HYUNDAI

# DIESEL ENGINE
# J3
## *(DELPHI COMMON RAIL)*

# Shop Manual

**SUPPLEMENT**

## FOREWORD

This shop manual is intended for use by service technicians of authorized Hyundai dealers to help them provide efficient and correct service and maintenance on Hyundai vehicle.

To ensure customer satisfaction with Hyundai products, proper service and maintenance by Hyundai technicians is essential. Consequently, it is important that service personnel fully understand the contents of this manual, which should be kept in a handy place for quick and easy reference.

All the contents of this manual, including photographs, drawings, and specifications, are the latest available at the time of printing. As modifications affecting service occur, dealers will be provided technical service bulletins or supplementary volumes. This manual should be kept carefully up-to date upon receipt of the new information.

Hyundai Motor Company reserves the right to make changes in design or to make additions to or improvements in its products without imposing any obligations upon itself to install them on its products previously manufactured.



If you don't use HYUNDAI Genuine Parts (Engine oil, Transaxle oil, etc.) or use bad fuel, it can cause damage to the vehicle.

CONTENTS



This is the supplement shop manual of the J3 Engine equipped with fuel injection system of DELPHI Common Rail.
This Diesel Engine, named J3 for 4 cylinders, is applied to the vehicle of Terracan.
For any information not covered in this supplement, please refer to the related shop manual published earlier.

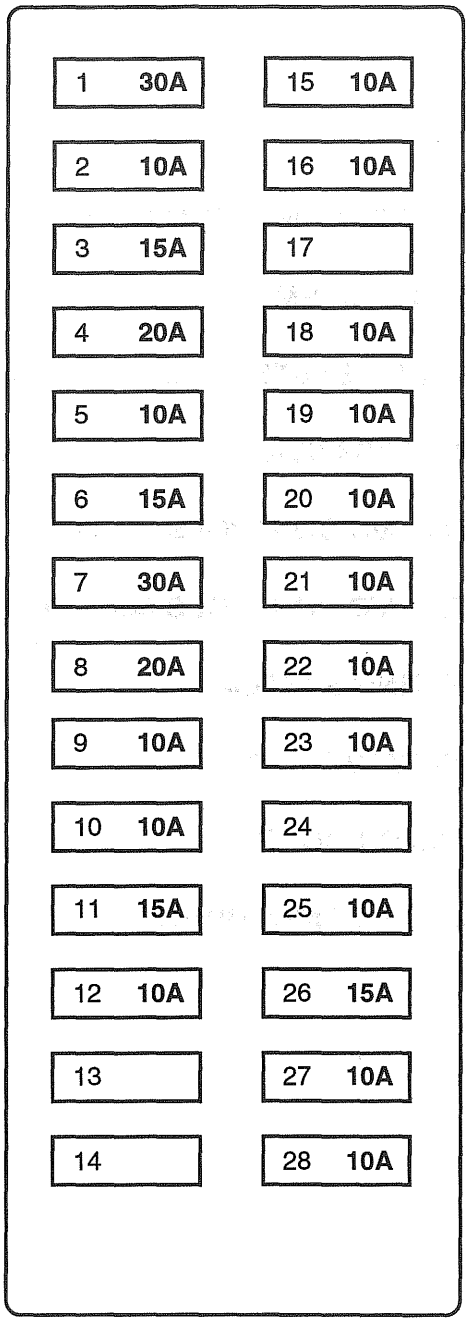
JUL. 2001,
Printed in Korea

# Schematic Diagrams

# FUSE AND RELAY INFORMATION

## PASSENGER COMPARTMENT FUSE BOX

### LAYOUT




E2MB001A-A

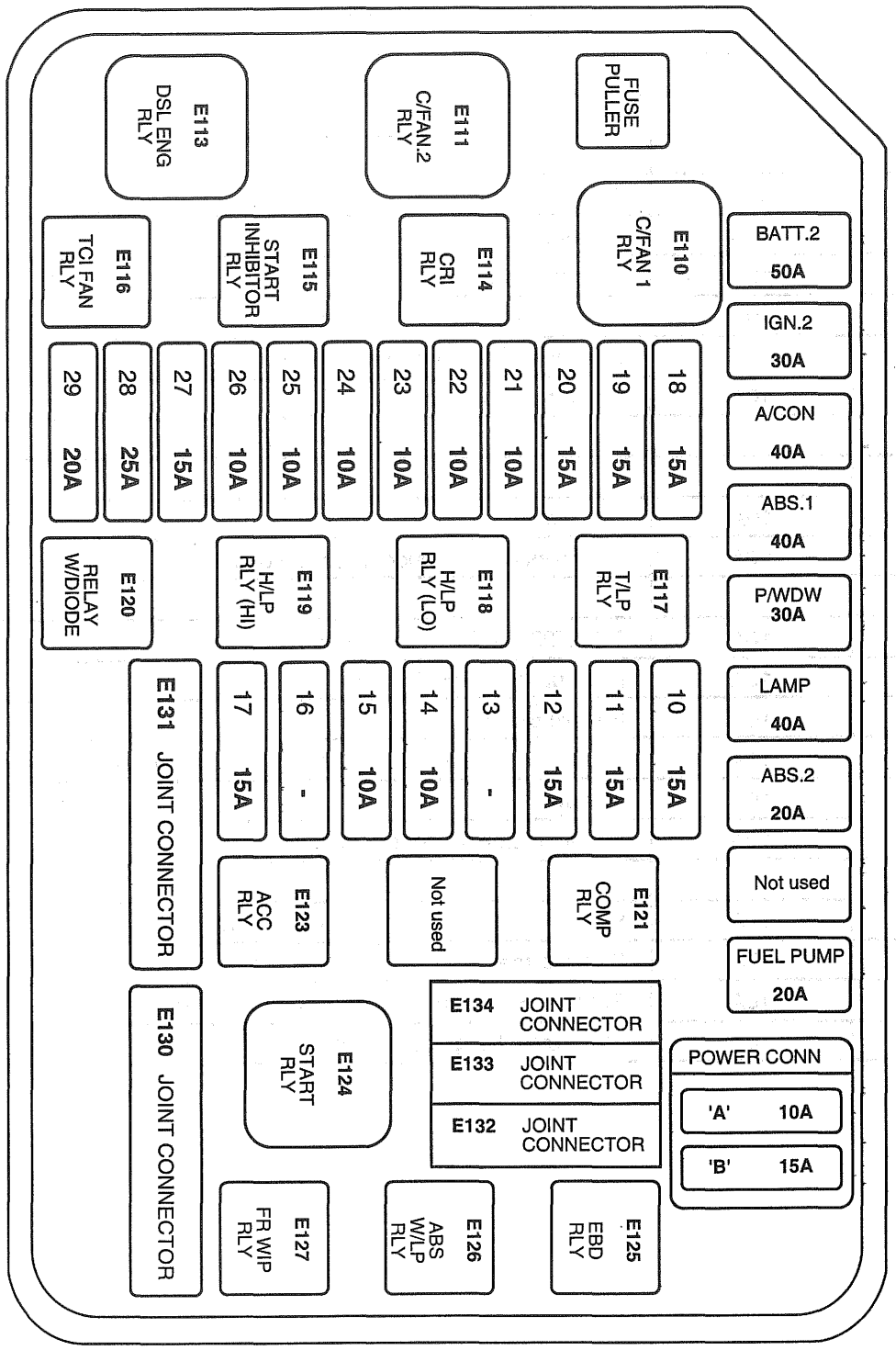
## CIRCUIT

| NO | Amperages(A) | Circuit protected |
|---|---|---|
| 1 | 30A | Defogger |
| 2 | 10A | Hazard relay, Hazard switch |
| 3 | 15A | Stop lamps |
| 4 | 20A | Transfer |
| 5 | 10A | SMATRA |
| 6 | 15A | Sunroof |
| 7 | 30A | Blower motor |
| 8 | 20A | Power door locks |
| 9 | 10A | Rear fog lamp relay |
| 10 | 10A | Audio, Overhead console lamp |
| 11 | 15A | Cigarette lighter, Accessory socket |
| 12 | 10A | Outside mirror & folding |
| 13 | - | |
| 14 | - | |
| 15 | 10A | A/C switch |
| 16 | 10A | Rear window & outside mirror defogger |
| 17 | - | |
| 18 | 10A | TCM, TCCM(EST), Transaxle range switch |
| 19 | 10A | Back-up lamp, Inside mirror |
| 20 | 10A | Hazard switch |
| 21 | 10A | Instrument cluster, ETACM, Vehicle speed sensor, DRL control module |
| 22 | 10A | Air bag |
| 23 | 10A | Air bag ind., ABS control module |
| 24 | - | |
| 25 | 10A | Blower & A/C, ETACM, Defogger relay |
| 26 | 15A | Seat warmer |
| 27 | 10A | Sunroof, Rear wiper & washer, Rain sensor |
| 28 | 10A | Start relay, Burglar alarm relay |

# ENGINE COMPARTMENT FUSE & RELAY BOX #1

## ENGINE COMPARTMENT FUSE & RELAY BOX #1

### LAYOUT




E2MB001A-C

## CIRCUIT

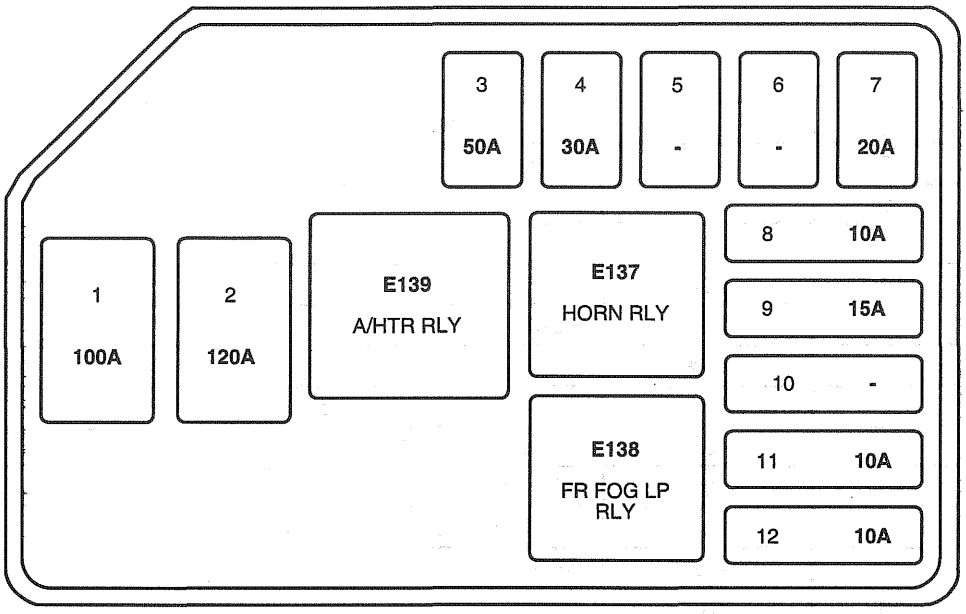
| | NO | Amperages(A) | Circuit protected |
|---|---|---|---|
| FUSE | 10 | 15A | Fuel heater |
| | 11 | 15A | Head lamp relay(Low), DRL control module |
| | 12 | 15A | Head lamp relay(High) |
| | 13 | - | - |
| | 14 | 10A | A/C compressor relay |
| | 15 | 10A | TCI fan relay |
| | 16 | - | - |
| | 17 | 15A | - |
| | 18 | 15A | ECM |
| | 19 | 15A | ECM |
| | 20 | 15A | ECM, Air heater relay #1 |
| | 21 | 10A | Illuminations, Combination lamp |
| | 22 | 10A | License lamp, Combination lamp |
| | 23 | 10A | ABS control module |
| | 24 | 10A | ECM, Radiator fan relay, Condenser fan relay |
| | 25 | 10A | ABS |
| | 26 | 10A | Cruise |
| | 27 | 15A | Front wiper & washer |
| | 28 | 25A | Power seat |
| | 29 | 20A | Accessory relay |
| FUSIBLE LINK | BATT.2 | 50A | Power connector(A, B) |
| | IGN.2 | 30A | Start relay, Ignition switch |
| | A/CON | 40A | A/C compressor relay, Condenser fan relay |
| | ABS.1 | 40A | ABS control module |
| | P/WDW | 30A | Power window relay, Head lamp washer motor |
| | LAMP | 40A | Tail lamp relay |
| | ABS.2 | 20A | ABS control module |
| | FUEL PUMP | 20A | Fuel pump motor |
| POWER CONNECTOR.A | | 10A | A/C, TCM, Data link connector, ETACM, Siren, Mirror folding |
| POWER CONNECTOR.B | | 15A | Audio, Courtesy lamps, Overhead console lamp |

# USE THE DESIGNATED FUSE ONLY

E2MB001A-D

# ENGINE COMPARTMENT FUSE & RELAY BOX #2

## LAYOUT



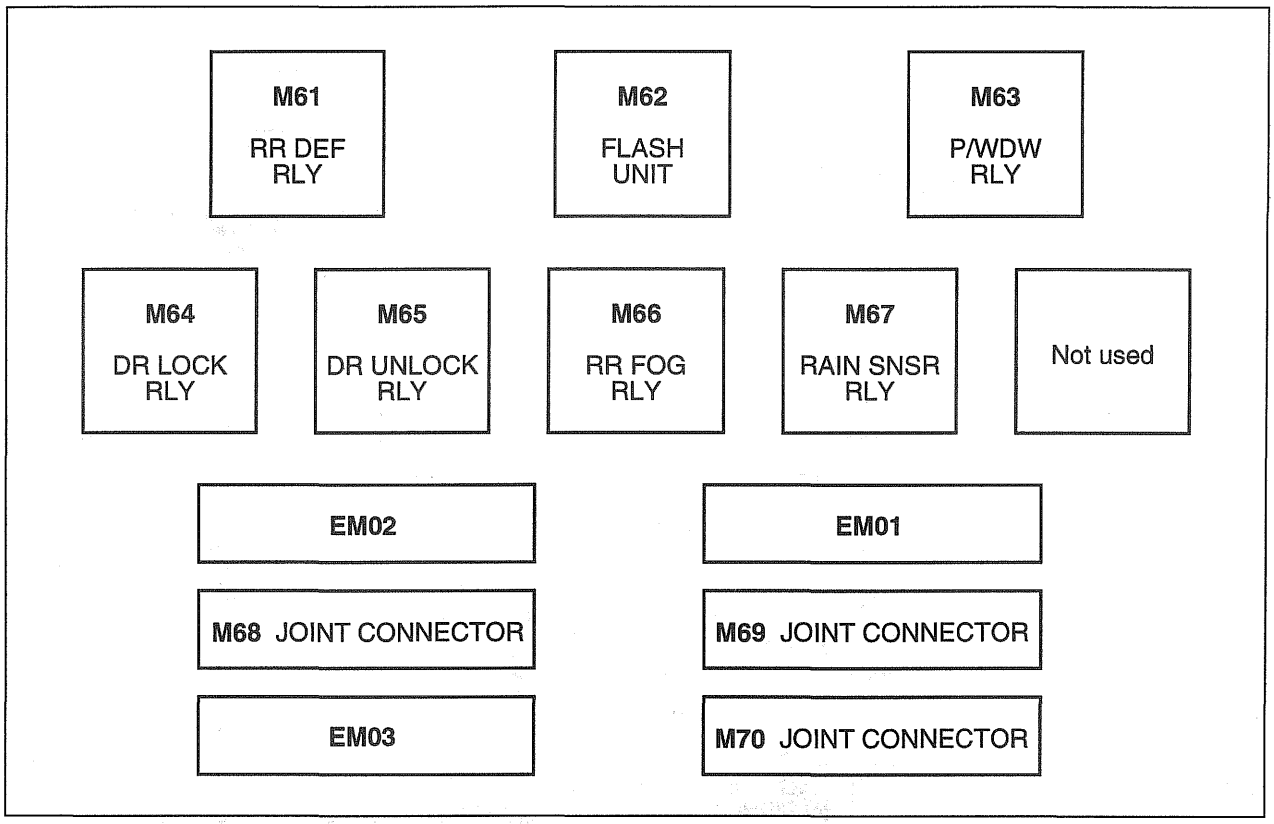

## CIRCUIT

| | NO | Amperages(A) | Circuit protected |
|---|---|---|---|
| FUSIBLE LINK | 1 | 100A | Air heater relay #1 |
| | 2 | 120A | Engine compartment fuse & relay box #1 |
| | 3 | 50A | Passenger compartment fuse box(1, 2, 3, 4, 5), Engine compartment fuse & relay box #2(8, 9), Fuel heater control module |
| | 4 | 30A | Generator |
| | 5 | - | - |
| | 6 | - | - |
| | 7 | 20A | Engine control relay |
| FUSE | 8 | 10A | Horn relay |
| | 9 | 15A | Front fog lamp |
| | 10 | - | - |
| | 11 | 10A | ECM |
| | 12 | 10A | ECM |

E2MB001A-E

# PASSENGER COMPARTMENT RELAY BOX

## LAYOUT

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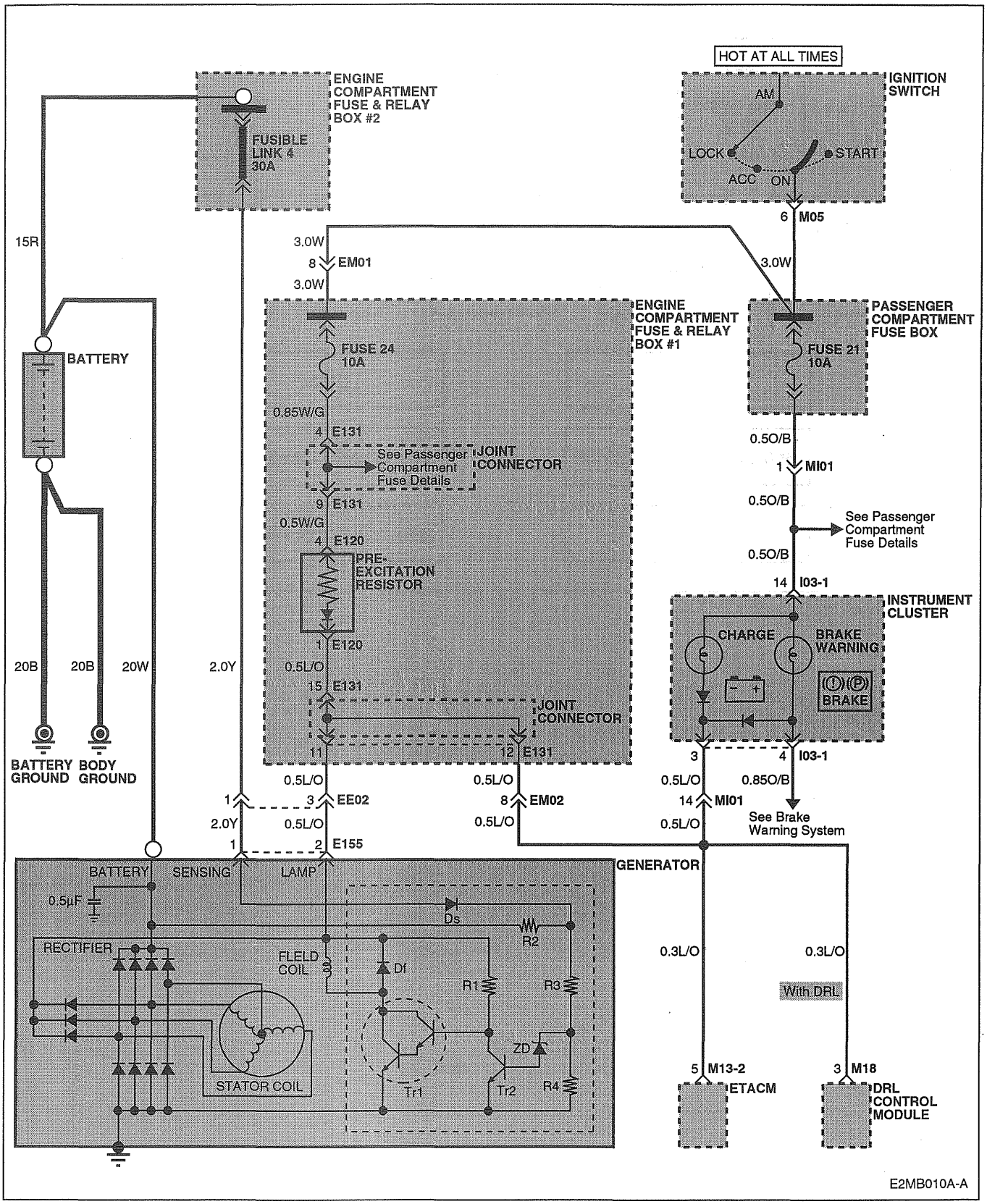
# CHARGING SYSTEM

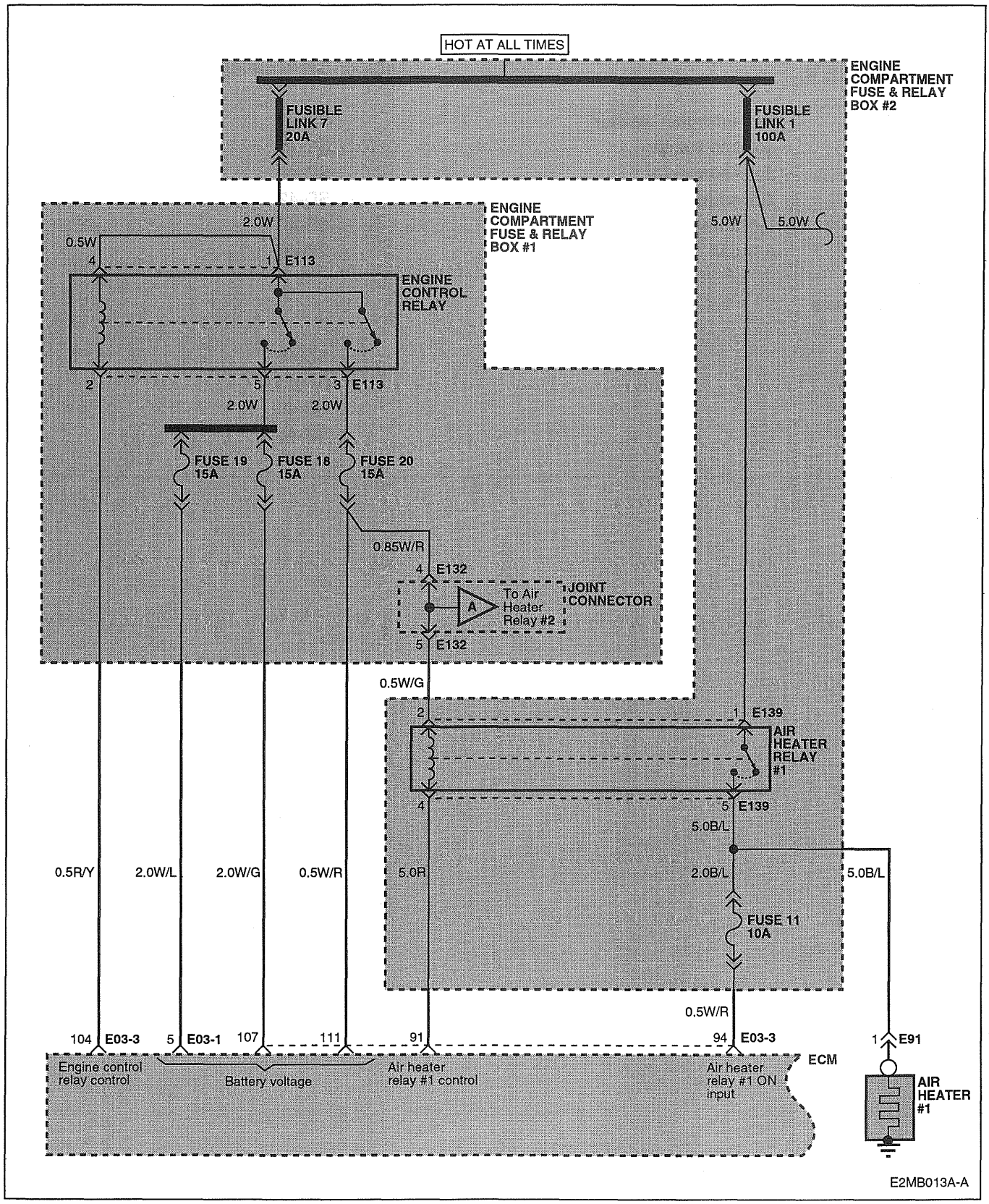
## CHARGING SYSTEM (1)



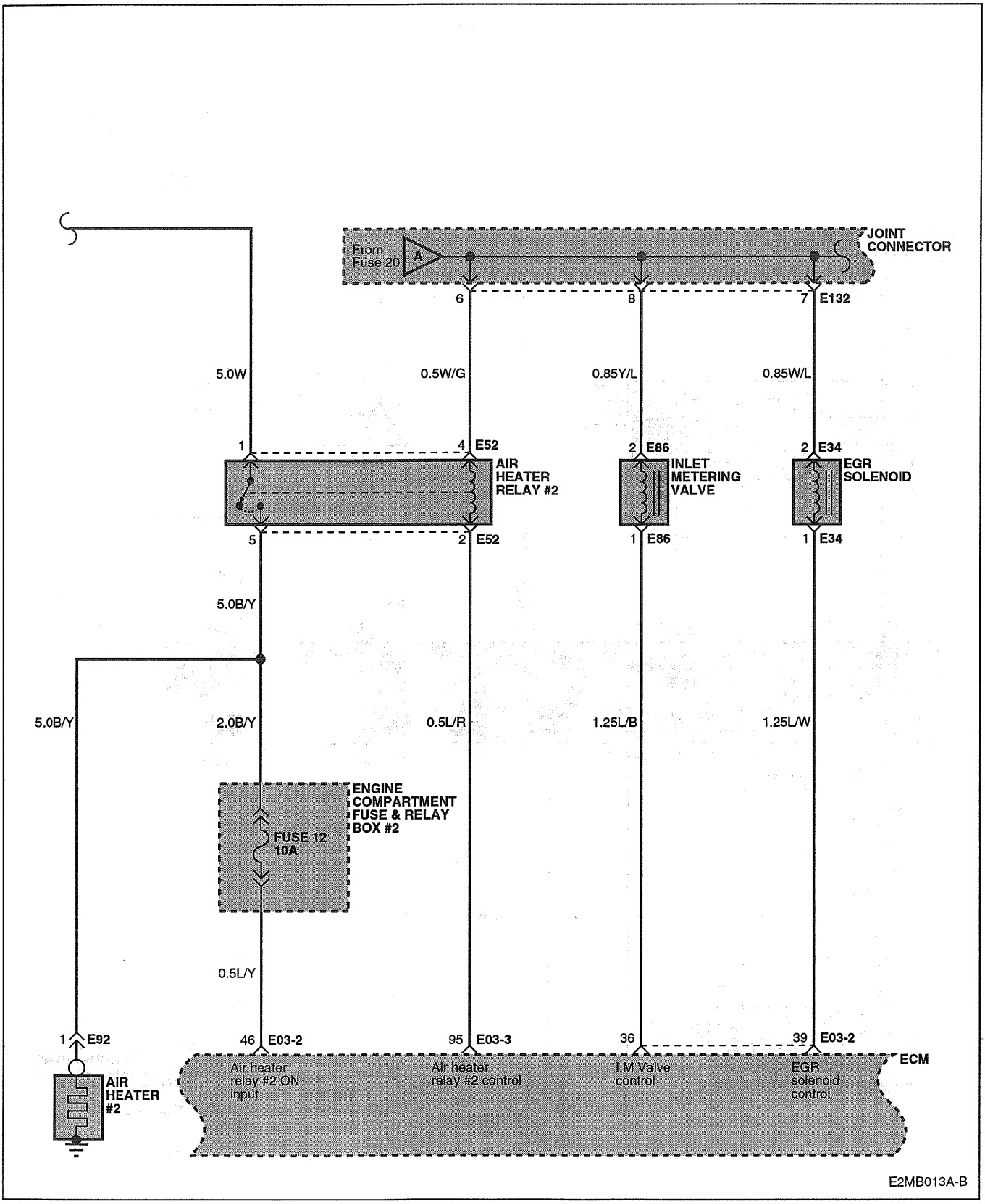
## COMPONENT LOCATION INDEX

# MFI CONTROL SYSTEM

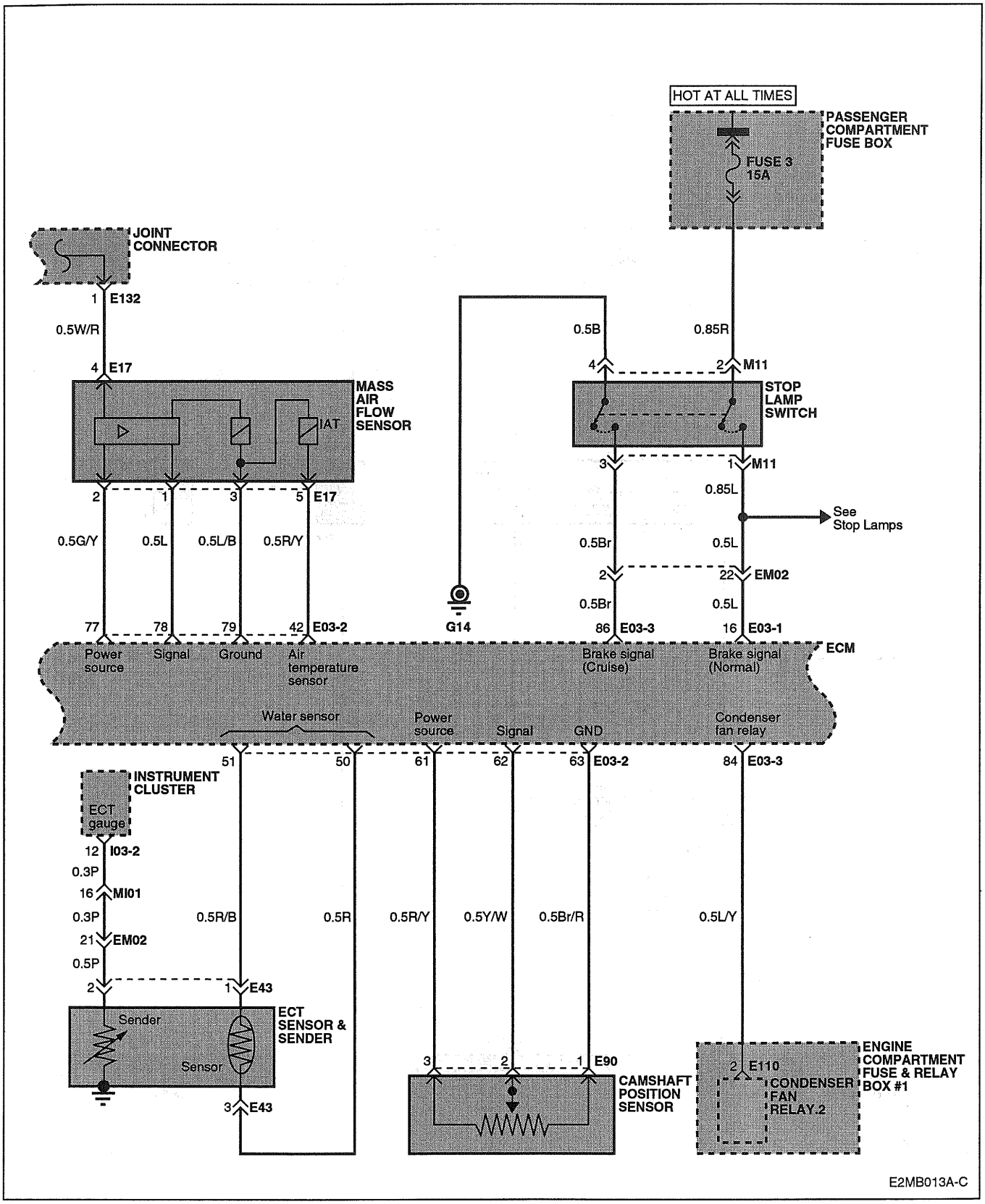
## MFI CONTROL SYSTEM (1)



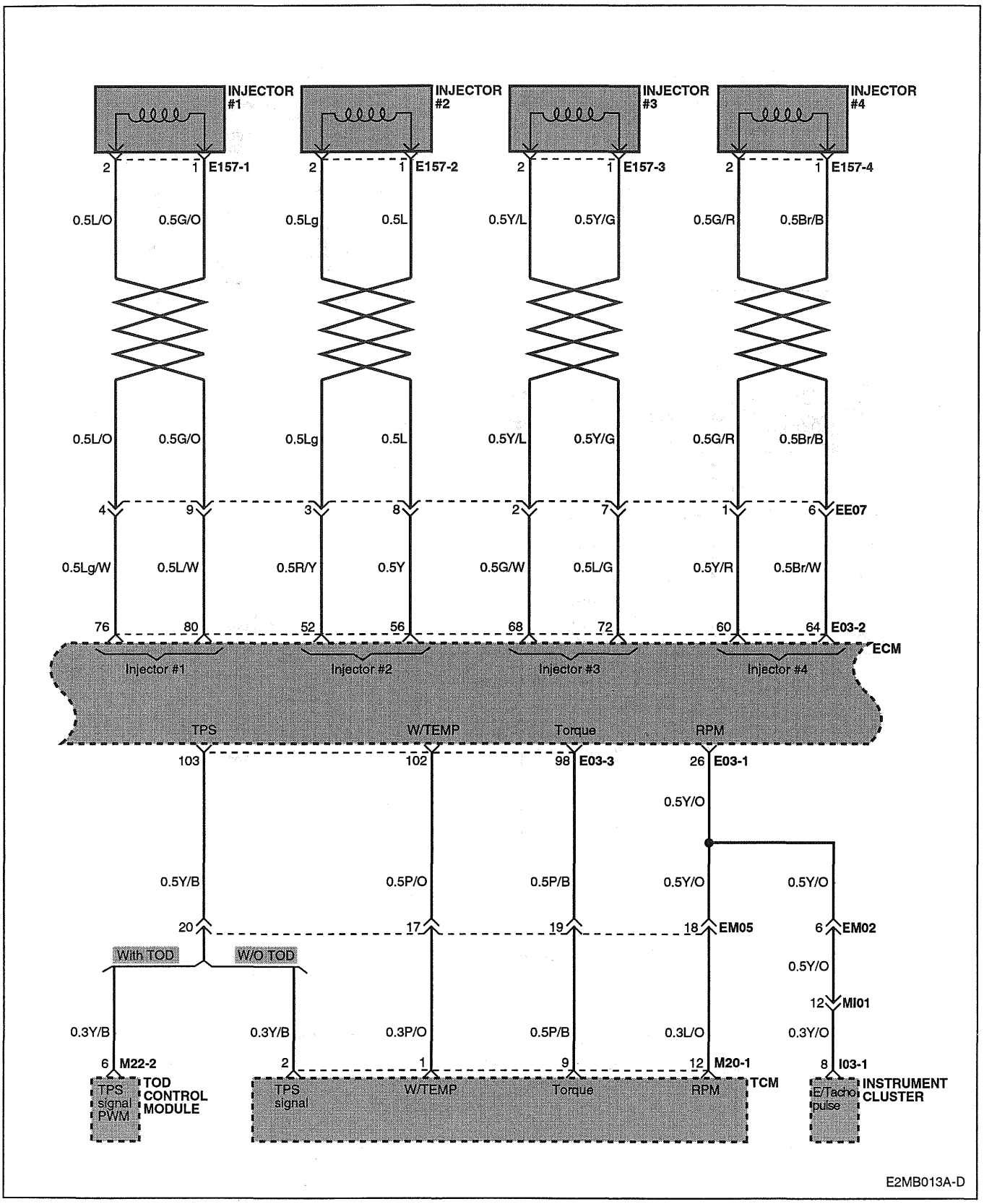
## MFI CONTROL SYSTEM (2)



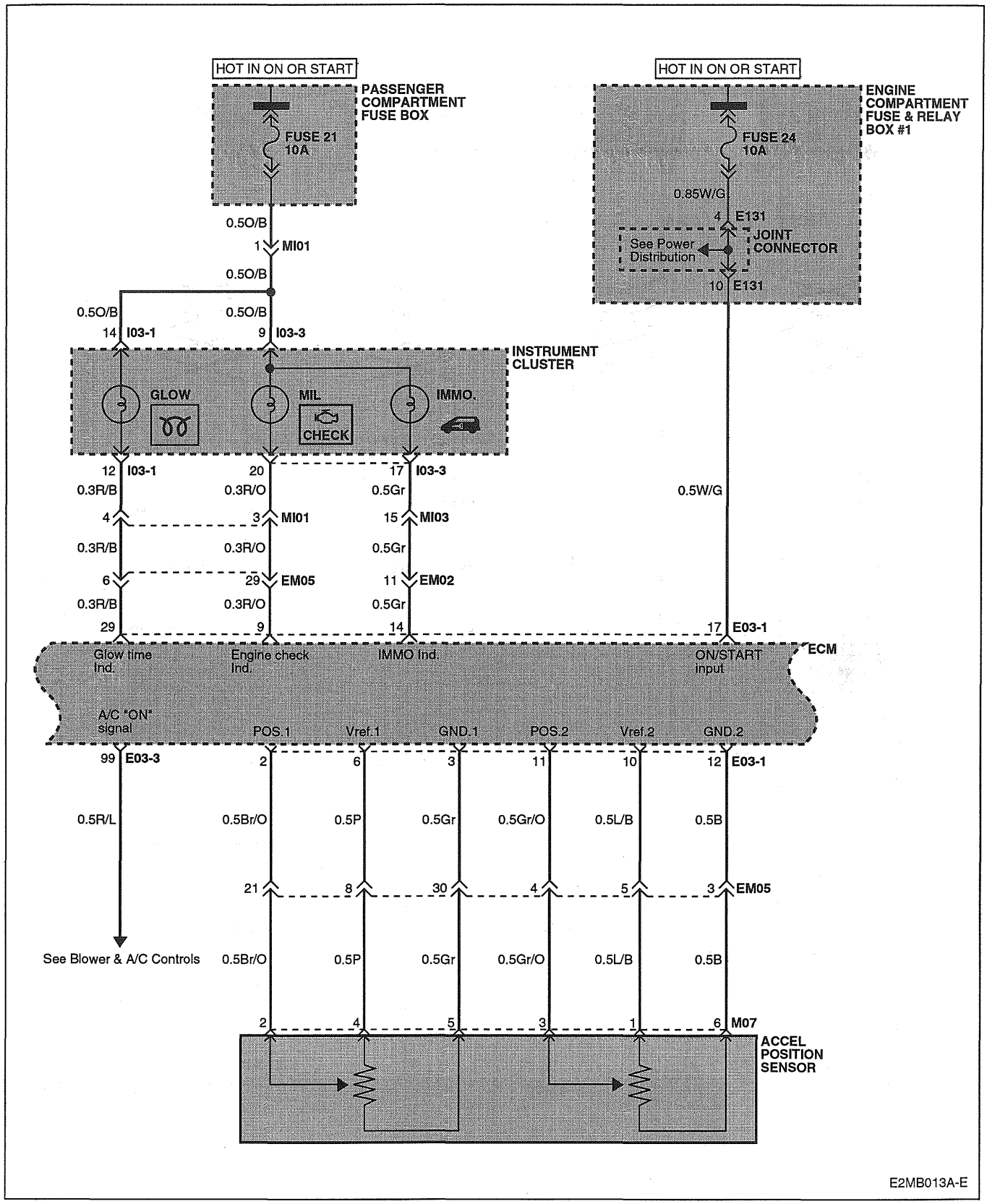
## MFI CONTROL SYSTEM (3)



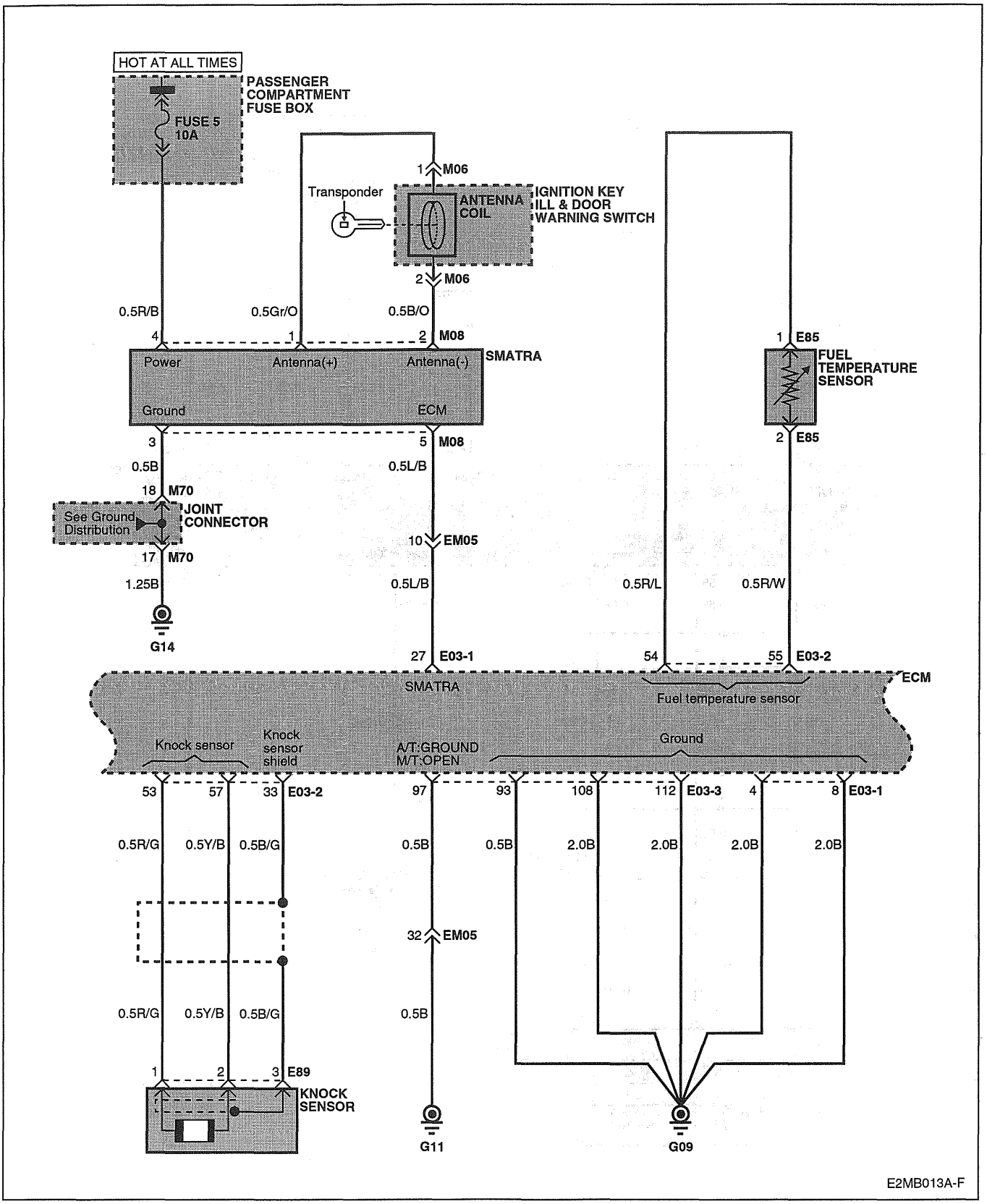
## MFI CONTROL SYSTEM (4)



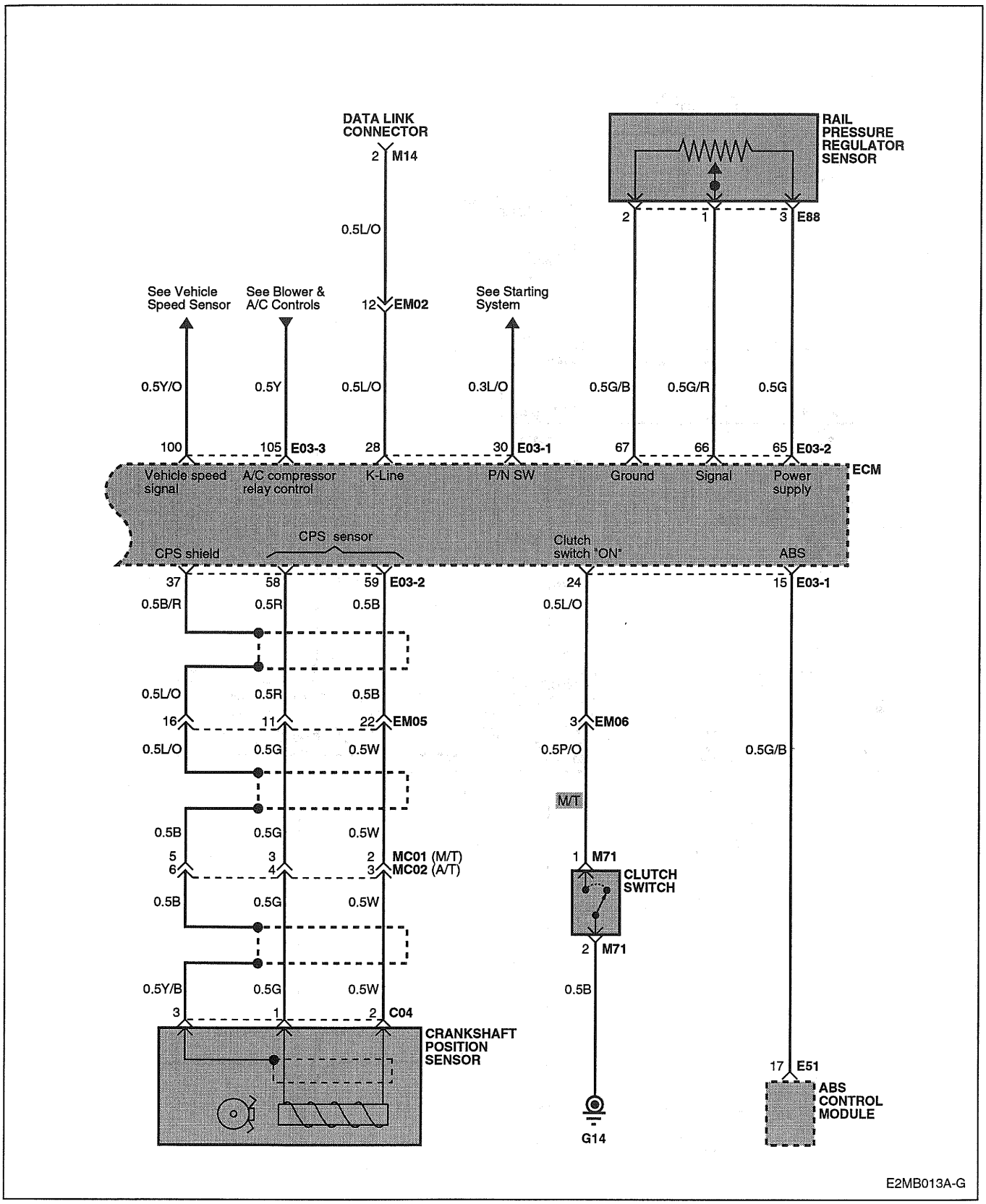
## MFI CONTROL SYSTEM (5)



## MFI CONTROL SYSTEM (6)



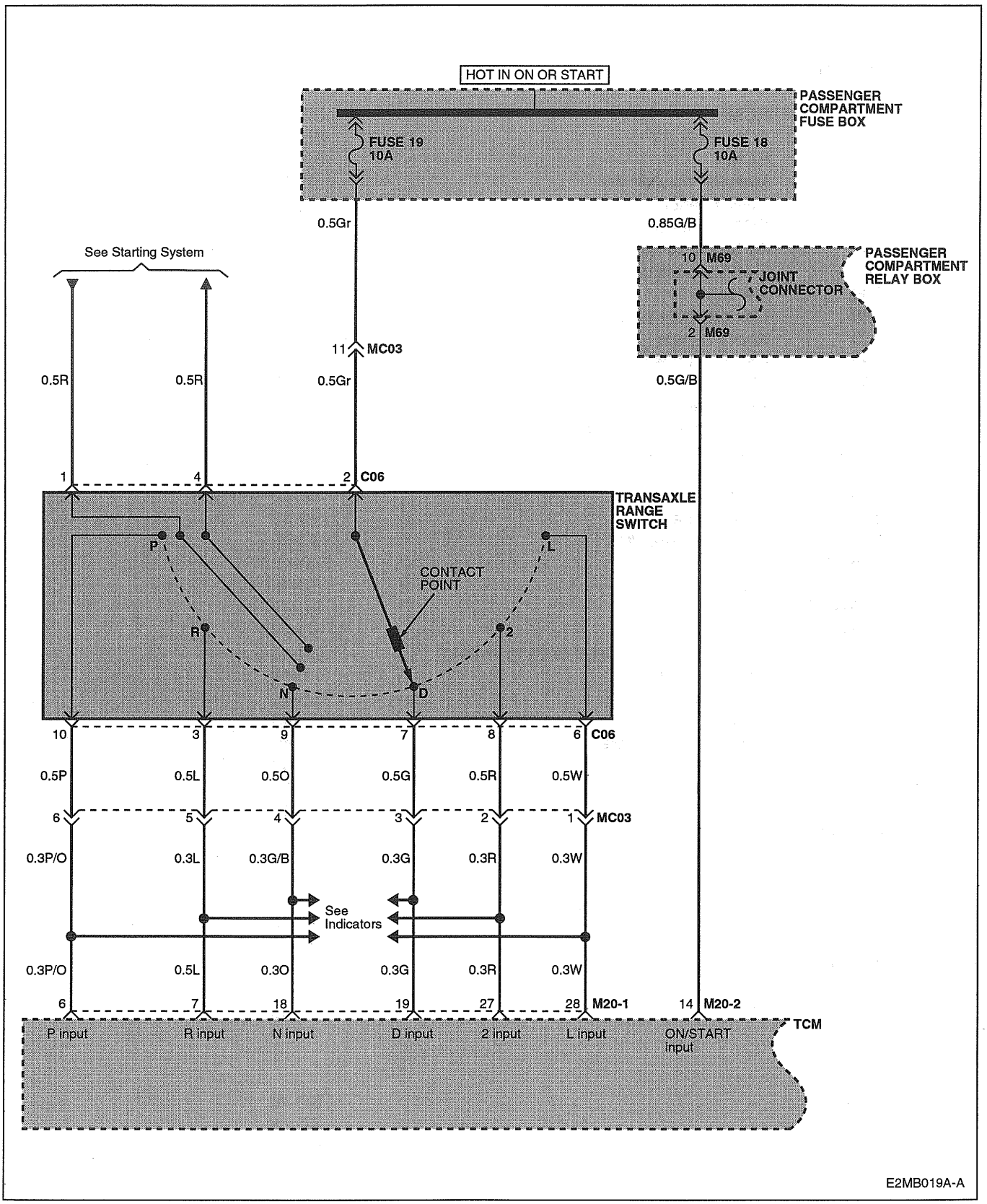
## MFI CONTROL SYSTEM (7)



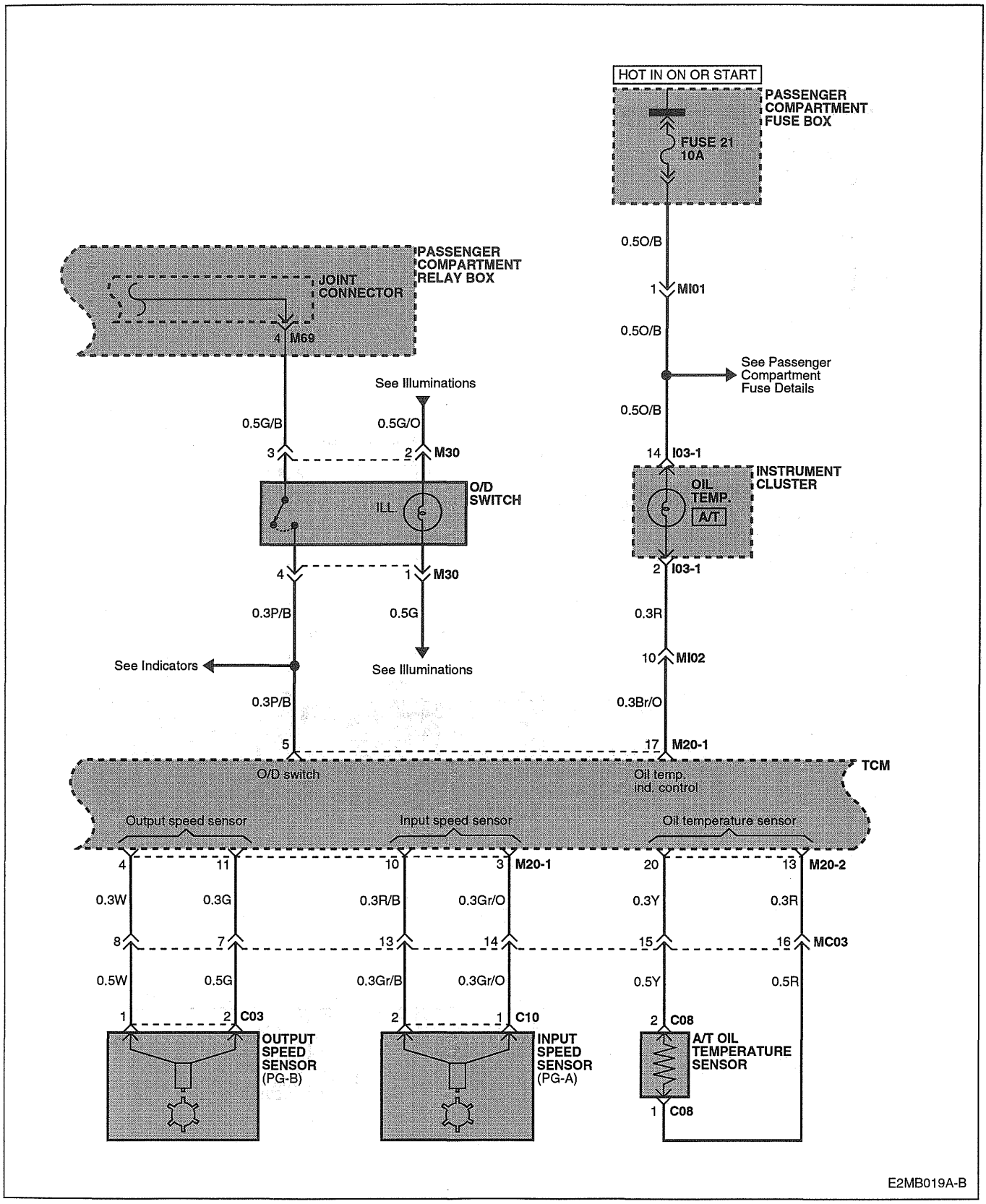
## COMPONENT LOCATION INDEX

# AUTOMATIC TRANSAXLE CONTROL SYSTEM

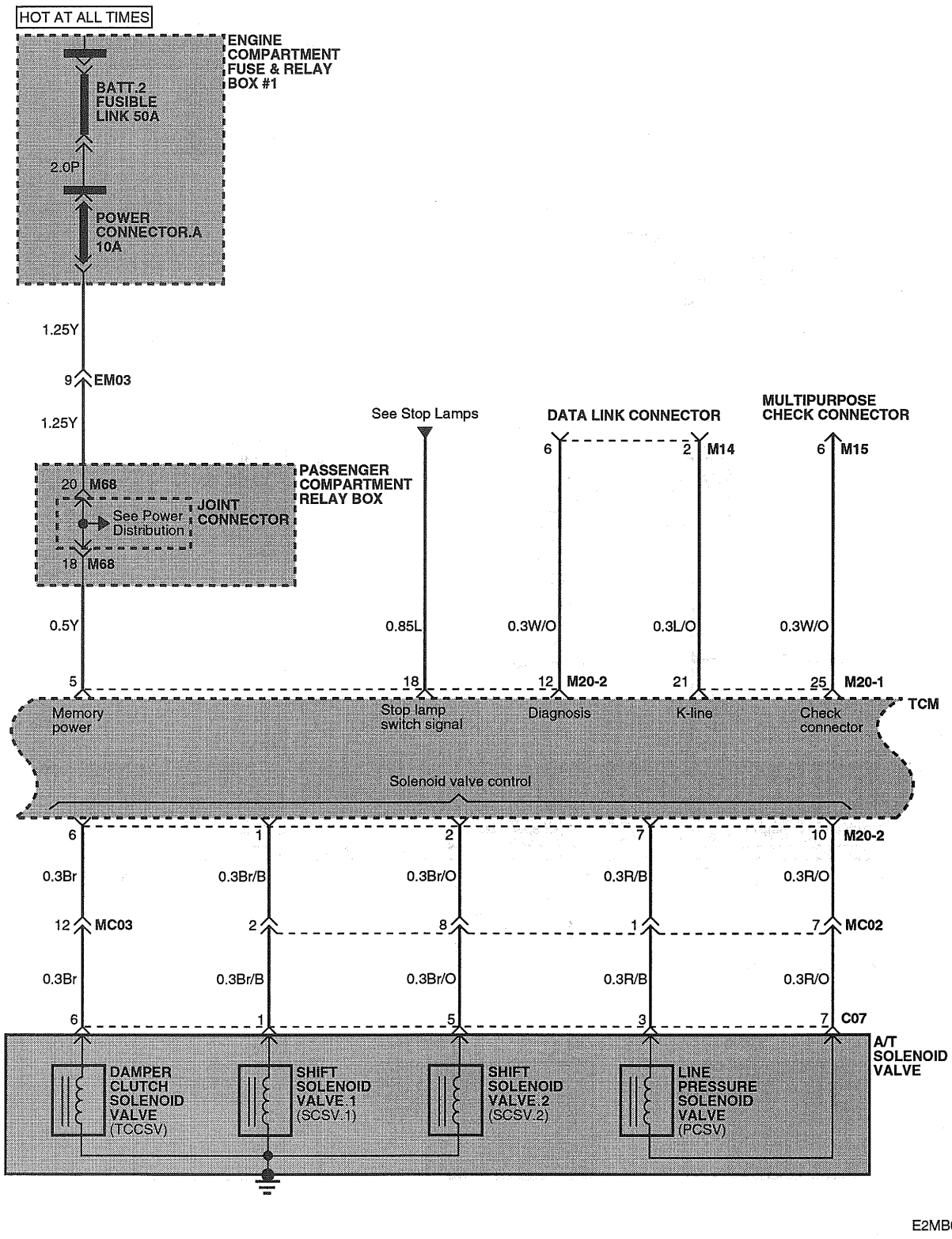
## AUTOMATIC TRANSAXLE CONTROL SYSTEM (1)



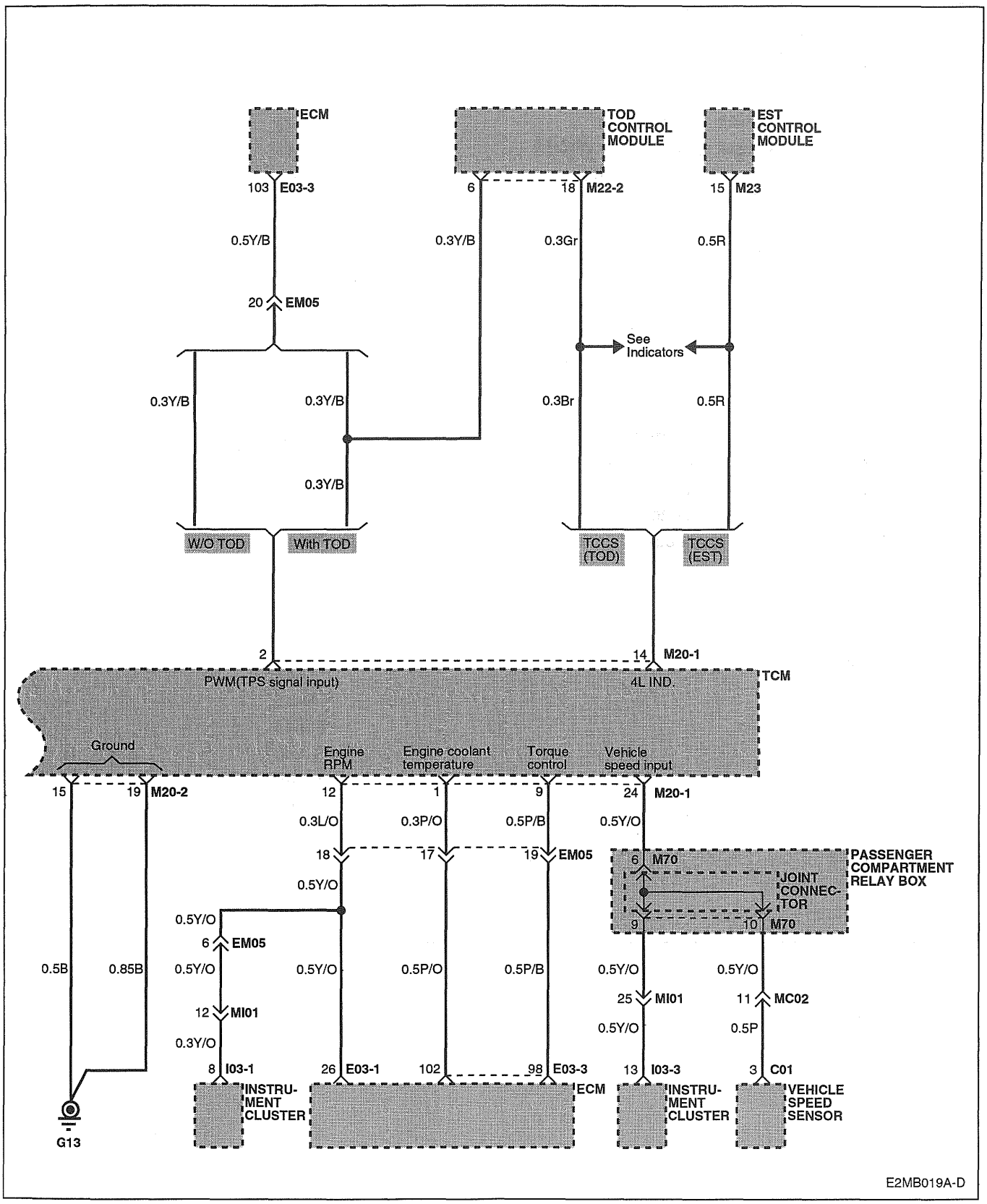
## AUTOMATIC TRANSAXLE CONTROL SYSTEM (2)



## AUTOMATIC TRANSAXLE CONTROL SYSTEM (3)



## AUTOMATIC TRANSAXLE CONTROL SYSTEM (4)

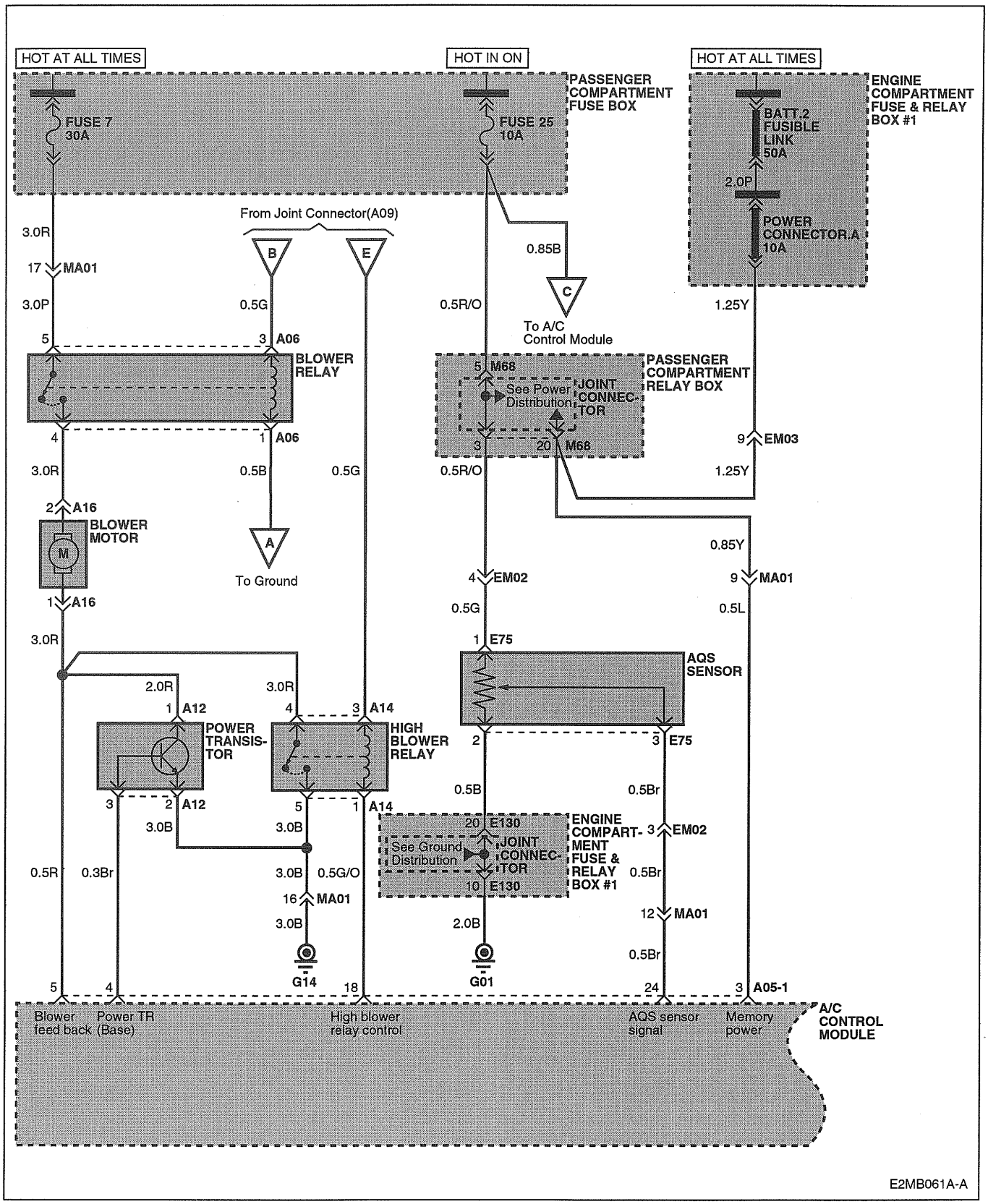


## COMPONENT LOCATION INDEX

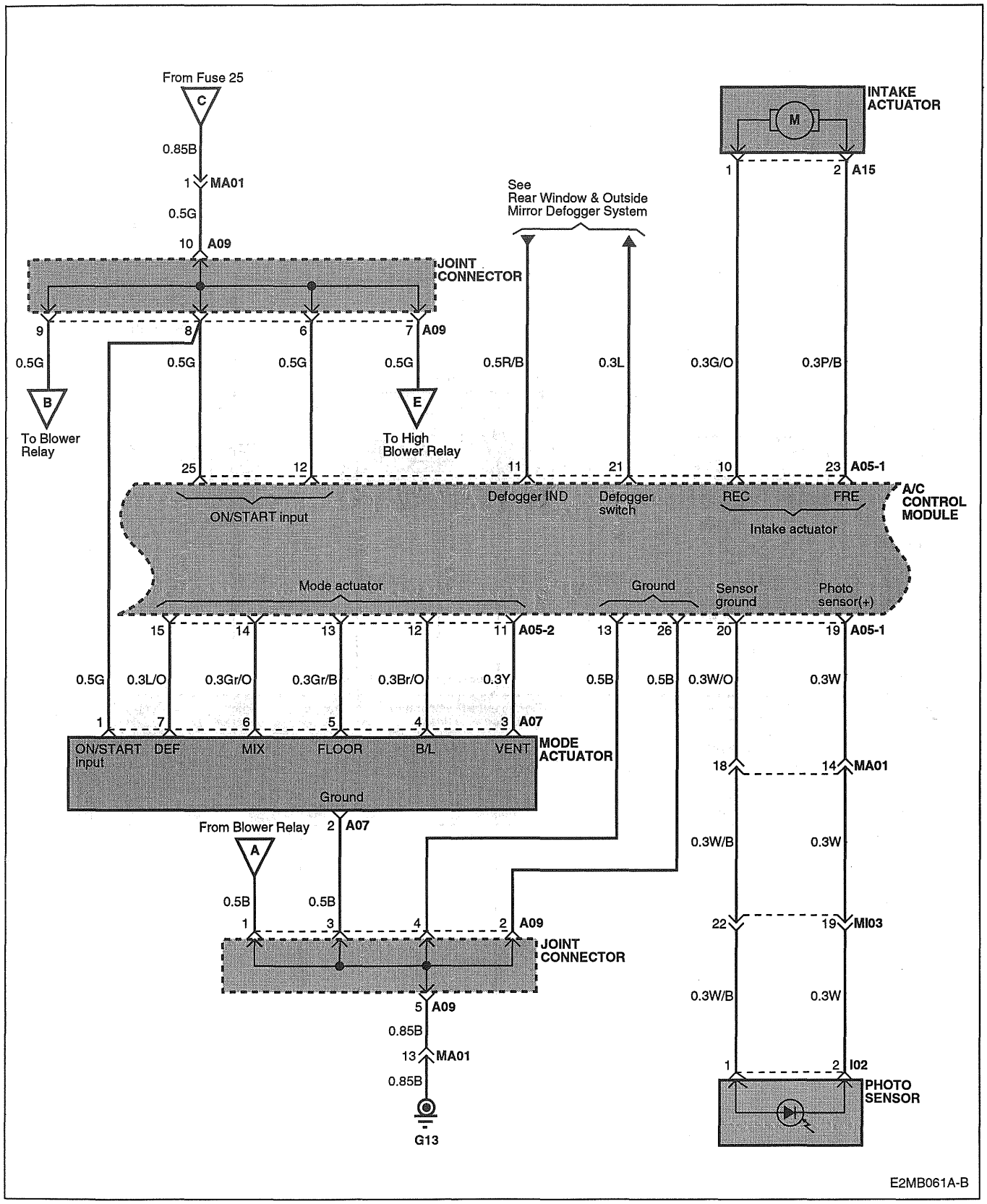
MEMO

# BLOWER & A/C CONTROLS (AUTO)

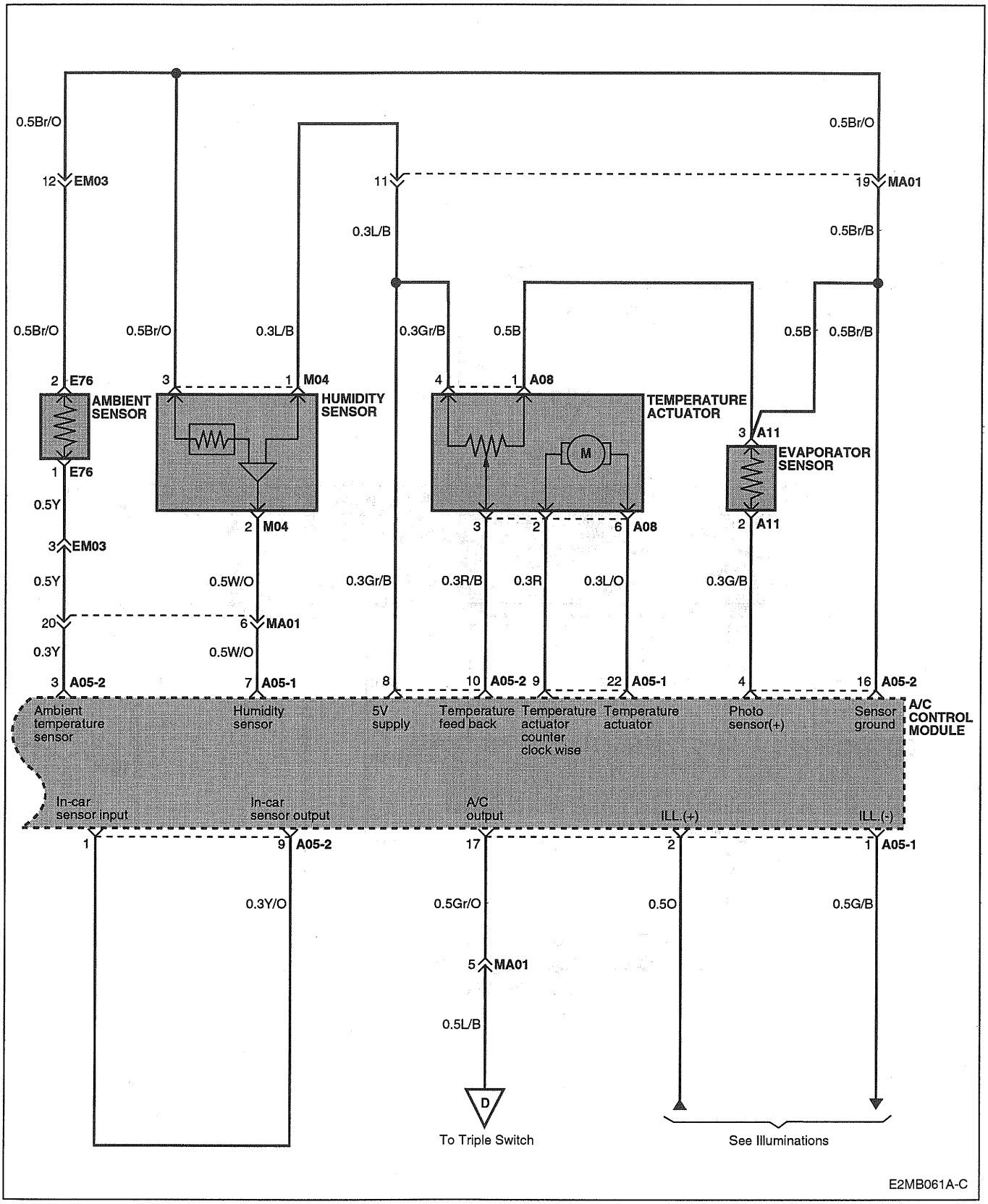
## BLOWER & A/C CONTROLS (AUTO) (1)



