AIR CONDITIONING LIFE EXTENDER
ACX10 FIELD INSTALLATION AND PERFORMANCE EVALUATION

Tony Thorne

Manager of Electrical Engineering

Index Sensors and Controls, Stanwood, WA 98292 USA

ABSTRACT

Air conditioning systems used in heavy truck applications operate under extreme underhood environmental conditions, and vary according to how the trucks are utilized. Cement or dump trucks may spend 90% of the time idling whereas freight carrier trucks may operate 60% of the time under heavy interstate highway speeds. [Ref 1].

The amount of idle time and exposure to higher under hood temperatures has a direct effect on the A/C system operational characteristics. Control systems that manage and protect the A/C system can reduce annual systems maintenance costs by decreasing or eliminating catastrophic failures.

BACKGROUND

Over the past several years, maintenance operators have repaired air conditioning (A/C) system failures attributed to high cycling rates of the A/C clutch caused by factors such as low operating system pressure, improper condenser or evaporator airflow, or low DC voltage applied to the clutch (causing clutch slippage). These conditions lead to premature system failure by overheating the clutch pads or compressor front shaft bearing and seal.

Costs associated with A/C system failures range from $150.00 (if the repair occurs during a routine shop maintenance cycle), to over $2000.00 (if repaired on the road at third party service shops). Minimizing A/C system degradation or eliminating the failure mode can significantly decrease truck down time and save the system from catastrophic failures.

A/C protection systems have been available since 1995 that control the operation of the compressor based on information from cab controls, pressure sensors, and in some cases, temperature sensors. The objective of A/C protection is to prevent sudden changes or adverse conditions within the A/C system from damaging the compressor or clutch components. The results are reduced system failures, decreased down time, and reduced overall operating expenses.

The issues associated with A/C failures are mitigated by controlling the operation of the A/C system depending on various signals, sensors, and control logic. An A/C control typically takes input from the "A/C on" switch located in the cab control panel, and the low and high pressure switches. With this information, the controller can:

- Control cycle rates of the clutch (based on time)
- Establish minimum time the A/C compressor must run
- Control the minimum time the compressor must remain at rest before re-engaging the clutch
- Prevent operation during under or over voltage conditions
- Prevent the system's low pressure side from developing a vacuum, which can destroy the compressors seals from lack of oil

A/C LIFE EXTENDER (ACX SERIES)

To properly control the A/C system operation, a device must tie into the existing system and sensors and manage the A/C compressor clutch. The ACX-10 is the latest version of a family of A/C protection systems that evolved over 7 years of field experience on over 500,000 trucks.

The ACX-10 is an epoxy-sealed electronic device that accepts inputs from the thermostat, low-side, and high-side pressure switches (connected in series), and power from an ignition switched DC source. The output of the ACX-10 directly drives the A/C clutch. The design also complies with the under-hood environment requirements in SAE J1455. [Ref 2]

The ACX control monitors the input control signal and operates the clutch by varying the clutch-on and clutch-off timing parameters in response to changes in battery or system voltage or input switch states. The ACX-10 reduces clutch and compressor degradation by limiting cycles to four per minute.

ACX SYSTEMS DIAGRAMS

There are two basic types of A/C systems: The *Cycling Clutch Orifice Tube* (CCOT) and the *Thermal Expansion Valve* (TXV) system. The system differences determine which input sensors and connections are needed as shown in the following examples:

Cycling Clutch Orifice System (CCOT)

The CCOT utilizes an accumulator storage container to separate the gas and liquid so that liquid does not enter the compressor. It also contains desiccant that removes moisture from the refrigerant.

