ACCEL EMIC

ENGINE MANAGEMENT INSTALLATION CENTER

TRAINING MANUAL

DFI ELECTRONIC FUEL INJECTION

MR. GASKET CO.®

PERFORMANCE GROUP®

A NOTE FROM THE AUTHOR


Ray T. Bohacz

As the author of this manual I would personally like to welcome you into the EMIC program, and I applaud your decision to become a part of the aftermarket fuel injection industry. Here at ACCEL, we are very proud of our standing as the market's leading supplier of programmable ECU's, while complimenting them with offering the most comprehensive line of ancillary fuel injection and ignition system components. Our dedication to this segment of the performance aftermarket is unparalleled and includes not only in house engineering and technical support teams, but our own dedicated world class electronics manufacturing plant. This investment allows us to remain at the cutting edge of technology and produce products of only the highest quality, but also allows you to represent our line with confidence to the end user. In today's competitive market place, it is comforting for a dealer to know that the organization they represent is backed by a group of people that will have the ability to support your efforts in every way from start to finish.

A further example of ACCEL'S commitment to remaining the market leader in both fuel injection and ignition components is the formation of the EMIC training program and the creation of this manual. By associating ourselves with Northwestern College in Lima Ohio, it has allowed us to become the "industry standard" for fuel injection training. Due to this facilities ability to fill the unique class room needs of our training program, along with their complete dyno cell facilities, that are required for our indepth technical presentation.

On behalf of myself and the whole Mr. Gasket Performance Group, we again welcome you to the industry elite, as only the "best of the best" are chosen to join the ranks as EMICS. Your business standing and knowledge has earned you a reputation in this field that you should be proud of, and will afford you the opportunity to increase your market share of one of the fastest growing segments of the business today, ACCEL fuel injection.

Congratulations and the best of luck.

Ray T. Bohacz

TABLE OF CONTENTS

Page

CHAPTER 1

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 1: ENGINE MANAGEMENT REVIEW

Why Fuel Injection?

Even though in racing, fuel injection is usually associated with the ultimate in performance, the reason behind its proliferation onto main stream automobiles is for quite the opposite purpose. With increasingly stricter emission standards and the EPA's implementation of a required minimum fuel economy, the days of the carburetor were ended. Without electronic engine controls, it simply wasn't possible to accurately command all the parameters of fueling and spark that were needed to remain compliant, without having finite control of the administration of the fuel into the engine. The advent of cold start emission tests made apparent the needed decrease in catalytic converter light-off time and made critical the cold start and intermediate warm-up fueling.

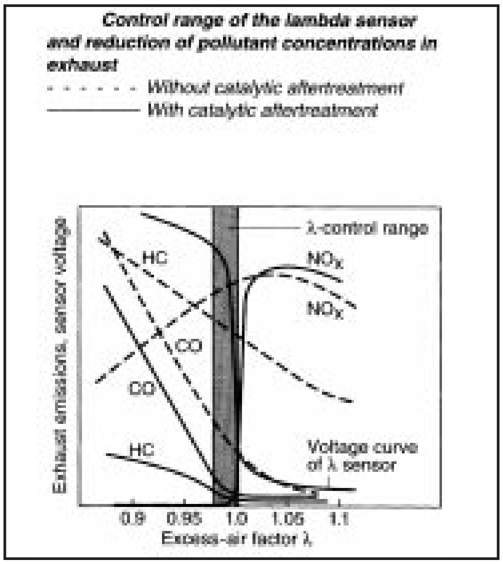


Fig. 1.1 *– The catalytic converter along with the Lambda, or more commonly known as the oxygen sensor play a huge role in the decrease of tailpipe emissions.*

Even though fuel injection made its debut in America in the mid 1950's, with General Motors using it on certain Chevrolet and Pontiac models, today's injection bears no resemblance to its ornary beginnings. The Europeans, working in conjunction with Bosch, were the pioneers of todays injection systems. The high cost of fuel in Europe and the taxation of large powerplants forced the development of fuel stingy small displacement engines. With no need to respond to the same conditions, American manufacturers were late to the injection game and first introduced electronic fuel injection as opposed to their earlier mechanical systems in the mid 1970's with Cadillac and Lincoln leading the way. These were very crude non feedback systems that utilized very slow analog microprocessors. The next foray by the industry was to feedback carburetors with a transistion to throttle body injection and then on to todays multipoint injection systems. What does the future hold for fuel management? The next logical step is the development of direct port injection where the fuel is injected under extremly high pressure directly into the combustion chamber allowing for mixtures in the 40:1 range.

With computer technology making great strides in the 1980's it was now possible to interface electronics with fuel management and today's fuel injection systems were born. Not only did that prove to be a major factor in gaining EPA compliance but it also spawned a Muscle car renaissance with the arrival of the 5.0 Mustang, Buick GN, TPI Chevrolets and Pontiacs. It was only a matter of time before these late model injection systems found their way under the hood of an old hot rod to only be met with at best, disastrous results. The age of electronic hot rodding was born, and it was quickly discovered that changes needed to be made to the ECU's stock program to have it work with traditional speed parts. Due to the complexity of the OE ECU and its propriatory nature, reprogramming by the enthusiast was impractical. That is where ACCEL stepped in and developed a user friendly reprogrammable ECU that allowed the enthusiast to employ today's technology. Not stopping with just the electronics, the deficiencies of air and fuel flow were also addressed with a complete line of manifolds, throttle bodies, camshafts and injectors.

Recognizing that supplying parts alone would not be enough, the Engine Management Installation Center (EMIC) program was established as an outlet to support the new age of electronic hot rodding.

IDENTIFYING THE COMPONENTS

Since an engine has no idea of how it is being fueled, most of the dynamics of the fuel requirements stay constant whether the engine is injected or carburetorated and still need to be applied. The only area that does change is that heat is no longer needed in the intake manifold to help vaporize cold fuel and the function of load needs to be inputted independently to the ECU as part of a decision making process in lieu of a dynamic action.

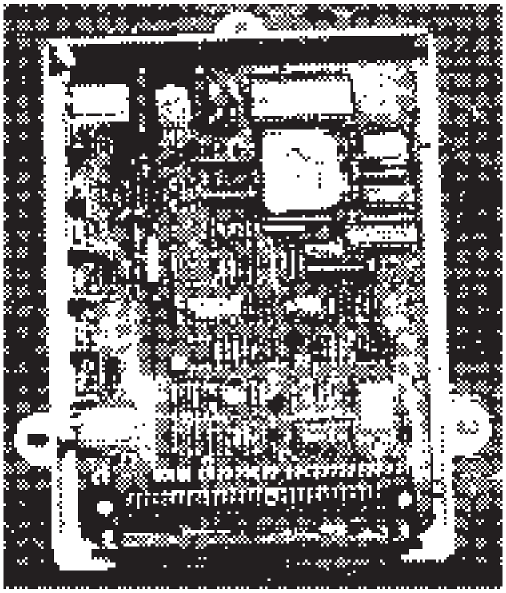
To establish this further, refer to the following component comparison chart on the next page.

CARBURETOR vs. INJECTION COMPONENTS

A) Float and bowl assembly	A) Fuel rail and pressure regulator
B) Choke circuit	B) Coolant and air charge sensor
C) Fast idle cam	C) Idle air control (IAC)
D) Idle circuit	D) Base injector pulse width
E) Main metering	E) Base injector pulse width
F) Power enrichment	F) MAP sensor
G) Accelerator pump	G) TPS

THE ECU

As in any electronic fuel injection system, the ECU is the core component. Since the ACCEL fuel injection system utilizes readily available OE hard components only, only our ECU is unique. It is a Motorola based microprocessor that employs a Packard head connector and internal components that are reliability rated to 70°C. It is designed and manufactured in house with final assembly taking place in a Echlin owned and operated facility in Independence, Kansas. It is available in two distinct forms with the differentiation being in the injector firing patterns. The most common unit is generally referred to as a spark/fuel ECU and that is designed to pulse all of the injectors at once. The companion ECU is identified internally as a SEFI unit which is a acronym for sequential fuel injection and will control injector firings in time with valve events. Both ECU's have part number variations due to ignition compatibility and desired options.



The batch fire spark and fuel ECU incorporates a series of 4 internal peak and hold 4/1 drivers and has the ability to run 8 low impedance injectors at full duty cycle for short periods of time. The SEFI unit is capable of controlling 8 low impedance injectors with no time or duty cycle constraints.

Through the use of ACCEL'S CALMAP software, and a IBM compatible PC, either ECU is easily reprogrammed and can be configured to work either in open or closed loop control with a set point of stoichometric, 4, 6 or 8 cylinder configuration, speed density based in 1, 2 or 3 Bar MAP input or a throttle angled based function called Alpha-N.

The ECU's are housed in either a sheetmetal enclosure or a extruded case for packaging in more hostile environments where water infiltration would become a issue.

Common with traditional OE ECU's, the ACCEL/DFI utilizes 5 volt signals to most sensors.

At the present time no ACCEL/DFI ECU offers self diagnostics.

ACCEL markets both ECU's as a standalone component to utilize an existing OE wiring harness with an outside vendor supplied interface harness or as a complete kit with a ACCEL produced main and injector harness. All ACCEL harnesses are made to meet or exceed OE quality and incorporate Packard connectors.

ECU INPUTS AND OUTPUTS

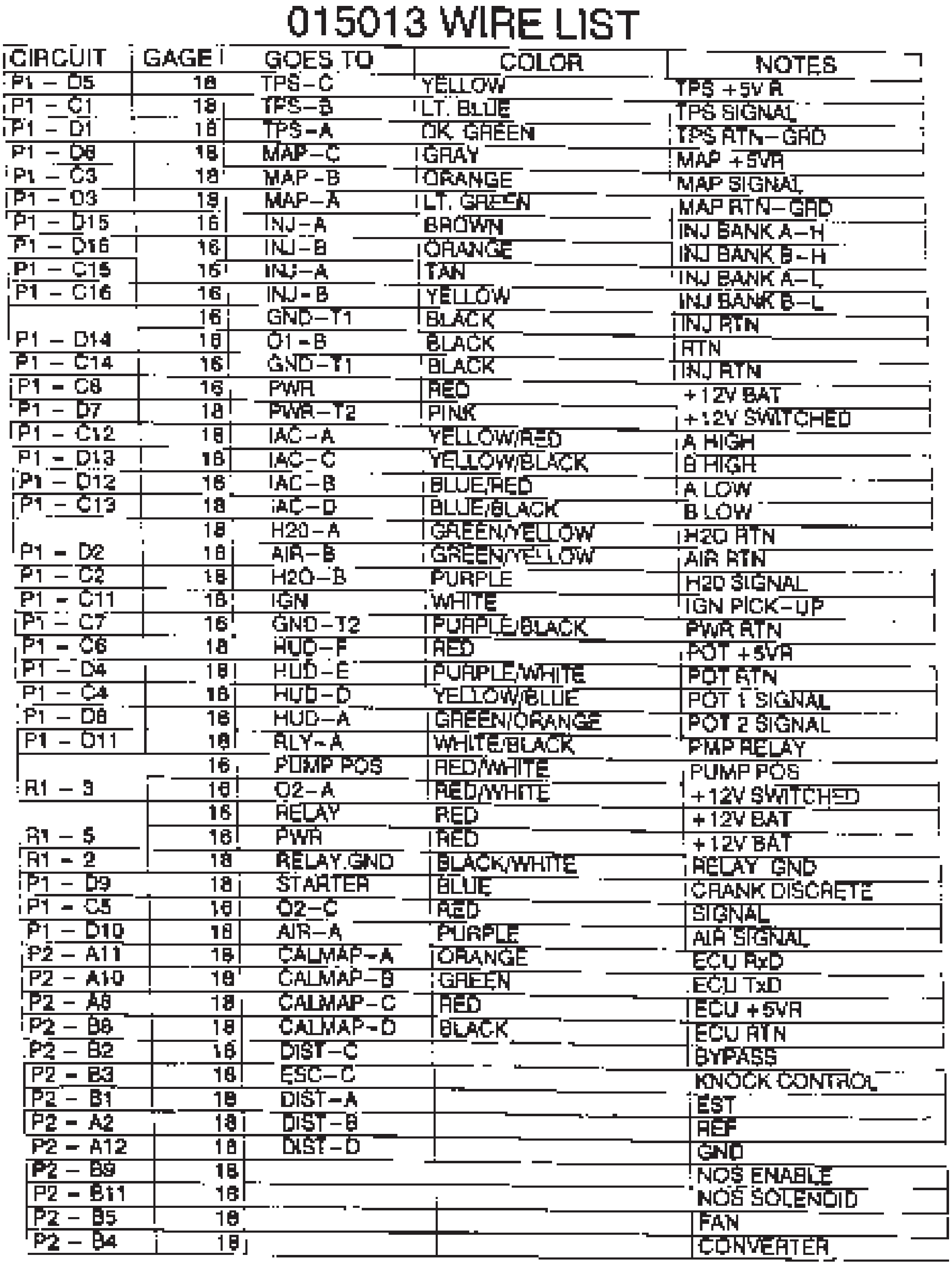
Figure 1.2 *(shown on next page)* is a pin out list for the most commonly used ACCEL ECU. The header connectors are identified by their respective number of cavities with the 32 cavity being labeled P-1 and the 24 cavity identified as P-2. Within each individual connector the pin locations are identified alpha numerically. For example connector P-1 C8 is 12 volts battery power. The alpha mumeric code is molded into the plastic connector and requires a little searching to identify the first time.

The following is a overview of each sensor and its input to the ECU.

Coolant temperature -

TEMPERATURE TO RESISTANCE VALUES FOR ACCEL COOLANT SENSORS
(Approximate)

DEGREE F	DEGREE C	OHMS
210	100	185
160	70	450
100	38	1,800
70	20	3,400
40	-4	7,500
20	-7	13,500
0	-18	25,000
-40	-40	100,700



015013 WIRE LIST

CIRCUIT	GAGE	GOES TO	COLOR	NOTES
P1 – D5	18	TPS – C	YELLOW	TPS +5V R
P1 – C1	18	TPS – B	LT. BLUE	TPS SIGNAL
P1 – D1	18	TPS – A	DK. GREEN	TPS RTN – GRD
P1 – D6	18	MAP – C	GRAY	MAP +5VR
P1 – C3	18	MAP – B	ORANGE	MAP SIGNAL
P1 – D3	18	MAP – A	LT. GREEN	MAP RTN – GRD
P1 – D15	16	INJ – A	BROWN	INJ BANK A – H
P1 – D16	16	INJ – B	ORANGE	INJ BANK B – H
P1 – C15	16	INJ – A	TAN	INJ BANK A – L
P1 – C16	16	INJ – B	YELLOW	INJ BANK B – L
	16	GND – T1	BLACK	INJ RTN
P1 – D14	18	O1 – B	BLACK	RTN
P1 – C14	16	GND – T1	BLACK	INJ RTN
P1 – C8	16	PWR	RED	+12V BAT
P1 – D7	18	PWR – T2	PINK	+12V SWITCHED
P1 – C12	18	IAC – A	YELLOW/RED	A HIGH
P1 – D13	18	IAC – C	YELLOW/BLACK	B HIGH
P1 – D12	16	IAC – B	BLUE/RED	A LOW
P1 – C13	18	IAC – D	BLUE/BLACK	B LOW
	18	H2O – A	GREEN/YELLOW	H2O RTN
P1 – D2	18	AIR – B	GREEN/YELLOW	AIR RTN
P1 – C2	18	H2O – B	PURPLE	H2O SIGNAL
P1 – C11	18	IGN	WHITE	IGN PICK – UP
P1 – C7	16	GND – T2	PURPLE/BLACK	PWR RTN
P1 – C6	18	HUD – F	RED	POT +5VR
P1 – D4	18	HUD – E	PURPLE/WHITE	POT RTN
P1 – C4	18	HUD – D	YELLOW/BLUE	POT 1 SIGNAL
P1 – D8	18	HUD – A	GREEN/ORANGE	POT 2 SIGNAL
P1 – D11	18	RLY – A	WHITE/BLACK	PMP RELAY
	16	PUMP POS	RED/WHITE	PUMP POS
R1 – 3	16	O2 – A	RED/WHITE	+12V SWITCHED
	16	RELAY	RED	+12V BAT
R1 – 5	16	PWR	RED	+12V BAT
R1 – 2	18	RELAY.GND	BLACK/WHITE	RELAY GND
P1 – D9	18	STARTER	BLUE	CRANK DISCRETE
P1 – C5	16	O2 – C	RED	SIGNAL
P1 – D10	18	AIR – A	PURPLE	AIR SIGNAL
P2 – A11	18	CALMAP – A	ORANGE	ECU RxD
P2 – A10	18	CALMAP – B	GREEN	ECU TxD
P2 – A8	18	CALMAP – C	RED	ECU +5VR
P2 – B6	18	CALMAP – D	BLACK	ECU RTN
P2 – B2	16	DIST – C		BYPASS
P2 – B3	18	ESC – C		KNOCK CONTROL
P2 – B1	18	DIST – A		EST
P2 – A2	18	DIST – B		REF
P2 – A12	18	DIST – D		GND
P2 – B9	18			NOS ENABLE
P2 – B11	16			NOS SOLENOID
P2 – B5	18			FAN
P2 – B4	18			CONVERTER

Fig. 1.2

Mounted in the intake manifold water jacket the coolant sensor calibration that the DFI is coded to acknowledge is the common Delco two wire unit. It is a thermistor, which is the opposite of a resistor. Where a resistor's impedance increases with exposure to heat, a thermistors resistance decreases when heated. A 5 volt analog signal originates at pin P1-C2 and is sent out to the coolant sensor and returns back at pin P1-D2. Due to the design nature of the circuit, if it fails open it will be interrupted as a extremly cold cooltant temperature. The coolant sensor value is extremely important and is used to envoke warm-up fueling, IAC starting position, fast idle speed, closed loop parameter and idle spark functions. Other than GM installations still require the use of the DFI supplied sensor for proper operation.

Air charge temperature - This sensor is identical to the coolant sensor except that it is mounted in the plenuum in most cases, and is used to calculate incoming air temperature as a correction factor. Air temperature correction is used as a trim function to the base fuel map to compensate for the decrease in VE due to the heating of the charge air. Five volts analog originate at P1-D10 and share return P1-D2 with the coolant sensor.

Manifold absolute pressure (MAP) - This Delco sourced piece is available in 1, 2 and 3 Bar configurations and is used as an input to determine load on the engine. This 3 wire analog output sensor reads pressure changes in the intake manifold. Since the input voltage of the signal stays constant at 5 volts, resolution is cut down proportionally when 2 or 3 bar sensors are used. Location P1-D6 is the originating point for the 5 volt reference signal. P1-C3 is the output of the sensor which is identified as the signal return with P1-D3 being a internal ground supplied by the ECU. MAP sensor input is used by the ECU to calculate load in both the fuel and timing matrix and is also used as an input to invoke load based fuel enrichment. If the ECU is configured to read in Alpha-N then the MAP sensor is retained but is not connected to a vacuum source and is used for barometric compensation.

Throttle position sensor (TPS) - Hooked mechanically to the throttle body this 3 wire Delco sourced sensor inputs throttle angle position data to the ECU. Circuit P1-D5 feeds the TPS with a analog 5 volts while P1-C1 returns the sensor's output to the ECU, and P1-D1 is a internally supplied ground. Throttle position input is used to promote IAC tracking and is also used to trigger acceleration enrichment which takes the place of an accelerator pump. Not only is the position of the throttle monitored, but also the rate of change to determine the amount of enrichment needed. It's input is also used as a threshold for transition out of closed loop and to engage and disengage the torque converter clutch and to invoke the idle spark function. Additionally, at 100% TPS the coolant fan circuit that is controlled by the ECU shuts off if engaged. If engaged during Alpha-N configuration, TPS input replaces MAP load as a function of fueling. Slotted TPS's are used so that base values can be adjusted to coincide with closed throttle. Ford installations retain a Motorcraft sourced sensor with the mounting holes elongated to make them adjustable.

Oxygen sensor (O_2) - Only used for closed loop stoicohmetric fuel control. This sensor is a 3 wire heated Bosch unit. By nature, a oxygen sensor will not operate accurately until it reaches a temperature of 600°F. The heating element brings the sensor on-line sooner and keeps its output voltage more stable. The heater also allows for more freedom in the placement of the sensor which is critical in a performance application that utilizes headers. Terminal P1-C5 accepts the sensors output voltage and the ECU correlates that to an air fuel ratio. The sensor has an accurate range from 0-1 volt with aproximatly .5 being 14.7:1. Output voltge degrades below .5 with air fuel ratios

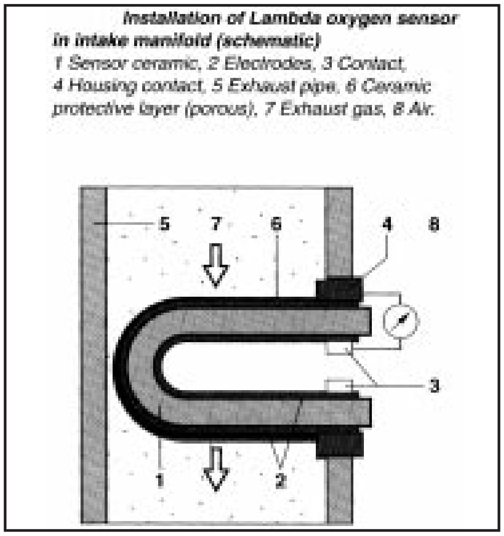


***Figure 1.3A** – Located as close to the exhaust port as possible for the most accurate readings, the oxygen sensor is considered a galvonic battery that needs to sample the exhaust and reference it against atmosphere.*

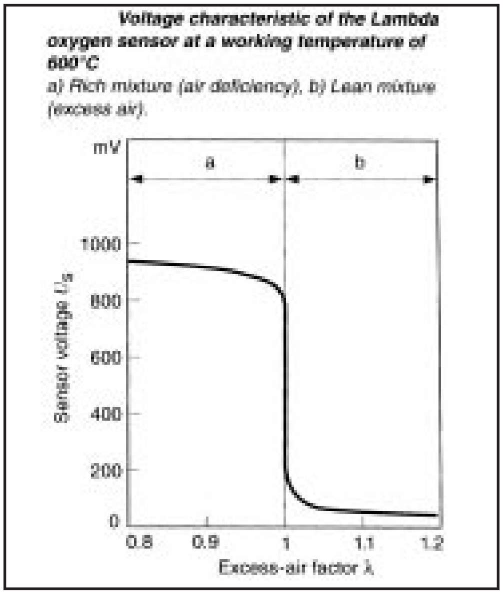


***Fig. 1.3B** – A standard ACCEL ECU utilizes a Bosch Lambda=1 sensor that is capable of accurately identify an air fuel ratio of 14.7:1. At this air fuel ratio the sensor produces an output voltage that switches rapidly from approximately 200-800 mv.*

leaner than stoich and increase to over .5 with mixtures richer than stoich. The 12 volts that are supplied for the heater originate at Relay terminal R1-3 that it shares with the fuel pump. P1-D4 is the heating element ground that is supplied internally by the ECU.

Knock Sensor - Optional knock sensor control kits are available from ACCEL for both Small and Big Block Chevrolet engines. The Delco supplied kit contains a knock sensor and a wiring harness and an Electronic Spark Control module (ESC) which is essentially an analog to digital converter. The sensor its self is a piezoelectric acceloro-meter specific to either engine, and even though physically looks the same, is tuned to detect a different knock frequency in a Small Block vs. a Big Block. *(See Fig. 1.3C on this page)*. This sensor during detonation produces a low voltage sine wave output that is then converted by the ESC module to a digital signal. The output signal of the ESC module that correlates to detonation is then sent to ECU terminal P2-B3 and is processed internally to retard the ignition timing (see ECU outputs for further explanation). Buick GN applications must source the proper ESC module and sensor directly from Buick. They are not interchangable with the Chevrolet parts even though they share the same enclousure. The output of the ESC module would still input the ECU at the same terminal. There are no known knock kits that will interface with a Ford at this point.

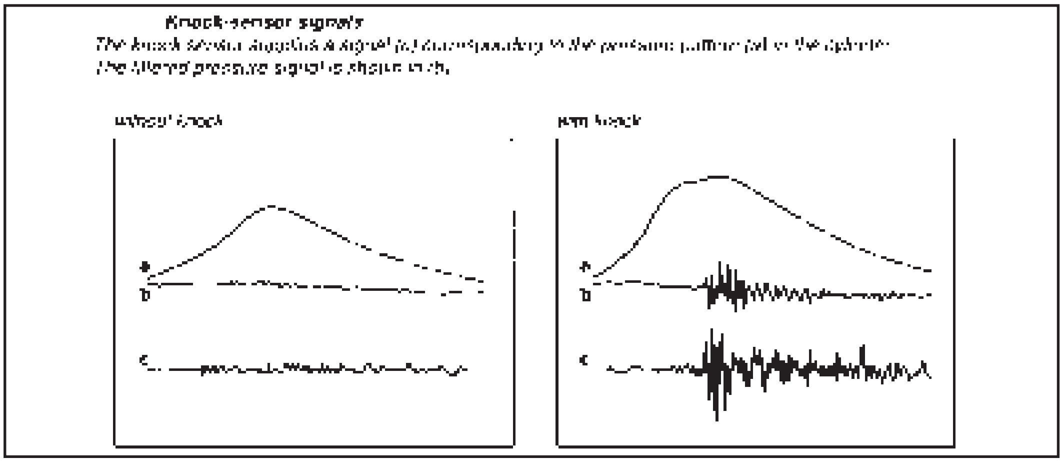


***Fig. 1.3C** – Abnormal combustion creates an uncontrolled release of the end gases energy in the cylinder as represented by **(a)** in the above graphs. The corresponding harmonic that is created by the colliding flame fronts cause oscillations of the piston, rings and bearings and is detected by the knock sensor and is represented by **(c)** in the graph.*

Tach Reference - When utilizing a EST distributor a square wave that is originated at the ignition module is sent to terminal P2-A2 to be interperated as a RPM signal.