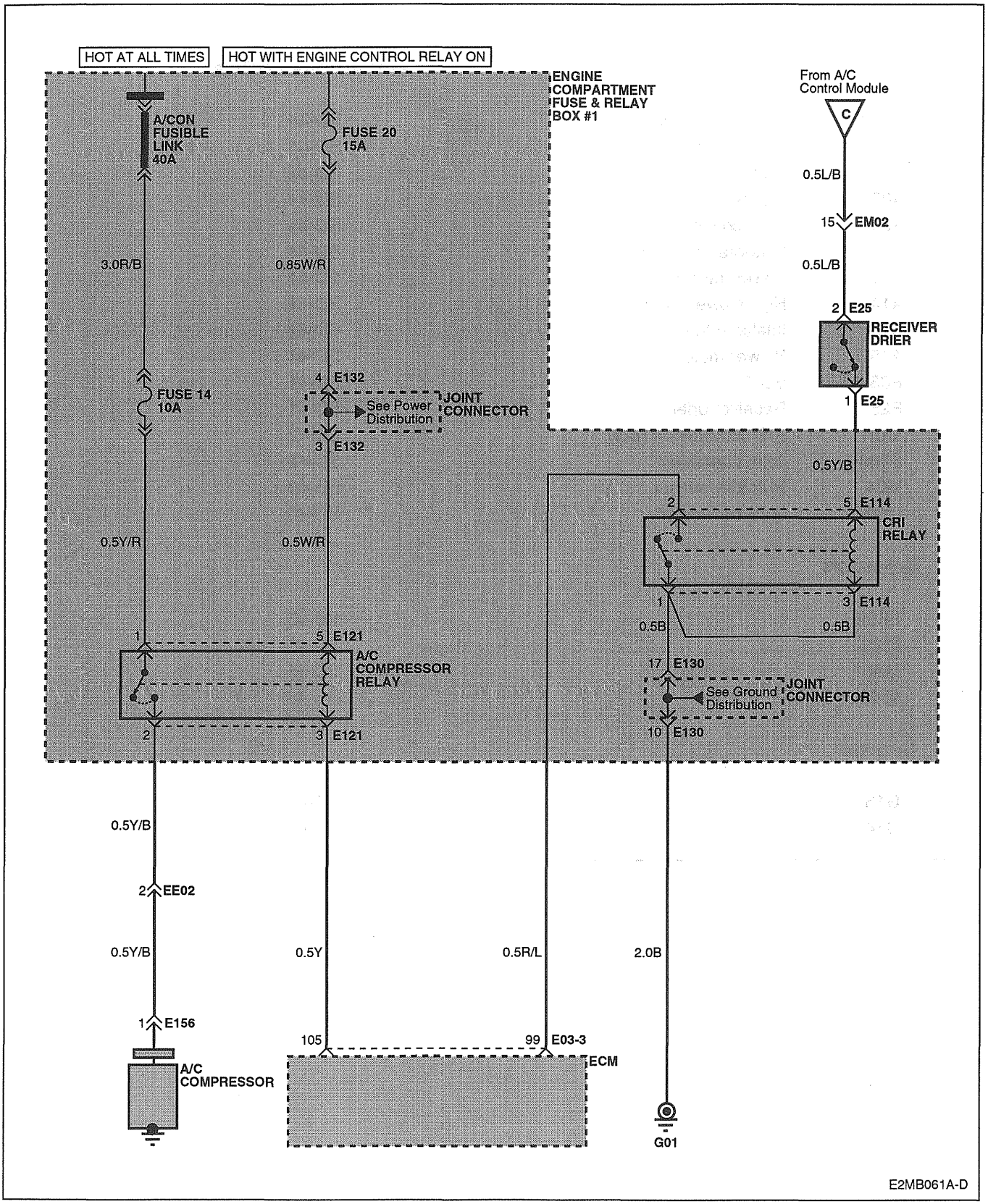
## BLOWER & A/C CONTROLS (AUTO) (2)



## BLOWER & A/C CONTROLS (AUTO) (3)



## BLOWER & A/C CONTROLS (AUTO) (4)

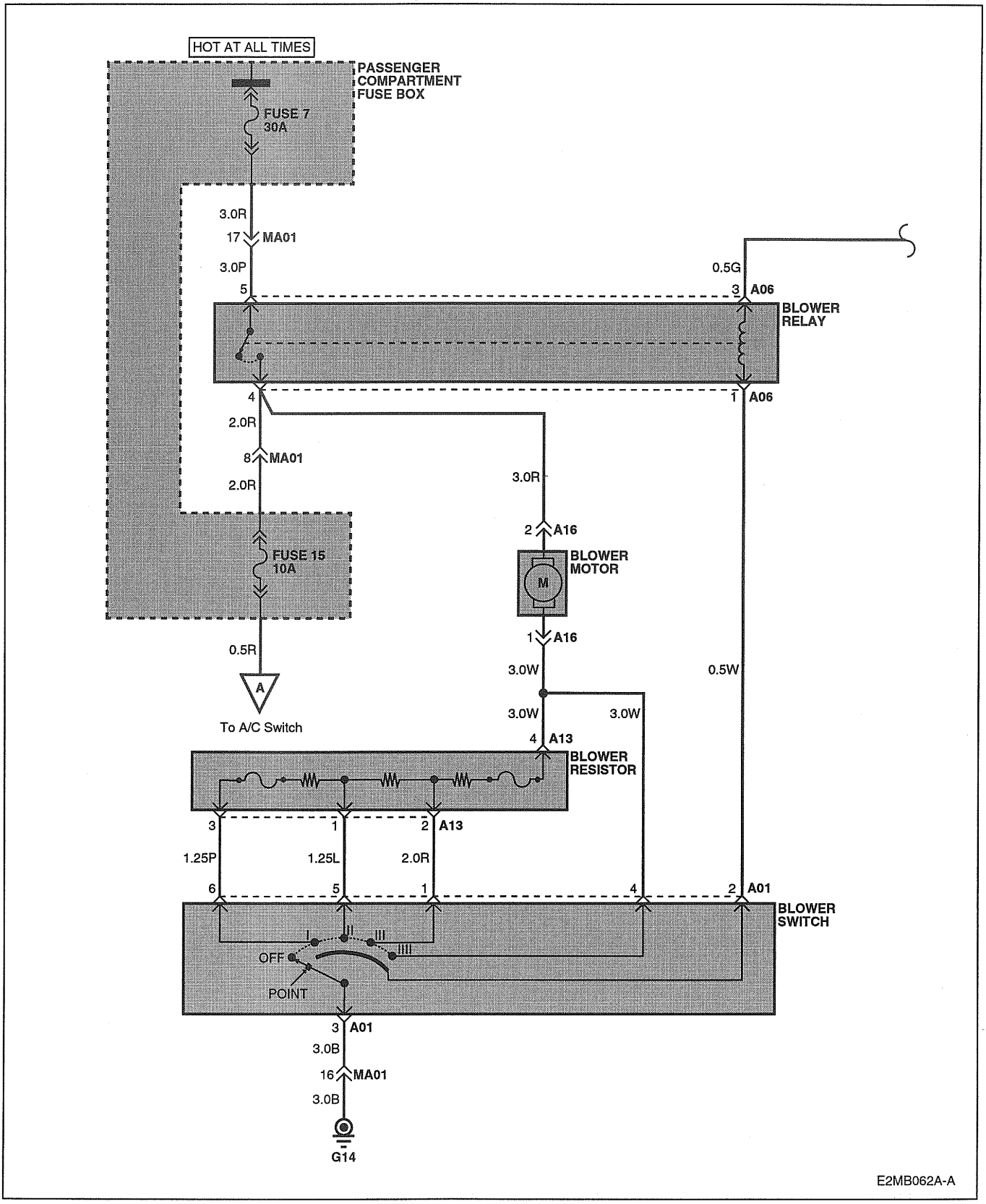


## COMPONENT LOCATION INDEX

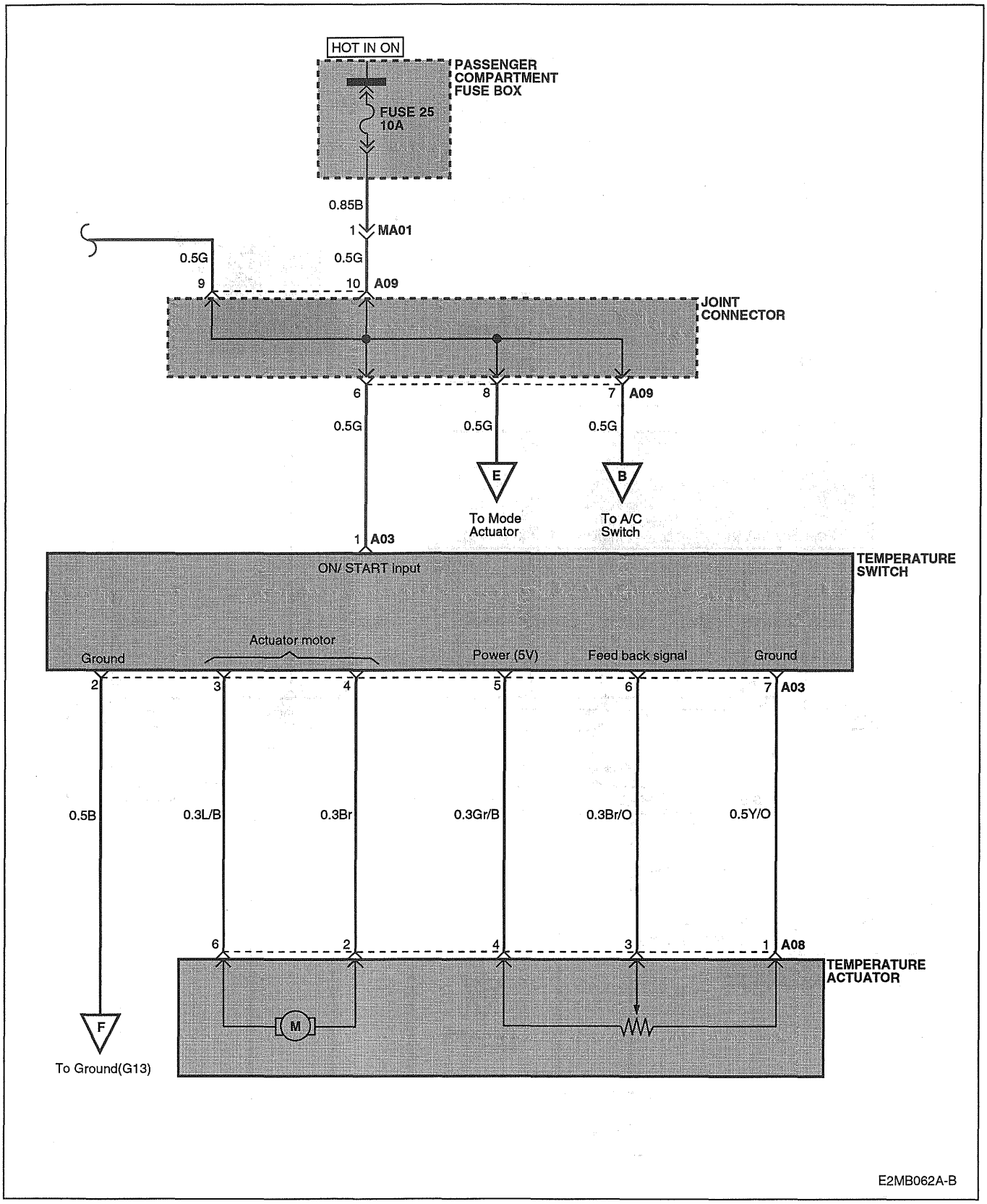
MEMO

# BLOWER & A/C CONTROLS (MANUAL)

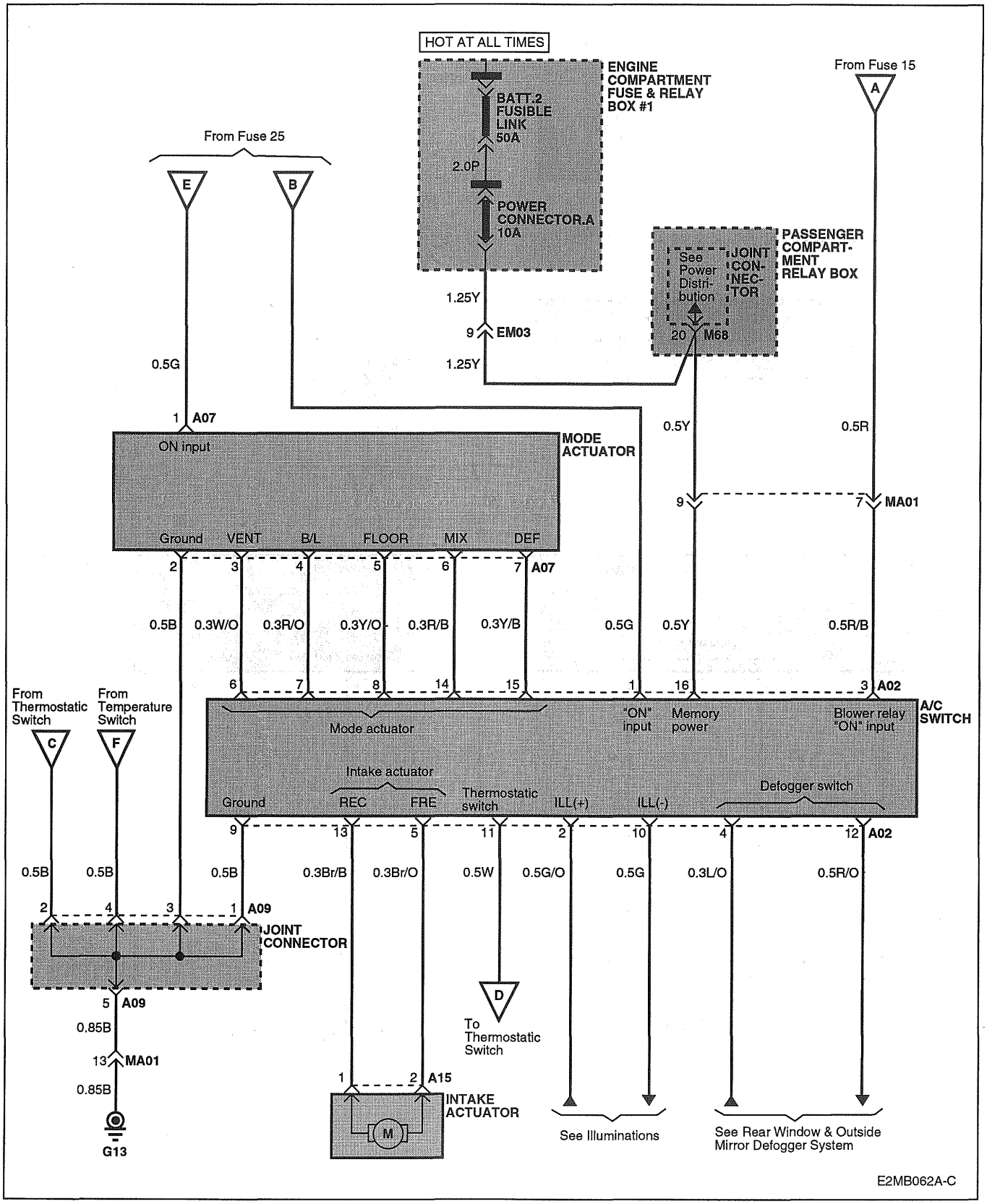
## BLOWER & A/C CONTROLS (MANUAL) (1)



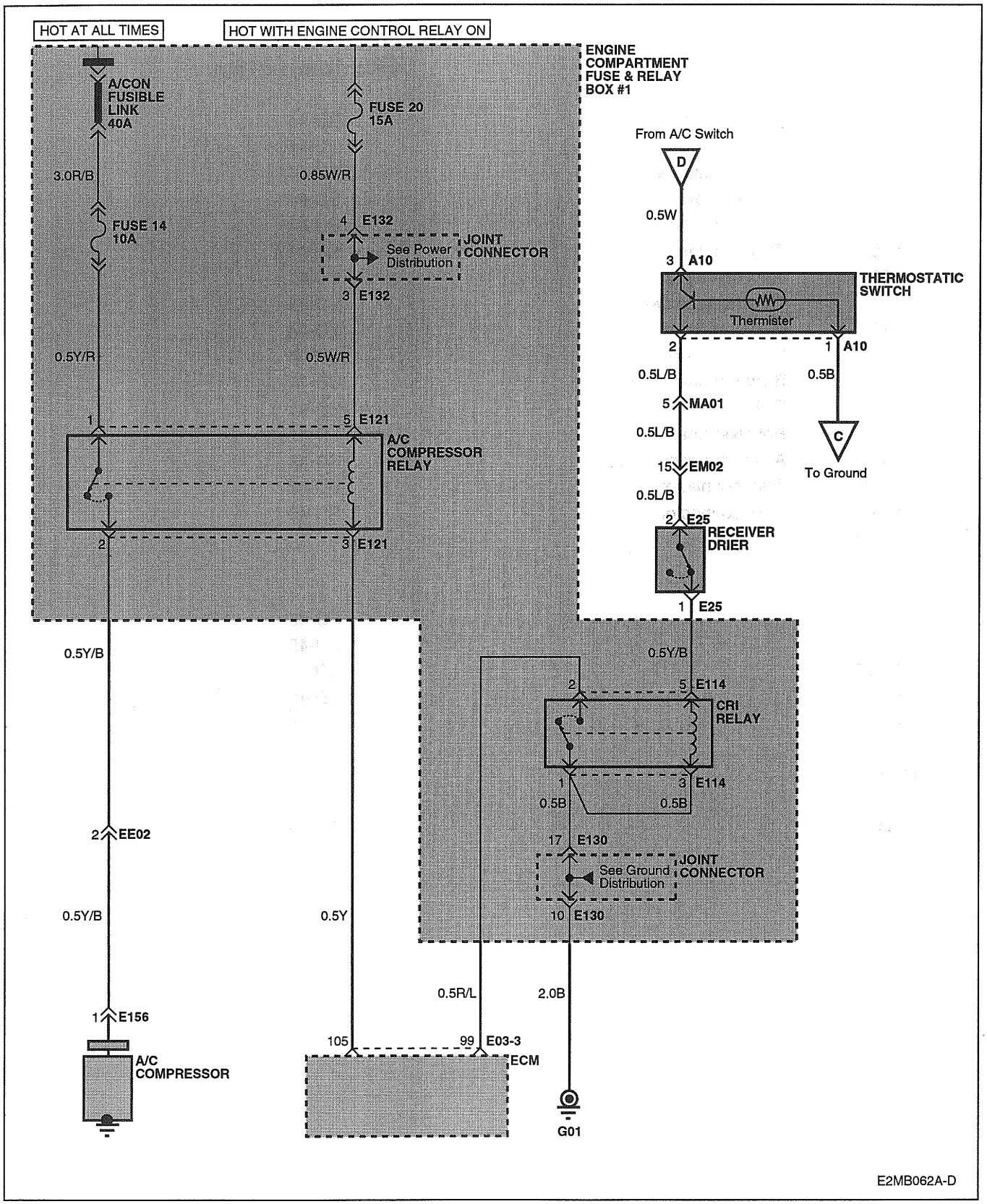
## BLOWER & A/C CONTROLS (MANUAL) (2)



## BLOWER & A/C CONTROLS (MANUAL) (3)



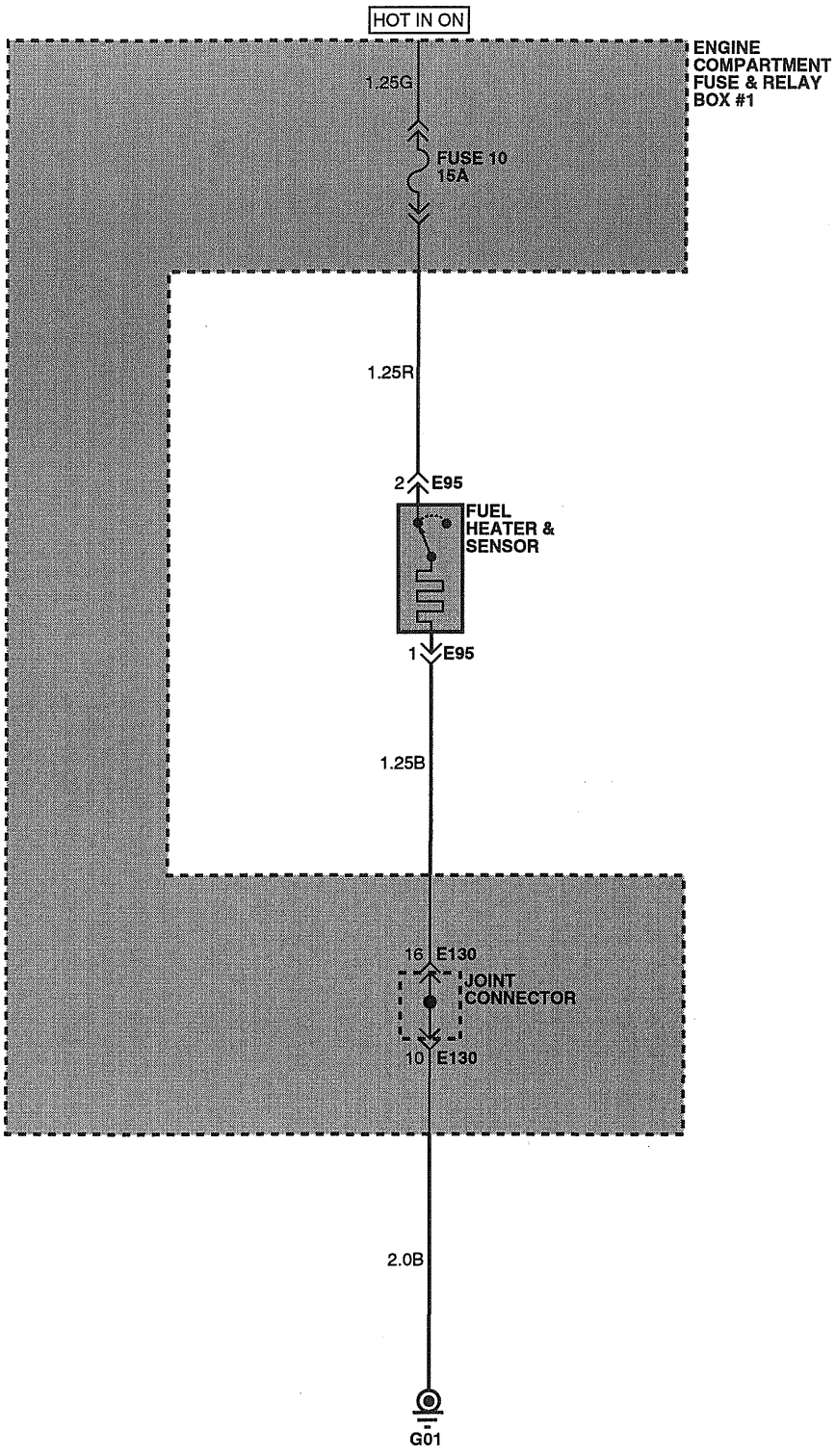
## BLOWER & A/C CONTROLS (MANUAL) (4)



## COMPONENT LOCATION INDEX

MEMO

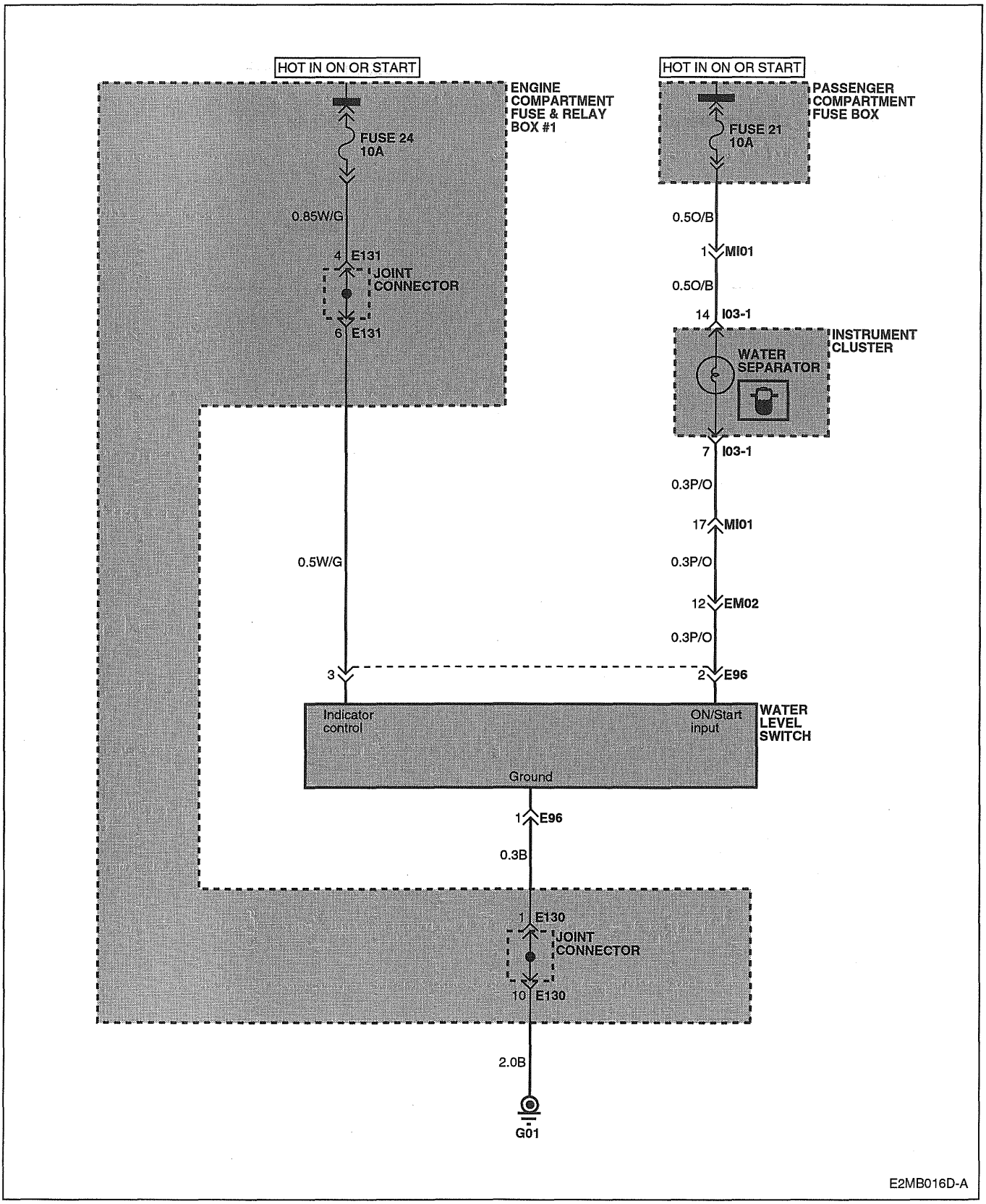
## FUEL & HEATING SYSTEM




E2MB016A-A

## COMPONENT LOCATION INDEX

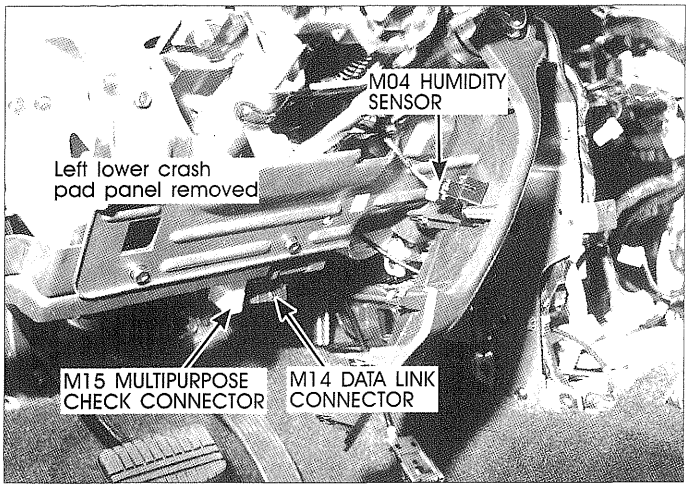
## WATER SEPARATOR SYSTEM



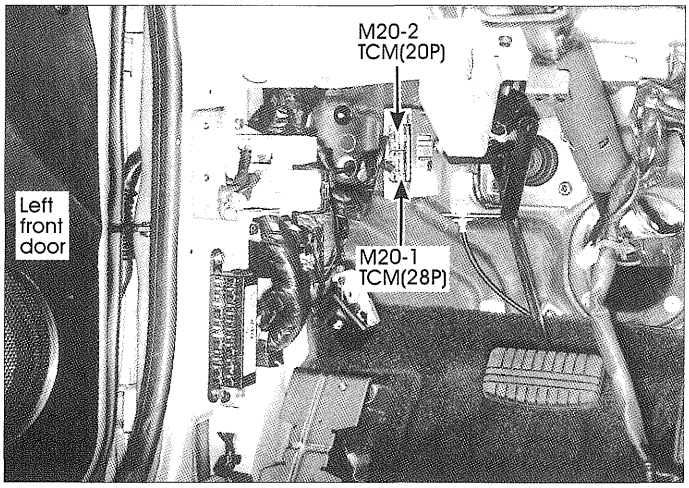
## COMPONENT LOCATION INDEX

# COMPONENT LOCATIONS

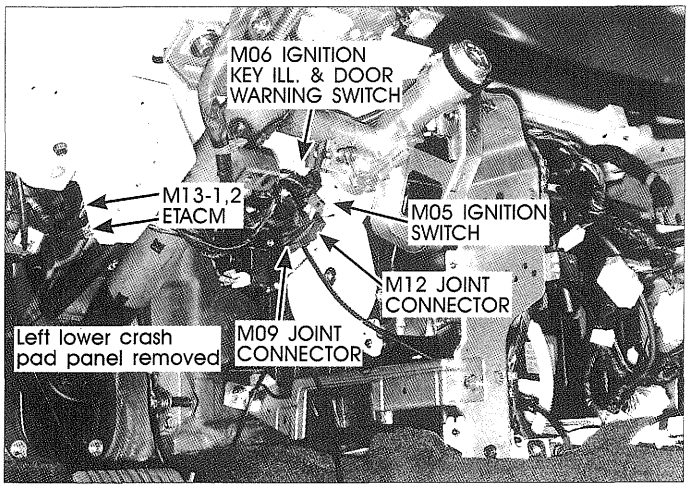
## COMPONENT LOCATIONS(1)



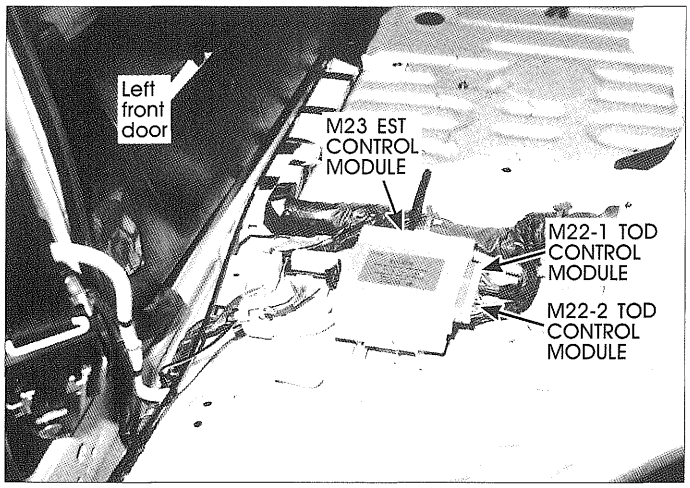

**M04,M14,M15** E3MB001A



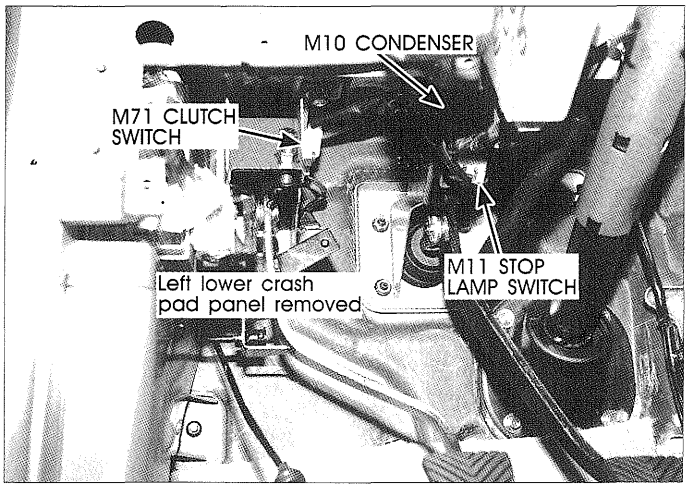

**M20-1,M20-2** E3MB001D



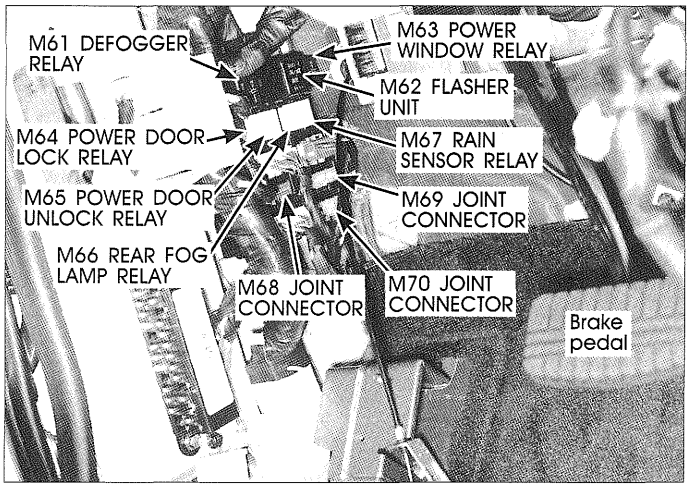

**M05,M06,M09,M12,M13-1,M13-2** E3MB001B




**M22-1,M22-2,M23** E3MB001E

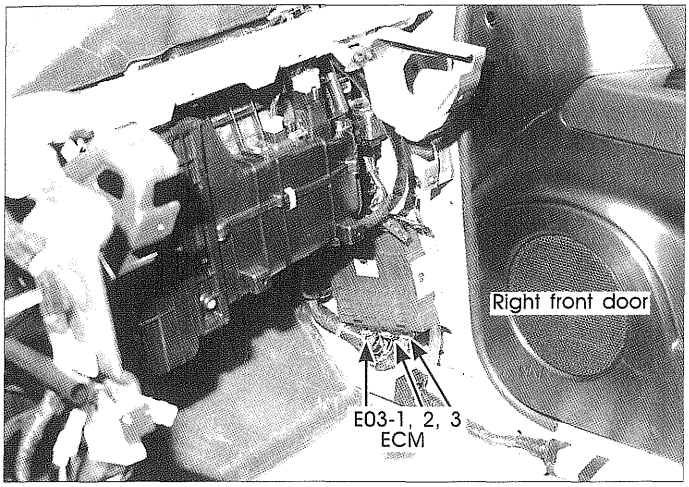



**M10,M11,M71** E3MB001C

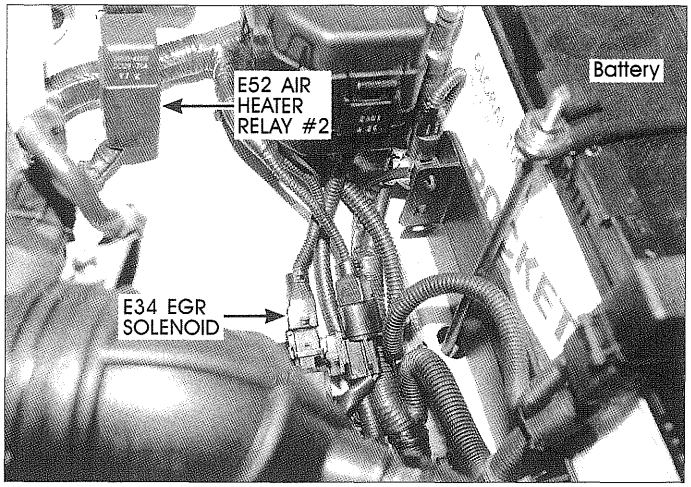



**M61,M62,M63,M64,M65 M66,M67,M68,M69,M70** E3MB001F

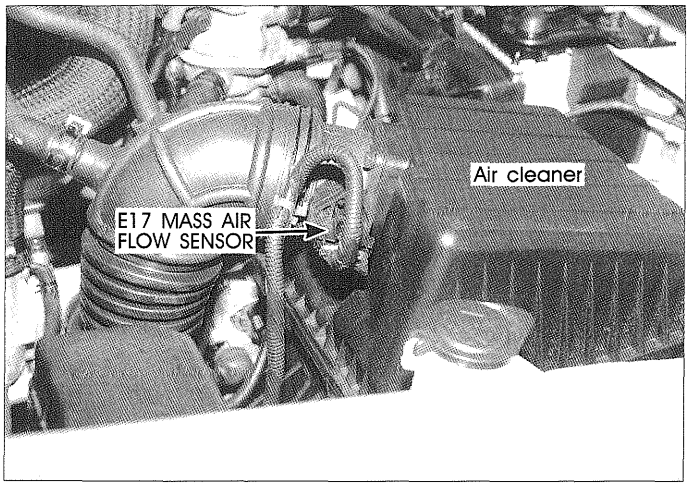
## COMPONENT LOCATIONS(2)



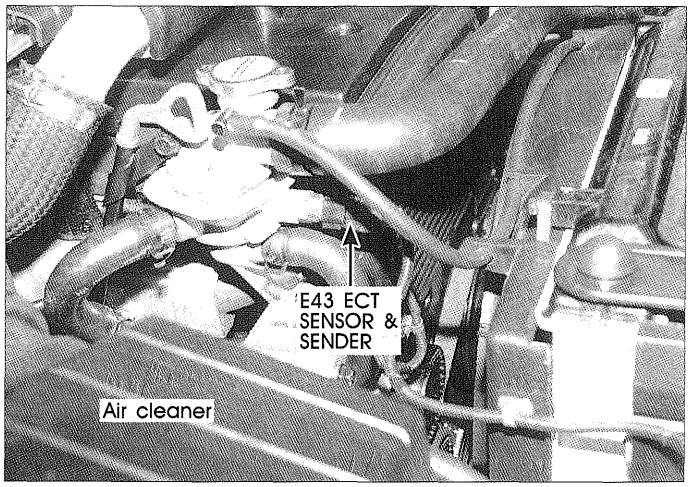

**E03-1,E03-2,E03-3** E3MB001G



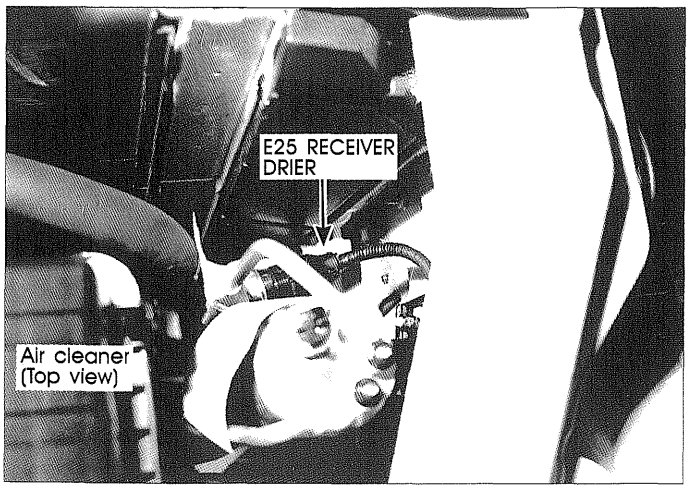

**E34,E52** E3MB001K



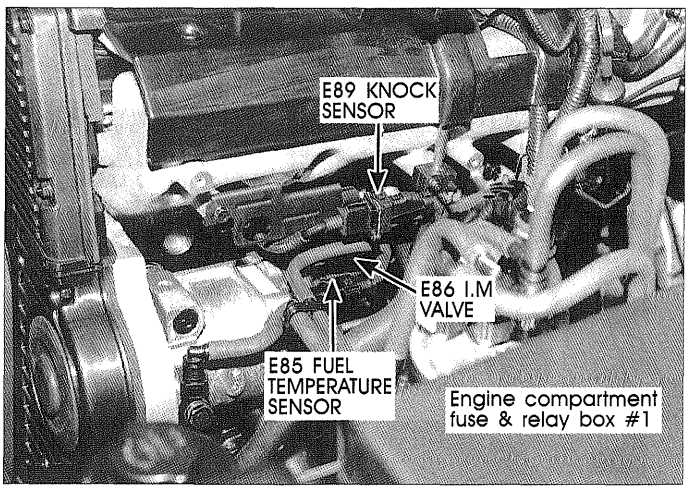

**E17** E3MB001H




**E43** E3MB001L

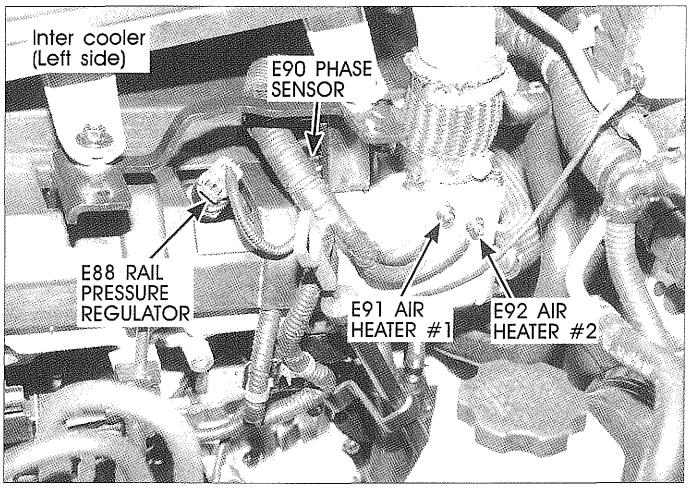



**E25** E3MB001J

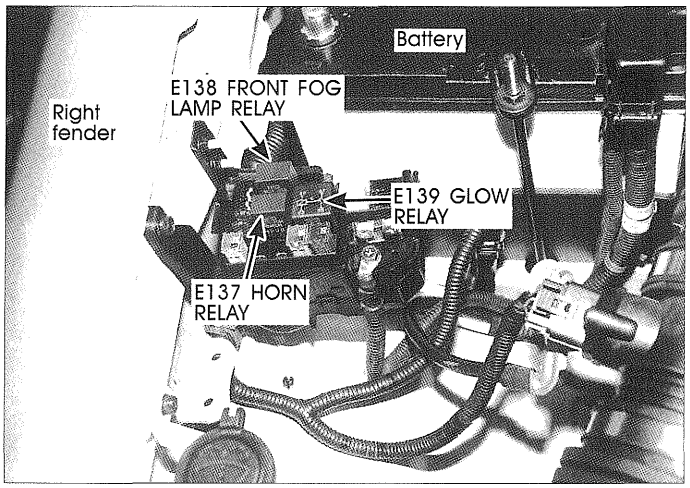



**E85,E86,E89** E3MB001M

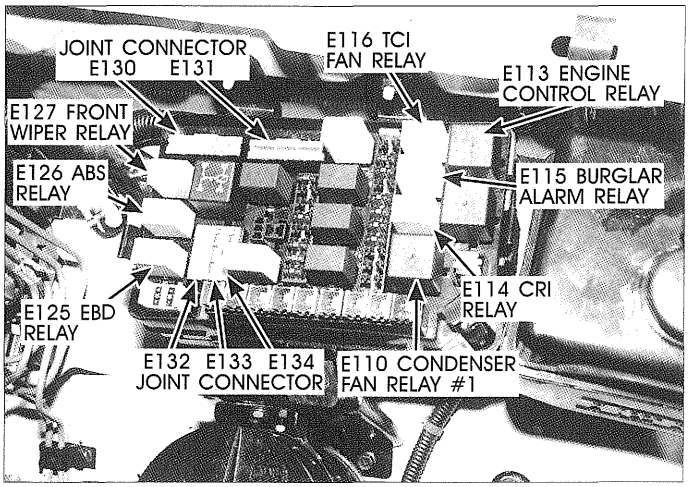
## COMPONENT LOCATIONS(3)



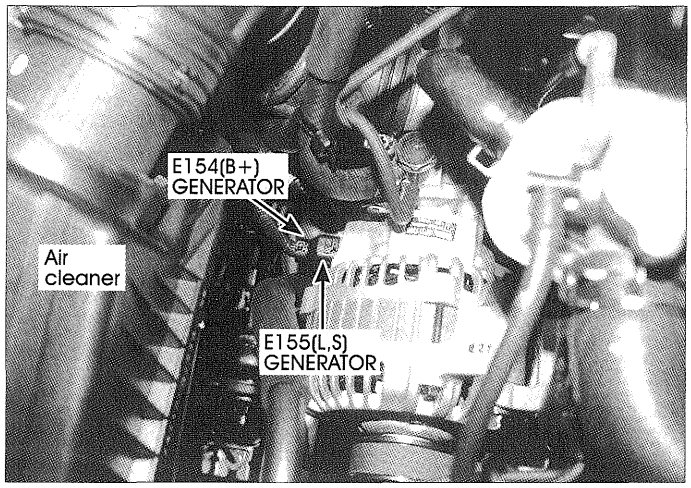

**E88,E90,E91,E92** E3MB001N



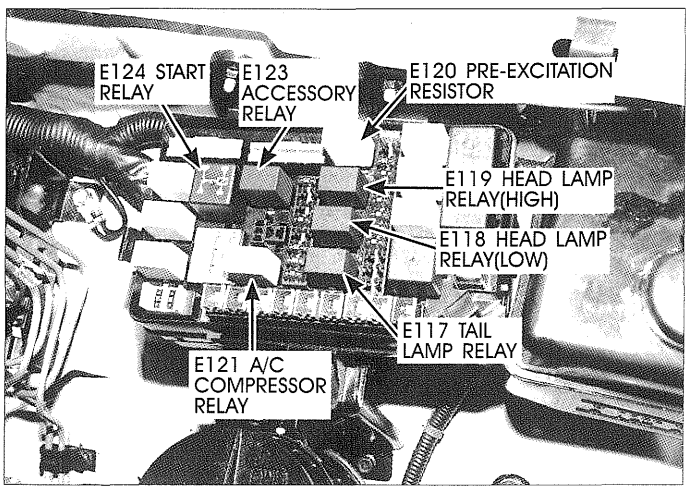

**E137,E138,E139** E3MB001R



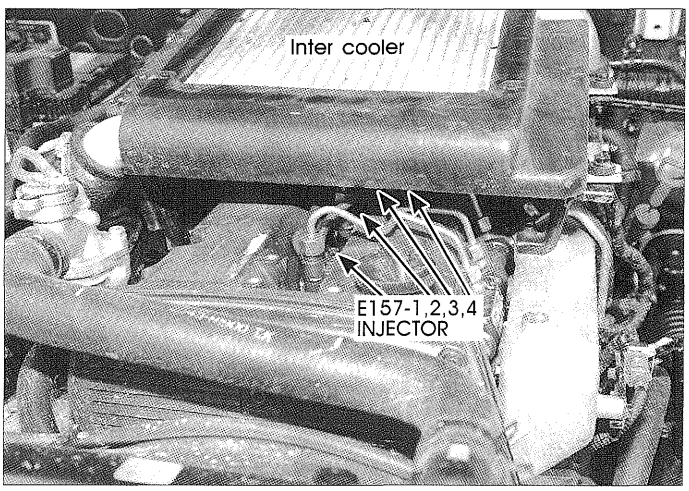

**E110,E113,E114,E115,E116,E125,E126**
**E127,E130,E131,E132,E133,E134** E3MB001P




**E154,E155** E3MB001S

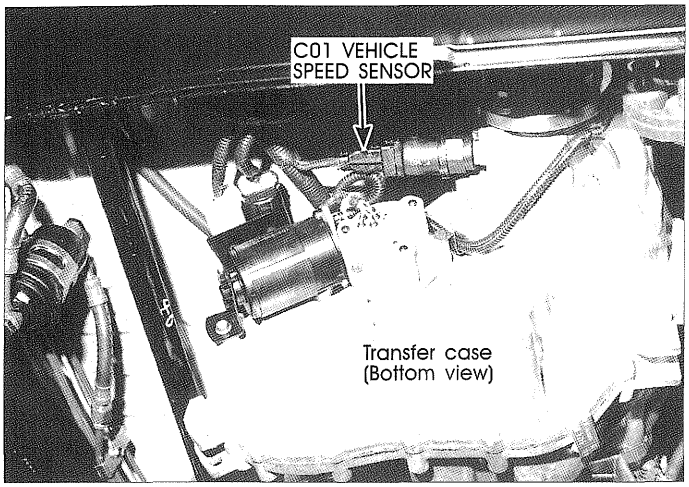



**E117,E118,E119,E120,E121,E123,E124** E3MB001Q

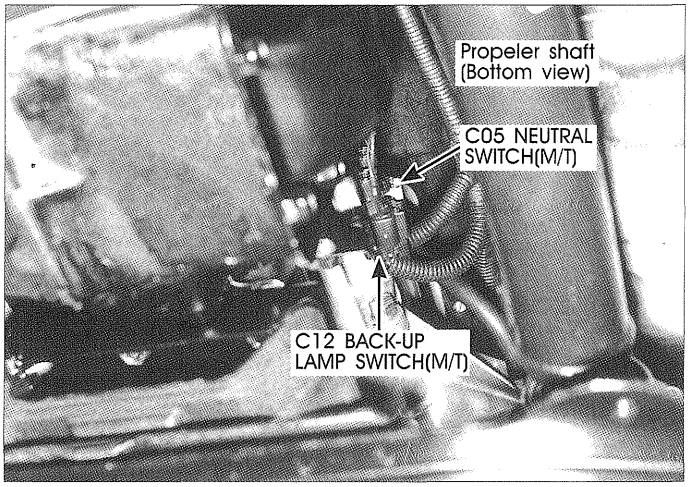



**E157-1,E157-2,E157-3,E157-4** E3MB001T

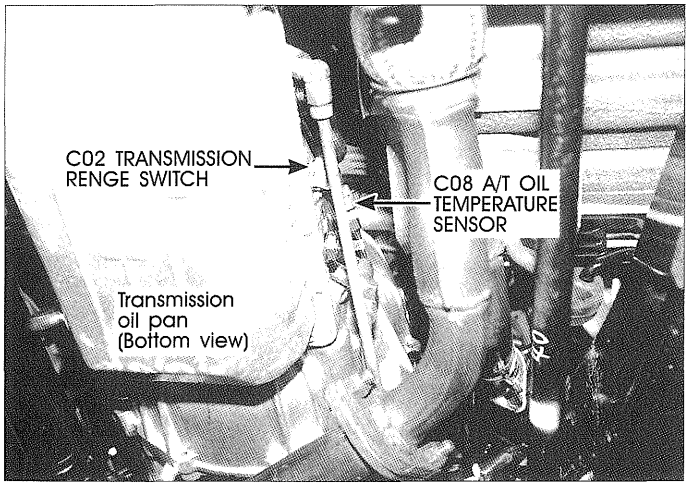
## COMPONENT LOCATIONS(4)



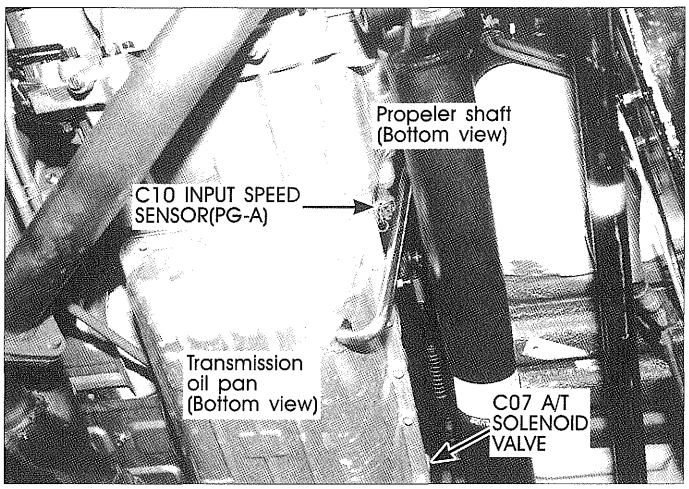

**C01** E3MB001U



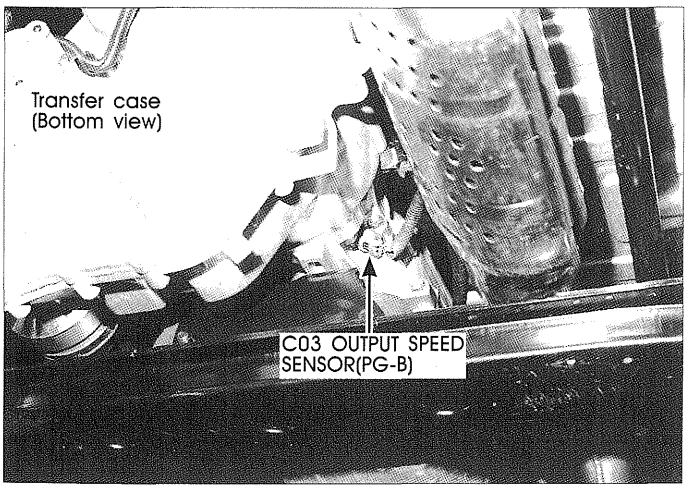

**C05,C12** E3MB001X



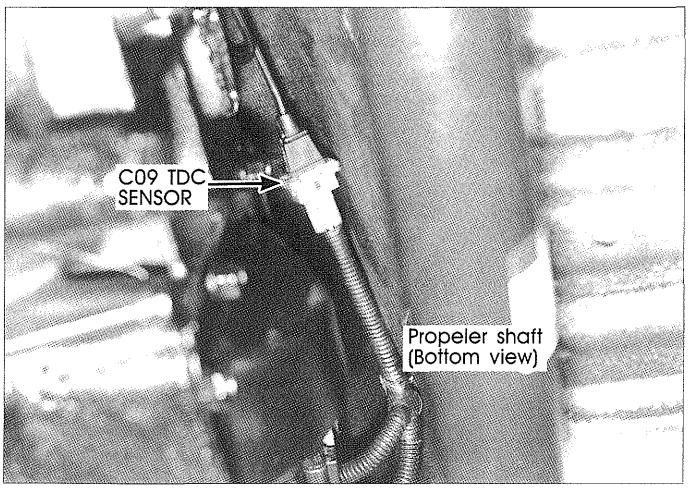

**C02,C08** E3MB001V




**C07,C10** E3MB001Y

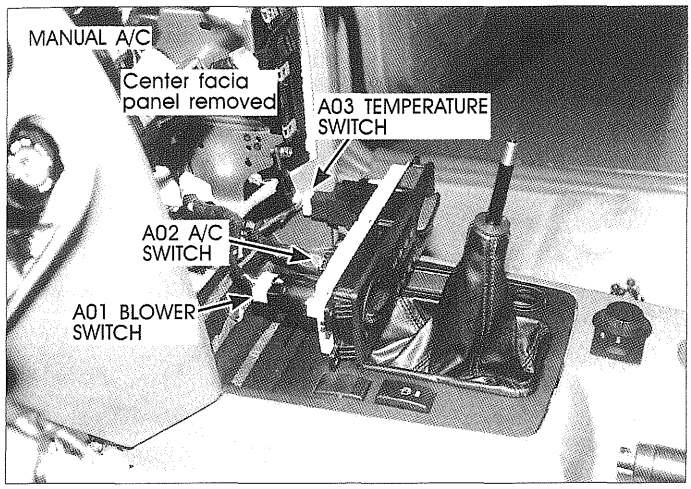



**C03** E3MB001W

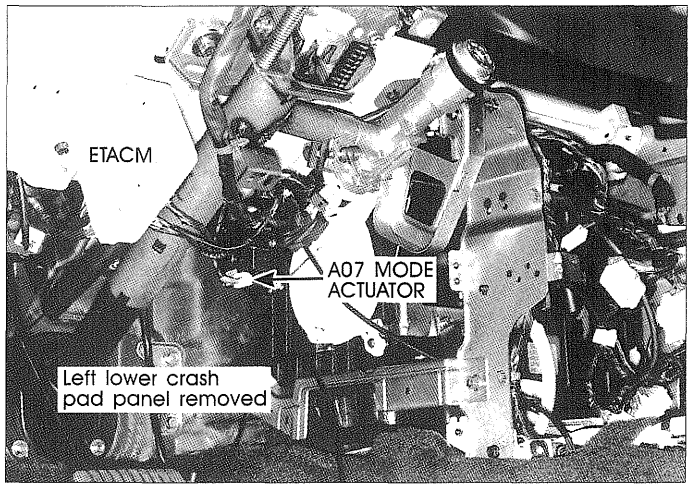



**C09** E3MB001Z

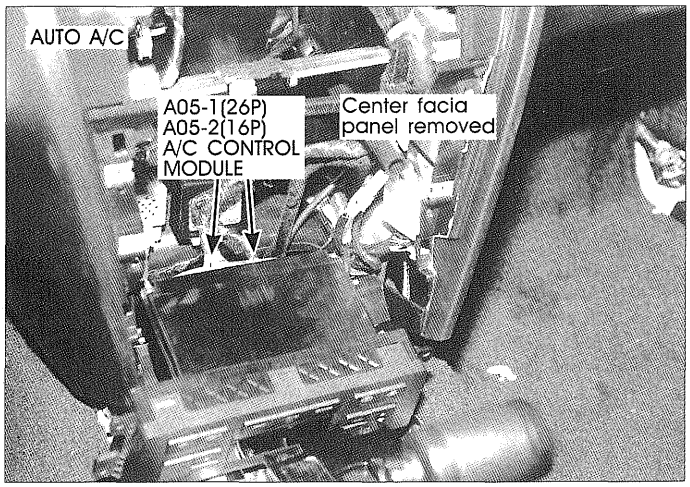
## COMPONENT LOCATIONS(5)



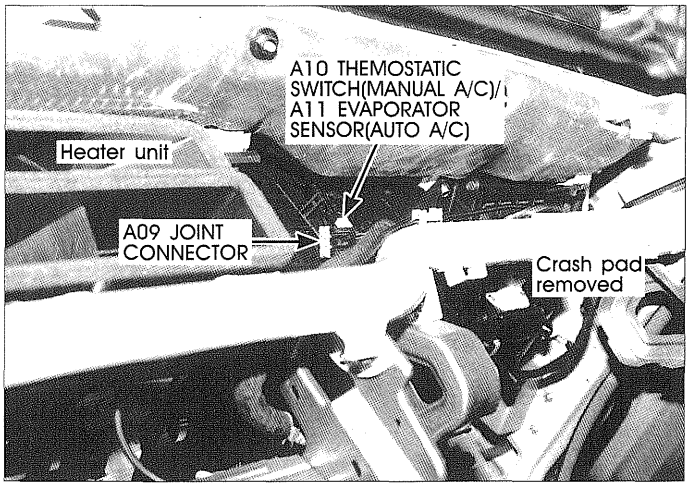

**A01,A02,A03** E3MBA01A



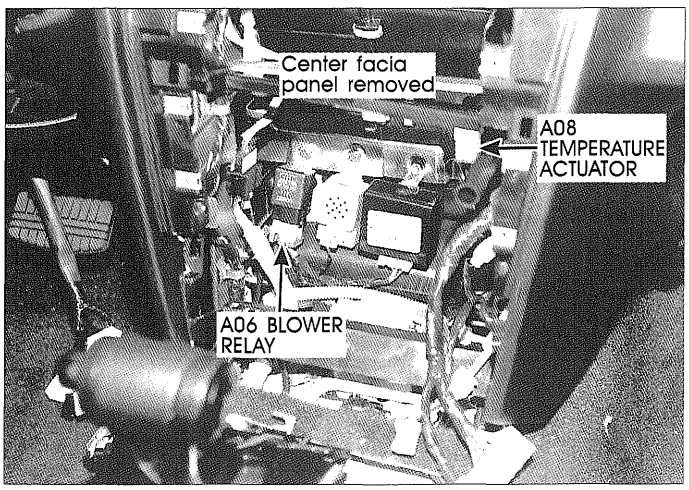

**A07** E3MBA01D



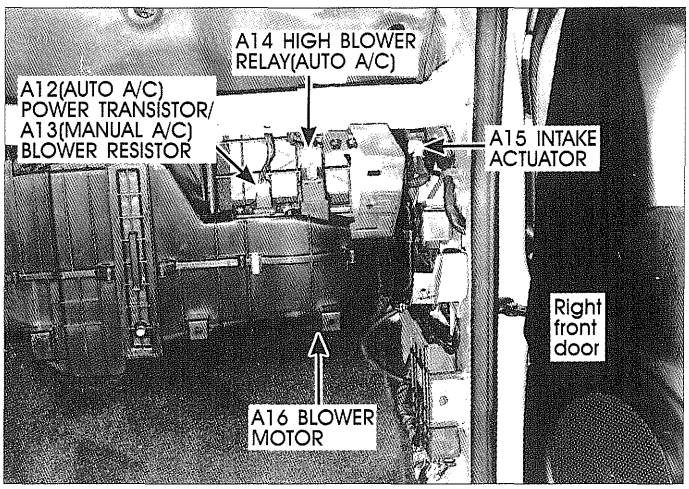

**A05-1,A05-2** E3MBA01B




**A09,A10,A11** E3MBA01E

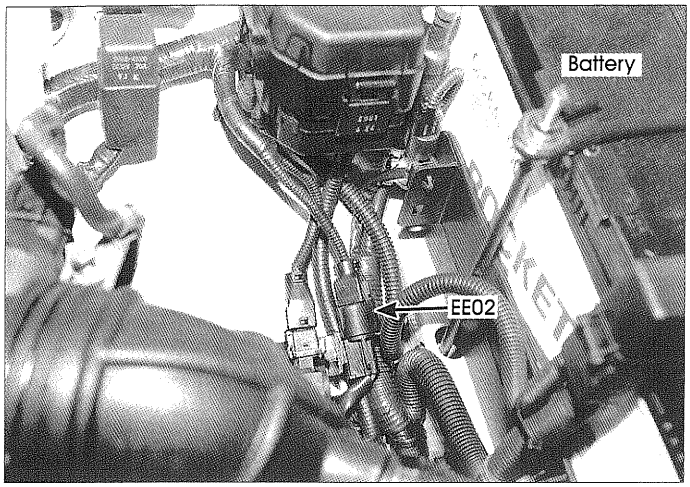



**A06,A08** E3MBA01C

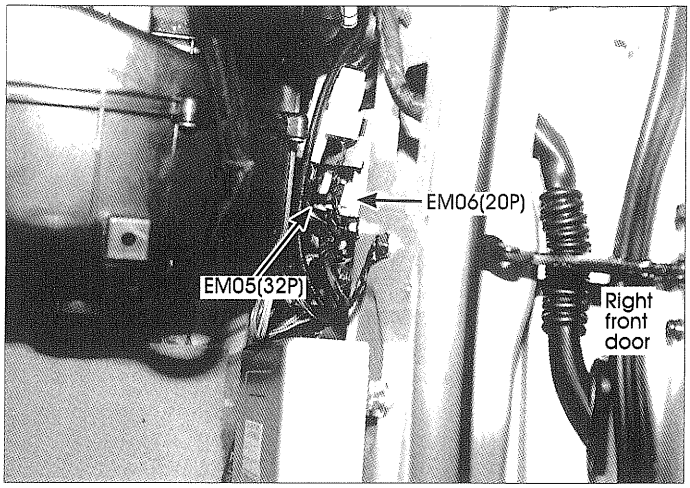



**A12,A13,A14,A15,A16** E3MBA01F

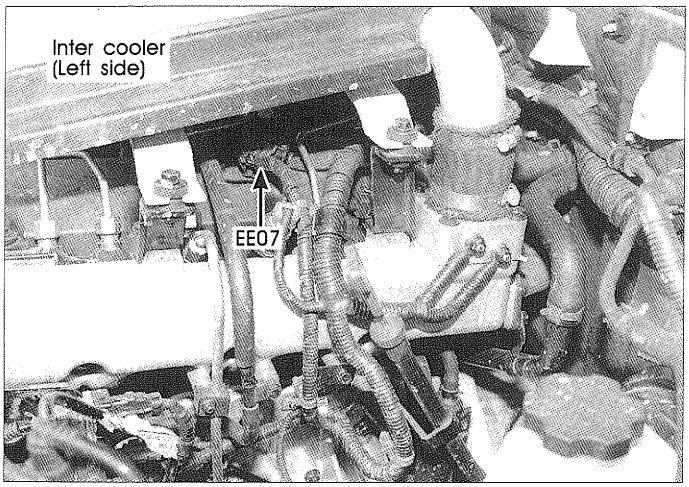
## COMPONENT LOCATIONS(6)



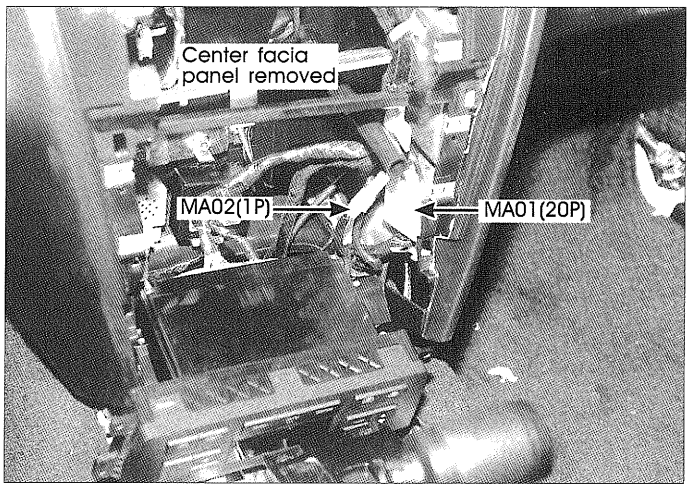

**EE02** E3MBA01G



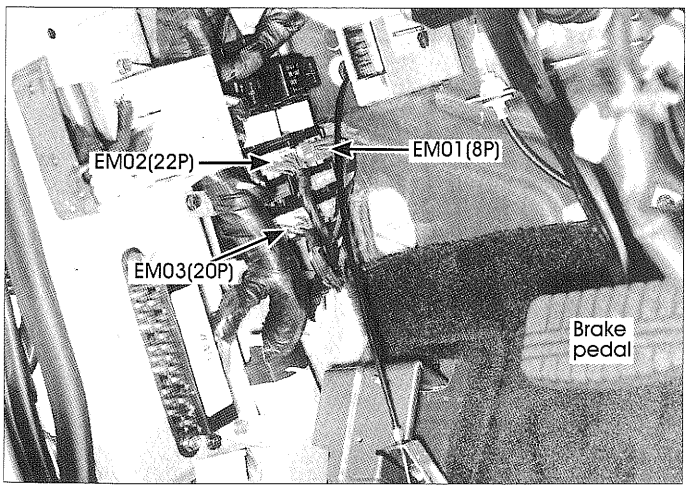

**EM05,EM06** E3MBA01K



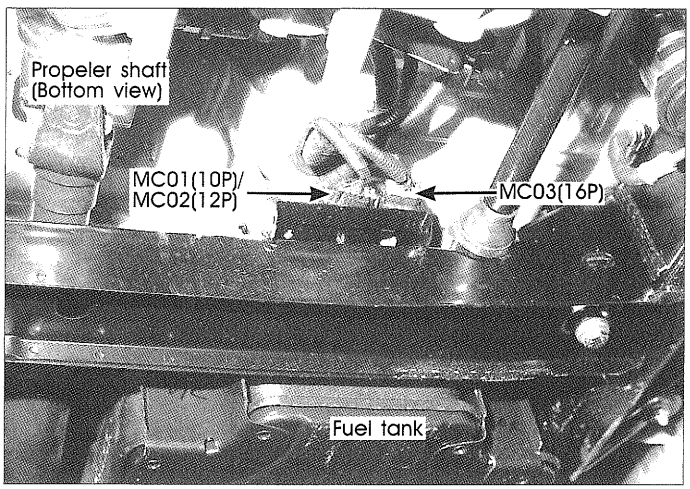

**EE07** E3MBA01H




**MA01,MA02** E3MBA01L

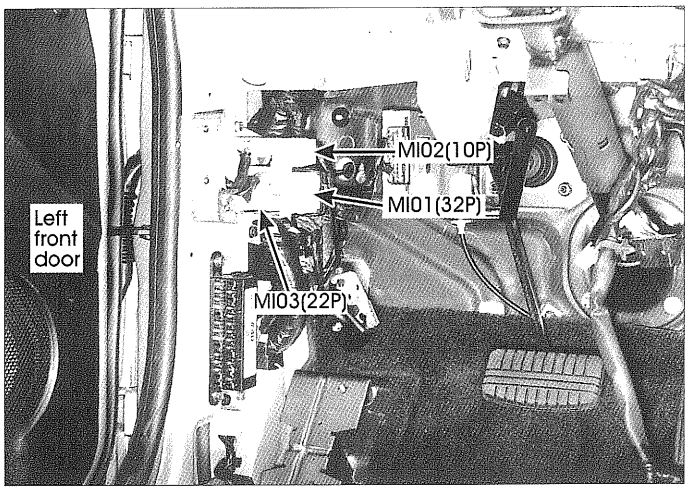



**EM01,EM02,EM03** E3MBA01J

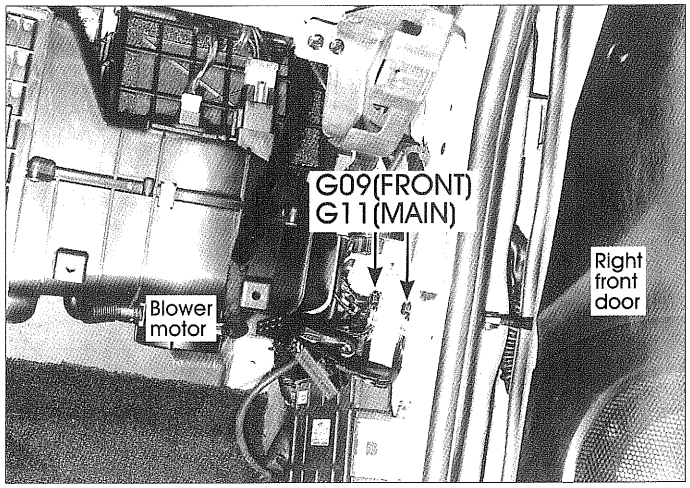



**MC01,MC02,MC03** E3MBA01M

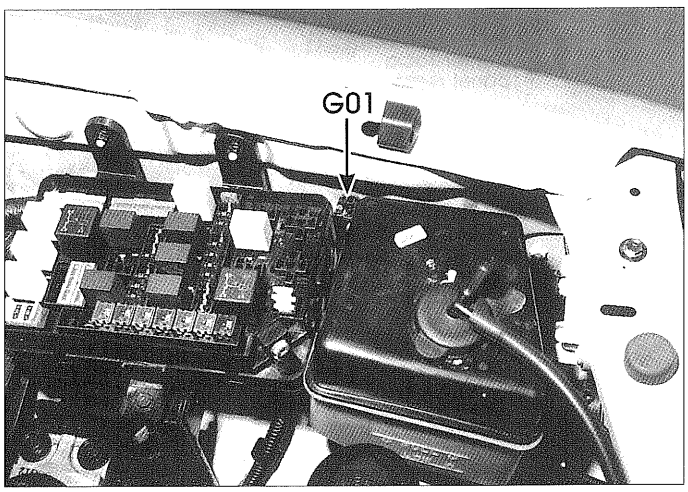
## COMPONENT LOCATIONS(7)



