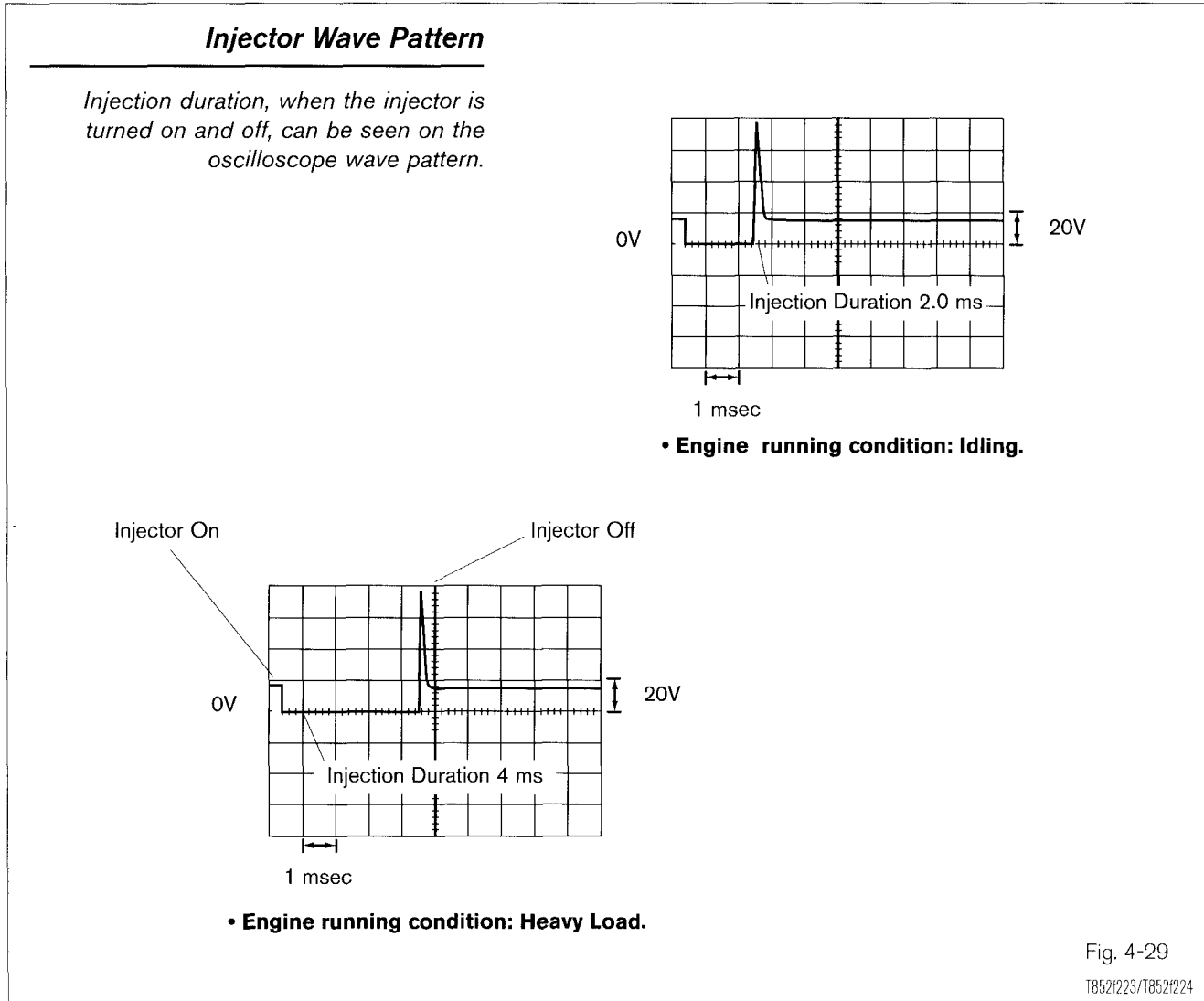**Injector Timing/Drive Circuits**
The design of the injector drive circuit and ECM programming determines when each injector delivers fuel in relation to the operating cycle of the engine. If the injectors are turned on according to the crankshaft position angle, it is called synchronous injection. That is, the injectors are timed to turn on according to crankshaft position. Depending on engine application, the three main types of synchronous injection designs are: Simultaneous, Grouped, or Sequential. In all these types, voltage is supplied to the injectors from the ignition switch or EFI main relay and the ECM controls injector operation by turning on the driver transistor grounding the injector circuit. Simultaneous and grouped are the oldest styles, and are no longer used.

