# TRAINING PROGRAM

## *JAGUAR ENGINE MANAGEMENT SYSTEMS AND ADVANCED EMS DIAGNOSTICS - BOOK A*



## PUBLICATION CODE – 870A


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## COURSE OBJECTIVES

- Locate and identify all components of the V6 and V8 engine management systems
- Identify relevant technical information to diagnose emissions, drivability and DTC related complaints.
- Recognize possible failure modes and default operation for subsystems.
- Assess the condition of engine management system components

## PROGRAM CONTENT

1. INTRODUCTION
2. GENERAL INFORMATION
3. ELECTRICAL OVERVIEW
4. ON-BOARD DIAGNOSTICS
5. DENSO 16-BIT EMS

## DISCLAIMER

# TRAINING PROGRAM

## *JAGUAR ENGINE MANAGEMENT SYSTEMS AND ADVANCED EMS DIAGNOSTICS - BOOK A*



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## COURSE CONTENT

Jaguar Service Training Course 870 covers three Engine Management Systems (EMS), and techniques to diagnose these systems:

- Jaguar / Denso 16–Bit EMS (AJ26/AJ27)
- Jaguar / Denso 32–Bit EMS (AJ61/AJ62/AJ33/AJ34)
- Jaguar PTEC EMS (AJ60/AJ28)

Most Jaguar Service Training courses concentrate on the technical details of a specific vehicle system; how the components function and how to determine if the system is functioning correctly. Advanced Diagnostics portions of this course have a different focus; they concentrate on the processes used to diagnose faults.

To get the most from Advanced Diagnostic training, you should practice the structured diagnostic process that will be presented and apply some critical thought to the process that you use. Time spent developing your diagnostic technique here will be paid back as you solve problems more efficiently at the dealership. Combining the structured diagnostic process with your existing experience will result in:

- More effective troubleshooting
- More 'Fixed right the first time' repairs
- More confidence in the repair

Most importantly, the enhancement of your diagnostic skills will increase customer loyalty and promote your professional image.

We have all developed diagnostic techniques that we use on a regular basis and this course provides the opportunity to examine and further develop these techniques and share them with other technicians.

### System Applicability

System applicability and variants are included in each section of this Student Guide.

### Table 1 Jaguar V6/V8 Engine management evolution (1997–Onwards)

| Vehicle | Model Year | Engine management type | Comments |
|---|---|---|---|
| XJ8<br>XK8 | 1997 - 98 NA<br>1998–99 S/C | Denso 16 bit with 1st generation electronic throttle | AJ-26 Electronic throttle with mechanical guard |
| XJ8<br>XK8 | 1999 - 03<br>1999 - 02 | Denso 16 bit with 2nd generation electronic throttle | AJ-27 Electronic throttle with mechanical limp home mode, New continuous VVT, air assist, new CKP, O2, KS, MAF on N/A, new coils, top fed injectors |
| XJR<br>XKR | 2000 - 03<br>2000 - 02 | Denso 16 bit, 2nd generation electronic throttle | S/C adopts AJ-27 strategies |
| S-TYPE | 2000 - 02 | PTEC Visteon 32 bit with full authority throttle | New returnless fuel system, V6 with cylinder head temp sensor, AJ-28 V8 new sensors, transmission control, full authority throttle (no cable) |
| S-TYPE | 2003 – | Denso 32 bit with full authority throttle | CarryOver (C/O) S-TYPE - New V8 components, no air assist, no CHT on V6. |
| X-TYPE 2.5 and 3.0L | 2002 – | Denso 32 bit with full authority throttle | Returnless fuel system, flight recorder, no CHT |
| XJ | 2004 – | Denso 32 bit with full authority throttle | C/O S-TYPE 2003MY |
| XK | 2003 – | Denso 32 bit with full authority throttle | C/O S-TYPE 2003MY |

**Table 2 Jaguar Model Year and Model Code Information**

| Model year | Model (Engineering Designation) |
|---|---|
| 1998-2003 | XJ Sedan Range (X308) |
| 2004–Onwards | XJ Sedan Range (X350) |
| 1997-2002 | XK Range (X100) |
| 2003–2004 | XK Range (X103) |
| 2005–Onwards | XK Range (X105) |
| 2000–2002 | S-TYPE (X200) |
| 2003–2004 | S-TYPE (X202) |
| 2005–Onwards | S-TYPE (X204) |
| 2002–2003 | X-TYPE (X400) |
| 2004–Onwards | X-TYPE (X404) |

## ACRONYMS AND ABBREVIATIONS

**NOTE:**

A large majority of these abbreviations conform to the standards of SAE J1930

- AACV — Air Assist Control Valve
- AAI — Air Assisted Injection
- ABS — Anti-lock Braking System
- A/C – Air Conditioning
- A/C CM Air Conditioning Control Module
- ACC — Adaptive Cruise Control
- APP sensor – Accelerator Pedal Position Sensor
- ASL — Automatic Speed Limiter
- B+ – Battery Voltage
- CAN – Controller Area Network
- CCV — Canister Close Valve
- CKP sensor – Crankshaft Position Sensor
- CHT sensor — Cylinder Head Temperature sensor
- CM — Control Module
- CMP sensor (A) 1 – Camshaft Position Sensor - RH Bank
- CMP sensor (B) 2 – Camshaft Position Sensor - LH Bank
- C/O — Carry Over
- CO — Carbon Monoxide
- CPU – Central Processing Unit
- D2B — Digital Data Bus
- DC — Direct Current
- DIN — Deutsche Industrie Normen
- DLC – Data Link Connector
- DPFE — Differential Pressure Feedback EGR
- DTC – Diagnostic Trouble Code
- DSC — Dynamic Stability Control
- ECATS — Enhanced Computer Active Technology Suspension
- ECM – Engine Control Module
- ECT sensor – Engine Coolant Temperature Sensor
- ECU — Electronic Control Unit
- EPROM — Erasable Programmable Read Only Memory
- EEPROM — Electrically Erasable Programmable Read Only Memory
- EFT sensor – Engine Fuel Temperature Sensor
- EGR – Exhaust Gas Recirculation
- EMS — Engine Management System
- EOT sensor – Engine Oil Temperature Sensor
- EVAP Canister Close Valve – Evaporative Emission Canister Close Valve
- FPDB — Front Power Distribution Box
- FEM – Front Electronic Control Module
- FTP — Federal Test Procedure
- FTP sensor – Fuel Tank Pressure Sensor
- FSC — Fail Safe Cooling strategy
- GEM – Generic Electronic Module
- HC — Hydrocarbons
- HO2 sensor 1/1 –Heated Oxygen Sensor - RH Bank/Upstream
- HO2 sensor 1/2 –Heated Oxygen Sensor - RH Bank/Downstream
- HO2 sensor 2/1 –Heated Oxygen Sensor - LH Bank/Upstream
- HO2 sensor 2/2 –Heated Oxygen Sensor - LH Bank/Downstream
- IAT sensor – Intake Air Temperature Sensor
- IC — Instrument Cluster
- IG – Ignition
- IMT Valve – Intake Manifold Tuning Valve (1 = top, 2 = bottom)
- IP sensor – Injection Pressure Sensor
- ISO — International Standards Organization
- JTIS — Jaguar Technical Information System
- KAM — Keep Alive Memory
- KS 1 – Knock Sensor RH bank

- KS 2 – Knock Sensor LH bank
- KTM — Key Transponder Module
- LED — Light Emitting Diode
- LEV — Low Emissions Vehicle
- LTFT — Long Term Fuel Trim
- MAF sensor – Mass Air Flow Sensor
- MIL — Malfunction Indicator Lamp
- N/A – Normally Aspirated
- NAS – North American Specification
- NTC – Negative Temperature Coefficient
- NOx — Oxides of Nitrogen
- OBD – On-Board Diagnostics
- O/C — Open Circuit
- ORVR — On-board Refuelling Vapor Recovery
- PATS — Passive Anti-Theft System
- PAD — Passenger Airbag Deactivation light
- PCB — Printed Circuit Board
- PJB — Passenger Junction Box
- PTEC — PowerTrain Electronic Control
- PPS – Pedal Position Sensor
- PCM – Powertrain Control Module
- PWM — Pulse Width Modulation
- RAM — Random Access Memory
- RCM — Restraints Control Module
- RCCM — Remote Climate Control Module
- RCCP — Rear Climate Control Panel
- REM – Rear Electronic Module
- ROM — Read Only Memory
- RHS — Right Hand Side
- RPDB — Rear Power Distribution Box
- ROW – Rest of the World Specification
- SAE — Society of Automotive Engineers
- S/C – Super Charged
- SCP – Standard Corporate Protocol Network
- STFT — Short Term Fuel Trim
- SWAS — Steering Wheel Angle Sensor
- TACM — Throttle Actuator Control Module
- TCM — Transmission Control Module
- TFT sensor – Transmission Fluid Temperature Sensor
- TLEV — Transitional Low Emission Vehicle
- TM – Throttle Motor
- TOT — Transmission Oil Temperature
- TP– Throttle Position
- ULEV — Ultra Low Emissions Vehicle
- VIS – Variable Intake System
- VSV — Vacuum Solenoid Valves
- VVT 1 – Variable Valve Timing solenoid valve - RH Bank
- VVT 2 – Variable Valve Timing solenoid valve - LH Bank
- WOT — Wide Open Throttle

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## *JAGUAR ENGINE MANAGEMENT SYSTEMS AND ADVANCED EMS DIAGNOSTICS - BOOK A*

INTRODUCTION

GENERAL INFORMATION

**ELECTRICAL OVERVIEW**

ON-BOARD DIAGNOSTICS

DENSO 16-BIT EMS

**PUBLICATION CODE – 870A**

# REVIEW — BASIC ELECTRICAL

## Electrical Units and Quantities

**Table 3**

| Base Unit | Symbol | SI Unit | Symbol |
|---|---|---|---|
| Electrical Current | I | Ampere | A |
| Electrical Potential | U | Volt | V |
| Electrical Resistance | R | Ohm | Ω |
| Quantity of electricity | Q | Ampere Hour | Ah |
| Electrical Capacitance | C | Farad | F |
| Time | T | Second | Sec |
| Power | P | Watts | W |

The international engineering and scientific communities have adopted standards for quantities and units in order to do away with the confusion caused by converting between the various measurement systems used by individual countries.

The ISO (International Organization for Standardization) published the standards in their documents ISO 31 and ISO 1000. The units used in this standardized measurement system are known as SI (Systéme International) units

**Table 4**

| Quantity | Prefix | Prefix Symbol |
|---|---|---|
| 1,000,000,000 (billion) | Giga | G |
| 1,000,000 (million) | Mega | M |
| 1,000 (thousand) | Kilo | K |
| 100 (hundred) | Hecto | H |
| 10 (ten) | Deka | Da |
| 0.1 (tenth) | Deci | D |
| 0.01 (hundredth) | Centi | C |
| **Quantity** | **Prefix** | **Prefix Symbol** |

| | | |
|---|---|---|
| 0.001 (thousandth) | Milli | m |
| 0.000001 (millionth) | Micro | µ |

Electrical power is expressed in Watts: **W (Watts) = E (volts) X I (amperes)**

**Energy Conversion**

1 Watt = 0.0013 Horsepower (HP)

1 Kw = 1.341 HP

1 HP = 745.7 Watts

**Rules Governing Electrical Circuits**

Ohm's Law describes the relationship between voltage and resistance in solid and liquid conductors: Electrical potential (E) is equal to the electrical current (I) multiplied by the electrical resistance (R). The formula is written as E = I x R [E (volts) = I (amperes) x R (ohms)]. Ohm's Law can be useful during diagnoses to help determine the effect of voltage, current flow or resistance in a circuit. If two values are known, the third value can easily be calculated.

The diagram below is designed to simplify the use of Ohm's Law. The horizontal line indicates that two values should be divided; the vertical line indicates that two values should be multiplied. To use the formula, substitute the known or measured values for their symbols, cover the unknown value with your thumb and multiply or divide, as indicated, to find the missing value. For example, if the electrical potential (E) and the current (I) are known, but the resistance (R) is not, divide the electrical potential (E) by the electrical current (I) to find the electrical resistance (R): R (ohms) = E (volts) ÷I (amperes).

Electrical resistance depends on the dimensions, material and temperature of the conductor. Resistance in metal conductors generally increases with the length and temperature of the conductor. Conductors with larger cross sectional areas have less resistance than conductors with smaller cross sectional areas.

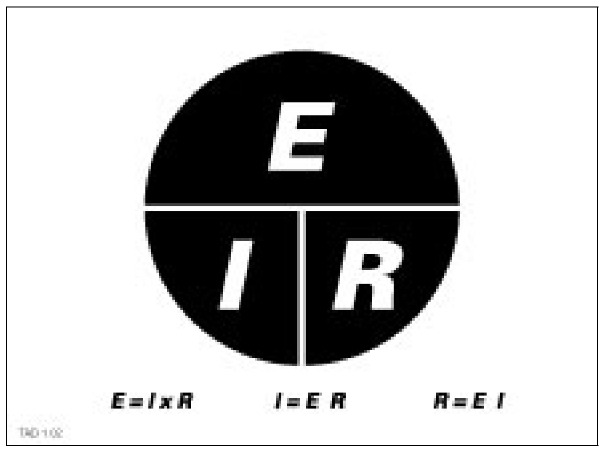


**Fig. 1 Diagram for Using Ohm's Law**

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## EMS TERMS

### Bit

A bit is an information unit used in computing and information theory. It is the smallest unit of storage currently used in these fields, although much research is going on in quantum computing with qubits. A single bit (short for binary digit) is a 0 or a 1, or a true or a false, or for that matter any two mutually exclusive states. A byte is a collection of bits, originally variable in size but now usually eight bits. 8-bit bytes are also known as octets. There are also terms for multiple bits using the standard range of prefixes, e.g. Kilobit (Kb), Megabit (Mb) and Gigabit (Gb).

### 16 Vs. 32 Bit system

The 16-bit processors are sufficiently powerful for a wide variety of engine management applications. But, with the introduction of new and faster sub-systems, returnless fuel system, ACC, 6–speed transmissions to name a few, these applications require the added power of a 32-bit processor to handle the higher number of computing operations at the same or at a higher rate of speed.

### Random Access Memory (RAM)

RAM may be defined as memory that has both read and write capabilities so that the stored information can be retrieved (read) and changed by applying new information to the cell (write).

### Read Only Memory (ROM)

Read Only Memory as the name implies is memory that can be read but not written to. ROM is used for storage of data that does not change since it is a nonvolatile memory that retains its contents after power is removed.

### EPROM

An EPROM, or erasable programmable read-only memory, is a type of computer memory chip that retains its data when its power supply is switched off. In other words, it is non volatile. It is programmed by an electronic device that supplies higher voltages than those normally used in electronic circuits. Once programmed, an EPROM can be erased only by exposing it to strong ultraviolet light.

### EEPROM

An EEPROM, or Electrically-Erasable Programmable Read-Only Memory, is a non volatile storage chip used in computers and other devices. Unlike an EPROM, an EEPROM can be programmed and erased multiple times electrically. It may be erased and reprogrammed only a certain number of times, ranging from 100,000 to 1,000,000, but it can be read an unlimited number of times. Flash memory is a later form of EEPROM.

**Flash memory**

Flash memory is a form of EEPROM that allows multiple memory locations to be erased or written in one programming operation. Normal EEPROM only allows one location at a time to be erased or written. All types of flash memory and EEPROM wear out after a certain number of erase operations.

## NATIONAL LOW EMISSION VEHICLE PROGRAM

**LEV Emissions Standards**

The California Air Resource Board (CARB) initiated the Low Emission Vehicle program, mandating a staged reduction in vehicle emissions for vehicles sold in the state of California. The EPA adopted this strategy for national compliance which became the National Low Emission Vehicle Program (NLEV).

The NLEV program has been used voluntarily by the northeastern states of the US to address increasing smog problems. The NLEV program became law in 1999 and requires all vehicles sold in northeastern states comply with the NLEV standards. Complete national phase in will be realized by 2004.

The NLEV program requires that vehicle manufacturers reduce total emission levels through a series of stages over a specified time period. The total number of vehicles a manufacturer schedules to build for the given year is also factored into the equation. The stages of compliance for internal combustion engines are identified as:

- Tier 1 = 1998 EPA Standard Requirements
- TLEV = Transitional Low Emission Vehicle
- LEV = Low Emission Vehicle
- ULEV = Ultra Low Emission Vehicle

The vehicle components and control systems must maintain set emission levels through the life span of the vehicle (accumulated mileage).

Tailpipe emissions are categorized as:

- NMHC = Non Methane Hydrocarbon
- CO = Carbon Monoxide
- NOx = Oxides of Nitrogen

Prior to the NLEV program the most stringent national compliancy was Tier 1. The benefit of exhaust emission reductions that the NLEV program provides compared with Tier 1 standards are as follows:

- TLEV - 50% cleaner than 1998 requirements
- LEV - 70% cleaner than 1998 requirements
- ULEV - 84% cleaner than 1998 requirements

While 100% LEV compliance was intended by 2004, some low volume vehicle lines are exempt from meeting the 2004 Standards until 2006. These vehicles are classified as meeting 'Interim' standards for Federal requirements, and 'Tier 2 Bin 9' for CARB standards.

**AUTOMOBILE EMISSION SOURCES**

Tailpipe emissions are not the only contributor of pollutants from an automobile. The vehicle contributes to air pollution by emitting Hydrocarbon based gasses identified as Non Methane Organic Gasses (NMOG) and Volatile Organic Compounds (VOC). NMOG and VOC emissions are classified to stationary emission sources which escape to atmosphere and contribute to poor air quality.

NMOG and VOC are released from a vehicle through evaporation and outgassing from the fuel system evaporative system, evaporating engine oil, windshield washer fluid, paints and solvents. Gradual outgassing of petroleum based vehicle components such as plastics, rubber materials and compounds also contribute to VOC generation.

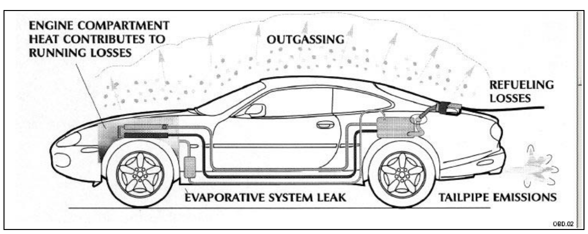


**Fig. 2**

The EPA has addressed outgassing or release of VOC to atmosphere by categorizing and mandating the following:

- Minimize generation of VOC outgassing caused by component materials.
- Running Loss Compliance (Integrate Non Return Fuel Systems).
- Monitor the vehicle evaporative system for leaks (OBD II Compliance).
- On-board Refueling Vapor Recovery (ORVR) Compliance.

The combination of the NLEV program and On Board Diagnostics results in a future national vehicle fleet that is cleaner and has the capability of detecting and alerting the driver of mechanical and electrical malfunctions prior to failure.

**Table 5 Federal and California Emissions Certification**

| Federal / CARB | X-TYPE | S-TYPE 3.0 | S-TYPE V8 | S-TYPE R | XJ8 | XJR | XK8 | XKR |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| **1999 Tailpipe Emissions** | | | | | TLEV | Tier 1 | TLEV | Tier 1 |
| | | | | | | | | |
| **2000 Tailpipe Emissions** | | NLEV / TLEV | NLEV / TLEV | | NLEV / LEV | Fed / Tier 1 | NLEV / LEV | Tier 1 |
| | | | | | | | | |
| **2001 Tailpipe Emissions** | | NLEV / TLEV | NLEV / TLEV | | NLEV / LEV | Fed / Tier 1 | NLEV / LEV | Tier 1 |
| | | | | | | | | |
| **2002 Tailpipe Emissions** | NLEV / LEV | NLEV / LEV | NLEV / LEV | | NLEV / LEV | Fed / Tier 1 | NLEV / LEV | Tier 1 |
| | | | | | | | | |
| **2003 Tailpipe Emissions** | NLEV / LEV | NLEV / LEV | Tier 2, Bin 5 / LEV | NLEV / LEV | NLEV / LEV | Fed / Tier 1 | NLEV / LEV | NLEV / LEV |
| **EVAP / Refueling** | | | En-hanced | | En-hanced | | En-hanced | |
| | | | | | | | | |
| **2004 Tailpipe Emissions** | Interim / Non-Tier 2 Bin 9 (LEV I) | Interim / Non-Tier 2 Bin 9 (LEV I) | Tier 2 Bin 5 (LEV II) | Interim / Non-Tier 2 Bin 9 (LEV I) | Tier 2 Bin 5 (LEV II) | Interim / Non-Tier 2 Bin 9 (LEV I) | Tier 2 Bin 5 (LEV II) | Interim / Non-Tier 2 Bin 9 (LEV I) |
| **EVAP / Refueling** | Tier 2 | Tier 1 | Tier 1 | Tier 1 | Tier 1 | Tier 1 | Tier 1 | Tier 1 |

## ON-BOARD DIAGNOSTICS (OBD)

### ON BOARD DIAGNOSTICS I

A large portion of technology used in engine control systems is due to the legislative requirement of complying with emission regulations to reduce air pollution. Engine control system self monitoring provides an alert system to the driver in the event of a malfunction in the emission control functions of the system. The self monitoring capabilities are called On Board Diagnostics.

The California Air Resources Board (CARB) established regulations for vehicles that would be sold in California beginning with the 1988 model year. These regulations are known as On Board Diagnostics - version 1 (OBD I). The Environmental Protection Agency (EPA) adopted the California program for all manufactures selling vehicles in the US starting with the 1988 model year.

However, Jaguar vehicles did not have an instrument cluster check engine light until the 1990 model year. 1988 & 89 vehicles have the check engine light function incorporated with the VCM. Diagnostic fault codes are also provided with the VCM.

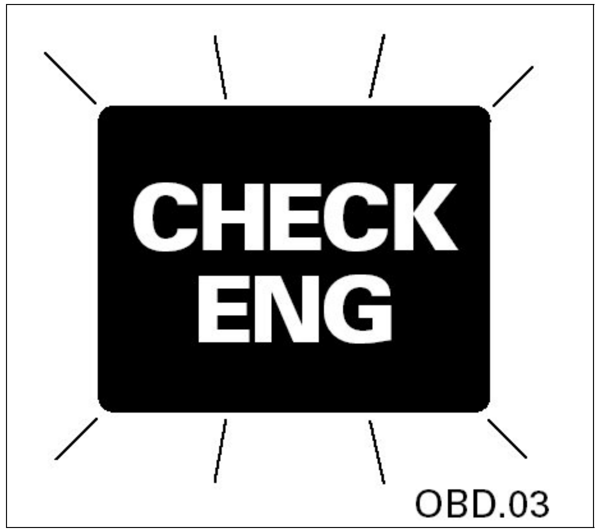


Fig. 3

**OBD I monitoring requirements include:**

- Correct function of the Engine Control Module (ECM)
- Fuel metering system
- Exhaust gas recirculation system
- Emission related components

To achieve these requirements, the OBD I system monitors all sensors used for fuel, EGR, and other emission controls for opens and shorts in the components or their circuits. Fuel trim, EGR and oxygen sensors were also monitored for functionality. Any malfunctions required:

- The Malfunction Indicator Light (MIL) to light while the malfunction was present.
- A Diagnostic Trouble Code (DTC) to be set in the Engine Control Module which is accessed with the PDU or WDS.
- A procedure for activating flashing codes of the MIL to provide fault information to all technicians for diagnosis. This procedure is not necessary for Jaguar Dealers since the JDS/PDU/WDS are used for fault code access.

**ON BOARD DIAGNOSTICS II**

In their continuing efforts to improve vehicle emission levels and on board monitoring capabilities, CARB implemented a more stringent program for their state requirements known as On Board Diagnostics, version 2 (OBD II) .

OBD II implements further refinements in the ability to monitor the proper function of a vehicle drivetrain ensuring emission levels do not exceed accepted levels. Drivetrain systems that affect emission levels if impaired include:

- Engine Management
- Transmission Control
- Traction Control

The Environmental Protection Agency (EPA) adopted the CARB program and made it a federal requirement based on the Clean Air Act amendment of 1990. The EPA required a complete phase in of OBD II compliance for all vehicles sold in the US by 1996 model year. All Jaguar vehicles sold in the US were compliant by 1995.

The complete compliance document is titled, 1968.1 Malfunction and Diagnostic System Requirements. This document was then amended as 1968.2 in 2004, with enhanced requirements required by 2008. Visit the EPA web site at www.epa.gov for detailed information.

In preparation of mandating OBD II, the EPA and CARB consulted the SAE (Society of Automotive Engineers) to establish common standards for all vehicle manufactures ensuring consistency from one manufacture to the next. These standards include:

- J 1930 - common acronyms of system components.

- J 1850 - common Diagnostic Equipment Communication Protocol.
- J 1962 - common Data Link Connector (DLC), and guidelines for its location in the vehicle.
- J 1978 - recommended practices for common OBD II Scan Tool
- J 1979 - common generic scan tool software.
- J 2190 - common Diagnostic Test Modes.
- J 2012 - common Diagnostic Trouble Codes.

The standards simplify diagnosis by mandating a common scan tool communication protocol and Data Link Connector, accessing information, providing standard component names, test modes and diagnostic trouble codes (DTCs) for all vehicles.

**OBD II MONITOR REQUIRMENTS**

To facilitate the expanded monitoring requirements of OBD II, emission related vehicle systems require additional software capabilities and components such as:

- Post catalytic converter oxygen sensors
- Fuel tank pressure sensor
- Evaporative Fuel System Shut off valve

The Engine Management System is continuously checked during vehicle operation by the ECM on-board diagnostic (OBD) facilities. Powertrain OBD incorporates nine diagnostic monitors. Each monitor has an associated group of DTCs. The diagnostic monitors will complete the diagnostic test(s) if a specified service "drive cycle" is carried out.

The nine diagnostic monitors are as follows:

- Comprehensive Component Monitor
- Heated Oxygen Sensor Monitor
- Catalytic Converter Efficiency Monitor
- Engine Misfire Detection Monitor
- Evaporative Emission Systems Monitor
- Secondary Air Injection System Monitor
- Fuel System Monitor
- Exhaust Gas Recirculation System Monitor
- Engine Coolant Thermostat Monitor

Technicians can ensure that an OBD diagnostic monitor drive cycle is completed and that all or specific components have been checked by completing a specified drive cycle.

These drive cycles are detailed in the relevant "Powertrain DTC Summaries" publications (DTC Summaries CD or JTIS).

Completion of diagnostic monitor drive cycles can be verified by checking for flagged DTCs P1000 and P1111.

- If DTC P1000 is flagged after DTCs have been cleared, all engine management OBD diagnostic monitor drive cycles have not been completed.
- If DTC P1111 is flagged after DTCs have been cleared, all engine management OBD diagnostic monitor drive cycles have been completed.
- For PTEC S-Type, P1111 is NOT flagged when all OBD diagnostic monitors have been completed. Instead, completion is indicated by the absence of P1000.

**Warm up, Drive Cycles & Trips**

To conclusively test the function of an emission component or system function the vehicle must be operated under varied running conditions which is known as a Drive Cycle. Segments of the Drive Cycle are also identified such as Warm Up Cycle and Trip.

During the Drive Cycle the ECM activates the various emission systems to monitor their function. If faults are detected during the monitoring stages, the ECM will store the event in its memory. If it happens a second time on the next successive drive cycle, the driver is alerted via the CHECK ENGINE MIL.

Drive Cycle parameters are based on the Federal Test Procedure (FTP). The FTP is a set driving cycle established by CARB that allows the engine to warm up and the vehicle to drive through varied engine speed and load conditions ensuring the emission systems are activated and monitored.

OBD II DTCs are for the most part two "TRIP" DTCs. This means that the DTC will not be flagged and the CHECK ENGINE MIL activated until the fault has occurred on two consecutive "trips". The OBD system defines 1 TRIP as an ignition cycle (ignition key OFF; wait 30 seconds; ignition key ON) plus a minimum engine coolant temperature increase of 22 °C (40 °F) after which, the engine coolant temperature has to reach a minimum of 71°C (160 °F).

**Warm-up Cycle :** operation of the vehicle to the point of warming the coolant by at least 40°F higher than the last engine off and reaching at least 160°F.

**Drive Cycle:** takes the warm-up cycle one step further by operating the vehicle to the point whereby it will go into closed loop control and include the operating conditions that are necessary to initiate or even complete a specific OBD II monitor. These specific Drive Cycles are provided in the DTC summary publications.

**Trip:** Beginning with an engine off period, after the engine is started, the vehicle must travel a specified distance to allow the following five of the nine OBD II monitors to complete all of their tests:

1. Misfires
2. Fuel System
3. Comprehensive components
4. EGR
5. HO2S

### Check Engine Light (MIL)

MIL activation changed with the introduction of OBD II. The MIL is activated when the ignition is switched to the ON position before cranking which serves as a bulb check function of the instrument cluster.

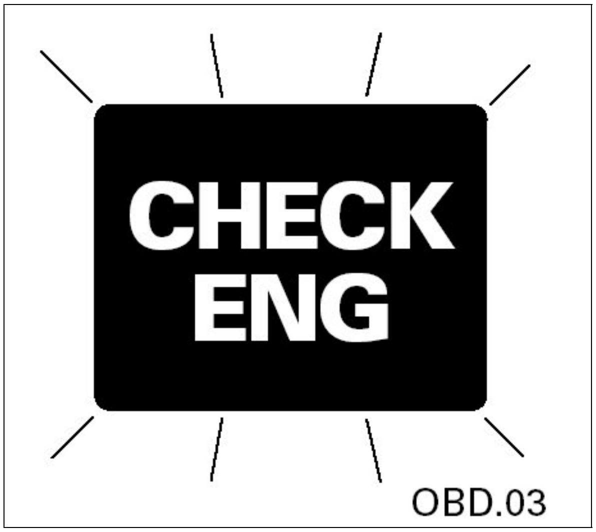


**Fig. 4**

Illumination of the MIL is in accordance with the FTP which requires activation when:

- A malfunction of a component that can affect the emission performance of the vehicle occurs and causes emissions to exceed 1.5 times the standards required by the FTP.
- An OBD II monitored input signal is out of range, open or shorted (Comprehensive Component Monitoring).
- Misfire faults occur.
- A leak is detected in the evaporative fuel system.
- The oxygen sensors observe no purge flow from the purge valve/evaporative system.
- Engine control module fails to enter closed-loop operation within a specified time period.
- Engine or transmission control enters a limp home mode.
- Jaguar defined specifications are exceeded.

To prevent erroneous illumination, if a fault is detected once, it must also be detected a second time on the next consecutive driving cycle. At the point in which the fault is conclusively confirmed in the drive cycle, the MIL is then activated. However, faults that are monitored as catalyst damaging will cause the MIL to illuminate immediately.

Jaguar instrument clusters also inform the operator with additional information via RED and AMBER MILs along with Message Center information. Refer to the DTC summary guides.

**Data Link Connector (DLC)**

To comply with SAE specification J 1962, the DLC has a standardized shape for connection with all generic scan tools and the WDS.

Communication between the engine/powertrain control modules and the diagnostic equipment is carried out via specific communication ports in the DLC based on diagnosis or programming.

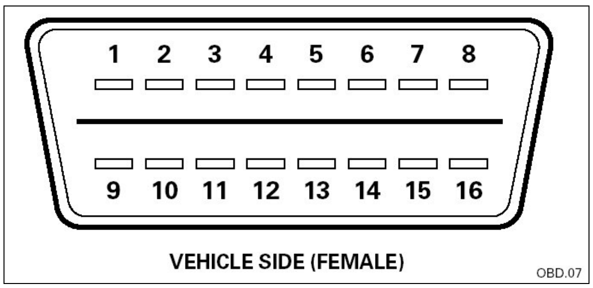


**Fig. 5**

**Table 6**

| PIN Description | Application |
|---|---|
| 1. Ignition Switch | Ignition Switch Position II (RUN) |
| 2. J1850 Communication Protocol | SCP BUS (+) |
| 3. Airbag Diagnostic Link | Serial Communication for Airbag Diagnostics (XK Only) |
| 4. Chassis Ground | |
| 5. Signal Ground | |
| 6. CAN_H | CAN data link (high) |
| 7. ISO-9141 Diag. Communication | Diagnostic communication serial data link to vehicle modules |
| 8. Ignition Switch | Ignition Switch Position I “ACC” |
| 9. Battery Power (switched) | Vehicle battery power via Ignition switch or Ignition Control |
| 10. J1850 Common Protocol | SCP BUS (–) |
| 11. Vacant | Not utilized at this time |
| 12. Flash EEPROM | Flash programming communication port |
| 13. Flash EEPROM | Flash programming power link (power supply to module for programming) |
| 13. Flash EEPROM | Flash programming communication port (2000–2002MY S-TYPE) |
| 14. CAN_L | CAN data link (low) |
| 15. ISO-9141 Diag. Comm. | Diagnostic communication serial data link to vehicle modules |
| 16. Battery Power | Vehicle Battery power available at all times (unswitched) |

**OBD II Diagnostic Trouble Codes (DTC):**

Flagged DTCs are either OBD II related DTCs (required by emission control legislation) or Jaguar DTCs. OBD II DTCs always activate the CHECK ENGINE MIL; Jaguar DTCs do not activate the CHECK ENGINE MIL.

- SAE specification J 2012 established the Diagnostic Trouble Codes (DTC) used for OBD II systems.
- The SAE has designated the emission related DTCs to start with the letter "P" for powertrain related systems.
- Jaguar also follows the SAE convention for other non OBD II monitored systems such as Body and Chassis. Their Alpha structure is identified "B" and "C" respectively.
- The source digit indicates that this particular code is one that will be found on all manufacturers' products as noted by the second digit is 0. When there is a 1 in this position, the code would be specific only to a Jaguar specific component or function. Due to the increased number of available codes, generic codes (found on all manufacturers' products) are also designated when the second digit is a 2. Codes unique to Jaguar may also be designated when the second digit is a 3.

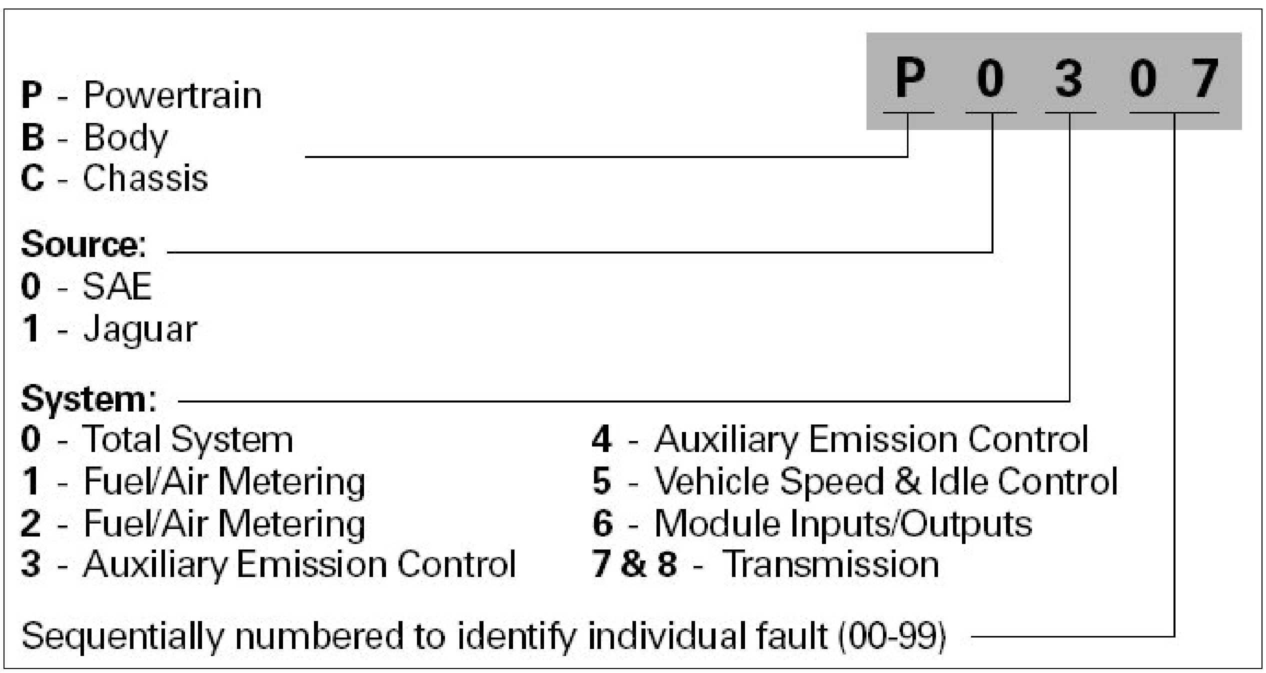


**Fig. 6**

Therefore the DTC P0307 indicates:

- P - Powertrain problem
- 0 - SAE sanctioned
- 3 - Related to an ignition system/misfire
- 07 - The misfire has been detected at cylinder # 7.

WDS is used to access all Jaguar vehicle system DTCs. A generic scan tool (i.e.: GDS 500E/510) can also be used to access OBD II specific DTCs (SAE sanctioned only).

**DTC Summaries**

The publication “Powertrain DTC Summaries” contains all DTC related vehicle and system details including:

- Fault descriptions
- Drive cycles (monitoring conditions)
- ECM Default action(s)
- Possible causes of the fault

JAGUAR

# TRAINING PROGRAM

## *JAGUAR ENGINE MANAGEMENT SYSTEMS AND ADVANCED EMS DIAGNOSTICS - BOOK A*



**PUBLICATION CODE – 870A**

## DENSO 16-BIT EMS OVERVIEW

**AJ26 / AJ27 EMS**

The Denso 16-Bit (AJ26) engine management system was designed for the introduction of the V8 engine to the Jaguar range of vehicles starting with the 1997 model year XK8. A supercharged version was added for 1998 model year.

The AJ27 engine management system is a further development of the Denso 16-Bit system designed to meet more stringent emission control standards and enhance engine performance.

The naturally aspirated AJ27 system was introduced for the 1999 model year; the supercharged AJ27 system was introduced for the 2000 model year.

System application is as follows:

**Table 7**

| Engine Management System | Model Year | Models |
|---|---|---|
| AJ26 | 1997 | XK N/A |
| | 1998 | XK & XJ N/A |
| | 1999 | XJR (S/C) |
| AJ27 | 1999 | XK & XJ N/A |
| | 2000 | XK & XJ N/A and S/C |
| | 2001 | XK & XJ N/A and S/C |
| | 2002 | XK & XJ N/A and S/C |
| | 2003 | XJ N/A and S/C |

Both systems are built around a two-microprocessor based Engine Control Module (ECM). The ECM is linked to and communicates with other powertrain control modules and other vehicle systems via the Controller Area Network (CAN).

The ECM governs all engine operating functions including:

- Air induction via an electronically controlled throttle
- Fuel delivery
- Sequential fuel injection
- Ignition via on-plug ignition coils
- Idle speed control
- Exhaust emission control
- Evaporative emission control
- Intake valve timing
- Exhaust gas recirculation (certain variants only)
- Cooling system radiator fan control
- Air conditioning compressor control
- Cruise control
- Engine speed limiting
- Engine torque reduction to aid transmission shift quality and enhance traction / stability control
- EMS and OBD II diagnostics
- Default operating modes including engine speed and throttle limits

## CONTROL SUMMARIES

### AJ26 & AJ27 EMS

The AJ26 and AJ27 engine management systems are comprehensive engine control systems that allow complete electronic control over all engine functions.

The following pages provide control summaries for the four system variants. Specific pin-out data can be found in the applicable Electrical Guide.

