

TECH CORNER



BY KEN LENZ

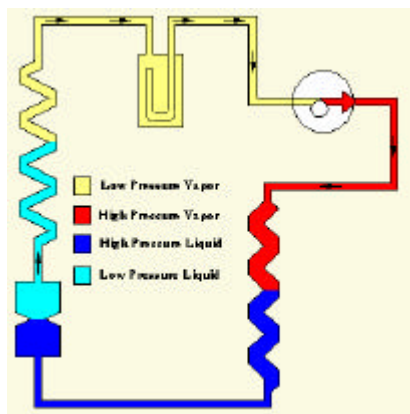
Air Conditioning, like many items on fire apparatus, is often specified by numbers or components and not overall system performance. In this installment of *Tech Corner* I'll give a brief explanation of A/C system operation and component specification.

Before we begin the component information, here is an explanation of the A/C cycle to give you an understanding of the system operation.

The Refrigeration Cycle

The following diagram shows a typical refrigeration cycle. By "cycle," we mean the series of operations that allow for

Chart 1
The A/C cycle



the continuous process of refrigerant absorbing heat from inside the cab and transferring the heat to the outside air.

The series of operations that make up this continuous cycle include the following four phases:

1. Vaporization

In the **evaporator** the liquid refrigerant is at low temperature and low pressure. There it absorbs the heat from the surrounding atmosphere inside the cab. In the course of performing this work, the liquid refrigerant boils and turns into a gas (vaporizes).

At this point, the physical laws of "heat transfer", "latent heat" and "relative humidity" are at work. As a result, a certain amount of latent heat is transferring to the refrigerant. This cools the air in the passenger compartment to a comfortable level and lowers the relative humidity.

Air Conditioning

2. Compression

A **compressor** draws the heat-laden vapor out of the evaporator through the compressor inlet line. In automotive applications, the compressor draws the refrigerant in through the suction pressure, compresses the refrigerant, and then discharges the refrigerant under high pressure.

The refrigerant is experiencing the effects of the application of pressure. As a result of the compression (applied pressure) provided by the A/C compressor, both the temperature and the pressure of the refrigerant vapor is increased. The refrigerant is compressed so that it will transfer heat to the outside air. After being compressed, the refrigerant is discharged to the condenser.

3. Condensation

When the high temperature refrigerant vapor enters the **condenser**, it is still under high pressure. While inside the condenser, the refrigerant is exposed to the outside of the vehicle. As a result, the refrigerant is also experiences the physical laws of "heat transfer" and "latent heat of vaporization."

The heat that the refrigerant received from inside the cab is transferred to the outside air because the temperature of the refrigerant is higher than the outside air. As the refrigerant transfers heat to the outside air, the refrigerant is cooled below the now higher boiling point. This causes the refrigerant vapor to condense from a vapor to a liquid. The newly formed liquid refrigerant then leaves the condenser under high pressure and enters a restriction.

4. Pressure Reduction

As the compressor draws the refrigerant from the evaporator, a supply of low-pressure refrigerant must be available to enter the evaporator and continue the heat absorption process. To meet this need for low-pressure refrigerant, a restriction is placed between the condenser and the evaporator. This restriction separates the high and low-pressure segments of the system. High-pressure liquid refrigerant that was cooled by the outside air leaves the condenser and enters this restriction. Because of the restriction, the refrigerant encounters a drop in pressure as it passes through the fixed orifice tube on its way to the evaporator.

At this point the refrigerant experiences the physical

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laws of “latent heat of vaporization”, “heat transfer”, and the effects of pressure on liquids. As the liquid refrigerant leaves the restriction, its boiling point and pressure are lowered as a result of the pressure reduction. As the liquid refrigerant enters this low-pressure condition in the condenser, its temperature is well below that inside the cab. As a result, the refrigerant cycle begins all over again as heat is transferred from inside the cab to cool the refrigerant in the evaporator.

Components and Basic Operation

Now let’s take a closer look at all of the components and how the refrigeration system completes the previously explained four phases through the use of these components.

