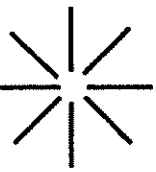
Natural Gas Engines



OPERATION AND MAINTENANCE MANUAL

Bulletin #OM911201-04-12/2001

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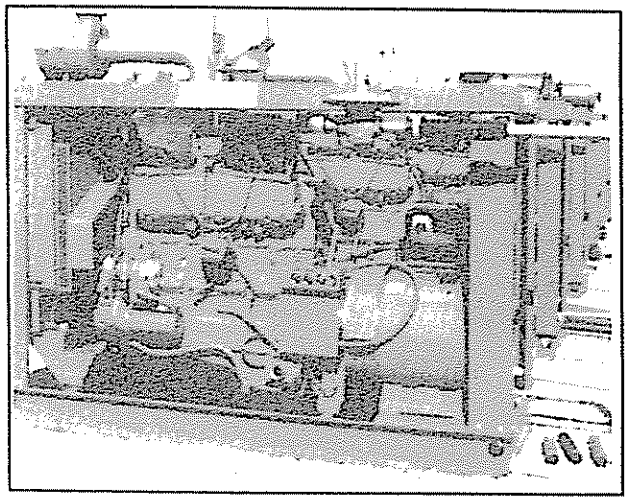


Important Reference Numbers

The blank spaces provided below are for recording engine identification data and part numbers of frequently used maintenance items. These reference numbers will be needed for ordering replacement parts or requesting service.

Engine Model _____

Serial Number _____

Filter Part Numbers:

..Air Cleaner _____
..Oil (Full Flow)_____
..Oil (ByPass)_____
..Fuel-Gas _____
..Coolant _____

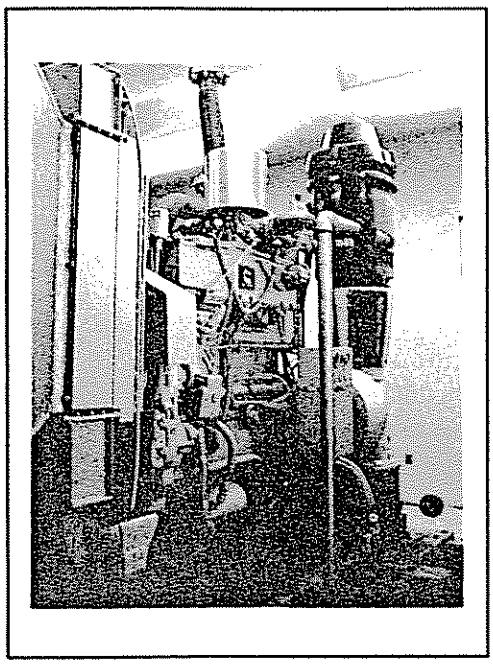
Belt Part Numbers:

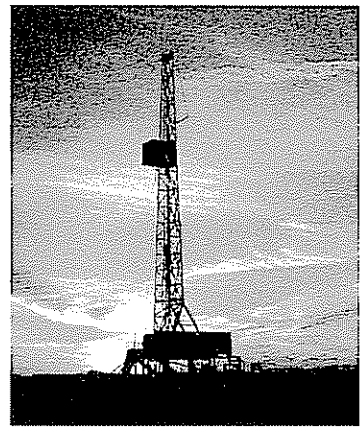
..Fan Belt _____
..Water Pump Bel _____
..Auxiliary Water Pump Belt_____
..Alternator Belt _____
Spark Plug _____
Spark Plug Wires _____
Ignition Coils _____

Section 1 - Engine and Component Identification

Table of Contents

Engine Model Specifications:





Engine Dataplate

Refer to the enclosed illustration for the dataplate location.

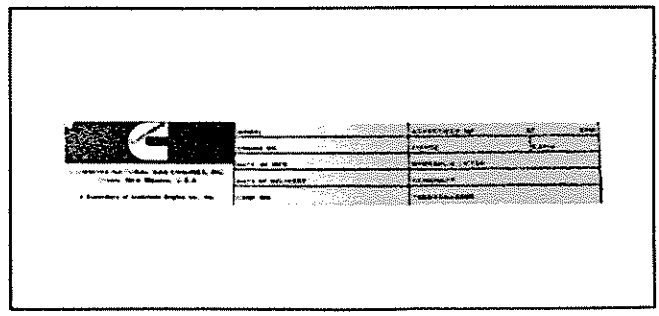


Photo #1-01 - Engine Dataplate

Note: The engine dataplate must not be changed unless approved by Cummins Natural Gas Engines, Inc.

The engine dataplate shows specific information about your engine, such as

- Model Type
- Engine Serial Number
- Date of Manufacture
- Date of Delivery
- Configuration No.
- Advertised HP (Horsepower)
- Rated RPM (Revolutions Per Minute)
- Piston Part Number
- Compression Ratio
- Camshaft Part Number
- Turbocharger Part Number

* The date of delivery will be stamped on the dataplate by the local Cummins Distributor or authorized CNGE Dealer at the time of new engine inspection. The date of delivery will be used as a starting point to measure warranty for the end user customer.

ENGINE AND COMPONENT IDENTIFICATION (Cont'd)

How to Identify Your Engine

The model name provides the following data:

G T A 855 B

- B = Higher Hp than Model "A" & Piston Cooled
- 855 = Displacement (C.I.D.)
- A = Aftercooled
- T = Turbocharged
- G = Gas Engine-Spark Ignited

G T A 19

- 19 = Displacement (Liters)
- A = Aftercooled
- T = Turbocharged
- G = Gas Engine-Spark Ignited

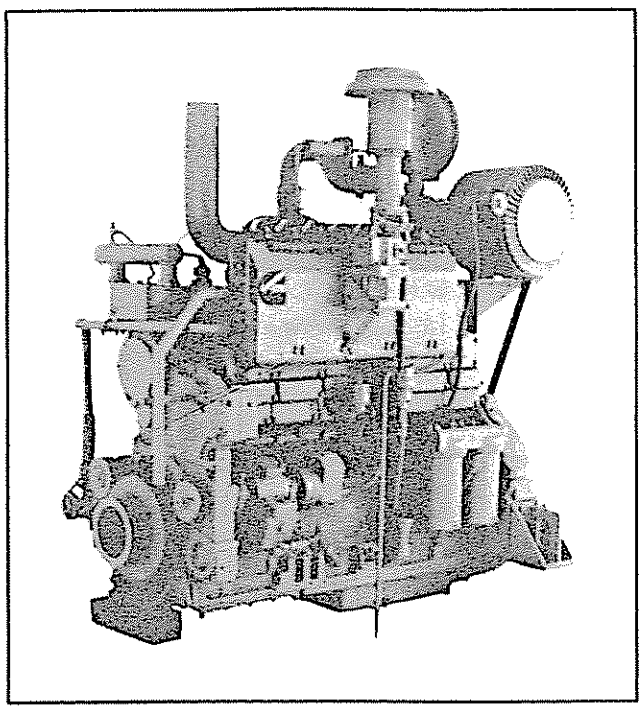


Photo: # 1-02 - GTA19

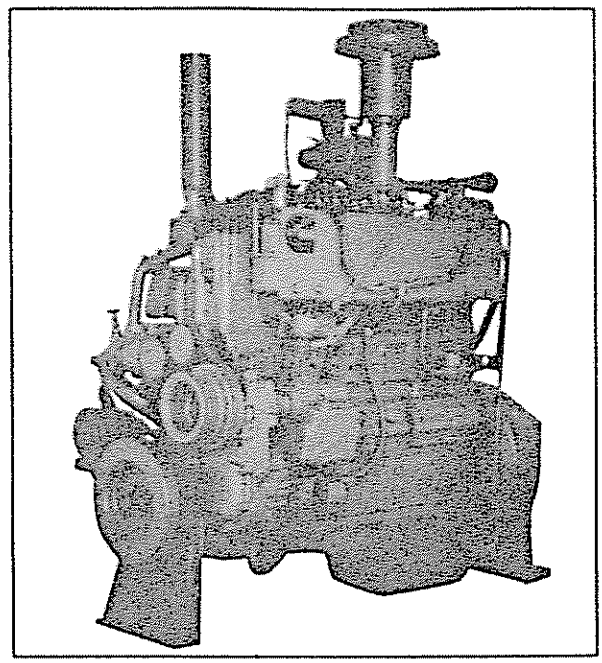


Photo # 1-03 - GTA855B

Turbocharger Data Plate

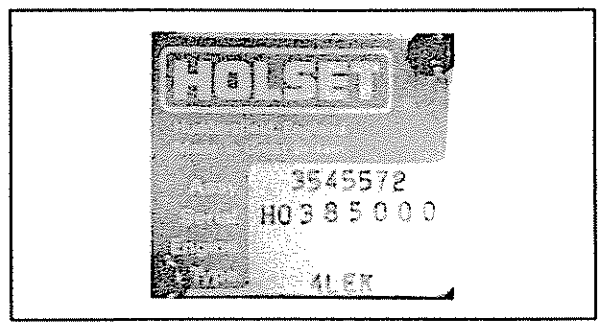


Photo # 1-04 Turbocharger Data Plate

External Engine Components

The illustrations that follow show the locations of the major external engine components, filters and other service and maintenance points. Some external components will be at different locations for different engine models.

Note: The illustrations are only a reference to show a typical engine.

Engine and Component Identification (Cont'd)

GTA855-B - Aftercooler Side

1. Fan Hub
2. Aftercooler
3. Ignition Generator
4. Alternator
5. Ignition Coils
6. Governor
7. Throttle Butterfly
8. Vibration Damper
9. Gas Regulator
10. Fuel Shutoff Valve
11. Fuel Primer
12. Boost Limiter
13. Air Cleaner

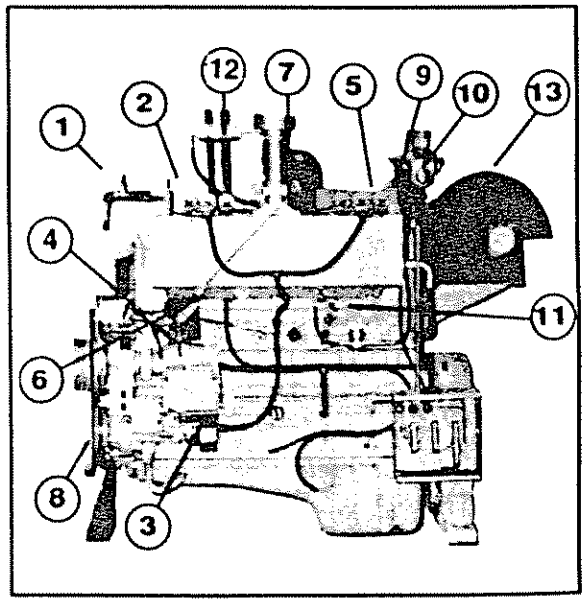


Photo # 1-05 GTA855-B Aftercooler Side

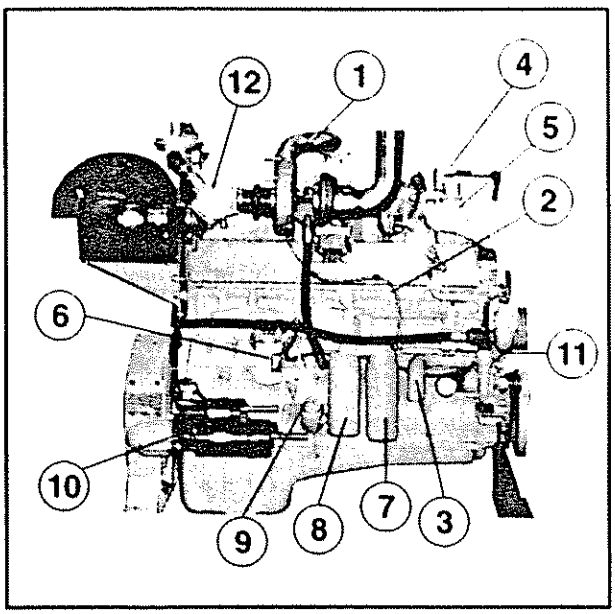


Photo # 1-06 - GTA855-B Exhaust Side

GTA855-B - Exhaust Side

1. Turbocharger
2. Oil Cooler
3. Coolant Inlet
4. Coolant Outlet
5. Thermostat Housing
6. Coolant Filter
7. Lubricating Oil Full Flow Filter
8. Lubricating Oil By-Pass Filter
9. Dipstick Location
10. Starter
11. Auxiliary Water Pump
12. Carburetor

Engine Model Specifications

Note: Listed below are the general specifications for each engine model. Refer to the specific System Section for additional specifications.

G12

EngineSpeed(RPM) at standard rating- - - - - 1800

Note: Refer to the engine datasheet for optional engine speed rating.

No.of cylinders - 6
Displacement - - - - - - - - - - - 12.2 liters [743 C.I.D.]
Bore -130mm [5.125 in.]
Stroke -153mm [6.0 in.]
Available Compression Ratio
Natural Gas - - - - - - - - - - - - 8.5 : 1, 10 : 1, 12 : 1
Propane - - - - - - - - - - - - - - - - - - - 8.5 : 1, 10 : 1

Note: Refer to engine dataplate for your specific compression ratio.

Dry Engine Weight - - - - - - - - - - - - - - - 2600 lbs.
Firing Order- - - - - - - - - - - - - - - - - - 1-5-3-6-2-4
Valve Settings (Room Ambient Temperature)
Intake Valve - - - - - - - - - - - .36mm [.014 in.]
Exhaust Valve - - - - - - - - - .69mm [.027 in.]

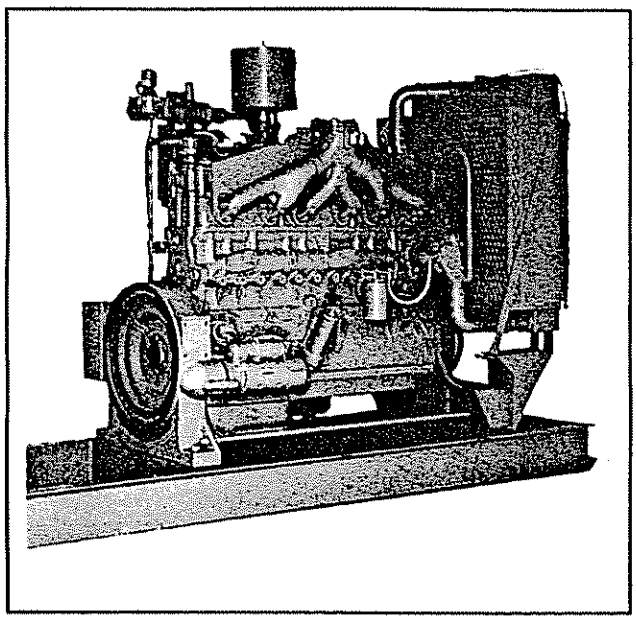


Photo # 1-07 - G12

GTA12

EngineSpeed(RPM) at standard rating- - - - - 1800

Note: Refer to the engine datasheet for optional engine speed rating.

No.of cylinders - 6
Displacement - - - - - - - - - - - 12.2 liters [743 C.I.D.]
Bore - 130mm [5.125 in.]
Stroke - 152mm [6.0 in.]
Available Compression Ratio
Natural Gas - - - - - - - - - - - - - - - - - - - 8.5:1, 10:1
Propane - 8.5:1

Note: Refer to engine dataplate for your specific compression ratio.

Dry Engine Weight - - - - - - - - - - - - - - - 2700 lbs.
Firing Order - - - - - - - - - - - - - - - - - - - 1-5-3-6-2-4
Valve Settings (Room Ambient Temperature)
Intake Valve - - - - - - - - - -.36mm [.014 in.]
Exhaust Valve - - - - - - - - .69mm [.027 in.]

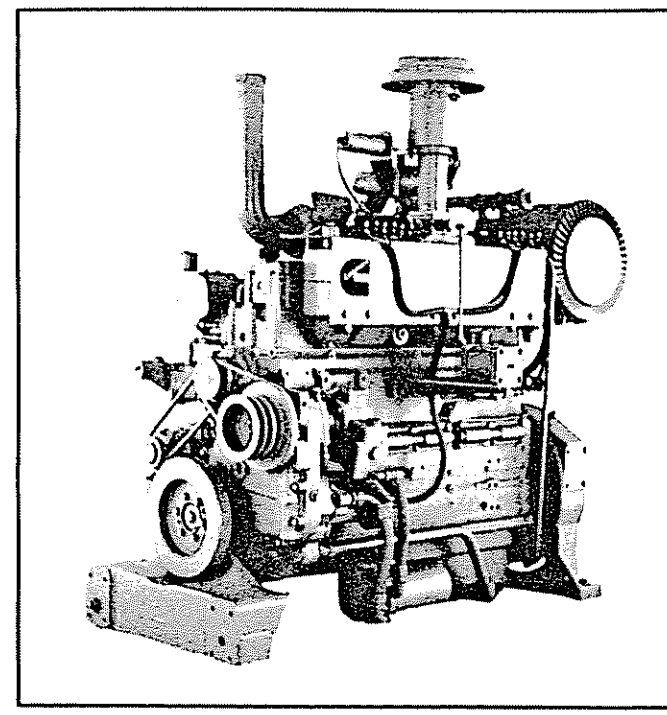


Photo # 1-08 - GTA12

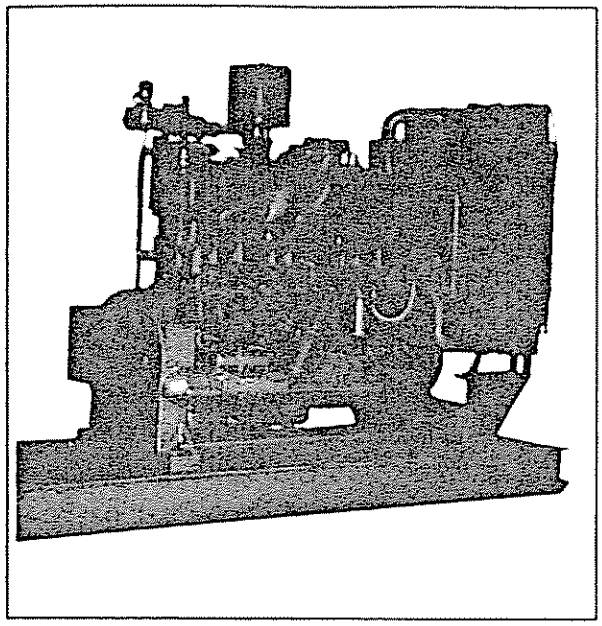


Photo # 1-09 - G855

G855

Engine Speed (RPM) at standard rating - - - 1800

Note: Refer to the engine datasheet for optional engine speed rating.

No. of cylinders - 6
Displacement - - - - - - - - - - - 14.0 liters [855 C.I.D.]
Bore - 140mm [5.5 in.]
Stroke- 152mm [6.0 in.]
Available Compression Ratio
Natural Gas- - - - - - - - - - - - - - - - - 8.5:1, 10:1, 12:1
Propane- 8.5:1, 10:1

Note: Refer to engine dataplate for your specific compression ratio.

Dry Engine Weight- - - - - - - - - - - - - - - - 2870 lbs.
Firing Order - 1-5-3-6-2-4
Valve Settings (Room Ambient Temperature)
Intake Valve- - - - - - - - - - - .36mm [.014 in.]
Exhaust Valve- - - - - - - - - -.85mm [.033 in.]

GTA855-A

Engine Speed (RPM) at standard rating - - - 1800

Note: Refer to the engine datasheet for optional engine speed rating.

No. of Cylinders - 6
Displacement - - - - - - - - - - - 14.0 liters [855 C.I.D.]
Bore - 140mm [5.5 in.]
Stroke - 152 mm [6.0 in.]
Available Compression Ratio
Natural Gas- - - - - - - - - - - - - - - - - - - 8.5:1, 10:1
Propane - 8.5:1

Note: Refer to engine dataplate for your specific compression ratio.

Dry Engine Weight - - - - - - - - - - - - - - - 2970 lbs.
Firing Order - - - - - - - - - - - - - - - - - - - 1-5-3-6-2-4
Valve Settings (Room Ambient Temperature)
Intake Valve- - - - - - - - - - - .36mm [.014 in.]
Exhaust Valve- - - - - - - - - -.85mm [.033 in.]

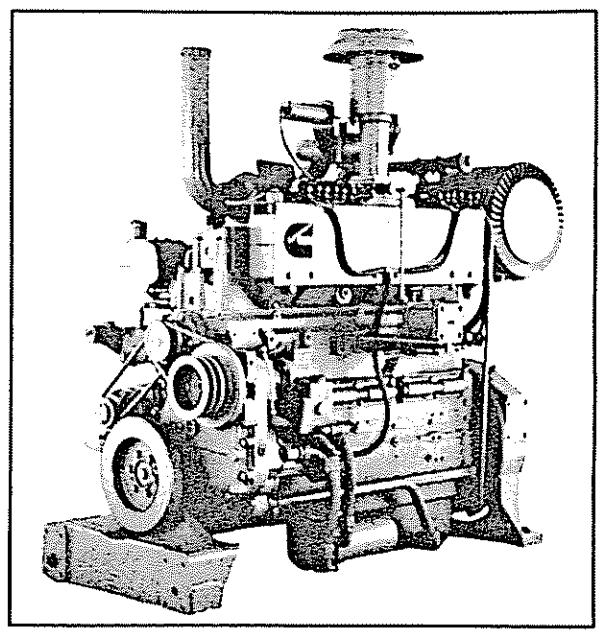


Photo # 1-10 - GTA855-A

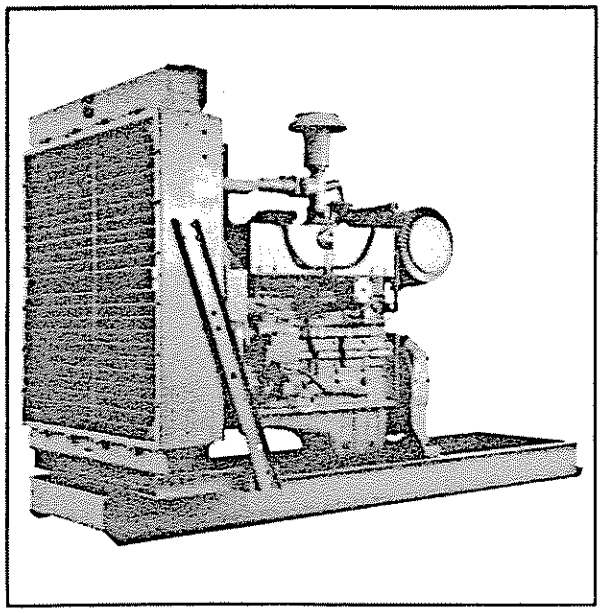


Photo # 1-11 - GTA855-B

GTA855-B

Engine Speed (RPM) at standard rating - - - 1800

Note: Refer to the engine datasheet for optional engine speed rating.

No. of Cylinders - 6
Displacement - - - - - - - - - - - 14.0 liters [855 C.I.D.]
Bore- 140 mm [5.5 in.]
Stroke- 152 mm [6.0 in.]
Available Compression Ratio
Natural Gas- 8.5:1, 10:1
Propane- 8.5:1

Note: Refer to engine dataplate for your specific compression ratio.

Dry Engine Weight - - - - - - - - - - - - - - - - - 2970 lbs.
Firing Order - 1-5-3-6-2-4
Valve Settings (Room Ambient Temperature)
Intake Valve - - - - - - - - - - - .36mm [.014 in.]
Exhaust Valve - - - - - - - - - .85mm [.033 in.]

GTA19

Engine Speed (RPM) at standard rating - - - 1800

Note: Refer to the engine datasheet for optional engine speed rating.

No. of Cylinders - 6
Displacement - - - - - - - - - -18.8 liters [1150 C.I.D.]
Bore- 159 mm [6.25 in.]
Stroke - 159 mm [6.25 in.]
Available Compression Ratio
Natural Gas- 8.5:1, 10:1
Propane - 8.5:1

Note: Refer to engine dataplate for your specific compression ratio.

Dry Engine Weight - - - - - - - - - - - - - - - - - 3800 lbs.
Firing Orde - 1-5-3-6-2-4
Valve Settings (Room Ambient Temperature)
Intake Valve - - - - - - - - - .36mm [.014 in.]
Exhaust Valve - - - - - - - - - .69mm [.027in.]

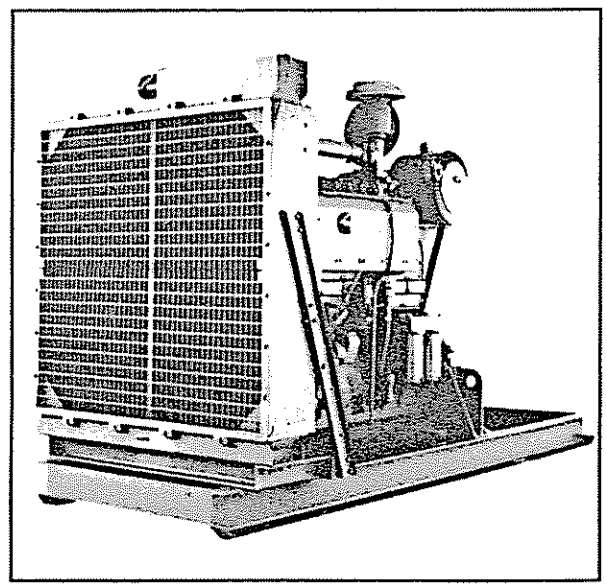


Photo # 1-12 - GTA19

GTA28

Engine Speed (RPM) at standard rating - - - 1800

Note: Refer to the engine datasheet for optional engine speed rating.

No. of Cylinders - 12
Displacement - - - - - - - - - - 28.0 liters [1710 C.I.D.]
Bore - 140 mm [5.5 in.]
Stroke -152 mm [6.0 in.]
Available Compression Ratio
Natural Gas- 8.5:1, 10:1
Propane - 8.5:1

Note: Refer to engine dataplate for your specific compression ratio.

Dry Engine Weight - - - - - - - - - - - - - - - 6960 lbs.
Firing Order - - - - - - - - - - - - - - -1L-6R-2L-5R-4L-3R
6L-1R-5L-2R-3L-4R
Valve Settings (Room Ambient Temperature)
Intake Valve - - - - - - - - - - - .36mm [.014 in.]
Exhaust Valve - - - - - - - - - - .85mm [.033 in.]

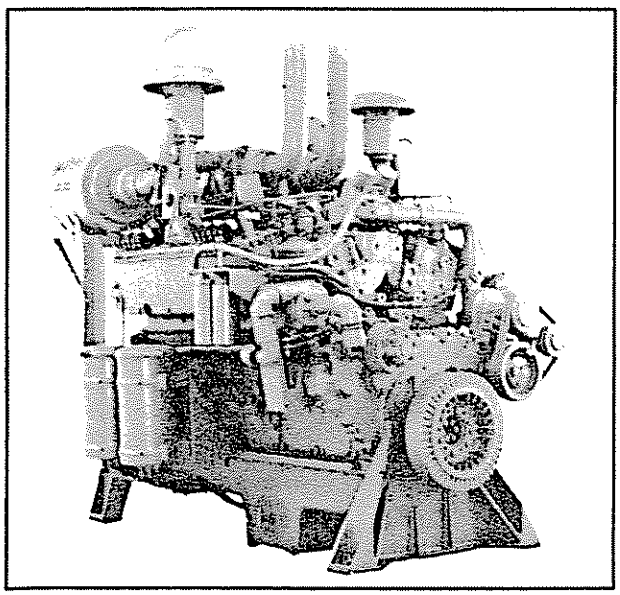
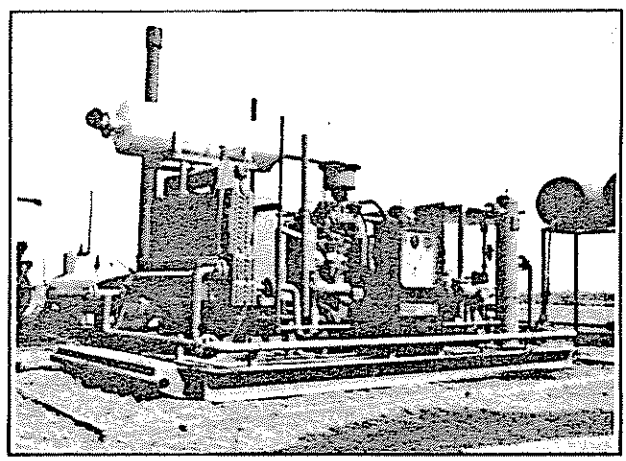


Photo # 1-13 - GTA28

Reference Notes:



SECTION 2 - INTRODUCTION

Contents

INTRODUCTION

About the Manual

This manual contains information needed to correctly operate and maintain your engine as recommended by Cummins Natural Gas Engines, Inc. Additional service literature (Shop Manual, Troubleshooting and Repair, etc.) that is primarily for the CUMMINS DIESEL may contain information that will be helpful and can be ordered from your local Cummins distributor.

This manual does not cover equipment maintenance procedures. Consult the equipment manufacturer for specific maintenance recommendations.

Both metric and U.S. customary values are listed in this manual. The metric value is listed first, followed by the U.S. customary in brackets.

Each section is preceded by a "Table of Contents" page to aid in locating information more quickly.

Abbreviations Used in this Manual

A	Aftercooled
API	American Petroleum Institute
ASTM	American Society of Testing and Materials
BHP	Brake Horsepower
BTU	British Thermal Units
C	Celsius
CCW	Counter Clockwise
C.I.D.	Cubic Inch Displacement
CM	Centimeter
cSt	Centistrokes
CW	Clockwise
cu.	Cubic
DBTDC	Degrees Before Top Dead Center
DCA	Diesel Coolant Additive
F	Fahrenheit
FTM	Federal Test Method
ft.	Feet
ft-lb	Foot Pound
"G"	Ground
"G"	Gas-Spark Ignited
"H"	High
Hg	Mercury
HHV	High Heat Value
HP	Horsepower
hr.	Hour
H_20	Water
in.	Inch
in-lb	Inch Pound
kg	Kilogram
kPa	Kilopascal
"L"	Low
l	Liter
lb.	Pound
LHV	Lower Heat Value
max.	Maximum
m	Meter
min.	Minimum
mm	Millimeter
MPa	Megapascal
NA	Naturally Aspirated
N	Newton
N•m	Newton-meter
O_2	Oxygen
OEM	Original Equipment Manufacturer
ppm	Parts Per Million
psi	Pounds Per Square Inch
PWB	Parts Warranty Bulletin
qt.	Quart
RPM	Revolutions Per Minute
SAE	Society of Automotive Engineers
ST	Service Tool
T	Turbocharged
(™)	Trademark
U.S.	United States
"VS"	Valve Set
WB	Warranty Bulletin
W.C.	Water Column
WF	Water Filter

General Safety Precautions and Warnings

Read and understand all of the safety precautions and warnings before performing any repair. This list contains the general safety precautions that must be followed to provide personal safety. Special safety precautions have been included in the procedures when they apply.

Note: It is not possible for Cummins Natural Gas Engines, Inc. to anticipate every possible circumstance that can involve a potential hazard.

Warning: Disconnect the battery and discharge any capacitors before beginning any repair work. Disconnect the air starting motor, if equipped, to prevent accidental engine starting. Put a " Do Not Operate" tag in the operator's compartment or on the controls.

Warning: Always shut down your CNGE Spark-Ignited engine by either using an automatically operated fuel shutdown valve as close to the engine as possible or by shutting off the manual shutoff valve upstream of the gas pressure regulator and allowing the engine to burn off all residual fuel-gas. CNGE recommends that all fuel-gas be shut off before turning off the ignition switch.

Warning: Use ONLY the correct crankshaft barring techniques for manually rotating the crankshaft. Do not attempt to rotate the crankshaft by pulling or prying on the fan. This practice can cause serious personal injury, property damage, or damage to the fan blade(s), causing premature fan failure. Always shut off the fuel supply and ground the ignition before manually barring the engine.

Warning: If an engine has been operating, and the coolant is hot, allow the engine to cool before you slowly ollsen the filler cap and relieve the pressure from the cooling system.

Warning: Do not work on anything that is supported ONLY by lift jacks or a hoist. Always use blocks or correct stands to support the product before performing any service work.

Warning: To avoid burns, be alert for hot component parts just after the engine has been shut off and hot fluids in lines, tubes, and compartments.

Warning: Relieve all pressure in the air, fuel, oil, and cooling systems before any lines, fittings, or related items are removed or disconnected. Be alert for possible pressure when disconnecting any device from a system that uses pressure. Do not check for pressure leaks with your hand. High pressure oil or water can cause personal injury.

Warning: Corrosion inhibitor contains alkali. Do not get the substance in your eyes. Avoid prolonged or repeated contact with skin. Do not swallow internally. If skin is contacted, immediately wash with soap and water. In the event eyes are contacted, immediately flood with water for a minimum of fifteen minutes. **IMMEDIATELY CALL A PHYSICAN. KEEP OUT OF REACH OF CHILDREN.**

Warning: Always use tools that are in good condition. Make sure you understand how to use them before performing any service work.

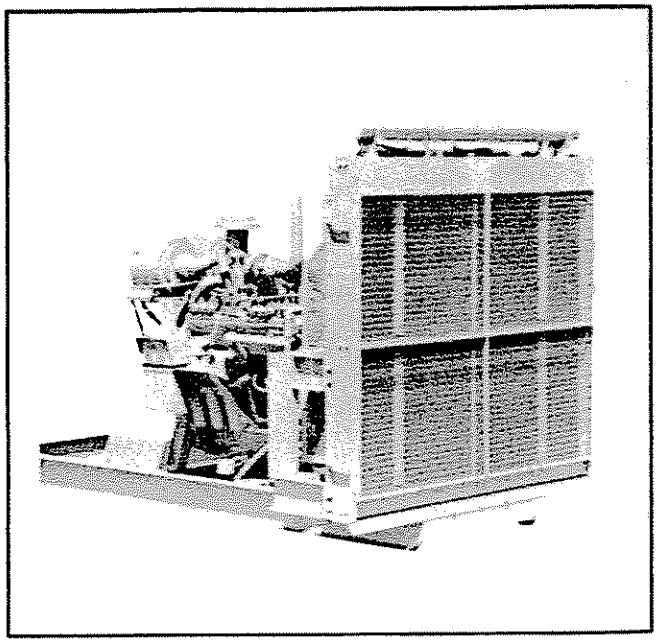
Warning: Always use the same fastener part number (or equivalent) when replacing fasteners. Do not use a fastener of lesser quality if replacements are necessary.

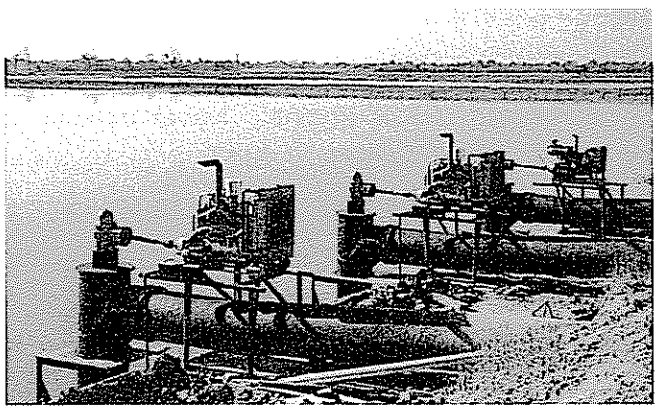
Warning: Never use gasoline or other flammable materials to clean parts. Always use approved cleaning solvent.

Warning: Use caution when working around a spark-ignited CNGE engine. Never expose the engine to an open flame or spark.

SECTION 3 - OPERATING PRINCIPLES

CONTENT





The Fuel System

CUMMINS NATURAL GAS ENGINES OPERATING PRINCIPLES

The most satisfactory service can be expected from a CNGE Spark-Ignited Engine when the operation procedure is based on a clear understanding of the engine working principles. Each part of the engine affects the operation of every other working part and of the engine as a whole. CNGE Engines described in this manual are four-stroke-cycle engines that burn a spark-ignited, controlled mixture of fuel-gas and air. The fuel-gas may be a pipeline quality of natural gas or a liquid propane gas (HD-5) or in some cases a "field" gas.

Horsepower ratings and other engine specifications are tabulated in Table #3-01.

Table #3-01 - Industrial - BHP - Continuous Duty **

Engine Models	Displ. Cu. In.	Aspiration *	HP Range
G12	743	N	98 to 167
G855	855	N	117 to 200
GTA12	743	TA	167 to 250
GTA855-A	855	TA	184 to 275
GTA855-B	855	TA	189 to 304
GTA19	1150	TA	256 to 400
GTA28	1710	TA	400 to 630

* N = Naturally Aspirated
T = Turbocharged
A = Aftercooled

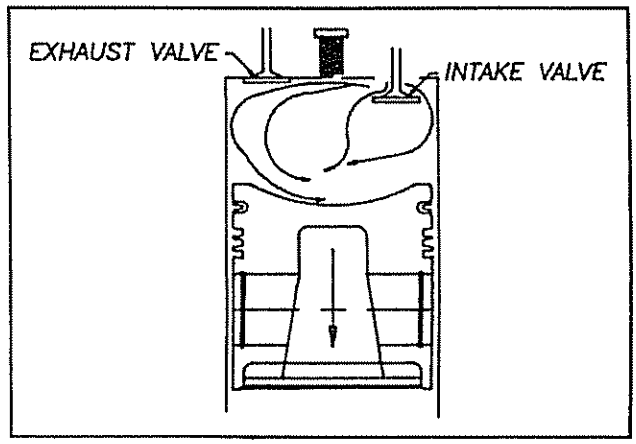
** Continuous horsepower ratings are based on operation up to 457m [1500 ft.] and 38°C [100°F] on naturally aspirated engines and 1524m [5000 ft.] and 38°C [100°F] on turbocharged engines.

Cummins Natural Gas Combustion Cycle

CNGE engines operate under the principle of a four cycle engine. A four cycle engine will go through four strokes of the piston during two complete revolutions of the crankshaft. The four strokes in proper order are: Intake Stroke, Compression Stroke, Power Stroke, and Exhaust Stroke.

Intake Stroke

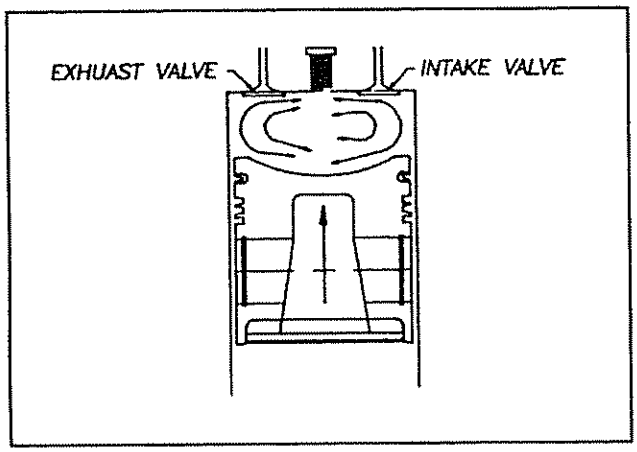
During the intake stroke, the piston travels downward permitting air and fuel-gas mixture from the carburetor to enter the combustion chamber through the open intake valves.



Sketch #3-02 - Intake Stroke

Compression Stroke

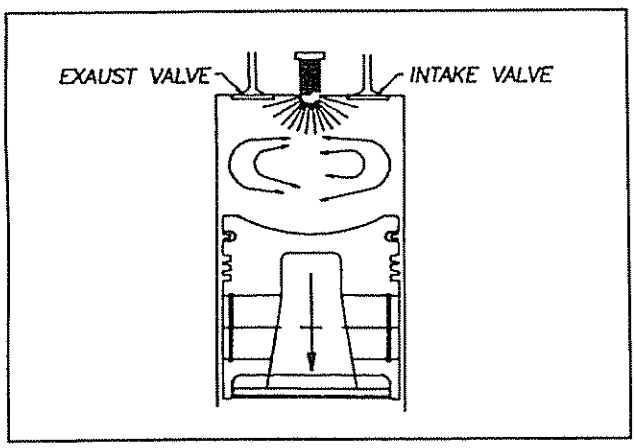
At the end of the intake stroke, the intake valves close and the piston starts upward on the compression stroke. The exhaust and intake valves remain closed. At the end of the compression stroke, the air and fuel-gas mixture in the combustion chamber are forced by the piston to occupy a space that is considerably smaller than the space it occupied at the beginning of the stroke. For example: if the space is reduced by a factor of twelve, we would say that the compression is 12:1. Near the end of the compression stroke and before top dead center, the mixture will be ignited by the spark plug.



Sketch #3-03 - Compression Stroke

Power Stroke

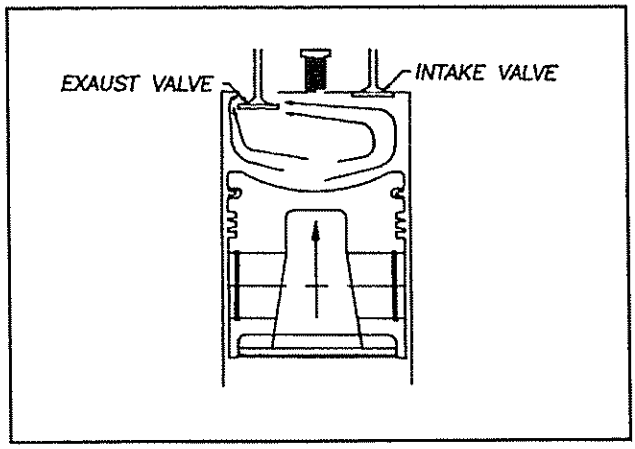
During the power stroke, with both the intake and exhaust valves closed, the burning fuel causes an increase in temperature, expanding the gas volume and increasing the pressure above the piston, which pushes the piston downward and adds impetus to the crankshaft rotation.



Sketch #3-04 - Power Stroke

Exhaust Stroke

During the exhaust stroke, the exhaust valves are open, the intake valves are closed, and the piston is on its upstroke. The upward travel of the piston forces burned gases out of the combustion chamber through the open exhaust valve ports in to the exhaust system.



Sketch #3-05 - Exhaust Stroke

The Fuel System

Fuel must be clean, free of acids, sulphur, and halogen compounds, water, pipe scale, and other foreign materials that could cause corrosion or abrasion of cylinder liners, bearings, and internal engine parts. Dry processed natural gases usually have the liquids removed and contain primarily methane and a small percent of ethane gases. This type of gas is generally about 1000 BTU/cu. ft. H.H.V. (high heat value) and can be used in all Cummins Natural Gas Engines.

The application of CNGE engines on HD-5 liquid propane and non-processed gas requires careful anaylsis of the fuel to decide the proper compression ratio selection. Check with your CNGE dealer or distributor for proper compression ratio and power rating for individual applications.

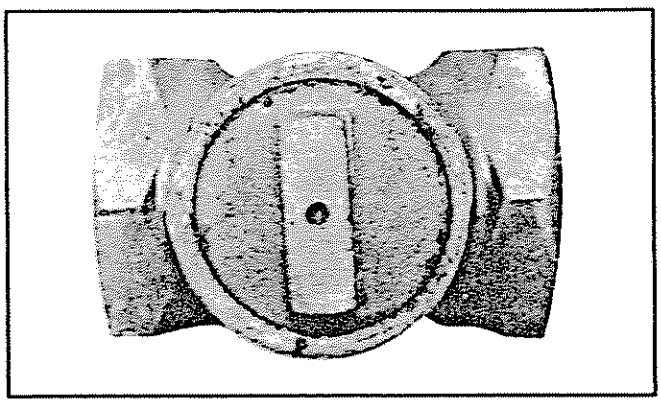


Photo #3-06 - Manual Gas Shut-Off Valve

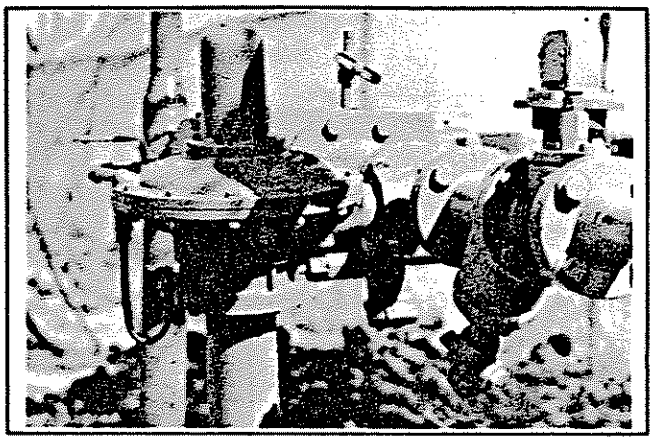


Photo #3-07 - Line Pressure Regulator

Located between the gas supply line and the engine intake manifold are the following units that make up the fuel system:

1. Manual Gas Shut-Off Valve
2. Line Pressure Regulator
3. Gas Filter
4. Automatic Gas Shut-Off Valve
5. Engine Mounted Pressure Regulator
6. Carburetor
7. Butterfly Valve
8. Charge Air Cooler (Turbocharged)
9. Boost Limiter (Turbocharged Engines)

Manual Gas Shut-Off Valve

This valve, on dry pipeline natural gas, will generally be found upstream on the gas system. The local gas company will normally supply this valve.

Line Pressure Regulator

The line gas pressure regulator is required to reduce the gas from its line pressure down to a maximum of 125 psi or less. The minimum outlet pressure must never be lower than 2 psi if the Engine Mounted regulator is a Fisher regulator, or 15 inches of W.C. (water column) if a Maxitrol regulator.