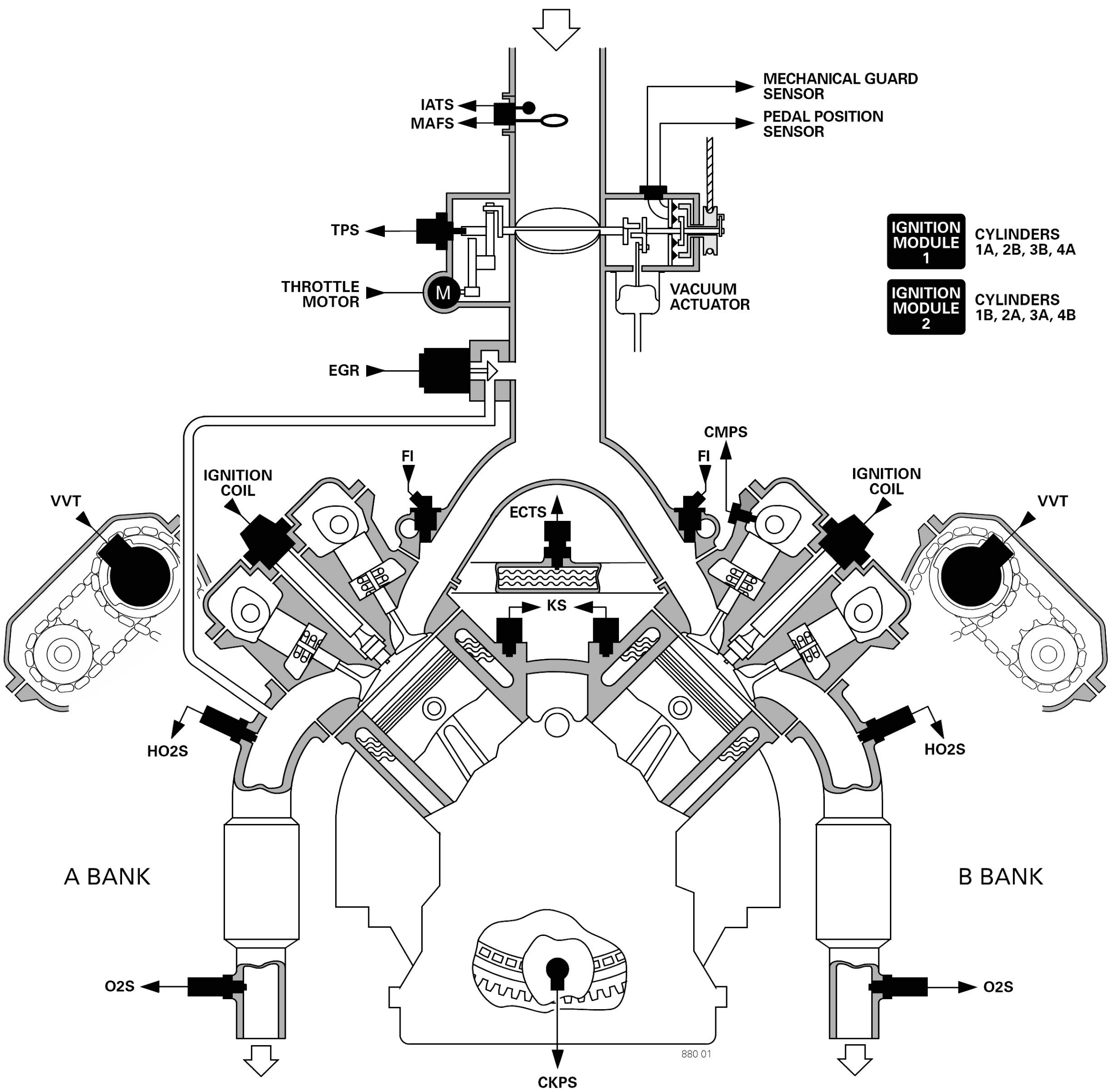


**Fig. 7 AJ26 N/A ENGINE MANAGEMENT SENSORS AND COMPONENTS**

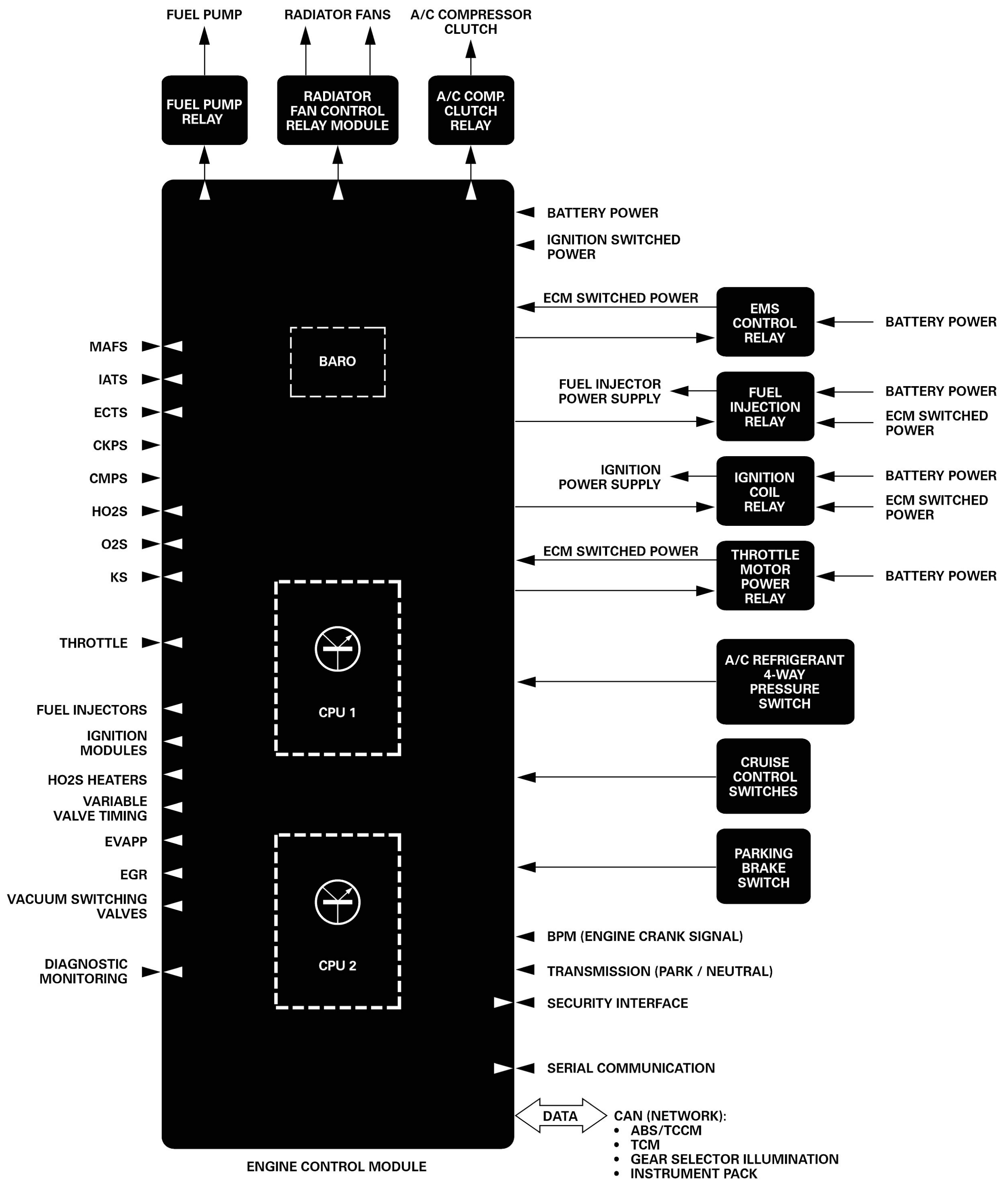


**Fig. 8 AJ26 N/A ENGINE MANAGEMENT INPUTS / OUTPUTS**

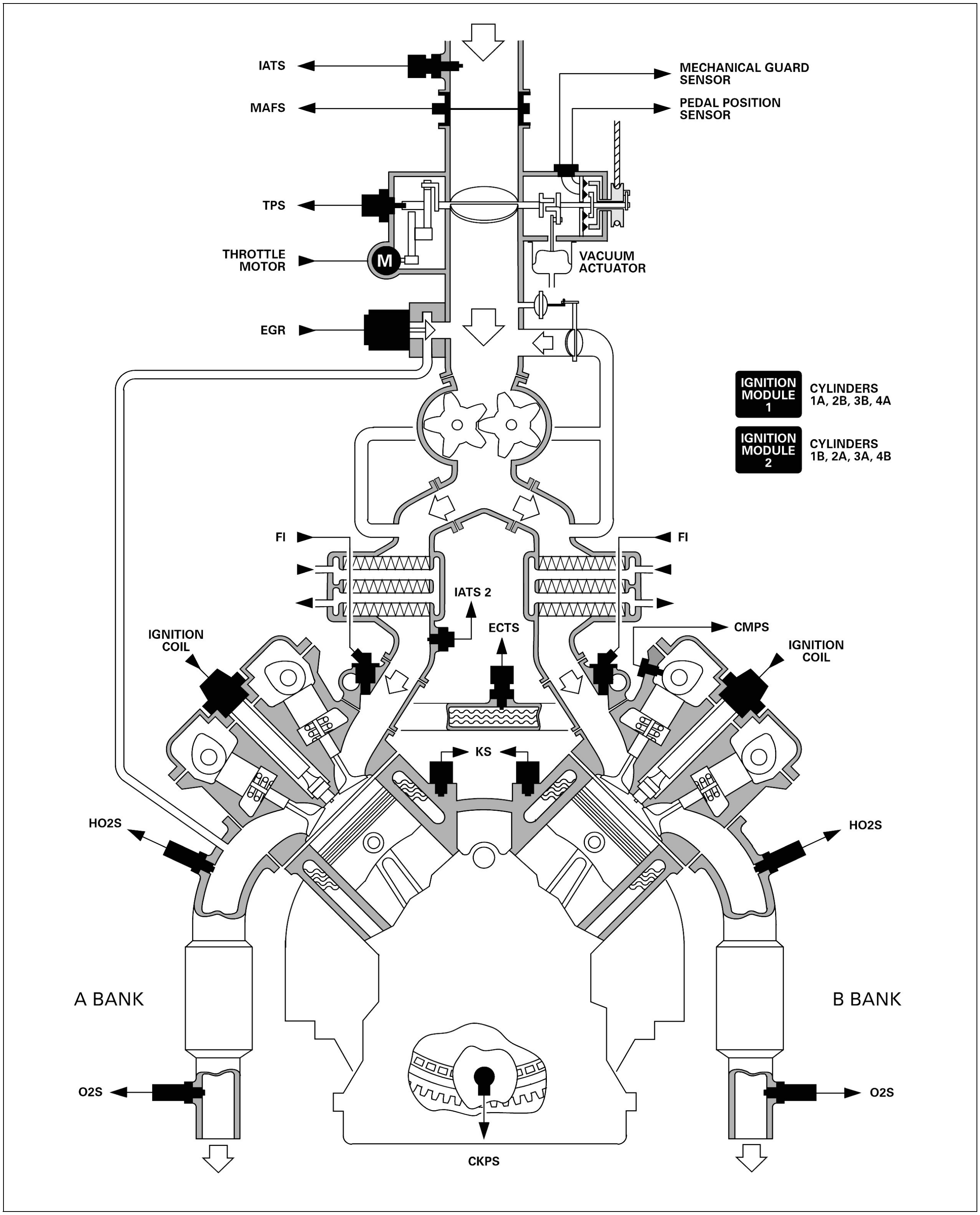


**Fig. 9 AJ26 SC ENGINE MANAGEMENT SENSORS AND COMPONENTS**

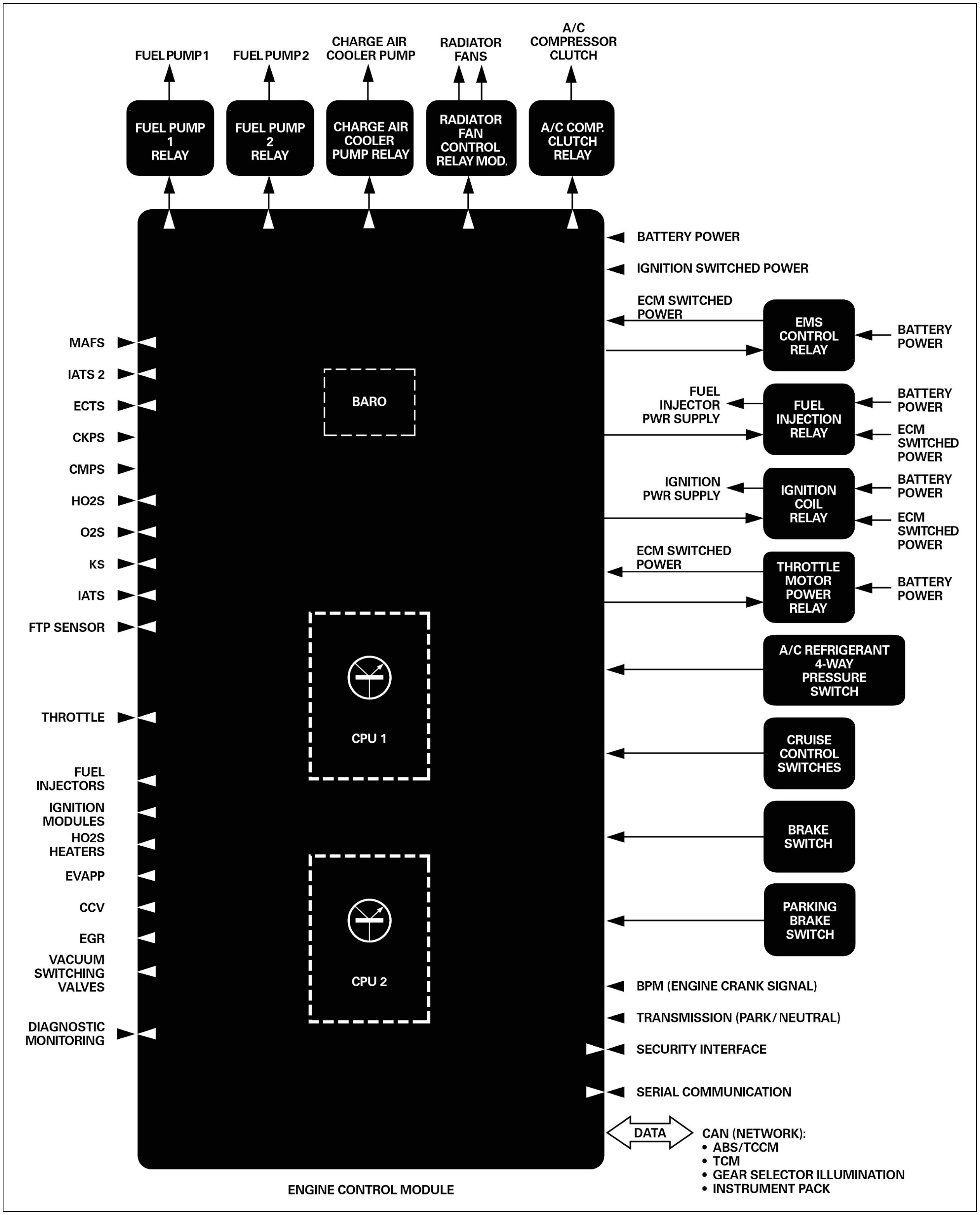


**Fig. 10 AJ26 SC ENGINE MANAGEMENT INPUTS / OUTPUTS**

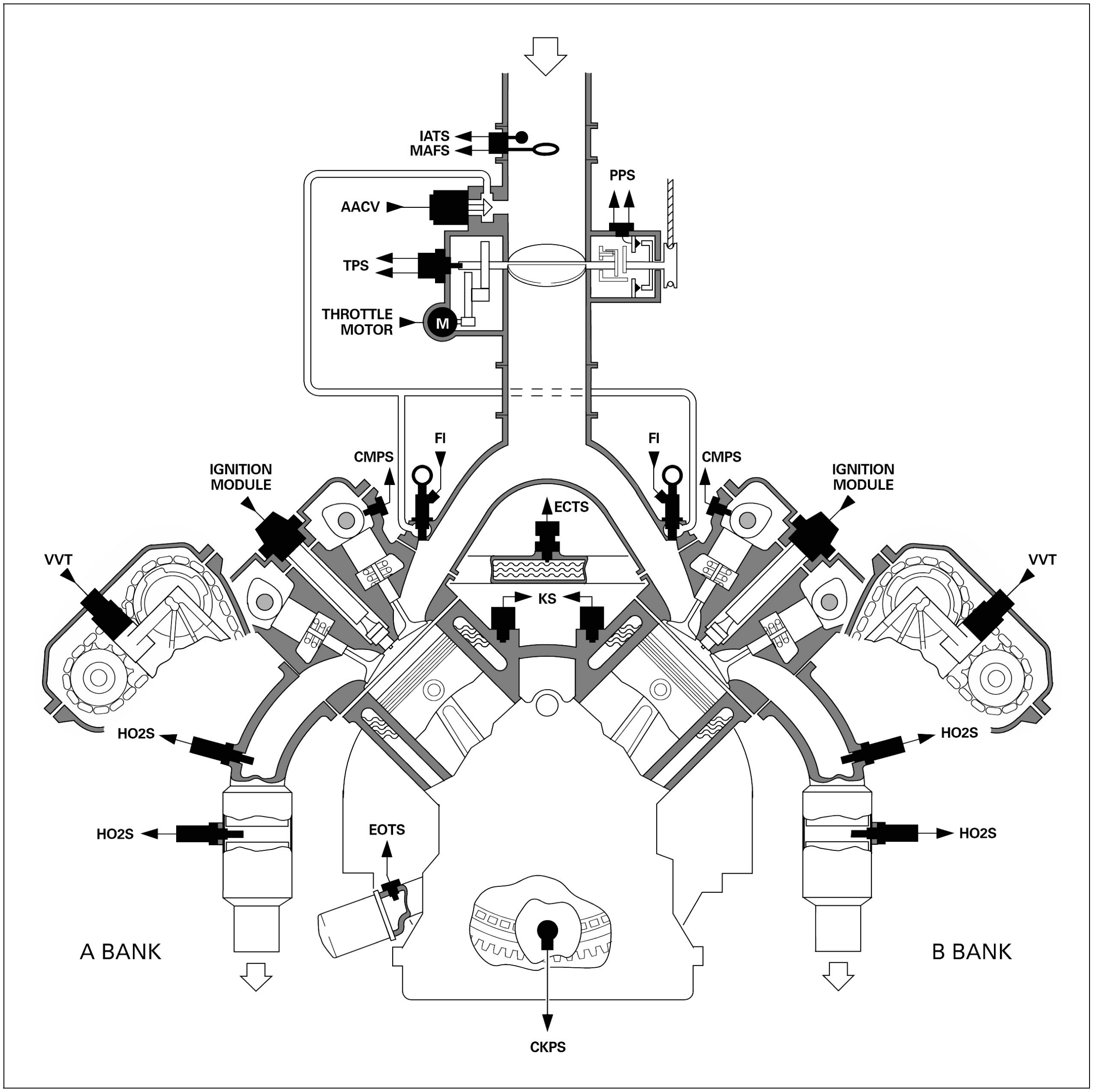


**Fig. 11 AJ27 N/A ENGINE MANAGEMENT SENSORS AND COMPONENTS**

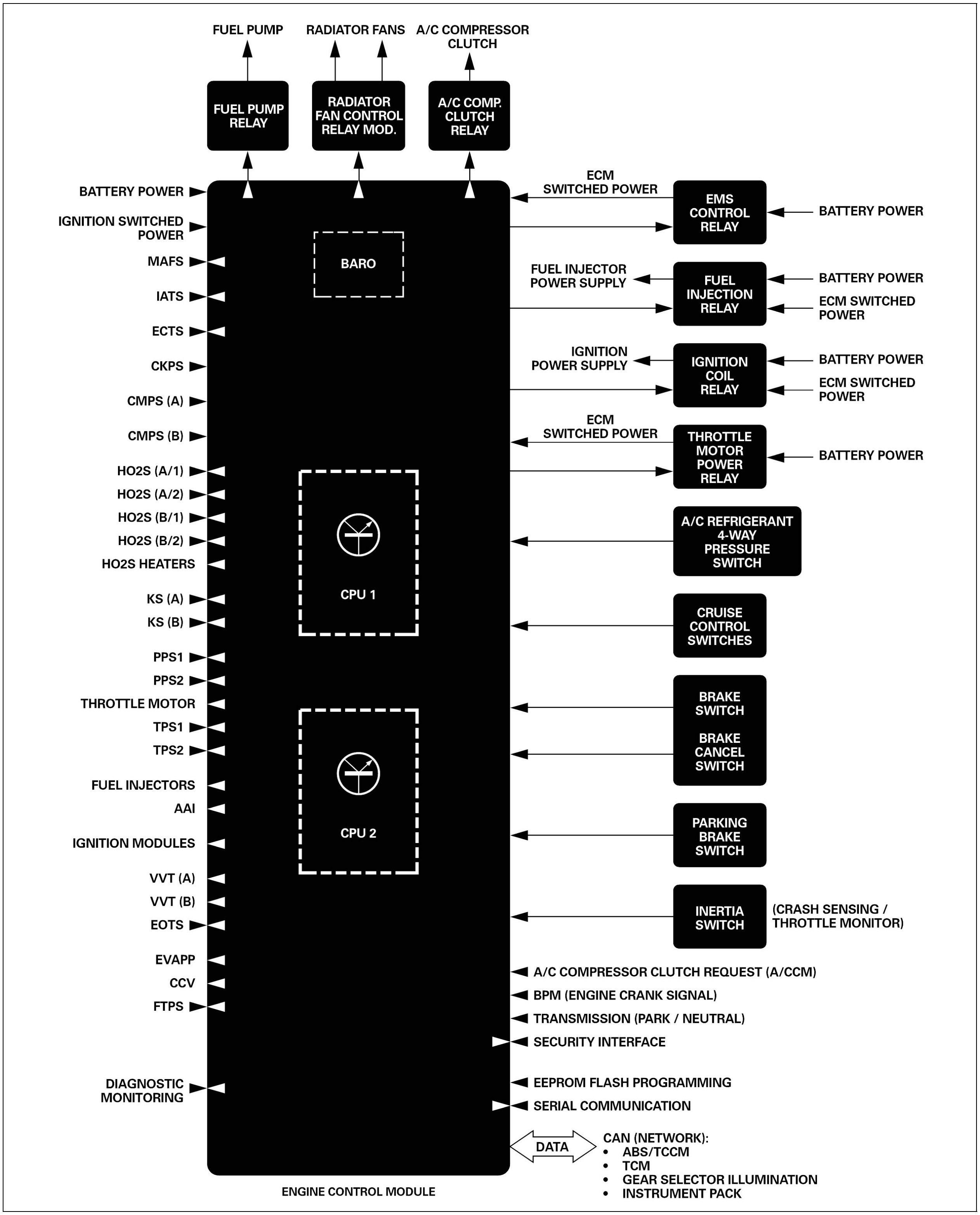


**Fig. 12 AJ27 N/A ENGINE MANAGEMENT INPUTS / OUTPUTS**

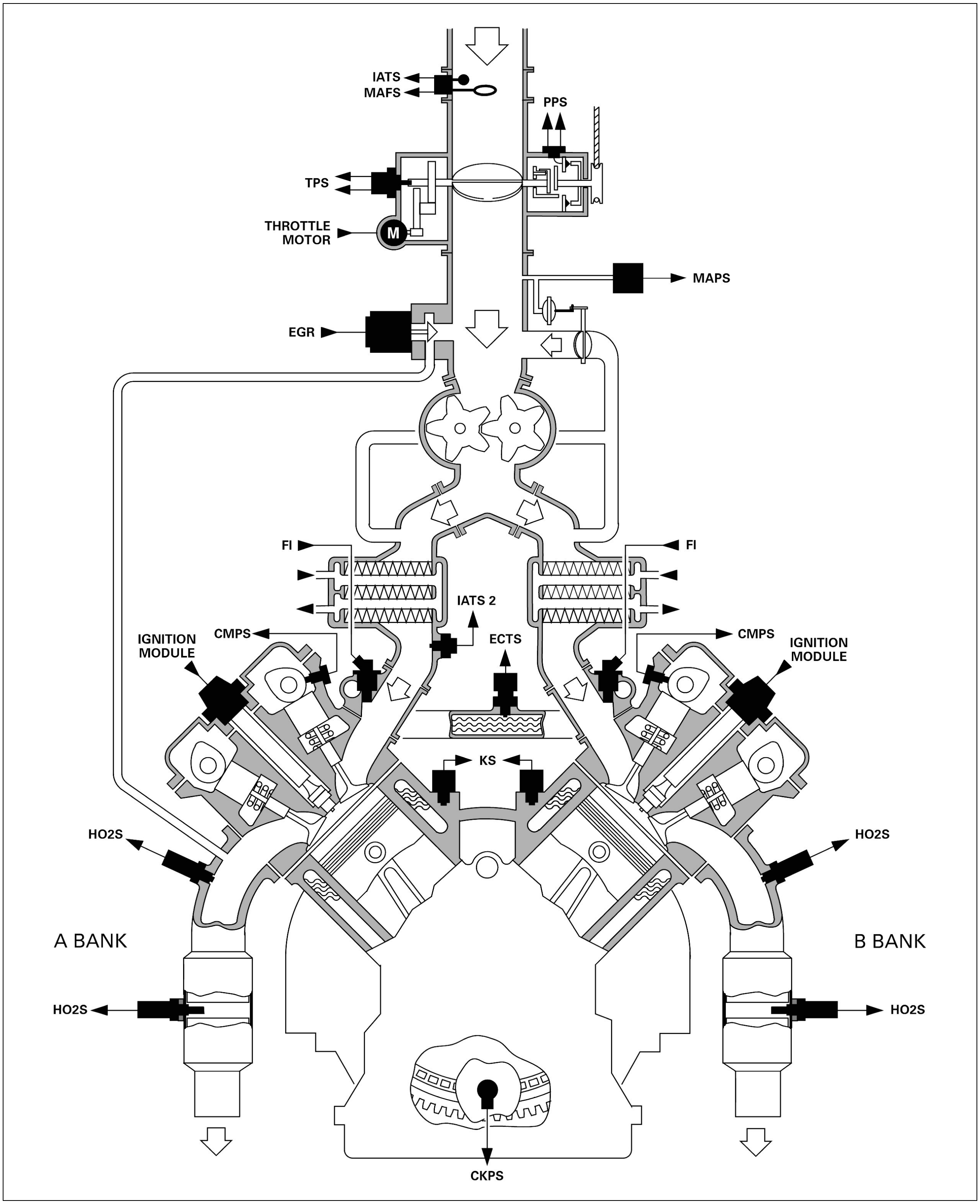


**Fig. 13 AJ27 SC ENGINE MANAGEMENT SENSORS AND COMPONENTS**

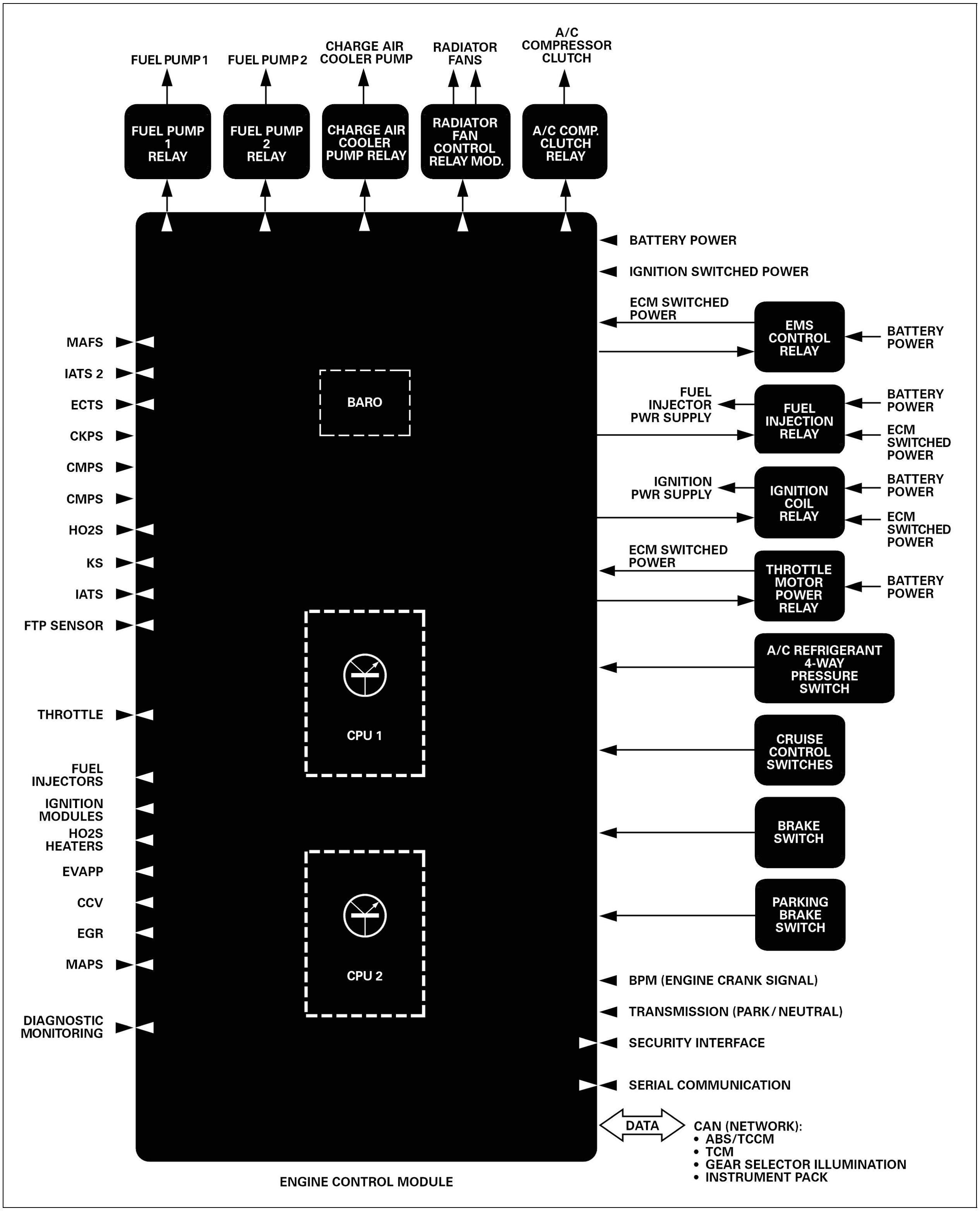


**Fig. 14 AJ27 SC ENGINE MANAGEMENT INPUTS / OUTPUTS**

# ENGINE CONTROL MODULES

### AJ26 Engine Control Module

The two-microprocessor ECM is located in the engine compartment right hand control module enclosure (cool box).

If fitted, the cooling fan is operated continuously while the ECM is active from an ECM controlled power supply.

Volatile memory — Quiescent current from the vehicle battery is used to keep the ECM random access memory (RAM) active so that OBD generated DTCs and adaptive values are maintained. If the vehicle battery is disconnected, the ECM will “relearn” adaptive values during the next driving cycle.

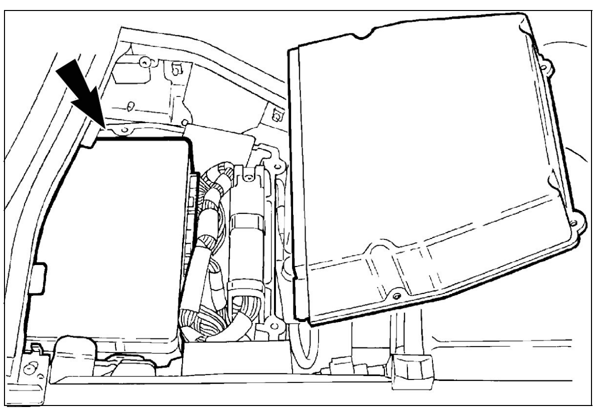

**Fig. 15 AJ26 ENGINE CONTROL MODULE**

The ECM has several adaptive learning functions, including:

- Closed loop fuel metering
- Closed loop throttle control
- Idle speed
- Long term fuel metering feedback correction

Nonvolatile memory — A nonvolatile memory stores the vehicle identification number (VIN).

### Barometric Pressure Sensing

A barometric pressure sensor (BARO) is incorporated into the ECM. The BARO input is used for fuel metering barometric pressure correction. In addition, certain diagnostic monitoring is inhibited at high elevation. The BARO cannot be replaced separately.

### ECM Default Action(s)

Most detected faults are accompanied by an ECM default action. In instances where the driver will notice a difference in vehicle performance and/or the vehicle requires fault correction, visual indication is displayed on the instrument pack.

The indicators include: the general warnings – RED and AMBER MILs, the CHECK ENGINE MIL, and the message display. Specific ECM default action(s) are included with each DTC listed in the applicable DTC Summaries book.

### ECM Cooling

On XK, XKR and XJR, a fan is used to cool the ECM and the TCM. To prevent ECM overheating and subsequent degrading of performance, this fan, located in the control module enclosure, operates at all times when the ignition is switched ON and circulates air from the passenger compartment through the “cool box”.

## ECM Electrical Connection

The ECM connects to the engine management harness via six multi-pin connectors. The applicable Electrical Guide shows the connector pin / wire color codes for the particular variant.

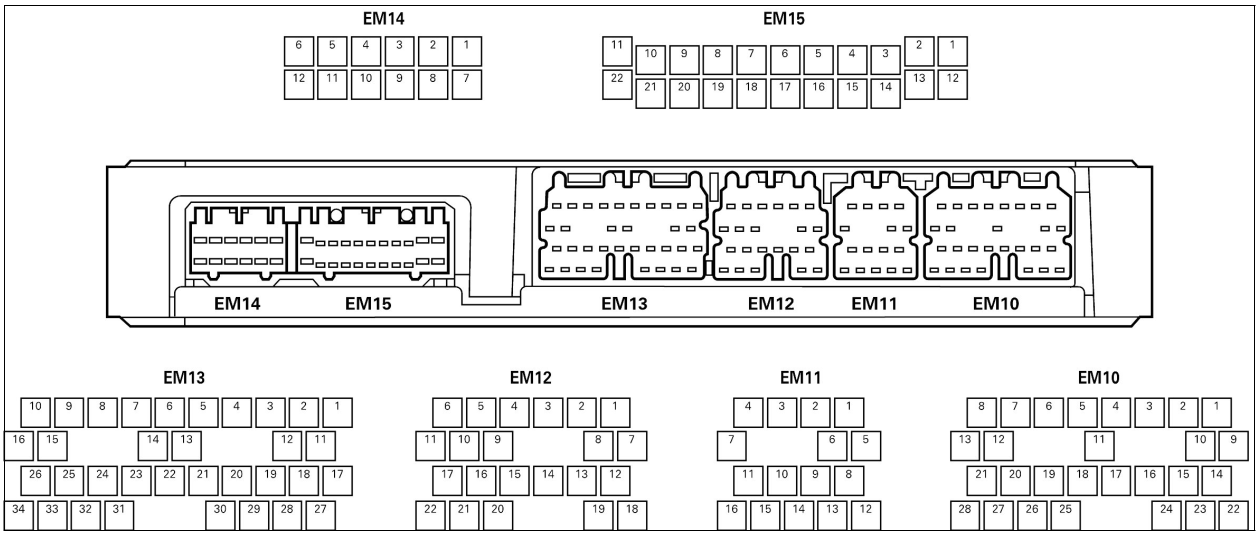


**Fig. 16 AJ26 ECM CONNECTOR SOCKETS**

**EMS Power Supplies**

Engine management and transmission control module power supplies flow through the engine management fuse box located in the engine compartment.

The engine management power bus is controlled by the ECM via the EMS control relay located in the fuse box. When the ignition is switched to position II, the ECM completes the relay coil circuit to ground to power the bus.

When the ignition is switched OFF, the ECM will continue to activate the EMS control relay for a period of four seconds minimum to five minutes maximum. The power supplied during this period allows the ECM to complete diagnostics, perform closed throttle adaptations, close the EGR valve (if fitted), and operate the radiator fans.

Refer to the applicable appropriate Electrical Guide for relay and fuse box locations

**ECM "Limiting" Control**

The ECM performs "limiting" functions to achieve refinement, aid in vehicle control, and to protect certain components from damage. The table summarizes how the ECM implements "limiting" control.

**Table 8 AJ26 ECM LIMITING CONTROL**

| Function | ECM Intervention | | | ECM Control |
|---|---|---|---|---|
| | Throttle | Fuel Injection | Ignition | |
| Engine overspeed protection | | X | X | Engine speed limited to 7100 rpm. |
| Engine default speed | | X | | Engine speed limited to 3000 rpm. |
| Engine power limiting | X | | | Throttle valve opening limited to 18 deg. maximum – when TCM detects a transmission fault or when reverse gear is selected. |
| Vehicle speed limiting | X | | | Vehicle speed limited to 155 m.p.h. (248 km/h). |
| Traction / Stability control | X | X | X | Engine torque momentarily reduced for traction / stability control. |
| Shift energy management | | | X | Engine torque momentarily reduced to enhance transmission shift quality. |

**Engine overspeed protection**

The ECM limits engine speed for overspeed protection by canceling fuel injection at 7100 rpm. Fuel injection is reinstated at 7050 rpm. Ignition retard is used to "smooth" the transition between fuel injection on / off / on.

**Engine default speed**

When the ECM detects an EMS fault that warrants a reduction in the available engine speed range, it limits the maximum engine speed to 3000 rpm. Engine default speed is limited by fuel injection intervention.

**Engine power limiting**

Engine power is limited in two instances – transmission faults and reverse gear selection. If the TCM detects a fault that requires engine torque reduction, it communicates with the ECM by the CAN message CAN TRANSMISSION OVERLOAD. In response, the ECM limits engine power by limiting the throttle valve opening to 18° maximum in all forward gears. Normal throttle operation is reinstated when the CAN message is no longer communicated by the TCM.

As REVERSE gear is selected, the TCM also communicates the CAN message CAN TRANSMISSION OVERLOAD and the ECM limits engine power by limiting the throttle valve opening to 18° maximum. Normal throttle operation is reinstated when the transmission is shifted out of REVERSE and the CAN message is no longer communicated by the TCM.

**Vehicle speed limiting**

The maximum vehicle speed is limited to 155 m.p.h. (248 km/h) by throttle intervention. The ECM receives vehicle speed data from the CAN message CAN VEHICLE SPEED, transmitted by the ABS/TCCM.

**Traction / Stability control**

The ABS/TCCM determines when engine torque reduction is necessary for traction control and/or stability control. In addition, the ABS/TCCM determines what type of engine intervention should be applied, and the amount of torque reduction required. This determination is made based on the CAN data provided by the ECM CAN message CAN TRACTION CONTROL ESTIMATED ENGINE TORQUE. Three distinct ABS/TC CAN messages can be communicated by the ABS/TCCM:

- CAN TORQUE REDUCTION THROTTLE
- CAN FAST STABILITY CONTROL RESPONSE – CYLINDER FUEL CUTOFF
- CAN FAST STABILITY CONTROL RESPONSE – IGNITION RETARD.

In response, the ECM reduces engine torque by applying intervention to throttle, fuel injection, and/or ignition. Fuel injection and ignition intervention are used to provide an instantaneous response and to smooth the transition to throttle intervention. The ECM acknowledges that torque reduction is taking place by confirming with the CAN message CAN TRACTION ACKNOWLEDGE.

**Shift energy management**

Transmission shift quality is enhanced by “shift energy management”. The ECM provides engine torque data by the CAN message CAN SHIFT ENERGY MANAGEMENT ESTIMATED ENGINE TORQUE. The TCM determines the amount of torque reduction required. As gear shifts occur, the TCM communicates the CAN message CAN TORQUE REDUCTION REQUEST. The ECM responds by retarding the ignition to momentarily reduce torque.

**AJ27 Engine Control Module**

The AJ27 ECM incorporates two microprocessors (CPU) with increased processing power and memory capacity over the AJ26 module, and has expanded hardware to accommodate the increase in the number of system sensors and components.

Non-volatile memory — OBD generated DTCs and adaptive values are stored and maintained in non-volatile memory. All stored DTCs and the adaptive values will be maintained if the vehicle battery is disconnected.

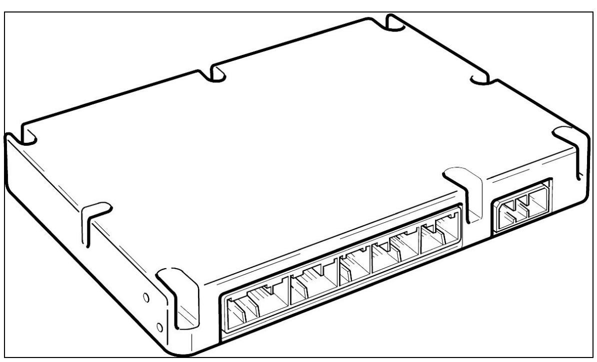

**Fig. 17 AJ27 ENGINE CONTROL MODULE**

The ECM has new and revised functions as compared to AJ26. These include:

- Revised failure management modes.
- Revised traction and stability control
- Revised air conditioning interface
- Revised transmission interface
- “Black box, flight recorder” / Inertia switch monitor
- “Cool box” fan control
- Revised throttle control and cruise control operation.

**AJ27 Revised Failure Management Modes**

The ECM controls four failure management modes: cruise control inhibit, limp-home mode, engine shutdown mode, and power limiting mode. As with AJ26, driver warnings (CHECK ENGINE MIL, Red MIL, Amber MIL, Message) and DTCs accompany the initiation of these modes. Cruise control inhibit and engine shutdown mode remain unchanged. Specific revised ECM default actions are included with each DTC in the applicable section(s) of the DTC Summaries book.

**Limp-home mode**

In limp-home mode the full authority throttle is deactivated by the ECM. The throttle is then operated directly by the cable from the accelerator pedal. When the throttle limp-home lever is against the closed stop, the ECM maintains an idle speed of less than 1500 rpm (no load, Neutral / Park) by fuel injection intervention. Cruise control is inhibited.

**Power limiting mode**

When intake air flow cannot be controlled by the throttle (mechanical jam, large air leak), the ECM deactivates the throttle as in limp-home. Engine power is controlled by the ECM via fuel cutoff to some of the fuel injectors, disabling those cylinders. The amount of cylinder disablement is determined by the ECM from driver demand (PPS) and engine speed (CKP).

**AJ27 Air Conditioning Interface**

The radiator fan control strategy is based on the air conditioning four-way pressure switch inputs. This control strategy is applied only while the engine is running.

**AJ27 Transmission Interface**

Engine power limiting due to transmission control module (TCM) input occurs only when one or more of the following conditions occur:

- the transmission is in Reverse
- the transmission overload message is present (CAN)
- a gear selector fault occurs
- the TCM is not present on the CAN network

**“Cool box” Fan Control**

On vehicles equipped with a “cool box” fan, the ECM operates the fan when the engine is running. Additionally, the fan is operated after engine shutdown as required based on operating and “heat soak” conditions.