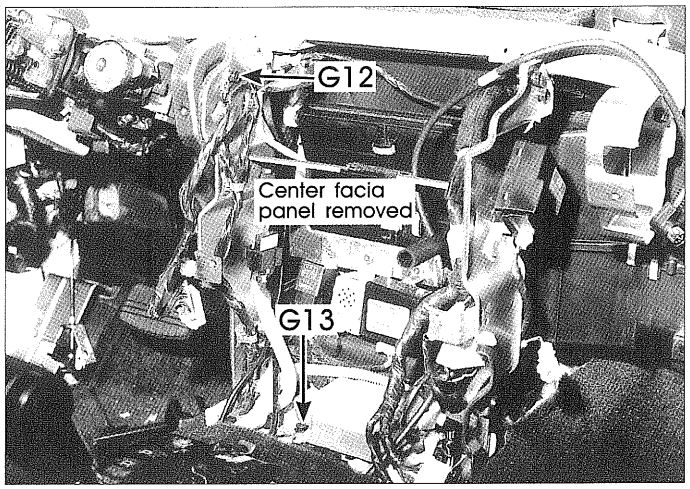

**MI01,MI02,MI03** E3MBA01N



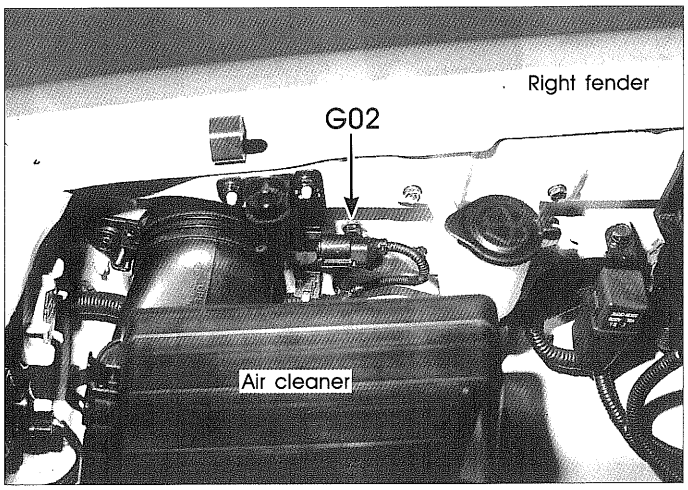

**G09,G11** E3MBA01R



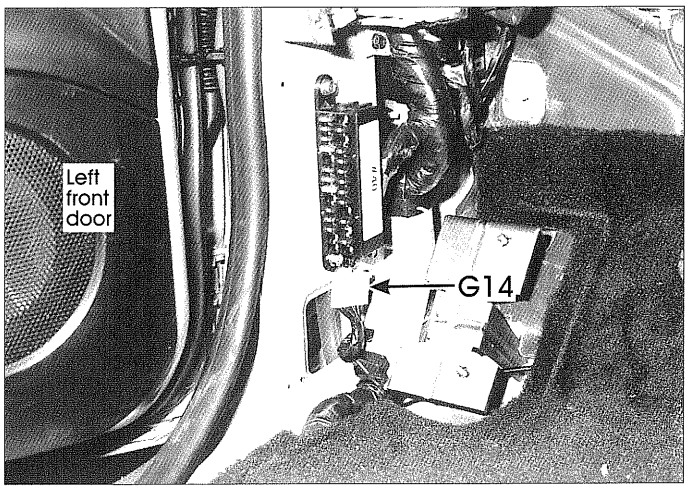

**G01** E3MBA01P




**G12,G13** E3MBA01S




**G02** E3MBA01Q

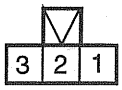



**G14** E3MBA01T

# CONNECTOR CONFIGURATION

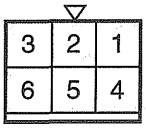
## CONNECTOR CONFIGURATION (1)

### M04



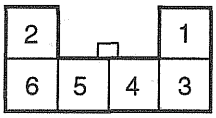

CR03F007

### M05



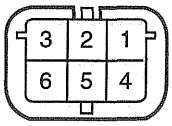

CR06F037

### M06



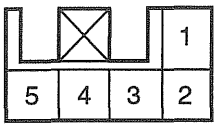

CR06F003

### M07



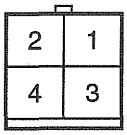

CR06F043

### M08



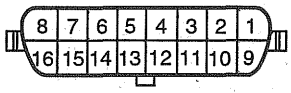

CR05F013

### M11



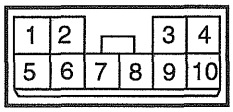

CR04F016

### M14




CR16F022

### M15




CR10M003

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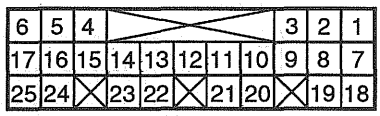
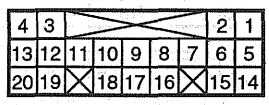
### M20-1



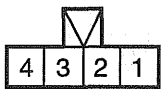

CR25F004

### M20-2




CR20F043

### M30




CR04F010

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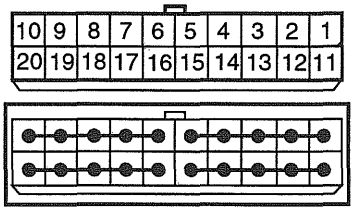
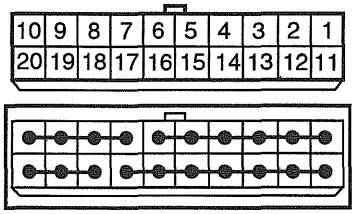
### M68



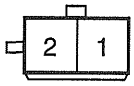

CR20F038

### M70



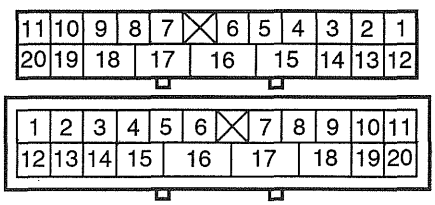

CR20F040

### M71



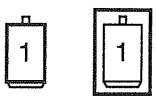

CR02F046

### MA01




CR20B019

### MA02

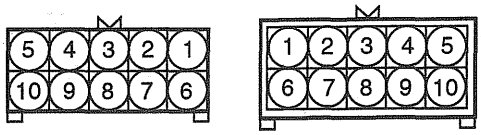



CR01B005

E4MB001A-A

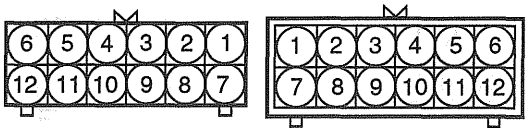
## CONNECTOR CONFIGURATION (2)

### MC01



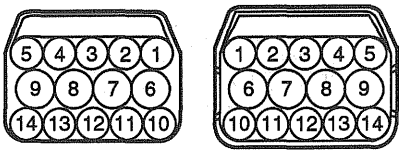

CR10B008

### MC02




CR12B005

### MC03

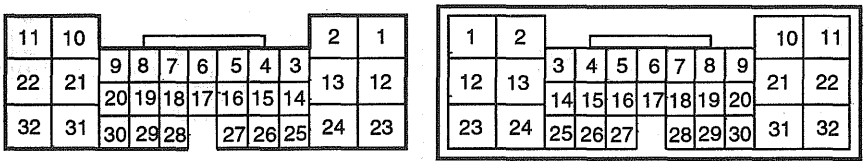



CR14B016

### BLANK

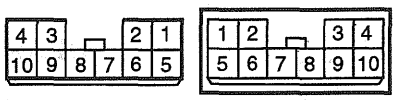
### BLANK

### MI01



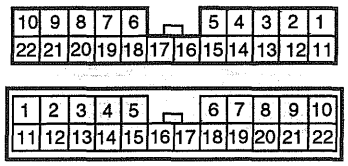

CR32B002

### MI02




CR10B006

### MI03




CR22B007

E4MB001A-B

## CONNECTOR CONFIGURATION (3)

### E03-1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 5 | 9 | 13 | 17 | 21 | 25 | 29 |
| 2 | 6 | 10 | 14 | 18 | 22 | 26 | 30 |
| 3 | 7 | 11 | 15 | 19 | 23 | 27 | 31 |
| 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 |

CR32F002

### E03-2

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | 37 | 41 | 45 | 49 | 53 | 57 | 61 | 65 | 69 | 73 | 77 |
| 34 | 38 | 42 | 46 | 50 | 54 | 58 | 62 | 66 | 70 | 74 | 78 |
| 35 | 39 | 43 | 47 | 51 | 55 | 59 | 63 | 67 | 71 | 75 | 79 |
| 36 | 40 | 44 | 48 | 52 | 56 | 60 | 64 | 68 | 72 | 76 | 80 |

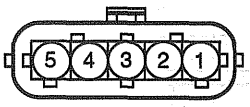
CR48F001

### E03-3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 81 | 85 | 89 | 93 | 97 | 101 | 105 | 109 |
| 82 | 86 | 90 | 94 | 98 | 102 | 106 | 110 |
| 83 | 87 | 91 | 95 | 99 | 103 | 107 | 111 |
| 84 | 88 | 92 | 96 | 100 | 104 | 108 | 112 |

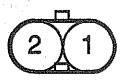
CR32F003

### E17



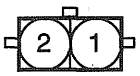

CR05F039

### E25



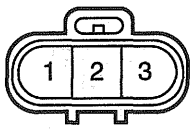

CR02F014

### E34



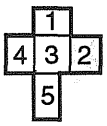

CR02F009

### E43




CR03M015

### E52




CR05F007

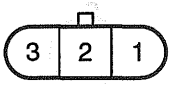
### E55


CR01F037

### E70


CR01M005

### E75

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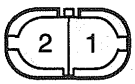


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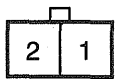


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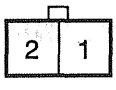


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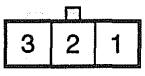


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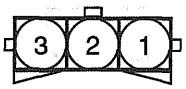


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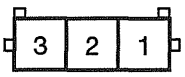


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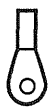
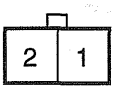


CR01F002

### E92

CR01F002

### E95

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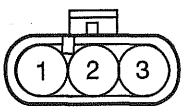


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E4MB001A-C

## CONNECTOR CONFIGURATION (4)

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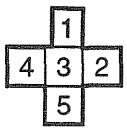


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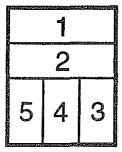


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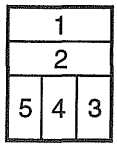


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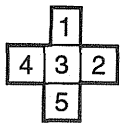


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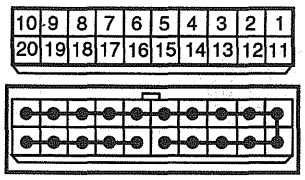


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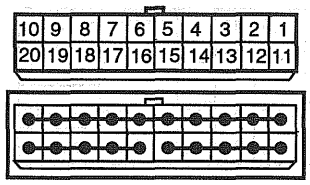


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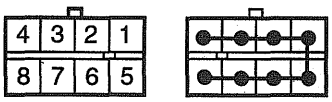


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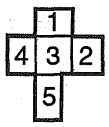


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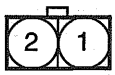
CR01F002

### E154

CR01F002

### E155

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CR01F038

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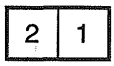


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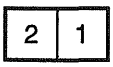


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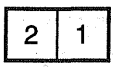


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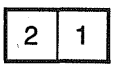


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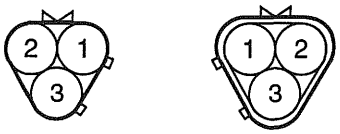


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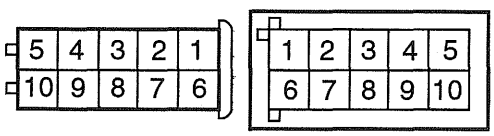


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E4MB001A-D

## CONNECTOR CONFIGURATION (5)

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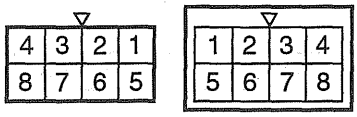


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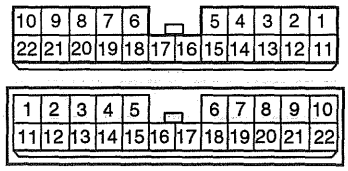


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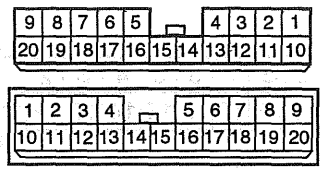


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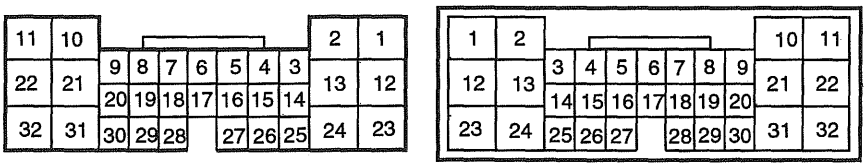


CR32B002

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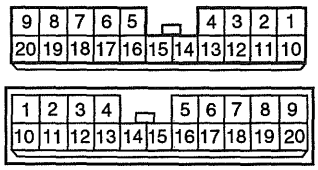


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E4MB001A-E

## CONNECTOR CONFIGURATION (6)

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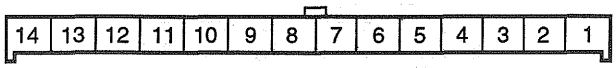
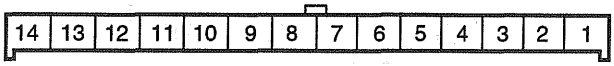


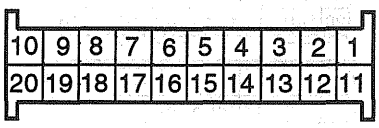

CR14F007

**I03-2**




CR14F007

**I03-3**




CR20F020

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E4MB001A-F

# Fuel System

# COMMON RAIL ACCUMUALTOR FUEL-INJECTION SYSTEM

## Field of application

The in-line fuel-injection pump's main area of application is still in all sizes of commercial-vehicle diesel engines, stationary diesel engines, locomotives and ships. Injection pressures of up to approx. 1600 bar are used to generate output powers of up to about 160 kW per cylinder.

Over the years, a wide variety of different requirements, such as the installation of direct-injection (DI) engines in small delivery vans and passenger cars, have led to the development of various diesel fuel-injection systems which are aligned to the requirements of a particular application. Of major importance in these developments are not only the increase in specific power, but also the demand for reduced fuel consumption, and the call for lower noise and exhaust-gas emissions. Compared to conventional cam-driven systems, the Delphi "Common Rail" fuel-injection system for direct-injection (DI) diesel engines provides for considerably higher flexibility in the adaptation of the injection system to the engine, for instance:

- Extensive area of application (for passenger cars and light commercial vehicles with output powers of up to 30kW/cylinder, as well as for heavy-duty vehicles, locomotives, and ships with outputs of up to approx. 200kW/cylinder,
- High injection pressures of up to approx. 1400 bar.
- Variable start of injection,
- Possibility of pilot injection, main injection, and post injection,
- Matching of injection pressure to the operating mode.

## Funtions

Pressure generation and fuel injection are completely decoupled from each other in the "Common Rail" accumulator injection system. The injection pressure is generated independent of engine speed and injected fuel quantity. The fuel is stored under pressure in the high-pressure accumulator (the "Rail") ready for injection. The injected fuel quantity is defined by the driver, and the start of injection and injection pressure are calculated by the ECU on the basis of the stored maps. The ECU then triggers the solenoid valves so that the injector (injection unit) at each engine cylinder injects accordingly. The ECU and sensor stages of such a CR fuel-injection system comprise:

- ECU,
- Crankshaft angle sensor,
- Phase sensor,
- Accelerator-pedal sensor,
- Rail-pressure sensor,
- Water temperature sensor and,
- Air-flow sensor.

Using the input signals from the above sensors, the ECU registers the driver's requirements (accelerator-pedal setting) and defines the instantaneous operating performance of the engine and the vehicle as a whole. It processes the signals which have been generated by the sensors and which it receives via data lines. On the basis of this information, it can then intervene with open and closed-loop controlling action at the vehicle and particularly at the engine. The engine speed is measured by the crankshaft-Angle sensor, and the phase sensor and the phase sensor determines the firing sequence (phase length). The electrical signal generated across a potentiometer in the accelerator-pedal module informs the ECU about how far the driver has depressed the pedal, in other words about his (her) torque requirement.

The ari-flow sensor meter provides the ECU with data on the instantaneous air flow in order that combustion can be adapted so as to comply with the emissions regulations.

## Basic functions

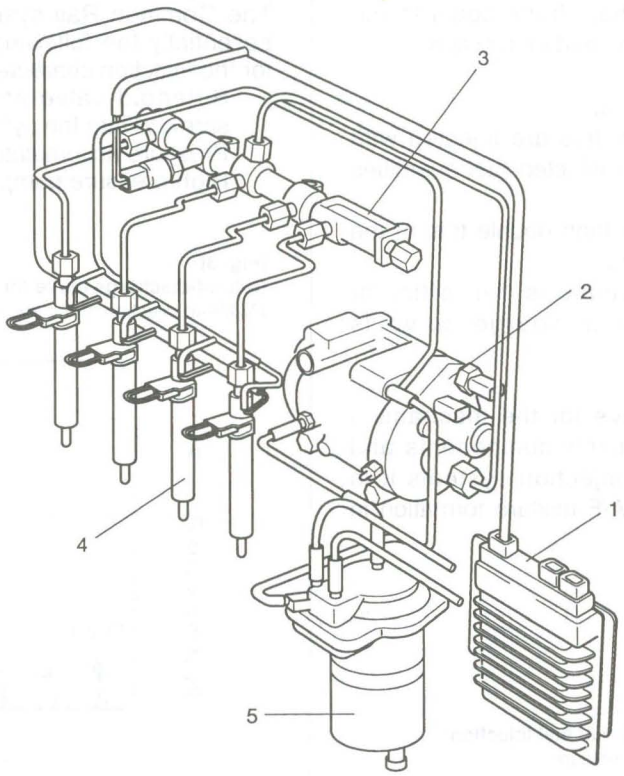
The basic functions control the injection of the diesel fuel at the right moment, in the right quantities, and with the correct injection pressure. They ensure that the diesel engine not only runs smoothly, but also economically.

## Auxiliary functions

Auxiliary closed and open-loop control functions serve to improve both the exhaust-gas emission and fuel-consumption figures, or are used for increasing safety, comfort, and convenience. Examples here are Exhaust-Gas Recirculation (EGR), vehicle-speed control, and electronic immobilizer etc.

The CAN bus system permits the exchange of data with other electronic systems in the vehicle. During vehicle inspection in the workshop, a diagnosis interface permits evaluation of the stored system data.

[Fig. 1]
**Common Rail accumulator injection system on a 4-cylinder diesel engine**




**NOTE**
**This drawing is not exactly same with real lay-out.**

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1. ECU
2. High-pressure pump(Lift pump integrated)
3. High-pressure accumulator (rail)
4. Injectors
5. Fuel filter

# Injection characteristics

## Conventional injection characteristics

With conventional injection systems, using distributor and in-line injection pumps, fuel injection today comprises only the main injection phase - without pilot and post-injection phases (Fig. 2). On the solenoid-valve-controlled distributor pump though, developments are progressing towards the introduction of a pilot-injection phase. In conventional systems, pressure generation and the provision of the injected fuel quantity are coupled to each other by a cam and a pump plunger. This has the following effects upon the injection characteristics:

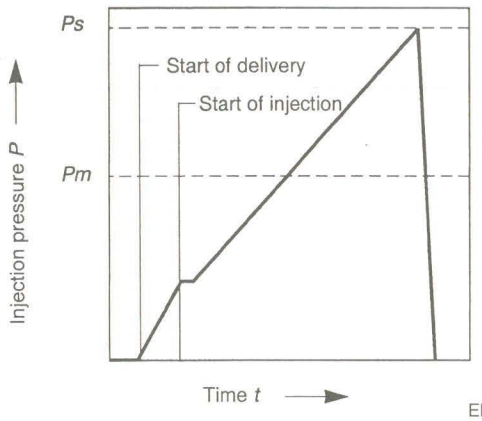
- The injection pressure increases together with increasing speed and injected fuel quantity
- During the actual injection process, the injection pressure increases and then drops again to the nozzle closing pressure a the end of injection

The consequences are as follows:

- Smaller injected fuel quantities are injected with lower pressures than larger injected fuel quantities (refer to Fig. 2)
- The peak pressure is more than double that of the mean injection pressure, and
- In line with the requirements for efficient combustion, the rate-of discharge curve is practically triangular.

The peak pressure is decisive for the mechanical loading of a fuel-injection pump's components and drive. On conventional fuel-injection systems it is decisive for the quality of the A/F mixture formation in the combustion chamber.

**[Fig. 2]**
**Rate-of-discharge curve for conventional fuel injection**
*Pm* Mean injection pressure, *Ps* Peak pressure




## Injection characteristics with common rail

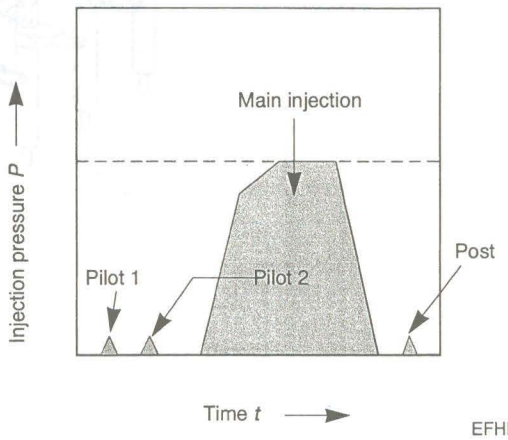
Compared to conventional injection characteristics, the following demands are made upon an ideal injection characteristic:

- Independently of each other, injected fuel quantity and injection pressure should be definable for each and every engine operating condition (provides more freedom for achieving ideal A/F mixture formation)
- At the beginning of the injection process, the injected fuel quantity should be as low as possible (that is, during the ignition lag between the start of injection and the start of combustion).

These requirements are complied with in the Common rail accumulator injection system with its pilot and main, post-injection features (Fig. 3).
The Common Rail system is a modular system, and essentially the following components are responsible for the injection characteristic:

- Solenoid-valve-controlled injectors which are screwed into the cylinder head,
- Pressure accumulator (rail), and
- High-pressure pump

**[Fig. 3]**
**Rate-of-discharge curve for Common Rail fuel injection**
*Pm* Mean injection pressure, *PR* Rail pressure




The following components also required in order to operate the system:

- Electronic control unit (ECU),
- Crankshaft-angle sensor, and
- Phases sensor.

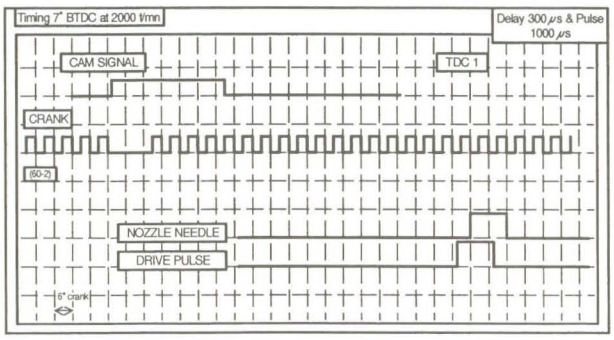
For passenger-car systems, a radial-piston pump is used as the high-pressure pump for pressure generation. Pressure is generated independently of the injection process. The speed of the high-pressure pump is coupled directly to the engine speed with a non-variable transmission ratio. In comparison with conventional injection systems, the fact that delivery is practically uniform, means that not only is the Common Rail high-pressure pump much smaller, but also that its drive is not subject to such high pressure-loading peaks.

The injectors are connected to the rail by short lines and, essentially, comprise a nozzle, and a solenoid valve which is energized by the ECU to switch it on (start of injection). When the solenoid valve is switched off (de-energized) injection ceases. Presuming constant pressure, the injected fuel quantity is directly proportional to the length of time the solenoid valve is energized. It is completely independent of the engine or pump speed (time-controlled fuel injection).
The required high-speed solenoid switching is achieved by using high voltages and currents. This means that the solenoid-valve triggering stage in the ECU must be designed accordingly.
The start of injection is controlled by the angle-time control system of the EDC (Electronic Diesel Control). This uses a sensor on the crankshaft to register engine speed, and a sensor on the camshaft for phase detection (working cycle).

## Gerneral principle

This system is a pressure-time injection equipment for which the injected quantity is the result of injection pressure and duration.
Given that each injector is electrically driven by the ECU, and that fuel under pressure is continuously available for injection, the ECU fixes with certitude when and which injector has to be energised. For this purpose a period signal equal to the engine cycle(2 engine revolutions) is considered by the ECU.
The generic system uses a 60-2 events type flywheel (2 consecutive events missing, located at an angle configured in the software between TDC of cylinder n°1 and the previous cylinder in the firing order). It also uses one cam event signal every two engine revolutions in phase with the flywheel signal sungularity.

[Fig. 4]

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For the generic system, the flywheel sensor is a "variable reluctance type" and the cam event sensor is a "Hall effect type".
Special strategies with several cam events can be developed within the context of specific customer demand, likewise other sensor technologies may be used.

The engine speed can vary from:
-0 to 5000 erpm in full load,
-5000 to 6000 erpm with gradual injection cut-off,
-6000 to 7000 erpm accidentally.

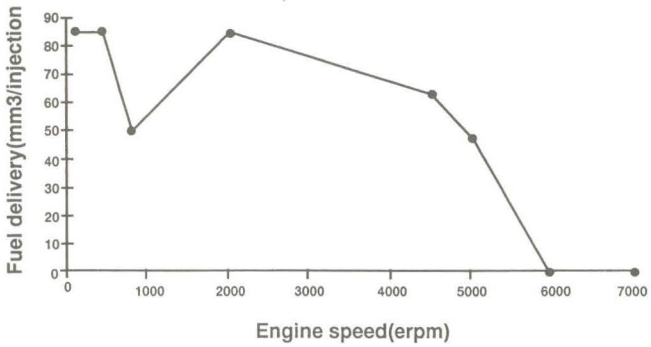
The software module which procdsses cam and flywheel events provides to other system functions the necessary events for tasks scheduling and the injector number data.
Two states exists:
Synchronising state: During this state, no outputs are provided.
Synchronised statd: During this state, the normal and rebuilt (missing teeth) events are provided.
When synchronisation is lost, injections are cut-off until synchronisation is recovered.

There is no general engine state but states per function i.e. cranking and running modes are defined for fuelling and timing control.

## Fuelling control

Diesel fuel may be injected into each cylinder 4 times as a maximum: one far pilot injection, one close pilot injection, the main injection and a post injection.
Typical pilot injection amount are from 0.8 mm3/st at idle to 5 mm3/st in full load, any value between these values being possible. The use of pilot injections is possible throughout the whole engine speed and load range.
The sum of the pilot and main injections can be included within the maximum injected delivery mentioned on the follwing graph:

[Fig. 5]



# EXHAUST-GAS REDUCTION

## Mixture formation and combustion behavior

Compared to SI engines, diesel engines burn low-volatility (high-boiling) fuel, and not only prepare the air/fuel mixture in the period between injection and start of combustion, but also during the actual combustion process. The result is a less homogenous mixture. The diesel engine always operates with excess air (¥≥ 1).
Fuel consumption, and the emissions of soot, CO, and HC increase if there is insufficient excess air.
The A/F mixture formation is defined by the following parameters:

- Injection pressure,
- Rate of discharge (injection time),
- Spray distribution (number of spray jets, spray cross-section, spray direction),
- Start of injection,
- Air movement, and
- Air mass.

These quantities all have an effect upon the engine's emissions and fuel consumption. High combustion temperatures and high levels of oxygen concentration lead to increased NOx generation. Soot emissions rise due to lack of air and poor A/F mixture formation.

## Measures at the engine

The configuration of the combustion chamber and air-intake tract can have a positive effect upon the exhaust-gas emissions. If the air movement in the combustion chamber is carefully matched to the fuel jets leaving the nozzle, this promotes efficient mixing of air and fuel and thus complete combustion of the injected fuel. In addition, positive effects are achieved with a homogenous mixture of air and exhaust gas and a cooled EGR tract. Four-valve techniques and turbochargers with variable-turbine geometry (VTG) also contribute to lower emissions and higher power density.

The system is capable of balancing line to line injections over a range of engine speeds, and partly compensating the fuel delivery and engine drifts in the couse of time.
The post injection is used as a reduction agent for exhaust after-treatment in a DeNox catalyst. The post injection is activated when the required fuel amount reach the minimal controllable quantity (function of rail pressure). The post injection can be induced up to once per injection cycle.

## Start of logic pulse

The injection start is fixed as being the angle between when the injector starts to inject and the top dead center(TDC) of the cylinder where the injection is made. The TDC position is known thanks to the engine events and data configured in the software.
For far pilot injection, the start of injection may vary between 90° before TDC and 10° before TDC.
The start of close pilot injection may vary from 40° before TDC to TDC.
Main injectionstart may be situated between 25° before TDC and 15° after TDC.
The post injection start may occur between 75° and 220° after TDC.
The separation between the far and close pilots, and between close pilot and main injection, defined as the difference between the end of the first and the start of the second is capable of reaching a limit of 100 §` under stable operation of the injected guantities.

## Exhaust-gas recirculation (EGR)

Without EGR, NOx emissions are excessive from the emission-control legislation standpoint, whereas soot emissions are within limits. Exhaust-gas recirculation (EGR) is a method for reducing the emissions of NOx without drastically increasing the engine's soot output. This can be implemented very efficiently with the common rail system thanks to the excellent A/F mixture formation resulting from the high injection pressures. With EGR, a portion of the exhaust gases are diverted into the intake tract during part-load operation. This not only reduces the oxygen content, but also the rate of combustion and the peak temperature at the flme front, with the result that NOx emissions drop. If too much exhaust gas is recirculated though (exceeding 40% of the intake air volume), the soot, CO, and HC emissions, as well as the fuel consumption rise due to the lack of oxygen.

## Influence of fuel injection

Start of injection, rate-of discharge curve, and atomization of the fuel also have an influence upon fuel consumption and upon exhaust-gas emissions.

### Start of injection

Due to lower process temperatures, retarded fuel-injection reduces the NOx emissions. But if it is too far retarded, HC emissions and fuel consumption increase, as do soot emissions under high loading conditions. If the start of injection deviates by only 1°cks (crankshaft) from the desired value, NOx emissions can increase by as much as 5%. Whereas a deviation of 2°cks in the advance (early) direction can lead to a 10 bar increase in the cylinder peak pressure, a deviation of 2°cks in the retarded (late) direction can increase the exhaust-gas temperature by 20°C. Such high sensitivity demands utmost accuracy when adjusting the start of injection.

### Rate-of-discharge curve

The rate-of discharge curve defines the variations in fuel mass flow during a single injection cycle (from start of injection till end of injection). The rate-of-discharge curve determines the mass of fuel delivered during the combustion lag (between start of injection and start of combustion). Furthermore, since it also influences the distribution of the fuel in the combustion chamber it also has an effect upon the efficiency of the air utilization. The rate-of-discharge curve must climb slowly in order that fuel injection during the combustion lag is kept to a minimum. This fuel, namely, combusts suddenly as soon as combustion is initiated with the attendant negative effects upon engine noise and NOx emissions. The rate-of-discharge curve must drop-off sharply in order to prevent poorly atomized fuel leading to high HC and soot emissions, and increased fuel consumption during the final phase of combustion.

### Fuel atomization

Finely atomized fuel promotes the efficient mixing of air and fuel. It contributes to a reduction in HC and soot emissions. High injection pressure and optimal geometrical configuration of the nozzle injection orifices lead to good atomization. To prevent visible soot emission, the injected fuel quantity must be limited in accordance with the intake air quantity. This necessitates excess air in the order of at least 10...40% ($\lambda$=1.1 ...1.4).

Once the nozzle needle has closed, the fuel in the injection orifices can vaporize (in the case of sac-hole (blind-hole) nozzles the fuel vaporizes in the sac-hole volume) and in the process increase the HC emissions. This means that such (harmful) volumes must be kept to a minimum.

# FUEL SYSTEM

The fuel system in a "Common Rail" fuel-injection system (Fig. 1) comprises a low-pressure stage for the low-pressure delivery of fuel, a high-pressure stage for the high-pressure delivery, and the ECU (9).

## Low-pressure delivery

The low-pressure stage of the Common Rail fuel system incorporates:

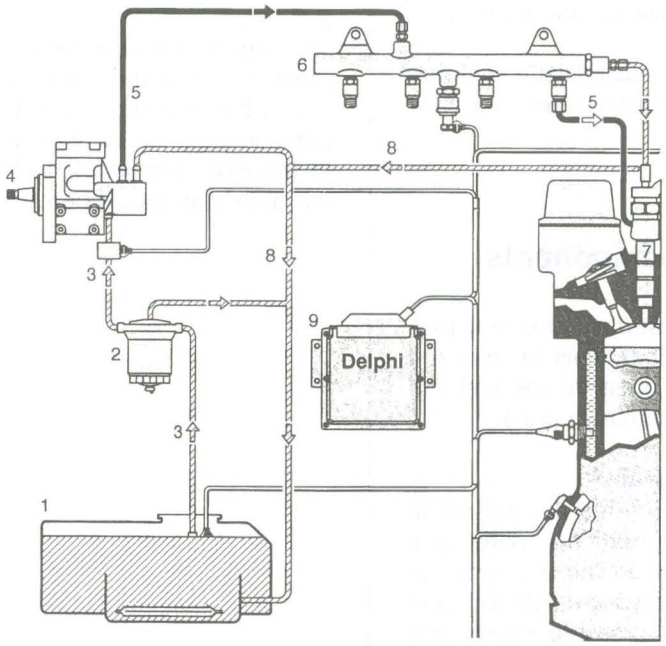
- Fuel tank with pre-filter,
- Lift pump(Transfer pump),
- Fuel filter, and
- Low-pressure fuel lines.

## Fuel lines for the low-pressure stage

As an alternative to steel pipes, flme-inhibiting steel-braid-armoured flexible fuel lines can be used for the low-pressure stage. They must be routed so that they cannot be damaged mechanically, and fuel which has dripped or evaporated must not be able to accumulate, nor must it be able to ignite.

When the vehicle twists, or the engine moves etc., this must have no derogatory effects upon fuel-line function. All parts which carry fuel must be protected against the effects of heat. In the case of buses, fuel lines must not be located in the passenger compartment or in the driver's cab, nor may fuel be delivered by force of gravity.

[Fig. 1]




**Fuel system for a Common Rail fuel-injection system**

EFHB121A

1. Fuel tank
2. Fuel filter
3. Low-pressure fuel lines
4. High-pressure pump(Lift pump integrated)
5. HIgh-pressure fuel lines
6. Rail
7. Injector
8. Fuel-return line
9. ECU

## Low-pressure system components

### Lift pump(Transfer pump)

The lift pump is included in the housing of the HP pump. The lift pump is of the volumetric blade type pump. The pump draws the fuel from the fuel tank and continually delivers the required quantity of fuel in the direction of the high-pressure pump.

### Fuel filter

Inadequate filtering can lead to damage at the pump components, delivery valves, and injector nozzles. The fuel filter cleans the fuel before it reaches the lift pump, and thereby prevents premature wear at the pump's sensitive components.

## High-pressure delivery

The high-pressure stage of the fuel system in a Common Rail installation comprises:

- High-pressure pump with pressure-control valve,
- High-pressure fuel lines,
- The rail as the high-pressure accumulator with rail-pressure sensor, pressure-limiting valve, and flow limiter, injectors, and
- Fuel-return lines.

## High-pressure system components

### High-pressure pump

The high-pressure pump pressurises the fuel to a system pressure of up to 1,600bar. This pressurized fuel then passes through a high-pressure line and into the tubular high-pressure fuel accumulator (rail).

### High-pressure accumulator (rail)

Even after an injector has taken fuel from the rail in order to inject it, the fuel pressure inside the rail remains practically constant. This is due to the accumulator effect arising from the fuel's inherent elasticity. Fuel pressure is measured by the rail-pressure sensor and maintained at the desired level by the pressure-control valve. It is the job of the pressure-limiter valve to limit the fuel pressure in the rail to maximum 1,600bar. The highly pressurized fuel is directed from the rail to the injectors by a flow limiter, which prevents excess fuel reaching the combustion chamber.

### Injectors

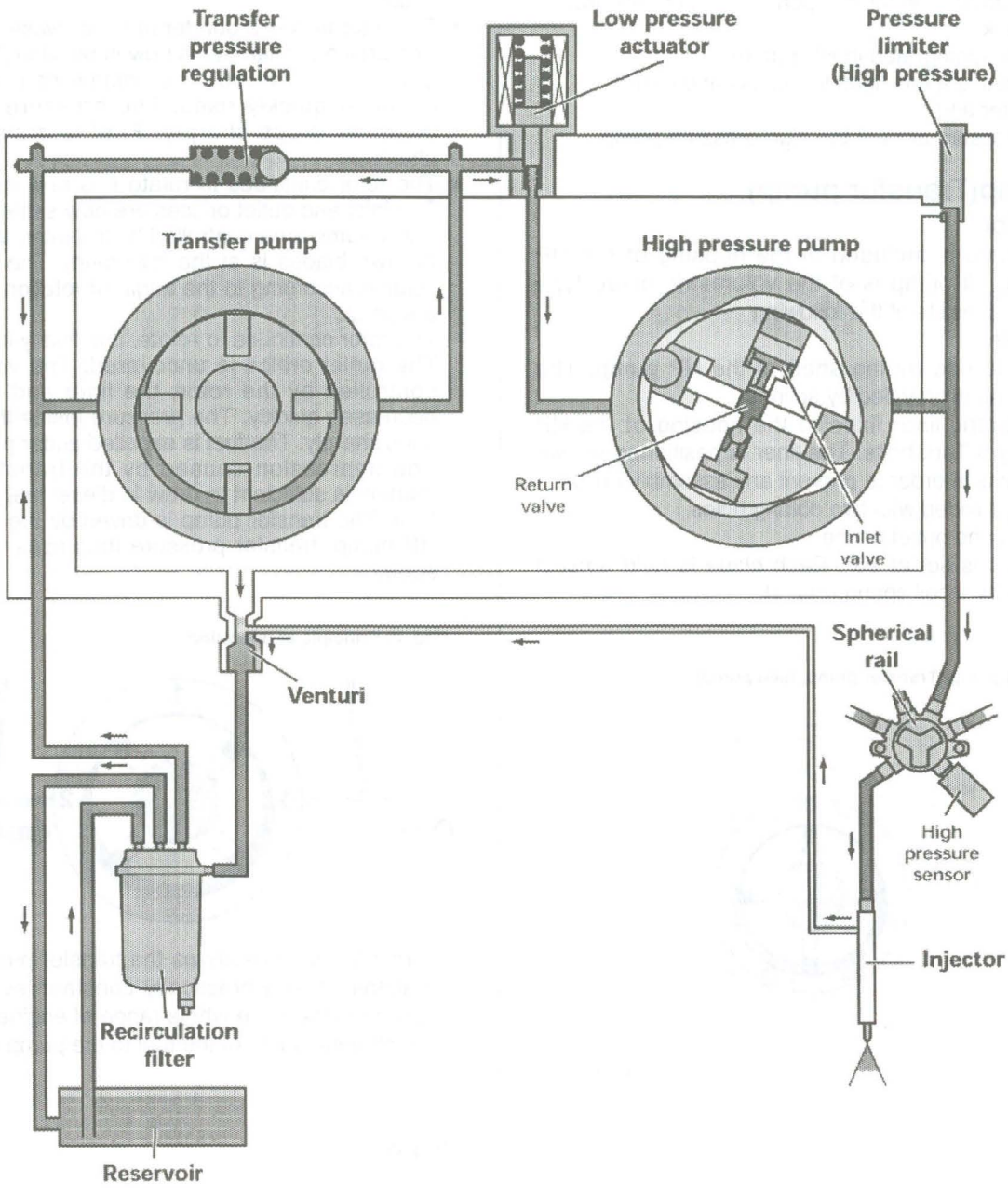
The nozzles of these injectors open when the solenoid valve is triggered and permit the flow of fuel. They inject the fuel directly into the engine's combustion chamber.
The excess fuel which was needed for opening the injector nozzles flows back to the tank through a collector line. The return fuel from the pressure-control valve and from the low-pressure stage is also led into this collector line together with the fuel used to lubricate the high-pressure pump.

### Fuel lines in the high-pressure section

These fuel lines carry the high-pressure fuel. They must therefore be able to permanently withstand the maximum system pressure and, during the pauses in injection, the sometimes high-frequency pressure fluctuations which occur. They are therefore manufactured from steel tubing. Normally, they have an outside diameter of 6 mm and an internal diameter of 2.4 mm.
The injection lines between the rail and the injectors must all be of the same length. The differences in length between the rail and the individual injectors are compensated for by using slight or pronounced bends in the individual lengths of tubing. Nevertheless, the injection lines should be kept as short as possible.

# Hydraulic circuit

[Fig. 1] Hydraulic circuit



# DESIGN AND FUNCTION OF THE COMPONENTS

## Low-pressure stage

The low-pressure stage provides enough fuel for the high-pressure section. The most important components are:

- Fuel tank,
- Lift pump(integrated in HP-pump),
- Low-pressure fuel lines for supply and return,
- Fuel filter and
- Low-pressure area of the high-pressure pump.

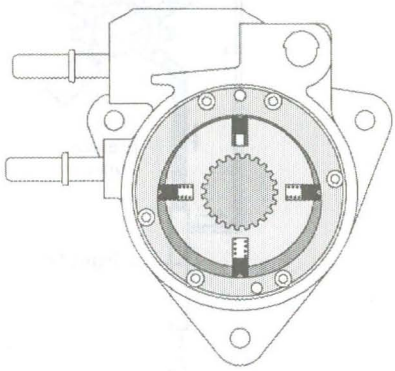
## Lift pump(Transfer pump)

### Description

The lift pump is included in the housing of the HP pump. The lift pump is of the volumetric blade type pump: and consists of the following components:

- A rotor turned by the shaft of the HP pump. The connection is provided by splines.
- An eccentric liner fixed to the housing of the HP pump by 6 Torx bolts. The liner is positioned by two off-set pins in order to prevent any assembly errors.
- A plate provided with two oblong holes.
- The inlet and outlet orifice.
- Four blades set at 90°. Each blade is held against the liner by a coil spring.(Fig. 1)

[Fig. 1] Lift pump (Transfer pump, feed pump)



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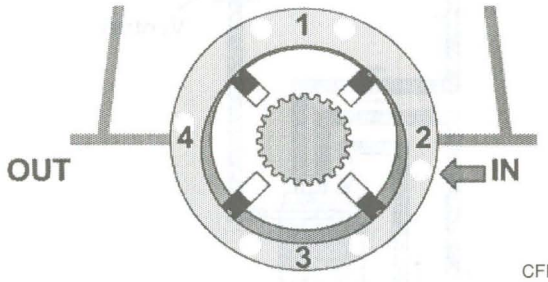
### Principle of operation

Consider the chamber between the rotor, the liner and two successive blades. (Fig. 2)

- When the chamber is in position 1, the volume of the chamber is minimal. The changes in volume according to the angle of rotation of the rotor are small.
- The rotor makes a quarter turn clockwise.
  The previous chamber is now in position 2. The inlet orifice is uncovered. The volume contained in the chamber quickly rises. The pressure inside the chamber drops sharply. Fuel is drawn into the chamber.
- The rotor continues to rotate It is now in position 3. The inlet and outlet orifices are now sealed off.
  The volume area controlled by the rotor, the liner and the two blades is at the maximum. The changes in volume according to the angle of rotation of the rotor are small.
- The rotor continues to rotate. It is finally in position 4. The outlet orifice is uncovered. The volume area controlled by the rotor, the liner and the blades decreases quickly. The pressure inside the chamber rises sharply. The fuel is expelled under pressure.
  The depression caused by the transfer pumpís rotation is sufficient to draw in diesel fuel through the filter. The transfer pump is driven by the shaft of the HP pump, transfer pressure thus rises with engine speed.

[Fig. 2] Principle of operation

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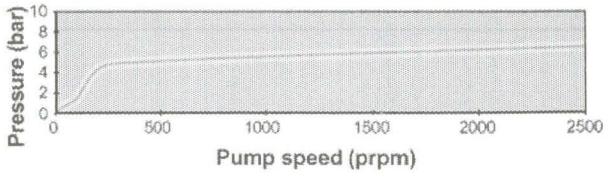
A regulating valve allows the transfer pressure to be maintained at a practically constant level (about 6 bar) throughout the whole range of engine operations by returning some of the fuel to the pump inlet.

[Fig. 3]

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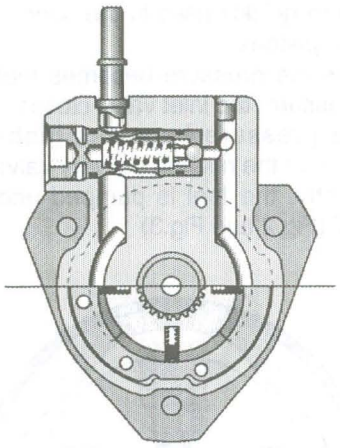
### Characteristics of the transfer pump

| | |
|---|---|
| Regulating pressure: | 6 bars |
| Volume controlled: | 5.6 $cm^3$ / revolution |
| Flow: | 90 l/h at 300 rpm pump.<br>650 l/h at 2500 rpm pump. |
| Intake capacity: | 65 mbar at 100 rpm pump. |

[Fig. 4]



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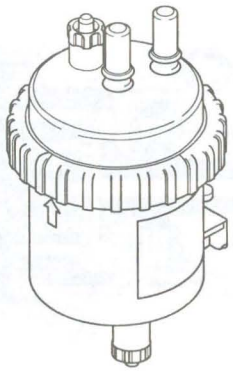
## Fuel filter

Contaminants in the fuel can lead to damage at the pump components, delivery valves, and injection nozzles. This, therefore, necessitates the use of a fuel filter which is specifically aligned to the requirements of the particular injection system, otherwise faultless operation and a long service life cannot be guaranteed. Diesel fuel can contain water either in bound form (emulsion) or in free form (e.g. condensation of water due to temperature change). If this water enters the injection system, it can lead to damage as a result of corrosion.

Similar to other injection systems, the Common Rail also needs a fuel filter with water reservoir, from which the water must be drained at regular intervals. The increasing number of diesel engines used in passenger cars, has led to the demand for an automatic water warning device which indicates by means of a warning lamp when water must be drained (this is binding in those countries in which there is a high level of water in the fuel).

[Fig. 5] Fuel filter



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## High-pressure stage

In addition to high-pressure generation, fuel distribution and fuel-metering also take place in the high-pressure stage. The most important components are:

- High-pressure pump,
- High-pressure accumulator(rail),
- Rail-pressure sensor,
- Pressure-limiter valve,
- High-pressure pipe,
- Injectors,
- IMV.

## High pressure pump

### Description

The high pressure pump makes use of the cam and radial plungers principle which has already demonstrated its worth in the rotary pumps. For engines requiring a high flow-rate, the pump has two chambers offset at an angle of 45°

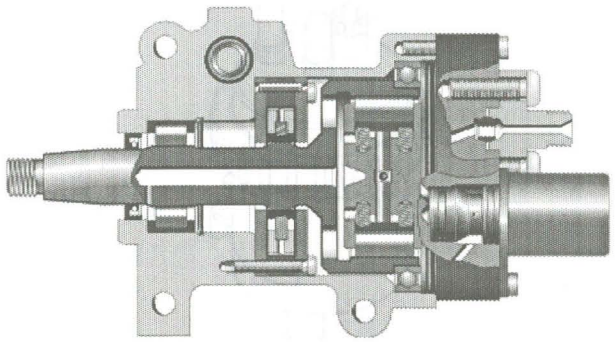
This offset allows peak torques and pressure fluctuations in the rail to be reduced.

The cam with four lobes is identical to that of conventional rotary pumps, but since the pump no longer determines the injection period it is possible to extend the pumping phase in order to considerably reduce drive torque, vibration and noise.

The difference from conventional rotary pumps lies in the fact that it is no longer the hydraulic head rotor which turns inside the cam, but the cam which turns around the hydraulic head.

Thus, any problems of dynamic pressure tightness are eliminated because the high pressure is generated in the fixed part of the pump.(Fig.1)

[Fig. 1] High pressure pump



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### Principle of operation

#### a) Pump feed

The fuel is drawn in through the filter by the transfer pump. Then passed into the intake of the HP pump at a practically constant pressure known as the transfer pressure.

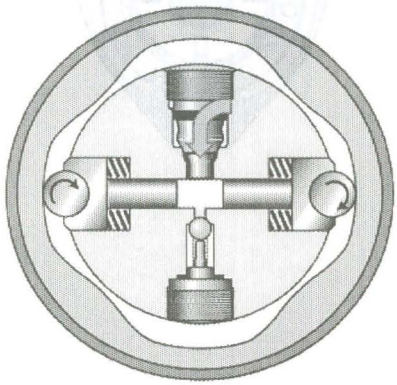
A filling control actuator is located upstream of the HP pump. It controls the amount of fuel sent to the pumping elements by adjusting the cross-section area of the passage. The ECU determines the value of the current sent to the coil in order to obtain the cross-section area of the passage required to reach the pressure demanded according to the engine? operating conditions.

When the pressure demand falls the current rises, and vice-versa.

#### b) The pumping principle

- During the filling phase, the rollers are kept in contact with the cam by means of coil springs mounted on either side of each shoe. The transferpressure is sufficient to open the inlet valve and to move the pumping plungers apart. Thus, the dead volume between the two plungers fills with fuel.
- When the diametrically opposite rollers simultaneously encounter the leading edge of the cam, the plungers are pushed towards each other. The pressure quickly rises in the space between the two plunger pistons.
- As soon as the pressure becomes higher than the transfer pressure, the inlet valve closes. When the pressure becomes higher than the pressure inside the rail, the delivery valve opens. Consequently, the fuel is pumped under pressure into the rail.(Fig.2 and Fig.3)

[Fig. 2]



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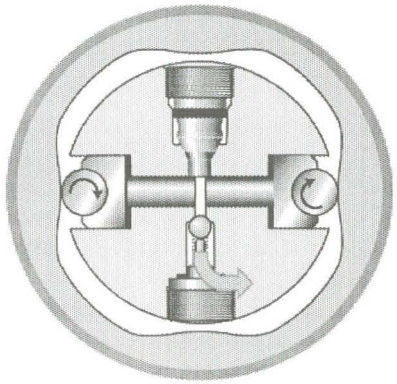
[Fig. 3]



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**c) The inlet and delivery valves**

During the input phase, transfer pressure the inlet valve. Fuel enters the body of the pumping element. Under the effect of the transfer pressure, the two plungers are forced apart.

When the rollers simultaneously encounter the leading edge of the cam, pressure suddenly rises in the body of the pumping element. The valve closes as soon as the pressure in the pumping element becomes higher than the transfer pressure.

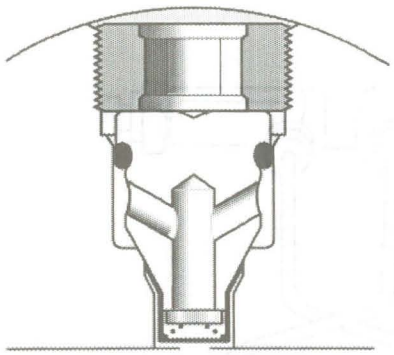
During the input phase, the ball of the delivery valve is subjected to the rail pressure on its outer face and to the transfer pressure on its inner face.

Thus the ball rests on its seat, ensuring the pressure tightness of the body of the pumping element. When the two diametrically opposite rollers encounter the leading edges of the cam, the plungers are forced together and pressure quickly rises in the body of the pumping element.

When the pressure in the element becomes higher than the pressure in the rail, the ball is unbalanced and it opens (spring calibration is negligible compared with the pressure forces).

Fuel is then pumped into the rail at high pressure. (Fig.4 and Fig.5)

[Fig. 4] Inlet valve



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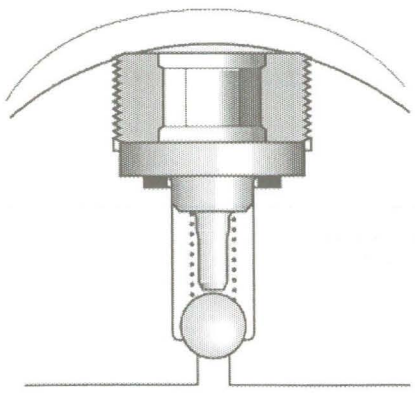
[Fig. 5] Delivery valve



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**d) Lubrication and cooling of the pump**

Lubrication and cooling of the pump are provided by the fuel circulation. The minimum flow required to ensure adequate operation of the pump is 50 l/h.

**e) Phasing of the pump**

Conventional fuel injection pumps ensure pressurising and distribution of the fuel to the different injectors. It is essential to set the pump in such a way that the injection occurs at the required place during the cycle. The HP pump of the common rail system is no longer used for the fuel distribution, it is therefore not necessary to set the pump in relation to the engine.

Nevertheless, the setting or phasing of the pump offers two advantages:

- It allows the torque variations of the camshaft and the pump to be synchronised in order to reduce the stresses on the timing belt.
- It allows pressure control to be improved by synchronising peak pressures produced by the pump with pressure-drops caused by each injection. This phasing allows pressure stability to be improved, which helps to reduce the difference in flow between the cylinders (line to line).

The phasing of the pump is acheved by means of a pin located on the pump? drive shaft.

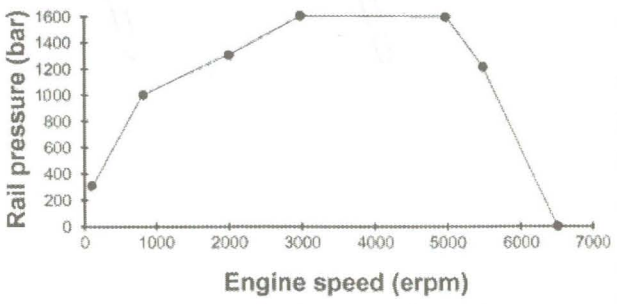
## Performance of the HP pump

**a) Pressure rise time**

The time required to obtain a sufficient pressure in the rail to enable the engine to start depends on the volume of the system (definition of the rail, length of the pipes, ...). The aim is to reach a pressure of 200 bars in 1.5 revolutions (3rd compression). (Fig.6)

**b) Max. pressure curve**

[Fig. 6]

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## High-pressure accumulator (rail)

### Assignments

The high-pressure accumulator (the Rail in Fig. 7) stores the fuel at high pressure. At the same time, the pressure oscillations which are generated due to the high-pressure pump delivery and the injection of fuel are damped by the rail volume.

This high-pressure accumulator is common to all cylinders, hence its name "common rail". Even when large quantities of fuel are extracted, the common rail maintains its inner pressure practically constant. This ensures that the injection pressure remains constant from the moment the injector opens.

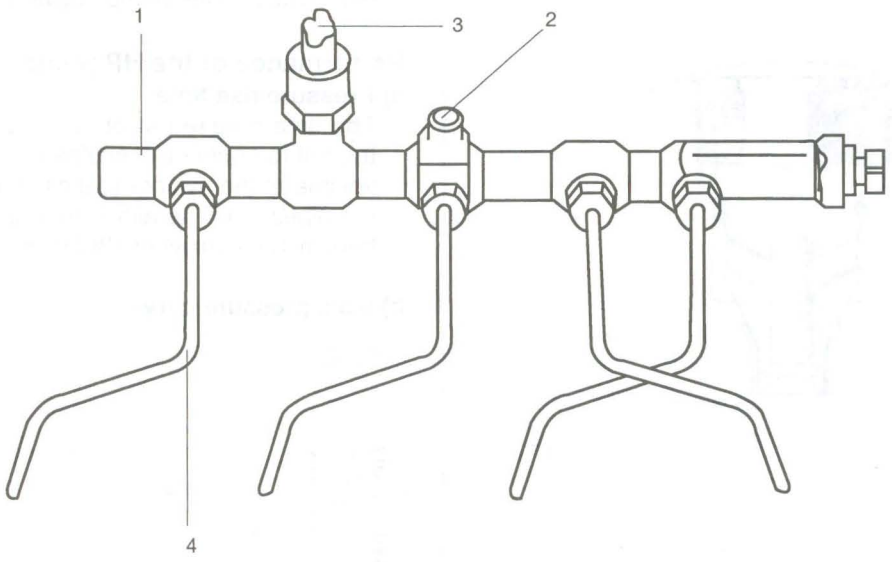
### Design and construction

In order to comply with the wide variety of engine installation conditions, the rail with its flow limiters and the provisions for attaching rail-pressure sensor, pressure-control valve, and pressure-limiter valve is available in a number of different designs.

### Function

The available rail volume is permanently filled with pressurized fuel. The compressibility of the fuel resulting from the high pressure is utilised to achieve the accumulator effect. When fuel leaves the rail for injection, the pressure in the high-pressure accumulator remains practically constant. Similarly, the pressure variations resulting from the pulsating fuel supply from the high-pressure pump are compensated for.

[Fig.8] High-pressure accumulator (rail)

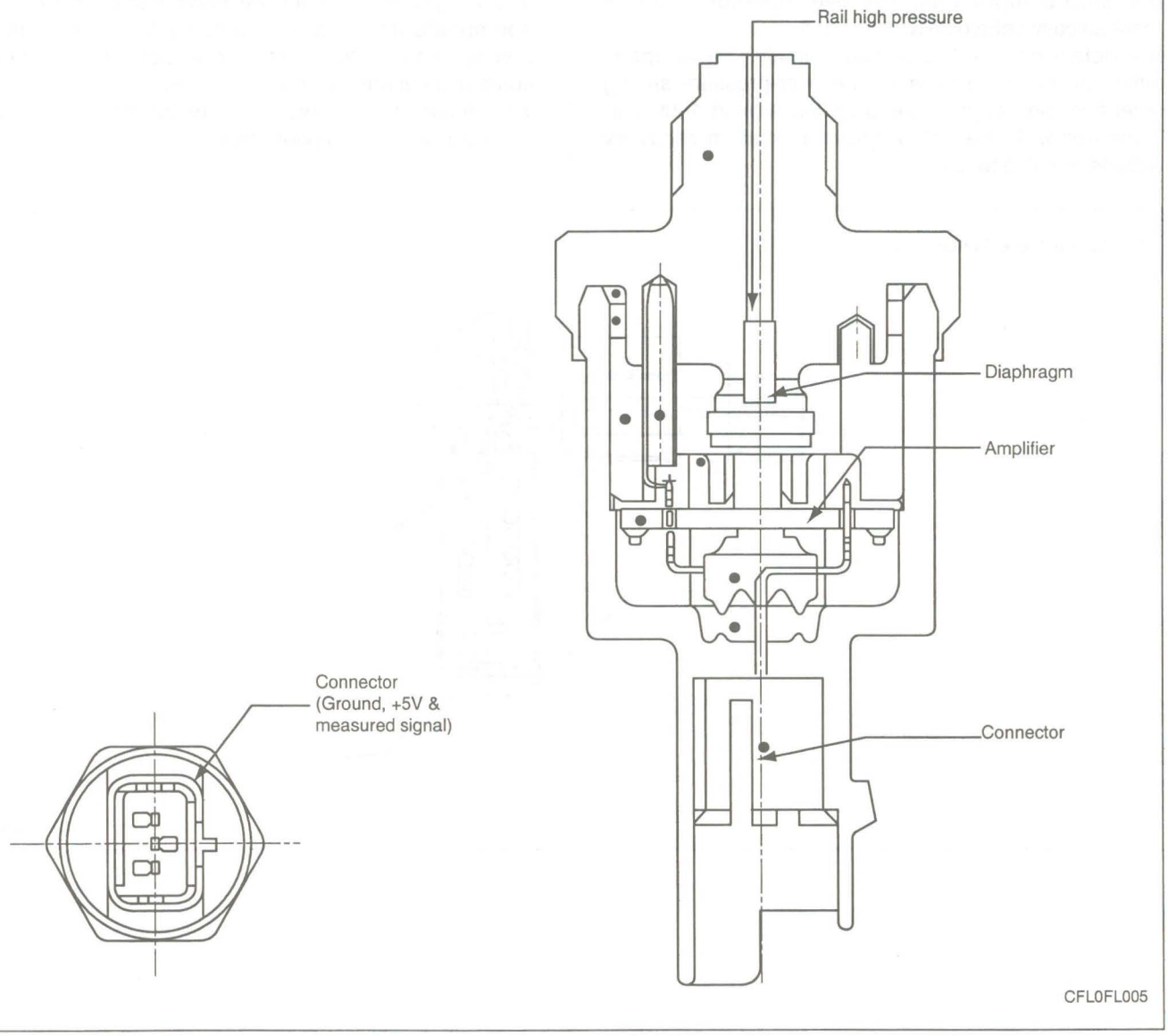



1. Rail
2. Inlet from the high-pressure pump
3. Rail-pressure sensor
4. Line to the injector

## Rail-pressure sensor

The high pressure sensor aim is to provide to the ECU the current voltage signal corresponding to fuel high pressure in the HP accumulator (rail pressure). This information is used for fuelling and timing calculations.
It is located on the rail.

[Fig.9] Rail-pressure sensor




### Frunctions

The sensor operates as an analog resistor. The change in resistance is proportional to the rail pressure acting upon the diaphragm. A rail pressure change lead to a geometry change. This movement changes the electrical resistance. A bridge circuit on the diaphragm supplies a voltage which is amplified to a range from 0.5V to 4.5V (respectively 0 and 1800 bar).

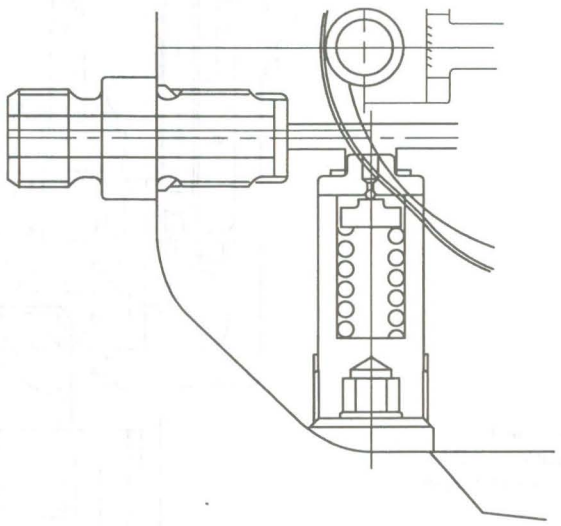
## Pressure limiter valve

When the HP actuator is not used in the system, a pressure limiting valve has to be included in high pressure module.
It is mounted at pump HP outlet.
Its aim is to prevent against over-pressure in the high pressure components. The over-pressure latch is mechanically set(typically: 1800 bar).
If a defect occurs, the pressure limiting valve opens when the pressure exceeds the over-pressure setting level and the rail pressure is limited around 1600 bar. Together with the valve opening, system recovery actions are also taken.

## High-pressure pipe

The high pressuer pipes used in the Common Rail system must withstand high pressures up to 2100 bar.
They are made with the appropriate steel.
Typical dimensions are 6*2.4 mm with M12 connection nuts.
The HP pipes route on the engine should have the appropriate design to compensate for manufacturing and assembly tolerances, and to accept the specific constraints during engine operations.
The design rules have to be discussed with LVDS engineering for each poolication.

[Fig.10] Pressure limiter valve



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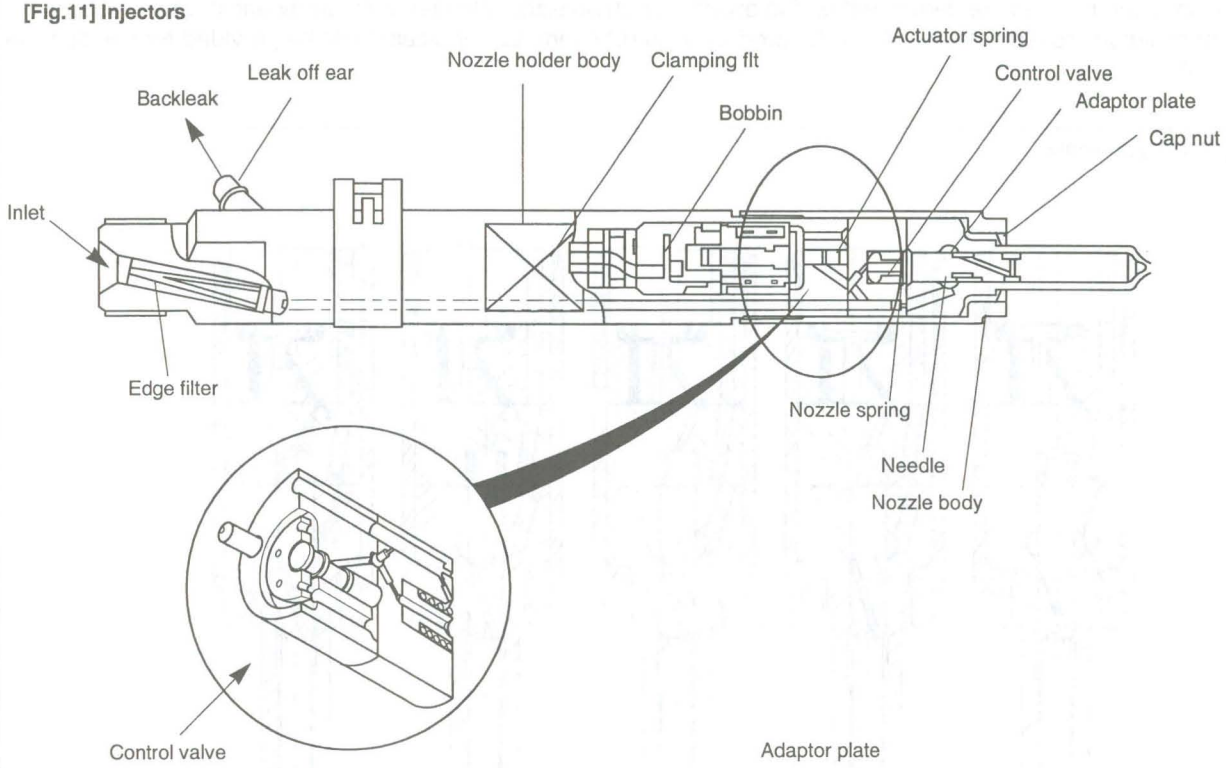
## Injectors

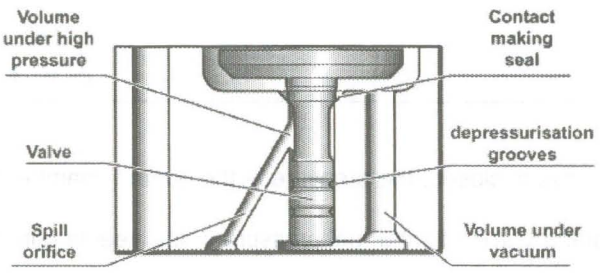
The injector of the Common Rail system is electronically controlled. It has been designed:

- To allow multiple injections with short intervals between each injection.
- To be fully electronically controlled.
- To release a small amount of heat.

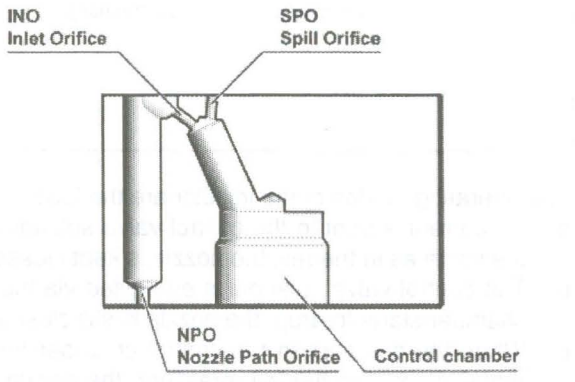
[Fig.11] Injectors




[Fig. 12]



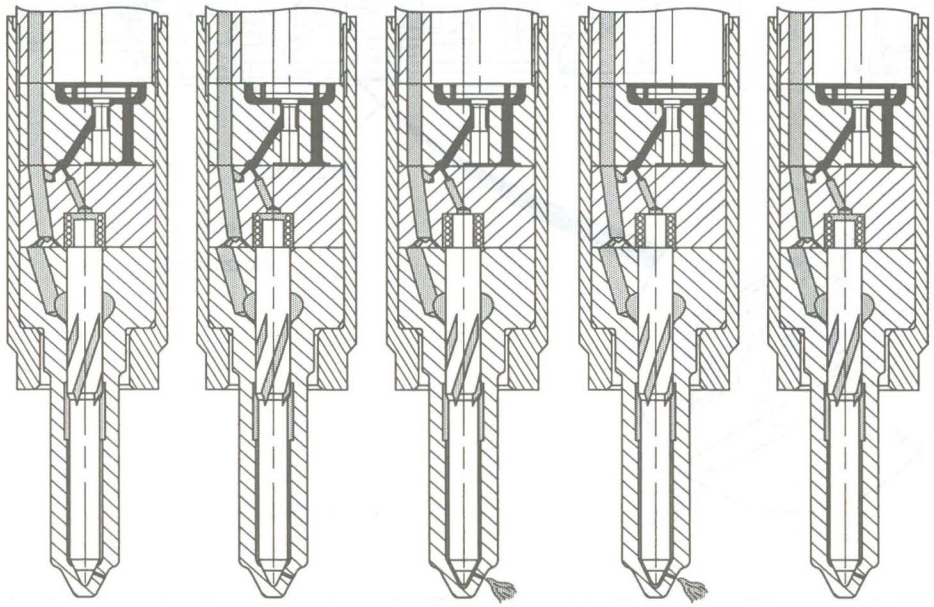

[Fig. 13]



## Method of operation

The purpose of the injector is to inject the required amount of fuel at the right time with variation of injection and start of injection as small as possible between engine cylinders.
The various orifice diameters in the hydraulic assembly are calibrated to achieve optimal control.
An edge filter is included in the inlet to protect the orifices and injection nozzles from contamination.
To ensure a robust behaviour for small delivery control up to 1600 bar, the pressure in the injectors back leak has be negative(the vacuum permits to avoid perturbations in the control valve chamber which are due to a non consistent diphasic mixture).
The definition of the nozzles are dependent on the application (hole size, hole diameter, spray angle,...).
The current minimum hole diameter suitable for production is 0.14 mm. Lower sizes could be provided for investigation purposes only.

[Fig.14] Working principle




The operating modes of the injector are the following:

a. No current is sent to the control valve solenoid, the control valve is closed, the pressure in the control chamber is the same as in the rail, the nozzle is kept closed.
b. The control valve solenoid is energised via the ECU, the control valve lifts, the fuel pressure in the needle control chamber starts to drop, the nozzle is still closed.
c. When the pressure in the control chamber has sufficiently dropped and as the fuel pressure at the nozzle seat remains equal to the rail pressure, the nozzle needle is unbalanced and moves upwards, the injection holes are open and the injection begins. The energising time on the control valve solenoid will depend on the operating point, it will control the injection quantity for a given rail pressure.
d. The ECU cuts the current on the control valve solenoid, the control valve solenoid, the control valve returns to its seat due to the solenoid spring force, the pressure in the needle control chamber increases and becomes slightly larger than the pressure in the nozzle seat thus closing the needle and stopping the injection.