Component Selection

Evaporator

The evaporator is housed in an enclosure and mounted within the cab. The evaporator receives a low-pressure input of refrigerant from a restriction known as the fixed orifice. The coils inside the evaporator are cooled by the refrigerant and move heat and humidity from the air circulating in the passenger compartment of the cab. As hot, humid air passes over the evaporator, heat from the moisture in the air transfers to the refrigerant in the evaporator leaving you with cool air inside the cab. As heat is transferred to the refrigerant in the evaporator, two things happen: 1) the refrigerant boils and changes to a vapor, and 2) moisture condenses on the evaporator coils and fins causing water to form on the evaporator.

A lack of system performance can result because:

- There is low refrigerant charge. Solution – Fully charge the A/C refrigerant.
- The evaporator coil has a blockage preventing airflow across the refrigerant coil. Solution – Clean the evaporator coil.
- The evaporator coil is undersized for the amount of cooling required in the cab. Remember the coil removes heat from the cab into the refrigerant. Solution – Change the evaporator unit to one with a larger capacity.
- The blower fan may be too small to provide adequate airflow for heat transfer to occur. Solution – Replace the blower unit to increase airflow across the evaporator coil.

A/C Compressor

The A/C compressor is usually mounted on the engine and driven by an accessory drive belt. The A/C compressor, like the fixed orifice, separates the low-pressure and the high-pressure sides of the A/C system. The compressor is a device that takes in low-pressure refrigerant from the suction accumulator / drier, compresses the refrigerant, and then discharges the refrigerant to the condenser under high pressure.

The compressor’s main function is to compress low-pressure vapor refrigerant from the evaporator so that it will become a high-pressure vapor with a temperature higher than the surrounding outside air. Changing the refrigerant to high-pressure and high temperature state will allow it to transfer heat to the outside air when the refrigerant reaches the condenser.

Another important function of the compressor is that it is responsible for circulating refrigerant and oil throughout the A/C system. Refrigerant oil is mixed with the refrigerant in the system in order to lubricate the moving parts of the compressor to prevent them from damage and wear. The compressor draws in the mixture of refrigerant and refrigerant oil from the low-pressure (suction) side of the system and pumps it out into the high-pressure (discharge) side of the system.

A lack of system performance can result because:

- Refrigerant charge is low. Solution – Fully charge the A/C refrigerant.
- The compressor drive speed is too slow not moving enough refrigerant to transfer heat out of the cab. This can be a result of:
 - Low engine speed Solution - Increase engine speed to high idle.
 - Slow engine to A/C compressor drive ratio Solution – Change either drive or driven pulley to increase refrigerant flow at low engine speeds typically found on fire apparatus idling while “on scene”.
- The compressor size is inadequate Solution – Change the A/C compressor to a model that provides increased output at engine idle speed.

Condenser

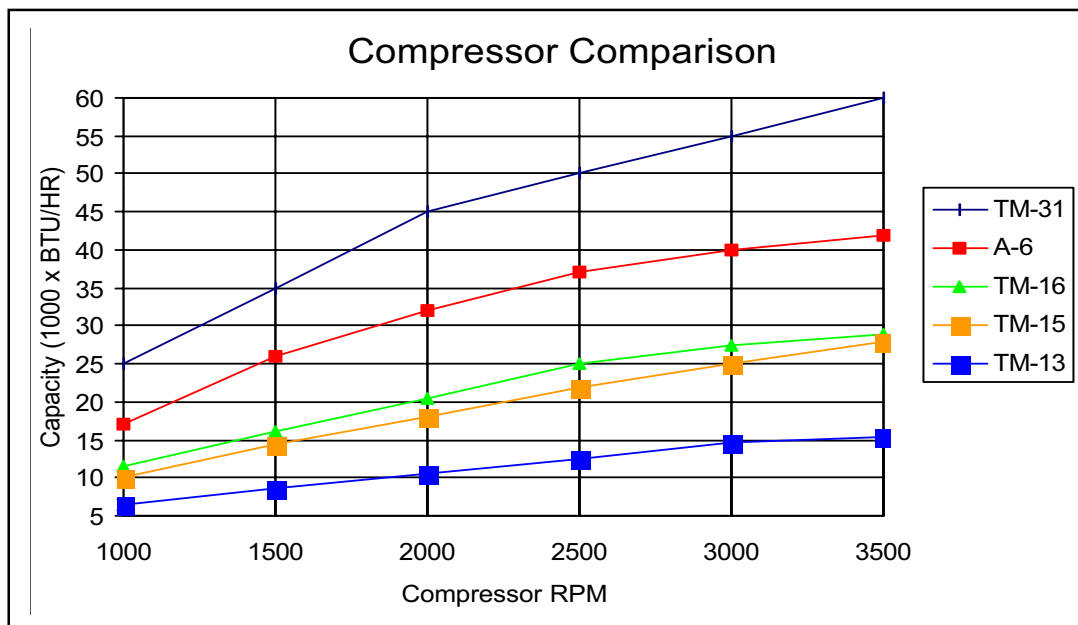
The condenser is mounted either in front of the vehicle’s radiator or in a housing mounted on top of the cab roof. In the case of radiator mounted condensers, airflow across the coil is created by the engine cooling fan or ram air as the fire