Gas Filter

The filter is a single pass element made of pleated paper and will filter down to a five micron particle size. The filter should be inspected regularly and replaced when necessary. Refer to the maintenance schedule listed in this manual.

This filter may plug prematurely if subjected to liquid contaminants in the fuel-gas causing a restriction of gas flow.

CAUTION: It is important that the filter is installed with the gas flow going from the outside toward the inside of the element.

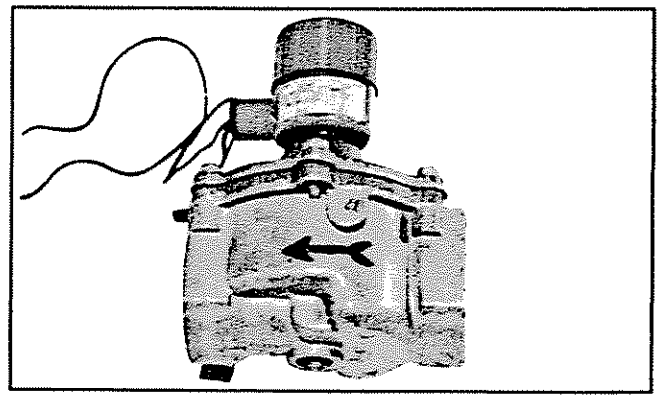


Photo #3-08 - Automatic Gas Shut-Off Valve

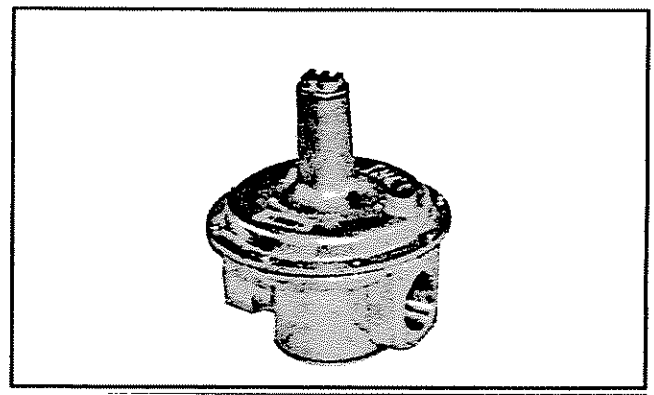


Photo #3-09 - Engine Pressure Regulator

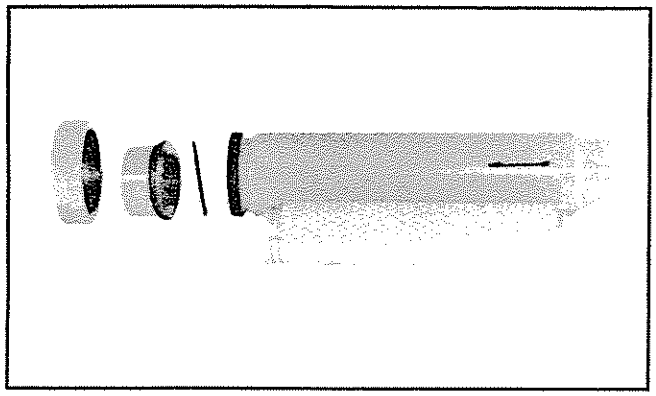


Photo #3-10 - Gas Filter

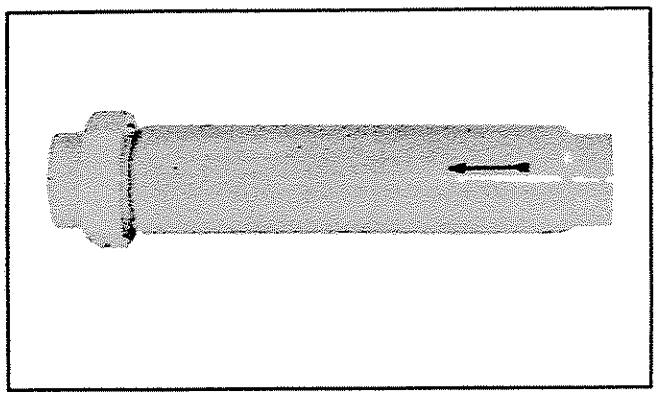


Photo #3-11 - Gas Filter

Automatic Gas Shut-Off Valve

A gas shut-off valve may be mounted between the line pressure regulator and the gas filter to assure a positive gas shut-off. The valve may be operated manually, electrically, or actuated from the ignition system or oil pressure as a safety system.

CAUTION: When installing the gas shut-off valve, it is important to insure that the arrow (if equipped) is pointing in the direction of gas flow.

CAUTION: Do not mount gas shut-off valve between engine mounted regulator and carburetor.

Engine Mounted Pressure Regulator

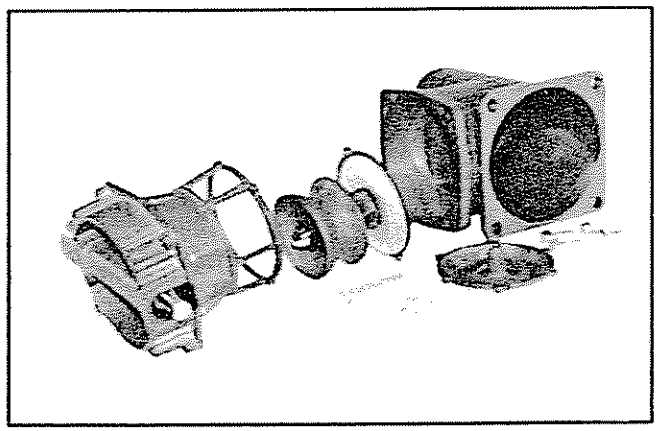
The engine mounted pressure regulator will reduce the gas pressure at the engine down to a working pressure at the carburetor of from three to five inches of W.C.. Refer to Table 3-12 for information concerning specific regulators.

Table #3-12 - Gas Pressure Regulators

Engine Models	Regulators (Maxitrol)
G12	RV 60
G855	RV 60
G28	RV 60
GTA12	RV 81
GTA855-A	RV 81
GTA855-B	RV 81
GTA19	RV 91
GTA28	RV 91

Note: Regulators have been sized for a gas flow with an LHV of 905 BTU at 0.6 specific gravity at 16° C [60° F].

Photo #3-13 - Disassembled Carburetor



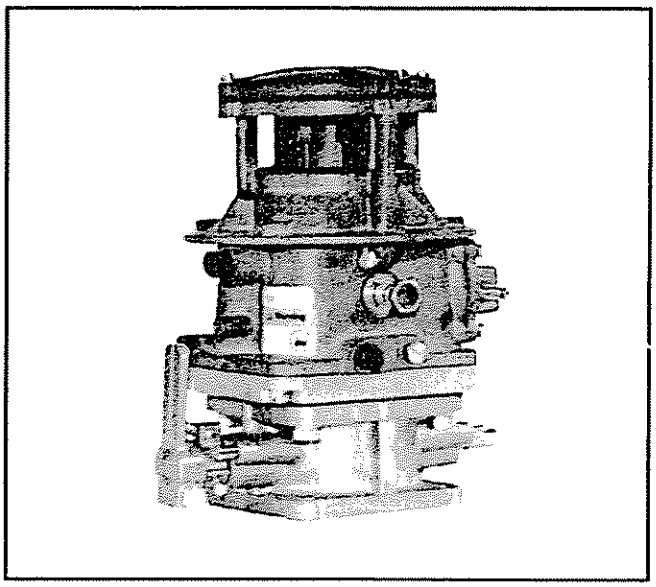


Photo #3-14 - Carburetor

Carburetor

The air-gas valve controls the air-gas mixture that flows through the carburetor. The air-gas valve meters both air and fuel gas in proper proportions at any throttle setting. It also seals gas flow when the engine is off and provides an automatic choke action during starting.

The butterfly valve controls the flow of air through the carburetor on to the intake manifold. The air metering valve, which is mounted on a diaphragm, measures this air flow. As the air flow increases, the higher the air metering valve will rise.

The gas metering valve that is connected directly to the air valve will rise the same amount. The gas valve is designed to admit the correct amount of gas at any height to which the air metering valve rises. The natural gas pressure to the carburetor inlet should be between three to five inches of W.C. from no load to a full load condition.

Refer to Table #3-15 for the specific carburetor for your engine model.

Table #3-15 - Carburetors

Engine Model	Impco Model #
G12	425
G855	425
GTA12	600 VF(vari-fuel)
GTA855-A	600 VF
GTA855-B	600 VF
GTA19	600 VF
GTA28	600 VF(2)

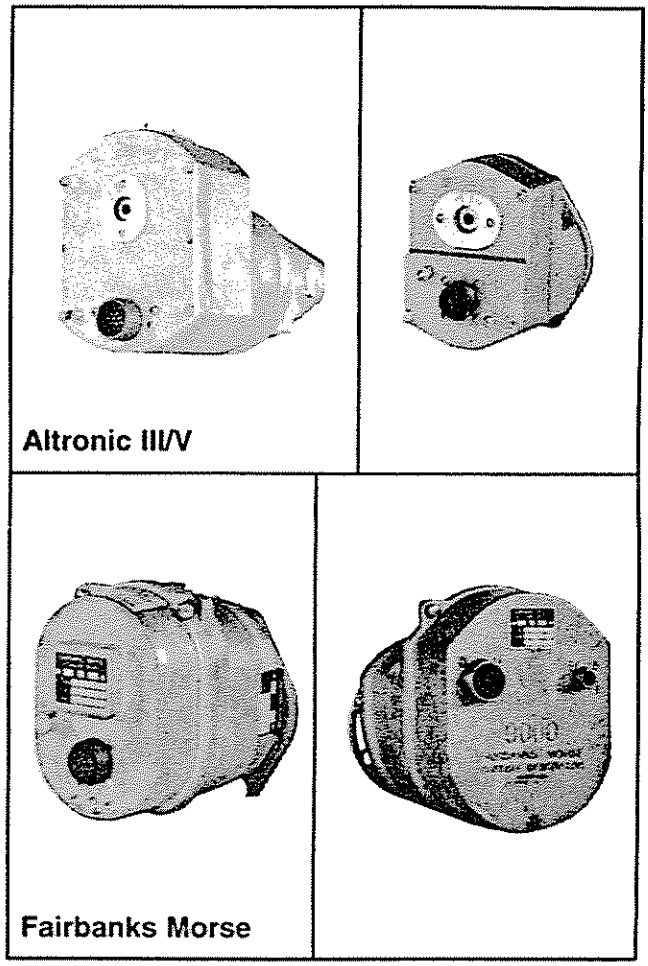


Photo #3-16 - Ignition Generators

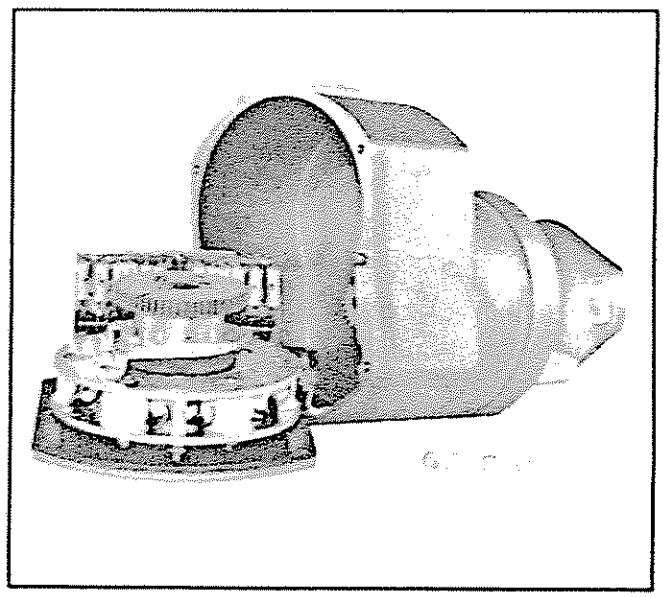


Photo #3-17 - Altronic III Breakdown

IGNITION SYSTEM

The Cummins Natural Gas Engine currently uses the Altronic Ignition System as standard with the Fairbanks Morse System as an option.

The Altronic V is used on the G8, G12, GTA12, G855, GTA855-A & -B engine models and the Altronic III is also available as an option on the four and six cylinder engines.

The Altronic III unit is a self-contained 12-pole permanent magnet alternator powering a solid state timing and distribution circuit. A wiring harness and ignition coil for each spark plug complete the system.

The Altronic V unit is a self-powered, low tension, capacitor discharge ignition system consisting of an 8-pole permanent magnet alternator, timing, and distribution circuits. A wiring harness and one ignition coil per cylinder complete the system.

Some applications may require the use of a shielded ignition system. This generally means that the spark plug, spark plug coil, low tension wires, and spark plug wires are inside the protective shield.

There are two types of shielded spark plugs: (1) Aircraft style shielded spark plugs, and (2) Shielded integral coil spark plugs. CNGE recommends the use of aircraft style shielded plugs when shielded ignition systems are required.

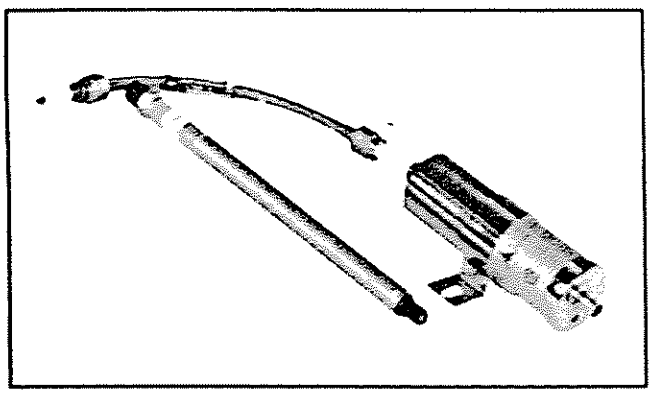


Photo #3-18 - Shielded Ignition System

Primer Valve

On low pressure systems, a gas primer is used to promote starting. CNGE uses two types of primer valves.

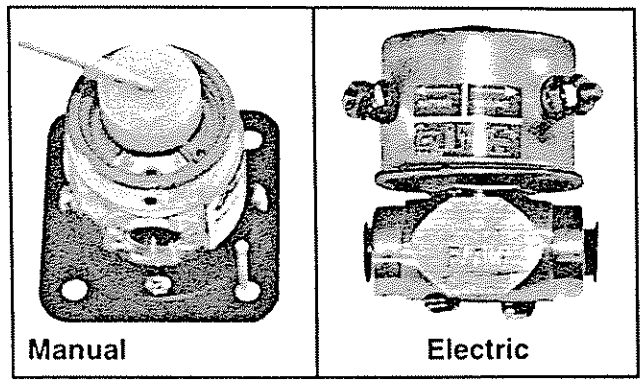


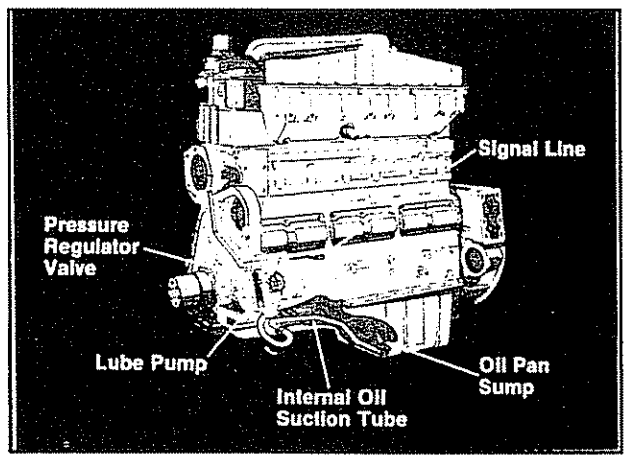
Photo #3-19 - Gas Primer Valve

THE LUBRICATION SYSTEM

Cummins Natural Gas Engines, Inc. engines are pressure lubricated. The pressure is supplied by a gear-driven positive displacement lubricating oil pump.

A pressure regulator is mounted in the lubricating oil pump housing to control lubricating oil pressure.

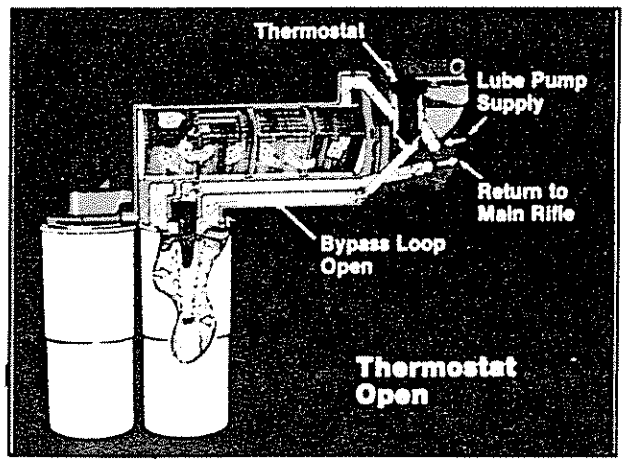
A by-pass valve is provided in the full-flow oil filter as insurance against interruption of oil flow by a dirty or plugged element.



Flow Diagram #3-20 - Lube Oil System GTA855-B

1. Oil is drawn into the pump through an external oil line connected to the oil pan on all G12, GTA12 and the small cam G/GTA855 engines.
   The GTA28, GTA19 and the GTA855-B (Big Cam III) engines use an internal oil suction line to the engine oil pump.

2. Oil flow on the twelve cylinder engines (GTA28) is from the oil pump to the engine mounted oil cooler directly into the engine mounted full flow oil filter. From the filter, the oil flows through the rear of the cylinder block to the main oil rifle. The oil then flows to each bank and to all moving parts within the engine.

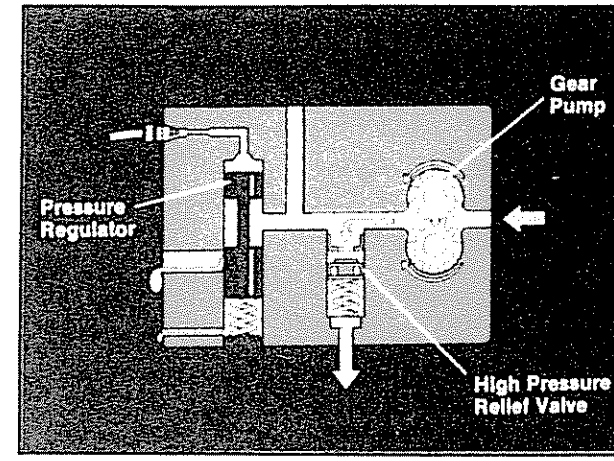


Flow Diagram #3-21 - Lube Oil System GTA855-B

3. Engine oil flow on four and six cylinder engines is from the pump through a full-flow filter back again into the pump casting, to the cylinder block, to the oil cooler, and then to the block cross drilling to the main oil rifle.

   An oil header, drilled the full length of the block on the accessory drive side, delivers oil to branch passages and on to moving parts within the engine.

   The filter is mounted directly to the rear of the pump or directly beneath the oil pump. On some models, the filter is mounted below the oil cooler package.



Flow Diagram #3-22 - Lube Oil System GTA855-B

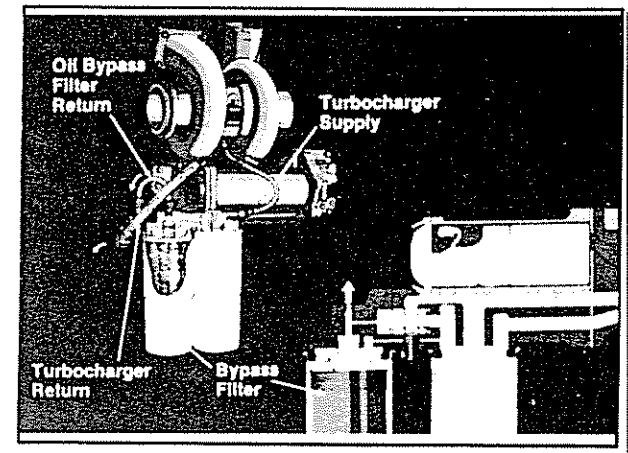


Photo #3-23 - Lube Oil System GTA855-B

4. Oil pipes, or a combination of pipes and passages, carry oil from the oil galley to the upper rocker housings and various drilling throughout the block, crankshaft, connecting rods, rocker levers, and oil spray nozzles completing the oil circulating system.

5. Lubricating oil pressure is controlled by a pressure regulator located in the lubricating oil pump casting.

6. Turbocharged engine applications at the high load factors when operating under a continuous or prime power rating may require a by-pass filter in the lubricating oil circuit. The addition of the by-pass filter will help remove the smaller wear particles that can create premature engine wear.

Lube Oil Specifications are in Section 7 & 17.

THE COOLING SYSTEM

On four and six cylinder engines, except the GTA19, coolant is circulated by a centrifugal-type water pump mounted in the block at the gear cover end and driven by a belt(s) from the accessory drive. The GTA19 has a gear driven water pump.

The water circulates through the water header around the wet-type cylinder liners and through the cylinder head. Discharge connections between the heads are provided by a water manifold.

The water manifold houses a single thermostat to control engine operating temperature.

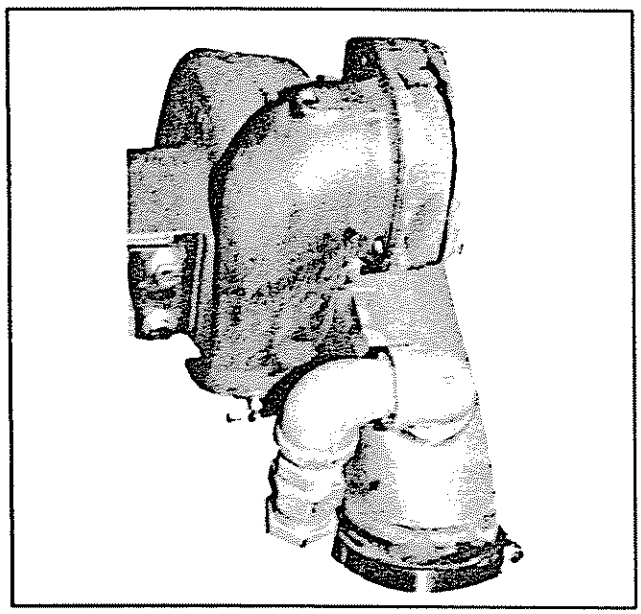


Photo #3-25 - GTA28 - Water Pump

On 12 cylinder engines, coolant is circulated by a centrifugal-type water pump mounted on the front of the engine and driven by belts from the accessory drive.

The coolant is drawn from the radiator or heat exchanger by the water pump and delivered to the oil cooler, then to the center of the block, through the ports, to the cylinder block water jackets and the cylinder heads.

Then, the coolant flows into a return header surrounding the water-cooled exhaust manifolds (if equipped). The hot exhaust quickly warms the cold water when the engine is started and keeps it warm during slow-speed and light-speed operations.

From the header, the water goes to the thermostat housing where it is directed to the radiator for cooling. If the water has not been heated sufficiently enough to actuate the thermostats (vented type), it will be directed through a by-pass tube to the water pump for recirculation.

The engine coolant is cooled by a radiator or by heat exchangers, depending on the type of installation.

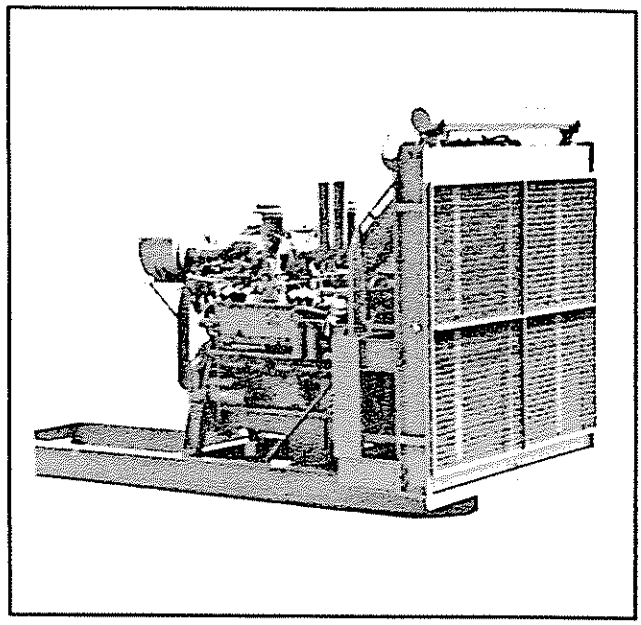


Photo #3-26 - GTA28 - Radiator

Irrigation Application

The cooling system on irrigation engines consists of a cooling coil in the product water discharge line. This enables the engine to have a cooling system, without the use of a radiator.

Aftercooler Circuit- Water to Air

Whenever water-cooled aftercoolers are used on turbocharged Cummin Natural Gas Engines, an auxiliary water pump circulates water through the aftercooler and its separate heat exchanger or radiator core.

Aftercooler Circuit- Air to Air

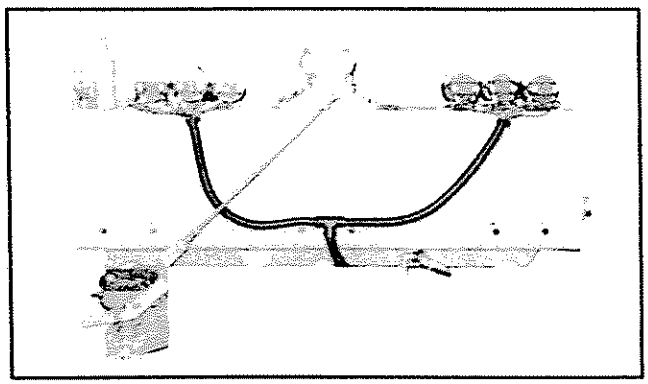
Several models of CNGE engines use an aftercooler section that uses an air-to-air section of the engine radiator package.

Cummins Natural Gas Engines, Inc. recommends that all cooling systems used on CNGE

engines be of a design that offers a deaerating feature with properly designed radiator top tanks or through the addition of auxiliary surge tanks. Both systems should contain fill lines to the suction side of the engine water pump and vent lines from the highest point of the engine cooling system before the thermostat.

For Coolant Specifications refer to Sections 6 & 17.

Photo #3-27 - GTA855 - Aftercooler



Cooling System Notes:

THE AIR SYSTEM

The required function of the air intake system is to supply clean, dry air to the engine without excessive restriction and at a temperature consistent with good engine efficiency.

The total system design should provide minimum intake restrictions to maintain an adequate air flow to the engine for good air-fuel mixture. Refer to your engine datasheet for allowable intake air restriction limits for your specific model.

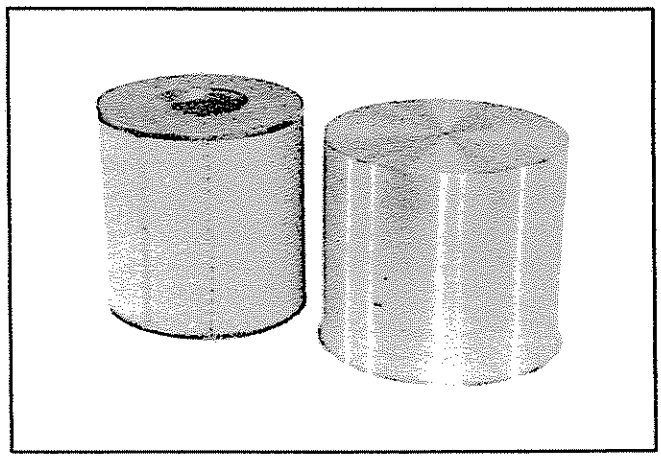


Photo #3-28 - Air Cleaner - Single Stage

The air cleaner is mounted on the engine. The engines, depending on the type of application, may use either a single stage or a two stage dry type paper element.

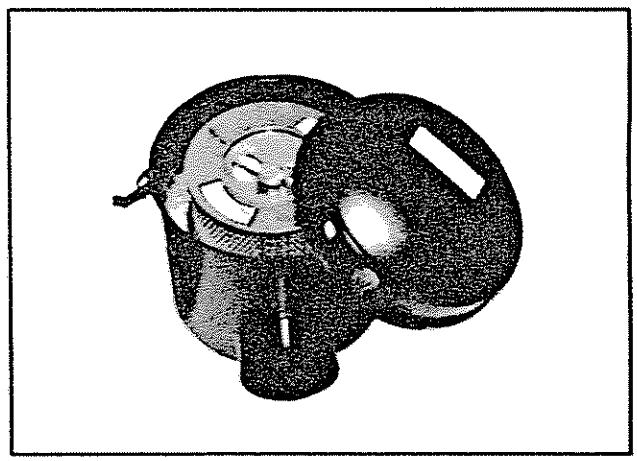


Photo #3-29 - Air Cleaner- Two Stage

Air is routed from the air cleaner directly to the carburetor, where it mixes with a metered amount of fuel gas and is dispersed into the intake manifold(s) and on into the cylinders.

On turbocharged engines with a low pressure system, the air will mix in carburetor before the turbocharger. On high pressure systems, the air will flow through the turbocharger and then to the carburetor for air fuel mixing.

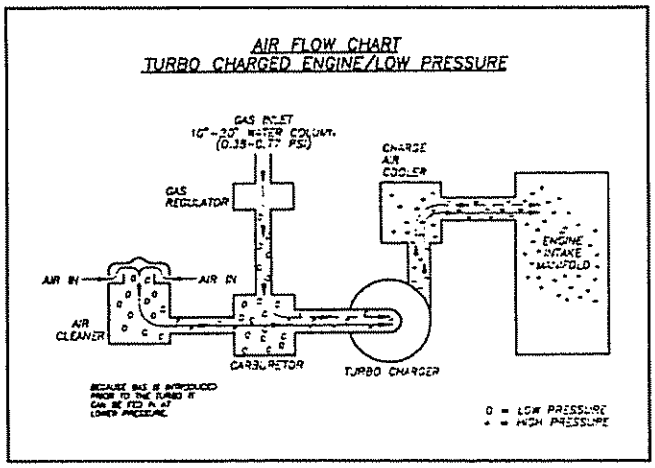


Illustration #3-30 - Low Pressure System

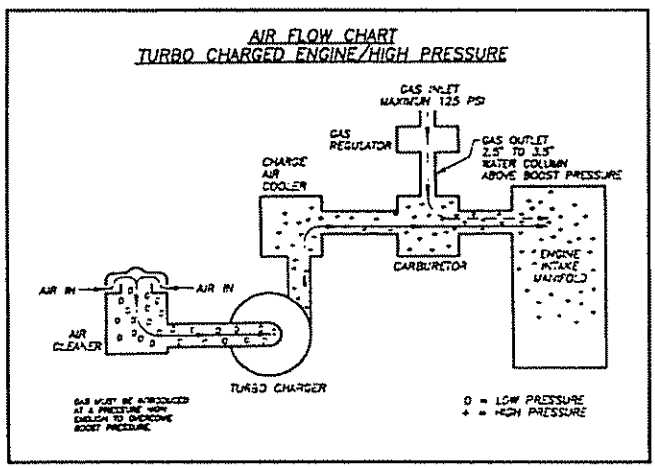


Illustration #3-31 - High Pressure System

Caution: Spark-Ignited Gas types of engines are more critical on air cleaner restrictions than diesels. As air cleaner restriction increases, the air-fuel mixture will become rich, increasing the combustion and exhaust gas temperature.

Air System Notes:

SECTION 4 - OPERATING INSTRUCTIONS

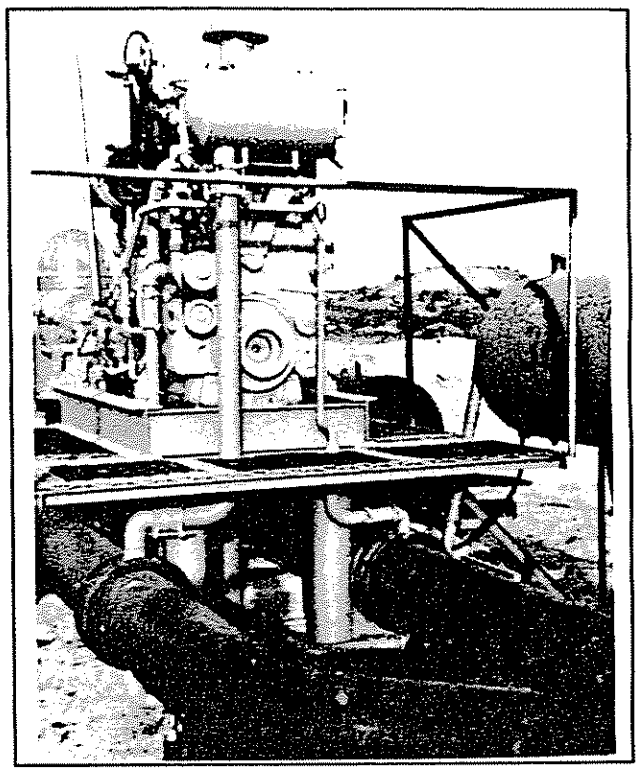
CONTENT

CUMMINS NATURAL GAS ENGINES, INC.
Start-Up & New Engine Inspection Claim

Claim #:_____ Engine Model:_____ C.R.: ___ Engine S.N._____

End User Customer Name:	Equipment Manufacturer:
Address:	Equipment Model:
City: State:	Equipment Serial #:
Country: Zip:	Application:
Engine Site Location:	Type of Fuel:
Engine Start-Up Readings: Mandatory Requirements	Altitude: Ambient:
1. Gas Pressure (inches of water). A. Regulator(Maxitrol RV)_____. B. Carburetor_____. 2. Ignition Timing @ Load ___BBTDC. 3. Exhaust Temperature ___F. (Taken @ Load @ manifold plug) 4. Engine R.P.M.: Idle___Load___. 5. Type of Oil:___Viscosity:___. 6. Engine Coolant Temperature: Top Tank @ Max. Load:____F. 7. Intake Manifold: A. Vacuum and/or Pressure: Idle____Load____(in.hg./ B. Temperature(F.)Idle___Load___	Optional Readings if engine is equipped with gauges. 1. Hourmeter Operating Hours:_____. 2. Oil Pressure: Idle___ Load___. 3. Oil Temperature: Load ____F. 4. Engine Jacket Coolant Pressure: Load: _____ (p.s.i.) Preferred Method for adjustment of Air/Fuel Power Valve is with an Oxygen Meter to record excess O2 in the downstream Exhaust System ___%
Safety Shutdown Settings:(If Avail. 1. Coolant Temperature: ___F. 2. Coolant Pressure: ___p.s.i. 3. Oil Pressure: ___p.s.i. 4. Intake Manifold Vacuum or Pressure: _____ hg./p.s.i. 5. Exhaust Gas Temperature:_____F. (@ Manifold prior to Turbocharger) 6. Overspeed Device: ___R.P.M. 7. Oil Level Shut-Off ___Yes___No	Inspection: Date: _____ (Mo/Dy/Yr) Inspection Performed By: Technical Representative:_____ Authorized CNGE Dealer):_____ Distributor:_____ Signature:_____ (Service Manager)
Customer Acceptance: Item: Yes No Was technician courteous? ___ ___ Was operation explained? ___ ___ Was maintenance covered? ___ ___ Was start-up performed to your satisfaction? ___ ___ Did you receive Operation & Maintenance manual? ___ ___ Was warranty explained? ___ ___ Did you receive a warranty certificate? ___ ___ Comments:_____ Signature:_____Date:_____	CUMMINS NATURAL GAS ENGINES, INC. 8713 Airport Freeway, Suite 315 Fort Worth, Texas 76180 (817) 581-7575 Fax (817) 581-4548

ORIGINAL - CUSTOMER



GENERAL - ALL APPLICATIONS

Correct care of your engine will result in longer life, better performance, and more economical operation.
Follow the daily maintenance checks listed in the Maintenance Guidelines in Section 5 of this manual.

Check the oil pressure indicators, temperature indicators, warning lights, and other gauges daily to make sure that they are operational.

Warning: DO NOT OPERATE A NATURAL GAS ENGINE IN LOCATIONS WHERE THERE ARE OR CAN BE COMBUSTIBLE VAPORS IN THE ATMOSPHERE. These vapors can be sucked through the air intake system and cause the air/fuel ratio to become excessively rich, which could elevate combustion and exhaust gas temperature.

Start-Up and Inspection

CNGE recommends that all new CNGE engines have a start-up and inspection by either the local Cummins distributor or an authorized CNGE dealer. This presents to the end user of the CNGE engine the opportunity to ensure that the engine is properly adjusted for the onsite conditions. Proper start-ups and adjustments will generally avoid having unnecessary premature failures.

In addition, it offers an opportunity for the end user operator to become familiar with the proper start-up and operation of the equipment. It also allows the end user to establish a source for proper supply of genuine service parts and maintenance supplies.

The Cummins distributor or dealer service representative will generally give the engine and its related systems a visual inspection looking for any items that will need to be adjusted or corrected before starting the unit. The service technician will check to ensure that all fluids such as lubrication oil, engine coolant, aftercooler coolant, etc. are at their proper levels. All belts will be checked to ensure that none are operating either too loose or too tight.

The engine will then be instrumented with the necessary gauges to measure some key parameters for future reference. The technician will start the unit following the instuctions covered in this section and will make final adjustments to the engine.

Final adjustments include, but are not limited to:

1. Confirming that the onsite load is within range of the specific engine.

2. Confirming with the customer that the engine rating is at the proper level for the type of fuel being used and for the specific altitude at the job site.

3. Measuring and adjusting ignition timing to the specific load, altitude and type of fuel used.

4. Adjusting the air/fuel ratio for the proper gas mixture required for the lowest exhaust gas temperature (EGT) within the proper load range.

5. Adjusting the turbo boost limiter (if equipped) to the site conditions.

6. Confirming that all equipment supplied by CNGE is working and that the following baseline readings will be recorded if the engine is equipped with the required gauges:

   .. Gas pressure to regulator
   .. Gas pressure to carburetor
   .. Ignition timing
   .. Oil pressure at idle RPM
   .. Oil pressure at rated RPM
   .. Engine coolant cylinder block pressure at load
   .. Engine coolant top tank temp at loaded conditions
   .. Intake manifold vaccum/pressure and temperature at idle & at load.
   .. Excess oxygen reading in exhaust gas at rated load and RPM
   .. Exhaust gas temperature at manifold at rated load and RPM
   .. Engine RPM at idle and at load
   .. Hourmeter reading
   .. Ambient temperature
   .. Altitude

7. If equipped with Safety Shutdowns, the service technician will confirm the set points and correct if required and if applicable.
   .. Water temperature
   .. Water pressure
   .. Oil pressure
   .. Intake manifold vacuum/pressure
   .. Intake manifold temperature
   .. Overspeed device
8. The engine dataplate will be stamped with the inspection date.
   At the conclusion of the inspection, the service technician will supply to the customer a copy of the inspection report that will later be filed with CNGE.

New and Rebuilt Engines Break-In

CNGE engines are run-in on dynamometers before being shipped from the factory and are ready to be put to work in applications such as emergency stand-by generator sets.

CAUTION: All CNGE engines do require an onsite adjustment to the engine at the time of installation. Refer to the Start-Up and Initial Inspection.

In other applications, the engine can be put to work after start-up and inspection, but the operator has an opportunity to establish conditions for optimum service life during the initial 100 hours of service by:

1. Operating the unit at no more than 75% of its rated load.
2. Avoiding operation for long periods of engine idle speed.
3. Avoiding operation at the maximum horsepower levels more than five minutes.
4. Developing the habit of watching the engine instruments closely during operation and reducing the load on the engine if the lubricating oil temperature reaches 121° C [250° F] or the engine coolant temperature exceeds 91° C [195° F].
5. Checking the oil level every 8 to 10 hours during the break-in period.

Pre-Starting Instructions - First Time

Priming Lubricating System - First Time

Note: On turbocharged engines, remove the oil inlet line from the turbocharger and prelubricate the bearing by adding 50 to 60 cc (2 to 3 oz.) of clean lubricating oil. Reconnect the supply line.

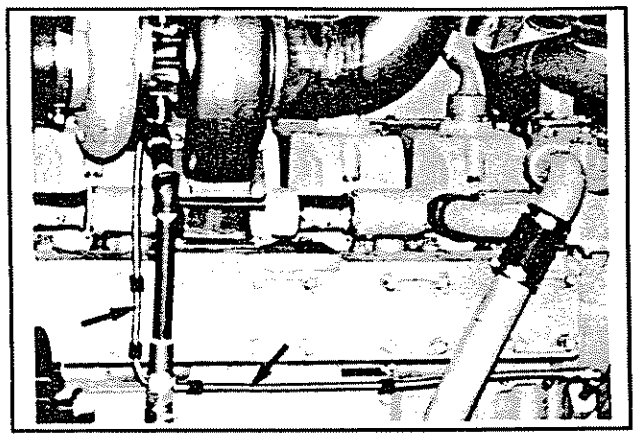


Photo #4-01 - Turbo Oil Supply Line

1. Fill the crankcase to the "L" (low) mark on the dipstick. Reference Lubricating Oil Specifications in Sections 7 and 17.

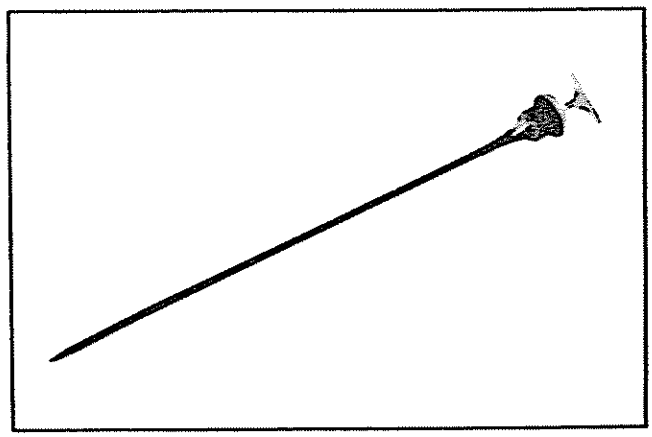


Photo #4-02 - Dipstick

2. Remove the plug from the lubricating oil crossover passage on G855 and GTA855 engines, Photo 4-03. Remove the plug from the head of the lubricating oil filter housing on the GTA28, Photo 4-04. On the GTA19, remove the plug from the front of the oil cooler housing,

Photo 4-05. The G12, and GTA12 engines can be primed at a similar location as the G855 and GTA855.

Caution: Do not prime the engine lubricating system from the by-pass filter.

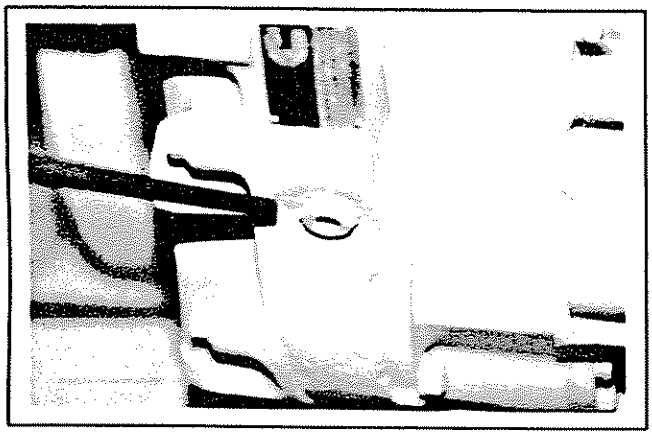


Photo #4-03 - Lube Oil Crossover G855/GTA855

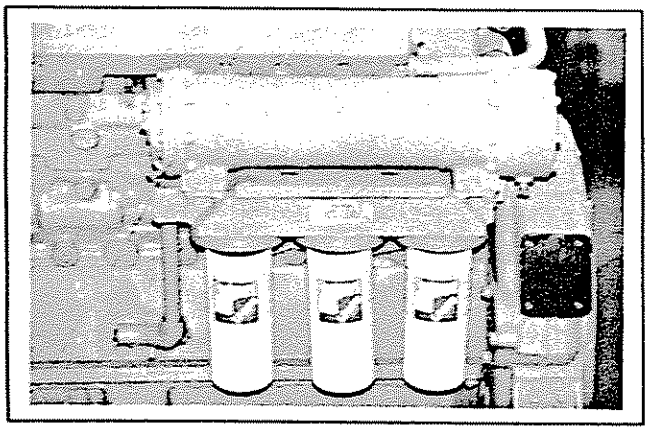


Photo #4-04 - Lube Oil Filter Housing GTA28

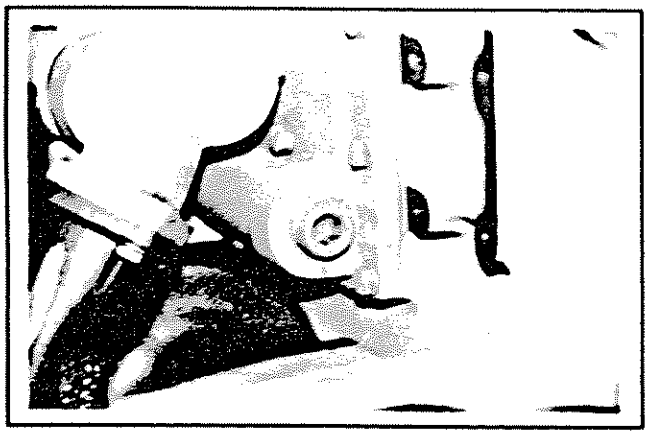


Photo #4-05 - Oil Cooler Housing GTA19

3. Connect a hand or motor-driven priming pump line from a source of clean lubricating oil to the plug boss in the housing.