12 volt inputs - Though not a sensor input a constant 12 volt source is applied to terminal P1-C8 and a switched 12 volts at P1-D7.

CALMAP - ECU terminals P2-A11, P2-A10, P2-A8 and P2-B8 are all used in conjunction with communicating to the ECU.

ECU OUTPUTS

The following is a list of circuits that are controlled by the ECU.

Injector firings - With a 015013 designated ECU all of the injectors are fired simultaneously with 1/2 their programmed pulse width for each crank rotation. Therefore, it is given the name of Simultaneous Double Fire (SDF). Incorporated into the ECU are four drivers with each one having the duty of pulsing 2 injectors. The harness is broken down into 4 banks of two injectors each identified as A-H, A-L, B-H and B-L. Pin P1-D15, D16, C15, C16 all supply 12 volt power to the injectors with pins P1-D14 and P1-C14 supplying returns to the drivers. The drivers supply a ground internally in the ECU.

Fan control - The ECU has the ability to control the fan circuit by the grounding of an independent relay. The fan enable temperature is programmable through the CALMAP software and operates with a 10 degree F. hystersis. For example, if the fan is programmed to turn on at 180°F it will not turn back off until the coolant reaches 170°F. Also, as stated under the ECU inputs section, at 99% TPS the coolant fan circuit is automatically shut off. The fan control is grounded through the ECU at terminal P2-B5.

Fuel pump - The ACCEL/DFI supplied harness incorporates a Bosch micro relay to power-up the fuel pump and supply 12 volts to the heated O_2 sensor. Through terminal P1-D11, 12 volts is supplied to close the fuel pump relay and to turn the pump on. As soon as the ignition is turned on, P1-D11 is supplied with a 2 second prime signal to charge the fuel rail. If an RPM signal is not seen on terminal P2-A2 the relay is shut off. Once P2-A2 becomes active again, the fuel pump is turned back on.

Timing control - The ECU has the ability to interface with either a GM EST module or a Ford EEC-IV ignition, for programmable timing control. Timing control can still be obtained if a aftermarket ignition like the ACCEL 300 Plus system is used in lieu of an OE ignition module. When terminal P2-A2 sees an input that equates to over 400RPM, it applies 5 volts on terminal P2-B2 which is reffered to as the bypass lead and takes control of the ignition module. Then P2-B1 controls the timing to the ignition module by varying the frequency of the square wave out-put. The circuit is completed by having P2-A12 supply a ground.

Idle air control - The ECU has the ability to have closed loop idle speed control through the use of a Delco stepper motor air bypass valve. This is a four wire design that uses pins P1-C12, D13, D12 and C13 to alternate the pulsing of an internal ground circuit to command the idle air control position. This function works in counts and is not actually aware of where the IAC pintle is. It just knows how many commands it has issued from a zero starting point. Other than GM installations still rquire the use of a Delco IAC, if idle speed control is desired. ACCEL offers a retrofit kit for Ford applications.

Torque converter clutch - An optional TCC clutch engagement kit for GM 200 and 700 series overdrives is available that includes a relay and wiring harness and is controlled from port P2-B4. A ground is supplied and the timing of the engagement is controlled through the CALMAP software.

Nitrous control - In its standard form, a 015013 ECU has the ability to control one stage of nitrous. It needs to see 12 volts applied from the vehicle's nitrous enable switch to terminal P2-B9 to become active. When the parameters are met, that are programmable through the CALMAP software, circuit P2-B11 becomes a ground for the nitrous solenoid. Up to three stages of nitrous can be controlled by the loss of either the TCC control circuit and the cooling fan control. That modification needs to be done by ACCEL/DFI. When the nitrous is engaged, the ECU will automatically retard the timing and richen the fuel curve to the values programmed by the user.

THE ECU'S DECISION MAKING PROCESS

Now that you have a basic familiarzation with the ACCEL/DFI ECU lets discuss some of

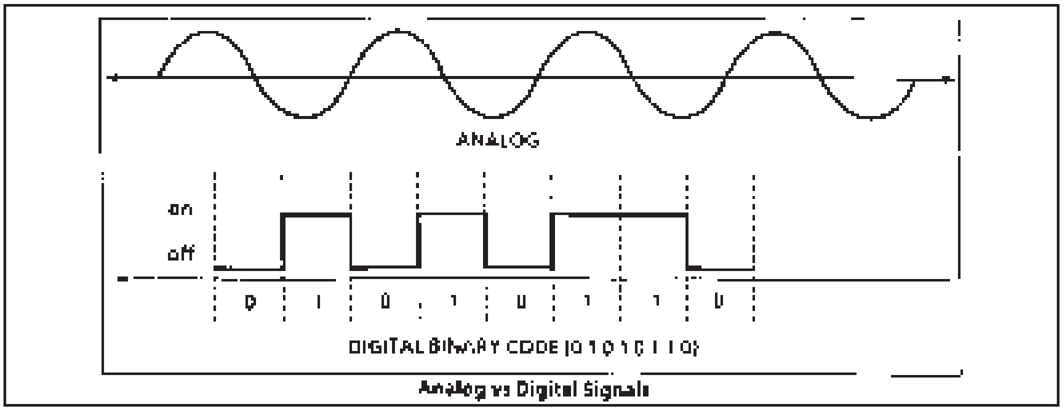


Fig. 1.4 *– A digital signal creates what is commonly referred to as a "square wave". The length of time that the wave is either high or low is used by the ECU to identify a parameter. A square wave is what the ECU uses to determine engine RPM when utilizing a stock OE electronic spark control ignition.*

Producing a varying voltage, an analog signal is able to be used to identify a certain condition. The TPS and all of the other sensors create analog outputs that are recognized by the ACCEL ECU.

NOTE: The above analog signal represents an AC sine wave that experiences a crossing of the polarity line that is referred to as a "zero crossing". Not all analog signals are sine waves but can also remain in either the positive or negative states.

the logic it uses to make control decisions. The ACCEL/DFI ECU is based to some extent on a GM TPI ECM, but uses a proprietary version of a speed density coded software to interput load and to allow end user reprogramming. The reason behind the decision to use speed density was due to the fact that use of a MAF always posed three major problems. The first being the room needed to package the actual sensor and the second being the flow limitations of the sensor. A stock GM TPI MAF is only capable of flowing approximately 550-600 CFM @ 28 inches of H_2O.
A fully ported MAF will still only approach 750 CFM. The third obstacle with MAF is the inability to interface it with unique manifold designs, for example an individual runner intake. Intially, but not a major concern today, the Bosch supplied MAF that GM used on its early TPI systems had a 9 out of 10 failure rate. By employing a quality Delco produced analog MAP sensor, all of these issues were addressed at a substantially lower cost than with a MAF.

The unique aspect of the ACCEL/DFI ECU is not its actual operation but its ability to allow the end user to tune the fuel and spark curves with relative ease. This procedure is accomplished with the CALMAP software and an IBM compatible PC. Even though the software is menu driven, and extremely user friendly the actual tuning decisions require a complete understanding of how an engine and fuel injection system functions. With the CALMAP software you are able to change the complete fuel curve and spark curves along with additional functions of idle speed, warm up enrichment, air temperature correction, etc. Even though CALMAP gives you access to these areas, what it doesn't tell you is the proper numbers to input.

Prior to concerning ourselves with programming decisions, lets follow the procedure the ECU will take to gather data and then lets start to think like the ECU.

As in any electronic fuel injection system all the ECU does is gather values from its sensors and uses them to identify different points in what is called look up tables. A good analogy of a look up table is the chart that is used in a road atlas to determine mileage between two points. For example, if we needed to find the distance between NYC and LA using a mileage chart we can find the two points and see where they intersect and derive the mileage. Now according to the publisher of these maps, those values are the foremost direct route from city hall to city hall. So, to carry this futher if I was traveling from Nassau County Long Island to Malibu, California the chart would only be a reference point and not truly accurate do to the different points that I am beginning and ending my trip. Well, that is exactly what is happening inside the ECU. Even though we have base values inputed, we also have numerous trim factors that are used to adjust to conditions to zero in on the proper fuel mixture.

Since the ECU is an electronic device it can only understand voltages and has no way to interrupt mechanical conditions. For that reason, there needs to be a sensor that has the ability to convert a mechanical conditional to an electrical signal for interruption by the ECU. For example, the ECU does not understand WOT but it does know what 5 volts output on the TPS signifies. Since the

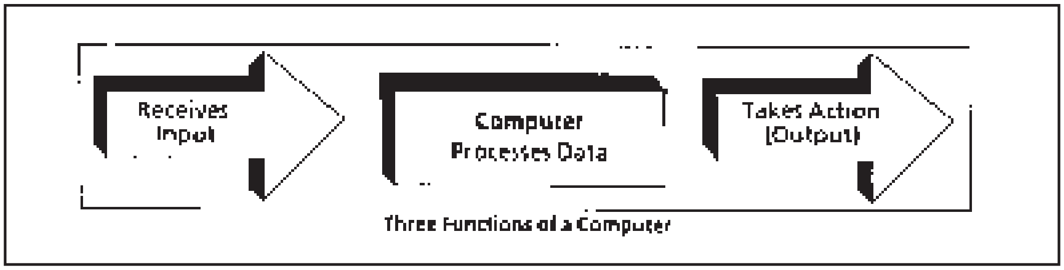
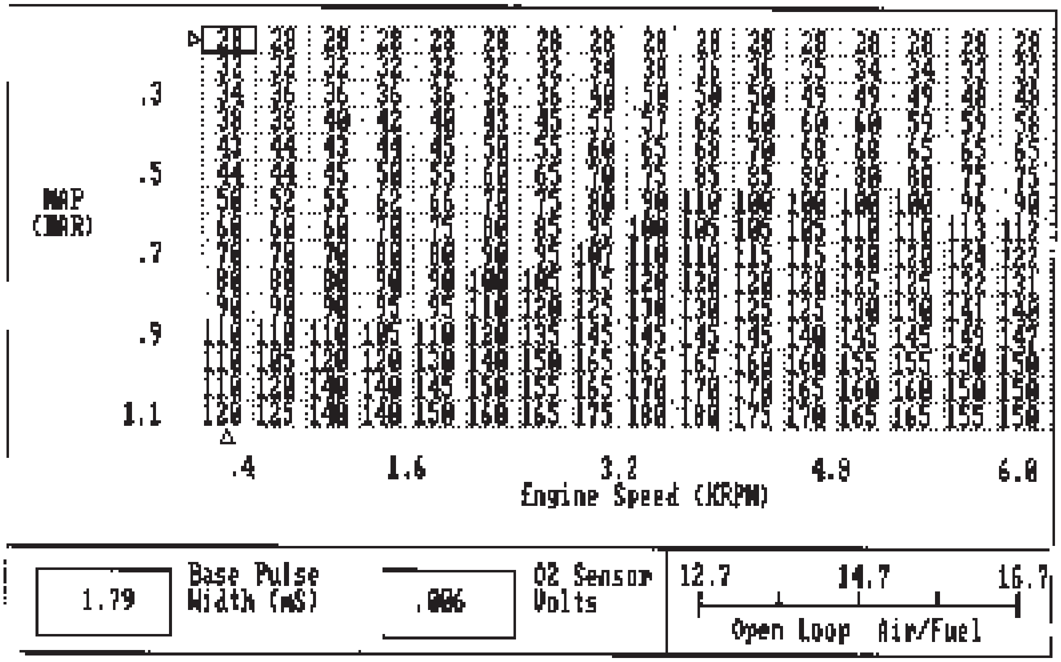


Fig. 1.5



MAP (BAR)																
	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
	32	32	32	32	32	32	32	34	38	36	36	35	34	34	33	33
.3	34	36	36	36	36	36	36	40	50	50	50	49	49	49	48	48
	38	38	40	42	40	43	45	55	57	62	60	60	60	59	59	58
	43	44	43	44	45	50	55	60	65	68	70	68	68	65	65	65
.5	44	44	45	50	55	60	65	70	75	85	85	80	80	80	75	75
	50	52	55	62	66	70	75	80	90	110	100	100	100	100	96	90
	60	60	60	70	75	80	85	95	100	105	105	105	110	110	113	112
.7	70	70	70	80	80	90	95	107	110	110	115	115	120	120	124	122
	80	80	80	90	90	100	105	115	120	120	120	120	125	125	132	131
	90	90	90	95	95	110	120	125	150	130	125	125	130	130	141	140
.9	110	110	110	105	110	120	135	145	145	145	145	140	145	145	149	147
	110	105	120	120	130	140	150	165	165	165	160	160	155	155	150	150
	110	120	140	140	145	150	155	165	170	170	170	165	160	160	150	150
1.1	120	125	140	140	150	160	165	175	180	180	175	170	165	165	155	150

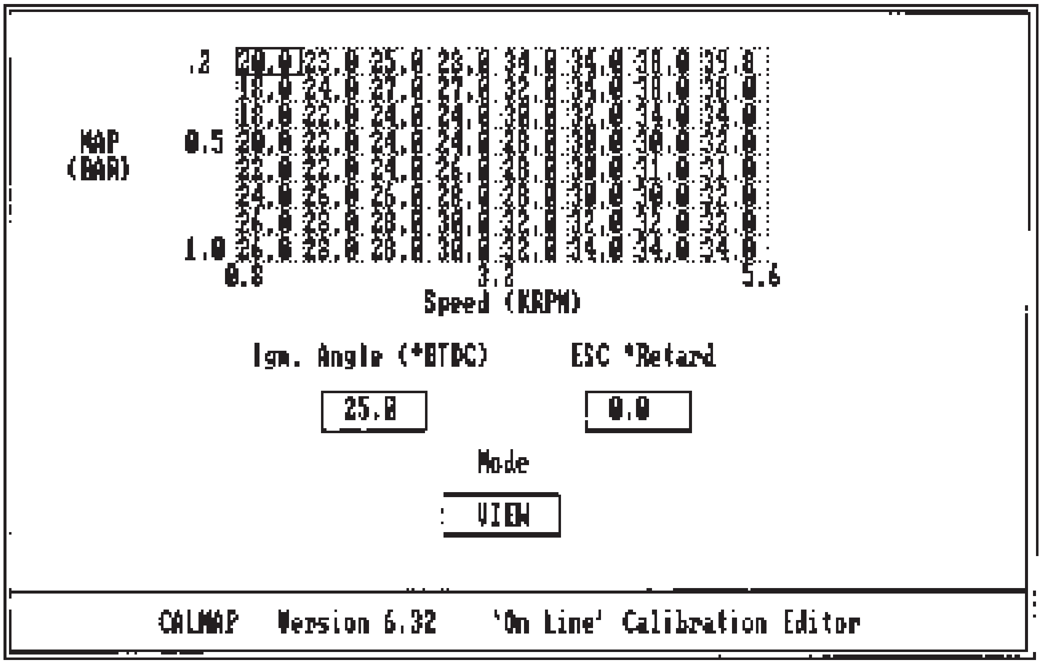
.4 1.6 3.2 4.8 6.0

Engine Speed (KRPM)

1.79 Base Pulse Width (mS)

.006 O2 Sensor Volts

Fig. 1.6



MAP (BAR)								
.2	20.0	23.0	25.0	28.0	34.0	35.0	38.0	39.0
	18.0	24.0	27.0	27.0	32.0	34.0	30.0	30.0
	18.0	22.0	24.0	24.0	30.0	32.0	34.0	34.0
0.5	20.0	22.0	24.0	24.0	28.0	30.0	30.0	32.0
	22.0	22.0	24.0	26.0	28.0	30.0	31.0	31.0
	24.0	26.0	26.0	28.0	28.0	30.0	30.0	32.0
	26.0	28.0	28.0	30.0	32.0	32.0	32.0	32.0
1.0	26.0	28.0	28.0	30.0	32.0	34.0	34.0	34.0

0.8 3.2 5.6

Speed (KRPM)

Ign. Angle (*BTDC) 25.0

ESC *Retard 0.0

Mode VIEW

CALMAP Version 6.32 'On Line' Calibration Editor

Fig. 1.7

ECU is inanimate it has no way of determining if a sensor's input is accurate and takes that value as the truth. As with any computer, garbage-in is garbage-out and proper decisions can only be made with accurate data inputs.

In essence, what the ECU does is gather data from all of its sensors and then use that data to find a place in the fuel and spark look-up tables to determine an injector pulse width or spark advance command. *(See Fig. 1.6 & 1.7 on page 1-8.)* In the ACCEL/DFI ECU the MAP sensor input along with the RPM signal are the only data that is needed to find a place in the fuel and timing look up tables. Other sensor inputs are used as trim tables to the core fuel program. For example, if the look up table identified a load and RPM cell that placed the base injector pulse width at 10 MS, and the coolant look up table identified at that given coolant value we should add 10% enrichment we would end up with a a gross injector pulse width of 11MS (Base pulse plus or minus the trim value = gross pulse width). What the CALMAP software enables you to do is change all the values in the look up tables to suit the demands of the particular engine that you are working on.

Once we understand this, we can very easily break the ECU software down into two simple categories - core and trim tables.

CORE TABLES	TRIM TABLES
Cranking fuel	Idle spark
Base fuel map	Coolant enrichment
Timing map	Warm up enrichment
Idle speed	Coolant temperature vs. idle speed
Configuration	Oxygen sensor correction
	Air temperature correction
	MAP and TPS enrichment

Since the ECU uses the trim tables in conjunction with the core tables, it is essential to have the values in the core tables as close to being correct as possible, since the trim tables have limited control.

FUEL FLOW DYNAMICS

All late model injection systems utilize an electric fuel pump to maintain the constant supply of fuel that is needed. ACCEL offers two fuel pumps for EFI engines. Part number 74701 supports engines up to 450 HP while 74702 will supply power levels to 800 HP. Power levels above that will require tandem pumps. All of ACCEL's pumps can either be mounted internally in the fuel tank or cell or externally on the vehicles frame rail.

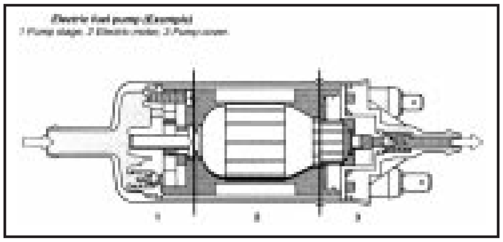


Fig. 1.8 – *A generic overview of an electric fuel pump. ACCEL supplied pumps are modified in critical areas to increase the volume of fuel pumped while maintaining OE levels of reliability.*

A common misunderstanding when dealing with electronic fuel injection is the concept of pressure vs. flow. To maintain a given pressure it is essential to maintain a certain volume of fuel flow. If fuel flow ramps down under load condition, fuel pressure will drop. To establish this fact, think of a simple garden hose. In a residential water system the amount of water volume to the hose spiget remains constant (the fuel pump). When hooking up a garden hose with a nozzle you are creating a orifice that causes a directing of the water (the injector). If a second hose is connected to the same source what happens to the flow from the original nozzle? As we all know, the amount of pressure and flow at the nozzle will decrease. In essence the same pressure flow relationship happens with a fuel injector. As load is applied to the engine, an increase of pulse width is required to supply the proper amount of fuel and if fuel flow is not sufficient in the rail, pressure at the injector will drop. For this reason, fuel pressure should always be checked at idle and then under load.

The function of the fuel pressure regulator is to maintain a preset pressure in the fuel rail. The way all electronic fuel injection systems function is that they pump more fuel than they consume, constantly returning fuel back to the supply tank. The fuel pressure regulator is connected in series with the fuel supply and controls the amount of fuel returned to the tank. The less fuel returned, the higher the rail pressure. Referenced to an engine vacuum source for enleanment under light load and coast down, (lower pressure), the regulator consists of a diaphragm and a calibrated spring. An adjustable regulator has the ability to

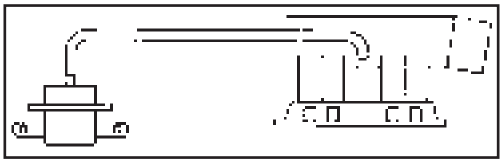


Fig. 1.9

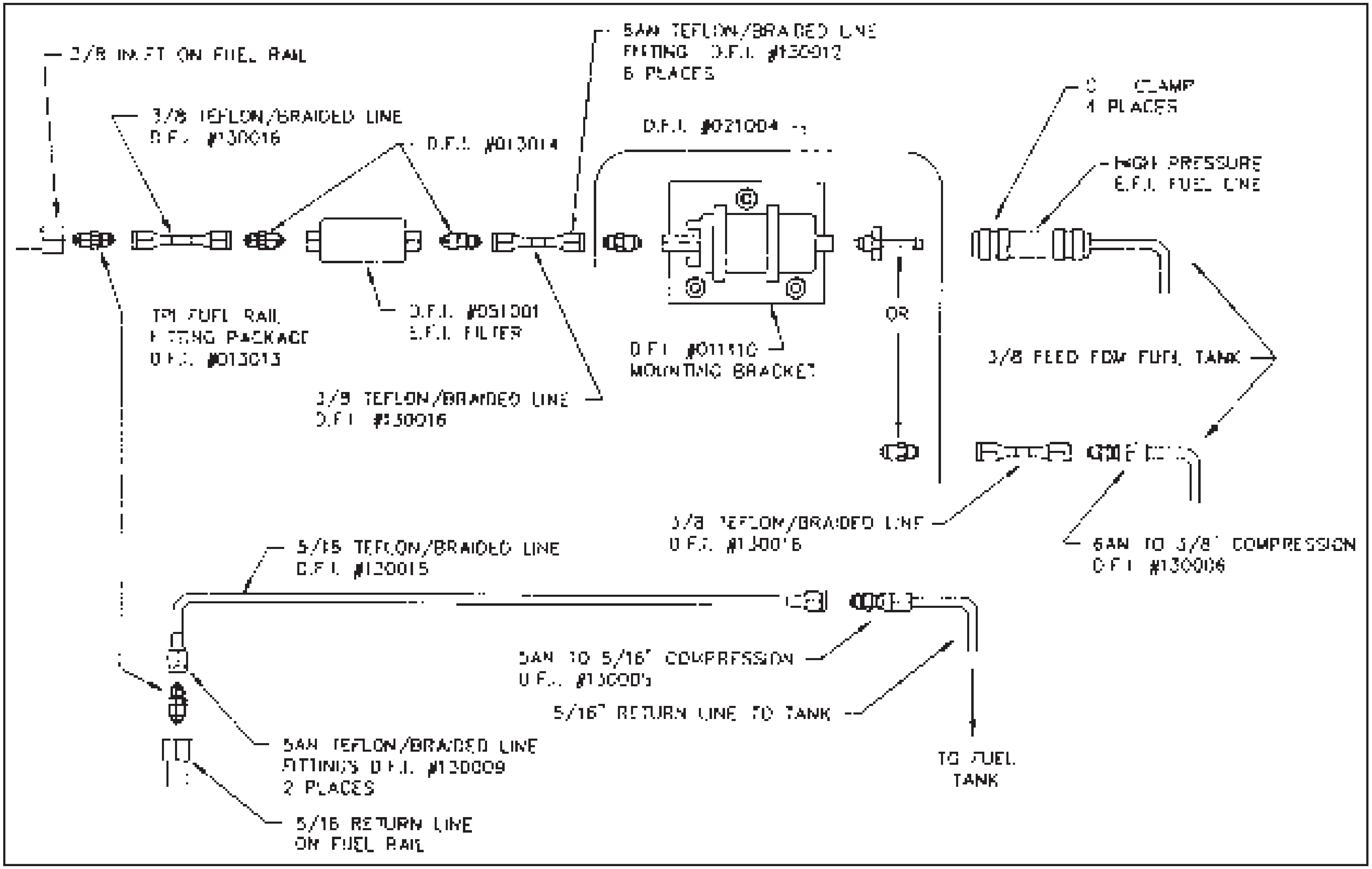


Fig. 1.10 – *This is the suggested installation of a fuel injection supply system.*

change the diaphrams position and thus control the amount of return fuel to achieve a given pressure. If fuel flow volume is insufficient, then regardless of the diaphram's position in the regulator, fuel pressure cannot be maintained. Remember, to maintain the pressure set point, there needs to more fuel volume supplied than fuel consumed.

