packard with air conditioner.

Evaporative cooling systems soon followed. In 1939, Packard produced the first passenger cars using refrigeration components. The huge evaporator was mounted in the trunk, leaving little room for luggage, and the only way to shut the evaporator off was to stop, raise the hood, and remove the drive belt from the compressor. Cadillac followed suit in 1941 with an air-conditioned car, and in 1954, Delphi Harrison Thermal Systems engineered an air-conditioning system that located all the major components of the air-conditioning system under the car's hood **(Figure 1-1).**

TODAY'S AIR-CONDITIONING SYSTEMS

Thanks to recent advances in modern technology, today's vehicles are extremely comfortable no matter what the weather is like outside the vehicle. Innovations such as computerized automatic temperature control (which allows you to set the desired temperature and have the system adjust automatically) and improvements to overall durability, have added complexity to today's air-conditioning systems. When today's truck drivers travel through regions of differing climates throughout the United States and Canada, they can enjoy the same comfort levels that they are accustomed to at home. With the simple slide of a lever or

the push of a button, the climate-control system will make the transition from heating to cooling and back without the driver ever wondering how these changes occur.

For vehicles operating in northern United States, or Canada, heating systems keep the occupants warm and comfortable and also keep the windshield clear of ice and snow, improving visibility dramatically.

For vehicles operating in southern United States, or Canada, air conditioning greatly improves the comfort level of the occupants by cooling the cabin of the vehicle far below the temperatures outside the vehicle and, as an added benefit, also removes humidity (water vapor) from the circulating air.

Due to the complexity of today's air-conditioning systems, the "do it yourself" approach to air-conditioning repair is a thing of the past. To add to the complications, technicians are now faced with stringent environmental regulations that govern even the simplest of tasks. The technician is required to be certified to purchase refrigerant and to repair air-conditioning systems. The shop in which the technician works must also incur the cost of purchasing expensive dedicated equipment that is capable of removing all of the refrigerant from a vehicle, in order to prevent any of the ozone-depleting chemicals from escaping into the environment. This is required any time the air-conditioning system must be opened for repairs.

VEHICLE HEAT AND COLD SOURCES

The heat and cold that an HVAC (heating, ventilation, and air-conditioning) system is required to overcome originate from many different sources. Ambient air temperature (the outside air temperature), whether hot or cold, is one such source. Another source of heat is solar radiation. Solar radiation is the reason that the interior of a truck can be much hotter than the ambient temperature when the vehicle is parked in the sun. The tinting of windows can reduce the effects of solar radiation. Other sources of heat are those generated by the engine and cooling system. These include heat from the transmission, heat from the exhaust system, and heat that is radiated up through the floor of the vehicle from the surface of the road. Heat is also generated by the driver and, if applicable, the passenger in the vehicle. The heat that the human body constantly radiates to the air in the cab, as well as the warm moist air expelled from the human lungs, all add to the heat and moisture that must be removed from an HVAC system **(Figure 1-2).**

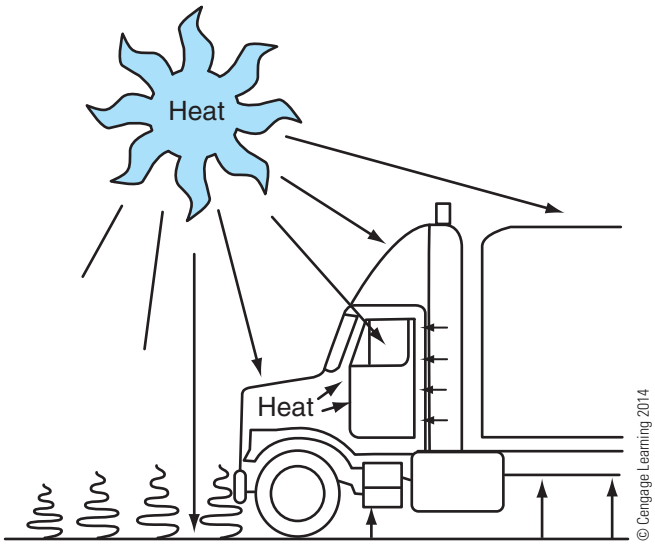


Figure 1-2 Heat enters the cab through windows, engine heat enters through the firewall, and heat radiates up through the floor from the hot pavement.

Another source of hot or cold air is the fresh air **ventilation** system. This system helps drivers stay more alert by changing or refreshing the air in the cab once or twice per minute. The air is circulated by a fan, usually referred to as a blower motor. The outside air coming into the cab must be either heated or cooled before it reaches the vehicle interior, depending upon whether the driver has selected heating or air conditioning. The ventilation system improves the performance of the air-conditioning or heating system by improving air flow within the vehicle. These air currents inside the vehicle guarantee that all areas inside the vehicle receive fresh air, whether heated or cooled.