4. Prime until a 207 kPa [30 psi] minimum pressure is obtained.

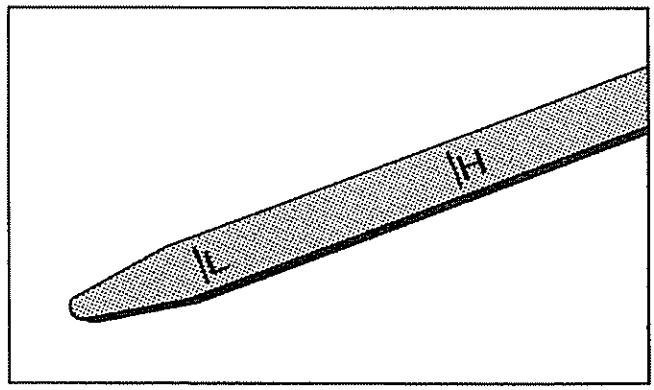
5. Check the oil reservoir on the oil lubricator if equipped with an air-gas starter.

6. Crank the engine at least 15 seconds with the ignition in the "off" position, while maintaining the external oil pressure at a minimum of 103 kPa [15 psi].

7. Remove the external oil supply and replace the plug. Tighten to the proper torque value.

Warning: Clean the area of any lubricating oil spilled while priming or filling the crankcase.

8. Fill the crankcase to the "H" (high) mark on the dipstick with the oil meeting specifications, listed in Section 17. No change in oil viscosity or type is needed for new or newly rebuilt engines.



Sketch # 4-06 - Dipstick, Low and High

Priming Lubricating System - Alternative Method

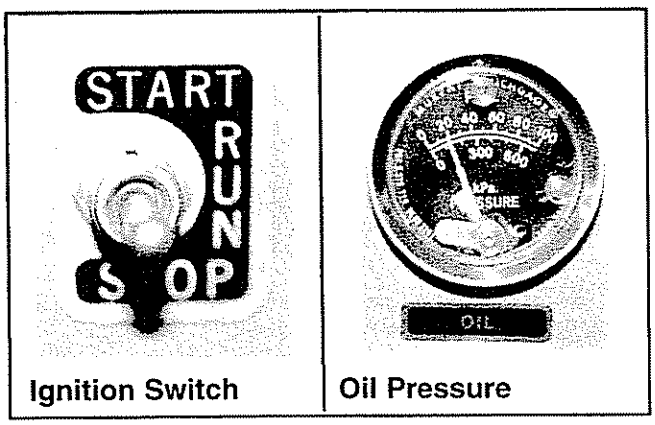
Caution: This method should not be used when priming the engine for the first time.

A dipstick oil gauge is located on the side of the engine. The dipstick supplied with the engine has a "H" (high) and "L" (low) level mark to show proper operating oil levels. The dipstick supplied with the engine is not interchangeable with other dip-

sticks supplied with similar engines for similar oil pans.

Always check the oil level when the engine has been stopped and sufficient time has passed for the oil to drain back to the engine crankcase.

1. Fill crankcase to the "H" mark on the dipstick. Refer to the Lubricating Oil Specifications in Section 17 under Specifications for proper lubricating oil.



Ignition Switch | Oil Pressure

Photo #4-07

2. Crank the engine for 15 seconds (with the ignition in the "OFF" position) until oil pressure appears on the gauge or the warning light goes out.
3. Refill crankcase to the "H" mark on the dipstick.

Caution: After the engine has run for several minutes, it will be necessary to add lubricating oil to compensate for the oil that is absorbed by the filter element(s) and oil cooler.

Check Hydraulic Governor

Many engines used in stationary power applications are equipped with hydraulic governors that use lubricating oil as an energy medium, same weight as used in the engine. Oil level in the governor sump must be at the full mark on the dipstick.

Note: Engine applications in a cold environment should use a lighter weight oil in the governor sump. Refer to the manufacturer's recommendations.

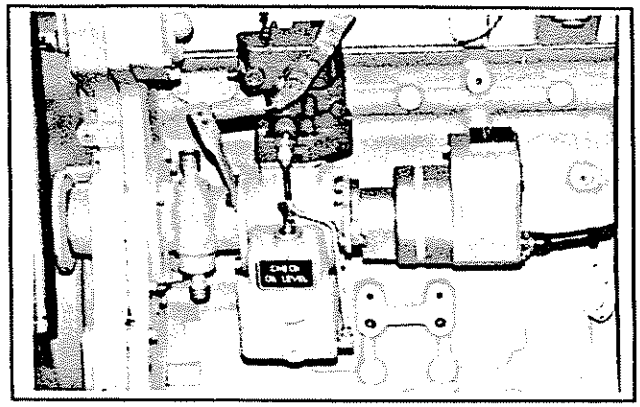


Photo #4-08 Governor Sump Housing

Check Air Connections

Check the air connections to any air equipment, if used, and to the air cleaners and air crossovers to assure that are all secure and have no damage.

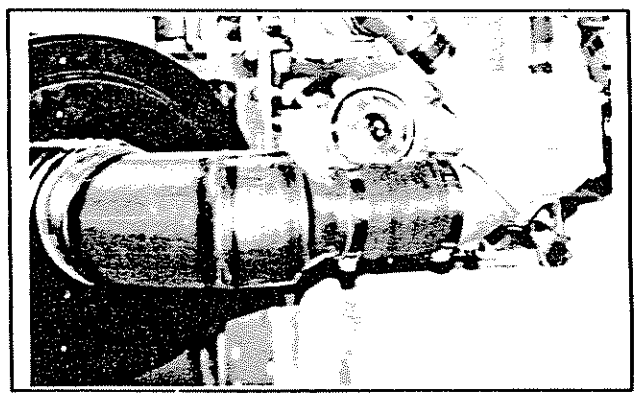


Photo #4-09 Air Connection

Check Engine Coolant Supply

1. Remove the radiator or expansion tank cap and check the engine coolant supply. On systems with a separate reservoir(s) for the aftercooler water circuit, check to see that they are properly filled. Add coolant to both systems as needed. See Sections 6 and 17 for coolant specifications.
2. Make a visual check for leaks and open the water filter shut-off valves.

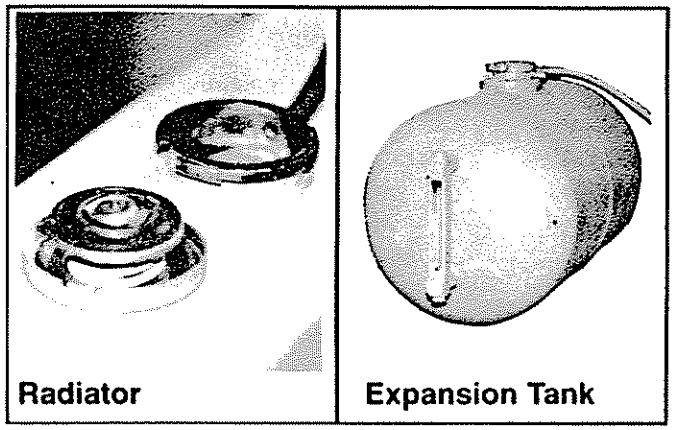


Photo #4-10 - Coolant Pressure Caps

Starting the Engine

Starting requires only that clean air and fuel are supplied to the combustion chamber in proper quantities and are spark-ignited at the correct time.

Normal Starting Procedure
(Above O° C [32° F])

Warning: Before starting, be sure that everyone is clear of the engine and the equipment. If the engine is equipped with an overspeed stop, push the "Reset" button before attempting to start the engine.

1. Check the lubricating oil level and engine coolant levels.

2. Set the throttle for idle speed.

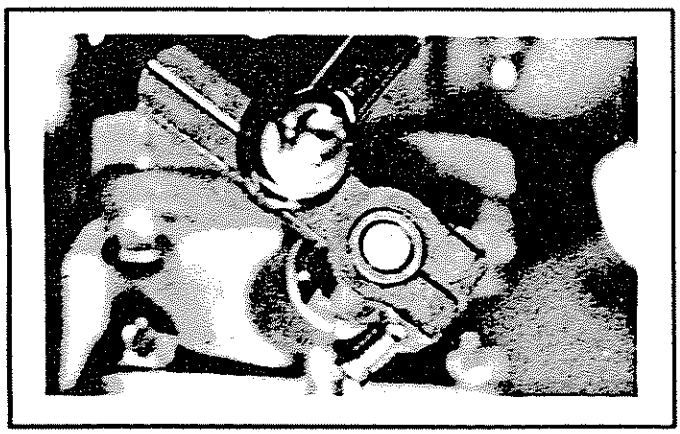


Photo #4-11 - Throttle Idle Speed

3. Disengage the clutch (if equipped) or open the main circuit breaker on generator set applications.

4. Open the gas supply shut-off valve.

5. If equipped with a Sentinel safety, turn off the cam on safety shut-off valve clockwise to the open position. The lever will lock in the open position. (It will return to normal position after the oil pressure rises.)

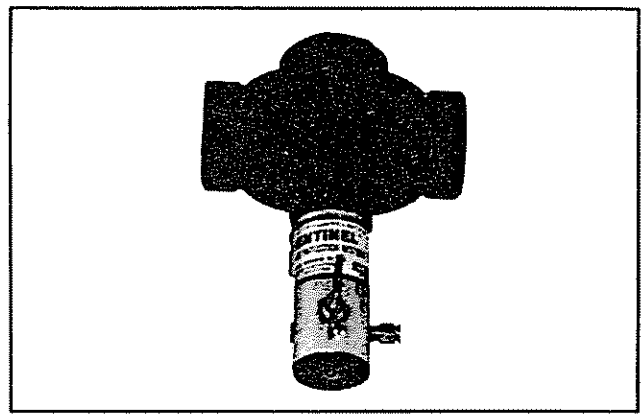


Photo #4-12 - Sentinel Safety

6. Push the "Reset" button on the instrument panel. On low pressure systems, a gas primer valve is used to promote starting. There are two types: 1) manual push button, and 2) electric solenoid.

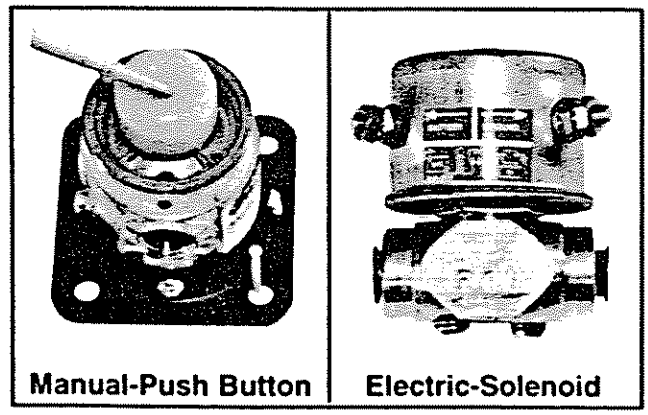


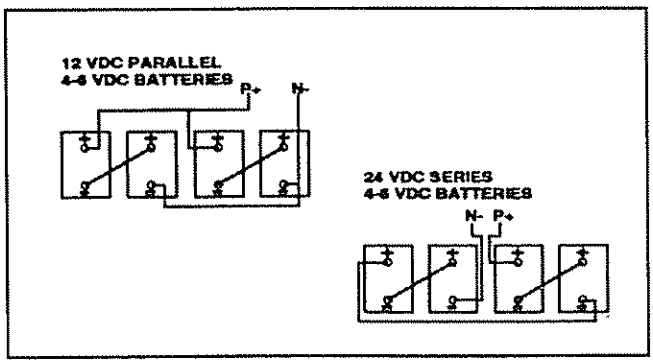
Photo #4-13 - Gas Primer Valves

The electric solenoid opens up when the starter is engaged and is used with the automatic start systems. Also, the electric solenoid primer valve can be used with a manual start 24 volt system. The manual push button type of primer valve must be engaged for 5 seconds before engaging starter. Both are located at the lower rear of the intake manifold.

7. Hold in the safety switch override button or turn the timer past 20 seconds and push the start button.

Caution: To prevent electric cranking motor damage, do not crank the engine for more than 30 seconds at a time. If the engine fails to start in the first 30 seconds, wait for two minutes before attempting to crank the engine again.

Caution: When using jumper cables to start the engine, make sure to connect the cables in parallel positive (+) to positive (+) and negative (-) to negative (-). When using an external electrical source to start the engine, turn the "disconnect" switch to the "OFF" position. Remove the key before attaching the jumper cables.



Sketch #4-14 - Battery Terminals

Note: Engines equipped with air-gas starting motors allow a maximum of 1035 kPa [150 psi] inlet pressure.

Warning: Caution should be taken when operating starters on gas because of the danger of fire, explosion, or inhalation.

8. Release the override button when the oil pressure gauge shows an increase in oil pressure. Oil pressure must be indicated within 15 seconds after starting.

9. Engage the clutch, if equipped, and run the engine at just above idle to allow the engine coolant to warm up. When starting a cold engine, increase the engine speed (RPM) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

Caution: Do not idle the engine for excessively long periods of time. Long periods of time (more than 10 minutes) can damage an engine.

10. Idle the engine no more than 3 to 5 minutes at 1000 RPM before applying the load or until the engine water temperature reaches 140° F (60° C). If the application permits, run the engine for the next 10 to 15 minutes or until the water temperature reaches 160 to 165° F (71.0° to 73.9° C) at a reduced load before applying full load.

Cold Weather Starting

Note: A jacket water and oil heater is recommended for stand-by emergency generator set applications installed in cold climate locations.

Engine Warm-Up

When the engine is started, it takes a while to get the lubricating oil film re-established between the shafts and the bearings and between the pistons and liners. The most favorable clearances between the moving parts are obtained only after all engine parts reach normal operating temperature. Avoid seizing pistons in liners and running dry shafts in dry bearings by bringing the engine up to operating speed gradually as it warms up.

On some emergency equipment, warm-up may not be necessary due to the equipment being housed inside a heated building. For an engine starting with a parasitic load, such as an emergency stand-by generator set, the coolant temperatures must be at a minimum of 49° C [120° F].

INSTRUMENT PANELS

Operate by the Instruments

Whatever the application, the operator must use the panel board instruments. The instruments show at all times the engine's operating characteristics.

Tachometer

Governed engine speed is the maximum rated RPM that a properly adjusted governor will allow the engine to turn under full load.

Never override the governor under normal operation or allow the engine to exceed the rated RPM during operation.

Water Temperature

A water temperature of 71° to 93° C [160° to 200° F] is the best assurance that the working parts of the engine have expanded evenly to the most favorable oil clearances. Maximum engine coolant top tank temperatures should not exceed 93° C [200° F].

Keep thermostats in the engine always, summer and winter, and avoid long periods of idling.

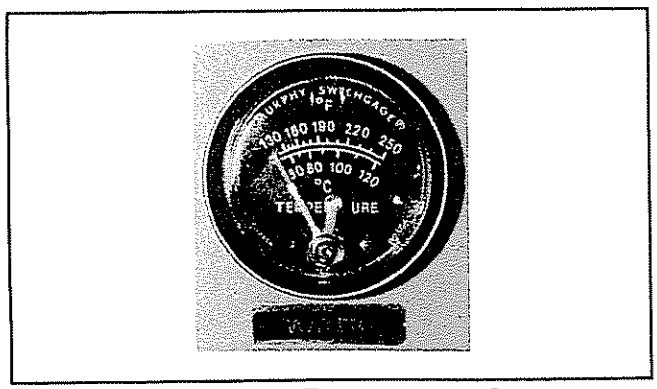


Photo #4-15 - Water Temperature Gauge

Never operate the engine at temperatures below 71° C [160° F]. If necessary in cold weather, use radiator shutters to assist in preventing overcooling.

Under stabilized operating temperature and for best results CNGE recommends an engine jacket water temperature of 88 to 91 C [190/195 F]. Overheating conditions indicate the need for mechanical correction. Excessive temperatures may be due to loose water pump belts, clogged radiator or heat exchanger cooling systems, excessive concentration of antifreeze in the coolant mixture or just insufficient cooling capacity for the operating load and associated ambient conditions. Report all cases of overheating to the maintenance department for corrections.

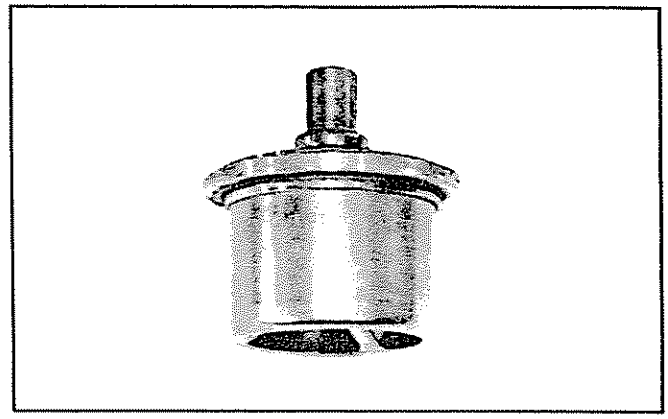


Photo #4-16 - Thermostat

Oil Temperature

The oil temperature gauge should read between 82° C [180° F] and 107° C [225° F] for best lubrication. Under full load conditions, a temperature of 116° C [240° F] for a short period is not to be considered a cause for alarm.

Caution: Any sudden increase in oil temperature that is not caused by an increase in load is a warning of possible mechanical failure and should be investigated at once.

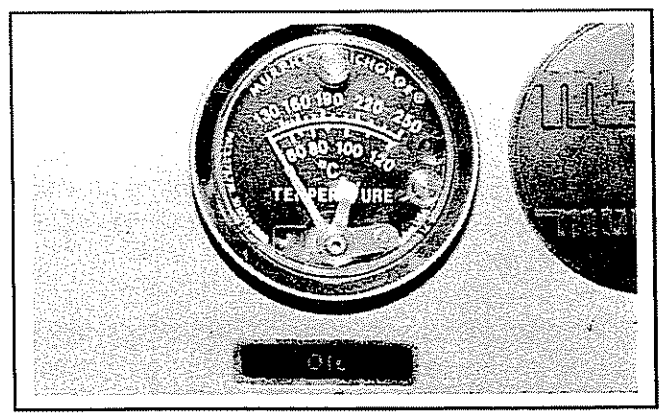


Photo #4-17 - Oil Temperature Gauge

During the warm-up period, apply the load gradually until the oil temperature reaches the 60° C [140° F]. While the oil is cold, it does not do a good job of lubricating. Continuous operation or long periods of idle with oil temperatures below 60° C [140° F] may cause a water and acid formation in the crankcase that will quickly accelerate engine wear.

Oil Pressure

The oil pressure gauge indicates the operating pressure in the lubricating oil system. Any sudden drop in oil pressure shows a mechanical malfunction in the lubricating oil system. The operator should take note of the loss of oil pressure and shut down the engine before major damage occurs.

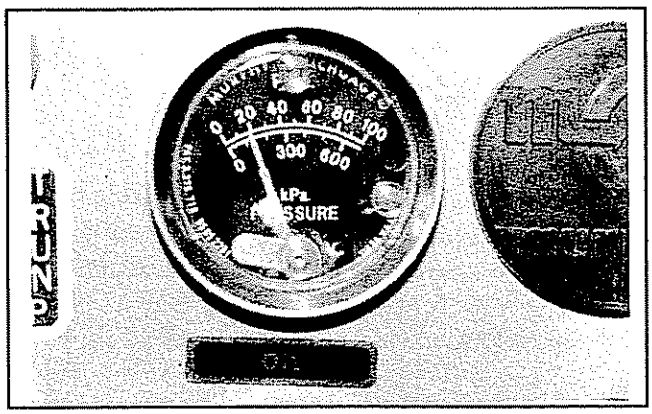


Photo #4-18 - Lube Oil Pressure Gauge

Table #4-19 - Operating Oil Pressure - Hot [kPa (psi)]

Engine Model	Idle Speed 900 RPM	RatedSpeed 1800 RPM	
		Min.	Max.
G12/GTA12	103[15]	310[45]	621[90]
G855/GTA855A	" "	" "	" "
GTA855B	" "	241[35]	310[45]
GTA19	138[20]	345[50]	483[70]
GTA28	" "	" "	621[90]

Note: Individual engines may vary from the above normal pressures. Observe and record pressures when the engine is to serve as a guide for indication of engine wear.

High Altitude Operation - De-Rating Requirements

Naturally Aspirated Engines

The engine may be operated at the **MAXIMUM or EMERGENCY STAND-BY RATING** up to 152m [500 ft.] altitude and 29° C [85° F] inlet air temperature, and at the **CONTINUOUS or PRIME POWER RATING** up to 457m [1500 ft.] altitude and 38° C [100° F] inlet air temperature. For sustained operation at high load factors at higher altitudes, the engine rating should be adjusted to limit performance by 3% per 305m [1000 ft.] altitude and 1% per 10° F inlet air temperature.

Altitude and temperature de-rating factors are to be considered as additive when temperatures exceed 85° F and when altitudes are over 500 ft.

Turbocharged Engines

The engine may be operated at the **MAXIMUM or EMERGENCY STAND-BY RATING** up to 914m [3000 ft.] altitude and 38° C [100 F] inlet air temperature, and at the **CONTINUOUS or PRIME POWER RATING** up to 1524m [5000 ft.] altitude and 38° C [100 F] inlet air temperature. For sustained operation at high load factors at higher altitudes and temperatures please consult the factory.

Altitude and temperature de-rating factors are to be considered as additive when temperatures exceed 100° F and when altitudes are over 3000 ft.

Engine Shut-Down

Let the engine idle a few minutes before shutting it down. Idle the engine 3 to 5 minutes before shutting it down to allow lubricating oil and water to carry heat away from the combustion chamber, bearings, shafts, etc.

Turn off the fuel-gas with either the automatic or manual shut-off valve and allow the engine to come to a complete stop. Next, turn the Ignition Switch to the "OFF" position.

The engine can be shut down by turning off the ignition switch on those engines equipped with a gas shut-off valve that is actuated by the ignition system. When the ignition switch is moved to the "OFF" position, the ignition system will also close the gas valve, shutting off the gas supply to the carburetor.

Stop the Engine Immediately if Parts Fail.

Practically all failures give some warning to the operator before the parts fail and ruin the engine.

Many engines are saved because an alert operator heeds warning signs (sudden drop in oil pressure, unusual noises, etc.) and immediately shuts down the engine.

A delay of ten seconds after a bearing failure may result in a ruined crankshaft or allow a block to be destroyed from a broken connecting rod.

Never continue to operate the unit after the engine indicates that something is wrong.

For operations that will not have an operator, the engines should be specified with the appropriate safety shutdown devices to protect the engine from unnecessary progressive damage. Consult your local Cummins distributor for details.

Cold Weather Protection

1. For cold weather protection, use a proper antifreeze and soft water mixture. CNGE recommends the use of Fleetguard's "Compleat"™ or a proper DCA4™ - Antifreeze - Water package.

Photo #4-20 - Fleetguard Compleat™

Refer to Coolant Specifications in Sections 6 and 17.

2. If an engine is to be shut down for an extend ed period during winter operating conditions, it is important to drain the engine cylinder heads, cylinder block, oil cooler, aftercooler cooling system (if used), and other water-cooled accessory, if used. Open all vent cocks and all petcocks on the top and side of the engine.

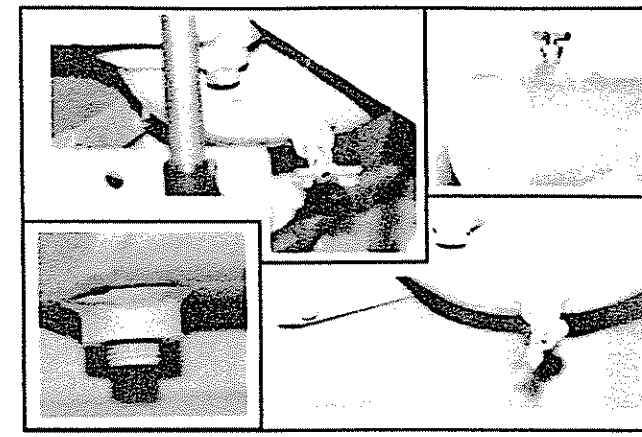


Photo #4-21 - Vent and Drain Petcocks and/or Drain Plugs

On the GTA28 engine, remove the drain plug in the water pump. Oil coolers may have to be removed to drain the cooler completely. Failure to drain any of these units may lead to serious freeze damage.

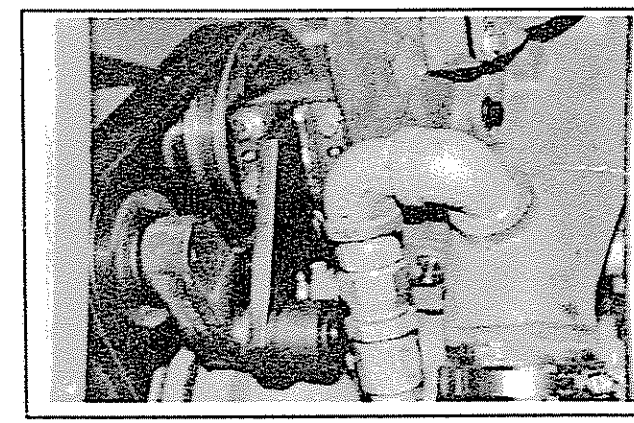


Photo #4-22 - GTA28 Water Pump Drain

Caution: On CNGE Water-to-Air Aftercooler systems, the aftercooler must be drained separately form the engine since it is a separate system. The aftercooler system also will need to be properly treated for freeze and corrosion protection.

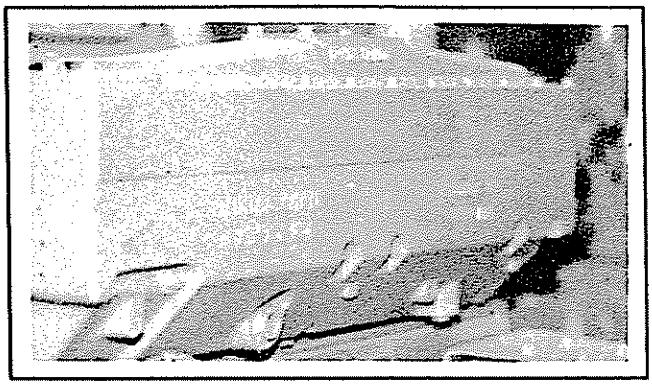


Photo #4-23 - Aftercooler

3. Immersion-type water and oil heaters are available for engines used in cold-weather operations and to maintain temperatures to permit the engine to operate at full load start-up.

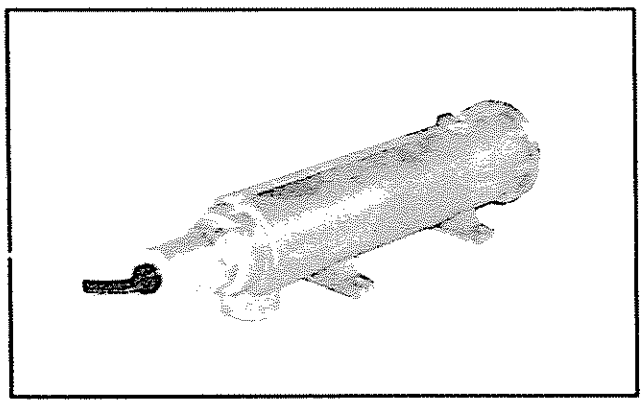


Photo #4-24 - Immersion-Type Heater

Engine Operation in Cold Weather

Satisfactory performance of a CNGE engine operating in low ambient temperature conditions requires modification of the engine, surrounding equipment, operating practices and maintenance procedures. The colder the temperatures encountered, the greater the amount of modification required; and yet with the modifications applied, the engines must still be capable of operation in warmer climates without extensive changes. The following information is provided to engine owners, operators, and maintenance personnel on how the modifications can be applied to get satisfactory performance from their natural gas engines.

There are three basic objectives to be accomplished:

1. Reasonable starting characteristics followed by practical and dependable warm-up of the engine equipment.
2. A unit or installation that is as independent as possible from external influences.
3. Modifications that will maintain satisfactory operating temperatures with a minimum increase in the maintenance of equipment and accessories.

If satisfactory engine temperature is not maintained, higher maintenance cost will result due to increased wear, poor performance and formation of excessive carbon, varnish, and other deposits. Special provisions to overcome low temperatures are definitely necessary. However, a change to warmer climate should normally require only a minimum of revision. Most of the accessories should be designed so that they can be disconnected so there is little effect on the engine when they are not in use.

Two of the most commonly used terms associated with low temperature operation are "Winterizing" and "Arctic" specifications.

Winterizing

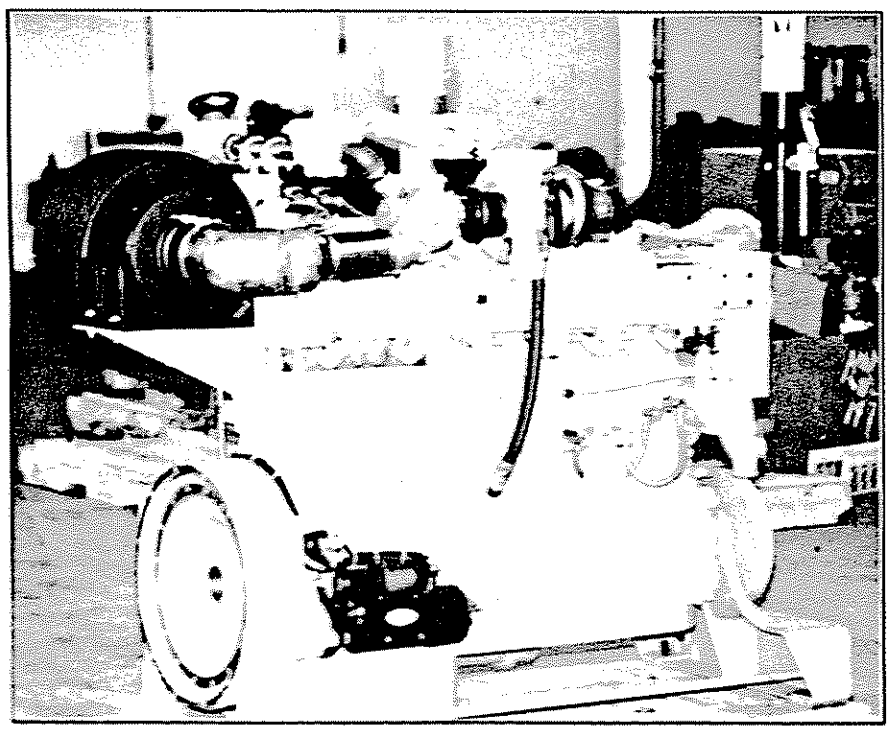
Winterizing of the engine or components so starting and operation are possible in the lowest temperature to be encountered requires:

1. Use of correct materials.
2. Proper lubrication, low temperature lubricating oils.
3. Protection from low temperature air. The rate of heat dissipation is effected from low temperature air.
4. Heating to be provided to increase the engine cylinder block and component temperature to a minimum of -32° C [-25° F] for starting in lower temperatures.
5. Proper external heating source.
6. Electrical equipment capable of operating in the lowest expected temperature.

Arctic Specifications

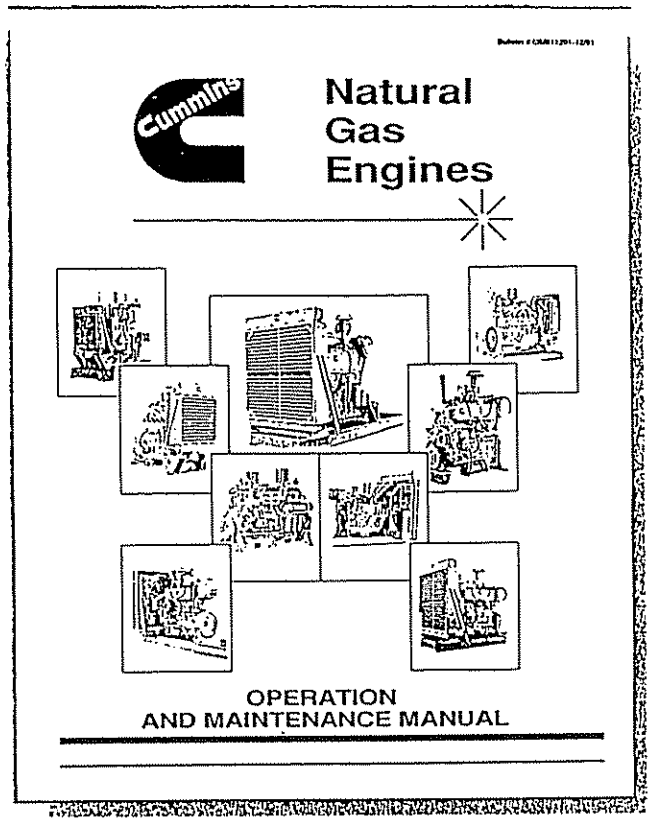
Arctic Specifications refer to the design material and specifications of the components necessary for satisfactory engine operation in extreme low temperatures to -54° C [-65° F]. Contact Cummins Natural Gas Engines, Inc. or the equipment manufacturer to obtain the special items required.

Reference Notes:



SECTION 5 - GAS ENGINE MAINTENANCE

CONTENT



Detailed Maintenance Schedule Index

GAS ENGINE MAINTENANCE

General

Maintenance is the key to lower operating costs. A CNGE engine requires regularly scheduled maintenance to keep it running efficiently. Good preventive maintenance will help in reducing unnecessary repair costs for repairs that occur because of either poor or no maintenance.

Upon investigation of successful operations where gas engines are used, you will find good, regularly scheduled maintenance programs in effect.

SCHEDULED MAINTENANCE

Preventive maintenance is the key to long engine life and low operating expense. If the engine is properly maintained, most potential problems can be corrected before causing a major unscheduled breakdown of the engine.

Accessories must be included in a maintenance program. Accessory failures may put an engine out of operation.

MAINTENANCE SCHEDULE

Use the following maintenance schedule as a guide to establish your specific maintenance program.
Engines operating in ambient temperatures consistently below -18° C [0 F] or above 38° C [100 F] should have maintenance performed at shorter intervals than those listed in these schedules. Shorter maintenance intervals are also required if the engine is operated in a dusty environment or if frequent starts and stops are made. Also, extended periods of idle may dictate the need for more frequent maintenance.

EXTENDING THE MAINTENANCE SCHEDULE

Extending maintenance intervals should be based on previous operational experience with the engine and through a good oil analysis program. Without these factors, caution should be used in extending maintenance intervals.

SERVICE TOOLS OR SPECIALIZED MECHANICS

Some maintenance procedures require special tools and should be performed by qualified personnel. These procedures and tools will be covered in your various engine shop manuals. CNGE use the Cummins Diesel Shop Manuals where appropriate.

For specialized gas engine tools, refer to Section 17.

DAILY CHECK

* Check operator's report.
* Check and bring to proper level:
  .. Engine Oil
  .. Engine Coolant
* Check for gas leaks and correct.
* Check Governor sump oil level.
* Visually inspect engine for damage, leaks, loose or frayed belts, loose hoses, and clamps and correct.
* Visually inspect radiator core externally for contamination and clean if required.

EVERY 250 HOURS, OR 6 MONTHS

* Change/Replace
  .. Lubricating Oil
  .. Lubricating Oil Filters
  .. Coolant Filter

* Check
  .. Engine Coolant DCA4™ concentration level. Add make-up DCA4™ if required.
  .. Check air intake system for wear points or damage to piping, loose clamps, and leaks.
  .. Check air cleaner restriction, element, and change if required.
  .. Shielded Spark Plugs (if used).

EVERY 750 HOURS, OR 6 MONTHS

* Adjust
  .. Valves, Crossheads

* Check
  .. Ignition Timing
  .. Compression
  .. Spark Plugs

* Clean
  .. Crankcase Breather

EVERY 1500 HOURS, OR 1 YEAR

* Check/Clean/Replace
  .. Spark Plugs
  .. Gas Fuel Filter

* Check Gas Pressure to Carburetor

* Check Carburetor Adjustment for Excess Oxygen Analyzer or Oxygen Meter.

EVERY 6000 HOURS, OR 3 YEARS

* Exchange/Rebuild
  .. Water Pump
  .. Fan Hub
  .. Water Pump Idler Pulley Assembly

* Inspect/Exchange
  .. Turbocharger
  .. Vibration Damper

* Check
  .. Cylinder Compression

ANNUAL

* Steam clean engine (if possible).

* Check torque on engine mounting nuts.

* Replace hoses as required.

* Clean cooling system (internally and externally) and change coolant and antifreeze (every 2 years).

SPECIAL NOTES

1. The maintenance interval may be adjusted based on a good oil analysis program.

2. At each scheduled maintenance interval, per form all checks in addition to the ones specified.

3. Replace the Vibration Damper at 15,000 hours.

4. Follow the manufacturer's recommended maintenance procedures for the Starter, Alernator, Generator, Batteries, Electrical Connections, Magnetos or Ignition Generators, Carburetors, Gas Regulators, Propane Convertors, Governors, and any other accessory item that may be supplied with your CNGE engine.

5. CNGE recommends that a daily log is maintained showing all maintenance performed.

MAINTENANCE SCHEDULE INDEX

DAILY CHECK

EVERY 250 HOURS, or 6 MONTHS

EVERY 750 HOURS, or 6 MONTHS

EVERY 1500 HOURS, or 1 YEAR

EVERY 6000 HOURS, or 3 YEARS

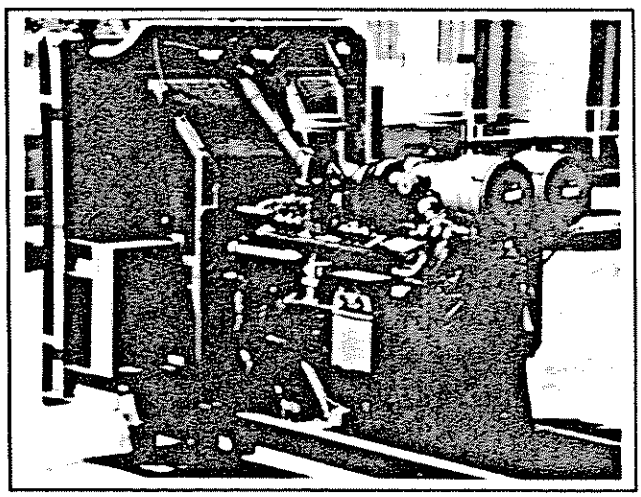
ANNUAL

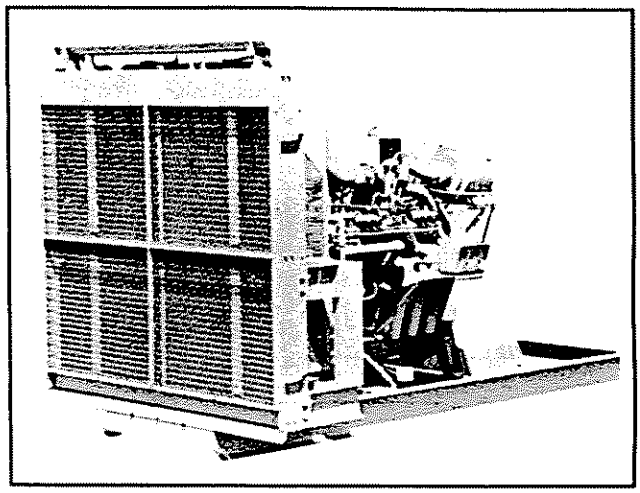
SPECIAL NOTES

MAINTENANCE NOTES

SECTION 6 - THE COOLING SYSTEM

CONTENT





THE COOLING SYSTEM

Cooling System Specifications

Specifications- Metric (U.S. Customary)	Engine Models			
	G12	GTA12	G855	GTA855-A
Coolant Capacity- Liters (U.S. Quarts)				
Engine System	19 [20]	23 [24]	21 [22]	21 [22]
Aftercooler System	NA [NA]	2.8 [3]	NA [NA]	2.8 [3]
Cylinder Block Maximum Coolant Water Pressure - Cap Removed [kPa (psi)]	241 [35]	241 [35]	276 [40]	276 [40]

Specifications- Metric (U.S. Customary)	Engine Models		
	GTA855-B	GTA19	GTA28
Coolant Capacity Liters (U.S. Quarts)			
Engine System	21 [22]	30 [32]	80 [85]
Aftercooler System	2.8 [3]	4.7 [5]	5.6 [6]
Cylinder Block Maximum Coolant Water Pressure - Cap Removed (kPa [psi])	276 [40]	241 [35]	241 [35]

Specifications- Metric (U.S. Customary)	ALL Engine Models
Maximum Allowable Top Tank Temperature C/F	93° C [200° F]
Coolant Alarm Activation Temperature C/F	96° C [205° F]
Minimum Recommended Pressure Cap [kPa (psi)]	48 [7]
Standard Thermostat Range C/F - Starts Open	79° [175° F]
Fully Open	91° [195° F]

Coolant Recommendations

Cummins engines require a balanced coolant mixture of water, antifreeze, and supplement coolant additives. This can be best accomplished by using Fleetguard's Compleat™. Compleat™ comes in either a concentrate mixture that is used with a high quality water or in a premix, where no additional water is required. Drain and replace the mixture every two years or 6000 hours, whichever occurs first.

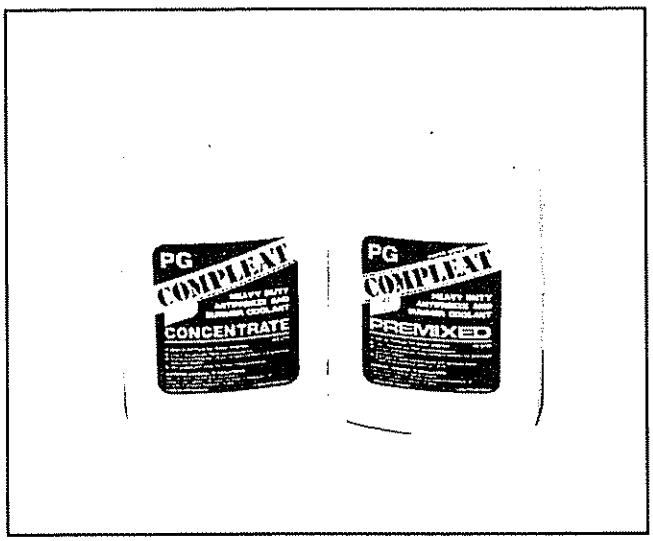


Photo #6-01 - Fleetguard's Compleat™

When not using Fleetguard's Compleat™,CNGE recommends the following:

1. DCA4™ is recommended for use in all Cummins engines.
2. In climates where the temperature is above -37°C [-34° F], use a coolant mixture that con tains 50% antifreeze. Antifreeze is essential in any climate. It broadens the operating temperature range by lowering the coolant freeze point and by raising its boiling point. Do not use more than 50% antifreeze in the mixture unless additional freeze protection is required.

Caution: Never use more than 68% antifreeze under any condition.

3. Use low silicate antifreeze that meets Engineering Standard GM 6038-M or that contains no more than 0.1 % anhydrous alkali meta-silicate and meets either Engineering Standard GM 1825-M or GM 1899-M that are performance specifications.
4. Use soft water in the coolant mixture. Contaminants in the hard water neutralize the corrosion inhibitor components. Water must not exceed 300 ppm hardness or contain more than 100 ppm of either chloride or sulfate.

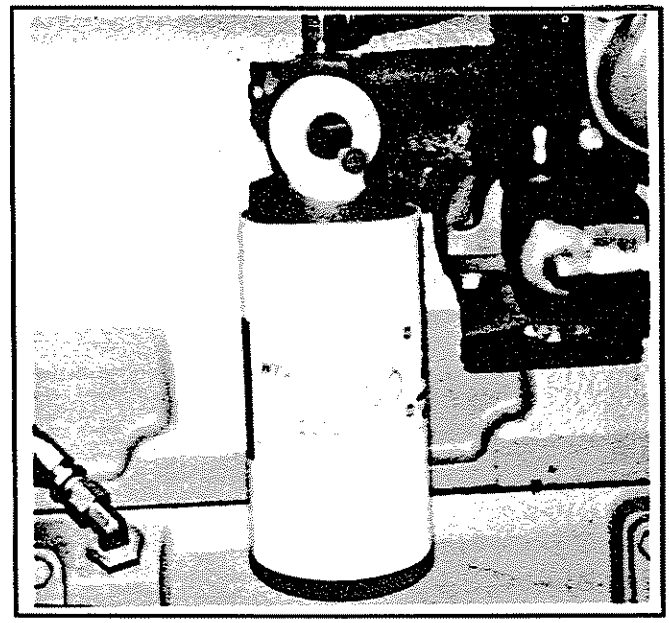


Photo #6-02 - Coolant Filter

5. Maintain supplemental coolant additive levels at 1 unit of DCA4™ per 3.8 liters [1 U.S. Gallon] of coolant by changing the coolant filter at each lubricating oil and filter change interval.