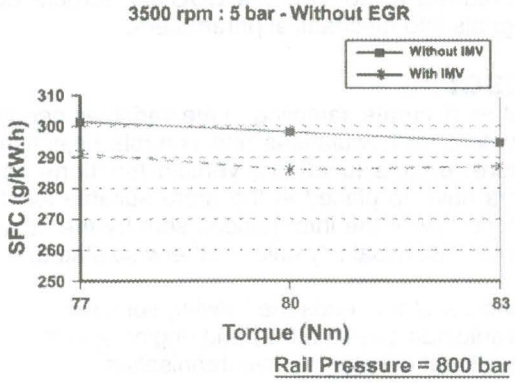
## THE IMV(INLET METERING VALVE)

### Function

The LP actuator, also called the Inlet Metering Valve, is used to control the rail pressure by regulating the amount of fuel which is sent to the pumping element of the HP pump. This actuator has two purposes:

- Firstly, it allows the efficiency of the injection system to be improved, since the HP pump only compresses the amount of fuel necessary to maintain in the rail the level of pressure required by the system as a function of the engineís operating conditions.(Fig. 15)

[Fig. 15] Inlet metering valve effect

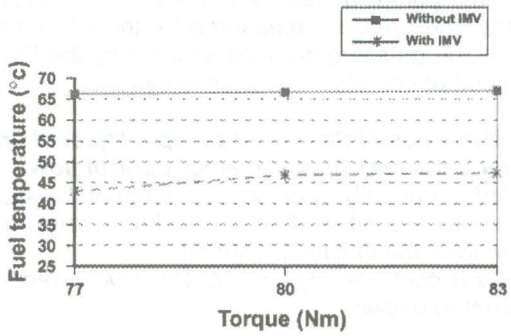



CFL0FL077

- Secondly, **it allows the temperature to be reduced in the fuel tank.** When the excess fuel is discharged into the back leak circuit, the pressure reduction in the fluid (from rail pressure down to atmospheric pressure) gives off a large amount of heat. This leads to a temperature rise in the fuel entering the tank. In order to prevent too high a temperature being reached, it is necessary to limit the amount of heat generated by the fuel pressure reduction, by reducing the back leak flow. To reduce the back leak flow, it is sufficient to adapt the flow of the HP pump to the engineís requirements throughout its operating range.(Fig. 16)

✱ *Notice*
*To cool the fuel in a heat exchanger would be an expensive, bulky and not very effective solution.*

[Fig. 16] Fuel temperature at system backleak

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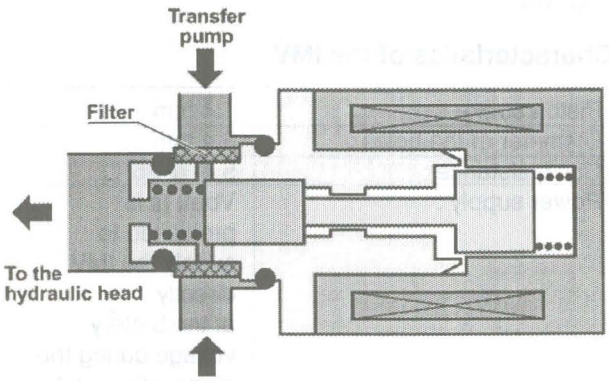
### Description

The IMV is located on the hydraulic head of the pump. It is fed with fuel by the transfer pump via two radial holes. A cylindrical filter is fitted over the feed orifices of the IMV. This makes it possible to protect not only the LP actuator, but also all the components of the injection system located downstream of the IMV. The IMV consists of the following components:

- A piston held in the fully open position by a spring.
- A current controlled coil.
- A sleeve held against the piston by a spring whose calibration is set lower than that of the first spring.
- A body provided with two radial inlet holes an axial outlet hole.
- A cylindrical filter positioned on the inlet holes.
- Two O-rings ensuring pressure-tightness between the hydraulic head and the body of the IMV. (Fig. 17)

[Fig. 17]

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### Principle of operation

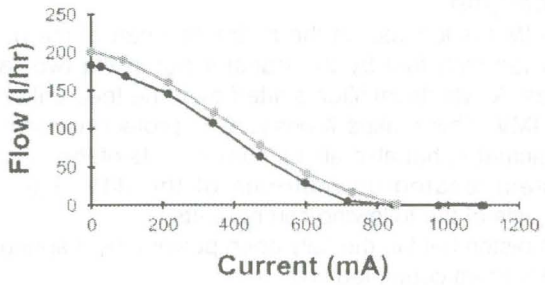
The LP actuator is used to proportion the amount of fuel sent to the pumping element of the HP pump in such a way that the pressure measured by the HP sensor is equal to the pressure demand sent out by the DCU. At each point of operation it is necessary to have:

***Flow introduced into the HP pump = Injected flow + Injector back leak flow + Injector control flow.***

The IMV is normally open when it is not being supplied with fuel. It cannot therefore be used as a safety device to shut down the engine if required.

The IMV is controlled by current. The flow/current law is represented below:

**[Fig. 18] Flow/current law**

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The ECU determines the value of the current to be sent to the IMV according to:

- The engine speed.
- The flow demand.
- The rail pressure demand.
- The measured rail pressure.

(Fig. 18)

### Characteristics of the IMV

| | |
|---|---|
| Piston stroke : | 1.4 mm |
| Diameter of the holes : | 3.4 mm |
| Coil resistance : | 5.4 at 25°C |
| Power supply : | Vbatt (it is prohibited to supply the IMV directly at the battery voltage during the diagnostic tests!) |
| Max. current : | 1A |
| Weight : | 260 g |
| Operating temperatures : | 40<T<125°C |
| Fluid temperatures : | 40<T<90°C |
| Control logic : | Normally open without power. The flow decreases as the current rises. |

# SYSTEM CONTROL USING EDC

## Sysem blocks

The Electronic Diesel Control (EDC) for Common Rail comprises three major system blocks:

1. Sensor and setpoint generators for registration of the operating conditions and the desired values. These convert a variety of physical parameters into electrical signals.
2. The ECU for generating the electrial output signals by processing the information using specified arithmetic operations (control algorithms)
3. Actuators to convert the ECU's electrical output signals into mechanical parameters.

## Sensor

To get an accurate sampling of the variables needed by the system for calculations and controls (injection, rail pressure, engine functions, vehicle functions,...), the sensors have to placed in the more suitable locations. The accuracy of the informations sent by the sensor is customer responsability unless otherwise stated.

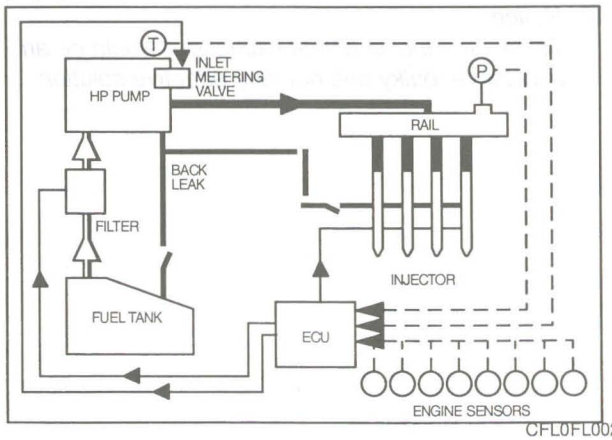
The basic system needs the follwing sensors:

- Crankshaft events (60-2) and engine speed,
- Camshaft event(s) for synchronisation,
- Rain pressure,
- Accelerator pedal,
- Inlet manifold pressure,
- Inlet manifold temperature,
- Coolant temperature,
- Accelerometer (knock sensor),
- Vehicle speed,
- Brake switch,
- Fuel temperature (under LVDS responsability).

Other sensors can also be used depending on the required functionalities:

- Air mass flow or EGR valve lift,
- Clutch,
- Neutral recognition for automatic transmission,
- Kick down,
- Atmospheric pressure,
- ...

**[Fig.1] Sensors**

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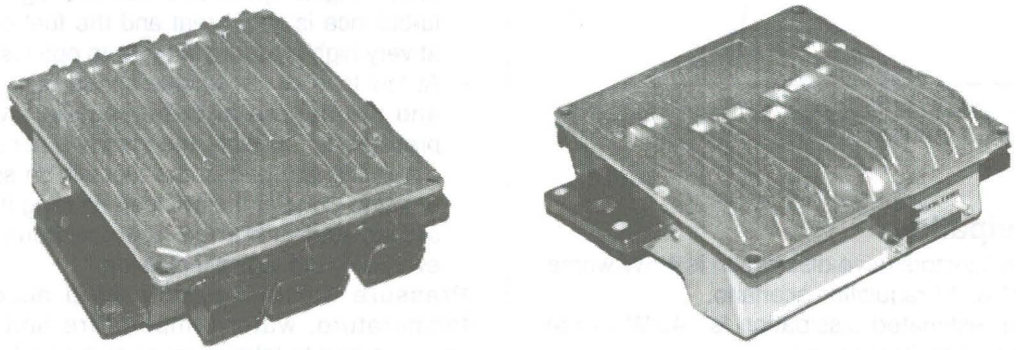
## ECU

The ECU can be located either in the passenger or in engine compartment.
For each operating point, the Control Unit receives the sensors signals, realises the calculations needed by the functions, controls the rail pressure and the injection (amount, position, multi-injection), drives the actuators associated to the engine and vehicle functions. It also provides system monitoring and diagnosis function;

## Generic control unit description

- ECU with metal + plastic box,
- The envelope and pin allocations are available,
- Siemens CS167-32FM processor with intermal Flsh,
- 112 pins, 3 block modular connector,

[Fig.2] ECU



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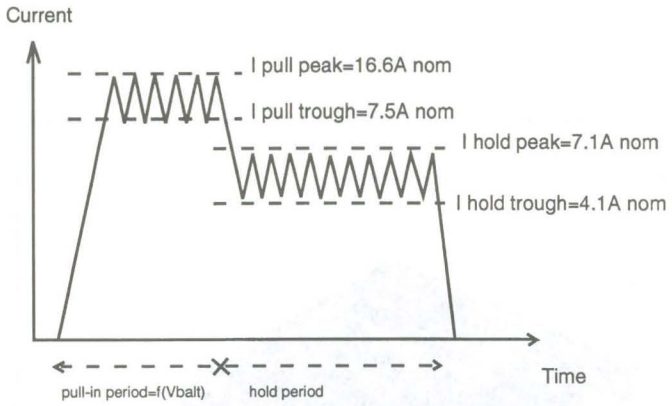
## Injector drive current definition

The injector definition allows for low drive currents:

- I pull mean = ~10.5 A at 12V
- I hold mean = ~5A at 12V

[Fig.3]




## Power dissipation

•The maximum injectors drive dissipation is 4.5W worse case with a EURO IV regulation scenario.
•The maximum estimated dissipation is 14.2W worse case for the complete Control unit.

## Electrical limits

The ECU supply is the voltage between the ECU supply and ground pins.
The voltage drop inside the wires from the battery to the ECU supply must be as low as possible.

Nominal voltage at Control Unit: 12V
Nominal system functionalities: 10 to 16V
Limited system functionnalities: 6 to 10V
Derated functionalities: 16 to 18V (18V for 1 hour max)
No damage: 24V during 2 minutes

# INJECTION CONTROL

## PRESSURE CONTROL

Pressure control consists of two principal modules:

- The first determines the rail pressure demand value as a function of the engineís operating conditions.
- The second is responsible for controlling the IMV to ensure that the rail pressure reaches the required value.

## Pressure demand

Pressure demand is determined according to engine speed and load on the engine. The aim is to adapt the injection pressure to the engineís requirements:

- When engine speed and load are high, the degree of turbulence is very great and the fuel can be injected at very high pressure in order to optimise combustion.
- At low load or low engine speed, the filling is slower and the degree of turbulence is low. If injection pressure is too high, the nozzleís penetration will be excessive and part of the fuel will be sprayed directly onto the sides of the cylinder, causing the formation of smoke and unburned hydrocarbons and perhaps eventually damaging the piston.

Pressure demand is corrected according to air temperature, water temperature and atmospheric pressure and to take account of the added ignition time caused by cold running or by high altitude driving.
A special pressure demand is necessary in order to obtain the additional flow required during starts.
This demand is determined according to injected fuel and water temperature.
The pressure demand is limited as a function of fuel temperature. In fact, not all of the fuel compressed by the HP pump is injected into the engine. Part of the compressed fuel is sent back to the fuel tank through the back leak circuit. The reduction in pressure of the fuel from rail pressure to atmospheric pressure causes a large amount of heat to be released into the fuel tank.

## Main flow demand

The main flow represents the amount of fuel injected into the cylinder during the main injection. The pilot flow represents the amount of fuel injected during the pilot injection. The total fuel injected during one cycle (main flow + pilot flow)is determined in the following manner:
The driverís demand (which represents the movement of the pedal position in flow demand)is compared with the value of the minimum flow determined by the idle speed controller.

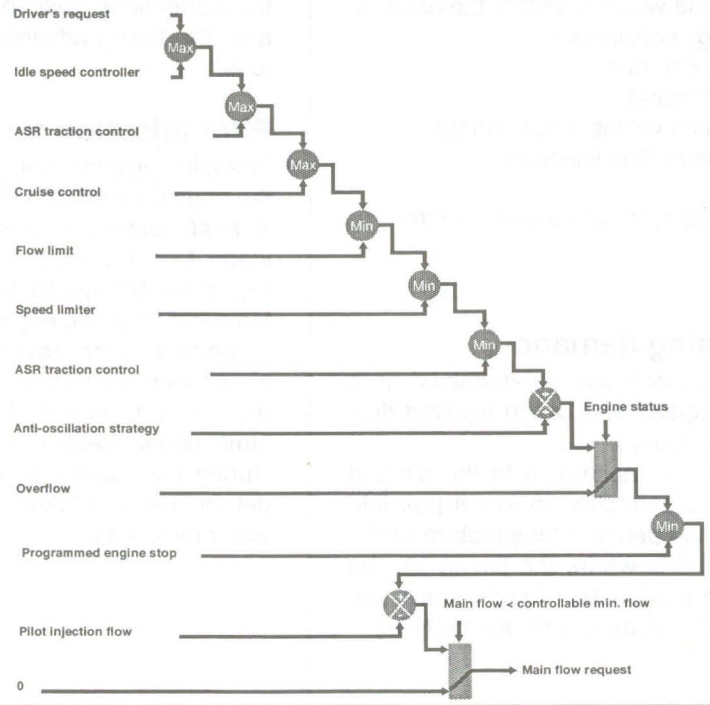
- When the driver depresses the pedal, it is his demand which is taken into account by the system in order to determine the fuel injected.
- When the driver releases the pedal, the idle speed controller takes over to determine the minimum fuel which must be injected into the cylinder to prevent the engine from stalling.

It is therefore the greater of these two values which is retained by the system.
This value is then compared with the lower flow limit determined by the ASR trajectory control system. As soon as the injected fuel becomes lower than the flow limit determined by the ASR trajectory control system, the antagonistic torque (braking torque due to the engine brake)transmitted to the drive wheels exceeds the adherence capacity of the vehicle and there is therefore a risk of the drive wheels locking.
The system thus chooses the greater of these two values in order to prevent any loss of control of the vehicle (due to the locking of the drive wheels) during a sharp deceleration. This value is then compared with the flow limit determined by the cruise control. As soon as the injected fuel becomes lower than the flow limit determined by the cruise control, the vehicle? speed falls below the value required by the driver. The system therefore chooses the greater of these two values in order to maintain the speed at the required level.
This value is then compared with the flow limit determined by the flow limitation strategy. This strategy allows the flow to be limited as a function of the operating conditions of the engine.
The system therefore chooses the smaller of these two values in order to protect the engine.
This value is then compared with the flow limit determined by the speed limiter. As soon as the injected fuel becomes higher than the flow limit determined by the speed limiter, the vehicleís speed exceeds the maximum threshold determined by the driver.The system therefore chooses the smaller of these two values in order to maintain the speed below the maximum threshold determined by the driver.
This value is then compared with the fuel limit determined by the ASR trajectory control system.
As soon as the injected fuel becomes higher than the fuel limit determined by the ASR trajectory control system, the engine torque transmitted to the wheels exceeds the adhesion capacity of the vehicle and there is a risk of the drive wheels skidding.
The system therefore chooses the smaller of the two values in order to avoid any loss of control of the vehicle during accelerations.The anti-oscillation strategy makes it possible to compensate for fluctuations in engine speed during transient conditions. This strategy leads to a fuel correction which is added to the total fuel of each cylinder. The correction is determined before each injection as a function of the instantaneous engine speed and of the gear engaged.
A switch makes it possible to change over from the supercharge fuel to the total fuel according to the state of the engine.

- Until the starting phase has finished, the system uses the supercharge fuel.
- Once the engine changes to normal operation, the system uses the total fuel.

The main fuel is obtained by subtracting the pilot injection fuel from the total fuel. A mapping determines the minimum fuel which can control an injector as a function of the rail pressure.
As soon as the main fuel falls below this value, the fuel demand changes to 0 because in any case the injector is not capable of injecting the quantity demanded. (Fig. 1)

[Fig. 1]



**a) Driver demand**

The driver demand is the translation of the pedal position into the fuel demand. It is calculated as a function of the pedal position and of the engine speed. The driver demand is filtered in order to limit the hesitations caused by rapid changes of the pedal position. A mapping determines the maximum fuel which can be injected as a function of the driver demand and the rail pressure. Since the flow is proportional to the injection time and to the square root of the injection pressure, it is necessary to limit the flow according to the pressure in order to avoid extending the injection for too long into the engine cycle. The system compares the driver demand with this limit and chooses the smaller of the two values. The driver demand is then corrected according to the water temperature. This correction is added to the driver demand.

**b) Idle speed controller**

The idle speed controller consists of two principal modules:

The first module determines the required idle speed according to:

- The operating conditions of the engine (water temperature and gear engaged).
- Any activation of the electrical consumers (electric windscreen, power assisted steering, air conditioning, thermoplungers).
- The battery voltage.
- The presence of any faults liable to interfere with the rail pressure control or the injection control. In this case, the accelerated idle speed is activated to prevent the engine from stalling when operating in degraded mode.
- It is possible to increase or to reduce the required idle speed with the aid of the diagnostic tool.

The second module is responsible for providing closed loop control of the engine? idle speed by adapting the minimum fuel according to the difference between the required idle speed and the engine speed.

**c) Flow limitation**

The flow limitation strategy is based on the following strategies:

- The flow limitation depending on the filling of the engine with air is determined according to the engine speed and the air flow. This limitation allows smoke emissions to be reduced during tabilised running.
- The flow limitation depending on the atmospheric pressure is determined according to the engine speed and the atmospheric pressure. It allows smoke emissions to be reduced when driving at altitude.
- The full load flow curve is determined according to the gear engaged and the engine speed. It allows the maximum torque delivered by the engine to be limited.
- The flow limitation under transient conditions is determined according to the engine speed and the flow demand. This limitation allows smoke emissions to be avoided under transient conditions.
- A performance limitation is introduced if faults liable to upset the rail pressure control or the injection control are detected by the system. In this case, and depending on the gravity of the fault, the system activates:

  ***Reduced flow strategy 1*** which guarantees 75% of the performance without limiting the engine speed.

  ***Reduced flow strategy 2*** which guarantees 50% of the performance with the engine speed limited to 3000 rpm.

  ***Reduced flow strategy 3*** which limits the engine speed to 2000 rpm.

  The system chooses the lowest of all these values. A correction depending on the water temperature is added to the flow limitation. This correction makes it possible to reduce the mechanical stresses while the engine is warming up. The correction is determined according to the water temperature, the engine speed and the time which has passed since starting.

**d) Supercharge flow demand**

The supercharge flow is calculated according to the engine speed and the water temperature.

A correction depending on the air temperature and the atmospheric pressure is made in order to increase the supercharge flow during cold starts.

It is possible to alter the supercharge flow value by adding a flow offset with the aid of the diagnostic tool.

## Pilot flow demand

The pilot flow represents the amount of fuel injected into the cylinder during the pilot injection. This amount is determined according to the engine speed and the total flow.

**A first correction** is made according to the air and water temperatures. This correction allows the pilot flow to be adapted to the operating temperature of the engine. When the engine is warm, the ignition time decreases because the end-of-compression temperature is higher. The pilot flow can therefore be reduced because there is obviously less combustion noise when the engine is warm.

**A second correction** is made according to the atmospheric pressure. This correction is used to adapt the pilot flow according to the atmospheric pressure and therefore the altitude.

During starting, the pilot flow is determined on the basis of the engine speed and the water temperature.

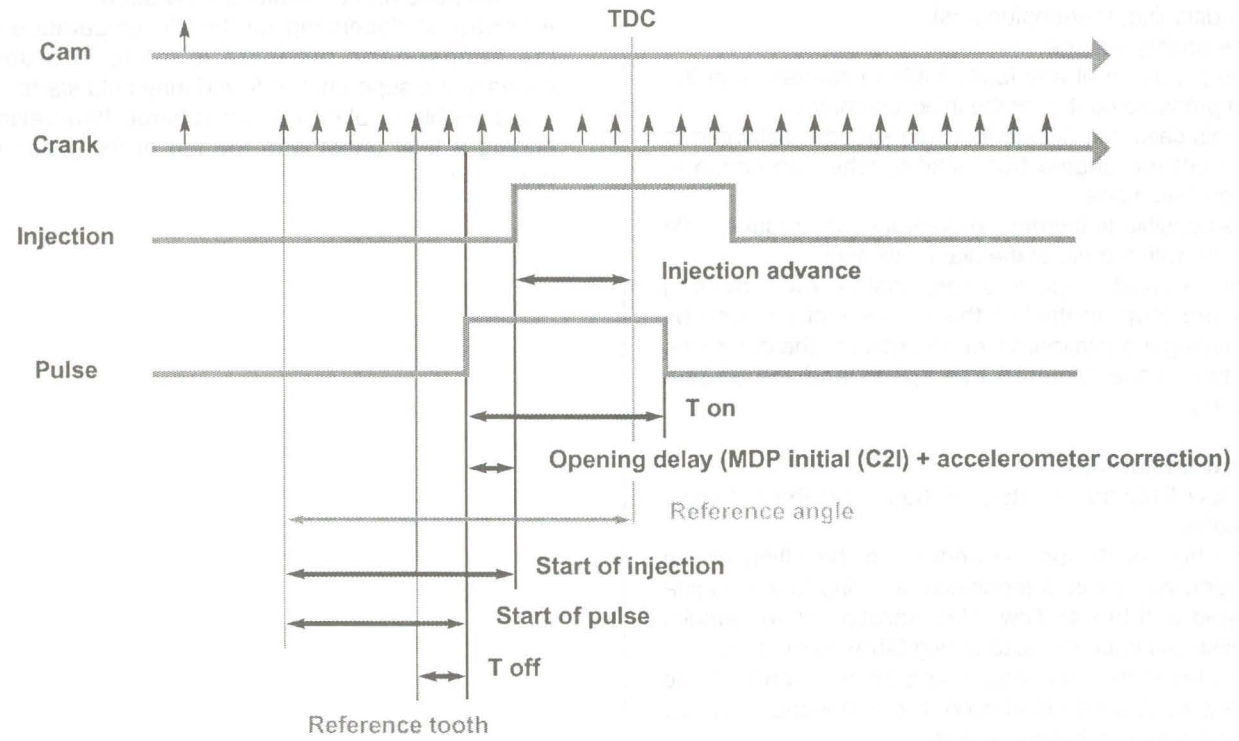
## Pulse determination

The system at this point knows when the injections should begin (timing)and it also knows the amount of fuel which must be injected into the cylinders during each injection (flow). It therefore still has to determine for each injector the number of pulses, their time and their position in the engine cycle.

In point of fact, this function allows the previously determined timing advances and flows to be translated into data that can be understood by the control system of the injectors:

- A reference tooth (CKPS).
- A time between this tooth and the start of the pulse (Toff).
- The pulse time (Ton). (Fig. 2)

[Fig.2]

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**a) Determination of the reference tooth**

The injection timing advance is expressed in crankshaft degrees in relation to TDC. The advance is positive if the injection begins before TDC and is negative if it begins afterwards.

The angular position of the gap in relation to TDC is a piece of application data which depends on the orientation of the flywheel in relation to the crankshaft and on the position of the engine speed sensor on the clutch housing.

The injector opening time depends:

- On the initial characteristics of the injector (C2I).
- On the battery voltage and the resistance of the wiring loom (BRC strategy).
- On the deviation of the injector (resetting of the MDP by the accelerometer).

The opening time makes it possible to determine the angular position at which the pulse should be sent to the injector in order to ensure that the injection actually begins at the angle corresponding to the injection timing advance.

If it is known where the pulse should begin, it is possible to determine the position of the reference tooth.

**b) Calculation of the Toff value**

The Toff represents the time between the reference tooth and the beginning of the pulse.

The Toff value is obtained by dividing the angle between the reference tooth and the start of the pulse by the instantaneous engine speed.

**c) Calculation of the Ton value**

The Ton represents the pulse time. The Ton value is determined according to the flow demand and the rail pressure. The result of this calculation is then corrected by:

- The C2I, to take account of the initial characteristics of the injector.
- The BRC strategy, to take account of the variations in wiring loom resistance and battery voltage.
- The balancing strategy of the point to point flows (cylinder balancing).

## Cylinder balancing strategy

**a) Balancing of the point to point flows**

This strategy allows the point to point flows to be balanced. The pulse of each injector is corrected according to the difference in instantaneous speed measured between two successive injections:

- The instantaneous speeds on two successive injections are first calculated.
- The difference between these two instantaneous speeds is then calculated.
- Finally, the time to be added to the main injection pulse for the different injectors is determined.

For each injector, this time is calculated according to the initial offset of the injector and the instantaneous speed difference.

**b) Detection of an injector which has stuck closed**

The cylinder balancing strategy also allows the detection of an injector which has stuck closed.

The difference in instantaneous speed between two successive injections then exceeds a pre-defined threshold. In this case, a fault is signalled by the system.

## Accelerometer strategy

**a) Resetting the pilot injection**

The accelerometer is used to reset the pilot injection flow in closed loop for each injector.

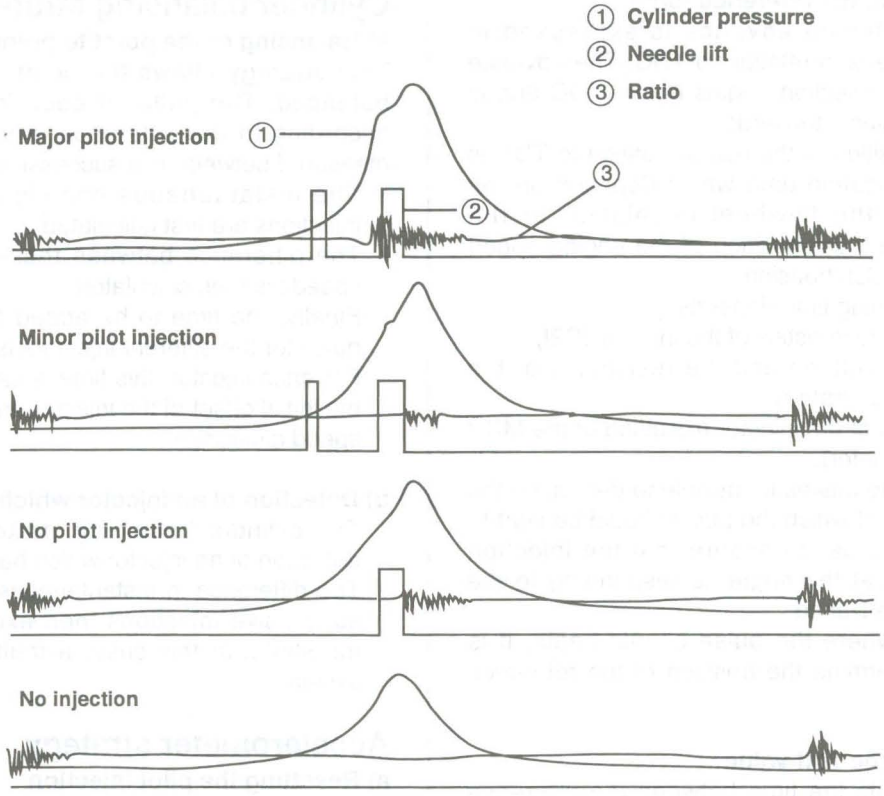
This method is self-adaptive and therefore allows the correction of any injector deviations over a period of time.

The principle of use of the accelerometer is based on the detection of the combustion noises. The sensor is positioned in such a way as to receive the maximum signal for all the cylinders.

The raw signals from the accelerometer are processed to obtain a variable which quantifies the intensity of the combustion. This variable, known as the ratio, consists of the ratio between the intensity of the background noise and the combustion noise.

- A first window is used to establish the background noise level of the accelerometer signal for each cylinder. This window must therefore be positioned at a moment when there cannot be any combustion.
- The second window is used to measure the intensity of the pilot combustion. Its position is such that only the combustion noises produced by the pilot injection are measured. It is therefore placed just before the main injection. (Fig. 3)

[Fig. 3]




The accelerometer does not allow any evaluation of the quantity injected. However, it does allow the pulse value from which the injector begins to inject to be accurately known. This pulse value is called the MDP (Minimum Drive Pulse). On the basis of this information, it is possible to efficiently correct the pilot flows because small flows are very sensitive to variations in the MDP.

The pilot injection resetting principle therefore consists of determining the MDP, in other words the pulse corresponding to the start of the increase in value of the ratio. This is done periodically under certain operating conditions.

When the resetting is finished, the new minimum pulse value replaces the value obtained during the previous resetting. The first MDP value is provided by the (C2I). Each resetting then allows the closed loop of the MDP to be updated according to the deviation of the injector.

**b) Detection of leaks in the cylinders**

The accelerometer is also used to detect any injector which may have stuck open. The detection principle is based on monitoring the ratio. If there is a leak in the cylinder, the accumulated fuel self-ignites as soon as the temperature and pressure conditions are favourable (high engine speed, high load and small leak). This combustion is set off at about 20 degrees before TDC, i.e. well before the combustion caused by the main injection. The ratio therefore increases considerably in the detection window.

It is this increase which allows the leaks to be detected. The threshold beyond which a fault is signalled is a percentage of the maximum possible value of the ratio. Because of the severity of the recovery process (engine shut-down), the detection must be extremely robust.

Now, an increase in the ratio can be the consequence of various causes:

- Pilot injection too strong.
- Main combustion offset in the detection window (too much advance or window offset).
- Fuel leak in the cylinder.

If the ratio becomes too high, the strategy initially restricts the pilot injection flow and retards the main injection. If the ratio remains high despite these interventions, this shows that a real leak is present, a fault is signalled and the engine is shut down.

**c) Detection of an accelerometer fault**

This strategy permits the detection of a fault in the sensor or in the wiring loom connecting the sensor to the DCU. It is based on detection of the combustion. When the engine is idling, the detection window is set too low for the combustion caused by the main injection. If the ratio increases, this shows that the accelerometer is working properly, but otherwise a fault is

signalled to indicate a sensor failure. The recovery modes associated with this fault consist of inhibition of the pilot injection and discharge through the injectors.

# GENERAL

## Specification

| Input sensors | |
|---|---|
| Mass air flow sensor | HFM5 (Hot Film Sensor) |
| Intake air temperature sensor<br>Resistance | Thermistor type<br>2.22 ~ 2.82kΩ at 20°C (68°F)<br>0.299 ~ 0.375kΩ at 80°C (176°F) |
| Engine coolant temperature sensor<br>Resistance | Thermistor type<br>2.20 ~ 2.70kΩ at 20°C (68°F)<br>0.297 ~ 0.339kΩ at 80°C (176°F) |
| Vehicle speed sensor | Hall effect type |
| Camshaft position sensor | Hall effect type |
| Crankshaft position sensor | Magnetic type |
| Accel position sensor | Variable resistor type |
| Fuel pressure sensor | Piezo electricity type |
| Fuel temperature sensor<br>Resistance | Thermistor type<br>2.27 ~ 2.73kΩ at 20°C (68°F)<br>0.298 ~ 0.322kΩ at 80°C (176°F) |
| Fuel tank capacity | 75liter |
| Fuel filter | High pressure type |
| Fuel pump<br>Driven by | Gear driven |
| Fuel pressure at high pressure side | 1600 bar. |
| Injectors | Electronic type |

## Sealant

| | |
|---|---|
| Engine coolant temperature sensor | LOCTITE 962T or equivalent |

## Service standard

| | | | |
|---|---|---|---|
| Curb idle speed (rpm) | N-range | A/CON: OFF | 800 ±100 |

## Tightening torques

| Item | Nm | kg•cm | lb•ft |
|---|---|---|---|
| Delivery pipe (Common Rail) installation | 18.6 - 22.6 | 190- 230 | 13.7 - 16.6 |
| Pipe from rail to Injector 1/2/3/4 | 35.8 - 42.7 | 365 - 435 | 26.4 - 31.5 |
| Clamp bolt for Injector | 19.6 - 21.6 | 200- 220 | 14.5 - 15.9 |
| Retaining bolt for high pressure pump | 35.8 - 42.7 | 365 - 435 | 26.4 - 31.5 |
| High pressure pump - bolt | 21.6 - 25.5 | 220 - 260 | 15.9 - 18.8 |
| High pressure pump bracket - bolt | 34.3 - 40.2 | 350 - 410 | 25.3 - 29.7 |
| CKP - bolt | 0.09 - 0.1 | 90 - 100 | 6.5 - 7.23 |
| Knock sensor | 14.7 - 24.5 | 150 - 250 | 10.8 - 18.1 |
| Air heater terminal | 3.4 - 4.9 | 35 - 50 | 2.5 - 3.6 |
| Engine control module - nut | 34.3 - 40.2 | 350 - 410 | 25.3 - 29.7 |
| Air mass flow sensor - bolt | 5.9 - 8.8 | 60 - 90 | 4.3 - 6.5 |

# Troubleshooting

| Problem | Possible cause |
|---|---|
| Engine does not start | Run out of petrol |
| | Starter out of order |
| | Pump hose supply cut |
| | High pressure leakage |
| | Fuse out of order |
| | The compensation of individual injector not adapted |
| | Drift of the water temperature sensor not detected |
| | Drift of the rail pressure sensor not detected |
| | Cam and Crank signals missing simultaneously |
| | Battery voltage too low |
| | Faulty antitheft |
| | EGR valve blocked open (engine doesn't start) |
| | IMV contaminated, stuck, jammed |
| | Fuel quality / presence of water |
| | Inversion of low pressure fuel connections |
| | Fuel filter not adapted |
| | Low pressure fuel circuit sealed |
| | Sealed fuel filter |
| | Intermittent fault connection |
| | Air ingress in the low pressure fuel circuit |
| | Back leak circuit of the pump sealed |
| | Air heaters out of order |
| | Engine compression too low |
| | Leakage at the injector valve |
| | Transfer pump out of order |
| | High pressure pump out of order |
| | Injector jammed open |
| | Bug soft or hardware fault not detected |
| Engine starts with difficulty or starts and stalls | Run out of petrol |
| | Back leak hose of nozzle holder cut |
| | High pressure leakage |
| | Fuse out of order |
| | Air filter sealed |
| | Alternator or voltage regulator out of order |
| | The compensation of individual injector not adapted |
| | Drift of the water temperature sensor not detected |
| | Drift of the rail pressure sensor not detected |
| | Battery voltage too low |
| | EGR valve blocked open (engine doesn't start) |
| | IMV contaminated, stuck, jammed |
| | Fuel quality / presence of water |
| | Inversion of low pressure fuel connections |
| | Fuel filter not adapted |
| | low pressure fuel circuit sealed |
| | Sealed fuel filter |
| | Oil level too high/too low |
| | Catalytic converter sealed or damaged |
| | Intermittent fault connection |
| | Air ingress in the low pressure fuel circuit |
| | Back leak circuit of the pump sealed |
| | Air heaters out of order |
| | Engine compression too low |
| | Back leak hose of nozzle holder sealed |

| Problem | Possible cause |
|---|---|
| | Carbon deposit on the injector (sealed holes) |
| | Needle stuck (injection possible over a certain pressure) |
| | Petrol in fuel |
| | Bug soft or hardware fault not detected |
| Poor starting when hot | The compensation of individual injector not adapted |
| | Drift of the rail pressure sensor not detected |
| | Drift of the water temperature sensor not detected |
| | EGR valve blocked open (engine doesn't start) |
| | IMV contaminated, stuck, jammed |
| | Air filter sealed |
| | Fuel filter not adapted |
| | Air ingress in the low pressure fuel circuit |
| | Fuel quality / presence of water |
| | Back leak circuit of the pump sealed |
| | Sealed fuel filter |
| | Engine compression too low |
| | Intermittent fault connection |
| | Carbon deposit on the injector (sealed holes) |
| | Needle stuck (injection possible over a certain pressure) |
| | Petrol in fuel |
| | Bug soft or hardware fault not detected |
| Unstable idling | Back leak hose of nozzle holder cut |
| | The compensation of individual injector not adapted |
| | Drift of the rail pressure sensor not detected |
| | Drift of the sensors used to evaluate the air flow not detected |
| | Harness resistance increased |
| | Fuel filter not adapted |
| | Air ingress in the low pressure fuel circuit |
| | Fuel quality / presence of water |
| | Sealed fuel filter |
| | Air filter sealed |
| | Back leak hose of nozzle holder sealed |
| | High pressure leakage |
| | Air heaters out of order |
| | Engine compression too low |
| | Bad flnging of the injector |
| | High pressure pump out of order |
| | Injector not adapted |
| | Carbon deposit on the injector (sealed holes) |
| | Needle stuck (injection possible over a certain pressure) |
| | Injector jammed open |
| Idle speed too high/too low | Drift of the water temperature sensor not detected |
| | Incorrect state of the electrical pack devices |
| | Alternator or voltage regulator out of order |
| | Clutch not well set |
| | Bug soft or hardware fault not detected |
| Blue, white, black smokes | The compensation of individual injector not adapted |
| | Drift of the sensors used to evaluate the air flow not detected |
| | Drift of the water temperature sensor not detected |
| | Drift of the rail pressure sensor not detected |
| | EGR valve blocked open (engine doesn't start) |
| | IMV contaminated, stuck, jammed |
| | Oil level too high/too low |
| | Fuel quality / presence of water |
| | Catalytic converter sealed or damaged |
| | Air filter sealed |

| Problem | Possible cause |
|---|---|
| | Oil suction (engine racing) |
| | Air heaters out of order |
| | Engine compression too low |
| | Bad flnging of the injector |
| | Injector washer not adapted, forgotten, doubled |
| | Injector not adapted |
| | Carbon deposit on the injector (sealed holes) |
| | Injector jammed open |
| | Petrol in fuel |
| Engine rattling, noisy engine | The compensation of individual injector not adapted |
| | EGR valve blocked closed (noisy engine) |
| | EGR valve blocked open (engine doesn't start) |
| | Drift of the water temperature sensor not detected |
| | Drift of the sensors used to evaluate the air flow not detected |
| | Air heaters out of order |
| | Engine compression too low |
| | Back leak hose of nozzle holder sealed |
| | Drift of the rail pressure sensor not detected |
| | Injector washer not adapted, forgotten, doubled |
| | Injector not adapted |
| | Carbon deposit on the injector (sealed holes) |
| | Needle stuck (injection possible over a certain pressure) |
| | Injector jammed open |
| Burst noise | The compensation of individual injector not adapted |
| | Intermittent fault connection |
| | Drift of the rail pressure sensor not detected |
| | IMV contaminated, stuck, jammed |
| | Bug soft or hardware fault not detected |
| Untimely acceleration/deceleration and engine racing | Pedal sensor blocked (cable jammed) |
| | EGR valve blocked open (engine doesn't start) |
| | Intermittent fault connection |
| | Oil suction (engine racing) |
| | Drift of the rail pressure sensor not detected |
| | Bug soft or hardware fault not detected |
| Gap when accelerating and at re-coupling (response time) | Air inlet circuit open |
| | Incorrect state of the electrical pack devices |
| | Pedal sensor blocked (cable jammed) |
| | EGR valve blocked open (engine doesn't start) |
| | Turbo charger damaged |
| | Fuel filter not adapted |
| | Sealed fuel filter |
| | Engine compression too low |
| | High pressure leakage |
| | IMV contaminated, stuck, jammed |
| | Needle stuck (injection possible over a certain pressure) |
| | Bug soft or hardware fault not detected |
| Engine stop/ stalling | Run out of petrol |
| | Pump hose supply cut |
| | High pressure leakage |
| | Fuse out of order |
| | Fuel quality / presence of water |
| | low pressure fuel circuit sealed |
| | Sealed fuel filter |
| | Cam and Crank signals missing simultaneously |
| | EGR valve blocked open (engine doesn't start) |
| | IMV contaminated, stuck, jammed |

| Problem | Possible cause |
|---|---|
| | Alternator or voltage regulator out of order |
| | Intermittent fault connection |
| | Catalytic converter sealed or damaged |
| | Oil suction (engine racing) |
| | Transfer pump out of order |
| | High pressure pump out of order |
| | Faulty ignition key |
| | Petrol in fuel |
| | Bug soft or hardware fault not detected |
| Engine judder | Run out of petrol |
| | Back leak hose of nozzle holder cut |
| | Incorrect state of the electrical pack devices |
| | The compensation of individual injector not adapted |
| | Drift of the sensors used to evaluate the air flow not detected |
| | EGR valve blocked open (engine doesn't start) |
| | Fuel filter not adapted |
| | Air ingress in the low pressure fuel circuit |
| | Fuel quality / presence of water |
| | Sealed fuel filter |
| | Intermittent fault connection |
| | Harness resistance increased |
| | Air heaters out of order |
| | Engine compression too low |
| | Back leak hose of nozzle holder sealed |
| | Valve clearance |
| | Transfer pump out of order |
| | Injector washer not adapted, forgotten, doubled |
| | Carbon deposit on the injector (sealed holes) |
| | Needle stuck (injection possible over a certain pressure) |
| | Injector jammed open |
| | Petrol in fuel |
| | Bug soft or hardware fault not detected |
| Lack of power | The compensation of individual injector not adapted |
| | Pedal sensor blocked (cable jammed) |
| | Incorrect state of the electrical pack devices |
| | Drift of the sensors used to evaluate the air flow not detected |
| | EGR valve blocked open (engine doesn't start) |
| | Air inlet circuit open |
| | Air filter sealed |
| | Oil level too high/too low |
| | Catalytic converter sealed or damaged |
| | Turbo charger damaged |
| | Fuel filter not adapted |
| | Sealed fuel filter |
| | Leakage at the injector valve |
| | Back leak circuit of the pump sealed |
| | Back leak hose of nozzle holder sealed |
| | Engine compression too low |
| | Injector not adapted |
| | Carbon deposit on the injector (sealed holes) |
| | Valve clearance |
| Too much power | EGR valve blocked closed (noisy engine) |
| | The compensation of individual injector not adapted |
| | Oil suction (engine racing) |
| | Injector not adapted |
| | Bug soft or hardware fault not detected |

| Problem | Possible cause |
|---|---|
| Excessive fuel consumption | Back leak hose of nozzle holder cut |
| | Leakage at the IMV |
| | Leakage at fuel temperature sensor |
| | Leakage at the spacers |
| | High pressure leakage |
| | Air inlet circuit open |
| | Air filter sealed |
| | The compensation of individual injector not adapted |
| | EGR valve blocked open (engine doesn't start) |
| | Incorrect state of the electrical pack devices |
| | Oil level too high/too low |
| | Fuel quality / presence of water |
| | Catalytic converter sealed or damaged |
| | Turbo charger damaged |
| | Engine compression too low |
| | Injector not adapted |
| | Bug soft or hardware fault not detected |
| Over speed engine when changing the gear box ratio | Pedal sensor blocked (cable jammed) |
| | The compensation of individual injector not adapted |
| | Intermittent fault connection |
| | Clutch not well set |
| | Oil suction (engine racing) |
| | Turbo charger damaged |
| | Injector not adapted |
| | Bug soft or hardware fault not detected |
| Exhaust smells | EGR valve blocked open (engine doesn't start) |
| | Oil suction (engine racing) |
| | Turbo charger damaged |
| | Oil level too high/too low |
| | The compensation of individual injector not adapted |
| | Catalytic converter sealed or damaged |
| | Bad flnging of the injector |
| | Injector washer not adapted, forgotten, doubled |
| | Injector not adapted |
| | Carbon deposit on the injector (sealed holes) |
| | Needle stuck (injection possible over a certain pressure) |
| | Injector jammed open |
| | Bug soft or hardware fault not detected |
| Smokes (black, white, blue) when accelerating | The compensation of individual injector not adapted |
| | EGR valve blocked open (engine doesn't start) |
| | Drift of the sensors used to evaluate the air flow not detected |
| | Air filter sealed |
| | Fuel quality / presence of water |
| | Oil level too high/too low |
| | Turbo charger damaged |
| | Catalytic converter sealed or damaged |
| | Oil suction (engine racing) |
| | Air heaters out of order |
| | Engine compression too low |
| | High pressure leakage |
| | Intermittent fault connection |
| | Bad flnging of the injector |
| | Injector washer not adapted, forgotten, doubled |
| | Injector not adapted |
| | Carbon deposit on the injector (sealed holes) |
| | Needle stuck (injection possible over a certain pressure) |

| Problem | Possible cause |
|---|---|
| | Injector jammed open |
| | Petrol in fuel |
| | Bug soft or hardware fault not detected |
| Fuel smells | Pump hose supply cut |
| | Back leak hose of nozzle holder cut |
| | Leakage at the IMV |
| | Leakage at fuel temperature sensor |
| | Leakage at the spacers |
| | High pressure leakage |
| The engine collapses at take off | Pedal sensor blocked (cable jammed) |
| | Incorrect state of the electrical pack devices |
| | Air filter sealed |
| | Inversion of low pressure fuel connections |
| | Fuel filter not adapted |
| | Fuel quality/presence of water |
| | Air ingress in the low pressure fuel circuit |
| | Sealed fuel filter |
| | Catalytic converter sealed or damaged |
| | Clutch not well set |
| | Intermittent fault connection |
| | Drift of the rail pressure sensor not detected |
| | IMV contaminated, stuck, jammed |
| | Petrol in fuel |
| | Bug soft or hardware fault not detected |
| The engine does not stop | Faulty ignition key |
| | Oil suction (engine racing) |
| | Bug soft or hardware fault not detected |
| Different mechanical noises | Buzzer noise (discharge by the injectors) |
| | Clip broken (vibrations, resonance, noises) |
| | Incorrect state of the electrical pack devices |
| | Catalytic converter sealed or damaged |
| | Air inlet circuit open |
| | Bad flnging of the injector |
| | Clutch not well set |
| | Turbo charger damaged |
| | Valve clearance |

| Trouble symtoms / Check items | Engine will not start | Engine shut off and then restart | Engine starts only with difficult | High idle no throttle take-up | Knocking on accel. (warm-up phases) | Vibration at idle | Reduced power | Engine does not run smoothly, misfiring, knocking | Bucking |
|---|---|---|---|---|---|---|---|---|---|
| Rail Pressure Sensor | | | 18 | | | 12 | 17 | 17 | |
| Accel. Position Sensor | | | | 2 | | | 8 | | |
| Mechanical fault in accel. | | | | 3 | | | 9 | | |
| EGR | | | | | | 7 | 10 | | |
| HFM5 (Air Flow Meter) | | | | | | 9 | 14 | | |
| Air filter clogged | | | 12 | | | 8 | 3 | | |
| Vacuum system leaking | | | | | | | 2 | | |
| Turbocharger defective | | | | | | | 11 | | |
| Waste-gate valve connection | | | | | | | 12 | | |
| Fuel Temp. Sensor | | | | | | | 16 | | |
| Checking belt tension | | | | | | | | 18 | |
| Clutch switch | | | | | | | | | 6 |
| Brake switch | | | | | | | | | 7 |
| Vehicle speed signal | | | | | | | | | 8 |
| Checking oil level | | | | | | | | | |
| Radiator fan | | | | | | | | | |
| Radiator defective or clogged | | | | | | | | | |
| IG switch defective | | | | | | | | | |
| AC compress. SW | | | | | | | | | |
| AC SW | | | | | | | | | |
| Plug contacts | | | 6 | | | | | | |
| Connection between turbo. and Intake manifold. Leaking | | | 6 | | | | 13 | | |

# Troubleshooting guide chart

| Trouble symtoms / Check items | Engine will not start | Engine shut off and then restart | Engine starts only with difficult | High idle no throttle take-up | Knocking on accel. (warm-up phases) | Vibration at idle | Reduced power | Engine does not run smoothly, misfiring, knocking | Bucking |
|---|---|---|---|---|---|---|---|---|---|
| Self-diagnosis | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Immobilizer | 2 | | | | | | | | |
| Vehicle supply volt. | 3 | | 2 | | | | | 9 | 3 |
| Main Relay | 4 | 3 | 3 | | | | | 11 | 4 |
| Fuse/plug wiring harness | 5 | 2 | | | | | | 8 | 2 |
| Terminal 15 | 6 | 4 | 4 | | | | | 10 | 5 |
| Crankshaft Position Sensor | 7 | | | | | | | 12 | |
| NO fuel | 8 | | | | | | | | |
| Wrong fuel | 9 | 5 | 7 | | | 2 | 4 | 3 | |
| Lack of fuel | | | | | | | | 2 | |
| Air in fuel system | 10 | 6 | 8 | | | 3 | | 4 | |
| Low-pressure circuit(fuel) | 11 | 7 | 13 | | | 4 | 5 | 7 | |
| High-pressure circuit(fuel) | 16 | 8 | 14 | | | 14 | 19 | 16 | |
| Fuel filter | 12 | | 9 | | | 5 | 6 | 5 | |
| Electric fuel pump | 15 | | 11 | | | | | 6 | |
| Fuel pre-heater | 13 | | 10 | | | 6 | 7 | | |
| Pressure Regulator Valve | 18 | 9 | 16 | | | 13 | | 15 | |
| Incorrect connection of injector | 14 | | 17 | | 3 | 11 | | 13 | |
| Injector | 17 | 10 | 19 | | 4 | 10 | 18 | 14 | |
| Mechanical componenet (compression, valve clearance...) | 19 | | 20 | | | | 20 | 19 | 9 |
| ECU defective | 20 | | | | | | | | |
| TDC sensor | | | 5 | | | | | | |
| Water Temp. Sensor | | | 15 | | 2 | | 15 | | |
| Loss of coolant | | | | | | | | | |
| Glow-plug system | | | 16 | | | | | | |

TROUBLE-1

| Trouble symtoms / Check items | Engine overrun, Accel. | White/Blue smoke | Clouds of black smoke | Engine overheating | Can not shut off with IG key | Diagnosis lamp not go out or flickers | AC cannot be switched on | RAD. Fan constantly in operation |
|---|---|---|---|---|---|---|---|---|
| Self-diagnosis | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Immobilizer | | | | | | | | |
| Vehicle supply volt. | | | | | | | | |
| Main Relay | | | | | | | | |
| Fuse/plug wiring harness | | | | | 4 | 2 | 2 | 4 |
| Terminal 15 | | | | | 3 | | | |
| Crankshaft Position Sensor | | | | | | | | |
| NO fuel | | | | | | | | |
| Wrong fuel | | | | 2 | | | | |
| Lack of fuel | | | | | | | | |
| Air in fuel system | | 3 | | | | | | |
| Low-pressure circuit(fuel) | | 6 | | | | | | |
| High-pressure circuit(fuel) | 7 | | | | | | | |
| Fuel filter | | 4 | | | | | | |
| Electric fuel pump | | | | | | | | |
| Fuel pre-heater | | 5 | | | | | | |
| Pressure Regulator Valve | 6 | | | | | | | |
| Incorrect connection of injector | | | | | | | | |
| Injector | | | | | | | | |
| Mechanical component (compression, valve clearance...) | | | 7 | 7 | | | | |
| ECM defective | | | | | 5 | | | |
| TDC sensor | | | | | | | | |
| Water Temp. Sensor | 8 | 2 | 6 | 3 | | | 5 | 3 |
| Loss of coolant | | | | 6 | | | | |
| Glow-plug system | | | | | | | | |

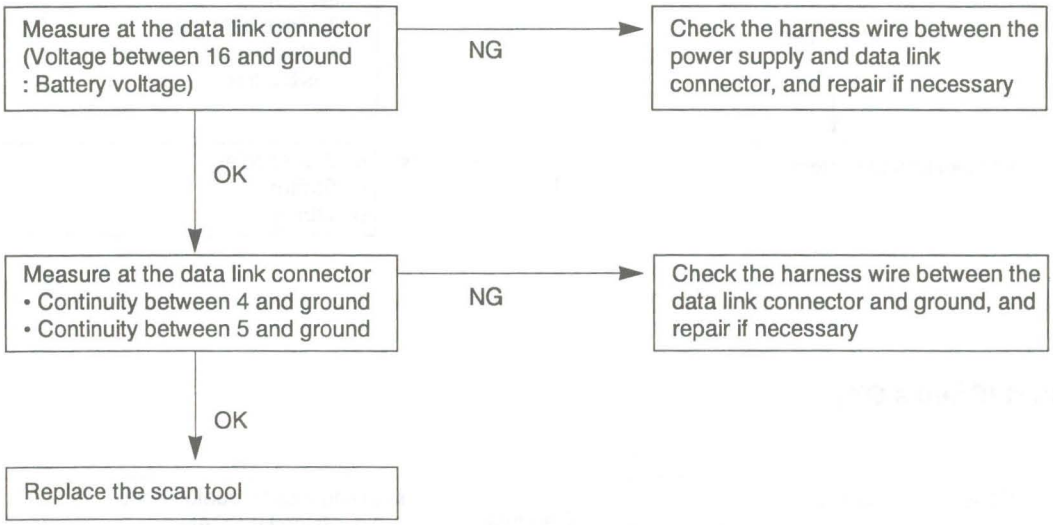
TROUBLE-3

| Trouble symtoms / Check items | Engine overrun, Accel. | White/Blue smoke | Clouds of black smoke | Engine overheating | Can not shut off with IG key | Diagnosis lamp not go out or flickers | AC cannot be switched on | RAD. Fan constantly in operation |
|---|---|---|---|---|---|---|---|---|
| Rail Pressure Sensor | | | | | | | | |
| Accel. Position Sensor | 3 | | | | | | 6 | |
| Mechanical fault in accel. | 2 | | | | | | | |
| EGR | | | 3 | | | | | |
| HFM5 (Air Flow Meter) | | | 5 | | | | | |
| Air filter clogged | | | 2 | | | | | |
| Vacuum system leaking | | | 4 | | | | | |
| Turbocharger defective | 4 | | | | | | | |
| Waste-gate valve connection | 5 | | | | | | | |
| Fuel Temp. Sensor | 9 | | | | | | | |
| Checking belt tension | | | | | | | | |
| Clutch switch | | | | | | | | |
| Brake switch | | | | | | | | |
| Vehicle speed signal | | | | | | | | |
| Checking oil level | | 7 | | | | | | |
| Radiator fan | | | | 4 | | | | |
| Radiator defective or clogged | | | | 5 | | | | |
| IG switch defective | | | | | 2 | | | |
| AC compress. SW | | | | | | | 4 | 2 |
| AC SW | | | | | | | 3 | |
| Plug contacts | | | | | | | | |
| Connection between turbo. and Intake manifold. Leaking | | | | | | | | |

# TROUBLESHOOTING PROCEDURES

## Problem

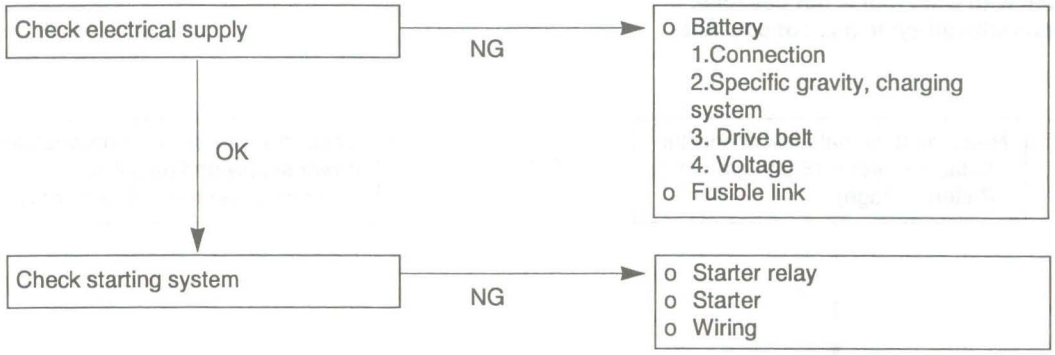
**Communication with scan tool is not possible.**
**(Communication with all system is not possible)**



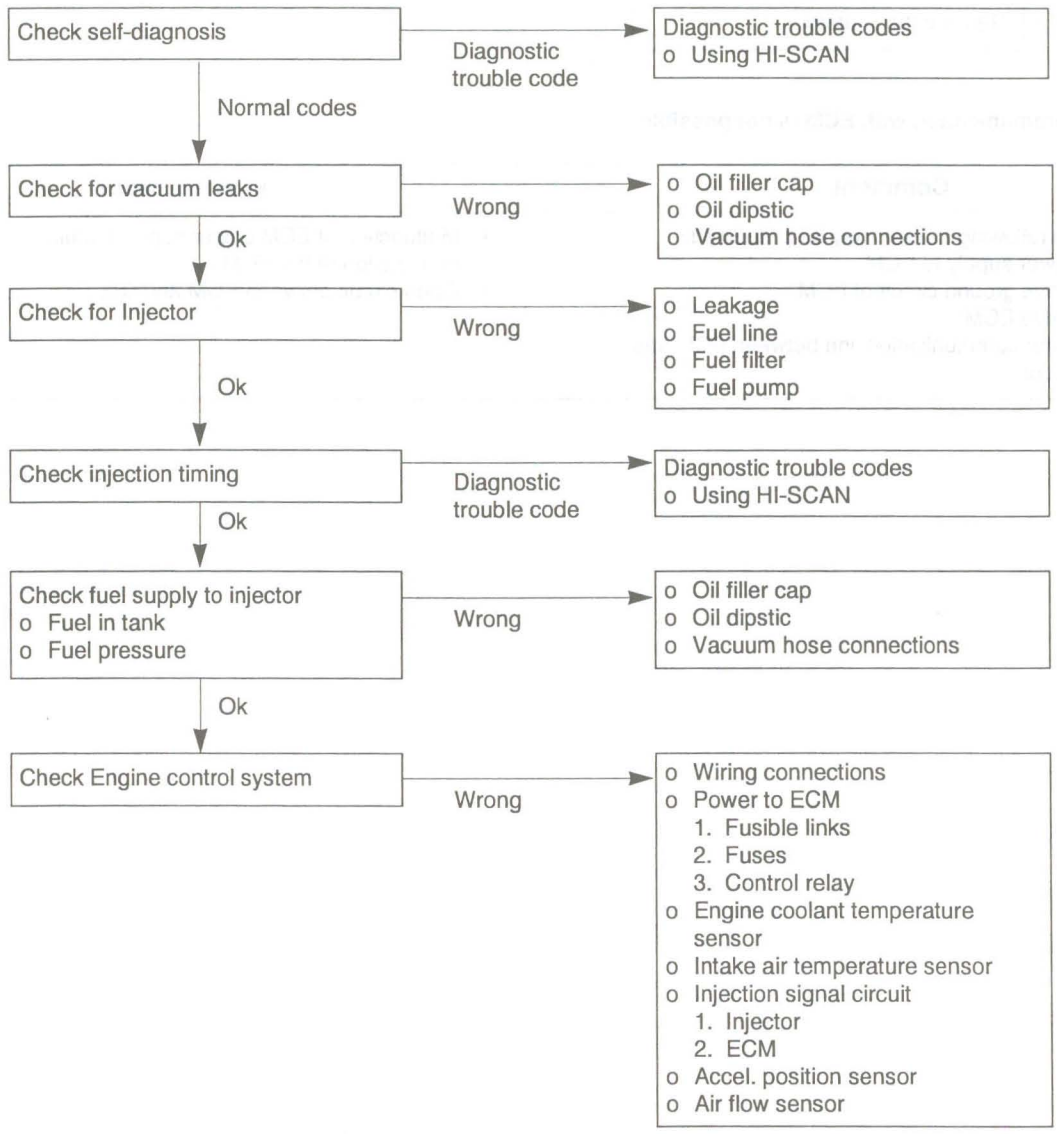

**Scan tool communication with ECM is not possible**

| Comment | Probable cause |
|---|---|
| One of the following causes may be suspected.<br>• No power supply to ECM<br>• Defective ground circuit of ECM<br>• Defective ECM<br>• Improper communication line between ECM and scan tool | • Malfunction of ECM power supply circuit<br>• Malfunction of the ECM<br>• Open circuit between ECM and DLC |

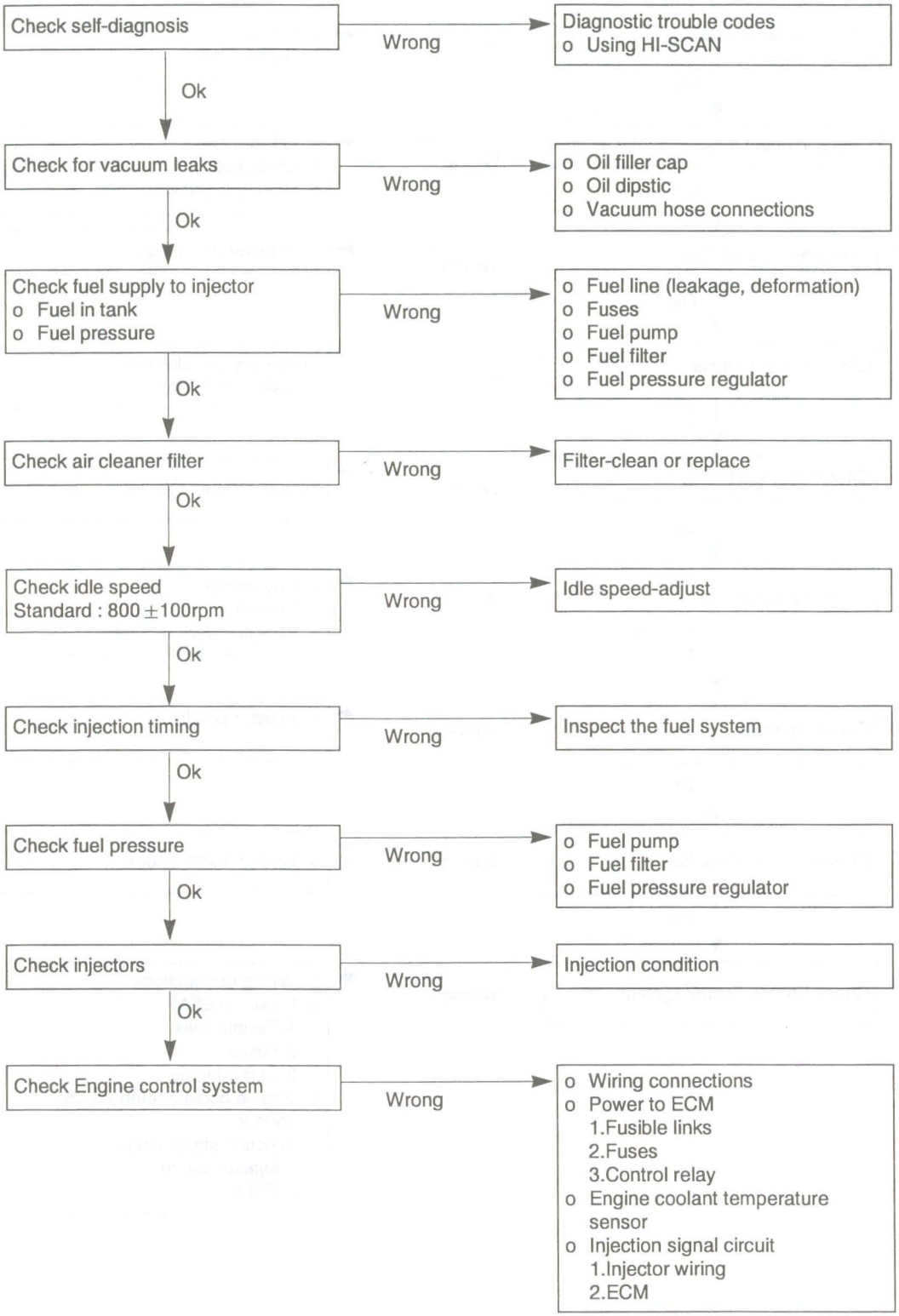
## Engine will not start



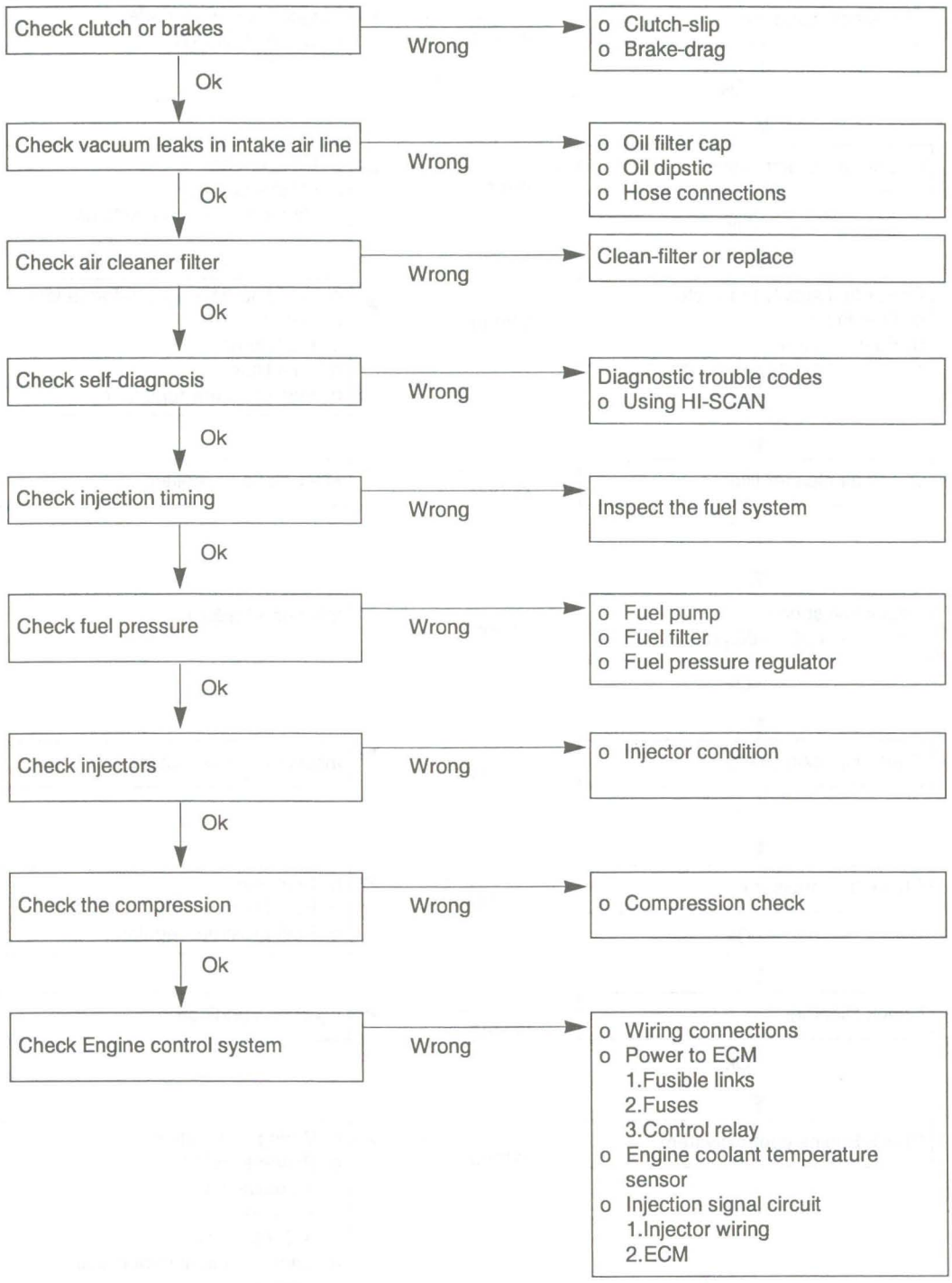

## Hard to start (Cranks OK)



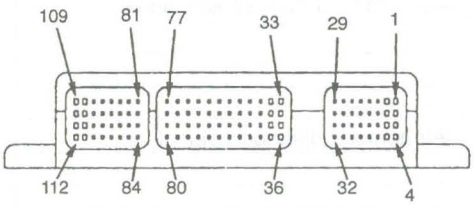
## Rough idle or engine stalls



## Engine hesitates or accelerates poorly



## ECM Terminal layout




## Connector B-01

| Terminal | Signal | Connected to |
|---|---|---|
| 1 | - | - |
| 2 | Acceleration position sensor 1 signal | APS |
| 3 | Acceleration position sensor 1 ground | APS |
| 4 | Power ground | Chassis ground |
| 5 | Battery voltage | Main relay |
| 6 | Acceleration position sensor 1 reference voltage | APS |
| 7 | - | - |
| 8 | Power ground | Chassis ground |
| 9 | MIL control | MIL |
| 10 | Acceleration position sensor 2 reference voltage | APS |
| 11 | Acceleration position sensor 2 signal | APS |
| 12 | Acceleration position sensor 2 ground | APS |
| 13 | - | - |
| 14 | IMMO lamp control | IMMO lamp |
| 15 | Brake switch signal 1 | Brake switch |
| 16 | - | - |
| 17 | Key sensing signal | Ignition switch |
| 18 | - | - |
| 19 | - | - |
| 20 | - | - |
| 21 | - | - |
| 22 | - | - |
| 23 | - | - |
| 24 | Clutch switch signal | Clutch switch (MT) |
| 25 | - | - |
| 26 | Engine RPM | Tachometer |
| 27 | Immobilizer K-line | Immobilizer |
| 28 | Communication K-line | Data link connector |
| 29 | Glow lamp control | Glow lamp |
| 30 | P/N switch signal | Inhibitor switch (AT) |
| 30 | Ground | Chassis ground (MT) |
| 31 | - | - |
| 32 | - | - |
| 33 | Knock sensor shield ground | KS |
| 34 | - | - |
| 35 | - | - |
| 36 | Inlet metering valve control | Inlet metering valve |
| 37 | Crankshaft position sensor shield ground | CKPS |
| 38 | - | - |
| 39 | EGR solenoid valve control | EGR solenoid valve |
| 40 | - | - |
| 41 | - | - |

| Terminal | Signal | Connected to |
|---|---|---|
| 42 | Intake air temperature sensor signal | MAFS |
| 43 | - | - |
| 44 | - | - |
| 45 | - | - |
| 46 | Air heater 2 diagnosis signal | Air heater 2 |
| 47 | - | - |
| 48 | - | - |
| 49 | - | - |
| 50 | Engine coolant temperature sensor signal | ECTS |
| 51 | Engine coolant temperature sensor ground | ECTS |
| 52 | Injector 4 low signal driver | Injector 4 |
| 53 | Knock sensor signal | KS |
| 54 | Fuel temperature sensor signal | FTS |
| 55 | Fuel temperature sensor ground | FTS |
| 56 | Injector 4 high signal driver | Injector 4 |
| 57 | Knock sensor ground | KS |
| 58 | Crankshaft position sensor + signal | CKPS |
| 59 | Crankshaft position sensor - signal | CKPS |
| 60 | Injector 3 low signal driver | Injector 3 |
| 61 | Camshaft position sensor reference voltage | CMPS |
| 62 | Camshaft position sensor signal | CMPS |
| 63 | Camshaft position sensor ground | CMPS |
| 64 | Injector 3 high signal driver | Injector 3 |
| 65 | Rail pressure sensor reference voltage | RPS |
| 66 | Rail pressure sensor signal | RPS |
| 67 | Rail pressure sensor ground | RPS |
| 68 | Injector 2 low signal driver | Injector 2 |
| 69 | - | - |
| 70 | - | - |
| 71 | - | - |
| 72 | Injector 2 high signal driver | Injector 2 |
| 73 | - | - |
| 74 | - | - |
| 75 | - | - |
| 76 | Injector 1 low signal driver | Injector 1 |
| 77 | Mass air flow sensor reference voltage | MAFS |
| 78 | Mass air flow sensor signal | MAFS |
| 79 | Mass air flow sensor ground | MAFS |
| 80 | Injector 1 high signal driver | Injector 1 |
| 81 | - | - |
| 82 | - | - |
| 83 | - | - |
| 84 | - | - |
| 85 | - | - |
| 86 | Brake switch signal 2 | Brake switch |
| 87 | Cooling fan high relay control | High relay |
| 88 | Cooling fan low relay control | Low relay |
| 89 | - | - |
| 90 | Water heater diagnosis signal | Water heater 1 |
| 91 | Air heater relay 1 control | Air heater relay 1 |
| 92 | - | - |

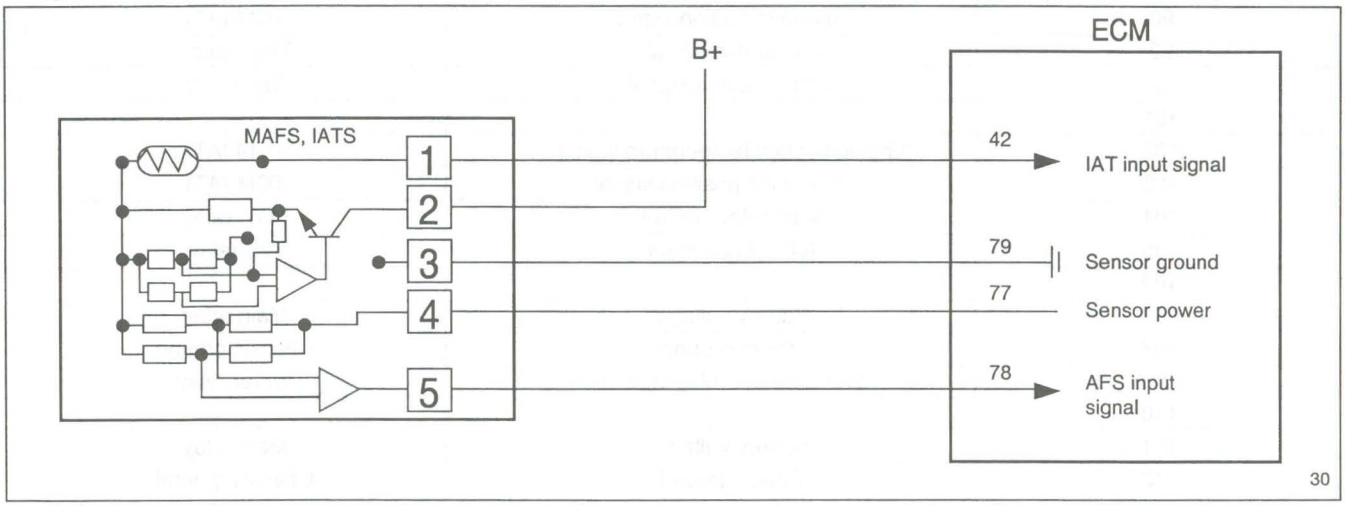
| Terminal | Signal | Connected to |
|---|---|---|
| 42 | Intake air temperature sensor signal | MAFS |
| 43 | - | - |
| 44 | - | - |
| 45 | - | - |
| 46 | Air heater 2 diagnosis signal | Air heater 2 |
| 47 | - | - |
| 48 | - | - |
| 49 | - | - |
| 50 | Engine coolant temperature sensor signal | ECTS |
| 51 | Engine coolant temperature sensor ground | ECTS |
| 52 | Injector 4 low signal driver | Injector 4 |
| 53 | Knock sensor signal | KS |
| 54 | Fuel temperature sensor signal | FTS |
| 55 | Fuel temperature sensor ground | FTS |
| 56 | Injector 4 high signal driver | Injector 4 |
| 57 | Knock sensor ground | KS |
| 58 | Crankshaft position sensor + signal | CKPS |
| 59 | Crankshaft position sensor - signal | CKPS |
| 60 | Injector 3 low signal driver | Injector 3 |
| 61 | Camshaft position sensor reference voltage | CMPS |
| 62 | Camshaft position sensor signal | CMPS |
| 63 | Camshaft position sensor ground | CMPS |
| 64 | Injector 3 high signal driver | Injector 3 |
| 65 | Rail pressure sensor reference voltage | RPS |
| 66 | Rail pressure sensor signal | RPS |
| 67 | Rail pressure sensor ground | RPS |
| 68 | Injector 2 low signal driver | Injector 2 |
| 69 | - | - |
| 70 | - | - |
| 71 | - | - |
| 72 | Injector 2 high signal driver | Injector 2 |
| 73 | - | - |
| 74 | - | - |
| 75 | - | - |
| 76 | Injector 1 low signal driver | Injector 1 |
| 77 | Mass air flow sensor reference voltage | MAFS |
| 78 | Mass air flow sensor signal | MAFS |
| 79 | Mass air flow sensor ground | MAFS |
| 80 | Injector 1 high signal driver | Injector 1 |
| 81 | - | - |
| 82 | - | - |
| 83 | - | - |
| 84 | - | - |
| 85 | - | - |
| 86 | Brake switch signal 2 | Brake switch |
| 87 | Cooling fan high relay control | High relay |
| 88 | Cooling fan low relay control | Low relay |
| 89 | - | - |
| 90 | Water heater diagnosis signal | Water heater 1 |
| 91 | Air heater relay 1 control | Air heater relay 1 |
| 92 | - | - |

| Terminal | Signal | Connected to |
|---|---|---|
| 93 | Blower switch signal | Blower switch |
| 94 | Air heater 1 diagnosis signal | Air heater 1 |
| 95 | - | - |
| 96 | Air heater relay 2 control | Air heater relay 2 |
| 97 | MT/AT detection signal | Chassis ground (AT) |
| 97 | MT/AT detection signal | Not connected (MT) |
| 98 | Torque reduction signal | TCM (AT) |
| 99 | A/C switch signal | Thermocon |
| 100 | Vehicle speed signal | Meter set |
| 101 | - | - |
| 102 | Engine coolant temperature signal | TCM (AT) |
| 103 | Acceleration position signal | TCM (AT) |
| 104 | Main relay control | Main relay |
| 105 | A/C relay control | A/C relay |
| 106 | - | - |
| 107 | Battery voltage | Main relay |
| 108 | Power ground | Chassis ground |
| 109 | Water heater relay control | Water relay |
| 110 | - | - |
| 111 | Battery voltage | Main relay |
| 112 | Power ground | Chassis ground |

# COMPONENT INSPECTION

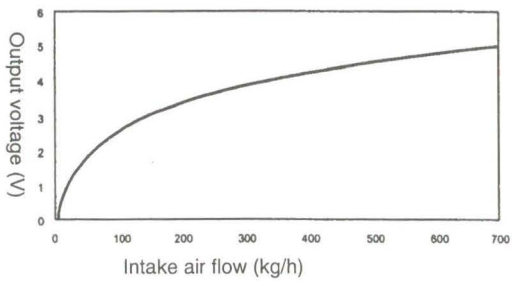
## MAFS, IATS

The air flow sensor adopts the feature of maintaining a certain temperature of the heater for sensor to make the hot film element detect the air flow and send related signal to the ECM.
The ECM then determines the fuel amount and ignition timing and check the information to apply the fuel and A/C load correction.
The IAT is used to detect the temperature of intake air to support the correction of fuel flow and ignition timing, and the compensation of air temperature for idle control.




