UNITED STATES MARINE CORPS

ENGINEER EQUIPMENT INSTRUCTION COMPANY
MARINE CORPS DETACHMENT
686 MINNESOTA AVE
FORT LEONARD WOOD, MISSOURI 65473-8963

LESSON PLAN

AIR CONDITIONING SYSTEMS

NCOM-F01

ENGINEER EQUIPMENT MECHANIC NCO

A16ACU1

REVISED 17 JULY 2012

APPROVED BY ______________________________ **DATE** ________________

INTRODUCTION **(10 MIN)**

(ON SLIDE #1)

1. **GAIN ATTENTION**: When you are sitting in 110 degree weather what do you want the most in your vehicle? Air conditioning! At the end of this period of instruction, you will have more confidence in your abilities to repair an air conditioner when it breaks down.

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(ON SLIDE #2)

2. **OVERVIEW**. This period of instruction will cover laws and principles of refrigerant, refrigerant system components, service equipment, and air conditioner troubleshooting.

(ON SLIDE #3)

3. **LEARNING OBJECTIVES**.

INSTRUCTOR NOTE
Introduce the learning objectives.

a. **TERMINAL LEARNING OBJECTIVE**. Provided a service request, malfunctioning air conditioner, appropriate tools/test equipment, and references, repair an engineer equipment air conditioner malfunction, to restore system to proper function. (1341-MANT-2009)

b. **ENABLING LEARNING OBJECTIVES**.

1. Without the aid of references, identify the operation of an air conditioning system per the FOS5708NC. (1341-MANT-2009a)

2. Provided a piece of engineer equipment, a refrigerant recovery system, and references, recover the refrigerant per the CR700. 1341-MANT-2009b

3. Provided a piece of engineer equipment, references, and a vacuum pump, vacuum the system per the TM 11956A-OR/1. 1341-MANT-2009c

4. Provided a piece of engineer equipment, references, gauges and manifold set, and refrigerant, charge the system per the TM 11956A-OR/2. 1341-MANT-2009d

(ON SLIDE #4)

4. **METHOD/MEDIA**. This period of instruction will be taught using the informal lecture, demonstration and practical application methods, aided by computer generated graphics, student handouts, actual items and class participation.

INSTRUCTOR NOTE
Explain the Instructional Rating Forms to the students.

5. **EVALUATION**. There will be a thirty question, multiple choice, closed book examination and performance exam.

6. **SAFETY/CEASE TRAINING (CT) BRIEF**. During the lecture portion of the class there is low risk assessment, but when you go out to the bay there is a chance to get refrigerant in your eyes or on your skin. Wear the proper personal protective gear when handling and opening air conditioning systems.

(ON SLIDE #5)

TRANSITION: Now that you understand the purpose of this presentation, the terminal learning objective, enabling learning objective, how the period of instruction will be taught, and how you'll be evaluated. Do I have any questions? Let's begin with a discussion the principles of refrigeration.

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BODY **(41 HRS 40 MIN)**

(ON SLIDE #6)

1. **PRINCIPLES OF REFRIGERATION. (1.5 HRS)** Automotive air conditioning (A/C) systems are designed based on the laws of physics, chemistry, and electronics. A basic familiarity with these laws, together with an understanding of A/C components and their operation, provides the skills necessary for quick, accurate A/C system diagnosis.

(ON SLIDE #7-8)

a. **PHYSICS**. Physics is the science of matter and energy. Simply put, it teaches us how things interact in our universe. Areas of physics that we are going to discuss are: Behavior of heat, Properties of liquids and gases, Behavior of refrigerants (R-12 and R-134a), and the effects of heat and pressure on liquids and gases.

(ON SLIDE #9-10)

(1) Behavior of Heat. It is natural for humans to want to be comfortable. To achieve this in the automotive A/C systems must be able to remove moisture (humidity), dust, heat, and pollen particles from circulating air.

(ON SLIDE #11)

(a) Relative humidity directly affects moisture evaporation rate.

(b) The evaporation rate governs the amount of heat absorbed during a given time.

(ON SLIDE #12)

1 When the air is dry, moisture evaporates very rapidly, absorbing heat from the surrounding area. Place a drop of rubbing alcohol on your skin and this will be demonstrated within a matter of seconds. The alcohol will evaporate quickly and leave the skin feeling cooler then what it was.

(ON SLIDE #13)

2 When the air around you contains a lot of moisture, evaporation occurs much slower then it would in dry

climates. If it is humid outside and you were to place a drop of water on your skin it will take a long time for the water to evaporate and little heat would be absorbed.

(ON SLIDE #14)

3 By reducing humidity, comfort is possible even at higher temperatures. Tests have shown that people feel just as cool at 79° with 30% humidity as they do at 72° with 90% humidity.

(ON SLIDE #15)

(2) Heat Verses Temperature.

(a) Everything contains some heat no matter what it is. In fact, there is no such thing as "cold". The definition of cold is the lack of heat. Just as "darkness" is the lack of light.

(ON SLIDE #16)

1 Thermometers measure temperature or heat energy intensity. Heat intensity is the level of activity of the molecules in a given substance. Temperature is measured in degrees Celsius and degrees Fahrenheit. Most thermometers are calibrated to read both but if placed in boiling water Celsius will read 100° degrees and Fahrenheit will read 212°.

(ON SLIDE #17-18)

2 Thermometers can only measure intensity level of heat; they cannot measure the quantity of heat present. The British Thermal Unit (BTU) is the measure of heat in an object. One BTU is the amount of heat needed to raise one pound of water one degree Fahrenheit at sea level.

(ON SLIDE #19)

(b) The terms "heat" and "temperature" are not interchangeable. For example, hot coals in a barbecue contain less total heat than the water in a child's swimming pool. This is true even though the temperature of the coals is much higher than that of the water. Similarly, things at the same temperature can contain very different quantities of energy heat. The BTU is used to measure the amount of heat energy a furnace is capable of transferring to the air it circulates. A

BTU is used to measure the amount of heat energy an air conditioning system can remove.

INTERIM TRANSITION: Are there any questions before we take a break?

(BREAK 10 min)

INTERIM TRANSITION: Are there any questions before we move on and talk about heat transfer?