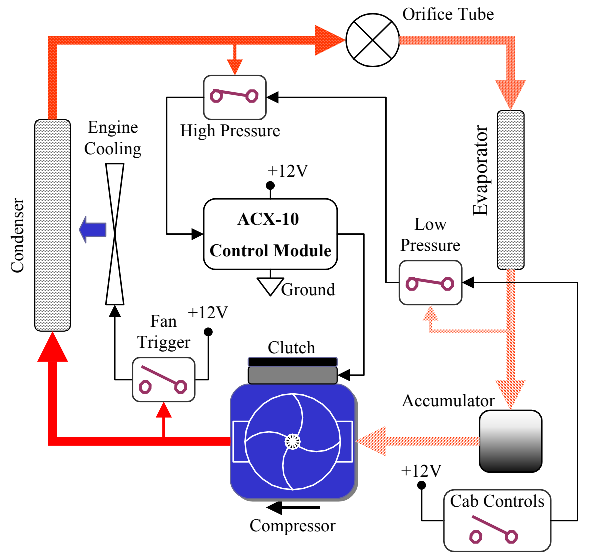

Fig 1 CCOT System

Thermal Expansion Valve System (TXV)

The TXV system utilizes a receiver / drier device that acts as a filter, separate the gas and liquid so that liquid does not enter the compressor removes moisture from the refrigerant, and provides a small storage container.

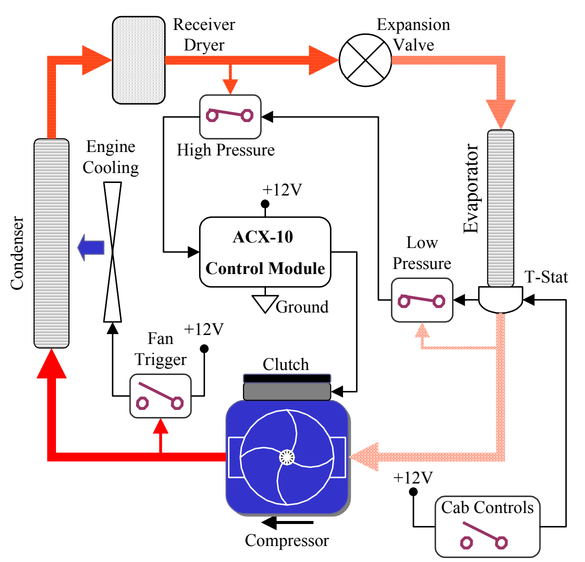

Figure 2: TXV System

The ACX-10 series products can be utilized for either TXV or CCOT systems to dynamically control the operation of the A/C compressor clutch. The ACX-10 is compatible with one or two wire clutches. (See figure 3 below)

- The one wire clutch is internally grounded to engine (compressor) chassis. To engage the clutch, a positive DC voltage is applied to the input wire
- The two wire clutch relies on the control circuit to provide both power and ground. One wire is connected to chassis ground and positive DC voltage is applied to the other wire.

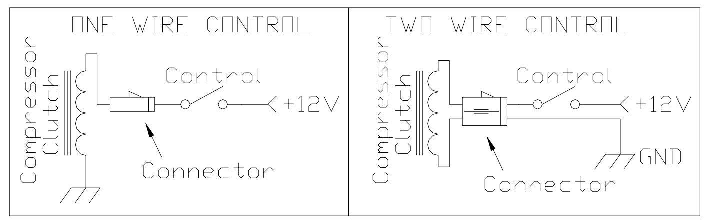

Figure 3: Typical A/C Compressor Clutch Control Diagram

FIELD DATA

The ACX field test program provides vital A/C operational statistics utilizing data loggers connected to the ACX-10 and air conditioner (A/C) clutch control. The fleet trucks in the field test program were divided into two groups: 50% were fitted with both specialized event data loggers (X-Logger) and ACX control units, and the other 50% were fitted with X-Loggers only.

The data loggers capture the events during normal "in-service" operation and collect several types of key data points:

- Engine ON cycles (number of times the engine is started)
- Number of hours of engine operation
- Number of AC Clutch cycles (closures)
- Number of accumulated hours the AC unit is running

In addition, the following information is recorded separately for each truck monitored:

- Miles of truck operation
- Hours of truck operation
- Truck serial (identifier) number

SYSTEM INSTALLATION & TEST METHODOLOGY

Typical in most fleets today, there are a variety of engine configurations, A/C compressor manufacturers, locations of the A/C compressor on the engine, and access to the wiring harnesses. The protection control system has been designed to accommodate these variables to assure easy installation of the ACX in OEM or aftermarket situations.