On simultaneous, all injectors are pulsed at the same time by a common driver circuit. Injection occurs once per engine revolution, just prior to TDC No. 1 cylinder. Twice per engine cycle, one-half of the calculated fuel is delivered by the injectors. With grouped drive circuits, injectors are grouped in combinations. There is a transistor driver for each group of injectors. On sequential drive circuits, each injector is controlled separately and is timed to pulse just before the intake valve opens.

There are times when the ECM needs to inject extra fuel into the engine regardless of crankshaft position and this is called asynchronous injection. Asynchronous injection is when fuel is injected into all cylinders simultaneously when predetermined conditions exist without relation to the crankshaft angle. Two common conditions are starting and acceleration.
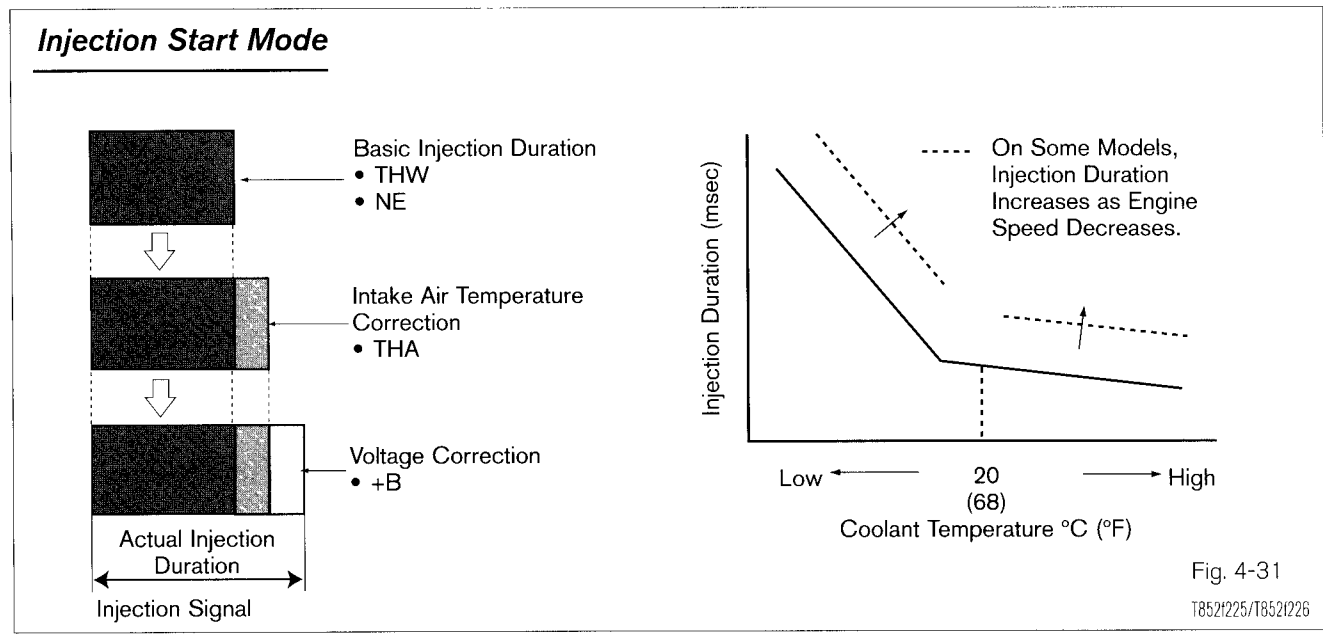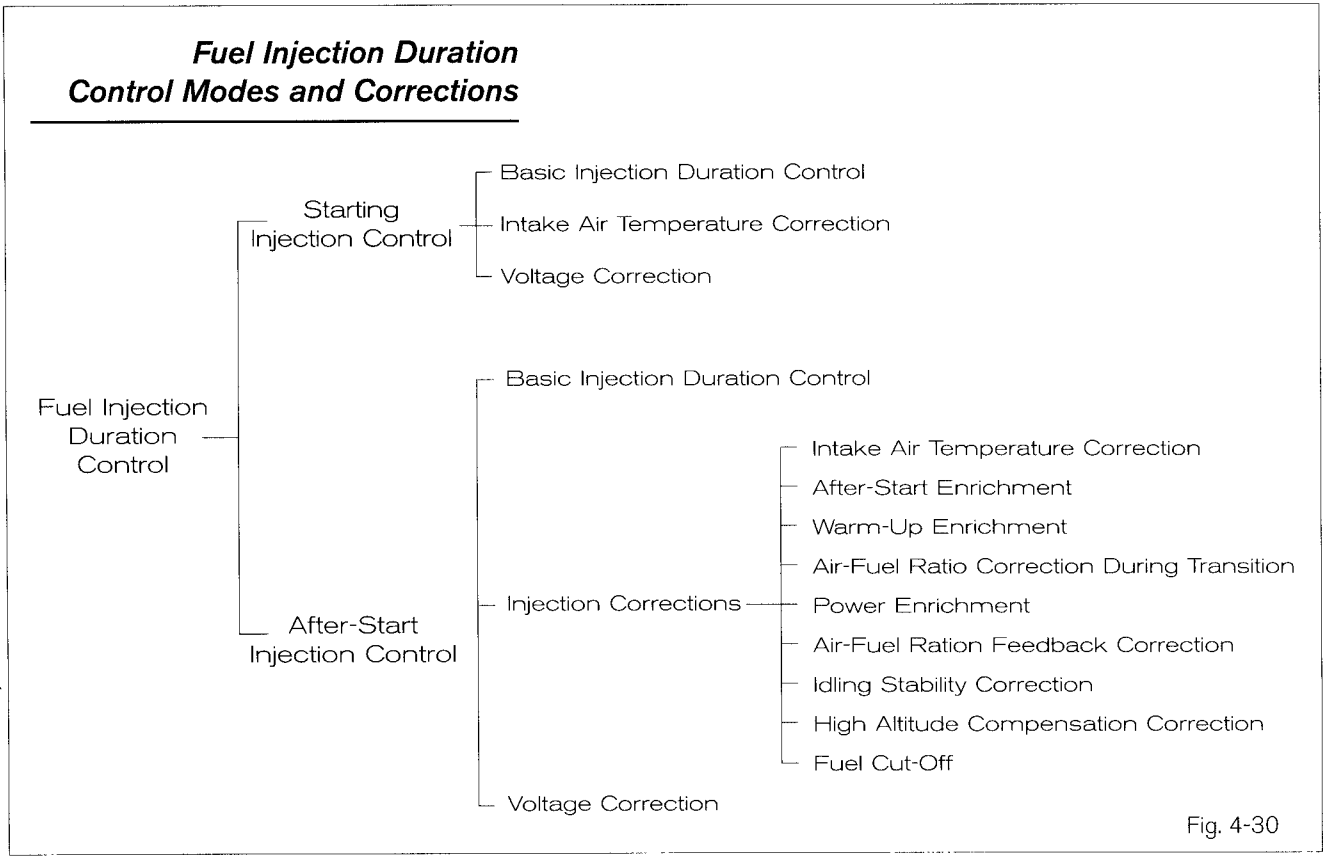
Note: The EWD injector circuit can identify if the injection system is a grouped or sequential. A sequential system will have one injector per injector driver.