**ECM Electrical Connection**

The ECM connects to the engine management harness via six multi-pin connectors. The applicable Electrical Guide shows the connector pin / wire color codes for the particular variant.

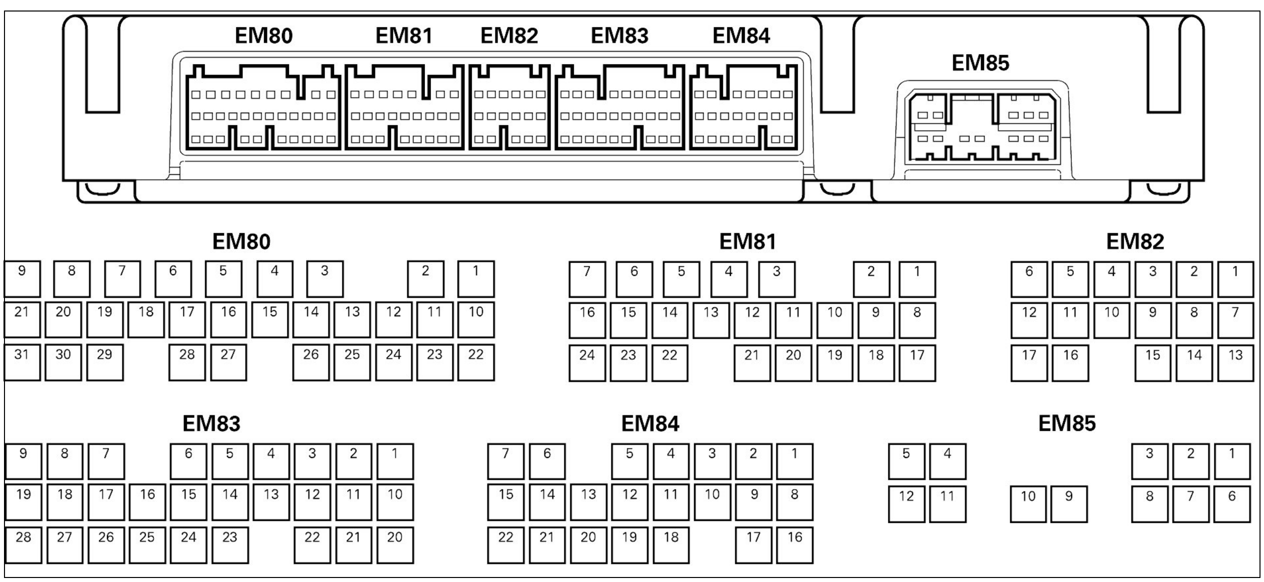


**Fig. 18 AJ27 ECM CONNECTOR SOCKETS**

### AJ26 and AJ27 ECM Service "Flash Programming"

The ECM EEPROM can be flash programmed in service using WDS via the data link connector (DLC). If such a service action is required, instructions are included in a Service Bulletin.

**NOTES**

- ECMs must not be switched from one vehicle to another because the VIN will be mismatched.
- If an ECM has been replaced in service, the VIN will display as 999999.
- If a replacement ECM has not been factory programmed, a "PECUS" message will be displayed on the driver message center.
- The following originally equipped ECMs cannot be flash programmed in service:
  - 1998 MY XK8 VIN 020733 – 031302
  - 1998 MY XJ8 VIN 819772 – 853935
  - These vehicles require a new pre-programmed replacement ECM. Refer to Technical Service Bulletins.
- Always check the VIN before carrying out ECM flash programming.

## EMS PRIMARY SENSING COMPONENTS

### Generic Sensing Circuit

All inputs to the PCM are sensed by measuring the return signal based on a 5 volt output from the PCM. The PCM then converts the 0 to 5 volt return signal to a 10 bit digital value in 0.488 millivolt (mV) increments.

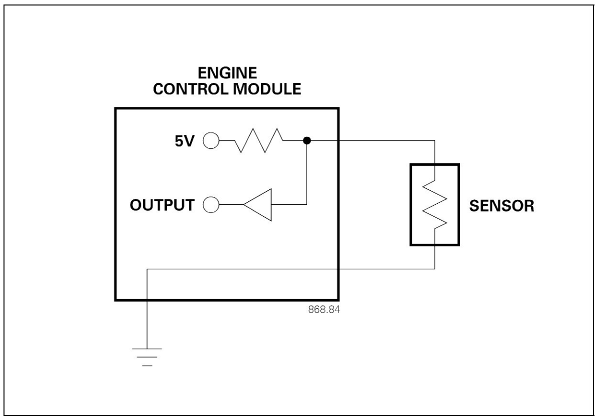


**Fig. 19 GENERIC SENSING CIRCUIT**

### Mass Air Flow sensor (MAF) – AJ26

The MAF, located between the air cleaner and the air intake duct, provides the ECM with an engine load input signal.

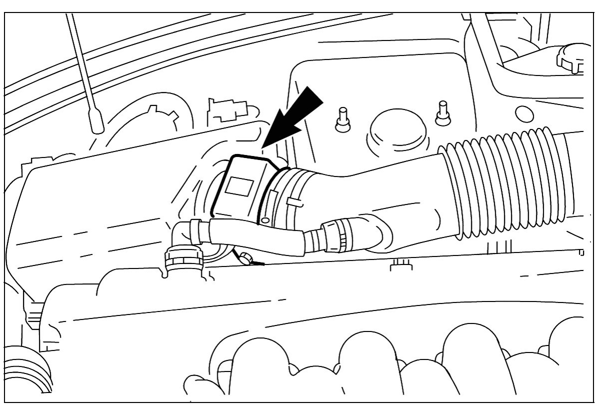

**Fig. 20 MAF – AJ26**

**Intake Air Temperature sensor (IAT) – AJ26**

The IAT, located within the MAF housing, provides the ECM with an intake air temperature signal.

The IAT is not serviceable separately from the MAF.

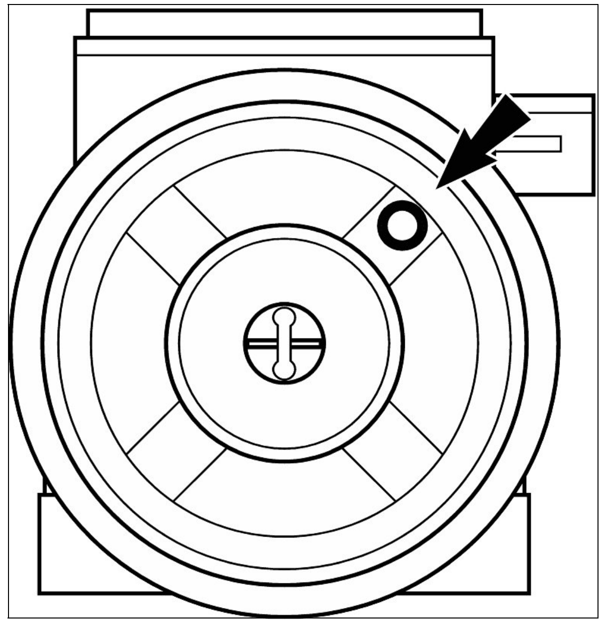

**Fig. 21 IAT (IN MAF HOUSING) – AJ26**

**Table 9 IAT Temperature / Resistance**

| Intake air temperature | | Resistance |
|---|---|---|
| C | F | (kΩ) |
| –20 | –4 | 15 |
| 0 | 32 | 5.74 |
| 20 | 68 | 2.75 |
| 40 | 104 | 1.15 |
| 60 | 140 | 0.584 |
| 80 | 176 | 0.32 |
| 100 | 212 | 0.184 |

### Mass Air Flow and Intake Air Temperature Sensors (MAF and IAT) – AJ27

The AJ27 MAF and IAT are combined in an integral, plug-in unit, secured by two screws to the duct. Sensor characteristics remain the same.

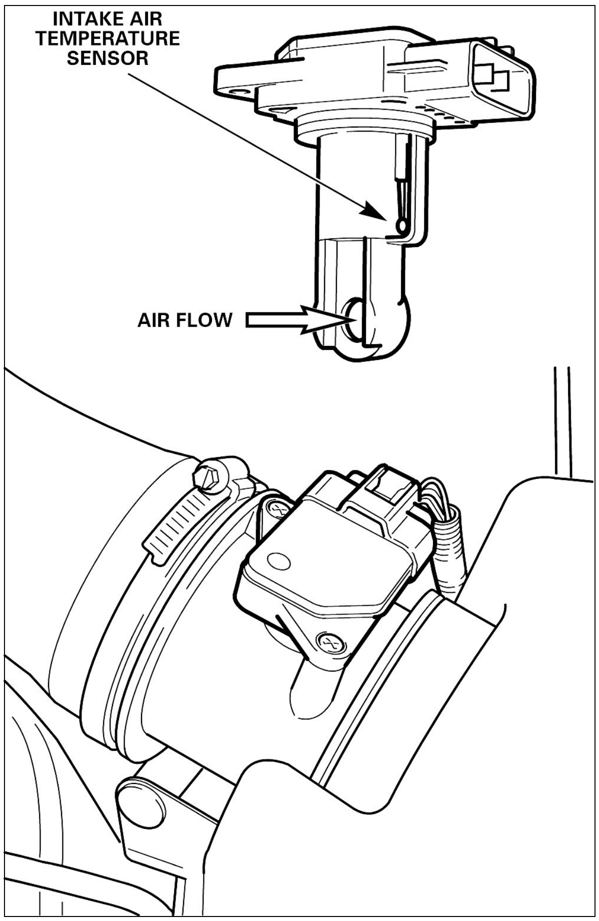


**Fig. 22 MAF AND IAT – AJ27**

### Engine Coolant Temperature Sensor (ECT) – AJ26/27

The ECT is located on the coolant outlet elbow between the A and B bank cylinder heads.

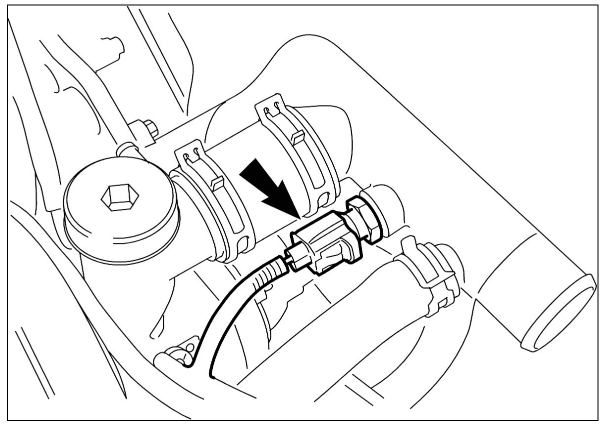

**Fig. 23 ECT LOCATION**

**Table 10 ECT Temperature / Resistance AJ26/27**

| Coolant temperature | | Resistance |
|---|---|---|
| C | F | (kΩ) |
| –20 | –14 | 9.20 |
| 0 | 32 | 5.90 |
| 20 | 68 | 2.50 |
| 40 | 104 | 1.18 |
| 60 | 140 | 0.60 |
| 80 | 176 | 0.325 |
| 100 | 212 | 0.19 |

**Table 11 ECT Temperature / Voltage AJ26/27**

| Coolant temperature | | Voltage |
|---|---|---|
| C | F | (Volts) |
| –20 | –14 | 4.05 |
| 0 | 32 | 3.64 |
| 20 | 68 | 2.42 |
| 40 | 104 | 1.78 |
| 60 | 140 | 1.17 |
| 80 | 176 | 0.78 |
| 100 | 212 | 0.55 |

**Crankshaft Position sensor (CKP) – AJ26**

The CKP, located at the rear of the engine structural sump, provides the ECM with pulsed signals for crankshaft position and engine speed. The timing disc for the sensor is spot-welded to the front face of the transmission drive plate.

The timing disc has 34 spokes spaced at 10° intervals, with two spokes deleted. The sensor is a variable reluctance device that provides a pulse to the ECM at 10° intervals.

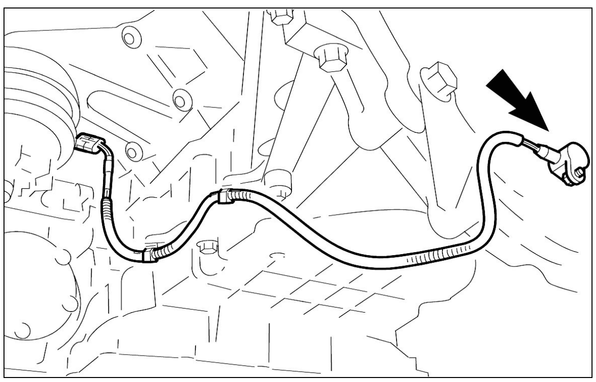

**Fig. 24 CKP – AJ26**

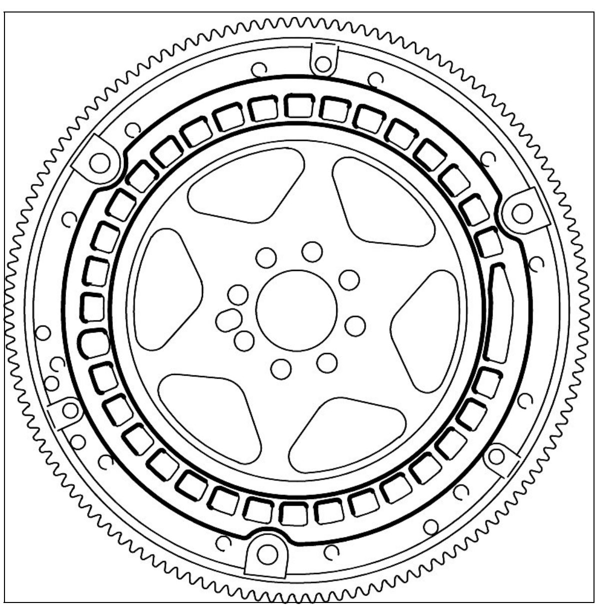

**Fig. 25 CKP RELUCTOR – AJ26**

**Crankshaft Position sensor (CKP) – AJ27**

The AJ27 CKP has a revised 35-tooth reluctor. The electrical connection to the CKP is direct.

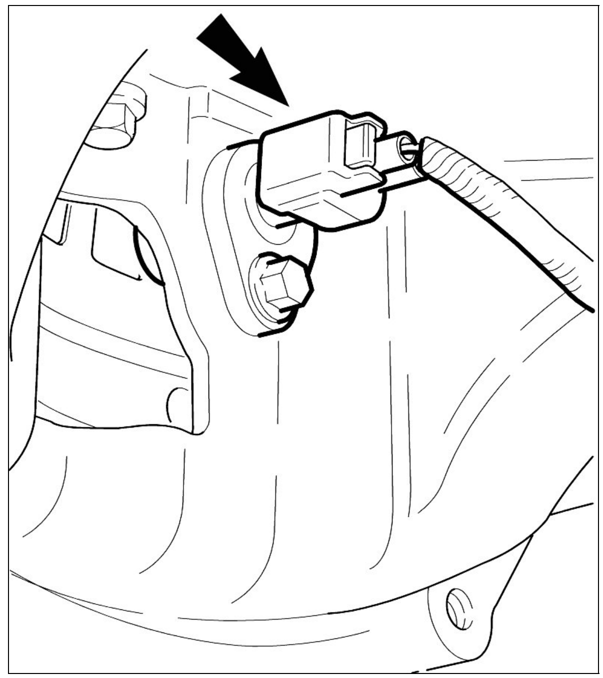

**Fig. 26 CKP – AJ27**

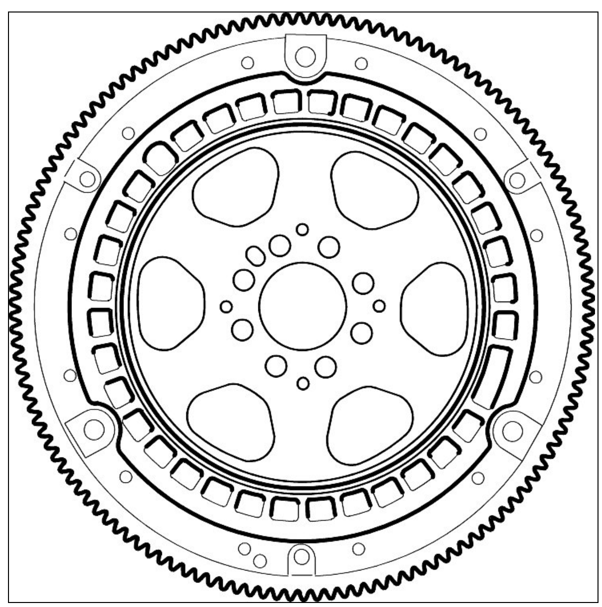

**Fig. 27 CKP RELUCTOR – AJ27**

**Camshaft Position sensor (CMP) – AJ26**

The variable reluctance CMP, located on the rear of the B bank cylinder head, provides the ECM with a pulsed signal for cylinder 1A compression stroke identification (one pulse per two crankshaft revolutions).

In addition, the CMP signal is used for variable valve timing (VVT) diagnostic monitoring.

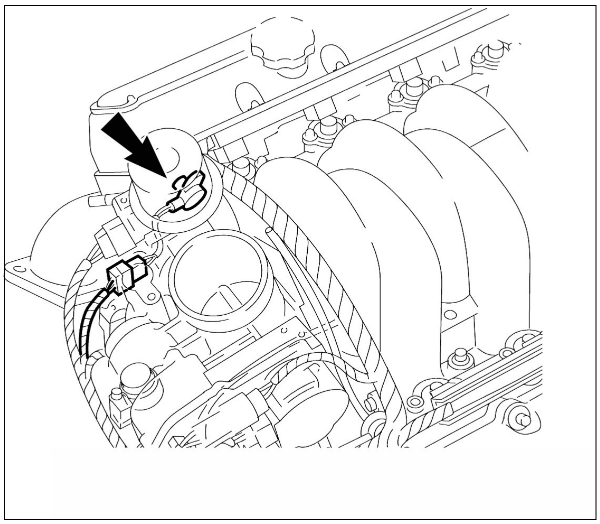

**Fig. 28 CMP LOCATION – AJ26**

**Camshaft Position sensor (CMP) – AJ27**

Both engine banks incorporate camshaft position sensors that sense the position of the intake camshafts.

The CMP sensors are inductive pulse generators. The sensors have four-toothed reluctors mounted on the rear of both intake camshafts. The four-tooth reluctors provide faster camshaft position identification, improving engine start-up speed.

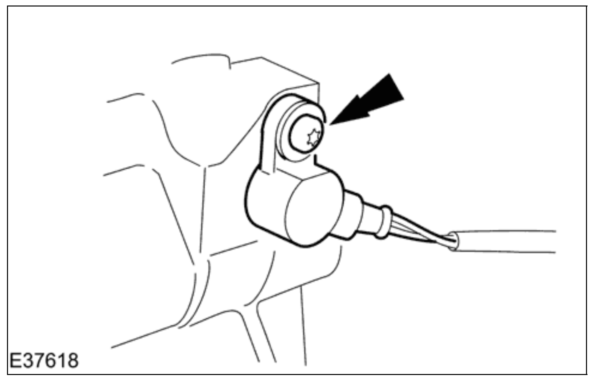


**Fig. 29 CMP– AJ27**

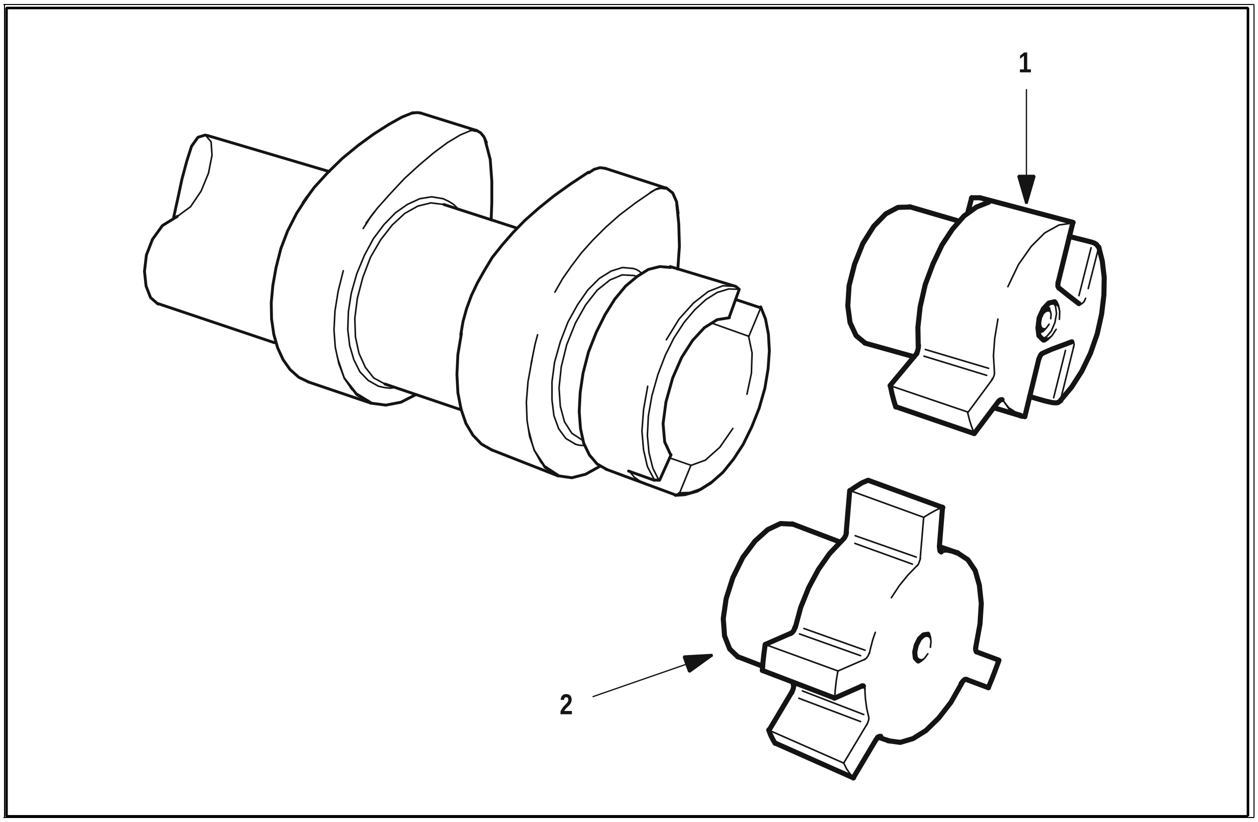


**Fig. 30 CMP Timing Rings**

1. AJ26
2. AJ27

**Engine Cycle Synchronization: CKP and CMP**

The engine cycle sensor pulse traces illustrate the relationship between the CKP and the CMP.

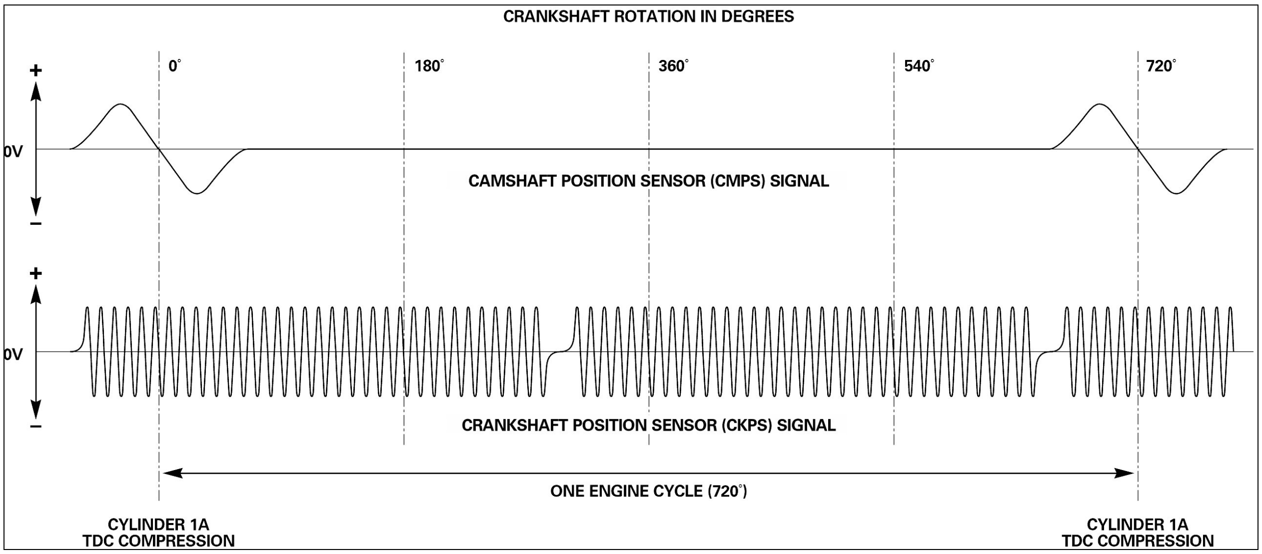


**Fig. 31 CKP / CMP 720° CRANKSHAFT ENGINE CYCLE – AJ26**

**Engine Start: CKP / CMP – AJ27**

Faster engine firing on start-up is assisted by the four-toothed sensor rings on each camshaft. Each sensor ring provides 4 pulses per engine cycle (720 deg.) to the ECM, compared with 1 pulse from the AJ26 single-tooth sensor ring fitted to B bank.

The sensor teeth are asymmetrically positioned and produce a corresponding pulse pattern over the engine cycle, which is compared with the crank sensor output (one missing pulse per revolution). This feature enables the ECM to more quickly identify where the engine is positioned in the firing order and thus trigger ignition and fueling to fire the correct cylinder.

In normal operation, the ECM uses the inputs from the crank sensor and the A bank cam sensor for cylinder identification and ignition/fuel synchronization. If the A bank sensor system fails, the ECM switches to the B bank inputs.

If the crank sensor system fails, the engine will start and run using the inputs from both cam position sensors.

## INDUCTION AIR THROTTLE CONTROL – AJ26

### ECM Throttle Control

The electronic throttle allows the ECM to perform the following functions:

- Intake air flow control
- Idle speed control
- Cruise control
- Engine torque reduction requirements for traction / stability control
- Engine power limiting
- Vehicle speed limiting
- Throttle diagnostics
- Adopt default modes of operation

### Electronic Throttle Assembly

Engine induction air is metered by the electronic throttle assembly in response to driver input and control by the ECM. ECM throttle control allows several previously independent subsystems such as engine power limiting and idle control to be incorporated as EMS functions.

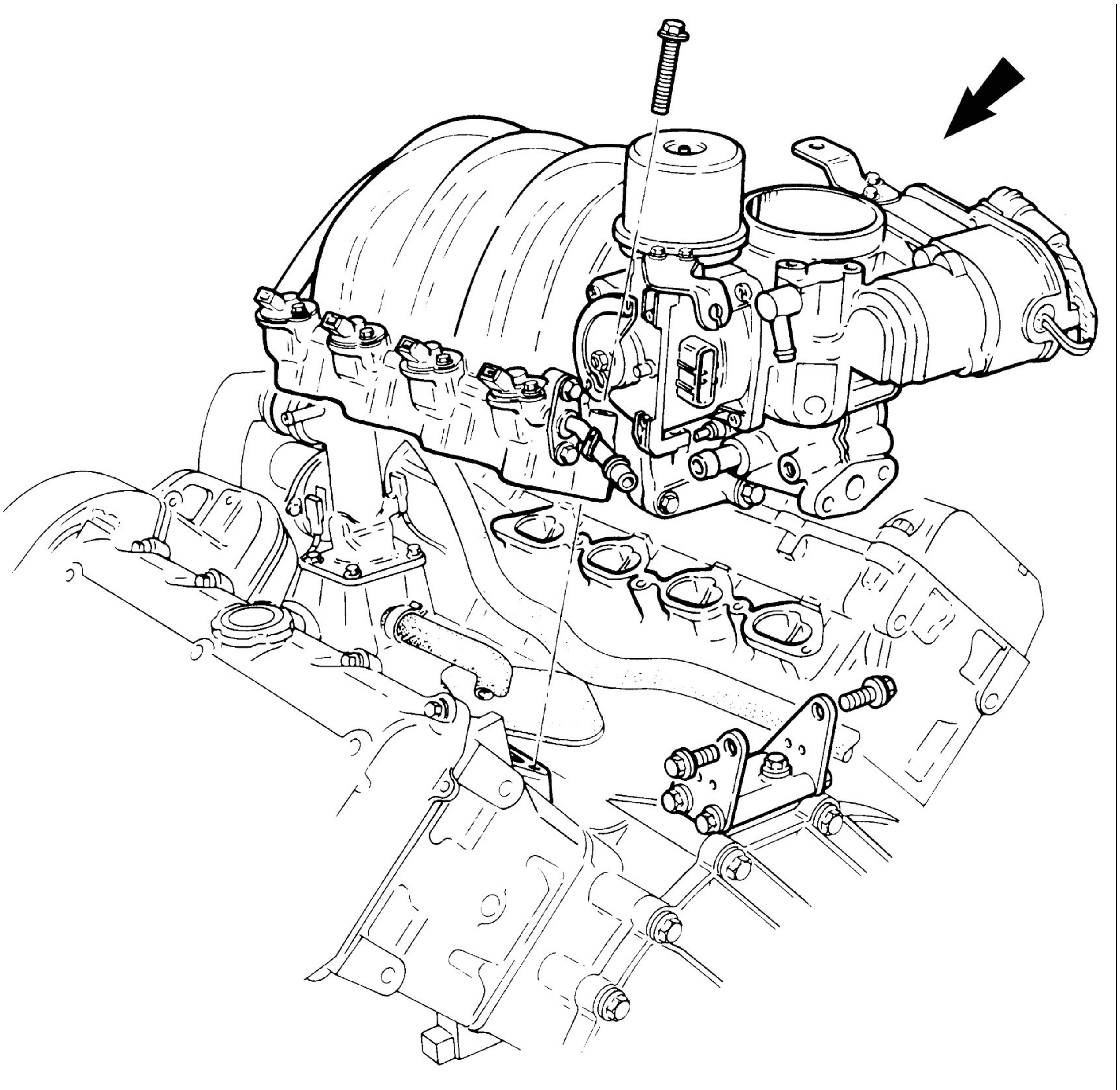

**Fig. 32 THROTTLE ASSEMBLY – AJ26 N/A**

**Throttle Assembly Components Identification**

The main components of the AJ26 throttle assembly include:

- Input shaft — Receives driver inputs from the accelerator pedal via a conventional throttle cable.
- Pedal position sensor — A twin-track sensor (potentiometers) provides redundant pedal position signals to the ECM.
- Mechanical guard — A device that prevents the throttle valve from opening beyond driver demand. The mechanical guard allows the throttle to be operated mechanically in the case of electronic control failure.
- Mechanical guard sensor — A single-track sensor provides a mechanical guard position signal to the ECM.
- Vacuum actuator — Active (vacuum applied to diaphragm chamber) when cruise control is activated. Operates the mechanical guard independently of the input shaft in cruise control mode.
- Throttle valve — Conventional shaft/plate arrangement. Sprung toward open position. Mechanical guard lever holds throttle plate in closed position.
- Thermostatic air valve — Controls throttle valve bypass port during engine warm-up. Fully closes during engine warm-up period.
- Throttle motor — Driven by the ECM to operate the throttle valve only in the close direction.
- Throttle Position sensor (TP) — Twin "hall-effect" sensor provides redundant throttle position signals to the ECM.
- Springs — Springs connected to the input shaft and mechanical guard provide force against the driver input and provide the "feel" of an accelerator. Springs connected to the throttle motor drive gear and the throttle valve provide force against the throttle closing.

The arrangement of the sensors on both "sides" of the throttle valve allows the ECM to have closed loop throttle control.

**Thermostatic air valve operation**

- Before engine start-up, the throttle valve is in the default closed position (sprung against mechanical guard lever with throttle plate slightly open).
- At low engine temperature, the idle air opening at the throttle plate is insufficient to provide enough air flow for the engine to start.
- The thermostatic air valve is a wax capsule-operated valve that provides throttle bypass air for starting and fast idle.
- The bypass valve is fully open at approximately -30 °C (-22 °F) and progressively closes until it is fully closed at 40 °C (104 °F).
- Engine coolant flow through the throttle body provides the temperature source to operate the valve.

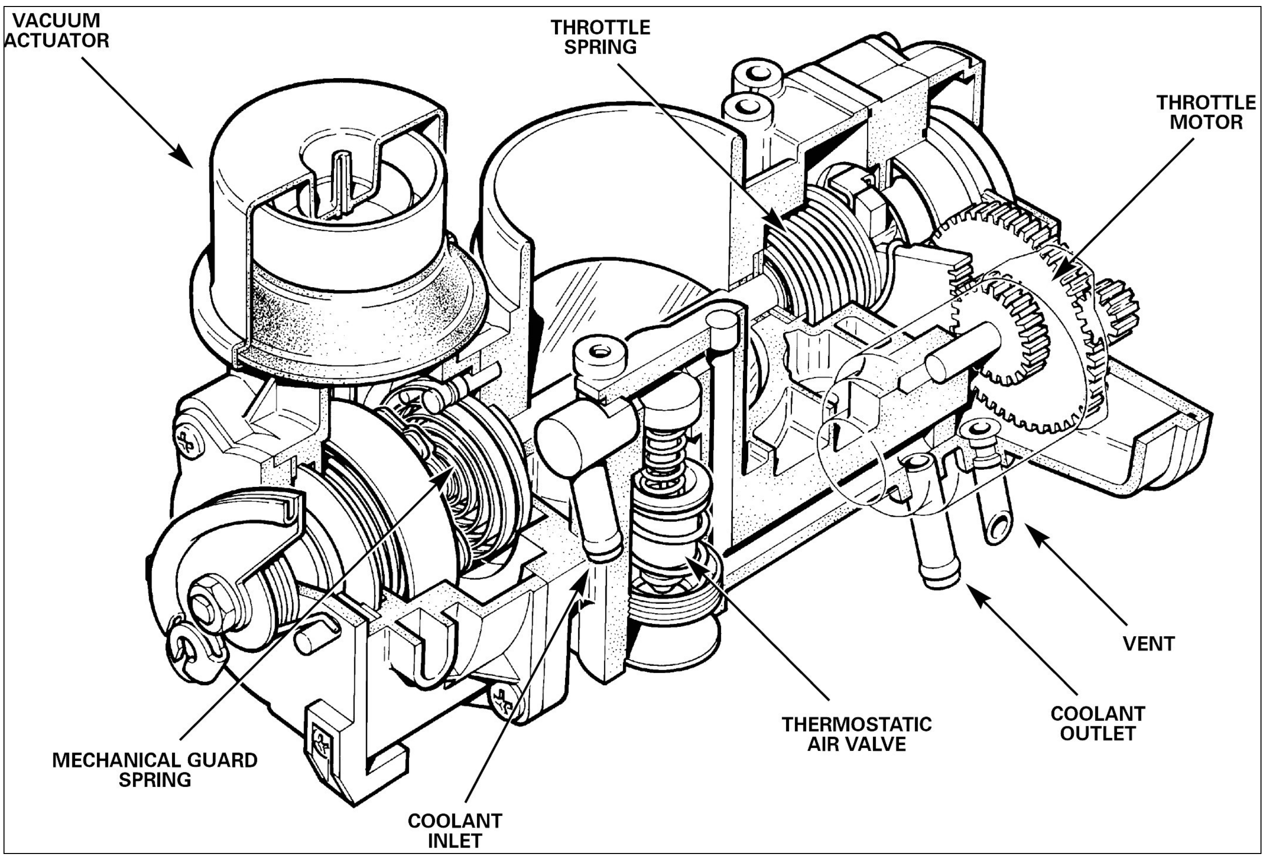


**Fig. 33 ELECTRONIC THROTTLE – AJ26**

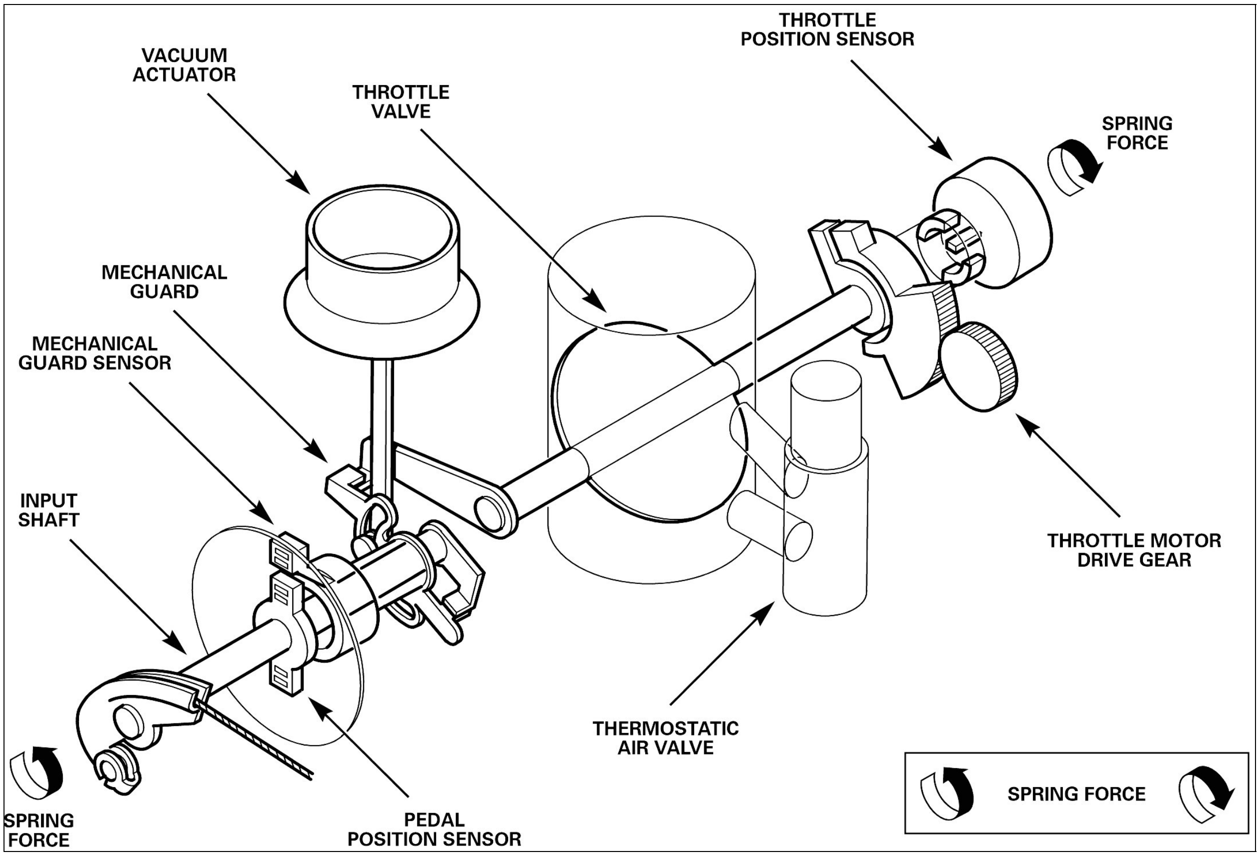


**Fig. 34 SIMPLIFIED VIEW OF ELECTRONIC THROTTLE – AJ26**

### Throttle Sensors

The throttle assembly incorporates three sensors:

- A twin "hall-effect" throttle position sensor (TP)
- A twin-track pedal position sensor (PPS)
- A single-track mechanical guard sensor

The input signals from the three sensors allow the ECM to control the throttle (closed loop), perform diagnostics, perform adaptation, and adopt throttle default modes. The three sensors share common power supply reference voltage, and reference ground circuits. The reference ground circuit is also shared with the ECT and the IAT.

### Throttle Position sensor (TP)

The throttle position sensor (TP) is located at the throttle motor side of the throttle assembly. The throttle valve shaft drives the sensor mechanism, which acts upon the two Hall effect elements to provide the ECM with redundant TP voltage signals.

### Pedal Position Sensor

The pedal position sensor is located at the accelerator cable side of the throttle assembly. The throttle input shaft drives the potentiometer wipers to provide the ECM with redundant pedal position voltage signals.

**Mechanical Guard Sensor**

The mechanical guard sensor is a single track potentiometer, located at the accelerator cable side of the throttle assembly. The mechanical guard shaft drives the potentiometer wiper to provide the ECM with a mechanical guard position signal voltage.

The signal voltage ranges from approximately 0.5 V at closed to 4.75 V at full open.

