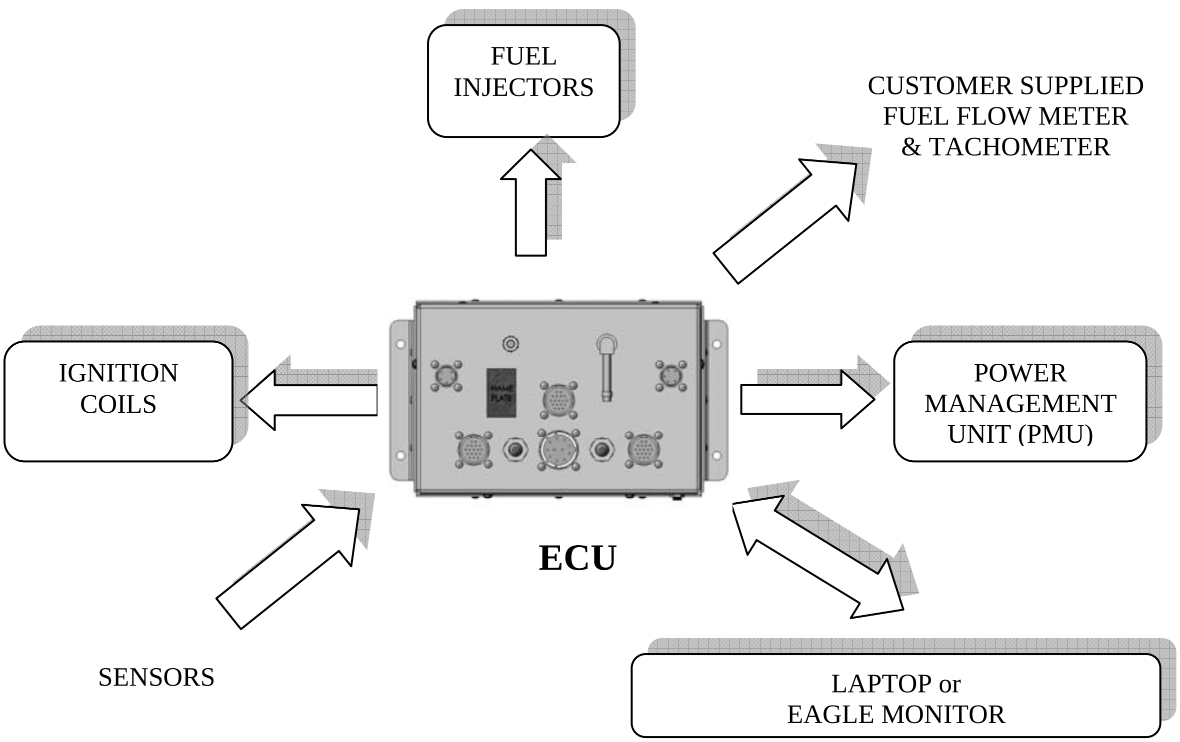

EAGLE SYSTEM THEORY OF OPERATION

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Reference Documents

- 20-001, Eagle Owner's Manual
- 20-020, Eagle Installation Manual
- 20-030, Eagle Calibration Manual
- 20-040, Eagle Post Installation Trouble Shooting Manual
- 20-050, Eagle Oxygen Sensor Manual
- 20-060, Eagle Computer Communication Link Procedure

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EAGLE SYSTEM
THEORY OF OPERATION

1. Purpose

The purpose of this document is to describe how the Eagle EMS (Electronic Engine Management System) functions and how the components are related.

2. Scope

This document includes:

- An overview of how the system and individual parts operate
- An overview of the software
- Descriptions of the system's physical components
- A glossary of terms used in the document
- An appendix discussing the following as they relate to the Eagle EMS: Air/fuel relationships, using an air fuel ratio meter, and engine operation

The Theory of Operation document has a large number of terms and abbreviations related specifically to the Eagle EMS. As you read through the document, it will be helpful to refer to Section 7 (Physical Components) and Section 8 (Glossary of Terms) if you encounter an unfamiliar term or abbreviation.