Injector Wave Pattern

Injection duration, when the injector is turned on and off, can be seen on the oscilloscope wave pattern.

Injection Duration 2.0 ms

1 msec

• **Engine running condition: Idling.**

Injector On Injector Off

Injection Duration 4 ms

1 msec

• **Engine running condition: Heavy Load.**

Fig. 4-29

T852f223/T852f224

Fuel Injection Volume Control
The amount of fuel injected depends on fuel system pressure and the length of time the injector is turned on. Fuel system pressure is controlled by the pressure regulator, and injector on time is controlled by the ECM. The time the injector is on is often called duration or pulse width, and it is measured in milliseconds (ms). Cold starting requires the highest pulsewidth. Pulsewidth is dependent primarily **on engine load and engine coolant temperature**. The higher the engine load and the more the throttle is opened to let air in, the greater pulsewidth increases. The ECM determines the duration based on the input sensor signals, engine conditions, and its programming.

*Fuel Injection Duration
Control Modes and Corrections*

Fuel Injection
Duration
Control

Starting
Injection Control
- Basic Injection Duration Control
- Intake Air Temperature Correction
- Voltage Correction

After-Start
Injection Control
- Basic Injection Duration Control
- Injection Corrections
  - Intake Air Temperature Correction
  - After-Start Enrichment
  - Warm-Up Enrichment
  - Air-Fuel Ratio Correction During Transition
  - Power Enrichment
  - Air-Fuel Ration Feedback Correction
  - Idling Stability Correction
  - High Altitude Compensation Correction
  - Fuel Cut-Off
- Voltage Correction

Fig. 4-30

Injection Start Mode

Basic Injection Duration
- THW
- NE

Intake Air Temperature
Correction
- THA

Voltage Correction
- +B

Actual Injection
Duration

Injection Signal

On Some Models,
Injection Duration
Increases as Engine
Speed Decreases.

Injection Duration (msec)

Low ◄─────── 20
(68)
─────► High

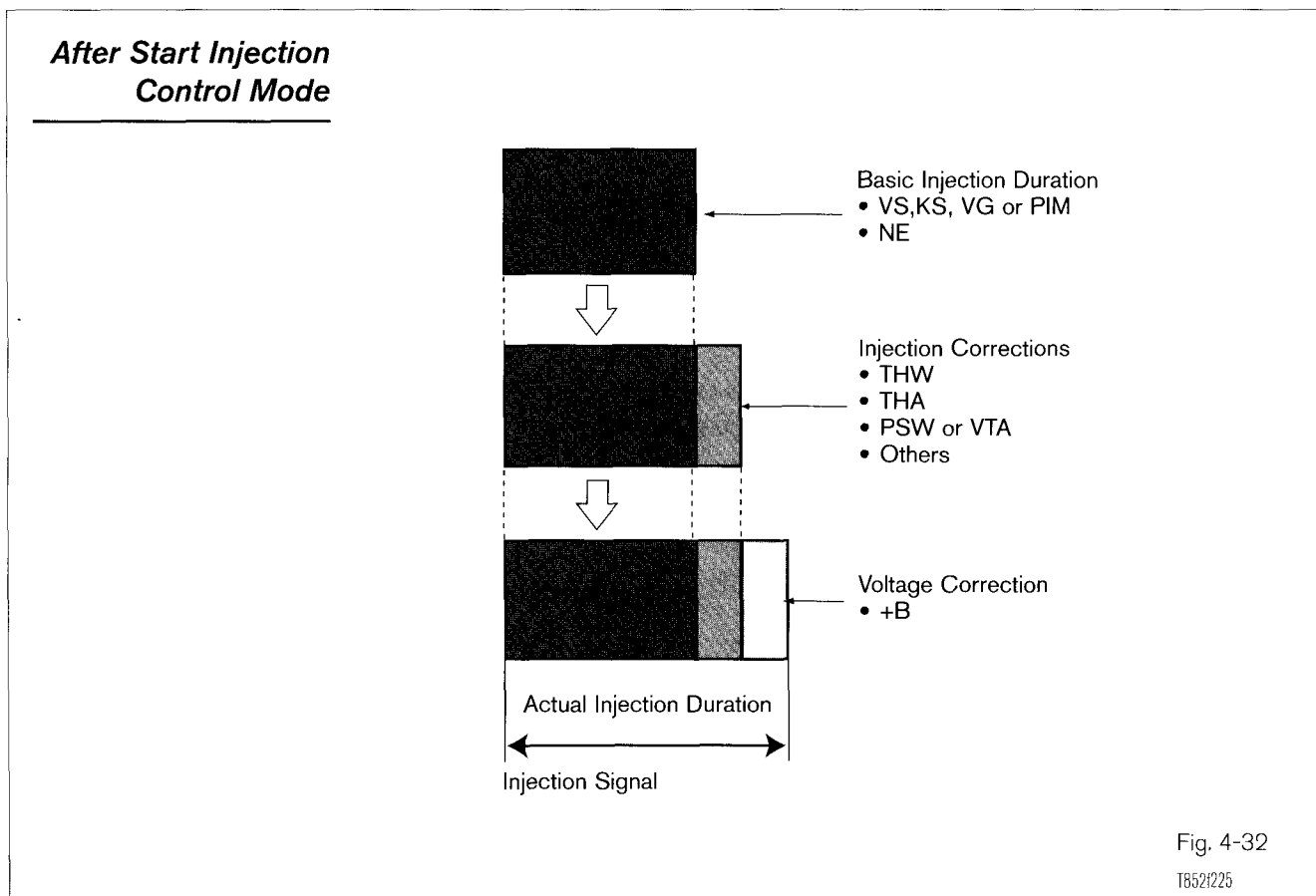Coolant Temperature °C (°F)

Fig. 4-31

T852I225/T852I226

Start Mode

When the ignition switch is in the Start position, the ECM receives a voltage signal at the STA terminal. The ECM determines basic injection duration based on the ECT (THW) signal. On MAP sensor equipped engines the ECM will then modify this duration based on the IAT (THA) signal.