(ON SLIDE #20)

(3) Heat Transfer The law of heat transfer states that: **Heat always flows from an area of higher temperature to an area of lower temperature.**

(ON SLIDE #21)

(a) Just as water flows downhill, heat always flows down the temperature scale. When a cup of hot coffee set aside for awhile, it begins to cool. Heat moves out of the hot coffee (46°C,) into the cooler room temperature air (21°C), until both are the same temperature.
The law of heat transfer states that:

1 The greater the difference in temperature, the faster heat flows.

2 Heat continues to flow until both temperatures are equal.

3 Liquids absorb heat when changed from liquid to gas.

4 Gases give off heat when changed from gas to liquid.

(ON SLIDE #22)

(b) Mediums of heat transfer In principle, an air conditioning system does the same job as an engine cooling system. An engine cooling system carries heat away from the engine via coolant, while the A/C system carries heat away from air in the passenger compartment via refrigerant. Both systems release stored heat to the outside air.

(ON SLIDE #23)

INSTRUCTOR NOTE
Image of engine an evaporator transferring heat.

(ON SLIDE #24)

(4) States of matter: solid, liquid, and gas

(a) Because the A/C and engine cooling systems use different mediums for heat transfer, there are some important differences between the two systems.

(b) Engine coolant is an ethyl glycol-based liquid. Ideally, it remains a liquid as it transfers heat. Refrigerant, on the other hand, evaporates and condenses each time it absorbs and transfers heat. As a result, it changes from a liquid to a vapor and back to a liquid as it flows through the A/C system.

(ON SLIDE #25)

(c) In physics, a change in state occurs when the molecular structure of a substance is rearranged as it changes between any two of the three physical states: solid, liquid, or gas. For example, an ice cube is a solid. Yet, when dropped onto a hot griddle, the ice undergoes a change of state as it melts into a liquid. Then, as the water evaporates into a vapor, another change of state occurs.

(ON SLIDE #26)

(5) Latent heat and the vaporization of liquids

(a) **Another law of physics is the heat of vaporization law. It states:**

1 A specific amount of heat is needed to change a liquid into a vapor.

2 The greatest quantity of heat movement occurs during a change of state.

(ON SLIDE #27)

(b) The amount of heat needed to change one gram of liquid into a vapor is called its heat of vaporization. The heat of vaporization is also known as latent heat. Latent heat refers to the heat absorbed as the liquid changes state. It is called latent (hidden) heat because, even though a lot of heat is absorbed as a change in state occurs, the liquid and vapor remain at the same temperature.

(c) When water has absorbed enough heat to boil, it turns to vapor. Water at 100°C (212°F) turns into vapor at the same temperature. Under normal circumstances, adding more heat to the water does not increase the temperature of the water. Boiling water at atmospheric pressure (101.4 kPa/14.7 psi) cannot be heated above 100°C. Any heat above the quantity necessary to boil the water only produces greater quantities of vapor in less time.

(ON SLIDE #28)

(d) Vaporization and condensation when vapor changes to liquid, it is said to "condense." A common example of condensation is found on the bathroom mirror during a steamy shower. Moisture from the steamy air condenses as it comes in contact with the cool mirror. This moisture collects on the mirror and drips down the surface in the form of a liquid.

(e) When vapor condenses, it releases its latent heat. The latent heat of condensation is the amount of heat released as a vapor changes to a liquid.

(ON SLIDE #29)

(6) The pressure-temperature relationship of heat and gases

(a) The science of physics includes laws describing the relationship between pressure and the boiling point of liquids:

1 If the pressure acting on a liquid is increased, the boiling point of the liquid increases.

2 Lowering the pressure acting on a liquid lowers its boiling point.

(ON SLIDE #30)

(b) Thus, water in a vacuum boils at a very low temperature, while water in a pressurized engine cooling system boils at well above 100°C (212°F).

(c) Latent heat exchange is the same amount at both altitudes but water turns to steam at different temperatures.

(ON SLIDE #31)

(7) Boiling point of fluids under pressure

(a) An engine cooling system readily demonstrates the effect of pressure on the boiling point of water. As water in the cooling system warms up, pressure builds in the sealed system. This pressure increases the boiling point of the water well above 100°C. As long as the system remains sealed and pressure is maintained, the water can be heated above its normal boiling point without boiling.

(b) However, if the radiator cap is removed, the pressure in the cooling system is released. This means the pressure acting on the water is now ambient air pressure. The water, heated under pressure to more than 100°C, will boil as soon as the pressure is released. This example is useful, as pressure affects all liquids the same way it affects water.

(ON SLIDE #32)

(8) Effect of pressure on gases and vapors

(a) Pressure also affects the temperature of gases and vapors. Compressing a gas or vapor increases its temperature, because the same amount of heat is concentrated into a smaller area. Thus, the temperature of the gas or vapor can be increased without adding extra heat. This is what happens inside an A/C compressor.

(b) A compressor uses pressure to concentrate the heat of a vapor. A heat transfer occurs when the vapor contacts a cooler surface. Transferring heat away from the hot, high-pressure vapor condenses it into a liquid. Lowering the pressure of this liquid causes it to boil and absorb heat as it changes states.

(ON SLIDE #33)

(9) Refrigerants for heat transfer

(a) Like the liquid in an engine cooling system, refrigerant in an air conditioning system absorbs, carries, and releases heat. The refrigerant used for automotive A/C systems has been Refrigerant 12, called R-12.

(b) R-12 (dichlorodifluoromethane) has all the qualities necessary to be a good refrigerant. It is harmless to refrigerant system materials, such as steel, copper, iron, aluminum, and neoprene. In turn, it is unaffected by these materials. R-12 readily dissolves in 525-viscosity oil, an important attribute, as R-12 circulates through the system with oil. R-12 is neither explosive nor flammable, and is not corrosive except when in contact with water.

(c) When R-12 was first introduced in 1930, its many positive qualities earned it a reputation as a miracle chemical. Unfortunately, recent scientific findings show that R-12, a chlorofluorocarbon (CFC), is contributing to the depletion of Earth's ozone layer. As a result, the production of CFC materials is being limited and will eventually be phased out of automotive A/C systems.