3. Design Overview

3.1. **General Description.** The Eagle is an electronically controlled fuel injection and ignition system. It is designed for general aviation piston aircraft; specifically, aircraft with Lycoming style engines. The Eagle is composed of two separate redundant systems, operating independently of each other, called LEFT and RIGHT side. Each system has its own computer (Electronic Control Unit –ECU), ignition coils, spark plug wires, sensors, system status lights, and wiring harness. Both systems share the throttle body, Power Management Unit (PMU), key switch, Eagle Battery, distribution block, and electronic fuel injectors.

3.2. **System Software.** The Eagle is an open-loop, software-configured system. The system relies on measured values, conversion tables, and algorithms for different flight and engine conditions that define the correct pulse width for the fuel injectors and the correct ignition timing.

3.3. **Operator Interaction.** The aircraft operator interacts with the Eagle System by operating the aircraft, collecting data, and making changes to the calibration file.

3.3.1. The pilot controls engine performance by simply opening and closing the throttle to the desired power. The pilot monitors the annunciator lights like all other aircraft panel lights, uses the key switch to check that the LEFT and RIGHT systems are working, and switches the master buss switch off and on to ensure that the Eagle Battery can run the system. As an additional feature of the Eagle kit, a lean pot is included to lean the fuel flow out beyond the normal calibration settings.

3.3.2. System information, including errors, can be acquired by connecting a laptop computer or the Eagle Monitor Companion. Engine run data can be recorded and an error history analysis can be performed.

3.3.3. Changes to the Eagle System calibration file can be performed with a laptop or with the Eagle Monitor Companion. These changes are normally done if fine tuning of the default calibration file is desired.

3.4. **System Electrical Power.** The Eagle system can be configured for either a 12 or 24 volt electrical system. The Eagle system uses the "Eagle Battery" as its primary power source. This battery is charged by the Aircraft Buss by means of a Power Management Unit (PMU). The PMU constantly monitors the state of the Eagle Battery. Should the aircraft have a complete electrical system failure, the Eagle battery will continue to operate the system until the Eagle battery voltage drops to 8 volts. The Eagle draws approximately 2 amps per hour at maximum RPM. The lower the RPM, the lower the current draw.

3.5. **Fuel System.**

3.5.1. **General Description.** The fuel injection system has one electronic fuel injector per cylinder (multiport fuel injection). Each injector sprays once per combustion cycle (sequential fuel injection). The amount of fuel sprayed is determined by the following: engine displacement, RPM, the density of the air entering the engine, and the desired A/F. This type of system is called a “Speed Density” system.

3.5.2. **Compact and Simple.** The whole fuel system is very compact and simple because it has a Lycoming fuel injected engine driven pump, no fuel return lines, and no pressure regulator.

3.5.3. **Special Aircraft Fuel Injectors.** The fuel injectors are specifically designed to handle the heat, reliability, and performance requirements of an air-cooled aircraft engine.

3.6. **Ignition System.**

3.6.1. **General Description.** The ignition system is an inductive wasted spark system. The ignition coil and electronic circuit are designed to deliver high energy with a long burn time which is desirable for a low-RPM aircraft engine. Cylinders 1&2, and 3&4, are fired at the same time. This is possible because one of the cylinders is on the compression stroke while the other cylinder is on the exhaust stroke (wasted spark).

3.6.2. **Shielded.** For safety, the ignition wires and coil are shielded to suppress ignition noise, preventing interference with the aircraft’s avionics.

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4. System Operation

4.1. **System Check.** The ignition, fuel injection, and Eagle battery can be monitored by observing the annunciator lights and performing simple checks at startup. Specific checks can be found in the Eagle Owners Manual and in the Eagle Post Installation Troubleshooting Manual. One check is verifying that the LEFT and RIGHT systems work by looking at the annunciator panel lights and moving the key switch from both to left and right to ensure that both the LEFT and RIGHT systems are functioning normally. Another simple check is to turn off the master buss and verify that Eagle battery allows the engine to keep running.

4.2. **Review of System Errors.** Errors that are actively occurring can be found by observing the annunciator lights and positioning the key switch in the correct position. The specifics of deciphering the lights are documented in the Eagle Owner's Manual and in the Eagle Post Installation Troubleshooting Manual. All errors, including intermittent and historical, can be viewed by connecting a laptop computer or the Eagle Monitor to the ECU comm ports.