The ECM will adjust the duration based on battery voltage. During cranking, battery voltage is much lower causing the injector valve to lift slowly. The ECM corrects for this by increasing injection duration.

When the ECM receives the NE signal (Crankshaft Position Sensor), all the injectors are turned on simultaneously. This insures there is enough fuel for starting the engine. Note that below freezing, injection duration increases drastically to overcome the poor vaporization characteristics of fuel at these temperatures.

After Start Injection Control Mode

Basic Injection Duration
• VS,KS, VG or PIM
• NE

Injection Corrections
• THW
• THA
• PSW or VTA
• Others

Voltage Correction
• +B

Actual Injection Duration

Injection Signal

Fig. 4-32

T852f225

Engine Running (After Start) Injection Duration Control

Total fuel injection duration is determined in three basic steps:
- • Basic injection duration.
- • Injection corrections.
- • Voltage correction.

Basic injection duration is based on air volume and engine RPM. Air volume on MAF equipped engines is determined by the MAF voltage signal.

On MAP sensor equipped engines, the ECM calculates air volume based on the PIM signal, engine RPM, THA signal, and volumetric efficiency values stored in the ECM.

Injection corrections adjust the basic injection duration to accommodate different engine modes and operating conditions. It is based on a variety of input signals.

Voltage correction adjusts the injection duration to compensate for differences in the electrical system voltage.


Fig. 4-33

T852i227
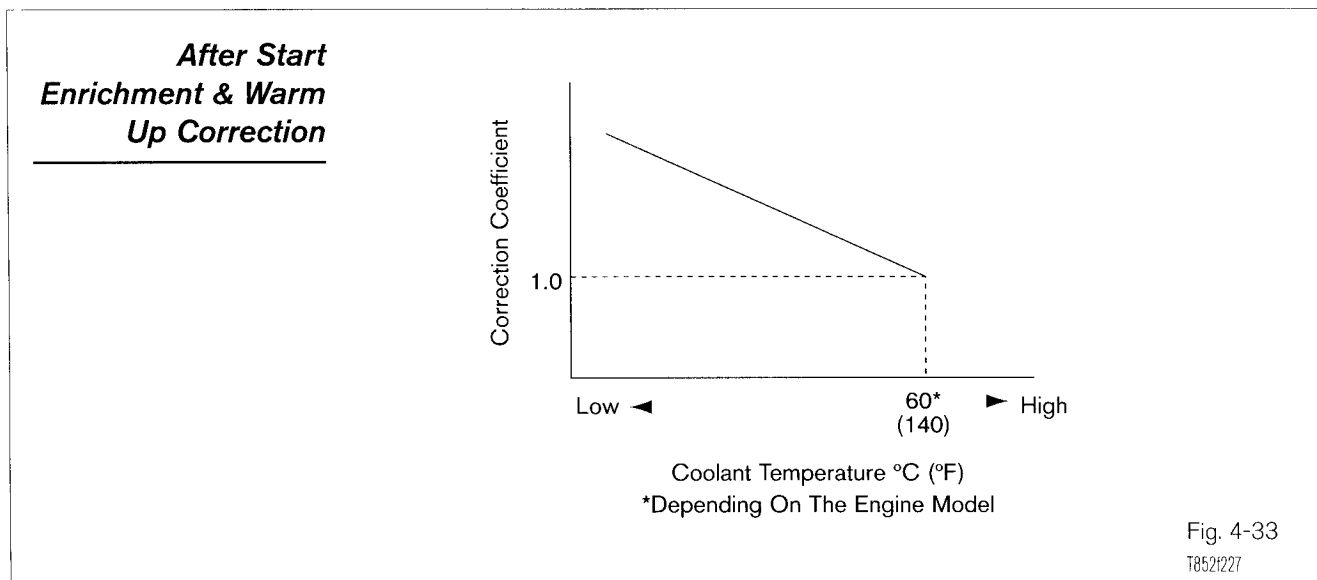
After Start Enrichment
Immediately after starting (engine speed above a predetermined level), the ECM supplies an extra amount of fuel for a certain period of time to stabilize engine operation.