### [Major features of HOT FILM AFS]

| Item | Features | Remarks |
|---|---|---|
| Power supply | 7.5 ~ 16 v | |
| Temperature regulating range | -40°C ~ 125°C | |
| Flow detecting range | 7 ~ 640kg/h | |
| Output voltage | 0 ~ 5V | |
| Connector | PIN1: Intake air temperature sensor output | |
| | PIN2: Battery power | |
| | PIN3: Sensor ground | |
| | PIN4: Sensor power (5V) | |
| | PIN5: Air flow sensor output | |




KFW5239A

## Troubleshooting hints

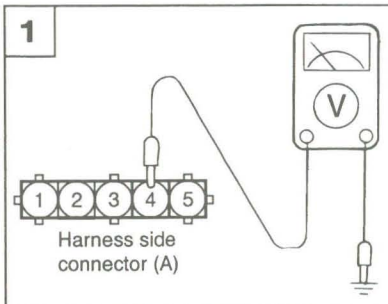
1. If the engine stalls occasionally, start the engine and shake the MAFS harness. If the engine stalls, check for poor contact at the MAFS connector.
2. If the MAFS sensor output voltage is other than 0 when the ignition switch is turned ON(do not start the engine), check for faulty MAFS and ECM.
3. If the engine can idle even if the MAFS output voltage is out of specification, check the conditions as below:
   - Air flow distributed from MAFS, disconnected air duct and clogged air cleaner filter.
   - Poor combustion in the cylinder, faulty spark plug, ignition coil, injector and incorrect comparison.
4. Though no MAFS malfunction occurs, check the mounting direction of the MAFS.

✱ *Notice*

1. *The air quantity of mass air flow sensor will be about 10% higher in case of new vehicle (within initial running of about 500km (300 miles)).*
2. *Use an accurate digital voltmeter.*
3. *Before checking, warm up the engine until the engine coolant temperature reaches 80~90°C (175~198°F)*

## Harness inspection (MAFS)

**1**



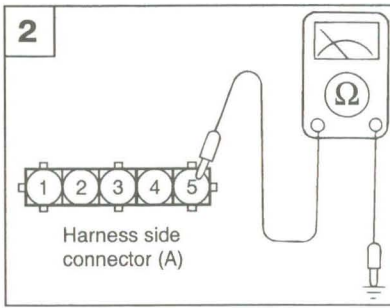

Measure the power supply voltage for the MAFS sensor.
- Connector: Disconnected.
- Ignition switch : ON.
- Voltage (V) : 4.8-5.2 V.

OK ⇒ 2

NG ⇒ Repair the harness.

EFJB705B

**2**



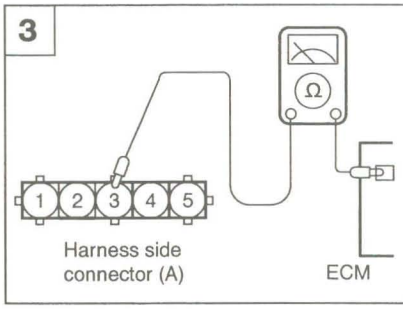

Check for an open circuit, or a short circuit to ground between the powertrain control module and the MAFS sensor.
- Connector : Disconnected
- PCM connector : Disconnected

OK ⇒ 3

NG ⇒ Repair the harness.

EFJB705C

**3**



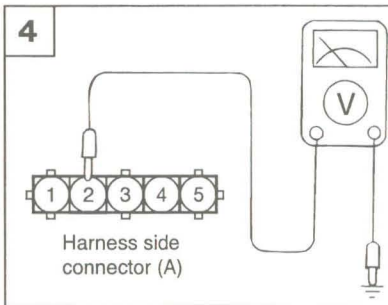

Check for continuity of the sensor ground circuit.
- Connector : Disconnected.

OK ⇒ 4

NG ⇒ Repair the harness.

EFJB705D

**4**



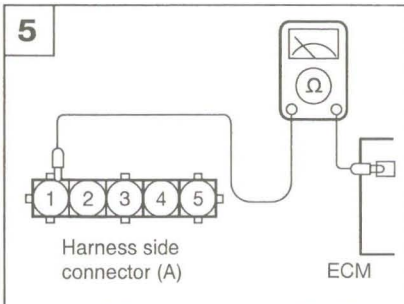

Check the power supply(Bat) voltage for MAF sensor.
- Connector : Disconnected
- PCM connector : Connected
- Voltage : Battery voltage

OK ⇒ 5

NG ⇒ Repair the harness.

EFJB705E

**5**




Check for an open-circuit, or a short-circuit to ground between the PCM and MAF sensor.
- Connector : Disconnected
- PCM connector : Disconnected

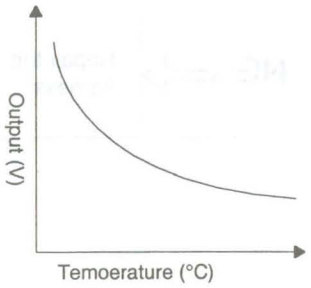
OK ⇒ END !

NG ⇒ Repair the harness.

EFJB705F

## Features of IAT output

For the measure feature of the IAT at malfunction, if the coolant temperature is normal, the intake air substitution value is 0°C when the coolant temperature is below 69.75°C while the value is 60°C when the coolant temperature is over 69.75°C. The substitution value should be 60°C when the engine coolant temperature sensor is failed simultaneously.

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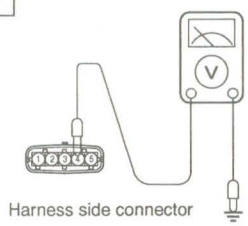
## Using voltmeter

| Item to check | Data output | Condition to check | Intake air temp. | Resistance |
|---|---|---|---|---|
| Intake air temp. sensor | Intake air temp. | Ignition switch: ON or starting | -40°C | 33.85~61.20 kΩ |
| | | | 20°C | 2.22~2.82 kΩ |
| | | | 80°C | 0.299~0.375 kΩ |

## Harness inspection (MAFS)

1



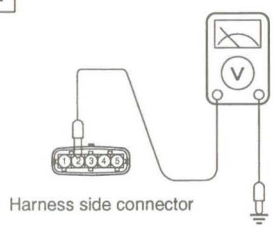

Meaure the reference power supply voltage.
- Connector : Disonnected
- Ignition switch : ON
- Power(V) : 4.8~5.2

OK ⇨ 2

NG ⇨ Repair the harness

KFW5240A

2



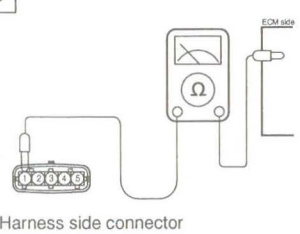

Measure the voltage of power supply for sensor.
- Connector : Disonnected
- Ignition switch : ON
- Voltage (V) : B+

OK ⇨ 3

NG ⇨ Repair the harness

KFW5241A

3

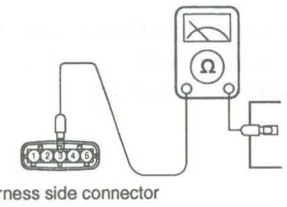



Check for an open or short circuit between ECM and IAT signal circuit.
- ECM connector : Disconnected.
- IAT sensor connector : Disconnected

OK ⇨ 4

NG ⇨ Repair the harness

KFW5244A

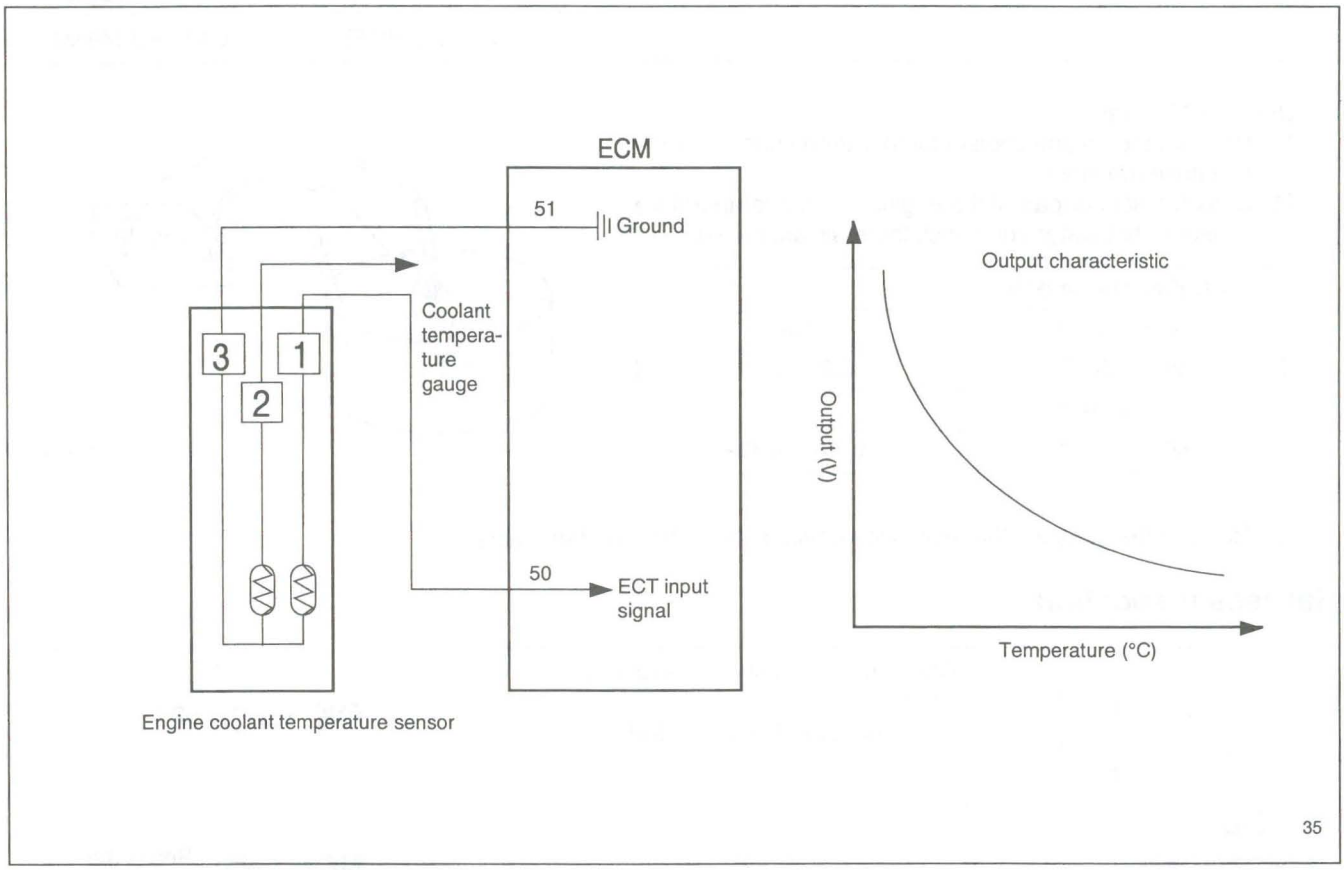
| | | | |
|---|---|---|---|
| 4   Harness side connector | Check for continuity of the sensor ground circuit.<br>• Connector : Disconnected | OK ⇨ | END |
| | | NG ⇨ | Repair the harness |

KFW5243A

## ECTS

Measure engine coolant temperature using NTC (Negative temperature coefficient) element. The thermistor resistance of NTC element decrease in response to rise of temperature.
It's used in determination of basic fuel quantity and ignition timing at starting, determination of basic idle control duty at starting, fuel and cooling fan control, and emission gas temperature modeling necessary for controlling emissions.

[ECTS circuit and output features]




The measure at sensor malfunction is to take the initial intake air temperature as basic substitution value of coolant temperature and increase it up to max. 110°C in the interval of 0.5 sec in response to the quantity of air.
In case of the intake air temperature sensor malfunction, first take the substitution value of coolant temperature at 20°C and increase it up to 110°C in the interval of 0.5 second by the air quantity.
In case of intake air temperature sensor malfunction during engine running, first determine a proper temperature before first finding the trouble cause, and then increase it up to 110°C in the interval of 0.5 second by the air quantity.

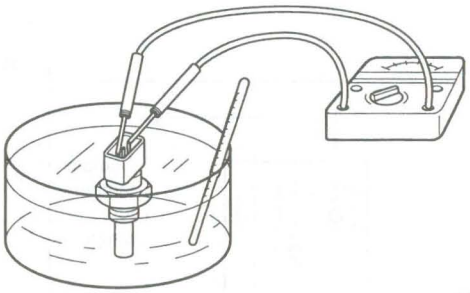
## Checking the sensor

1. Using Hi-scan

| item | display | conditions | temp. sensor | |
|---|---|---|---|---|
| Coolant temperature sensor | Coolant temperature sensor | Ignition switch: ON or starting condition | -40 °C (-4 °F) | 43.51 ~ 53.26 kΩ |
| | | | 20 °C (68 °F) | 2.20 ~ 2.70 kΩ |
| | | | 80 °C (176 °F) | 0.297 ~ 0.339 kΩ |
| | | | 110 °C (230 °F) | 0.145 ~ 0.149 kΩ |

2. Using multi-tester
   1) Remove the engine coolant temperature sensor from air intake manifold.
   2) Soak the sensor part of the engine coolant temperature sensor to hot water and check the resistance value.

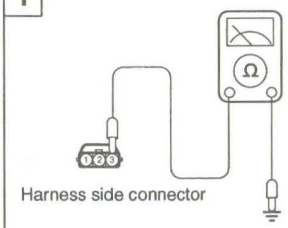
| (°C )Resistance (kΩ) | |
|---|---|
| 0 °C (32 °F) | 5.9 |
| 20 °C (68 °F) | 2.20 ~ 2.70 |
| 40 °C (104 °F) | 1.1 |
| 80 °C (176 °F) | 0.297 ~ 0.339 |



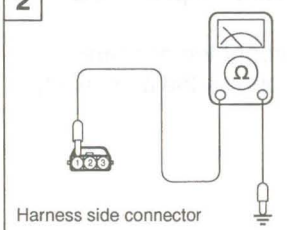
KFW5223A

   3) Replace the sensor if the resistance deviates from the standard value.

## Harness inspection

| | | | |
|---|---|---|---|
| 1  Harness side connector | Check for continuity of the ground circuit.<br>• Connector: Disconnected. | OK ⇒ | 2 |
| | | NG ⇒ | Repair the harness |

KFW5245A

| | | | |
|---|---|---|---|
| 2  Harness side connector | Check for an open or short circuit between ECM and coolant temperature sensor. | OK ⇒ | END |
| | | NG ⇒ | Repair the harness |

KFW5246A

## Troubleshooting hints

If the fast idle speed is not enough or the engine gives off dark smoke during the engine warm-up operation, the engine coolant temperature sensor might be faulty.

## Installation

1. Apply sealant LOCTITE 962T or equivalent to the threaded portion.
2. Install the engine coolant temperature sensor and tighten it to specified torque.

   **Tightening torque**
   **Engine coolant temperature sensor : 14.5~28.9 lb•ft (200~400 kg•cm)**

3. Securely connect the harness connector.

## Knock sensor

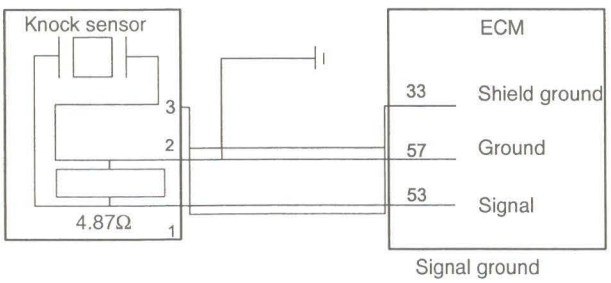
A knock sensor with piezoelectric element (ceramic) is attached to the center of cylinder block of each bank #1/#2 to sense the engine knocking condition (Check for knocking for each cylinder).
The piezoelectric device output (V) = Q/C =2dF/C (d= piezoelectric integer, C = Electrostatic capacity).
The ignition timing for MBT, Minimum spark advance for best torque, is located at the positions front and rear to the knocking limit and the ECM performs the control to make the engine to operate in optimum condition before the knocking limit.

## (Knock sensor circuit diagram)

When the knock sensor malfunctions, the ignition timing is corrected by the MAP values such as engine rate, air flow and engine coolant temperature, etc.

## Trobleshooting hints

1. The MIL is ON or the DTC is displayed on the HI-SCAN under following condition.
   - The knock sensor signal is not detected when the engine is in overload condition.
2. The knock sensor signal is abnormally low.

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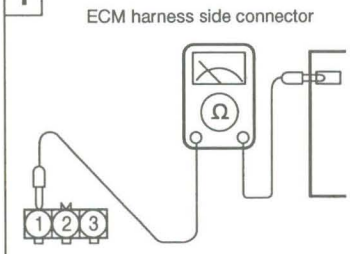
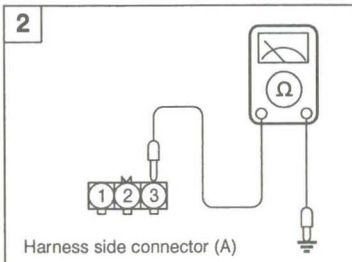
## Harness inspection procedures

| | | | |
|---|---|---|---|
| 1<br>  <br> | Check for an open or short circuit between ECM and knock sensor.<br>• ECM connector: Disconnected.<br>• Knock sensor connector: Disconnected. | OK ⇨<br>NG ⇨ | 2<br>Repair the harness |

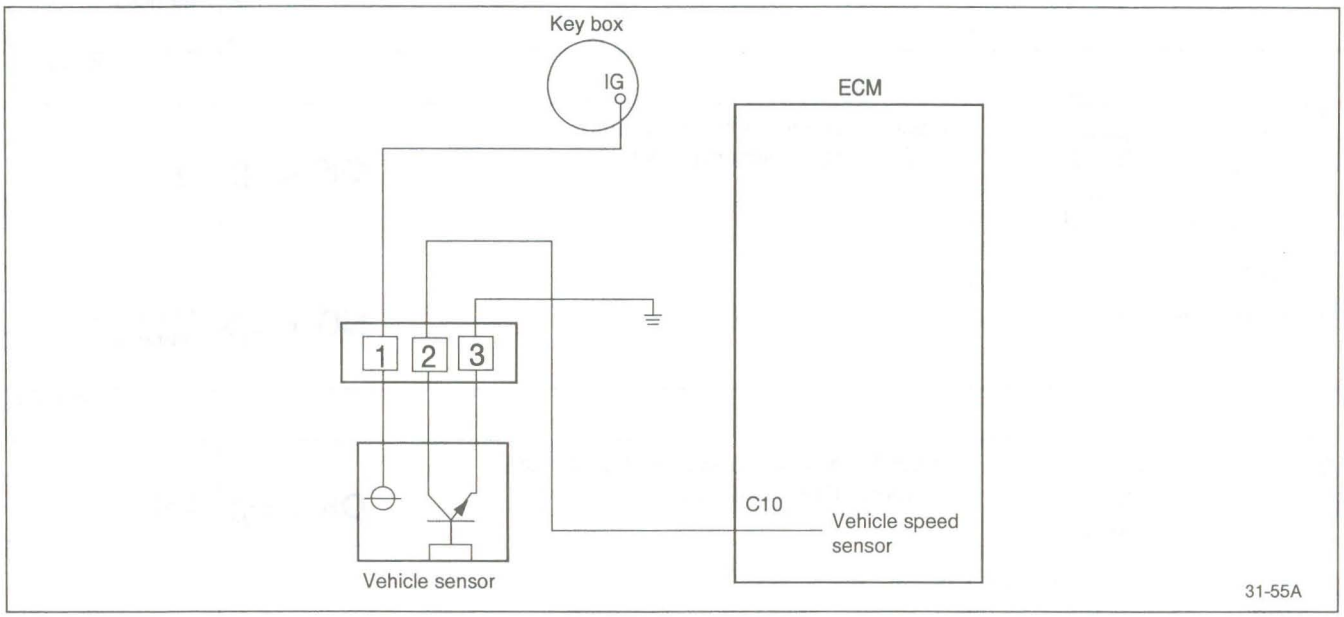
KFW5262A

| | | | |
|---|---|---|---|
| 2<br>  <br> | Check for continuity of the ground circuit.<br>• Connector: Disconnected. | OK ⇨<br>NG ⇨ | END<br>Repair the harness |

KFW5263A

## Vehicle speed sensor

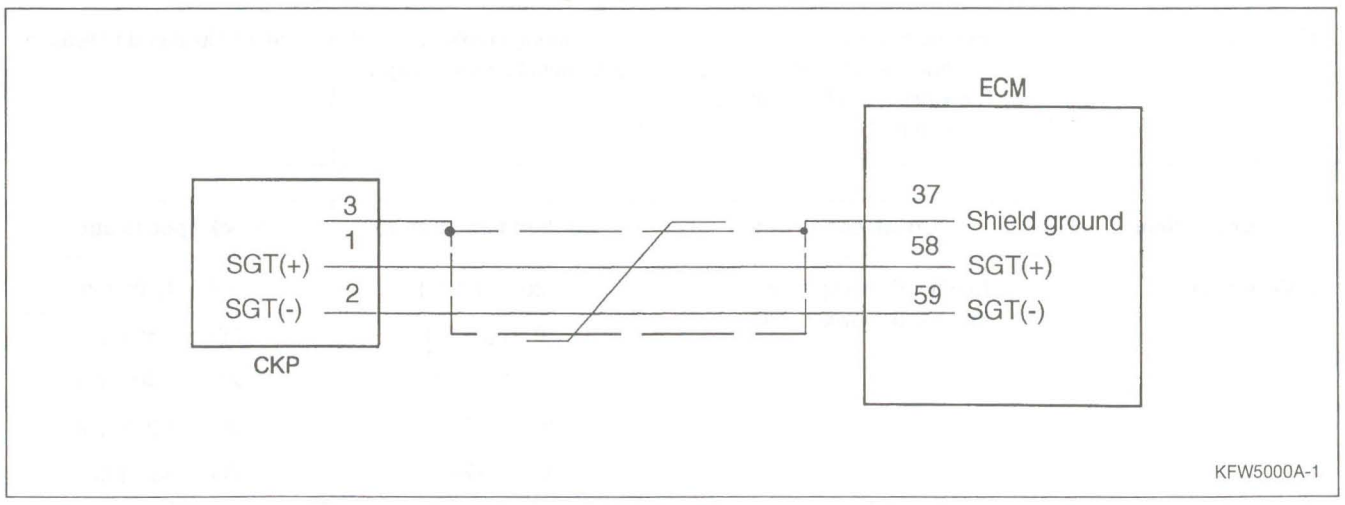
The function of vehicle speed sensor is to sense the TOOTH signal in T/M housing (4 pulses are output per 1 turn) and send relevant signal to ECM. The signal is used for computing the vehicle speed and the speed display on the tachometer as well.
The information is used for idle control correction duty range (the range of correction is limited with the vehicle speed and A/C load), cooling fan control, fuel injection prohibition at over vehicle speed, vehicle jerk control and traction control (At the torque being reduced with the exhaust gas modeling).
The action against malfunctions of the sensor is to fix the speed at 0 KPH. (The highest engine revolution should be limited to 2500 rpm)




## CKPS

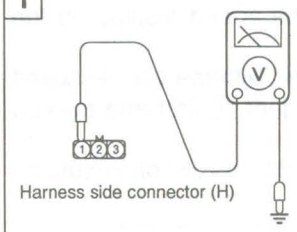
The CKP sensor compares the signal from the crank position sensor with that from TDC sensor to measure the upper dead point of each cylinder piston. The position of CAM is detected immediately at the same time when the ignition key is turned ON.
It outputs digital signal by two hall devices.

### [CKP sensor circuit diagram and output signal]

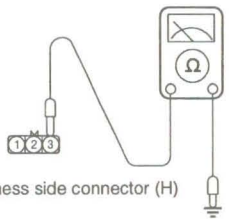



In case of faulty TDC sensor, the CKP signal can be used to compute the TDC (The probability of cylinder #1 TDC is 50%) and engine rate to control the fuel quantity and ignition timing and provide availability of driving the engine.

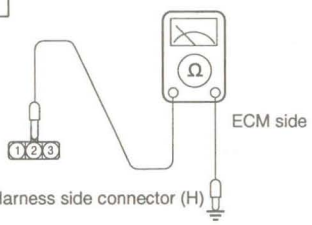
## Harness inspection

| | | | |
|---|---|---|---|
| 1   | Measure the voltage.<br>• Connector: Disconnected.<br>• Ignition switch: ON<br>• Voltage (V) : 4.8~5.2V | OK ⇨ | 2 |
| | | NG ⇨ | Repair the harness |

KFW5272A

| | | | |
|---|---|---|---|
| 2   | Check for continuity of the ground.<br>• Connector: Disconnected. | OK ⇨ | 3 |
| | | NG ⇨ | Repair the harness |

KFW5273A

| | | | |
|---|---|---|---|
| 3   | Check for an open circuit or short circuit between ECM and CMPS. | OK ⇨ | END |
| | | NG ⇨ | Repair the harness |

KFW5274A

## Using HI-SCAN

| Check item | Check conditions | Check content | Normal state |
|---|---|---|---|
| CMP sensor | • Engine cranking<br>• Tachometer connection (Check the ignition coil for on/off by tachometer) | Comparing cranking speed and multi-tester reading. | Permissible speed indication |

| Check item | Check conditions | Coolant temperature | Check specification |
|---|---|---|---|
| CMP sensor | • Engine: Running at idle<br>• Idle position switch: ON | -20 °C (-4 °F) | 1,500 ~ 1,700 rpm |
| | | 0 °C (32 °F) | 1,350 ~ 1,550 rpm |
| | | 20 °C (68 °F) | 1,200 ~ 1,400 rpm |
| | | 40 °C (104 °F) | 1,000 ~ 1,200 rpm |
| | | 80 °C (176 °F) | 700 ~ 900 rpm |

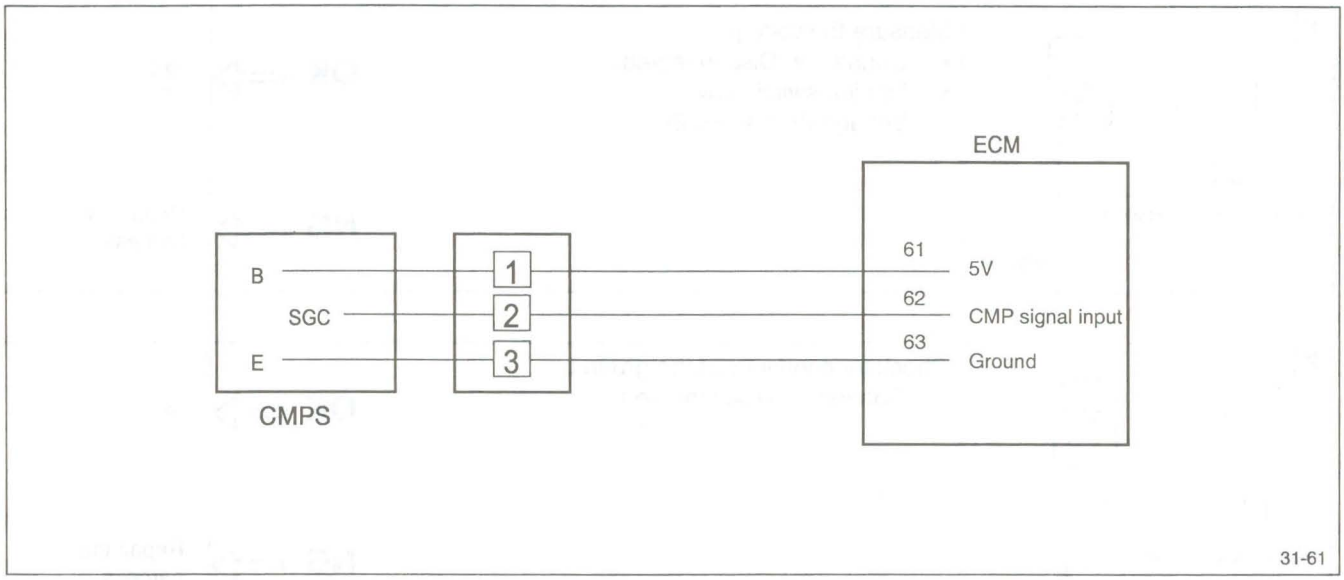
## Troubleshooting hints

An abnormal operation of camshaft position sensor may cause engine stall, engine hesitation in idling or acceleration unavailability due to abnormal injection.

## CMPS

The camshaft position sensor senses the position of crankshaft (piston) in reference to the upper dead point of compression of each cylinder and send the signal, based on which the ECM computes the engine speed and controls the fuel injection timing and ignition timing. Engine running condition (idle, partial load and full load) is determined in this process. It outputs digital signal by two hall devices.

[Circuit diagram and CMP signal features]

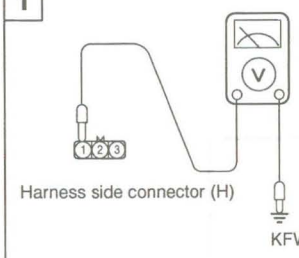
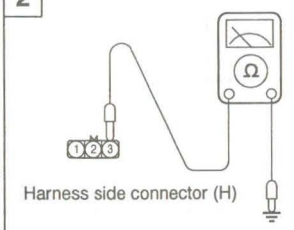
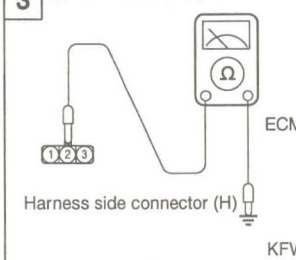



In case of faulty CMP, the TDC signal is analyzed to computing the crank position and engine rpm to further control the fuel quantity and ignition timing. Engine running is available at the same time. There is no engine stall at faulty CMP like existing system. (When the CMP is failed during engine running, the engine stalls, but restart of engine is available by the procedures of operation as IG KEY OFF → ON. )

## Troubleshooting hints

1. If an unexpected shock or engine stall occurs in running, try to shake the harness of crankshaft position sensor. Check the sensor connector(s) for defective contacts if engine stalls in the case.
2. If 0 rpm is indicated on tachometer with the engine in idling, check for faulty crankshaft angle sensor, damaged timing belt or faulty ignition system.
3. Check for the points as below if the crankshaft angle sensor indicates a value out of the specification though the engine is available of starting in idle.
   - Faulty engine coolant temperature sensor.
   - Faulty idle speed control motor.
   - Failed standard idle speed control.

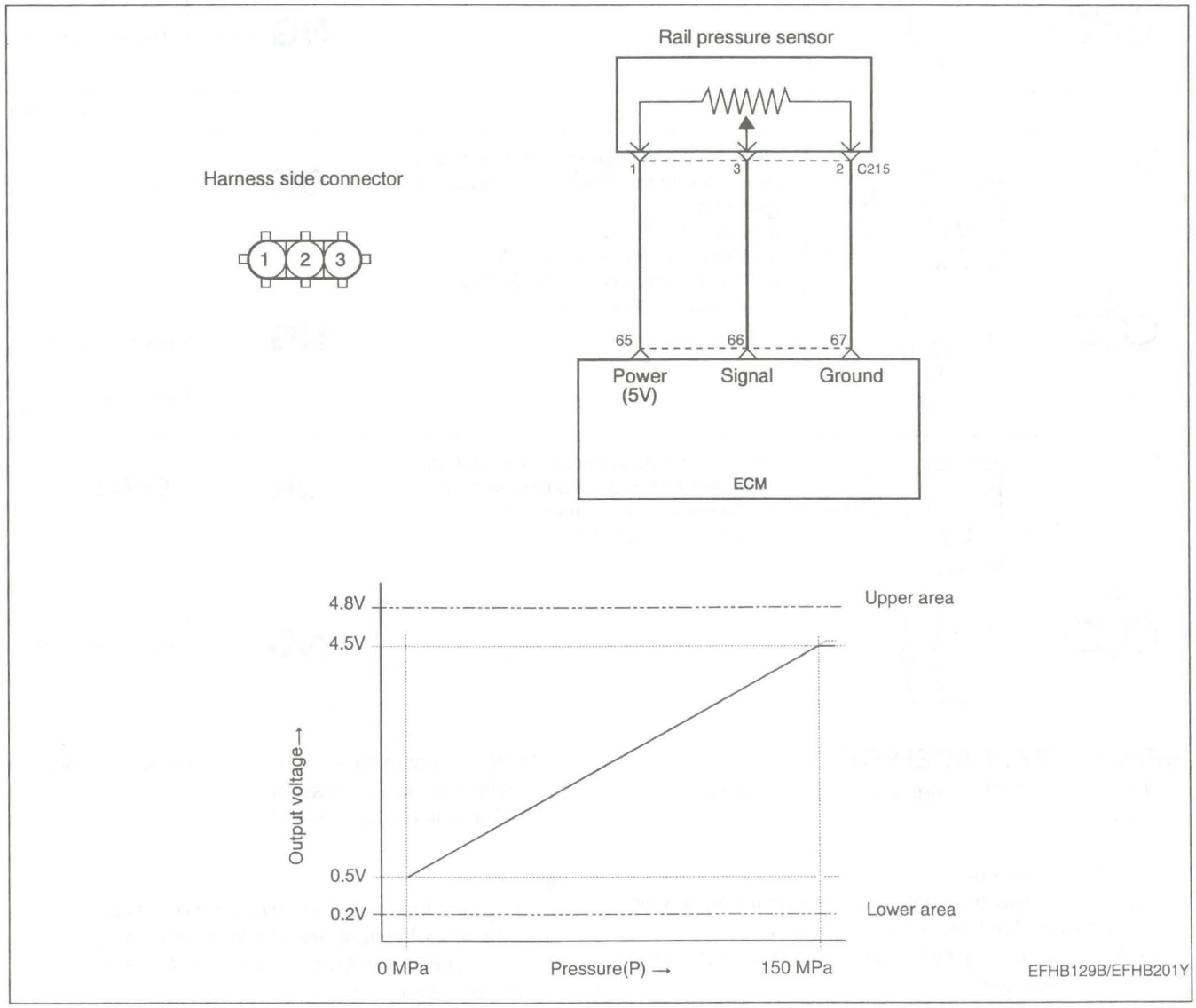
## Harness inspection procedures

| | | | |
|---|---|---|---|
| 1<br>  <br><br>KFW5272A | Measure the voltage.<br>• Connector: Disconnected.<br>• Ignition switch: ON<br>• Voltage (V) : 4.8~5.2V | OK ⇒<br>NG ⇒ | 2<br>Repair the harness |
| 2<br>  <br><br>KFW5273A | Check for continuity of the ground.<br>• Connector: Disconnected. | OK ⇒<br>NG ⇒ | 3<br>Repair the harness |
| 3<br>  <br><br>KFW5274A | Check for an open circuit or short circuit between ECM and CMPS. | OK ⇒<br>NG ⇒ | END<br>Repair the harness |

## RAIL PRESSURE SENSOR (RPS)

In order to output a voltage signal to the ECM which corresponds to the applied pressure, the rail-pressure sensor must measure the instantaneous pressure in the rail.
The fuel flows to the rail-pressure sensor through an opening in the rail, the end of which is sealed off by the sensor diaphragm. Pressurized fuel reaches the sensor's diaphragm through a blind hole. The sensor element (semiconductor device) for converting the pressure to an electric signal is mounted on this diaphragm. The signal generated by the sensor is inputted to an evaluation circuit which amplifies the measuring signal and sends it to the ECM.

### [CIRCUIT DIAGRAM]

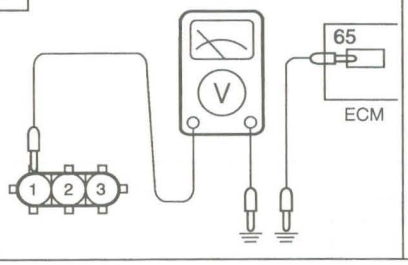


## SENSOR INSPECTION
### USING HI-SCAN

| Check item | Data display | Check conditions | Set value | Standard value |
|---|---|---|---|---|
| Rail pressure sensor | Rail pressure value | Engine at idle | -220 - 300bar | 260bar |

## HARNESS INSPECTION PROCEDURES

**1**



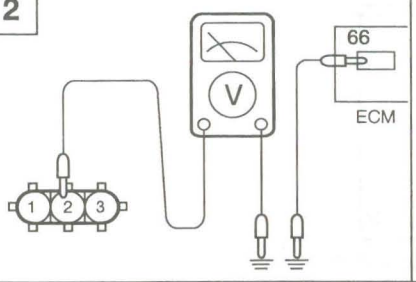

Measure the power supply voltage
- o Connector : Disconnected
- o Ignition switch : ON
- o Voltage(V) : 4.5 - 5.5V

**OK** ⇒ **2**

**NG** ⇒ Repair the harness

EFHB130B

**2**



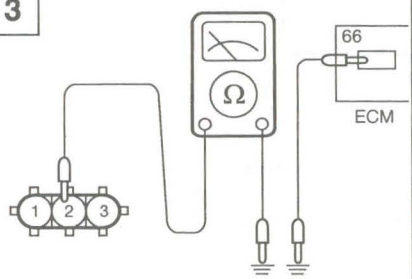

Measure the voltage of RPS harness side connector #2 terminal to the ground with ignition on.
- o Set value : 0.5V
- o Engine idling set value : 1V
- o Voltage increases with inereasing pressure : Max. 4.5V

**OK** ⇒ **3**

**NG** ⇒ Repair the harness

EFHB131B

**3**




Check for an open circuit, or a short circuit between ECM and rail pressure sensor.
- o Connector : Disconnected
- o Ignition switch : OFF

**OK** ⇒ **END !**

**NG** ⇒ Repair the harness

EFHB131C

## SENSOR REPLACEMENT

1. Replace the RPS if signal voltage exceeds the set value.

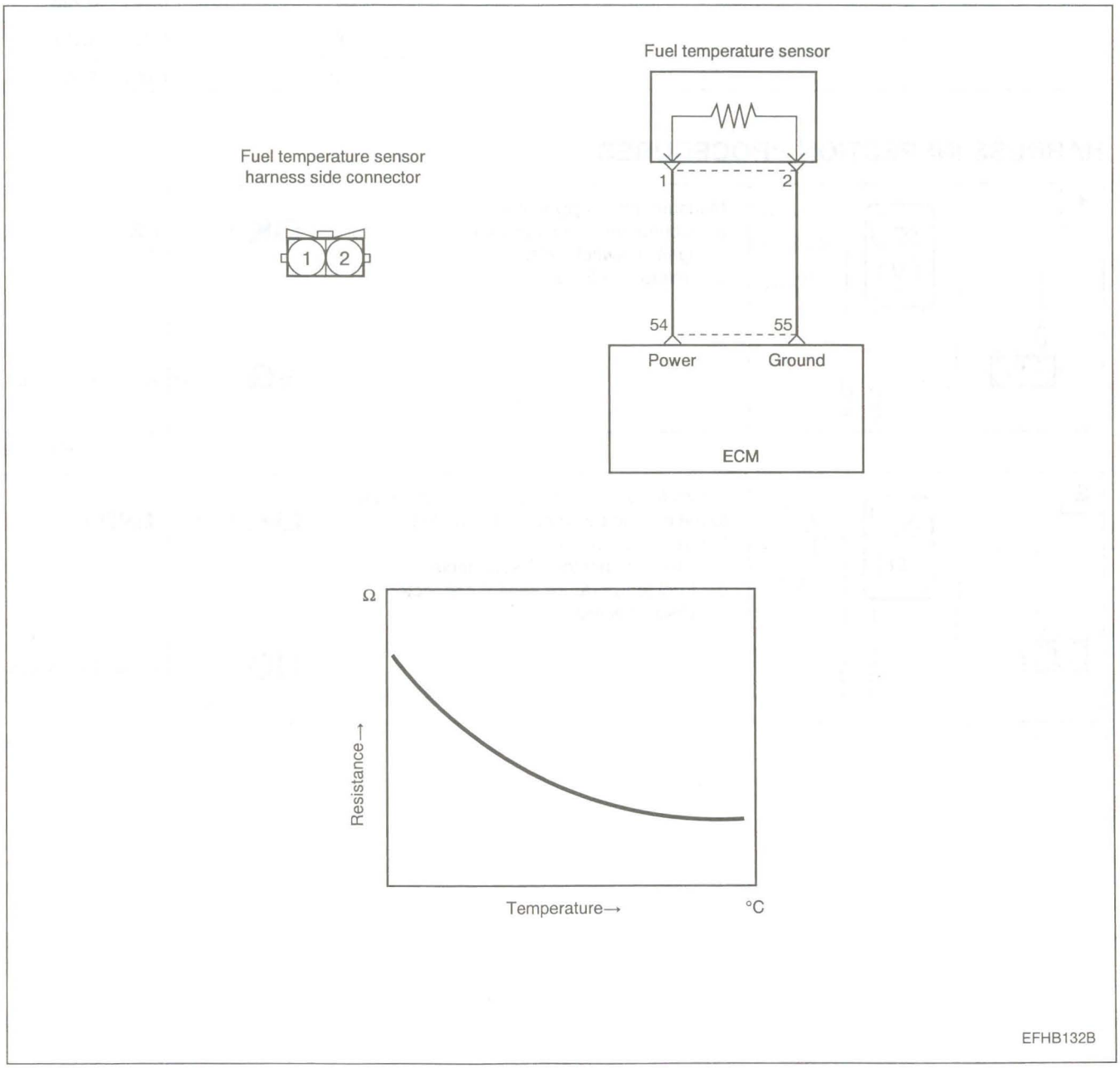
2. Note the followings.
   1) Always renew the sealing washer (soft iron sealing ring) even if old sensor is re-used.
   2) When removing seal, take care not to damage sealing surface.
   3) When installing RPS, provide the sealing washer with grease if necessary.
   4) Tightening torque is 40 Nm.

✱ *Notice*
*Replace the faulty fuel rail assembly in case of new model vehicle within a year, or replace the faulty parts of vehicle of which model year is more than a year.*

## FUEL TEMPERATURE SENSOR (FTS)

The fuel temperature sensor is equipped with a temperature-dependent resistor with a negative temperature coefficient (NTC) which is part of a voltage-divider circuit across which 5V are applied.
The voltage drop across the resistor is inputted into the ECM through an analog-to-digital converter (ADC) and is a measure for the temperature. A characteristic curve is stored in the ECM microcomputer which defines the temperature as a function of the given voltage value.

## [CIRCUIT DIAGRAM]



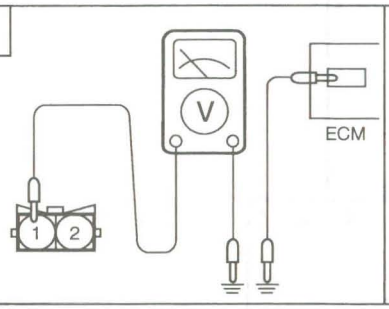
## SENSOR INSPECTION

### USING VOLTMETER

| Check item | Output data | Check condition | Fuel temperature (°C) | Resistance (KΩ) |
|---|---|---|---|---|
| Fuel temperature sensor | Fuel temperature | Ignition switch : ON or START | -30 | 22.22 ~ 31.78 |
| | | | -20 | 13.24 ~ 18.10 |
| | | | 0 | 5.18 ~ 6.60 |
| | | | 20 | 2.27 ~ 2.73 |
| | | | 40 | 1.059 ~ 1.281 |
| | | | 60 | 0.538 ~ 0.650 |
| | | | 80 | 0.322 ~ 0.298 |
| | | | 100 | 0.185 ~ 0.167 |
| | | | 120 | 0.097 ~ 0.127 |

## HARNESS INSPECTION PROCEDURES

1



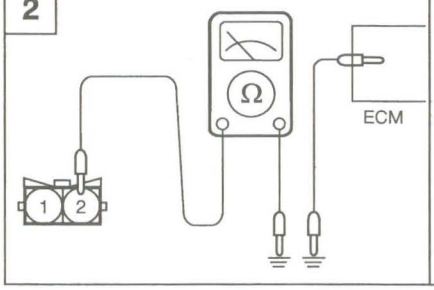

Measure the supply voltage
- o Connector : Disconnected
- o Ignition switch : ON
- o Voltage : 4.8 - 5.2V

OK ⇨ 2

NG ⇨ Repair the harness

EFHB133B

2




Check for an open circuit, or a short circuit to the ground between ECM and fuel temperature sensor.
- o ECM Connector : Disconnected
- o Fuel temperature sensor connector : Disconnected

OK ⇨ END !

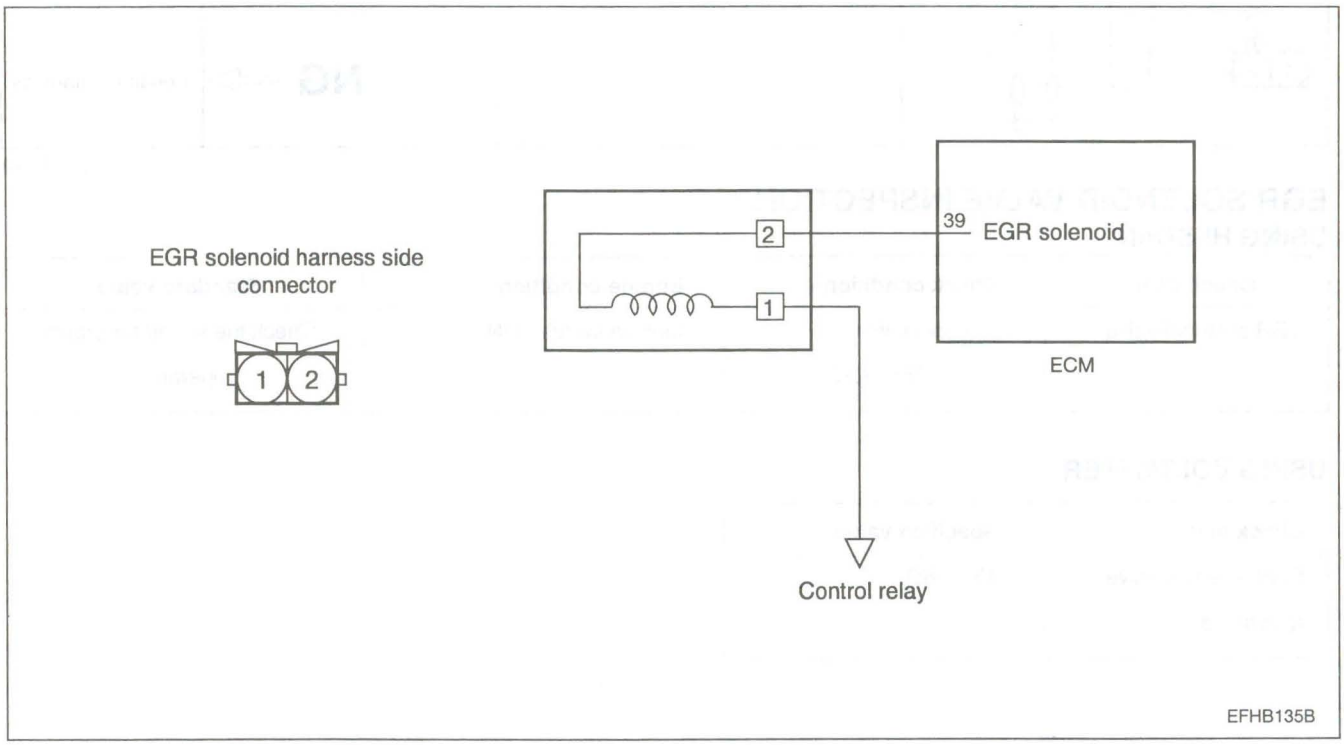
NG ⇨ Repair the harness

EFHB134B

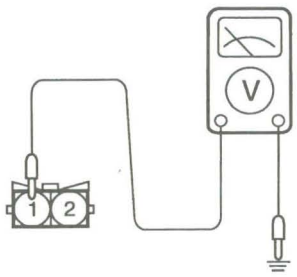
## EGR SOLENOID VALVE

With exhaust-gas recirculation (EGR) a portion of the exhaust gas is led into the engine's intake tract. Up to a certain degree, an increasing portion of the residual exhaust gas content has a positive effect upon energy conversion and therefore upon the exhaust-gas emissions. Depending upon the engine's operating point, the air/gas mass drawn into the cylinders can be composed of up to 40% exhaust gas.
For ECM control, the actual drawn-in fresh-air mass is measured and compared at each operating point with the air-mass setpoint value. Using the signal generated by the control circuit, the EGR valve opens so that exhaust gas can flow into the intake tract.

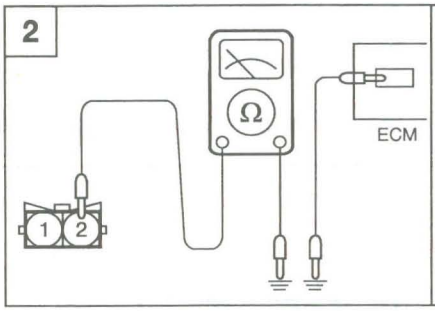
## [CIRCUIT DIAGRAM]



## HARNESS INSPECTION PROCEDURES

| | | | |
|---|---|---|---|
| 1  | Measure the supply voltage<br>o Connector : Disconnected<br>o Ignition switch : ON<br>o Voltage(V) : Battery voltage | OK ⇒<br>NG ⇒ | 2<br>Repair the harness |

EFHB136B

| | | | |
|---|---|---|---|
| 2  | Check for an open circuit, or a short circuit to the ground between ECM and EGR solenoid valve.<br>o Connector : Disconnected | OK ⇒<br>NG ⇒ | END !<br>Repair the harness |

EFHB137B

## EGR SOLENOID VALVE INSPECTION

### USING HI-SCAN

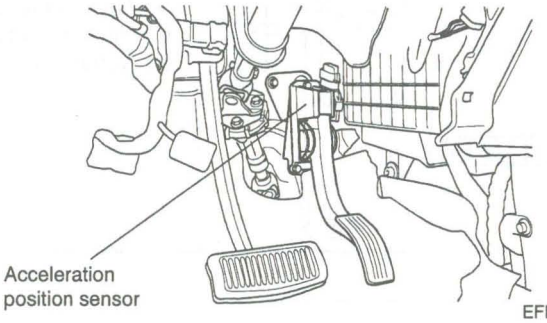
| Check item | Check condition | Engine condition | Standard value |
|---|---|---|---|
| EGR solenoid valve | solenoid valve<br>OFF / ON | Ignition switch : ON | Check the sound for proper operation |

### USING VOLTMETER

| Check item | Specified value |
|---|---|
| EGR solenoid valve resistance | 15 ~ 16Ω |

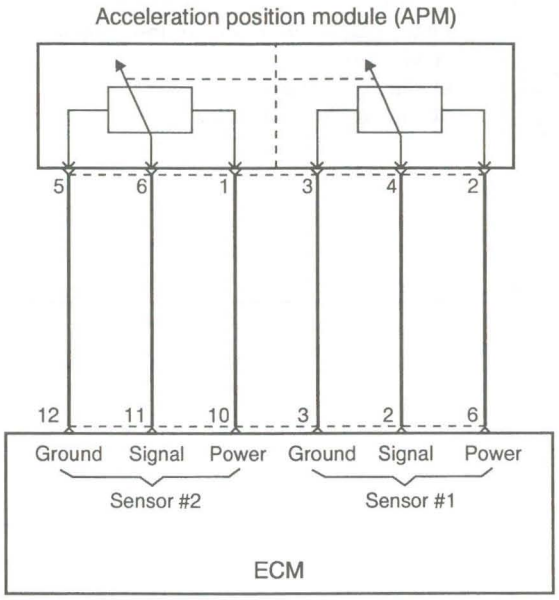
## ACCELERATION POSITION SENSOR (APS)

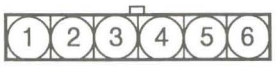
In contrast to conventional distributor and in-line injection pumps, with EDC the driver's acceleration input is no longer transmitted to the injection pump by Bowden cable or mechanical linkage, but is registered by an acceleration position sensor and transmitted to the ECM (this is also known as drive-by-wire).
A voltage is generated across the potentiometer in the acceleration position sensor as a function of the accelerator-pedal setting. Using a programmed characteristic curve, the pedal's position is then calculated from this voltage.



EFHB105B

## [CIRCUIT DIAGRAM]

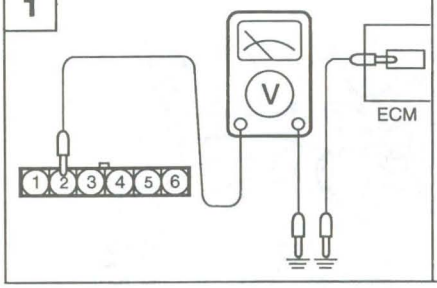


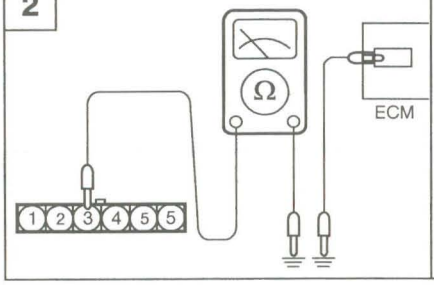

APM harness side connector

EFHB141B

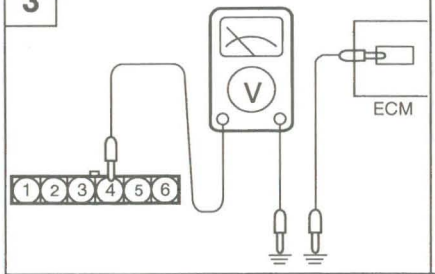
## APPLYING ACCELERATION POSITION MODULE (APM)

| | | | |
|---|---|---|---|
| 1 |  | Measure the sensor supply voltage<br>o Connector : Disconnected<br>o Ignition switch : ON<br>o Voltage(V) : 4.5 - 5.5V | OK ⇨ 2<br>NG ⇨ Repair the harness |

EFHB145B

| | | | |
|---|---|---|---|
| 2 |  | Check for an open circuit, or a short circuit between ECM and acceleration position sensor<br>o Connector : Disconnected<br>o Ignition switch : OFF | OK ⇨ 3<br>NG ⇨ Repair the harness |

EFHB146B

| | | | |
|---|---|---|---|
| 3 |  | If contact lead is OK, measure the sensor signal voltage<br>o at idle : 0.6 - 0.9V<br>o at full throttle : 3.6 - 4.6V | OK ⇨ END !<br>NG ⇨ Repair the harness |

EFHB147B

# REMOVAL AND REASSEMBLY

## Special features of the common rail system

### Principle of operation

The common rail injection system permits individual control of the timing advance and of the flow, allowing perfect control of combustion on a cylinder-by-cylinder basis. Furthermore, the injection pressure can be adjusted over a wide range of values according to the engine's operating conditions:

- When idling and on low load, the low injection pressures (of roughly 200 bars)mark it possible to obtain low injection rates and very accurate adjustment of the amount of fuel injected.
- On full load, the high injection pressures (of roughly 1400 bars) ensure very fine atomization of the fuel.

In the common rail system, the fuel is pumped at high pressure (up to 1400 bars) into a reservoir known as the rail. This pressure is electronically controlled according to the engine's operating conditions. The opening and closing of the injectors is electronically controlled by electromagnets fitted to each injector holder.

### Risk of engine damage

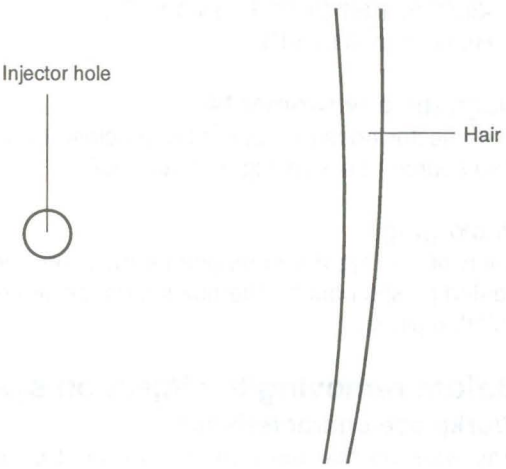
In a conventional injection system, if an injector needle seizes in the open position it is impossible to achieve injection pressure, thereby disrupting fuel supply to the combustion chamber. As atomization is no longer assured, combustion becomes unreliable. This results in serious contamination of the cylinder, considerable oil dilution, smoky exhaust emissions and loss of performance. The injection flow and timing are not however changed, since it is the pump which is responsible for distributing the correct amount of diesel fuel to each injector at the right moment.

In a common rail injection system, if an injector needle seizes in the open position, all or part of the fuel held in the rail is injected into the cylinder. The volume of diesel fuel thus accumulated in the cylinder will auto-ignite as soon as the temperature and pressure conditions allow (high engine speed, high load and low leakage). This combustion occurs at about 20 degrees before TDC, i.e. well before the main injection. In this case, the combustion pressure can reach very high values (>250 bars) which th eengine will obviously be unable to withstand for very long.

Furthermore, the high pressure required by the common rail injection system makes it necessary to have much smaller holes and much tighter adjustments than those found in conventional injection systems.

It is therefore absolutely essential to ensure impeccable cleanliness whenever work is being done on a common rail type injection system.

[Fig. 1]



# General cleanliness instructions

## Storage of parts

### Environmental conditions

- -30°C to + 60°C(-22°F to + 140°F).
- Humidity of 0 to 80%.

### Magnetic environments

The injector holder must not be left close to a magnetic field source at a level higher than 400A/m.

### Packaging

Each of the system components must be packed in a sealed plastic pouch. The holes must be protected with suitable plugs.

## Before removing the injection system

### Workplace characteristics

Any work on the injection system must be done in a clean area. The dedicated area:

- Must be cleaned periodically to prevent the accumulation of dust;
- Must not be co-located with any machine-tools or welding equipment liable to produce swarf of metal particles;
- Must be separated from areas where the ordinary mechanical operations are carried out, in opder to prevent any risk of contamination of the injection system by brake pad dust for example.

### Preparation of repair area and tooling

The work station and the tools must be cleaned with a brush and a solvent. Blow the cleaned parts with compressed air.

The work station must be fabricated from materials offering no risk of detachment of particles of fibers liable to contaminate the injdection system (wood should be avoided). DELPHI DIESEL SYSTEMS recommend covering the work surface with a stainless steel or aluminium plate.

### General remarks

The garments worn by the operator must be clean.

**The operator must wash his hands before and during the work if necessary.**

For obvious reasons of safety and cleanliness, it is strictly forbidden to smoke while working on the injection system.

### Cleaning the engine and the injection system

Before starting cleaning, protect the electrical components from any liquid damage (starter motor, alternator).

It is essential to clean the repair area before opening up the fuel circuit and removing any part of the injection system.

Cleaning of the repair area and the injection system must be done with a new brush and an effective solvent. The solvent must be dispensed from a clean container. Never reuse contaminated solvent.

Carefully clean each connection to be undone, sealing surfaces and all external surfaces of the injection system. Wherever possible, use a suction device to collect impurities. The use of a high pressure cleaner and a blower is prohibited because of the risk of impurities getting into inaccessible areas.

## During the removal of the injection system

When the injection system has been opened, it is strictly prohibited to use a blower, a brush or a tubebrush, since these tools might cause impurities to get into the system.
As soon as an orifice has been opened, it is essential to block it using the appropriate plug.

**⚠ WARNING**
**THE PLUGS MUST BE DISCARDED AFTER USE.**

After operning up and blocking the holes, each component of the injection system must be stored in a new sealed pouch.

Cleaning of the injector is strictly forbidden, even with an ultrasonic cleaner. Moreover, the separation of the injector from the injector holder is prohibited.

## During reassembly of the injection system

The packaging of the spare parts should be opened just before they are used. Moreover, the sealing plugs must not be removed until the final connection is made. The plugs and the sealed pouches must be discarded after use.

Any part which has been dropped must be returned to DELPHI DIESEL SYSTEMS for assessment.
Before fitting the injector, is it essential to ensure that its socket is clean.

## Safety instructions

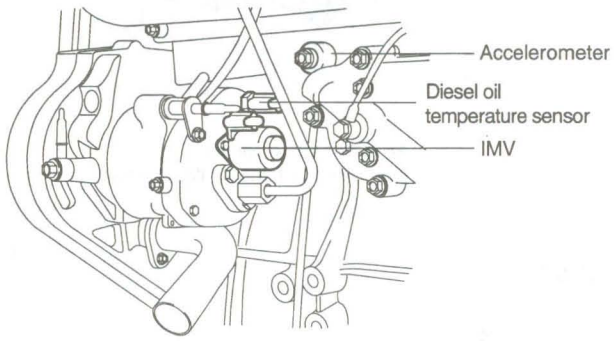
- It is strictly prohibited to smoke or to eat while working on the Common Rail injection system.
- It is essential to disconnect the battery before any work is done on the Common Rail injection system.
- It is strictly forbidden to work on the Common Rail injection system with the engine running.
- It is necessary to read the value of the rail pressure and of the diesel oil temperature with the aid of the diagnostic tool before any work is done on the fuel circuit. The opening of the circuit can only begin if the diesel oil temperature is less than 50°C(122°F) and the rail pressure is close to 0 bar. If it is not possible to communicate with the computer, wait for 5 minutes after the engine has stopped before starting any work on the fuel circuit.
- It is strictly prohibited to supply an actuator directly off an external power supply.
- The injector must not be dismantled.
- The HP sensor must not be removed from the rail. If the HP sensor fails, it is essential to replace the complete rail.
- The IMV, the diesel temperature sensor and the venturi must not be removed from the pump. If one of these components is faulty, the whole pump must be replaced.
- The HP pipes are not reusable: a removed pipe must be replaced.
- Decarbonizing the injector in an ultrasonic bath is strictly prohibited.
- The computer's metal casing must never be used as an earth!
- During welding jobs (bodywork repairs), the ECU must be carried out by qualified staff who have received training at the DELPHI DIESEL SYSTEMS training center.

## Presentation of the injection system

### Sensors and actuators

#### Diesel oil temperature sensor, IMV and accelerometer

[Fig.1]

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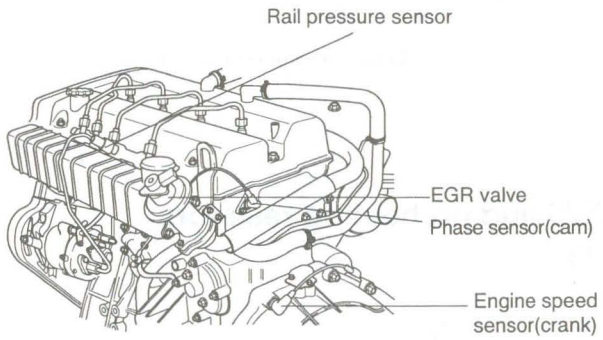
#### Rail pressure, engine speed, phase sensors and EGR valve

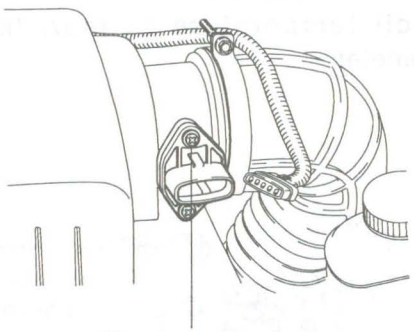
[Fig.2]




CFL0FL011

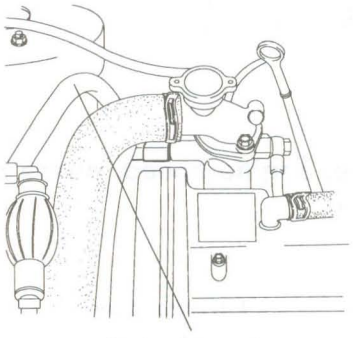
## Air temperature and coolant temperature sensor

[Fig.3]




CFL0FL012

[Fig.4]

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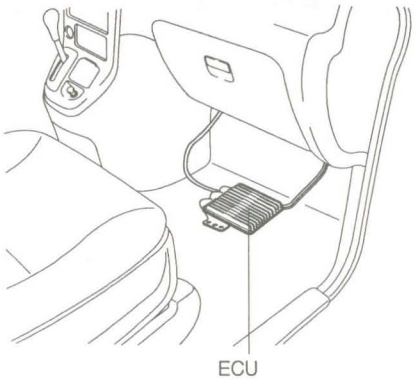
## ECU and preheating resistors

[Fig.5]

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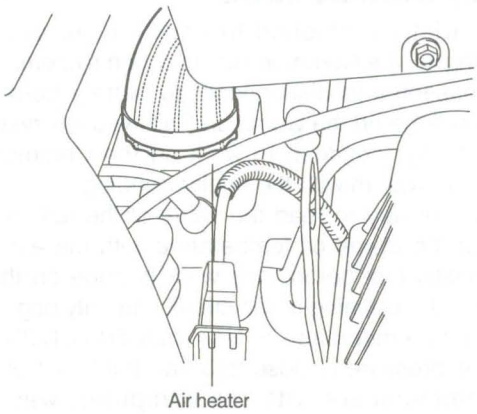
[Fig.6]

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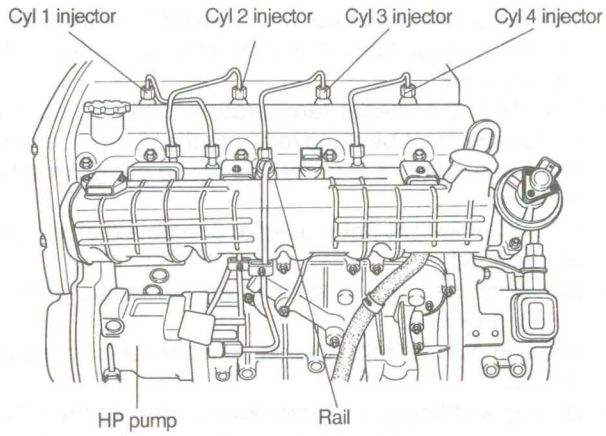
## Rail, Pump and injectors

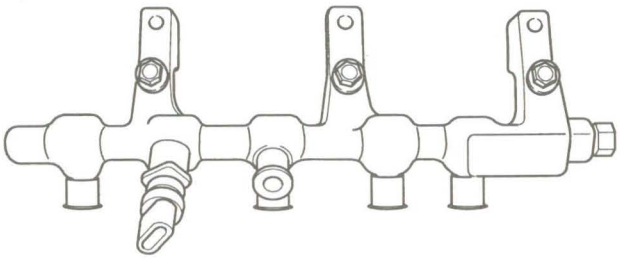
[Fig.7]




CFL0FL016

## Rail

[Fig.8]



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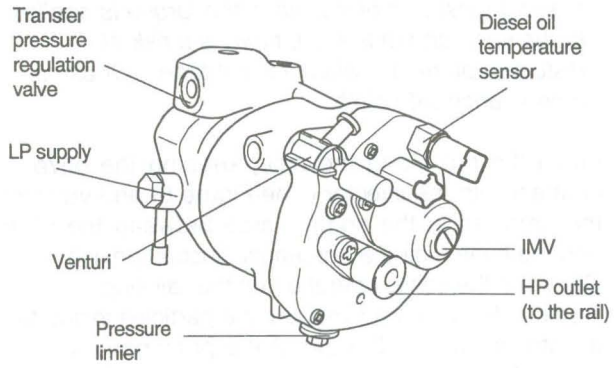
## Pump

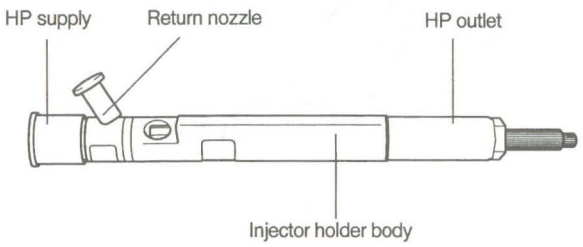
[Fig.9]




CFL0FL018

## Injector

[Fig.10]

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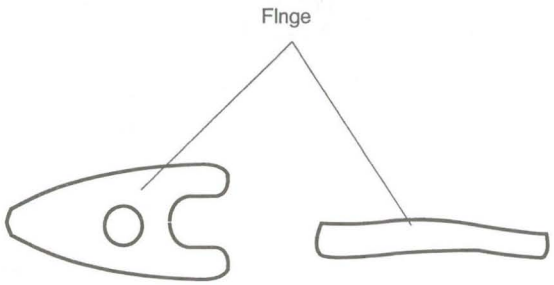
[Fig.11]

[Fig.12]

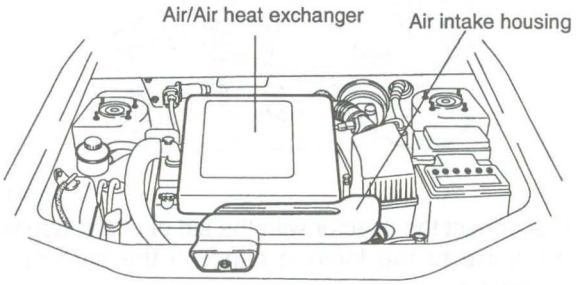



# High pressure pipes

## Removal a rail / injector pipe

- Remove all the items liable to restrict access:
- Remove the intake housing
- Remove the air / air heat exchanger.