Cummins recommends the use of DCA4™ for the following reasons:

1. Improved compatibility with high-silicate antifreeze to minimize hydro-gel formation if overconcentration occurs.

2. Provides engine protection in the following areas:
   - Solder corrosion/bloom
   - Oil Fouling
   - Aluminum cavitation corrosion
   - Copper corrosion/erosion/stress cracking
   - Liner cavitation/corrosion
   - Seal and gasket degradation

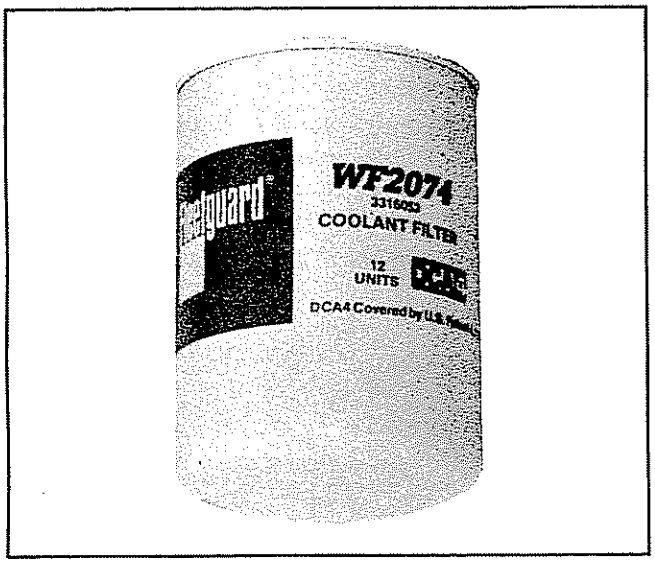


Photo #6-03 - DCA 4™Element

DCA4™ Unit Maintenance Guide

Use supplemental coolant additives (corrosion inhibitors) to protect the engine cooling system from corrosion. Antifreeze alone does not provide enough corrosion protection for a heavy duty natural gas engine.

Supplemental corrosion protection must be supplied through periodic additions of supplemental coolant additives to the coolant.

To protect against corrosion, a new coolant charge must be brought up to 0.26 DCA4 unit per liter [one DCA4 unit per U.S. Gallon] of coolant (initial charge). Maintain the correct DCA4 concentration by changing the maintenance coolant filter at each oil drain interval.

Each time the coolant is drained and replaced, the coolant must be recharged with supplemental coolant additives. Use the appropriate DCA4 spin-on filter listed Table #6-04. The mixture must be drained and replaced every two years or 6000 hours of operation, whichever comes first.

The amount of replacement inhibitor is determined by the length of the service interval and the coolant system capacity. Refer to Table #6-04 DCA4 ( ) Coolant Filter Service Chart for selection of the correct filter to replenish the DCA4.

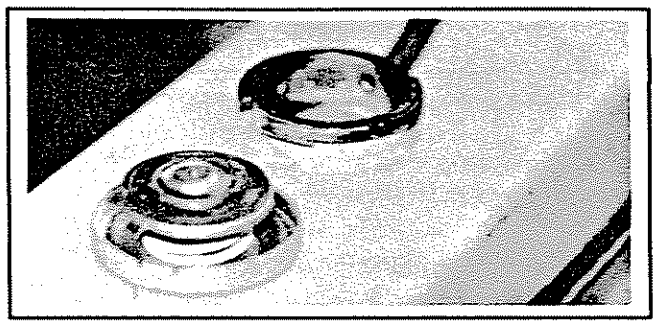
When using other supplemental coolant additives, refer to the manufacturer's instructions.

Table #6-04 - DCA4™ Coolant Filter Service Chart

Liters (Gallons) To Be Serviced	DCA4 Filter(s) To Use
19 - 34 [5 - 9]	WF2070
38 - 76 [10 -20]	WF2071
80 -114 [21 -30]	WF2072
117 - 190 [31 -50]	WF2073 or (2)WF2071
382-570 [101-150]	(2)WF2074

Coolant Level - Checking

Warning: **Do not remove the radiator cap from a hot engine. Wait until the temperature is below 50° C [120° F] before removing the pressure cap. Failure to do so can result in personal injury from heated coolant spray or steam. Remove the cap slowly to relieve coolant system pressure.**



Caution: Never use a sealing additive to stop leaks in the cooling system. This can result in cooling system plugging and inadequate coolant flow.

The coolant level must be checked daily.
Caution: Do not add cold coolant to a hot engine. Engine castings can be damaged. Allow the engine to cool to below 50° C [120° F] before adding coolant.

Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill or expansion tank. Do not fill the radiator fill tank above the bottom of the fill neck.

Note: Some radiators have two fill necks, both of which must be filled when the cooling system is drained.

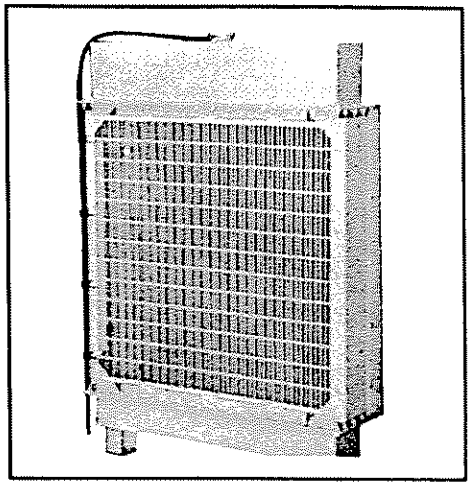


Photo #6-06 - Radiator

Fill the cooling system with the correct mixture of antifreeze, water, and the correct number of DCA4 units.

Coolant Filter - Replacement

Change the coolant filter or DCA4 corrosion resistor cartridge at every oil change.

The correct coolant filter to be used is determined by the total cooling system capacity and other operational factors.

Refer to the DCA4 Maintenance Guide earlier in this section for the correct filter selection.

Warning: **Do not remove the radiator cap from a hot engine. Hot steam will cause serious personal injury. Remove the coolant system pressure cap slowly and close the shutoff valve(s), if equipped, before removing the coolant filter. Failure to do so can result in personal injury from heated coolant spray.**

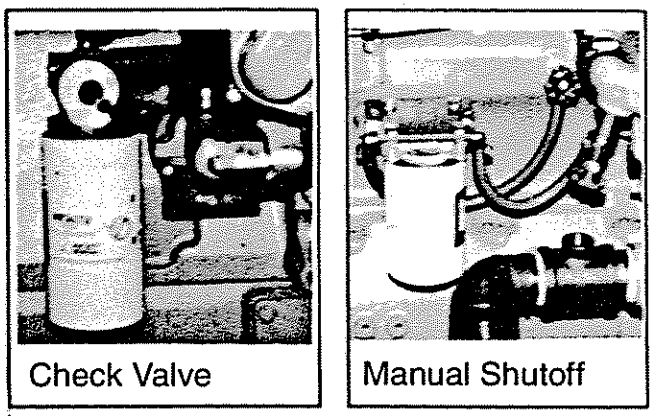


Photo #6-07 - Coolant Filter Valves

On some engine configurations, check valves are used to prevent coolant leakage while changing the filter. On other engine configurations, a manual shut-off valve is incorporated in the filter head.

Remove and discard the filter. Clean the gasket surface.

Apply a light film of lubricating oil to the gasket sealing surface before installing the coolant filter.

Caution: Mechanical overtightening can distort the threads or damage the filter head.

Install the filter as specified by the filter manufacturer.
Open the shutoff valve(s), if equipped, and install the coolant system pressure cap.

Cooling System - Cleaning, Coolant, and Antifreeze - Changing

Caution: Do not use caustic cleaners in the cooling system. Aluminum components will be damaged.

Every 2 years or 6000 hours, change the coolant or antifreeze.

The cooling system must be cleaned to work correctly. Drain the system, and flush with clean water. If the system shows mineral build-up, scale, rust, or oil, clean with a heavy duty engine coolant cleaner and follow the manufacturer's directions.

Fill the cooling system with the correct mixture of antifreeze, water, and the DCA4 units as outlined earlier in this section.

Warning: **Check the coolant level only when the engine is stopped. Wait until the coolant temperature is below 50° C [120° F] before removing the pressure cap. Failure to do so can cause personal injury from heated coolant spray.**

Operate the engine and check for coolant leaks. After the air has been purged from the system, check coolant level again.

Cooling Fan - Inspection

Warning: **Personal injury can result from a fan blade failure. Never pull or pry on the fan. This can damage the fan blade(s) and cause fan failure.**

Note: Rotate the crankshaft by using the crankshaft barring tools released and recommended by CNGE.

A visual inspection of the cooling fan is required daily. Check for cracks, loose rivets, and bent or loose fan blades. Check the fan to make sure it is securely mounted. Tighten the capscrews to the recommended capscrew torque as listed in the Technical Specifications in this manual. Replace any fan that is damaged.

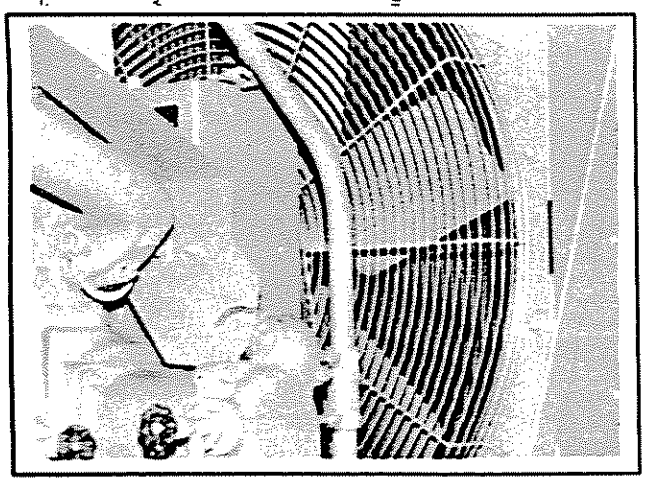


Photo #6-08 - Cooling Fan

Shutterstats and Thermatic Fans-Checking

Check the shutterstats and the thermatic fans anually.

Shutterstats and the thermatic fan controls must operate in the same temperature range as the thermostat with which they are used. Refer to Table #6-10 for proper Thermal Control Settings.

Thermostats and Seals - Checking

Remove the thermostats from the thermostat housings and check for proper opening and closing temperature.

All CNGE engines are equipped with a modulating range thermostat. It is considered a good practice to check the thermostat for opening and closing in the fall of each year.

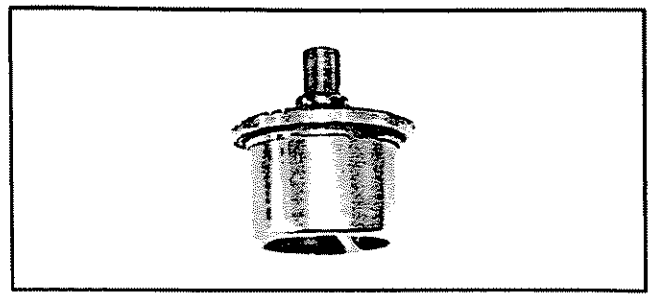


Photo #6-09 - Thermostat

Thermal Control Settings

Table # 6-10 - Thermal Control Settings

Control	Settings With Thermostat 160/175		170/185		180/195	
	O	C	O	C	O	C
Thermatic Fan	185	170	190	182	---	---
Shutterstat	180	172	185	177	195	187
Modulating Shutters Open	175		185		195	

Hoses - Checking and Replacement

Hoses and hose connections should be checked daily for leaks.

Annually inspect the cooling system hoses and hose connections for leaks and deterioration. Particles of deteriorated hose can be carried through the cooling system and slow or partially stop circulation.

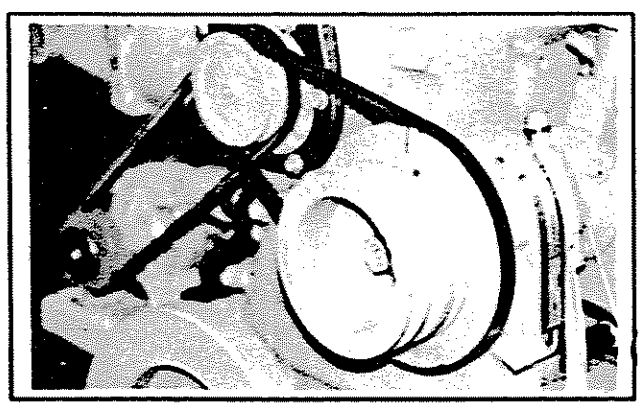


Photo #6-11 - Water Pump - GTA855-A

Water Pump - Inspection

Every 6000 hours or 3 years, whichever occurs first, inspect the water pump for drive pulley wobble and grease or water leakage around the water pump shaft. Replace the water pump with a new or rebuilt unit as necessary. Refer to the Cummins Troubleshooting and Repair Manual for removal and replacement instructions.

Auxiliary Water Pump - Inspection

Follow the manufacturer's recommendations for proper maintenance of the auxiliary water pump used on the aftercooled engines with the water-to-air aftercooling cooling systems.

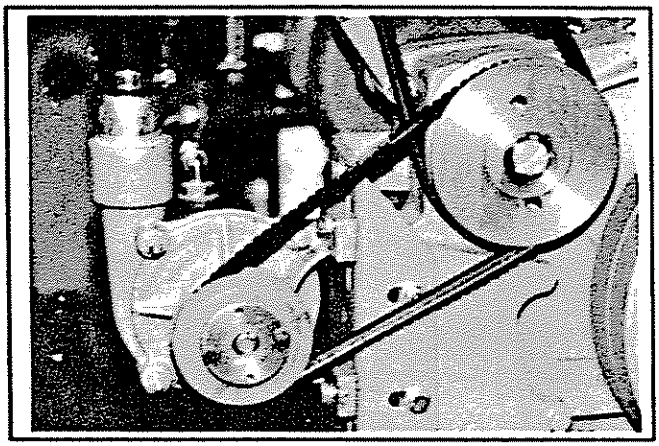


Photo #6-12 - Auxiliary Water Pump

Idler Pulley - Inspection

Every 6000 hours or 3 years, whichever occurs first, inspect the water pump idler pulley. Rebuild or replace the water pump idler pulley as necessary. Refer to the Troubleshooting and Repair Manual for rebuild or replacement procedures.

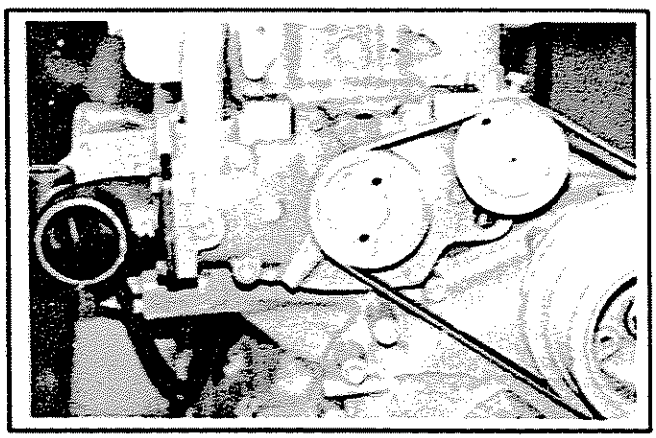


Photo #6-13 - Idler Pulley

Fan Hub (Belt Driven) - Inspection

Every 6000 hours or 3 years, whichever occurs first, inspect the fan hub for wobble and grease leakage. Replace with a new or rebuilt unit as necessary. Refer to the Troubleshooting and Repair Manual for removal and replacement instructions.

Radiator Core & Aftercooler Core (if equipped) - Inspect

The radiator or aftercooler core must be inspected daily for external damage and contamination. Blow out all insects, dust, dirt, and debris such as leaves, bits of paper, rags, etc. that may be on the front of the radiator or aftercooler core or lodged between the radiator/aftercooler and the cooling fins and tubes. Contamination of the radiator/aftercooler cores will affect the ability of the cooling system to transfer heat and properly cool the engine and intake manifold.

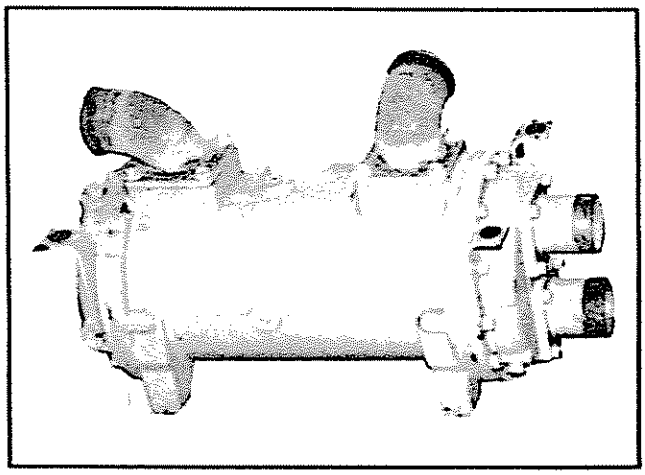


Photo #6-14 - Heat Exchangers

Caution: The aftercooler coolant temperature must be maintained below 32° C [90° F] with a 10.0:1 compression ratio and below 54° C [130° F] with an 8.5:1 C.R. piston.

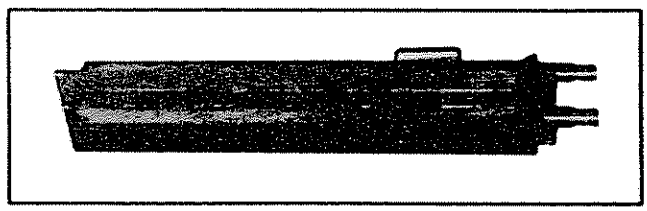
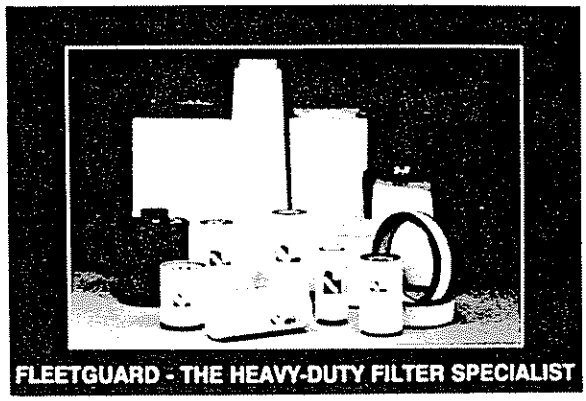
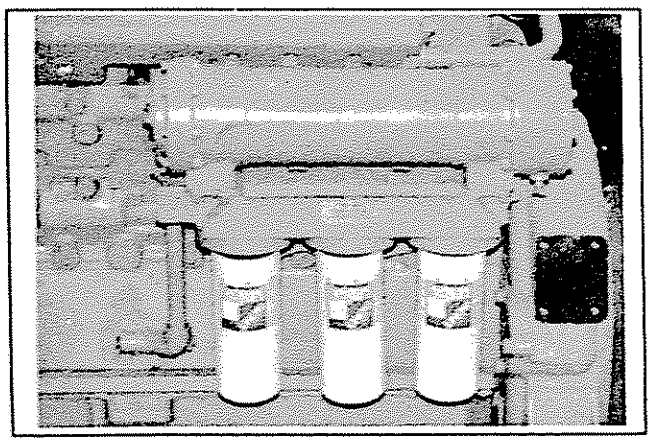


Photo #6-15 - Water-to-Air Aftercooler

SECTION 7- LUBRICATING SYSTEM

CONTENT





THE LUBRICATING SYSTEM

Lubricating Oil System Specifications

Specifications (Metric [U.S. Customary])	Engine Models			
	G12	GTA12	G855	GTA855-A
Oil Pressure [kPa (psi)]				
Minimum @ Idle	103 [15]	103 [15]	103 [15]	103 [15]
@ Governed Speed - Min.	345 [50]	345 [50]	345 [50]	345 [50]
(Max. RPM) Max.	483 [70]	483 [70]	483 [70]	483 [70]
Oil Capacity Standard Eng. Liters (Gallons)				
Oil Pan "H"	24.6 [6.5]	24.6 [6.5]	24.6 [6.5]	24.6 [6.5]
Oil Pan "L"	20.8 [5.5]	20.8 [5.5]	20.8 [5.5]	20.8 [5.5]
Full Flow Filter	3.785 [1]	3.785 [1]	3.785 [1]	3.785 [1]
By-Pass Filter (Replaceable Element)	11 [3]	11 [3]	11 [3]	11 [3]
Oil Temperature - Max.	107° C 225° F	107° C 225° F	107° C 225° F	107° C 225° F
Oil Consumption Limit Max. 1/hr. (Qt./hr.)	.24 [.25]	.24 [.25]	.24 [.25]	.24 [.25]

Specifications Metric (U.S. Customary)	Engine Models		
	GTA855-B	GTA19	GTA28
Oil Pressure [kPa (psi)]			
Minimum @ Idle	103 [15]	38 [20]	138 [20]
@ Governed Speed - Min.	241 [35]	345 [50]	345 [50]
(Max. RPM) Max. [kPa (psi)]	310 [45]	483 [70]	621 [90]
Oil Capacity Standard Eng. Liters (Gallons)			
Oil Pan "H"	34.1 [9]	37.9 [10]	68 [18]
Oil Pan "L"	26.5 [7]	32.2 [8.5]	61 [16]
Full Flow Filter	3.028 [.8]	3.785 [1]	11.355 [3]
By-Pass Filter (Replaceable Element) * Engine Mounted	* 2.81 [.73]	11 [3]	22 [6]
Oil Temperature - Max.	107° C 225° F	107° C 225° F	107° C 225° F
Oil Temperature - Max.	107° C 225° F	107° C 225° F	10° C 225° F
Oil Temperature - Max.	.24 [.25]	.31 [.33]	.47 [.50]

Engine Lubricating Oil

The use of a high quality lubricating oil combined with appropriate oil drain and filter change intervals is a critical factor in maintaining engine performance and durability.

Recommended Oil Specifications

Cummins Natural Gas Engines, Inc. recommends the use of a **high quality SAE 15W-40 heavy duty natural gas engine oil** that meets the **American Petroleum Institute (API)** performance classification **CE** or **CF-4**.

Note: CC/CD or CD/SF oils can be used in areas where CE oil is not yet available.

Note: In 1991, a new CF-4 oil will be released that will replace the CE classification. The new CF-4 oil requires oil to meet a new lower standard for piston crown deposits and for lower levels of oil consumption in the Cummins NTC 400 test. CF-4 oils can be used in place of CE.

A maximum sulfated ash limit of .85 mass percent or below is suggested for optimum valve and piston deposit and oil consumption control. **A minimum ash content of .15 mass percent is required for CNGE spark ignited engines.**

Caution: Some catalytic convertor manufacturers require that the sulfated ash content not exceed .5 mass percent. Also, certain additives can be harmful to the proper operation of a catalysis. Contact your respective catalytic convertor manufacturer for operation and maintenance requirements, as well as ash limit and other restrictions.

Arctic Operation

If an engine is operated in ambient temperatures consistently below -23° C [-10° F] and there are no provisions to keep the engine warm when it is not in operation, use a CE/SF engine oil with adequate low temperature properties such as a synthetic 5W-20 or 5W-30.

The oil supplier must be responsible for meeting the performance specifications required for natural gas engines.

Caution: The use of synthetic base oil does not justify extended oil change intervals. Extended oil change intervals can decrease engine life due to factors such as corrosion, deposits, and wear.

Photo #7-01 - Cummins Blue

New Engine Break-In Lubricating Oils

Special "break-in" engine lubricating oils are not recommended for new or rebuilt CNGE engines. Use the same type of oil during the "break-in" period that is used in normal operation.

Caution: A maximum sulfated ash limit of .85% has been placed on all engine lubricating oils recommended for use in CNGE gas engines. Higher ash oils can cause valve or piston damage and lead to excessive oil consumption.

Additional information regarding lubricating oil availibility throughout the world is available in the E.M.A. Lubricating Oils Data Book for Heavy Duty Automotive and Industrial Engines. The data book may ordered from:

Engine Manufacturers Association
One Illinois Center
111 East Wacker Drive
Chicago, Ill. U.S.A. 60601
Telephone: (312) 644-6610

Oil Level - Checking

Check the engine oil level daily.

Never operate the engine with the oil level below the **"L" (Low)** mark or above the **"H" (High)** mark. Wait at least 5 minutes after shutting off the engine to check oil. This will allow time for the oil to drain to the oil pan. The oil level should be as close to the "H" mark as possible.

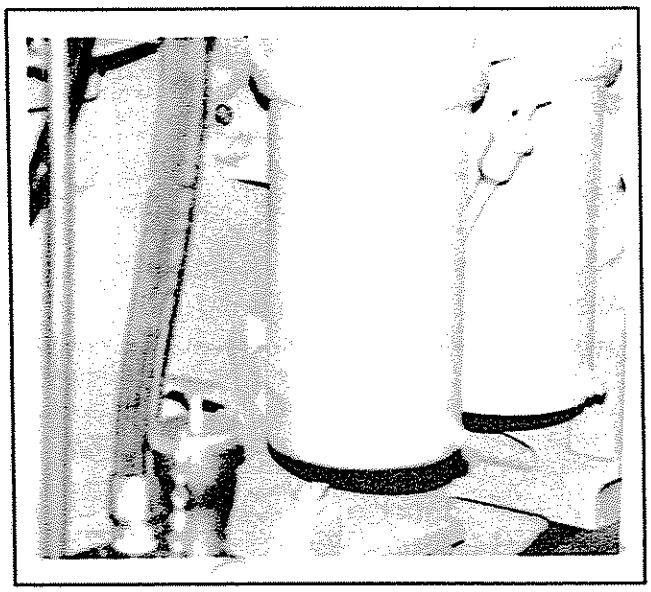


Photo #7-02 - Dipstick Location

Lubricating Oil and Filter Change Interval

Engine oil becomes contaminated, and essential oil additives are depleted with use. The amount of contamination is related to the total amount of fuel-gas and oil consumed.

There are two methods available to decide the oil drain interval:

1. Fixed number or hours or calendar time, whichever comes first as described in this manual in the maintenance schedule.

   Note: CNGE recommends the fixed oil change method for deciding the oil change period.

2. Utilization of a detailed oil analysis program.

As the engine oil becomes contaminated, essential oil additives are depleted. Lulbricating oils protect the engine as long as these additives are functioning properly. Progressive contamination of the oil between oil and filter change intervals is normal. The amount of contamination will vary depending on the type operation of the engine, the fuel-gas being consumed and the hours of operation.

Caution: Under no circumstances can the oil drain interval extend beyond 400 hours of operation or 6 months, whichever occurs first.
Extended oil drain intervals can decrease engine life due to factors such as corrosion, deposits, and wear.

Special Notes:

Oil Analysis Method

Laboratory Analysis

Laboratory analysis of engine oil can be used to establish oil drain/filter change intervals if a properly designed test and evaluation program is carried out. New oil must be anayzed before being put into an engine to establish baseline data. This oil must then be analyzed 150 hours, 250 hours, and then at 50 hour intervals not to exceed the maximum point of 400 operating hours.

If any of the samples show that the oil has failed to pass any of the ASTM test criteria, then the oil and filters in that engine need to be changed. Under no circumstnace does CNGE approve of extended oil change intervals that would exceed the maximum point of 400 operating hours.

The laboratory test should be repeated if either the brand of oil or type of oil is being changed, or if engine operational conditions change.

Following is a listing of the tests that must be performed and the guideline limits that must be followed. These tests were established by the American Society for Testing and Materials, ASTM.

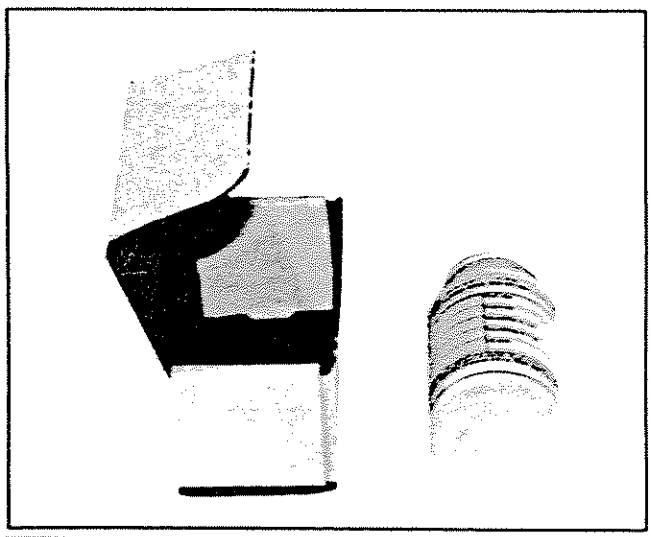


Photo #7-03 - Oil Analysis Kit

Table # 7-04 - Oil Analysis Test

Property	ASTM Method	CNGE Oil Guideline Limit
Viscosity @ 40 & 100 C	D445	+ or - 1 SAE Grade
VI	D2270	
Sulfated Ash	D874	.85% Max. .15% Min.
Insolubles	D893/GCM359	1.0% Max.
Total Acid Number	* D664	2.5 Number Increase Above New Oil
Total Base Number	D664/D289	2.5 minimum or 50% Reduction of New Oil or equal to TAN number, whichever is reduced first.
Water Content	D95	.2% Max.
Additive Reduction	AES or AAS	25% Max.

* The most **CRITICAL TEST** for the Natural Gas or Propane Engines.

In addition, CNGE recommends that the following infra-red analysis be used when measuring either Nitration or Oxidation of the Oil.

Nitration	The maximum for nitration should not exceed 20 absorbance units/cm at a wave number of 1630.
Oxidation	The maximum for oxidation should not exceed 20 absorbance units/cm at a wave number of 1710.

Special Note: The guideline limits specified in Table #7-04 should be used to decide the useful life of the specific oil under test. This group of analyses and the methods recommended are not generally part of the oil analysis offered by most commercial laboratories.

These analysis are not low cost tests and can run to a very high level of cost on an individual sample basis.

High Nitration or Oxidation will cause an oil degradation to occur that generally leads to the oil becoming thicker and forming a lacquer and maroon colored deposits. In both cases, the oil change interval must be lowered. In the case of high nitration, the air-to-fuel ratio may have to be adjusted. Engines that have been optimized for the maximum fuel economy will be running at an air-to-fuel ratio that will tend to produce higher nitrous oxide (NOx).

Adjustments to the air-fuel ratio should be done with caution since changes to reduce NOx may lead to a reduction of power or an increased in Exhaust Gas Temperature, affecting service life of the engine.

Spectrographic (Spectrochemical) Analysis

Spectrographic analysis determines only the wear metals and particulate matter level in lubricating oil. Therfore, Spectrographic analysis alone should not be used to decide the oil change interval.

Change the oil and the filters to remove the contaminants suspended in the oil.

Lubricating Oil and Filter - Changing

Change the lubricating oil and filter(s) at every oil change.

Warning: **Avoid direct contact of hot oil with your skin. Hot oil can cause personal injury.**

Reduce the load and operate the engine until the water temperature reaches 60° C [140° F]. Shut off the engine. Remove the oil immediately to make sure all the oil and suspended contaminants are removed from the engine.

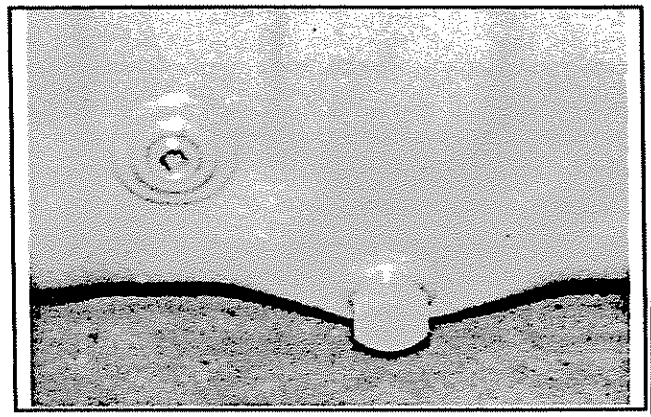


Photo #7-05 - Oil Pan Drain Plug

Note: Your local oil companies may have a process for disposal of contaminated oil. Check with them for details.

Clean the area around the lubricating oil filter head. Remove the filter. Clean the gasket surface of the filter head.

Note: The o-ring can stick on the filter head. Make sure it is removed.

Photo #7-06 - Lube Oil Filter - Spin-On LF-670

All CNGE engines are equipped with one of more of the following filters:

Full Flow Filters

Cummins Part No. 299670
Fleetguard Part No. LF-670 (Spin-On)
Cummins Part No. 158139
Fleetguard Part No. LF 516 (Cartridge)

Combination Filter (Full Flow and By-Pass)

Cummins Part No. 3318853
Fleetguard Part No. LF-3000

By-Pass Filter - Engine Mounted

Cummins Part No. 3304232
Fleetguard Part No. LF-777

By-Pass Filter - Remote Mounted

Cummins Part No. 256838
Fleetguard Part No. LF750

Caution: Fill the oil filters with clean lubricating oil. The lack of lubrication during delay until the filters are pumped full of oil is harmful to the engine.

Apply a light film of lubricating oil to the gasket sealing surface before installing the filters.

Caution: Mechanical over-tightening can distort the threads or damage the filter element seal.

Install the filter as specified by the filter manufacturer. Check and clean the oil drain plug threads and seal surface. Install and tighten the oil drain plug.

Torque Value: 65 ft-lbs (90 N*m)

Note: Use a **high quality 15W40 multi-viscosity natural gas engine oil.** Choose the correct oil as follows:

ENGINES	CLASSIFICATION
Turbocharged	CE/SF/CF-4
Naturally Aspirated	CC/CD/CE/SF/CF-4
Ash Content	- Minimum .15% - Maximum .85%

Fill the engine with clean oil to the correct level. Total system capacity for CNGE engines is listed earlier in this section.

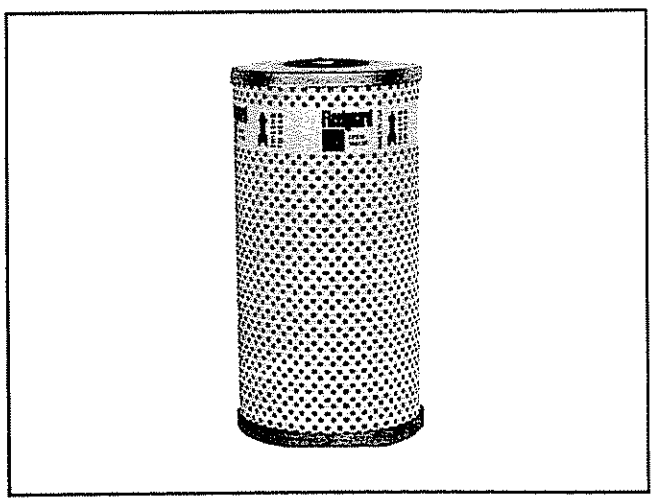


Photo #7-07 - Full Flow Cartridge

Change the LF-777 Lubricating Oil Spin-On By-Pass Filter

1. Unscrew the spin-on filter from the filter he and discard the filter element.
2. Apply a light even coat of lubricating oil to the gasket sealing surface, prior to installing filter.
3. Position the filter to the filter head. Tighten by hand until the seal touches the filter head and then tighten one additional turn.
4. Run the engine, check for leaks, shut down the engine. Add oil as necessary to bring the oil level to the "H" mark on the dipstick.

Change Lubricating Oil By-Pass Filter Element

Note: By-pass filters may be mounted either vertically, horizontally, or inverted. All are serviced in a like manner.

1. Remove the drain plug and drain oil.
2. Remove the clamping ring capscrew and lift off the cover.
3. Unscrew the support hold-down assembly and lift out the element and the hold-down assembly. Discard the element.
4. Clean the housing and the hold-down assembly in solvent.
5. Inspect the hold-down assembly spring and seal. Replace if damaged.
6. Inspect the drain plug and connections. Replace if damaged.
7. Check the orifice plug inside the oil outlet connection or standpipe. Blow out with air to open and clean.
8. Check the filter cover o-ring. Replace if necessary.
9. Install the new element in the housing.
10. Replace the support hold-down assembly the filter and tighten down to stop.

11. Position the o-ring seal on the housing flange.

12. Install the cover and clamping ring. Tighten the capscrews until the clamping lugs are indexed.

13. Run the engine, check for leaks. Add enough extra oil to the crankcase to fill to the "H" mark on the dipstick.

Caution: Before starting the engine, complete the steps given in "Priming Lubricating System - Alternative Method" under Operating Instructions to make sure the engine receives correct lubrication. Lack of lubrication will damage the engine.

Operate the engine at idle speed to inspect for leaks at the filters and the drain plug.

Shut off the engine. Wait for approximately 5 minutes to let the oil drain from the upper parts of the engine. Check the oil level again.

Add oil as required to bring the oil level to the "H" (High) mark on the dipstick.

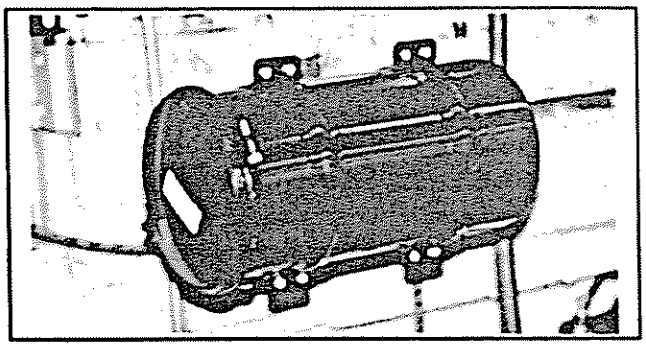


Photo #7-08 - By-Pass Filter

Special Notes:

Reference Notes

SECTION 8- AIR INTAKE SYSTEM

CONTENT

Air Intake System Specifications

Caution: Engine intake air must be filtered to prevent dirt and debris from entering the engine. If intake air piping is damaged or loose, unfiltered air will enter the engine and cause premature engine wear.

Maximum temperature rise between ambient air and engine air inlet (ambient above 0°C [32° F] - - - - - - - - - - - - - - - 15°C [30° F]

Maximum inlet restriction (clean filter)
Light duty element - 127 mm H_2O [10in. H2O]
Heavy duty element - 254 mm H_2O [15 in. H2O]

Maximum inlet restriction (dirty filter)
Light duty element - 254 mm H_2O [10in. H2O]
Heavy duty element - 381 mm H_2O [15 in. H2O]

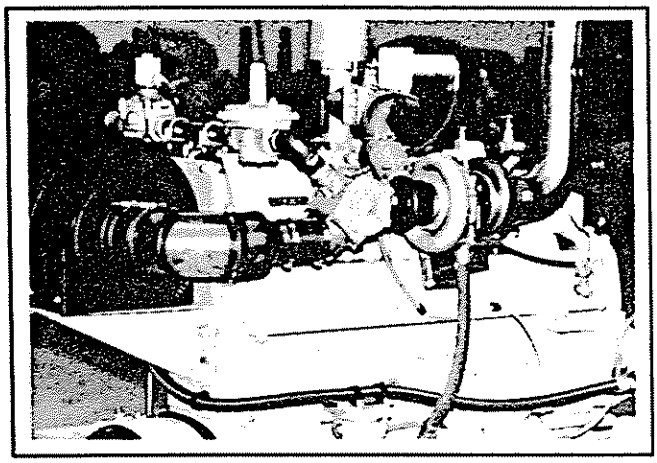


Photo #8-01 - GTA12/GTA855-A/B

Air Intake System - Inspection

Every 250 hours or 6 months, whichever comes first, inspect the intake piping for cracked hoses, loose clamps, or punctures that can damage the engine.

Tighten or replace parts as necessary to make sure the air intake system does not leak.

Check for corrosion of the intake system piping under the clamps and hoses. Corrosion can allow corrosive products and dirt to enter the intake system. Disassemble and clean as required.

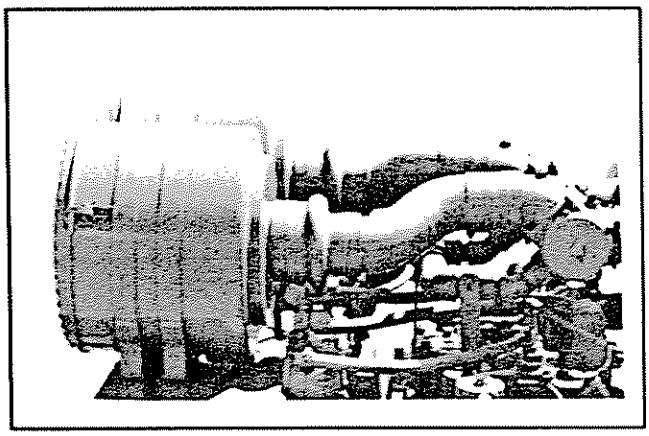


Photo #8-02 - GTA28

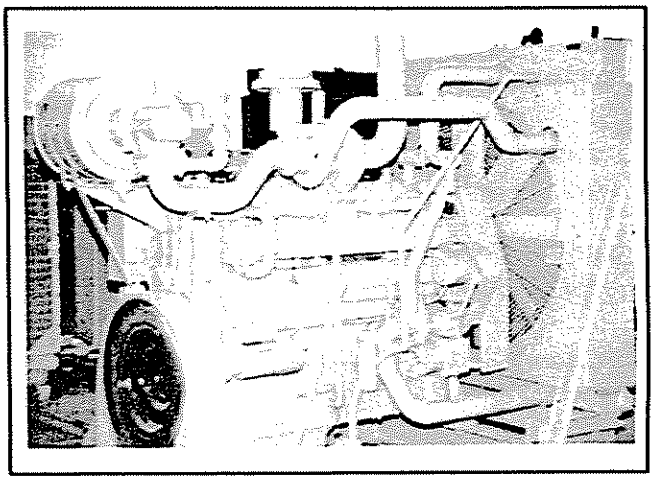


Photo #8-04 - GTA19

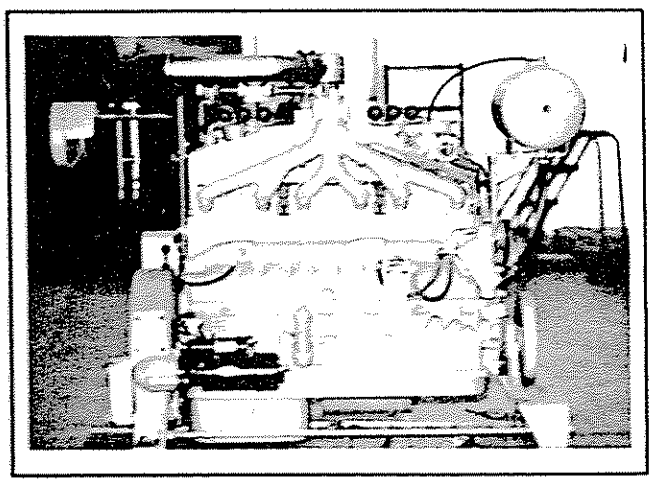


Photo #8-03 - G12/G855

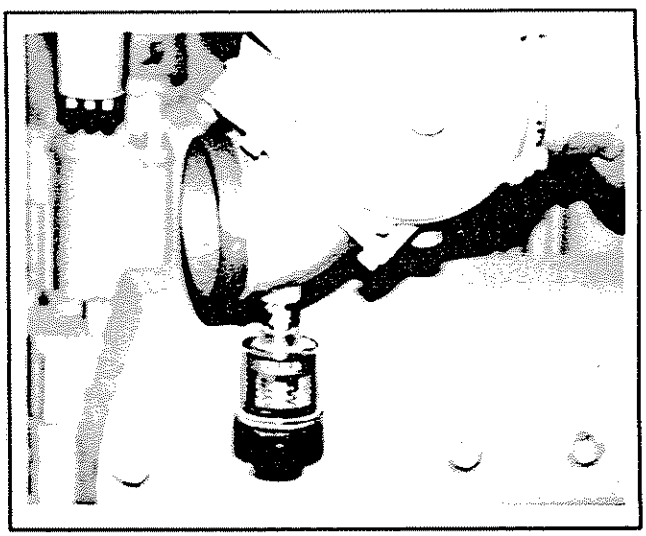


Photo #8-05 - Air Cleaner Restriction Indicator

Air Cleaner Restriction - Checking

Every 250 hours or 6 months, whichever comes first, check the air cleaner restriction. Refer to Air Intake System Specifications on page 8-1.

Both naturally aspirated and turbocharged engines need to be operating at rated RPM and full load to check the air cleaner element when the restriction reaches the maximum allowable limit.

Note: Follow the manufacturer's istructions when cleaning or replacing the air cleaner element.

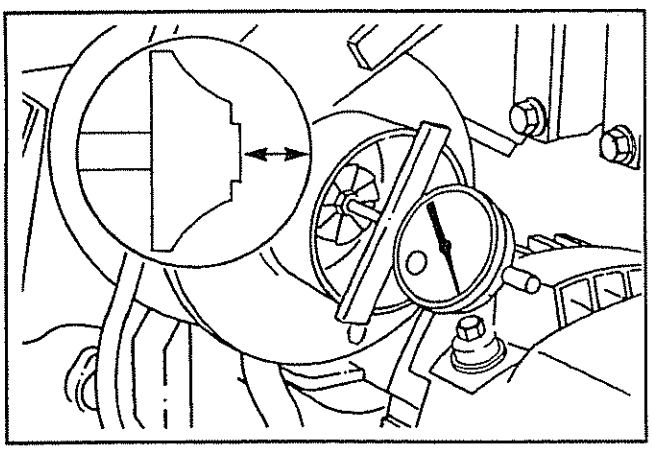
Check the air cleaner service indicator or gauge, if equipped.

Change the filter element when the red indicator flag is at the raised position in the window.

After the air cleaner has been serviced, reset the button in the end of the service indicator.

Caution: The settings used on air cleaner indicators for diesel engines will be too high for spark ignited engines. Check with your supplier to insure that you have an indicator that has been set CNGE engine settings.

Caution: Never operate the engine without an air cleaner. Intake air must be filtered to prevent dirt and debris from entering the engine and causing premature wear.



