Frequently the engine used to drive the generator in a standby or prime power generator system is a 4-stroke spark ignition (SI) engine. While many smaller portable generators use SI engines fueled by gasoline, the majority of SI engine driven generators above 10kW are fitted with SI engines fueled by gaseous fuel, either natural gas (NG), or liquid petroleum gas (LPG). The majority of gaseous powered SI engines within a generator system are frequently referred to as having a Closed-Loop Engine Control System. In understanding necessary maintenance required to maintain optimum operation and performance of an SI engine using a closed-loop system, it is important to be aware of all the components within the system, their functions, and the advantages a closed-loop system.

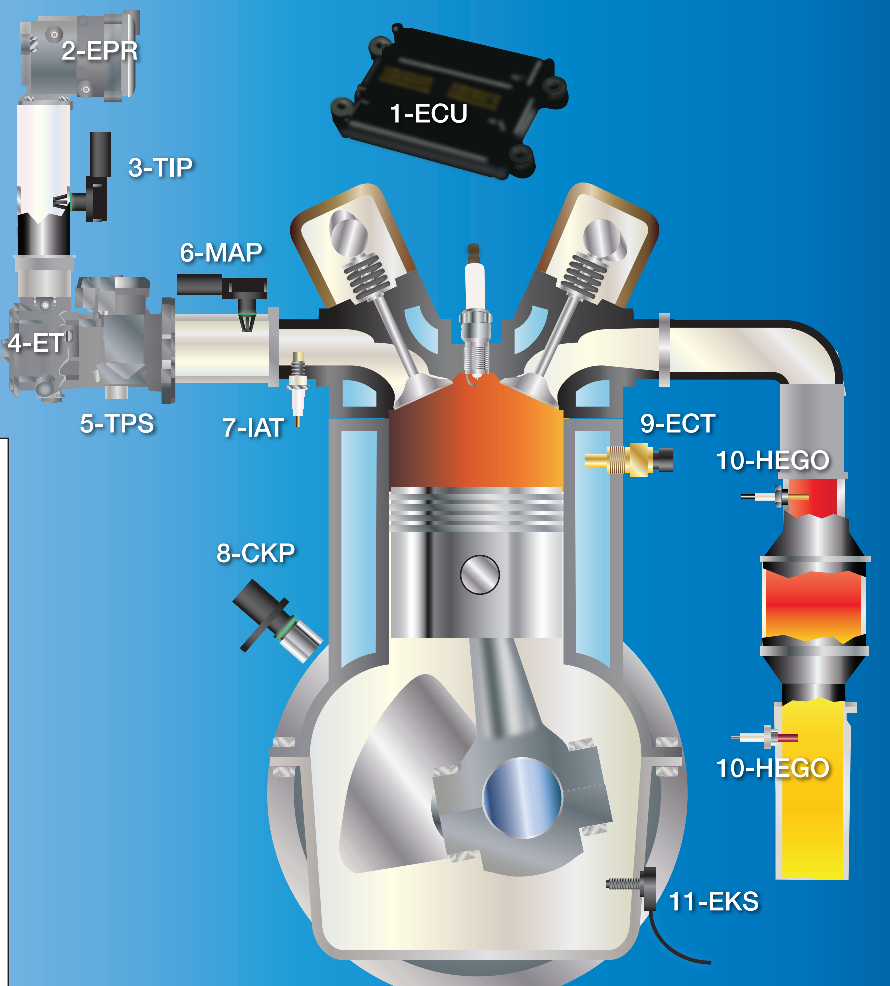
1.0 WHAT IS A CLOSED-LOOP SYSTEM:

The term "loop" in a control system refers to the path taken through various components to obtain a desired output. Used in conjunction with the word "closed" it refers to sensors measuring actual output along the path against required output. The various outputs measured along the path, or loop, are referred to as feedback signals. In a closed-loop system, the feedback along the path constantly enables the engine control system to adjust and ensure the right output is maintained as variations in ambient temperature, load, altitude, and humidity influence combustion and required output. So, in brief, closed-loop systems employ sensors in the loop to constantly provide feedback so the ECU can adjust inputs to obtain the required output. (*See Diagram 2*)