[Fig.1]




[Fig.2]

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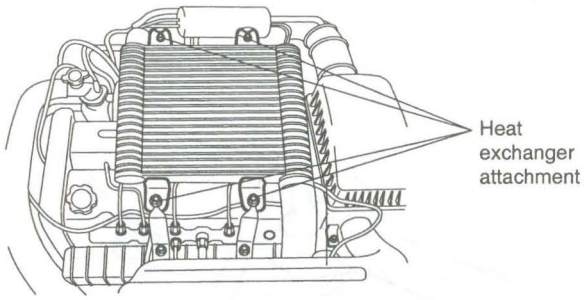
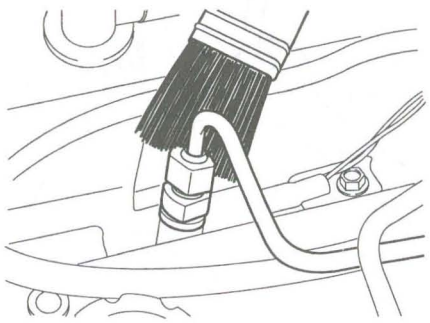



CFL0FL021

- Clean the nuts of the HP unions with a solvent (CARCLEAN type) applied with a clean brush (Figure 3).
- Vacuum the particles with the aid of a 'BLOVAC BV11' type suction device (Figure 4).

[Fig.3]



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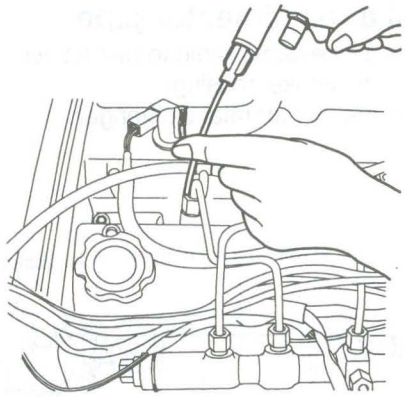
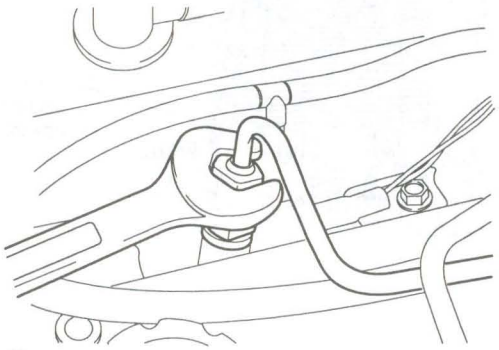
[Fig.4]



CFL0FL023

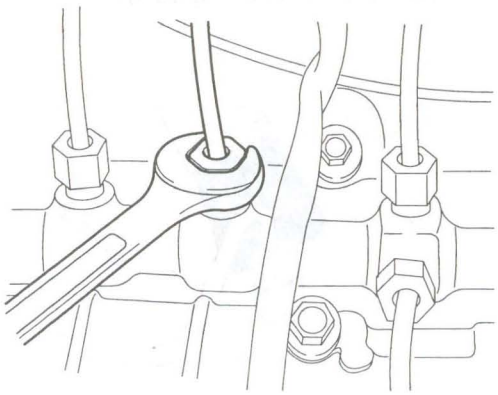
- Disconnect the injector with the aid of pliers, applying pressure to the locking clips on the side of the connector.
- Slacken the nut screwed onto the injector using a 17 mm (0.67 in) open wrench (Figure 4).
- Slacken the nut screwed onto the rail using a 17 mm (0.67 in) open wrench (Figure 5).

[Fig.4]



CFL0FL024

[Fig.5]



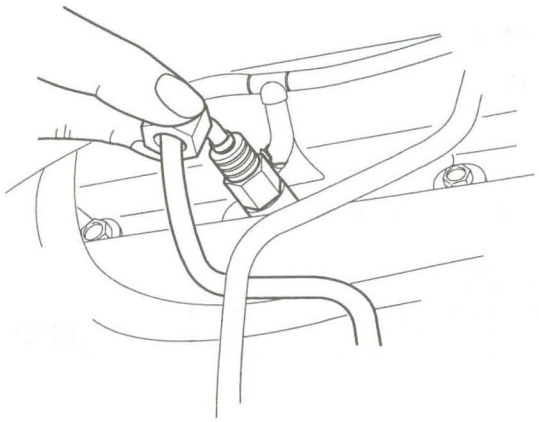
CFL0FL025

✱ *Notice*

*It is improtant to position the wrench level with the solid end of the nut, in order to apply the stresses to the strongest part of the nut. If the torque is applied to the open end of the nut, there is a risk of distortion of the nut when it is tightened. Or use a pipe-wrench with cloth.*

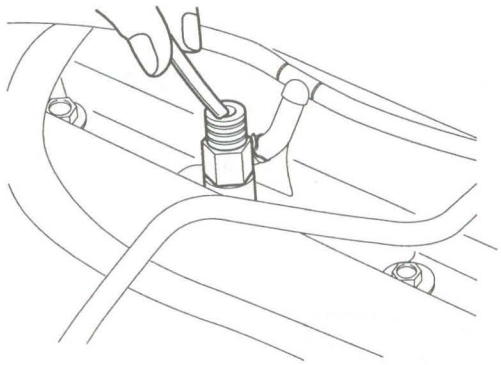
- Move the nut along the pipe, keeping the olive in contract with the injector cone(Figure 6) and vacuum the particles in the contact area between the olive and the cone, using a pneumatic suction device.
- Carry out the same operation on the rail side.
- Remove the pipe and vacuum the particles inside the injector cone with the aid of the pneumatic suction device(Figure 7).
- Carry out the same operation on the rail side.

[Fig.6]



CFL0FL026

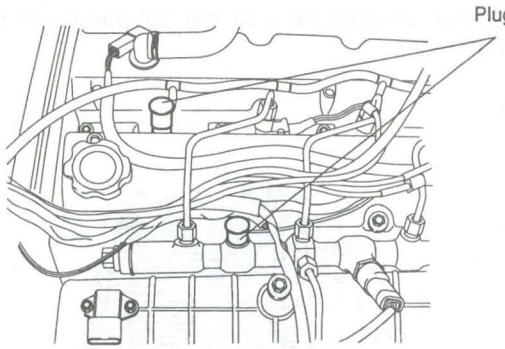
[Fig.7]



CFL0FL027

- Immediately seal the HP outlets with the aid of the recommended plugs(Figure 8).

[Fig.8]




CFL0FL028

## Reassembly a rail/injector pipe

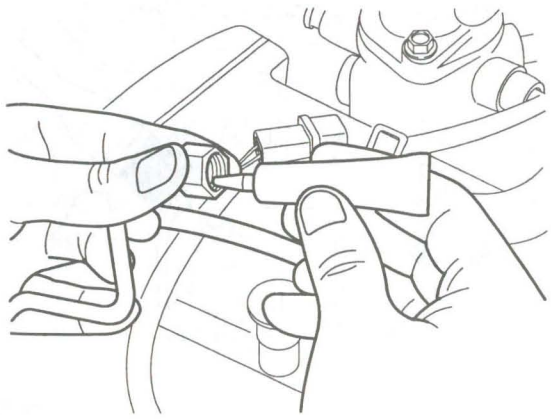
- Reconnect the injector.
- Take the new pipe out of its packing just before fitting it.

**⚠ WARNING**
**IT IS FORBIDDEN TO RE-USE AN OLD PIPE.**

- Remove the plugs inserted at each end of the pipe.
- Lubricate the threads of the nuts with the lubricant supplied in the kit before fitting the pipe (Figure 9).

- Remove the protective plugs from the HP outlets of

[Fig.9]



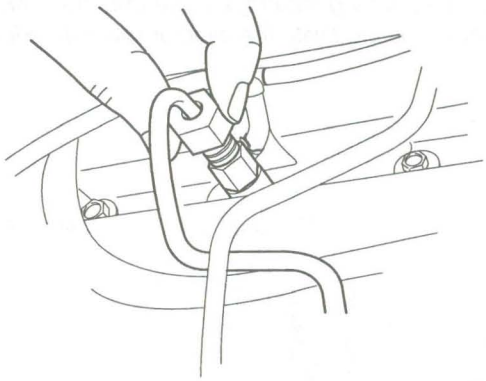
CFL0FL029

the rail and the injector.

**⚠ WARNING**
**THE PLUGS MUST BE DISCARDED AFTER USE.**

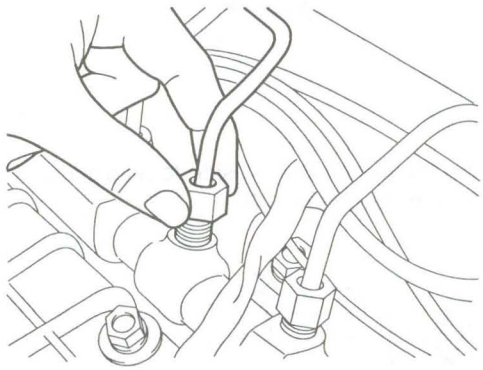
- Fit the pipe olive into the injector cone and tighten the nut by hand (Figure 10).
- Fit the pipe olive into the rail cone and tighten the nut by hand (Figure 11).

[Fig.10]



CFL0FL030

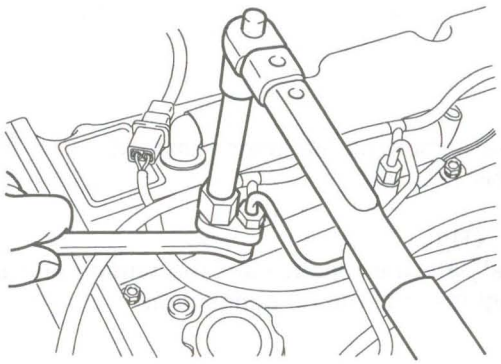
[Fig.11]



CFL0FL031

- Tighten the nut on the injector side to 40 Nm(29.5 lb-ft), applying reverse torque with the support tool for the injector holder (Figure 12).

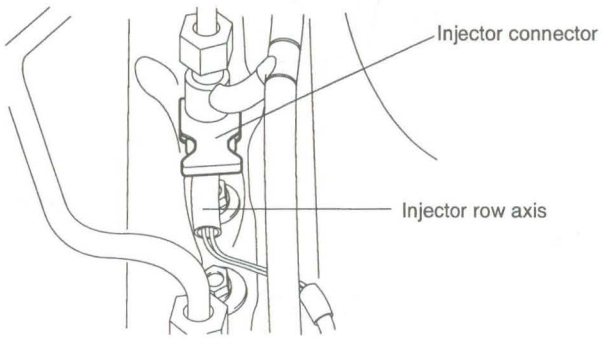
[Fig.12]



CFL0FL032

✱ *Notice*
*When tightening the nut, ensure that the connector remains aligned with the injector row axis (Figure 13).*

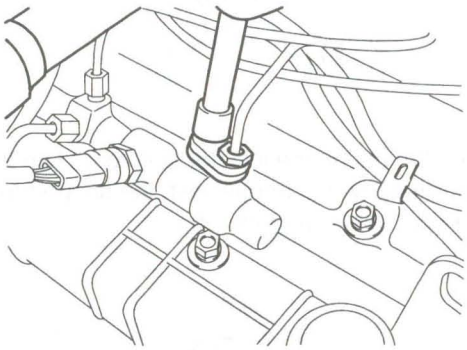
[Fig.13]




CFL0FL033

- Tighten the nut on the rail side to a torque of 40 Nm(29.5 lb-ft) (Figure 14).

[Fig.14]



CFL0FL034

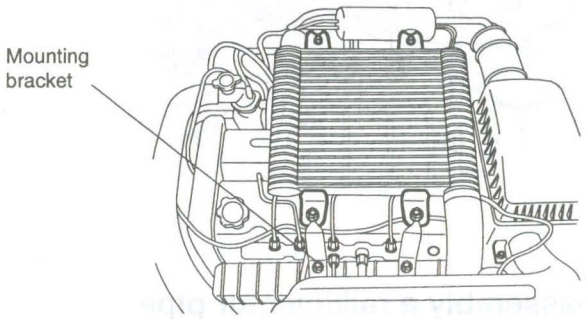
- Reassembly all the items removed to assist access.

**ESSENTIAL**
**To validate the repair, start the engine and check the tightness of the HP connection.**

## Removal of rail/pump pipe

- Remove all the items liable to restrict access:
- Remove the air intake housing
- Remove the mounting bracket of the air/air heat exchanger situated next to the rail/pump HP pipe (Figure 15).

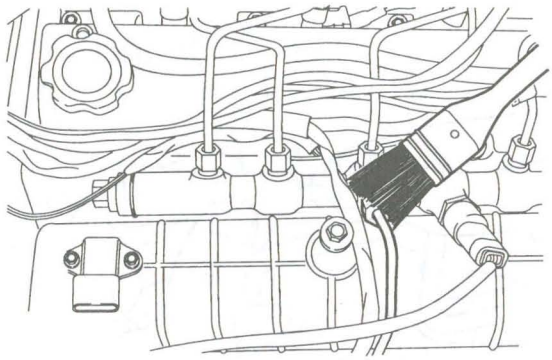
[Fig.15]




CFL0FL021

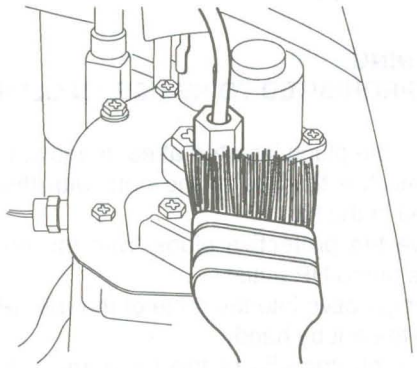
- Clean the HP connections with a solvent (CARCLEAN type) applied with a clean brush (Figures 16 and 17).
- Vacuum the particles with a 'BLOVAC BV11' type pneumatic suction device (Figures 18 and 19).

[Fig.16]



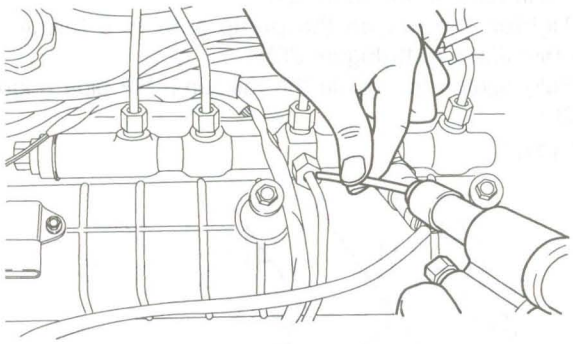
CFL0FL035

[Fig.17]



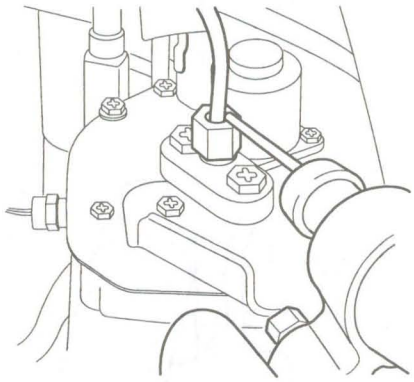
CFL0FL036

[Fig.18]



CFL0FL037

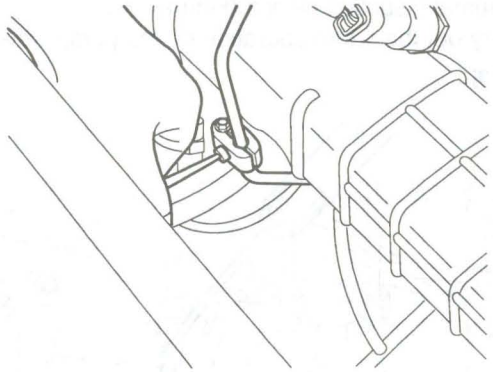
[Fig.19]



CFL0FL038

- Partially release the clip of the rail/pump HP pipe (Figure 20).

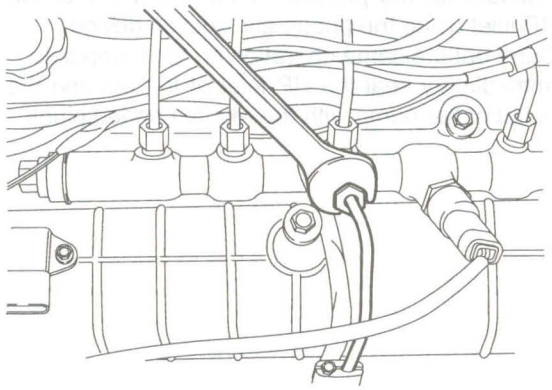
[Fig.20]



CFL0FL039

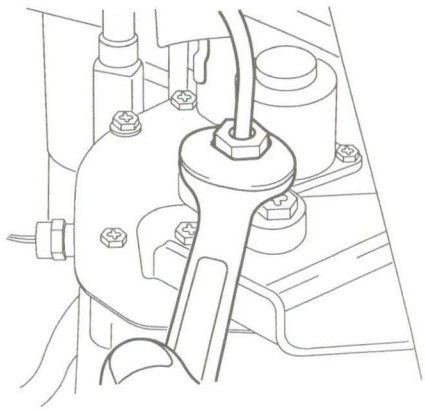
- Slacken the nut screwed onto the rail using a 19 mm(0.748 in) open wrench (Figure 21).
- Slacken the nut screwed onto the pump using a 19 mm (0.748 in) open wrench (Figure 22).

[Fig.21]



CFL0FL040

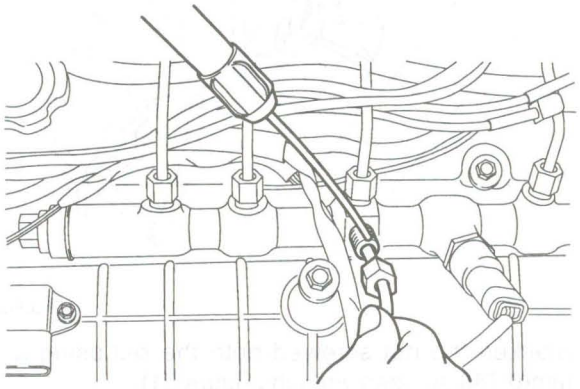
[Fig.22]



CFL0FL041

- Move th nut along the pipe, keeping the olive in contact with the cone of the HP inlet of the rail and vacuum up the particles in the area of contact between the olive and the cone with the aid of the pneumatic suction device (Figure 23).
- Carry out the same operation on the pump side.

[Fig.23]



CFL0FL042

- Remove the clip of the rail/pump HP pipe.
- Remove the rail/pump HP pipe.
- Vacuum up the particles inside the cone of the rail HP inlet using the pneumatic suction device.
- Carry out the same operation on the pump side.
- Immediately seal the HP inlet of the rail and the HP outlet of the pump with the recommended plugs.

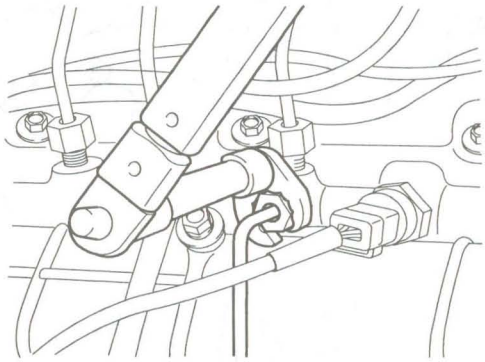
## Reassembly fo rail/pump pipe

- Take the new pipe out of its packing just before fitting it.

**⚠ WARNING**
**IT IS PROHIBITED TO RE-USE AN OLD PIPE.**

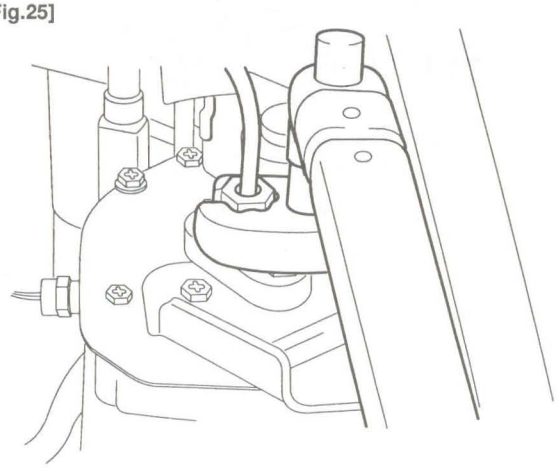
- Remove the plugs inserted at each end of the pipe.
- Lubricate the threads of the nuts with the lubricant supplied in the kit.
- Remove the protective plugs from the rail HP inlet and the pump HP outlet.
- Fit the pipe olive into the cone of the rail HP inlet and tighten the nut by hand.
- Reassembly the clip of the rail/pump HP pipe and partially tighten it.
- Fit the pipe olive into the cone of the pump HP outlet and tighten the nut by hand.
- Tighten the nut on the rail side to a torque of 40Nm(29.5 lb-ft)(Figure 24).
- Tighten the nut on the pump side to a torque of 40Nm(29.5 lb-ft)(Figure 25).
- Fully tighten the clip fo the rail/pump HP pipe (Figure 26).

[Fig.24]



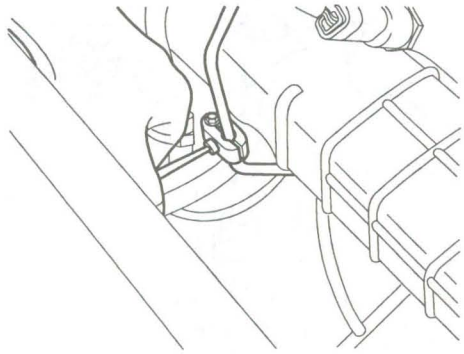
CFL0FL043

[Fig.25]



CFL0FL044

[Fig.26]



CFL0FL039

- Reassembly all the items removed to assist access.

**ESSEMTIAL**
**To validate the rapair, start the engine and check the tightness of the HP connections.**

## Replacement of a full set of pipes

The HP pump and the injectors are considered to be in place.
The HP pipes are considered to have been removed according to the recommended method.
The HP inlets/outlets are assumed to be sealed.

- Fit the pump/rail HP pipe:
  - Remove the plugs inserted at each end of the pipe.
  - Lubricate the threads of the nuts with the lubricant suplied in the kit.
  - Remove the protective plugs from the pump HP outlet and the rail HP inlet.

**⚠ WARNING**
**THE PLUGS MUST BE DISCARDED AFTER USE.**

  - Insert the rail side olive into the cone of the rail HP inlet.
  - Reassembly the pump/rail HP pipe clip and partially tighten it.
  - Insert the pump side olive into the cone of the pump HP outlet
  - Tighten the HP nuts of the pump/rail pipe by hand.
  - Fit the rail/injector HP pipes. For each pipe:
  - Remove the plugs inserted at each end of the pipe.
  - Lubricate the threads of the nuts with the lubricant supplied in the kit.

**⚠ WARNING**
**THE PLUGS MUST BE DISCARDED AFTER USE.**

  - Remove the protective plugs from the rail HP outlet and the injector HP inlet.
  - Insert the injector side olive into the cone of the injector HP inlet.
  - Insert the rail side olive into the cone of the rail HP outlet.
  - Tighten the nuts of the rail/injector HP pipe by hand.

✱ *Notice*
*The order in which the pipes are fitted is of no importance.*

- Tighten the HP connections of the pump/rail pipe
  - Tighten the rail side HP connection to a torque of 40Nm(29.5 lb-ft).
  - Tighten the pump side HP connection to a torque of 40Nm(29.5 lb-ft).
- Tighten the HP connections of the rail/injector pipes. For each pipe:
  - Tighten the injector side HP connection to a torque fo 40Nm(29.5 lb-ft).
  - Tighten the rail side HP connection to a torque of 40Nm(29.5 lb-ft).

- Reassembly all the items removed to assist access.

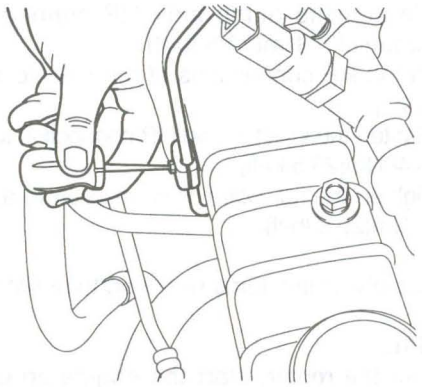
**ESSENTIAL**
**To validate the repair, start the engine an check the tightness of the HP connections.**

# Injector holder-removal and reassembly

## Removal of injector holder

- Remove the HP pipe of the injector being removed (following the method indicated in refer to page).
- Disconnect the injector, respecting the following procedure:
  - Apply pressure to the locking clips with a set of pliers (Figure 1).
  - Pull the connector in the direction of the arrow (Figure 1).
  - Check that the connector gasket has not remained stuck to the injector.

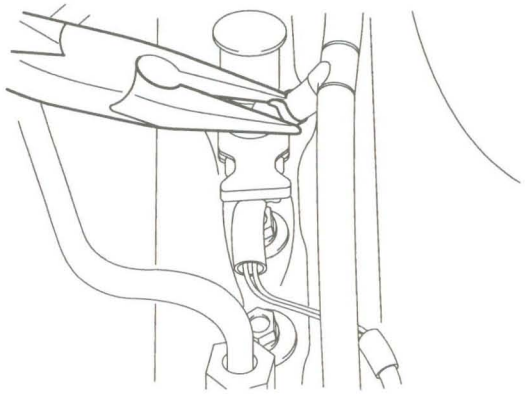
[Fig.1]



CFL0FL045

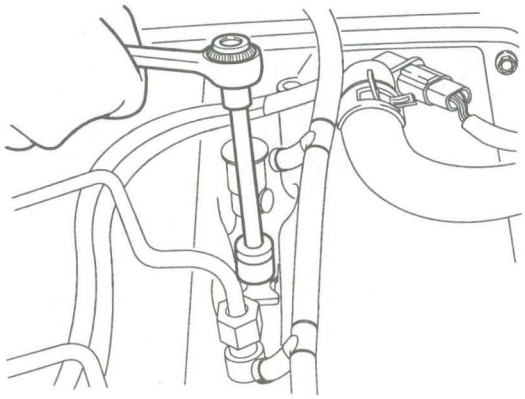
- Disconnect the injector leakage return hose (Figure 2).
- Slacken off the flnge of the injector holder (Figure 3).

[Fig.2]



CFL0FL046

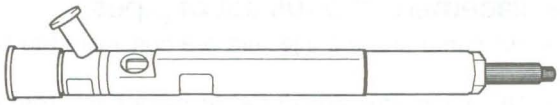
[Fig.3]



CFL0FL047

- Remove the injector with the flnge and its bolts.

[Fig.4]

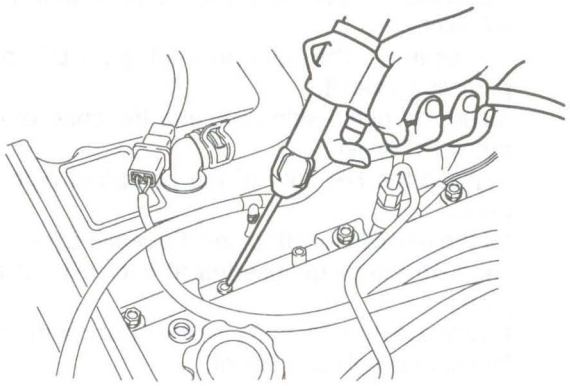


CFL0FL019

## Reassembly of injector holder

- Clean the socket of the injector holder and vacuum the particles using the pneumatic suction device (Figure 5).
- Clean the flnge of the injector holder with solvent (CARCLEAN type) using a clean brush.
- Place a new geat protection washer on the seat of the injector holder.

[Fig.5]

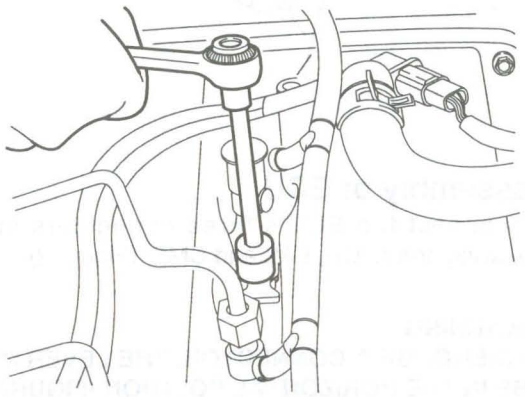


CFL0FL051

**⚠ WARNING**
**IT IS PROHIBITED TO RE-USE AN OLD HEAT PROTECTION WASHER!**

- Fit the injector holder with its flnge.
- Tighten the injector holder flnge bolt to a torque of 19 Nm(14.01 lb-ft) (Figure 6).
- Reconnect the return hose of the injector holder.
- Reconnect the injector.
- Reassembly the HP pipe, referring to the method described in page.

[Fig.6]



CFL0FL047

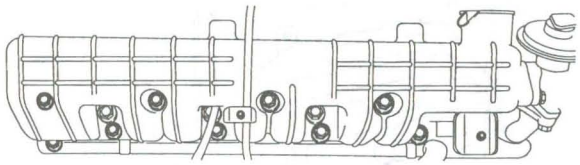
**⚠ WARNING**
**THE NEW INJECTOR POSSESSES DIFFERENT CHARACTERISTICS FROM THE ONE WHICH WAS ORIGINALLY FITTED TO THE ENGINE. THESE CHARACTERISTICS ARE SUMMARIZED IN THE 16-CHARACTER CODE SHOWN ON THE LABEL STUCK TO THE TOP OF THE INJECTOR HOLDER (C2I). THIS CODE MUST BE ENTERED INTO THE COMPUTER MEMORY WITH THE AID OF A SERVICE AVAILABLE ON THE DIAGNOSTIC TOOL (WRITING A NEW C2I). REFER TO THE DIAGNOSTIC MANUAL.**

# Rail-Removal and reassembly

## Removal of rail

- Remove the five HP pipes (following the method indicated in refer to page.
- Disconnect the HP sensor.
- Unscrew the EGR valve.
- Remove the inlet mainfold (Figure 1).

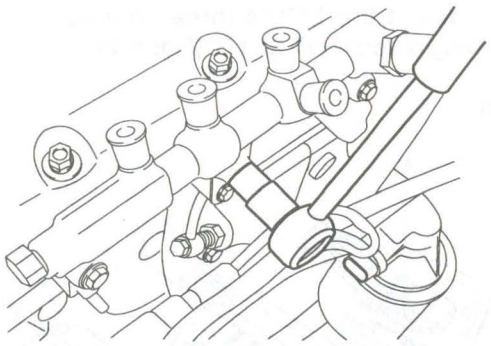
[Fig.1]



CFL0FL052

- Remove the rail from its supports (Figure 2).

[Fig.2]



CFL0FL053

## Reassembly of rail

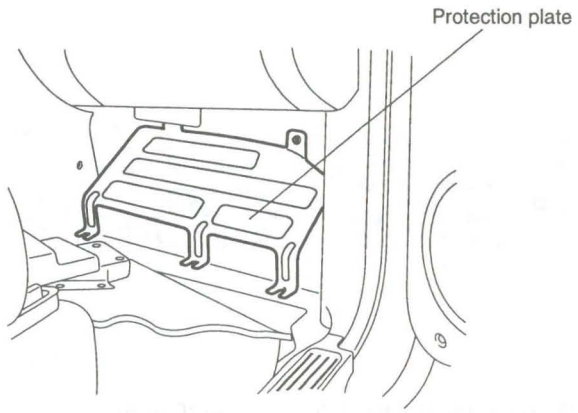
- Tighten the three rail mounting bolts to a torque of 19Nm(14.01 lb-ft).
- Replace the inlet manifold and the EGR valve.
- Reconnect the HP sensor.
- Replace the HP pipes by new parts (following the procedure described in refer to page).

# ECU Raemoval and reassembly

## Removal of ECU

- Switch off the ignition and wait for 30 seconds.(End of the Power Latch phase).
- Disconnect the battery earth terminal connector.
- Lift the passenger side carpet, then remove the protection plate (Figure 1).

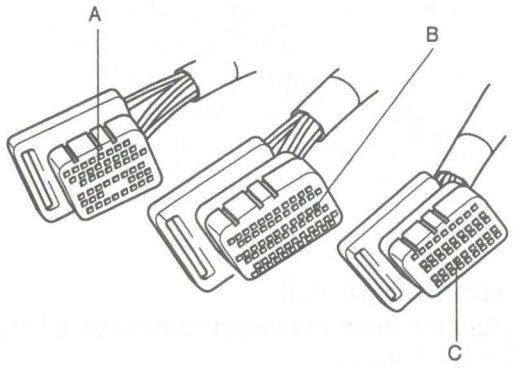
[Fig.1]




CFL0FL054

- Remove the ECU mounting nuts.
- Disconnect the ECU's three connectors in the following order: 'A, BI and C' (Figure 2).

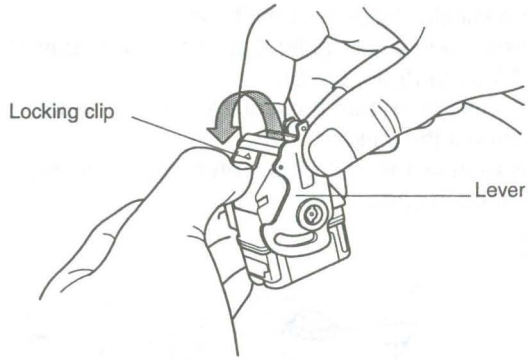
[Fig.2]




CFL0FL055

To release a connector, press on the locking clip then turn the lever in the direction of the arrow (Figure 3).

[Fig.3]



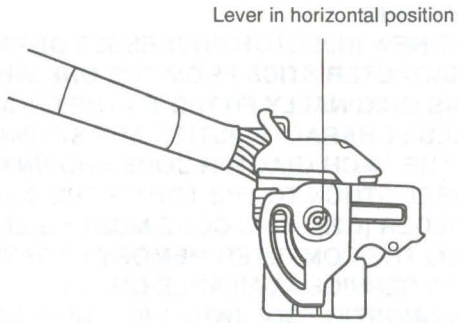

CFL0FL056

## Reassembly of ECU

- Reconnect the ECU's three connectors in the following order: 'CH, CMI and CME' (Figure 2).

**⚠ WARNING**
**TO ENGAGE A CONNECTOR, THE LEVER MUST BE IN THE HORIZONTAL POSITION (FIGURE 4).**

[Fig.4]

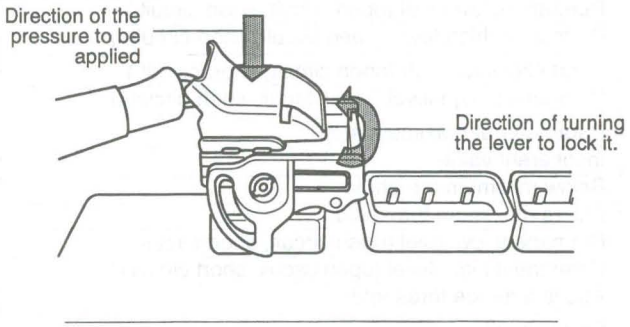



CFL0FL057

To lock the connector, apply a light pressure to it then the lever in the direction of the arrow to bring it to the vertical position (Figure 5).

- Tighten the three ECU mounting nuts.
- Reassembly the protection plate then put back the carpet.
- Reconnect the battery earth terminal connector.

[Fig.5]




CFL0FL058

✱ *Notice*

- *It is essential to set the C2 of all the injectors before starting the vehicle. Unless this has been done, a recovery strategy fixes the engine speed at 1300 rpm, without pedal control.*
- *It is also necessary to re-copy the programmed values to the memory of the new DCU and to programme coded keys in order to re-initialize the engine immobiliser.*
- *For these operations, refer to the instructions given in the diagnostic manual.*

## Tightening torques

| Component being tightened | Torque |
|---|---|
| HP pipes | 40 ¡ 10N•m(29.5 ¡ 7.38 lb-ft) |
| Rail mounting bolt | 19N•m(14.01 lb-ft) |
| Pump mounting bolt | 19N•m(14.01 lb-ft) |
| Injector holder flnge bolt | 19N•m(14.01 lb-ft) |
| Pump pulley nut | 65N•m(47.94 lb-ft) |
| Low pressure actuator mounting bolt (IMV) | 5.5 ¡ 0.6Nm(4.1 ¡ 0.44lb-ft) |
| Venturi mounting bolt | 5.5 ¡ 0.6Nm(4.1 ¡ 0.44lb-ft) |
| Diesel oil temperature sensor | 15 ¡ 1.5Nm(11.1 ¡ 1.1lb-ft) |

# DIAGNOSTIC TROUBLE CODES TABLE

| Number | Title | Status |
|---|---|---|
| 0100 | Air flow test | Parameter at minimum stop |
| | | Parameter at maximum stop |
| 0101 | Air flowmeter sensor circuit | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 0115 | Coolant temperature sensor circuit | Short circuit to earth (short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 0120 | Pedal sensor track 1 circuit | Incoherent value |
| | | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 0180 | Fuel temperature sensor circuit | Short circuit to earth (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 0190 | Rail pressure sensor circuit | Parameter at maximum stop |
| | | Incoherent value |
| | | Below minimum threshold |
| | | Above maximum threshold |
| | | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| | | Above average threshold |
| 0201 | Cylinder 1 control circuit | Open circuit |
| | | Parameter at minimum stop |
| | | Line in short circuit (short circuit) |
| | | Combustion too low |
| | | Combustion too hight |
| 0202 | Cylinder 3 control circuit | Open circuit |
| | | Parameter at minimum stop |
| | | Line in short circuit (short circuit) |
| | | Combustion too low |
| | | Combustion too high |
| 0203 | Cylinder 4 control circuit | Open circuit |
| | | Parameter at minimum stop |
| | | Line in short circuit (short circuit) |
| | | Combustion too low |
| | | Combustion too high |
| 0204 | Cylinder 2 control circuit | Open circuit |
| | | Parameter at minimum stop |
| | | Line in short circuit (short circuit) |
| | | Combustion too low |
| | | Combustion too high |
| 0220 | Padal sensor track 2 circuit | Short circuit to earth (short circuit-) |
| | | Short circuit to +$V_B$ (short circuit+) |
| | | Permanent low level (open circuit, short circuit-) |
| | | Permanent high leve (open circuit, short circuit+) |
| 0226 | Pedal fault | Incoherent value |
| | | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 0325 | Accelerometer circuit | No signal |
| | | Above maximum threshold |
| 0335 | Engine speed sensor circuit | Incoherent value |
| | | No signal |
| | | Too many additional teeth |
| | | Teeth missing |
| | | Additional teeth |
| | | Too many teeth missing |
| 0340 | Cylinder reference sensor circuit | Incoherent value |
| | | No signal |

| Number | Title | Status |
|---|---|---|
| 0380 | Preheating command 1 | Short circuit to +$V_B$ (short circuit+) |
| | | Permanent low level (open circuit, short circuit-) |
| 0381 | Preheating warning light circuit | Short circuit to +$V_B$ (short circuit+) |
| | | Permanent low level (open circuit, short circuit-) |
| 0382 | Preheating command 2 | Short circuit to +$V_B$ (short circuit+) |
| | | Permanent low level (open circuit, short circuit-) |
| 0400 | EGR control circuit | Short circuit to +$V_B$ (short circuit+) |
| | | Permanent low level (open circuit, short circuit-) |
| 0560 | Battery voltage | Below minimum threshold |
| | | Above maximum threshold |
| 0650 | Fault warning light circuit | Short circuit to +$V_B$ (short circuit+) |
| | | Permanent low level (open circuit, short circuit-) |
| 1119 | Rail pressure test fault | Trim<min high flow |
| | | Trim>max high flow |
| | | Trim<min low flow |
| | | Trim>max low flow |
| 1120 | Low pressure actuator circuit | Short circuit to +$V_B$ (short circuit+) |
| | | Parameter at minimum stop |
| | | Parameter at maximum stop |
| | | Below minimum threshold |
| | | Permanent low level (open circuit, short circuit-) |
| 1140 | Air temperature sensor circuit | Short circuit to earth (short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 1150 | Atmospheric pressure sensor circuit | Short circuit to +$V_B$ (Short circuit) |
| | | Permanent low level (open circui,t short circuit-) |
| 1300 | C2I data fault | Incorrect injector parameters |
| 1310 | Injector control | Short circuit to earth (Short circuit-) |
| | | Short circuit to +$V_B$ (Short circuit+) |
| 1458 | Air conditioning input signal | Incoherent value |
| 1500 | Vehicle speed circuit | Incoherent value |
| | | No signal |
| 1540 | Clutch switch circuit | |
| 1543 | Brake switch circuit | Short circuit to earth (Short circuit-) |
| | | Short circuit to +$V_B$ (Short circuit+) |
| | | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| | | Line in short circuit (Short circuit) |
| 1608 | Sequencer fault | Overload |
| | | Analogue/digital converter fault |
| 1610 | Sensor feed voltage | Below minimum threshold |
| | | Above maximum threshold |
| 1611 | Coded immobiliser fault | Transponder data corrupt |
| | | Transponder error |
| | | Transponder programming error |
| 1612 | Coded immobiliser fault | Transponder antenna fault |
| | | ECU-SMARTRA communication fault |
| | | No response from SMARTRA |
| | | SMARTRA-ECU communication fault |
| 1613 | Coded immobiliser fault | SMARTRA fault |
| | | Communication fault |

| Number | Title | Status |
|---|---|---|
| 1614 | Computer fault | EEPROM write fault |
| | | EEPROM read fault |
| | | RAM integrity fault |
| | | Software fault |
| | | Watchdog fault |
| | | Injector control line noise |
| | | Watchdog fault |
| 1620 | Air conditioning relay command | Short circuit to +$V_B$ (short circuit+) |
| | | Permanent low level (open circuit, short circuit-) |
| 1626 | Immobiliser warning light circuit | Short circuit to + $V_B$ (short circuit+) |
| | | Permanent low level (open circuit, short circuit-) |
| 1640 | Feed relay | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 1672 | Control GMV 1 | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 1673 | Control GMV 2 | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 1674 | Air conditioning fan control | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 1690 | Water heater control | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 1780 | Torque reduction request | Incoherent value |
| | | Above maximum threshold |
| | | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |
| 1786 | Engine speed information output | Permanent low level (open circuit, short circuit-) |
| | | Permanent high level (open circuit, short circuit+) |

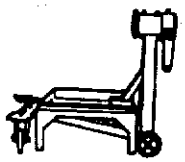
# Engine Mechanical System

# SPECIAL SERVICE TOOLS

## Engine
### Special service tools

**0K130 990 007**

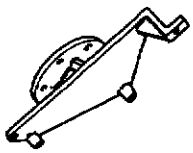
**Engine stand**



Used to disassemble and assemble engine.

**0K410 101 004**

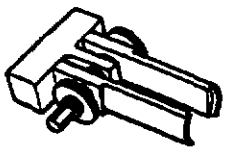
**Hanger, engine stand**



Used to disassemble and assemble engine.

**0K993 120 004**

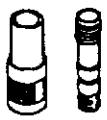
**Pivot, valve spring lifter**



Used to remove and install valve.

**0K710 120 004**

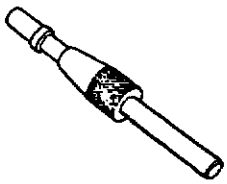
**Installer, valve seal**



Used to install valve seal.

**0K130 160 010**

**Centering tool, clutch disc**



Used to install clutch disc and clutch cover.

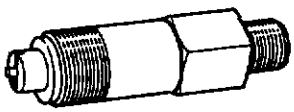
**0K552 111 001**

**Holder, camshaft pulley**

Used to install camshaft pulley.

**0K552 131 002**

**Adapter, compression gauge**



Used to measure compression pressure.

**0K993 120 001**

**Arm, valve spring lifter**

Used to remove and install valve.

| Problem | Possible Cause | Action to be taken |
|---|---|---|
| **White smoke out of exhaust** | Usually caused by water vapor, which is a normal by product of combustion on cold days.<br>Excessive white smoke with engine warmed up could be caused by a failed cylinder head or intake gasket, could also be cracked block, cylinder head or intake manifold. | None required<br><br>Repair or replace |
| **Black smoke out of exhaust** | Malfunction of fuel system<br>Malfunction of emission system | Refer to section FL, fuel system<br>Refer to section EC, emission control system |
| **Abnormal combustion** | Sticking or burned valve<br>Weak or broken valve spring<br>Carbon accumulation in combustion chamber | Replace<br>Replace<br>Eliminate the carbon |
| **Poor idling** | Malfunction of fuel system<br>Malfunction of emission system<br><br>Uneven cylinder compression<br>Poor valve to valve seat contact<br>Broken valve spring<br>Failed cylinder head gasket | Refer to section FL, fuel system<br>Refer to section EC, emission control system<br>Repair<br>Repair or replace<br>Repair<br>Replace |
| **Turbocharger noise** | Contaminated air cleaner element<br>Foreign material in intake duct or compressor housing<br>Foreign material between intake manifold and compressor<br>Foreign material in engine exhaust system<br>Carbon deposit on turbine housing<br>Interference between turbocharger rotating parts<br>Loose connecting parts of intake and exhaust system | Replace<br>Clean<br>Clean<br>Clean<br>Clean<br>Repair or replace<br>Tighten |
| **Engine knocks when hot and at idle** | Loose or worn accessory drive belt/tensioner<br>Improper oil viscosity<br><br>Excessive piston pin clearance<br><br>Connecting rod alignment<br>Insufficient piston to bore clearance<br>Faulty timing belt tensioner or guide<br>Loose damper pulley | Replace if necessary<br>Install proper oil viscosity for expected temperature<br>Install new piston pin and/or connecting rod<br>Check and replace<br>Hone and fit new pistons<br>Replace<br>Tighten or replace |
| **Slight noise at idle, becomes louder as engine speed is increased** | Valve spring clicking on cap, off square or broken<br>Excessive stem to guide clearance<br>Excessive valve seat runout<br>Holed exhaust pipe | Repair or replace<br>Repair<br>Repair<br>Replace |
| **Engine knoks when cold** | Excessive piston to wall clearance<br>Loose or broken damper pulley | Replace<br>Tighten or replace |
| **Knock increase with torque** | Excessive piston to bore clearance<br>Bent connecting rod | Replace piston<br>Replace |
| **Engine has heavy knock when hot and torque is applied** | Broken damper pulley<br>Accessory belts too tight or damaged<br>Belt tensioner damaged<br>Flywheel cracked or loose clutch plate<br>Excessive main bearing clearance<br>Excessive rod bearing clearance | Replace<br>Adjust or replace belt<br>Replace<br>Replace flywheel or clutch plate<br>Repair<br>Repair |

| Problem | Possible Cause | Action to be taken |
|---|---|---|
| **Engine has light knock when hot and under light load conditions** | Improper timing<br>Piston pin and/or connecting rod<br>Poor quality fuel<br>Exhaust leak at manifold<br>Excessive rod bearing clearance | Check timing<br>Replace<br>Replace<br>Tighten or replace<br>Repair |
| **Engine knocks on initial start up and knock lasts only a few seconds** | Improper oil viscosity | Install proper oil viscosity for expected temperature |
| **Interference of turbocharger, poor rotation** | Damaged compressor blades due to external cause<br>Interference of turbine and compressor blades with housing<br>Excessive deposit on compressor housing or wheel<br>Excessive carbon deposit on the back of turbine blade<br>Burn out of center housing | Repair or replace<br>Repair or replace<br>Clean or repair<br>Clean or repair<br>Replace |
| **Leakage from turbocharger turbine shaft** | Excessive initial oil applying<br>Blocked crankcase breather<br>Obstacle in turbocharger oil drain line<br>Burn out of center housing<br>Wear on turbocharger bearing, bearing bore or shaft journal<br>Excessive crankcase oil | Burn it normally<br>Repair<br>Clean and repair<br>Clean and replace<br>Repair or replace<br>Correct oil amount |
| **Leakage from turbocharger compressor** | Contaminated air cleaner element<br>Blocked duct between compressor and air cleaner<br>Loose compressor and intake system connecting duct<br>Leakage from intake manifold<br>Obstacle in turbocharger oil drain line<br>Blocked blowby passage in crankcase<br>Worn or damaged compressor blades<br>Wear or turbocharger bearing bore, bearing or shaft journal | Replace<br>Repair<br>Tighten<br>Repair<br>Repair or replace<br>Repair<br>Clean or replace<br>Replace |
| **Wear on turbocharger bearing, bore or shaft journal** | Contaminated oil<br>Insufficient oil supply<br>Obstacle in turbocharger oil supply line<br>Plugged oil filter<br>Poor oil pump operation | Replace<br>Check<br>Check and repair<br>Replace<br>Check and repair |

**0K993 120 006**

**Remover, valve seal**

Used to remove valve seal.

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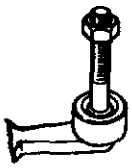
**0K590 111 001**

**Ring gear brake set**



Used to prevent engine rotation.

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**0K130 111 004**

**Holder, coupling flange**

Used to remove camshaft gear.

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# SYMPTOM-RELATED DIAGNOSTIC PROCEDURE

## Engine

### Diagnostic chart

| Problem | Possible Cause | Action to be taken |
|---|---|---|
| **Insufficient power smoke generation** | Insufficient compression caused by:<br>1. Contaminated air cleaner element<br>2. Loose hose connection between compressor and intercooler<br>3. Leakage from intake manifold<br>4. Leakage from exhaust manifold<br>5. Leakage from turbocharger mounting flange<br>6. Interference between turbocharger compressor turbine and case<br>7. Blocked duct between air cleaner and turbocharger compressor<br>8. Blocked duct between compressor and intake manifold<br>9. Interference between intake and exhaust manifolds<br>10. Leakage from valve seat<br>11. Seized valve stem<br>12. Weak or broken valve spring<br>13. Failed cylinder head gasket<br>14. Cracked or distorted cylinder head<br>15. Sticking, damaged, or worn piston ring<br>16. Cracked or worn piston | |
| | Malfunction of fuel system | Refer to section FL, fuel system |
| | Slipping clutch | Refer to section CH, clutch |
| | Wrong tire size | Refer to section SS, wheel and tires |
| | Restricted exhaust system | Refer to section EM-IE, exhaust system |
| **Excessive oil consumption** | Abnormal engine oil viscosity | Replace |
| | Leakage from turbocharger compressor (adhesion of oil to housing or wheel) | Repair |
| | Leakage turbocharger turbine | Repair |
| | Worn or sticking piston ring or groove | Replace |
| | Worn piston or cylinder | Repair or replace |
| | Bad valve seal | Replace |
| | Worn valve stem or guide | Replace |
| **Engine cranks normally, but does not start** | Malfunction of fuel system | Refer to section FL, fuel system |
| | Malfunction of electrical system | Refer to section EE, starting system |
| | Restricted exhaust system | Refer to section EM-IE, exhaust system |
| | Timing belt and/or related parts | Replace |
| | Low compression | |
| | Camshaft worn | |
| **Blue smoke out of exhaust** | Usually caused by oil burning in the combustion chamber from: worn rings, worn valve guides, worn valve seals or failed cylinder head gasket | Replace |
| | Contaminated air cleaner element | |
| | Loose hose connection between compressor and intercooler | Tighten |
| | Leakage from intake manifold | Repair |
| | Blocked oil filter | Replace |
| | Blocked duct between air cleaner and turbocharger compressor | Repair |
| | Leakage from turbocharger compressor | Repair |

# SPECIFICATION

## Engine

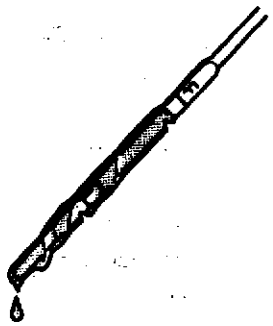
### Specification

| Item \ Engine model | | | J3 COMMON RAIL SYSTEM |
|---|---|---|---|
| Type | | | Diesel, 4-Cycles |
| Number of cylinders | | | 4-Cylinder in-line |
| Combustion chamber | | | Re-entrant |
| Displacement cu. in (cc) | | | 177 (2902) |
| Bore and stroke in (mm) | | | 3.82 X 3.85 (97.1 X 98) |
| Compression ratio | | | 19.3 |
| Compression pressure psi (kPa, kg/cm²)-rpm | | | 426.6 (2943, 30) - 200 |
| Valve timing | Intake | Open | BTDC 26° |
| | | Closed | ABDC 50° |
| | Exhaust | Open | BBDC 50° |
| | | Closed | ATDC 29° |
| Valve clearance(cold engine) in (mm) | | Intake | 0 : Maintenance-free |
| | | Exhaust | 0 : Maintenance-free |
| Idle speed rpm | | | 800 ±100 |
| Injection order | | | 1-3-4-2 |

# ON-VEHICLE SERVICE PROCEDURE

## Engine oil

1. Be sure the vehicle is on level ground.
2. Warm up the engine to normal operating temperature and stop it.
3. Wait for 5 minutes.
4. Remove the oil level gauge and check the oil level and condition.



AGX010A022

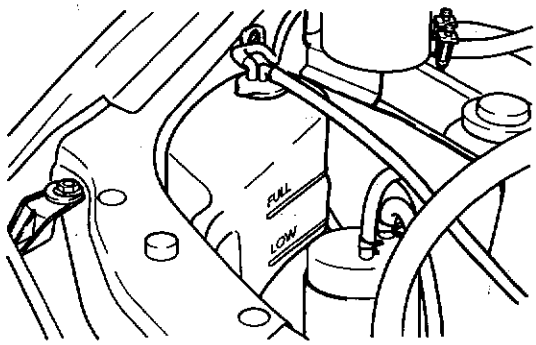
5. Add or replace oil if necessary.

## Engine coolant

### Coolant level

⚠ **WARNING**
**A) NEVER REMOVE THE RADIATOR CAP WHILE THE ENGINE IS HOT.**
**B) WRAP A THICK CLOTH AROUND THE CAP WHEN REMOVING IT.**

1. Verify that the coolant level is near the radiator filler neck.
2. Check that the level in the coolant reservoir is between the "Full" and "Low" marks.




AV2A10020

3. Add coolant if necessary.

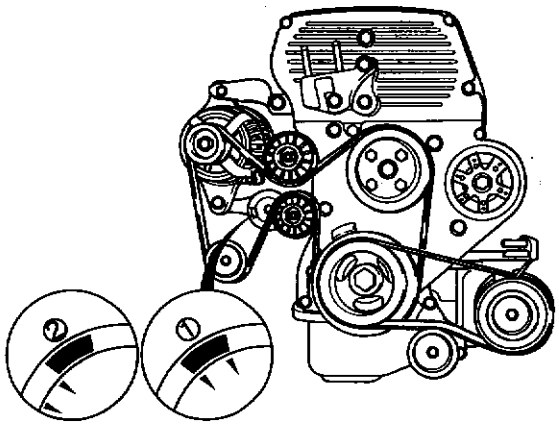
### Coolant quality

1. Verify that there is no build up of rust or scale around the radiator cap of radiator filler neck.
2. Verify that the coolant is free of oil.
3. Replace the coolant if necessary.

# Drive belt

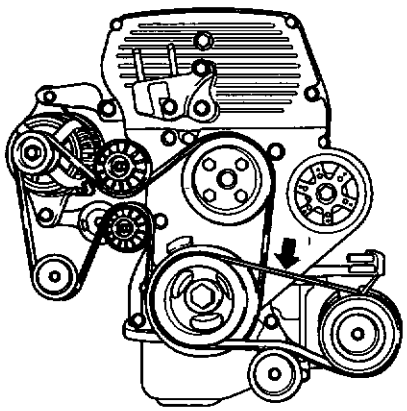
## Inspection

1. Check the drive belts for wear, cracks, and fraying. Replace if necessary.
2. Verify that the drive belts are correctly mounted on the pulleys.
3. Verify that "▼" mark of auto-tensioner align "▮ ▮" mark. If two marks align as shown ①, the tension of auto-tensioner is good. If not align as shown ②, re-install the auto-tensioner or replace the drive belt.




AV2A10B001

4. Check the A/C drive belt deflection by applying moderate pressure (22 lb, 98 N, 10 kg) midway between the pulleys.



AV2A10B002

***Caution***

***a) Measure the belt deflection between the pulleys.***

***b) Consider the belt as a new one if it has been used on a running engine for less than five minutes.***

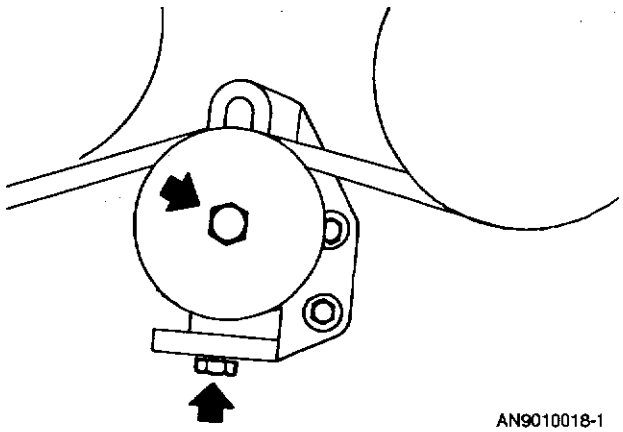
***c) Check the belt deflection when the engine is cold or at least 30 minutes after the engine is stopped.***

**A/C belt deflection:**

**New one: 0.28~0.35 in (7~9 mm)**

**Used one: 0.35~0.43 in (9~11 mm)**

## Adjustment



AN9010018-1

1. Loosen the idler pulley mounting bolt.
2. Adjust the belt deflection by turning the adjusting bolt.

**Deflection (When applying 22 lb, 98 N, 10 kg)**

**New one: 0.28~0.35 in (7~9 mm)**

**Used one: 0.35~0.43 in (9~11 mm)**

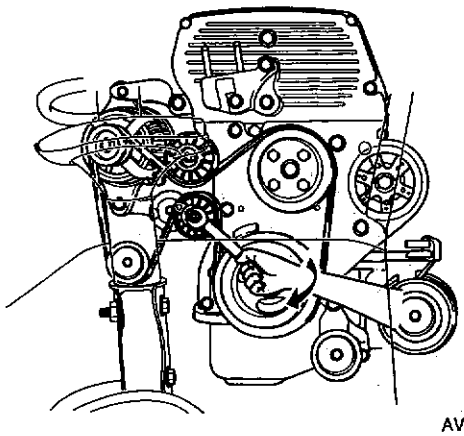
3. After making the adjustment, tighten the idler pulley mounting bolt.

**Tightening torque:**

**28~38 lb-ft (37~52N•m, 3.8~5.3 kg-m)**

## Replacement

1. Raise the vehicle and support it with safety stands.
2. Remove the RH side wheel.
3. Loosen the idle pulley mounting bolt.
4. Remove the A/C drive belt.
5. Lower the auto tensioner with spanner and then remove the drive belt.



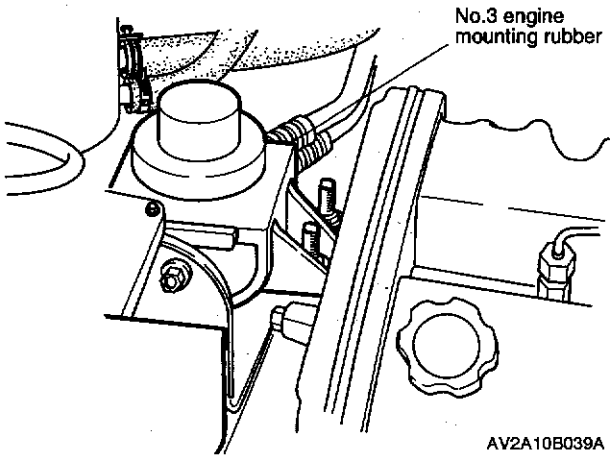
AV2A10B038

6. Lower the auto tensioner with spanner and then install the drive belt.
7. Install the A/C drive belt.
8. Check the A/C drive belt deflection. (*Refer to Inspection and Adjustment, page EM-9*)

# Timing belt

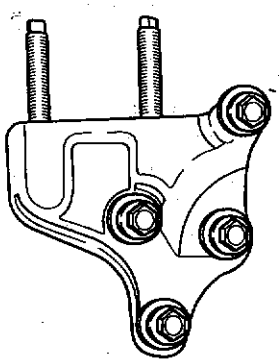
## Removal

1. Raise vehicle and support it with safety stands.
2. Remove the radiator upper hose.
3. Remove the fuel filter hoses still connected.
4. Remove the No.3 engine mounting rubber.



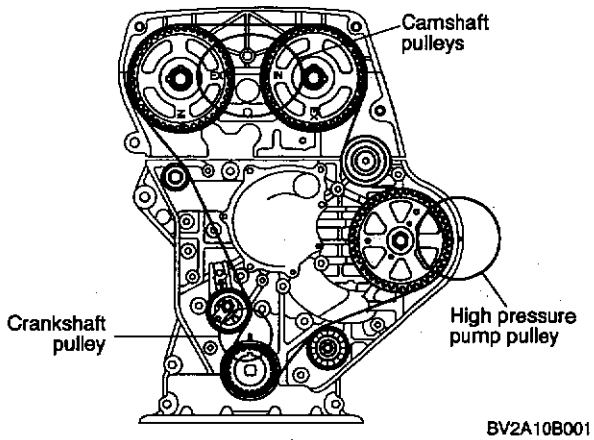

AV2A10B039A

5. Remove the No.3 engine mounting bracket.



AV2A10B040

6. Remove the RH side wheel.
7. Remove the A/C drive belt.
8. Remove the drive belt.*(Refer to Drive belt replacement, page EM-9)*
9. Remove the auto tensioner.
10. Remove the water pump pulley.
11. Remove the crankshaft pulley.
12. Remove the upper timing belt cover.
13. Remove the lower timing belt cover.
14. Rotate crankshaft and align timing mark on timing belt pulley with timing mark on engine block.

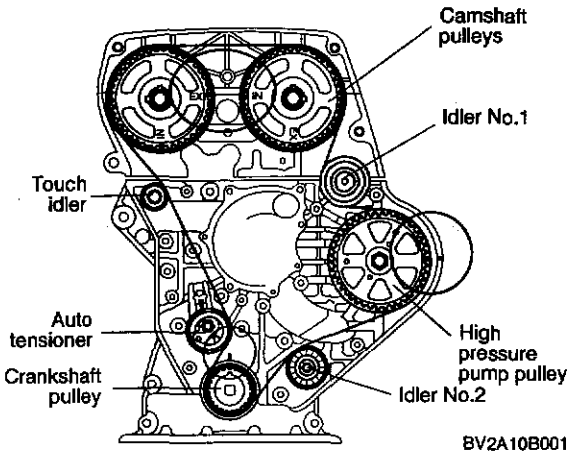



BV2A10B001

15. Remove the auto tensioner.
16. Remove the timing belt.

## Replacement

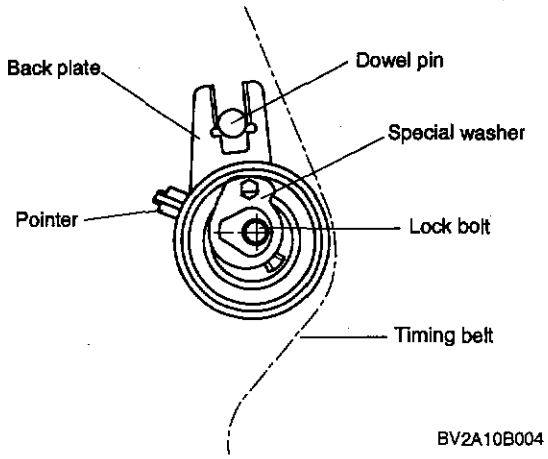
1. Check that timing mark on timing belt pulley, camshaft pulley and high pressure pump pulley is aligned with timing mark on engine.




2. Install the timing belt.
   1) The timing belt is installed in sequence crank shaft pulley, idler No.2, high pressure pump pulley, idler No.1 and camshaft pulley.

✱ *Notice*
   *a) The auto-tensioner must be mounted onto the engine after the timing belt is installed.*
   *b) Keep the tension of timing belt when install timing belt.*

3. Install the auto-tensioner.
   1) Install the auto-tensioner as shown illust. The dowel pin has to be located between the tensioner fork (back plate).



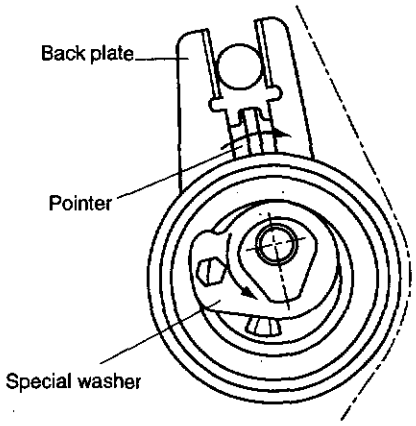

   2) Pretighten the auto-tensioner.

**Tightening torque:**
**2.9lb-ft (3.9N•m , 0.4kg-m)**

✱ *Notice*
   *a) Oil must not get in contact with the tensioner. The tensioner has to be replaced by a new one, if it is oily.*
   *b) The positions of the pointer, the back plate and the special washer are in accordance to the illust.*

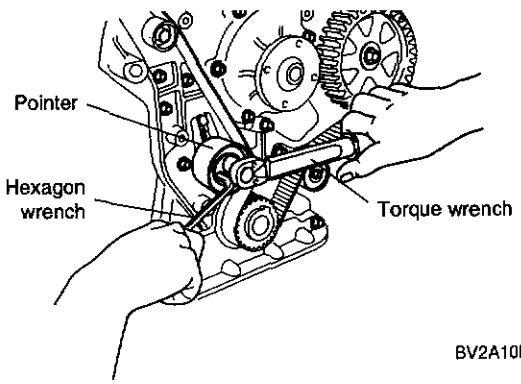
4. Check again if the alignment marks of camshafts, crankshaft and high pressure pump are aligned with the marks on the timing case.

5. Adjust the auto-tensioner, and then tighten it.
   1) Align the pointer to the back plate by rotating the special washer in counter-clockwise using the hexagon wrench as shown illust.




   2) Tighten the auto-tensioner lock bolt with holding the special washer by the hexagon wrench when the pointer is aligned with the back plate.

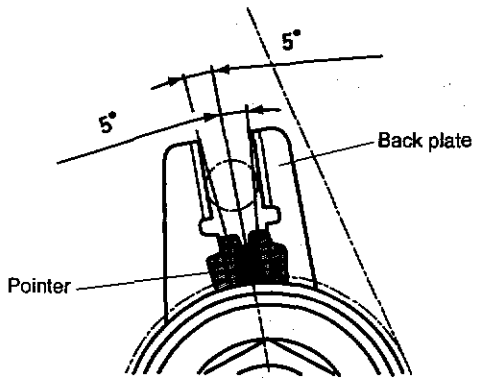
**Tightening torque :**
**17.4lb-ft (23.5N•m , 2.4kg-m)**




   3) Remove the hexagon wrench.

✱ *Notice*
*If the pointer can not be aligned with the back plate, then a new belt has to be used.*

6. Rotate the crankshaft two full revolutions in clockwise to align the TDC mark.
7. Check again if the alignment marks of camshafts, crankshaft and high pressure pump are aligned with the marks on the timing case.
8. Check the alignment of the pointer and back plate.




BV2A10B007

**Allowance misalignment : ±5°**

9. If the misalignment between pointer and back plate is bigger than ±5°, repeat step 4~8.

10. Install the upper and lower timing belt cover.

**Tightening torque:**
**5.1~7.2 lb-ft (6.9~9.8 N•m, 70~100 kg-cm)**

11. Install the crankshaft pulley.

**Tightening torque:**
**253~289 lb-ft (343~392 N•m, 35~40 kg-m)**

12. Install the water pump pulley.

**Tightening torque:**
**13.0~20.9 lb-ft (17.6~28.4 N•m, 1.8~2.9 kg-m)**

13. Install the auto tensioner.

**Tightening torque:**
**13.0~20.9 lb-ft (17.6~28.4 N•m, 1.8~2.9 kg-m)**

14. Install the drive belt and A/C drive belt.
*(Refer to Drive belt, page EM-9)*
15. Install the RH side wheel.

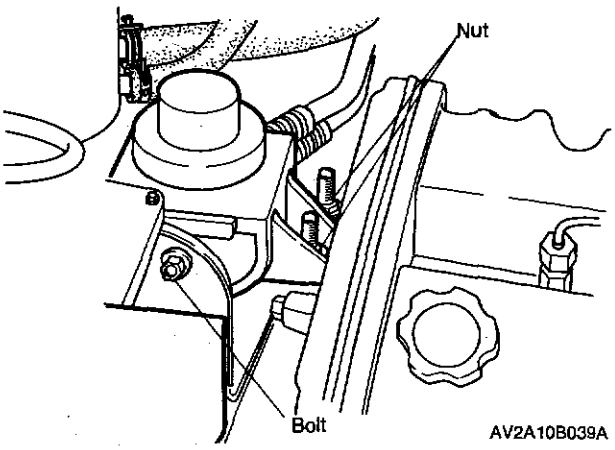
**Tightening torque:**
**65~79 lb-ft (88~108 N•m, 9.0~11.0 kg-m)**

16. Install the No.3 engine mounting bracket.

**Tightening torque:**
**26.7~39.8 lb-ft (36.2~53.9 N•m, 3.7~5.5 kg-m)**

17. Install the No.3 engine mounting rubber.

**Tightening torque:**
**Nut: 49.1~68.7 lb-ft (66.7~93.1 N•m, 6.8~9.5 kg-m)**
**Bolt: 62.9~86.0 lb-ft (85.3~116.7 N•m, 8.7~11.9 kg-m)**




AV2A10B039A

18. Install the fuel filter.
19. Install the radiator hose.
20. Fill engine coolant with specified type and amount.*(Refer to section EM-CL, Cooling system)*
21. Start engine and then check for leaks.

# Compression pressure

## Inspection

1. Warm up the engine upto the normal operating temperature, then stop the engine and disconnect the connector of fuel cut solenoid.
2. Remove all injection pipes, nozzles and washers.
3. Attach the **SST** to the nozzle hole.
4. Measure the compression pressure during cranking.