PURPOSE OF THE HVAC SYSTEM

In today's trucks, the heating, ventilation, and air-conditioning (HVAC) systems perform three very important functions:

- Temperature control: The HVAC maintains the temperature within the passenger compartment as selected by the operator. It accomplishes this by adding or removing heat from the vehicle interior.
- Humidity control: The HVAC system reduces the **humidity** (water level in the air) within the passenger compartment, preventing condensation on the windows. Dehumidification or drying of the air helps the driver feel much more comfortable.

- Air circulation control: The HVAC refreshes the air in the vehicle's interior by circulating and replacing stale air, while maintaining the selected interior air temperature.

AIR-CONDITIONING COMPONENTS

Today there are two different types of air-conditioning systems, which differ only slightly. The concept and design of these two types are very similar. The most common components that make up these truck air-conditioning systems are as follows:

1. Compressor
2. Condenser
3. Pressure regulating devices
   a. Orifice tube
   b. Thermostatic expansion valve
4. Thermostatic expansion valve
5. Evaporator
6. Receiver-drier
7. Accumulator

Compressor

The **compressor** can be referred to as the heart of the system. Compressors are bolted to the engine and are belt-driven by either a V-belt or a serpentine belt. The compressor is responsible for compressing and transferring refrigerant gas **(Figures 1-3** and **1-4).**

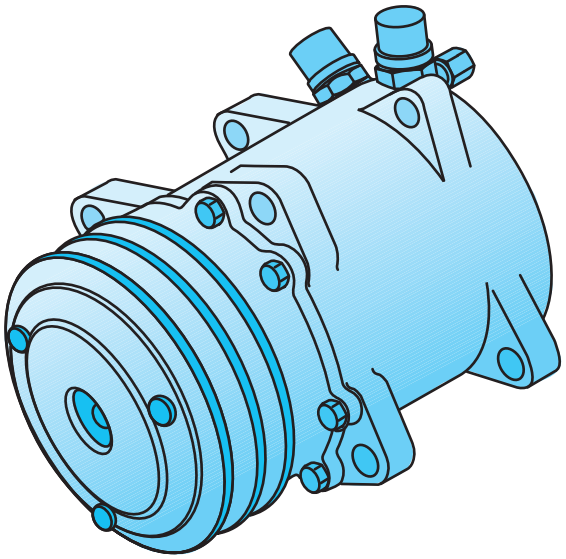


Figure 1-3 A swash plate compressor. Compressors are mounted in the engine compartment and are belt-driven by the truck's engine. The compressor includes an electromagnetic clutch to engage or disengage the compressor.

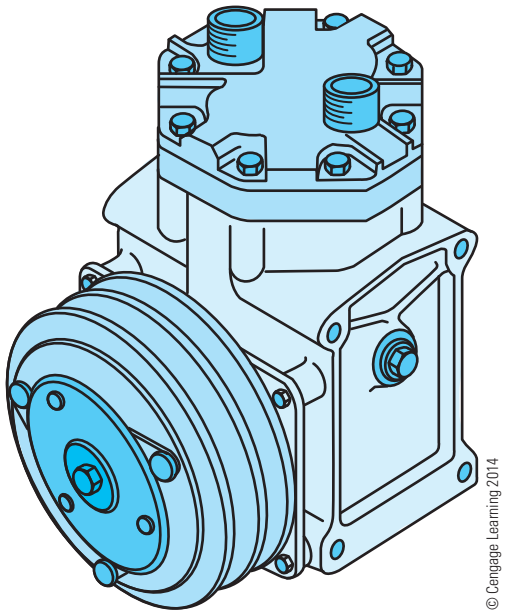


Figure 1-4 A two-piston type compressor.

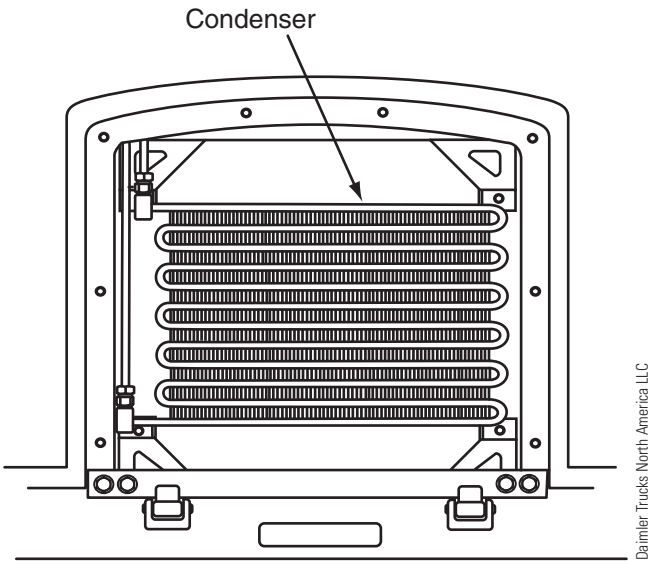
The air-conditioning system may be divided into two different sides: the high-pressure side (commonly referred to as the discharge side) and the low-pressure side (also known as the suction side). The compressor is the dividing point between the suction and discharge sides of the air-conditioning system.