Sketch #8-06 - Axial Clearance

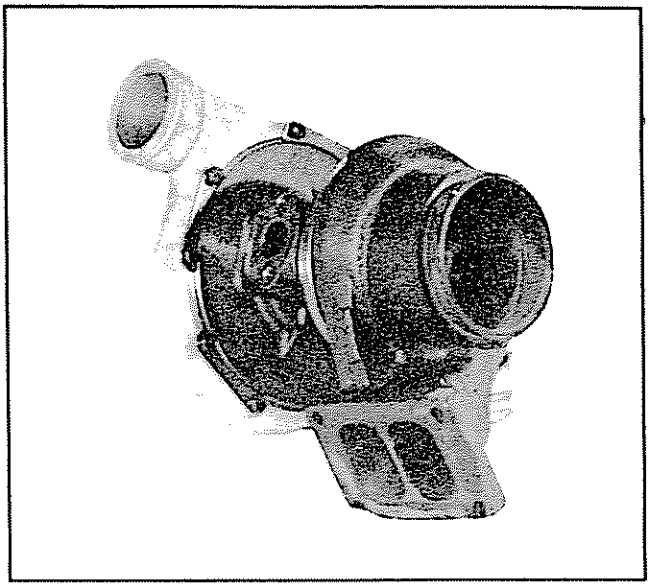


Photo #8-07 - Holset Turbocharger

Turbocharger - Inspection

If the engine is equipped with a turbocharger(s), inspect the turbocharger(s) every 6000 hours or 3 years, whichever occurs first. Remove the air intake and the exhaust piping. Check the turbocharger as follows:

- Look for damaged or cracked compres sor or turbine blades.
- Check to see that the turbocharger shaft spins freely.

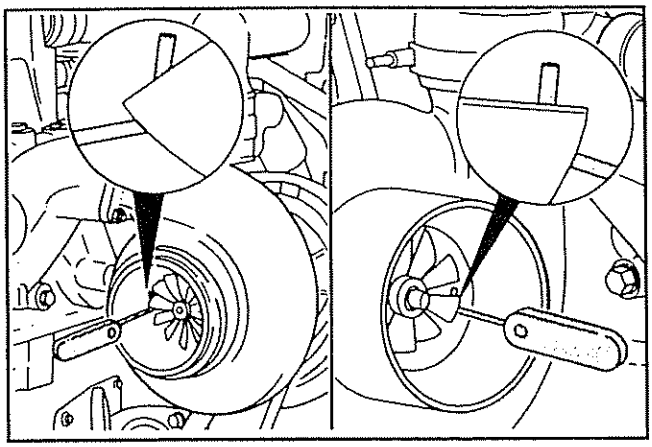
Note: If visual inspections or dimensional checks indicate a problem, contact a Cummins Authorized Repair Location for assistance. Refer to the model number on the turbocharger dataplate.

Table #8-08 Axial Clearance

(Measure end to end)

Turbocharger Model No.	Dimension Min.		Max.	
4LEK	.025	[.004in.]	.102mm	[.004in.]
BHT4-C	.05mm	[.002in.]	.13mm	[.005in.]

Rebuild or replace the turbocharger if axial clearance is greater than specified. Refer to the Cummins Troubleshooting and Repair Manual for removal procedures and to the Cummins Turbocharger Rebuild Manual for rebuild procedures.



Sketch #8-09 - Turbocharger Radial Clearance

Measure radial clearance (side to side).

Note: Hold the shaft toward the feeler gauge to check the dimension.

Turbocharger Model No.	Dimension mm [in.]
4LEK	
.Compressor Impeller	Min. 0.15 [0.006] Max. 0.46 [0.018]
Turbine Wheel	Min. 0.20 [0.008] Max. 0.53 [0.021]
BHT4-C	
.Compressor Impeller	Min. 0.18 [.007] Max. 0.36 [.014]
.Turbine Wheel	Min. 0.28 [.011] Max. 0.48 [.019]

Table #8-10 - Radial Clearance

Install the air intake and the exhaust piping.

Turbocharger Boost Pressure - Adjustment

All Cummins Natural Gas Turbocharged Engines require that the "Turbo Boost Controller" be adjusted at the customer's job site to insure that the Turbocharger Intake Manifold Pressure (BOOST) is adjusted for the proper altitude conditions.

Adjustment for Site Altitude

1. Each CNGE Turbocharged Engine contains a "RED" tag, attached to the Controller, speci fying the factory setting for altitude and horsepower. Refer to this tag to determine if an adjustment is required.

2. Make sure that the engine has been stopped.

3. Disconnect the hose located at the bottom of the controller.

4. Remove the end cap from the cylinder by pushing in and rotating in a counter-clockwise direction.

5. Install or remove spacers as necessary between the cap and spring to achieve proper setting. (Refer to site altitude Table #8-11 on page 8-5 for correct number of spacers.)

Extra spacers have been bolted to the exhaust side of the cylinder block or on the left bank side of the G28 or GTA28 engines.

6. Loosen the lockscrew on Turbo Boost Controller butterfly lever and adjust to a fully opened position. Tighten lockscrew on lever.
7. Start engine and record Turbo Boost at full load condition.

Caution: Excessive turbo boost may cause an engine failure.

8. Every time a shim or spring is removed, it will be necessary to repeat steps # 6 & 7.

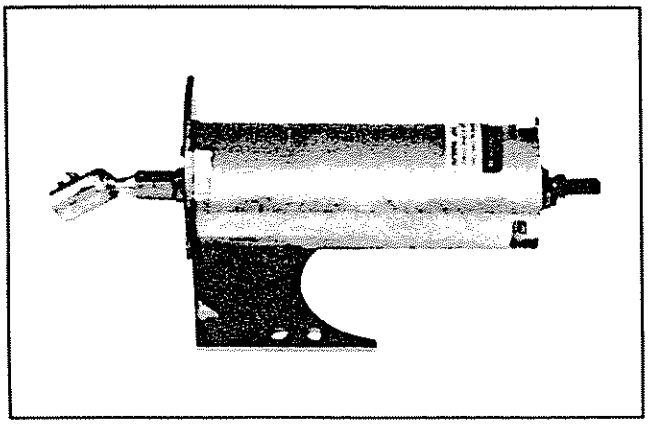


Photo #8-11 - Turbo Boost Controller

Site Altitude Chart

The following Site Altitude Chart is a representative usage of spacers required to adjust the turbo boost controller for the specific spring listed.

There may be circumstances, especially on generator drive engines, where the turbo boost controller will tend to interfere with the engine speed governor. When this occurs, it may be necessary to add additional spacers or a stronger spring to move the turbo boost controller out of the range of the governor for proper generator operation.

Caution: The turbo boost limiter may need to be adjusted for the site conditions of altitude and load factor. Avoid reaching excessive turbo boost pressure in the intake manifold. Contact your local Cummins Distributor if an adjustment is required.

Table #8-12 - Number of Spacers

SITE ALTITUDE TABLE		
ALTITUDE	CONTINUOUS H.P.	INTERMITTENT H.P.
1000 FEET	- 2 SPACERS	- 3 SPACERS
2000 "	- 3 "	- 4 "
3000 "	- 4 "	- 5 "
4000 "	- 5 "	- 6 "

In the event that the turbo boost controller needs additional adjustment that may require a spring change, use a combination of springs and spacers to adjust the turbo boost controller to react at 20 bhp above the maximum purchased horsepower.

Turbocharger Mounting Nuts - Checking

If the engine is equipped with a turbocharger(s), check the turbocharger mounting nuts annually.

Tighten the mounting nuts.

Torque Value: 50 ft-lb [65 N•m]

Backfire Relief Valve

CNGE engines may be equipped with a backfire relief valve. The purpose of this valve is to relieve excessive pressure that occurs in the intake manifold during an unexpected backfire.

Warning: This valve should be checked to insure that the O-Ring Seal is intact and that there are no leaks.

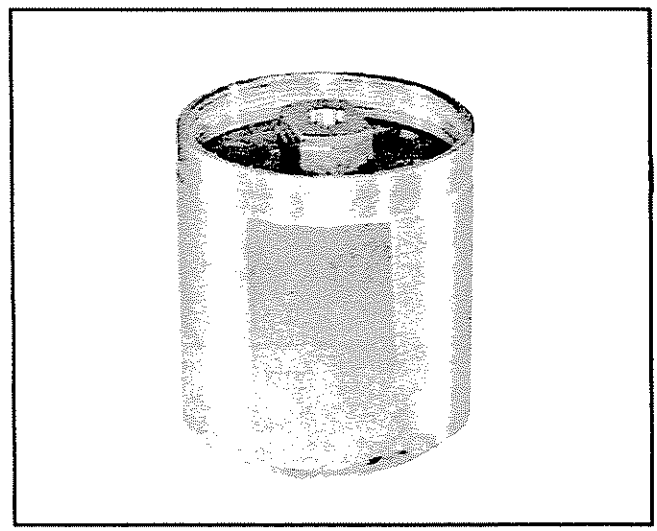
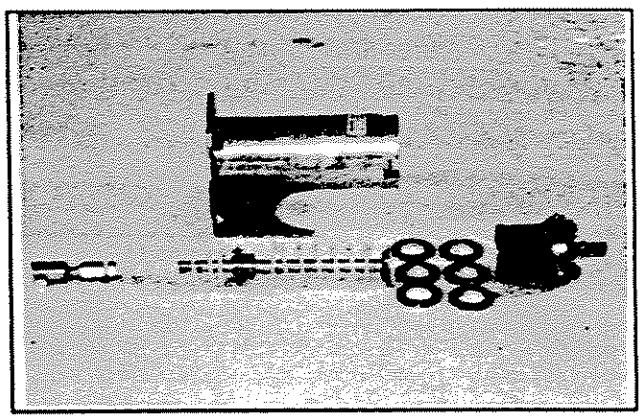
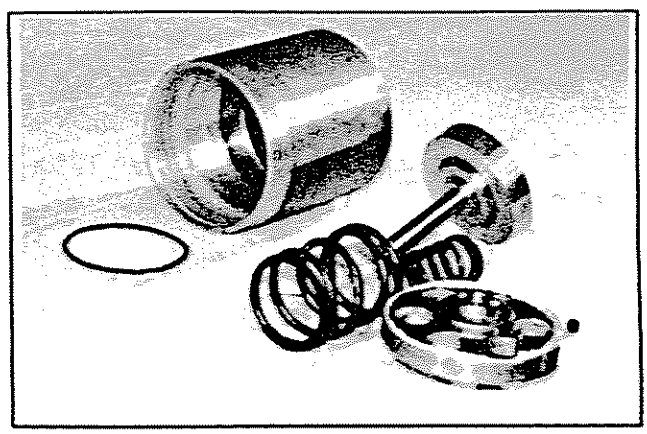


Photo #8-13 - Backfire Relief Valve

Reference Notes:



Turbo Boost Controller



Backfire Relief Valve

SECTION 9 - IGNITION SYSTEM

CONTENT

Altronic III

The Altronic III is currently used on the GTA19 and GTA28 CNGE engine models. It is also available as an option on the 4 & 6 cylinder engine models.

The Altronic III unit is a self-contained 12-pole permanent magnet alternator powering a solid state timing and distribution circuit.

The Altronic III back covers are equipped with plug in circuit board assemblies, which consist of the circuit board, connector and a zener diode.

Replacement circuit boards and back covers, as well as replacement Altronic III units, are available through your local Altronic dealer.

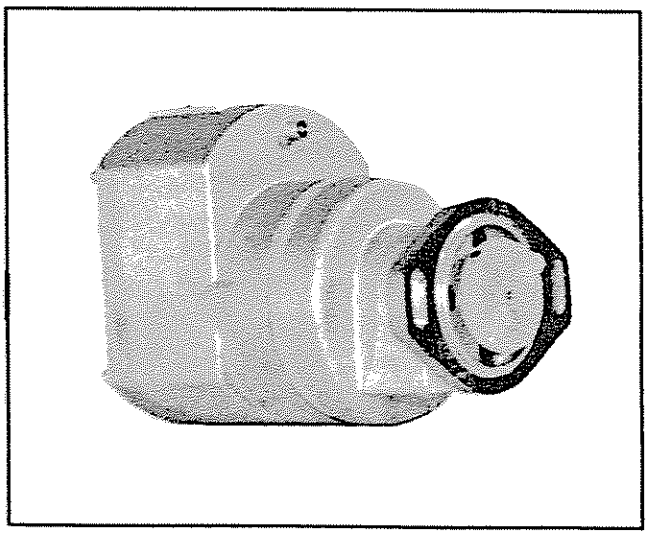


Photo #9-01 - Altronic III

Altronic V

The Altronic V is currently used on the G12, GTA12, G855, GTA855-A, and GTA855-B CNGE engine models.

The Altronic V unit is a self-contained 8-pole permanent magnet alternator powering a solid state timing and distribution circuit.

The Altronic V back covers are equipped with plug in circuit board assemblies, which consist of the circuit board, connector, and a zener diode.

Replacement circuit boards, back covers, and complete Altronic V units are available through your local Cummins Distributor or Altronic dealer.

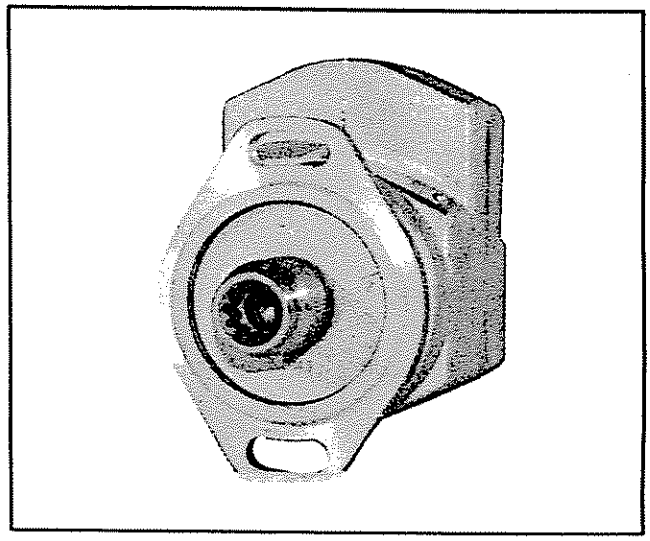


Photo #9-02 - Altronic V

Model Numbers

The following table shows those Altronic Unit Model Numbers that are currently listed as the standard ignition.

Table #9-03 - Altronic Models

Engine Model	Altronic III	Altronic V
G12	-	6A34-GV
GTA12	-	6A34-GV
G855	-	6A34-GV
GTA855-A	-	6A34-GV
GTA855-B	-	6A34-GV
GTA19	6A29-D	-
GTA28	12Z23-D	-

Installation Instructions

1. Set the engine with #1 cylinder at the desired firing point on the compression stroke. Adjust the timing to the required settings as specified in Table #9-09 in this section on page 9-7. On the GTA28 use #1 cylinder on the "left" bank.

2. Establish the rotation of the Altronic unit by examining the drive end of the unit.

3. Rotate the unit shaft until the red mark on the shaft lines up with the marks on the housing, The GTA28 will use the CCW mark and all other CNGE engines will use the CW mark.

4. Mount the unit on the engine keeping the two red lines together as close as possible.

5. If the two lines cannot be made to meet, then it will be necessary to pull the back cover assembly away from the unit approximately 2". Carefully tilt the top of the cover away from the unit, keeping the internal plug (underside of the circuit board) connected.

6. Rotate the distributor shaft until the marks described above line up. Then reinstall the cover to the unit by placing over the two dowel pins and engaging the gears, keeping the red marks together.

7. Securely tighten the four fastening screws.

8. Final timing should be set with the engine at operating speed.

9. Then tighten the two 3/8" bolts, securing the unit to the engine.

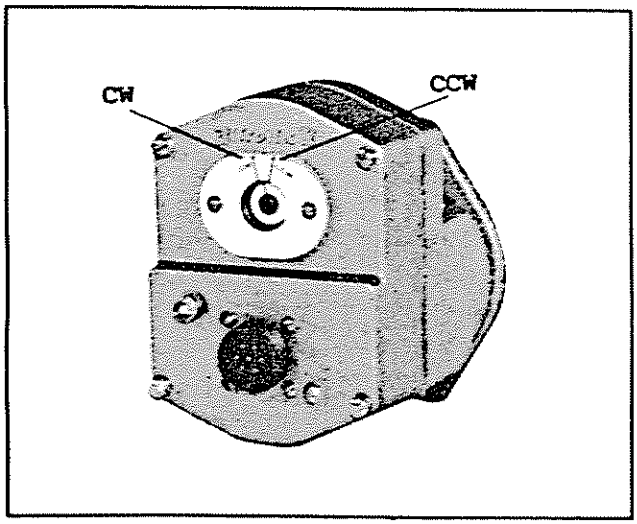


Photo #9-04 - Altronic Rotation Marks

Primary Wiring

GTA28
CCW Rotation

Altronic III Wiring Harness Coding
A-B-C-D-E-F-H-I-J-K-L-M

CNGE GTA28 Firing Order
1L-6R-2L-5R-4L-3R-6L-1R-5L-2R-3L-4R

Start with the lead **"A"** to the coil of #1L cylinder. The harness leads are connected in accordance with the engine's firing order to the positive (+) terminals of the coils (Refer to Wiring Diagram #4 in Section 13, Page 13-7).

The **"G"** harness lead is the switch or shutdown panel wire. A common ground lead should be connected to the negative (-) terminal of the coils as shown in the wiring diagram and connected to the **"N"** lead and grounded to the engine cylinder block.

GTA19
CW Rotation

Altronic III Wiring Harness Coding
A-F-E-D-C-B

CNGE GTA19 Firing Order
1-5-3-6-2-4

Start with the lead **"A"** to the coil of #1 cylinder. The harness leads are connected in accordance with the engine's firing order to the positive (+) terminals of the coils (Refer to Wiring Diagram #5 in Section 13, Page 13-8).

The **"G"** harness lead is the switch or shutdown panel wire. A common ground lead should be connected to the negative(-) terminal of the coils as shown the wiring diagram and connected to the **"N"** lead and grounded to the engine cylinder block.

CNGE 6 Cylinder Engines
CW Rotation

Altronic V Wiring Harness Coding
A-F-E-D-C-B - 6 Cylinder Engine

CNGE Firing Order
1-5-3-6-2-4 - 6 Cylinder Engine

Start with the lead **"A"** to the coil of #1 cylinder. The harness leads are connected in accordance with the engine's firing order to the positive (+) terminals of the coils (Refer to Wiring Diagram #6 in Section 13, Page 9).

The **"E"** harness lead is the switch or shutdown panel wire. A common ground lead should be connected to the negative (-) terminal of the coils as shown in the wiring diagram and connected to one of the mounting screws on the back cover of the Altronic V unit and to the engine cylinder block.

Optional Ignition Systems

Fairbanks Morse Model FM 3000

The FM 3000 ignition generator feeds external transformers for individual cylinder firing. The unit is contained in a moisture resistant housing with o-ring seals. All electronic components are housed in a replaceable end cap.

The drive ratio is 1.5:1 and is normally driven by the lubricating oil pump drive.

The FM 3000 is available as an option on the G12/GTA12, G855/GTA855-A/GTA855-B.

The primary voltage is 200 volts DC with a secondary voltage of 35 KV.

Fairbanks Morse Model FM 9000RV

The FM 9000RV has the same basic construction as the FM 3000. The primary voltage is 225 volts with the secondary voltage of 46 KV. The FM 9000 is available as an option on all CNGE engines.

Installation and wiring diagrams are available on both the Fairbanks Morse FM 3000 and the FM 9000RV from your local Fairbanks Morse dealer.

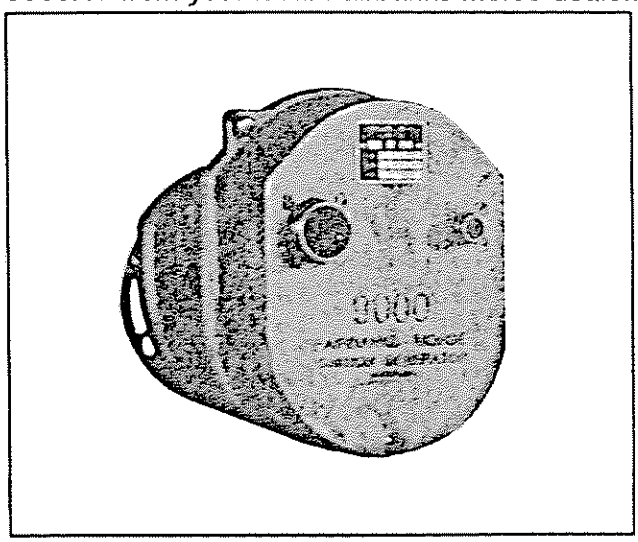


Photo #9-05 - Fairbanks Morse

Spark Plug Removal

1. Disconnect the spark plug wire at the coil.
2. Lift off the rubber cap with the extension.
3. Using an extra long 0.8125 mm (13/16 in.) deep-well rubber insert spark plug socket, remove the spark plug from the adaptor. Lift out the spark plug and gasket.

Note: The upper rocker valve covers do not need to be removed to either check or replace the spark plugs.

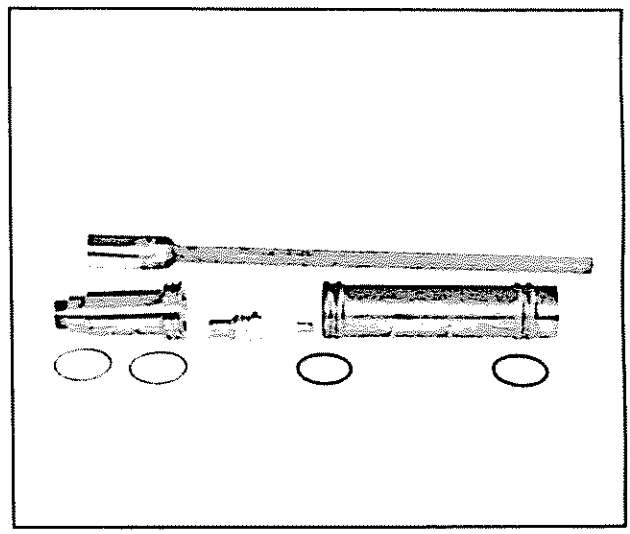


Photo #9-06 - Spark Plug Removal

Spark Plug Well - Inspection

A visual inspection of the spark plug well for traces of water or oil should be made.

If oil is present, the o-rings on the spark plug adapter tubes will need to be replaced. If water is present inside the cylinder, then the spark plug adapter o-rings and the adapter gasket must be replaced.

Removal of the spark plug adapter requires the use of special tools. Contact your local CNGE Distributor or Authorized CNGE Dealer for assistance.

Spark Plugs - Inspection

Careful examination of the spark plug(s) can be very helpful in preventing future damage to your engine.

Examples:

1. Orange colored residue may indicate a cooling system additive in the combustion chamber and serious cooling system problems.

2. A molten center electrode is an indication of temperatures more than 2800 °F and could be signs of pre-ignition or detonation.

3. Crusty white ash deposits may indicate excessive barium or calcium in the oil and usually occur due to a "high-ash" oil.

4. Black carbon deposits may suggest a rich air fuel ratio.

Spark Plug Gap - Checking

CNGE recommends that the spark plug gap for all CNGE engines should be set at .020 in. The measurement should be made with a spark plug gap wire gauge. CNGE recommends the Snap-on GA461B or equivalent.

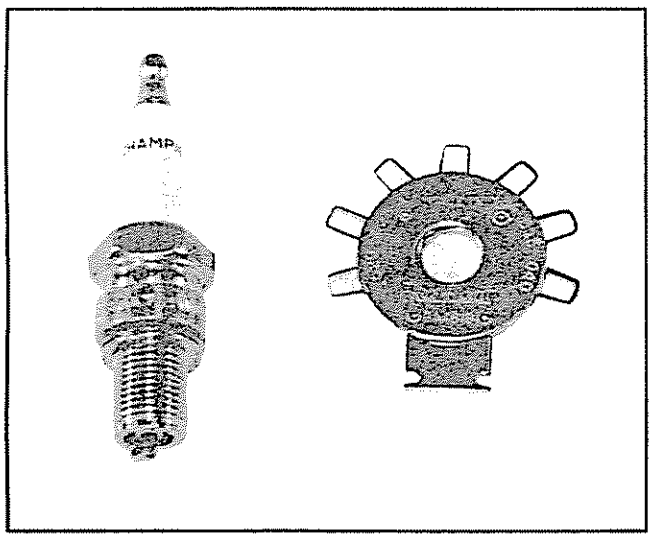


Photo #9-07 - Spark Plug Gap

Spark Plug Installation

1. Inspect the spark plug seating area in the adapter and clean to insure a good seating surface for the spark plug.

2. Position the new spark plug gasket on the spark plug; insert the spark plug in the adapter and tighten to 3.18-4.15 k-gm (28-30 ft-lb) torque.

Shielded Spark Plugs

CNGE use part number S-40XLBEX13 or the S-40XLBEX15, whichever is appropriate for your specific engine model. CNGE recommends this plug or its equivalent.

The shielded spark plug should be checked visually every 250 hours or 6 months.

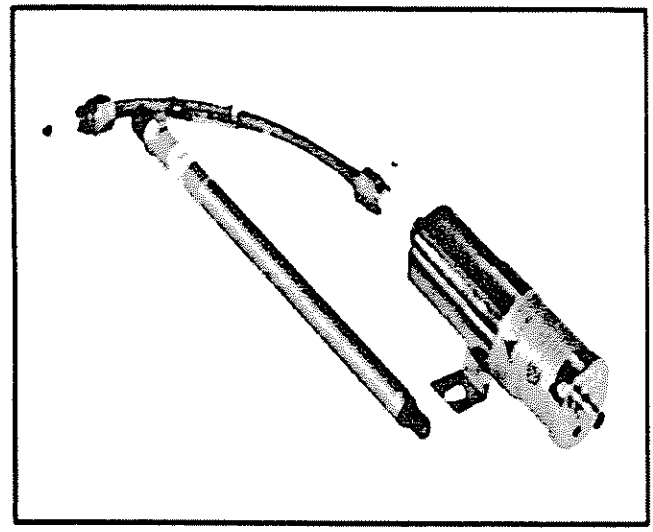


Photo #9-08 - Shielded Spark Plug

Non-Shielded Spark Plugs

CNGE use as a standard spark plug part number 3803897 for continuous duty and the N_2C for emergency stand-by applications. CNGE recommends this spark plug or its equivalent when required.

The non-shielded spark plug should be checked visually and replaced every 1500 hours or one (1) year.

Spark Plug Wires - Checking/Replacing

Check to insure that spark plug wires are not showing signs of wear due to physical damage or vibration. CNGE uses deep spark plug wells and insure that the wires are protected by the use of insulated extenders covered by a boot.

The use of a clear silicone grease is recommended to help seal out moisture and prevent corrosion.

Ignition Coils - Checking/Replacing

The resistance of the ignition coil should be checked by a good OHM meter to decide if it is

within the manufacturer's recommended specifications for the type of coil being used.

Low Tension Wiring Harness

CNGE uses a low tension wiring harness between the ignition generator and the ignition coil. Periodic examination should be made to decide if the wiring needs to be replaced due to signs of physical damage and corrosion.

Ignition Timing - Checking/Adjusting

Engine timing is not a fixed value but depends upon the load, type and quality of the fuel, altitude, and the rated speed (RPM) of the engine.

It is therefore important that this adjustment is made by a qualified CNGE distributor or CNGE authorized dealer service technician at the time of engine installation and start-up.

Set initial engine timing to the appropriate value listed in Table #9-09.

Caution: CNGE sets all engines at Clovis, New Mexico conditions of 4200 feet altitude and to the limits in Table #9-09 for the initial engine timing.

Timing will have to be readjusted due to altitude, temperature, load, type of fuel and the air/fuel excess Oxygen setting.

Table #9-09 - Initial Engine Timing (@ 4000 ft. Clovis, N.M.)

Model	Timing Range	DBTDC
	Nat. Gas	LPG Gas (HD-5)
G8	26-30	18-23
G12	26-30	18-23
G855	26-30	18-23
G28	26-30	18-23
GTA12	24-28	18-22
GTA855-A	24-28	18-22
GTA855-B	24-28	18-22
GTA19	24-28	18-22
GTA28	24-28	18-22

Final timing adjustments are made in connection with the adjustment of the power screw on the carburetor. In addition, there is a requirement to hold the excess Oxygen reading in the exhaust gas to a predetermined level. This establishes the Air/Fuel ratio. All of this is done while searching for the lowest possible exhaust gas temperature and highest intake manifold vacuum on naturally aspirated models or lowest manifold boost pressure on turbocharged models without sustaining a power or RPM loss.

Refer to Carburetor Adjustment on page 12-3 in Section 12 and to Start-Up and Inspection on page 4-7 in Section 4.

Special Notes:

SECTION 10 - EXHAUST SYSTEM

CONTENT

Exhaust System Specifications

Maximum allowable back pressure imposed by system piping, catalytic converter, and exhaust silencer- - - - - - - - - - - - - - - - 50 mm Hg (2 in.Hg)

Maximum bending movement to turbocharger flange - - - - - - - - - - - - - - - - - 27 N.m. (20 ft-lb)

Exhaust pipe size (normally acceptable inside diameter)

G8 - 102 mm (4 in.)
G12/GTA12 - - - - - - - - - - - - - - - - 102 mm (4 in.)
G855/GTA855-A/GTA855-B - - - - 102 mm (4in.)
GTA19 - - - - - - - - - - - - - - - - - - - 127 mm (5in.)
G28/GTA28 (Dual Exhausts) - - - - 102 mm (4 in.)

Caution: The additions of exhaust silencers, catalytic convertors, long runs of piping, and 90 degree elbows may require that the inside diameter of the exhaust pipe size is increased along with the Turbo Outlet Flange Connection in order to avoid excessive Turbocharger Back-Pressure.

Exhaust System Flow

1. Exhaust Valve Ports
2. Exhaust Manifold
3. Turbocharger Exhaust Outlets

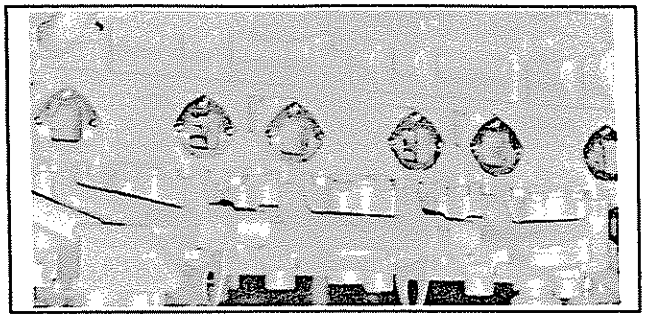


Photo #10-01 - Exhaust Valve Ports

Photo #10-02 - Exhaust Manifold - Wet

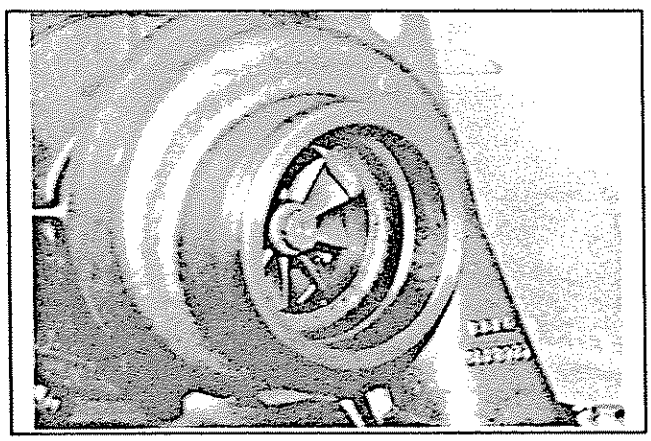


Photo #10-03 - Turbocharger Exhaust

Catalytic Convertor

Many locations will, by local code, require the use of a Catalytic Convertor to be placed in the exhaust system to help in exhaust emission control. When this occurs, it may be necessary to lower the power requirement on the engine to avoid excessively high exhaust gas temperatures.

CNGE engines are factory set at a Stoichiometric Air/Fuel ratio toward the "lean" side of Stoichiometric for the express purpose of providing the lowest possible Exhaust Gas Temperature required for Exhaust Valve durability.

The use of a Catalytic Convertor will generally require that the Air/Fuel ratio is set toward the "Rich" side of Stoichiometric. When this occurs, the Exhaust Gas Temperature will elevate to a higher level that may reduce exhaust valve life.

Caution: Some manufacturers of catalytic convertors require that the engine oil have an ash content of not more than .5 percent mass of sulfated ash. In addition, there may be restrictions placed on the amount of phosphorus and zinc that can be allowed in the additive packages that are used in some natural gas engine oils.
Catalytic convertor manufacturers also place a limit on the maximum allowable temperature that a catalyst can be exposed to before experiencing damage to the convertor.

Special Notes:

SECTION 11 -

COMPRESSED AIR SYSTEM

CONTENT

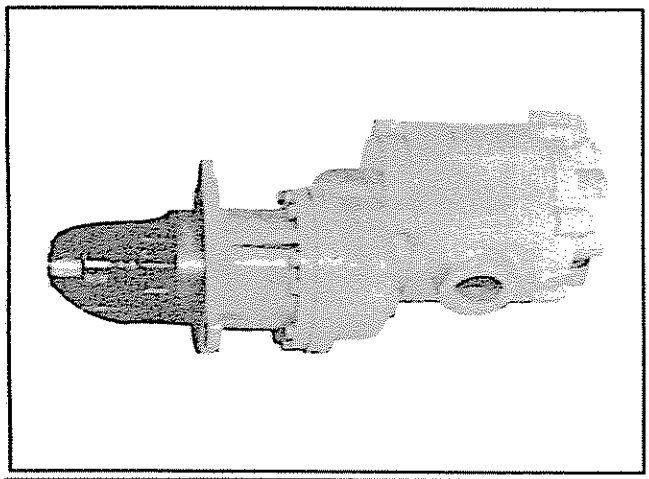


Photo #11-01 - Air-Gas Starter

Compressed Air System

Air Starting

Air starting is available as an engine option for most CNGE engine models and is acceptable for use on all Cummins engines. It provides a generally higher cranking speed than electric starting motors and the compressed air source suffers less energy loss at low ambient than electric storage batteries.

Air-Gas Starters

The air-gas starter system (tanks, line sizes, and valves) is disigned and installed by the original equipment manufacturers and the starter suppliers. Refer any questions about the air starting systems to the manufacturer.

Air Starters - Maintenance

Do not operate air starting motors with air pressure lower than 480 kPa (70 psi).

Air-Gas Starters - Maintenance

Refer to the original equipment manufacturers' and starting motor manfacturers' manuals for specific information regarding the starting motors, valves, and systems.

Lubricator - Air-Gas Starter

CNGE pre-lubes the lubricator and then ships the unit in a dry state. It is therefore necessary to add a clean non-detergent, preferably a SAE 10 (90SSU), or lighter. The rate of oil delivery is adjusted by turning the adjusting screw either clockwise for less oil or counterclockwise for more oil delivery.

CNGE recommends that you follow the manufacturer's instructions for proper operation and maintenance of the "Economist" lubricator.

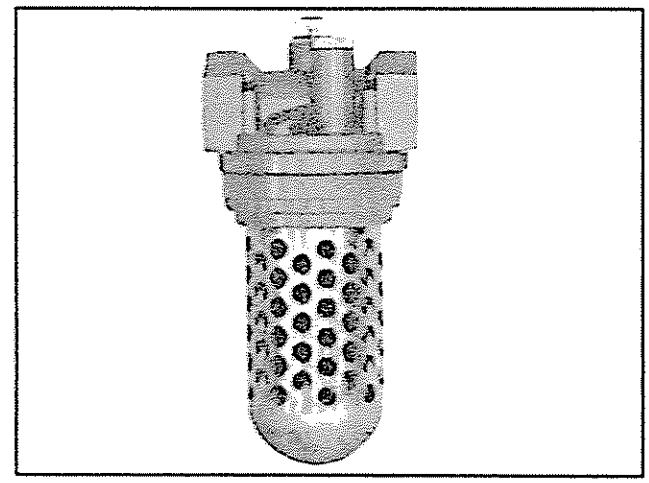


Photo #11-02 - Economist Lubricator

Reference Notes:

SECTION 12 - FUEL SYSTEM

CONTENT

Specifications

Standard Carburetor - IMPCO

Low Pressure Dry Processed Natural Gas

Maximum pressure to Carburetor
(After Regulation) - - - - - - - - 9 mm hg [5 in. H_2O]

Minimum Pressure to Carburetor
(After Regulation) - - - - - - - - 6 mm hg [3 in. H_2O]

Minimum Gas Supply Line
@ Engine- - - - - - - - - - - - - - - - - 51 mm [2 in.]

Gas Supply Filter
Pressure Rating - - - - - - - - - - - 690 kPa [100 psi]

Lower Heat Value - - - - - - - - - - - 905 BTU/ cu. ft.

Low Pressure Propane (HD-5) Industrial Grade

Maximum Pressure to LPG Convertor
& Safety Valve- - - - - - - - - - 1724 kPa [250 psi]

Minimum LPG Supply Pipe Size:
(LIQUID) - - - - - - - - - - - - 13 mm [0.50 in.]
(VAPOR) - - - - - - - - - - - - 51 mm [2 in.]

Caution: Above pipe sizes are only recommended, and piping may vary with temperatures, distance of fuel tanks, and application of local codes. Gas must be available at adequate volumes and pressure for the CNGE engine at the engine regulator.

Table #12-01 - FUEL APPLICATION GUIDE

Naturally Aspirated CNGE Engines Compression Ratio	8.5:1	10:1	12:1
Dry Processed Natural Gas	Yes	Yes	Yes
Propane (HD-5)	Yes	Yes	NA
Turbocharged\Aftercooled CNGE Engines Compression Ratio	8.5:1	10:1	12:1
Dry Processed Natural Gas	Yes	Yes	NA
Propane (HD-5)	Yes	NA	NA

NA = Not Applicable

Type of Fuel-Gas

CNGE engines are primarily specified to run off a good pipeline quality of dry processed natural gas. With the correct configuration, CNGE engines can be specified to also run off LPG (HD-5) propane gas. With pre-approval from the CNGE factory, these engines can be adjusted to run off digester gas and field gas.

Engines that are run off "landfill" gas require that the gas is run through a scrubber to remove any sulfur compounds and a drier to remove any moisture such as water. In addition, a high ash multi-viscosity oil may be required to combat contaminants that will get into the engine lube oil from "blow-by" gases.

Manual Shut-Off Valve

Generally, local codes will require that a manual shut-off valve is installed upstream of the line pressure regulator. This is generally the responsibility of the local gas company.

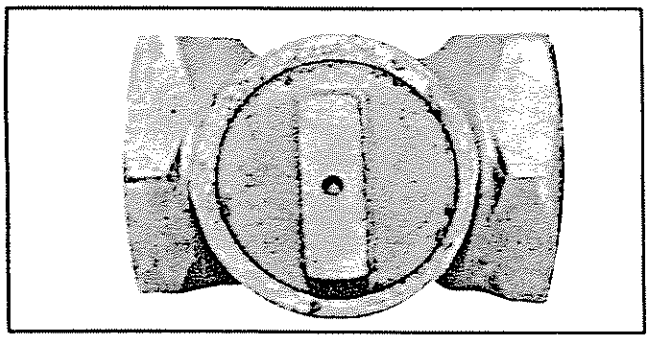


Photo #12-02 - Manual Shut-Off Valve

Line Pressure Regulator

The main pipeline must be equipped with a line pressure regulator to insure that there is an adequate supply of gas available and at a maximum pressure not to exceed 125 psi. The minimum pressure required depends on the pressure drops between the Line Pressure Regulator and CNGE Engine Mounted Pressure Regulator. A minimum pressure of 10 in. H_2O must be supplied to the CNGE engine mounted regulator.

Gas Filter - Replace

CNGE recommends that the gas fuel filter be installed before the engine mounted regulator. The inlet fuel pressure should be at a maximum of 100 psi to the filter.

CNGE supplies a filter as a kit option that is capable of filtering down to 5 micron.

CNGE recommends that the gas fuel filter should be checked every 1500 hours or 1 year, whichever occurs first.

Caution: When replacing the element, specific attention needs to be placed on the gas flow to insure that the filter is reassembled with the filter installed in the proper direction.

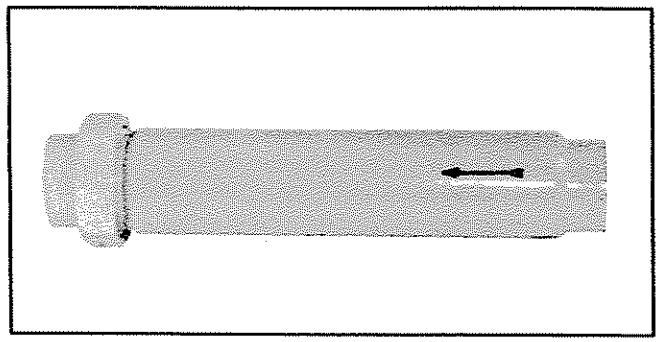


Photo #12-03 - Gas Filter

Check Gas Leaks and Correct

Check for evidence of gas leakage at the gas pressure regulator and at all pipe connections.

1. Apply liquid soap around the regulator to check for leaking gaskets and ruptured diaphragms.
2. Check for leaks at all line connections by soaping.
3. On CNGE Turbocharged engine models, check throttle shaft seals for leaks with the engine at rated power.

Engine Mounted Pressure Regulator

Effective 3/01/91, CNGE began installing an engine mounted regulator that requires a minimum gas pressure to the regulator after the filter, shutoff valves, and line pressure drops of 10 in. to 20 in. of water in full load conditions. For CNGE engines manufactured before that date, CNGE used various pressure regulators. Refer to Table #12-05 for your specific engine.

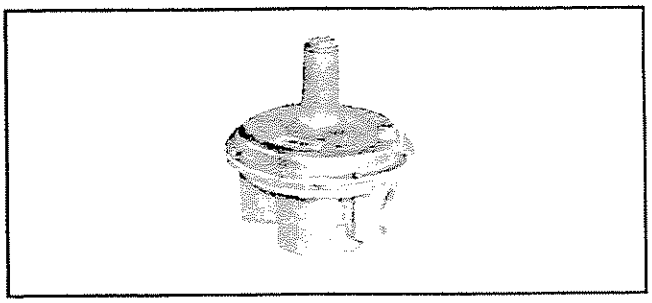


Photo #12-04 - Gas Regulator

Table #12-05 - Gas Pressure Regulators

Engine Model	Fisher	Maxitrol
G12	S-301	RV-60
G855	S-301	RV-60
GTA12	S-301	RV-81
GTA855-A	S-301	RV-81
GTA855-B	S-301	RV-81
GTA19	S-201	RV-91
GTA28	S-201	RV-91

Check Gas Pressure to Carburetor

Every 1500 hours or 1 year, whichever occurs first, the gas pressure to the carburetor should be checked and, if required, the gas regulator adjusted to insure that the required minimum pressure is being supplied. Refer to Fuel Specifications for fuel pressure requirements.

Carburetor - Excess Oxygen Adjustment

The air-gas "power valve" on the carburetor should be adjusted for the specific engine model's excess oxygen requirement. Refer to Table #12-06.

Table #12-06 - Excess Oxygen - Without Catalytic Converter

Engine Model	O_2 Reading - %	
Application	Stand-By (Maximum)	Prime (Continuous)
G12	.7 - 1.0	1.9 - 2.5
G855	.7 - 1.0	1.9 - 2.5
GTA12	2.0 - 2.5	2.7 - 4.0
GTA855-A	2.0 - 2.5	2.7 - 4.0
GTA855-B	2.0 - 2.5	2.7 - 4.0
GTA19	2.0 - 2.5	2.7 - 4.0
GTA28	2.0 - 2.5	2.7 - 4.0

Caution: When making the adjustment, it may be necessary to readjust engine ignition timing. Refer to Page 9-7 for proper timing adjustment procedure.

Caution: CNGE sets all engines at Clovis, New Mexico conditions of 4200 feet altitude and to the specifications listed in Table #12-06.

Adjustment of Air-Gas Power Valve

The power valve location will vary depending on the carburetor model.

Impco Model # 225 & 200D

The power valve is at the gas inlet to the carburetor. Both sides of the carburetor have markings indicating either rich **"R"** or lean **"L"** with 5 lines between the two markings.

The adjustment is made with the engine under a full load condition, together with the utilization of an oxygen meter used to measure the excess oxygen in the exhaust system. The measurement of excess oxygen is taken downstream of the turbocharger exhaust gas outlet or downstream of the exhaust manifold outlet flange on a naturally aspirated engine.

If the O_2 reading is below the required specification, adjust the power valve toward the lean mark. If above the proper setting, adjust toward the rich mark. Allow for several minutes to pass after each adjustment in order to record a stabilized oxygen reading.
For additional information on how to measure the excess oxygen, refer to the technical specification section.

Impco Model # 425 & 600

On models 425 and 600, the power valve can be identified as a hex-head screw with a spring on the side of the carburetor. The adjustment would be to turn the screw in a clockwise "CW" direction to adjust toward the lean mixture and counterclockwise "CCW" to adjust toward rich.

With the exception of the model 600, all of the above carburetors have idle adjustment screws on the carburetors. Refer to the appropriate photo in this section for clarification.