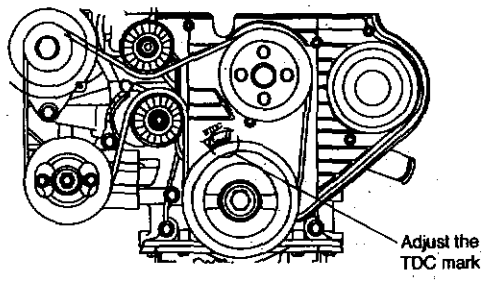
| Item \ Engine model | | J3 COMMON RAIL SYSTEM |
|---|---|---|
| Compression pressure psi (kPa, kg/cm²)-rpm | Normal | 426.6(2943, 30)-200 |
| | Limit | 383.9(2649, 27)-200 |
| Cylinder-to-cylinder pressure difference psi (kPa, kg/cm²) | | below 42.7(294,3.0) |

5. Do above step 3~4 again for each cylinder.
6. If the measure value is below the limit, consider it as abrasion or damage of piston and piston ring, misalignment of valve, damage of gasket, and etc..

# Ladder frame

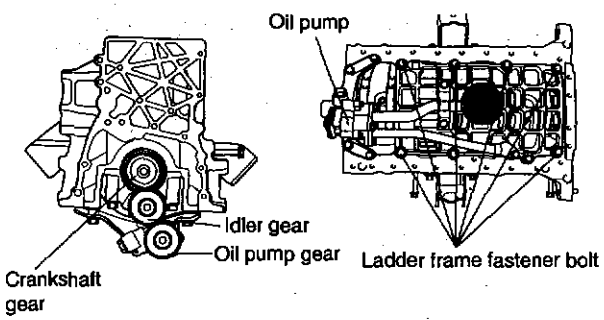
## Removal

1. Remove oil pan. *(Refer to section EM-LU, Lubrication system)*
2. Adjust the V groove TDC mark on the outside of pulley to the TDC mark "T" on the timing cover, by rotating the crank shaft pulley.




AV2A10B031

3. When disassembling ladder frame, separate the oil feeding pipe from the oil pump by loosening the oil feeding pipe bolt.




AV2A10B036

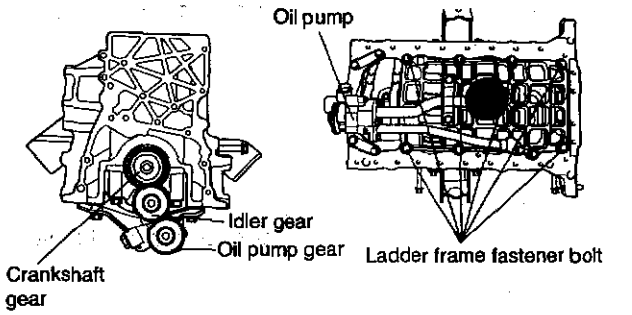
4. Loosen the ladder frame fastener bolt. Remove ladder frame.

## Replacement

1. Install the ladder frame into block. Check the dowel pin of ladder frame is matched with lower surface of block and insert the oil level gauge into the ladder frame hole.

**Tightening torque (ladder frame bolt):**
**32.5 lb-ft (44 N•m, 4.5 kg-m)**

2. Install crankshaft sprocket and oil pump sprocket.
3. Install the oil feeding pipe into the ladder frame, oil pump and block and then tighten bolts.




AV2A10B036

4. Install the oil pan. *(Refer to section EM-LU, Lubrication system)*
5. Fill engine oil with specified type and amount. *(Refer to section EM-LU, Lubrication system)*
6. Start engine and then check for leaks.

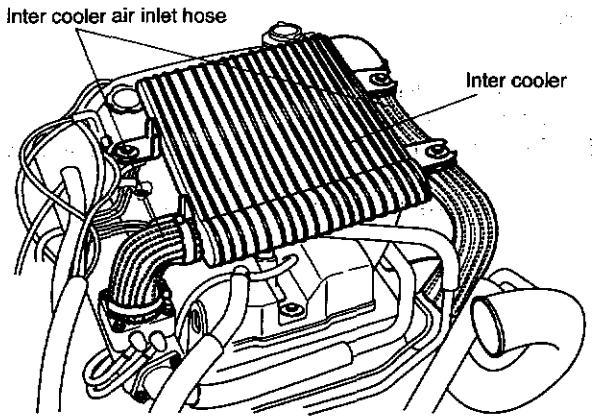
# DISASSEMBLY, INSPECTION AND REASSEMBLY PROCEDURE

✱ *Notice*
- *a) Code all identical parts(such as pistons, piston rings, connecting rods, and valve springs) so that they can be reinstalled in the cylinder from which they were removed.*
- *b) Clean the parts with steam, blow off any remining water with compressed air.*
- *c) Care should be taken during the disassembly of any part or system to study its order of assembly. Any deformation, wear or damage should also be noted.*

## Auxiliary parts

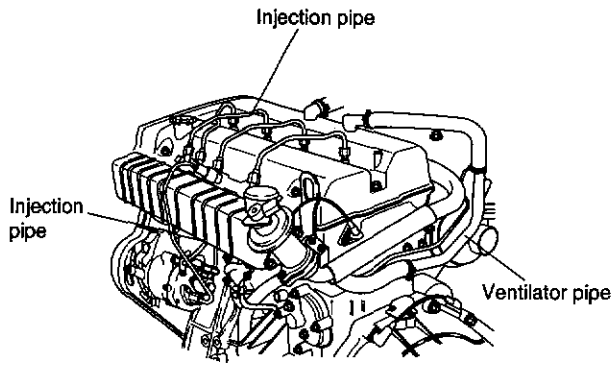
### Disassembly

1. Remove inter cooler cover.
2. Remove inter cooler and inter cooler air inlet hose.



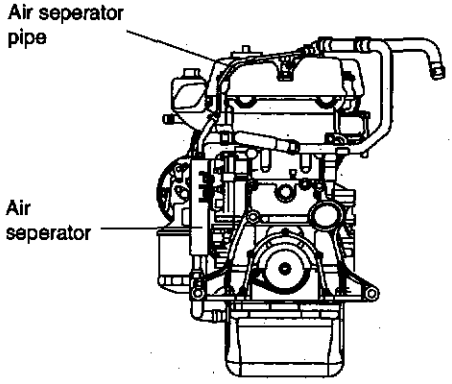

AV2A10B052

3. Remove engine harness.
4. Remove ventilator hose.
5. Remove fuel injection pipe.



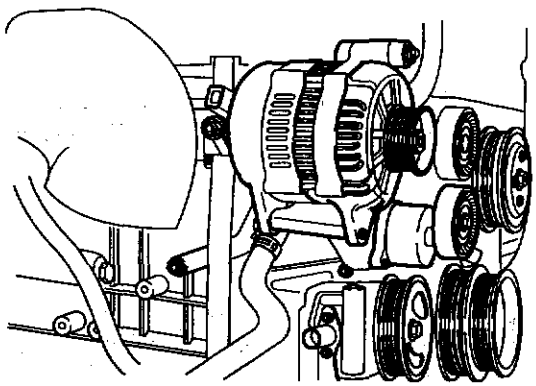

EFL0FL011

6. Remove air separator and air separator hose/pipe.



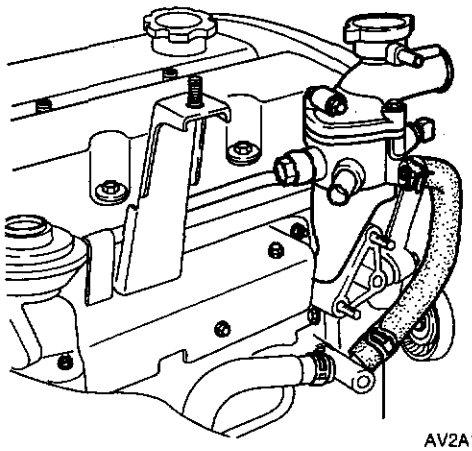

EFL0FL060

7. Remove ventilation pipe and hose.
8. Remove lower water hose from cylinder block.
9. Remove EGR pipe.
10. Remove alternator, hose, alternator bracket and auto tensioner.



AV2A10B056

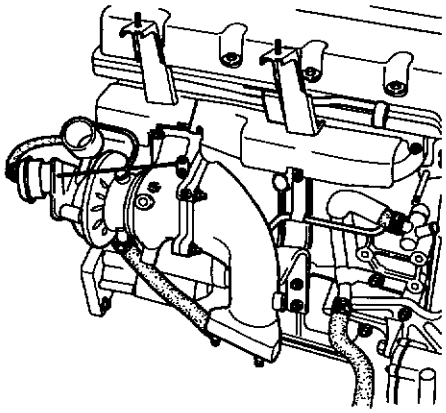
11. Remove thermostat housing assembly.



AV2A10B057

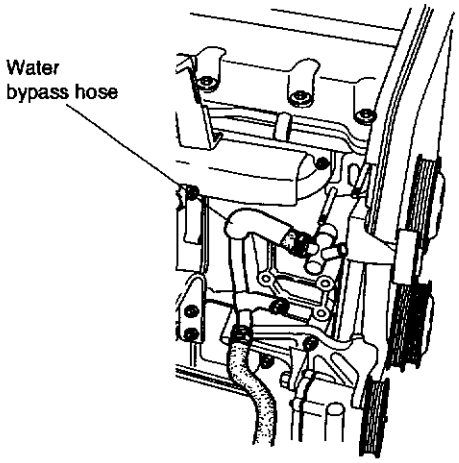
12. Remove turbo charger insulator.

13. Remove turbo charger assembly.



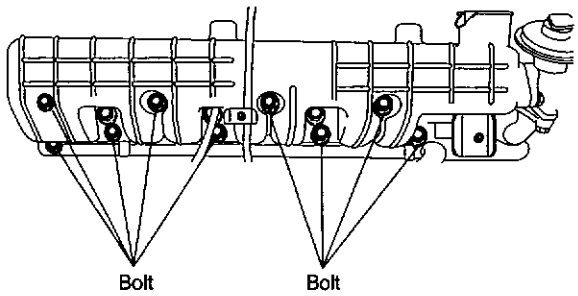
AV2A10B058A

14. Remove water bypass hose and water bypass pipe.



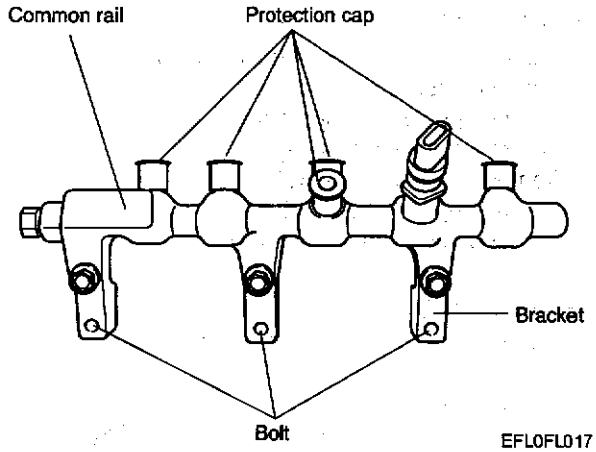

AV2A10B059

15. Remove power steering pump bracket.
16. Remove exhaust manifold insulator, exhaust manifold and gasket.
17. Remove EGR valve and gasket.
18. Remove intake manifold and gasket.



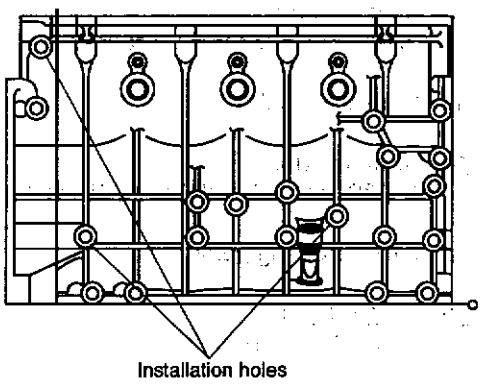

EFL0FL052

19. Remove common rail.(Refer to section FL)



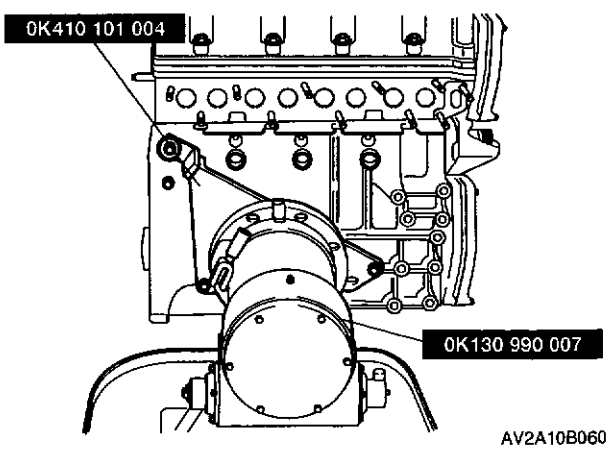

EFL0FL017

20. Install **SST (0K410 101 004)** to engine.




AV2A10B037

21. Mount engine on the **SST (0K130 990 007)**.




AV2A10B060

## Reassembly

Assembly will be performed in the reverse order.

# Timing belt cover

## Disassembly

1. Remove No.3 engine mounting bracket.
2. Remove water pump pulley.
3. Remove power steering pump.
4. Remove crankshaft pulley.
5. Remove idler and bracket.
6. Remove upper timing belt cover.
7. Remove lower timing belt cover.

## Reassembly

1. Install upper and lower timing belt cover.

   **Tightening torque:**
   **5.1~7.2 lb-ft (6.9~9.8 N·m, 0.7~1.0 kg-m)**

2. Install idler and bracket.

   **Tightening torque:**
   **27.5~38.3 lb-ft (37.2~51.9 N·m, 3.8~5.3 kg-m)**

3. Install crankshaft pulley.

   **Tightening torque:**
   **253~289 lb-ft (343~392 N·m, 35~40 kg-m)**

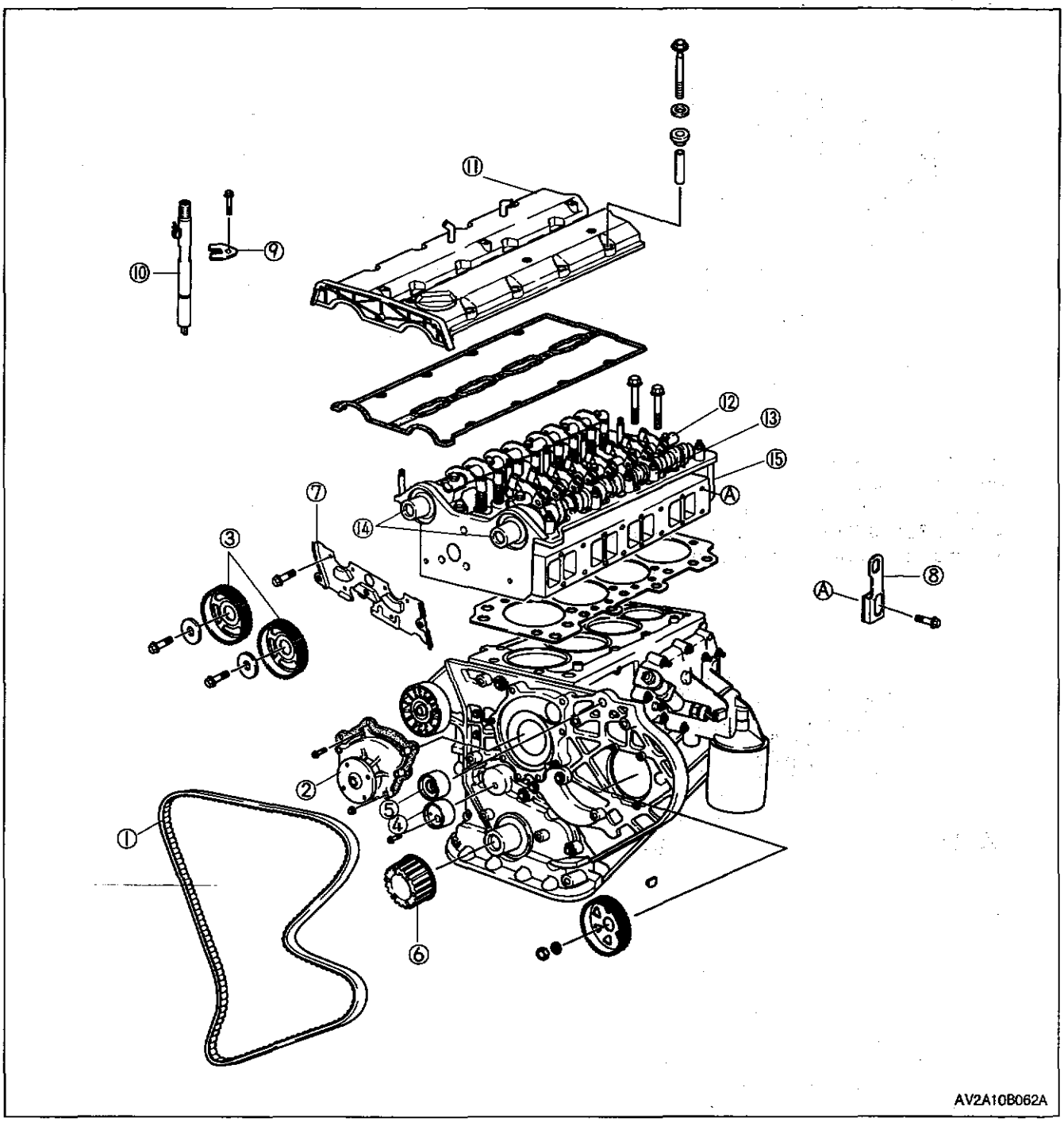
4. Install power steering pump.

   **Tightening torque:**
   **21.7~28.9 lb-ft (29.4~39.2 N·m, 3.0~4.0 kg-m)**

5. Install No.3 engine mounting bracket.

   **Tightening torque:**
   **49.2~68.7 lb-ft (66.6~93.1 N·m, 6.8~9.5 kg-m)**

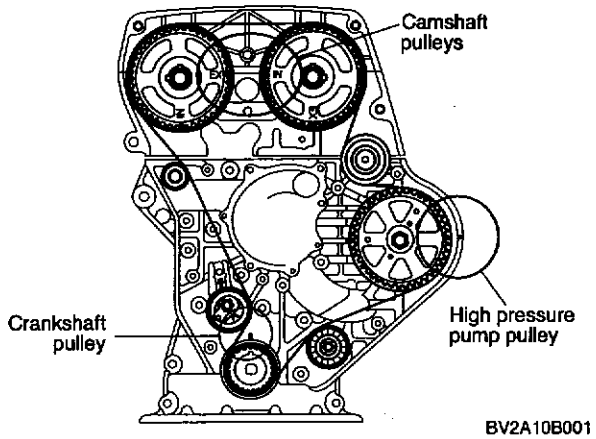
## Timing belt




(1) Timing belt
(2) Water pump
(3) Camshaft pulley
(4) Tensioner
(5) Idler
(6) Timing belt pulley
(7) Upper plate assembly
(8) Engine hanger
(9) Injector bracket
(10) Injector
(11) Cylinder head cover
(12) Rocker arm shaft assembly
(13) Camshaft cap
(14) Camshaft
(15) Cylinder head

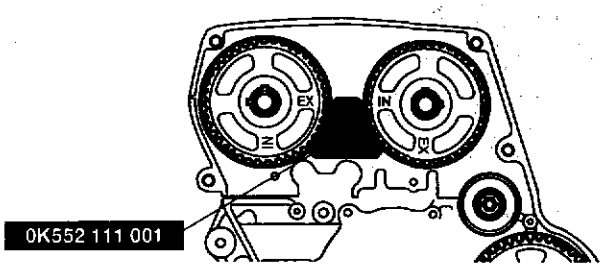
## Disassembly

1. Rotate crankshaft and align timing mark on timing belt pulley with timing mark on engine block.



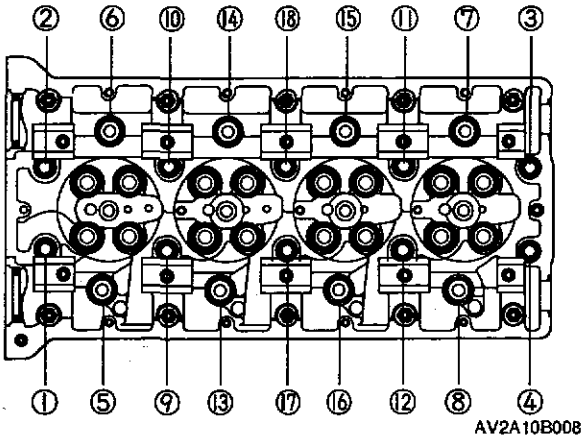

BV2A10B001

2. Remove the auto tensioner.
3. Remove the timing belt.
4. Remove the high pressure pump.
5. Install the **SST (0K552 111 001)** as shown in the figure and the remove the camshaft pulley.




AV2A10B022

6. Remove the idler.
7. Remove the timing belt pulley.
8. Remove the upper plate assembly.
9. Remove the engine hanger.
10. Remove the injector bracket and injector.
11. Remove the cylinder head cover.
12. Remove the rocker arm shaft assembly.
13. Remove the camshaft cap and camshaft.
14. Remove the cylinder head bolts in the order shown in the figure.



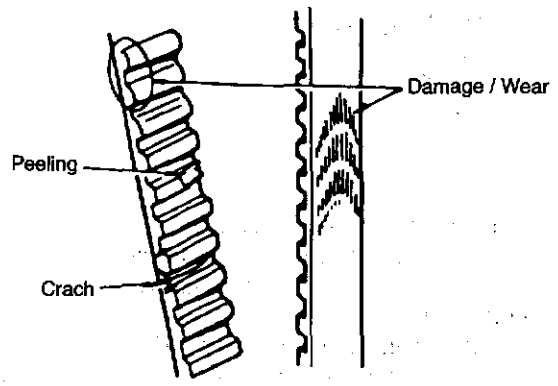

AV2A10B008

## Inspection

### Front timing belt

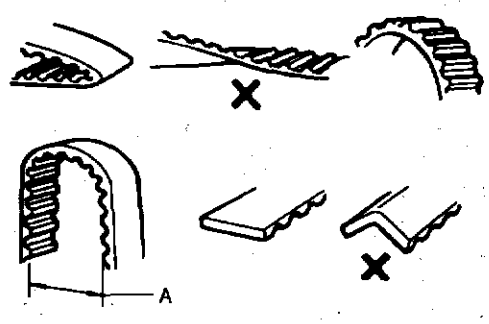
✱ *Notice*
*a) Never forcefully twist, turn inside out or bend timing belt.*
*b) Do not allow oil or grease to come in contact with timing belt.*

1. Replace timing belt if it is contaminated with oil or grease.
2. Check timing belt for uneven wear, fraying, peeling, cracking and hardening. Replace timing belt if necessary.




ABT010217

3. Bend timing belt into a "U" shapes as shown in figure. Distance "A" must be at least 1.0 in (25 mm).




ABT010216

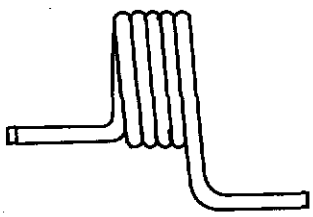
### Camshaft pulleys and timing belt pulley

✱ *Notice*
*Do not clean pulleys with cleaning fluids. If needed, use a soft cloth to wipe them clean, and avoid scratching the pulleys as it will affect integrity of the timing belt.*

1. Check pulley teeth for wear, deformities and other damage. Replace pulleys if necessary.

### Tensioner spring

1. Check the tensioner spring. Replace tensioner spring if necessary.

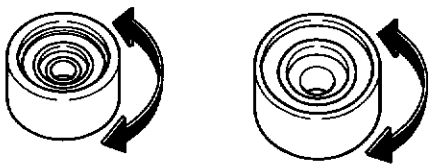


AV2A10B083

### Tensioner and idler

✱ *Notice*
*Do not clean tensioner pulley or idler pulley with cleaning fluids. If needed, use a soft rag to wipe them clean. Avoid scratching tensioner pulley or idler pulley as it can affect integrity of timing belt.*

1. Check tensioner pulley and idler pulley for smooth rotation and proper sound. Replace tensioner pulley and idler pulley if necessary.

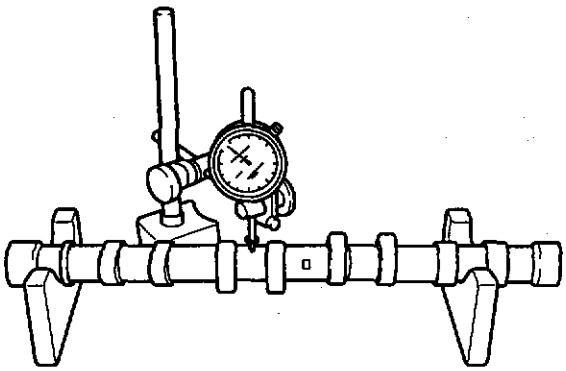


AV2A10B064

## Camshaft

1. Set front and rear camshaft bearing journals on V-blocks.
2. Position a dial indicator on center bearing journal and zero dial.
3. Rotate camshaft in V-blocks and check runout.

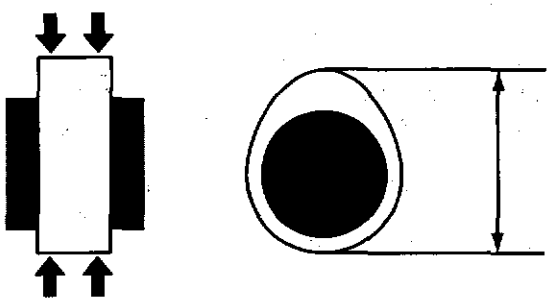
**Runout: 0.0031 in (0.08 mm) maximum**



AV2A10B066

4. Check camshaft for uneven wear patterns, cracks, or damage.
5. Measure cam lobe heights at two points as shown.

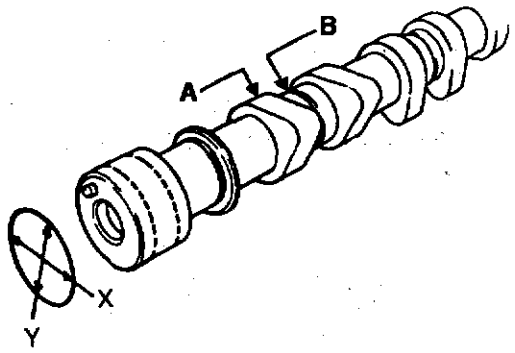
**Lobe height**
**Intake : 0.8857 in (22.497 mm)**
**Exhaust : 0.8894 in (22.593 mm)**



AV2A10B067

6. Check camshaft bearing journal diameter (X and Y directions) on both sides (A and B) of journal as shown in figure.

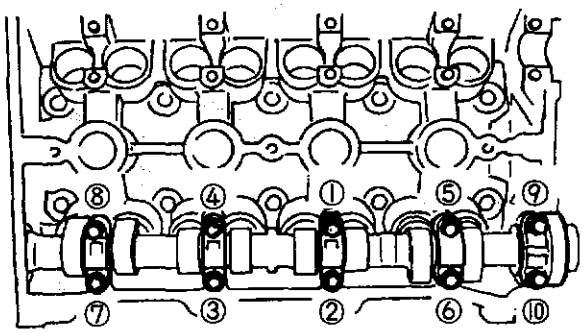
**Minimum diameter:**
**1.1000~1.1032 in (27.941~27.960 mm)**




BSX010B089A

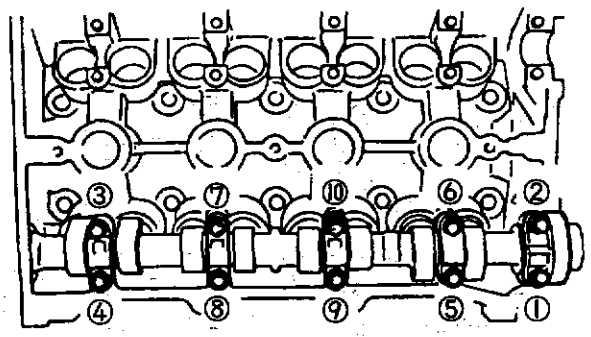
7. Replace camshafts if necessary.
8. Measure camshaft journal oil clearance.
9. Remove all foreign material and oil from journals and bearing surfaces.
10. Set camshafts onto cylinder head.
11. Position plastigage® on journals in axial direction.
12. Do not rotate camshafts.
13. Install camshaft caps according to cap number and arrow mark.
14. Install cap nuts. Tighten them in five or six steps in order shown.

**Tightening torque:**
**13.0~19.5 lb-ft (17.6~26.5 N·m, 1.8~2.7 kg-m)**




AS2A10107

15. Loosen camshaft cap nuts in five or six steps in order shown.
16. Remove camshaft caps.

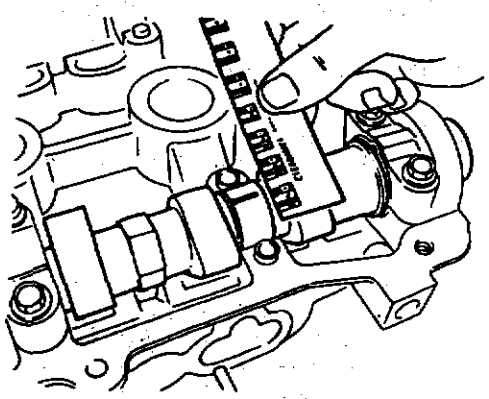



AS2A10107

17. Measure oil clearances.

**Oil clearance:**
**0.0016~0.0031 in (0.04~0.08 mm)**

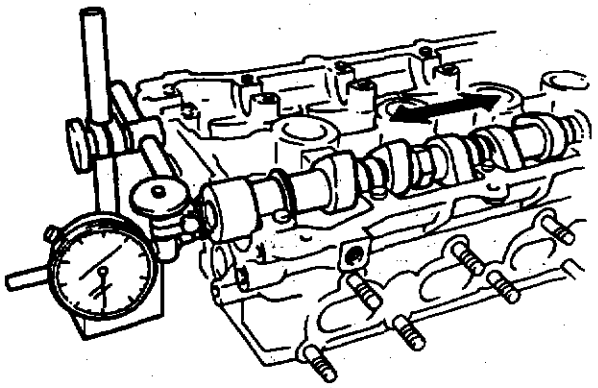
18. If oil clearance exceeds specification, replace cylinder head.



BSX010B093

19. Install camshafts.
20. Place a dial indicator against end of camshaft.
21. Using a prying tool, move camshaft as far forward as possible.
22. Zero dial.
23. Using prying tool, move camshaft as far rearward as possible.
24. Check gauge to determine how much end play is present.

**End play:**
**0.0031~0.0046 in (0.08~0.11 mm)**



BSX010B094

### Rocker arm and rocker arm shaft

1. Measure the rocker arm inner diameter.

**Inner diameter:**
**0.7862~0.7874 in (19.97~20.00 mm)**

2. Measure the rocker arm shaft outer diameter.

**Outer diameter:**
**0.7875~0.7866 in (19.959~19.980 mm)**

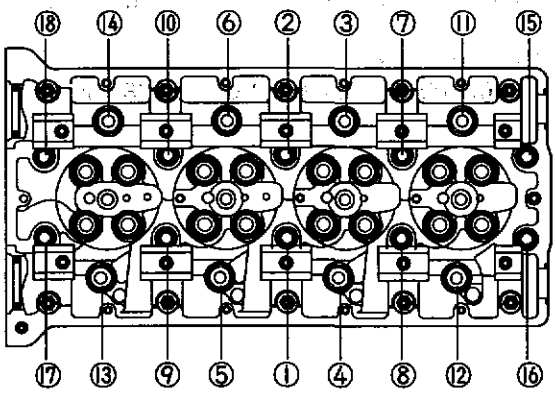
## Reassembly

1. Remove all foreign material from the top of the cylinder block.
2. Place the new cylinder head gasket in position.

***Caution***
***Measure the length of cylinder head bolt, replace if necessary.***
***Long bolt: 5.2 in (132 mm)***
***Short bolt: 3.7 in (93 mm)***

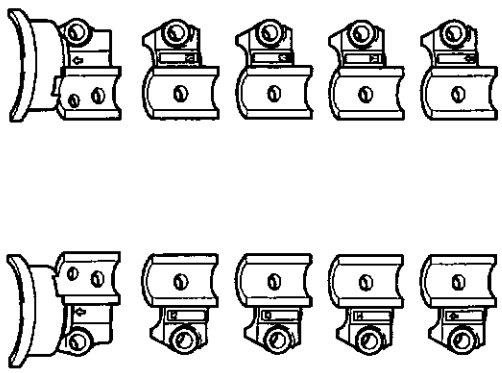
3. Install the cylinder head.
4. Apply an engine oil into the surface and thread of cylinder head bolt, and install the cylinder head bolts to the cylinder head.
5. Tighten the cylinder head bolts in the order shown in the figure.

**Tightening torque:**
**Angle contorl**
**Long bolt: 25.32 lb-ft (34.3 N•m, 3.5 kg-m)+45°+70°**
**Short bolt: 25.32 lb-ft (34.3 N•m, 3.5 kg-m) +40°+45°**



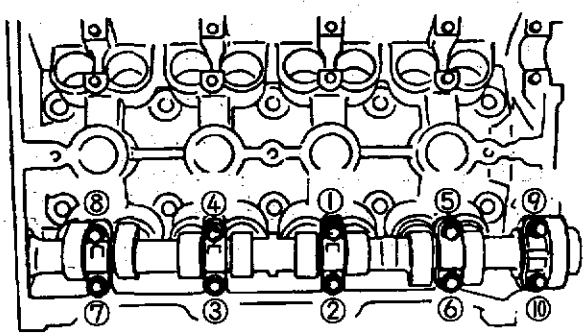
AV2A10B008

6. Remove all foreign material and oil from the journals and bearing surface.
7. Set the camshaft onto the cylinder head.
8. Install the camshaft caps according to the cap number and arrow mark.


AV2A10B065

9. Install the camshaft cap nuts and tighten them in two or three steps in the order shown in the figure.

**Tightening torque:**
**13.0~19.5 lb-ft (17.6~26.5 N•m, 1.8~2.7 kg-m)**

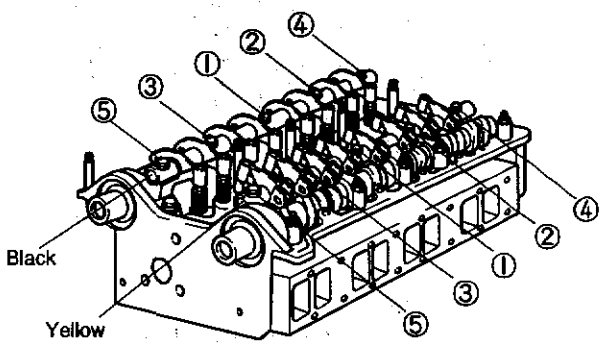


AS2A10107

✱ *Notice*
*Do not exchange intake rocker arm shaft and exhaust rocker arm shaft each other.*
- *Intake side: Yellow*
- *Exhaust side: Black*

10. Install the intake rocker arm shaft and exhaust rocker arm shaft and tighten them in two or three steps in the order shown in the figure.

**Tightening torque:**
**13.0~19.5 lb-ft (17.6~26.5 N•m, 1.8~2.7 kg-m)**



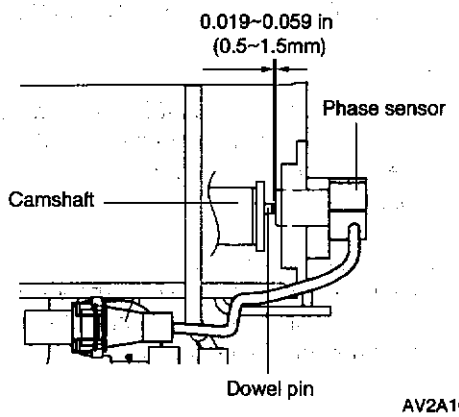
AV2A10B025

11. Install the cylinder head cover.

**Tightening torque:**
**5.1~6.5 lb-ft (6.9~8.8 N•m, 70~90 kg-cm)**

✱ *Notice*
*Inspect clearance between dowel pin of camshaft end and phase sensor, before install cylinder head cover.*

**Clearance: 0.019~0.059in (0.5~1.5mm)**



AV2A10B084

12. Install the injector and install the injector bracket. (Refer to section FL)

**Tightening torque:**
**14.5~15.9 lb-ft (19.6~21.6 N•m, 2.0~2.2 kg-m)**

13. Install the front and rear engine hanger.
14. Install the upper plate assembly.
15. Install the idlers.

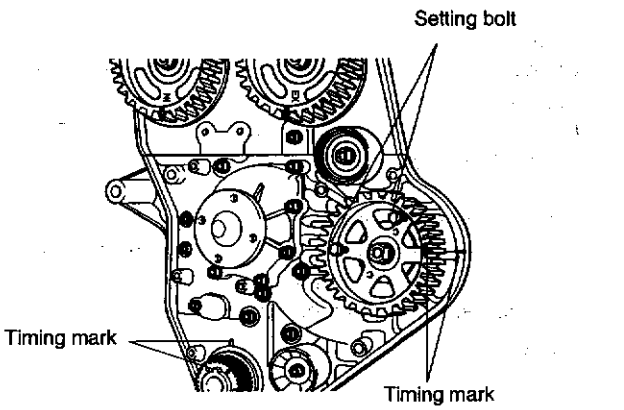
**Tightening torque :**
**29.7lb-ft (40.2N•m , 4.1kg-m)**

✱ *Notice*
*Be careful that the idlers does not change.*
*Idler No.1( ø 2.36in( ø 60mm)),Idler No.2( ø 2.16in ( ø 55mm))*

16. Install the high pressure pump.
    1) Tighten the high pressure pump assembly fixing bolts after installed the high pressure pump to the timing case.

**Tightening torque :**
**15.9~18.8lb-ft (21.6~25.5N•m , 2.2~2.6kg-m)**

    2) Pre-tighten the high pressure pump pulley lock nut after installed the high pressure pump pulley to the high pressure pump shaft with key.
    3) Fix the high pressure pump pulley by used to two setting bolts, after aligned the high pressure pump pulley timing mark as shown illust.



BV2A10B002A

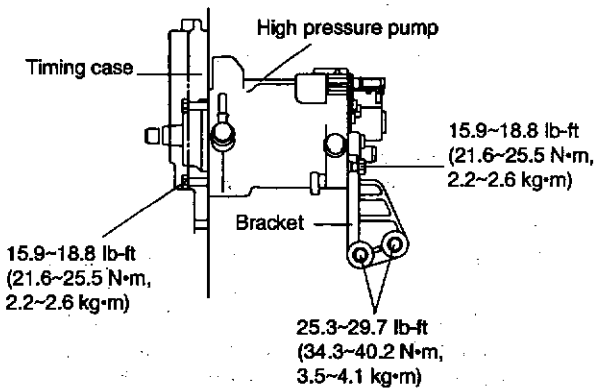
    4) Tighten the high pressure pump pulley lock nut.

**Tightening torque :**
**47.0lb-ft (63.7N•m , 6.5kg-m)**

    5) Install the high pressure pump bracket to the high pressure pump and cylinder block.

***Caution***
***First tighten the cylinder block side bolts and then second tighten the pump side bolts after checking that there is no clearance between bracket and pump.***

**Tightening torque :**
**Pump side :**
**15.9~18.8lb-ft (21.6~25.5N•m , 2.2~2.6kg-m)**
**Cylinder block side :**
**25.3~29.7lb-ft (34.3~40.2N•m , 3.5~4.1kg-m)**

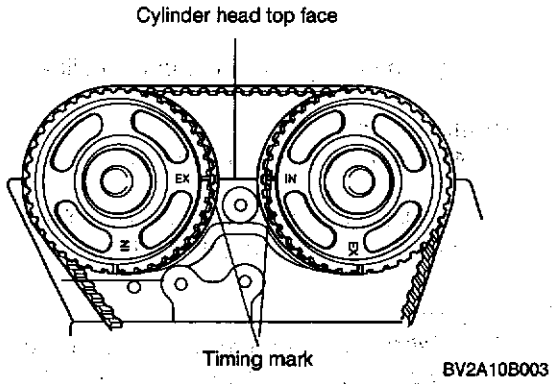



17. Align the crankshaft pulley timing mark.

***Caution***
***When the crankshaft is rotated without timing belt, could damage piston and valve.***
***Before assemble the cylinder head, align TDC for No.1 piston.***

18. Align the camshaft pulley timing mark.
    1) Align "EX"mark of the left camshaft pulley and "IN" mark of the right camshaft pulley to the cylinder head top face as shown illust

***Caution***




***When the camshaft is rotated without timing belt, could damage piston and valve.***
***Before assemble the cylinder head, align the camshaft pulley timing mark***

    2) Install the camshaft fixing tool (SST) between two camshaft pulleys.
    3) Tighten the camshaft pulley lock nut.

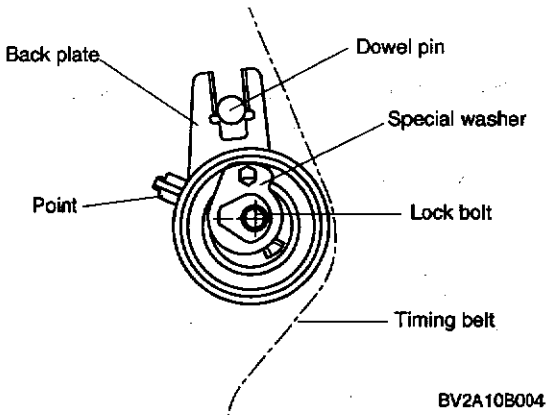
**Tightening torque :**
**47.0lb-ft (63.7N•m , 6.5kg-m)**

    4) Remove the camshaft fixing tool (SST).

19. Install the timing belt.
    1) The timing belt is installed in sequence crank shaft pulley, idler No.2, high pressure pump pulley, idler No.1 and camshaft pulley.

✱ *Notice*
*a) The auto-tensioner must be mounted onto the engine after the timing belt is installed.*
*b) Keep the tension of timing belt when install timing belt.*

20. Install the auto-tensioner.
    1) Install the auto-tensioner as shown illust. The dowel pin has to be located between the tensioner fork (back plate).




    2) Pretighten the auto-tensioner.

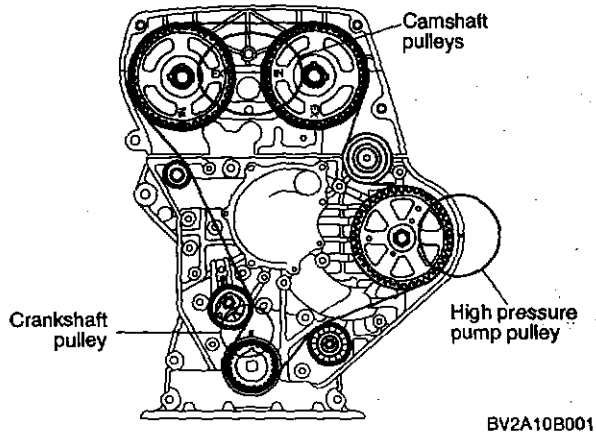
**Tightening torque :**
**2.9lb-ft (3.9N•m , 0.4kg-m)**

✱ *Notice*
*a) Oil must not get in contact with the tensioner. The tensioner has to be replaced by a new one, if it is oily.*
*b) The positions of the pointer, the back plate and the special washer are in accordance to the illust.*

21. Install the touch idler.

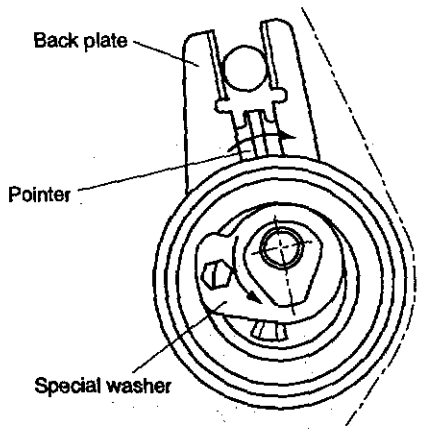
**Tightening torque :**
**17.4lb-ft (23.5N•m , 2.4kg-m)**

22. Remove two setting bolts from the high pressure pump pulley.
23. Check again if the alignment marks of camshafts, crankshaft and high pressure pump are aligned with the marks on the timing case.




BV2A10B001

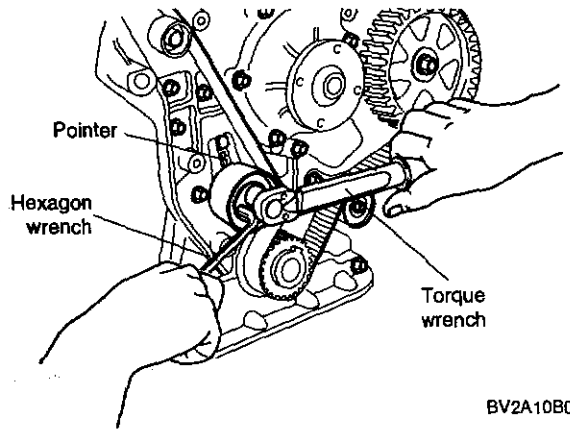
24. Adjust the auto-tensioner, and then tighten it.
    1) Align the pointer to the back plate by rotating the special washer in counter-clockwise using the hexagon wrench as shown illust.




BV2A10B005

    2) Tighten the auto-tensioner lock bolt with holding the special washer by the hexagon wrench when the pointer is aligned with the back plate.

**Tightening torque :**
**17.4lb-ft (23.5N•m , 2.4kg-m)**

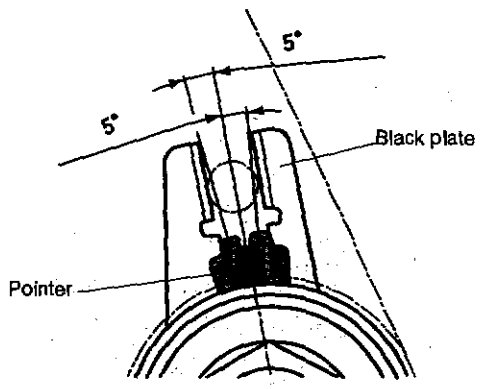



BV2A10B006

    3) Remove the hexagon wrench.

✱ *Notice*
*If the pointer can not be aligned with the back plate, then a new belt has to be used.*

25. Rotate the crankshaft two full revolutions in clockwise to align the TDC mark.
26. Check again if the alignment marks of camshafts, crankshaft and high pressure pump are aligned with the marks on the timing case.
27. Check the alignment of the pointer and back plate.

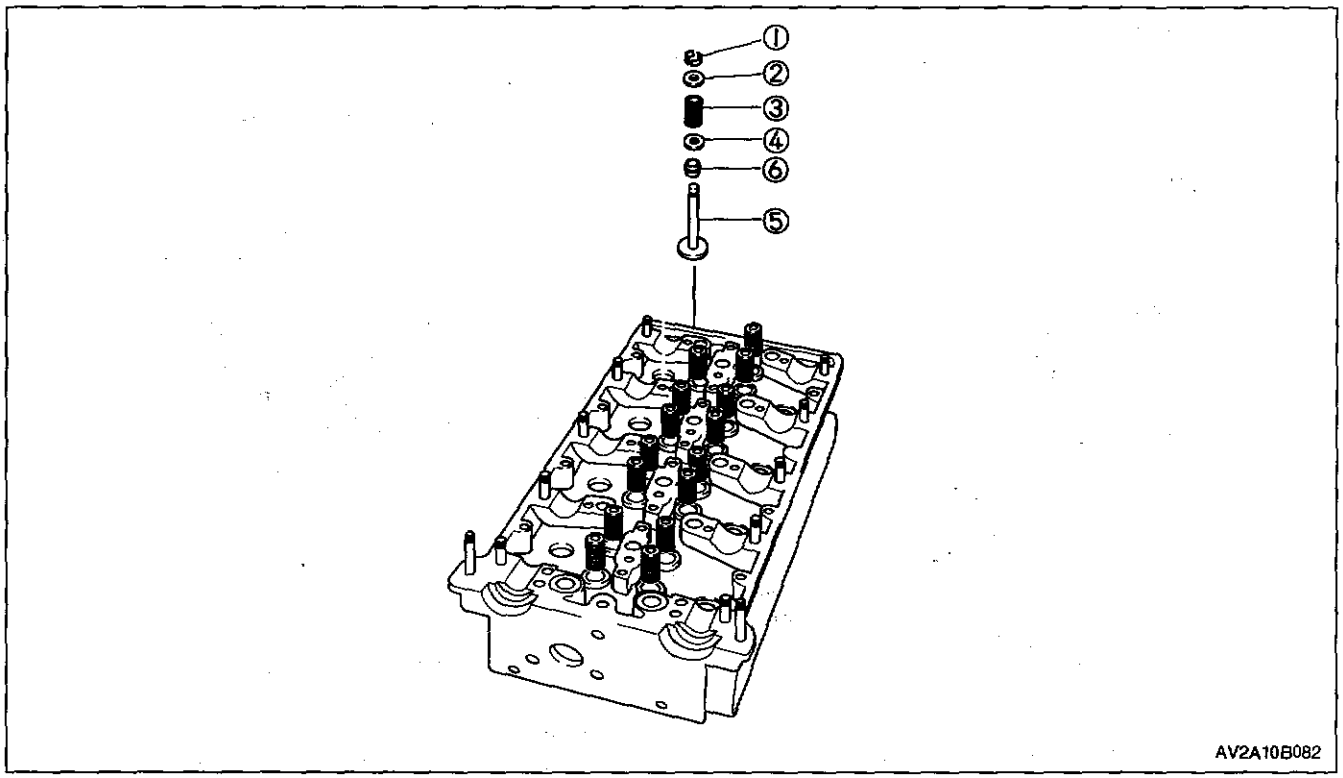



BV2A10B007

**Allowance misalignment : ±5°**

28. If the misalignment between pointer and back plate is bigger than (±5°), repeat step 23~27.

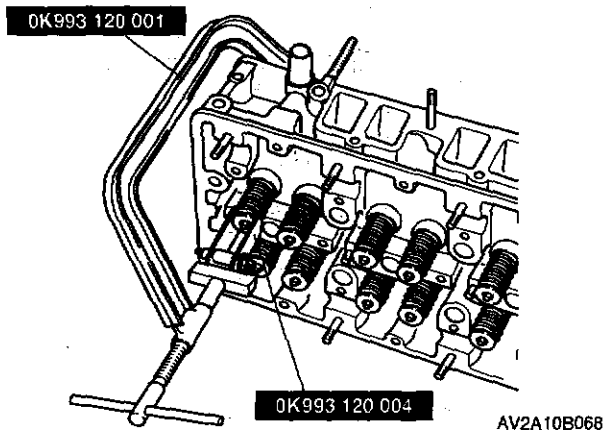
## Cylinder head




(1) Valve cotter
(2) Valve spring upper seat
(3) Valve spring
(4) Valve spring lower seat
(5) Valve
(6) Valve seal

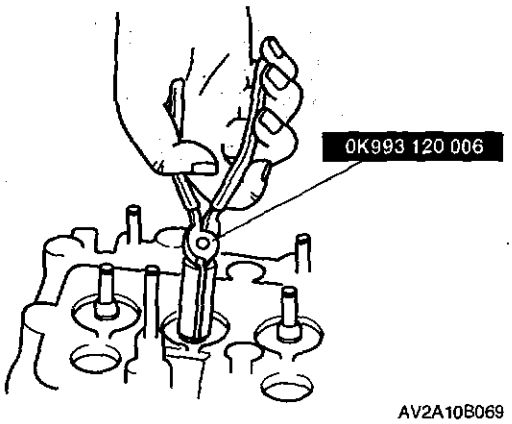
### Disassembly

1. Remove the valve cotter by using the **SST (0K993 120 001 / 0K993 120 004)**.




2. Remove the valve spring upper seat, valve spring, valve spring lower seat and valve.

3. Pull the valve seal out by using the **SST (0K993 120 006)**.



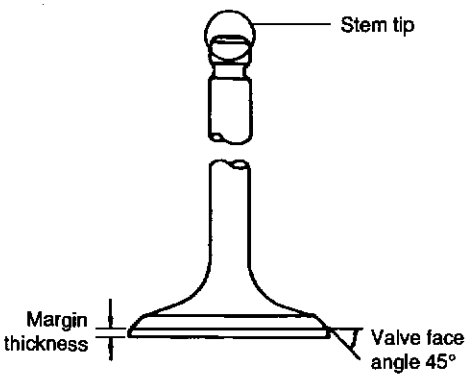
## Inspection

### Valve mechanism

1. Inspect each valve for following:
   a. Damaged or bent valve stem
   b. Rough or damaged face
   c. Damaged or unevenly worn stem tip

2. Resurface or replace valve as needed.

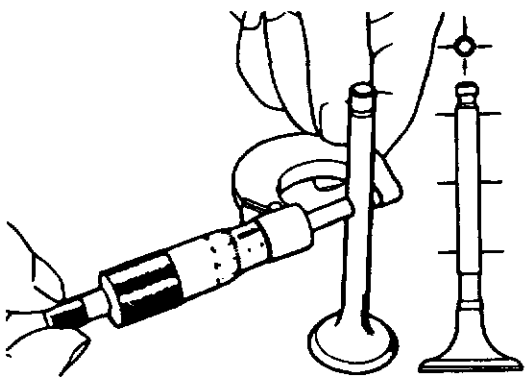
   **Margin thickness**
   **Intake: 0.047 in (1.2 mm)**
   **Exhaust: 0.043 in (1.1 mm)**




BSX010A110

3. Measure diameter of each valve stem.

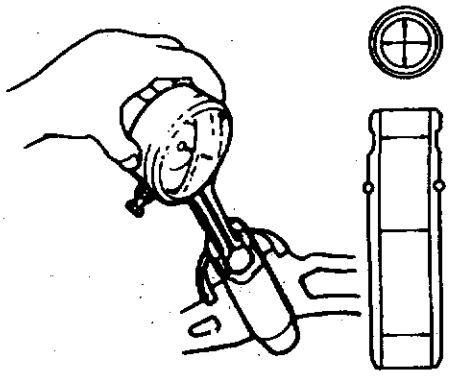
   **Diameter**
   **Intake: 0.2742~0.2748 in (6.965~6.980 mm)**
   **Exhaust: 0.2734~0.2740 in (6.945~6.960 mm)**



BSX010A111

4. Measure inside diameter of each valve guide at points shown in figure.

   **Diameter intake and exhaust valve guide:**
   **0.2759~0.2767 in (7.010~7.030 mm)**

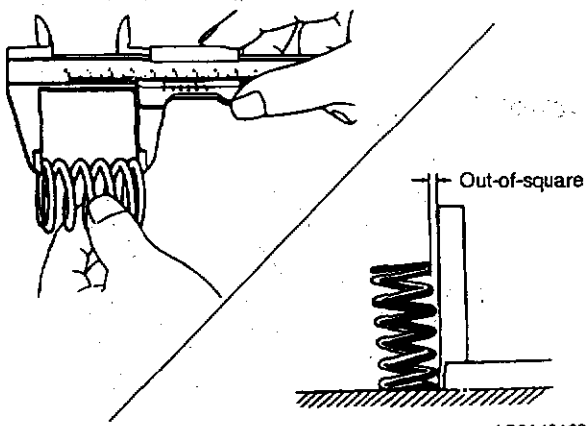


BSX010A112

### Valve spring

1. Inspect each valve spring for cracks and damage.
2. Measure free length and out-of-square. Replace valve springs as needed.

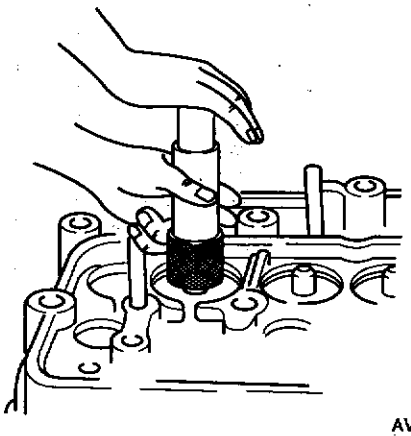
   **Free length: 2.066 in (52.47 mm)**
   **Out-of-square: 2° maximum**




AS2A10139

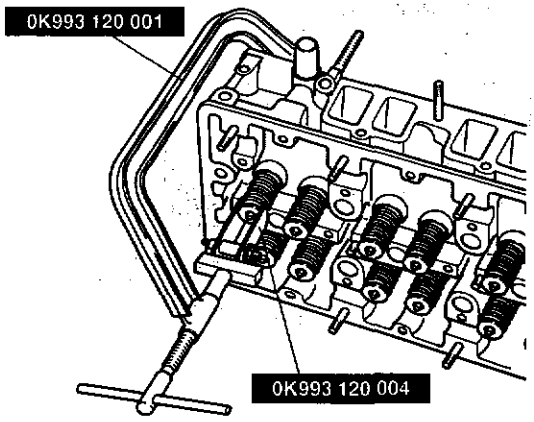
## Reassembly

1. By using the proper tool, press the valve seal.



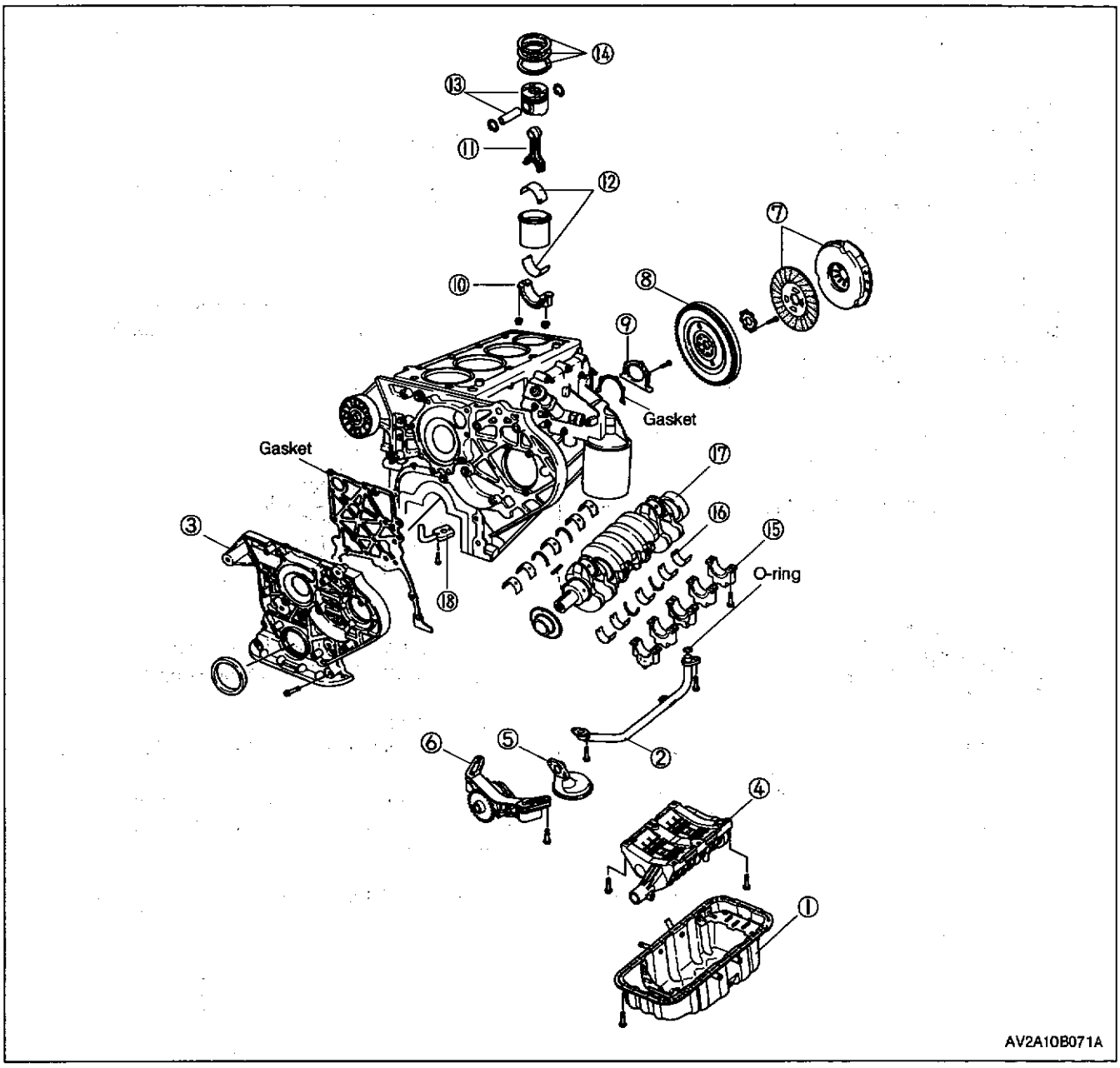
AV2A10B070

2. Install the valve, valve spring lower seat, valve spring and valve spring upper seat.
3. By using **SST (0K993 120 001 / 0K993 120 004)**, compress the valve spring and place the valve cotter securely.
4. By using a plastic hammer, tap the stem lightly to assure proper fit.




AV2A10B068

## Cylinder block




(1) Oil pan
(2) Oil feed pipe
(3) Timing belt case
(4) Ladder frame
(5) Oil strainer
(6) Oil pump
(7) Clutch cover and clutch disc (MTX only)
(8) Flywheel (MTX only)
(9) Rear cover
(10) Connecting rod cap
(11) Connecting rod
(12) Main bearing
(13) Piston and piston pin
(14) Piston rings
(15) Main bearing cap
(16) Main bearing
(17) Crankshaft
(18) Oil jet

## Disassembly

1. Remove the clutch cover, clutch disc and flywheel.
2. Remove the oil pan mounting bolts.
3. Remove oil pan with a screwdriver or suitable tool.

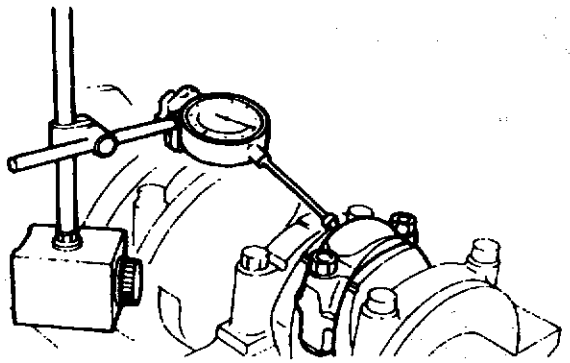
***Caution***

***a) Do not force tools between cylinder block and oil pan as this may damage sealing surface.***

***b) Do not damage sealing surface when removing old sealant.***

4. Remove the oil feed pipe.
5. Remove the timing belt case.
6. Remove the ladder frame.
7. Remove the oil strainer and oil pump.
8. Remove the lever, tensioner and guide.
9. Remove the rear cover.
10. Before removing the connecting rod, measure the connecting rod side clearance.

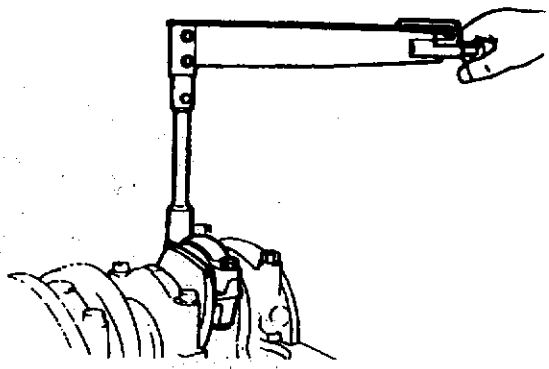
**Side clearance: 0.0055~0.0153 in (0.14~0.39 mm)**



AN9010052

11. Remove connecting rod cap.
12. Measure the connecting rod bearing oil clearance.
    1) Remove all foreign material and oil from the crank pin and bearing surface.
    2) Position Plastigage atop the crank pin in the axial direction.
    3) Install the connecting rod cap and tighten.

**Tightening torque:**
**Tighten 50.6 lb-ft (68.6 N•m, 7.0 kg-m), tighten 21.7 lb-ft (29.4 N•m, 3.0 kg-m) and then tighten 90°.**



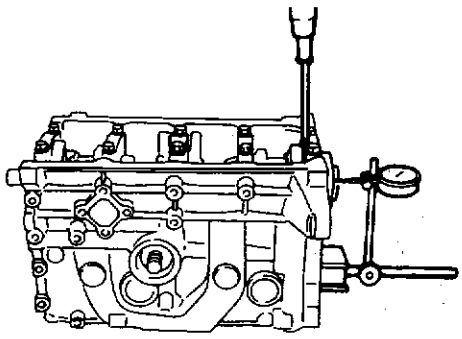
AN9010049

    4) Loosen the connecting rod cap nuts.
    5) Measure the oil clearance at each crank pin.

**Oil clearance:**
**0.00169~0.00303 in (0.043~0.077 mm)**

13. Remove the connecting rod and piston.
14. Before removing the main bearing cap, measure the crankshaft end play.

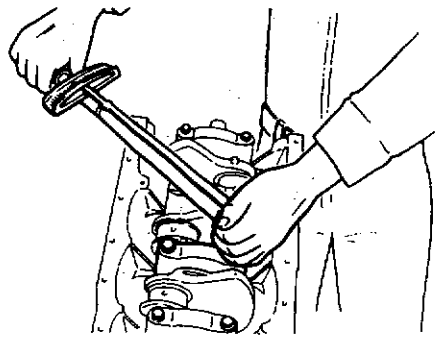
**End play: 0.0055~0.0153 In (0.14~0.39 mm)**



AN7010A165

15. Remove main bearing cap.
16. Measure the main bearing oil clearance
    1) Remove all foreign material and oil from the journals and bearing surface.
    2) Position Plastigage atop the journals in the axial direction.
    3) Install the main bearing cap and tighten as shown in the figure.

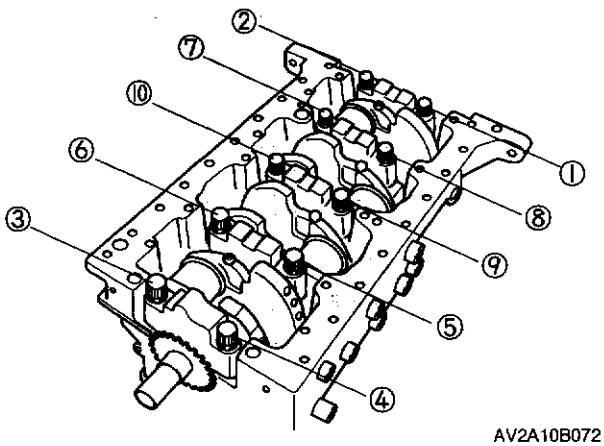
    **Tightening torque:**
    **Pretighten 54.97 lb-ft (74.5 N•m, 7.6 kg-m), and then tighten 60°.**



AN7010A164

    4) Loosen the main bearing cap bolts and remove main bearing cap.
    5) Measure the oil clearance at each journal.

    **Oil clearance:**
    **No.1,2,4,5: 0.00177~0.00311 in (0.045~0.079 mm)**
    **No.3: 0.00267~0.00397 in (0.068~0.101 mm)**
17. Loosen the main bearing cap bolts in two or three steps in the order shown in the figure.
18. Remove the main bearing cap, main bearing and crankshaft.




AV2A10B072

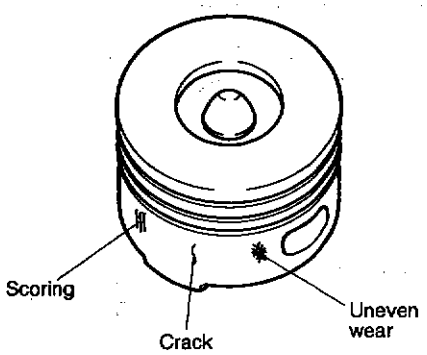
19. Remove the balance shaft and thrust plate.
20. Remove the balance gear.
21. Remove the oil jet.
22. Remove the snap ring with snap ring pliers and then remove the piston pin.
23. Using a piston ring expander, remove piston rings.

## Inspection

### Piston

✱ *Notice*
*Replacing a piston also requires replacing piston rings.*

1. Check circumference of piston for damage, scoring, or unusual wear patterns. Replace piston as needed.

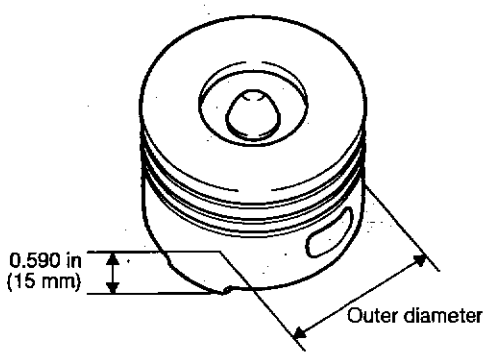



AV2A10B073

2. Check outside diameter of each piston at a 90° right angle to piston pin, 0.16 in (15 mm) above lower end of piston.

    **Piston diameter**
    **A grade: 3.8195~3.8201 in (97.015~97.030 mm)**
    **B grade: 3.8201~3.8207 in (97.030~97.045 mm)**

✱ *Notice*
*If piston is collapsed or bell mounthed, replace piston.*

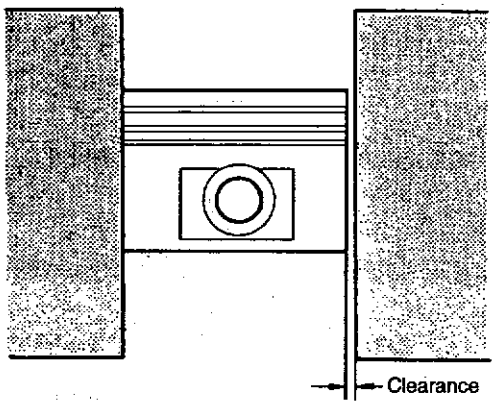



AV2A10B074

3. Check piston-to-cylinder liner wall clearance by subtracting piston diameter from the largest cylinder liner wall diameter, at each cylinder.

   **Clearance: 0.0028~0.0039 in (0.070~0.098 mm)**

4. If clearance exceeds maximum, replace piston or cylinder liner.

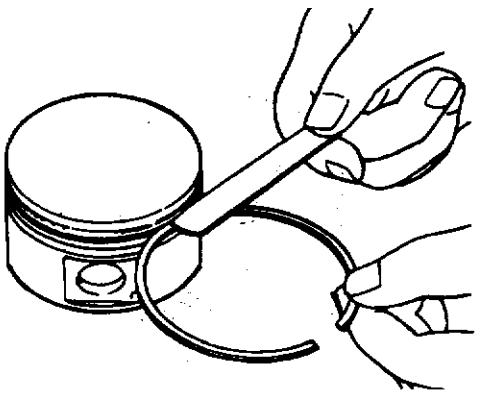



AS2A10080

## Piston rings

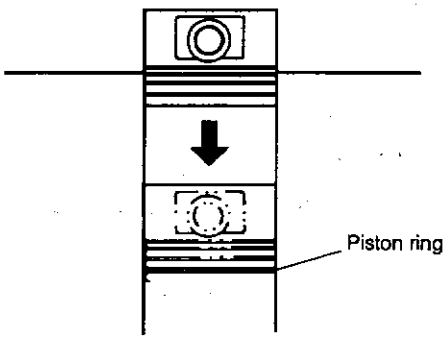
1. Insert a new piston ring into a piston ring groove and check piston ring-to-side clearance. Piston ring groove clearance.

   **Piston ring groove clearance:**
   **Top ring: 0.0029~0.0040 in (0.076~0.102 mm)**
   **Second ring: 0.0016~0.0031 in (0.040~0.080 mm)**
   **Oil ring: 0.0012~0.0028 in (0.030~0.070 mm)**
   **Limit: 0.0118 in (0.30 mm)**



AS2A10081

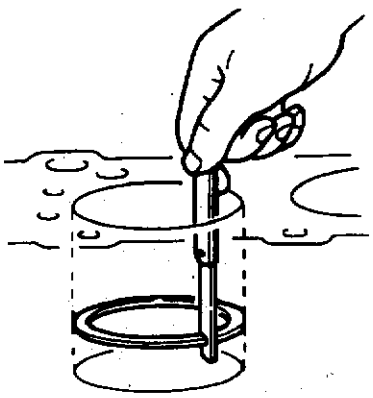
2. If clearance exceeds the limit, replace piston.
3. Inspect piston rings for damage, abnormal wear, or breakage.
4. Replace piston rings if necessary.
5. Insert piston ring into cylinder by hand.
6. Square ring in cylinder by inverting a piston into cylinder and pushing ring to the bottom of its travel in cylinder liner.