This correction volume is highest immediately after the engine has started and gradually decreases. The maximum correction volume value is based on engine coolant temperature. The hotter the engine, the less volume of fuel injected.

Warm-Up Enrichment
A rich fuel mixture is needed to maintain driveability when the engine is cold. The ECM injects extra fuel based on engine coolant temperature. As the engine coolant warms up, the amount of warm-up enrichment decreases. Depending on the engine, warm-up enrichment will end at approximately 50'C-80'C (122'F-176'F).

If the ECM is in Fail-Safe Mode for DTC PO 115, the ECM substitutes a temperature value, usually 80'C (176'F).

Fig. 4-34

T852f228
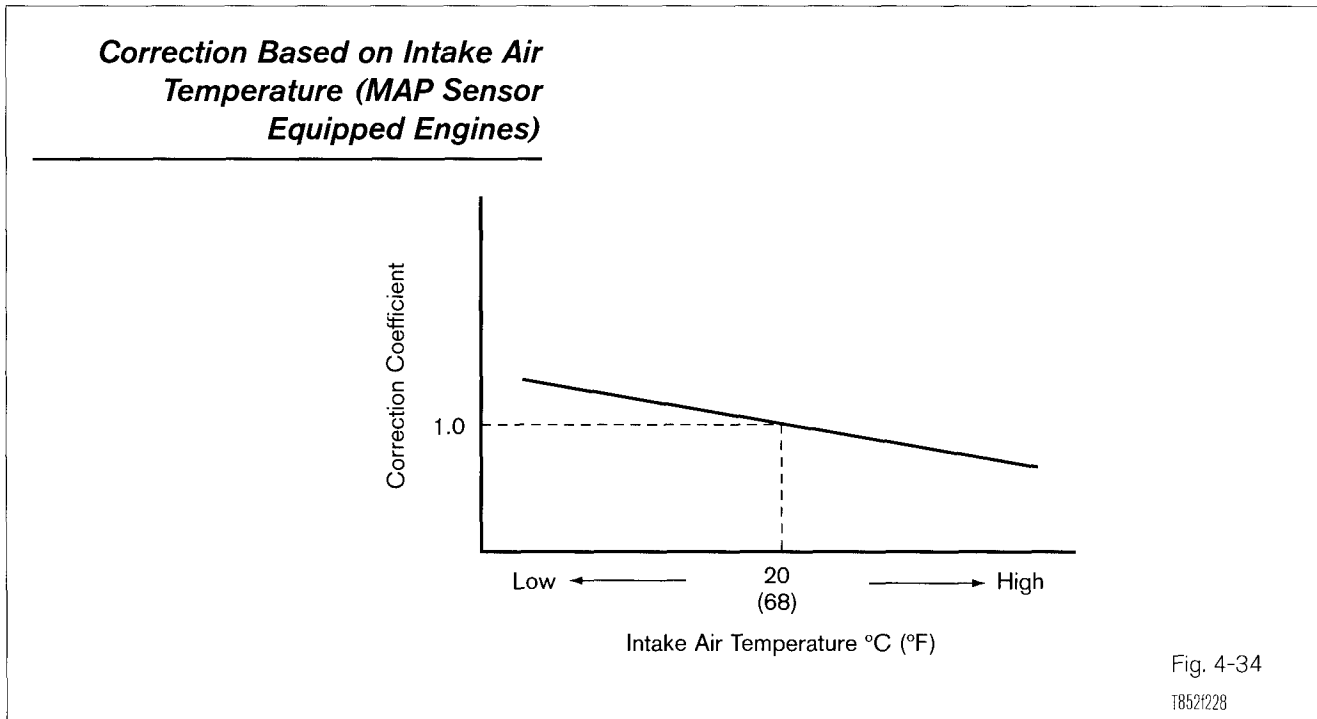
Correction Based on Intake Air Temperature (MAP Sensor Equipped Engines)
The density of the intake air decreases as temperature increases. Based on the IAT (THA) signal, the ECM adjusts the fuel injection duration to compensate for the change in air density. The ECM is programmed so that at 20'C (68'R no correction is needed. Below 20'C (68'F), duration is increased, above 20'C (68'F), duration is decreased.

If the ECM is in Fail-Safe Mode for DTC P0110, the ECM substitutes a temperature value of 20'C (68'F).