(**ON SLIDE #34)**

(d) An alternate refrigerant, R-134a (tetrafluoroethane) has replaced R-12. In many ways, it works and acts the same as R-12. It is harmless to refrigerant system materials. It is nonflammable and absorbs, carries, and releases heat efficiently. It does not, however, mix well (is insoluble) with 525 -viscosity oil; therefore, a synthetic oil (polyalkylene glycol) has been developed.

(**ON SLIDE #35)**

(e) Major differences exist between the two refrigerants in the areas of pressure characteristics and lubrication requirements.

(**ON SLIDE #36)**

(10) Temperature-pressure relationships

(a) Pressure in an A/C system raises the boiling point of the refrigerant. Thus, automotive A/C systems are designed to operate at pressures that keep the boiling point of refrigerant at just the right temperature for taking heat out of the passenger compartment.

(b) A definite temperature and pressure relationship exists between liquid refrigerants and their vapors. Heating refrigerant causes it to expand. When confined in a closed space, an increase in temperature is always accompanied by an increase in pressure, even though no compressor is present.

(c) For every temperature increase, a corresponding pressure will exist in a container of R-12 or R-134a. The Pressure/Temperature chart shows this temperature-pressure relationship. Pressures are expressed either as positive gauge pressure (above atmospheric, in kPa [psi]) or negative gauge pressure (below atmospheric, inches of vacuum).

(d) This temperature-pressure relationship can be easily demonstrated. A pressure gauge attached to a container of R-12 at 21°C (70°F) reveals a pressure of about 484 kPa (70 psi). At 38°C (100°F), the gauge will register about 808 kPa (117 psi).

(e) The pressure characteristics of R-134a differ from those of R-12. The boiling point of R-134a is 3°C (6°F) higher (-27°C [-16°F]) at sea level (101.4 kPa [14.7 psi]) than R-12, which boils at -30°C (-22°F). This changes the temperature-pressure relationship curve. Because of this pressure difference, gauge readings will differ slightly from previous R-12 systems.

(ON SLIDE #37)

(11) Lubrication The A/C system carries a charge of lubricating oil. This oil is designed to mix thoroughly with the refrigerant. Since the refrigerant and oil mix completely, the refrigerant carries oil throughout the system to lubricate moving parts such as the compressor and thermal expansion valves. It is important to remember that R-12 and R-134a system oil types differ.

(a) R-12 uses mineral-based oil with a 525 viscosity.

(b) R-134a uses synthetic oil, polyalkylene glycol (PAG). Consult the appropriate service manual for the correct PAG oil for compressors.

(c) **Never mix system components or equipment between R-12 and R-134a, as damage to the system will result.**

<u>TRANSITION</u>: Over the past hour we have covered the principals of refrigeration. Are there any questions? If not I have some questions for you.

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(ON SLIDE #38-39)

QUESTION: What is physics?
ANSWER: The science of matter and energy.
QUESTION: What are the three states of matter?
ANSWER: Solid, liquid and gas.
QUESTION: What is a BTU?
ANSWER: The measurement of heat in an object. One BTU is the amount of heat needed to raise one pound of water one degree Fahrenheit at sea level.

(ON SLIDE #40)

(BREAK 10min)

<u>TRANSITION</u>: Now that we understand the principles of refrigerant we can move into how the refrigerant moves though out the A/C system in the vehicle. Now the refrigerant can be put to work in the systems by applying the basic principles that we discussed.

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(ON SLIDE #41)

2. **<u>BASIC REFRIGERATION CYCLE</u> (1 HR 30 MIN)**

a. Automotive A/C systems move heat from one place to another by compressing, condensing, and evaporating refrigerant. The A/C system creates these special conditions by using pressure and heat transfer to control the changing states of liquid and vapor.

(ON SLIDE #42)

INSTRUCTOR NOTE
Picture of the refrigeration cycle.

(ON SLIDE #43)

b. An A/C refrigerant system consists of several components connected together with tubing and hoses to form a closed loop for the refrigeration cycle. Refrigerant flows through the closed loop, absorbing heat in the evaporator and releasing it in the condenser.

(ON SLIDE #44-45)

(1) Most automotive A/C systems contain these components and have these functions:

(a) Compressor

(b) Condenser

(c) Evaporator

(d) Receiver-Drier

(e) Oil Flow Through a Compressor

(f) Oil charge in the a/c system

(g) Thermostatic Expansion Valve

(h) Compressor Control Components

(i) Water Control Valve

(ON SLIDE #46)

c. **<u>A/C Compressors</u>**. The compressor performs one main function: to compress the low-pressure refrigerant vapor from the evaporator into a high-pressure, high-temperature vapor. From the compressor the refrigerant heads to the condenser.

(ON SLIDE #47)

d. **<u>Condenser</u>**. The condenser is normally located near the radiator. To help increase air flow through the condenser, the system uses the cooling fan or a separate fan specifically for the condenser. The fans turn on when the compressor high side pressure exceeds the manufacture's specification. When the pressure is below the manufacture's specification, the condenser fans turn off.

(ON SLIDE #48-49)

e. **Evaporator**. The evaporator consists of fins (which rapidly transfer heat) and refrigerant-carrying coils. The evaporator cools and dehumidifies the airstreams entering the passenger compartment.

(1) During all system operation, liquid refrigerant flows from the metering device (TXV) into the low pressure area of the evaporator. This action creates a very cool evaporator surface. As the passenger compartment airstreams flows over the evaporator fins, the air loses its heat to the cooler surfaces of the evaporator fins. Moisture (humidity) present in the airstreams condenses on the cool surfaces of the evaporator and drains off as water.

(2) If the evaporator surfaces are too cold, the moisture collecting on the fins will not drain off as water. Instead, it will freeze. This freezing occurs when low side pressure is so low that the refrigerant boils at less than the freezing point of water.

(ON SLIDE #50)

f. **Receiver-drier**. The receiver-drier is a storage tank for the liquid refrigerant from the condenser. The liquid flows into the upper portion of the receiver tank, which contains a desiccant (chemical drying agent). As the refrigerant flows through an opening in the lower portion of the receiver, it is filtered through a mesh screen attached to a baffle at the bottom of the receiver. The desiccant absorbs any moisture that might enter the system. These features prevent obstruction to the valves or damage to the compressor.