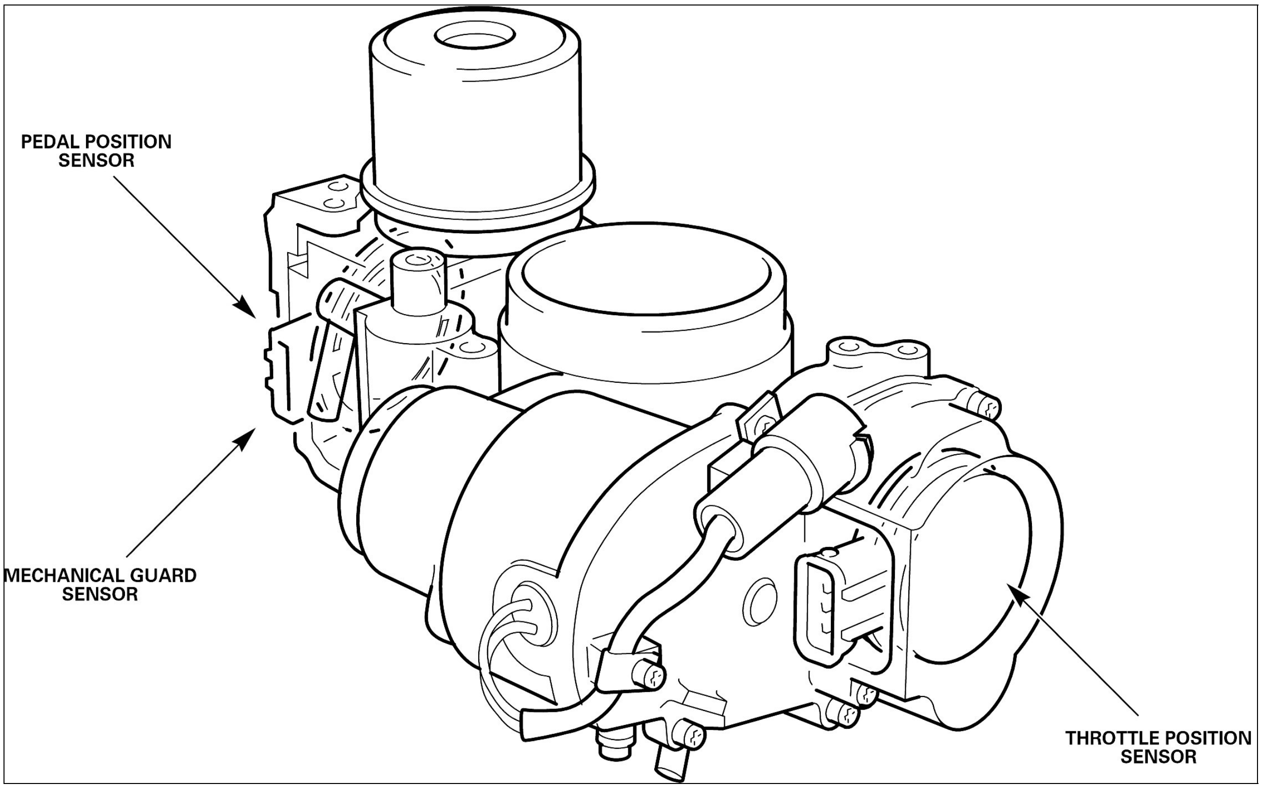


**Fig. 35 THROTTLE AND SENSORS – AJ26**

**Throttle Assembly Design Overview**

The throttle assembly rotating components are arranged such that no fixed connection is made during normal operation.

The input shaft moves the mechanical guard via a lever. The throttle valve is restrained by the mechanical guard lever on one side and rotated by spring force on the drive side.

The throttle motor segment gear rotates in one direction to allow throttle opening by spring force or motors in the other direction to close the throttle against spring force.

The design of the input shaft and the mechanical guard, and the counter force applied by their respective springs, ensures that they always rotate together when driver input is being applied from the accelerator pedal.

The accelerator rotates the input shaft and the mechanical guard in the open direction; the springs keep their adjacent levers in contact and rotate them in the closed direction.

The motor acts only to close the throttle valve from the mechanical guard position. The ECM controls engine idle speed by activating the motor closed to regulate an idle air way in the throttle bore with throttle plate. This is achieved by closing the throttle plate past the default mechanical guard open limit to the factory-set stop on the throttle motor segment gear.

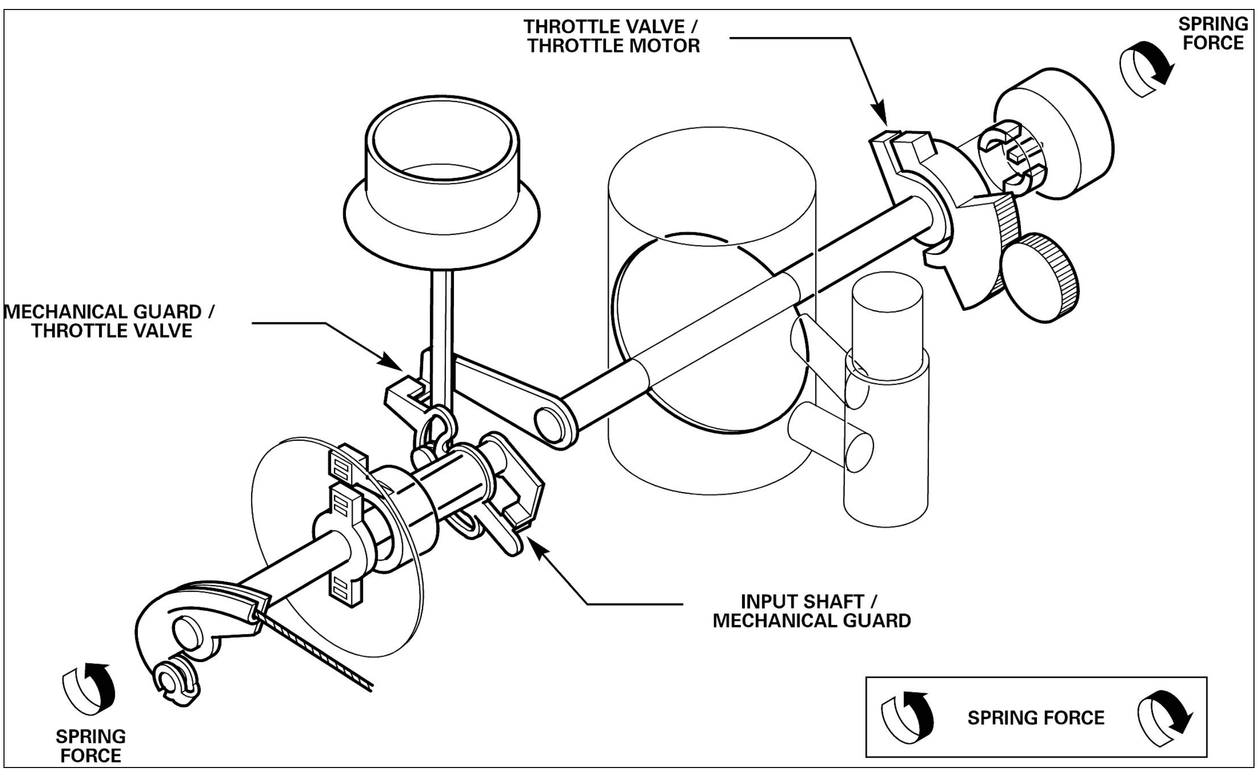


**Fig. 36 THROTTLE LEVERS AND GAPS – AJ26**

**Throttle Operation — Normal Mode**

The ECM monitors the position of the input shaft and the mechanical guard using signals from the pedal position and mechanical guard sensors.

In response to the pedal position signal input, the ECM drives the throttle motor to follow the input shaft and mechanical guard rotation to maintain a constant gap between the mechanical guard and throttle valve levers.

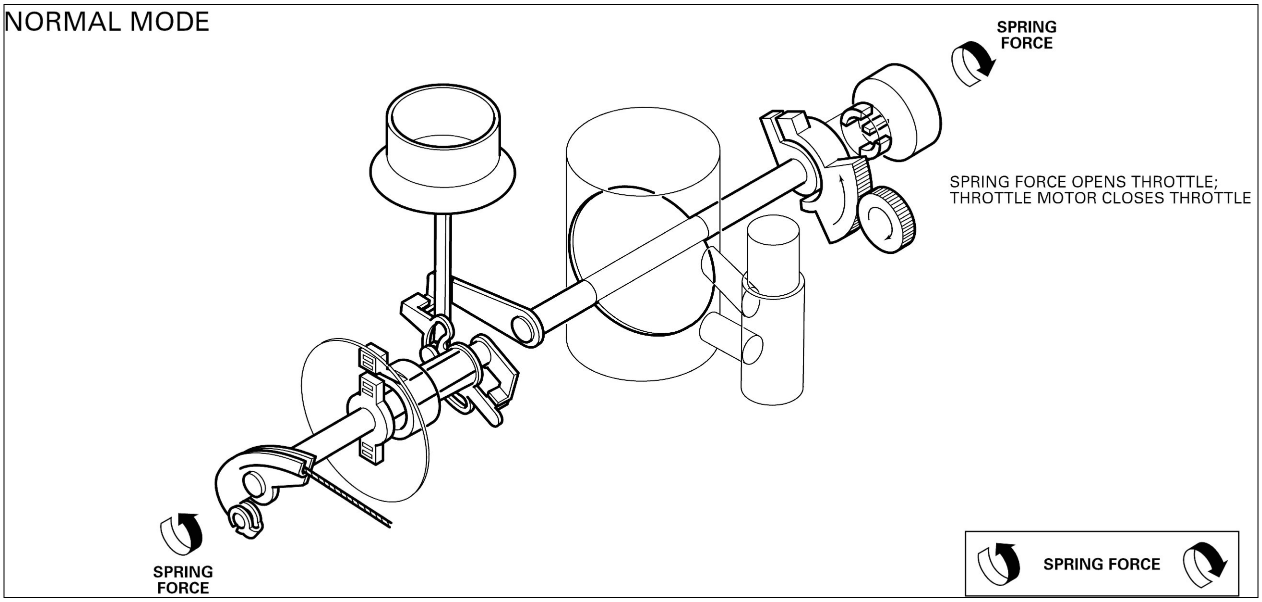


**Fig. 37 THROTTLE OPERATING MODES – AJ26**

The throttle motor drive gears rotate the throttle valve in the closed direction; the throttle valve spring turns the throttle valve in the open direction while maintaining contact between the motor side throttle lever and the segment gear.

The arrangement of the throttle valve drive prevents the ECM from exceeding driver demand. If the throttle is driven open (without driver input to move the mechanical guard), the drive side throttle lever will disengage from the segment gear, and the input side throttle lever will contact the mechanical guard lever preventing further throttle opening.

Since the mechanical guard restricts throttle movement only in the open direction, the arrangement of the throttle valve also allows the ECM to reduce throttle opening to less than driver demand. Throttle opening is reduced during traction control / stability control and during engine power limiting.

At idle, the ECM controls engine speed using the limited range of throttle valve movement available between the mechanical guard (open limit) and the factory set stop on the throttle motor segment gear (closed limit).

### Throttle Operation — Mechanical Guard Mode

If a throttle fault is detected, the ECM defaults to mechanical guard operating mode. In mechanical guard mode, the throttle valve spring turns the throttle valve in the open direction until it engages the mechanical guard, and the ECM does not drive the throttle motor.

The input shaft, mechanical guard and throttle valve are then effectively locked together by their springs, so that the accelerator pedal is in direct control of the throttle via the throttle cable.

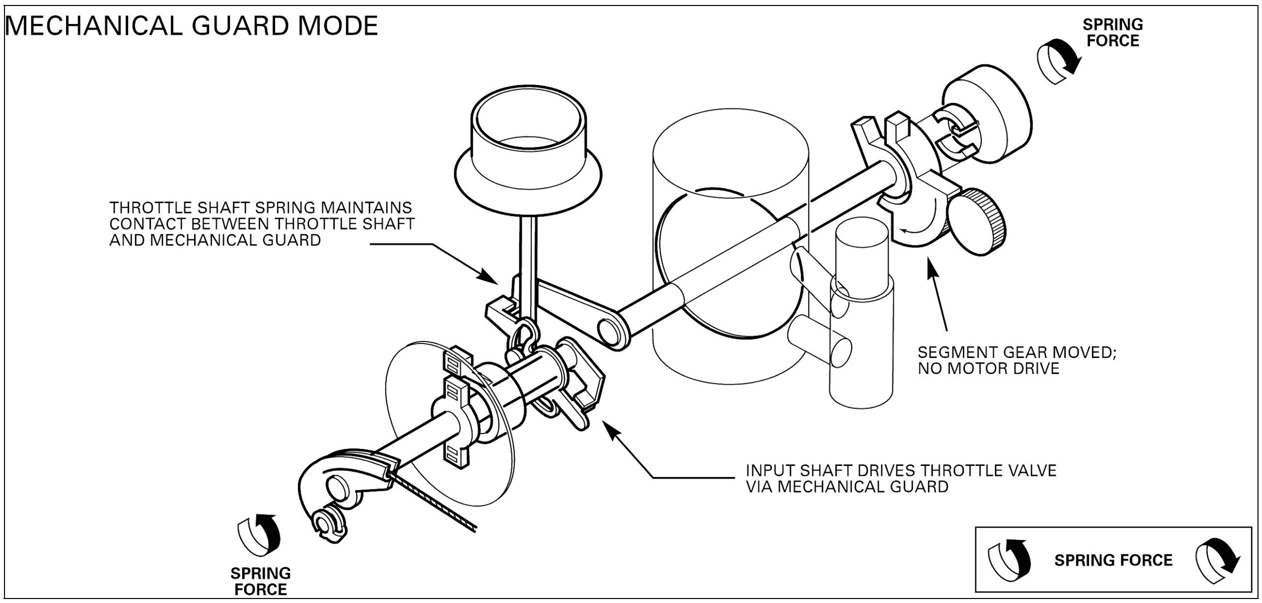


**Fig. 38 THROTTLE OPERATING MODES – AJ26**

Full throttle is available and engine speed is not limited in mechanical guard mode. Fuel injection intervention smooths the transition from normal mode to mechanical guard mode to prevent a sudden increase in engine speed. In addition, fuel injection intervention limits idle speed by switching off selected injectors.

Without fuel injection intervention, the idle speed would be approximately 2000 rpm and cause excessive shock loads on the transmission when shifting out of P or N. As engine load increases, the ECM progressively cancels idle fuel injection intervention.

**Cruise Control Mode**

When cruise control is engaged, the ECM calculates the required throttle valve angle and ports vacuum to the vacuum actuator. The vacuum actuator moves the mechanical guard to a position that allows the throttle to move the throttle valve to the desired angle.

Using the input signals from the throttle sensors, the ECM monitors and adjusts the mechanical guard and the throttle valve to maintain the cruise control set speed. As the driver releases the accelerator pedal, the input shaft disengages from the mechanical guard.

When accelerating above the set speed during cruise control, the accelerator pedal has a "lighter feel" until the input shaft engages with the mechanical guard.

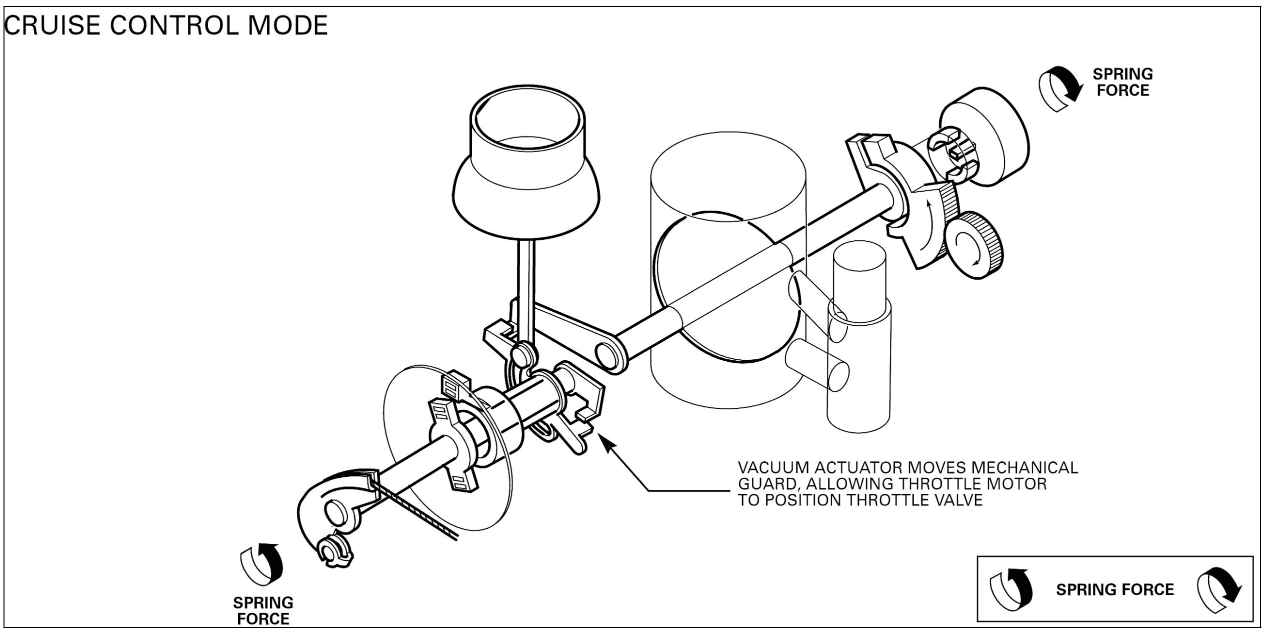


**Fig. 39 THROTTLE OPERATING MODES – AJ26**

**Cruise Control – AJ26 Vacuum Components**

Vacuum is supplied from the intake manifold and is applied to the mechanical guard vacuum actuator on the throttle assembly. The vacuum components include:

- One check valve
- Two vacuum reservoirs
- Three vacuum solenoid valves (VSV)

The XK vacuum components are installed in the right front fender, behind the wheel arch liner.

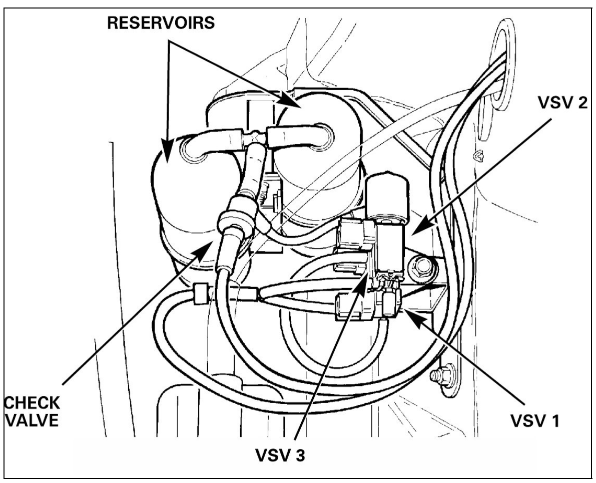


**Fig. 40 CRUISE CONTROL VACUUM COMPONENTS (XK8) – AJ26**

On the XJ, the vacuum switching valves and the check valve are installed on the front firewall driver's side enclosure of the engine compartment. The vacuum reservoirs are installed in the engine compartment behind the right hand side headlamps.

**Vacuum check valve**

The check valve maintains vacuum in the system when the throttle valve is in a position where little or no manifold vacuum is available (approximately 3/4 to full throttle).

**Vacuum reservoirs**

If the throttle valve is positioned so that little or no manifold vacuum is available, the vacuum reservoirs can maintain system vacuum for up to 20 minutes. If the reservoirs are depleted of vacuum, normal system operation can be restored by reducing vehicle speed for a short period of time.

**VSV 1 (vacuum)**

When cruise control is engaged, the ECM grounds the VSV 1 circuit and VSV 1 is driven to port vacuum to operate the mechanical guard vacuum actuator.

**VSV 2 (atmosphere)**

The ECM grounds the VSV 2 circuit. VSV 2 is driven to port the operating vacuum to atmosphere until the mechanical guard is set to the required position. The ECM determines the required position via the mechanical guard sensor. When cruise control is disengaged, the ECM grounds the VSV 2 circuit and VSV 2 is driven to port the operating vacuum to the atmosphere and release the mechanical guard vacuum actuator.

**VSV 3 (release)**

VSV 3 is driven by the ECM to act as a safety back up for VSV 2. The ECM switches the supply side of the VSV 3 circuit.

**VSV Filters**

VSV 2 and 3 incorporate filters to prevent moisture and debris from entering the system.

**Cruise Control Operation**

The driver communicates with the ECM through the master switch in the center console and the SET+, SET-, CANCEL, and RESUME switches on the steering wheel.

The ECM also monitors two brake switch inputs and the parking brake switch to cancel operation. The cruise control system is powered when the master switch is ON. Battery voltage is applied to the ECM directly from the master switch and via the normally closed brake cancel switch.

With the system powered, a momentary press of either the SET+ or the SET- switch engages cruise control if the vehicle speed is 17.5 m.p.h. (28 km/h) or greater.

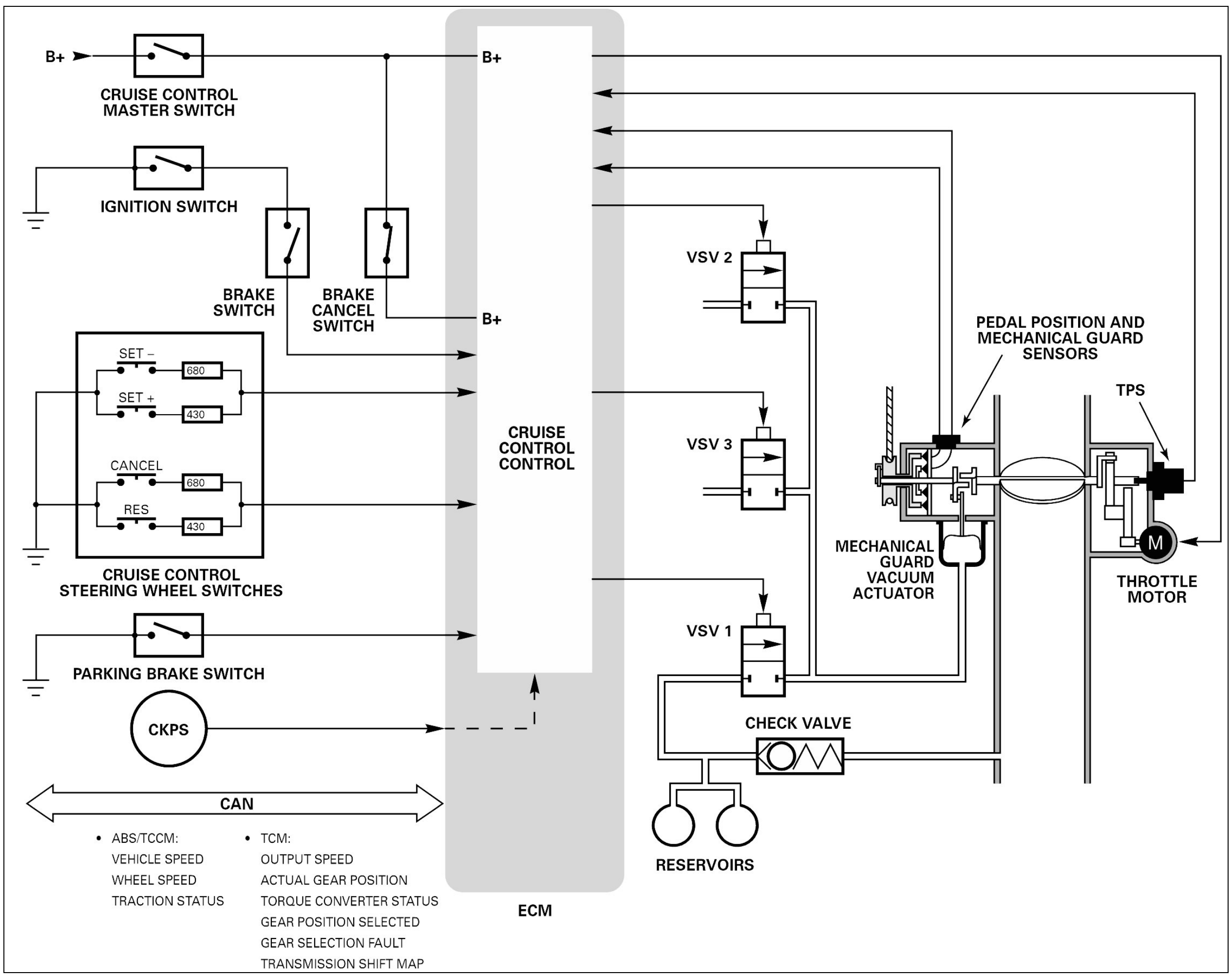


**Fig. 41 CRUISE CONTROL LOGIC – AJ26**

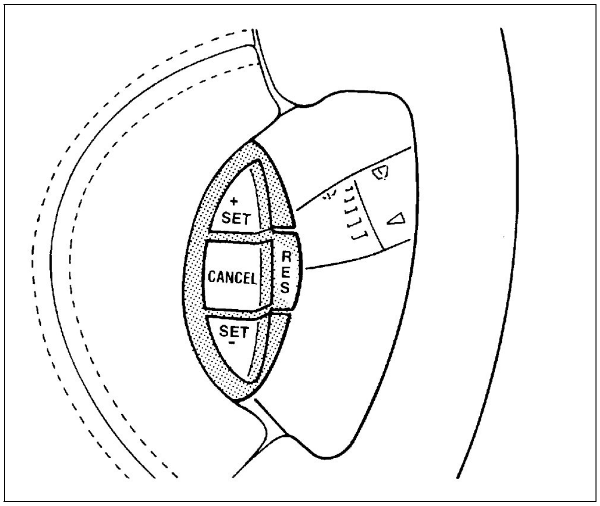


**Fig. 42 CRUISE CONTROL STEERING WHEEL SWITCHES**

The ECM responds by "memorizing" the current vehicle speed (CAN data) as the "set" speed. The ECM drives the vacuum system to position the mechanical guard so that the throttle can maintain the set speed. The input signals from the pedal position, mechanical guard and throttle sensors allow the ECM to monitor and adjust the mechanical guard and the throttle valve.

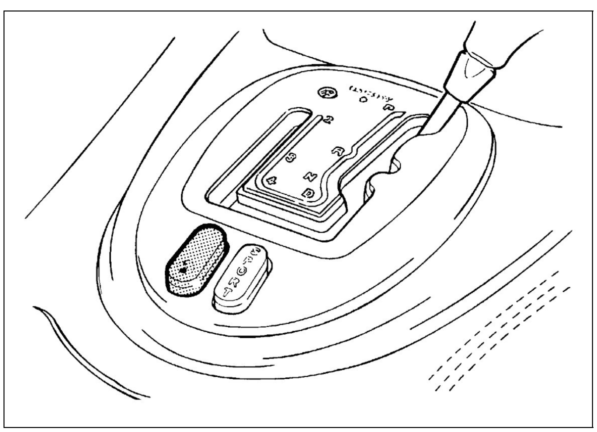

**Fig. 43 CRUISE CONTROL MASTER SWITCH**

Accelerator pedal control

**Change in Set Speed (accel/decel)**

- Once cruise control is engaged, a momentary press of the SET+ or SET- switches accelerates or decelerates the vehicle speed incrementally by 1 m.p.h. (1.6 km/h).
- Pressing and holding the SET+ or SET- switches causes the ECM to smoothly accelerate or decelerate the vehicle until the switch is released.
- The ECM distinguishes the switched ground inputs by a difference in circuit resistance.
- The ECM stores a maximum of five SET+ / SET - incremental acceleration or deceleration commands at any one time.
- Once the first stored command has been carried out, a further command can be added.
- If the opposite SET switch is pressed, the ECM deletes the last command from memory.
- After the vehicle is accelerated / decelerated incrementally, the ECM will adopt this speed as the set speed.

**Accelerator Pedal Control**

- Pressing the accelerator pedal will accelerate the vehicle higher than the set speed without disengaging cruise control.
- Since the vacuum actuator holds the mechanical guard "open", there is noticeably less accelerator pedal load up to the point at which the throttle input shaft begins to move the mechanical guard.

**CANCEL / RESUME**

The ECM disengages cruise control and clears the set speed from memory if any of the following conditions occur:

- The master switch is moved to OFF
- A fault is detected in the throttle assembly
- A fault is detected in the brake switch
- A fault is detected in the cruise control switches
- The parking brake is applied
- The engine speed exceeds 7100 rpm

The ECM disengages cruise control but retains the set speed in memory if any of the following conditions occur:

- The brake pedal is pressed
- The vehicle decelerates too fast (in case the brake switch is not operating)
- The gear selector is moved to P, N, R
- Traction control / stability control operation
- Vehicle speed falls below 16 m.p.h. (26 km/h)
- The vehicle fails to accelerates to more than 50% of the set speed after the RESUME button is applied (due to a steep incline)

**Full Authority Electronic Throttle Control — AJ27**

A full authority throttle body is fitted to the AJ27 engine. The throttle body does not incorporate a mechanical guard.

The main features of the AJ27 throttle body are:

- Full motorized control of the throttle valve from the ECM
- Mechanical, cable operated ‘limp home’ fail safe mode (restricted throttle opening)
- Mechanical, electrical and software safety features
- ECM cruise control drive (no vacuum components)
- Built-in air assist control valve (AACV) with integral air feed (normally aspirated only)

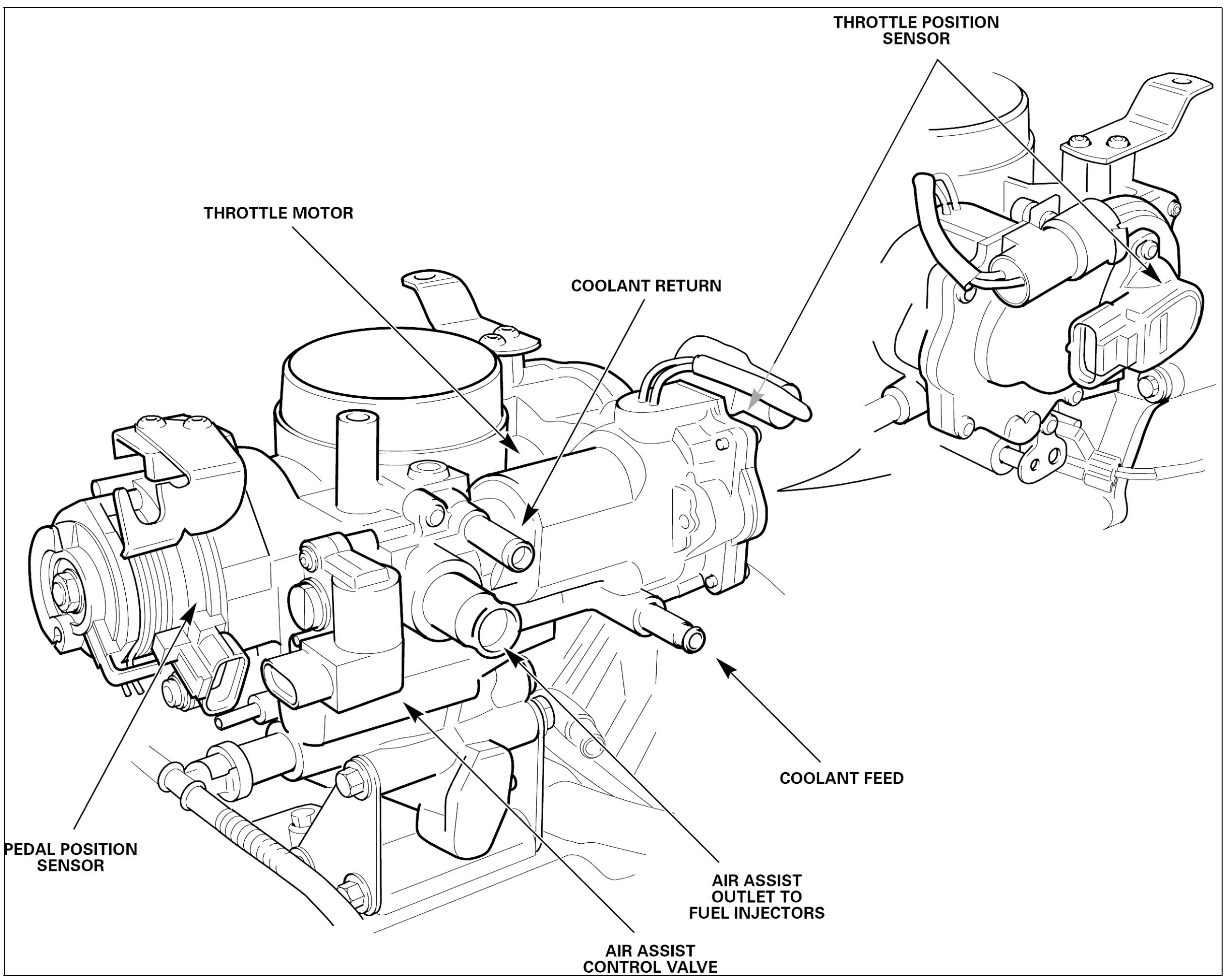


**Fig. 44 THROTTLE BODY – AJ27 N/A**

### Throttle Components

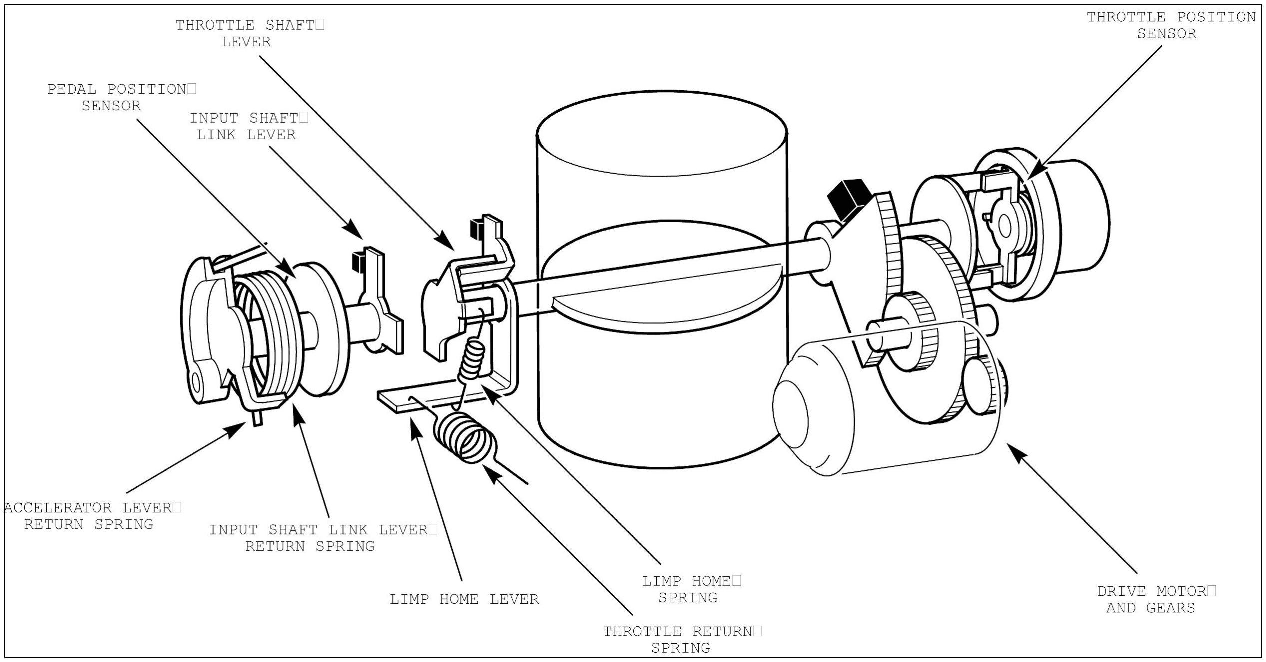


**Fig. 45 THROTTLE BODY COMPONENTS – AJ27**

#### Input Assembly

The accelerator pedal is linked to the input shaft link lever of the throttle assembly.

During normal operation, as the driver depresses the pedal, the link lever is rotated against spring pressure with no mechanical connection to the throttle valve.

#### Motorized Throttle Valve

The throttle valve is coupled to a DC motor via reduction gears and is positively driven by the ECM in both directions between fully closed and fully open. The throttle position sensor on the motor end of the throttle shaft provides direct feedback of the actual valve angle to the ECM and is similar to the pedal position sensor in operation.

**Throttle Operation**

The throttle body contains two moving assemblies:

- The accelerator input assembly, which provides the driver demand to the ECM
- The motorized throttle valve, driven and controlled by the ECM in accordance with driver demand and other EMS factors.
- In normal operation, there is no mechanical coupling between the two assemblies.

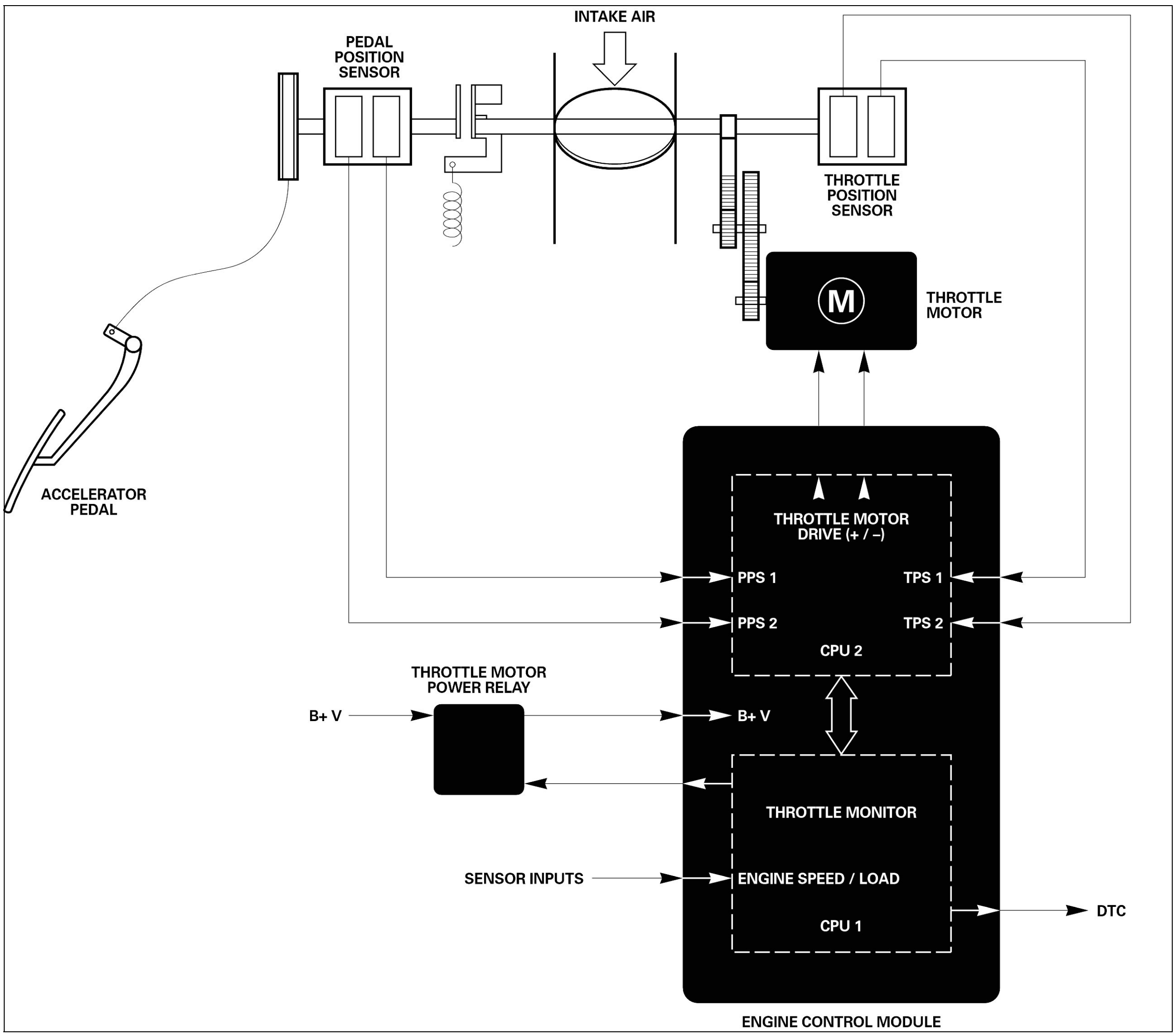


**Fig. 46 ECM THROTTLE CONTROL AND MONITORING – AJ27**

### Limp Home Mechanism

The limp home mechanism consists of the accelerator input shaft link lever and the two throttle shaft levers, all three levers being interlocked for limp home operation. On the throttle assembly, one lever is fixed to the end of the shaft and the second, the 'limp home' lever, pivots around the shaft.

The two levers are connected by a spring and the throttle return spring is also connected to the limp home lever. As the throttle rotates, the action of the throttle lever (valve opening) and the springs (valve closing) maintain the two levers in contact.

At the idle speed position, there is an angular separation between the accelerator link lever and the limp home lever and under normal closed loop control this difference is maintained as both input and drive assemblies rotate.

### Limp Home Operation

If a failure in the throttle mechanism or control system occurs, the ECM defaults throttle control to the limp home mode.

- The ECM de-energizes the throttle motor power supply relay and / or deactivates the ECM internal PWM motor drive signals.
- The throttle valve is operated mechanically from the drivers pedal and throttle opening is restricted to a range from idle to a maximum of approximately 30°.
- Due to the angular difference between the input shaft link lever and the limp home lever, there is no engagement of the two levers until the input shaft has rotated approximately 60° from idle.
- When the link lever contacts the limp home lever, causing it to rotate, the throttle valve is pulled open. With the pedal fully depressed the throttle valve is open to a maximum of approximately 30°.
- On releasing the accelerator pedal, the throttle return spring causes the limp home lever to rotate to its stop at the throttle idle speed position.
- If loss of motor power occurs when the throttle is open beyond the idle position, the limp home lever will close to the point where it contacts the link lever. If the throttle has been driven closed (past the idle position) when loss of power occurs, the limp home spring will return the throttle to the idle position.
- When the throttle is in limp home mode, the ECM adjusts the fuel metering strategy as necessary to control engine power. At low throttle opening, fuel cutoff to individual cylinders may occur.