Another area that comes into play in regard to pressure vs. flow, is the voltage supply to the fuel pump. The pump itself is a rotary vane design that needs a constant supply of voltage to maintain the proper fuel volume. Applying Ohms' law, if current demand increases, then voltage will drop if the voltage supply is constant. The following chart shows a direct correlation of fuel pump output in regard to supply voltage. *(Refer to Fig. 1.11 on this page).*

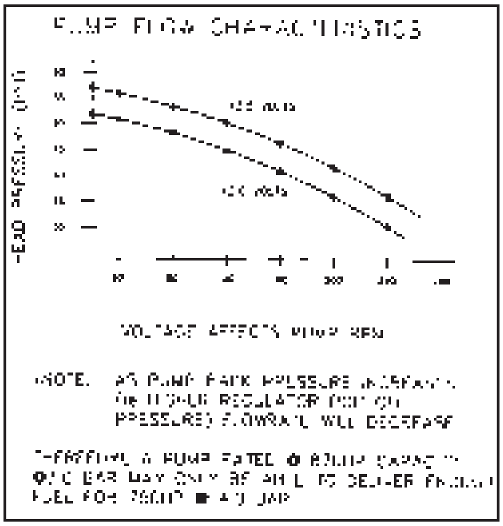


Fig. 1.11

Not only does fuel pump voltage affect pressure, but the size of the fuel supply lines and the area of the fuel filter become paramount. Fuel injected engines always have large fuel filters in comparison to carbureted engines due to the volume of fuel pumped. Remember there is always more fuel pumped than used, and to allow sufficient area as not to disturb flow characteristics. Keep in mind that a fuel injection system has no real reservoir to store fuel like a carburetor does. The only storage it has is whatever is in the fuel rail.

The sequence that the injectors are fired also has a effect on the fuel rail dynamics. Simultaneous double fire is the least complicated system electronically and in theory has less components to possibly fail but is the hardest to keep the fuel rail pressure constant with and the rail charged. When eight injectors all open simultaneously, there is a great depletion of fuel from the rail and this causes the pressure regulator to close off the return quickly to maintain presssure. This surging of the rail may actually cause a phonomena called fuel rail knock, specifically on an engine with large injectors. This knock is produced by the rail being shocked by the rapid discharging of the fuel supply and the rush of replacement fuel. Sequential injector firings are the most fuel rail friendly due to the minimal discharging of the fuel rail by the firing of only one injector at a time.

The diagram on page1-10 *(Fig. 1-10)* depicts an average port fuel injection fuel supply system. A common feature in these systems is the incorporation of a fuel pressure check valve that will maintain fuel pressure back to the regulator. This is used to aid in starting the engine by keeping the fuel system charged and to help combat percolation of the fuel in the rail and lines during heat soak conditions. ACCEL supplied fuel pumps incorporate a one way check valve internally at the outlet side of the fuel pump to accomplish this.

The Fuel Injector

Other than the ECU, the main component of an injection system is its name sake the fuel injector. It is customary to identify an injector by a number of different characteristics. Its flow capacity, fuel feed point, attachment to the fuel rail, electrical resistance and tip design. In GM OE applications, another criteria is the placement of the injector. General Motors uses completely different designed injectors in their port fuel injec-

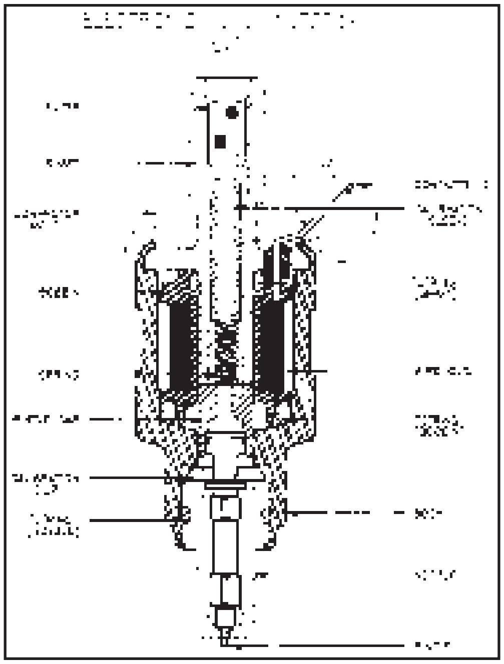
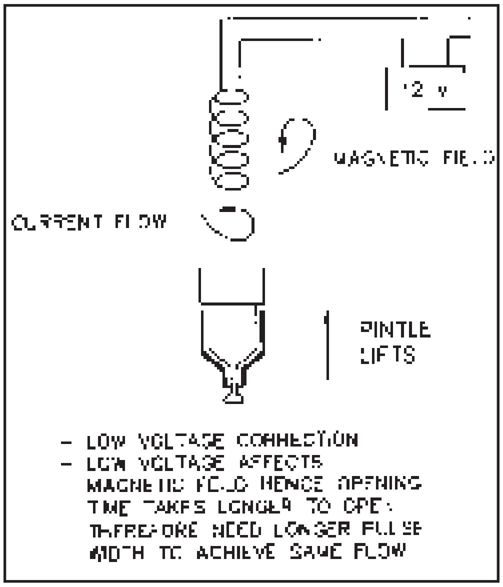


Fig. 1.12

tion systems vs. throttle body vs. central port injection. ACCEL distributes only individual port style injectors.



- LOW VOLTAGE CONNECTION
- LOW VOLTAGE AFFECTS MAGNETIC FIELD HENCE OPENING TIME TAKES LONGER TO OPEN; THEREFORE NEED LONGER PULSE WIDTH TO ACHIEVE SAME FLOW

Fig. 1.13

Before extrapolating on injector differences we need to understand the basics of an electronic fuel injector. At ACCEL we currently distribute injectors produced by Bosch and Siemens. They are generally classified by their flow and resistance values. All of our injectors are top feed with o-ring attachment to the fuel rails. All electronic injectors consist of the same core components and are are simply a soleniod that is attached to a fixture that opens and closes a fuel flow orifice. When the ground circuit is completed by the ECU, the solenoid is energized, lifting the fuel flow closing device and exposing an orifice to pass fuel. When the ground circuit is removed, the solenoid closes and fuel flow stops. When I spoke earlier about the core fuel table and the programmable amount of injector pulse width, we were describing the amount of time the circuit was grounded and the signal to open the injector was applied. This seems very straightforword, but there are other crucial factors that need to also be applied. The length of time the injector ground circuit is applied is measured in milliseconds or thousands of a second. That is referred to as injector pulse width. The length of time it takes for the solenoid to lift and completely uncover the fuel flow orifice is called the rise time. Even though to the human eye the opening of the injector is quicker than the eye and mind can capture, once broken down to the finite measurement of 1/1000 of a second the slowness of the injector opening becomes apparent. By applying OHM’s law, we can see that with the voltage remaining constant, if we increase current flow we are able to charge the solenoid quicker and make it respond faster.

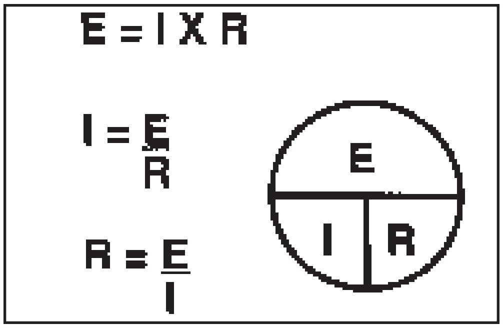


Fig. 1.14 *– Ohms Law is a mathematical relationship between the properties of Voltage (E), Current flow in Amperage (I), and Resistance in Ohms (R). When any two properties are known the third can be calculated.*

By changing the resistance of the injector windings we are able to pass additional current and decrease injector rise time. Most OE applications use high impedance (12-16 ohm) injectors due to their lower cost and the ability to use saturated drivers in the ECU. Lower impedance injectors (2-4 ohms) respond quicker (shorter rise time) but necessitate the use of peak and hold drivers which are not only more complicated but more costly to manufacture. By design, a saturated driver will keep current draw constant during its whole duty cycle. Conversely a peak and hold driver will

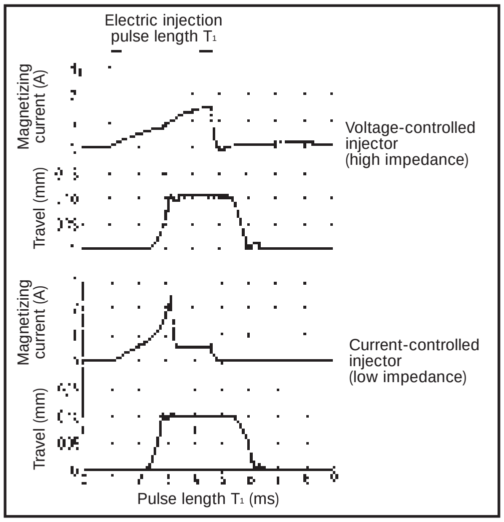
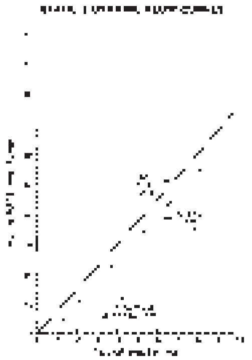


Fig. 1.15 *– Voltage controlled or saturated driver injectors have a substantially longer rise time than current controlled or peak and hold units as visualized by the above graphs. It is interesting to note the bouncing of the pintle that occurs during full travel open and closed as seen by the bumps in the travel portion of the graph. Note the excentuated bounce that is experienced by the high impedance injector.*

initially surge the current up and then step it down to a lower value and maintain that value throughout the event. If a peak and hold injector or driver is rated at 4/1 amps that translates as 4 amps to open the injector and 1 amp to keep it opened. Historically, tests have proven that a low impedance injector will have a rise time of just below 1.5 MS, while a high impedance unit can approach 2 MS.

Fuel delivery at or below the minimal injector rise time skews the atomization and leads to high emissions and poor idle quality. A standard 015013 ECU incorportes 4 4/1 drivers and has the ability to fire 8 low impedance injectors for short periods of time. Due to the drivers used in this ECU, long duty cycles in conjunction with the fact that it is simultaneous double fire coded will cause overheating of the ECU (see tuning section for futher explanation). The ACCEL sequential fired ECU uses 8 individual drivers and has no current or duty cycle constraints.

The second most important identifying aspect of an injector is its rated flow capacity. Think of injector flow capacity as you would a carburetor jet orifice dimension. ACCEL uses one of the three industry standards of lbs/hr to rate their injectors. The other two standards are gm/sec and cc/second. The rating of fuel in lbs/hr is always at a test pressure of 43.5 PSI which equates to the metric equivilent of 3 bar. Given this, an ACCEL injector that is rated at 24 lbs/hr flows 24 lbs of fuel at 43.5 PSI pressure. If the pressure is increased above the test value the injector flow capability increases. Conversely if the test pressure degrades, flow suffers accordingly. To establish this fact further and to explore injector flow in regard to pressure, use the charts in this chapter. Rule of thumb is that for our Bosch supplied injectors, anything over 36 lbs/hr are low impedance.



- NEED ABOUT 1.5msec FOR GOOD STROKE TO STROKE REPEATABILITY PW<1.5 NOT ENOUGH TIME FOR MAGNETICS TO HOLD INSURING SAME RESPONSE EACH TIME
- OFFSET DUE TO OPENING AND CLOSING TIMES
- DUTY CYCLE EXCEEDS 90%, INJECTOR DOES NOT HAVE ENOUGH TIME TO CLOSE (PINTLE BOUNCES ON SEAT, DOESN'T SEAL) THIS IS WHY CURVE APPROACHES STATIC FLOW CURVE

Fig. 1.16

The previous mentioned flow values are not only at the given 3 bar test pressure but also at 100% duty cycle. That brings us to another area that is related to injectors. This subject is not a fuction of injector design but is affected by it. Because an injector has to supply fuel for a multitude of engine operating conditions it has to be very addaptive. It must respond fast enough (rise time) to supply proper atomization at short pulse widths during idle or light load, which is hard for it to accomplish, while also providing enough fuel flow at high RPM with very brief valve opening times. The easiest way to understand injector duty cycle is to think of it as the length of ignition event time that the ECU is grounding the injector for. Since the ECU is going to fire the injectors in time with the ignition events, it only has a given amount of time to get the fuel into the cylinder before the event for the next cylinder comes up. The length of time between ignition events is much shorter at 6000 RPM than it is at 3000 RPM. If the injector is staying open longer than the ignition event time, then it is considered to be going static and not able to control fuel flow. That is why injectors are offered in different resistance

INJECTOR STATIC CHART FOR SDF

RPM	PW	MATRIX VALUE
3500	17.14	273
3750	16.00	255
4000	15.00	239
4250	14.12	225
4500	13.33	212
4750	12.63	217
5000	12.00	191
5250	11.42	182
5500	10.90	173
5750	10.43	166
6000	10.00	159
6250	9.60	153
6500	9.23	147
6750	8.88	141
7000	8.57	136
7250	8.28	132
7500	8.00	127
7750	7.74	123
8000	7.50	119

NOTE: For SEFI ECU's use same matrix values to identify static opening but due to the frequency difference in the firings of the injectors in SDF vs. SEFI the indicated gross pulse width in the VIEW screen will be double the matrix value.

Fig. 1.17

values and flow rates. If you can not pass enough fuel during one event to satisfy the engine, you need to either raise the fuel pressure or the flow capacity of the injector to accomplish the task at hand. Decreased injector resistance allows for quicker response and in turn the ability to increase the amount of usable time between ignition events. Original equipment applications do not usually like to raise fuel pressure above 3 bar due to the possibility of fuel leakage past the closed pintle on high mileage injectors causing excessive coast down emissions. A good rule of thumb concerning injector duty cycle on an engine that will see short bursts of high RPM, is that you can run near static with usually no problem as long as the air fuel ratio is maintained. When sizing an injector for an endurance engine always allot for a maximum of of 80% duty cycle to allow for the injector and drivers to cool.

To properly choose the needed injector size for an engine, not only do you need to know all of the above, but also the brake specific fuel consumption data of the engine (BSFC) and accurate horsepower numbers. This will tell you how much fuel in pounds it takes to produce one horsepower. A text book rule states that a normally aspirated engine will use 1/2 pound of fuel (.5 BSFC) for each horsepower produced, while a forced induction engine will consume slightly more fuel at .55 pounds. Then again, the equations at the end of this chapter will establish this fact further and a more indepth discussion of factors that affect BSFC will be covered in the tuning section of this manual. Using the .5 value, a 30 lb/hr ACCEL injector at 3 bar fuel pressure and 100% duty cycle can support 60 HP per cylinder, and a total of 480 HP on a 8 cylinder engine.

So far through this section of the manual I have been very careful to be vague in regard to making mention to any tip designs of injectors, often referring to it as the fuel flow metering device. The reason being, not all injectors incorporate the same fuel metering orifice that is opened up while the windings are energized and allowing fuel to pass. ACCEL injectors made by Bosch utilize a pintle to stop the fuel flow out of the injector. Rochester produced injectors utilize a ball valve with a director plate and Lucas uses a disk shape. Each injector design has its own weaknesses and strengths but the pintle design that ACCEL uses has proven to be the most accurate and repeatable out of the three, albeit the most costly to manufacture.

The next area of concern is injector stroke to stroke repeatability and its effect on engine performance. Most people take the approach of out-of-sight out-of-mind and feel that as long as the injector is pulsing that all is well. When dealing with a port fuel injected engine, think of it as multiple carburation. Anyone who has worked with mutiple carbs, specifically of the Webber type, on IR runner manifolds has a full understanding of fuel distribution and the problems it can cause. Since each injector is responsible for all of the fuel requirements for that particular cylinder, any flow variation from injector-to-injector will cause differences in mixture for each bore. When injectors become dirty, they lose their ability to properly atomize the fuel, causing high emissions and idle instability. With today's fuels, injectors tend to stay cleaner than they did 10 years ago, but tip fouling is still a concern. Even if the tip of the

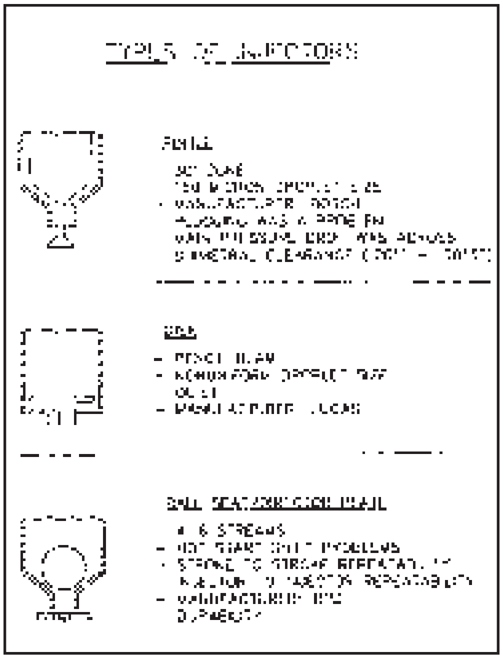


Fig. 1.18

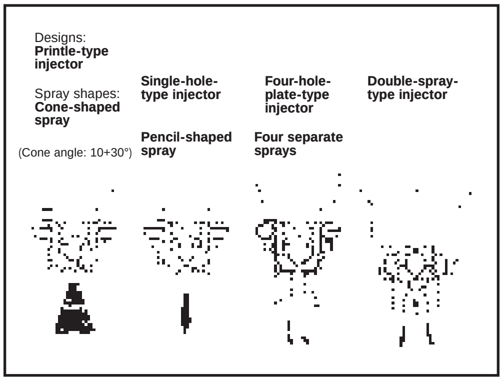


***Fig. 1.19** – ACCEL supplied injectors incorporate a pintle design that creates a conical 30 degree spray pattern. The dual spray injector is usually reserved for 4 valve engines with each one of the spray patterns directed into the corresponding individual cylinder head intake runner.*

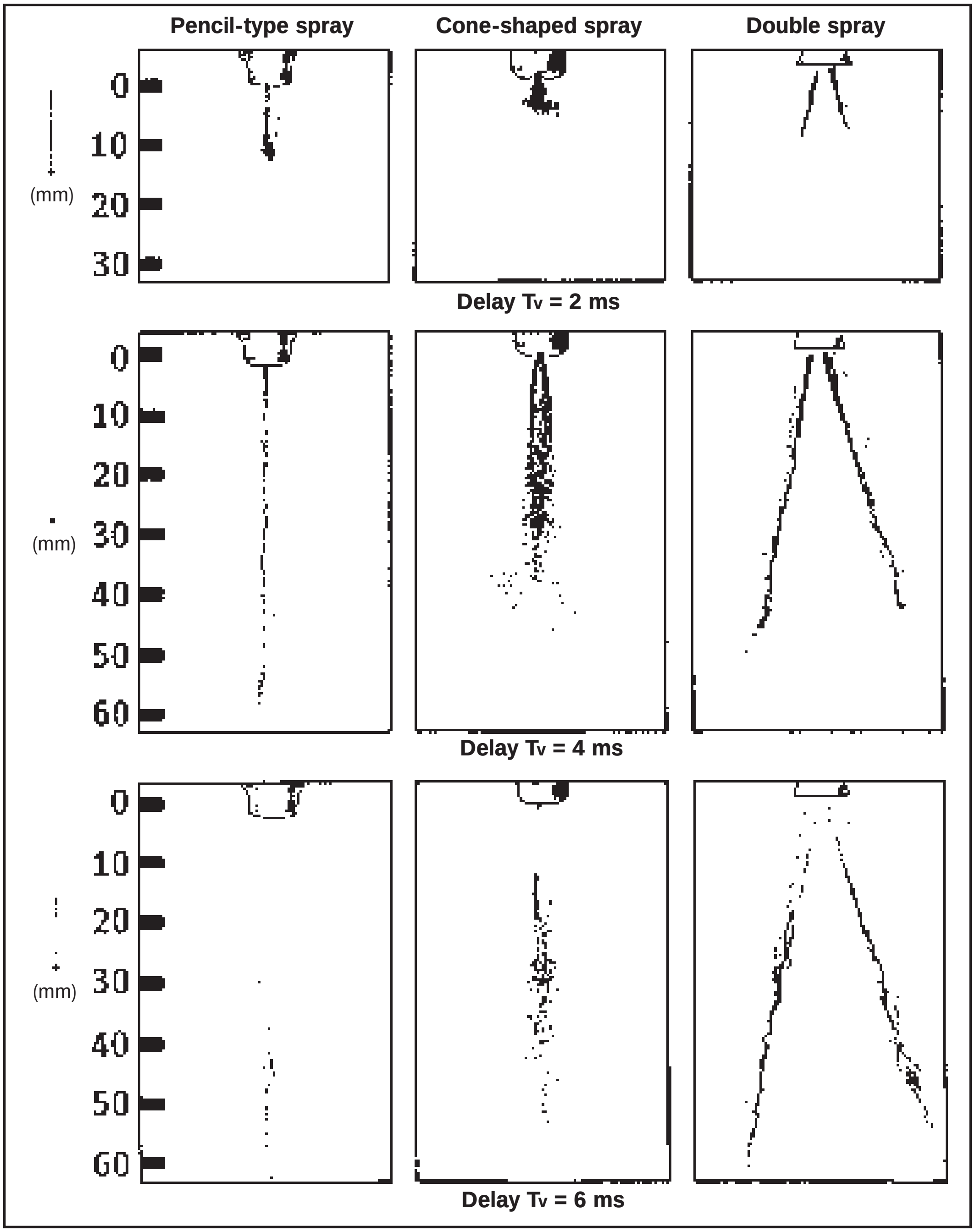


Fig. 1.20 *– The atomization of the fuel by the injector in regard to the amount of duty cycle is visually shown above. The need to enter the dynamic flow range is evident by examining both the top and bottom drawings in comparison with the center.*

INJECTOR FLOW IN LBS/HR vs. FUEL PRESSURE

INJECTOR SIZE @ 3 BAR	FUEL PRESSURE				
	40	45	50	55	60
19lb/hr	18.21	19.32	20.37	21.36	22.31
22lb/hr	21.09	22.37	23.58	24.73	25.83
24lb/hr	23.01	24.41	25.73	26.98	28.18
30lb/hr	28.76	30.51	32.16	33.73	35.23
36lb/hr	34.52	36.61	38.59	40.47	42.27
55lb/hr	52.74	55.94	58.96	61.84	64.59
83lb/hr	79.59	84.41	88.98	93.32	97.47

***Fig 1.21** – This chart establishes the use of fuel pressure as a tuning aid and also shows how increased fuel pressure fills the gaps in injector sizing that are available.*

8 CYLINDER HORSEPOWER vs. BSFC vs. FUEL PRESSURE

FUEL PRESSURE	BSFC				
	.42	.45	.47	.50	.55
19 LB/HR INJECTOR					
40	346.85	323.73	309.95	291.36	264.87
45	368.00	343.46	328.85	309.60	281.01
50	388.00	362.13	346.72	325.92	296.29
55	406.85	379.73	363.57	341.76	310.69
60	424.95	396.62	379.74	356.96	324.50
22 LB/HR INJECTOR					
40	401.71	374.93	358.97	337.44	306.76
45	426.09	397.68	380.76	357.92	325.38
50	449.14	419.20	401.36	377.28	342.98
55	471.04	439.64	420.93	395.68	359.70
60	492.00	459.20	439.65	413.28	375.70
24 LB/HR INJECTOR					
40	438.28	409.60	391.65	368.16	334.69
45	464.95	433.95	415.48	390.56	355.05
50	490.09	457.92	437.95	412.16	374.25
55	513.90	479.64	459.23	431.68	392.43
60	536.76	500.97	479.65	450.88	409.89
30 LB/HR INJECTOR					
40	547.80	511.28	489.53	460.16	418.32
45	581.14	542.40	519.31	488.16	443.78
50	612.57	571.73	547.40	514.56	467.78
55	642.47	599.64	574.12	514.56	467.78
60	671.04	626.84	599.65	563.68	512.43
36 LB/HR INJECTOR					
40	657.52	613.68	587.57	552.32	502.10
45	697.73	650.84	623.14	585.76	532.50
50	735.04	686.04	656.85	617.44	561.30
55	769.52	719.46	688.85	647.52	588.65
60	805.14	751.46	719.48	676.32	614.83
55 LB/HR INJECTOR					
40	1004.57	937.60	897.70	843.84	767.12
45	1065.52	994.48	952.17	895.04	813.67
50	1123.04	1048.17	1003.57	943.36	857.60
55	1177.90	1099.37	1052.59	989.44	899.49
60	1230.28	1148.26	1099.40	1033.40	939.49
83 LB/HR INJECTOR					
40	1516.00	1414.93	1354.72	1273.44	1157.67
45	1607.80	1500.62	1436.76	1350.56	1227.78
50	1694.85	1581.86	1514.55	1423.68	1294.25
55	1777.52	1659.02	1588.42	1493.12	1357.38
60	1856.57	1732.80	1659.06	1559.52	1417.74

***Fig. 1.22** – Small gains in BSFC efficiency allow for substantial gains in the injectors ability to support a given horsepower level.*

injector does remain clean, the constant charging and discharging of the injector solenoid will eventually lead to a lazy injector electrically with an increased rise time. *(See Fig. 1.20 on page 1-15.)* The only true way to quantify injector performance is to remove the injectors and fire them on a test bench like our Asnu injector tester and cleaner. This will give you the ability to view atomization patterns and to measure flow accurately. It is not uncommon for out-of-the-box injectors to have flow variations of up to 15%, and this is why ACCEL sells only matched sets of injectors. *(See Fig. 1.20 on page 1-15.)*

EMISSIONS

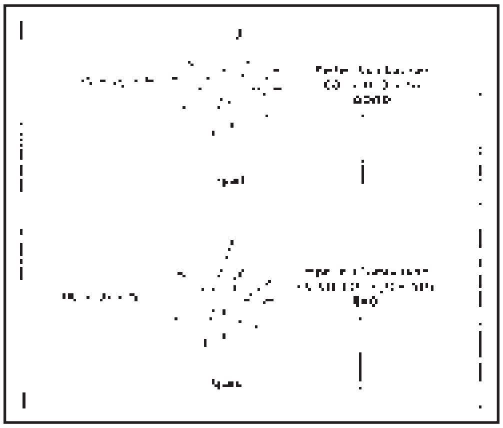


Fig. 1.23 *– An ideal combustion cycle produces minimal emission output while an imperfect cycle fills the atmosphere with polutants.*

To produce power in an internal combustion engine, we need to burn fuel. The byproduct of that combustion event is generally referred to as emissions. Whenever modifying a street legal vehicle, most states require it to still remain emmission compliant, which has prompted ACCEL to discuss emissions in this manual.