(ON SLIDE #51)

(a) A sight glass, if used, is located on the top of the receiver-drier or in the liquid line through which the refrigerant flows. The sight glass reveals the amount of refrigerant in the system.

(ON SLIDE #52)

g. **<u>Oil flow through a compressor</u>**. The A/C system refrigerant carries a charge of lubricating oil. Since the refrigerant and oil mix, the refrigerant carries droplets of oil throughout the system to lubricate moving parts. The most common compressors used today (HR-6, DA-6, R-4, and V-5) rely totally upon the oil-saturated refrigerant to lubricate their internal moving parts. However, since the majority of A/C compressors rely completely on oil-saturated refrigerant, it is imperative that the proper oil level, viscosity, and purity be maintained for proper operation and longevity.

(a) As the refrigerant enters the compressor, some of the oil droplets that separate from the refrigerant fall into the crankcase and lubricate the moving parts. The oil is then picked up by the exiting refrigerant and continues through the system.

(ON SLIDE #53)

(b) It is not recommended that compressor oil level be checked as a matter of course. Generally, compressor oil level should be checked only when there is evidence of a major loss of system oil. This could be caused by:

<u>1</u> A broken refrigerant hose.

<u>2</u> A hose fitting leak. A bad compressor seal leak.

<u>3</u> Collision damage to the system components

(ON SLIDE #54)

h. **<u>Oil charge in the a/c system</u>**. During A/C operation, there is a small amount of oil located in all system components. The total oil charge for systems using an R-4, DA-6, or V-5 compressor is 8 ounces. (This may vary from 6 to 9 ounces; check the service manual for specific applications). Rear A/C systems also require additional oil. A breakdown of oil location throughout a typical system during operation or shortly after shutdown is as follows. (Values are approximate).

(ON SLIDE #55)

(1) Evaporators - 2 oz. oil front 2 oz. oil rear

(2) Condenser - 1 oz. oil

(3) Receiver-driers - 2 oz. oil front .5 oz. oil rear

(4) Compressor - (.25 to .5 oz) .5 oz. oil

(5) Lines - (.5 to .75 oz) .5 oz oil

(6) Total - 8 oz. oil in A/C system

For specific information regarding oil replacement, refer to the Air Conditioning section of the applicable service manual.

INTERIM TRANSITION: Are there any questions before we take a break?

(BREAK 10 min)

INTERIM TRANSITION: Are there any questions before we move on and talk about the Thermostatic expansion valve?

(ON SLIDE #56)

i. **Thermostatic expansion valve**. The thermostatic expansion valve (TXV) is installed at the evaporator inlet and outlet pipes. The valve converts the high-pressure liquid refrigerant from the receiver-drier to a low-pressure liquid refrigerant by forcing it through a small port before entering the evaporator.

(ON SLIDE #57)

(1) When the heat load increases or decreases, the expansion valve supplies the correct quantity of refrigerant to the evaporator for maximum heat transfer.

(ON SLIDE #58)

(2) The expansion valve consists of a power element, body; actuating pins, seat, and orifice. The orifice is actuated by a diaphragm. The diaphragm closes in response to evaporator pressure against the bottom of the diaphragm and superheat (return) spring pressure against the orifice; it opens in response to remote bulb and capillary tube vapor against the top of the diaphragm. A fine mesh screen located at the high pressure liquid inlet prevents dirt, metal chips, or other foreign matter from entering the valve orifice.

(ON SLIDE #59)

INSTRUCTOR NOTE
Image of thermostatic expansion valve

(ON SLIDE #60)

(3) The remote bulb is clamped to the low-pressure vapor line just beyond the evaporator outlet. The remote bulb is filled with highly expansive gas. As evaporator outlet temperature changes, the gas inside the remote bulb expands and contracts, regulating valve operation.

(ON SLIDE #61)

(4) The TXV provides three interrelated functions: throttling, modulation, and metering.

(ON SLIDE #62)

(a) Throttling: The flow of refrigerant is restricted, or throttled, across the valve. High-pressure liquid enters the valve, while low-pressure liquid leaves it. This drop in pressure is accomplished without changing the state of the refrigerant.

(ON SLIDE #63)

(b) Modulation: The TXV adjusts the amount of low pressure liquid that enters the evaporator for proper cooling. The valve modulates from wide open to closed for proper volume control.

(ON SLIDE #64)

(c) Metering: Load or temperature changes affect the volume entering the evaporator. More loads require more refrigerant to maintain the optimum evaporator temperature.

(ON SLIDE #65)

(d) All TXVs are adjusted to compensate for superheat conditions. "Superheat" is defined as the difference between evaporator inlet and outlet temperatures and is created in the evaporator as liquid refrigerant changes into vapor.

Ideally, all liquid refrigerant boils before it reaches the evaporator coil outlet. In fact, the refrigerant temperature is above the boiling point. For example, refrigerant in an evaporator at 196 kPa (28.5 psi) has a temperature of -1°C (30°F). As the refrigerant boils, the temperature of the vapor rises until, at the outlet, it reaches 1.6°C (35°F). The inlet-to-outlet differential, or superheat, is 2.6°C (5°F). As evaporator size increases, so does superheating.

(ON SLIDE #66)

(e) To compensate for pressure/temperature differentials at the evaporator outlet, an internal equalizer modulates between actual pressure and measured temperature. This allows the valve to meter the refrigerant more accurately.

(ON SLIDE #67)

(f) Thermostatic expansion valve failure is indicated by the same symptoms as orifice tube failure. However, TXV failure is usually due to a malfunction of the power unit and the valve closure that accompanies this failure. The inlet and outlet screens of the TXV can also become plugged due to contamination, corrosion particles, or refrigerant drying chemicals loose in the refrigerant system.

(ON SLIDE #68-69)

j. **<u>Compressor control components</u>**

(1) <u>Trinary Switch</u>. The trinary switch has three functions.

(a) If pressure in the line is less than 28 psi, the switch opens preventing operation of the compressor clutch.

(b) If pressure in the line goes above 455 psi, the switch opens to prevent damage to the system from the high pressures. The switch closes when pressure is less than 370 psi.