4.3. **Fuel Injection System.** Both the LEFT and RIGHT computers run the fuel injection management software. However, only one side controls the fuel injectors at any one time. The LEFT side of the ECU controls the injectors when the key switch is in the both or left position. The RIGHT side will only control the fuel injectors when the key switch is in the right position or if the left side gets a significant error, e.g., RPM (speed sensor), MAP, FP, and BAP.

4.4. **Lean Pot.** The Eagle System automatically compensates for altitude and delivers an A/F ratio that is programmed in the calibration file. The Eagle System includes a lean pot that can be used for additional fuel leaning while the engine is running. The lean pot can also be used for troubleshooting and as an aid for finding best power and various other A/F ratios. Additional information about A/F ratios and engine performance is in the Appendix.

4.5. **Ignition System.** Within the ECU control box there are LEFT and RIGHT computer systems. Each side of the ECU controls one spark plug per cylinder. Therefore, in a 4-cylinder engine, the LEFT and RIGHT systems each control four spark plugs.

4.6. **Additional Features.** There are additional features that allow for smooth engine operation.

4.6.1. **Fuel Flow (FF) Cooling of CHT.** The A/F ratio can be programmed for all engine running conditions via the calibration file. Outside of the user-adjustable settings are features that allow fuel enrichment for CHT, if the cylinder temperature rises over 400°F.

4.6.2. **Engine Over Speed.** Within the calibration settings is a user-adjustable "Anti-Over Speed." When this maximum programmed RPM is obtained, the fuel injectors and ignition cycle between completely off and then back on, thus limiting peak RPM.

4.7. **Key Switch Position and Significant System Errors.**

4.7.1. **Key Switch, Both; Errors, None.** The LEFT and RIGHT computers, ignition, and fuel injectors run as noted in the preceding paragraphs.

4.7.2. **Key Switch, Left or Right; Errors, None**. Both computers are running, but control of ignition and injectors is disabled on the opposite side from the position where the key is placed.

4.7.3. **Key Switch, Both; Errors, Left.** LEFT computer and ignition keep running if physically possible, but control of injectors is disabled. RIGHT system automatically takes over control of injectors.

4.7.4. **Key Switch, Both; Errors; Right.** RIGHT computer and ignition keep running if physically possible and fuel injectors remain under the control of the LEFT system.

4.8. **Inputs, Computation, and Outputs.** The Eagle system uses inputs from the sensors listed below, combined with calculations to determine how long to turn the fuel injectors on and when to start ignition.

4.8.1. **Inputs to ECUs**

CHT - Cylinder Head Temp
IAT - Inlet Air Temp
MAP - Manifold Pressure
BAP - Barometric Pressure
FP - Fuel Pressure
RPM – Speed Sensor
Voltage
Key Switch position; Both, L, R, Off, Start
Lean Pot - Only connected to the LEFT ECU

4.8.2. **Outputs from ECUs**

Ignition Coil Signal
Fuel Injector Signal
Annunciator Warning Lights

4.8.3. **Extras** (Not necessary for running)

Communication Ports - One for each ECU
RPM Signal Output to Customer Meter
FF – Fuel Flow Output Signal to Customer Meter
A/F Ratio Meter Output. Only the LEFT ECU reads and displays this information.

4.9. **Communication with Eagle System.** The aircraft operator can interact and communicate with the Eagle System via the comm ports by connecting a laptop computer or the Eagle Monitor Companion. The operator can then do the following:

Observe and record engine performance data
Time the speed sensors

Check current and historical errors
Change calibration settings and tables

5. Fuel Injection System

5.1. **Delivering the Desired A/F.** The speed density system is based upon delivering a specific air - fuel ratio (A/F). The customer-desired ratio is entered into the calibration file in the ECU computer. The computer reads all the previously listed inputs along with the information in the calibration file to determine the RPM (speed of the engine), the density (manifold pressure and inlet temperature) of the air entering the engine, and the altitude (barometric pressure). Once the air flow is known, the appropriate amount of fuel is added to the engine, thus achieving the desired A/F.