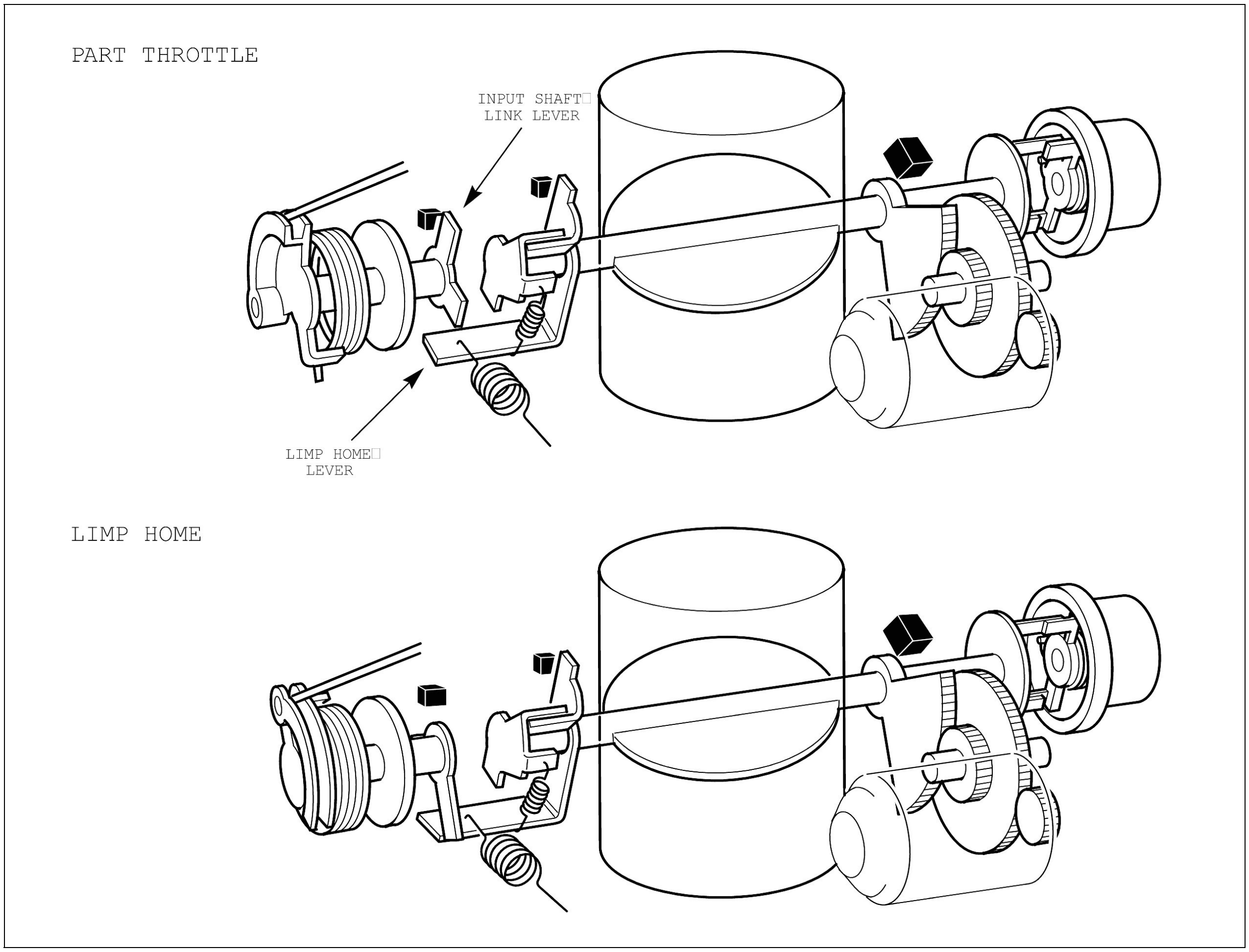


**Fig. 47 THROTTLE OPERATION – AJ27**

# FUEL DELIVERY

## System Overview

The fuel system uses a rear mounted over-axle fuel tank installed in the trunk. Fuel and vapor pipes travel under the left hand side of the vehicle to the engine and evaporative emission components.

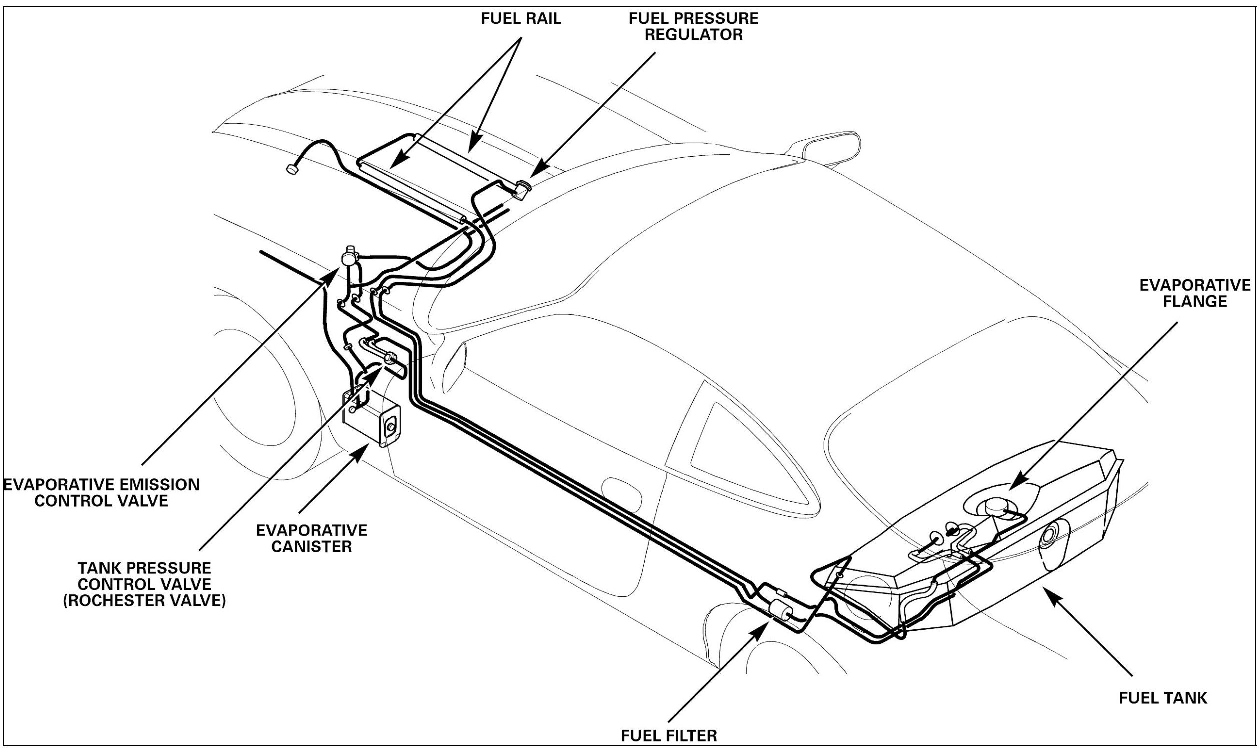


**Fig. 48 FUEL SYSTEM – AJ26 WITHOUT ENHANCED EVAPORATIVE EMISSION CONTROL**

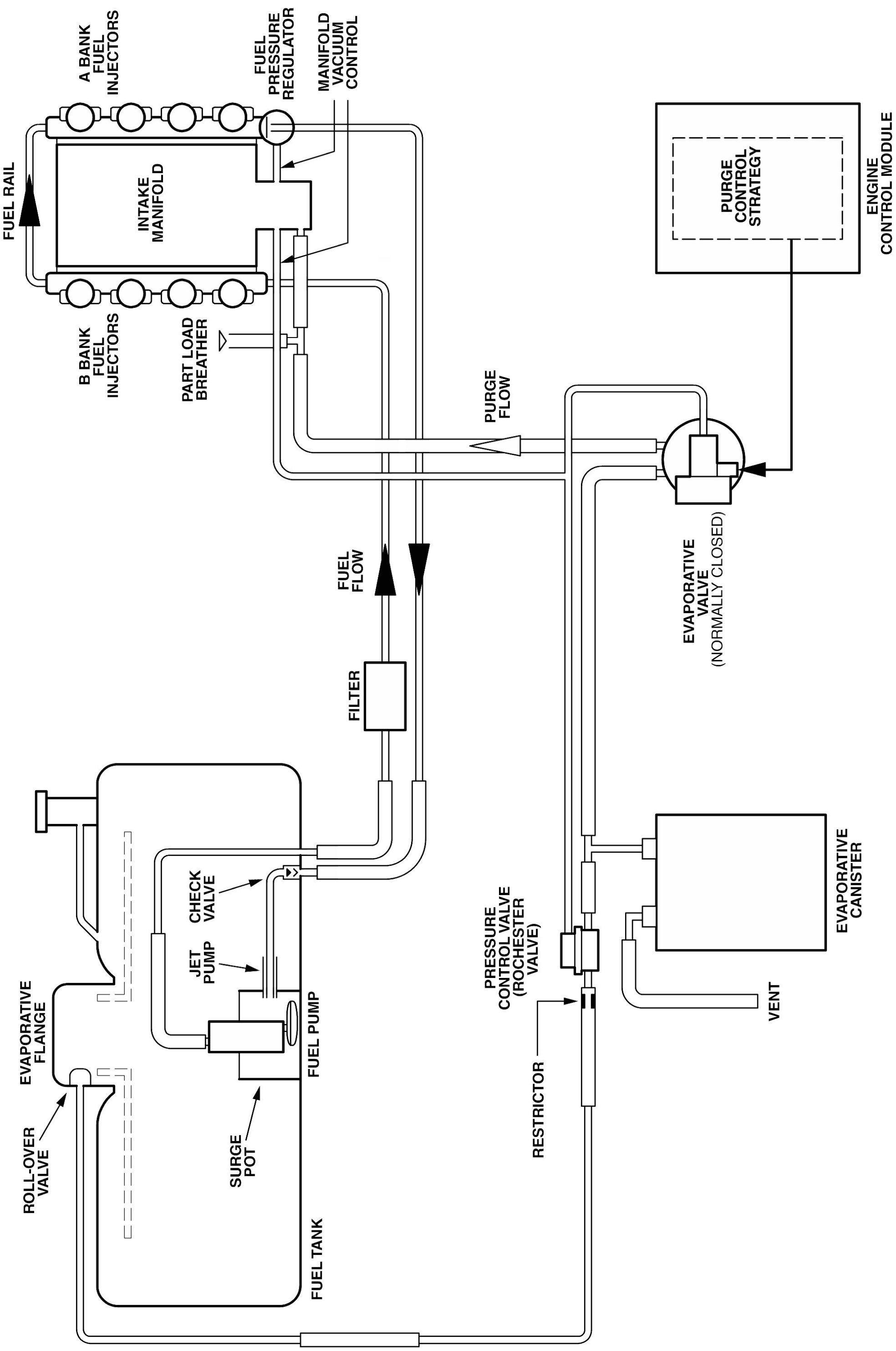


**Fig. 49 FUEL DELIVERY AJ26**

**Fuel Delivery**

The fuel tank incorporates the fuel pump and the necessary plumbing for fuel supply and return. The pump is located by a rubber mount and clamp attached to the surge pot.

The tank interior piping incorporates a jet pump and a check valve in the fuel return line. Returning fuel flows through the jet pump, which draws additional cool fuel from the tank to supply the surge pot.

This supplemented return flow ensures that the surge pot remains full of fuel. The return check valve prevents reverse flow through the fuel return line when it is disconnected.

Access to the tank interior is through the evaporative flange at the top of the tank.

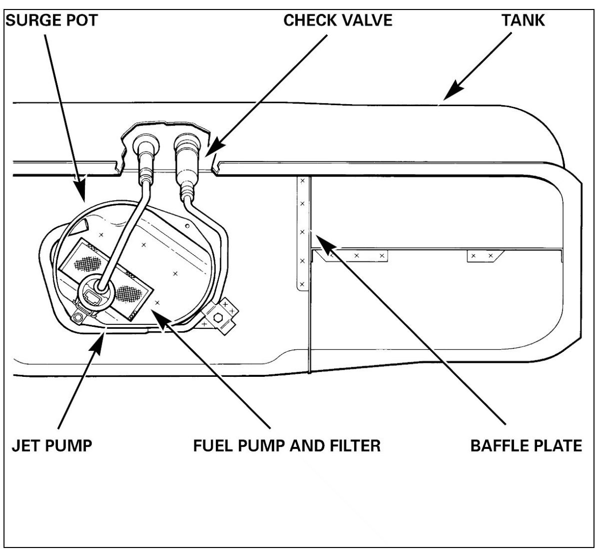


**Fig. 50 FUEL TANK ARRANGEMENT – XK8**

**In-Line Fuel Filter**

A replaceable in-line fuel filter is located in the supply line.

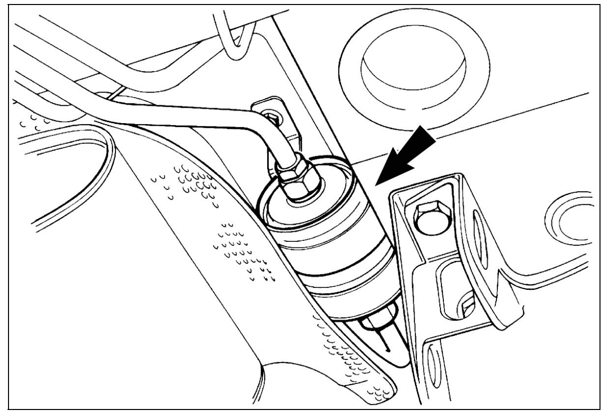

**Fig. 51 FUEL FILTER – XK8**

**Fuel Level Sensor**

The fuel level sensor is a conventional potentiometer that provides the instrument pack (INST) with a variable voltage signal indicating fuel tank fill level. The fill level signal voltage ranges between approximately B+ at empty to 0 V at full.

The INST transmits two fuel level CAN messages: CAN FUEL LEVEL RAW – the raw (undamped) fuel tank level, and CAN FUEL LEVEL DAMPED – the damped (averaged over a period of time) fuel tank level.

The INST provides the damped level message to compensate for surges within the fuel tank.

### Fuel Pump

The single fuel pump unit consists of a turbine driven by a DC motor, a check valve and an inlet filter.

The fuel output from the turbine pump provides a cooling flow around the motor before being discharged through the outlet check valve. The check valve prevents rapid fuel pressure loss when the engine is switched off.

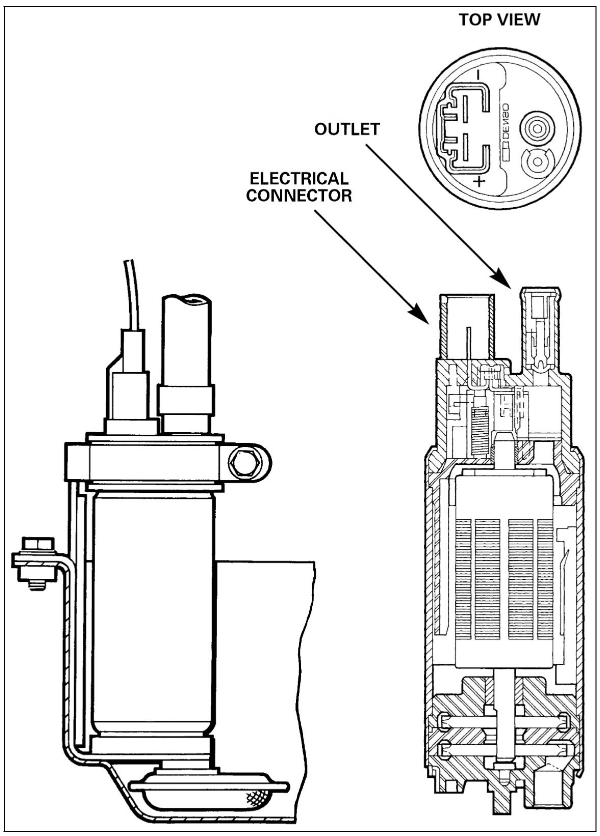


**Fig. 52 FUEL PUMP WITH CROSS-SECTION**

### Fuel pump specifications

Nominal pump delivery 26.45 gallons per hour at 3 bar (43.5 psi).

Current draw 7 amps at 13.2 V at 3 bar (43.5 psi).

### Fuel pump operation

The fuel pump is switched by the ECM via the fuel pump relay. When the ignition is switched on (position II), the ECM switches on the fuel pump after a delay of 0.1 second.

If the ignition switch remains in position II without moving the key to crank (position III), the ECM will switch off the pump after a maximum of 2 seconds. When the ignition switch is moved to crank (position III), the fuel pump is activated and operates continuously while the engine is running.

If the engine stops with the ignition on (position II), the ECM will switch OFF the pump after two seconds.

**NOTE:**

In the event of a vehicle impact, the inertia switch will switch off all ignition powered circuits including EMS power and fuel pump relay power. This action will switch off the fuel pump and prevent fuel flow.

**Fuel Pressure Regulator**

Fuel is pumped to the fuel rail and injectors, where fuel pressure is controlled by the fuel pressure regulator. Excess fuel, above the engine requirement, is returned to the fuel tank through the fuel pressure regulator.

The pressure regulator spring chamber above the diaphragm is referenced to intake manifold vacuum. The differential pressure across the fuel injector nozzles is therefore maintained constant and the quantity of fuel injected for a given injector pulse duration is also constant. Fuel pressure, measured on a test gauge, will vary between 2.7 bar (39 psi) at idle to 3.1 bar (45 psi) at full load to compensate for intake manifold absolute pressure.

The fuel pressure regulator is located on the rear of the A bank fuel rail. This design provides the same pressure across each injector, and delivers an equal quantity of fuel to each of the eight cylinders. Fuel flows through the B bank fuel rail, across the crossover pipe and through the A bank fuel rail. The fuel rails are integral with the intake manifold.

The test valve, located in the crossover pipe allows the fuel rail to be de pressurized and pressurized during testing and servicing. A standard fuel pressure gauge kit is used to connect to the test valve.

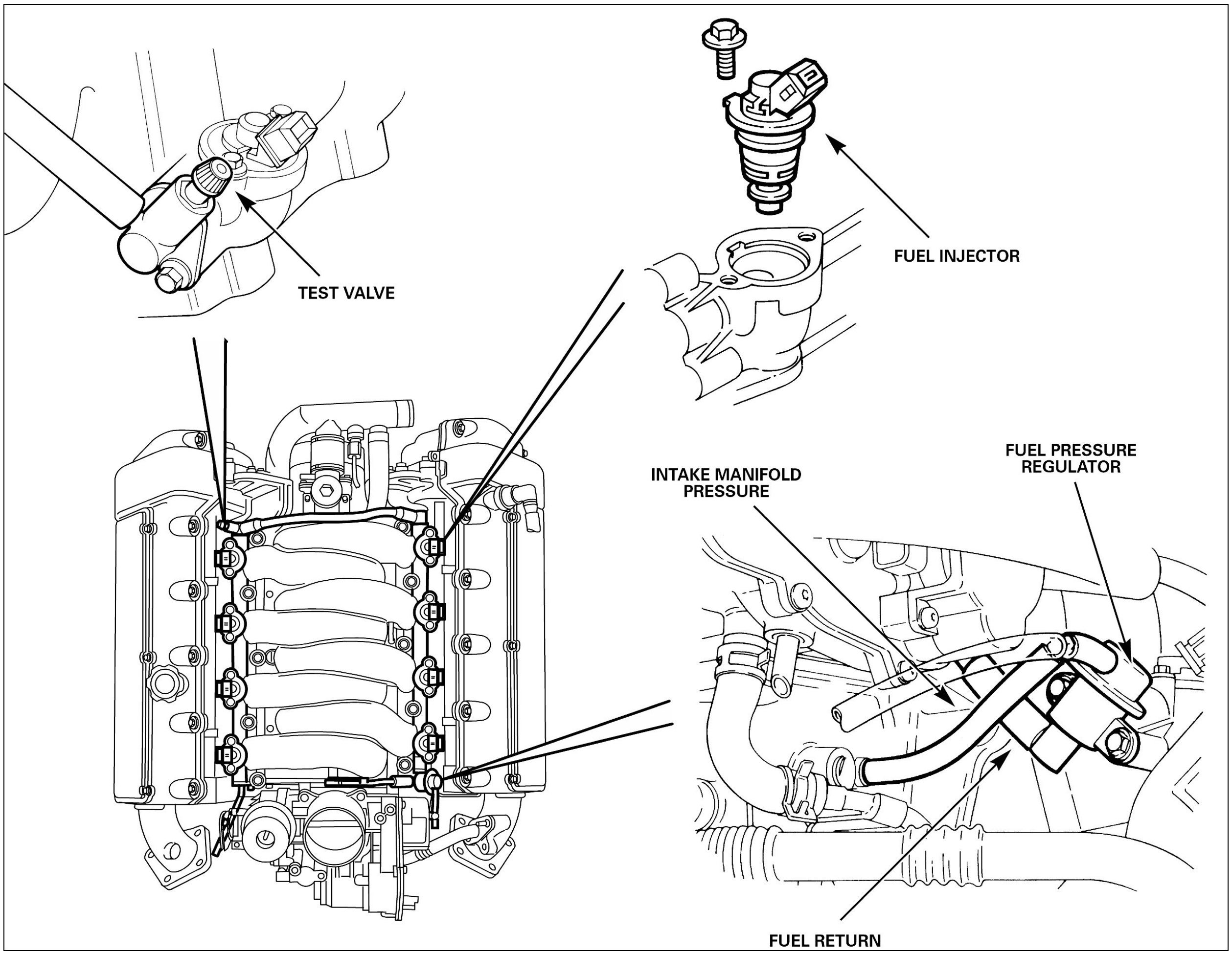


**Fig. 53 INTAKE MANIFOLD, FUEL RAILS AND FUEL PRESSURE REGULATOR – AJ26 N/A**

**Fuel Injectors – AJ26**

Eight solenoid operated fuel injectors are secured to the fuel rail by cap screws. The unique fuel injectors are side fed and have dual straight jets.

The fuel spray from each jet is directed toward the adjacent intake valve. Two O-rings seal each injector in the fuel rail bores. B+ voltage is supplied to the injectors via the ignition switch activated (position II, III) fuel injection relay.

The ECM drives the injectors with a single pulse and modulates the pulse width to control the injector pulse duration.

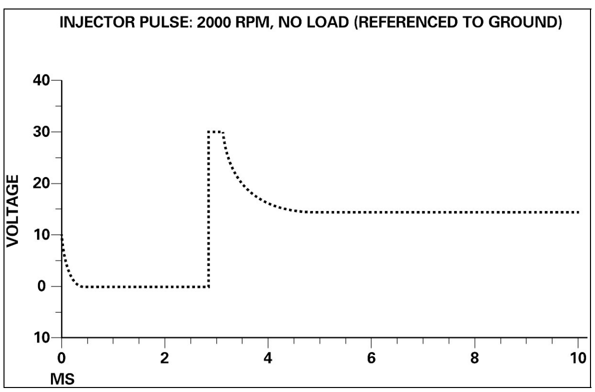


**Fig. 54 FUEL INJECTOR CHARACTERISTIC (TYPICAL)**

A special tool is required for injector removal. Refer to JTIS for more information.

**Evaporative Emission Control System – 1997 MY**

The fuel tank can be filled to approximately 90% of its capacity. The additional 10% of volume allows for expansion of the fuel, without escape to the atmosphere.

To limit evaporative emissions when the engine is switched off, the fuel tank pressure is limited at a positive pressure of 0.069 – 0.092 bar (1.0 – 1.33 psi) by the tank pressure control valve (Rochester valve). Pressure above 0.092 bar (1.33 psi) is released by the valve to the charcoal canister.

When the engine is running, manifold vacuum acts on the tank pressure control valve, which opens the vent line from the fuel tank to the charcoal canister. Air enters the charcoal canister and flows to the tank to replace the fuel delivered to the engine, and maintain atmospheric pressure in the tank.

If the tank pressure control valve fails, the fuel tank cap will vent the fuel tank to the atmosphere at 0.138 – 0.172 bar (2.0 – 2.5 psi).

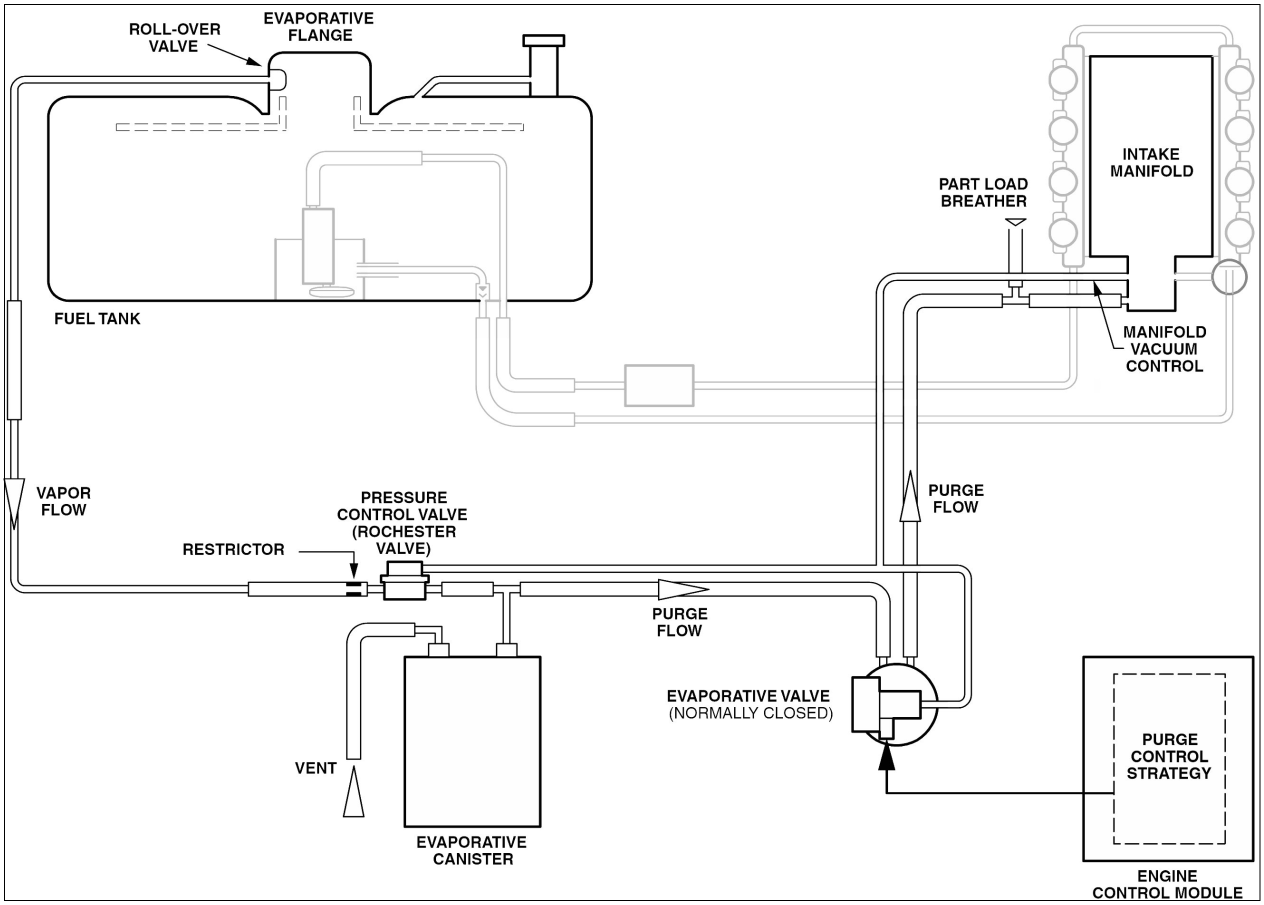


**Fig. 55 NON-ENHANCED EVAPORATIVE EMISSION CONTROL SYSTEM**

**ECM Canister Purge Control**

When the ECM enables canister purge, air flows in the vent and through the charcoal canister to the intake manifold via the normally closed evaporative emission control valve (EVAP) (purge valve).

The ECM drives the EVAP to control purge using a variable pulsed duty cycle from a mapped strategy. The purge flow rate is based on engine operating conditions and the concentration of fuel vapor in the charcoal canister.

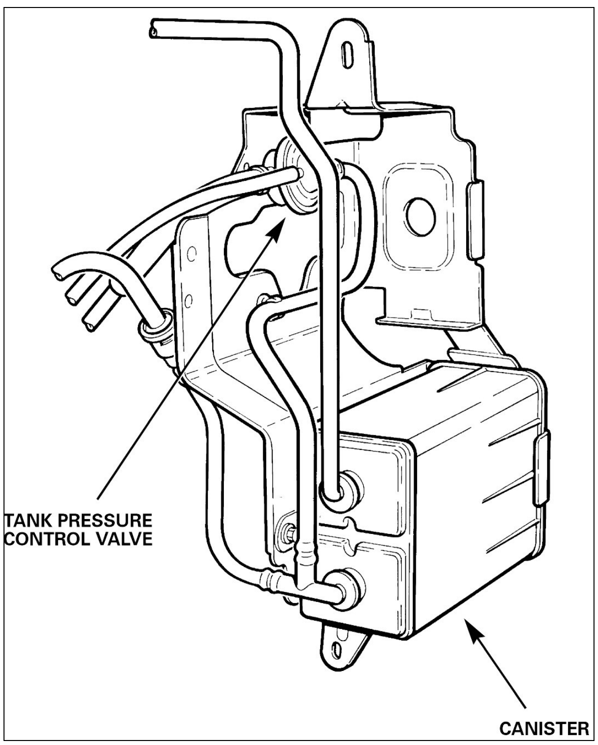


**Fig. 56 EVAPORATIVE CANISTER ASSEMBLY XK8**

**Engine operating conditions**

The engine operating conditions that determine the rate of canister purge are:

- Engine load and speed
- Coolant temperature
- Time since engine starting
- Closed loop fuel metering correction

**Determination of fuel vapor concentration**

The ECM determines the concentration of fuel vapor being drawn from the charcoal canister and makes a correction to the base fuel metering map.

The determination is made by the ECM making step changes to the purge flow rate while watching the O2 sensor output for changes.

The ECM determines the fuel vapor concentration by analysis of the amount of fuel pulse width change necessary to make the O2 sensor continue switching.

### Evaporative Emission Control Valve (EVAP)

The EVAP is a vacuum operated, normally closed purge valve. The EVAP incorporates a vacuum switching valve (VSV) that is supplied with EMS switched B+ voltage.

The ECM drives the VSV portion of the EVAP (ground side switching), which ports manifold vacuum to a diaphragm and opens the valve to allow purge flow to the intake manifold. The valve opening is modulated by the ECM from an operating strategy to control purge flow.

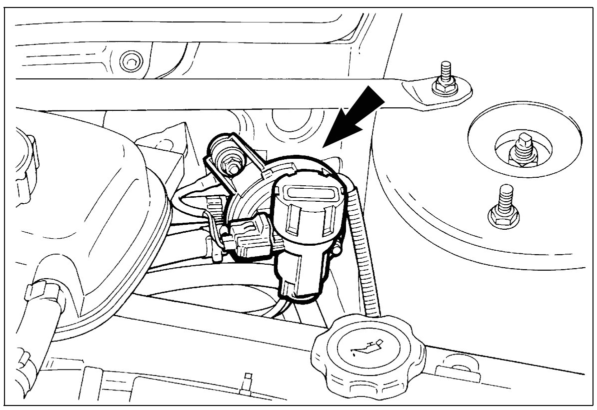

**Fig. 57 EVAPORATIVE EMISSION CONTROL VALVE (EVAP)**

### Enhanced Evaporative Emission Control System – 1998 MY ON

1998 MY ON vehicles are equipped with a twin canister enhanced evaporative emission system that provides reduced evaporative emissions and enhances the system's on-board diagnostic capabilities.

The enhanced evaporative emission system consists of the following components:

- Fuel tank pressure sensor (FTP Sensor)
- Fill level vent valve
- Two evaporative canisters
- Canister close valve (CCV) and filter
- Evaporative emission valve (EVAP)

**Enhanced Evaporative Emission Control System Operation**

When the engine is switched off, the fill level vent valve and/or the roll-over valve allow fuel tank vapors to flow through the vent line to the two carbon canisters. To maintain atmospheric pressure in the tank, air enters the canisters through a filter via the normally open canister close valve.

When the engine is running and canister purge is enabled, the ECM meters purge flow from the canisters and tank via the evaporative emission control (purge) valve (EVAP). The ECM enables canister purge using a mapped strategy.

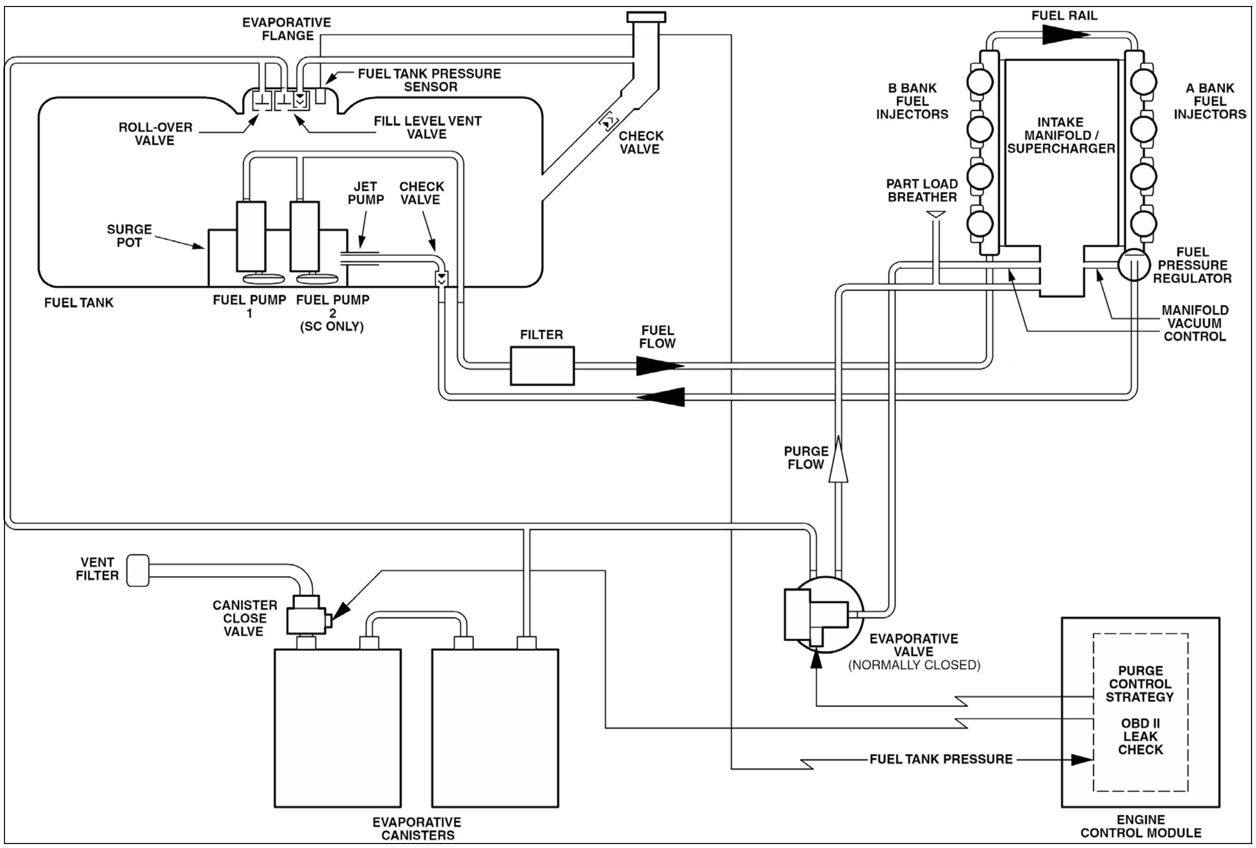


**Fig. 58 FUEL DELIVERY AND ENHANCED EVAPORATIVE EMISSION CONTROL SYSTEM – AJ26**

**Fuel Tank Pressure Sensor (FTP Sensor)**

The FTP sensor, located on the fuel tank evaporative flange, incorporates a pressure sensor capsule connected to a resistive element.

The ECM supplies 5 volts to the resistive element, which outputs a voltage signal proportional to the fuel tank pressure.

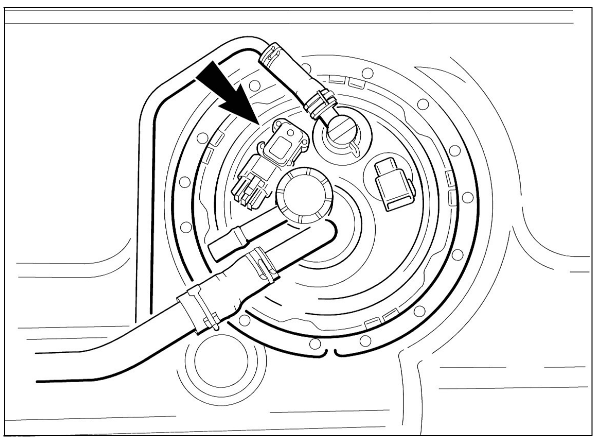

**Fig. 59 FUEL TANK PRESSURE SENSOR**

**Canister Close Valve (CCV)**

The normally open CCV, located on the second evaporative canister outlet, is operated by the ECM from the purge control / leak check strategy.

A filter is installed on the vent hose to prevent debris from entering the canister.

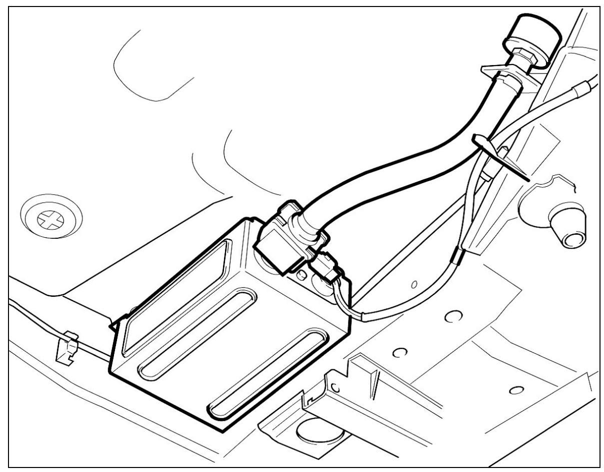

**Fig. 60 CANISTER CLOSE VALVE AND FILTER – XJ8 SEDAN**

**On-Board Refueling Vapor Recovery (ORVR)**

ORVR, common to all XJ 1998 MY onwards and XK 1999MY onwards vehicles, prevents the fuel tank vapor from being vented directly to the atmosphere during refueling.

During refueling, vapor is vented through the EVAP system. The ORVR system consists of a unique fuel tank filler neck incorporating a check valve, unique vent lines and a fill level vent valve.

The valve sets the maximum fuel level in the tank and provides outlets to the EVAP system and to the filler neck.

The lower part of the filler neck has a reduced diameter. During refueling, the incoming fuel seals the gap between the reduced part of the filler neck and the refueling filler nozzle to prevent vapor from escaping up the filler neck.

The check valve, located at the neck outlet to the tank, prevents fuel from backing-up in the filler neck. The fill level vent valve, located in the fuel tank evaporative flange, incorporates a float valve and a pressure relief valve.

The roll-over valve also vents to the EVAP system. Note that the vapor inlet to the roll-over valve is located higher in the fuel tank than is the inlet to the fill level vent valve.