(ON SLIDE #70)

(c) The trinary switch operates the condenser fans. When pressure is approximately 227 psi, the switch closes causing the condenser fans to operate. When pressure falls below 185 psi, the switch opens stopping fan operation.

(ON SLIDE #71)

l. **Thermostatic Switch**

(a) In some systems, a thermostatic switch is placed in series with the compressor clutch circuit. It fulfills the same function as the pressure cycling switch, but in a different way. The switch acts as a deicing control by disengaging the compressor if the evaporator is at the freezing point.

(ON SLIDE #72)

(b) The thermostatic switch has a metallic sensing bulb that contains a highly expansive gas, usually carbon dioxide. This gas-filled tube is either inserted between the evaporator fins or is located in the evaporator discharge airstreams. The tube attaches to a bellows-operated electrical switch. As temperature rises, the gas inside the tube expands. This increases bellows pressure, expanding the bellows and closing the electrical switch attached to the bellows.

(ON SLIDE #73)

(c) When evaporator temperature approaches the freezing point (the low setting of the switch), the switch opens the compressor clutch circuit and disengages the clutch. The compressor remains inoperative until evaporator temperature rises to the preset temperature. When the preset temperature is reached, the switch closes and compressor operation resumes. The switch normally opens at -2°C (27°F) and closes at 2°C (36°F).

(ON SLIDE #74)

m. **Low Pressure Switch**

(1) The low pressure switch is used to prohibit compressor operation when the system pressure is low. This happens primarily when there has been a loss of refrigerant. A loss of refrigerant can cause low system pressure. Under such conditions the compressor is shut off to avoid damage due to the oil loss that occurs when the refrigerant is not circulating through the system. Another condition is when the ambient air temperature is low. The refrigerant pressure is low due to the pressure temperature relationship of refrigerant. The compressor will not operate during cold weather.

(ON SLIDE #75)

n. **Water Control Valve**

(1) Some vehicles are equipped with a water control valve located in the heater inlet hose. The valve consists of a tube, a piston assembly, and either a vacuum diaphragm or an electrical or mechanical solenoid. On most applications, the water valve is closed when air conditioning controls are set for maximum cooling.

TRANSITION: Over the past hour we have covered the basic refrigeration cycle. Are there any questions? If not I have some questions for you, then we will take a 10 minute break.

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(ON SLIDE #76)

QUESTION: What is the main function of an A/C compressor?
ANSWER: To compress low-pressure refrigerant vapor from the evaporator into a high-pressure, high temperature vapor.
QUESTION: What does the evaporator do to the air entering the passenger compartment?
ANSWER: Cools and dehumidifies.
QUESTION: What is the purpose of the Thermostatic Expansion Valve?
ANSWER: It converts high-pressure liquid refrigerant from the receiver-drier to a low-pressure liquid refrigerant.

(ON SLIDE #77)

(BREAK – 10Min)

INSTRUCTOR NOTE
Break Slide

TRANSITION: Are there any other questions? Now that we understand the basic refrigeration cycle we can move into how we control the refrigerant flow. We need to be able to control the refrigerant in order to adjust the temperature of the operators cab.

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(ON SLIDE #78)

3. **CONTROLLING REFRIGERANT FLOW (1 HR 30 Min)**

Depending on design, automotive A/C systems use several methods to control the flow of refrigerant. Central to each design, however, is the continuous interaction of the compressor with a flow control device, such as an orifice tube. The volume of flow is adjusted based on the pressure-temperature load, which is monitored at a key location in the system.

(ON SLIDE #79)

a. **Controlling refrigerant in the a/c system.**

(1) Pressure and Flow In addition to the compressor, condenser, and evaporator, All systems require some method of controlling refrigerant pressure and flow. The compressor can pump refrigerant vapor through the system. But unless it has something to push against, it cannot build up system pressure and maintain the conditions necessary to achieve the refrigeration effect.

(ON SLIDE #80)

(a) Refrigerant system pressure is necessary. Low-side system pressure keeps the boiling point of the refrigerant at the proper level. High evaporator pressure would slow the boiling of refrigerant and reduce the refrigeration effect. High-side system pressure allows the refrigerant to condense at normal ambient temperatures.

(ON SLIDE #81)

INSTRUCTOR NOTE
Image of A/C System

(ON SLIDE #82)

(b) A metering device is used to help the compressor build pressure and maintain the refrigerant cycle. Most A/C systems use two types of metering devices: orifice tubes and thermostatic expansion valves (TXV). Orifice tubes have openings of fixed diameters for metering refrigerant flow. TXVs vary refrigerant flow based on evaporator outlet temperatures.

(ON SLIDE #83)

INSTRUCTOR NOTE
Pictures of the TXV

(ON SLIDE #84)

b. **High and low-pressure areas**

(1) The refrigerant system is divided into two portions: a high-pressure area (high side) and a low-pressure area (low side). These two areas are separated by a metering device (orifice tube or TXV) and compressor.

(2) Because the compressor can move more refrigerant than is able to pass through the metering device in a given time, pressure builds between the compressor outlet and the metering device. Therefore, the high side of the refrigerant system extends from the compressor outlet, through the condenser, to the metering device inlet. During operation, the high-pressure side is also the high-temperature side of the system.

(a) Tube diameter - High-side tubing is often smaller than low-side tubing.

(b) Feel - High-side tubing is hotter than low-side tubing.

(c) Sight - Low-side tubing is often cool enough to collect frost or water droplets on high humidity days.

(d) Pressure - A gauge set can be used to measure the pressures in an A/C system.

(e) Refrigerant temperature - Various methods can be used to determine refrigerant temperature.

(ON SLIDE #85)

(3) Inside an operating A/C system, the following process continuously occurs:

(a) Low-pressure refrigerant vapor is drawn into the compressor. During compression, this vapor becomes a hot, high-pressure vapor.

(b) The hot, high-pressure vapor then passes into the condenser. Here, the vapor transfers its heat to the condenser surfaces.

(ON SLIDE #86)

(c) As the refrigerant vapor gives up its heat, it condenses and cools into a high-pressure liquid.

(d) The high-pressure liquid then goes to the receiver drier which acts as a filter and storage tank.