truck moves down the road. With roof-mounted condensers, a separate cooling fan system is mounted to draw cool air across the condensing coil.

The purpose of the condenser is just the opposite of that of the evaporator. In the condenser, heat-laden refrigerant from the compressor in the form of high-pressure vapor is condensed (liquefied). The hot, high-pressure vapor enters the top of the condenser through its inlet pipe. As the hot

Chart 2

Chart 2 illustrates that all compressors are not equal.



vapor flows down through the condenser coils the cooler air flowing across the coils and fins absorbs its heat. As refrigerant loses its heat, its temperature drops to the point where it changes from a hot vapor to a hot liquid. At this point, the liquid refrigerant has been cooled by the outside air and continues on to the fixed orifice tube under high-pressure and relatively high temperature.

A lack of system performance can result because:

- Refrigerant charge is low. Solution – Fully charge the A/C refrigerant.
- The condensing coil has a blockage preventing airflow across the refrigerant coil. Solution – Clean the condensing coil.
- The condensing coil is undersized for the amount of cooling required in the cab. Remember the coil removes heat-laden refrigerant from the cab. Solution – Change the condensing unit to one with a larger capacity.
- The airflow across the condensing coil may be inadequate for heat transfer to occur. Solution – Replace the blower unit to increase airflow across the condensing coil.

Fire Apparatus generally will have high demands on an A/C system with low engine speeds. Low engine speeds will result in low A/C compressor speeds and low engine

cooling fan speeds. By selecting A/C compressors with the highest possible pulley speed ratios the refrigerant flow will be adequate for proper cooling.

Radiator mounted condensers, generally used for automobile applications or over-the-road trucks where a high volume of ram air is available do not provide adequate airflow for fire apparatus. A fire apparatus does not receive ram air when parked at an incident and requires roof mounted condensers with electrically operated fans running at a constant high speed to provide optimal cooling of the heat laden refrigerant.

Evaluating the Specifications

When an apparatus is said to have a certain size system check out all of its components. Make sure the lowest rated component is the resulting system rating. For a proper evaluation in your bid specifications ask the manufacturer to spell out the evaporator, condenser and compressor ratings.

- Ask if the condenser is mounted on the radiator, if so watch out for poor cooling performance at engine idle. There just isn't enough airflow

across the coil at engine idle.

- Regarding the compressor rating, ask the drive ratio (engine to compressor speed ratio).
- Ask for the component rating charts.
- Verify that the systems provide adequate cooling at engine idle.

After all, the air conditioning is used for rehab in the apparatus isn't it?

And, oh yes, don't be fooled by the controversy of BTU's and tons of cooling. One ton of cooling equals 12,000 BTU; therefore the two-ton system is the equivalent of only 24,000 BTU of A/C.

Chart3

Chart 3 illustrates the performance of an A-6 compressor at varying engine speeds.

Drive Ratio	High Idle Setting	Compressor Speed	Cooling Output 1,000 BTU's	Percent Improvement
2.1	700	1470	17	
	900	1890	26	52.94%
	1000	2100	32	88.24%
	1100	2310	32	88.24%
	1200	2520	37	117.65%
	1300	2730	37	117.65%
	1400	2940	38	123.53%

NOTE: Engine idle 700 RPM

A-6



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