Power Enrichment Correction
When the ECM determines the engine is operating under moderate to heavy loads, the ECM will increase the fuel injection duration. The amount of additional fuel is based on the MAF or MAP sensors, TPS, and engine RPM. As engine load (and air volume) increases, fuel injection duration increases. As engine RPM increases, injection frequency increases at the same rate.

Acceleration Correction
On initial acceleration, the ECM extends the injection duration richening the mixture to prevent a stumble or hesitation. The duration will depend on how far the throttle valve travels and engine load. The greater the throttle travel and engine load, the longer the injection duration.

*Deceleration
Fuel Cut*

Fig. 4-35

T852f229
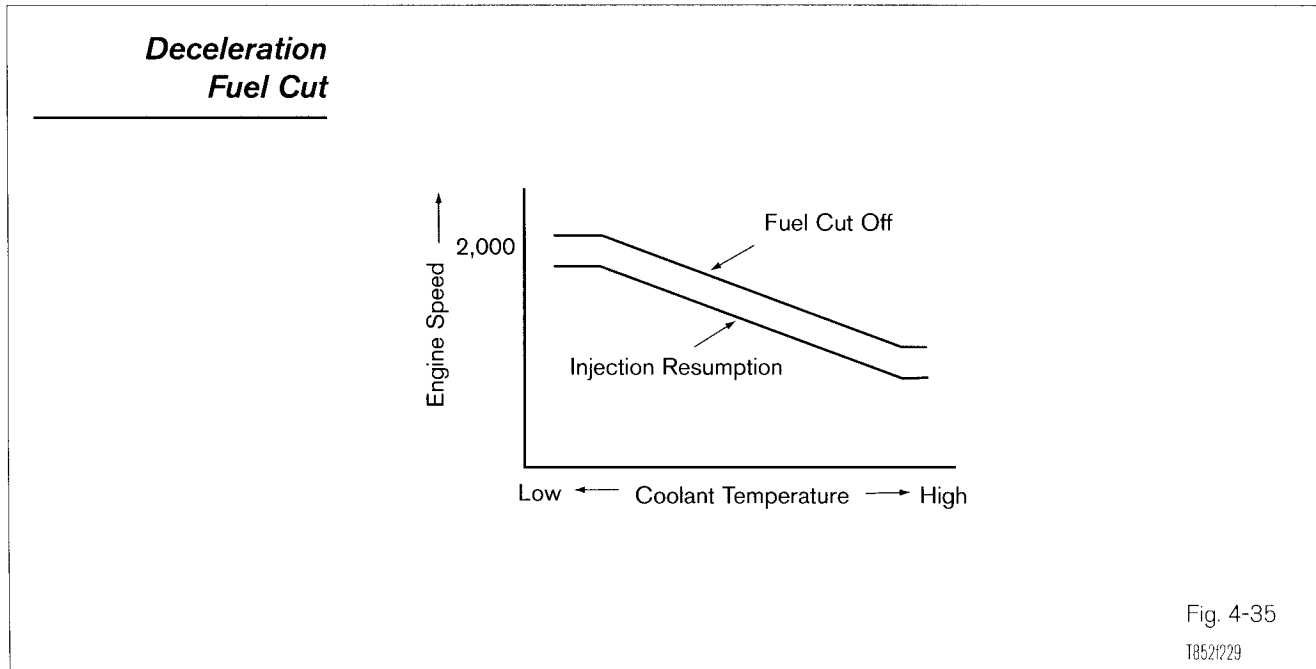
Deceleration Fuel Cut
During closed throttle deceleration periods from moderate to high engine speeds, fuel delivery is not necessary or desirable. To prevent excessive decel emissions and improve fuel economy, the ECM will not open the injectors under certain decel conditions. The ECM will resume fuel injection at a calculated RPM.

Referring to the graph, fuel cut-off and resumption speeds are variable, depending on coolant temperature, A/C clutch status, and the STA signal. Essentially, when extra engine loads are present, the ECM will begin fuel injection earlier.

Fuel Tau Cut is a mode employed on some engines during long deceleration time with the throttle valve closed. During these times, excess oxygen would enter the catalytic converter. To prevent this, the ECM will very briefly pulse the injectors.

Engine Over-Rev Fuel Cutoff
To prevent engine damage, a rev-limiter is programmed into the ECM. Any time the engine RPM exceeds the pre-programmed threshold, the ECM shuts off the injectors. Once RPM falls below the threshold, the injectors are turned back on. Typically, the threshold RPM is slightly above the engine's redline RPM.