5.2. **Timing of Fuel Injectors.** The fuel injection system, as described and explained earlier, is a sequential multiport speed density system. There is one injector in each cylinder head. When the engine is running, each fuel injector will spray one time during a combustion cycle. This occurs at 30° ATDC on the intake stroke or on the power stroke. When the engine is being cranked over during starting, each fuel injector will spray two times during a combustion cycle. These occur at 30° ATDC on the intake stroke and on the power stroke.

5.3. **Control of Air Flow through the Engine.** The air flow, and thus engine power, are controlled by the pilot operating the throttle. Idle speed is controlled by a screw located on the throttle body like most other fuel control devices, i.e., a carburetor or an RSA mechanical fuel injection system. The idle speed is controlled only by the mechanic setting the screw, not by the software.

5.4. **Lean Pot.** The lean pot allows the aircraft operator to lean beyond the desired A/F in the calibration file. The resolution of the lean pot can be calibrated along with what RPM range it functions at.

5.5. **Built-In Compensations.** The Eagle program has built-in compensations for numerous variables such as: battery voltage, fuel pressure, air density, cylinder head temp, and altitude. The compensations occur automatically and are not part of the user-adjustable calibration file.

5.6. **Fuel Calibration File Settings.** The customer fills out an installation questionnaire when purchasing the Eagle system. Precision Airmotive then uses this information to program the calibration file. With this file, the engine should start and run adequately. If so desired, the customer can then fine-tune the adjustable settings in the calibration file, including volumetric efficiency, desired A/F, hot/cold start enrichment, and acceleration/deceleration.

5.6.1. Prior to setting up or changing the calibration file, the programmer must fully understand the aircraft/engine on which the system will be used, e.g., engine displacement, compression ratio, exhaust system design, air box, HP, max allowable RPM, and the various manufacturer warranty requirements (i.e., engine, propeller, and governor).

5.6.2. The aircraft/engine information is then used to determine the adjustments to the calibration file. The file is based on five groups of adjustments which are shown next. The group "adv" is only for ignition timing, which will be discussed later.

Adjustment Group	Definition
vet	Table for Engine Volumetric Efficiency.
afr	Table for defining desired Air –Fuel Ratio (A/F)
adv	Table for ignition timing advance
cal	Defines a series of variables that can be changed by the customer.
cfg	Defines a series of variables that can be changed by the customer.

5.7. **Engine Running Conditions.** Below is a list of events that an engine goes through during normal operation. These events are not necessarily in order. A basic understanding of these events and how they are related to the adjustment groups used in the calibration file is required in order to make the correct changes.

Pre-start and engine shut down
Cold or hot starting
Engine warm up
Open and close throttle response
Taxiing
Climbing, Descending, and Windmilling
Cruise
Full power
Touch and go

5.8. **Adjusting the Calibration File.** The calibration manual discusses the definition of each adjustment group and what the values can be changed to. The programmer must have a thorough understanding of the calibration manual in order to make the correct changes. After the programmer makes changes to the calibration file, the engine test results are reviewed and then it is determined whether additional adjustments are needed. Each change may involve one or all five groups of variables.

5.8.1. **Calibration Groups "cal" and "cfg."** The first step is to review all the items in the "cal" and "cfg" adjustment groups and ensure that the variables meet the engine and owner requirements. They should not be adjusted until they are completely understood. These two groups control numerous items e.g. acceleration/deceleration, volume of each engine cylinder, engine RPM limit, and resolution of the mixture control knob.

5.8.2. **Calibration Groups "vet" and "afr."** These two groups work together. The vet table is the volumetric efficiency of the engine at specific RPMs, MAPs, and BAPs. The afr table is the desired A/F for specific MAP and BAP readings.

5.8.2.1. The first step is to determine the volumetric efficiency at various engine running conditions. This is done by setting every entry of the afr table to the desired 12.5. The engine is then run while monitoring the actual A/F. The vet table values are then adjusted up or down until the actual A/F equals the desired 12.5. This completes the adjustments to the volumetric efficiency table.

5.8.2.1.1. The preferred method of determining the actual A/F is using a wide band O_2 meter/sensor. The O_2 meter/sensor often has an additional output that can be plugged into the LEFT side of the ECU. The ECU will then display the actual A/F (OXY) on the data output at the same time as other variables.