The ACX-10 units and data loggers installed in these examples comprise of a mixture of configurations. The data collected is a summation that includes the A/C cyclic operation among the various platforms of trucks tested.

The ACX-10 installation is performed in three steps;

1. Access and connect wire harness to ignition switched power and ground
2. Bolt ACX-10 to bulk head (or other fixed and secure point)
3. Plug in connectors to the A/C compressor and input pressure switches

The kits were configured for single wire A/C clutch control, dual wire A/C clutch control, and the single and dual wire installations with data logger only.

Figure 4: Data logger and ACX-10 Field Trial Kits

The trucks were rotated through the maintenance facility, each requiring between 10 to 30 minutes to install each kit.

Figure 5: Data Logger and ACX Installation

The trucks' vintage varied, as did the brands of A/C compressors and their installed locations.

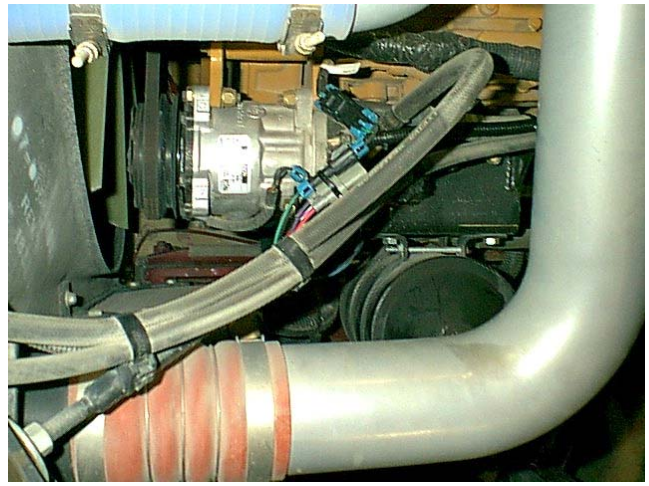

Figure 6: Side Engine View - A/C Compressor Mounting

Top mounted compressors, shown in figure 7, required more consideration in routing the wire harness and securing the connectors to clear the radiator fan and drive belts.

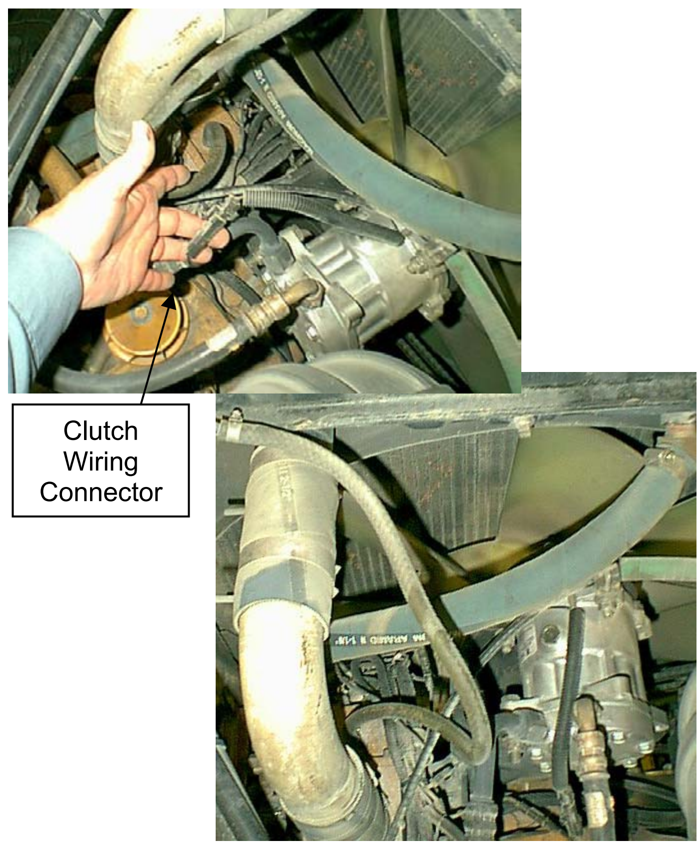

Figure 7 Top View of A/C Compressor Mounting Locations

Step 1: Access Wire harness for Power & Ground:

There are differences among trucks based on their make, vintage, and configuration. Some have extra coolant capture tanks which may make installation more of a challenge.

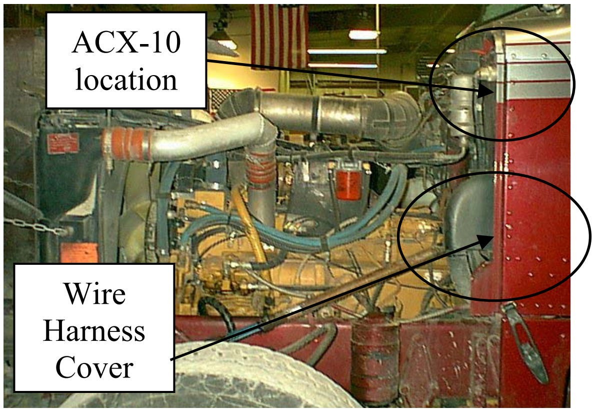

Figure 8: Engine Compartment Locations

The cab and truck wire harness access cover (shown in figure 8) provides access to the 12V switched and fused accessory wire that powers the ACX module when the ignition is turned on.

Figure 9: Cab and Truck Wire Harness Access Cover

The manufacturer wiring diagrams may not show all connections to the auxiliary (AUX) lines, so care must be taken when selecting a source of switched power. Utilizing the vehicle wiring diagram, an accessory switched DC wire was located.

Figure 10: Selecting Switched Power Line

The cab wire access cover is re-installed. Special attention was placed in ensuring the connector was protected from abrasion and zip tied for relief:

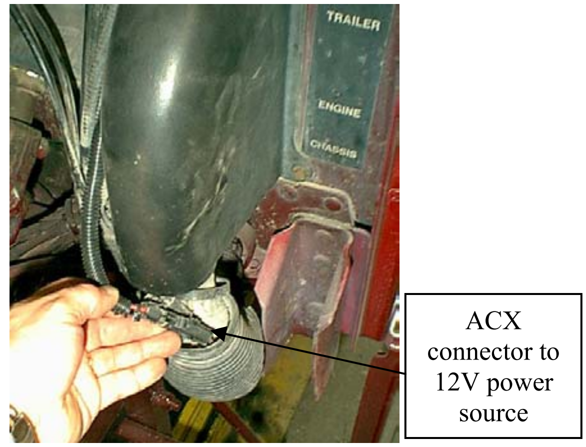

Figure 11: Connection to Switched Power

Step 2: Install and Mount ACX-10:

In the examples below, the ACX-10 is mounted to the bulkhead (fire wall). This point also provided a good chassis ground connection for the harness ground wire.

Figure 12: Mounting the ACX-10

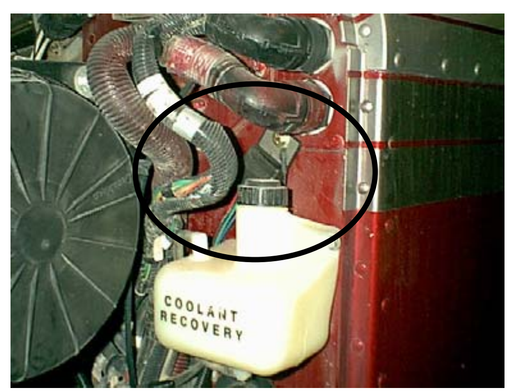

Figure 13: Installation Example

Step 3: Route and Connect the Interface Wires:

Route the wires along the A/C hoses securing with Zip Ties©.