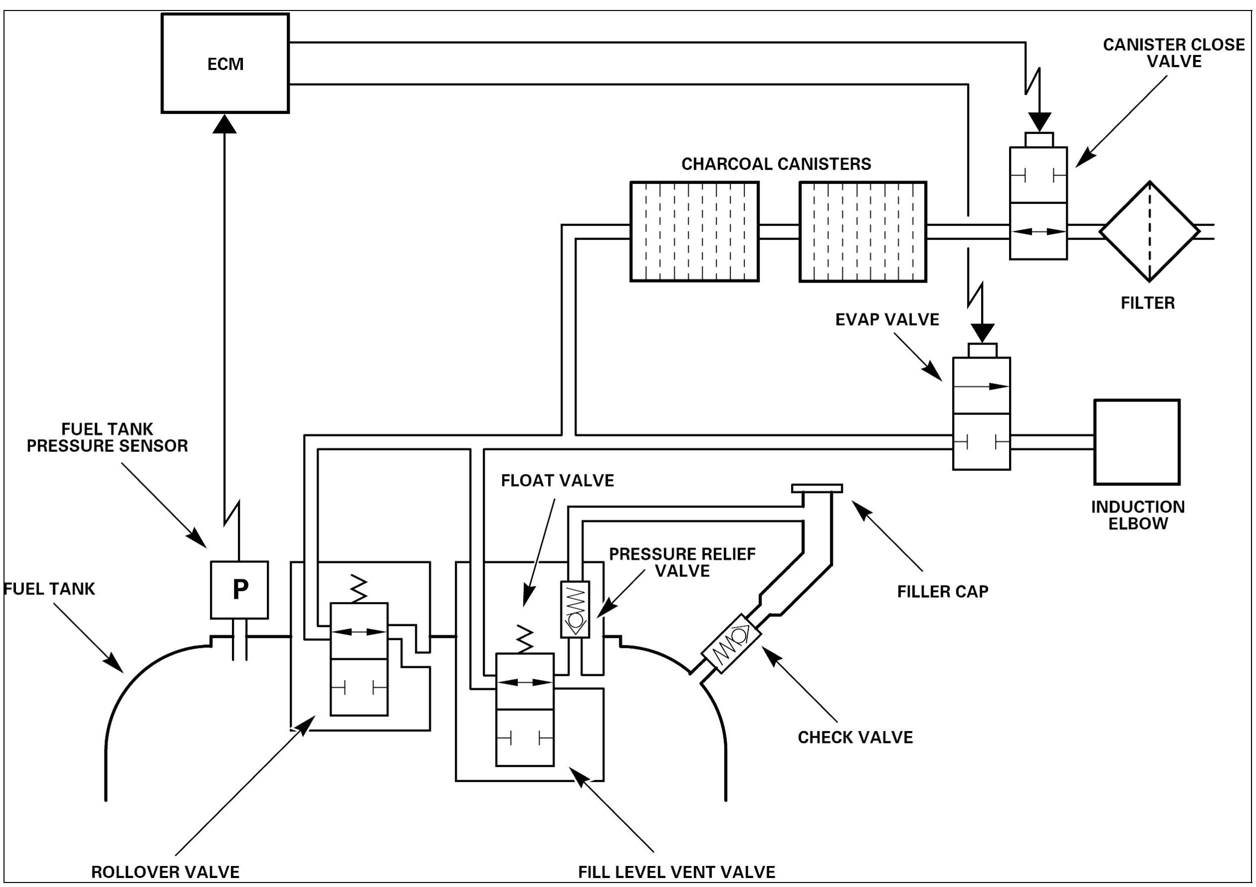


**Fig. 61 XK ORVR SYSTEM DIAGRAM**

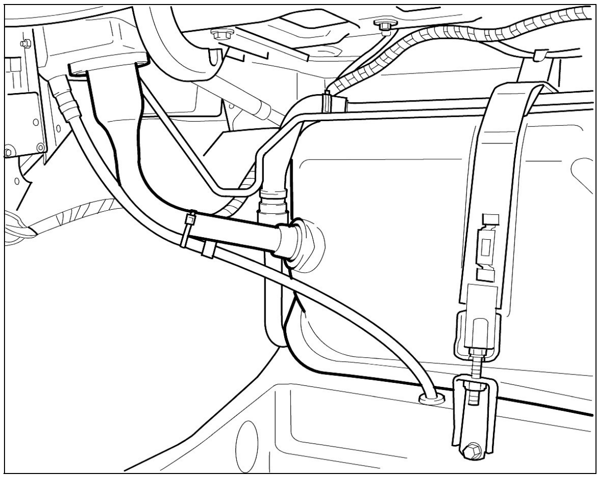

**Fig. 62 ORVR FUEL TANK – XJ8 SEDAN**

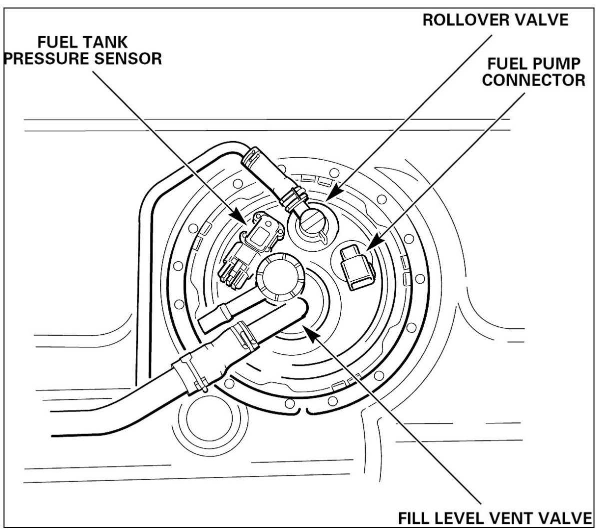


**Fig. 63 FUEL TANK EVAPORATIVE FLANGE**

**On-Board Refueling Vapor Recovery (ORVR) – XK8**

The XK8 enhanced evaporative emission system with ORVR is similar to the system used on the XJ8 Sedan. Due to the large bore hoses required, the EVAP canisters and associated components are relocated to the rear of the vehicle behind the rear suspension/final drive assembly.

The canister close valve (CCV) and vapor hoses are fixed directly to the bodywork. The EVAP canisters are bolted directly and via brackets to the body.

The atmospheric vent pipe from the second canister is routed through a hole in the RH suspension housing with the CCV air filter fitted to the end of the pipe inside the housing.

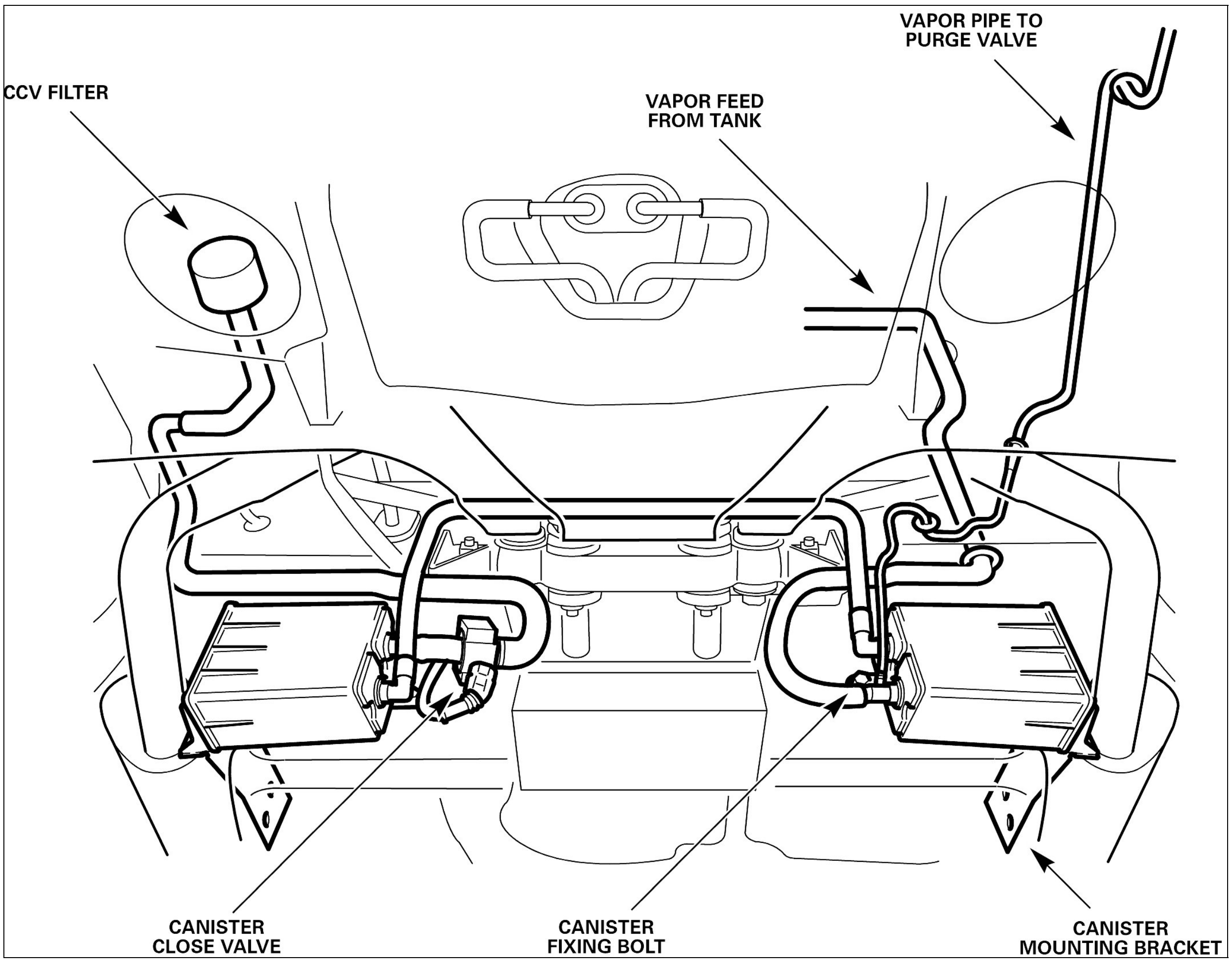


**Fig. 64 EVAP CANISTER INSTALLATION – XK8**

**Crankcase Ventilation System**

The engine crankcase is ventilated through a part load and a full load breather. Each camshaft cover incorporates a wire gauze air / oil separator.

The part load breather connects between the B bank air / oil separator and the intake manifold induction elbow, and tees to the canister purge line.

The full load breather connects between the A bank air / oil separator and the intake air duct, downstream from the MAF.

The breather hoses have quick release fittings.

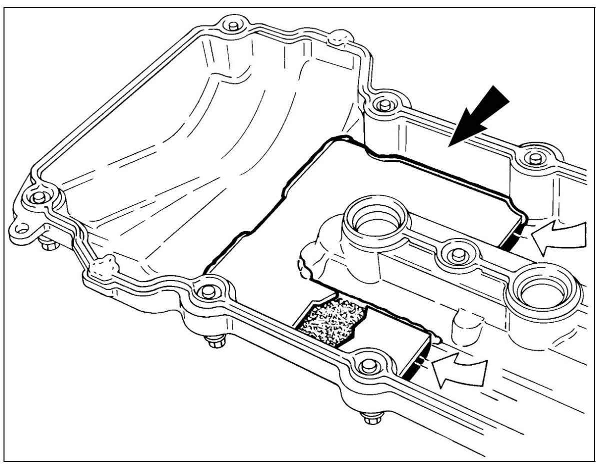

**Fig. 65 AIR / OIL SEPARATOR**

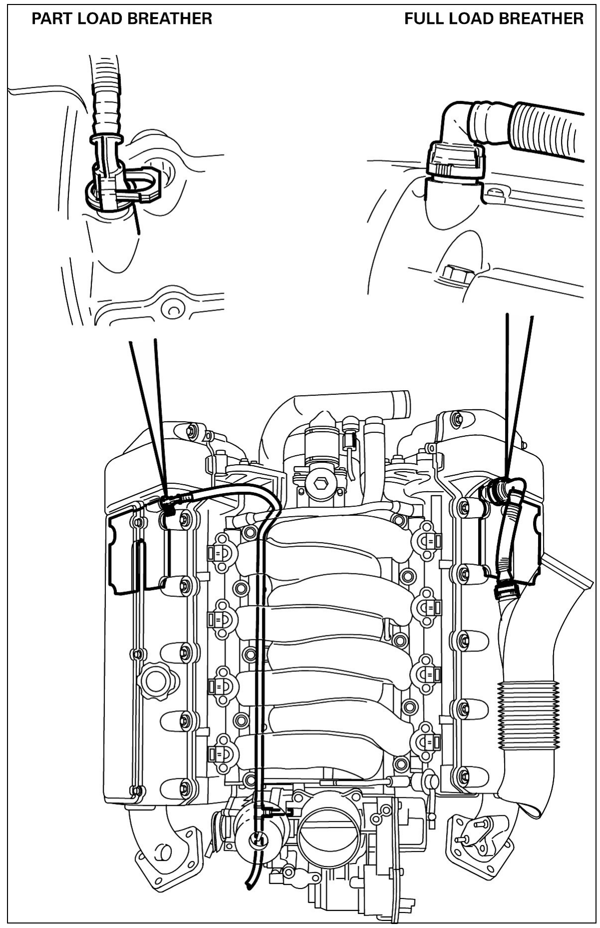


**Fig. 66 CRANKCASE VENTILATION SYSTEM**

**Oxygen Sensors – AJ26**

The AJ26 EMS uses four zirconium dioxide type oxygen sensors. A heated oxygen sensor (HO2S) is located upstream of each catalytic converter; an unheated oxygen sensor (O2S) is located downstream of each catalytic converter.

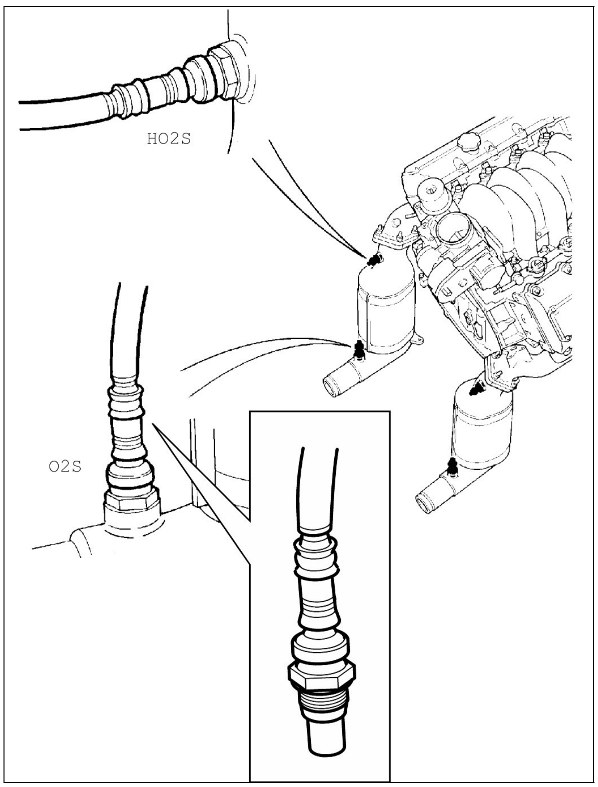


**Fig. 67 OXYGEN SENSORS – AJ26**

**Catalytic Converters – AJ26**

The AJ26 engine exhaust system uses a single catalytic converter for each engine bank. The placement of the catalysts in the down pipes, adjacent to the exhaust manifolds, ensures rapid "light off" and eliminates the need for secondary catalysts.

Deterioration of catalytic conversion efficiency will create unacceptable HC, CO and NOx exhaust emission. The efficiency of the catalytic converter system is monitored and any deterioration in efficiency is flagged as a fault by the ECM. Catalyst efficiency is monitored by sampling both the incoming and outgoing exhaust gas at the catalysts. Two oxygen sensors are positioned in each exhaust downpipe assembly – one HO2S upstream of the catalyst and one O2S downstream of the catalyst. By comparing the voltage swings of each set of sensors, the ECM can detect when catalyst efficiency drops off.

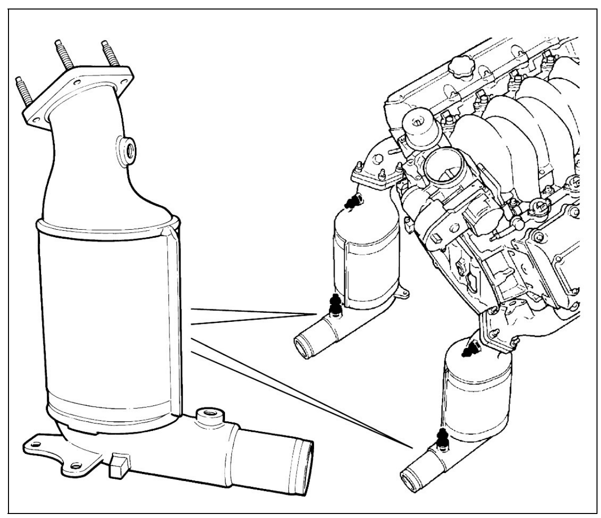

**Fig. 68 CATALYTIC CONVERTERS – AJ26**

**Oxygen Sensors – AJ27**

In order to improve air : fuel ratio (AFR) control under varying engine conditions, a "universal" type heated oxygen sensor is fitted in the upstream position. The universal sensor has varying current response to changes in exhaust gas content.

The AFR can be maintained more precisely within a range from approximately 12:1 to 18:1, not just stoichiometric. Voltage is maintained at approximately 450 mV by applying a current.

The current required to maintain the constant voltage is directly proportional to the AFR. A higher current indicates a leaner condition; a lower current indicates a richer condition.

The current varies with the temperature of the sensor and is therefore difficult to measure for technician diagnostic purposes. The downstream heated oxygen sensors, used for catalyst efficiency monitoring, remain unchanged. However, the location in the exhaust system has changed.

**HO2S Heater Control - AJ27**

The universal oxygen sensors require precise heater control to ensure accuracy and prevent sensor damage.

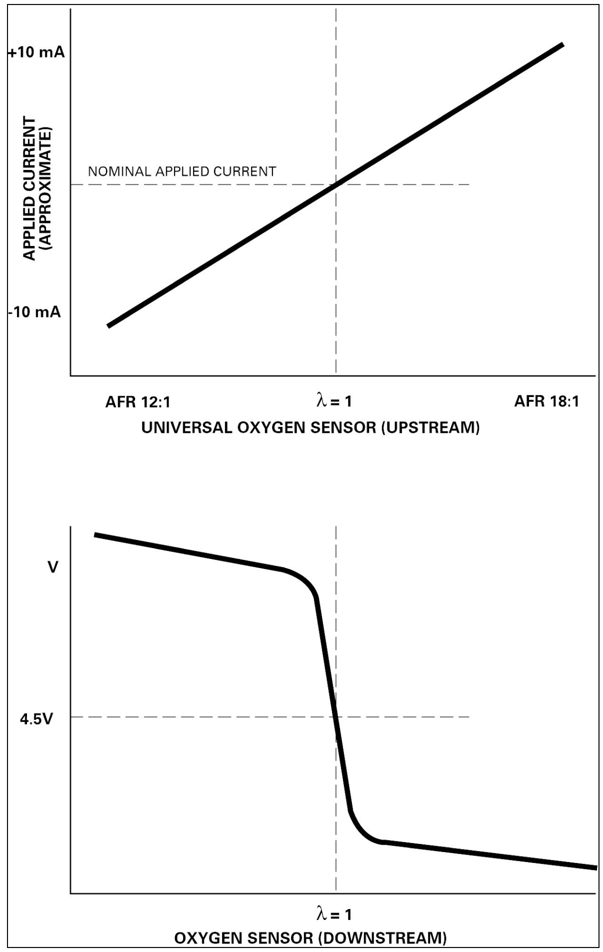


**Fig. 69 OXYGEN SENSOR CHARACTERISTIC – AJ27**

After engine start, the ECM initially applies B+ voltage to the heaters to quickly warm the sensors, then reduces the voltage as necessary to maintain sensor temperature. The ECM varies the voltage by PWM control of the individual heater ground side circuits.

**Catalytic Converters – AJ27**

The AJ27 EMS produces very low levels on exhaust emission. In order to allow detection of catalytic converter deterioration at these very low levels, a split element catalytic converter is used.

To improve catalyst efficiency monitoring, the spacing between the two internal ceramic catalytic elements has been increased to allow the downstream HO2 sensor to be relocated to the new position between the two elements. Due to the lower efficiency of the first (top) element compared to the second element, the level of exhaust emission at this location is sufficiently high to ensure accurate monitoring.

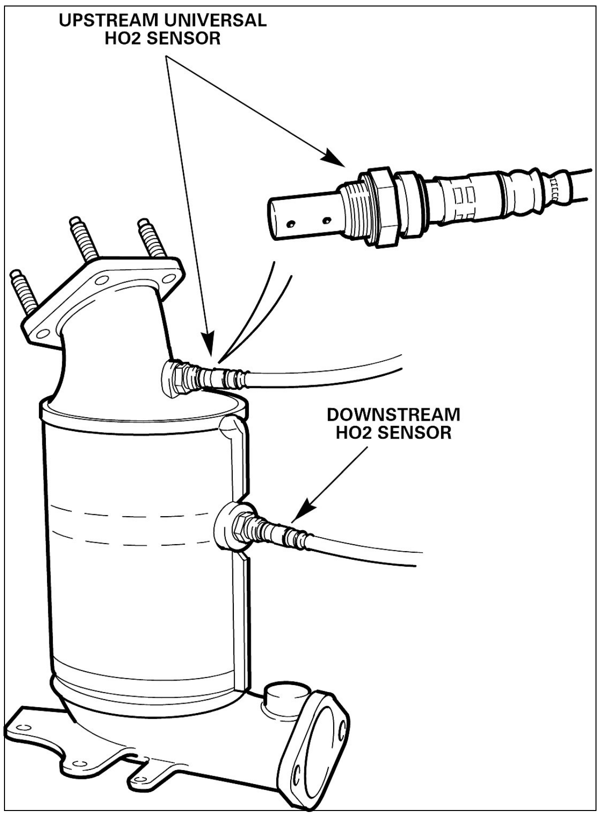


**Fig. 70 SPLIT ELEMENT CATALYTIC CONVERTER**

**Air Assisted Fuel Injection – AJ27 NA**

Air assisted fuel injection (AAI) improves combustion stability when the engine is cold, allowing the use of increased ignition retardation for faster catalyst warm-up, thus producing a further reduction of HC emission.

Under cold start/part throttle conditions, the system uses intake manifold vacuum to draw air through a modified injector nozzle, producing an air jet which mixes with the fuel spray to increase atomization. At higher engine loads, the manifold vacuum is insufficient to have this effect. The injector air assistance supply is controlled by the ECM.

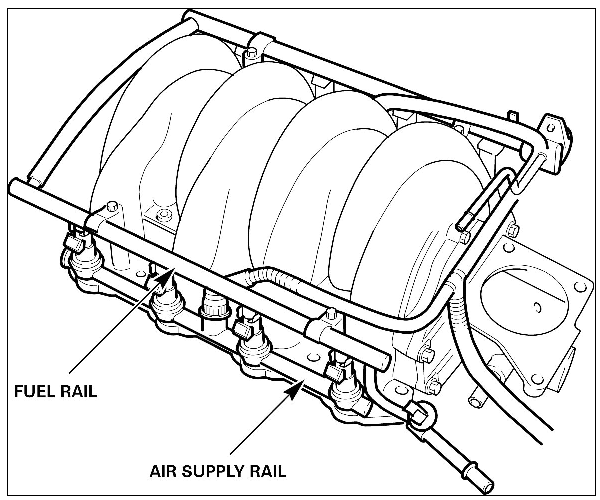


**Fig. 71 AAI INTAKE MANIFOLD – AJ27 NA**

**Injector Fuel and Air Supply**

Operation is based on the use of top (fuel) fed injectors with an air feed around the nozzle regions and therefore requires a modified induction manifold.

The injectors are seated in two air supply rails which are integral with the manifold.

The rails are closed at both ends and are center fed via plastic hoses and 'T' piece from the air assist control valve (AACV).

Two fuel rails, with a connecting crossover pipe, form a detachable assembly and are a push fit onto the injectors to which they are secured with clips. The fuel rails are then bolted to the induction manifold.

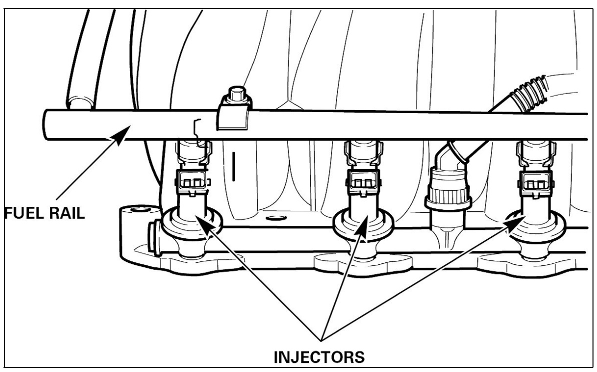


**Fig. 72 FUEL RAIL AND INJECTORS – AJ27 NA**

**Fuel Injectors — AJ27 NA**

The injectors incorporate a shroud fitted over the nozzle end to direct the AAI air flow.

Air from the supply rail is drawn by manifold vacuum through four small holes in the side of the shroud and past the fuel nozzle to exit via the two spray orifices in the shroud.

When fuel is injected into this airflow, an improved spray mixture with reduced droplet size is produced.

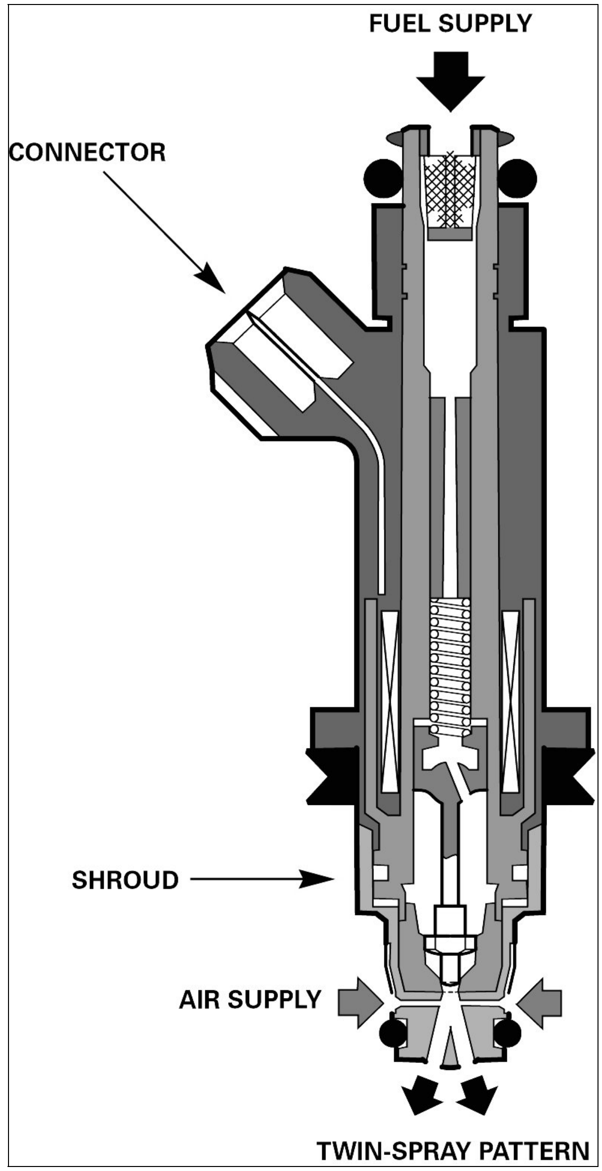


**Fig. 73 AAI FUEL INJECTOR CROSS-SECTION – AJ27 NA**

**Air Assist Control Valve (AACV)**

The air supply to the injectors is controlled by the solenoid operated air assist control valve (AACV), which is bolted to the throttle body.

The control valve receives air, via an integral passage in the throttle body, from an entry hole in the upper throttle bore above the throttle valve.

The ECM drives the AACV by a pulse width modulated (PWM) signal. The valve opens in direct proportion to an increase in the duty cycle.

The valve is fully open from cold until a coolant temperature of 60°C (140 °F). Above 60°C (140 °F) a 50% duty cycle is applied until 70 °C (158 °F), at which point the valve is fully closed.

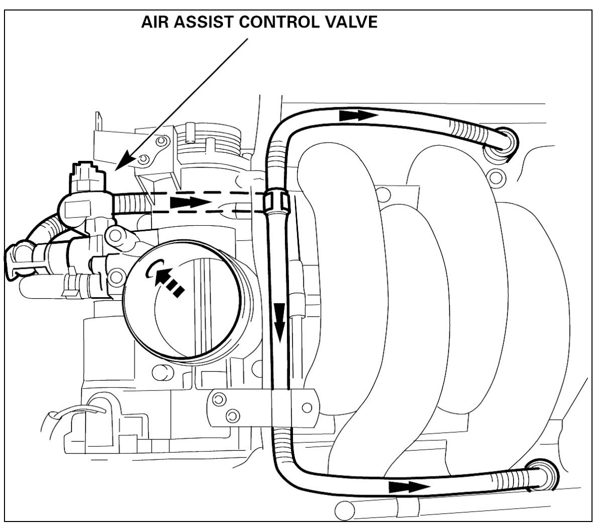


**Fig. 74 AAI SYSTEM – AJ27**

# IGNITION

## Engine Firing Order

A1 – B1 – A4 – A2 – B2 – A3 – B3 – B4

## Ignition Coils and Modules – AJ26

Two ignition modules (amplifiers) are installed. The modules receive ignition drive signals from the ECM and, in turn control the primary current switching of the on-plug ignition coils. Dwell control for the ignition system is performed within the ECM.

- Module 1 switches coils A1, A4, B2, B3.
- Module 2 switches coils A2, A3, B1, B4.

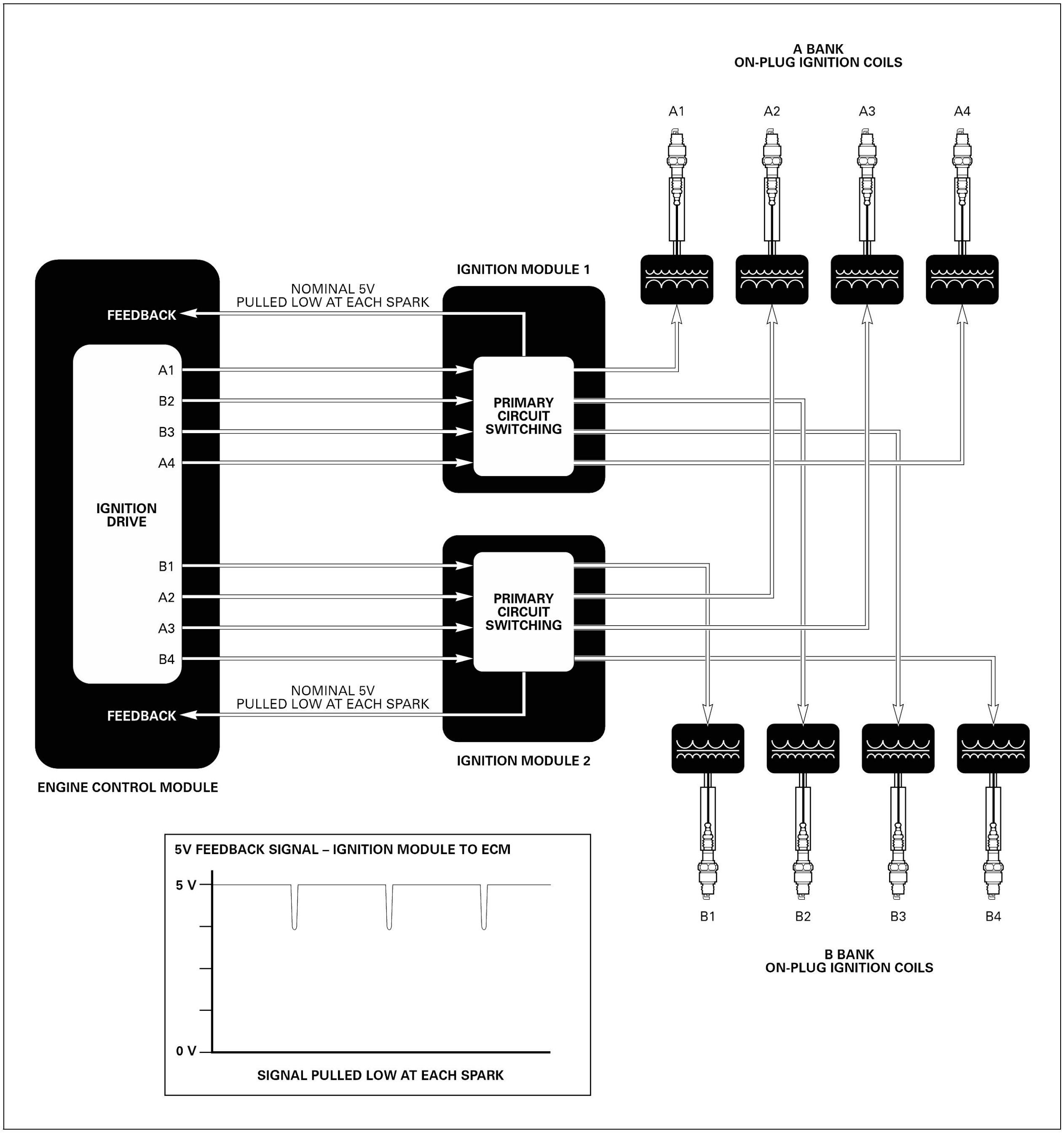


**Fig. 75 IGNITION ARRANGEMENT – AJ26**

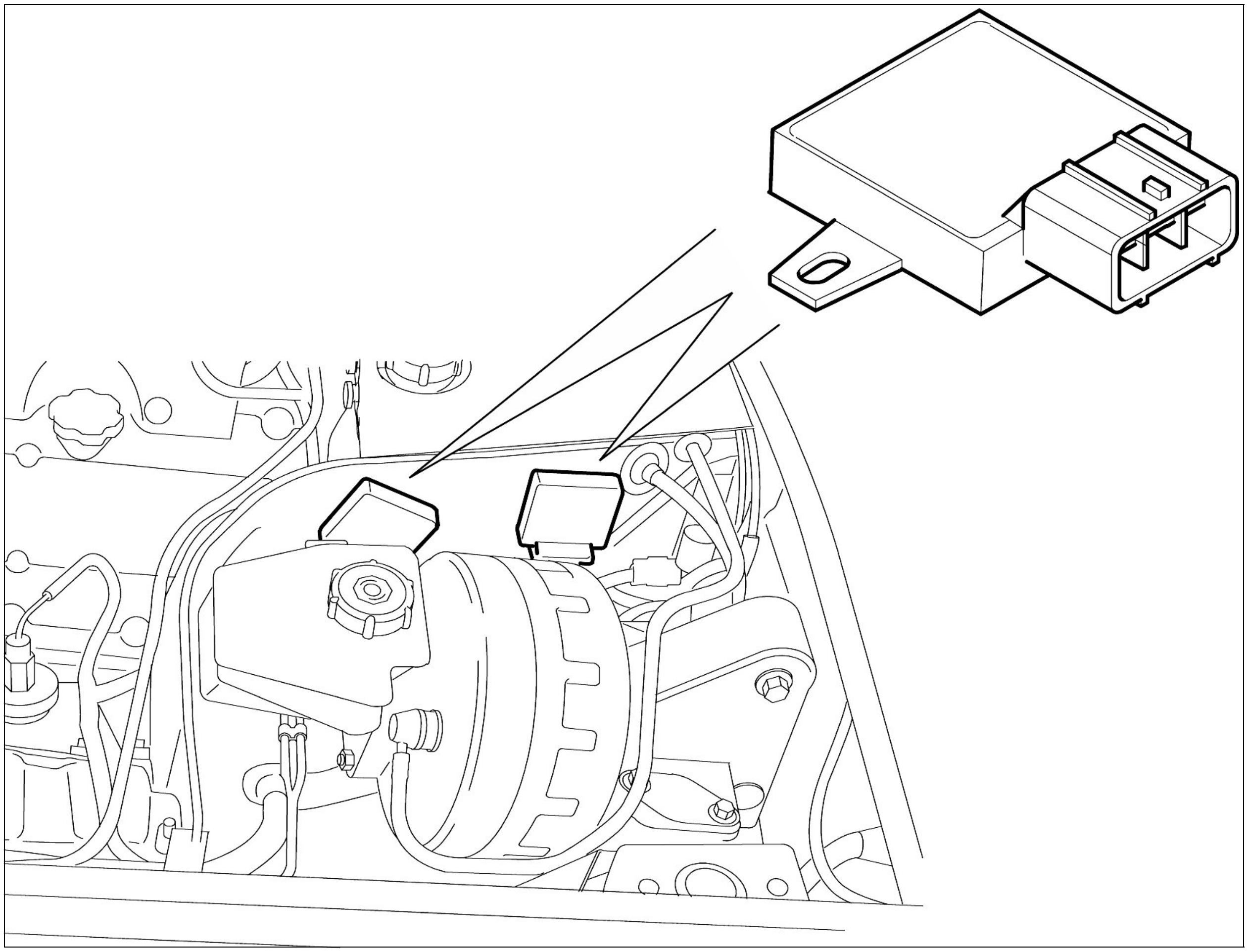

**Fig. 76   IGNITION MODULES – XJ8 AJ26**

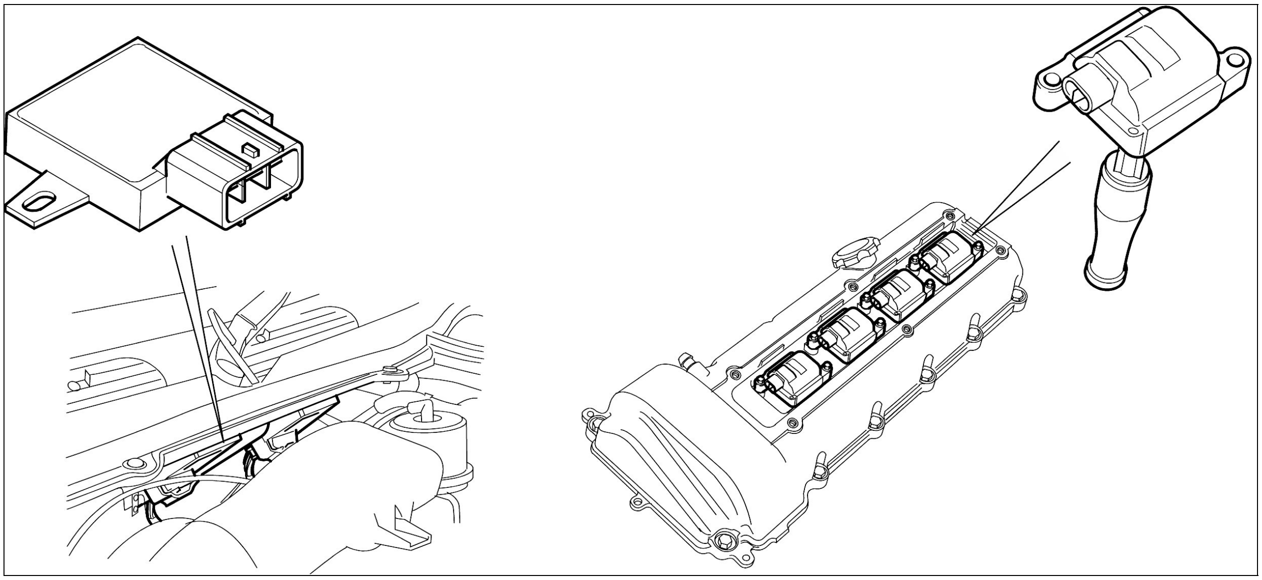

**Fig. 77 IGNITION COILS AND MODULES – XK8 AJ26**

**Ignition Coil-on-Plug Units – AJ27**

Each AJ27 coil-on-plug unit incorporates its own ignition module. The ignition modules are triggered directly from the ECM and drive the coil primary circuit, controlling current amplitude, switching point and dwell.

Each ignition module provides a monitor output to the ECM. When an ignition trigger signal is received, an acknowledge pulse is sent to the ECM if the current drive to the coil primary is satisfactory. This pulse is initiated when the current reaches 2 amps and is terminated at 4 amps.

If the trigger signal is not received or the coil current does not rise to 2 amps, the monitor line will remain at logic high, signaling an ignition failure to the ECM.

As with AJ26, two ignition monitor inputs (one per group of four ignition coils) are provided to the ECM. Ignition monitor circuits from cylinders 1A, 2B, 3B and 4A are spliced together; ignition monitor circuits from cylinders 1B, 2A, 3A and 4B are spliced together.

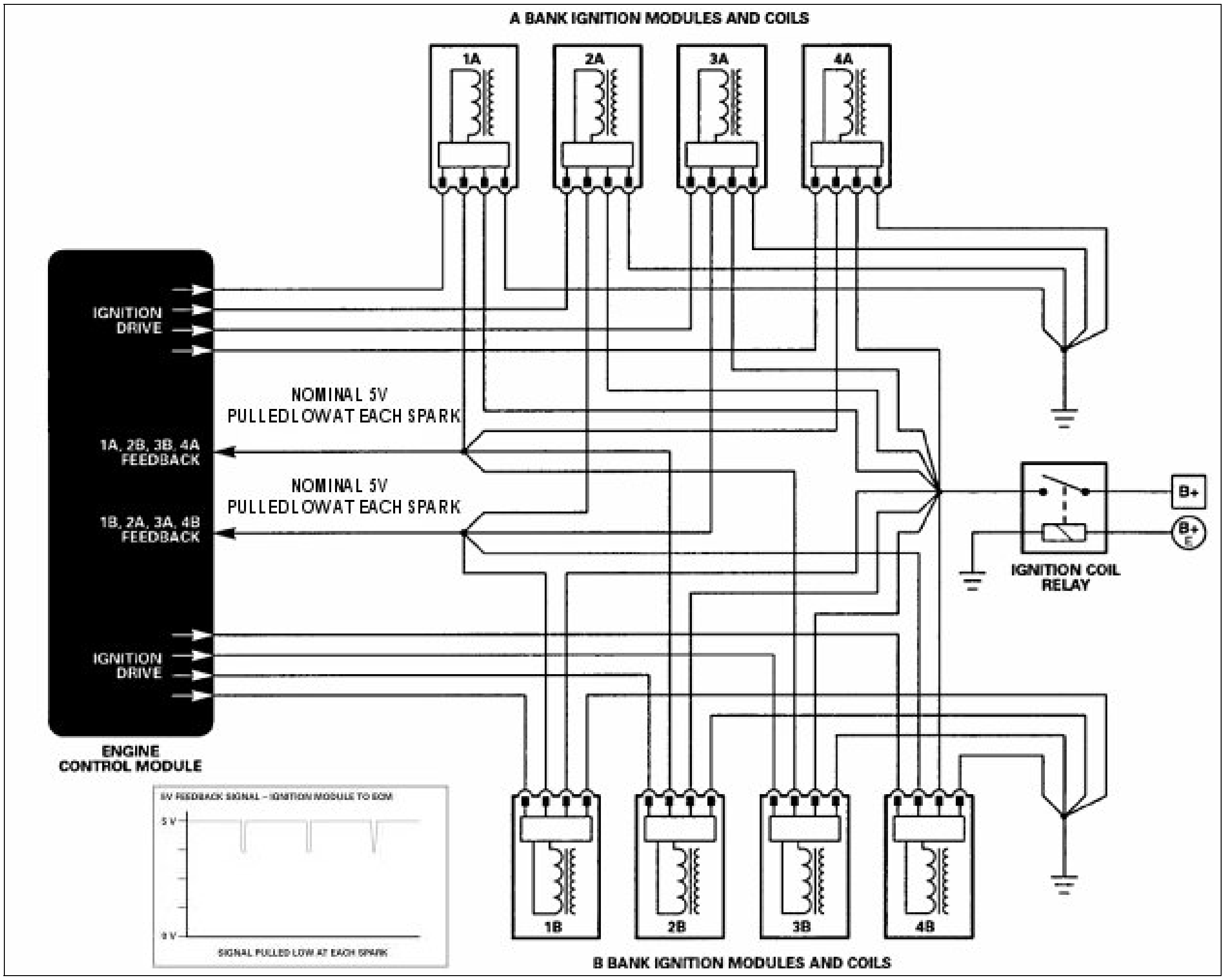


**Fig. 78 IGNITION ARRANGEMENT – AJ27**

### Ignition Knock (Detonation) Control

The ECM retards ignition timing to individual cylinders to control ignition knock (detonation) and optimize engine power. Two knock sensors (KS) are positioned on the cylinder block in the engine vee to sense engine detonation.