Vehicle Over-Speed Fuel Cutoff
On some vehicles, fuel injection is halted if the vehicle speed exceeds a predetermined threshold programmed into the ECM. Fuel injection resumes after the speed drops below this threshold.

Battery Voltage Correction

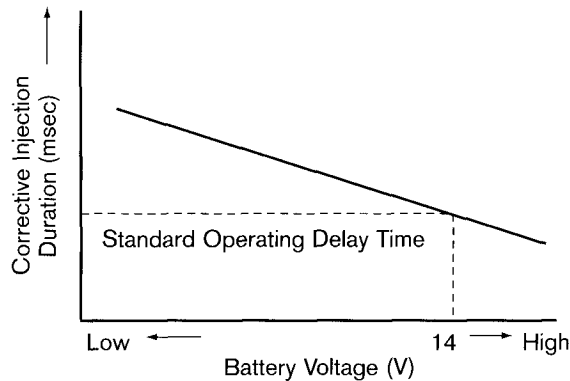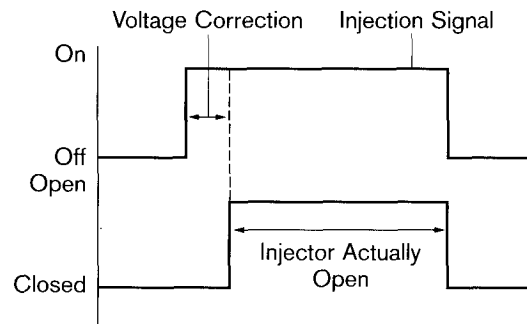*With lower battery voltage, a longer injector ON time is needed.*

Fig. 4-36

T852f230/T852f231

Battery Voltage Correction

The applied voltage to the fuel injector will affect when the injector opens and the rate of opening. The ECM monitors vehicle system voltage and will change the injection on time signal to compensate. If system voltage is low, the injection on time signal will be longer, but the actual time the injector is open will remain the same (if system voltage were higher).

***High Altitude
Compensation***

*To compensate for less
air at higher altitudes,
fuel injection duration is
decreased.*

Correction Coefficient

1.0

101.3
(760,29.9)

kPa
mmHg, in. HG

High   ← Atmospheric Pressure →   Low
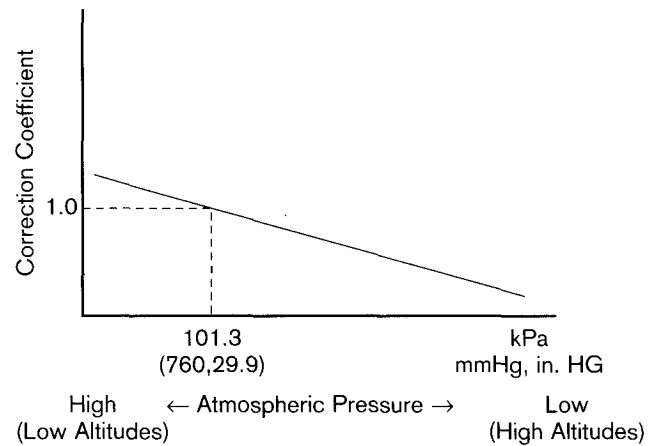(Low Altitudes)   (High Altitudes)

Fig. 4-37

T8521232

EVAP Purge Compensation
When the evaporative purge valve is on, fumes from the charcoal canister are drawn into the intake manifold. The ECM will compensate based on the oxygen sensor output and shorten the injector pulse width.

ASSIGNMENT   NAME: _____

1. Explain in detail both Grouped Injection and Sequential Injection?

2. What inputs are use for Injection Duration control during "After start"?

3. Explain detail "Afterstart Enrichment Correction"

4. Explain in detail "Warm-Up Enrichment Correction"

5. Explain explain the "Fuel Correction" based on Intake Air Temperature (MAP sensor equipped engines:

6. Explain in detail "Power Enrichment Correction"

7. Explain in detail "Acceleration Enrichment Correction"

8. Explain in detail "Deceleration Fuel Cut"

9. Explain in detail the "Engine Over-Rev Fuel Cutoff"

10. Explain in detail "Vehicle Over-Speed Fuel Cutoff"

11. Explain in detail "Battery Voltage Correction"

12. Explain in detail "EVAP Canister Purge Compensation"