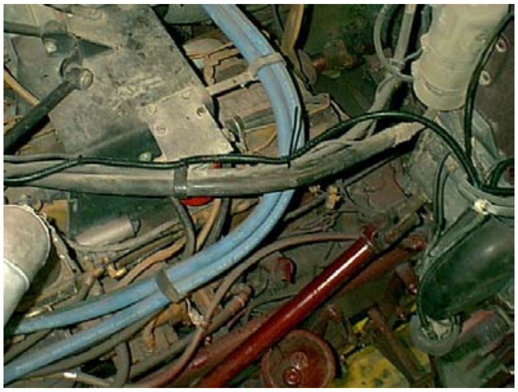

Figure 14: Wire Harness Installation

For the field tests, the Index Sensors *X-Logger* is mounted to a spare compressor mounting lug (depending on the application). The data collection port is shown below and very accessible:

Figure 15: Data Logger Installation (Typical)

The ACX also utilizes a refrigerant low pressure switch. This switch is located on the suction side of the compressor to prevent the compressor from operating below a safe pressure level, or from drawing a vacuum in the system. A typical A/C refrigerant pressure switch is shown below located on the cab bulk head refrigerant line:

Figure 16: Pressure Switch Example

FIELD TEST RESULTS

The data logger provided information on hours of A/C operation, number of clutch cycles closures, and hours of engine run time.

Truck Number	Mileage	Power Cycles	Power On Time (hrs)	Clutch Cycles	Clutch On Time (hrs)	ACX	Log
52835	359159	278	1361.33	17653	600.79	X	X
53490	298400	140	1784.35	50270	1022.45	X	X
90987	84550	1266	3617.05	32190	1480.79		X
52187	490289	901	1892.4	9670	288.3		X
53119	366077	1443	1912.59	13916	261.37		X
53657	**136473**	**1856**	**1919.73**	**42039**	**402**		X
52897	**317560**	**2847**	**1889.71**	**59073**	**245.6**		X
53443	**303261**	**1026**	**988.26**	**47068**	**776.55**	X	X
53395	196061	512	1426.5	22028	962.97	X	X
52932	**106662**	**1391**	**1381.81**	**44363**	**1031.84**	X	X
52392	459230	512	524.72	37134	339.55	X	X
Sum	X	12172	18698.45	375404	7412.21		
Avg/June-Nov	5-Month	716.0	1099.9	22082.6	436.0		
	Per Month	143.2	220.0	4416.5	87.2		
Approx	Per Year	1718.4	2639.8	52998.2	1046.4		

Table 1: Data Logger Results (Compliments of CR England Fleet, Salt Lake City Utah)

The average results from the 5 month field test are that for every 10 hours of engine operation, the A/C ran for an equivalent of 3 hours. The ratio of A/C to truck operation for 3000 hours per year equates to 1000 hours A/C operation with over 40,000-50,000 clutch cycles per year (assumptions depend on regional climates and system integrity).

CLUTCH CYCLING VERUS REFRIGERANT CHARGE

Tests were also conducted on CCOT and TXV systems to determine the relationship between the refrigerant state of charge and the cycling rate of the compressor. The test utilized a R134a refrigerant recovery station to recharge the refrigerant in the system to factory specifications, then remove the refrigerant in 0.5 pound (liquid weight) decrements out of the system for each test. The engines were run at 1500 RPM with the A/C cab controls turned on to maximum.

As the refrigerant level (state of charge) decreases, (I.E. removing the number of pounds of refrigerant liquid during each test), the pressure on the low suction side of the compressor drops more rapidly when the compressor is turned on and the clutch engaged. The test conducted shows the correlation between amount of refrigerant and the dynamic effects on the compressor on command.

Each of the CCOT and TXV systems tested included low pressure switches on the suction side that turned off the A/C clutch when pressure dropped below 14PSI, and re-engaged the clutch when the pressure then recovered above 34PSI. Some TXV systems do not utilize a low pressure switch.