One KS is positioned on A bank and the other on B bank. Each knock sensor has a piezo electric sensing element to detect broad band (2 – 20 kHz) engine accelerations.

Knock control is active from 700 to 6800 RPM. If detonation is detected, the ECM uses the crankshaft position sensor (CKP) signal to determine which cylinder is firing, and retards the ignition timing for that cylinder only.

If, on the next firing of that cylinder, the detonation reoccurs, the ECM will further retard the ignition timing; if the detonation does not reoccur on the next firing, the ECM will advance the ignition timing incrementally with each firing.

The knock sensing ignition retard / advance process can continue for a particular cylinder up to a maximum retard of 9.4 degrees.

During acceleration at critical engine speeds, the ECM retards the ignition timing to prevent the onset of detonation. This action occurs independent of input from the knock sensors.

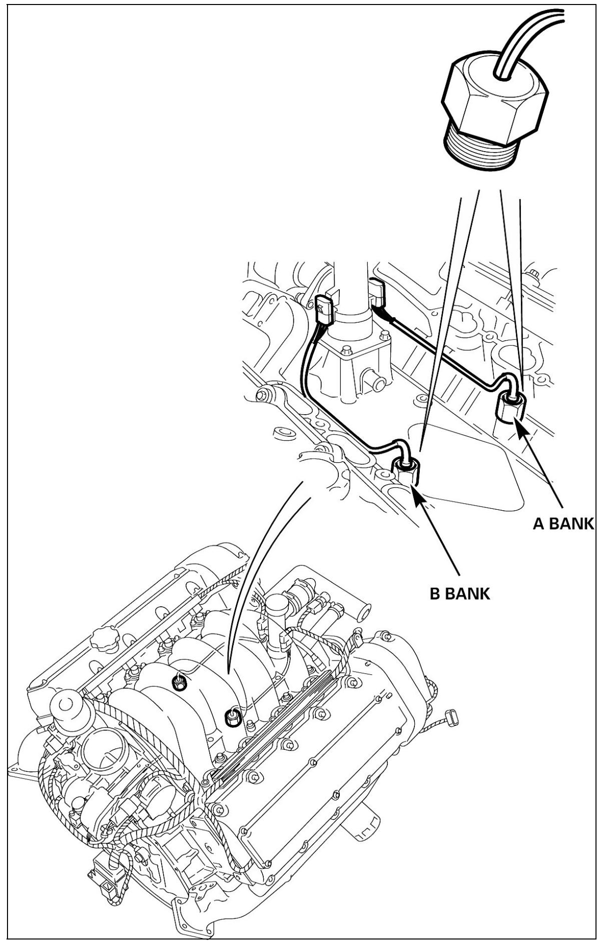


**Fig. 79 KNOCK SENSORS – AJ26**

**Knock Sensors (KS) – AJ27**

The AJ27 sensors are of an annular (doughnut) construction and are mounted via a stud and nut to the cylinder head. Torque accuracy at the specification of 20 NM is critical to knock sensor performance.

To improve cylinder identification, particularly at higher engine RPM, switched capacitive filters are incorporated in the ECM.

Knock sensing performance is further enhanced by the use of improved ECM signal processing software.

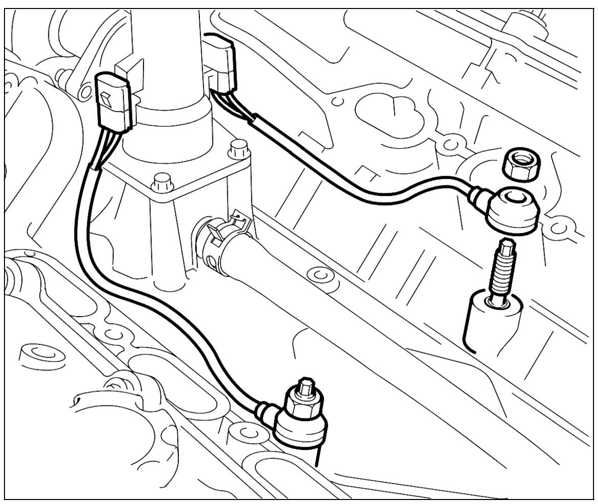

**Fig. 80 KNOCK SENSORS – AJ27**

## EXHAUST GAS RECIRCULATION (EGR)

**Exhaust Gas Recirculation – AJ26**

Exhaust gas recirculation (EGR) was fitted to 1997 model year XK8 vehicles and was deleted during the same model year.

**NOTE:**

EGR is fitted to AJ26 and AJ27 supercharged engines.

EGR is controlled by the ECM from a map that factors engine operating conditions such as engine load and speed, throttle position, and coolant temperature.

The EGR valve is mounted directly to the intake air induction elbow and connects to the A bank exhaust manifold by a transfer pipe. The EGR valve contains a four-pole stepper motor (60 step), which is driven by the ECM. Engine coolant returning from the throttle assembly is channeled through the valve to provide cooling.

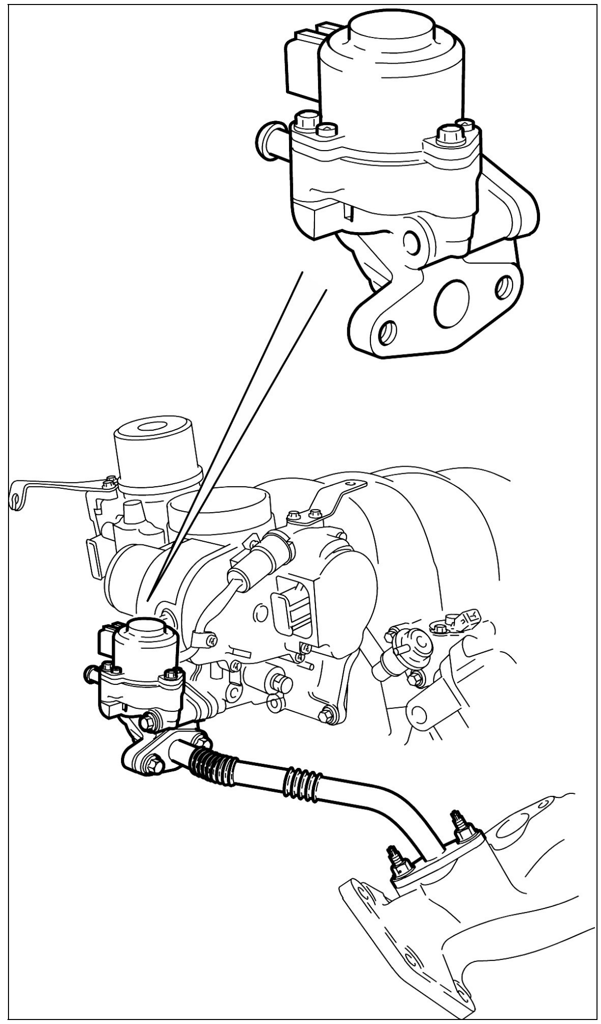

**Fig. 81 EGR VALVE – AJ26**

## VARIABLE VALVE TIMING

**Variable Valve Timing – AJ26**

The AJ26 two-position variable valve timing (VVT) system improves low and high speed engine performance, idle quality, and exhaust emission. VVT is a two-position system that operates on the intake camshafts only.

There are 30° of crankshaft rotation between the retarded and the advanced positions. The system is operated by engine oil pressure under the control of the ECM. The VVT hardware associated with each intake camshaft includes:

- Valve timing unit
- Bush carrier assembly
- Valve timing solenoid

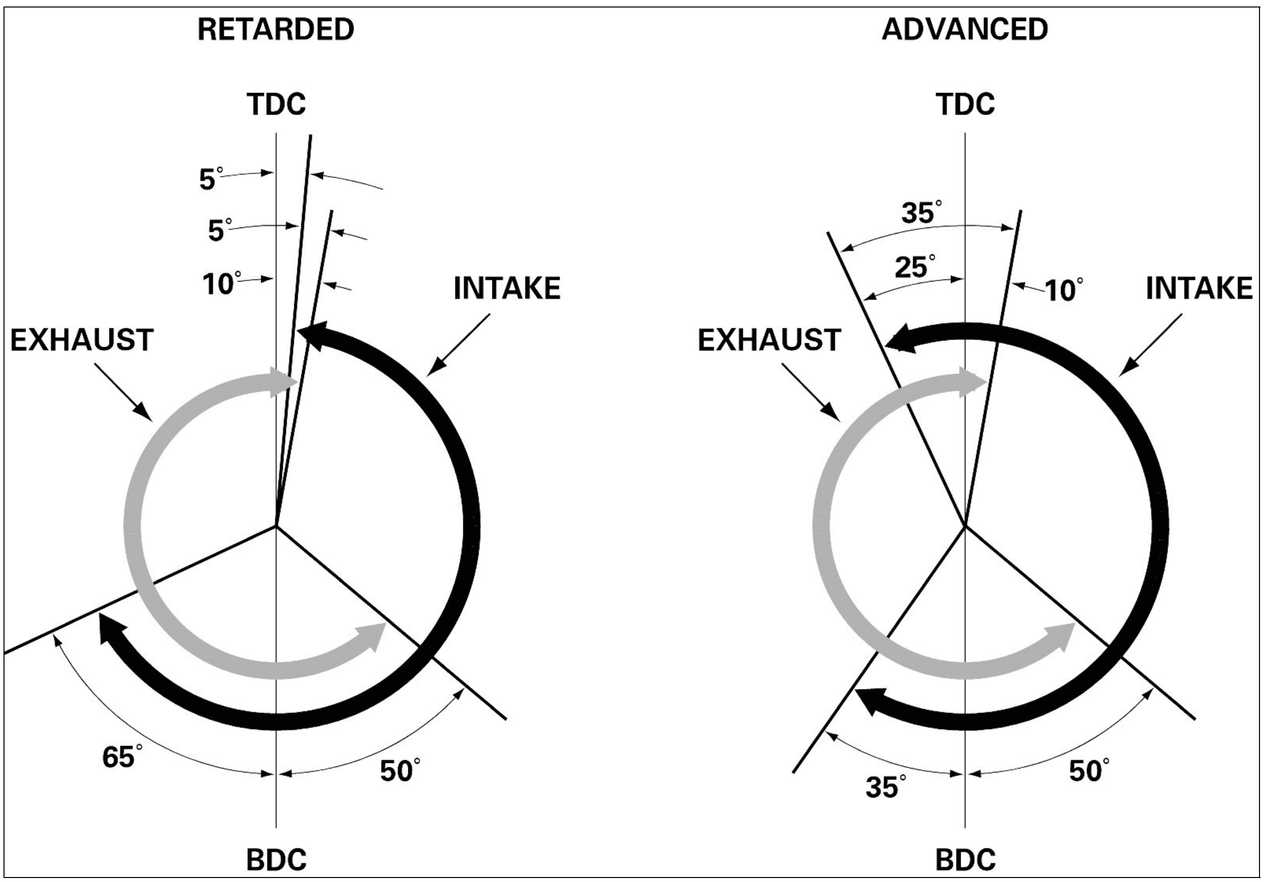


**Fig. 82 VARIABLE VALVE TIMING – AJ26 (CRANKSHAFT ROTATION SHOWN)**

**Valve Timing Unit**

The valve timing unit rotates the intake camshaft in relation to the primary chain to advance or retard the intake valve timing.

The unit is made up of a body and sprocket assembly separated from an inner sleeve by a ring piston and two ring gears.

A bolt secures the inner sleeve to the camshaft, and the outer ring gear is bolted to the cam drive sprocket. The outer ring gear engages in opposing helical splines on the outer circumference of the drive ring and piston assembly, and the inner circumference of the piston assembly engages with the sleeve.

The ring gears transmit the drive from the body and sprocket assembly to the inner sleeve and, when moved axially, rotate the inner sleeve in relation to the body and sprocket assembly.

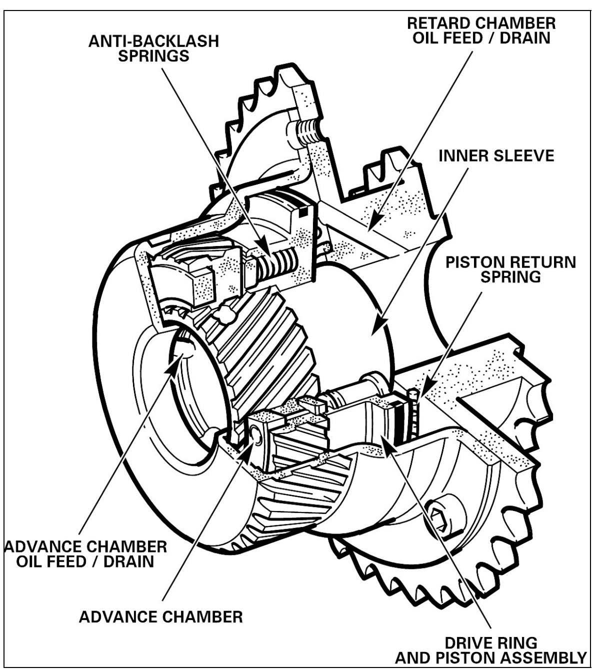


**Fig. 83 VALVE TIMING UNIT – AJ26**

Engine oil pressure ported by the valve timing solenoid moves the ring gears and piston to rotate the inner sleeve in the advance timing direction. A return spring moves the ring gears and piston to rotate the inner sleeve in the retard timing direction.

A series of small springs absorb backlash to reduce noise and wear. The springs between the ring gears absorb rotational backlash. The springs between the inner sleeve and the end of the body and sprocket assembly absorb axial backlash.

**Bush Carrier**

The bush carriers contain oil passages that link the engine oil supply to the valve timing unit.

The integral shuttle valve, connected to the valve timing solenoid and biased by a coil spring, controls the flow of oil through the passages.

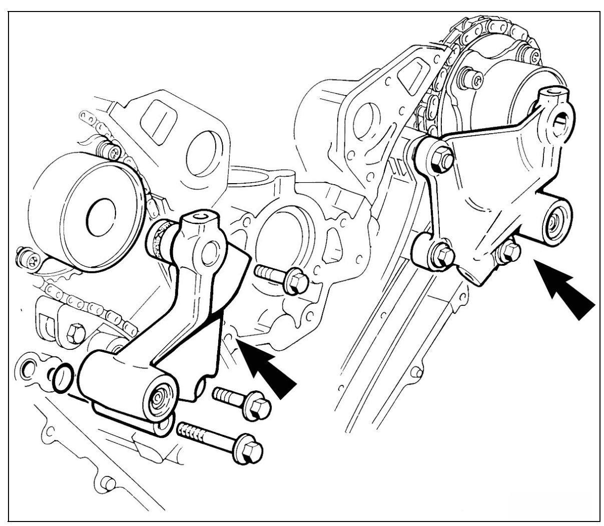

**Fig. 84 BUSH CARRIERS – AJ26**

**Valve Timing Solenoid**

The valve timing solenoid positions the shuttle valve in the bush carrier. A plunger on the solenoid extends a minimum of 6.8 mm (0.28 in.) when the solenoid is energized and retracts when the solenoid is de-energized.

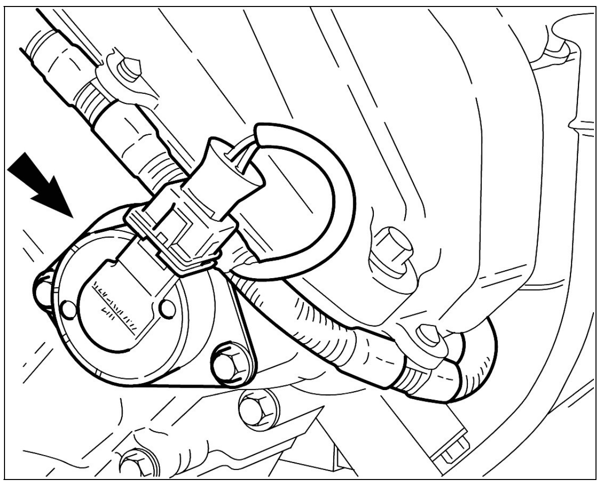

**Fig. 85 VALVE TIMING SOLENOID – AJ26**

**VVT Mechanical Operation**

Intake valve timing retarded — When the valve timing solenoids are de energized, the coil springs in the bush carriers position the shuttle valves to port the valve timing units to drain. The valve timing units return springs hold the ring pistons and gears in the retarded position.

Intake valve timing advanced — When the valve timing solenoids are energized, the solenoid plungers position the shuttle valves to port pressurized engine lubricating oil to the valve timing units.

The oil pressure moves the gears and ring pistons to the advanced position. System response times are 1 second maximum for advance, 0.7 second maximum for retard.

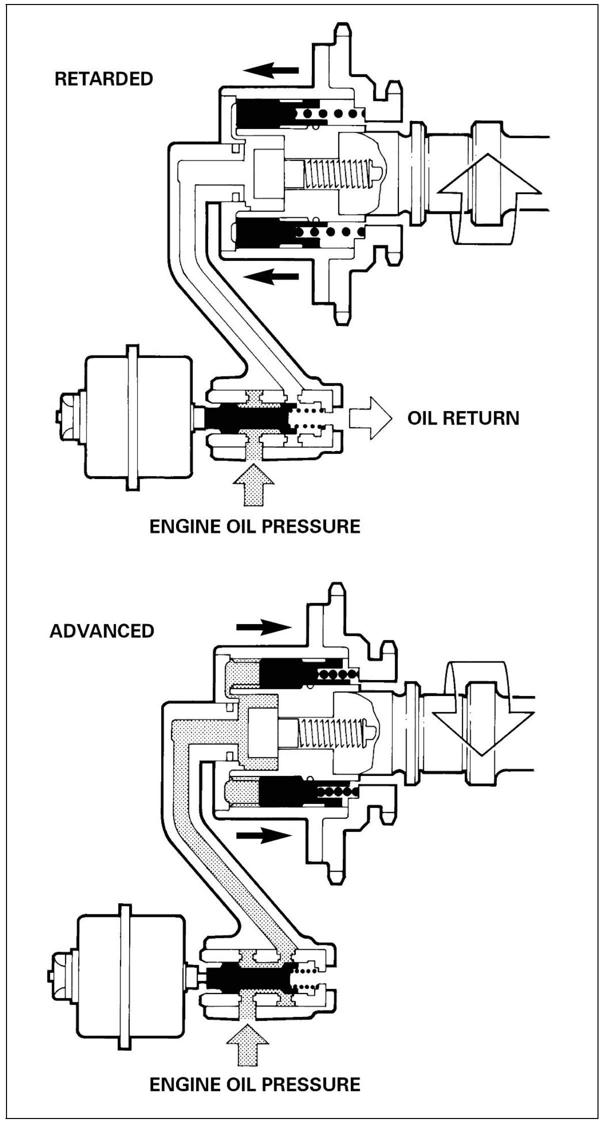


**Fig. 86 VARIABLE VALVE TIMING OPERATION – AJ26**

**ECM VVT Control**

The ECM switches the valve timing solenoids to advance / retard intake valve timing based on a map of engine load and speed.

The map incorporates both engine load and speed "hysteresis" (overlap) to prevent "hunting". Between 1250 and 4500 rpm (nominal), at engine load greater than approximately 25%, the intake valve timing is advanced.

The intake valve timing is retarded at low engine speed and at high engine speed. VVT is inhibited (intake valve timing remains retarded) at engine coolant temperatures less than -10 °C (14 °F).

While the valve timing is retarded, the ECM periodically drives the valve timing solenoid open with a momentary pulse.

This momentary pulse occurs every five minutes, and allows oil flow to the valve timing units to prevent wear. It is possible to hear the lubrication pulse with the engine running and the hood open.

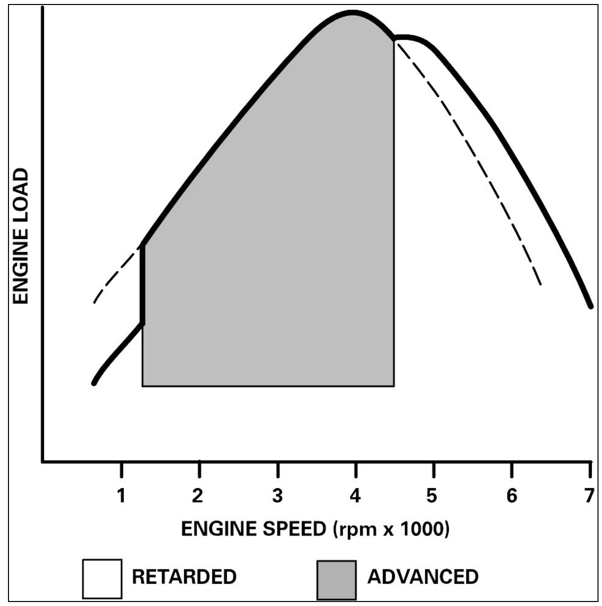


**Fig. 87 VVT MAP**

**Linear Variable Valve Timing – AJ27**

The AJ27 Linear VVT system provides continuously variable inlet valve timing over a crankshaft range of 48° ± 2°. Depending on driver demand and engine speed / load conditions, the inlet valve timing is advanced or retarded to the optimum angle within this range.

Compared to the two position system used on AJ26, inlet valve opening is advanced by an extra 8°, providing greater overlap and increasing the internal EGR effect (exhaust gases mixing with air in the inlet port).

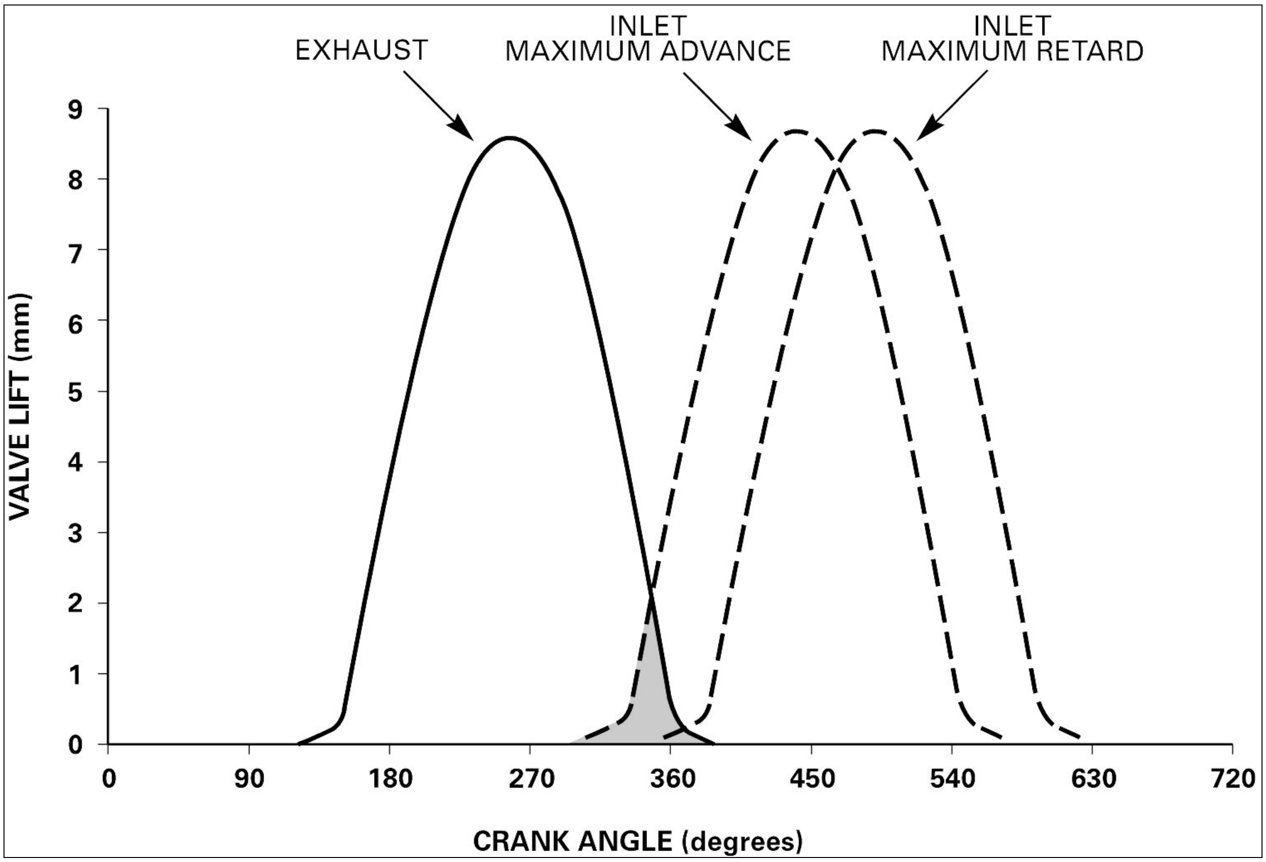


**Fig. 88 LINEAR VVT – AJ27**

The linear VVT system provides a number of advantages:

- Improves internal EGR, further reducing NOx emissions and eliminating the need for an external EGR system
- Optimizes torque over the engine speed range without the compromise of the two-position system: note that specified torque and power figures are unchanged
- Improves idle quality: the inlet valve opens 10° later, reducing valve overlap and thus the internal EGR effect (undesirable at idle speed)
- Faster VVT response time
- VVT operates at lower oil pressure

**Linear VVT Components**

Each cylinder bank has a VVT unit, bush carrier and solenoid operated oil control valve which are all unique to the linear VVT system.

The VVT unit consists of an integral control mechanism with bolted on drive sprockets, the complete assembly being non-serviceable. The unit is fixed to the front end of the inlet camshaft via a hollow bolt and rotates about the oil feed bush on the bush carrier casting. The bush carrier is aligned to the cylinder head by two hollow spring dowels and secured by three bolts.

The oil control valve fits into the bush carrier to which it is secured by a single screw. The solenoid connector at the top of the valve protrudes through a hole in the camshaft cover but the cover must first be removed to take out the valve.

Engine oil enters the lower oil way in the bush carrier (via a filter) and is forced up through the oil control valve shuttle spools to either the advance or retard oilway and through the bush to the VVT unit. Oil is also returned from the VVT unit via these oilways and the control valve shuttle spools, exiting through the bush carrier drain holes.

**NOTE:**

Only the bush carriers are left- and right-handed.

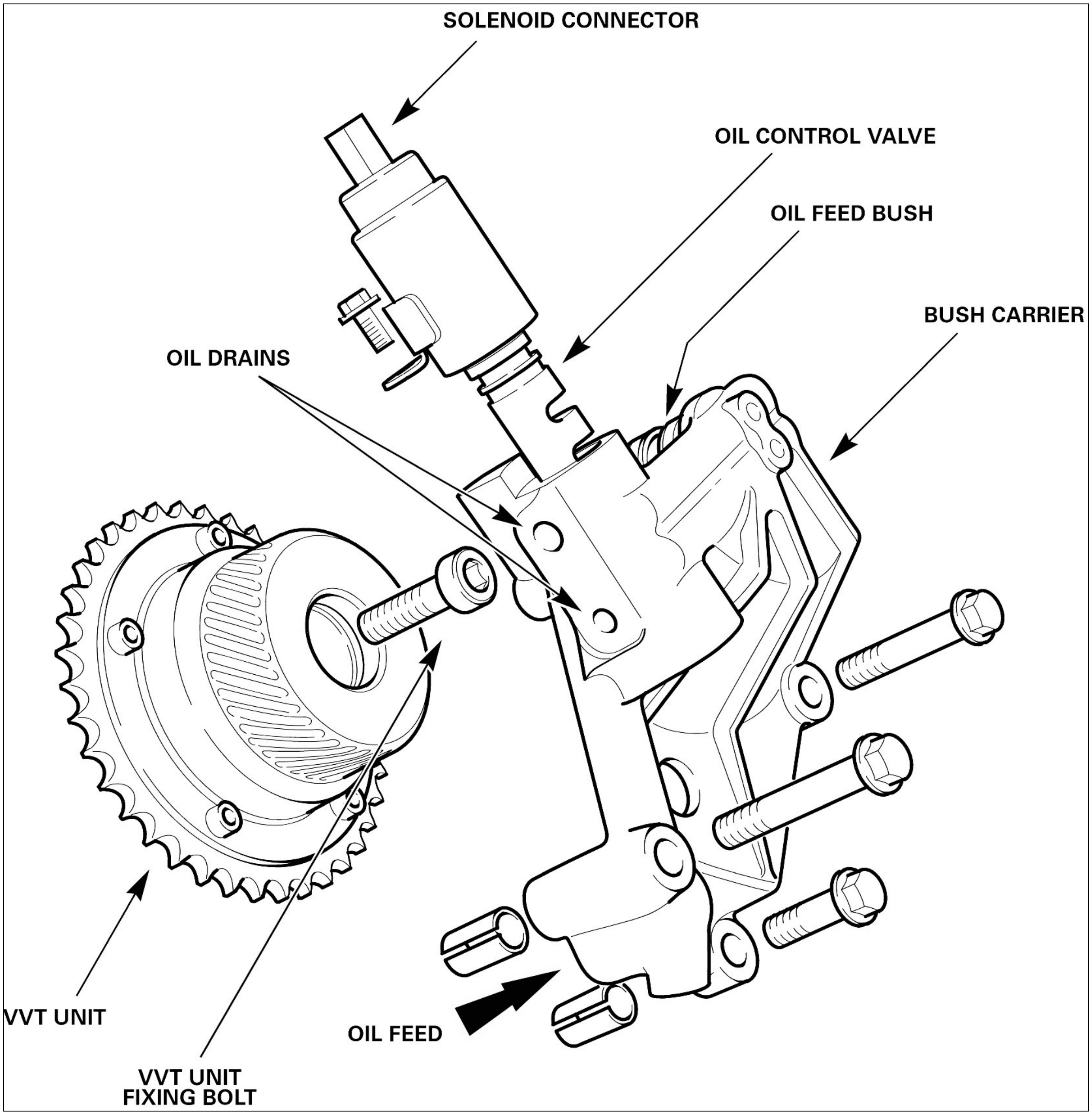


**Fig. 89 LINEAR VVT COMPONENTS – AJ27**

**Linear VVT unit**

The VVT unit transmits a fixed drive via the secondary chain to the exhaust camshaft. The inlet camshaft is driven from the body of the unit via internal helical splines. When commanded from the ECM this mechanism rotates the inlet camshaft relative to the body/sprocket assembly to advance or retard the valve timing.

The VVT unit has three main parts: the body/sprocket assembly, an inner sleeve bolted axially to the nose of the camshaft and a drive ring/piston assembly located between the body and inner sleeve and coupled to both via helical splines.

The basic operation is similar to that of the two position unit: oil pressure applied in the advance chamber forces the drive ring/piston assembly to move inwards along its axis while rotating clockwise on the helical body splines. Since the drive ring is also helically geared to the inner sleeve but with opposite angled splines, the inner sleeve is made to rotate in the same direction, turning the camshaft.

The use of opposing helical gears (the angle is more acute than in the two position unit) produces a relatively large angular rotation for a small axial movement, thus keeping the VVT unit to a compact size. Note that the inner sleeve does not move axially.

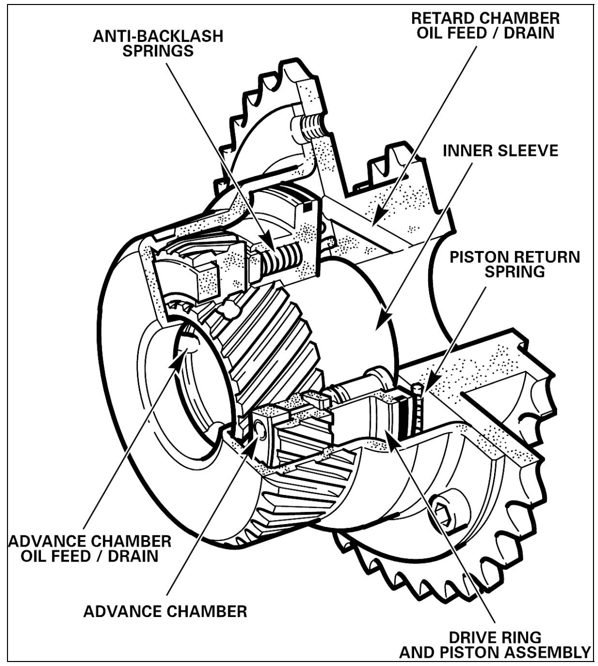


**Fig. 90 LINEAR VVT OIL CONTROL — RETARD**

To move back to a retard position, oil pressure is switched to the retard chamber and the piston and rotational movements are reversed. The use of oil pressure to move the piston in both directions eliminates the need for a return spring for VVT operation (as in the two position system). However, a lighter pressure spring is fitted in the retard chamber to assist the piston assembly to revert to the fully retarded position with the engine stopped.

Note that rotating the engine backwards from the stopped position will cause the VVT unit body to move relative to the camshaft, advancing the timing. To avoid the possibility of incorrect timing being set after any associated service work, reference must be made to JTIS for the correct procedures.

Due to the use of bidirectional oil pressure actuation and light spring pressure, a much lower oil pressure is required to advance the VVT unit, making its operation more consistent at high oil temperatures/low engine speed. Also, response times to move in the advance direction are reduced by approximately 50% compared with the two position actuator.

**Linear VVT Oil Control – Advance**

To fully advance the cams, the solenoid is energized pushing the shuttle valve down. This action causes the incoming oil feed to be directed through the lower oilway in the bush carrier and into the advance oil chamber where it pushes on the piston/drive ring assembly.

Oil is channeled through the hollow VVT fixing bolt and via oilways in the camshaft and sprocket unit to the retard chamber where it acts on the moveable piston/drive ring assembly. As the piston moves, oil is forced from the advance chamber back through the shuttle valve to the engine.

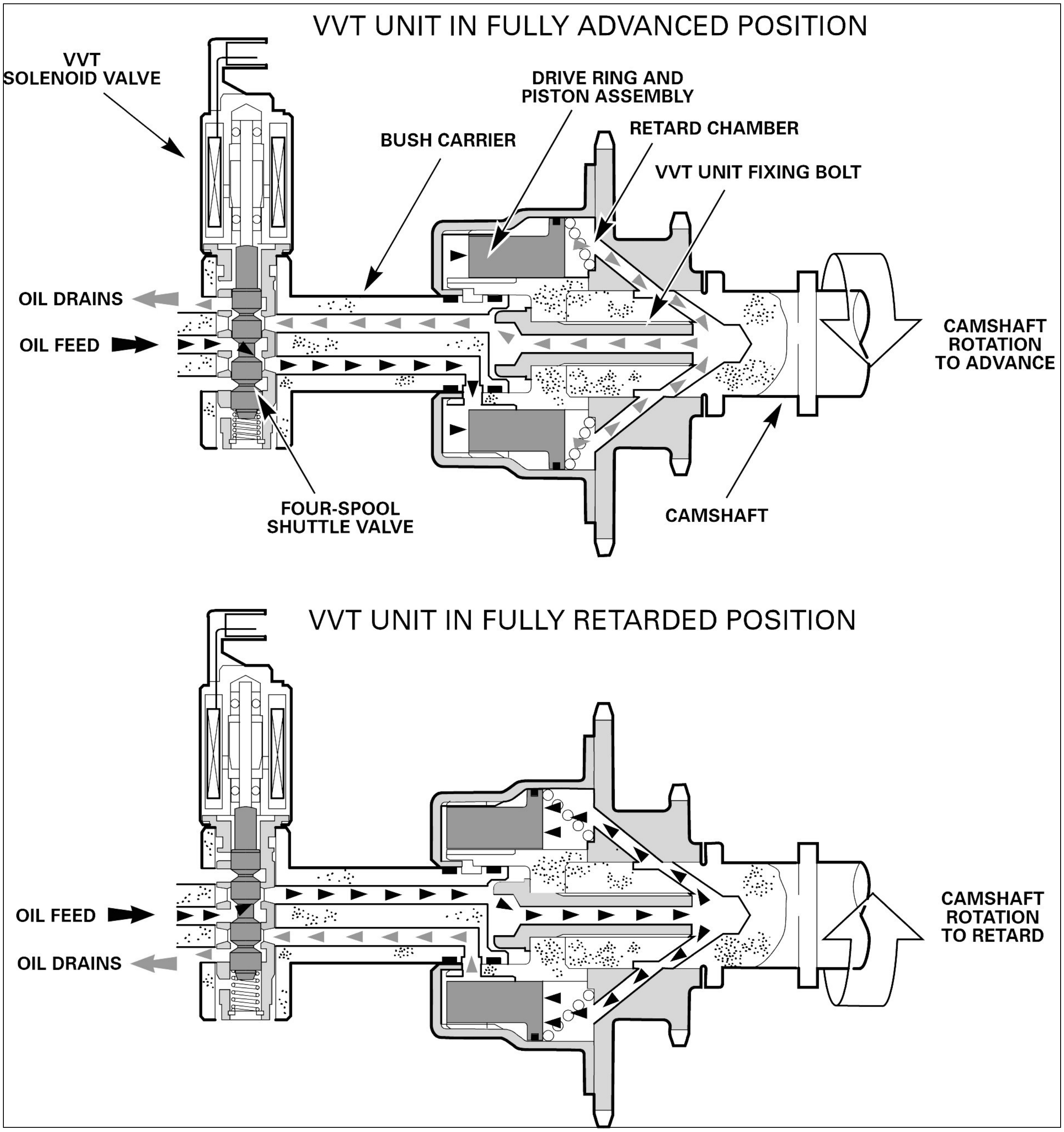


**Fig. 91 LINEAR VVT OIL CONTROL – AJ27**

**Closed loop control**

Continuously variable timing requires the VVT piston to be set to the optimal position between full advance and retard for a particular engine speed and load. The ECM positions the shuttle valve using a PWM control signal operating at a frequency of 300 Hz.

The shuttle valve assumes a position between the limits of travel proportional to the “duty cycle” of the signal. An increasing duty cycle causes an increase in timing advance.

The shuttle valve is continuously controlled by the ECM to maintain a given cam angle. The actual position of the inlet camshafts is monitored by a magnetic sensor which generates pulses from the toothed sensor ring keyed on to the end of the inlet camshaft and transmits them to the ECM. If a difference is sensed between the actual and demanded positions, the ECM will attempt to correct it.

The new cam sensor fitted to the A bank allows each bank to have its own feedback loop. The four tooth cam sensor rings increase the cam position feedback frequency, providing the enhanced control required by the new VVT system. The use of four-tooth sensor rings also improves starting.

**Engine oil temperature**

Engine oil properties and temperature can affect the ability of the VVT mechanism to follow demand changes to the cam phase angle. At very low oil temperatures, movement of the VVT mechanism is sluggish due to increased viscosity and at high temperatures the reduced viscosity may impair operation if the oil pressure is too low.

The VVT system is normally under closed loop control except in extreme temperature conditions such as cold starts below 0 °C (32 °F). At extremely high oil temperatures, the ECM may limit the amount of VVT advance to prevent the engine stalling when returning to idle speed. This could occur because of the slow response of the VVT unit to follow a rapid demand for speed reduction. Excessive cam advance at very light loads produces high levels of internal EGR which may result in unstable combustion or misfires.

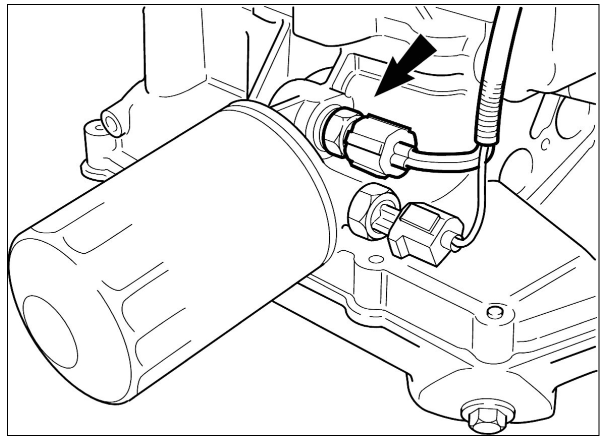

**Fig. 92 EOT – AJ27**

**Engine oil temperature sensor (EOT) — (AJ27)**

The EOT is a thermistor which has a negative temperature coefficient (NTC). Engine oil temperature is calculated by the ECM by changes in sensor resistance. The sensor is located on the engine block directly above the oil pressure switch.