On the state level, emissions are measured in a very crude manner when compared to the standards that an OE manufacturer or an aftermarket company like ACCEL must meet to certify their parts. To the best of my knowledge, all states that do emission checks do so using infared optical bench analyzers with the only difference being the actual test standard and the test cycle itself. With the growing implementation of the IM240 based test cycle, the relevance of understanding emission output becomes essential. Since most EMICs will be dealing with emission test standards that measure either PPM (parts per million) or percentages in lieu of grams/mile, all references will be made to the more common state level standards.

The five main emissions that we are concerned with are the following:

Carbon monoxide (CO). During a tail pipe emission test, CO is read in a percentage. Simply put, CO is the byproduct of a rich air fuel ratio. When too much fuel is present in the combustion chamber, it cannot be completely burned and the fuel that is only partially burned is registered as CO. Any time a vehicle fails an emission test for CO, the cause is a rich mixture. Dirty fuel injectors, clogged air filter, high fuel pressure and a degraded O_2 sensor are the biggest culprets.

Hydrocarbons (HC). If CO is partially burned fuel, then HC, which is read in PPM, is raw unburned fuel. Anything that will affect the combustion processs will have a effect on HC production. Ignition problems, incorrect spark advance curves, mechanical engine problems, cam overlap, lean mixtures and large crevice volumes will all raise HC.

Carbon dioxide (CO_2). Read in percent, CO_2 represents the bonding of the carbon and oxygen molecules that takes place during efficient combustion. It is the emission that you want the most of. The higher the CO_2 of your engine, the better the burn.

Oxygen (O_2). Measured in a percentage, this reading works inconjunction with CO_2. This value establishes the amount of O_2 that does not have a carbon molecule to bond with. It is inversely proportioned to the CO_2.

Oxides of nitrogen (NOX). Formed from NO (nitrogen monoxide) when in the presence of oxygen. It is a byproduct of very high combustion temperatures.

The Catalytic Converter

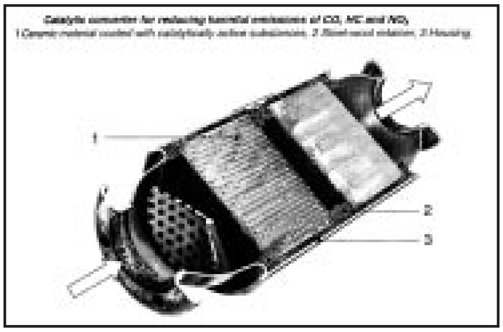
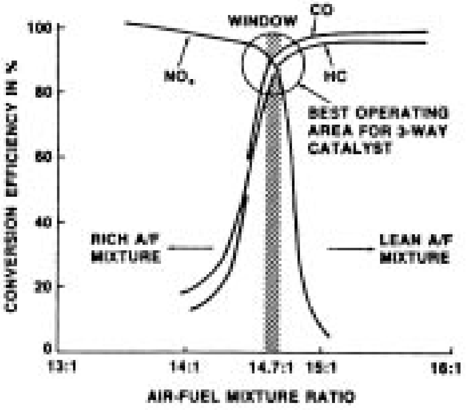


Fig. 1.24

The sole purpose of the catalytic converter is to clean up what does not get burned in the combustion chamber. For a catalyst to function properly, it must accomplish what is referred to as "lightoff" to start the chemical conversion process. To light-off, most converters must see temperatures of 1000°F or more to operate efficiently. It is also important to note that a converter will only operate within a range of 2% of stoich;

rich or lean. *(See Fig. 1.25 on this page).* A good, efficient converter will cover a multitude of tuning errors if lightoff can be accomplished. The need to maintain catalytic efficiency is the reasoning behind the set-point of 14.7:1 as the target air fuel ratio calibration of the oxygen sensor.



Converter Efficency vs. AFR

Fig. 1.25 *– The catalytic converter is the most efficient at an engine out air fuel ratio of 14.7:1 as shown above. Mixtures above or below stoichometric degrade the conversion efficiency of the catalyst.*

The ECU and its role in emission compliance

To date, all ACCEL ECUs, like a good majority of today's speed parts, are considered illegal for street use when following the EPA letter-of-the-law. When entered in the arena of just requiring a vehicle to pass a tail pipe emissions test, they are more than compliant when the engine is tuned properly. Since none of our ECUs have the ability to control EGR function, AIR switching and canister purge cycles, they are not considered EPA acceptable. Even though the ECU has total fuel and spark control, it is still going to be very hard to tune a new vehicle to pass an emissions test if a cam with any degree of overlap is installed. Increases in overlap will cause the hydrocarbon emissions to skyrocket, and will also have an effect on the oxygen sensor output due to the massive amounts of residual oxygen in the exhaust. Even though engine-out emission numbers will be high, if you utilize a original equipment catalyst, and are able to accomplish lightoff, the converters conversion efficiency should be able to clean up the exhaust.

The actual tuning process for reduced emissions will be covered in detail in the tuning section of this manual.

Intake manifold designs for fuel injection

ACCEL offers two distinct types of fuel injection systems - dry flow and wet flow. From that distinction on, the offerings break down into Small and Big Block Chevy and then futher down to short or long runner manifolds. With all of these being fuel injected, let's start by defining the major differences in the concepts of wet vs. dry flow.

In a traditional carbureted manifold the fuel is vaporized in the carburetor, added with additional oxygen and directed to the runners from the plenum. The actual intake runners of that particular type of manifold are considered to be wet flow, since the homogenized air fuel ratio is coursing through the runners. The carburetor serves dual duty as an air metering device and also for fuel administration. A throttle body fuel injection system shares the wet flow concept of a carbureted manifold, but leaves the delivery of the fuel up to either one or multiple electronic fuel injectors. All of the components that were mentioned in chapter one in "The Carburetor vs. Injection Components" chart on page 1-2, still apply in their comparison to a carburetor. The only differences being the placement and the number of injectors that are utilized.

Conversely, in a dry flow manifold as in a GM TPI, the fuel is administered by an individual injector for each cylinder at the base of the intake manifold with the injector placement usually 100MM from the seat of the intake valve.

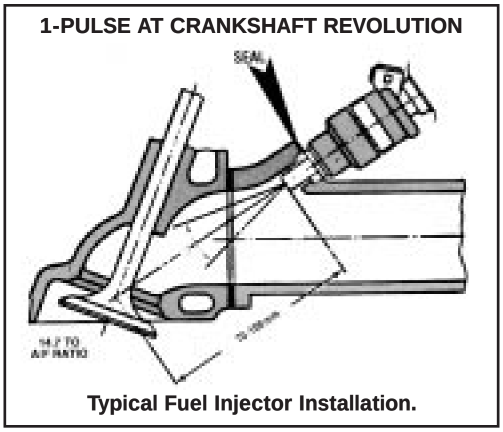


FIG. 1.26 *– The specified injector placement in the manifold will allow for the spray from the pintle to fan out completely prior to the turn in the cylinder head into the bowl area.*

Traditional performance applications have swayed toward the dry flow concept due to the freedom that it offers for runner length and packaging considerations.

In a direct comparison of wet vs. dry flow, as in any design, there are negative and positive aspects of each.

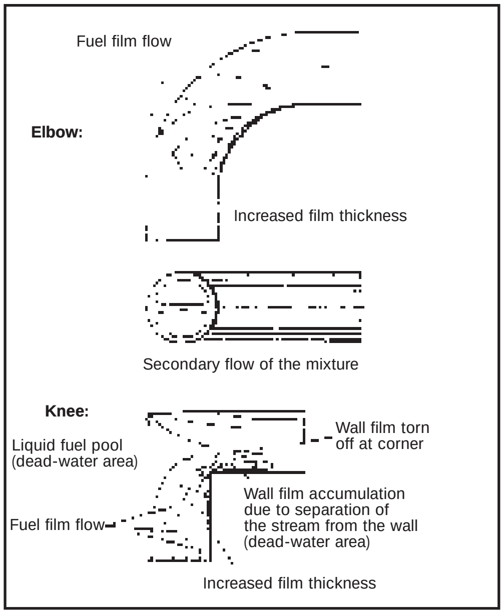


Fig 1.27 *– Basic gas flow theory through a pipe establishes what happens when fuel or air (both referred to as gasses) are asked to make turns. Wall friction in the pipe causes a higher flow velocity in the center when compared to the extremities. For this reason fuel lines and the air intake tract should incorporate as few bends as possible to create the best flow characteristics.*

In theory, a dry flow manifold should be able to offer better fuel distribution due to the lack of fuel loss from puddling or drop out while travelling through the manifold's runners. The negative aspect of that design though, is that you are now interjecting the variable of 8 injectors to administer fuel and are hoping that the rise time and atomization pattern of all 8 injectors are equal. With a wet flow style of manifold, specifically with throttle body style injection, the design is more forgiving to injector to injector variations. If the manifold is of a particular good design as far as distribution is concerned, then will mask alot of atomization problems.

Another area of concern with a dry flow manifold is that there is no cooling effect of the vaporizing of the fuel that takes place in a wet flow manifold, which tends to dramatically raise the charge air temperature and in many instances the charge actually cools down slightly when it enters the intake port of the head. A simple rule of thumb states, that for every 10°F that the charge air temperature escalates, the engine will lose 1% of its power output. That is the reason for the horsepower limitations that are usually discovered during magazine style testing of fuel injected vs. carburated race engines, but never explained or identified. The cooling effect of the phenomena that is reffered to as "the latent heat of vaporization" historically has given the carburetor a slight edge in maximum engine output to date. The use of a thermal barrier coating on the bottom of dry flow manifolds has proven very effective and has lessened the gap considerably.

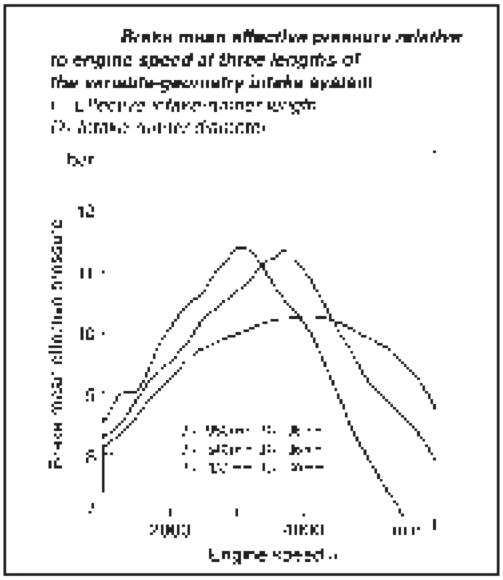


Fig. 1.28 *– Intake manifold runner lengths have a direct relationship on the RPM at which peak cylinder fill occurs. Maximum brake torque is experienced during peak cylinder fill (volumetric efficiency). The enthusiast market commonly refers to torque, but the actual way of measuring torque is through brake mean effective pressure (BMEP). Even though increases in runner length add dramatically to low RPM torque production they become a restriction in the air flow of an engine at high RPM creating major pumping losses.*

The real benefit of a dry flow intake manifold design is the ability to drastically increase runner length to add substantial amounts of torque. With there no longer being the concern of fuel drop out, the runners can be made to take whatever shape necessary to accomplish the desired length. The benefit to an OE manufacturer in adding runner length and building a torque biased engine are numerous. The torque per liter output rises dramatically, allowing for the use of smaller engines. Smaller engines have historically better BSFC numbers than larger ones, and run cleaner due to the EPAs method of grams/mile of output measurement and also due to their decreased swept volume. Adding to that, it is easier to control detonation on a small bore engine, and a torque heavy power plant requires less transistion of the throttle to move the vehicle forward or accelerate it. By decreasing throttle angle movement, there are less transitional emission formations and greater customer satisfaction due to the vehicle feeling more lively in the normal operating range. The negative of long runner intake manifolds is their inability to move sufficient volumes of air to allow the engine to RPM enough to make any considerable horsepower. Since torque is the amount of work an engine can do, but horsepower is how fast it can accomplish that work, you need RPM to make horsepower. For this reason the techniques that are used to extract power from a traditionally short runner carburated style manifold, for instance like an Edlebrock Victor Jr., do not work with a TPI and its extremely long intake runners. *(See Fig. 2.2 on page 2-1).*

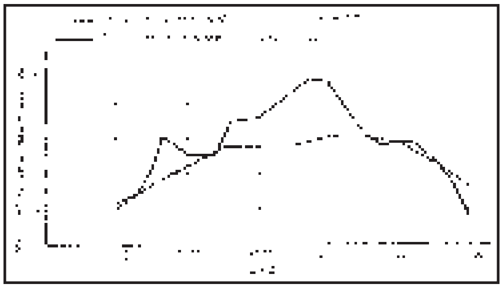


Fig. 1.29 *– A tuned intake system will have definitive points of resonance and inturn a very defined BMEP pattern. During resonance the phenomena's of Helmholtz ram and resonance along with the benefit of acoustical pressure wave formation actually cause a ram tuning effect in the manifold that increases the volumetric efficiency of the engine. This effect is referred to as inertia supercharging. Conversely a untuned intake has no defined efficient RPM range and produces less cylinder pressures.*

Since maximum brake torque (MBT) is accomplished at the point of maximun volumetric efficiency (VE), a tuned intake has the ability to take advantges of all the accoustical tuning phenomenas of Helmholtz resonance and ram, reflected waves and standing waves. A tuned intake will almost always produce more area under the curve, but usuallly has a trade off in RPM limitation to accomplish that.

Even though a dry flow manifold is much more forgiving than a wetflow system, air still doesn't like to make turns.

Whenever you ask air to change directions, velocity suffers and, in turn, flow rate drops. When looking at a TPI, keep in mind that the left runner feeds the right bank of cylinders and vice versa.

PORT AND THROTTLE BODY INJECTION

As stated earlier, ACCEL offers both port and throttle body based fuel injection systems. Even though the two ECU's function the same, they are not interchangeable due to the way they are coded to fire the injectors. ACCEL part number 74135 is designed for use with our throttle body injection kit and is not interchangable with a port fuel ECU. During our R&D, we discovered that the throttle body injecton firing sequence had to be altered to control fuel stand off (the spraying back of fuel out of the throttle bores). Unlike GM TBI systems, our unit is designed to utilize 4 port style injectors and to run the normal high pressure of an individual injection system. The stock GM TBI system has unique injectors and operates on low fuel pressure of 9-13 lbs. The basic CALMAP software is the same for both systems, and the utilization of all the sensors remains identical. Our throttle body fuel injection kit utilizes a common Holley bolt pattern, so it is compatible with almost any aftermarket intake manifold and does not limit its application to only Chevrolet produced engines.

CHAPTER 2: MATCHING ACCEL’S MANIFOLDS TO THE CUSTOMERS NEEDS

Air Volume of Various Intake Component Ports
(All flow testing done @ 28 in. H_2O with approx. temp. @ 68°F.)

Runners (measured individually)

Stock	203.17 cfm
ACCEL	242.02 cfm
Extrude/ACCEL	275.83 cfm
Super Ram	289.18 cfm

Intake manifold w/3/8-in. radiused inlet 222.45 cfm

Stock intake manifold w/runner

Stock	198.72 cfm
ACCEL	213.52 cfm
Extrude/ACCEL	217.11 cfm
Super Ram	220.67 cfm

ACCEL Hi-Flow intake manifold w/3/8-in. radiused inlet 251.51 cfm

ACCEL Hi-Flow intake manifold w/runner

Stock	215.83 cfm
ACCEL	232.53 cfm
Extrude/ACCEL	243.21 cfm
Super Ram	240.24 cfm

Extrude Honed ACCEL Hi-Flow intake manifold w/3/8-in. radiused inlet 275.83 cfm

Extrude Honed ACCEL Hi-Flow intake manifold w/ACCEL runner 266.94 cfm

Edelbrock Performer RPM manifold (stock) 286.51 cfm

Edelbrock Victor Jr.
275.24 cfm

1989 Corvette head CFM
(stock head w/3/8-in. radiused inlet, 6-in. extension, 1¾-in.-dia. exhaust)

Intake cfm @ Inches of Lift

60.68 @ .100
117.28 @ .200
156.81 @ .300
176.47 @ .410 (stock 1989 Corvette cam lift)
177.97 @ .437 (1.6:1 rockers)
183.89 @ .499 (1.5:1 rockers, 211°/219° split duration ACCEL cam)
185.37 @ .533 (1.6:1 rockers, 211°/219° split duration ACCEL cam)
186.85 @ .550 (port stall point)

Exhaust cfm @ Inches of Lift

38.53 @ .100
99.84 @ .200
137.28 @ .300
156.32 @ .423 (stock 1989 Corvette cam lift)
157.90 @ .451 (1.6:1 rockers)
161.05 @ .525 (1.5:1 rockers, 211°/219° split duration ACCEL cam)
162.63 @ .560 (1.6:1 rockers, 211°/219° split duration ACCEL cam)

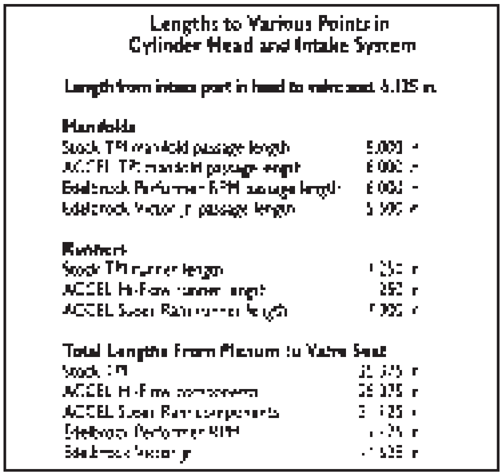
Intake/Exhaust Ratio @ Max. Lift

Stock	1.5	88.5%
	1.6	88.7%
211/219	1.5	87.5%
	1.6	87.0%

Fig. 2-1 *– Air flow testing confirms the frictional losses that were established in figure 1.27. Even though flow restrictions of Superam manifolds do not allow for extremely high RPM levels, bottom end torque and horsepower are dramatically increased in comparison to older carburated designs, which is extremely desirable on a street engine.*

The most common mistake engine builders and enthusiasts alike make when modifiying a TPI equipped engine is their lack of recognition of the extremely long runner length that this manifold possess, and its special needs in both cam timing and air flow considerations. They subliminally consider all that is attached to a TPI manifold to be necessary for fuel injection and base there modifications on what would work on a carburated application.

As an EMIC, you will probably see a varied customer base with a good mix of both street and race cars. Today, as in the past, you need to keep in mind that you usually get the best results with a systems approach. The customer with a 1991 L-98 Vette who is looking to increase its performance



Lengths to Various Points in Cylinder Head and Intake System

Length from intake port in head to valve seat 6.125 in.

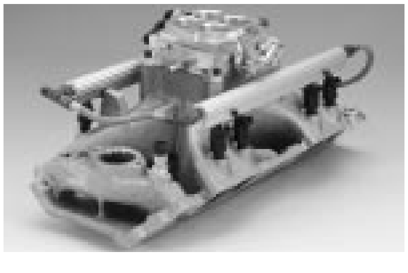
Manifolds	
Stock TPI manifold passage length	5.000 in.
ACCEL TPI manifold passage length	6.000 in.
Edelbrock Performer RPM passage length	6.000 in.
Edelbrock Victor Jr. passage length	5.500 in.
Runners	
Stock TPI runner length	[illegible] in.
ACCEL Hi-Flow runner length	[illegible] in.
ACCEL Super Ram runner length	[illegible] in.
Total Lengths From Plenum to Valve Seat	
Stock TPI	[illegible] in.
ACCEL Hi-Flow components	[illegible] in.
ACCEL Super Ram components	[illegible] in.
Edelbrock Performer RPM	[illegible] in.
Edelbrock Victor Jr.	[illegible] in.

Fig. 2.2

while maintaining relibility, drivability and emission compliance, will have completely different manifold needs than a bracket racer with a ’69 Nova and a 434 small block.

Due to its runner length, cross sectional area of the runners and manifold passages, a completely stock TPI only has the air flow capability to support 325-350 HP, if everything else in the engine is optimized, with a real world horsepower number of 275-300. What ACCEL has done with its runner and base manifold design, is not change the length of the runners, but increase their cross sectional diameter to support more air flow and in turn more RPM and cubic inches. Unbeknownst to many, is the fact that all of GM’s stock TPI components were based upon the air flow requirements of a unmodified 305 engine and were not upgraded for placement on a 350 cubic inch small block. For that reason, 350’s respond very well in stock configuration to upgrades in manifold and runner diameter, while a stock 305 sees little with these parts installed. Our SuperRam plenum and runner kit futher enlarges the runner diameter while utilizing the same ACCEL 74197 base manifold, but decreases total runner length by 4.250 inches, allowing for the ability to support more RPM and cubic inches. While these manifold and runners kits work excellent, when matched to the proper cylinder heads and cam shafts, they are primarly designed for street use and are still torque-biased designs. Due to the extremely poor intake manifold to intake port entry angle that GM needed to maintain hood clearance for placement in a C-4 Corvette, air flow rates of this design suffer considerably. My personal tests have shown that an ACCEL SuperRam manifold and plenum kit has the ability to flow a maximum of 240.24 CFM @ 28 inches H_2O while a completely stock TPI can only flow 198.72 CFM at the same test pressure. *(See Fig. 2.1 on page 2-1 for further flow data)*. The SuperRam flow can be increased with the benefit of either hand porting or abrasive flow media porting and can approach 295 CFM @ 28 inches H_2O. While these values are good on their own, once the connection to the cylinder head is added with its poor entry angle, substantial flow losses occur with a drop of usually 12-15% being common.

For this reason, ACCEL is working on bringing to market an excellent line of single plane carburated style manifolds that have been designed for optimal performance with fuel injection. These manifolds will have the same RPM and tuning characteristic as single plane carburated applications, but with the added efficiency of late model fuel injection. Since these designs will not allow for provisions for emission control hook up they are not going to be considered direct replacements for emission controlled vehicles.



Applications for Big Block Chevy engines have not been forgotten and currently include both short and long runner manifolds along with a complete line of single plane part numbers. The Stealth, being an excellent manifold for towing and RV applications while the Big Block SuperRam with its shorter runners and oval or rectangular port configuration allow for generous torque output while maintaining horsepower producing air flow numbers. The single plane designs are excellent for both street and strip use.

To compliment our unique manifold designs and the special camshaft needs of TPI engines, ACCEL offers a complete line of camshafts that produce excellent results in both flat tappet and roller hydraulic forms. Due to the runner length and plenuum volume, idle stability is greatly affected by the amount of overlap in a camshaft with the SuperRam plenum especially sensitive for idle stability. The increase in runner length of TPI manifolds also brings concerns regarding duration and the manifold’s ability to allow efficient cylinder fill at over 5000 RPM. Camshafts with intake durations of greater than 220° @ .050 usually do not work well due to their tuning point being above the RPM capabilities of the intake manifold on small block engines up to 400 cubic inches. Large small blocks can tolerate .050 durations up to 230° due to their larger cylinder fill requirements. The same basic theories also apply to our big block manifolds, with the Stealth liking durations to around 220 @ .050 and the Super Ram working well with durations to 236 @ .050.

Due to the substantial amount of development time that has gone into all of ACCEL’s camshafts and their compatability with fuel injection I strongly suggest their usage for proper performance. ACCEL’s camshaft work equally well with stock TPIs or with our manifold components. Do not fall into the trap of thinking our cams are too small to make power. Small block’s that I have built have historically made 525 HP and 600 lb/ft of torque with a SuperRam plenuum and a 74219 cam (219/219) from 406 inches. They are docile enough, that in many instances are driven daily by their owners.

Single plane ACCEL manifolds will not be as sensitive to duration and overlap as their Super Ram companions.

Camshaft profiles that are more in tune with what would work in carbureted applications historically work well with these designs. The only issue that may arrive is the envoking of fuel stand off with large amounts of reversion back into the plenuum. Again, I want to make clear that it is not the fact that the engine is being fuel injected that ultimately defines the modifications that will work well. But the consideration to intake manifold runner length that will dictate the modifications.

For more information on performace parts selection refer to the tuning section of this manual.

At present ACCEL has no offerings for Ford or Mopar manifolds. Through part number 74801 we have available the components needed to convert carburated style manifolds over to port injection. With the availabilty of these parts, there is never a need to turn a customer away for fuel injection. The possibilities are unlimited!

CHAPTER 3: ECU OPTIONS

015013	1 Bank Injectors, IAC, Converter, Fan, 1 Step NOS
015014	1 Bank Injectors, IAC, Fan, Linear 02
015015	1 Bank Injectors, IAC, Converter, Linear 02
015016	1 Bank Injectors, IAC, Linear 02, 1 Step NOS
015017	1 Bank Injectors, IAC, 3 Step NOS, Fan
015018	1 Bank Injectors, IAC, 3 Step NOS, Converter
015019	1 Bank Injectors, 3 Step NOS, Linear 02, Fan
015020	2 Bank Injectors, IAC, Converter, Fan
015021	2 Bank Injectors, IAC, Linear 02
015022	2 Bank Injectors, 3 Step NOS, Converter, Fan

Fig. 3.1 *– Each distinct ECU configuration is identified by its own code.*

Both the standard spark/fuel and the SEFI ECU's have a number of options available to enhance their operations. All options that are available could be installed at the time of the original purchase or added later as the needs of the management system change. The following discussion is in regard to actual hardware options, not changes in configuration thru the CALMAP software.