Some TXV systems do not include a low pressure switch, but instead rely on a bi-functional switch located on the high pressure side to infer a low pressure condition. In A/C systems that do not use a low pressure switch, the configuration cannot detect a problem such as low refrigerant charge, thereby putting the compressor at risk of failure.

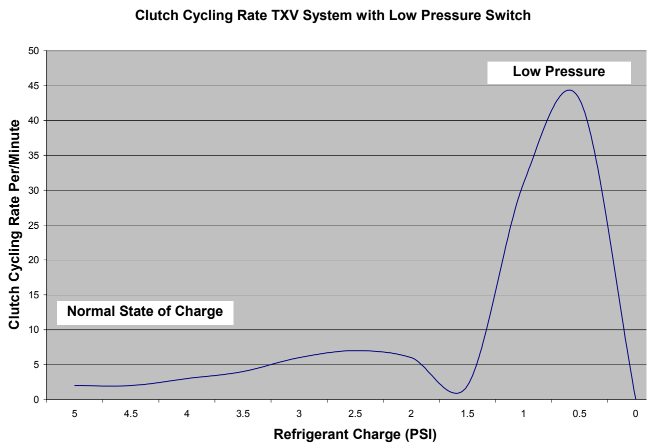

Figure 17: State of Charge -vs- Clutch Cycling

The results of the test showed that a system operated normally at 3-6 cycles per minute from full charge of refrigerant. When the refrigerant is removed down to 30% state of charge, the cycling rate of the compressor increased dramatically. Between 1 to 1.5 pounds of liquid refrigerant within the system, the cycling increased to over 31-43 times per minute, and over 1800 to 2500 clutch closures per hour.

In these low pressure conditions, the compressor clutch is subjected to severe heat caused by the constant friction when engaged repeatedly. Subsequent damage to compressor seals and clutch surfaces will result in catastrophic damage.

CONCLUSION

The ACX-10 air conditioner life extender module provides it's benefits when system conditions are not normal. The most common system abnormality is low pressure due to low refrigerant charge or gradual loss of charge.

A/C system operation data was recently gathered from 102 trucks under normal usage [Ref 3] indicated that 92% of the A/C system problems were attributed to low pressure. Of these test trucks, all those with more than 100,000 miles had logged low pressure conditions, as did with 67% of the trucks under 100,000 miles.

The ACX-10 saves wear & tear on A/C system components during common low-charge conditions, and protects compressor components form catastrophic failure in complete loss of charge situations.

Factors increasing the likelihood of low charge / low pressure conditions developing in a given vehicle include:

- High demand for A/C by driver
- High ambient temperature
- High ambient humidity
- Time at idle without sufficient ram air flow
- Elevated under hood temperatures:
  - Stop and Go traffic in hot weather
  - Stationary vehicle providing power take-off
  - Hauling heavy loads up steep grades
  - Higher temperatures of the 2002 engine standards

The impact of ACX-10 protection on a group of fleet trucks will be seen as the data and A/C repair for these test trucks are tracked over the next several months. Future white papers and test reports will provide insight into the cost of systems maintenance and annual failure cost analysis comparing systems with and without ACX protection modules.

REFERENCES

[1] Thorne T., Deleon D., 01 November, 2002, Field Report, ACX-10 Field Installation and Evaluation, ACX-10 Rpt 01Nov02.Doc, Index Sensors & Controls, Stanwood WA, 98292

[2] SAE J1455, Std, Joint SAE/TMC, Recommended Environmental Practices for Electronic Equipment Design (Heavy Duty Trucks). Society of Automotive Engineers International, 400 Commonwealth Drive, Warrendale, PA

[3] Test report, July 2002, Air Conditioning System Performance History, AC System Performance Data Analysis July 2002.Doc, Index Sensors & Controls, Stanwood WA, 98292

File history:

- Released ACX-10 Wht Paper 04Nov02-6.doc
- Revised ACX-10 Wht Paper 15Sept03 Rev-A.doc