AS2A10081

7. Place a feeler gauge in end gap and check end gap clearance.

   **End gap clearance:**
   **Top ring: 0.0118~0.0177 in (0.30~0.45 mm)**
   **Second ring: 0.0157~0.0217 in (0.40~0.55 mm)**
   **Oil rail: 0.0079~0.0157 in (0.20~0.40 mm)**
   **Limit: 0.0591 in (1.50 mm)**



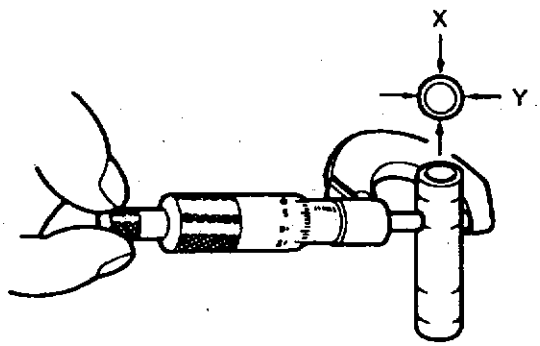
ABT010208

8. Replace piston ring if necessary.

### Piston pin

1. Measure each piston pin diameter at X and Y direction at four locations shown.

   **Diameter: 1.2596~1.2598 in (31.994~32.000 mm)**

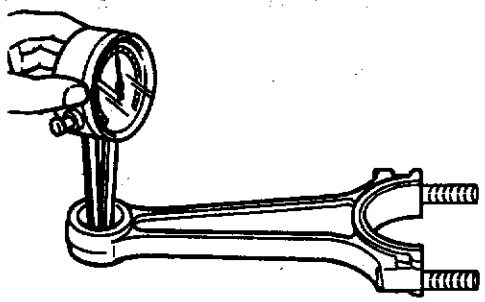



AS2A10142

### Connecting rod

1. Check connecting rod bushing inside diameter.

   **Inside diameter:**
   **1.2603~1.2611 in (32.012~32.033 mm)**

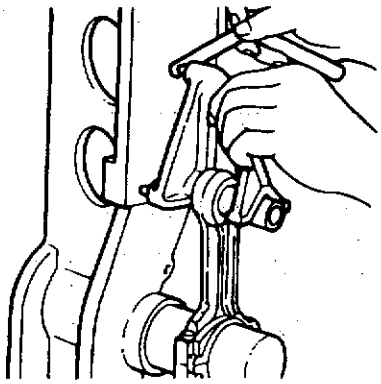


AS2A10143A

2. Subtract piston pin diameter from connecting rod bushing inside diameter to determine piston pin fit.

   **Clearance: 0.0005~0.0015 In (0.012~0.039 mm)**

3. If clearance is not within specification, replace connecting rod bushing.
4. Check each connecting rod for bending.



ABT010210

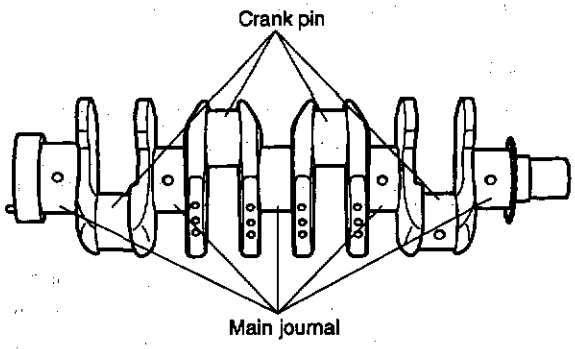
5. Replace connecting rods if necessary.

✱ *Notice*
*Connecting rods must always be replaced as an assembly. Rod cap, rod, bolts and nuts are a matched set.*

### Crankshaft

1. Check crankshaft bearing and crank pin journals for damage and scoring.
2. Check oil holes for clogging.
3. Set crankshaft on V-blocks.
4. Measure crankshaft run-out at center journal. Replace crankshaft if it is not within specification.

   **Run-out: 0.0055~0.0154 in (0.14~0.39 mm)**




AV2A10B075

### Pin journal bearing selection

1. Check the connecting rod big-end bore size code.

✱ *Notice*
*The code is carved on connecting rod cap bolt hole side.*

**Connecting rod big-end bore diameter**

| Grade | Connecting rod big-end bore diameter |
|---|---|
| 1 | 2.39499~2.39523 in (60.833~60.839 mm) |
| 2 | 2.39523~2.39550 in (60.839~60.846 mm) |

**Crankshaft pin journal diameter:**
**2.24827~2.24898 in (57.106~57.124 mm)**

2. Choose the proper pin journal bearing as below table.

**Pin journal bearing clearance:**
**0.00138~0.00272 in (0.035~0.069 mm)**

**Pin journal bearing selection table**

| Connecting rod grade | Pin journal bearing grade | Oil clearance |
|---|---|---|
| 1 | Blue | 0.00146~0.00272 in (0.037~0.069 mm) |
| 2 | Red | 0.00138~0.00268 in (0.035~0.068 mm) |

✱ *Notice*
*Painting mark is located on the bearing side face.*

**Pin journal bearing thickness**

| Color | Pin journal bearing thickness |
|---|---|
| Blue | 0.07213~0.07228 in (1.832~1.836 mm) |
| Red | 0.07228~0.07244 in (1.836~1.840 mm) |

3. Position properly upper bearing and lower bearing to connecting rod and connecting rod cap and then install connecting rod and connecting rod cap to crankshaft pin journal

**Tightening torque:**
**Tighten 50.6 lb-ft (68.6 N•m, 7.0 kg-m), tighten 21.7 lb-ft (29.4 N•m, 3.0 kg-m) and then tighten 90°.**

### Main journal bearing selection

1. Check the cylinder block main bearing bore size code.

✱ *Notice*
*The code is located on the side of ladder frame bolt hole.*

**Cylinder block main bearing bore diameter**

| Code | Cylinder block main bearing bore diameter |
|---|---|
| A | 2.91598~2.91633 in (74.066~74.075 mm) |
| • | 2.91633~2.91669 in (74.075~74.084 mm) |
| C | 2.91669~2.91700 in (74.084~74.092 mm) |

2. Check the crankshaft main journal size code.

✱ *Notice*
*The code is located on the between main journal and pin journal.*

**Crankshaft main journal diameter**

| Code | Crankshaft main journal diameter | |
|---|---|---|
| | No. 1, 2, 4, 5 | No. 3 |
| A | 2.75570~2.75598 in (69.995~70.002 mm) | 2.75483~2.75511 in (69.973~69.980 mm) |
| • | 2.75598~2.75625 in (70.002~70.009 mm) | 2.75511~2.75539 in (69.980~69.987 mm) |
| C | 2.75625~2.75649 in (70.009~70.015 mm) | 2.75539~2.75562 in (69.987~69.993 mm) |

3. Choose the proper main journal bearing in below table.

**Main journal bearing selection table**

| | | Cylinder block main bearing bore size code | | |
|---|---|---|---|---|
| | | A | • | C |
| Crankshaft main journal size code | A | Brown | Black | Black |
| | • | Green | Brown | Black |
| | C | Yellow | Green | Brown |

**Main journal bearing clearance:**
**No.1,2,4,5: 0.00146~0.00280 in (0.037~0.071 mm)**
**No.3: 0.00232~0.00366 in (0.059~0.093 mm)**

**Main journal bearing thickness**

| Color | Main journal bearing thickness |
|---|---|
| Black | 0.07925~0.07945 in (2.013~2.018 mm) |
| Brown | 0.07905~0.07925 in (2.008~2.013 mm) |
| Green | 0.07886~0.07905 in (2.003~2.008 mm) |
| Yellow | 0.07866~0.07886 in (1.998~2.003 mm) |

4. Position properly upper bearing and lower bearing to cylinder block and main bearing cap.
5. Set crankshaft to cylinder block and then install main bearing cap to cylinder block.

**Tightening torque:**
**Pretighten 54.97 lb-ft (74.5 N•m, 7.6 kg-m), and then tighten 60°.**

## Cylinder liner and piston selection

1. Check the cylinder bore inner diameter size code of cylinder block.

✱ *Notice*
*The code is carved on the top of each cylinder.*

**Cylinder bore inner diameter**

| Code | Cylinder bore inner diameter |
|---|---|
| Y | 3.9966~3.9971 in (101.513~101.526 mm) |
| X | 3.9960~3.9966 in (101.500~101.513 mm) |

2. Choose the proper cylinder liner as below table.

**Clearance between cylinder liner and cylinder bore of cylinder block :**
**0.0003~0.0013 in (0.007~0.033 mm)**

**Cylinder liner selection table**

| Cylinder bore size code | Cylinder liner mark | Oil clearance |
|---|---|---|
| Y | 3Y - Yellow | 0.0003~0.0013 in (0.007~0.033 mm) |
| Y | 3Y - Blue | 0.0003~0.0013 in (0.007~0.033 mm) |
| X | 3X - Yellow | 0.0003~0.0013 in (0.007~0.033 mm) |
| X | 3X - Blue | 0.0003~0.0013 in (0.007~0.033 mm) |

**Piston selection table**

| Cylinder liner mark | Piston mark | Oil clearance |
|---|---|---|
| Yellow | B | 0.0028~0.0039 in (0.070~0.098 mm) |
| Blue | A | 0.0028~0.0039 in (0.070~0.098 mm) |

✱ *Notice*
*The mark for outer diameter is carved on the out surface of liner and for inner diameter is painted on the top of liner.*

**Cylinder liner outer diameter and inner diameter**

| Code | Outer diameter | Color | Inner diameter |
|---|---|---|---|
| 3Y | 3.9958~3.9963 in (101.493~101.506 mm) | Yellow | 3.8234~3.8239 in (97.115~97.128 mm) |
| 3Y | 3.9958~3.9963 in (101.493~101.506 mm) | Blue | 3.8228~3.8233 in (97.100~97.113 mm) |
| 3X | 3.9953~3.9958 in (101.480~101.493 mm) | Yellow | 3.8234~3.8239 in (97.115~97.128 mm) |
| 3X | 3.9953~3.9958 in (101.480~101.493 mm) | Blue | 3.8228~3.8233 in (97.100~97.113 mm) |

**Piston outer diameter**

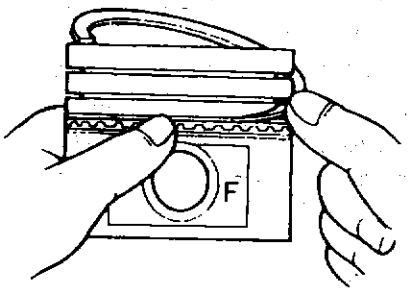
| Code | Piston outer diameter |
|---|---|
| A | 3.8195~3.8201 in (97.015~97.030 mm) |
| B | 3.8201~3.8207 in (97.030~97.045 mm) |

## Reassembly

✱ *Notice*
*a) Clean all parts before reassembly.*
*b) Apply new engine oil to all sliding and rotating parts.*

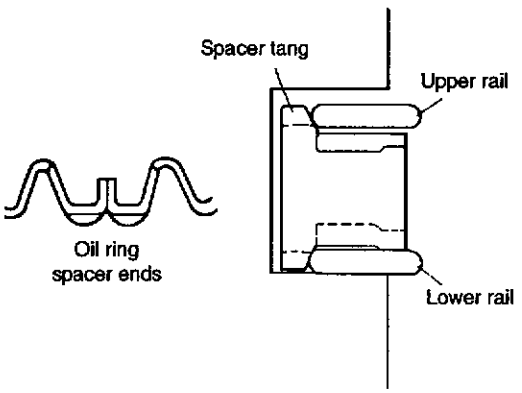
1. Install the three-piece oil rings on the pistons.
   1) Apply engine oil to the oil ring spacer and rails.
   2) Install the oil ring spacer so that the opening faces upward.
   3) Install the upper rail and lower rail.

✱ *Notice*
*a) The upper rail and lower rail are the same.*
*b) Each rail can be installed with either face upward.*




AS2A10085

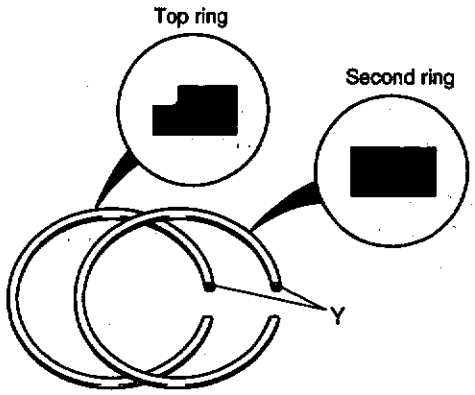
2. Check that both rails are expanded by the spacer tangs as shown in figure by checking that both rails turn smoothly in both directions.




ABT010170

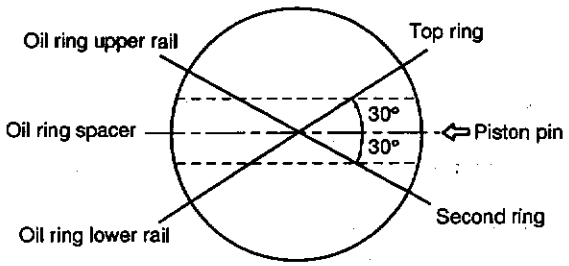
3. Install the second ring to the piston first, then install the top ring. Use piston ring expander.

✱ *Notice*
*The rings must be installed with the "Y" marks facing upward.*




AV2A10B076

4. Apply a liberal amount of clean engine oil to the second and top piston rings.
5. Position the opening of each ring as shown in the figure.

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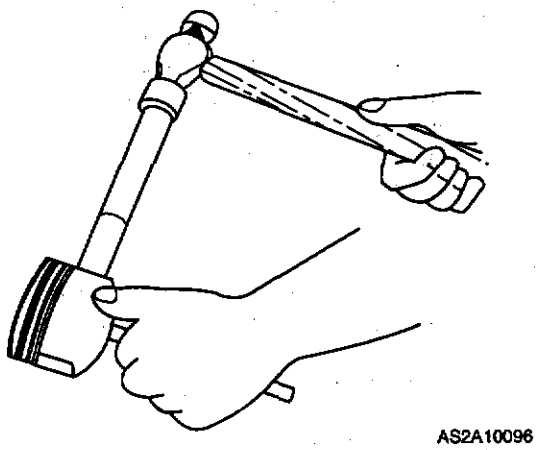
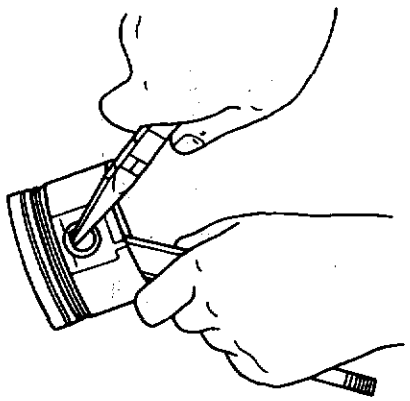
6. Install one piston pin snap ring into grooves on piston.
7. Insert connecting rod into piston and slide piston pin through piston and through connecting rod until it makes contact with the piston pin snap ring already installed.

✱ *Notice*
*Verify that piston and rod are assembled in same direction as they were prior to disassembly.*


AS2A10096

8. Install second piston pin snap ring grooves on opposite side of piston.


AS2A10097

9. Hold piston upright and move connecting rod back and forth. Check that rod moves freely.
10. Install the oil jet.
11. Before installing the crankshaft, inspect the main bearing oil clearance as follows.

### Oil clearance Inspection

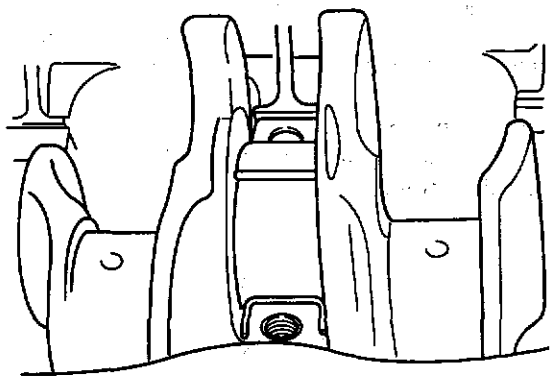
(1) Remove all foreign material and oil from the journals and bearings.

***Caution***
***a) Install the grooved upper main bearings in the cylinder block.***
***b) Install the thrust bearings with the oil groove facing the crankshaft.***

(2) Install the upper main bearings and thrust bearings.
(3) Set the crankshaft in the cylinder block.

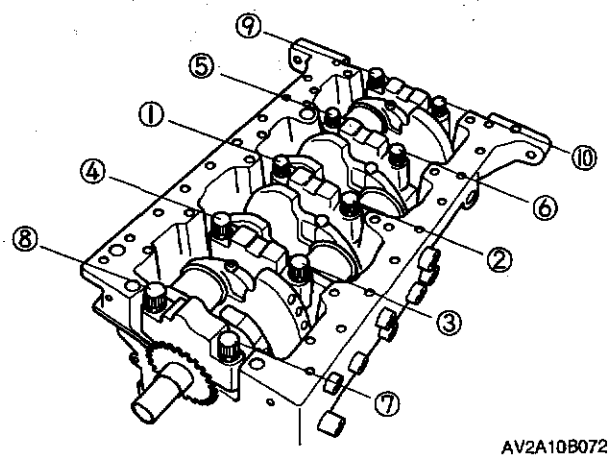
***Caution***
***Do not rotate the crankshaft when measuring the oil clearances.***

(4) Position plastigage atop the journals in the axial direction.


AV2A10B079

(5) Install the lower main bearings and the main bearing caps according to the cap number and ⇦ mark.
(6) Tighten the main bearing cap bolts in two or three steps in the order shown in the figure.

**Tightening torque:**
**Pretighten: 54.97 lb-ft (74.5 N·m, 7.6 kg-m) and then tighten 60°**



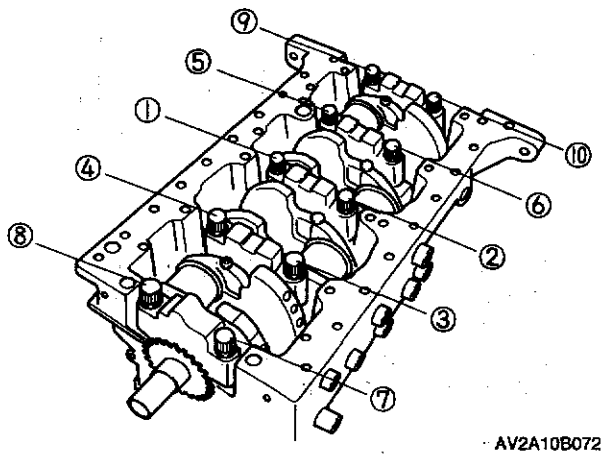
AV2A10B072

(7) Remove the main bearing caps, and measure the plastigage at each journal at the widest point for the smallest clearance and at the narrowest point for the largest clearance.
(8) If the oil clearance exceeds specification, grind the crankshaft and use undersize main bearings.

**Oil clearance:**
**No.1,2,4,5: 0.00146~0.00280 in (0.037~0.071 mm)**
**No.3: 0.00232~0.00366 in (0.059~0.093 mm)**

12. Apply a liberal amount of clean engine oil to the main bearings, thrust bearings and main journals.
13. Install the crankshaft and the main bearing caps according to the cap number and ⇦ mark.
14. Tighten the main bearing cap bolts in two or three steps in the order shown in the figure.

**Tightening torque:**
**Pretighten: 54.97 lb-ft (74.5 N•m, 7.6 kg-m) and then tighten 60°.**



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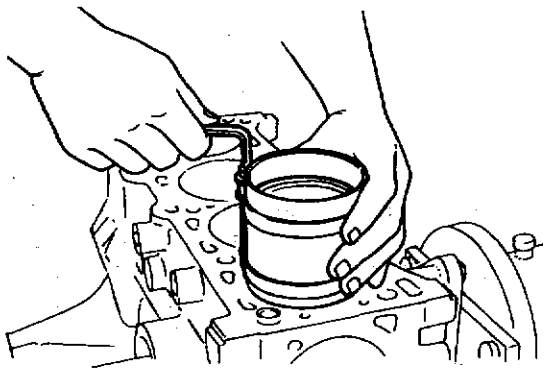
15. Before installing the connecting rod, inspect the connecting rod bearing oil clearance as follows.
    (1) Slip piston and connecting rod assembly into a piston ring compressor.
    (2) Rotate crankshaft so that crank pin journal for specific cylinder is at its lowest point(bottom dead center).
    (3) Lower piston and connecting rod assembly until piston ring compressor makes contact with dect surface of engine block.

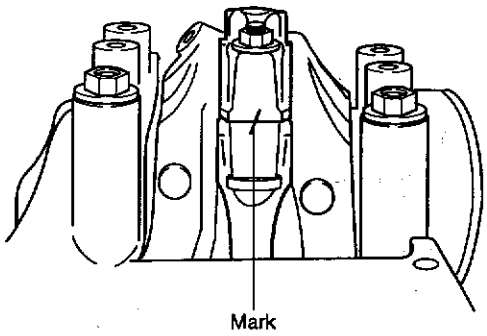

BSX010B103

    (4) Using butt end of a hammer, tap the top of piston into cylinder and continue tapping until connecting rod makes contact with crankshaft.
    (5) Install a connecting rod bearing in each connecting rod cap.
    (6) Place a piece of Plastigage® on crank pin journals.

✱ *Notice*
*Align the maching marks on the cap and connecting rod when installing the connecting rod cap.*

    (7) Install connecting rod caps.

**Tightening torque:**
**Tighten 50.6 lb-ft (68.6 N•m, 7.0 kg-m), tighten 21.7 lb-ft (29.4 N•m, 3.0 kg-m) and then tighten 90°**



AV2A10B080

    (8) Loosen and remove connecting rod caps.
    (9) Check the connecting rod bearing clearance.

**Oil clearance:**
**0.00138~0.00272 in (0.035~0.069 mm)**

    (10) If oil clearance exceeds maximum oil clearance specification, grind the crankshaft and use undersized connecting rod bearings.
    (11) Apply a coat of clean engine oil to connecting rod bearing in connecting rod cap.
    (12) Install connecting rod cap and torque to specification.

**Tightening torque:**
**Tighten 50.6 lb-ft (68.6 N•m, 7.0 kg-m), tighten 21.7 lb-ft (29.4 N•m, 3.0 kg-m) and then tighten 90°**

16. Install the oil pump and oil strainer.
17. Inatall the oil feeding pipe into the ladder frame, oil pump and block, and then tighten bolts.

    **Tightening torque (oil feeding pipe bolt):**
    **16.6 lb-ft (23 N•m, 2.3 kg-m)**

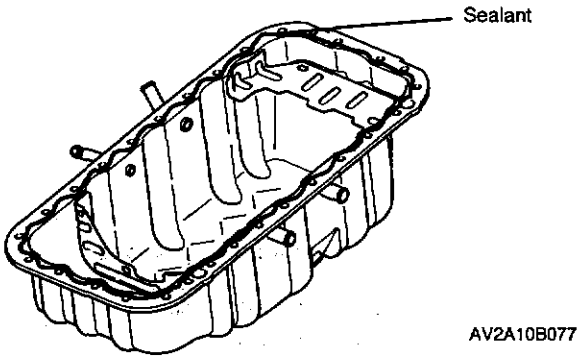
18. Install the crankshaft sprocket and oil pump sprocket.
19. Install the timing belt case.
20. Install the rear cover.

    **Tightening torque:**
    **5.8~7.9 lb-ft (7.8~10.8 N•m, 80~110 kg-m)**

21. Remove all foreign material from gasket surface.

✱ *Notice*
*Install oil pan within five minutes of applying silicone sealer.*

22. Apply a continuous bead of silicone sealant to oil pan contact surfaces.




23. Install the oil pan.
24. Install the flywheel, clutch disc and clutch cover.

# SYMPTOM-RELATED DIAGNOSTIC PROCEDURE

## Cooling system

### Diagnostic chart

| Problem | Possible Cause | Action |
|---|---|---|
| Overheating | Coolant level insufficient | Add |
| | Coolant leakage | Repair |
| | Radiator fins clogged | Clean |
| | Radiator cap malfunction | Replace |
| | Fan motor malfunction | Replace |
| | Thermostat malfunction | Replace |
| | Water passage clogged | Clean |
| | Water pump malfunction | Replace |
| Corrosion | Impurities in coolant | Replace |

# SPECIFICATION

## Cooling system

### Specification

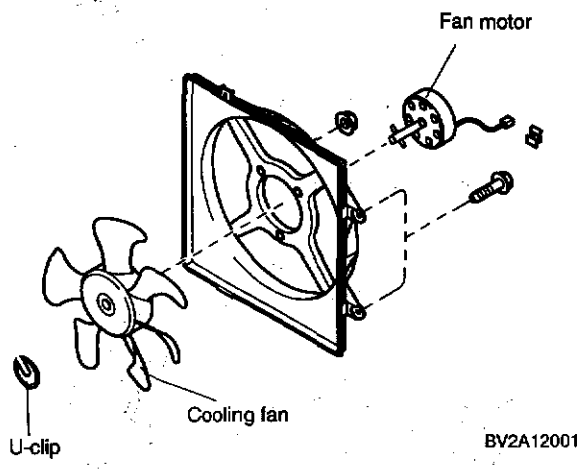
| Item \ Engine model | | | J3 COMMON RAIL SYSTEM |
|---|---|---|---|
| Cooling system | | | Water-cooled, forced circulation |
| Coolant capacity | | Us qt (liter, Imp qt) | 9.93 (9.4, 8.27) |
| Water pump | Type | | Centrifugal |
| Thermostat | Type | | Wax |
| | Initial opening temperature | °F (°C) | 187.7~193.1 (86.5~89.5) |
| | Full-open temperature | °F (°C) | 212 (100) |
| | Full-open lift | in (mm) | 0.33 (8.5) minimum |
| Radiator | Type | | Corrugated fin |
| | Cap valve opening pressure | Psi (kPa, kg/cm² ) | 10.7~14.9 (73.6~103.0, 0.75~1.05) |
| Cooling fan | Type | | Thermo type with plate type bimetal |
| | Operating temperature | °F (°C) | Above 208.4 (98) - Low speed |
| | | | Above 221 (105) - High speed |
| | Number of blades | | 5 |
| | Outer diameter | in (mm) | 14.4 (366) |

# REMOVAL AND REPLACEMENT PROCEDURE

## Cooling fan motor

### Removal

1. Disconnect negative battery cable.
2. Remove fresh air duct.
3. Disconnect cooling fan motor connector.
4. Remove three bolts securing cooling fan assembly.




5. Remove cooling fan assembly.
6. Remove U-clip securing cooling fan and remove cooling fan.
7. Remove nuts securing fan motor and remove fan motor.

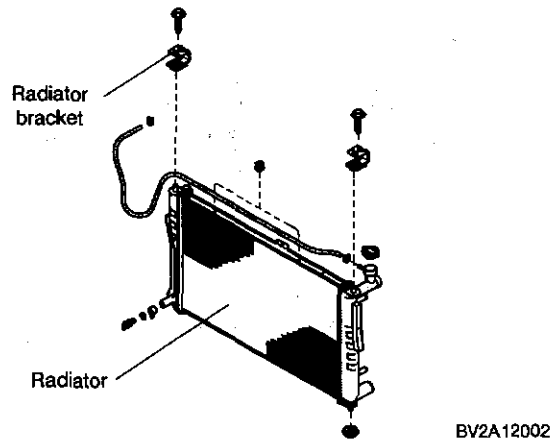
### Replacement

1. Install fan motor.
2. Install cooling fan to fan motor by use of U-clip.
3. Install cooling fan assembly.
4. Reconnect cooling fan motor connector.
5. Install fresh air duct.
6. Reconnect negative battery cable.

## Radiator

### Removal

1. Drain engine coolant.
2. Remove cooling fan assembly.
   *(Refer to cooling fan motor removal ; from step 1 to step 5.)*
3. Disconnect coolant upper hose.
4. Disconnect reserve tank hose.
5. Disconnect coolant lower hose.
6. Remove radiator brackets.




7. Remove radiator.

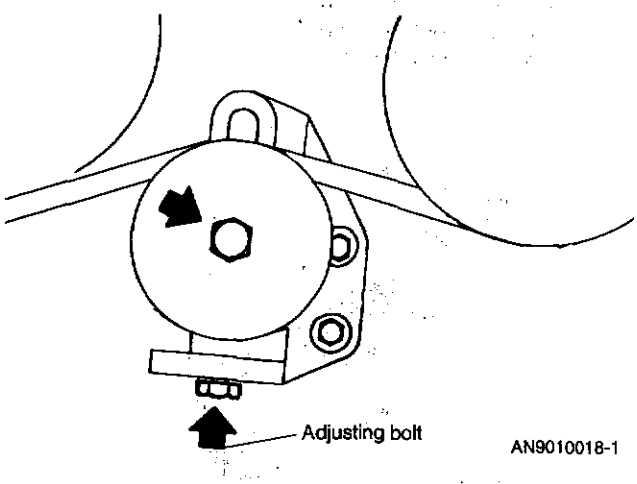
## Replacement

1. Install radiator.
2. Install radiator bracket.
3. Reconnect coolant lower hose.
4. Reconnect reserve tank hose.
5. Reconnect coolant upper hose.
6. Install cooling fan assembly.
7. Refill engine coolant.

# Water pump

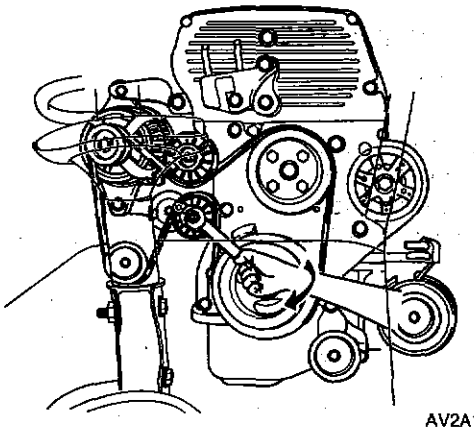
## Removal

1. Drain engine coolant.
2. Raise vehicle and support it with safety stands.
3. Remove RH side wheel.
4. Loosen A/C drive belt tension by turning idler adjusting bolt.



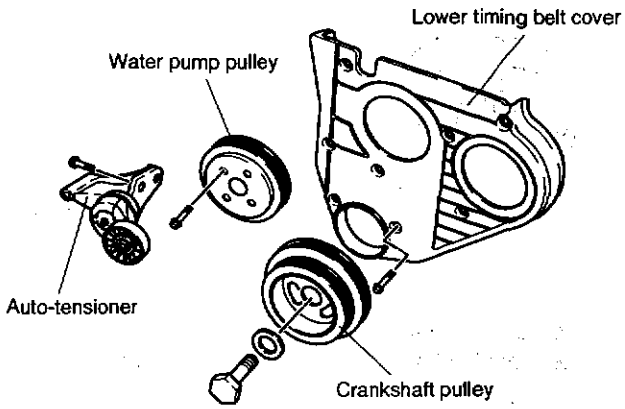

AN9010018-1

5. Remove A/C drive belt.
6. Lower auto-tensioner with spanner and then remove drive belt.



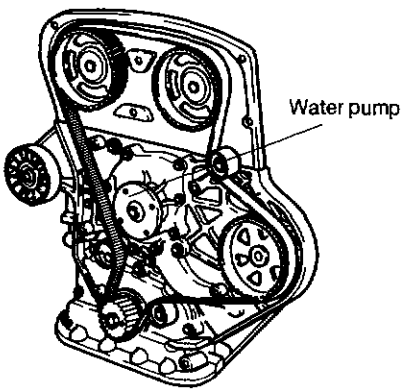
AV2A10B038

7. Remove auto-tensioner.




BV2A12003

8. Remove water pump pulley.
9. Remove crankshaft pulley.
10. Remove lower timing belt cover.
11. Remove water pump.




BV2A12004

## Replacement

1. Install new gasket and water pump.
2. Install lower timing belt cover.

   **Tightening torque:**
   **5.1~7.2 lb-ft (6.9~9.8 N•m, 0.7~1 kg-m)**

3. Install crank shaft pulley.

   **Tightening torque:**
   **253~289 lb-ft (343~392 N•m, 35~40 kg-m)**

4. Install water pump pulley.

   **Tightening torque:**
   **13.0~20.9 lb-ft (17.6~28.4 N•m, 1.8~2.9 kg-m)**

5. Install auto-tensioner.

   **Tightening torque:**
   **13.0~20.9 lb-ft (17.6~28.4 N•m, 1.8~2.9 kg-m)**

6. Lower auto-tensioner with spanner and then install drive belt.
7. Install A/C drive belt.
8. Adjust belt deflection by turning adjusting bolt.

   **Deflection (when applying 22 lb, 98 N, 10 kg)**
   **New one : 0.28~0.35 in (7~9 mm)**
   **Used one : 0.35~0.43 in (9~11 mm)**

9. Install RH side wheel.

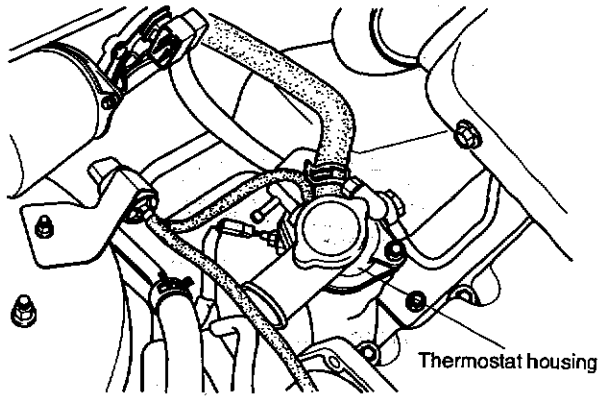
   **Tightening torque:**
   **65~79 lb-ft (88~107 N•m, 9~11 kg-m)**

10. Refill engine coolant.

# Thermostat

## Removal

1. Remove two bolts securing thermostat housing.




AV2A10B044

2. Remove thermostat and gasket.
3. Replace thermostat if necessary.

## Replacement

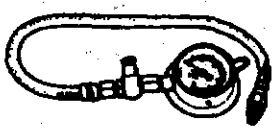
1. Install thermostat.
2. Install new gasket and thermostat housing.

# SPECIAL SERVICE TOOL

## Lubrication system
### Special service tool

**0K670 140 015**

**Oil pressure gauge**



Used to inspect oil pressure.

# SYMPTOM-RELATED DIAGNOSTIC PROCEDURE

## Lubrication system
### Diagnostic chart

| Problem | Possible Cause | Action |
|---|---|---|
| Engine hard starting | Improper engine oil<br>Insufficient engine oil | Replace<br>Add oil |
| Excessive oil consumption | Internal engine wear<br>Oil leak | *Refer to Section EM*<br>Repair |
| Oil pressure drop | Insufficient oil<br>Oil leakage<br>Worn and/or damaged oil pump gear<br>Worn plunger (inside oil pump) or weak spring<br>Clogged oil strainer<br>Excessive main bearing or connecting rod bearing clearance | Add oil<br>Repair<br>Replace<br>Replace<br>Clean<br>*Refer to Section EM* |
| Warning lamp illuminates while engine is running | Oil pressure drop<br>Malfunction of oil pressure switch<br>Malfunction of electrical system | As described above<br>*Inspect oil pressure switch*<br>*Inspect electrical system* |

# SPECIFICATION

## Lubrication system

### Specification

| Item \ Engine model | | | J3 COMMON RAIL SYSTEM |
|---|---|---|---|
| Lubrication system | | | Force-fed type |
| Oil pump | Type | | Trochoid gear |
| | Relief pressure | psi (kPa, kg/cm²) | 78.2~92.4 (539~637, 5.5~6.5) |
| Oil filter | Type | | Full-flow type, Paper element |
| | Relief pressure differential | psi (kPa, kg/cm²) | 11.4~17.1 (78~118, 0.8~1.2) |
| Oil pressure switch activation pressure | | psi (kPa, kg/cm²) | 2.8~4.9 (20~34, 0.2~0.35) |
| Oil capacity | Total (dry engine) | Us qt (liter, Imp qt) | 7.50 (7.1, 6.2) |
| | Oil pan | Us qt (liter, Imp qt) | 5.92 (5.6, 4.9) |
| | Oil filter | Us qt (liter, Imp qt) | 0.63 (0.6, 0.5) |
| Engine oil | | | API service CF-4, CG-4<br>SAE 10W-30 |

# ON-VEHICLE SERVICE PROCEDURE

## Engine oil replacement

**⚠ WARNING**
**BE CAREFUL WHEN DRAINING BECAUSE OIL IS HOT AND COULD CAUSE PERSONAL INJURY.**

1. Warm engine to normal operating temperature and turn engine off. Position a suitable container under oil pan.
2. Remove oil filler cap and oil pan drain plug.
3. Allow oil to be fully drained.
4. Install drain plug with new gasket.

   **Tightening torque:**

   **23.1~30.4 lb-ft (31.4~41.2 N•m, 3.2~4.2 kg-m)**

5. Refill engine with specified type and amount of engine oil.(*Refer to specification table; page EM-LU-3*)
6. Install oil filler cap.
7. Run engine and check for leaks.
8. Check oil level by level gauge and add oil if necessary.

## Oil pressure check

1. Disconnect and remove oil pressure switch.
2. Install oil pressure gauge into oil pressure switch installation hole.
3. Warm engine to normal operating temperature.
4. Run engine and note gauge readings.

   **Oil pressure:**

   **45.5~71.1 psi (314~490 kPa, 3.2~5.0 kg/cm² )-3,000 rpm**

5. If pressure is not within specification, check for cause, and repair. (*Refer to Symptom-related diagnostic procedure; page EM-LU-2.*)
6. Remove oil pressure gauge and install oil pressure switch.

   **Tightening torque:**
   **8.7~13.0 lb-ft (11.7~17.6 N•m, 1.2~1.8 kg-m)**

## Oil filter replacement

1. Remove oil filter with oil filter wrench. If rubber seal is stuck to engine, remove it.
2. Apply a small amount of clean engine oil to rubber seal of new filter.
3. Install oil filter and turn it by hand until rubber seal contacts base.
4. Tighten filter 1-1/6 turns with filter wrench.

   **Tightening torque:**

   **16~18 lb-ft (21.6~24.5 N•m, 2.2~2.5 kg-m)**

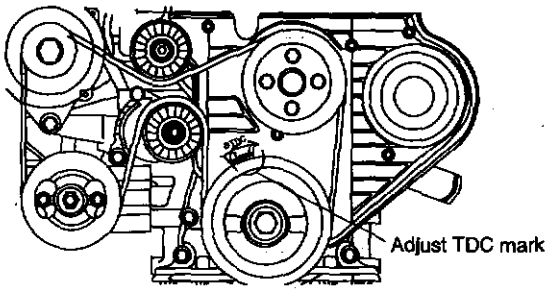
5. Start engine and check for leaks.
6. Turn engine off, and wait 5 minutes. Check oil level and add oil if necessary.

# REMOVAL AND REPLACEMENT PROCEDURE

## Oil pump

### Removal

1. Remove oil pan.
2. Adjust V groove TDC mark on outside of pulley to TDC mark "T" on timing cover, by rotating crankshaft pulley.

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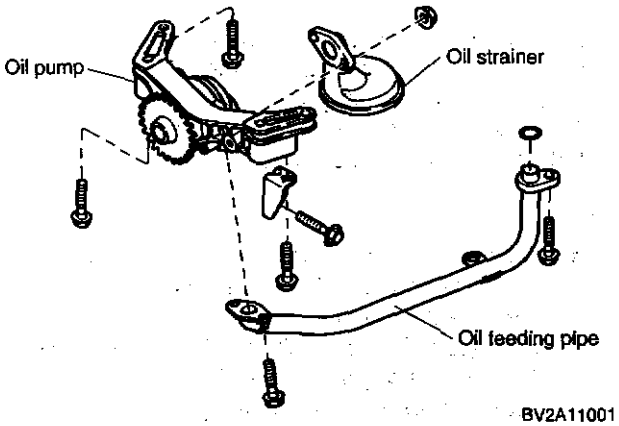
3. Remove oil feeding pipe from ladder frame.




BV2A11001

4. Remove oil pump with four bolts.
5. Remove oil pump.

### Replacement

1. Remove oil pump after loosen the chain by push the end of chain tensioner with the chain tensioner lever.
2. Install oil feeding pipe.

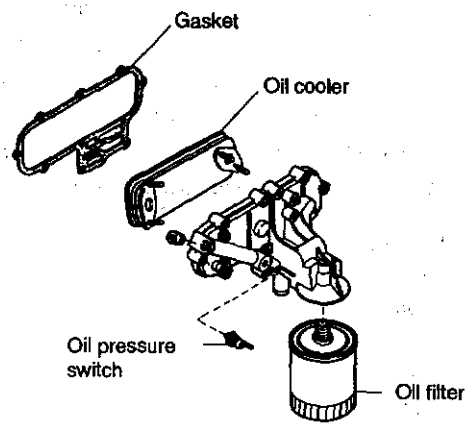
   **Tightening torque:**
   **16.6 lb-ft (23 N·m, 2.3 kg-m)**

3. Install oil pan.

## Oil cooler

### Removal

1. Remove fresh air duct.
2. Remove ventilator mounting bracket.




BV2A11002A

3. Remove oil filter assembly with two nuts and eight bolts.
4. Remove four nuts securing oil cooler.
5. Remove oil cooler from oil filter assembly.

### Replacement

1. Install new "O" rings and oil cooler to oil filter assembly.

   **Tightening torque:**
   **10.8~18.0 lb-ft (14.7~24.5 N·m, 1.5~2.5 kg-m)**

2. Install new gasket and oil filter assembly to cylinder block.
3. Install ventilate mounting bracket.
4. Install fresh air duct.

# ON-VEHICLE SERVICE PROCEDURE

## Turbocharger

After checking the turbocharger, replace the assembly in case of abnormality.

| Check point | Check result | Symptom | | | |
|---|---|---|---|---|---|
| | | Oil leak | Smoke | Abnormal noise | Lowpower, poor acceleration |
| Turbine rotor | Oil leakage | △ | ● | △ | △ |
| | Carbon deposit | △ | ● | ○ | ○ |
| | Friction with housing | △ | ○ | ● | ○ |
| | Bent or broken blade | | | ● | ● |
| Compressor oil | Contaminated intake inlet with oil | ○ | ○ | | |
| | Friction with housing | △ | ○ | ● | ○ |
| | Bent or broken blade | | | ● | ● |
| Turbine and compressor check in both directions | Heavy or catching feeling when rotated by finger<br>No movement when rotated | | △ | △ | ○ |
| | Excessive looseness in bearing | | | ○ | ● |
| | Carbon deposit in drain oil hole | △ | △ | ○ | △ |
| Observation on oil hole | Carbon deposit in drain oil hole | △ | ● | △ | △ |
| Operation of waste gate valve (aircon used) | No smooth operation when applied after removing positive pressure | | | | ● |

● : High possibility
○ : Medium possibility
△ : Low possibility

## Turbocharger

### On-vehicle Inspection

1. Warm up the engine to the normal operating temperature.
2. Disconnect the hose between the air inlet tube and the boost compensator from the air inlet side.
3. Install the pressure gauge by inserting the 3-way connector.
4. Read the maximum valve on the pressure gauge after starting the engine and increasing the engine speed.

| Pressure gauge reading | Check point |
|---|---|
| No positive pressure or low pressure | • Air exhaust gas leakage<br>• Abnormal turbocharger |
| Above the specified supercharging pressure (Standard value) | • Leakage by separation or breakage of actuator hose<br>• Abnormal operation of actuator |

### Removal

1. Discharge the coolant.
2. After removing the air duct, keep foreign material from entering the turbocharger inlet.
3. Remove the turbocharger insulator.
4. Remove the turbocharger water outlet pipe.
5. Remove the turbocharger oil supply pipe.
6. Remove the exhaust and front pipes.
7. Remove the turbocharger inlet and outlet pipes.
8. Remove the turbocharger by loosening the turbocharger mounting bolts.

***Caution***

***a) Don't carry the actuator by holding the actuator rod and the actuator hose.***

***b) Use the stud bolt of specified type when it is damaged. If one of different material is used, it may be elongated at high temperature and that can result in gas leakage.***

***c) The turbocharger is operated at high temperature and high speed that sufficient care should be taken on inclusion of foreign material into the oil pipe, deformation of the oil pump and etc..***

***d) After removing the turbocharger, attach the cap or tape on the air and exhaust gas inlets for foreign material not to be included.***

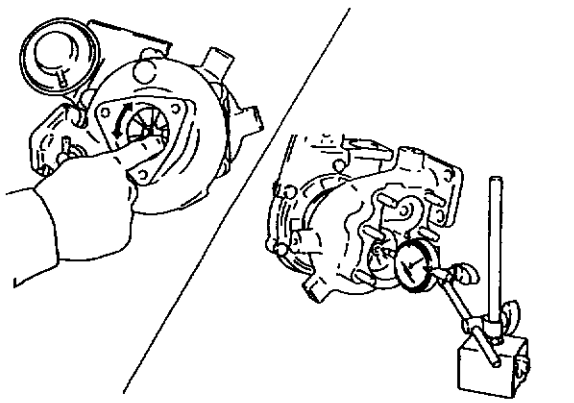
***e) If the oil in the sensor housing flows out to the turbine and the compressor housing inside, it can be wrongly judged as turbocharger trouble that the turbocharger should be placed horizontally as originally mounted after removal.***

### Installation
Install them in the reverse order of removal.

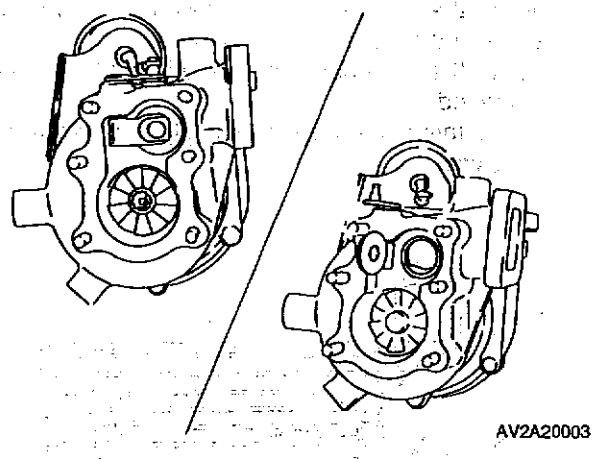
***Caution***
- ***a) When installing a new turbocharger, pour small amount of oil into the lubricant inlet of the turbocharger.***
- ***b) When starting the engine, be sure to connect the lubricant supply pipe and idle it for 1~2 minutes at low speed. Then increase the engine speed after lubricant has been supplied to the turbocharger sufficiently.***

### Inspection
1. Check if the rotor shaft is rotated smoothly when turned by a finger.
2. Check if there is looseness on the rotor shaft when moved up and down.
3. Install a dial gauge at the end of the shaft and check the free travel.

**Free travel**
**0.001~0.003 in (0.026~0.074 mm)**


AV2A20002

4. Check if there is oil attached or carbon deposit on the turbine or the compressor wheels.
5. Check if there is deformation or crack on the turbine or the compressor wheels.
6. Check if the turbine or the compressor wheels are interfered with housings.
7. Check if the waste gate valve is operated smoothly and if there is no deformation or crack after removing the fixing pin of the actuator rod.
8. Check if there is poor contact between the waste gate valve and the turbine housing seat.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## Tuborcharger actuator
### Inspection
1. Disconnect the air hose from the actuator.
2. Connect the pressure tester to one end of the actuator pipe and connect the other end to the actuator.
3. Install the dial gauge on the straight line of the actuator rod.
4. Check if the actuator is operated and if the reading of the dial gauge is moved by **0.08 in (2.0 mm)** when pressure of **1080~1170 mmHg** is applied by the pressure tester.

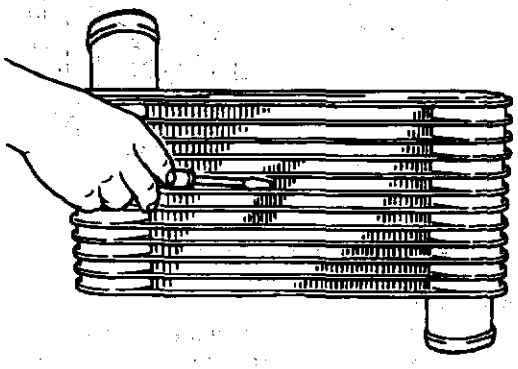
***Caution***
***If pressure over 1.5 kg/cm² is applied, the actuator may be damaged.***

5. If it is not operated or it does not reach the standard pressure, replace the actuator.

# Intercooler

## Inspection

1. Check if there is crack or damage on the intercooler visually and replace it if it is abnormal.
2. Check if the pin is damaged and adjust it by a driver if damaged.
3. Check if there is leakage after applying pressure of **1.5 kg/cm²**.



AV2A20004

# Engine Electrical System

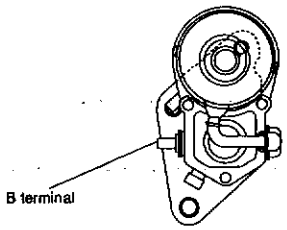
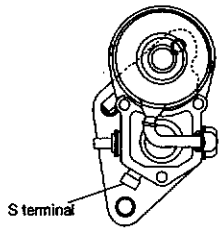
# SYMPTOM-RELATED DIAGNOSTIC PROCEDURE

## Starter

### Symptom guide

| No. | Items |
|---|---|
| 1 | Will not crank-starter motor does not operate |
| 2 | Will not crank-starter motor spins |
| 3 | Cranks slowly |
| 4 | Generator warning light illuminates with engine running |
| 5 | Discharged battery |

### Symptom troubleshooting

| 1 | Will not crank-starter motor does not operate | | |
|---|---|---|---|
| **Step** | **Inspection** | | **Action** |
| 1 | Check if engine cranks with fully charged battery. | Yes | Check charging system. |
| | | No | Go to next step. |
| 2 | Check if battery voltage is supplied at B terminal.<br>  <br><br>AV2A31001A | Yes | Go to next step. |
| | | No | Check wiring harness. |
| 3 | Check if battery voltage is supplied at S terminal with clutch pedal depressed (M/T), car in PARK (A/T), and ignition switch in START position.<br>  <br><br>AV2A31001A | Yes | Replace starter unit. |
| | | No | • Check transaxle range switch (A/T) (*Refer to, Auto transaxle*)<br>• Check ignition switch<br>• Check wiring harness |

| 2 | Will not crank-starter motor spins | | |
|---|---|---|---|
| **Step** | **Inspection** | | **Action** |
| 1 | Check if drive pinion is pulled out while cranking. (Click heard when pulled out.) | Yes | Remove starter and check flywheel ring gear teeth and starter drive pinion teeth. |
| | | No | Check solenoid.<br>Repair or replace as necessary. |

| 3 | Cranks slowly | | |
|---|---|---|---|
| **Step** | **Inspection** | | **Action** |
| 1 | Check if engine cranks normally when fully charged. | Yes | Check charging system. |
| | | No | Go to next step. |
| 2 | Check starter cable connection for looseness and corrosion. | Yes | Repair or replace connection. |
| | | No | Check for seized motor armature. Repair or replace as necessary. |

| 4 | Alternator warning lamp illuminates with engine running | | |
|---|---|---|---|
| **Step** | **Inspection** | | **Action** |
| 1 | Check for correct battery voltage at idle.<br><br>**Specification: 14.1~14.7V** | Yes | Check wiring harness between Alternator L terminal and generator warning lamp. |
| | | No | Check charging system. |

| 5 | Discharged battery | | |
|---|---|---|---|
| **Step** | **Inspection** | | **Action** |
| 1 | Check charging system. | Yes | Turn ignition switch **ON** and check dark current as shown.<br><br>**Dark current: Below 20mA** |
| | | No | Repair or replace parts as necessary . |

# SPECIFICATION

## Starter motor

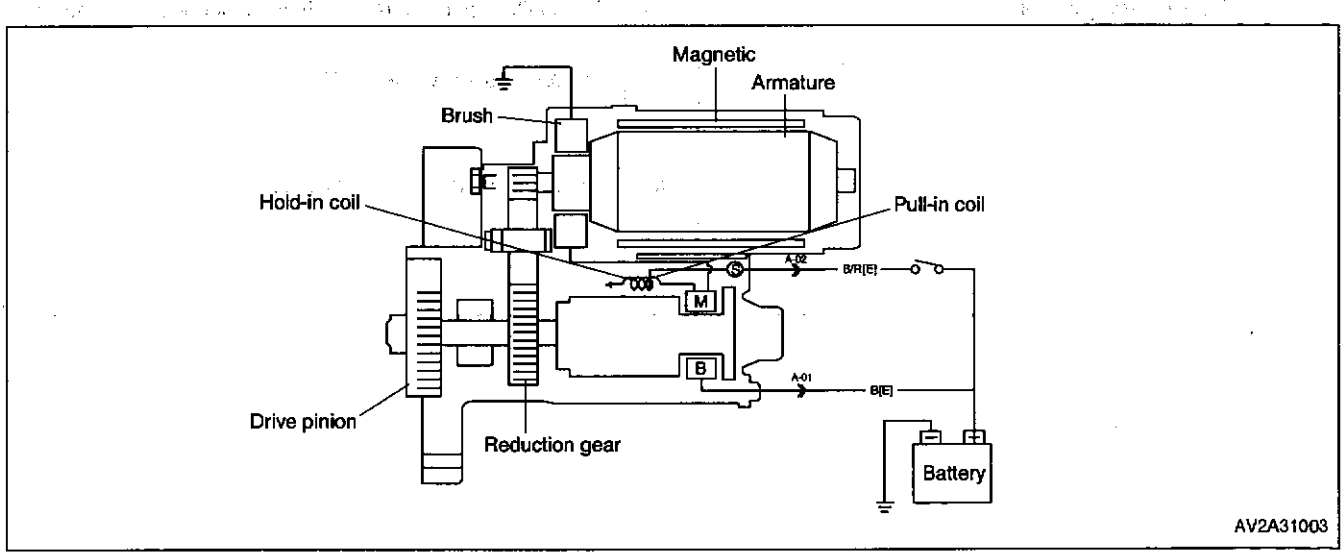
### Specification

| Item \ Engine / Transaxle | | J3 COMMON RAIL SYSTEM | |
|---|---|---|---|
| | | M/T | A/T |
| Starter motor | Type | Pre-engaged drive | |
| | Output (V-KW) | 12-2.2 | |

# DESCRIPTION AND OPERATION

## Starter motor

### Structural view



# ON-VEHICLE SERVICE PROCEDURES

## Starter motor

### Pull in voltage

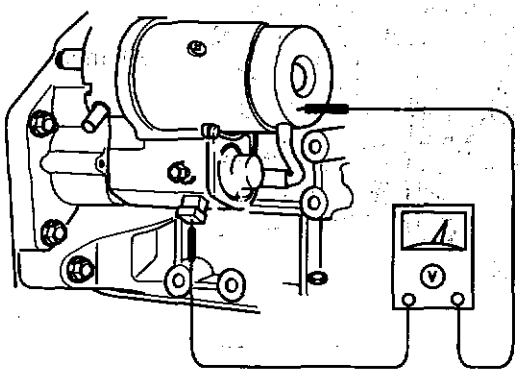
1. Inspect the battery voltage.

   **Voltage: above 12.4V**

2. After starting the engine, check if the starter rotates smoothly.
3. If the starter does not rotate, check the "S" terminal voltage during cranking engine.

   **Voltage: above 8V**

- Above 8V: Inspection the starter
- Below 8V: Inspect wiring (main fuse, ignition switch and transaxle range switch(A/T))



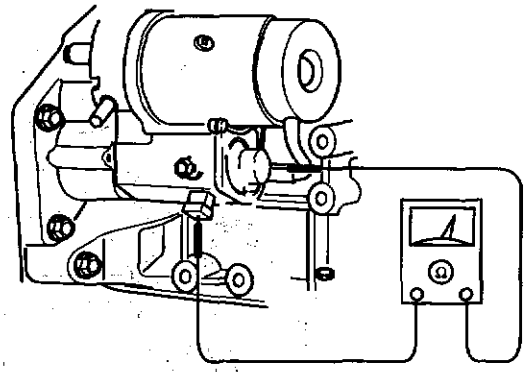
AV2A31005A

## Solenoid

### Pull-in coil

✱ *Notice*
*a) Remove the battery negative cable.*
*b) Remove the "M" terminal of starting motor.*

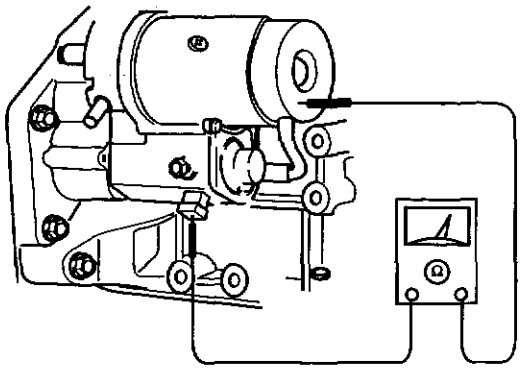
1. Do the continuity test between "S" and "M" terminal.
2. If it is opened, replace the solenoid.



AV2A31005B

### Hold-in coil

1. Do the continuity test between "S" and solenoid body.
2. If it is opened, replace the solenoid.



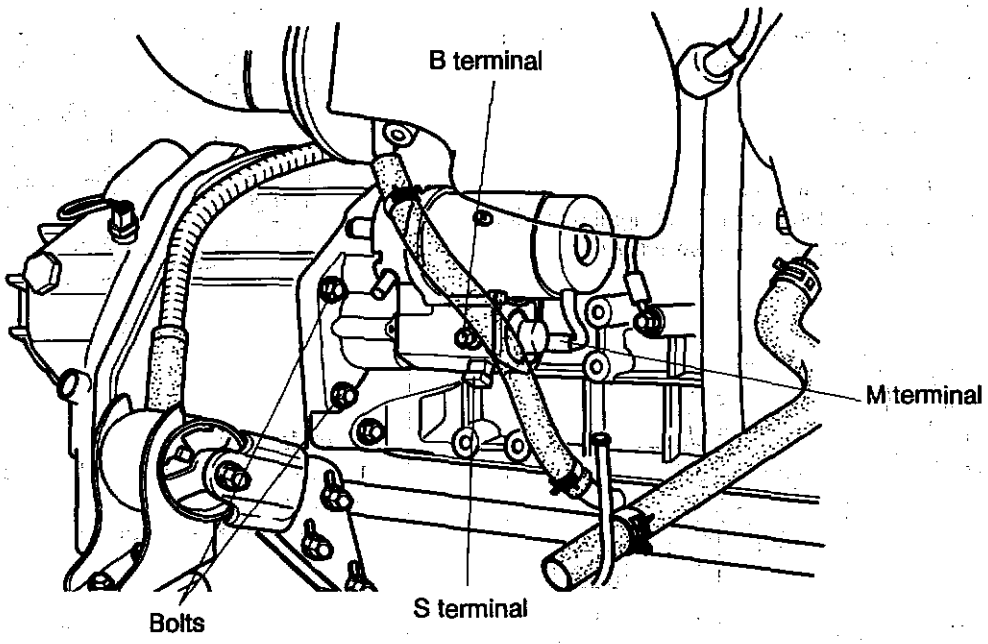
AV2A31005A

# REMOVAL AND REPLACEMENT PROCEDURES

## Starter

### Removal and replacement

1. Remove the battery negative cable.
2. Inspect the parts, replace and repair as necessary.
3. Install in the reverse order of removal.



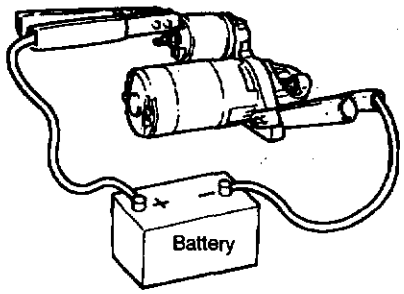
## Inspection

### Solenoid

### Pull-out test

✱ *Notice*
*Be careful not to let electricity flow continuously for more than 10 seconds.*

1. Apply battery power to the "S" terminal and ground starter motor body. Pinion will eject outward and the stop.

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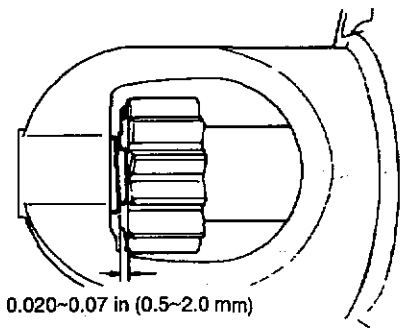
2. Measure clearance (pinion gap) between pinion and stopper.

**Pinion gap: 0.020~0.079 in (0.5~2.0 mm)**

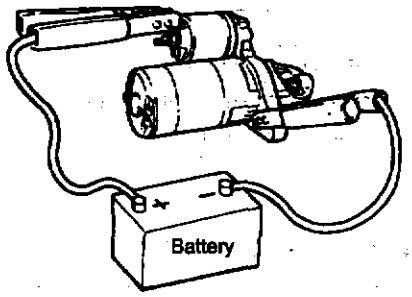



AT30031008

3. If pinion gap is not within specified range, adjust it by increasing or decreasing the number of washers used between solenoid and drive housing.
The gap will become smaller if the number of washers is increased.

### Return test

1. Disconnect the wire from the "S" terminal, and then connect the battery between the "M" terminal and the body.



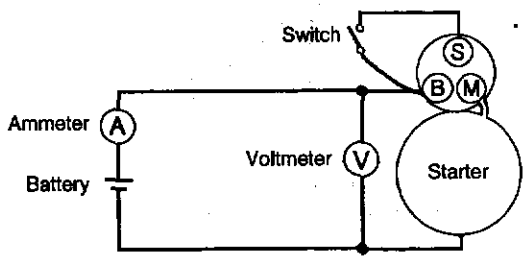

AT3031007

2. Pull out the over-running clutch with a flat-tip screwdriver, and then check that the over-running clutch returns to its original position when released.

### No-load test

1. Form a test circuit with a volt meter and an ammeter.

✱ *Notice*
*Use wires as thick as possible and tighten each terminal fully.*




AT3031010

2. Close switch to run the starter.
3. Check the following.

| | | J3 COMMON RAIL SYSTEM |
|---|---|---|
| Voltage | (V) | 11.0 |
| Current | (A) | Below 130 |
| Gear shaft speed | (rpm) | Above 4500 |

4. If any abnormality is noted, check it according to "INSPECTION".

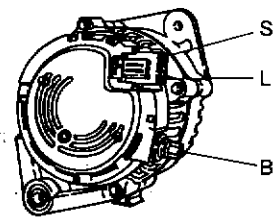
# SYMPTOM-RELATED DIAGNOSTIC PROCEDURE

## Alternator

### Diagnostic guide

| No. | Items |
|---|---|
| 1 | Being not charged |
| 2 | Engine starts-alternator warning lamp turns on |
| 3 | Discharging of battery |

### Symptom troubleshooting

| 1 | Being not charged | | |
|---|---|---|---|
| **Step** | **Inspection** | | **Action** |
| 1 | Check the battery voltage.<br>**Standard: about 12.4V** | Yes | Go to next step. |
| | | No | Check the battery. |
| 2 | Start engine and check if alternator warning lamp goes out. | Yes | Go to step 4. |
| | | No | Go to next step. |
| 3 | Check if voltage at alternator terminals are correct.<br>Terminal / IG: ON(V) / Idle(V)<br>B / Approx. 12V / 14.1~14.7<br>L / Approx. 1V / 14.1~14.7<br>S / Approx. 12V / 14.1~14.7<br>  <br>AT3032005 | Yes | Check wire harness between battery and terminal "B". |
| | | No | Check wiring harness.<br>Replace alternator. |
| 4 | 1. Connect an ammeter, (100A Max: KJ 2.9)] between terminal "B" and harness.<br>2. Start engine.<br>3. Check if engine is 2500~3000 rpm.<br>4. Check if ampere of load (turn more one of many electrical system on) higher than ampere of unload (Turns blower, head lamp, rear defroster, etc, off). | Yes | Charging system normal. |
| | | No | Go to next step. |
| 5 | Check if drive belt tension is OK. | Yes | Replace alternator. |
| | | No | Check drive belt tension. |

<table>
<tr><td>2</td><td colspan="3">Discharging of battery</td></tr>
<tr><td>Step</td><td>Inspection</td><td></td><td>Action</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Measure open circuit voltage of battery with a digital voltmeter capable of reading 0.01V.<br><br>Voltage: above 12.4V</td><td>Yes</td><td>Go to next step.</td></tr>
<tr><td>No</td><td>Quick charge for 2 hours and recheck voltage if the voltage is below 12.4V, replace battery.</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Apply load test to the battery by using a battery load tester.<br><br>Load test<br><table><tr><th>Battery</th><th>Load (A)</th></tr><tr><td>PT80 - 33FL</td><td>300</td></tr></table><br>Quick charge and record battery voltage at the end of 15 seconds; is the voltage more than specification?<br><br>Battery voltage with load<br><table><tr><th>Approximate battery temp.(°C)</th><th>Minimum voltage (V)</th></tr><tr><td>21</td><td>9.6</td></tr><tr><td>15</td><td>9.5</td></tr><tr><td>10</td><td>9.4</td></tr><tr><td>4</td><td>9.3</td></tr><tr><td>-1</td><td>9.1</td></tr><tr><td>-7</td><td>8.9</td></tr><tr><td>-12</td><td>8.7</td></tr><tr><td>-18</td><td>8.5</td></tr></table></td><td>Yes</td><td>Go to next step.</td></tr>
<tr><td>No</td><td>Replace battery.</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">Measure open circuit voltage of battery.<br><br>Standard: above 12.4V</td><td>Yes</td><td>Battery is OK.</td></tr>
<tr><td>No</td><td>Charge battery.</td></tr>
</table>

# SPECIFICATIONS

## Battery and alternator

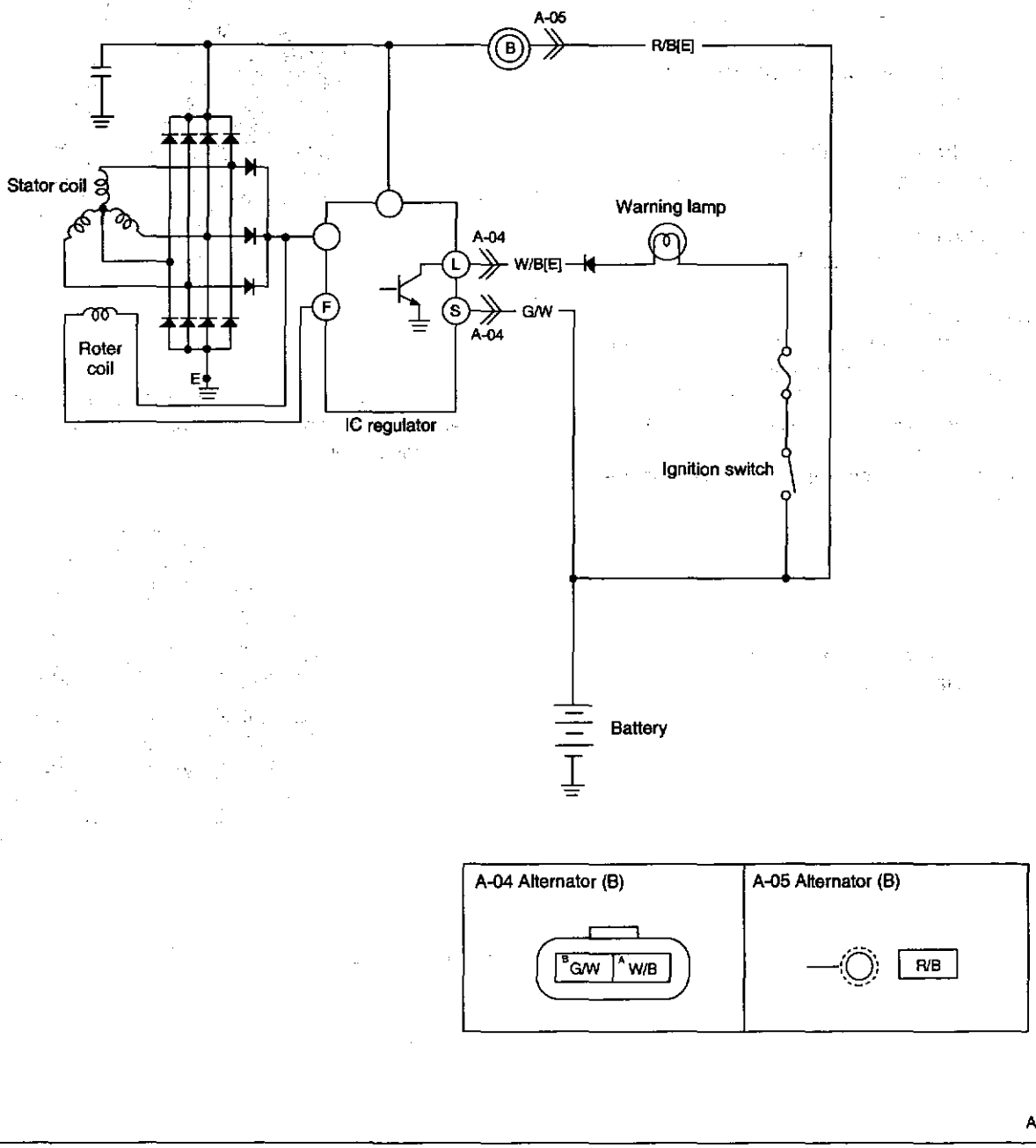
### Specifications

| Item \ Engine / Transaxle | | J3 COMMON RAIL SYSTEM | |
|---|---|---|---|
| | | M/T | A/T |
| Battery | Voltage (V) | 12V-negative | |
| | Type | PT80 - 33FL MF | |
| | Capacity (20 hour rate) (AH) | 80AH | |
| Alternator | Type | AC | |
| | Output (V-A) | 12-110 | |
| | Regulator type | Transistorized (Built - in IC regulator) | |
| | Regulator voltage (V) | 14.1~14.7 | |

# DESCRIPTION AND OPERATION

## Alternator

### Circuit diagram



# ON-VEHICLE SERVICE PROCEDURES

## Battery

### Inspection

#### Electrolyte level

1. Check whether or not the electrolyte level lines between "UPPER LEVEL" line and "LOWER LEVEL" line.
2. If low, add distilled water to "upper level" line. Do not overfill.

#### Specific gravity of electrolyte

1. Measure specific gravity with a hydrometer.

**Specific gravity:**
**1.27~1.29 (at 77°F[25°C])**

#### Terminal and cable

1. Check that battery terminal connections are tight to ensure good electrical connections.
2. Check for corroded or frayed battery cables.
3. Check rubber protector on positive terminal for proper coverage.
4. Clean terminals, if necessary, and lightly coat them with grease.

## Drive belt

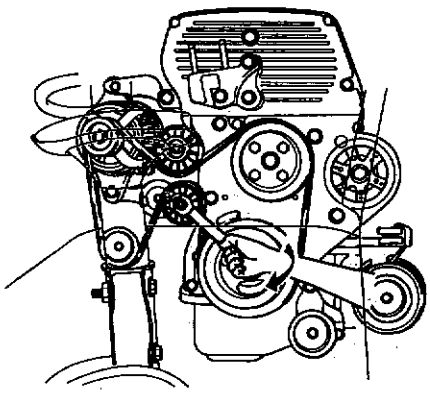
### Inspection

1. Check drive belt and pulley for wear, cracks and praying. Replace if necessary.

## Alternator

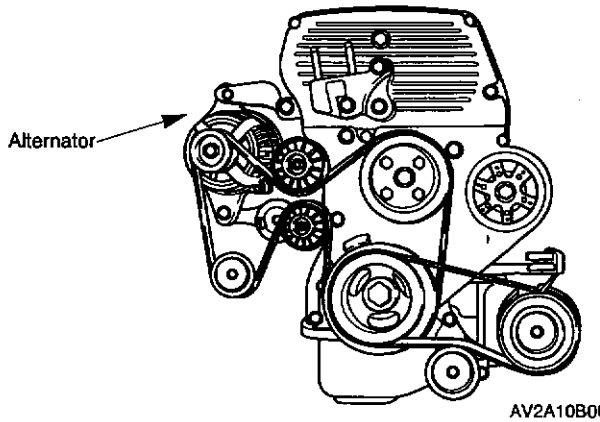
### Removal and replacement

1. Disconnect negative battery cable.
2. Lower an auto tensioner with spanner and then remove drive belt.



AV2A10B038

3. Remove "B" terminal lead and then disconnect alternator "L" and "S" terminal connector.
4. Remove alternator.




AV2A10B002

5. Install in reverse order of removal.

**Tightening torque:**
**33.2 lb-ft (45.1 N·m, 4.6 kg-m)**