The ECM applies 5 volts to the sensor and monitors the voltage across the pins to detect the varying resistance. The ECM uses the EOT signal for variable valve timing control.

## OTHER ECM CONTROL AND INTERFACE FUNCTIONS

### Engine Cranking / Starting (Normally Aspirated Engines)

When the ignition is switched ON (position II) and the transmission manual valve is in Park or Neutral, the ECM enables fuel injection and ignition, and outputs a "security acknowledge" encoded signal to the BPM. The Park / Neutral signal is received via the hard wired circuit from the transmission rotary switch. If the BPM receives a Park / Neutral signal from the gear selector neutral switch, it in turn, enables engine cranking.

When the ignition key is moved to CRANK (position III) and the gear selector is in Park or Neutral, the BPM drives the starter relay to crank the engine. The ECM receives a "cranking" signal from the BPM / starter relay drive circuit. The ECM initiates engine start EMS values for the duration of the cranking signal.

**NOTE:**

**Supercharged engines**
Both Park and Neutral signals are supplied from the dual linear switch located at the J-gate.

### Vehicles without Key Transponder Module (KTM) (1997 Model Year)

If the transmission manual valve is not in Park or Neutral (rotary switch signal) at ignition ON, the ECM inhibits fuel injection and ignition, and does not transmit the "security acknowledge" signal to the BPM.

### Vehicles with Key Transponder Module (KTM)

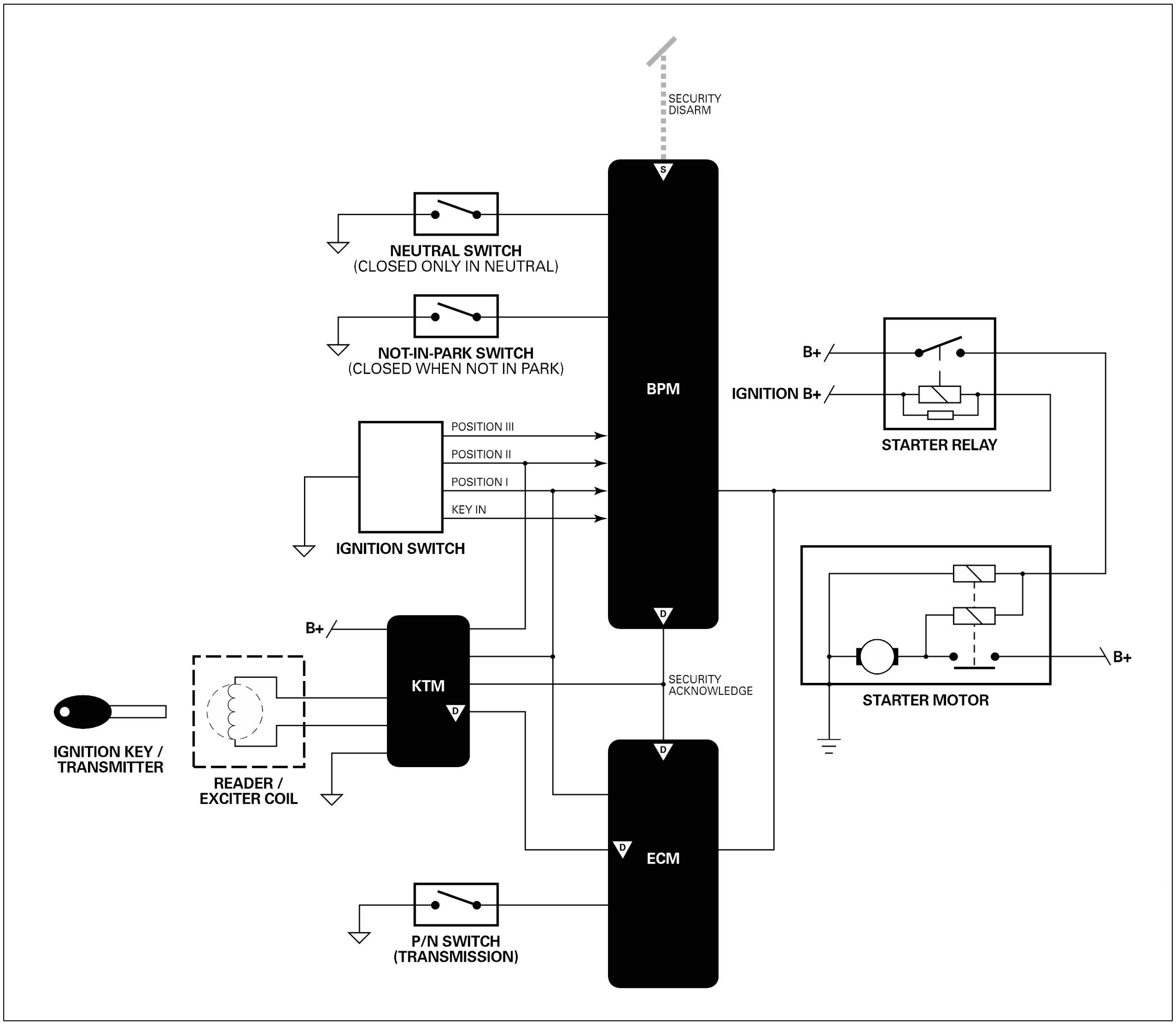


**Fig. 93 ENGINE CRANKING / STARTING with KTM**

The BMP will not allow the starter motor to crank if it does not receive the “security acknowledge” signal from the ECM. There are two situations for which the ECM will inhibit fuel injection, ignition, and the communication of the security acknowledge signal. If the KTM does not transmit an encoded “security acknowledge” signal to the ECM, the ECM will inhibit starting. Also, if the transmission manual valve is not in Park or Neutral (as indicated by the rotary switch signal) at ignition ON, the ECM will also inhibit starting, and withhold the transmission of the “security acknowledge” signal.

**Radiator Cooling Fan Control**

The ECM controls the radiator cooling fan operation. Using inputs from the air conditioning refrigerant four-way pressure switch and the ECT, the ECM drives the fans in series (low speed) or in parallel (high speed).

The four-way pressure switch contains a 12 bar (174 psi) switch element and a 22 bar (319 psi) switch element connected to the ECM. A two-pressure (2–30 bar) switch element signals the A/CCM for compressor operation. If A/C pressure is outside 2–30 bar, compressor operation is inhibited.

As the ECM switches the fans, “hysteresis” or overlap between switch on / switch off prevents “hunting” between the fan modes.

**Table 12**

| Radiator Fan Switching Points | | | | |
|---|---|---|---|---|
| **Mode** | **Engine coolant temperature** | | **Refrigerant pressure** | |
| | **ON** | **OFF** | **ON** | **OFF** |
| SLOW (SERIES) | 90 °C (194 °F) | 86 °C (187 °F) | 12 bar (174 psi) | 8 bar (116 psi) |
| FAST (PARALLEL) | 97.5 °C (207.5 °F) | 93.5 °C (200.5 °F) | 22 bar (319 psi) | 17.5 bar (254 psi) |

If the fans are operating when the engine is switched off, the ECM continues to drive the fans for up to five minutes or until the engine coolant temperature has fallen to a predetermined value, whichever occurs first.

If the fans are off when the engine is switched off and the coolant temperature rises to the switch-on point during the brief period that the ECM remains powered to complete throttle adaptations, the fans will switch on and continue to operate for up to five minutes, or until the engine coolant temperature has fallen to a predetermined value, whichever occurs first.

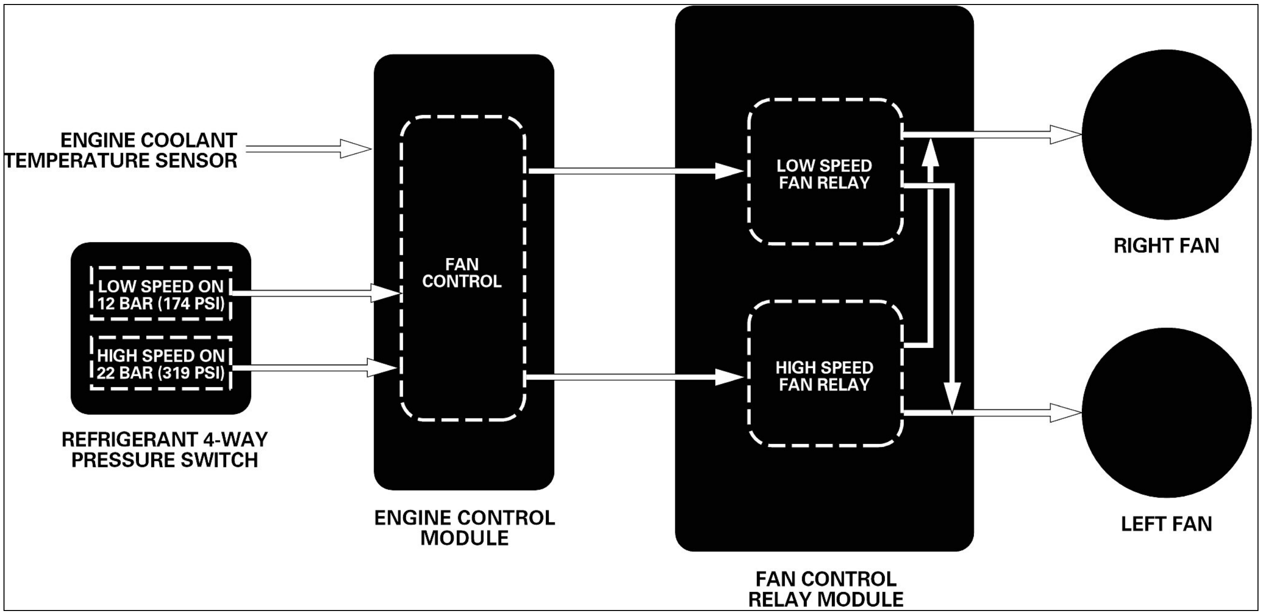


**Fig. 94 RADIATOR COOLING FAN CONTROL**

### Air Conditioning Compressor Clutch Control

The ECM controls the operation of the air conditioning compressor clutch to prevent idle instability and over heating. The air conditioning control module (A/CCM) determines when compressor clutch operation is required and signals the ECM via the A/C compressor clutch request hard wire circuit.

Depending on the engine operating conditions, the ECM drives the air conditioning compressor clutch relay to operate the air conditioning compressor. The A/CCM receives confirmation that the compressor is operating from the clutch relay parallel power circuit.

Engine conditions for compressor ON:

- Engine not at idle*
- Engine coolant temperature not greater than a programmed high temperature
- Throttle valve less than full load (WOT)

**NOTE:**

*Engine at idle – There is a momentary delay (approximately 50 ms) before the ECM drives the compressor clutch relay. This delay allows the ECM to compensate the idle speed for the impending high load.

Engine conditions for compressor OFF:

- Engine coolant temperature greater than a programmed high temperature
- Throttle valve at full load (WOT)

When the compressor clutch operation is inhibited, the ECM outputs a load inhibit signal to the A/CCM via the load inhibit hard wire circuit.

**Windshield and Backlight Heaters Control**

The ECM can also inhibit the operation of the windshield and backlight heaters to prevent idle instability. When the driver selects the heaters ON, the A/CCM signals the ECM for permission to switch ON the heaters via the electrical load request hard wire circuit.

Depending on the engine operating conditions, the ECM inhibits heater operation by outputting a load inhibit signal to the A/CCM via the load inhibit hard wire circuit.

Engine conditions for heaters ON:

- Engine not at idle*
- Engine coolant temperature not greater than a programmed high temperature
- Throttle valve less than full load (WOT)

**NOTE:**

*Engine at idle – There is a momentary delay (approximately 50 ms) before the ECM cancels the load inhibit signal. This delay allows the ECM to compensate the idle speed for the impending high load.

Engine conditions for heaters inhibited:

- Engine coolant temperature greater than a programmed high temperature
- Throttle valve at full load (WOT)

When the heaters are inhibited, the ECM outputs a load inhibit signal to the A/CCM via the load inhibit hard wire circuit.

## AJ26 / AJ27 SUPERCHARGED EMS

**AJ V8 Supercharged Engine**

The AJ V8 supercharged (SC) engine is mechanically similar to the normally aspirated engine with the exception of the pistons, the cylinder head gaskets and the repositioning of components to allow installation of the supercharger system. The normally aspirated intake manifold and induction elbow are replaced with unique supercharged components.

The supercharger is an Eaton M112 unit mounted in the engine vee, driven by a separate poly v-belt from the crankshaft. Supercharger lubrication is "filled for life". If servicing of the lubricant is required, the supercharger must be removed from the engine. The maximum boost pressure is 0.8 bar (11.6 psi).

Intake air flows through a revised mass air flow sensor (MAF), through the intake duct, the electronic throttle assembly and the induction elbow to the supercharger. The AJ26 SC throttle assembly is unchanged from the normally aspirated system with EGR.

The AJ27 SC throttle deletes AAI and adds EGR. A bypass valve attaches to the induction elbow. From the supercharger, compressed intake air flows through the outlet duct to the individual A and B bank air-to- liquid charge air coolers, then through the A and B bank charge air cooler adapters to the cylinder heads.

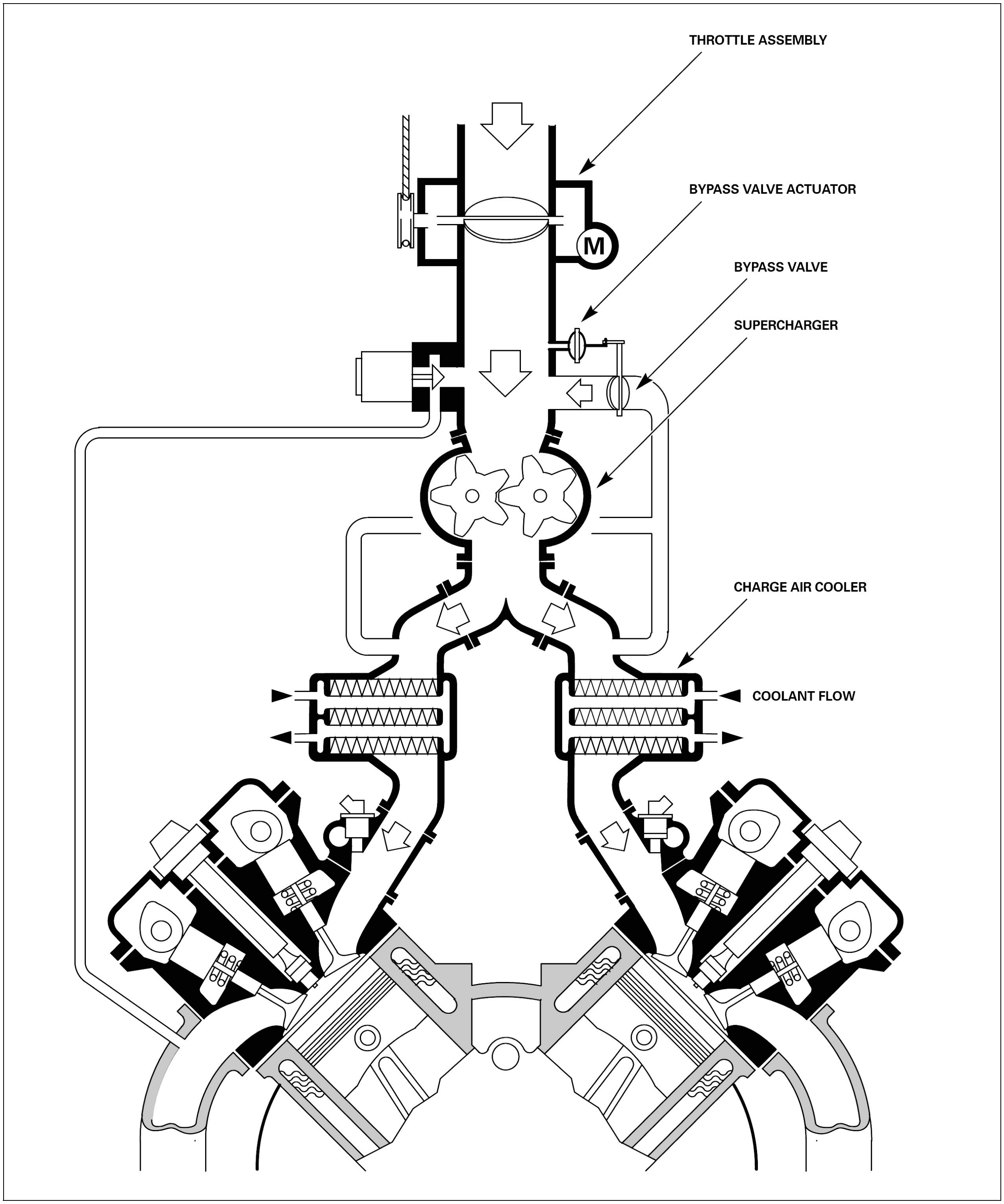


**Fig. 95 SUPERCHARGED INTAKE SYSTEM**

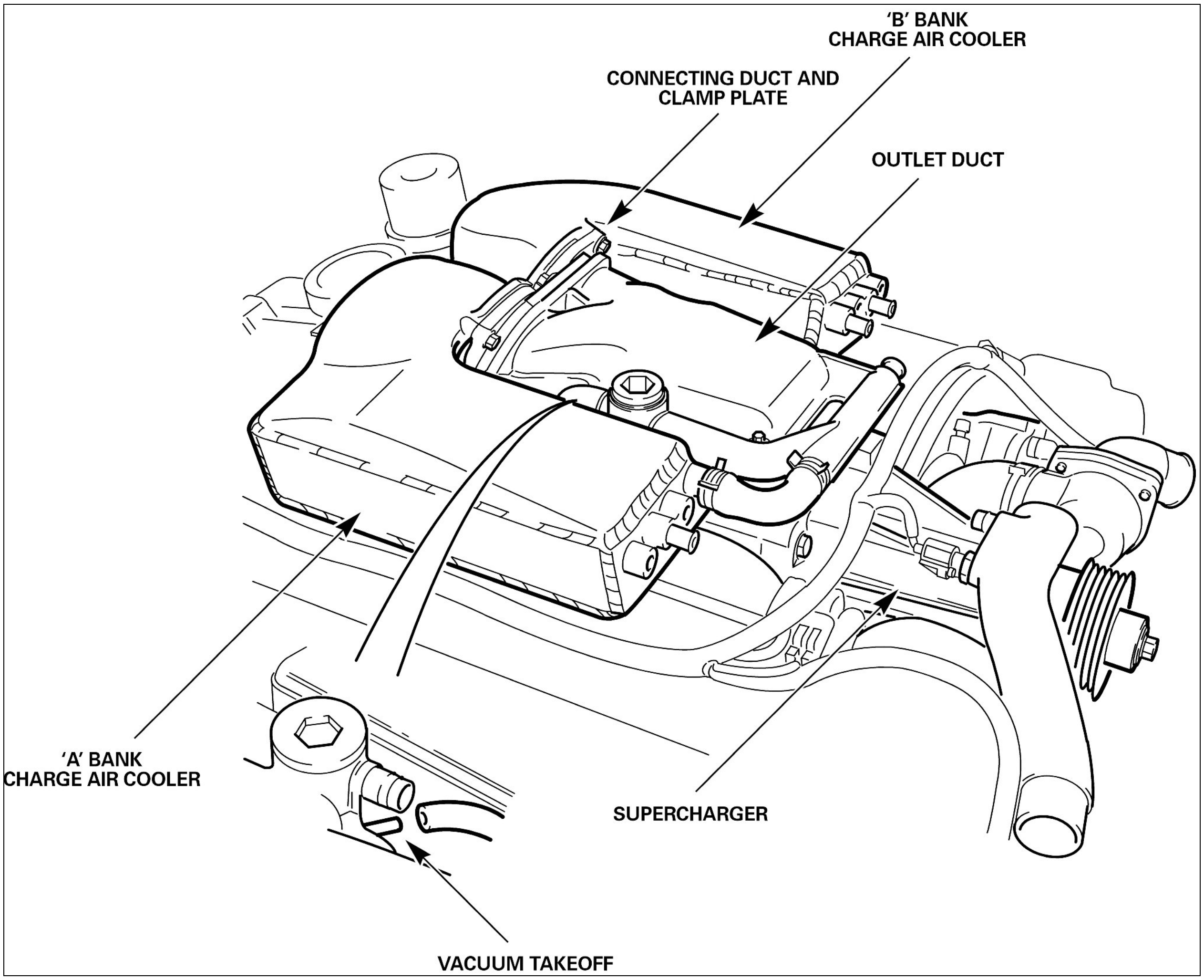


**Fig. 96 SUPERCHARGER EMS COMPONENTS**

**Bypass Valve and Actuator**

The "butterfly" bypass valve is contained in a housing attached to the induction elbow. The valve is operated by a vacuum actuator. The valve controls bypass air flow from the charge air coolers to the induction elbow in order to regulate supercharger "boost pressure". The valve is held closed by spring pressure.

With closed (idle) or partially open (cruise) throttle, intake vacuum (between the induction elbow and the supercharger) acts on the actuator diaphragm to hold the valve full open to provide maximum supercharger bypass and optimum fuel economy. As the throttle is opened, intake vacuum falls progressively and spring force moves the valve toward closed until the valve is fully closed at full throttle, providing maximum supercharger boost and power.

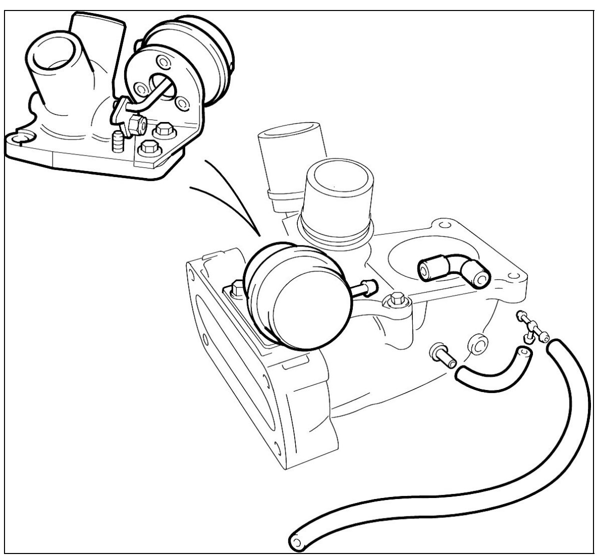

**Fig. 97 BYPASS VALVE AND ACTUATOR – AJ26**

**Outlet Duct**

The supercharger outlet duct directs the charge air from the supercharger to the two charge air coolers. The fill point and connections for the charge air cooler coolant circuit are integrated into the outlet duct. A vacuum source is provided for the fuel pressure regulator and for cruise control. Rubber ducts secured by clamp plates connect the outlet duct to the two charge air coolers.

**Charge Air Coolers**

Each cylinder bank has a separate charge air cooler assembly. The charge air coolers are fabricated fin and tube air-to- liquid heat exchangers with individual "risers" to supply charge air to each cylinder. The charge air coolers cool the charge air leaving the supercharger to increase the mass of the air entering the engine. Coolant flow is provided by a separate cooling system with an electric pump under ECM control.

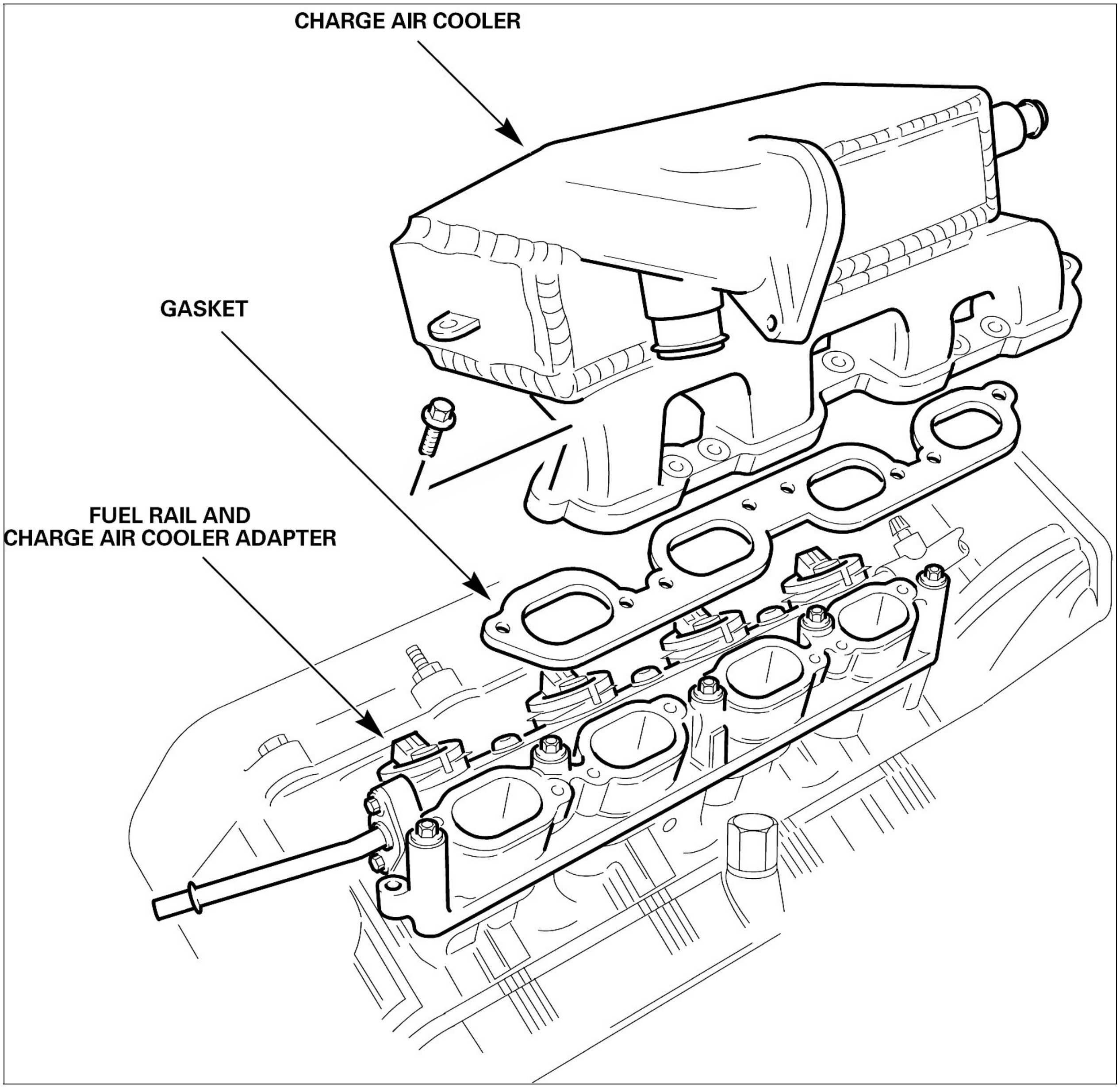


**Fig. 98 SUPERCHARGER CHARGE AIR COOLER, ADAPTER AND FUEL RAIL**

**Charge air cooler adapters / fuel rails**

The charge air cooler adapters provide the interface between the charge air coolers and the cylinder heads, and incorporate the fuel rails and fuel injector mountings. A crossover pipe connects the fuel rails.

**Fuel Injectors**

The fuel injectors are high flow units designed for the supercharged engine. They are secured in the fuel rails by spring clips.

**Charge Air Cooler Radiator and Pump**

The charge air cooler radiator is mounted ahead of the engine radiator and incorporates a bleed outlet and a purge cock.

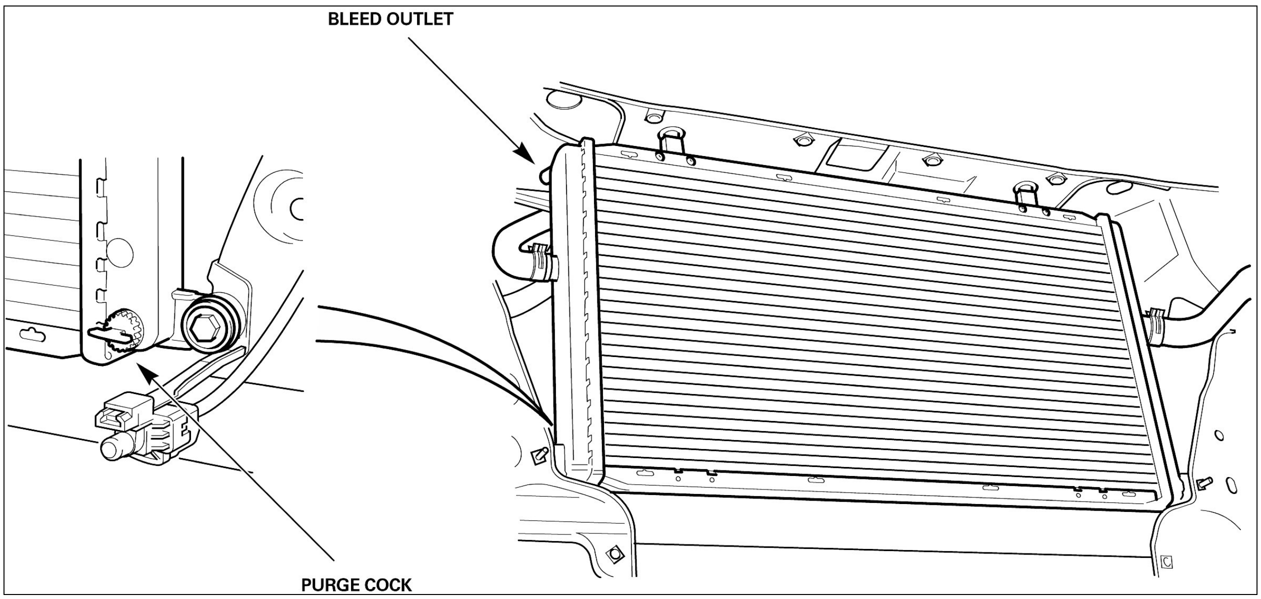


**Fig. 99 CHARGE AIR COOLER RADIATOR**

**Charge Air Cooler Coolant Pump**

The charge air cooler coolant pump is activated via a relay under ECM control. During normal conditions, the ECM operates the pump continuously with the ignition switched ON.

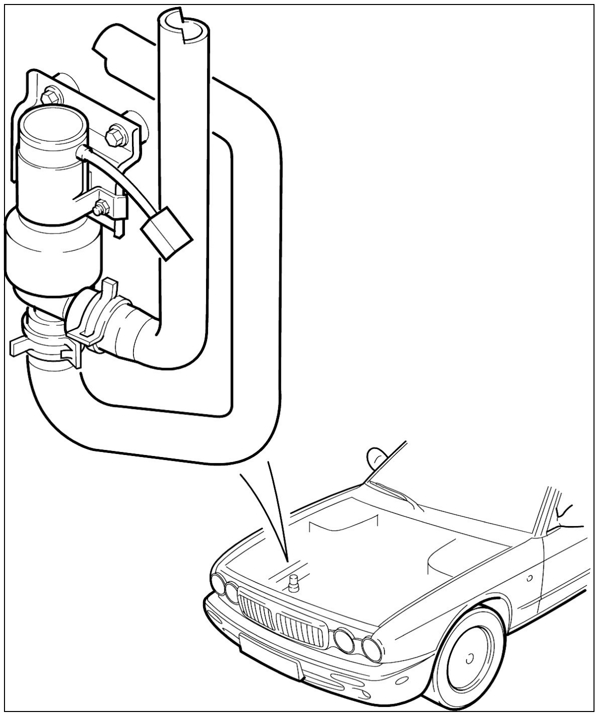

**Fig. 100 CHARGE AIR COOLER AND PUMP**

### AJ26 / AJ27 SUPERCHARGED EMS

The supercharged Engine Management System is essentially identical to the normally aspirated system with software revisions to accommodate the operating characteristics of the supercharged engine. Additional functions for operating two fuel pumps, the charge air cooler coolant pump, and EGR are included. Variable valve timing and air assisted fuel injection (AJ27) are deleted.

**Components / Functions deleted for Supercharged Engine Management:**

- Variable valve timing
- Air assisted fuel injection (AJ27)

**Components / Functions added for Supercharged Engine Management**

- Two fuel pumps
- Charge air cooler coolant pump
- Exhaust gas recirculation
- Second intake air temperature sensor (charge air temperature sensor)

#### Fuel Pumps

Two fuel pumps are used to provide adequate fuel flow during high engine loads. Both pumps are operated by the ECM via relays. Operation of fuel pump 1 is identical to the normally aspirated single fuel pump. Diagnostic monitoring for the N/A single fuel pump remains unchanged.

Fuel pump 2 is switched by the ECM as determined by engine operating conditions.

#### Intake Air Temperature sensor 2 (IAT 2)

A separate intake air temperature sensor (IAT 2), located on the A bank charge air cooler outlet, provides the ECM with a "charge air" temperature signal.

As with previous air temperature sensors, the IAT 2 is a negative temperature coefficient (NTC) thermistor. Charge air temperature is determined by the ECM by a change in sensor resistance. The ECM applies 5 volts to the sensor and monitors the voltage across the pins to detect the varying resistance.

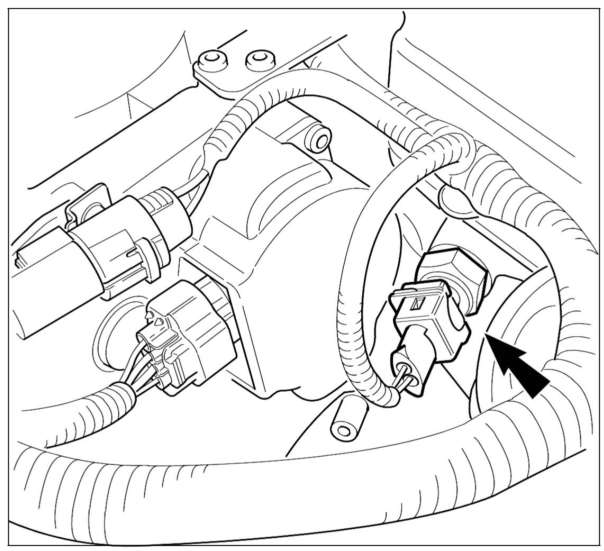

**Fig. 101 CHARGE AIR COOLER IAT 2**

**Table 13 IAT air temperature / resistance / voltage**

| Air temperature | | Resistance | Voltage |
|---|---|---|---|
| C | F | (kΩ) | Volts |
| –40 | –40 | 53.1 | 4.75 |
| –30 | –22 | 28.6 | 4.57 |
| –20 | –4 | 16.2 | 4.29 |
| –10 | 14 | 9.6 | 3.90 |
| 0 | 32 | 5.9 | 3.43 |
| 10 | 50 | 3.7 | 2.89 |
| 20 | 68 | 2.4 | 2.38 |
| 30 | 86 | 1.7 | 1.93 |
| 40 | 104 | 1.1 | 1.45 |
| 50 | 122 | 810 Ω | 1.15 |
| 60 | 140 | 580 Ω | .88 |
| 70 | 158 | 430 Ω | .69 |
| 80 | 176 | 320 Ω | .53 |
| 90 | 194 | 240 Ω | .41 |
| 100 | 212 | 190 Ω | .33 |
| 110 | 230 | 150 Ω | .26 |
| 120 | 248 | 120 Ω | .21 |

**Engine Coolant Temperature Sensor (ECT)**

On supercharged engines, the ECT is relocated to accommodate the supercharger installation.

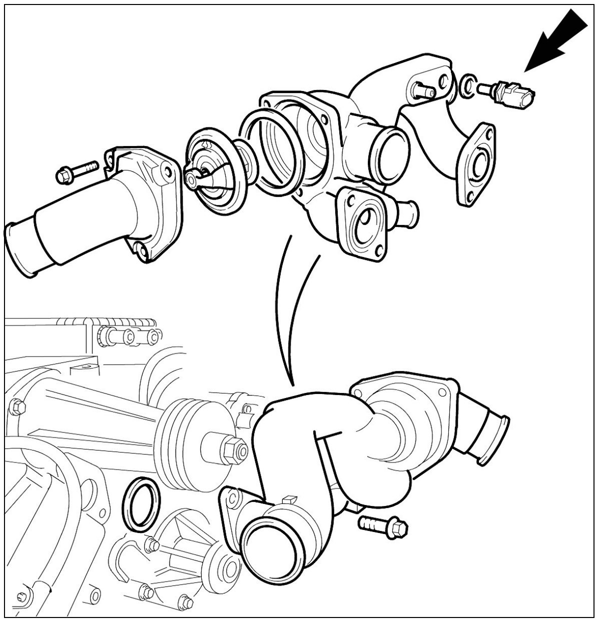

**Fig. 102 ECT – AJ V8 SUPERCHARGED**

**Exhaust Gas Recirculation – AJ26 SC**

The AJ26 SC EMS uses the same EGR system as early production naturally aspirated engines.

Exhaust gas recirculation lowers combustion temperature, which in turn reduces NOx exhaust emission. EGR is controlled by the ECM from a map that factors engine operating conditions such as engine load and speed, throttle position, and coolant temperature.

The EGR valve is mounted directly to the intake air induction elbow and connects to the A bank exhaust manifold by a transfer pipe. The EGR valve contains a four-pole stepper motor (60 step), which is driven by the ECM. Engine coolant returning from the throttle assembly is channeled through the valve to provide cooling.

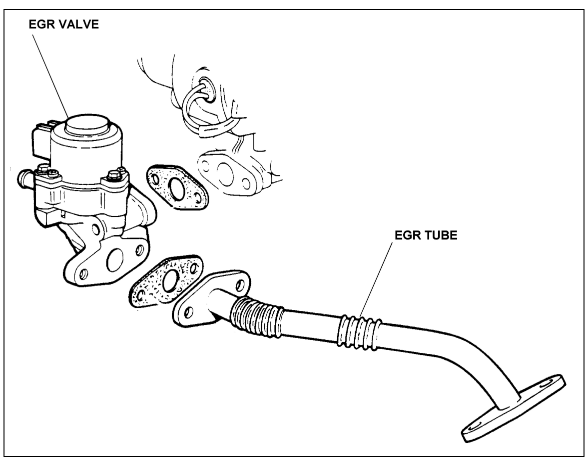


**Fig. 103 EGR VALVE – AJ26**

**Exhaust Gas Recirculation – AJ27 SC**

The AJ27 SC EGR system provides increased exhaust gas flow over the AJ26 SC system. ECM control is enhanced by an EGR flow monitoring feedback signal.

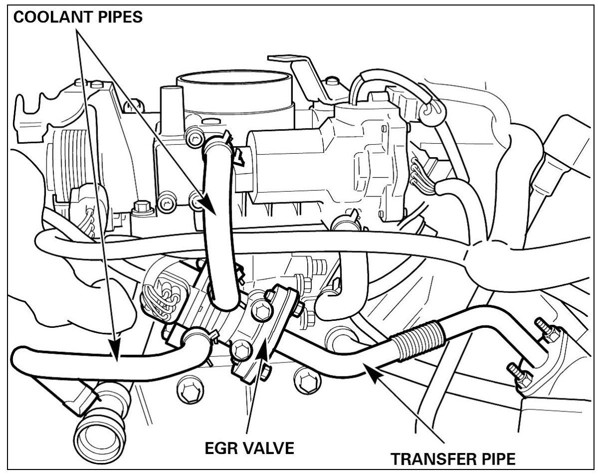


**Fig. 104 EGR VALVE – AJ27 SC**

**Manifold Absolute Pressure Sensor (MAP)**

AJ27 SC EGR systems include a MAP sensor, which enables the ECM to monitor EGR gas flow into the intake manifold. When the EGR valve opens to allow exhaust gas flow into the throttle elbow, the intake manifold absolute pressure will drop directly proportional to the amount the valve is open. The ECM applies 5 volts to the MAP sensor, which produces a linear output voltage signal to the ECM.

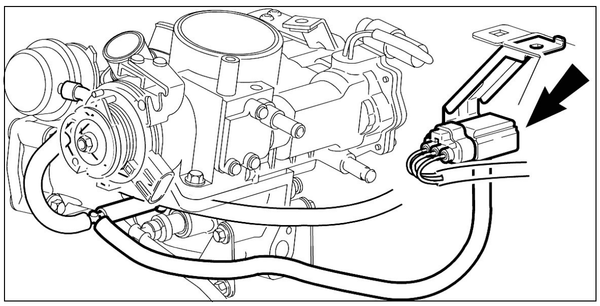

**Fig. 105 MAP SENSOR – AJ27**

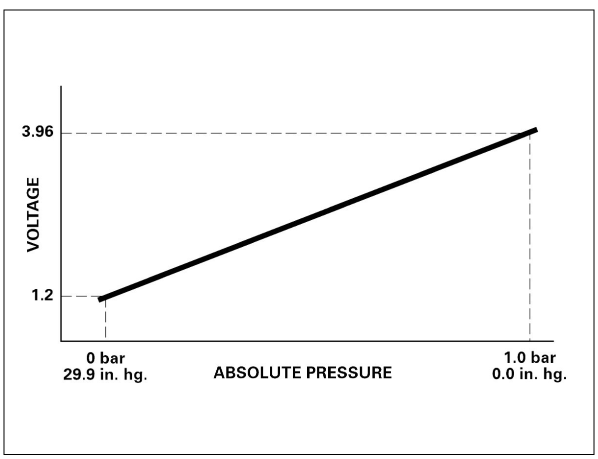


**Fig. 106 MAP SENSOR CHARACTERISTIC – AJ27**