IPU

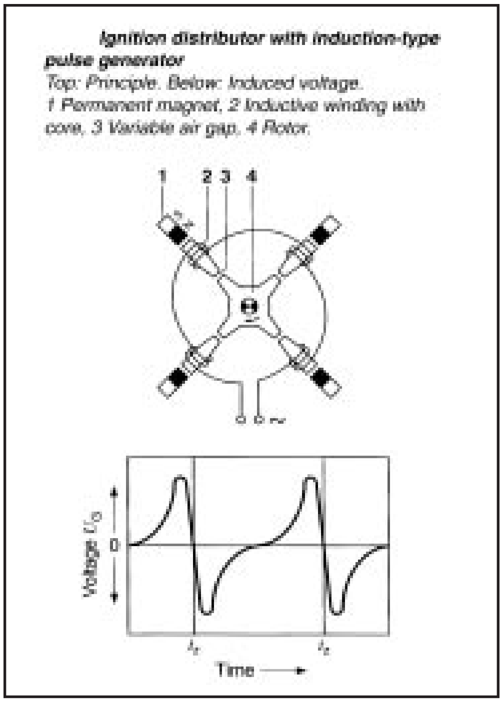


Fig. 3.2 *– When modified to acknowledge the primary interrupt signal of an inductive pick up, the ECU is now capable of recognizing the saw tooth sine wave output as a RPM reference inlieu of a square wave.*

As mentioned earlier, a very popular option is part #74043-I which allows the use of an inductive pick up distributor or crank trigger as the primary switching signal. The benefit of a crank trigger is the accuracy of identifying the actual piston position in the bore from the crankshaft. This is in lieu of the distributor, with its inherent stack up of tolerance from the timing chain and the interface with the distributor gear itself. This option also allows the use of ECU controlled programmable timing on engines that did not already incorporate an electronic spark timing distributor or were not originally ignition compatible with our ECU.

USER INTERFACE MODULE

The acronym UIM is used to describe a stand alone interface that gives the end-user the ability to alter the air fuel ratio that is programmed into the core fuel table either richer or leaner at idle and WOT. The module incorporates two knobs - one for idle and the other for WOT. Simple to install, the 4 leads plug into ECU bulk head connector P1 at terminals C6, D4, C4 and D8. The UIM has no control above 1% TPS and below 99% TPS. This is an excellent option for the end user who likes to do some minor tuning and is not interested in mastering the CALMAP software.

LINEAR O_2 SENSOR

When purchasing the linear O_2 option, no changes to the actual ECU, other than the prom, need to be made. The linear O_2 kit includes an NGK sourced wide band O_2 meter and a NGK 5 wire O_2 sensor that replaces the standard issue Bosch unit, along with the corresponding wiring harness to attach the above to the main wiring harness. The linear feedback option gives the user the ability to have multiple target air fuel ratios for total feedback control and correction.

In contrast to the standard ECU which if operated in closed loop, has a target air fuel ratio of 14.7:1 as its only set point, and is historically programmed to correct to that target only under certain operating conditions. The linear option will allow target air fuel ratios referenced from every two rows of the fuel matrix based upon load, ultimatley providing 8 target air fuel ratios. This option also incorporates the ability to set a target warm up air fuel ratio that will be maintained after the initial 45 seconds of start up and until the closed loop temperature parameter is met in the CALMAP software. Deacceleration enleanment through decel fuel shut off monitors TPS and RPM and offers programmable set points to shut down injector pulse width during closed throttle deacceleration for better coast down emission control.

ALTITUDE ADJUSTMENT

ACCEL offers an onboard change to the ECU and an additional 1 bar MAP sensor that is referenced to atmosphere to function as a correction to the base fuel map for changes in barometric pressure. This option would utilize the same ports in the bulk head connector as the UIM and cannot be used inconjunction with the UIM.

3 STAGE NITROUS

The standard spark/fuel ECU has the ability to control one stage of nitrous with the optional ability of adding two addidional stages. To add the additional stages, ports P2-B5 and B4 which originally controlled the coolant fan and TCC functions must be lost.

ECU OPTIONS AND DIFFERENTIATION

Although the majority of Spark/Fuel ECUs externlly resemble each other whether they are designated for Buick, Ford or Chevy usage, port or throttle body injection, with either OE style ignition or Inductive Pick Up modifications they are not interchangable and have major internal differences for ignition compatability. In the case of the TB, a major internal difference can be found in the firing sequence of the injectors. The SDF, sequential and marine also use different enclosures and are visually different along with their obvious internal changes.

SIMULTANEOUS DOUBLE FIRE

ALL INJECTORS ARE FIRED ONCE EVERY CRANKSHAFT REVOLUTION.

SEQUENTIAL

INJECTORS ARE FIRED ONE AT A TIME IN PRESCRIBED ORDER.

DIFFERENCES/BENEFITS OF EACH

SIMULTANEOUS DOUBLE FIRE

– LESS PARTS TO FAIL
  SEQUENTIAL HAS DRIVER/INJECTOR

– LESS POWER DISSIPATION

– LESS COST

– LESS COMPONENTS/NEED CAM POSITION SENSOR FOR SEQ.

– UNIVERSAL/EASE OF INSTALLATION

SEQUENTIAL

– TIMED INJECTION CAN MAKE MORE POWER

– SLIGHTLY BETTER FOR EMISSIONS

Fig. 3.2A

The wire list 015013 pertains to all spark/fuel ECUs regardless of vehicle make designation with the marine and SEFI sharing a dedicated wiring diagram.

The internal differences that are made to a standard spark/fuel ECU are limited to ignition compatability. The simplest way to think of ECU designation is to identify the type of ignition being used. Since the 015013 is coded for simultaneous double firing, the firing order of the cylinders is moot and gives the ECU wide based installation appeal. It is very common to see this ECU running fuel injection systems on imports, domestics other than Ford or GM and industrial engines.

To begin the identification of the ignition requirements you first need to determine in the case of a GM or Ford application whether it will use a standard OE style electronic timing control distributor. These are identified by a distributor that has no provisions for either mechanical or vacuum advance units. If electronic control of the timing is going to be used through the above mentioned OE systems than ACCEL part numbers pertaining to standard Chevy or Ford ECU will apply. The differences in the Chevy ECU listings (part #74021, 022, 023, 024) all refer to fuel and spark calibration changes for those particular cubic inch engines.

If ECU controlled timing is desired but there are no electronic spark timing distributors that are easily interfaced with our ECU (i.e. Mopar, Honda, industrial), then control of the spark timing can still be accomplished with the use of an inductive pick up either in a distributor or on a crank sensor and the interfacing of an aftermarket ignition amplifer (ACCEL 300 plus, MSD, etc.).

The ACCEL part number 74042 would then need to be ordered which is a standard ECU with a board modification to accept the inductive pick up signal. If your customer possesses any standard spark/fuel ECU and desires to have it converted to switch from an OE style timing control, he needs to send the ECU back to DFI and have an ACCEL part number 74043-I board modification done to the ECU. Once an inductive pick up modification is installed, then the ECU becomes nondescript and is not identified as a Chevy or Ford ECU.

ACCEL part number 74025 is a Buick GN spark/fuel ECU and is coded differently for the recognition of the hall effect crank and cam sensor signals. An inductive pick up generates a modified sine wave output signal while the Buick GN uses a square wave input signal from its ignition. The Buick ECU modification consists of an internal PROM and software change.

The Chevrolet LT-1 ECU (74022-L) also consists of a board change to interface with the output of the Delco Opti-Spark distributor. If the primary triggering function is desired to be moved out of the Opti-Spark and an IPU crank trigger is to be employed, then a 74042 needs to be ordered.

Also offered is a Marine ECU that simply consists of a 74022 in a weather tight enclosure with weather tight bulk head connectors. This ECU is not only used in marine applications but is commonly found in late model Corvettes that require the mounting of the ECU under the hood. Other uses for this product are industrial or severe environment duty.

Sequential spark/fuel ECU’s that are offered to interface with OE electronic timing controls are only applicable to Ford TFI and Buick GN configurtions. All other SEFI ECU’s are designed to work with inductive pick ups. Inductive pick up configuration is also available for Ford ECU’s. Other than ignition comptability, all SEFI ECU’s have dedicated injector harnesses for proper phasing of the injectors.

As covered in an earlier chapter, ECU’s for ACCEL throttle body kits are coded to fire the injectors differently than a conventional ECU. If electronic timing control is desired for a TB unit and an electronic spark control distributor is not available, then an IPU modification must be performed.

INTERFACE HARNESSES

Pioneered by EMIC Dan White, and now also produced thru other sources are jumper interface harnesses that allow the connection of a 015013 ECU to either a GM or Ford OE fuel injection harness. The benefit of this type of installation is the ease of connection with no cutting of the original car’s harness and the ability to change back quickly to the original factory ECU. The negative of this installation is that in many caseses the jumper harness is wired not up to utilize all of the available drivers and inturn limits the range of injectors that can be used.

CHAPTER 4: INTRODUCTION TO CALMAP

ACCEL's CALMAP software inconjunction with the spark/fuel ECU was the first truly affordable user friendly programmable fuel injection system that was brought to market. This software is partially responsible for the acceptance and popularity of todays new breed of performance cars.

The CALMAP software is a propriatory program that will only interface with ACCEL ECU's and is one of the few aftermarket programs that will allow on the fly tuning. When ordering ACCEL part number 74990-L or 74990-S you receive a 3.5 inch disk, instruction manual and an interface cable with a write protector. The part number designation identifies the interface cable length of either 5 or 25 feet. The longer of the two cables is usually purchased for dyno cell use with the standard 5 foot cable being sufficient for almost all applications. The end of the interface cable that connects to the ECU main harness utilizes a Packard 4 pin connector, while the IBM compatabile lap top connection incorporates a RS 232 fixture. With this software and serial cable you are now able to change any or all of the available 256 different points in the core fuel table along with timing, idle speed, enrichment circuits and configurations. The software package allows you to access an unlimited number of ACCEL ECUs and needs only to be purchased once for use on a multitude of applications. (The original software purchase does not entitle owner to free software upgrades. Cable does not need to be repurchased, only the upgraded disk.)

Due to the unique nature of our ECU, it does not need to be removed from the vehicle to reprogram and recalibration of all tables can be accomplished with either the engine running or the key on engine off. There are no proms to reburn and no additional expense for software needed after the original investment.

WORKING WITH CALMAP

After booting up your PC, at the DOS prompt, simply type in the words CALMAP (the software is not sensitive to capitalization) and wait for CALMAP to load. After the program is fully loaded the ACCEL screen will appear and you will be able to choose between either live monitor and tuning or the reworking of a file program.

While in any screen the user friendly prompt of Q will allow exit from that screen and a simple one key stroke will allow you to access most screens. *(See Fig. 5.9 on page 5-12).*

All programs and tuning screens can be stored on the hard drive or disk for either further reference or for the down loading into other ECU's. For a complete guide to CALMAP, reference the CALMAP manual.

As stated earlier in this manual, the CALMAP software is extremely user friendly, but still requires a knowledge of engines and fuel injection system function. The best way to learn to find yourself around the software is to just spend some time alone working with it without concerning yourself with doing an actual calibration. Familiarize yourself with the different screens and their corresponding sub menus. Practice how to save a file and then retrieve it. Learn the quick prompts and how to execute changes. The more time you spend in the software in the begining, the easier it will be to learn how to tune an engine. After you master the execution of CALMAP you will realize that even though it is a very powerful tool it is extremly easy to use.

Calibration Screens

The following is a screen by screen review of the CALMAP software and a description of its function. In this chapter I will only cover the execution and function of each screen. The actual tuning process will be covered in the tuning section of this manual.

ACCEL screen

Once the CALMAP program is loaded this screen will appear. On the bottom of the screen will be our copywrite and software version. Above that will be two selections with the cursor naturally returning to the EDIT ECU selection. To edit an existing program that has already been saved use the arrow key to move the cursor to EDIT FILE and then press enter.

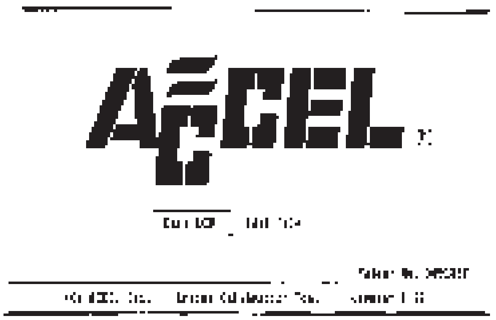


Fig. 4.1

Main Menu

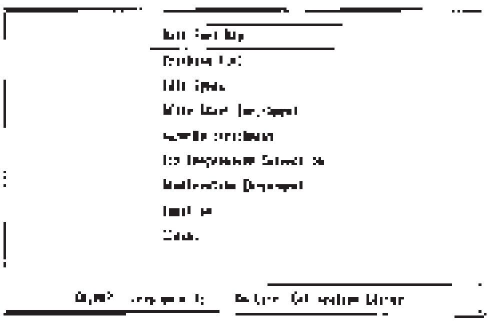


Fig. 4.2

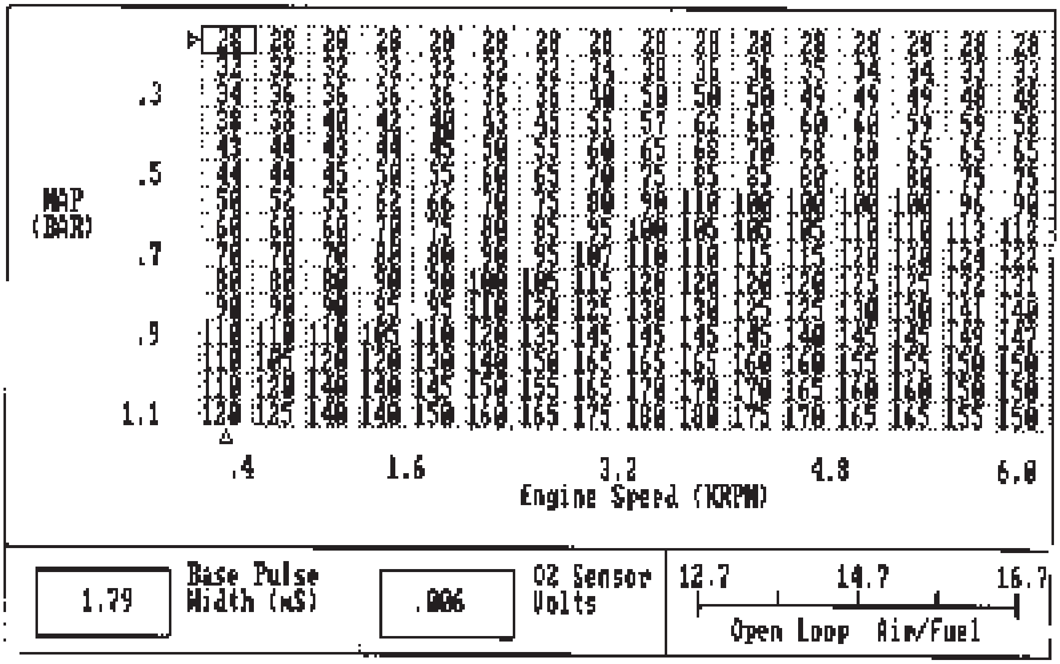
To edit the ECU the interface cable must be plugged into the main wiring harness and the ignition needs to be turned on to power up the ECU. If the ignition is not turned on or you have a bad connection at the MWH then a prompt will appear on the screen either identifying a communication error, or if the ECU is not powered up then a "waiting for ECU response" prompt will appear along with a beep and a graphic display of a car going across the screen.

To edit a file, after that prompt is selected, CALMAP will ask you for a configuration code. Enter 015013 for spark/fuel ECUs and 014013 for the Power Processor. Once in off-line editing, then a majority of the screens can be accessed.

After a selection is made, the main menu will appear. During off-line editing the only screen that will be missing is the Global function which sets some of the base parameters in the ECU. All other main menu screens will be available to you execept for a few of the sub menu functions. To choose a screen, simply move the cursor to the desired selection and press ENTER.To escape back to the ACCEL screen press Q.

Base-Fuel Map

When the base-fuel map is selected you will have two choices; either the actual core-fuel table or a graph selection. The base-fuel map selection is the actual programmable injector pulse widths while the graph display is a contour type of graph that is used to visualize any glaring errors in the program.



Base Pulse Width (mS): 1.79

O2 Sensor Volts: .006

Fig. 4.3

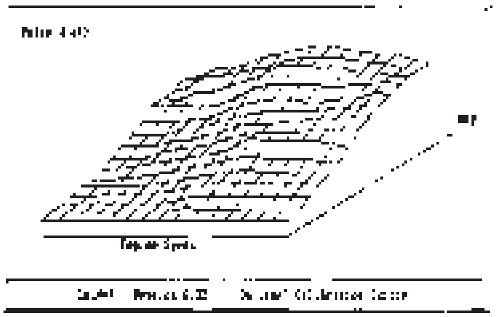


Fig. 4.4

The actual fuel map is called a matrix and consists of 256 set points with 16 rows across the horizontal portion and 16 rows in the vertical. The matrix is layed out with the horizontal representing RPM and the verticl load. Load will either be measured in BAR or % of TPS for Alpha-N configurations. As stated earlier, in this manual, this is a look-up table and the ECU will determine a place value by taking a reading for load and RPM and identifying that point in the matrix for an injector pulse width.

When in actual live monitor this screen will appear slightly different then in off-line editing. The matrix values will be the same, but during off-line editing the load part of the map will be read in % of load regardless of the ECU configuration. Also, the open loop air fuel monitor will be replaced by a RPM load table that identifies where the cursor is residing. During actual on-line editing and if the ECU is configured for closed loop operation, there will be an air-fuel ratio bar graph at the bottom of this screen. This graph has the ability to read either two air-fuel ratios rich or lean of stoich (12.7-16.7 A/F). This signifies what the air-fuel ratio would be if not corrected back to 14.7:1. As an example, if the air-fuel graph read 13.5, then, if the ECU was configured in open loop the pulse width in that place in the matrix would equate to an A/F of 13.5:1. Keep in mind though that the ECU will correct back to 14.7 and this is used to determine how much correction the ECU is actually invoking to achieve stoich. If the ECU is configured for open loop then the air-fuel graph is replaced by a coolant temperature reading.

All the values in the matrix are numbers when multiplied by 0.0627 equal the commanded injector pulse width. For example, if we had a matrix value of 119, the pulse width would be calculated as- 119 X 0.0627 = 7.4613 MS. Since the CALMAP also incorporates an interpalative and rounding function in its software, do not be alarmed if the mathematically calculated pulse width is slightly different from what the CALMAP determines. It will take values from surrounding cells and interperlate them into a pulse width.

The resolution of the load and RPM functions of the matrix can be altered to fit the tuning needs of a particular application. The RPM per horizontal cell can be varied from 350-650 RPM while the vertical load section of the matrix can be configured in 1, 2 or 3 Bar. Keep in mind though, that you are not changing the amount of set points available, just the steps between them. There are still only 256 places to work with regardless of the RPM and load configuration. The actual altering of the scaling in the matrix is covered during the discussion of the "global" menu.

During live monitor there will be a cursor that will identify which matrix cell the ECU is operating in for the current conditions. To change a programmed pulse width, press the E key for edit and then scroll the cursor to the desired position in the matrix and type in the new value. Press enter to execute the change.

Cranking pulse width

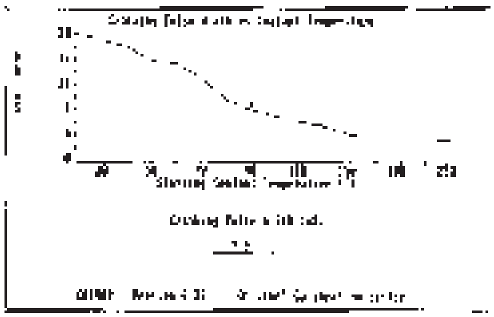


Fig. 4.5

This menu is used to program the pulse width that will be commanded to the injectors on engine crank and works independently of the base-fuel map. It is laid out as a graph with coolant temperature on the bottom and injector pulse width on the vertical. There is a box shaped cursor that identifies where the value is at that moment. Below 400 RPM, this is the injector pulse width that is used to start the engine and is not cumulative with the base-fuel matrix values. Once the 400 RPM thereshold is surpassed, then the values in the base-fuel map become relevant. During this mode of operation the programmed injector pulse width in this table is fired in a asyncronous mode, meaning that there are 4 pulses of the programmed value for each crank rotation as compared to 1 pulse per crank rotation during running.

By toggling the arrow keys, a set point can be defined, a new value typed in and entered by pressing the enter key.

Idle Speed

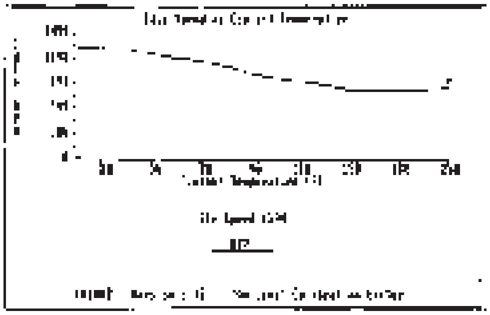


Fig. 4.6

Sub menu idle speed - Sharing the same basic graph configuration of the cranking-fuel table the idle speed program is altered the same way. The only difference being that the verticle side of the graph now depicts a commanded idle speed for the given coolant temperature. At the bottom of the screen is a box that will read the programmed idle speed of the graph. The floating cursor box will represent the actual idle speed as the engine is running, and has the ability to travel below or above the set point value if that is where the actual idle speed falls. The programmed idle speed can only be accomplished if the minimum throttle angle is sufficiently opened to allow for control through the idle air control.

Sub menu throttle follower

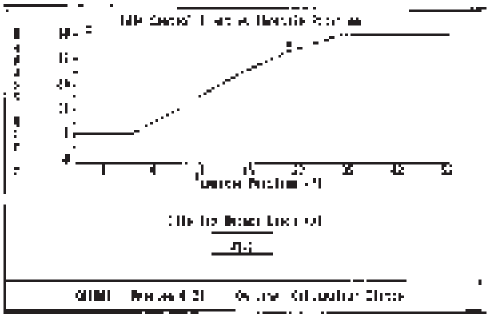


Fig. 4.7

Sharing the same layout as the previous mentioned tables, this represents the tracking of the idle air control in relation to the actual throttle angle. The verticle represents the actual amount of air bypassing the throttle plates through the IAC motor with the horizontal being the throttle angle inputted through the TPS. A floating cursor box will identify the actual amout of bypass air at that moment. This screen is used to set the minimum air rate by adjusting the air bypass screw and watching the cursor box. The function of throttle angle vs. bypass air is used to act like a dash pot on a carburetor and will dampen RPM degredation on rapidly closed throttle. As on the other screens, the actual bypass air in regard to the arrow placement is read in the box on the bottom of the screen.

Submenu Stall Saver

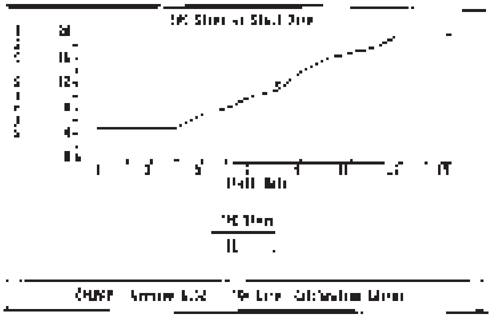


Fig. 4.8

The verticle designation of this table represents the amount of IAC steps commanded to a programmed amount of RPM degredation that is represented on the horizontal axis. The stall values are arbitrary numbers that are assigned to a coded rate of RPM drop. This table is used to compensate for a load dump on an engine that drastically affects idle RPM. Historically, this was used to compensate for a load such as the placing into gear of an automatic transmission with a tight torque converter or the load of an air conditioner compressor. Then again, the customary floating cursor box and set point arrow work in conjunction with the actual place value box on the bottom of the screen.

Submenu IAC starting position

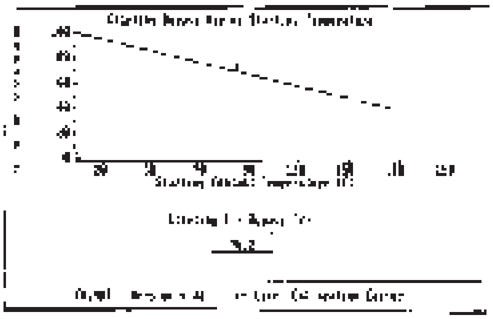


Fig. 4.9

As the name of this menu implies, this defines the IAC's position on start-up as a function of coolant temperature. The larger the number inputted in this screen the more the IAC will be commanded to move to allow for greater volumes of bypass air.