(e) The high-pressure liquid passes through a restriction (orifice tube or TXV) into the evaporator. The restriction controls the volume of refrigerant entering the low pressure side of the system.

(ON SLIDE #87)

(f) Inside the evaporator, the low-pressure refrigerant begins to vaporize as it soaks up heat from the evaporator surfaces.

(g) As the refrigerant vaporizes, it expands and increases low-side pressure. This refrigerant vapor is drawn into the compressor, and the cycle repeats.

(ON SLIDE #88)

INSTRUCTOR NOTE
Images of an A/C operating system

INTERIM TRANSITION: Are there any questions before we take a break?

(BREAK 10 min)

INTERIM TRANSITION: Are there any questions before we move on and talk about the Factors affecting heat transfer efficiency?

(ON SLIDE #89)

c. **Factors affecting heat transfer efficiency**. The heat transfer efficiency of automotive A/C systems is greatly affected by "heat load", the amount of heat that must be absorbed by the refrigerant. Factors affecting heat load are airflow at the condenser and evaporator, humidity, ambient temperatures, and sun load.

(ON SLIDE #90)

(1) Condenser fan: Condenser fans are an important part of the air conditioning system. A nonfunctional condenser fan hinders the heat transfer processes taking place at the condenser. Insufficient heat transfer at the condenser causes the compressor to work too hard at compressing the refrigerant vapor. This, in turn, causes compressor head pressure, or high-side pressure, to rise to unacceptable levels.

(ON SLIDE #91)

(2) Blower motor: The blower motor affects evaporator heat transfer in the same way that the coolant fan affects condenser heat transfer. However, the blower motor operates on a smaller scale than the condenser fan. Blower motor speed controls airflow speed, which determines the volume of air flowing over the evaporator. This, in turn, determines the amount of heat that can be absorbed by the refrigerant in a given time. Therefore, the blower speed directly affects the heat exchange rate at the evaporator.

(ON SLIDE #92)

(3) Humidity: Humidity is a measure of the water vapor present in air. When this water vapor condenses on the evaporator, the heat of vaporization of the water is absorbed by the cooler evaporator surface. This heat is then absorbed by the refrigerant in the evaporator. This reduces the amount of heat that can be removed from the air. Therefore, on a humid day, the air is not cooled as efficiently as it is on a dry day.

(ON SLIDE #93)

(4) Sun load: Sun load is the intensity of the long-wave heat rays from the sun. Ambient temperatures, together with the type and color of interior materials, affect heat load and, thus, the efficiency of the A/C system.

(ON SLIDE #94-97)

TRANSITION: Over the past 30 minutes we have covered controlling refrigerant in the A/C system. Are there any questions? If not I have some questions for you and then we will take a 10 minute break.

QUESTION: What components do all automotive A/C systems contain?
Answer: Compressor, Condenser, Evaporator, Refrigerant, and Lubricant.
QUESTION: What factors can affect heat transfer efficiency?
ANSWER: Airflow at the condenser and evaporator, humidity, ambient temperatures and sun load.
QUESTION: What does the receiver-drier do?
ANSWER: It filters the refrigerant though a desiccant agent to remove any moisture.
QUESTION: What are three things that the TXV provide?
ANSWER: Throttling, modulation, and metering.

(ON SLIDE #98)

(BREAK – 10Min)

TRANSITION: Now that we understand how to control the refrigerant in the A/C system we can move into the service equipment you may be using to service the A/C system.
(ON SLIDE #99)

4. **SERVICE EQUIPMENT (1 HR 30 MIN)**

INSTRUCTOR NOTE
Image of some of the tools you may use.

(ON SLIDE #100)

a. **Gauge and Manifold Set**

(1) Accurate testing requires the use of a test gauge set connected to the high and low sides of the air conditioning system. With these gauges, the serviceman can accurately pinpoint trouble within the system as well as determine if the system is operating as it should.

(2) The gauge manifold set is composed of a low side or compound gauge, a high side gauge, and the manifold to which the gauges are connected with a hand valve at each end.

(3) Fittings on gauge sets for R-134a systems have male threaded ends, while R-12 system gauge sets have female connections.

(ON SLIDE #101)

b. **Compound Gauge (Low Side)**

(1) The compound gauge derives its name from its function. It will register either pressure or vacuum. All air conditioning systems can, under certain conditions, drop from a pressure into a vacuum on the low side. It is necessary that a gauge be used that will show either pressure (psi and kPa) or inches of mercury vacuum (Hg.).

(2) The vacuum side of the gauge must be calibrated to show 0 to 30 inches (0 to 762 mm) Hg. The pressure side of the gauge must be calibrated to register accurately from 0 pressure to a minimum of 60 psi (414 kPa). The maximum reading of the pressure should not exceed 160 psi (1103 kPa). Practically all readings of the low side of the system will be less than 60 psi (414 kPa) with the system in operation.

c. **High Pressure Gauge (High Side)**

(1) The high pressure gauge is used to determine pressures in the high side of the system. The gauge is calibrated to register accurately from zero pressure to a minimum of 300 psi (2070 kPa). A few systems operate under high head pressure during normal operation conditions. This is why the high pressure gauge should have a reading of at least 600 psi (4140 kPa).

(ON SLIDE #102)

d. **Gauge Manifold**

(1) The gauge manifold mounts the high and low side gauges and connects the gauges into the high and low sides of the system by means of test hoses. The gauges connect to the upper part of the manifold through holes drilled and tapped to a 1/8-inch pipe thread. Test hose connectors below the gauges on the lower side of the manifold direct the refrigerant through the manifold to the gauges to obtain pressure readings.

(ON SLIDE #103)

(2) A center test hose connector on the lower side of the manifold is connected to both pressure gauges and the test hoses by a passage in the manifold. Refrigerant flow into the high and low side is controlled by a shutoff hand valve at each end of the manifold.

(ON SLIDE #104)

(3) With both hand valves in the "closed" position, refrigerant will be shut off from the center test hose fitting but will flow to the gauges.

(4) Opening the high side hand valve will allow refrigerant to flow through the passage and out the center test hose connector and at the same time continue to the high gauge to register pressure reading.