The suction side of the compressor draws in refrigerant gas from the outlet of the evaporator. In some cases, it does this via the accumulator. Once the refrigerant is drawn into the suction side, it is compressed. This concentrates the heat in the vapor, raising its temperature. The vapor leaving the compressor must be hotter than the atmosphere so that while it is in the condenser, it will dissipate the heat that it carries to the cooler ambient air. It is important to remember that these pumps are designed to compress only vapor. If liquid refrigerant gets into the inlet side of the compressor, it will damage the compressor by breaking valves or will cause the compressor's pistons to lock up.

Condenser

The **condenser** is the component that dissipates the heat that was once inside the cab of the truck. In most cases, the condenser has an appearance very similar to that of the radiator, because the condenser and radiator have very similar functions. The condenser is designed to radiate heat and is usually located in front of the radiator. In some retrofit applications, it may be located on the cab roof **(Figure 1-5).**

Condensers must have air flow any time the system is in operation. This is accomplished by the ram air



Daimler Trucks North America LLC

Figure 1-5 The condenser is the component in which the refrigerant surrenders heat from the cab to the ambient air.

effect of the truck as it runs down the road or by the engine cooling fan. Some manufacturers lock up the clutch fan whenever the air-conditioning system is operating.

The compressor pumps hot refrigerant gas into the top of the condenser. As the refrigerant is circulated through the condenser, the gas is cooled and condenses into high-pressure liquid refrigerant at the bottom of the condenser or condenser outlet.

Pressure Regulating Devices

As you will soon learn as you study thermodynamics **(Chapter 3),** the desired temperature of an evaporator can be maintained by controlling the refrigerant pressure. Over the years, many types of pressure regulating devices have been used. Today, the most common are the orifice tube and the thermostatic expansion valve.

Orifice Tube. The **orifice tube** is a simple restriction located in the liquid line between the condenser outlet and the evaporator inlet. In a properly running air-conditioning system, this will be a transition point at which the line is hot coming from the condenser and will immediately become cool as the refrigerant passes through the orifice tube. This restriction may be identified by small indentations placed in the line that keep the orifice tube from moving within the liquid line. Most orifice tubes used in today's trucks are approximately 3 inches long and consist of a small brass tube surrounded by plastic and covered with a filter

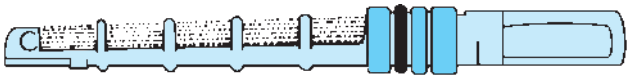


Figure 1-6 An orifice tube, used to meter the flow of refrigerant into the evaporator of an orifice tube air-conditioning system.

screen at each end. The inside diameter of the brass tube restricts the amount of liquid refrigerant that is able to pass through the valve. The orifice tube contains no moving parts. Truck manufacturers use different sized orifice tubes in order to balance the size of the air-conditioning system **(Figure 1-6).**

Thermostatic Expansion Valve. The other common pressure regulating device is the **thermostatic expansion valve**, or TXV for short. Thermostatic expansion valves are used by many truck manufacturers **(Figure 1-7).**

The thermostatic expansion valve, like the orifice tube, is situated between the condenser outlet and the evaporator inlet. This valve can sense both temperature and pressure, and is very efficient at controlling refrigerant flow through the evaporator. The expansion valve's job is to regulate the flow of refrigerant so that any liquid refrigerant metered through it has time to evaporate or change states from liquid to gas before leaving the evaporator. This is an important function because liquid refrigerant will destroy the compressor.

Expansion valves, although efficient, have maintenance characteristics different from those of orifice tubes. They can become clogged with debris just as orifice tubes can, but they also have small moving parts that may stick and malfunction due to corrosion; they may even freeze if enough water is able to enter the system.

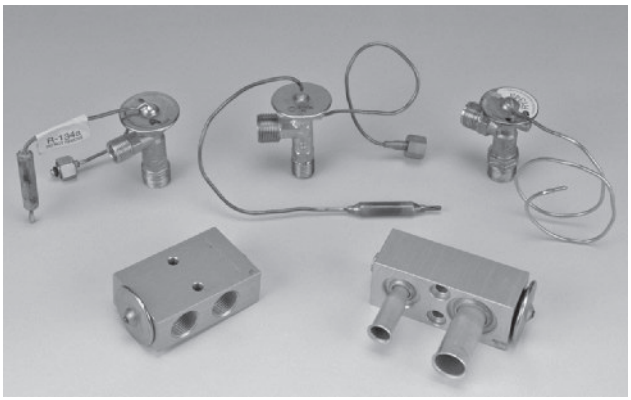


Figure 1-7 An assortment of thermostatic expansion valves.