AFTERSTART ENRICHMENT

Submenu Initial Afterstart Enrichment

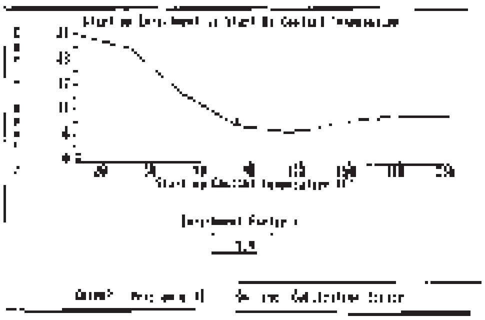


Fig. 4.10

The afterstart tables are the hardest to understand in the CALMAP software. They are the tables that control fueling during the transistion period from cranking fuel to running fuel and are used to help keep the engine running during this transistion from crank-to-run. Unlike the cranking fuel table, which worked independently of the base-fuel map, after start enrichment is an additive factor to the base-fuel matrix. Once the RPM reaches above 400 RPM, the engine is considered to be started and the cranking fuel shuts off. As a transistion to warm-up enrichment which acts like a choke function, is where the afterstart values come into play. Taking the standard format as described for the other tables, coolant temperature is scaled against a percentage of enrichment over the base-fuel map. Another function of this mode is to help in hot fuel handling during heat soak conditions where it is common to boil the fuel in the rail.

Submenu Beginning of Afterstart enrichment

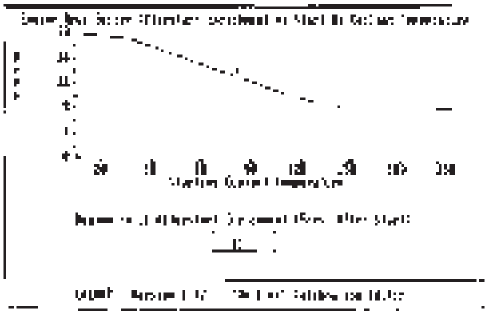


Fig. 4.11

Since the previous submenu defined the amount of enrichment that will be added, this table is the programmable trigger for invoking the start of that enrichment. Keyed from the number of revolutions of the engine after the cranking fuel set point threshold is crossed, in relationship to coolant temperature. Again, all aspects of this table in regard to the floating box, arrow and display hold true as before.

Submenu Afterstart Enrichment Decay Rate

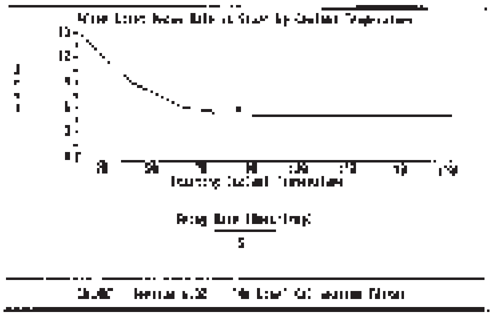


Fig. 4.12

Just the opposite of the previous table, this graph allows the user to set the rate that the afterstart enrichment will be removed in relationship to coolant temperature and revoutions of the engine. Unlike the invoking of the afterstart enrichment, the decay is controlled in coded step rates that are triggered with the programmable amount of revolutions that need to be met. As an example, if the value is set at 5 revolutions at 90° coolant temperature, that would equate to one coded step of degredation for every 5 revolutions of the crank.

WARM UP ENRICHMENT

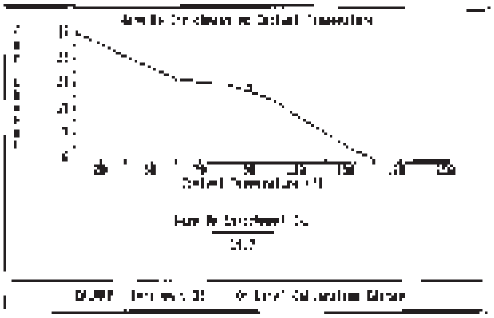


Fig. 4.13

Once the transistion from afterstart fueling is complete, the function of warm-up enrichment takes affect. This function is analogous to the setting of the choke spring tension on a carburetor and the rate at which it opens. Again scaled in the same format as the others, it looks at coolant temperture as a function of a percentage of enrichment from the base fuel matrix.

AIR TEMPERATURE CORRECTION

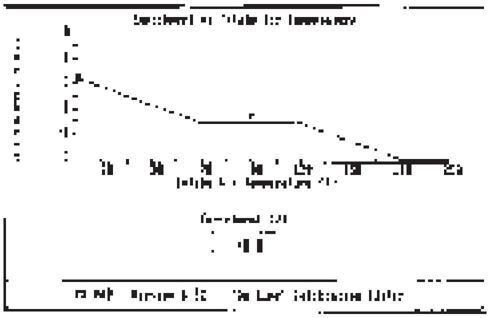


Fig. 4.14

When air gets hot it travels slower and loses some of its density, so it is essential to trim our base-fuel map to correct for this. The basic rule of thumb states that for every ten degrees that charge air temperature is raised, the power generation of the engine drops 1%. This trim table gives you the ability to either enrich from the base-fuel map for decreases in air temperature and to invoke enleanment for heated charge air. The floating cursor, arrow and identifying box fuction are all the same as in previous screens.

ACCELERATION ENRICHMENT

Submenu TPS Acceleration fuel

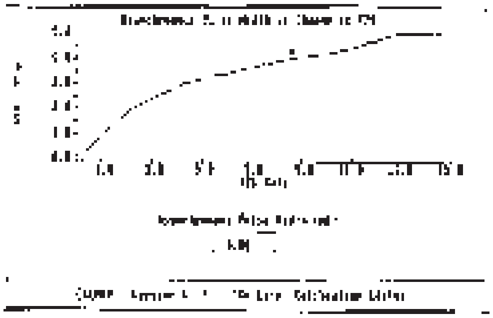


Fig. 4.15

This table controls what is referred to as asynchronous pulse width which is additional fuel pulses that are issued out of phase with the primary ignition pulses. During asynchronous injection, the injector firings are triggered independently and in between of each primary ignition interupt triggered injector pulse. In this mode there are more injector pulses than primary pulses. This function is used to act like an accelerator pump in a carburetor and to administer additional fuel to account for the rapid opening of the throttle blades. The quantity of additional pulses is coded in the board of the ECU and is not changeable through the software. What is programmable is the amount of pulse width vs. the arbitrary rate of change in the TPS. Using the same graph format as the other screens, changes are readily made and actual asynchronous pulse width seen.

Submenu MAP Acceleration Fuel

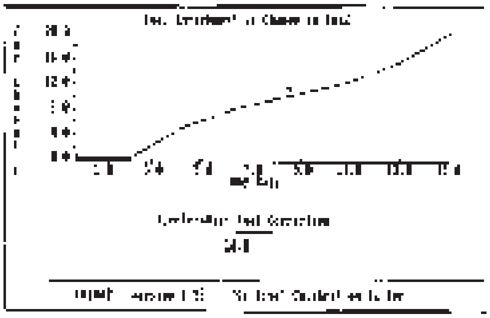


Fig. 4.16

The MAP invoked enrichment is analougus to the power valve in a carburetor and is used for enrichment to compensate for pressure changes in the intake manifold. It is keyed from an arbitrary rate of pressure drop in the manifold that is coded into the ECU, and works as a percentage of enrichment from the base-fuel map. Its primary function is to eliminate the need to richen the values in the base-fuel map to cover lean spots as the load is transistioned across the fuel matrix. Its layout and means of making changes mimics the previously mentioned configurations.

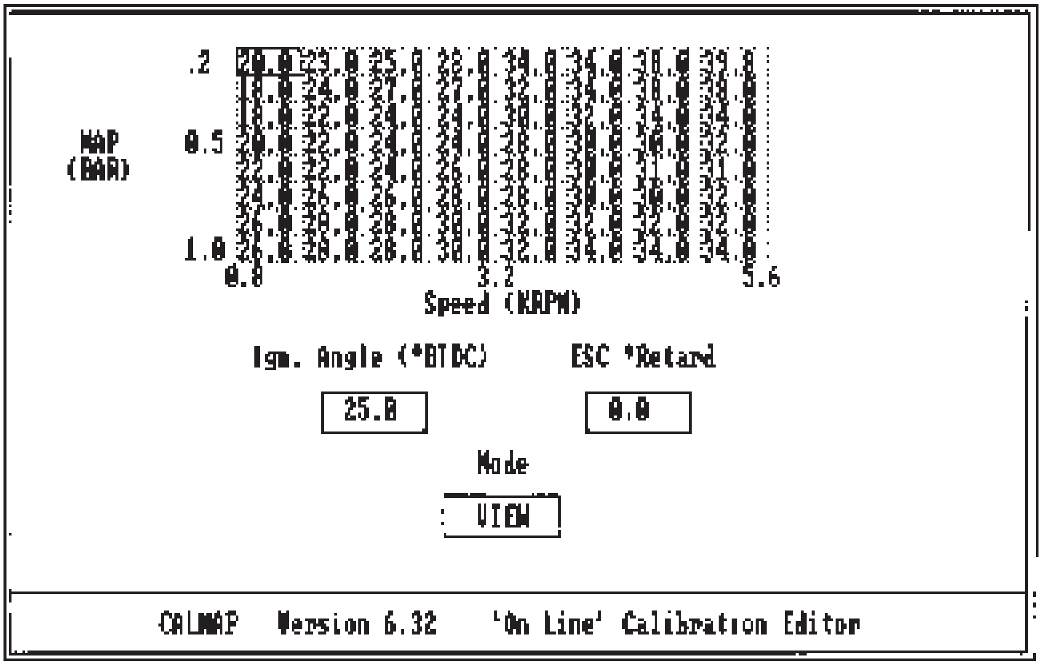
IGNITION

(See Fig. 4.17 on page 4-7)

Upon entering the ignition map function you will have the choice of either a timing matrix that resembles the fuel matrix in layout, but is comprised of a grid of 64 points, 8 horizontal referenced to RPM and 8 verticle keyed-to-load or a three dimensional plot of the timing matrix that can be chosen.

Submenu ignition map - As stated above, the ignition map will resemble a fuel map in appearance with the only notable difference being the scaling between the two. Since the fuel map is larger, it has more resolution which causes the timing map to be scaled at a rate of 1.5 between the two maps cell widths. Referenced from the RPM scaling chosen for the fuel map, the timing RPM cell width will be 1.5 times the fuel map value. To illustrate this, if a cell-to-cell rate of 400 RPM was chosen for the fuel matrix, then the timing map would be scaled at 1.5 X 400 or equal to 600 RPM cell widths.

Below the actual matrix is a boxed value that will read the actual timing command that the ECU is issuing. As with the fuel map, this value inter-



Ign. Angle (°BTDC) 25.0

ESC °Retard 0.0

Mode VIEW

CALMAP Version 6.32 'On Line' Calibration Editor

Fig. 4.17

polates from the surrounding programmed cells and may not agree with the value that the cursor is residing at. In actual live monitor, an additional boxed display will be available representing the amount of knock retard that is taking place to stop detonation if the ECU is equipped with an optional knock retard kit. The knock sensor will remove timing at the rate of 100° per second with the maximum of 20°. It then listens for knock and advances the timing at a rate of 1° per second.

Submenu graph ignition map

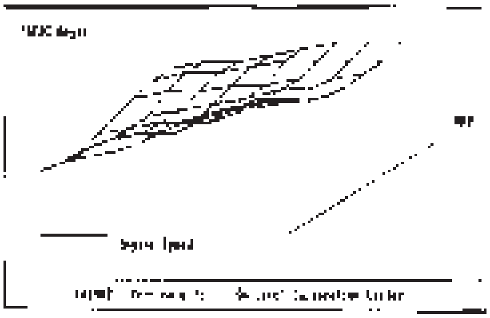


Fig. 4.18

This function is used to give a contour graph display of the programmed timing curve so that any discrepancies or error in your tuning will become glaringly obvious. This function is only available during on-line editing.

NOTE: *ALL OF THE ABOVE MENUS CAN BE SAVED IN A FILE SEPARATELY FROM OTHER MENUS. FOR EXAMPLE, IF YOU WANTED TO SAVE ONLY AN IDLE TABLE FROM A PARTICULAR PROGRAM IT CAN BE SAVED IN THE APPROPRIATE SUBMENU. ALL FILES THAT ARE SAVED AS SUBMENU FILES CAN ONLY BE ACCESED DURING ON-LINE COMMUNICATIONS.*

GLOBAL

When selected from the root menu a Global sub menu listing of 7 choices will appear.

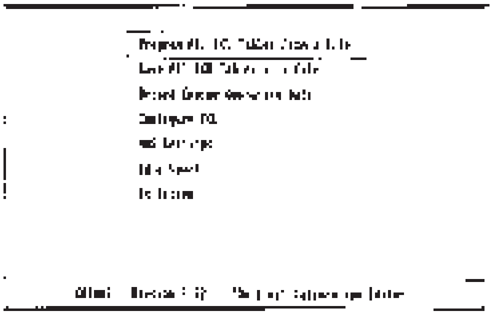


Fig. 4.19

Program all ECU tables from a file - If executed this will rewrite all of the ECU tables from a program that was already saved on this particular disk from a previous calibration. All aspects of the chosen program will be inputted into the the ECU that you are currently connected to. If the current ECU program is not saved prior to this function being executed, then it will be lost.

Save all ECU tables in a file - This will allow you to save the complete calibration of the ECU in a named file for further use. This is the routine that should be executed first if you are going to reprogram the whole ECU from a saved file. This will give you the ability to go back to the original program if need be.

PLEASE NOTE THAT THE ABOVE TWO SUBMENUS ARE A SAVING OR REPROGRAMING OF ALL OF THE ECU FUNCTIONS. TABLES THAT WERE SAVED AS FILES IN SUBMENUS WHILE DOING ON-LINE MONITORING WILL NOT BE ACCESED. FOR EXAMPLE, IF YOU DESIRE TO USE A PREVIOUS CALIBRATION IN A DIFFERENT VEHICLE THEN YOU WILL REPROGRAM THE WHOLE ECU. BUT IF YOU WANTED TO ADD JUST THE TIMING TABLE FROM A COMPLETELY DIFFERENT ECU THEN AFTER THE GLOBAL FUNCTION OF REPROGRAMMING IS ACCOMPLISHED YOU WILL NEED TO GO TO ON-LINE EDITING AND REPROGRAM THAT TABLE FROM A IGNITION SUBMENU.

Record engine operating data

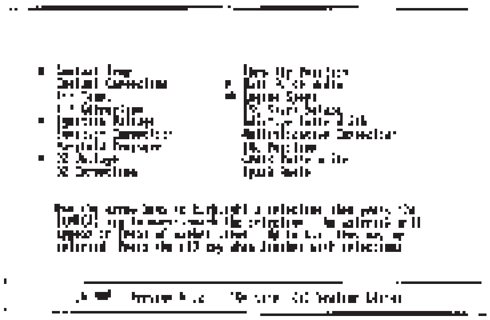


Fig. 4.20

When this function is selected, then the CALMAP software records up to 6 user-chosen data points and stores them on the disk for review. While this data is being logged, you will be able to see the actual data as the ECU sees it. This function is used as a dignostic and tuning aid. Refer to the actual CALMAP users guide for execution of this function.

Configure ECU

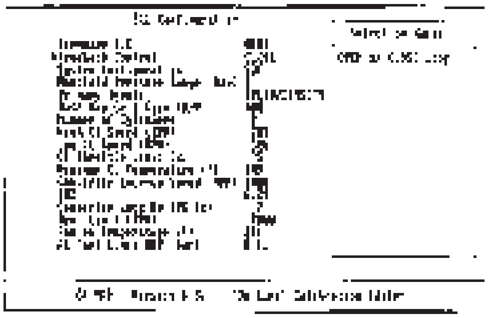


Fig. 4.21

Tied with the base-fuel map as far as importance is concerned, the configuration of the ECU sets all the base parameters that are needed for the CALMAP to interface the ECU properly with the engine that it is running.

The following is a listing of ECU configurations:

Firmware I.D. - The firmware ID is what CALMAP uses to distinguish between ECU types and cannot be changed.

Feedback control - Either open or closed loop.

System configuration - Simultaneous double fire is used for port fuel injection applications (SDF) or (TBI) for throttle body units. In a TBI system for a V-8, the injectors are fired once every two ignition events, however, a SDF approach fires once every fourth ignition firing.

Manifold pressure range - There are 3 ranges available. One, two and three bar configurations. A one bar sensor has the ability to read only vacuum. Two and three bar sensors have the ability to register 15 inches of vacuum to 15 or 30 pounds of boost respectively. This configuration will be used to load scale the timing and fuel matrix.

Primary inputs - This input is used to scale reference the Y axis of the fuel and timing maps. Either speed/density, which is manifold absolute pressure referenced or Alpha-N, which is throttle angle referenced can be chosen.

Base Map cell size - This function allows the cell width of the X axis of the fuel map to be either increased or decresed and can range from 300-650 RPM. This allows the end user to tailor the resolution for there particular engine.

Number of cylinders - This setting is used inconjunction with the system configuration to ensure the correct firing scheme is implemented. Choices are 4, 6 or 8 cylinders.

High speed closed loop - This sets the RPM that must be exceeded before switching to closed loop operation. This function works inconjunction with the low speed closed loop setting.

Low speed closed loop - Sets the low RPM threshold of the hysterisis of the operating range of open loop status. These two functions are used to allow a engine to idle in open loop and then return to closed loop operation after the high RPM setting is surpassed.

CL Throttle limit - This is the throttle limit expressed in percentage that when exceeded will revert the system back to open loop operation. This is done to avoid having the system try to maintain closed loop at or near WOT. Due to the nature of the CALMAP software, even though this setting has the ability to be at 100%, when reading TPS percentages in the record data or view screens, the ability to read up to only 99.9 % is shown.

Minimum CL temperature - Expressed in degrees of Fahrenheit is a parameter that must be met to operate in closed-loop. This is incorporated to prevent closed-loop operation during cold engine operation.

Converter Lock-up Speed (RPM) - Again, a threshold value that must be reached to command the engagement of the TCC when using a lock up kit.

Converter lock up MAP - Replaced by the 4th gear discrete signal of the 700R4 transmission. As a result, this function is no longer used.

Converter lock up TPS - This is the throttle position expressed in the percent of opening that must be exceeded in order for the TCC to engage.

Rev limit - This is the RPM at which a fuel shut off will be invoked to control the RPM of the engine. There is a 1000 RPM hystersis coded into this function, which requires that amount of RPM degredation before the fuel is turned back on.

Fan on Temperature - Read in degrees of Fahrenheit at which the electric coolant fan will be turned on. When this occurs the idle speed will be automatically increased by 50 RPM to compensate for the load on the charging circuit. There is a coded 10 degree hysteresis that needs to be met to turn the fan back off. Regardless of fan on temperature at WOT, the ECU will automatically open up the fan curcuit.

AE fuel limit map (BAR) - When in speed density configuration this value will be the limit of invoking the MAP acceleration fueling. In simpler terms, this is the point, when surpassed, that there will no longer be any MAP acceleration enrichment. It is analougus to the point at which the power valve in the carburetor will no longer give any additional enrichment. When configured for Alpha-N operation, the value will represent TPS % even though the configuration listing will still be read as bar.

NITROUS SETTINGS

The standard 015013 ECU has the ability to control one stage of nitrous and the corresponding tuning changes that need to be done for proper nitrous operation. Through this global function, the nitrous engagement throttle percentage, time delay, RPM setting and fuel enrichment through the injectors and timing retard can be controlled.

IDLE-SPARK

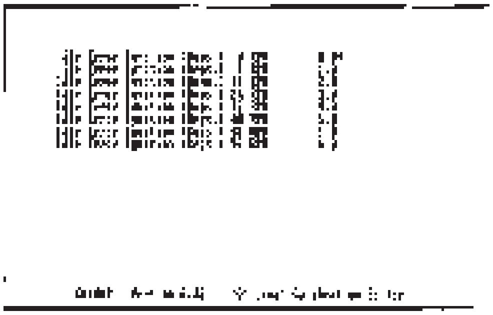


Fig. 4.22

The purpose of the idle-spark function is to add an additional measure of closed-loop idle control through the use of timing. As mentioned earlier in this manual, large capacitance intake manifolds are very sensitive to reversion from the camshaft and the inherit idle instability that it causes. ACCEL has found that by varying the amount of timing in accordance with the amount of idle instability works very well to control this problem. To enter the idle-spark function on software prior to 6.32, you must be on-line but choose the EDIT FILE selection on the ACCEL screen. In lieu of entering the configuration code, type in the word “IDLESPARK” and press enter. That will give you a screen that allows you to change the amount of timing control to tame the idle variation. By changing the timing command on ECU pin P2-B1 is how the idle-spark functions. The idle-spark function is only invoked above 100°F coolant and below 1.5% TPS.

CHAPTER 5: TUNING WITH CALMAP

TUNING

Now that you have a basic familiarization of the ACCEL fuel injection ECU and its companion components, I can now discuss the intricacies of tuning this system. As stated in the beginning of this manual, to tune this system you need to posses the basic working knowledge of an OE fuel injection system. Throughout this text the assumption was made that you posses this knowledge and the more familiar that you are with a stock configured fuel injection, the easier it will be to master the ACCEL ECU.

As mentioned in the Introduction to CALMAP section, your first step should be to become familiar with the software and not concern yourself with making any tuning decisions. If you try to learn the software and tune the engine at the same time you will not only drive yourself crazy, but you will also risk damaging the engine. Once you feel comfortable with accessing the different screens and are well voiced in their purposes, then the tuning of an engine can begin.

The difference with tuning a progammable ECU is that there is no real constant. What I am referring to, is that whenever working on a stock, or even slightly modified engine with an aftermarket PROM, the variables are down to a minimum, because you already know that the program has been established. When working with a programmable ECU, in a lot of instances your start-up program may be very much off the base and then it is up to you to determine if it is a programming problem or a mechanical problem with the engine or both. With a stock ECU, the only variable is the engine and its ancillaries, not the program. That is why ACCEL has spent the time to develop many different programs for the Chevrolet manifold and camshaft combinations that are popular. By ordering the proper part number ECU you will bring yourself closer to the mark right off the bat. As your tuning career grows, you will quickly see the benefit of establishing your own library of programs for different engine combinations that you run across. As the old saying goes “there is no need to reinvent the wheel” everytime you get involved with a tuning job.

WHERE TO START

Most tuning problems have their start with poor preparatory work. Either the operator is not familiar with basic engine and fuel injection functions, or he did not go back to basics in checking the engine over prior to the tuning session. From my experience, I believe that you will find a few distinct senerios when regard to tuning a spark/fuel ECU.

Scenerio one starts with an engine or ECU or both that were not installed or built at your shop. This is not saying that the engine, fuel injection or its components were installed improperly, but you have a better chance of finding something wrong then you do finding something done correctly. With this in mind, you now start your tuning and are trying to correct for either a vacuum leak, faulty ignition, a poorly assembled engine, a faulty ECU installation, poor atomization by the fuel injectors or a totally wrong combination.

The second most common case is that you do the installation of the ECU but the engine is an unknown variable. Another variation on this, is that you install the injection manifold on a unknown engine.

The best case scenerio is that you build the engine and install and tune the fuel injection system. Then you can choose the proper components to obtain the desired results.

It is quite often that you will find that the combination of components, especially the camshaft and intake manifold are wrong for that application. Referring back to the earlier sections of this manual, most individuals try to pick a camshaft or cylinder head that would work well with a carburated engine and a short runner intake manifold. It is also common to fall into the “drag racer syndrome” of bigger is better and install too large a fuel injector for that combination. For this reason the EMIC training manual and course were laid out the way they were. ACCEL wanted to cover the basics first and then build upon that.

Prior to doing any tuning on a vehicle that is unfamiliar to you, get as much information from the owner as possible. Question them about the compression ratio, camshaft specifications, cam installation position, fuel system installation and components and basic ignition condition.

Do a good visual inspection of the engine and of the installation and test drive the vehicle if possible. Also perform a scope analysis looking for possible potential problem areas. Since it is very common to have vacuum leaks with a poorly installed GM TPI, once the engine is running, go around the manifold and runners looking for leaks with a propane enrichment tool. Repair any problem that you find prior to doing any tuning.

With a used TPI make sure the throttle body and IAC are clean and carbon-free and then check the fuel pressure to comfirm you have 43-45 lbs at atmosphere (vacuum hose removed from the fuel regulator and the engine running). If a used TPI is being programmed, do a thorough on the car injector cleaning to insure good cylinder to cylinder distribution. It would also be advisable to “zero” out the idle spark since it does a very good job at masking ignition, air leak and injector problems.

BASE ADJUSTMENTS

Once you are confident that the installation of the fuel injection system and the engine are sound, you can now move on to making the base adjustments in preperation for doing a calibration.

These are the prescribed steps.

1) Configure ECU

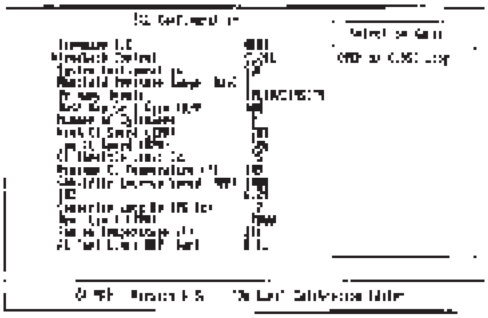


Fig. 5.1

The first step in any calibration is to check the configuration of the ECU. Make sure the configuration matches your vehicle in terms of primary inputs, number of cylinders, etc. I usually start by going from the top to bottom of the configuration list. Application-specific to the engine you are tuning, will determine the data inputted on this screen.

Here are some suggestions for configurations with explinations of their logic.