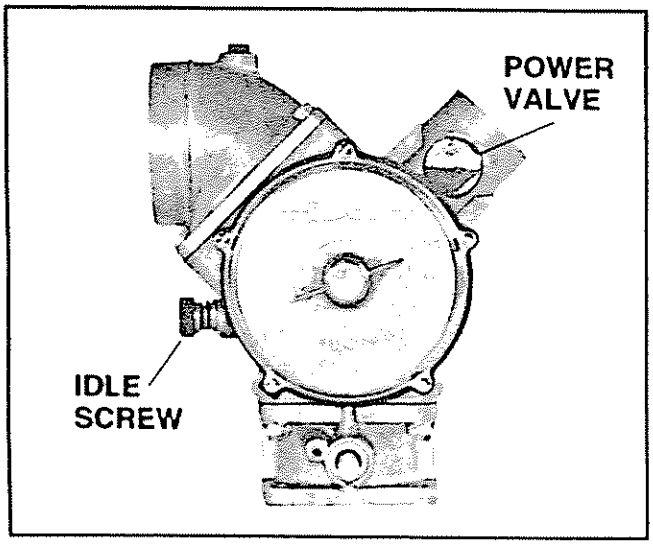


Photo #12-07 - Impco Model #200

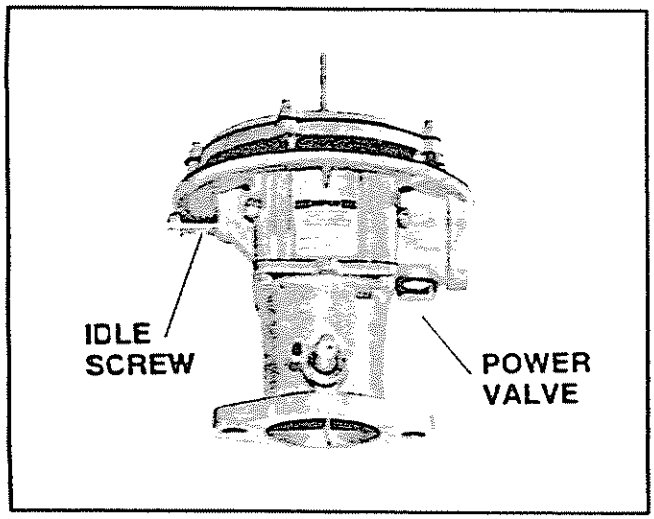


Photo #12-08 - Impco Model #225

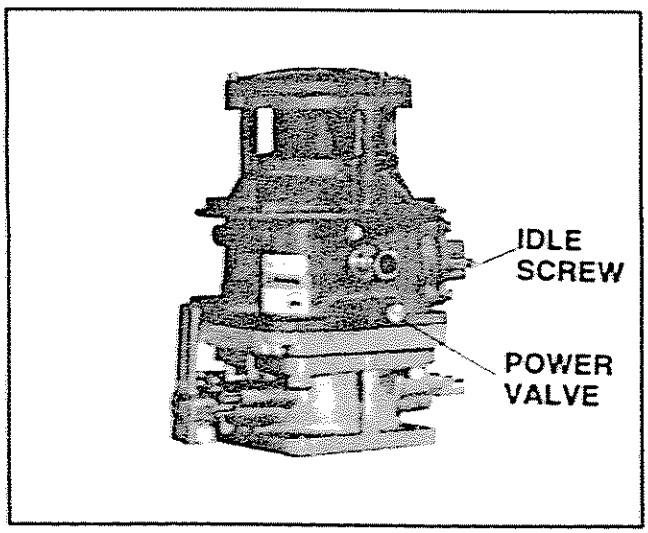


Photo #12-09 - Impco Model #425

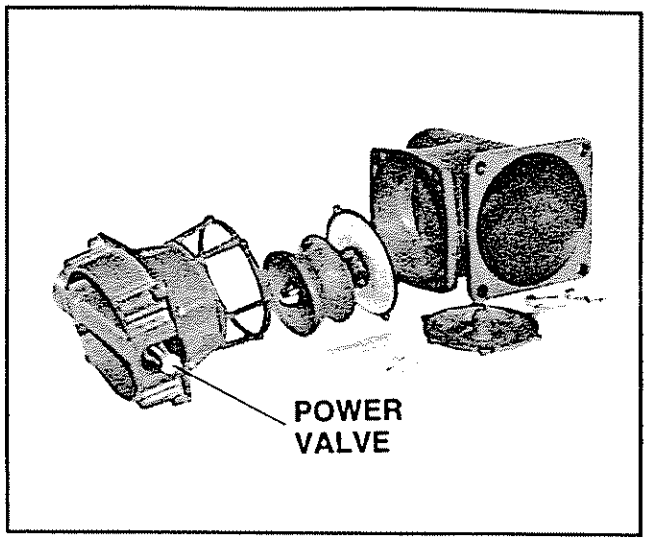


Photo #12-10 - Impco Model #600

Liquid Propane Convertor

When CNGE engines are using a liquid HD-5 propane fuel, a "converter" is used to allow the liquid propane to convert to a vapor at atmospheric conditions.

When propane in a liquid state is released to a low pressure area, the sudden change to a gas causes a refrigeration process. The gas will enter the vaporizer at a -42 °C [-44 °F]. To compensate the engine jacket coolant is plumbed to the vaporizer to raise the HD-5 gas temperature up to 4 °C [40 °F].

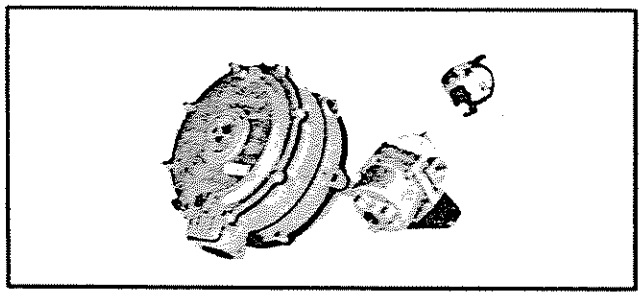


Photo #12-11 - Liquid Propane Convertor

Propane Vapor

In those cases where propane vapor is available from the propane storage tanks in sufficient quantities that will handle the specific propane engine, a converter will not be necessary.

When using a straight propane vapor from the top of a storage tank, it is important to insure that the vapor does not carry condensate or propane

"droplets" of liquid propane. It may be necessary to install a separate heater to increase the temperature of the propane vapor.

Caution: Check with the local authorities for the correct type and correct installation of any propane heater.

The propane vapor will flow through a pressure regulator, a shutoff valve, and then to an engine mounted regulator that has been inverted with the internal spring removed. The engine will then create a vacuum at the carburetor that will pull the propane vapor from the regulator in the desired quantities.

Propane will generally cause higher Exhaust Gas Temperatures and has a lower critical temperature point; therefore, CNGE requires that ALL CNGE Turbocharged engines be applied at a C.R. of 8.5:1 when using propane as a fuel.

Caution: Propane as a gas is generally heavier than air and will tend to fall rather than rise like methane gas. When using propane as a fuel, one needs to be aware and cautious at all times.

Hydraulic Governor Adjustments

CNGE engines may be equipped with hydraulic governors manufactured by Woodward Governor Company.

For proper operation and maintenance of the hydraulic governor, please refer to the manufacturer's manuals.

Linkage

CNGE gas engines use a butterfly type of throttle valve in the carburetor. The linkage will have to be "Non Linear."

With the linkage in a no-load position, the lever attached to the governor and the connecting link must be "in line" with the governor output shaft and the point of attachment of the connecting link to the butterfly valve. The butterfly lever must be at 90 degrees with the connecting link.

Hydraulic Governor Adjustments

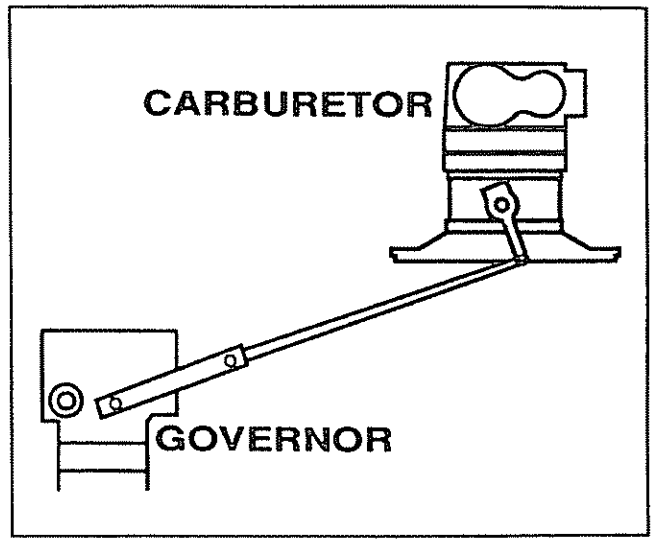


Chart #12-12 - Non Linear Linkage

Idle Adjustment

After the installation of the governor lever and linkage to the carburetor throttle, check carburetor throttle for idle position against the throttle stop pin. If the throttle plate idle adjustment screw does not rest against the stop pin, adjust linkage length until the screw rests against the stop pin.

Manually lift the governor lever through the carburetor throttle travel range and check for linkage bind. If necessary, adjust linkage length and carburetor throttle lever position to eliminate any binding through the throttle travel range. Tighten the linkage and lever assemblies.

Start the engine and adjust the low-speed stop screw on top of the governor head for the desired idling speed, approximately 900 RPM for CNGE engines.

Speed Droop Adjustments

Adjustments for Speed Droop require that the governor top cover be removed in order to expose the speed droop mechanism. Speed droop can then be adjusted by movement of the speed droop bracket either toward the front of the engine for less droop, or toward the rear for more droop.

Since there is no calibration for speed droop, the actual setting requires a trial and error procedure on the engine or adjustment by the use of a dial indicator on the speed droop lever while the governor terminal shaft is being "manually" rotated.

For additional instructions, please refer to the manufacturer's instruction manual.

Electric Governor Adjustments

CNGE uses both Barber Colman and Woodward Electric Governors as available options for CNGE engines.

Adjustments of these types of governors should be made with a clear understanding of the operation of the electronic governor. CNGE recommends that if your engine is equipped with an electronic governor, refer to that specific manufacturer's operation and maintenance instructions for proper adjustment.

Special Notes:

SECTION 13 - ELECTRICAL SYSTEM

CONTENT

Electronic System Specifications

Ambient Temperatures - - - - - - - - - - 18 °C [0 °F]

	Battery Size 12 Volt	24 Volt
Cold Cranking Amperes	1800	900
Reserve Capacity Amperes	640	320

Ambient Temperatures - - - - - - - - - - 0 °C [32 °F]

	Battery Size 12 Volt	24 Volt
Cold Cranking Amperes	1280	640
Reserve Capacity Amperes	480	240

The number of plates within a given battery size determines reserve capacity. Reserve capacity determines the length of time sustained cranking can occur.

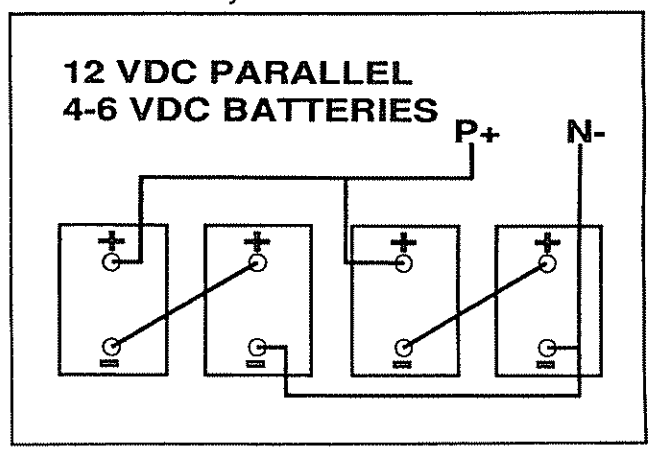
General Information

Caution: To avoid damage to the electrical system when using jumper cables to start the engine, make sure to connect the cables in parallel:

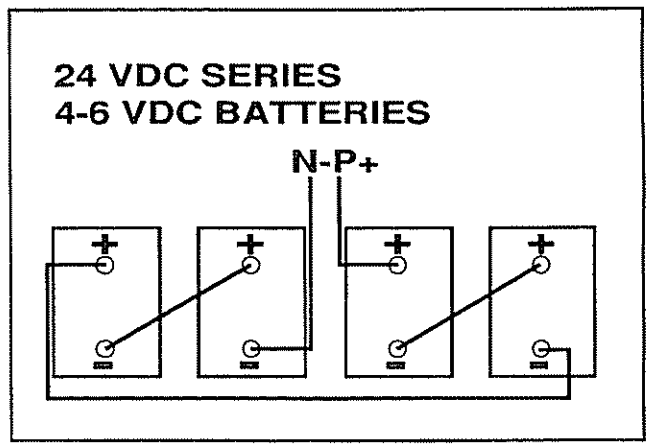
positive (+) to positive (+)
negative (-) to negative (-).

When using an external electrical source to start the engine, the disconnect switch should be turned to the **"OFF"** position and the key (if equipped) removed before attaching the jumper cables.

The enclosed illustrations show typical parallel and series battery connections.



Sketch #13-01 - Parallel Connection



Sketch #13-02 - Series Connection

Special Notes:

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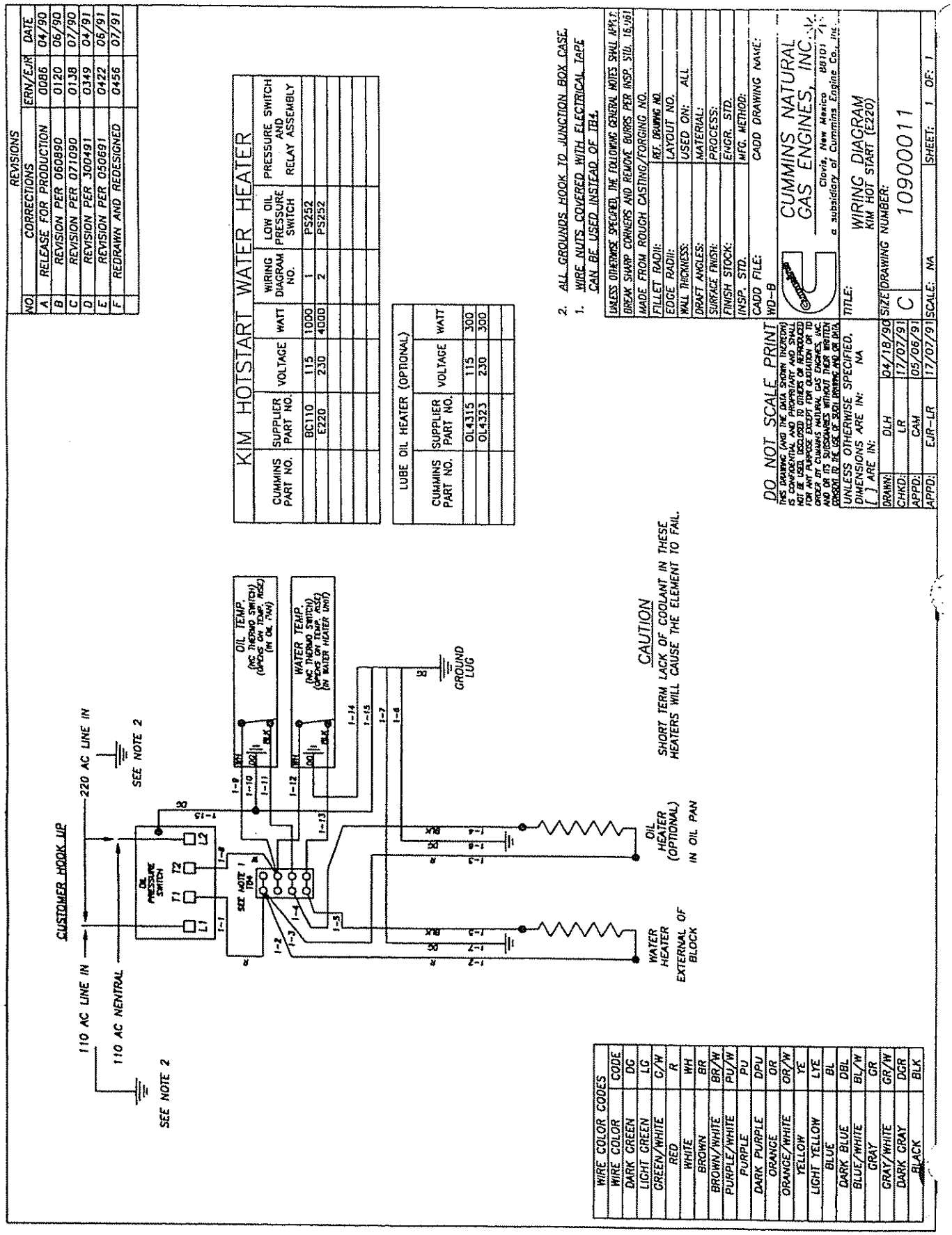
_____

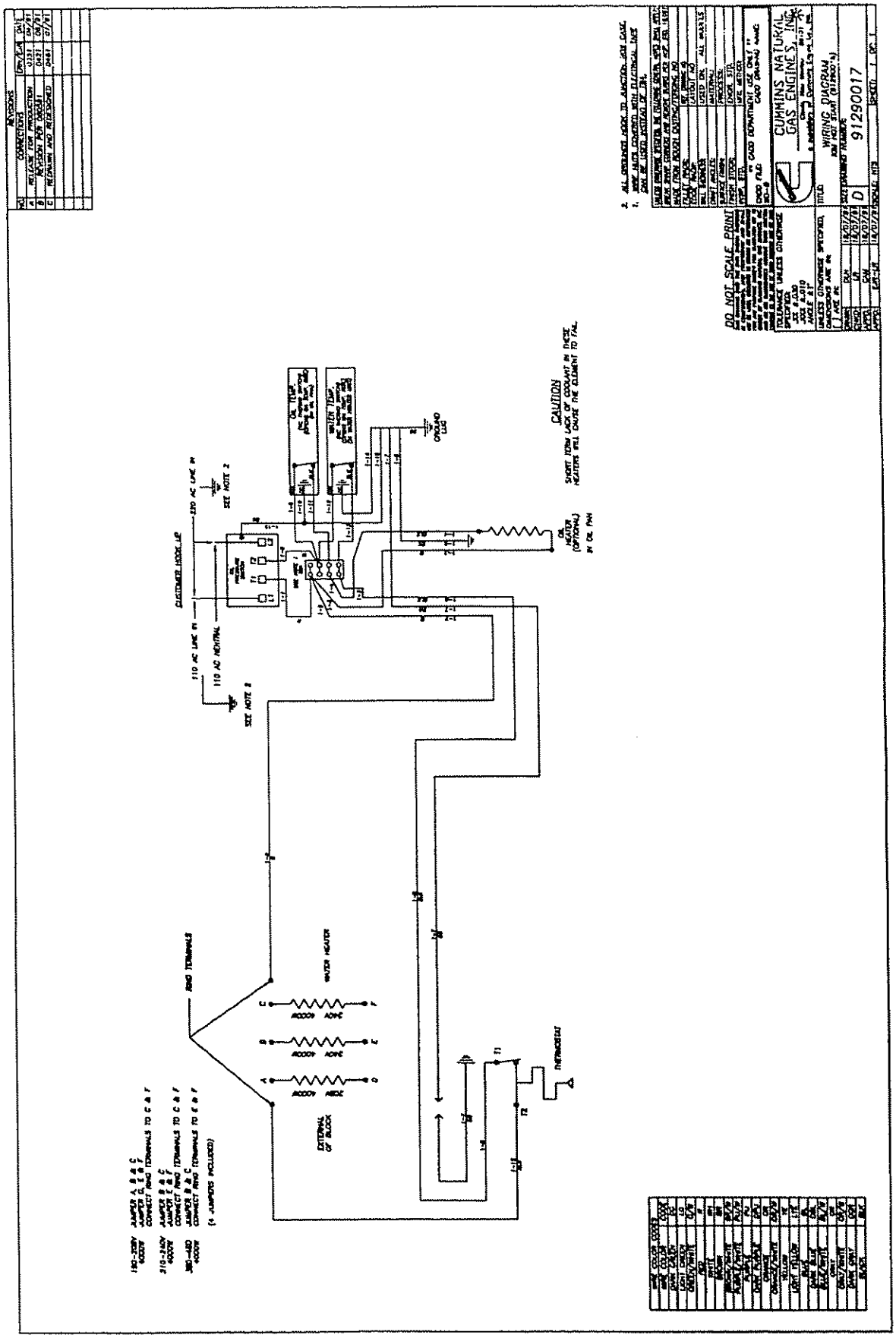
_____

_____

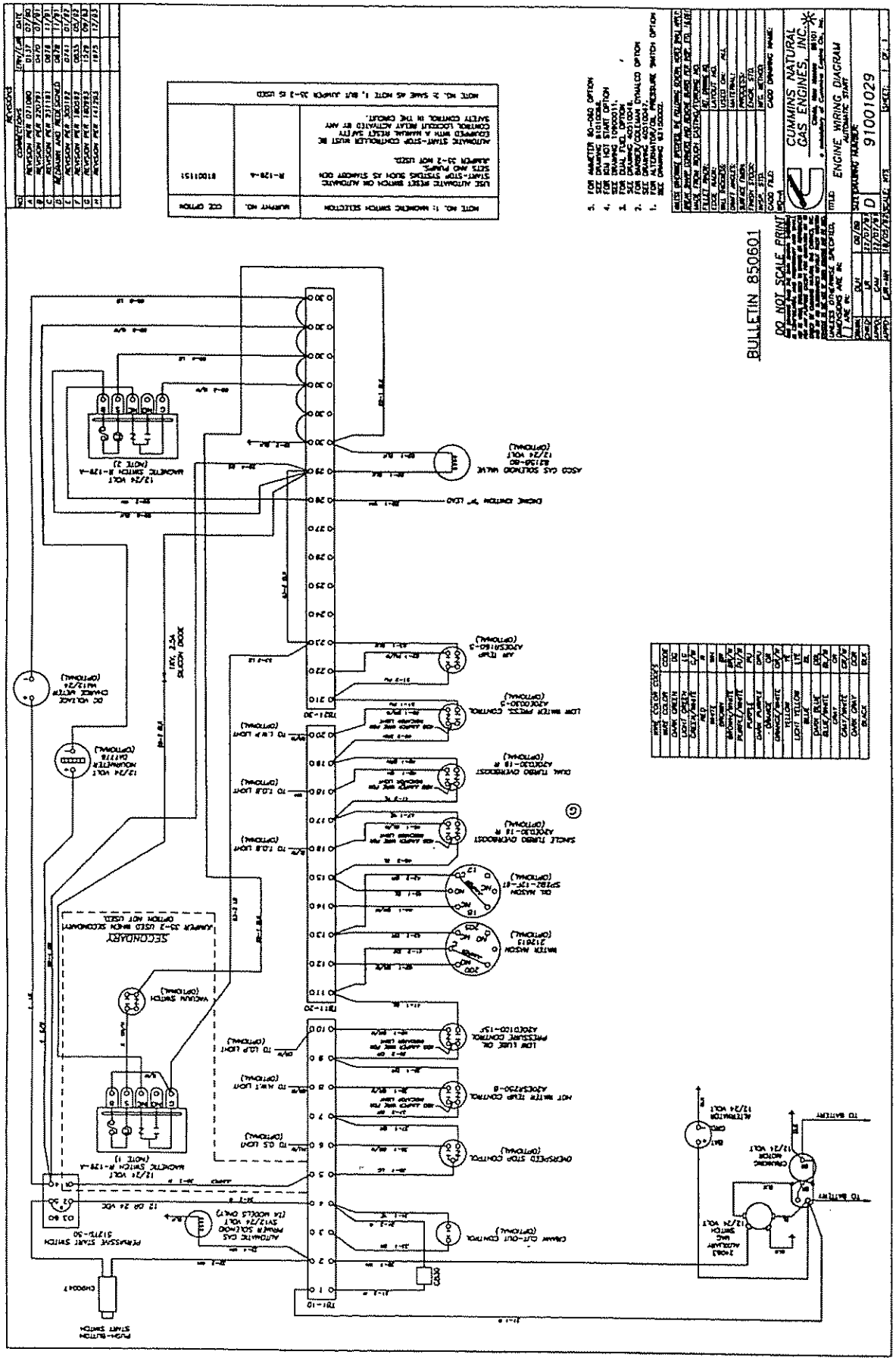
Kim Hotstart Wiring Diagram Part # E 220

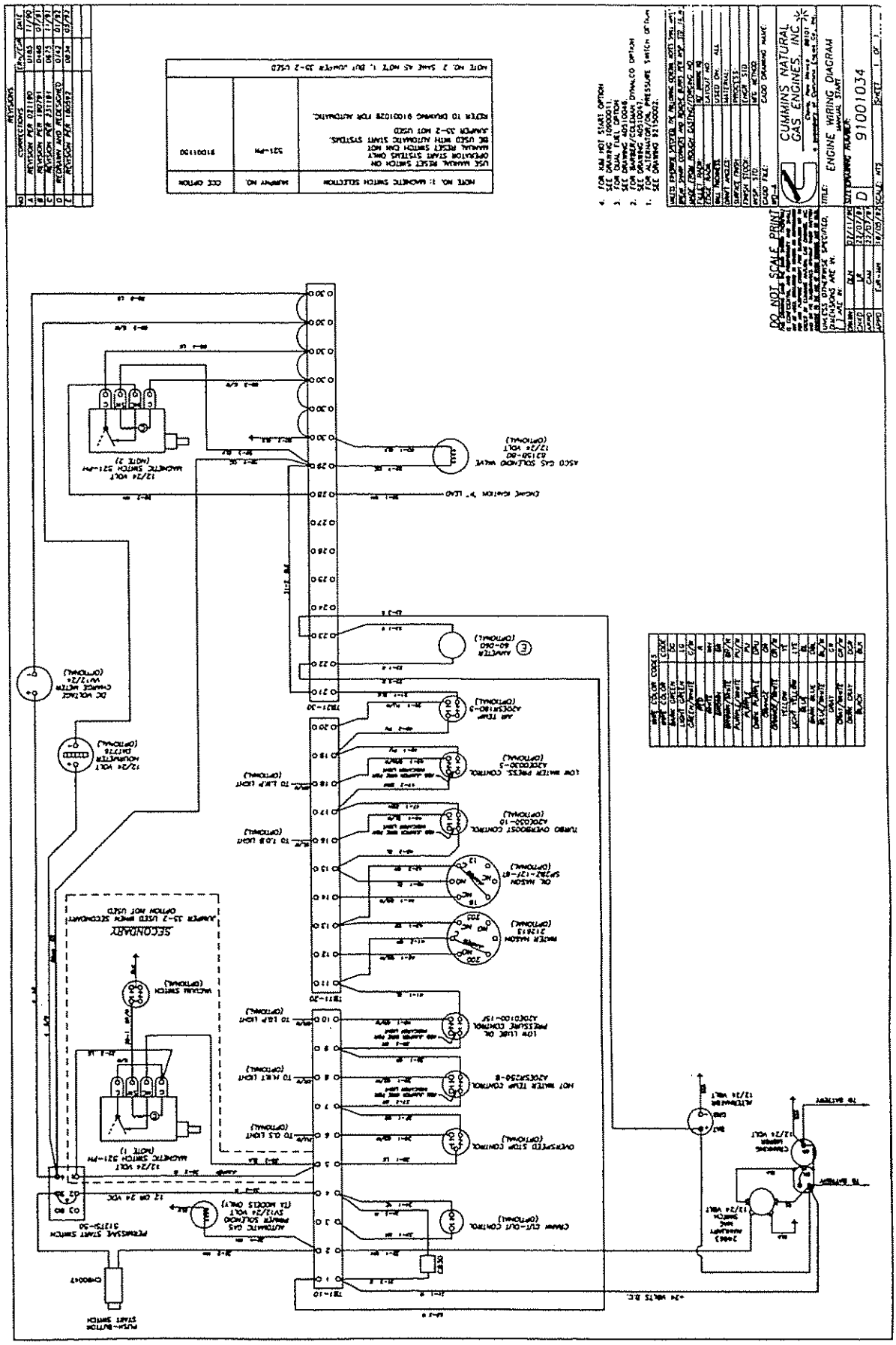


Kim Hart Wiring Diagram Part # 9120016



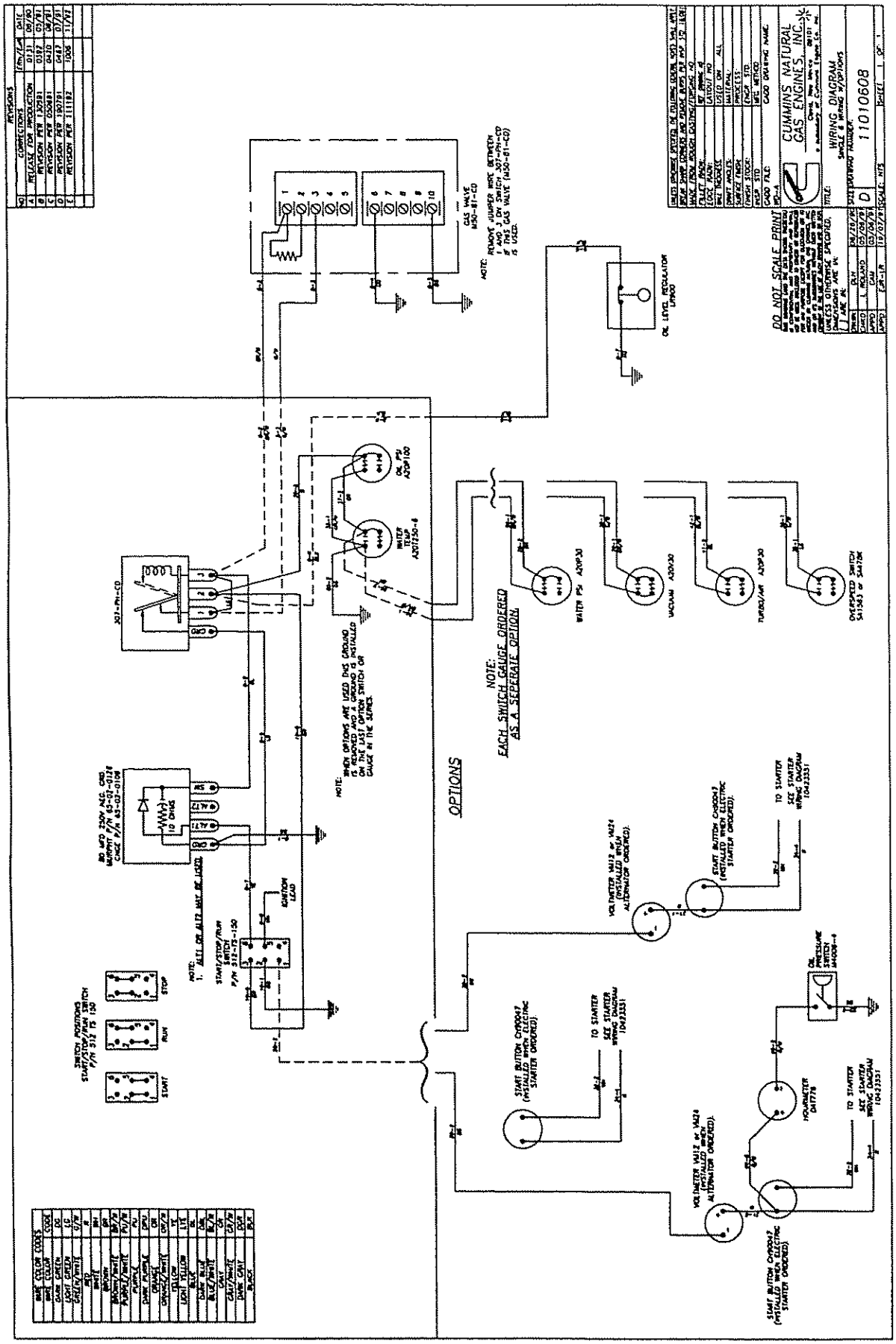
Automatic Start Engine Wiring Diagram #1



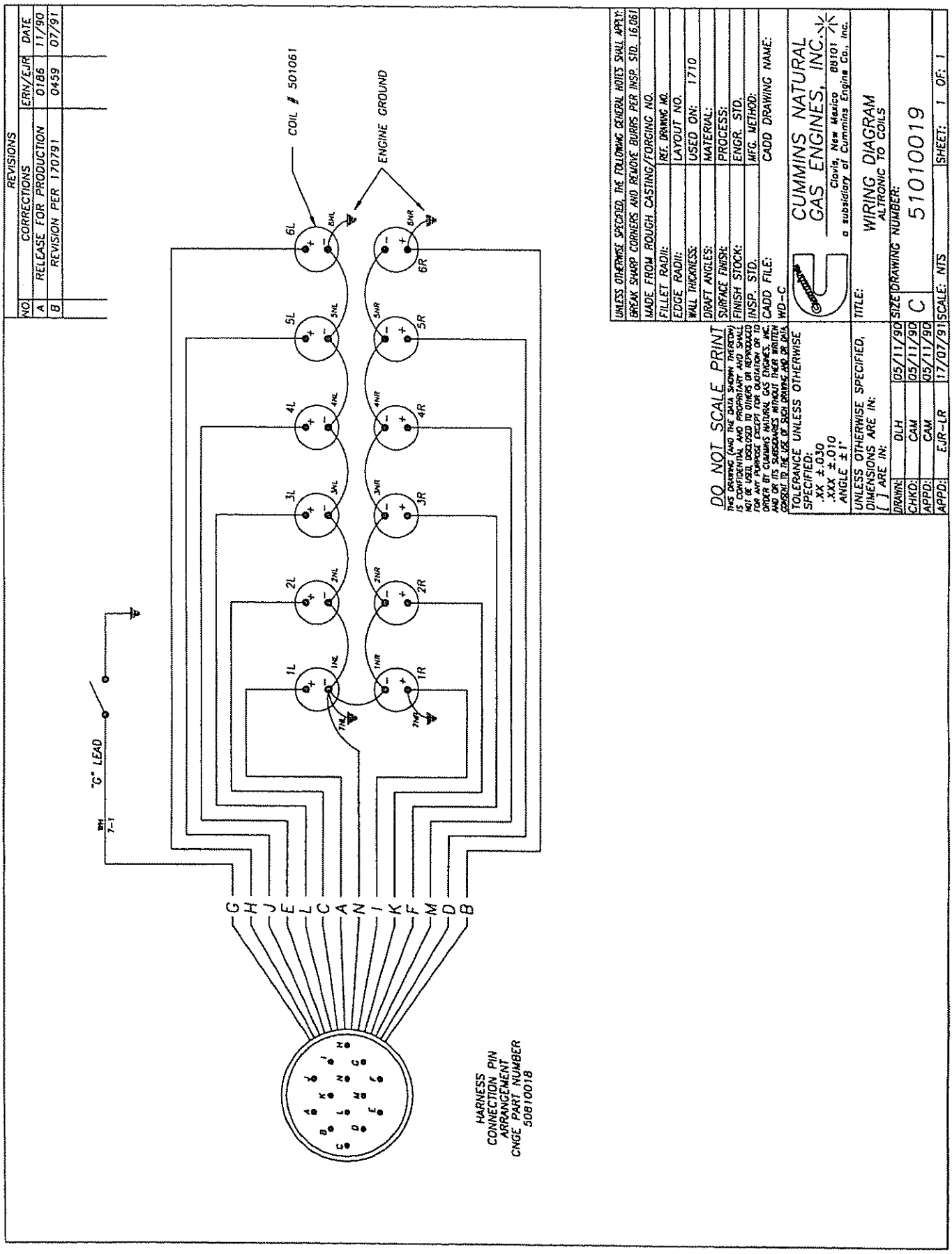


Manual Start Engine Wiring Diagram #2

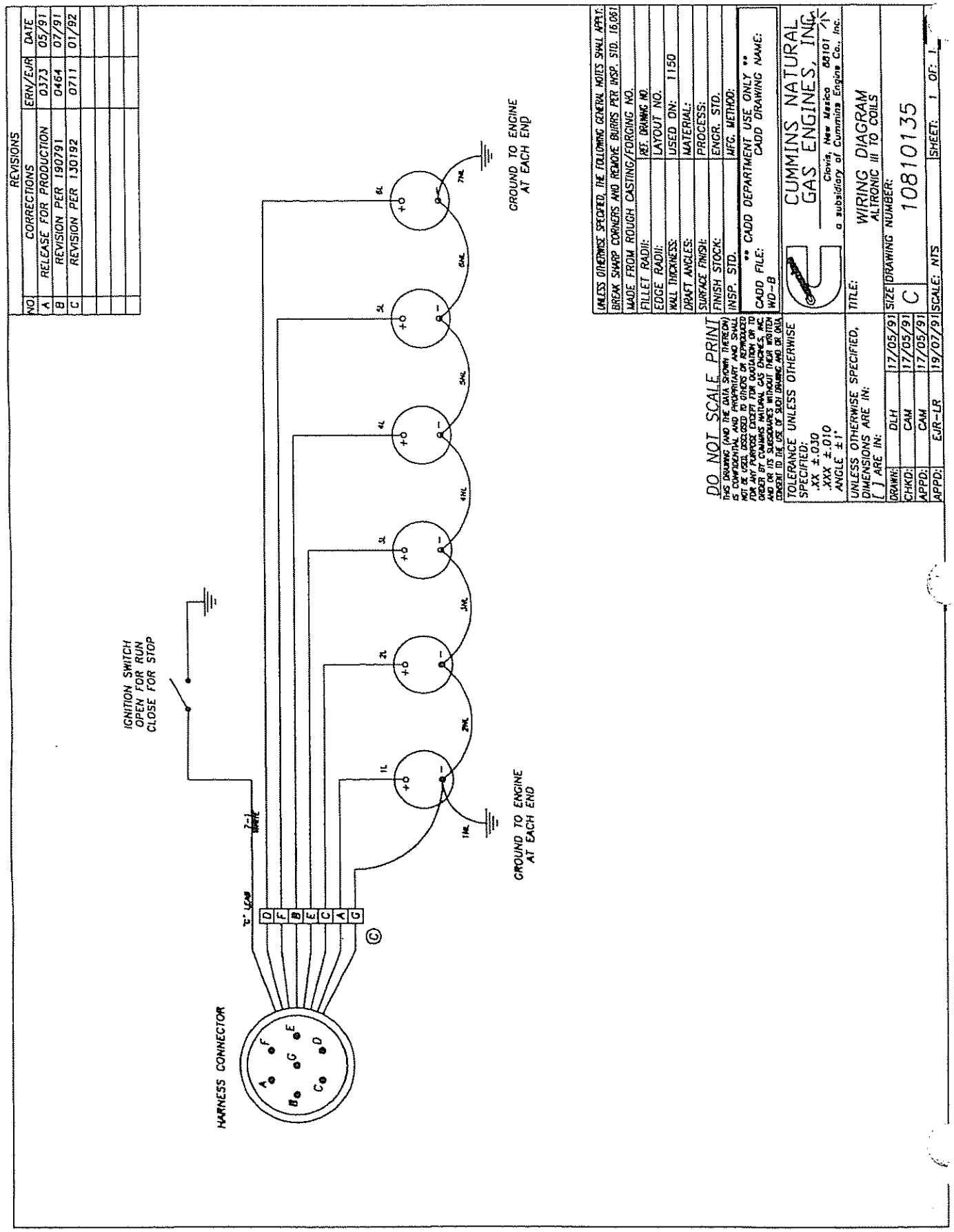
Six Gauge Panel Box Engine Wiring Diagram #3



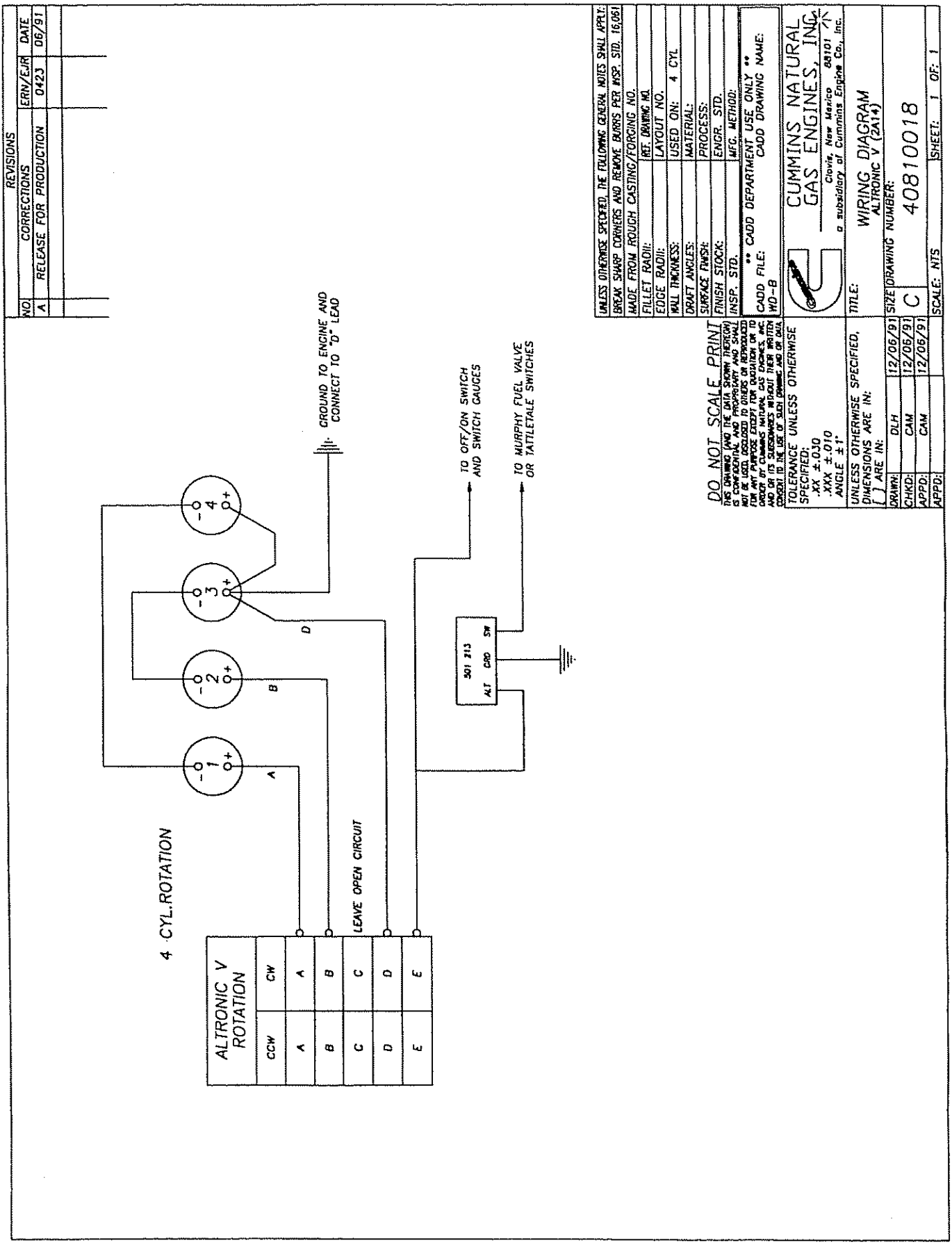
G28/G[illegible] - Altronic III Ignition Wiring Diagram #4



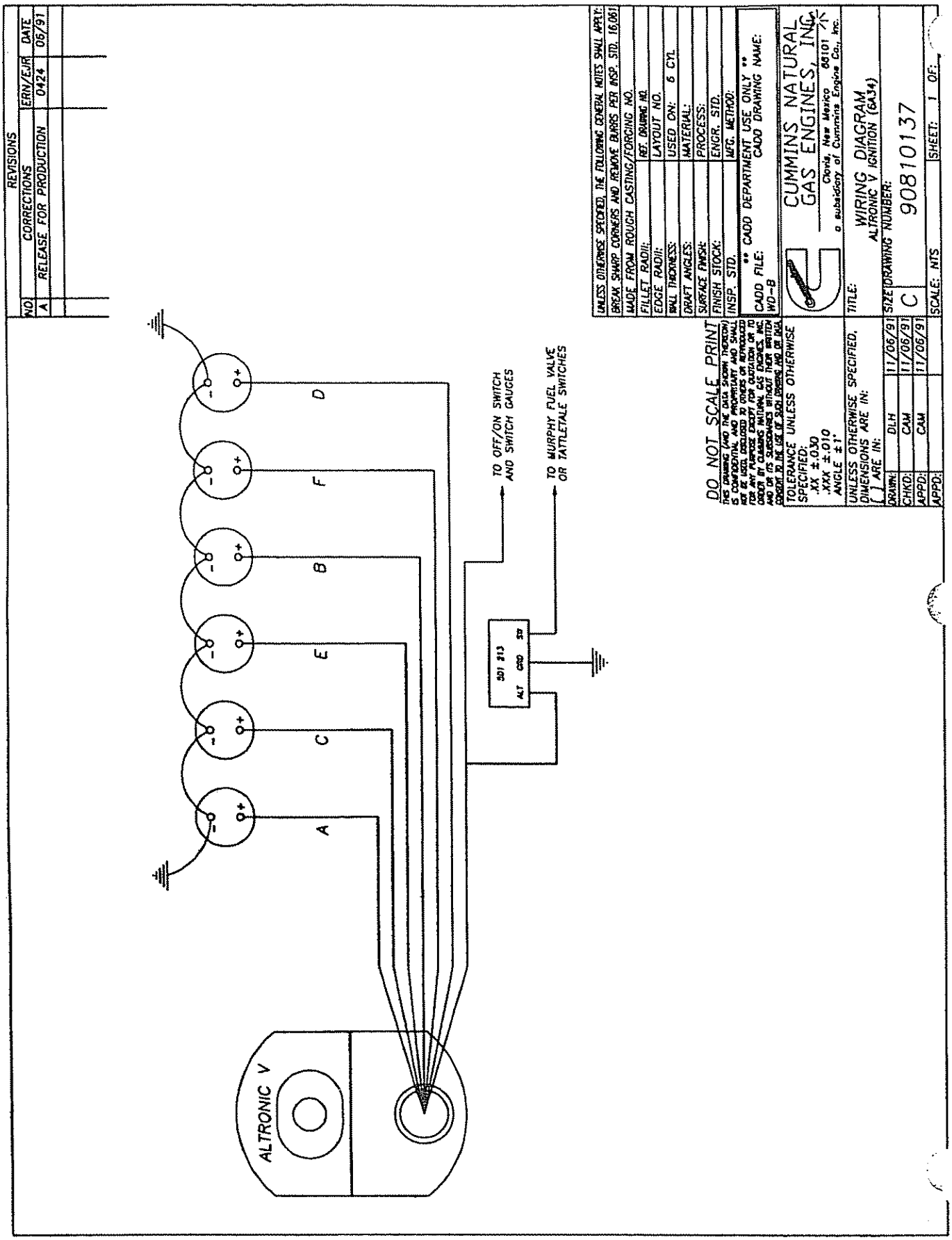
GTA19 - Altronic III Ignition Wiring Diagram #5