(ON SLIDE #105)

(5) Opening the low side gauge will open the low side refrigerant to the center test hose connection and the low side gauge.

(ON SLIDE #106)

(6) By opening and closing the hand valves on the manifold, the following jobs can be done:

(a) Recovering excess refrigerant from system

(b) Bleeding air from the hoses

(c) Recovering refrigerant before service work

(d) Removing air and moisture during pump-down

(e) Filling system with refrigerant

(ON SLIDE #107)

e. **Caution**. **DO NOT OPEN THE HIGH-SIDE VALVE DURING A/C SYSTEM CHARGING.** Opening the high-side hand valve during system operation delivers HIGH PRESSURE refrigerant to the refrigerant source and can cause the refrigerant container to burst.

(ON SLIDE #108)

INSTRUCTOR NOTE
Image of test hoses.

INTERIM TRANSITION: Are there any questions before we take a break?

(BREAK 10 min)

INTERIM TRANSITION: Are there any questions before we move on and talk about test hoses?

(ON SLIDE #109)

f. **Test Hoses**. The test hoses are the connections between the gauge manifold and the air conditioning system. They are connected to the gauge manifold test hose fittings by use of a screw-on connection and sealed with an internal seal. Hose connectors should be tightened only finger tight as this is sufficient to seal the hose onto the seal.

(2) The manifold is constructed so that the test hose and connector directly below the gauge will pass refrigerant to that gauge to show pressure readings. Opening the hand valve on the same side as the gauge is the only way the refrigerant can move in any direction other than to the gauge.

(3) The center test hose is not connected to the air conditioning system. It is used to allow refrigerant to purge from the system using a recovery/recycling station, or it may be connected to a vacuum pump for removing air and moisture from the system.

(4) Opening the hand valves on the manifold will control pump-down of the system into a vacuum for more effective moisture removal.

(5) Hoses with a depressor are available to fit the service connectors with a Schrader valve. Other hoses require the use of a Schrader valve adapter on the connectors before using the Schrader valve. The use of the Schrader valve in the service connector eliminates the need for a service valve in the system and the refrigerant is effectively sealed inside the system until the valve is opened.

(ON SLIDE #110)

g. **Service Valves**. The compressor is equipped with service valves which are used as an aid in servicing the air conditioning system. The manifold gauge set is connected into the system at the service valve ports and all procedures such as evacuating and charging the system are carried on here through the gauge and manifold set.

(1) Most compressors are equipped with two service valves. One services the high side, while the other services the low side. The high side service valve is quickly identified by the smaller discharge hose routed to the condenser, while on the low side valve the larger hose comes from the evaporator.

(2) Since all valves are the same, we will be concerned here with the operation of one valve in the system.

(ON SLIDE #111)

(3) The valves described here are the hand shutoff type. Many air conditioning systems now use only one valve having a shutoff feature, or one calve having no shutoff feature. The gauge hoses are still connected to the service valve fitting, in which a Schrader valve is incorporated. When the fitting in the end of the service hose is screwed onto the Schrader valve, a pin is depressed in the center of the valve allowing pressure to be read on the gauges. When the fitting is removed, the valve closes to hold refrigerant in the system. The hand shutoff type of valve has three positions:

(ON SLIDE #112)

a Shut off refrigerant flow. Gauge port out of the system.

b Normal refrigerant operation. Gauge port out of the system.

c Normal refrigerant operation. Gauge port in the system.

(ON SLIDE #113)

h. **Leak Detectors** Several types of leak detectors are available to the serviceman, colored dye additive, liquid detergent-type detector, and electronic leak detector

(ON SLIDE #114)

(1) A Colored Dye Additive is available which is added to the refrigerant. Operation of the system will show coloration at the point of leakage. A very slight leak requiring several weeks or even months to bleed off enough refrigerant to affect

system cooling can often be located using this additive when other methods of leak detection fail.

(ON SLIDE #115)

(2) A Liquid Detergent-Type Detector may be used around connections and any external point that might be a source of leak for the Refrigerant-12. Escaping refrigerant will cause the liquid to bubble, indicating a leak. Any parts that are not accessible, such as the coils in the condenser and the evaporator, cannot readily be coated with this liquid to check for leaks.

(ON SLIDE #116)

(3) The Electronic Leak Detector is a sensitive leak detector. Most electronic detectors can detect an equivalent of 1/2 oz. per year. However, the initial cost of this type detector has been a deterrent to individuals and small shops doing a minimum of air conditioning service. This instrument is electronic and must be handled with care to give accurate results. When cared for properly, the electronic detector will locate quickly and accurately leaks that are almost impossible to locate with other types of detectors.

(ON SLIDE #117)

(4) Leak detection must be performed with the system under pressure to obtain accurate results. Very small leaks often require that the system pressure be increased above normal before they can be located. A 50 percent charge of refrigerant in the system is enough to locate most leaks. Occasionally, a stubborn small leak will require overcharging the system.

(ON SLIDE #118)

(5) The **high side** of the system might require leak testing while in operation with air flow restricted to the condenser to raise the high side pressure above normal.

(6) The **low side** is checked in the "off" position with the pressures equalized in both sides of the system.

(7) When you use leak detectors, don't move the sniffer or snorkel faster than 1 inch (25 mm) per second. Many leaks can be found by looking for small oily spots or film at the source of the leak.

(ON SLIDE #119)

h. Vacuum Pump The vacuum pump is used to evacuate the air from the system.

(a) When the system is depressurized and opened for service, air enters the openings before they can be capped. To remove this air (and its harmful moisture), the system must be evacuated. This is done by removing air until a vacuum is created.

(ON SLIDE #120)

i. Scale This is used to measure the amount of refrigerant that you put into the system.

(ON SLIDE #121)

TRANSITION: Over the past hour we have talked about a lot of the service equipment that you will be using in your A/C troubleshooting and repair. At this time are there any questions? I have some questions for you and then we will take a break.

QUESTION: What are three types of leak detectors?
ANSWER: Colored dye additive, liquid detergent, and an electronic leak detector.
QUESTION: What is the main purpose of the vacuum pump?
ANSWER: To evacuate air from the system after opening.