Key to Closed-Loop Control System

#	Code	Description
1	ECU	Engine Control Unit
2	EPR	Electronic Pressure Regulator
3	TIP	Throttle Inlet Pressure Sensor
4	ET	Engine Throttle
5	TPS	Throttle Position Sensor
6	MAP	Manifold Absolute Pressure Sensor
7	IAT	Inlet Air Temperature Sensor
8	CKP	Crank Position Sensor
9	ECT	Engine Coolant Temperature Sensor
10	HEGO	Heated Exhaust Gas Oxygen Sensor
11	EKS	Engine Knock Sensor

Diagram 1 - Components & Sensors Within a Closed-Loop Engine Control System



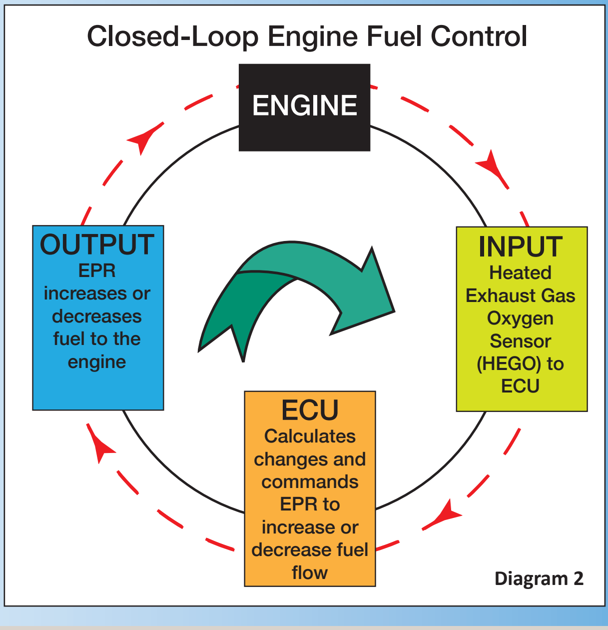


Diagram 2

1.0 WHAT IS A CLOSED-LOOP SYSTEM (CONTINUED):

The following are examples of closed-loop systems used to automatically adjust the output:

1.1 AUTOMATIC CHOKE – Without an automatic choke, an operator would have to manually pull a lever that temporally adjusts the air/fuel mixture when starting a cold engine. When the engine has started and run up to operating temperature, the choke is then pushed in to have the correct air/fuel mixture for a warm engine.

In a closed-loop system, an oxygen sensor, along the exhaust path, measures the oxygen to provide feedback regarding the air/fuel mixture and automatically adjusts the amount of fuel required for starting. As the engine temperature rises, sensors provide output to adjust the air/fuel for running. This is an example of a closed-loop system providing feedback on a path to adjust the output.

1.2 GENERATOR EXCITATION – A magnetic field provides the magnetism to induce the electricity in the field windings of a generator. The magnetic field uses a DC input to generate the magnetic field. The higher the DC voltage the higher the magnetism, and vice versa. Sensors read the AC voltage generated, if the voltage is too high, the DC voltage is reduced, and vice versa if too low. Again, this is an example of a closed-loop system controlling output.

2.0 ADVANTAGE OF A CLOSED-LOOP SYSTEM:

Most spark ignition engines in today's generator systems have closed-loop ignition systems. This was not always the case, as the fuel was fed through a carburetor to mix with the air in the inlet port. This is referred to an Open-Loop System.

2.1 DISADVANTAGES OF OPEN-LOOP SYSTEMS – In an open-loop system, no measurements are taken along the path of combustion, as more power is required more fuel is fed through the carburetor. The fuel/air mixture is not read along the path. This results in poor fuel management resulting in higher fuel consumption,and increased emissions due to unburnt fuel and/or insufficiently burnt fuel.