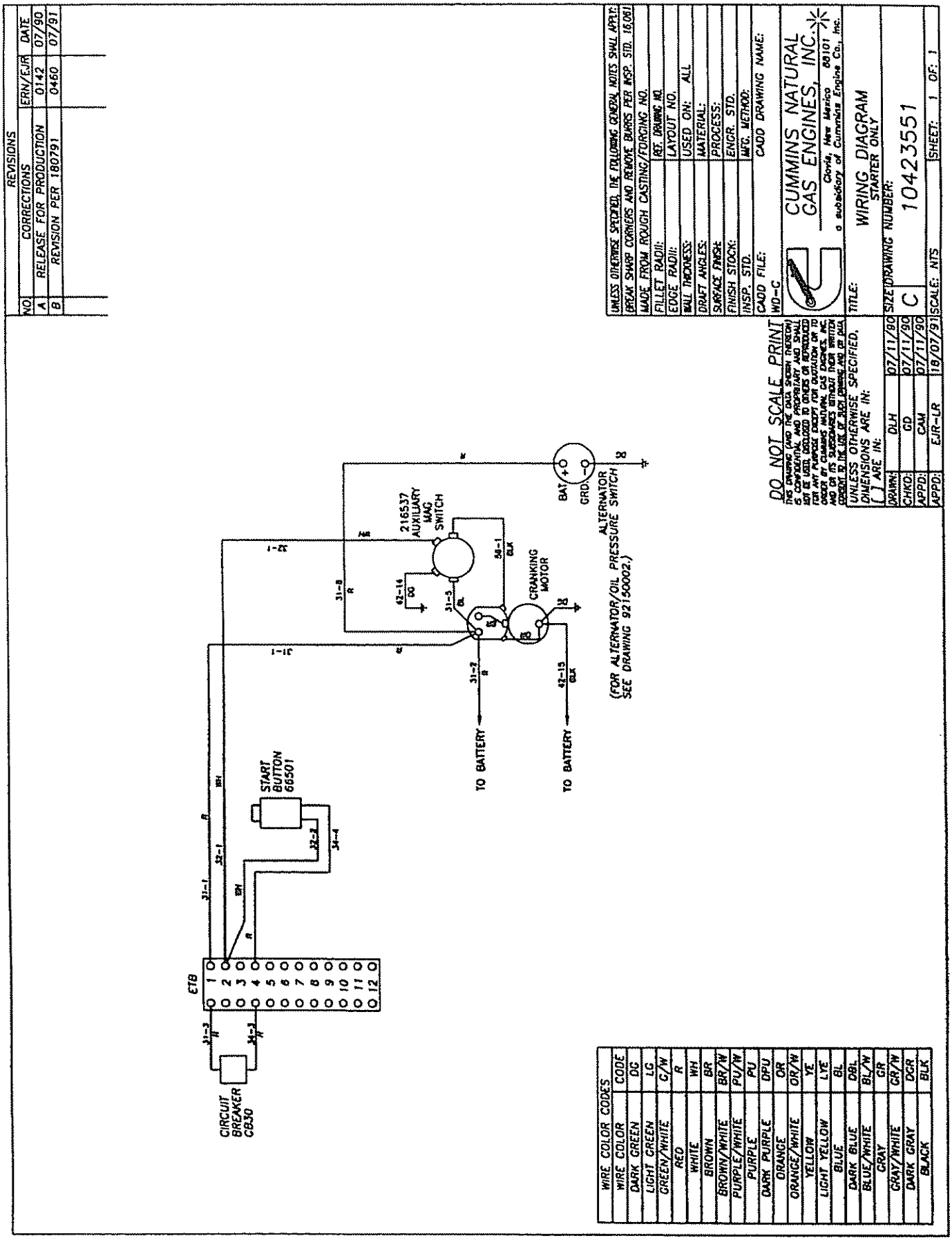
CNGE Cylinder Engines - Altronic V Ignition Wiring Diagram #6



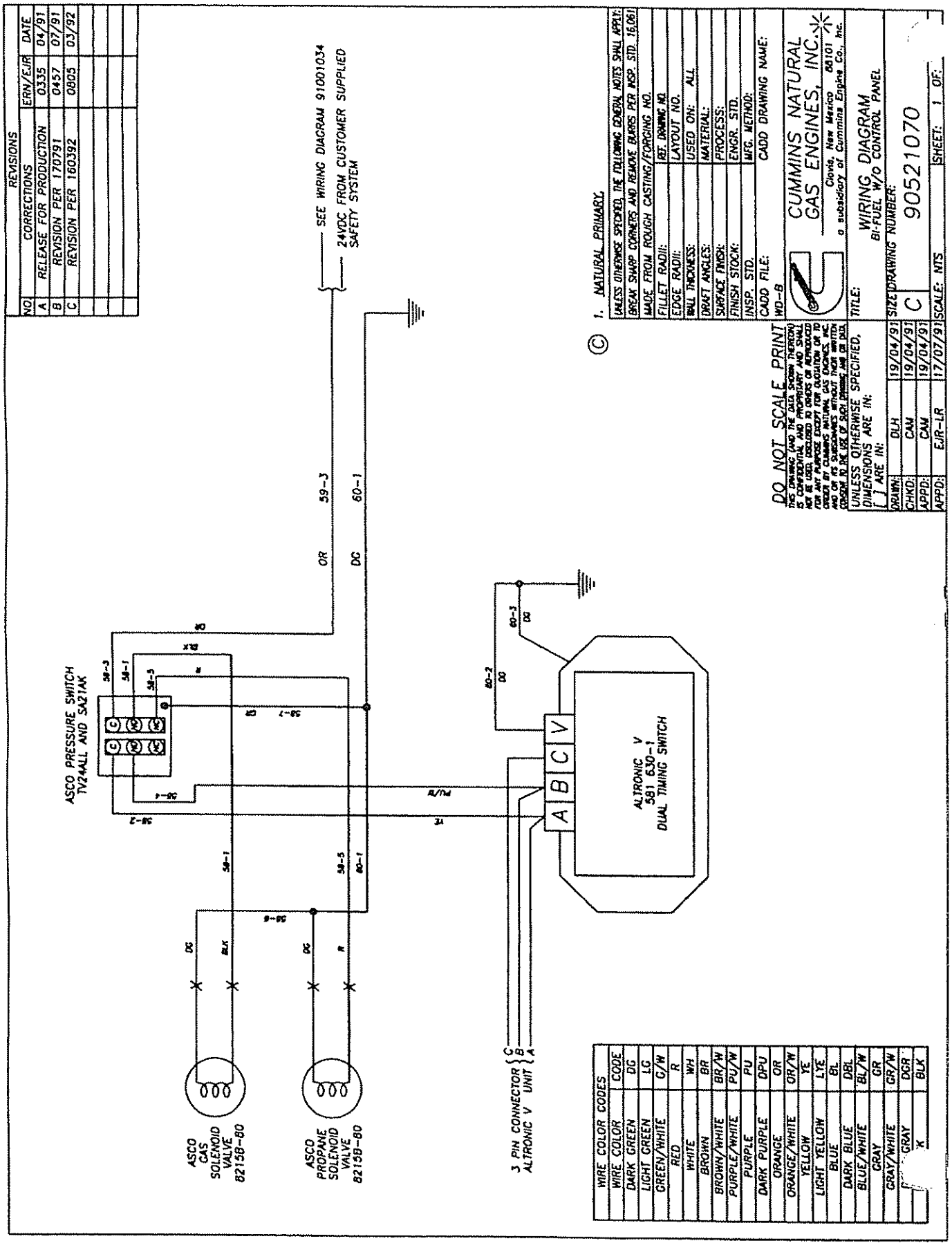
CNGE 6 Cylinder Engines - Altronic V Ignition Wiring Diagram #7



Starting Engine Wiring Diagram #8



Engine Wiring Diagram #9 Bi-Fuel Without Control Panel



SECTION 14 - DRIVE BELTS

CONTENT

Drive Belts

Belts - General Inspection

Visually inspect the belts. Replace belts that are cracked or frayed. Adjust belts that have a glazed or shiny surface, indicating belt slippage. Correctly installed and tensioned belts will show even pulley and belt wear patterns.

Belt damage can be caused by:

- Incorrect tension
- Incorrect size or length
- Pulley misalignment
- Incorrect installation
- Severe operating environment

All new belts will loosen during use. They must be adjusted to the values listed in the Belt Tension Chart.

Note: A belt is considered used if it has been in operation for 10 minutes or longer.

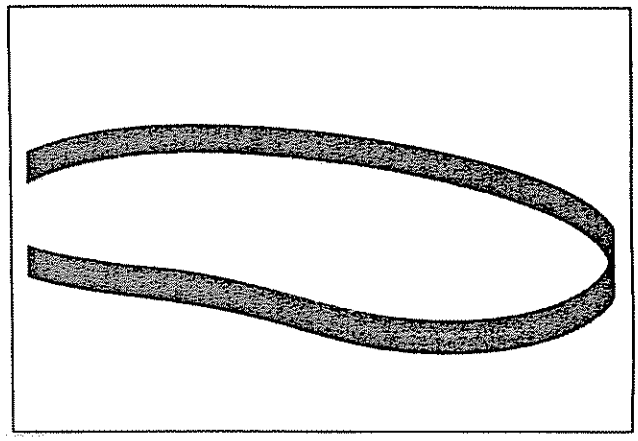


Photo #14-01 - Typical Belt

Belt Tension - Checking

Use a belt tension gauge to measure the tension of the belt. Refer to the Belt Tension Table #14-03. An alternative method (deflection method) can be used to check belt tension by applying 110 N [25 lbs.] force between the pulleys on v-belts. If the deflection is more than one (1) belt thickness per foot of pulley center distance, the belt must be adjusted.

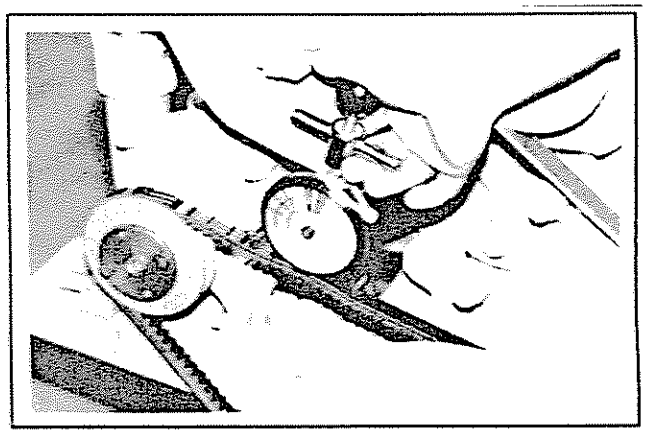


Photo #14-02 - Belt Tension Checking

Belt Tension Tools

Table #14-03 - Belt Tension Tools

Belt Tension Tools	
Part No.	Description
ST-1138	Use on v-belts (11/16 to 7/8 inch)
ST-1293	Use on v-ribbed belts
3822524	Use on v-belts (3/8 to 7/8 in.) and v-ribbed belts with 5 ribs or less
3822525	Use on v-belts larger than 7/8in. and v-ribbed belts with 6 or more ribs

Fan Drive Belt - Adjustment

Note: Do not adjust belt tension to full value with the adjusting screw. Belt tension can increase when the lock nut is tightened and reduce the belt and bearing life.

1. Loosen the four capscrews that secure the fan hub shaft to the bracket.
2. Turn the adjusting screw to increase belt tension.
3. Measure the belt tension.
4. Tighten the four capscrews until the fan hub is in correct alignment with the fan bracket.
5. Measure the belt tension.
6. Loosen the adjusting screw 1/2 turn to prevent breakage.

Special Notes:

_____

_____

_____

_____

_____

_____

Water Pump Belt - Adjustment

GTA855-B BCIII

1. Loosen the lock nut that secures the idler pulley to the water pump.
2. Turn the adjusting screw to adjust the v-ribbed belt tension to 623 N [140 lb].
3. Rotate the crankshaft one revolution to allow the belt to stretch, and check the tension again.

Note: Do not adjust belt tension to full value with the adjusting screw. Belt tension can increase when the lock nut is tightened and reduce belt and bearing life.

4. Secure the idler pulley in position by tightening the lock nut.
   Torque Value: 70 N•m [50 ft-lb]
5. Loosen the adjusting screw 1/2 turn to prevent breakage.
6. Measure the belt tension again. Adjust if necessary.

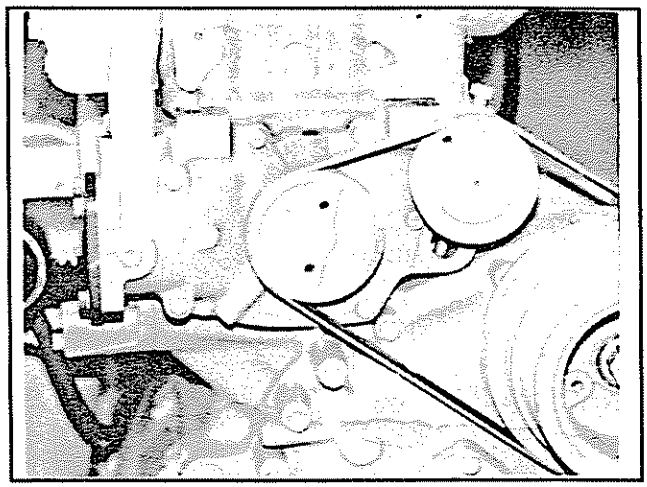


Photo #14-04 - GTA855 BCIII Water Pump Drive Belt

Auxiliary Water Pump Belt - Adjustment

Take special care when tightening the belt for the engine mounted aftercooler water pump. CNGE believes it is best accomplished by insuring that the deflection measures a minimum of 1 inch with 25 lbs. of force applied between the pulleys. Overtightening of this belt will cause the aftercooler water pump to suffer unnecessary failures.

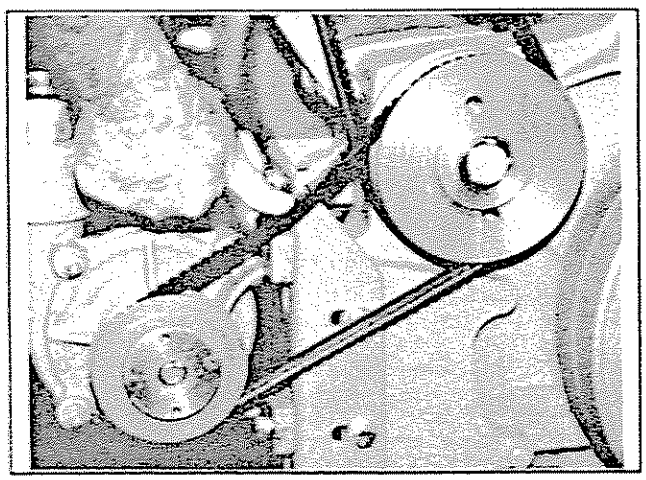


Photo #14-05 - Auxiliary Water Pump Drive Belt

Alternator Belt - Adjustment

Measure the belt tension. Refer to the alternator manufacturer's maintenance recommendations or refer to the Belt Tension Chart on page 14-3 for the correct gauge and tension values.

Drive Belts - Replacement

Note: When a drive uses two or more belts, replace the belts as a complete set.

Loosen the adjusting mechanism and move the pulley centers as close as possible. The belts can then be installed without excessive force.

To prevent damage, do not roll a belt over the pulley or pry it on with a tool.

Refer to the Belt Tension Chart on this page to select the correct gauge for the belt width.

Pulley misalignment must not exceed 6 mm for each meter [1/16 in. for each 12 inches] of distance between the pulley centers.

Belts must not touch the bottom of the pulley grooves nor must they protrude over 3 mm [3/32 in.] above the top edge of the groove.

When a drive uses two or more belts, the belt riding depth must not vary over 2 mm [1/16 in.] between belts.

Belt Tension Chart (Pounds)

Belt Width inches	Belt Gauge	New Belt Tension Min.-Max.	*Used Belt Tension Min.-Max.
.380	ST-1274	130-150	80-120
.440		130-150	80-120
.500		130-150	80-120
.6875		130-150	80-120
.750	ST-1138	130-150	80-120
.875		130-150	80-120
4 Rib		130-140	80-120
5 Rib	3822524	190-210	90-120
6 Rib	3822525	190-210	155-165
to 12 Rib	3822525	190-210	155-165

* Adjust used belts to the values in this column. If below minimum retension to maximum.

Note: Any belt in use with more than 10 minutes is considered USED.

Special Notes:

SECTION 15 - ENGINE AND COMPONENT MAINTENANCE

CONTENT

Engine - Steam or Chemically Cleaning

Steam clean the engine annually. Steam is the best method of cleaning a dirty engine or piece of equipment. If steam is not available, use a cleaning solvent to wash the engine.

Protect all electrical components, openings, and wiring from the full force of the cleaner spray nozzle.

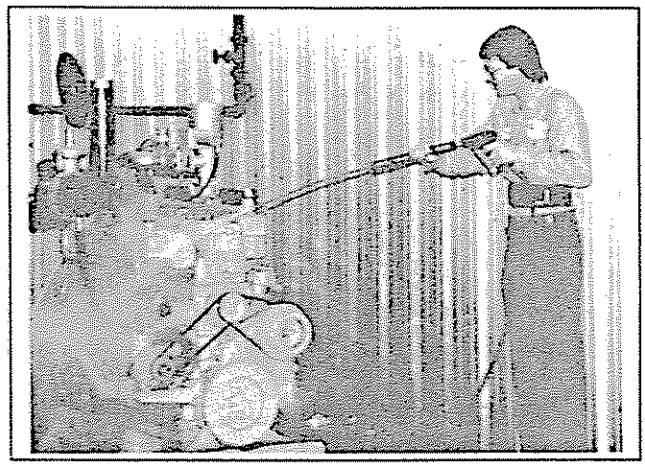


Photo #15-01 - Steam Cleaning

Check Operator's Report or Logsheet

The operator's report or logsheet should be checked daily. Investigate and take necessary corrective action as required. Examples of problem areas may be as follows:

1. A sudden shift of lubricating oil pressure either up or down.
2. Low Power
3. An increase in water or exhaust gas temperature to an abnormally high level.
4. New and unusual engine noises or vibrations.
5. Rough running or engine miss-firing.

Visually Inspect Engine

The engine should be inspected daily for engine damage, and for air, oil, fuel, gas and coolant external leakage. Check for loose or frayed belts, loose or damaged hoses, and loose clamps. Take the required corrective action.

Check Governor Sump Oil Level

Many engines used in statiionary power applications use hydraulic governors. For proper maintenance, refer to the specific governor manufacturer's recommendations.

The governors normally use the same lubricating oil as the engine. The oil level in the governor's sump must be at the half-way level on an inspection sight glass.

Engine Mounting Bolts - Checking

Check the torque on the nuts and bolts annually. Tighten any that are loose. Inspect the rubber for deterioration and age hardening. Replace any broken or lost bolts, capscrews, or damaged rubber.

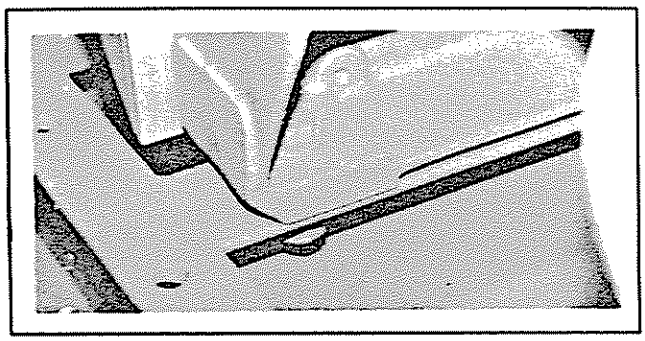


Photo #15-02 - Mounting Bolts

Intake and Exhaust Valve - Adjustment

Adjust the intake and exhaust valves at each 750 hours or 6 months maintenance interval. Also, check adjustment after any major repair.
Valves must be correctly adjusted for the engine to operate efficiently. Valve and crosshead adjustment values are listed in Table #15-03.

Table #15-03 - Valve Adjustment Settings (Cold Set)

Engine Model	Intake Valve [mm (in.)]	Exhaust Valve [mm (in.)]
G12/GTA12	.36 (.014)	.69 (.027)
G855/GTA855-A	.36 (.014)	.85 (.033)
GTA855-B	.36 (.014)	.85 (.033)
GTA19	.36 (.014)	.69 (.027)
GTA28	.36 (.014)	.85 (.033)

All CNGE engines require that the engine should be adjusted while at ambient temperature. When the engine has recently been shut down, allow sufficient time for the engine temperature to stabilize with the room or ambient conditions.

Valve Adjustment Procedures

1. Bar the engine in the direction of rotation until the No. 1 VS mark appears on the accessory drive pulley. The GTA19 marks will be on the Vibration Damper.
   In this position, both intake and exhaust valves will be closed if the cylinder is in the firing position. If valves are not closed, rotate the engine one complete revolution.
   Note: Some flywheels have holes and some housings have slots that are provided for a cranking bar. As an alternative method, ST-747 Barring Tool can be used on the accessory drive pulley to rotate the crankshaft.
   Caution: DO NOT USE THE OUTER MEMBER of the Vibration Damper to bar the engine. This will cause serious damage to the damper.

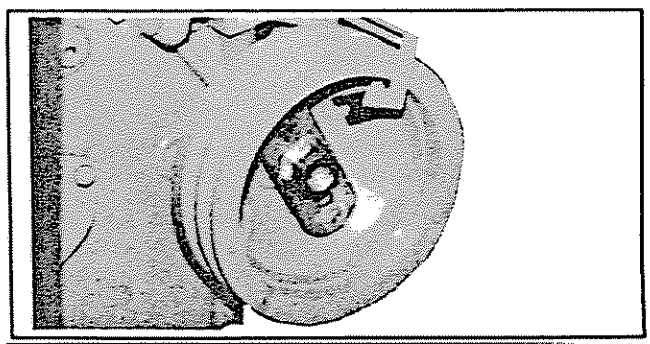


Photo #15-04 - Valve Set Marks

2. Continue to rotate the engine until the "VS" marks on the pulley line up with the marker on the engine block or engine water pump capscrew (GTA28).

3. Adjust the crossheads first, and then the valves. Follow the procedure in this section for the appropriate adjustment.

4. Continue turning the crankshaft in the direction of rotation, adjusting one cylinder at a time until all cylinders have been adjusted.

5. Two complete revolutions of the crankshaft are needed to adjust all intake and exhaust valves.

Crosshead Adjustment

1. Loosen the valve adjusting screw locknut and back off the screw one complete turn.

2. Use a light finger pressure at the rocker lever to hold the crosshead in contact with the valve stem nearest the push tube.

3. Turn down the crosshead adjusting screw until it contacts the corresponding valve stem.

4. Torque the locknut to 34-41 N•m [25-30 ft-lb] with a torque wrench to lock the adjusting screw in position. If ST-669 Tool is used with a torque wrench, tighten to 30-35 N•m [22-26 ft-lb]. Adjust both intake and exhaust valve crossheads.

5. Check clearance between crosshead and valve spring retainer with a wire gauge. Minimum clearance is .51 mm [.020 in.]. (The minimum clearance on the GTA19 is .64 mm [.025 in.]).

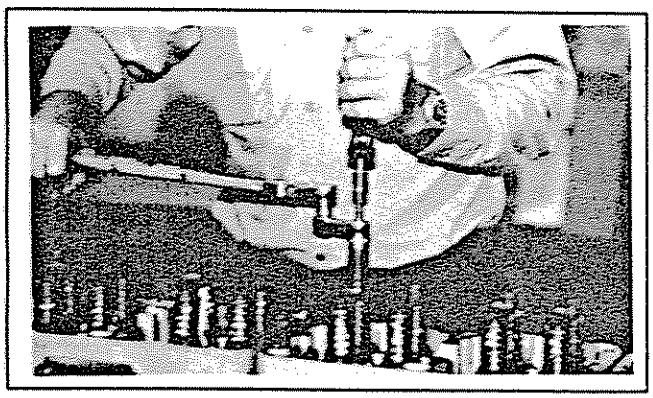


Photo #15-05 - Crosshead Adjustment

Valve Adjustment

1. Loosen the valve adjusting locknut and back off the adjusting screw one full turn.

2. Use a feeler gauge of proper thickness for the valve being adjusted and for the specific CNGE engine model (See Valve Adjustment Settings on page 15-2).

3. Insert the feeler gauge between the crosshead and rocker lever and turn the adjusting screw down until the lever just touches the feeler gauge.

4. Tighten the locknuts to 54-61 N•m [40-45 ft-lb] torque. If ST-669 service tool is used, tighten to 41-47 N•m [30-35 ft-lb] torque.

Viscous Damper - Inspection

Caution: The silicon fluid in the damper will become solid after extended service and will make the damper inoperative. An inoperative damper can cause major engine or driveline failures.

Every 4500 hours or 2 years, inspect the vibration damper. Check the damper for evidence of fluid loss, dents, or wobble. Visually inspect the vibration damper thickness for any deformation or raising of the damper front cover plate.

Note: If any variations or deformations are detected, contact your local Cummins Authorized Repair Location for specific details.

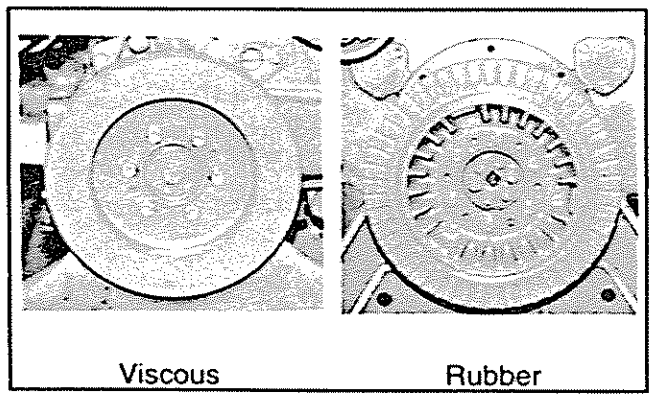


Photo #15-06 - Vibration Damper

Rubber Damper - Inspection

Every 4500 hours or 2 years inspect the rubber damper.

Check the index lines on the damper hub (inner member) and the inertia member (outer member). If the lines are more than 1/16 inch (2 mm) out of alignment, replace damper.

Inspect the rubber member for deterioration. If pieces of rubber are missing or if the elastic member is more than 3 mm (1/8 in.) below the metal surface, replace the damper.

The **VIBRATION DAMPER** should be replaced at 15000 hours of operation if not replaced at earlier inspections.

Checking Engine Cylinder Compression

CNGE recommends the following steps when checking cylinder compression:

1. Locate and shut off the gas fuel valve and tag the valve with a DO NOT OPEN tag.

2. Ground the ignition "G" lead to prevent any igniton spark.

3. Remove spark plug probes from the spark plug wells. Check for oil or water contamination and clean before continuing.

4. Remove the spark plugs from ALL cylinders using a proper spark plug removal tool.

5. Block the engine throttle wide open.

6. Install a compression gauge in #1 cylinder.

7. Crank the engine with the starter until the engine has rotated 6 to 8 revolutions. The compression gauge should be at a stable reading and not moving.

Caution: Before starting this check, it is important to verify that your batteries have a full charge.

8. Record the reading in pounds per square inch. Release the gauge pressure and remove the gauge.

9. Repeat steps 6 through 8 for each cylinder.

All cylinder pressures should be within a 10 percent variance. Recheck any cylinder that is not within this limit.

The engine must be turning over at the same speed for each individual cylinder during testing. If outside this limit, contact your local Cummins dealer for further assistance.

Storage for Engines Out of Service

If the engine will be out of service longer than 6 months, take special precautions to prevent rust. Contact the nearest Cummins authorized Repair Location, or consult the Cummins Engine Shop Manual for information concerning engine storage procedures.

SECTION 16 - TROUBLESHOOTING

CONTENT

Procedures and Techniques

This guide describes some typical engine operating problems, their causes, and some acceptable corrections to those problems. Unless noted, the problems listed are those that an operator can diagnose and repair. See a CNGE authorized repair location for diagnosis and repair of problems not listed.

Follow the suggestions below for troubleshooting:

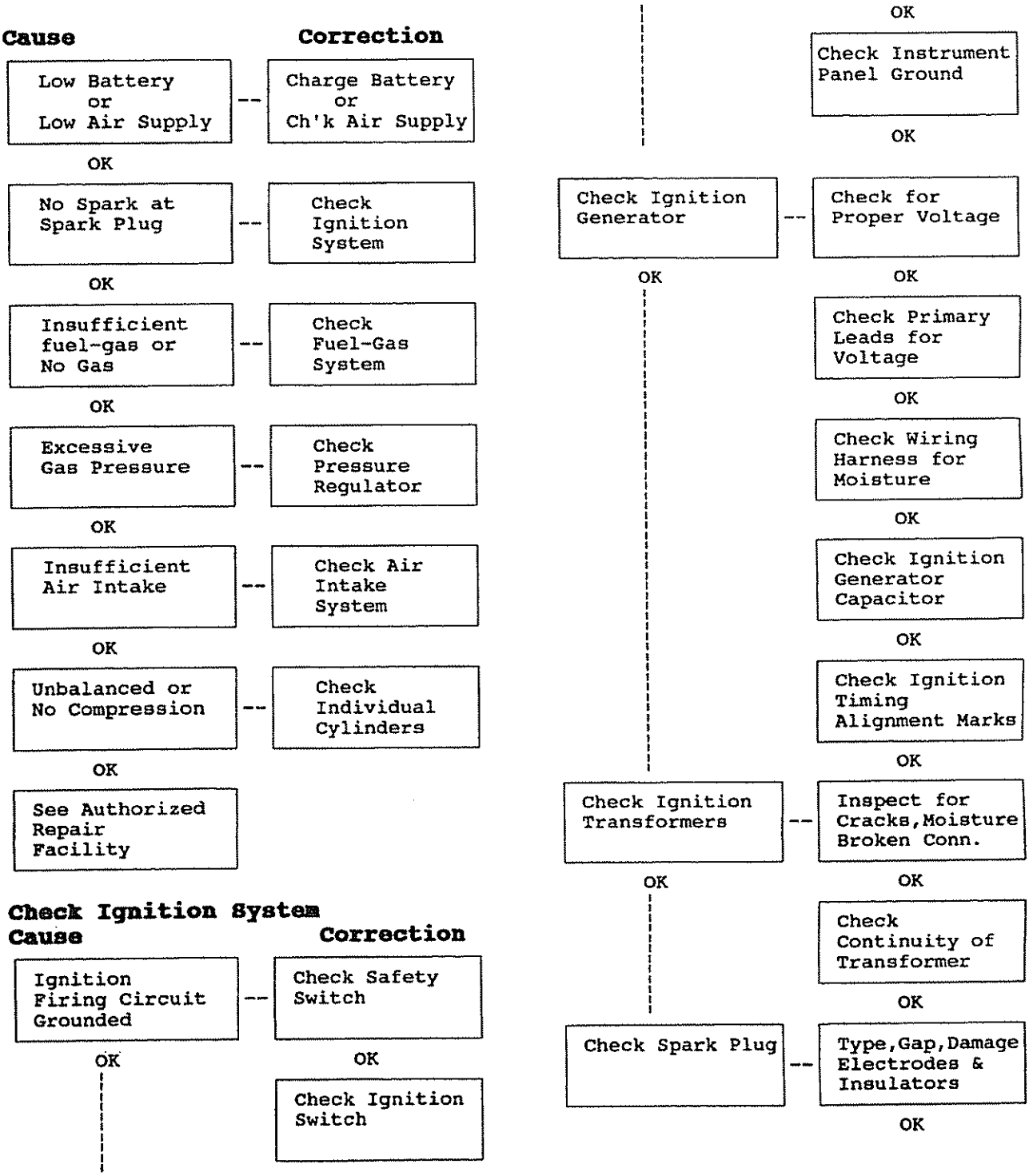
- Study the problem thoroughly before acting.
- Refer to the engine system diagrams.
- Do the easiest and most logical things first.
- Find and correct the cause of the problem.

Symtoms List

Instructions

Read each row of blocks from top to bottom. Follow the arrows through the chart to identify corrective action.

Engine Hard to Start or Will Not Start



Check Ignition System

Engine Hard Start or Will Not Start (Contd)

Check Ignition System (Contd)

Check for signs of water on plug or in Cylinder

If signs of water are found on the Spark Plug or there is evidence of water in the Cylinder, CNGE recommends that the customer contact an authorized repair facility to continue inspection and repair the engine.

Check Fuel-Gas System

Cause	Correction
Fuel-Gas Shut-Off Closed	Open Manual or Re-Set Electric
OK	OK
	Check Electric for Proper Voltage
Plugged Gas Filter	Replace with New CNGE Filter Element
OK	
Fuel-Gas Shut-Off Open Low Gas Pressure	Contact Local Gas Company & Request
OK	
	Check Main Line Gas Pressure & Adjust If Req'd

Check Pressure Regulator

Cause	Correction
Fuel-Gas Shut-Off Open Excessive Gas P.	Inspect & Adjust Gas Pressure Regulator
OK	
	Chk Atmospheric Vent for Leakage
OK	
	Check Carburetor air/gas Valve Diaphragm
OK	
	Check Gas Power Valve for proper setting
OK	

Check Air Intake System

Cause	Correction
Insufficient Air	Check Air Cleaner Restriction
OK	
	Check Carburetor Air Valve Spring
OK	

Check Individual Cylinders

Cause	Correction
Check Compression Each Cylinder	Check Valve or Piston Ring Leakage
OK	
	Check Valve & Crosshead Clearance
OK	
	Contact Local Authorized Repair Location

Engine Will Not Idle Properly

Cause	Correction
Uneven Firing of Cylinders	Check Ignition System See page 16-2&3
OK	
Improper Combustion	Check Fuel System See page 16-2&3
OK	
Unbalanced Compression	Check Individual Cylinders See page 16-2&3
Incorrect Timing	Check Valve & Ignition Timing See page 16-2&3

Engine Fails to Operate Properly Under Load - Has A Miss or Vibration

Cause	Correction
Ignition System is Mal-functioning	Check Ignition System
OK	
Engine Shakes or vibrates	Check Engine Timing
OK	OK
	Check Spark Plugs
	OK
	Check Ignition Transformers
	OK

Cause	Correction
Improper Fuel or Fuel Syst Adj.	Check Fuel System
Insufficient Air Supply	Check Air Intake System
OK	OK
Unbalanced Compression	Check Individual Cylinders
OK	OK
Loss of Engine Speed	Check Governor Operation
OK	OK
No Governor Action	Check Turbo Boost Limiter

Lubricating Oil Pressure Low

Cause	Correction
Incorrect Oil Level	Check for Leaks Add Oil or Check Dipstick Calibr.
OK	
Oil Pressure Gauge Malfunctioning	Check Oil Pressure Gauge
OK	
Incorrect Oil Specifications	Change Oil and Check Specifications
OK	

Lubricating Oil Pressure Low (Contd)

Cause		Correction
Oil Filter Plugged	--	Replace Full Flow Filter
OK		
Oil Temperature Above Normal	--	Refer to Coolant Temperature Above Normal Cht
OK		
See Authorized Repair Facility		

Coolant Temperature Above Normal

Cause		Correction
Low Coolant Level	--	Add Coolant
OK		
Radiator Fins Damaged or Obstructed	--	Inspect Fins Clean and Repair as Needed
OK		
Collapsed or Restricted Radiator Hose	--	Inspect Hoses Replace if Necessary
OK		
Loose Fan Drive or Water Pump Belt	--	Check Belt Tension and Adjust if Needed
OK		
Incorrect Oil Level	--	Add Oil or Drain and Check Dipstick Calibr.
OK		
Cooling Fan Shroud Damaged	--	Inspect Shroud and Adjust Fan to Shroud
OK		
Incorrect or Bad Radiator Cap	--	Check Radiator Cap and Replace if Needed
OK		
Temperature Gauge Malfunctioning	--	Test the Gauge Replace if Necessary
OK		
See Authorized Repair Facility		

The term **"trouble-shooting"** means locating the basic cause of the difficulty so that when repairs are made there will be no repetition of the failure. This guide describes some typical engine operating problems, their causes, and some acceptable corrections to those problems. Unless noted otherwise, the problems listed are those that an operator can diagnose and repair. See a Cummins or CNGE Authorized Repair location for diagnosis and repair of problems not listed.

SECTION 17 - TECHNICAL SPECIFICATIONS

CONTENT

Lubricating Oil & Grease

Functions of Lubricating Oil

The lubricating oil used in a CNGE engine must be mult-functional. It must do the primary functions of:

Lubrication by providing a film between the moving parts to reduce wear and friction.

Cooling by serving as a heat transfer media to carry heat away from critical areas.

Sealing by filling in the uneven surfaces in the cylinder wall, valve stems, and turbocharger oil seals.

Cleaning by holding contaminants in suspension to prevent a build up of deposits on the engine surfaces.

In addition, it also must provide:

Dampening and cushioning of components that operate under high stress, such as gears and push tubes.

Protection from oxidation and corrosion.

Hydraulic Action for components such as governors and various hydraulic controls.

Engine lubricating oil must be changed when it can no longer perform its functions within an engine. Oil does not wear out, but it becomes contaminated to the point that it can no longer satisfactorily protect the engine. Contamination of the oil is a normal result of engine operation. During engine operation, a variety of contaminants are introduced into the oil. Some of these are:

- By-products of Engine Combustion - oxides of nitrogen, carbon, soot, acids from partially burned fuel-gas and lubricating oils.
- Acids, varnish, and sludge that are formed because of oxidation of the oil as it breaks down or decomposes.
- Dirt entering the engine through the combustion air, fuel-gas, or while adding or changing lubricating oil.

The oil must have an additive package to combat these contaminants. The package generally consists of:

- **Detergents/Dispersants** that keep insouble matter in suspension until they are filtered from the oil or are removed with the oil change. This prevents sludge and carbon deposits from forming in the engine.

- **Inhibitors** to maintain the stability of the oil, prevent acids form attacking metal surfaces, and prevent rust during the periods the engine is not operating.
- **Other Additives** that enable the oil to lubricate highly loaded areas, prevent scuffing and seizing, control foaming, and prevent air retention in the oil.

Oil Performance Classification System

The American Petroleum Institute **(API)**, The American Society for Testing and Materials **(ASTM)**, and the Society of Automotive Engineers **(SAE)** have jointly developed and maintained a system for classifying lubricating oil by performance categories. The following are brief descriptions of the API categories used in the CNGE oil performance recommendations.

CC Diesel Engine Service

This category describes oils meeting the requirements of the military specification MIL-L-2104B. These oils provide for high temperature deposits such as sludge and rust in diesel engines and for low temperature deposits in gasoline engines. These oils are for moderate-duty service. (This classification is under review for possible modification or obsolescence).

CD Diesel Engine Service

This category describes oils meeting the requirements of the Series 3 specification and the MIL-L-45199B. These oils provide protection from deposits and oxidation at high temperature or when using fuels with a wide range of quality, such as high sulfur content diesel fuel. Oils in this category are for severe-duty service. (This classification has been replaced by API Engine Service Category CE).

CD II Severe Duty

This oil is for a Two-Stroke Cycle Diesel Engine Service.

CE 1983 Diesel Engine Service

This category is for naturally aspirated or turbocharged engines manufactured since 1983. These oils are recommended for low-speed/high-load operations. This oil may be used where API category CD is recommended.

CF-4 1991 Diesel Engine Service

This category is for naturally aspirated or turbocharged engines manufactured since 1991. This oil may be use where API CE is recommended.

SF 1980 Gasoline Engine Service

These oils were developed for increased oxidation protection, stability, and improved anti-wear performance. From 1980 to 1988 these oils were used in passenger cars and trucks operating under engine manufacturer's maintenance recommendations. These oils provide for maximum protection against rust, corrosion, and engine deposits.

SG 1989 Gasoline Engine Service

Oils developed under this classification are for use in passenger cars, vans, and light duty trucks that are operating under a manufacturer's recommended maintenance procedure.
These oils will provide improved control of engine deposits, oil oxidation, and engine wear, as well as improved protection against rust and corrosion.

Oils that meet API SG classification may be used when API SF, SG, SF/CC, or SE/CC are recommended.

Obsolete Classifications

Oil classification such as CB (Supplement 1 Oils), SC (1964 MS Oils), SD (1968-1971 MS Oils) and SE (1972 MS Oils) are considered obsolete classifications.

Engine Manufacturers Association - EMA

The Engine Manufacturers Association (EMA) publishes a book entitled EMA Lubricating Oils Data Book . Copies may be purchased from:

Engine Manufacturers Association
One Illinois Center
111 East Wacker Dr.
Chicago, IL 60601/USA

This book lists commercially available oils by company and brand name with the API performance categories met by each brand.

Oil Performance Recommendations

CNGE does not recommend the use of any specific brand of engine lubricating oil other than **"Cummins Blue."** CNGE does recommend the use of oil designed to meet the following API categories:

CC for use in naturally aspirated engines. (CC replaced by CD, that has been replaced by CE).

CC/CD for use in turbocharged engines. (CC replaced by CD, that has been replaced by CE).

CC/SC for use in engines that operate in a light-duty service, including standby and emergency operation. (CC replaced by CD, that has been replaced by CE; SC replaced by SD, that has been replaced by SE, that has been replaced by SF, that was replaced by SG).

Dual Categories

Dual Categories are used where more protection is required than is provided by a single category. CC/CD and CC/SC categories indicate that the oil is blended to meet the performance level required by each single category.

Sulfated Ash Limit

A sulfated ash limit has been placed on lubricating oil for use in CNGE engines. Experience has shown that oils with a high ash content may produce deposits on valves that can progress to guttering and valve burning. **A maximum sulfated ash content of .85% is recommended.**

CNGE does not recommend the use of ashless oil for natural gas engines. When the ash content is below .15 mass percent, the ash should represent organo-metallic anti-wear additives, provided such additives do not contain barium, or magnesium.

Break-In Oils

Special "break-in" lubricating oils are not recommended for either new or rebuilt CNGE engines. Use the same lubricating oils used in normal engine operation.

Photo #17-01 - Cummins Blue

Viscosity Recommendations

The viscosity of an oil is a measure of its resistance to flow. The Society of Automotive Engineers (SAE) has classified engine oils in viscosity grades; Table #17-02 shows the viscosity range for these grades. Oils that meet the low temperature -18°C [0°F] requirement, carry a grade designation with a "W" suffix. Oils that meet both the low and high temperature requirements are called multi-grade or multi-viscosity grade oils.

Multi-graded oils are generally produced by adding viscosity index improver additives to retard the thinning effects a low viscosity base oil will experience at engine operating temperatures. Multi-graded oils that meet the requirements of the API specifications are recommended for use in CNGE engines.

CNGE recommends the use of multi-graded lubricating oil with the viscosity grades shown in Table #17-03. This table shows Cummins viscosity grade recommendations at various ambient temperatures. The only viscosity grades recommended are those shown in this table.

Cummins has found that the use of multi-graded lubricating oil improves oil consumption control, engine cranking in cold conditions while maintaining lubricating at high operating tempera tures, and may contribute to improved fuel consumption. CNGE does not recommend the use of single grade lubricating oils. In the event that the recommended oil is not available, single grade oils may be substituted.

Caution: When single grade oil is used, be sure that the oil will be operating within the temperature ranges shown in Table #17-04.

The primary criterion for selecting an oil viscosity grade is the lowest temperature the oil will experience while in the engine oil sump.

Bearing problems can be caused by the lack of lubrication during the cranking and start up of a cold engine when the oil being used is too viscous to flow properly. Change to a lower viscosity grade of oil as the temperature of the oil in the engine oil sump reaches the lower end of ranges shown in the following table:

Table #17-02 -
SAE Viscosity Graded for Engine Oils

SAE Visc. Grade	1 Viscosity Centipoises at temp. °C Max.		2 Pumping Temp. Max.	Min.	3 Viscosity Centistokes at 100°C Min.	Max.
0W	3250	@	-30	-35	3.8	—
5W	3500		-25	-30	3.8	—
10W	3500		-20	-25	4.1	—
15W	3500		-15	-20	5.6	—
20W	4500		-15	-15	5.6	—
25W	6000		- 5	-10	9.3	—
20	——		—	—	5.6	9.3
30	——		—	—	9.3	12.5
40	——		—	—	12.5	16.3
50	——		—	—	16.3	21.9

1 - Cold cranking simulator ASTM D2602
2 - Mini-rotary viscometer ASTM D3829
3 - ASTM 0445

Table #17-03 -

Viscosity Grade vs Ambient Temperature

SAE Viscosity Grade	Ambient Temperature
10W-30	-25°C to 35° F [-13°F to 5° F]
15W-40	-10°C & above [14°F & above]
20W-40	0°C & above [32°F & above]
SAE-5W mineral oils should not be used. For temperatures consistently below [-13°F], See Table #17-04.	