5.8.2.1.2. Another method of determining the actual A/F is doing mixture control lean out rises; and recording the EGT, CHT, MAP, and RPM; and understanding the relationship between them.

5.9. **Not Recommended and Non-Adjustable Calibration Settings.** There are settings that should not be adjusted or are non-adjustable by the Eagle System Owner.

5.9.1. The variables that should not be adjusted are specifically pointed out in the calibration manual. Under certain circumstances a Precision Airmotive representative may direct the owner to alter these settings. Only then should they be changed.

5.9.2. The variables that are non-adjustable are in the core program and not in the calibration file. One such variable is fuel flow increased above the afr table value when the CHT rises above 400°F. This adjustment provides for additional cylinder cooling.

6. Ignition System

The inductive wasted spark ignition system uses a lot of the same inputs as the fuel control: MAP, BAP, RPM, CHT, and voltage. Most of the features of the ignition system have already been discussed in the "Design Overview" and "System Operation" sections.

6.1. Ignition Performance Profile.

6.1.1. **Dwell.** The ignition coil dwell is an adjustment-not-recommended value in the adjustment group "cal." The optimum dwell of the coil supplied with the Eagle Kit has already been determined and entered at Precision Airmotive.

CAUTION: It is VERY important that the timing of the engine matches the engine and propeller manufacturer's requirements during cruise and higher engine power. Propeller/engine harmonics, detonation, and pre-ignition cannot always be felt or heard.

6.1.2. **Default Factory Timing.** The Eagle System is delivered with default settings in the timing advance table. This table allows the engine to operate properly.

6.1.3. **Timing Advance Table.** The engine running ignition timing can be adjusted by altering the adjustment group "adv" in the calibration file. The timing can be adjusted for each of the following variables: RPM, MAP, CHT, and BAP. The final timing is the total amount from all four variables. The timing can vary from 0° BTDC to a max fixed value found in the calibration manual.

6.1.4. **Timing While Engine Is Being Started.** In accordance with the installation manual, the speed sensors are installed with cylinder #1 at TDC. When the engine is being cranked over (prior to running), the ECU computers adjust the timing for optimum smooth engine starting. These settings cannot be altered.

7. Physical Components

The major components of the Eagle EMS are listed below**.**

7.1. **Annunciator Panel.** The Annunciator Panel display provides system status information to the pilot. When the system is working correctly, the LEFT and RIGHT indicator lights will not blink or come on during engine operation. These lights may blink during start up. The CHG (charge) light should blink when the EMS battery is taking charge from the aircraft buss. If the LEFT and RIGHT indicator lights blink, the blink patterns can be decoded by referring to the EMS Installation Manual.

7.2. **Barometric Absolute Pressure Sensor.** There is one BAP sensor mounted on each side of the ECU. The sensors are vented to atmospheric pressure via a fitting on the ECU housing. The ECU displays on the laptop the pressure in inches of mercury absolute ("Hg).

7.3. **Boost Pump.** Also called a backup pump, and usually electrically driven. It generates fuel pressure when the engine's mechanical fuel pump is not operating. The mechanical pump does not build fuel pressure unless the engine is running and the system is primed. The boost pump is a customer-supplied component.

7.4. **Cylinder Head Temp Sensor.** There is one CHT sensor for each side of the ECU. The thermistor sensors are located in the heads of two different cylinders. The ECU displays the temp in °F.

7.5. **Eagle Battery.** Primary power source for the ECU, charged through the PMU from the aircraft buss. Battery voltage is shown on the laptop screen in the OPS data as volts. The battery is a customer-supplied component.

7.6. **Electronic Control Unit.** "ECU." The ECU case contains two computers called LEFT and RIGHT side. Both computers read all their sensors, run the ignition and fuel injectors, and communicate with the pilot.

7.7. **Fuel Distribution Block.** The fuel distribution block directs fuel from the mechanical engine pump and/or the electrical boost pump to the four individual injectors. The block also houses a fuel filter and two fuel pressure sensors. The pressure sensor output is shown on the laptop screen in the OPS data as FPSIa.

7.8. **Fuel Injectors.** There is one injector per cylinder.