2.2 ADVANTAGES OF CLOSED-LOOP SYSTEMS – Along the path of a closed-loop system are sensors that read engine speed, fuel content, oxygen in the exhaust, cylinder pressure, etc. All of these sensors along the ignition/combustion path feed to an Engine Control Unit (ECU) that in turn controls the fuel throttle to provide exactly the correct mixture of fuel and air for the power required. This results in greater power strokes, improved fuel efficiency, and reduced emissions.

3.0 SENSORS WITHIN A CLOSED-LOOP SYSTEM: (SEE DIAGRAM ONE)

The various sensors along the path of a closed-loop system in an SI engine feed their individual inputs to the ECU. The ECU compares these inputs to predetermined parameters and sends output signals to various controls within the engine's ignition system path to adjust and ensure the sensor feedback readings are within the predetermined parameters.

The key sensors along the closed-loop path are:

3.1 CRANK POSITION SENSOR (CKP) – The crank and cam sensors are fitted to measure engine speed. The signal sent to the ECU synchronizes the ignition system to the engine speed. For example, if the load pulls down the engine speed the throttle will increase fuel.

3.2 MANIFOLD ABSOLUTE PRESSURE SENSOR (MAP) – The Manifold Absolute Pressure Sensor monitors the vacuum changes within the intake manifold which results from engine load variations. The sensor also measures changes in atmospheric pressure.

3.3 INLET AIR TEMPERATURE SENSOR (IAT) AND ENGINE COOLANT TEMPERATURE SENSOR (ECT) – These sensors measure the temperatures of the inlet manifold air and the coolant to maintain at a constant even air/fuel mixture when air density changes.

3.4 THROTTLE INLET PRESSURE SENSOR (TIP) – This sensor senses the inlet manifold pressure for the ECU to determine how much fuel is required and when to ignite a given cylinder.

3.5 ENGINE KNOCK SENSOR (EKS) – When ignition timing is too advanced, it can create pre-ignition which has a characteristic knock/ping that can result in engine damage. The knock sensor senses changes in the internal engine pressure and when detected will send signals to the ECU to retard timing. The knock sensor permits the engine to run on the most advanced timing before knock occurs.

3.6 HEATED EXHAUST GAS OXYGEN SENSOR (HEGO) – This sensor is used to measure if the fuel flow to the engine is correct by measuring the oxygen content of the exhaust gas. If the engine is fitted with a catalytic converter a HEGO will be fitted upstream and downstream of the catalyst. If one is not used the engine will have only one fitted in the exhaust system. If the downstream sensor reads the exhaust is too rich with fuel, its signal to the ECU will cause the ECU output to the throttle to decrease or lean the fuel mixture. The upstream sensor with a catalytic converter enables the ECU to sense the performance of the catalyst.

3.7 ENGINE THROTTLE (ET) – The ECU sends signals to the ET to change the fuel supplied to the engine.

3.8 ENGINE CONTROL UNIT (ECU) – The ECU receives input from the various sensors in the closed-loop system and uses these inputs to calculate the outputs to the various devices that control engine operations such as the throttle and regulators.

3.9 THROTTLE POSITION SENSOR (TPS) – The sensor tracks the shaft movement and position (closed throttle, wide open throttle, or any position in between) and transmits an electrical signal to the ECU to make any changes required.

4.0 MAINTENANCE OF A CLOSED-LOOP SYSTEM

Your authorized distributor has planned maintenance programs for the ignition systems of all spark ignition engines utilized in generator systems. These programs will ensure all elements of the ignition system are operating to their original OEM specifications. For further information, contact your local distributor.

To fulfill our commitment to be the leading supplier in the power generation industry, the Buckeye Power Sales team ensures they are always up-to-date with the current power industry standards as well as industry trends. As a service, our Information Sheets are circulated on a regular basis to existing and potential power customers to maintain their awareness of changes and developments in standards, codes and technology within the power industry.

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