Feed back control - Depending on whether you are going to use a stand-alone air fuel monitor or not will dictate what you do here. The prescribed way of tuning is to utilize a Horiba style air-fuel ratio monitor to read actual A/F ratios. This will give you a more accurate and faster tuning job. If an independent monitor is going to be used, then you need to configure this mode for open-loop since you will be removing the ACCEL supplied O_2 sensor to replace it with the monitor’s sensor.

If a stand alone A/F monitor is not available, then you will want to configure the ECU for closed loop and then utilize the A/F monitor on the base-fuel map screen.

System configurtion - This choice is straight forward. SDF or TBI whichever is applicable.

Manifold pressure range - Application specific to the vehicle at hand. If it is normally aspirated always use the 1 Bar setting. If the vehicle is supercharged or turbo charged then you will need to examine the amount of boost that it will run. In theory, whenever forced induction is being used, you should employ a 2 bar sensor or even a 3 bar sensor for boost to 30 lbs. The problem that arises is that each successive time you raise the manifold pressure input, you reduce the resolution of the fuel and timing maps. A 2 bar sensor input will cut the resolution in half and a three bar will reduce it to 1/3 in comparison to a N/A setting of one bar. With every successive reduction of resolution, you are forced to try to tune the engine with much less fuel control.

I suggest for supercharged applications that are running below 10 lbs. of boost, for only short peroids of time, to use a 1 bar sensor. A forced induction application that will spend most of its time in boost (race engine) will neccesitate the use a 2 bar sensor. For almost all street driven turbos up to aproximately 24 lbs of boost, use a 2 bar for the best driveability. The reasoning behind these decisions is that in most supercharged street engines the majority of time is spent in vacuum or zero vacuum with boost only comming into play for short peroids of time at higher RPM. Since a turbo spools and builds boost independently of RPM, the time spent in boost is usualy greater than with a supercharger and therefore, you would want more resolution under boost.

Primary inputs - For most applications you will choose speed/density. All forced induction systems must use speed/density. If you are working with an engine with very little or no vacuum (below 5 inches), then there will be hardly any resolution in a speed/density based fuel map since there is no vacuum input. For that reason, you would be better off switching to Alpha-N and key the load calculations from throttle angle input. Whenever switching from speed/density to Alpha-N, the vacuum hose must be removed from the MAP sensor and only a 1 bar sensor can be used. Also, there is no direct correlation from a speed/density to an Alpha-N map so all the fuel and spark tables will need to be rewritten.

Base Map cell size - This function will control the amount of RPM referenced resolution the base-fuel and timing maps have. The natural tendency is to want to plot the map out to a high RPM. Again, think about how the vehicle is going to be driven and also the engine that is in it. If it is a long runner manifold (TPI or Super Ram) it will make peak power between 45-5500 RPM. By using a map cell size of 300-350 RPM you will have resolution to 4800-5600 RPM respectively. Even if the engine makes power to 6000 RPM, you can still use the 350 RPM scale. Once the RPM scales beyond the greatest value in the matrix, the CALMAP software just carries that last fuel or timing command out. For example, if your map is scaled to 4800 RPM with the injector pulse width for that cell being 9 MS, then it will continue to issue a 9 MS pulse above that point. What you are trying to accomplish is to allow yourself the maximum number of tuning set points at light to intermediate load. By doing this, you will achive the best driveability, throttle response and least emissions.

Number of cylinders - Self explanatory

High and low closed loop speeds - I have bunched these two together since they are dependent on each other. If you are configured to operate in open loop, these values are moot at this point, but will have to be inputted once you switch back to closed loop. If you are tuning in closed loop, you will have to decide if you want the engine to idle in closed or open loop. If you want to idle in closed loop, set both of these values below the idle speed with a 100 RPM difference. The reason that you may not want closed loop idle fuel control is due to the camshaft you have in the engine. Historically, any cam with some degree of overlap will want a richer than stoich mixture at idle. This can be accomplished by setting the low RPM value 100 RPM above base idle speed and the high rpm value 200 RPM above base idle speed. If emision readings are a concern, and a catalytic converter is being used, conversion efficiency ramps off considerably when the mixture drifts more than 2% richer or leaner than stoich. For that reason, you may want to idle in closed loop. If closed loop idle is desired , always use a heated O_2 sensor to maintain O_2 correction accuracy especially if headers are being used.

CL throttle limit - Once the closed loop speed threshold is surpassed, the ECU will stay in closed loop up until this programmable throttle input is reached. If you are not using a stand alone A/F meter, then during tuning only, you would want this set at 100%. The reason being is that you will be able to see the open loop A/F at WOT to use as a tuning aid. Do not do sustained WOT passes with this function set at 100%. If a stand alone A/F meter is being used, this setting is again moot until the system is put back in closed loop. For normal operation, once the tuning is complete a value of 70-80% is desirable.

Minimum closed loop temperature - This is the temperature criteria that needs to be met for closed loop operation. I find that in most applications it is best to set this at aproximately 150-160°F. Make sure though that whatever this is set at coincides with the decaying of the warm-up enrichment. Ideally the warm up enrichment should be zeroed 20° prior to this setting.

Converter Lock up RPM - Since our converter lock up function only looks at RPM and throttle angle, where as an OE also looks at coolant temperature and more importantly road speed, this function does not always give desirable results at lower RPM. Historically you need to try different settings with the best usually being at the RPM that the vehicle cruises at highway speeds.

Converter lock up MAP or TBD - Not used. Any changes here have no function.

Converter lock up TPS - Works in conjunction with the RPM setting and is usually sensitive to each particular installation. A good starting point is 20%.

Rev limiter - This is a fuel shut off with a 1000 RPM hystersis. Set it near the point that you choose to limit at. If the vehicle has a ignition induced rev limiter, this will not have the ability to override it if that limiter is set at a lower value.

Fan on temperature - It is usually best to set this value 10-20° above the thermostat setting so that the fan does not run constantly. Remember, there is a 10 degree hystersis that must be met to shut the fan back off.

AE fuel limit (BAR) - This is the point referenced to manifold pressure that MAP fuel enrichment will cease to be inputted. A good starting point on N/A engines is .70 and on turbos .90. Use this value to increase the crispness of the throttle at high loads. Lowering the value cancels enrichment sooner and raising it holds it in longer. In Alpha-N configuration these values refer to TPS percentages.

2) View screen

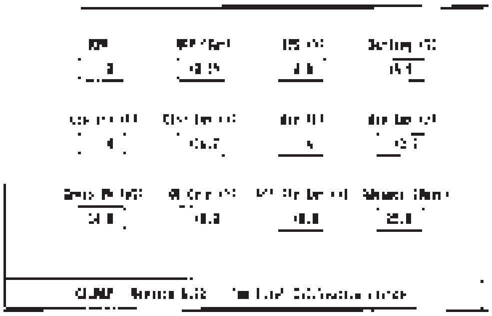


Fig. 5.2

After configuring the ECU and before starting the engine the view function should be employed (V key). When in this mode the CALMAP works like a scan tool and displays all of the sensor inputs and some of the ECU outputs. Use this to make sure the ECU is communicating with all of the sensors.

3) Review all screens - By reviewing all screens one by one you will have the opportunity to check the program before starting the vehicle. Pay attention to anything that would be detrimental to the engine (overly rich calibration, excssive timing or idle speeds, etc.).

4) Zero idle spark

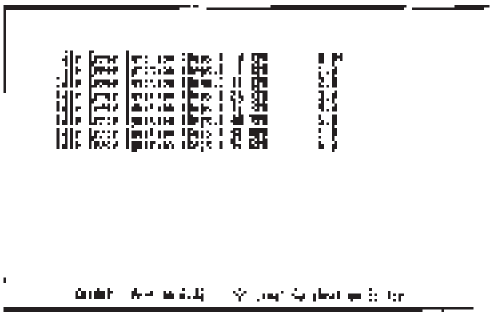


Fig. 5.3

The rationale behind negating the idle spark is to not allow it to mask any mechanical problems that might not have been discovered during your prestart testing. The idle spark function was added to help maintain constant idle speeds, not as a crutch.

5) Save program - Enter the global function and save the entire program under “Save all ECU tables in a file” and identify it with a name that you will associate with this particular vehicle. By executing this routine, especially in the early stages of your learning curve, if you get totally off base you can always revert back to your starting place. As your experience and your library of files grows, then you can bypass this step.

6) Start engine - If the engine fails to run on the third try STOP and re-examine what is going on. Pull a spark plug and check for flooding. If the plugs are wet, and the engine never really ran on your attempts, go into cranking fuel and lean it out. If the engine started and then stalled within the first 3-5 seconds of running, the problem is most likely in the afterstart enrichment. Do not concern yourself with that now. Try restarting the engine. It will probably run. If the opposite is happening when you examine a plug and you see no fuel, then richen the cranking fuel table. If the engine stays running but appears to be very rough, then it is most likely too rich. As long as it is not bellowing black smoke at this point, just let it warm up and the problem will be corrected later. Just keep in mind that it doesn’t take much to foul the plugs or wash the rings out of a port fuel injected engine due to the close proximity of the injector to the intake valve. Allow the engine to warm up until the cooling fan cycles once, if so equipped.

7) Adjust TPS - Go into the View screen (V) and adjust the TPS to 0-.5%. This will allow the ECU to recognize a closed throttle position.

8) Check Idle speed - While in the view screen check to see if the idle speed is in range. If it is continue to the next step. If it is either too high or low, enter the Idle Speed menu and check what speed is commanded. If the IAC cannot accomplish the commanded idle speed then the throttle plates are too far closed. If the actual idle speed is over the commanded value then the throttle plates are too far opened. Please keep in mind that we did not set the timing yet so we may need to come back to this table later.

To adjust the throttle plates, enter the throttle follower submenu in the idle speed tables and adjust the throttle stop screw to achive approximately 5-10% bypass air. Since the throttle plates were now readjusted you must repeat step 7 and readjust the TPS.

If the commanded idle speed is wrong, input the value you desire.

9) Set timing - When setting the timing on a ACCEL ECU it is critical to make sure you synchronize the timing between the harmonic balancer and the base timing matrix. If this is not done the timing program that you implement may not be accurate. To synchronize the timing, first enter the ignition menu and save the current timing map in a subfile by executing “save ignition map in a file” routine. This will allow you to revert back to the original timing program without reprogramming the whole ECU. Once the map is saved and titled, return to the timing matrix and press the E key to place CALMAP in edit mode. Since the timing map interperlates values from one cell to another, it is essential to make a set timing map of one value. It is usually best to use a value of 6° for Chevys and 10° for Fords.

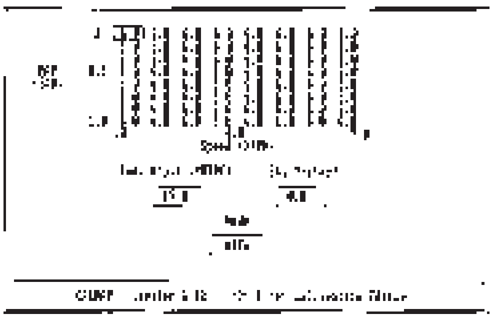


Fig. 5.4

Whatever value you use, convert the whole matrix to that number. You will now have a map with all the same numbers. Start the engine and let it idle. With your timing light hooked up, physically adjust the distributor until the value on the dampner reads the same as the value in the boxed area below the timing matrix. Please note that during this initial set up procedure, we have already zeroed the idle spark function. If you are just going to check the timing for sync on a vehicle and not executing the complete base set up, make sure you raise the TPS to over 1.5% to disable the idle spark function. It is easier to disable it this way in lieu of erasing an established idle spark program. For the initial set up I choose to zero the idle spark due to the fact that it has not yet been established as to what degree it will be needed. When the timing procedure is completed return the TPS to a setting of 0-.5% and re-enter the already saved timing map by executing the "program the ignition from a file" routine.

10) Drive vehicle - At this point I like to take the vehicle out and drive it for a few miles to clear it out and get some heat into the O_2 sensor. Do not make any WOT passes, but it is advisable to drive it aggresively to make sure the plugs are cleaned out. If the vehicle will not drive due to an improper fuel calibration (extreme bucking, hesitation or surging) do not try to force it. The fuel map will need to be reworked first.

11) Base Fuel Map (idle) - Once you return, start your programming by working from idle, to light load to intermediate load to WOT. Enter the base fuel map screen by either pressing B or enter through the base fuel map routine. Locate the cursor to see the commanded injector pulse width. If you are using a stand alone A/F meter or the CALMAP open loop scale, change the numbers in the matrix to achieve the best idle with the leanest possible air fuel ratio. As stated earlier, an engine equipped with a cam with some degree of overlap most likely will not want to idle at 14.7:1. If a satisfactory idle is unobtainable, then return back to global configure ECU and change the low and high closed loop setings to idle in open loop.

When working with the fuel matrix always remember that CALMAP is an interperlative software and the fuel cells around the cursor also affect the gross pulse width. It is common to have to make changes to the surrounding cells to achieve the proper mixture. An efficient way to dial in the fuel map is to look at the amount of correction needed to arrive at stoich and alter the map value by that percentage. For example, if you return to the view screen there will be a listing for the amount of O_2 correction. If that value is reading -12% and the cursor in the matrix is sitting at a value of 44, then multiply 44 X .88 = 38.72. Round this value out to 39 and enter that in the matrix. Then take the surrounding cells and do the same adjustment. To richen the matrix value by a percentage just add the desired percentage to 100 and multiply by that. To establish this, use the following equation. To add 12% enrichment to a matrix value using your calculator mutiply 44 X 1.12 = 49.28.

If it is determined that the complete fuel map needs to be altered you can either lean or richen the calibration from its current values using the following steps.

1) Save entire calibration to a file.

2) Access the base fuel map of the just saved calibration. This needs to be done in the "EDIT FILE" mode from the ACCEL screen.

3) Press M, A or S to increase or decrease by a percentage (M), add a number of counts (A) or subtract a number of counts (S) to the entire map.

4) Now save the updated calibration to a file.

5) Then enter "Program all ECU tables from a file" using the new calibration name.

THE UPDATED CALIBRATION HAS NOW BEEN LOADED INTO THE ECU.

This is usually needed if the injectors are either too large or small for the ECU configuration ordered. Keep in mind though, when modifying the base fuel map by counts, it will have a greater effect on the low load numbers of the map then the high load values.

It will most likely be necessary to alternate between the fuel map, timing map and idle speed tables to achieve the best idle characteristics. Adjust for idle quality just like you would on a carburated application but instead of using a screw driver, distributor wrench and timing light, it can all be accomplished from you lap top. If you are still unable to achieve a decent idle it is now time to invoke the idle spark function. To enter this screen on older software escape back out to the ACCEL screen and enter edit file.
In lieu of entering a configuration code type IDLESPARK, and enter that menu. Start entering a idle spark input for each RPM variation beginning with 0 for the least variation and arriving at a maximum of 6° for the largest variation. After the idle spark is programmed, return to the fuel map and work the idle cells for the best idle quality with the least emissions. It may be possible now to enter closed loop idle control. Try it and see.

12) Idle timing - Use the timing map to help achieve the best idle quality and throttle response, keeping in mind that like the fuel map, the cells around the matrix value will effect the actual timing command. If the idle spark function is enabled it is normal to see the actual timing command in the box below the matrix vary.

13) Base fuel Map light load - Since the idle calibration is now very close to being done, start to concern yourself with off idle fueling. You may want to start by simply raising the RPM without placing a load on the engine and calibrate the fuel cells the same way you did for idle. Do this to a maximum of 2000 RPM. If the vehicle is equipped with an automatic transmission, it is desirable to chock the wheels and set the parking brake and do some light throttle power brake tuning to 1500 RPM or the stall speed of the converter, whichever comes first. Historically, the acceleration enrichment functions are near enough to being correct, that once the base fuel map is correct little if any adjustment is needed in these tables.

To properly and safely tune a fuel map you will need to either bring along a driver or access a chassis dyno that has steady state capabilites. Part throttle driveability cannot be accomplished on a chassis dyno that has no ability to do steady state testing. Using the A/F readings at light load, try to obtain a mixture ratio of near 14.7:1. In almost all instances, and with our manifold and camshaft combinations this is a desirable target number. Follow the same procedure that you did for idle by employing the V key to see how much O_2 correction is needed and use that value to modify the fuel matrix. Instruct your driver to start out driving very easily and have him work his way upto more aggressive driving patterns so that the lookup table may identify different parts of the fuel matrix. A knowledegable tuner will try to emulate all types of driving conditions to make full use of the tuning capabilites of the ECU. If transistional fueling leaves huge holes to achieve the proper balance of drivability and A/F, then the functions of acceleration enrichment can be used to make the transistion smoother. It is usually the most desirable to arrive at a fuel map that at light load relies very little on the O_2 sensor to achieve stoich. The closer your Map is to being correct, the less correction from the O_2 sensor will be needed. If correction is to be made, it is usually desirable to have the O_2 lean out the calibration in lieu of richening it. This leaves an extra margin of safety aganst leaning out and damaging the engine if the O_2 sensor circuit fails. Follow this procedure upto aproximately 70% load.

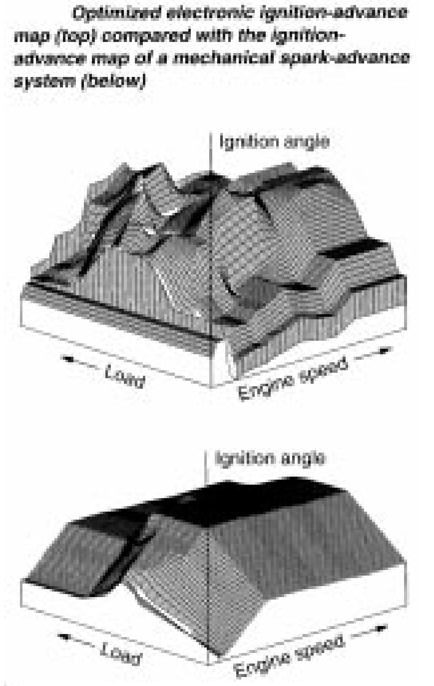
14) Ignition timing part throttle - Now that the base fuel map has been optimized up to 70% load, we can now alter the timing map and not have to be concerned about being lean in these areas. Since we have already syncronized the ECU with the distributor, all of our tuning can be accomplished with the lap top. If the subject vehicle is equipped with a knock sensor kit, then the task will be much simpler due to the sensor's ability to recognize detonation. Ideally, you would want to utilize as much spark lead as you can without invoking detonation. A "seat of the pants" feel is usually the best tool for this type of application. Keep in mind that the ECU has the ability to identify 64 set points for timing control. This differs from a conventional mechanical/vacuum advance distributor due to the ability to advance or retard the spark for the best performance during that load and RPM. The ECU has the ability to run more timing at idle, pull it back out at light load, add more under moderate load and then adjust for WOT conditions. In most instances the programmer doesn't recognize this ability and sets the timing curve as if it were a conventional distributor. Study the way the cursor traverses the matrix for varing load conditions and input timing commands, to achieve the best results. It is customary to start with a very conservative timing curve and then move toward the aggressive side in small increments until detonation is detected.

15) Wide open throttle fuel map - With the timing and fuel maps now calibrated up to the 70% load thereshold, we can now tune for maximum power. This is where a stand alone A/F analyzer comes in handy. Ideally you will find that most engines will want an air fuel ratio of between 12.7-12.9 at peak torque and lean out to 12.9-13.1 at peak horsepower. For this reason, when you go into the graph base fuel map function you will see peak injector on time at the torque peak. This segment of the tuning is best done on a chassis dyno due to its repeatability and the legal and morale issues of racing down the highway at WOT. If using an A/F meter, make a wide open throttle pull watching the way the cursor traverses the fuel matrix while recording the air fuel ratio readings. You will be able to identify the peak torque if a dyno is not used by the engines highest demand for fuel. Historically, with anyone of our manifolds, peak torque falls between 28-3500 RPM. To derive the needed injector pulse width, simply divide the actual A/F by the desired A/F and adjust the fuel map accordingly. For example if the actual air fuel ratio is 13.1 at peak torque and you desire 12.9 divide 13.1 ÷ 12.9 = 1.01%. Then richen the matrix in that area by 1%.

If an A/F monitor is not available, you can use the open loop air fuel ratio monitor on the bottom of the base fuel map screen. This scale reads what the A/F would be if not driven back to closed loop. The only problem with using this is the possibility of leaning the engine out since the mixture will be driven to 14.7:1. On normally aspirated applications, short bursts at this A/F usually will not hurt anything but forced induction engines are a completely different story. For this reason I do not suggest using this method for these engines. Historically, forced induction engines like a slightly richer A/F to help cool the charge. It may be advisable to run these engine at 12.2-12.5 at peak torque and 12.5-12.7 at the horsepower peak. It is better to give away a few HP than to blow a headgasket or lift a piston ring land.

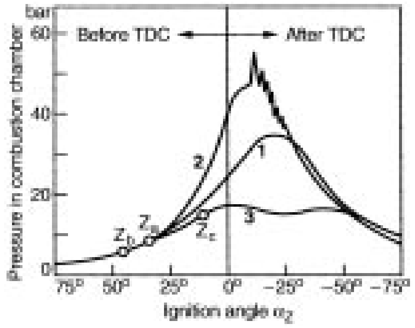
Always keep in mind that CALMAP is an interpalative program and the fuel cells around the actual cell that the cursor resides over, have an effect on determining the pulse width.

16) WOT timing - Now that the fuel curve is correct we can now maximize the WOT ignition function for the most power. Again, this area of tuning is best done on a chassis dyno for safety and the ability to quantify the results. Historically, prior to advent of electronic timing controls, most engines had a truly compromised spark curve. Being derived from RPM reference only, the ability to adjust the timing was relatively crude. As stated earlier, most individuals carry this same logic through to electronic spark timing, not truly optomizing the timing for different load conditions.



Optimized electronic ignition-advance map (top) compared with the ignition-advance map of a mechanical spark-advance system (below)

Fig. 5.5 *– Electronic spark timing enables the tuner to totally optimize the engines spark demand while previous mechanical advance systems allowed no where near the same level of control.*



Pressure curve in combustion chamber for different ignition points

1 Ignition (Z_a) at correct time
2 Ignition (Z_b) too soon (ignition knock)
3 Ignition (Z_c) too late

Fig. 5.6 *– The tuning of the ignition curve is paramount in extracting the most performance from the engine. The late initiation of the spark does not allow cylinder pressures to build early enough and power output drops. Conversely, extremely early ignition causes abnormal combustion and uses the burning of the fuel in a destructive way.*

The most important issue to understand with WOT timing is when using a closed loop timing control kit, there is the theory of the hystersis of knock. For example, a given engine if maximum brake torque is achieved at 30° BTDC, and the timing is now advanced to 31° BTDC, and abnormal combustion occurs, it may be necessary for the ESC system to retard the timing by as much as 10° to eliminate knock. Always keep in mind that once detonation is started, it takes a disproportional amout of timing to be removed to stop the detonation. For this reason the amount of knock retard that is displayed cannot be used to determine the amount of error as the O_2 correction is when working with the base fuel map.

Always start with a conservative timing map and work yourself up to a more aggressive program.

17) Cold start tables, IAC starting position and cold idle speed - At this point the vehicle should be completely tuned and the only issues that may be unresolved are in afterstart fueling and IAC control.

If the program is plagued with a cold start stall, then the after start enrichment needs to be adjusted due to a lean condition. Since this usually rears itself after a truly cold start, it will be hard to track down and for expeditious purposes it will probably be advisable to make drastic changes in this table to overcorrect. You will need to identify the coolant temperature that the problem occurs at and work in that area. Conversely if the engine stays running after a start but acts like it is very rich by running rough (much like a carburetor with a faulty choke pull off), then the afterstart enrichment is to rich.

A very helpful screen when working to alleviate these conditions is the view function. With this you will be able to actually watch the after-start enrichment decay rate and actual percentages that are employed.

To correct for a lean (stalling) condition, use a combination of either increasing the intial after-start enrichment at that temperature, have the afterstart enrichment invoked sooner by reducing the number of engine revolutions in the beginning of the afterstart enrichment curve or by maintaining afterstart enrichment longer by increasing the number of engine revolutions in the decay rate curve.

For the alleviation of a rich after start program, either lean out the amount of enrichment at that given temperature where the problem exists, increase the number of engine revolutions in the begining of the after start curve or decay the enrichment out quicker by reducing the number of revolutions in the decay rate curve.

These same tables can be used to address hot fuel handling problems that occur after a heat soak of the engine. A start and stall after a heat soak can be addressed best by enrichening the afterstart enrichment curve from 180° to 250°F, minimizing the number of engine revs at the beginning of the afterstart enrichment curve and delaying the decay rate.

Another area that can affect afterstart stalling or rough running is the IAC starting position vs. coolant temperature. If the starting position is set too high, it is common for the idle to grossly overshoot on start up and then as the IAC degrades out cause the engine to stall. The converse of this is if there is too little IAC on start up, then the engine will struggle to maintain RPM. Keep in mind that a fuel injection system unlike a carburetor does not utilize a fast idle cam to open the throttle plates to supply the additional air that is needed to compensate for the additional fuel, it relies strictly on the IAC for that function.

TUNING TIPS

To be successful tuning a fuel injection system requires a broad based background and an understanding of how all aspects of an engine interrelate with each other. Even though it would be impossible to anticipate every conceivable scenerio that may arrive, we will try to generalize the commonly asked questions to our tech line. More often than not, a programming problem usually has its roots in more than one area and is the result of a stack up of a few different issues.