7.9. **Fuel Pressure Sensors.** There is one FP sensor for each side of the ECU. The sensors are located in the fuel distribution block. The ECU displays the pressure in PSIA (pounds per square inch, absolute.)

7.10. **Inlet Air Temp Sensor.** There is one IAT sensor for each side of the ECU. The thermistor type sensors are located in the throttle body. The ECU displays the temp in °F.

7.11. **Lean Pot.** Leaning Potentiometer. The knob is mounted on the dash and adjustable by the pilot, allowing the system to run leaner than the desired A/F in the calibration file.

7.12. **Left and Right Side Ignition Coils.** There are two spark plugs per cylinder. The coils are a wasted spark style, firing two plugs at a time.

7.13. **Manifold Absolute Pressure Sensor.** There is one MAP sensor for each side of the ECU. There is a hose that connects the MAP sensor to the throttle body ports. The ECU displays the MAP reading in inches of mercury absolute ("Hg).

7.14. **Power Management Unit.** The PMU's primary function is to provide electrical power to the Eagle system from either the Eagle Battery or from the aircraft buss. The secondary function is to allow the main buss to charge the Eagle battery when each of the following occur; the main buss breaker is on, the key switch is in the left, right, or both position, and the main buss is higher than the Eagle battery by at least 0.5 volts.

7.15. **Speed Sensors**. There is one speed sensor for each side of the ECU. The sensors are located where the magnetos would have been installed, and they allow the computer to determine the engine speed RPM and timing.

7.16. **Throttle Body.** Controls the flow of air to the engine. The idle speed adjustment, two IAT sensors, and two MAP hoses are installed in the throttle body.

8. Glossary of Terms

A/F - Air Fuel Ratio. Weight of air divided by weight of fuel being consumed.
Absolute Pressure - Is zero-referenced against a perfect vacuum, so it is equal to gauge pressure plus atmospheric pressure.
AFR – Air Fuel Ratio. Weight of air divided by weight of fuel being consumed. The Eagle System uses this term for desired AFR, not actual.
ATDC – After Top Dead Center. Occurs after the piston has travelled past the top of the piston bore.
BAP - Barometric Absolute Pressure. Often this is used to determine pressure or density altitude.
Best Economy - A/F approximately 15.5, which is lean of Peak EGT. Often engine manufacturers do NOT recommend running this lean.
Best Economy Cruise – A/F approximately 14.7 for avgas, which is peak EGT for a normally aspirated engine. Operation in Best Economy Cruise is only recommended when the engine is making less than 75% power.
Best Power – Approximately 12.5 A/F for avgas. FF is enriched or leaned to acquire the lowest MAP value and highest RPM for a specific throttle position.
BTDC - Before Top Dead Center. Occurs before the piston arrives at the top of the piston bore.
CHT - Cylinder Head Temperature**.**

Dwell – Amount of time the ignition coil is being charged prior to firing the spark plugs.

8. Glossary of Terms (continued)

Eagle Monitor– Can be used to display system information or modify the calibration file, similar to using a laptop computer. The Monitor can be used as a handheld device or it can be permanently installed into the instrument panel.

ECU - Electronic Control Unit. The ECU contains the LEFT and RIGHT side computers.

EGT - Exhaust Gas Temperature.

FF – Fuel Flow.

FP - Fuel Pressure. Displayed in pounds per square inch absolute.

IAT - Inlet Air Temperature.

Ignition Timing Advance - As engine RPM increases, the spark must occur sooner and sooner to compensate for the time to burn the fuel. The quicker the burn, the less timing advance needed.

LEFT Side - All the components and the LEFT ECU computer controlling the engine (as viewed from the pilot's seat).

MAP - Manifold Absolute Pressure. The manifold pressure is measured in absolute pressure.

Max Power Cruise – Maximum Power Cruise air fuel ratio is approximately 14:1, which is rich of Peak EGT. This is established by operating the engine 150º F below the peak EGT.

Minimum Controllable Air Speed - The slowest air speed that a plane can maintain in flat level flight.

OPS – Once Per Second. This term refers to displaying the available information from the Eagle System via a laptop computer and how often a new line of data appears on the screen.

PSIA - Pounds per Square Inch Absolute.