(BREAK 10 min)

TRANSITION: Now that we have covered the service equipment that you will be using let's talk a little about some of the signs to look for when you are troubleshooting.
(ON SLIDE #122)

5. **TROUBLE SHOOTING (1 HR 30 MIN)**

a. **Trouble Shooting an A/C System**

(1) This section is for diagnosing and correcting general A/C problems on the various pieces of equipment. In most instances when a unit is brought in for an air conditioning problem, the complaint will be insufficient cooling or "Lack of cooling." It will then be the technician's first task to

determine why the A/C is not working efficiently.

(ON SLIDE #123)

(2) Start with a good visual inspection of the system while the engine is not running and again after the engine is running. With engine off, inspect all refrigerant lines to and from the compressor. Look for wet or oily spots. Make sure there are no kinks or restrictions in any of the refrigerant lines. Visually inspect the compressor and check that the drive belt is on and the clutch is dry. At times an oily or wet spot will appear on the inside of the hood in the area of the A/C compressor. This is an indication of a compressor seal leak.

(ON SLIDE #124)

(3) Start the engine and turn the A/C on. Give the system a few minutes to stabilize. Note the sight glass for indications of low refrigerant. Check the refrigerant lines again. System operation can be checked by touching the refrigerant lines. The high side of the system should be uniformly hot to the touch while the low side of the system should be uniformly cool to the touch. At times a restriction can be found by touching the line. The line will have a definite temperature change in area of restriction. It will feel warm before and then cooler after a restriction. At times a line will show condensation or frost in area after a restriction. Restrictions in condensers can be found in this same manner.

(ON SLIDE #125)

(4) Check areas around condenser and evaporator fins to make sure that air flows through without restrictions from dirt and debris. Air must flow freely through these for system to operate efficiently. Also confirm that the fan motors are operating on both of the evaporators and the condenser. Then turn off engine and prepare to connect pressure gauges.

(ON SLIDE #126)

(5) These are general troubleshooting steps and signs for any mechanic to check. They cover any piece of equipment that comes into the shop for A/C maintenance. Ensure you also always follow any troubleshooting steps that are located in the corresponding technical manual.

(ON SLIDE #127)

INTERIM TRANSITION: Now that we have discussed A/C troubleshooting and covered some of the things you should look for while doing maintenance let's take a break and then move on to a demonstration of how to hook up the Robinair to a piece of equipment, recover and recharge R-134a.

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(BREAK 10 min)

INTERIM TRANSITION: Any questions before the demonstration starts?

INSTRUCTOR NOTE
Conduct the following demonstration.

DEMONSTRATION. (1.5 Hrs) With a group no larger than 15 the instructor will be connecting the Robinair A/C machine to a piece of heavy equipment. Once it is connected the instructor will show how to recover and recharge the A/C system.

STUDENT ROLE: The students will gather around the Robinair, one student will be assigned to read the steps in the manual that is with the robinair. Students will follow along with each step.

INSTRUCTOR ROLE: The instructor will pick a piece of equipment and a Robinair A/C kit. The students should already be familiar with the components of the kit due to the class and the inventory. Get out the appropriate hoses and components that are listed in the Robinair directions. As the student reads the steps hook up, reclaim, and recharge the A/C system explaining what you are doing along the way.
1. Safety Brief: Brief students on safety precautions and what

to do if there is a mishap.)As applicable.
2. Supervision and Guidance: N/A
3. Debrief: (If applicable) (Allow students the opportunity to comment on what they experienced and/or observed. Provide overall feedback, guidance on any misconceptions, and review the learning points of the demonstration.)

(ON SLIDE #128)

INTERIM TRANSITION: Over the past two hours we saw how to hook up, recover, and recharge the A/C system using the Marine Corps Robinair A/C kit. Are there any questions before we start the practical application? We will take a break and then you will break down into groups of 2 and we will get some hands on with the A/C system.

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(BREAK 10 min)

INTERIM TRANSITION: Any questions before the practical application?

INSTRUCTOR NOTE

Conduct the following Practical Exercise.

Practical Exercise: (32 Hrs) In groups of 2 the students will select a piece of heavy equipment and a robinair kit. They will place all the kits and equipment online in the fenced in area behind Brown Hall. This exercise will ensure that the students can reclaim and recharge an A/C system properly.

STUDENT(S) ROLE: Once the students have positioned there equipment and kits they will ensure that they have the proper equipment and a set of robinair instructions. The student needs to also have a TM for the piece of equipment that they will be using. The students will then hook up there A/C kits and recover and recharge the refrigerant.
INSTRUCTOR(S) ROLE: The instructor will walk around to all the groups ensuring that all safety procedures are being followed and that the proper PPE is being worn. The instructor will also assist the students if help is needed and answer any questions about the recovery and recharge process.

1. Safety Brief: Follow any safety precautions outlined in the Technical Manuals and make sure that you are using proper PPE (eye protection, and gloves)
2. Supervision and Guidance: The instructor will supervise the class to make sure they are using the proper PPE and also performing the steps right with the Technical Manuals.
3. Debrief: Discuses with the students what they did properly and improperly at the end of the practical exercise.

(ON SLIDE #129-130)

TRANSITION: Over the past 32 hrs you have hooked up a Robinair kit, reclaimed and recharged the refrigerant in the A/C system. Do I have any questions about the prac app we just completed? I have some questions for you. Now let's sum up what we covered during this class.

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QUESTION: When removing test hoses what should you do before disconnection the hose?
ANSWER: Ensure all vales are closed.
QUESTION: When using the robinair test kit what steps should you use to evacuate the A/C system?
ANSWER: The steps located in the Robinair TM.
QUESTION: After he A/C system has been evacuated what is always the last step to follow.
ANSWER: Test the system to ensure it functions properly.

(ON SLIDE #131)

SUMMARY **(10 MIN)**

This period of instruction has covered laws and principles of refrigerant, refrigerant system components, service equipment, and air conditioner troubleshooting. With this information you can now go back to your units and begin to service, troubleshoot and repair A/C systems.

REFERENCE	**PUBLICATION ID**
Air Conditioning	FOS5708NC

Pro Set Vacuum Pump	TM 11956A-OR/1
Master Cool Manifold and Gauge Set	TM 11956A-OR/2
Commercial Refrigerant Recovery System	CR700