The following are common problems that arise during tuning and there respective corrective actions:

Idle quality (rolling or surging) - One of the most common areas of difficulty is in obtaining decent idle quality and a corresponding acceptable load dump characteristic. Since most of our ECU's are installed on modified engines, problems arise that would not normally be induced in a stock engine. The single largest offender with regard to idle quality is the issue of camshaft and intake manifold selection. As stated earlier, camshafts with a large degree of overlap do not interface well with long runner intake manifolds and large plenum volumes. The actual runners and plenum act as a storage for standing waves that are induced during reversion. What this actually causes is almost a tide like effect of pressure variations in the plenum that would be analogus to a liquid slushing around in a bucket or fuel in a half empty gas tank. These standing waves have a direct effect on cylinder fill and can also trigger MAP acceleration fueling.

One of the easiest ways to stabilize the idle quality is to first make sure the pressure variations are not invoking the MAP fuel enrichment. Do this by accessing that menu and zeroing the first few points of enrichment. If that doesn't resolve the issue, then try adding a little more idle spark to try to control the variation. Occasionally, a combination of the above with a slight increase in idle speed and a retarding of the base timing (through the use of CALMAP) will be all that is needed. It is also a good practice to utilize a vacuum hose that is 6-12 inches long to help isolate the sensor from these pulses.

Always keep in mind what was mentioned earlier in this manual in regard to injector repeatability at short pulse widths. Sizing an injector too large and trying to correct for it by decreasing pulse width will cause idle instability. Injectors that are issued pulse widths of less than 1.7 MS usually cause a rolling idle. Another common mistake is the lowering of fuel pressure to try to accommodate a large injector. These attempts are usually sucessful as long as the pressure with vacuum on the regulator does not degrade below 35 PSI, which is the borderline value for atomization. Even though pressure is always referenced with atmosphere off the regulator, we need to be concerned with the affect the engine vacuum has on the lowering of the fuel pressure. If the engine has very good vacuum (17-20 inches) then it will pull the fuel pressure down approximately 10 lbs from the atmospheric reading. Keeping this in mind, a atmospheric reading on the regulator of 40 lbs could become 30 lbs on an engine with excellent vacuum.

In regard to injector sizing, the best drivability and emissions are always found with a smaller injector than a larger one. The elasticity of an injectors ability to supply fuel is paramount on it entering its dynamic flow range. The DFR is the point in pintle travel where proper atomization of fuel will occur. Full travel of the pintle in most injectors require pulse widths as much as 3.25 and 2.75 MS respectively for high and low impedance units. Pulse widths below that never allow for complete travel of the pintle to the open position. The earlier quoted values of approximately 1.5-1.7 MS stated to obtain stroke to stroke repeatability are the window of time it takes for the injector to enter the lower part of the DFR. Obviously, concerns with idle quality are also shared with the issue of the injector being able to supply enough fuel at WOT. For this reason it is advisable to try to build an efficient engine inregard to BSFC values so that the fuel demand of the engine is decreased. Use the supplied charts to reference the relationship of injector flow vs. fuel pressure vs. BSFC to help choose the proper flow rate injector.

Another tip for idle stability is to keep the cells around the idle point at the same or very near the same value as the idle cell. This will stop large changes in injector pulse width during interpolation. Additionally, in some instances if too much air temperature correction enleanment is programmed, idle instability will result.

Once the idle is stabilized in park, the issue of now tranisitioning to a drive gear needs to be addressed. If the vehicle is using a torque converter from a stock 700 or 200 overdrive, you will find that the converter is very tight which causes a severe load dump on the engine and creates havoc with your program. If any sort of aftermarket camshaft is installed, the problem becomes accentuated. Since our ECU lacks the anticipation circuits of an OE unit (the stock GM ECU monitors gear position and commands the IAC out to compensate for a load dump from park to a drive gear), and needs to see an idle speed degredation to invoke the stall saver function, a delicate balance of fuel, idle speed and stall saver need to be created. First start by rocking the car from park to reverse and watching the fuel matrix to see the cell that it chooses. Often by richening the cell that the load invokes will cure a good portion of the stalling when placed in gear. Next, you will need to access the stall saver screen. By watching the cursor identify how many counts of the IAC is being issued to compensate for that degree of idle degredation. The stall saver function is coded to hold the commanded amount of IAC steps for 3 seconds after acknowledgement of the speed degradation. Raise the number of counts in the affected area to cure the problem.

Voltage drop due to underdrive pulleys - Another common area that affects idle quality and can even induce stalling and surging is the lack of voltage that is available at idle with certain underdrive pulley ratios. This condition usually shows its self during an extended idle condition such as would be caused by a long traffic light. It also is very electrical load dependent usually being induced at night with the lights on or by a large power hungry stereo. The only cure for it is either to idle up the engine which is not the accceptable method or to switch to a pulley ratio that will maintain at least 12.2 volts during an extended idle with the electrical load on. If a customer complains about a stalling problem that you may not have been able to duplicate, then ask them if it only happens with an electrical load applied.

Using fuel pressure as a tuning aid - The use of fuel pressure as a tuning aid is a very viable one that needs to be addresssed. The prescribed method for determining a fuel pressure starting point is to work from a 43.5 lb setting, which will deliver the rated capacity of the injector. Using the following charts, the actual flow of the injector can be determined with either a higher or lower setting. *(See Fig. 5.7 at bottom of this page.)* It is common to raise the fuel pressure to accommo-

INJECTOR FLOW IN LBS/HR vs. FUEL PRESSURE

INJECTOR SIZE @ 3 BAR	FUEL PRESSURE				
	40	45	50	55	60
19lb/hr	18.21	19.32	20.37	21.36	22.31
22lb/hr	21.09	22.37	23.58	24.73	25.83
24lb/hr	23.01	24.41	25.73	26.98	28.18
30lb/hr	28.76	30.51	32.16	33.73	35.23
36lb/hr	34.52	36.61	38.59	40.47	42.27
55lb/hr	52.74	55.94	58.96	61.84	64.59
83lb/hr	79.59	84.41	88.98	93.32	97.47

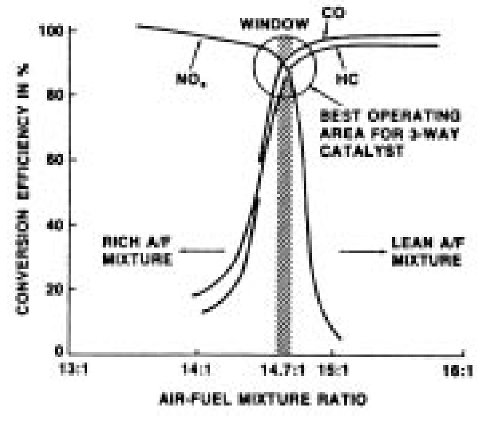
***Fig 5.7** – This chart establishes the use of fuel pressure as a tuning aid and also shows how increased fuel pressure fills the gaps in injector sizing that are available.*

date large fuel demands with a smaller injector. A maximum of 50-55 lbs of pressure should be used with pressure rises above that causing a increase in injector rise time and a increased current draw on the ECU. On forced induction engines you need to maintain one lb of fuel pressure increase for each pound of boost to maintain the proper relationship of fuel pressure to manifold pressure, which on high boost applications will place the fuel pressure over the above mentioned threshold. Since most high horsepower forced induction engines usually require the use of a low impedance injector, the available current to open the injector is greater, and has less an effect on the rise time.

One issue that needs to be addressed is the use of an FMU (fuel management unit) to drastically raise fuel pressure under boost. Usually the domain of supercharger manufacturers who are trying to sell their kits under the priviso of not having to modify the fuel system for their use, are a very poor method to fuel an engine. Based upon a rate of gain (the pressure increase proportional to the amount of boost. It is common to have these units raise fuel presssure 10 lbs for every pound of boost yeilding a total fuel pressure of 145 lbs), and skew injector rise timing to such an extent that at high RPM lean out occurs. The proper way, the prescribed way, especially if an ACCEL ECU is being used, is to size the injector properly and just maintain the boost/fuel pressure relationship.

It is common to over fuel an engine by the use of a large injector in both N/A and forced induction applications. The relationship of BSFC and injector sizing is often ignored and too large an injector is installed. Due to the close proximity of the injector to the intake valve (usually 100 mm in a OE manifold), it is very easy to wash a cylinder down with too rich an air fuel ratio in comparison to a carburetor. This not only causes the dilution of the engine oil, but rapid ring wear and inturn poor cylinder sealing. For this reason, a engine that you are going to calibrate should have the oil changed before your calibration procedure begins to eliminate any residual hydrocarbons from affecting the programmed air fuel ratio.

Tuning for emmissions - Trying to get an engine to pass an emissions test sometimes requires a slightly different technique than tuning with no regard to compliance. An engine equipped with a performance aftermarket cam historically will need to have less timing at idle to reduce hydrocarbon emissions. By running as close to stoich as possible, and raising the idle speed along with maintaining closed loop operation at idle should allow the engine to pass. A radical engine with a large cam and crevice volume in the bores will be hard to get through HC testing if you cannot achieve catalytic converter light off.



Converter Efficency vs. AFR

Fig. 5.8 *– The catalytic converter is the most efficient at an engine out air fuel ratio of 14.7:1 as shown above. Mixtures above or below stoichometric degrade the conversion efficiency of the catalyst.*

Throttle dampening - The throttle follower function tracks the IAC position in regard to throttle angle and is used as a dash pot function to control stalling on rapid throttle closings. A common occurance with enthusiasts is for them to free rev their engines. If the throttle follower function is not correct the idle speed will stay high when the throttle is released and will not respond like a carburetor will. To alleviate this, free rev the engine and then release the throttle while accessing the throttle follower screen in the idle speed menu. Note the value the cursor travels to when the idle speed remains high after release of the throttle and lower the amount of bypass air at that point. This function is also used on stick shift cars to eliminate stalling on deacceleration while the clutch is still engaged.

Warm up enrichment and air temperature correction - These functions cannot only be used as trim characteristics to the base fuel map but also as a tuning aid. If you are under the impression that the engine wants to be richer in all areas of the fuel map, and just want to try it out, simply access the warm up enrichment screen and add fuel as a percentage via this table. Conversely, if you would like to lean the whole program out temporarily, then access the air charge correction menu and lean the base fuel map out for test purposes by invoking this enleanment.

Ignition timing requirements - Currently most of our ECU's are equipped with a very conservative timing program as a starting point for your tuning. It is important to recognize that todays quick burn combustion chambers do not require as much spark advance as the older cylinder head designs do. Today's chamber designs usually make the most power with a maximum of 36° spark advance in lieu of the older customary 42°. Piston design also has a major affect on flame speed and in turn the amount of timing needed. The key here is to use your skills to optimize the timing curve and not input just one number for the complete matrix.

TPS Acceleration enrichment - Used to supply fuel during very abrupt throttle changes that create large drop offs in manifold vacuum. The TPS enrichment is considered an asyncronous pulse, and works like an accelerator pump. It is an independent injector pulse that is injected between the syncronous pulses. A syncronous pulse is defined as a continuous pulse repeated at the same rate. Access this menu and while stabbing the throttle at different rates, follow the cursor and add or subtract fuel until the throttle response is crisp.

Working in conjunction with the TPS fueling, the MAP based enrichment will work like a power valve in a carburetor. Once the base fuel map is close to being correct, the MAP Enrichment can be used to add crispness to the engine under load and as the throttle is crowded. If working in the fuel matrix leaves undesired results, such as the need to over fuel a cell at a certain load input, utilize the enrichment function of the MAP sensor. This functions will help deliver excellent tip in load characteristics such as the elimination of a flat spot that occurs as the vehicle starts to climb a hill while crusing down the highway. For applications that are being used for towing, this function is critical to prevent lean out under extreme loads while maintaining good fuel economy and emissions while cruising.

Idle surge during warm up - If you experience an idle surge during warm up, it is most commonly due to a lean A/F ratio. Use the warm up enrichment tables to add additional fuel in the coolant temperature range that surging takes place. Keep in mind that the idle spark function does a very good job of controlling this idle roll but is coded not to be invoked until 100° coolant temperature. Most of the idle stability problems during warm up will be exhibited below the 100° range.

No start trouble shooting - The first thing to remember when diagnosing a no start condition is to check over the basics. The ACCEL ECU is extremely reliable and is not prone to failure. Most no starts just after an installation are due to improper connections or incorrect hook ups of the ignition. Before condemning the fuel injection system always do a visual inspection not forgetting to check the fuses for the ECU. A good indicator of everything working is if the ECU can communicate with the lap top. This will establish that there is at least 12 volts getting to the ECU. Access the view screen and scan all of the sensor data for proper inputs. A common error during installation is the connection from the MWH switched ignition source being connected to a voltage supply that is available with the key on but disappears during crank. When the ignition is turned on you should hear the fuel pump prime for 2 seconds, and when going into crank, be able to read RPM data on the view screen. Another possible problem area is the connection of the MWH ground at some place other than the battery negative connection. By attaching this ground to another part of the vehicle you are referencing a different ground plane and in some instances may cause a problem.

It is important to keep in mind that on a EFI system if there is no spark there usually is no injector command. The only time that this is not applicable is if the ignition circuit fails after the RPM reference signal generation (ie. a faulty coil secondary windings). If the ECU does not receive a primary interupt then it is not cognizant that the engine is cranking and will not issue any injector commands.

If you have fuel but no spark, then the primary signal is being recognized by the ECU and you most likely have a problem with the secondary side of the ignition.

Spark but no fuel pulse scenerios need to be addressed by accessing the view screen and checking if the ECU is recognizing the RPM reference signal. If the ECU is registering a RPM reference signal, then also check that the TPS function is not triggering clear flood mode and that the MAP sensor values are correct. Also make sure to check both bulk head connectors at the ECU for a tight fit and the individual wires coming out of the connector for proper contact.

Dual fuel pumps - Due to the lack of access to some intank fuel pumps (third generaton GM F bodies), it is common to leave the stock pump in the tank and supplement its volume with the ACCEL pump. In most instances, this is fine as long as the intank pump is working properly and the engine's fuel consumption does not exceed the intank pumps ability to feed the ACCEL pump. Whenever employing multiple fuel pumps, always make sure each pump is fed from its own voltage source with a relay for each. Electric fuel pump volume out put ramps off dramatically with decreases in supply voltage (reference pump output vs. voltage chart in the fuel dynamics section of this manual).

Buick GN timing procedure - Due to the differences between this ignition system, in comparison to a Chevrolet or Ford, the timing verification procedue is unique. Our spark/fuel ECU that is identified for a GN (74025) is only compatible with the stock coil packs. The cam sensor must be set to the factory position of 25° ATDC, and as mentioned earlier, a Buick knock sensor and module needs to be sourced but can use our 74173 harness kit. Since there is no mechanical way to adjust the timing on this engine, the routine of using a map of all the same values does not apply. For these engines use the following procedure:

1) Use an adjustable timing light and the CALMAP software to verify timing.

2) There will be a difference between the timing read on the harmonic balancer vs. the CALMAP. The timing read in the ignition map will be the actual timing and what is read on the balancer will be twice what the actual timing is plus an error of 12°. For example: 52° on the balancer would actually be 52-12 = 40/2 = 20° actual timing.

3) This variation in the reading is due to the nature of this ignition system which incorporates a waste spark firing.

Buick GN coil packs - Whenever tuning a Turbo Buick always check the coil packs with an ohm meter for resistance. It is very common for these units to fail when the engine is equipped with faulty ignition wires. The resistance should be below 13 KOHMS and a new coil will read 11.7 KOHMS. Degraded coils will cause driveabilty problems of bucking and backfiring under boost.

CALMAP 6.32 UPDATE

Below are the Single Key strokes which enable you to get from one CALMAP screen to the next. By entering one of these letters the corresponding CALMAP screen will appear. This eliminates the cumbersome keystrokes it currently takes to get from one screen to the next.

Letter	Corresponding Screen
A	Acceleration Fuel (TPS)
B	Base Fuel Map
C	Cranking Fuel
F	Throttle Follower
I	Idle Speed
L	Data Log
M	Acceleration Fuel (MAP)
N	NOS Settings
R	Air Temperature Correction
S	ECU Configuration
T	Timing Map
U	Utilities
V	View Sensor Inputs
W	Warm Up Enrichment

The following keystrokes are useful when you’re in the Base Fuel map screen.

Letter	Corresponding Screen
P	Pulse Width (MS)
D	Duty Cycle (%)

Fig. 5.9

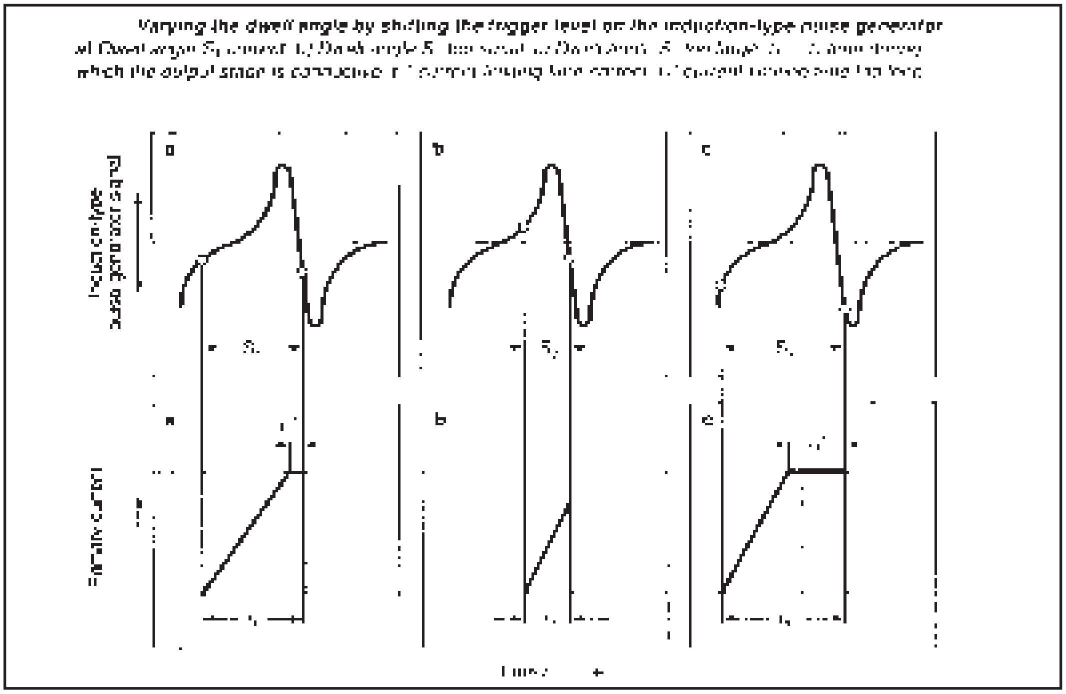


***Fig. 5.10** – When hooking up the output wires of an IPU, if the polarity is incorrect the resultant response will be a retarding of the ignition timing of approximately 40°. The difference in polarity causes a shift in the zero crossing of the saw tooth wave, which effectively retards the timing.*

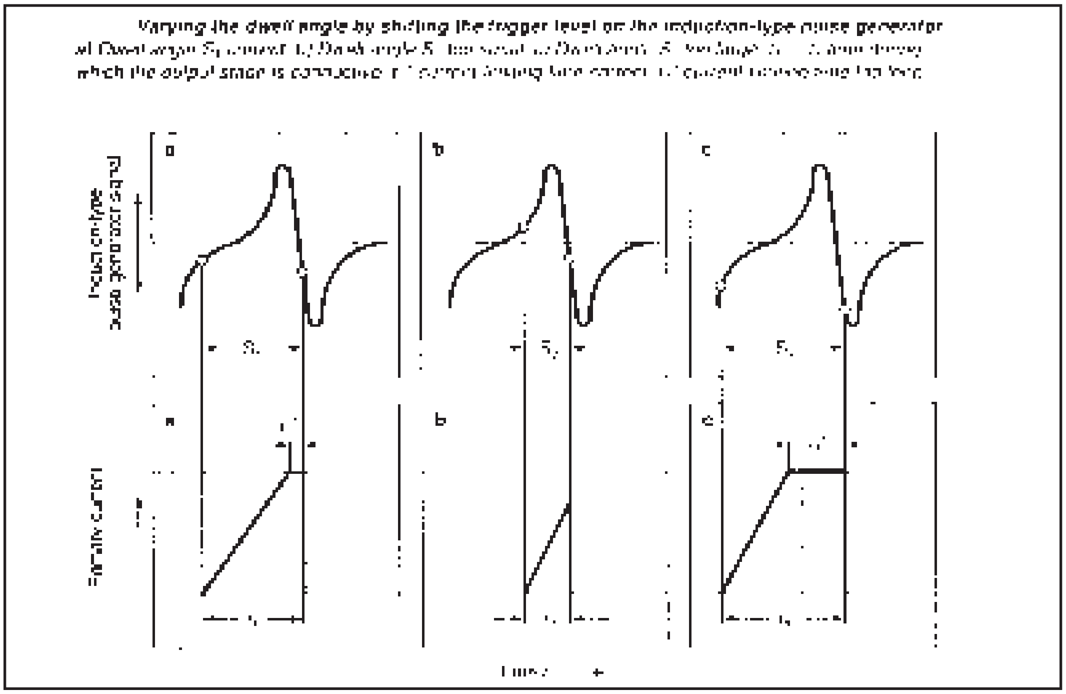


Fig. 49 – *When hooking up the output wires of an IPU, if the polarity is incorrect the resultant response will be a retarding of the ignition timing of approximately 40°. The difference in polarity causes a shift in the zero crossing of the saw tooth wave, which effectively retards the timing.*

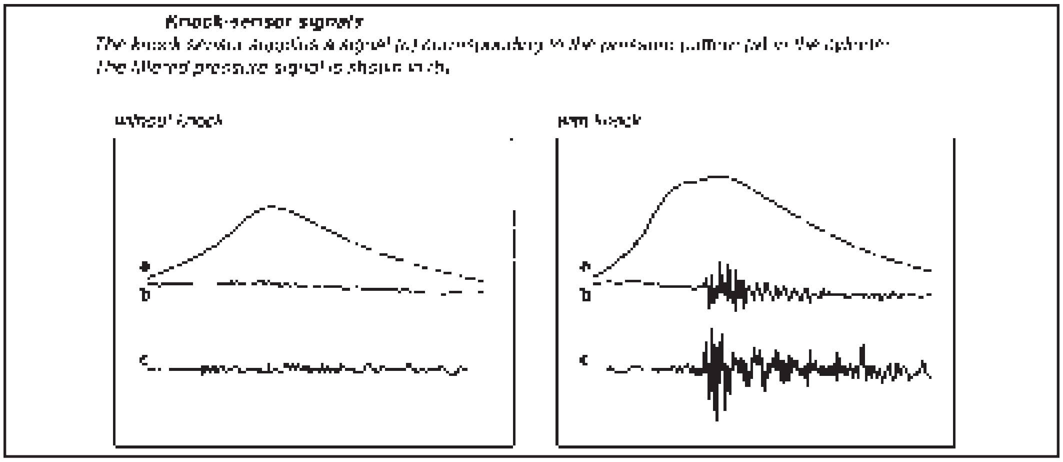


Fig. 54 – *Abnormal combustion creates an uncontrolled release of the end gases energy in the cylinder as represented by a) in the above graphs. The corresponding harmonic that is created by the colliding flame fronts cause oscillations of the piston, rings and bearings and is detected by the knock sensor and is represented by c) in the graph.*

TEMPERATURE TO RESISTANCE VALUES FOR ACCEL COOLANT SENSORS

(Approximate)

DEGREE F	DEGREE C	OHMS
210	100	185
160	70	450
100	38	1,800
70	20	3,400
40	-4	7,500
20	-7	13,500
0	-18	25,000
-40	-40	100,700

Fig. 77

CALMAP 6.32 UPDATE

Below are the Single Key strokes which enable you to get from one CALMAP screen to the next. By entering one of these letters the corresponding CALMAP screen will appear. This eliminates the cumbersome keystrokes it currently takes to get from one screen to the next.

Letter	Corresponding Screen
A	Acceleration Fuel (TPS)
B	Base Fuel Map
C	Cranking Fuel
F	Throttle Follower
I	Idle Speed
L	Data Log
M	Acceleration Fuel (MAP)
N	NOS Settings
R	Air Temperature Correction
S	ECU Configuration
T	Timing Map
U	Utilities
V	View Sensor Inputs
W	Warm Up Enrichment

The following keystrokes are useful when you're in the Base Fuel map screen.

Letter	Corresponding Screen
P	Pulse Width (MS)
D	Duty Cycle (%)

Fig. 97

SIMULTANEOUS DOUBLE FIRE

ALL INJECTORS ARE FIRED ONCE EVERY CRANKSHAFT REVOLUTION.

SEQUENTIAL

INJECTORS ARE FIRED ONE AT A TIME IN PRESCRIBED ORDER.

DIFFERENCES/BENEFITS OF EACH

SIMULTANEOUS DOUBLE FIRE

- LESS PARTS TO FAIL
  SEQUENTIAL HAS DRIVER/INJECTOR
- LESS POWER DISSIPATION
- LESS COST
- LESS COMPONENTS/NEE CAM POSITION SENSOR FOR SEQ.
- UNIVERSAL/EASE OF INSTALLATION

SEQUENTIAL

- TIMED INJECTION CAN MAKE MORE POWER
- SLIGHTLY BETTER FOR EMISSIONS

Fig. 95