PW - Pulse Width. The amount of time the Electrical Signal is applied to the fuel injectors. Pulse width is typically greater than 6000 microseconds and less than 56000 microseconds, or 6 milliseconds to 56 milliseconds.

RIGHT Side - All the components and the RIGHT ECU computer controlling the engine (as viewed from the pilot's seat).

Stoic - Short for Stoichiometric. The A/F that gives complete combustion of air and fuel. For avgas and autogas this is approximately 14.7 A/F.

TDC – Top Dead Center. Occurs when the piston reaches the top of the piston bore.

TFF - Transient Fuel Flow. This is associated with throttle response.

VE - Volumetric Efficiency.

Wasted Spark - A wasted spark ignition system uses one or more ignition coils. Each coil fires two spark plugs at one time during each crank shaft rotation. These plugs are in series with the ignition coil. The two plugs are placed in appropriate cylinders so that when one cylinder is at TDC on the compression stroke, the other cylinder is at TDC on exhaust.

Windmilling - In flight and especially on descent, air moving across the propeller can assist the engine's crank shaft in rotating. In some cases it might be possible that the propeller ends up driving the engine VS the engine driving the propeller. Manifold pressures can drop to a lower value than what would be seen at idle on the ground.

APPENDIX

1. **A/F Relationships**. The A/F values are approximate for avgas and autogas. The ratio may be different depending on the chemical structure of the fuel and variations between engines.

Engine Performance	A/F Approximate	EGT Relationship	RPM and MAP
Best Power	12.5	Approx. 150°F Rich of Peak EGT	Lean to peak RPM and min MAP, throttle & governor fixed
Max Power Cruise	12.5	Same as above	Same as above
Best Economy Cruise (75% power or less)	14.7	Peak EGT	RPM lower & MAP higher than the 12.5 A/F
Best Economy / only used at low power settings. **(Not Recommended)**	15.5	Approx 50°F Lean of Peak EGT	RPM lower & MAP higher than the 12.5 A/F