Table #17-04 - Alternative Oil Grades

10W	-25°C to 0°C	[-13°F to 32°F]
20W	-5°C to 20°C	[23°F to 68°F]
20W-20	-5°C to 20°C	[23°F to 68°F]
20	-5°C to 20°C	[23°F to 68°F]
30	4°C & above	[39°F & above]
40	10°C & above	[50°F & above]

Note: 20W-20 is not considered a multi-grade although it meets two grades.

Synthetic Lubricating Oil

Synthetic oils for use in natural gas engines are primarily blended from synthesized hydrocarbons and esters. These base oils are manufactured by chemically reacting lower molecular weight materials to produce a lubricant that has planned, predictable properties.

Synthetic oil was developed for use in extreme environments where the ambient temperature may be as low as -45°C [-50°F] and extremely high engine temperatures up to 205°C [400°F]. Under these extreme conditions, petroleum base stock lubricants (mineral oil) do not perform satisfactorily.

CNGE recommends synthetic lubricating oil for use in CNGE engines operating in areas where the ambient temperature is consistently lower than -25°C [-13°F]. Synthetic lubricating oils may be used at higher ambient temperatures provided they meet the appropriate API Service categories and viscosity grades.

CNGE recommends the same oil change interval is followed for synthetic lubricating oil as that for petroleum based lubricating oil.

Arctic Operations

For engine operation in areas where the ambient temperature is consistently below -25° C [-13° F] and where there is no provision to keep the engine warm when it is not operating, the lubricating oil should meet the requirements in the following table.

Table #17-05 - Arctic Oil Recommendations

Parameter Test Method	Specifications
Performance Quality Level	API classification CC/SC API classification CC/CD
Viscosity	10,000 mPa*s Max. at -35° C [-31° F] 4.1 mm2/s Min. at 100°C [212°F]
Pour Point (ASTM D-97)	Min. of 5° C [9° F] Below the Lowest Expected Ambient Temperature
Sulfated Ash Content (ASTM D-874)	.85% by Weight Maximum

Oils meeting these requirements usually have synthetic base stocks. SAE 5W viscosity grade synthetic oils may be used provided they meet the minimum viscosity requirement at 100C [212 °F].

Caution: Do not mix brands of grease. Damage to the bearings may result. Excessive lubrication is as harmful as inadequate lubrication. After lubricating the fan hub, replace both pipe plugs. Use of fittings will allow the lubricant to be thrown out, due to rotating speed.

Special Notes:

_____

_____

_____

Grease

CNGE recommends use of grease meeting the specifications of Mil-G-3545, excluding those of sodium or soda thickeners. Contact the lubricant supplier for grease meeting these specifications.

Test Procedure	Test
High-Temperature Performance	
Dropping point, °F.	ASTM D 2265 350 min.
Bearing life, hours at 300°F 10,000 RPM	*FTM 331 600 min.
Low-Temperature Properties	
Torque, GCM	ASTM D 1478
Start at 0°F	15,000 max.
Run at 0°F	5,000 max.
Rust Protection and Water Resistance	
Rust Test	ASTM D 1743 Pass
Water Resistance, %	ASTM D 1264 20 max.
Stability	
Oil Separation, % 30 hours @ 212°F	*FTM 321 5 max.
Penetration	
Worked	ASTM D 217 250-300
Bomb Test, PSI Drop	**ASTM D 942**
100 hours	10 max.
500 hours	25 max.
Copper Corrosion	***FTM 5309** Pass
Dirt Count, Particles/cc	***FTM 3005**
25 Micron +	5,000 max.
75 Micron +	1,000 max.
125 Micron +	None
Rubber Swell	***FTM 3603** 10 max.

*** Federal Test Method Standard No. 791a.**

Fuel-Gas

Dry Natural Gas

CNGE recommends the use of a dry processed natural gas, sometimes called "pipeline" natural gas. Commercial gases in this category should have less than 10 ppm of H_2S (Hydrogen Sulphide). Gas with more than 10 ppm of H_2S is considered a high sulfur fuel.

Dry natural gas will contain methane (CH_4), and ethane (C_2H_6). In some areas the gas may contain up to 5% of propane and a small amount of butane. Refer to pages 17-09 through 17-14 for the maximum permissible combustibles allowed in a CNGE engine before Fuel De-Ration of the engine is required.

CNGE published data is based on a dry processed natural gas fuel with 905 BTU per standard cubic foot (33.72 kJ/L) lower heating value.

Propane

Propane processed to HD-5 specification standards of 95% propane purity with the remaining 5% not heavier than butane may be used for non-lug applications only. Refer to the correct compression ratio for HD-5 propane in Table #12-01 in Section 12, page 12-01.

Caution: Since propane is heavier than air, engine room ventilation becomes a serious consideration. CNGE recommends that the local building codes should be checked when considering propane as a fuel. Many areas prohibit the use of liquid propane within the confines of a building and require that the liquid propane vaporizer be installed outside the engine room.

Note: Some commercially bottled gases called "liquid propane" or "liquid bottled gas" will not meet the HD-5 specification.

CNGE requires that ALL OTHER GASES have a Gas Analysis made to decide if they are suitable for use in a CNGE engine.

Examples of gases are:

Field Gas

Field gas is generally available at the wellhead in a gas field. Sometimes field gas is called "wellhead" gas. Due to the wide variation in gas fields, this gas will always require an analysis to decide its acceptability for use.

Sour Gas

This is a specific field gas that contains sulfur compounds such as hydrogen sulfide. When water vapor and sulfur oxides are present during combustion, sulfuric acid compounds will form. This condition will shorten the life of all internal components, specifically piston rings, cylinder liners, valve guides, and bearings.

Sour gas fuels will generally need to be treated to remove all presence of water vapor. In addition, if the hydrogen sulfide content is above 24 ppm, the sour gas will need to be treated to remove the hydrogen sulfide.

The use of sour gas as a fuel will require that a high ash oil not more than .85% of sulfated ash with a high TBN number that meets a CD API specification is used to help neutralize the acid.

Digester Gas

This gas is a by-product of digester tanks where various material is going through a bio-degrading process, such as sewage, animal waste, vegetable waste, etc.

This type of gas will be low in heat value.

Landfill Gas

Landfill operations, due to the variety and quantity of organic materials, can produce large amounts of methane gas. The gas is generally of low heat value and requires treatment of the gas. A filter capable of removing 99.5% A.C. fine dust is required in the fuel line to remove the abrasive material associated with landfill operations. In addition, a complete fuel gas analysis will be required to determine the specific treatment required for the gas. As a minimum, the fuel should be treated similarly as "sour gas."

Landfills may come under EPA jurisdiction and will require emission controls.

Special Notes:

Table # 17-06 - Fuel Gas BTU Content

Gas	Chemical Formula	BTU per ft_3 Vapor hhv
Methane	CH_4	1012
Ethene	C_2H_4	1601
Ethane	C_2H_6	1783
Propene	C_3H_6	2335
Propane	C_3H_8	2558
Iso-Butane	C_4H_{10}	3354
Butene-1	C_4H_8	3084
Iso-Butene	C_4H_8	3066
N-Butene	C_4H_{10}	3368
Iso-Pentane	C_5H_{12}	4003
Pentene-1	C_5H_{10}	3829
N-Pentane	C_5H_{12}	4015
Hexane	C_6H_{14}	4756
Heptane	C_7H_{16}	5503
Octane	C_8H_{18}	6250
Carbon Monoxide	CO	321
Carbon Dioxide	CO_2	0
Hydrogen	H	324
Hydrogen Sulfide	H_2S	672
Oxygen	O_2	0
Nitrogen	N_2	0
Air		0
Water	H_2O	-

FUEL, ALTITUDE, AND TEMPERATURE DE-RATING FACTORS

CNGE engines are capable of carrying standard published ratings when operated on clean "dry processed natural gas" fuels and on other combustible fuel mixtures.

The purpose of this bulletin is to define those factors of Altitude, Inlet Air Temperature, Choice of Compression Ratio, and Fuel Content that will affect engine performance as required by CNGE for proper engine application.

When engines must be operated beyond standard rating conditions, consideration must be given to the reduced breathing capacity and resultant power loss caused by lower air density, or to possibilities of engine damage by detonation resulting from the lower octane ratings of the higher hydrocarbon fuels. When either of these conditions occur, de-rating factors must be applied. In addition, there also may be a requirement to change to a lower compression ratio piston.

Caution: Improper fuel and incorrect compression ratio application may lead to burnt or detonation failures of pistons, valves, and cylinder heads. Failures of this nature are not considered to be of a warrantable nature.

Altitude De-Rating Requirements

Naturally Aspirated Engine

The engine may be operated at the MAXIMUM RATING up to 500 ft. [91m] altitude and 29°C [85°F] inlet air temperature, and at the CONTINUOUS RATING up to 457 m [1500 ft.] altitude and 38°C [100°F] inlet air temperature. For sustained operation at high load factors at higher altitudes, the engine rating should be adjusted to limit performance by 3% per 305 m [1000 ft.] altitude and 1% per 10°F inlet air temperature.

Altitude and temperature de-rating factors are to be considered as additive when temperatures exceed 29°C [85°F] and when altitudes are over 152 m [500 ft.].

Turbocharged Engines

The engine may be operated at the MAXIMUM RATING up to 914 m [3000 ft.] altitude and 38°C [100°F] inlet air temperature, and at the CONTINUOUS RATING up to 1542 m [5000 ft.] altitude and 38° C [100° F] inlet air temperature. For sustained operation at high load factors at higher altitudes and temperatures, please consult the factory.

Altitude and temperature de-rating factors are to be considered as additive when temperatures exceed 38°C [100°F] and when altitudes are over 914 m [3000 ft.].

Fuel De-Rating Requirements

Fuel de-rating factors are to be based on the percentages of each hydrocarbon constituent as a portion of the total combustibles in the fuel gas.

Inert gases such as nitrogen (N_2), carbon dioxide (CO_2) or water vapor (H_2O), etc. have no effect on engine performance except where they occur in sufficient percentages to lower the heat content of the fuel below the normal 1000 BTU per standard cubic feet of compressed natural gas.

Chart #1 Maximum Permissible Combustibles

This chart shows in percent (%) the maximum allowable fuel combustibles contents of the various hydrocarbons that can be present in the fuel.

Chart #2 Starting Point for De-Rating

This chart shows the maximum allowable fuel combustibles in percent (%) that can be present in the fuel before the beginning of any de-rating of the engine due to that specific fuel combustible.

Chart #3 De-Rate Percentages

This chart shows the percent of de-rate that is to be applied on a "per percent" of the specific combustible.

Water Vapor Content & Liquid Combustibles

Fuel gas must be as dry as possible. All liquid and droplets in the fuel MUST BE REMOVED from the fuel before the first pressure regulator. Condensation from water vapor in the fuel piping can cause engine damage. Liquid fuel droplets can cause uncontrolled fuel burning, detonation, etc., leading to engine damage.

EXCEPTION - HD-5 PROPANE

Propane processed to HD-5 specification standards of 95% propane purity with the remaining 5% not heavier than butane may be used for non-lug applications only. Refer to the correct compression ratio for HD-5 propane.

Only de-rating due to altitude and inlet air temperature will apply. The fuel de-rating is already built into the CNGE specification for HD-5 propane.

Special Notes:

1. Naturally aspirated low compression ratio pistons shoud be specified only in cases where the fuel quality is beyond the limits of acceptability for use in engines with higher compression ratio pistons. Operation with lower compression ratio pistons will provide a lower level of maximum power available and less fuel ecomony, with an increase in exhaust gas temperature.
2. High compression ratio pistons for both natu rally aspirated and turbocharged engines are extremely sensitive to fuel anti-knock characteristics, therefore a lower level of the maximum permissible percentages has been placed on the higher hydrocarbon constituents. If the percentage of any single constituent exceeds the maximum permissible figure, then the only alternative is to change to a lower compression ratio piston or a more suitable fuel.
3. Liquid water is not allowed to enter the engine intake system. The dew point of fuel gas should be at least 20°F below the minimum ambient temperature at the application site.
4. Hydrogen sulfides above the level of 10 ppm in the fuel can cause corrosive attack of internal engine components. When hydrogen sulfides are present, the need for a high ash natural gas lubricating oil should be considered.

   When the H_2S is above 24 ppm, the gas is described as a sour gas, and a treatment facility will be required to remove the hydrogen sulfides.

5. Chorinated hydrocarbons (halogenated hydrocarbons) can cause corrosive damage to the engine. Acceptable levels are similar to hydrogen sulfides, i.e., 10 to 24 parts per million.
6. Fuel gas should be filtered to a 5 micron level to eliminate such things as dust and foreign particles.

Calculations

1. First compute the amount of De-Rating required due to Altitude and Inlet Air Temperature.
2. Recalculate each fuel constituent with percentages for the Inert gases removed, considering only 100 percent of the combustibles. This step is required before the de-rating factors can be applied.
3. Compute the amount of de-rating required for each fuel hydrocarbon present.
4. Sum the amount of de-rating percent for each fuel hydrocarbon to obtain the required de-rate due to the fuel constituents.
5. Compare the amount of de-rating due to Altitude and Temperature against the amount of de-rating due to the fuel hydrocarbons and use the HIGHER of the two.

SECTION 17 - SPECIFICATIONS

FUEL, ALTITUDE, & TEMPERATURE DE-RATING FACTORS

Example Calculation

Specific Conditions:

Model	=	G855
Altitude	=	3500 feet
RPM	=	1800
Inlet Air Temperature	=	107°F
HP	=	176
C.R.	=	8.5:1

A. Altitude De-ration %

3500 - 1500	=	2000 feet subject to de-rating
2000/1000 X 3%	=	6%

B. Inlet Air Temperature

107 - 100	=	7°F subject to de-rating
7/10 X 1%	=	0.7%

C. Altitude & Temperature Combined

6% + 0.7% = 6.7%

D. Fuel Analysis

Con.	Inerts (%)	Hydrocarbons Analy. (%)	Corr. (%)	Max. Perm. prior to derate(%)	Excess (%)	Der. Fac. (%)	De-rating (%)
N_2	2.20	--	--	--	--	--	--
CO_2	1.86	--	--	--	--	--	--
C_1	--	63.42	66.10	100	--	--	--
C_2	--	14.56	15.18	100	--	--	--
C_3	--	9.18	9.57	100	--	--	--
C_4	--	1.71	1.78	50	--	--	--
NC_4	--	3.61	3.76	15	--	--	--
IC_5	--	1.05	1.10	15	--	--	--
NC_5	--	1.03	1.07	0	1.07	4.0	4.28
C_{7+}	--	1.38	1.44	0	1.44	4.0	5.76
Totals	4.06	95.94	100.00		2.51		10.04

E. Compare the fuel de-rating of 10.04% against the Altitude & Temperature de-rating of 6.7%. Use the higher of the two.

F. De-rate the engine from 176HP by 10.04% or 18 HP to 158HP.

SECTION 17 - SPECIFICATIONS

Chart #1

FUEL, ALTITUDE, & TEMPERATURE DE-RATING FACTORS

FUEL DE-RATING FACTORS

MAXIMUM PERMISSIBLE COMBUSTIBLES - %

	Naturally Aspirated			Turbocharged	
Compression Ratio	8.5:1	10.0:1	12.0:1	8.5:1	10.0:1
Type of Gas	see #1			see #1	
Methane (C_1)	100	100	100	100	100
Ethane (C_2)	100	100	100	100	100
Propane (C_3)	100	10	2	10	2
ISO-Butane (IC_4)	80	5	.2	7	.2
Hydrogen (H_2)	40	5	.2	7	TR.
Normal Butane (NC_4)	30	5	.2	3	.2
ISO-Pentane (IC_5)	30	1	.2	3	.2
Normal Pentane (NC_5)	3	1	.1	1	.1
(C_6)	3	1	.1	1	.1
(C_7)	3	1	.1	1	.1

Note #1: No de-rating is allowed. When the maximum permissible percentage of combustibles is exceeded in the fuel then the compression ratio under consideration needs to be lowered to the next available compression ratio.

SECTION 17 - SPECIFICATIONS

Chart #2

FUEL, ALTITUDE, & TEMPERATURE DE-RATING FACTORS

FUEL DE-RATING FACTORS

STARTING POINT FOR DE-RATING - %

	Naturally Aspirated			Turbocharged	
Compression Ratio	8.5:1	10.0:1	12.0:1	8.5:1	10.0:1
Type of Gas	----------see #1----------			----------see #1----------	
Methane (C_1)	NA	NA	NA	NA	NA
Ethane (C_2)	NA	NA	NA	NA	NA
Propane (C_3)	NA	5	*	5	*
ISO-Butane (IC_4)	50	2	*	2	*
Hydrogen (H_2)	20	2	*	2	*
Normal Butane (NC_4)	15	0	*	0	*
ISO-Pentane (IC_5)	15	0	*	0	*
Normal Pentane (NC_5)	0	0	*	0	*
(C_6)	0	0	*	0	*
(C_7)	0	0	*	0	*

Note #1: No de-rating is allowed. When the maximum permissible percentage of combustibles is exceeded in the fuel then the compression ratio under consideration needs to be lowered to the next available compression ratio.

SECTION 17 - SPECIFICATIONS

Chart #3

FUEL, ALTITUDE, & TEMPERATURE DE-RATING FACTORS

FUEL DE-RATING FACTORS

DE-RATE PERCENTAGE - % per %

	Naturally Aspirated			Turbocharged	
Compression Ratio	8.5:1	10.0:1	12.0:1	8.5:1	10.0:1
Type of Gas					
Methane (C_1)	0	0	0	0	0
Ethane (C_2)	0	0	0	0	0
Propane (C_3)	0	.5	0	.5	0
ISO-Butane (IC_4)	.5	.5	0	.5	0
Hydrogen (H_2)	.5	.5	0	.5	0
Normal Butane (NC_4)	1	1	0	1	0
ISO-Pentane (IC_5)	1	1	0	1	0
Normal Pentane (NC_5)	4	4	0	4	0
(C_6)	4	4	0	4	0
(C_7)	4	4	0	4	0

Coolant

Water should be clean and free of any corrosive chemicals such as chloride, sufates, and acids. It should be kept slightly alkaline with a pH value range of 8.5 to 10.5. Any water that is suitable for drinking can be treated as described in the following paragraphs for use in an engine.

Maintain the Fleetguard DCA4 Water Filter on the engine. The filter bypasses small amount of coolant from the system via a filtering and treating element that must be replaced periodically.

1. In summer, with no antifreeze, fill the system with water.

2. In winter, select an antifreeze and use with water as required by temperature.

Note: Some antifreezes also contain anti-leak additives such as inert inorganic fibers, polymer particles, or ginger root. These types of antifreezes should not be used together with the water filter because the filter element will filter out the additives or become clogged and ineffective.

3. Install or replace the DCA4 water filter as fol lows and as recommended in Sections 5 & 6.

New Engines Going into Service Equipped with DCA4 Water Filters

1. New engines shipped from CNGE are equipped with water filters containing a DCA4 precharge element. This element is compatible with plain water or all permanent-type antifreeze, except Methoxy Propanol.

2. At the first oil change period, the DCA4 precharge element should be change to a DCA4 Service Element. See Table #17-07.

3. Replace the DCA4 Service Element at each succeeding oil change period.
   a. If make-up coolant must be added between element changes, use coolant form a pretreated supply, such as the Fleetguard "Compleat." See Section 6 for additional information.

   b. Each time the system is drained, precharge per coolant specifications, Table #17-01.

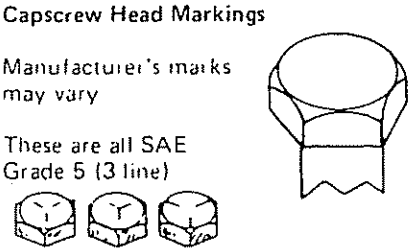
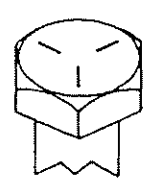
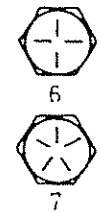
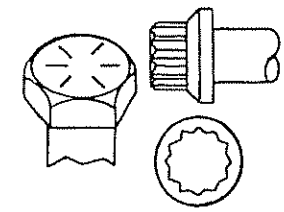
4. The service element change point may be extended to the next service interval if the DCA-4L direct chemical additive is added to the cooling system at each oil change period. One bottle of direct additive should be used for every 10 gallons of cooling system capacity.

5. To ensure adequate corrosion protection, have the coolant checked at each third element change or more often. See "Check Engine Coolant" in Section 6.

Table #17-07 - Spin-On Type DCA4 Water Filter

Cooling System Capacity U.S. Gallons	Ethylene Glycol-Base Antifreeze DCA-4L Precharge		Service Element
5-9	1		WF-2070
10-20	2		WF-2071
21-30	3		WF-2072
31-50	5		WF-2073
		or	WF-2071 (2)
51-100	10		WF-2073 (2)
		or	WF-2071 (4)

Capscrew Markings and Torque Values

Current Usage	Much Used	Much Used	Used at Times	Used at Times
Minimum Tensile Strength PSI MPa	To 1/2–69,000 [476] To 3/4–64,000 [421] To 1–55,000 [379]	To 3/4–120,000 [827] To 1–115,000 [793]	To 5/8–140,000 [965] To 3/4–133,000 [917]	150,000 [1 034]
Quality of Material	Indeterminate	Minimum Commercial	Medium Commercial	Best Commercial
SAE Grade Number	1 or 2	5	6 or 7	8
Capscrew Head Markings Manufacturer's marks may vary These are all SAE Grade 5 (3 line)				

Capscrew Body Size (Inches) – (Thread)	Torque Ft-Lbs [N•m]	Torque Ft-Lbs [N•m]	Torque Ft-Lbs [N•m]	Torque Ft-Lbs [N•m]
1/4 – 20	5 [7]	8 [11]	10 [14]	12 [16]
– 28	6 [8]	10 [14]		14 [19]
5/16 – 18	11 [15]	17 [23]	19 [26]	24 [33]
– 24	13 [18]	19 [26]		27 [37]
3/8 – 16	18 [24]	31 [42]	34 [46]	44 [60]
– 24	20 [27]	35 [47]		49 [66]
7/16 – 14	28 [38]	49 [66]	55 [75]	70 [95]
– 20	30 [41]	55 [75]		78 [106]
1/2 – 13	39 [53]	75 [102]	85 [115]	105 [142]
– 20	41 [56]	85 [115]		120 [163]
9/16 – 12	51 [69]	110 [149]	120 [163]	155 [210]
– 18	55 [75]	120 [163]		170 [231]
5/8 – 11	83 [113]	150 [203]	167 [226]	210 [285]
– 18	95 [129]	170 [231]		240 [325]
3/4 – 10	105 [142]	270 [366]	280 [380]	375 [508]
– 16	115 [156]	295 [400]		420 [569]
7/8 – 9	160 [217]	395 [536]	440 [597]	605 [820]
– 14	175 [237]	435 [590]		675 [915]
1 – 8	235 [319]	590 [800]	660 [895]	910 [1234]
– 14	250 [339]	660 [895]		990 [1342]

Notes:

1. Always use the torque values listed above when specific torque values are not available.
2. Do not use above values in place of those specified in other sections of this manual; special attention should be observed when using SAE Grade 6, 7 and 8 capscrews.
3. The above is based on use of clean, dry threads.
4. Reduce torque by 10% when engine oil is used as a lubricant.
5. Reduce torque by 20% if new plated capscrews are used.
6. Capscrews threaded into aluminum may require reductions in torque of 30% or more of Grade 5 capscrews torque and must attain two capscrew diameters of thread engagement.

Caution: If replacement capscrews are of a higher grade than originally supplied, adhere to torque specifications for that placement.

SPECIFICATIONS

CNGE Service Tools

Customer Service Tools

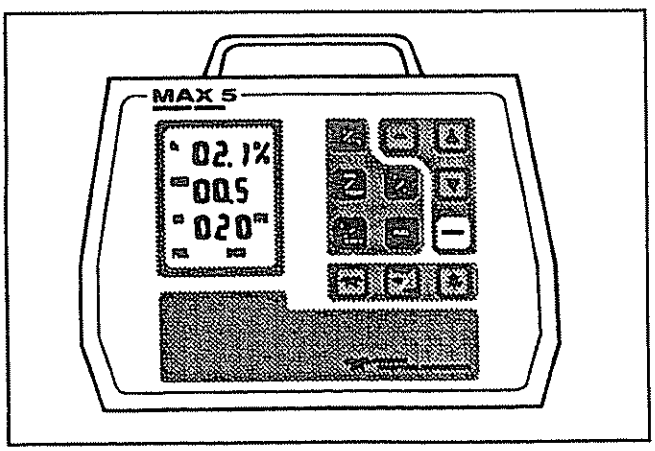
CNGE offers the following service tools required for a customer to do basic maintenance and some limited checking of the engine.

Tool Part Number	Description
10113858	O2 Meter Carrying Case
91372621	O2 Meter
	Does not include copper tubing & Filter media.
	Recommend 10 to 15 feet of 3/8" copper ot stainless tubing.
	Filter Media Recommended Aquarium Filter Media.
91400206	Laser Heat Gun & Carrying Case
91400207	Volt Meter & Hertz meter
91400208	Timing Light
91400202	Carrying Case Digital Manometer (each)
91400203	Digital Manometer 0 to 30 psi
91400204	Digital Manometer 0 to 19.99 WC
91400211	Digital Manometer 0 to 199.9 WC
91400205	Hand Held Digital Thermometer with case
91400037	Thermocouple for Digital Thermometer (each)
	Recommend a minimum of 6.
91400039	Fitting 1/8 npt Thremocouple (each)
	Recommend a minimum of 12.
60210006	Pliers for Ignition Wire Crimping
60210007	Spark Plug Removal 13/16 inch
60210008	Spark Plug Adapter Removal 2 & 4 Slot
60210018	Spark Plug Adapter Removal-Hex
91372624	Spark Plug Gap Tool
60110001	Compression Testor
60810002	Set of Feeler Gauges
3375049	Oil Filter Wrench
3375208	DCA4(™) Test Kit
ST-1274	Belt Tension Gauge
61210002	Tachometer hand held
60210002	Seat Sander
91400210	Carrying Case Small
91400909	Carrying Case Large

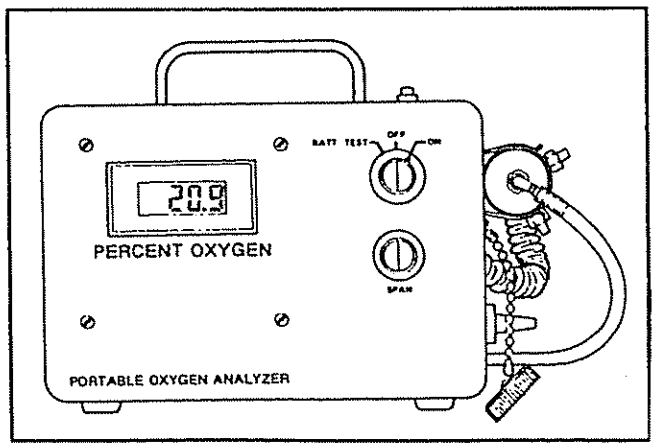
CNGE Specialty Tools

The following tools are recommended for proper optimization of the air/fuel gas ratio and for keeping the engine in a proper balance for emissions, and also to allow one to operate with the lowest possible exhaust gas temperatures.

91372621 Oxygen Meter - 320 P/D



91372622 Max 5 Oxygen Analyzer



Oxygen Meter Supplemental

Instructions

Operating Teledyne Model 320 P or 320 P/D Oxygen Meter

These suggestions are not intended to replace or to amend the instruction manuals issued with the meters from the manufacturer.

1. Read and Follow the manufacturer's manuals, in order to decide the correct procedure for initial startup of the meters.

2. Test the condition of the batteries before each use. If low (below 500 for the 320P/D or out of test limits for the 320P) then the unit must be recharged before use. It is recommended that the charge should be overnight for 14 hours.

3. Check the condition of the filter material on the back of the unit. Change if it is wet or dirty.

4. Remove the cell saver cap, check the Oxygen calibration with non-tainted or -polluted air ambient air (20.9%) with the 320P on the high range scale. The 320P/D will autorange. Adjust with the span dial as necessary. Then install the flow through adapter cap on the O_2 fuel cell holder.

5. Connect the temperature reducing tubing to the engine exhaust system.
   A. Turbocharged engines have a 1/4" npt fitting in the exhaust elbow after the turbocharger, and naturally aspirated engines have a 1/4" fitting in the exhaust manifold. Use 10 to 15 feet of 3/8" tubing (Copper or Stainless Steel) and connect to the 1/4" fitting.

NOTE: If there is no fitting, then the tubing should be inserted into the exhaust stack so it is at the halfway point when measuring the distance from the engine to the end of the stack.

   B. Ensure that the tubing is coiled several times or, at the minimum, has a dip sufficient to act as a water trap.

   C. Hook the other end of the tubing to a piece of hose that can be connected to the inlet of the analyzer filter/water trap.

      The purpose of this tubing is to lower the exhaust temperature down to a safe range to avoid damage to the meter.

6. With the tube attached to the engine exhaust system, depress the pump button on top of the unit to pull in the exhaust sample. Change the range switches as needed on the 320P model. The 320P/D model is automatic.

7. Draw the exhaust sample for no longer than 5 minutes. The temperature of the sample into the unit should be held close to the ambient temperature of the area where the unit is being operated.

8. Remember that the water trap will need to be cleared every 10 minutes. Excess moisture or temperature in the sample will damage the O_2 cell. The CO_2 in the exhaust gas will shorten the O_2 cell life when run through the unit for extended periods.

9. The back pressure in the exhaust system may be sufficient to allow use of the 320 without using the pump. Due to this pressure, caution should be taken to assure that the unit is not left hooked up to the exhaust system for more than 5 minutes when not in use or it will shorten the O_2 cell life.

10. After each 5 minutes of sampling, purge the unit with clean ambient air until the reading is close to 20.9% oxygen. Do not recalibrate at this time. The unit is ready for continued use.

11. When not in use, the unit should be turned off and the cell saver cap should be reinstalled. All moisture should be removed from the cooling tube after each operation.

Adjustment of the CNGE Engine

1. Allow a minimum of 30 seconds for the gas sample to reach the meter and be analyzed.

2. Adjust the power valve on the carburetor.

Naturally Aspirated Engines

Excess Oxygen reading from .7% to 1.0% for standby or maximum power, and 1.9% to 2.5% for prime or continuous power. (See Table #12-06 on page 12-3 in Section 12.)

Turbocharged Engines

Excess Oxygen reading from 2.0% to 2.5% for standby or maximum power, and 2.7% to 4.0% for prime or continuous power. (See Table #12-06 on page 12-3.)

3. After each adjustment of the power valve, it will be necessary for a time delay to occur prior to reading the meter. This is required for the gas sample to reach the meter and for analysis to occur. This may take from 15 to 45 seconds depending on the length of the gas sample tube.

4. All adjustments should be made at the intermittent rating with the inlet gas pressure to the carburetor set at 3" to 5" of water column. (For propane vapor, the carburetor should be measuring a vacuum between 1.5 and 4.5 inches of water - negative pressure.)

5. All adjustments for excess Oxygen are under stood to be made with the engine set at its published ignition timing for the appropriate model.

Operating the Teledyne Model Max 5 Oxygen Analyzer

These suggestions are not entended to replace or to amend the instruction manuals issued with the meters from Teledyne.

1. Read and Follow the Teledyne manuals for the initial startup of the meters.

2. Test the condition of the batteries before each use. If low or out of test limits, then the unit must be recharged before use. It is recommended that the charge should be overnight for 14 hours.

3. Check the condition of the filters on the Max 5 unit. If dirty or contaminated, exchange or replace media.

4. Switch unit on (the power switch is on the back of the case). The unit will go through a self check before normal display appears.

5. Switch on the sample and air pumps by pressing the membrane switch labeled on/off located on the control panel.

6. Check and adjust sample flowmeters on the back of the unit to indicate 2.0 scfm (standard cubic feet per minute).

7. Connect the temperature reducing tubing to the engine exhaust system.
   A. Turbocharged engines have a 1/4" npt fitting in the exhaust elbow after the turbocharger, and naturally aspirated engines have a 1/4" fitting in the exhaust manifold. Use 10 to 15 feet of 3/8" tubing (Copper or Stainless Steel) and connect to the 1/4" fitting.

      Note: If there is no fitting, the tubing should be inserted into the exhaust stack so that it is at least at the halfway point when measuring the distance from the engine to the end of the stack.

   B. Ensure that the tubing is coiled several times or, at the minimum, has a dip sufficient to act as a water trap.

      The purpose of this tubing is to cool the exhaust temperature down to a safe range in order to avoid damage to the analyzer.

8. Place the probe in an area where it can pull clean air and allow the analyzer to stabilize.

9. If O_2 reading is not 20.9% +/- 0.5% or CO reading is not 0 +/- 5 ppm, then the system needs to be calibrated. If measurement is OK, continue.

10. Connect Temperature Probe to the hose connected to the tubing.

11. Draw the exhaust sample for no longer than 5 minutes. The temperature of the sample into the unit should be held close to the ambient temperature of the area where the unit is operated.

12. Remember that the water trap will need to be cleared every 10 minutes. Excess moisture or temperature in the sample will dam age the O_2 cell. The CO in the exhaust gas will shorten the O_2 cell life when run through the unit for extended periods.

13. The back pressure in the exhaust system may be sufficient to allow use of the MAX 5 without using the pump. Due to this pressure, caution should be taken to assure that the unit is not left hooked up to the exhaust system for more than 5 minutes when not in use or it will shorten the fuel cell life.

14. After each 5 minutes of sampling, purge the unit with clean ambient air until the reading is close to 20.9% oxygen. Do not recalibrate at this time. The unit is ready for continued use.

15. When not in use, the unit should be turned off. All moisture should be removed from the cooling tube after each operation.

Adjustment of the CNGE Engine

1. Allow a minimum of 30 seconds for the gas sample to reach the meter and be analyzed.

2. Adjust the power valve on the carburetor.

   Naturally Aspirated Engines
   Excess oxygen reading from .7% to 1.0% for standby or maximum power, and 1.9% to 2.5% for prime or continuous power. (See Table #12-06 on page 12-3, Section 12.)

   Turbocharged Engines
   Excess oxygen reading form 2.0% to 2.5% for standby or maximum power, and 2.7% to 4.0% for prime or continuous power. (See Table #12-06 in Section 12.)

3. After each adjustment of the power valve it will be necessary for a time delay to occur before reading the meter. This is required for the gas sample to reach the meter and for gas analysis to occur. This may take from 15 to 45 seconds, depending on the length of the gas sample tube.

4. All adjustments should be made at the intermittent rating with the inlet gas pressure to the carburetor set at 3" to 5" of water column. (For propane vapor, the carburetor should be measuring a vacuum between 1.5 and 4.5 inches of water - negative pressure.

5. All adjustments for excess oxygen are understood to be made with the engine set at its published ignition timing for the appropriate model.

SECTION 18 - SERVICE ASSISTANCE

CONTENT

Emergency Service Assistance

If you should require emergency service assistance, check the yellow pages for the nearest Cummins distributor.

Should you be unable to reach the local distributor in the above manner, Cummins Engine Company has established a 24 hours a day, toll free number for service assistance. In 48 states, you can call Cummins Customer Relations toll free by dialing 1-800-343-7357. In Alaska, Hawaii, and Canada, call collect 1-812-379-6115.

Cummins Owner Assistance

Cummins Natural Gas Engines backs its engines with expert service and complete parts support through the Cummins Distributor Network on a worldwide basis. Cummins people are trained to provide the CNGE owner with sound advice, expert service, and professional treatment at all Cummins locations.

Any problem that you may have in connection with the sale, operation or service of your CNGE engine can be handled at the nearest Cummins location. Occasionally, you may feel a problem has not handled to your satisfaction. At those times, we urge you to pursue the problem until you are satisfied.

Many problems result from a breakdown in communications and can often be solved by bringing in a third party as a mediator. Bring your problem to the next higher authority to discuss.

CNGE recommends:

1. If a problem originates with a salesperson or service technician, talk to the sales or service manager.

2. If a problem originates with a sales or service manager, talk to the owner of the service location.

3. If a problem originates with a CNGE authorized dealer, talk to the Cummins distributor with whom the dealer has a service agreement.

4. If a problem originates with a distributor, please call the nearest CNGE Regional or Divisional Office. The majority of problems can be solved below the divisional office level. However, before you call, write down the following information and have it ready:

   A. Name and location of the Cummins distributor or dealer.

   B. Type and make of equipment.

   C. CNGE engine model and serial number.

   D. Total hours of operation.

   E. Nature of problem.

   F. Summary of the current problem, arranged in the order of occurence.

If you still have problems, please write:

Customer Relations
Cummins Natural Gas Engines, Inc.
8713 Airport Freeway, Suite 316
Fort Worth, Texas 76180
or
Customer Relations
Cummins Engine Company, Inc.
Box Number 3005
Columbus, Indiana 47202-3005

We do request that the above steps be followed in order. Most of the actual work on an engine can be performed at the original location, so please give them a chance to satisfy you first.

CNGE Regional Offices - CNGE Representatives for the following regions are located at CNGE Headquarter Office in Fort Worth, Texas, U.S.A.

Canadian Region
Central Region
Eastern Region
Western Region
International Region

Cummins Natural Gas Engines, Inc.
8713 Airport Freeway, Suite 316
Fort Worth, Texas 76180
Telephone: (817) 581-7575
Fax: (817) 581-4548
Telex: U.S.A.: 62129850
International: 469579

Cummins Natural Gas Engines, Inc.
Parts Distribution Center
409 South Norris Street
Clovis, New Mexico 88101
Telephone: (505) 769-2173
Fax: (505) 762-4203

Cummins Distributor Service Assistance

Cummins Distributors in Canada, Puerto Rico, and the United States are listed in the U.S. and Canadian Sales and Service Directory. For Directory Assistance, call 1-800-DIESELS.

International Distributor locations are contained in an International Sales and Service Directory Bulletin #3382133.

Special Notes:

SECTION 19 - COMPONENT MANUFACTURERS

CONTENT

Manufacturer

Component

COMPONENT MANUFACTURERS

Note: The following list contains addresses and telephone numbers of suppliers of accessories use on Cummins engines. Suppliers may be contacted directly for any specifications not covered in this manual.

Air Cylinders
Honeywell, Inc.
6 Center Point Dr.
La Palma, CA 90623
(800) 367-4757

Air Heaters
Fleetguard, Inc.
Route 8
Cookeville, TN 38501
(615) 526-9551

Air Starting Motors
Ingersoll-Rand Engine Starting Systems
888 Industrial Dr.
Elmhurst, IL 60126
(312) 530-3800

Air-Gas Staring Motors
Ingersoll-Rand Engine Starting Systems
888 Industrial Dr.
Elmhurst, IL 60126
(312) 530-3800

Alternators
Delco-Remy
P.O. Box 2439
Andersen, IN 46018
(216) 431-0740

Auxiliary Water Pumps
Berkley Pump
402 N. 37th Dr. Suite 102
Phoenix, AZ 85009
(602) 272-0012

Belts
Dayco Products
1 Prestige Place
P.O. Box 1004
Dayton, OH 15401
(800) 283-2926

Carburetors
Impco Technologies, Inc.
16804 Gridley Place
Cerritos, CA 90701

Coolant Heaters
Fleetguard, Inc.
Route 8
Cookeville, TN 38501
(616) 526-9551

Kim Hotstart, Inc.
E. 5724 Broadway
Spokane, WA 99212
(509) 534-6171

Electric Starting Motors
Delco-Remy
P.O. Box 2439
Andersen, IN 46018
(317) 646-7838

Fans
Hayes-Albion
1999 Wildwood Ave.
Jackson, MI 49202
(517) 782-9421

Brookside
McCordsville, IN 46055
(317) 873-5093

Filters
Fleetguard, Inc.
Route 8
Cookeville,TN 38501
(615) 526-9551

Gas Regulators
Fisher Mfg.
Vinson Supply
P.O. Box 94895
Tulsa, OK 74194
(806) 383-2276
Maxitrol Co.
P.O. Box 2230
Southfield, MI 48037
(313) 356-1400

Gauges
Frank W. Murphy Mfg.
P.O. Box 470248
Tulsa, OK 74147
(918) 627-3550

The Nasson Co.
P.O. Box 505
West Union, SC 29696
(803) 638-9521

Governors
Woodward Governor Co.
1000 E. Drake Rd.
Fort Collins, CO 80522
(303) 482-5811

Barber Colman Co.
1300 Rock Street
Rochford, IL 61101
(815) 877-0241

Heat Exchangers
Modine Mfg. Co.
1500 DeKoven Ave.
Racine, WS 53404
(414) 636-1200

Young Radiator Co.
2825 4 Mile Road
Racine, WS 53404
(414) 639-1011

Ignition Systems
Altronic, Inc.
1200 Stambaugh Bldg.
Youngston, OH 44501
(216) 545-9768

Fairbanks Morse Engine and
Accessory Operations
6402 Rockton Rd.
Bosco, IL 61073
(815) 389-4927

Oil & Coolant Heaters
Fleetguard,Inc.
Route 8
Cookeville, TN 38501
(615) 526-9551

Kim Hotstart Co.
West 917 Broadway
Spokane, WA 99210
(509) 534-6171

Radiators
Radiator Specialties
P.O. Box 28698
Sacramento, CA 95828
(916) 381-4790

G. & O.
160 Gando Dr.
New Haven, CN 06513

Spark Plugs
Champion Spark Plug Co.
910 Upton Ave.
Toledo, OH 43607
(419) 535-2458

Stitt Spark Plug Co.
P.O. Box 327
Conroe, TX 77305
(409) 756-7796

Fairbanks Morse
Engine and Accessory Operations
6402 Rockton Rd.
Bosco, IL 61073
(815) 389-4927

Shutoff Valves
Automatic Switch Co.
P.O. Box 13681
Newark, NJ 07188
(602) 483-2980

L.P. Gas & Equipment Co.
3216 S. Nordic Rd.
Arlington Heights, IL 60005
(708) 437-2345

Tachometers
Altronic, Inc.
1200 Stambaugh Bldg.
Youngston, OH 44501
(216) 545-9768

SECTION 20 - SERVICE LITERATURE

CONTENT

Cummins Service Publications

The following Cummins manuals have been written for the Cummins Diesel Engine. Although they will not contain specific information on the Spark Ignited CNGE engine, they will contain helpful information on those areas of the engine which are common to both Diesel and Spark Ignited engines. These manuals are listed only to provide additional supplemental information. For information about any Cummins or CNGE publication, contact your local Cummins distributor or dealer.

ENGINE MANUALS

CNGE Model	Bulletin Number	Type of Publication	Cummins Diesel Engine
G8/G12/ GTA12	3379067	Engine Shop Manual	H/NH (T) - 4 7/8 & 5 1/8 Bore
G855/ GTA855-A/ GTA855-B	3379076	Engine Shop Manual	NH/NT/NTA - 855 C.I.D.
GTA855-B	3810298	Troubleshooting & Repair	NT 855 Big Cam III
G8/G12/ GTA855-A GTA855-B	3379035	Alternative Repair	NH/NT
GTA19	3810263	Engine Shop Manual	K-19
GTA19	3810307	Troubleshooting & Repair	K-19
GTA19	3379035	Alternative Repair	K-19
G28/GTA28	3379120	Engine Shop Manual	V/VT/VTA - 1710
G855	3379528	Parts Catalog	NH - 855
GTA855-A	3379591	Parts Catalog	NT-855- Small Cam
GTA855-B	3884235	Parts Catalog	NTA855 Big Cam III
G8	3822019	Parts Catalog	NH-495 (KCL)
G28/GTA28		Parts Catalog	
G28/GTA28	3884342	Parts Catalog	VTA1710 Generator Drive
GTA19	3379559	Parts Catalog	KTA19-G
GTA19	3884227	Parts Catalog	KTA19 Construction
GTA19	3884308	Parts Catalog	KTA19 Power Unit

NATURAL GAS ENGINES

CNGE MODEL	Bulletin Number	Type of Publication
GTA855-B	PB961001	Parts Catalog
G5.9/GTA5.9	PB950101	Parts Catalog
G28/GTA28	PB950901	Parts Catalog
GTA19	PB951201	Parts Catalog
G855/GTA855-A	PB900706	Parts Catalog
G12/GTA12	N/A	Parts Catalog

Section 21 - Index

NOTES

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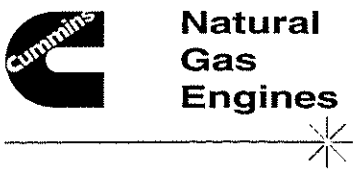

CUMMINS NATURAL GAS ENGINES, INC.
8713 Airport Freeway, Suite 316
Fort Worth, Texas 76180
(817)581-7575
Fax (817)581-4548

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