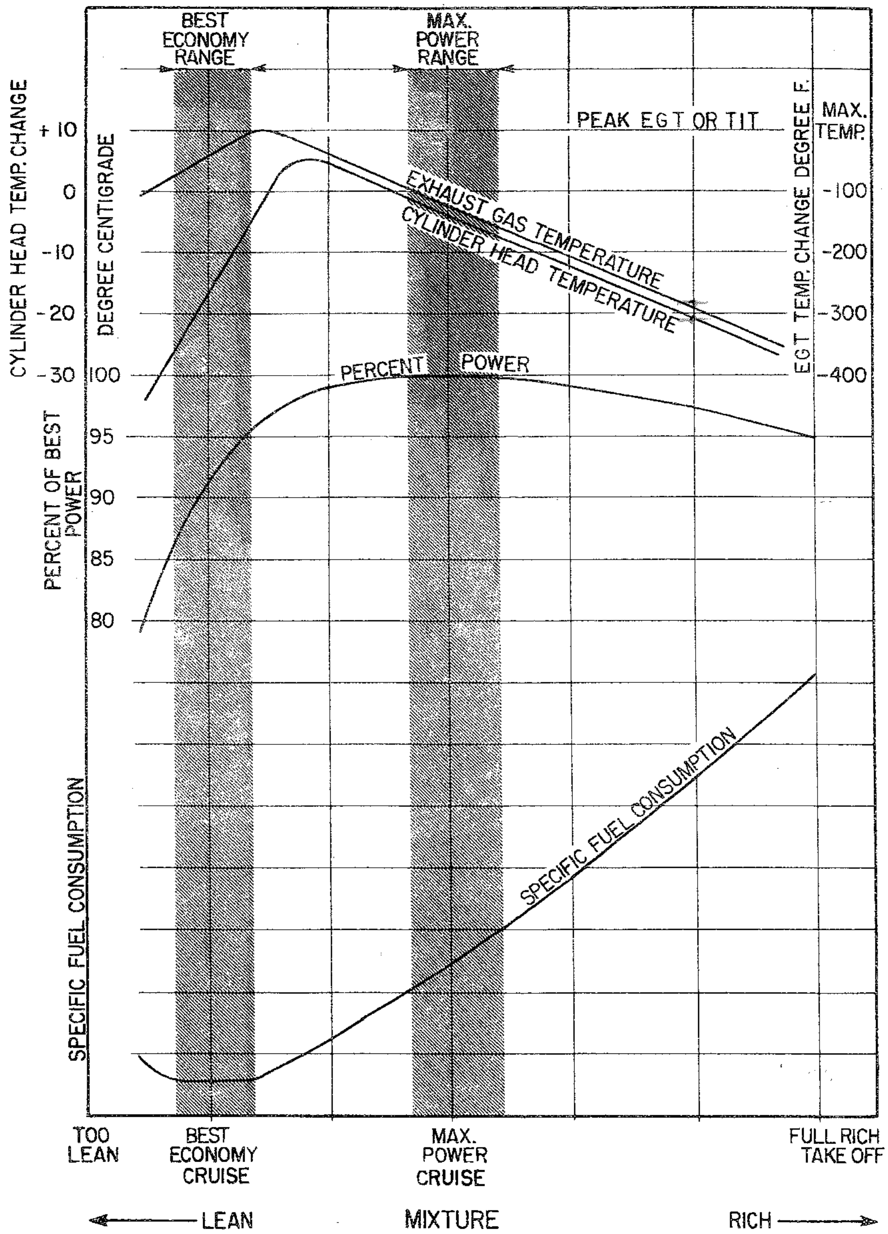
2. **Using an Air-Fuel Ratio Meter**

2.1. **The Benefits.** The various fuel economy and engine power settings can be found quickly and repeatedly by using an air fuel ratio meter as a monitoring tool. The Eagle system doesn't use this A/F for computations but it does synchronizes the A/F with the Eagle data output, allowing for quick analysis and calibration changes. The meter of choice is one that a) has an output that can be hooked up to the Eagle system and b) uses a wide band oxygen sensor. The Eagle Calibration Manual has a list of air fuel ratio meters that will work with the system. You can also go to our website, precisionairmotive.com, and review the Eagle help section for updated information.

2.2. **Calibration and Fouling.** A new A/F meter/sensor usually requires calibration which is performed by the buyer following the instructions in the owner's manual. The oxygen sensors that are used with the A/F meters are not specifically designed for leaded fuel use. The oxygen sensor MUST have electrical power to it prior to starting the engine and anytime the engine is running to keep it from becoming fouled. An oxygen sensor that has been fouled cannot be relied on to provide accurate readings.

2.3. **Additional Tools.** The engine operator should NOT rely solely on the A/F meter to verify engine performance. It should be considered as an additional tool to be used along with already existing tools and knowledge, including EGTs, engine smoothness, the lean pot (using it for mixture verification), CHTs, and previous aircraft flight experiences.

3. **Engine Manufacturer's Knowledge.** The knowledge of how to verify engine performance, whether it is best economy cruise or best power, is thoroughly defined and documented by the engine manufacturer. The same tests and procedures should be followed, i.e., monitoring EGTs, RPM, MAP, rate of climb, lean out rises, and engine smoothness. The engine manufacturers have published owner manuals and service information letters defining these processes. They need to be followed to ensure proper performance and engine life, and to avoid voiding the manufacturer's warranty**.**
4. **Table and Graph.** On the next page is a graph showing the engine characteristics vs. fuel mixture. This graph and the A/F relationships table on the previous page should be reviewed and understood. The table and graph will greatly assist in correlating how the A/F relates to the various engine running conditions.


BEST ECONOMY RANGE
MAX. POWER RANGE
CYLINDER HEAD TEMP. CHANGE
DEGREE CENTIGRADE
+10
0
-10
-20
-30
PEAK EGT OR TIT
MAX. TEMP.
EGT TEMP. CHANGE DEGREE F.
-100
-200
-300
-400
EXHAUST GAS TEMPERATURE
CYLINDER HEAD TEMPERATURE
PERCENT POWER
PERCENT OF BEST POWER
100
95
90
85
80
SPECIFIC FUEL CONSUMPTION
TOO LEAN
BEST ECONOMY CRUISE
MAX. POWER CRUISE
FULL RICH TAKE OFF
LEAN
MIXTURE
RICH