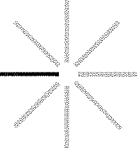


Natural Gas Engines



GTA 14 OPERATION AND MAINTENANCE MANUAL



Cummins Natural Gas Engines, Inc. Assembly Plant
Clovis, New Mexico

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Foreword

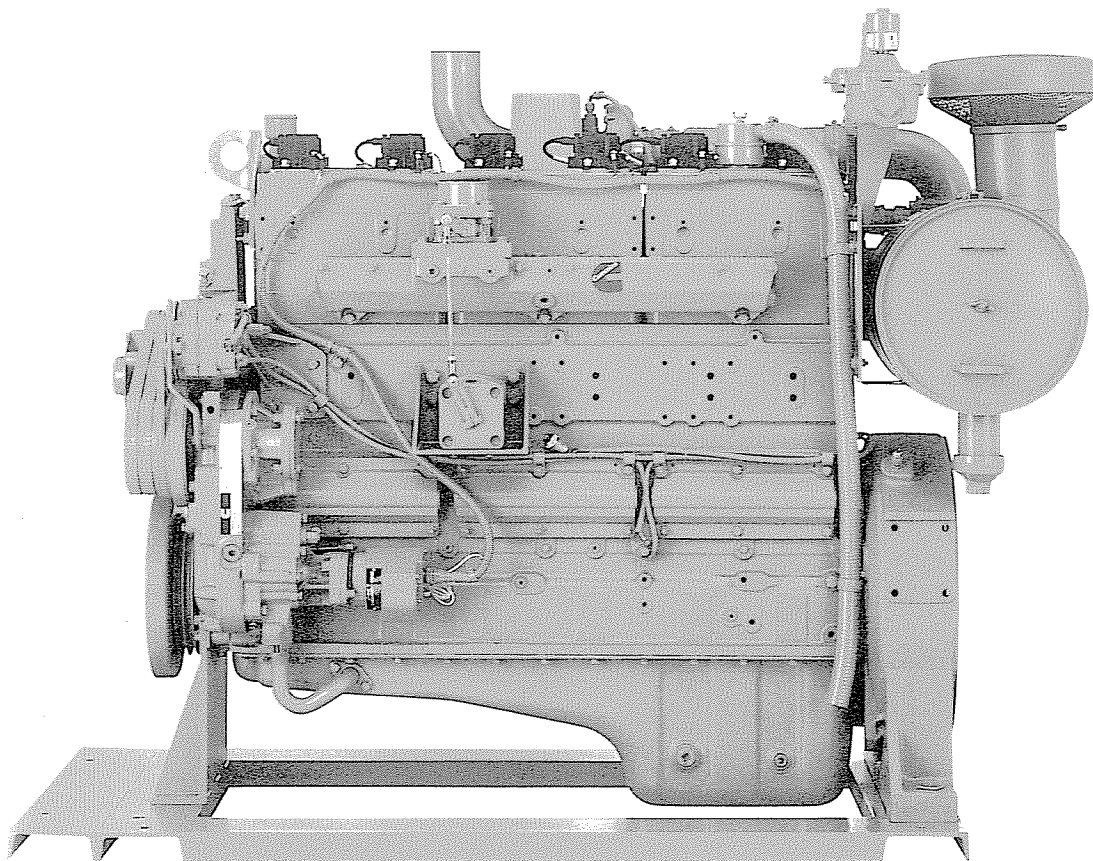
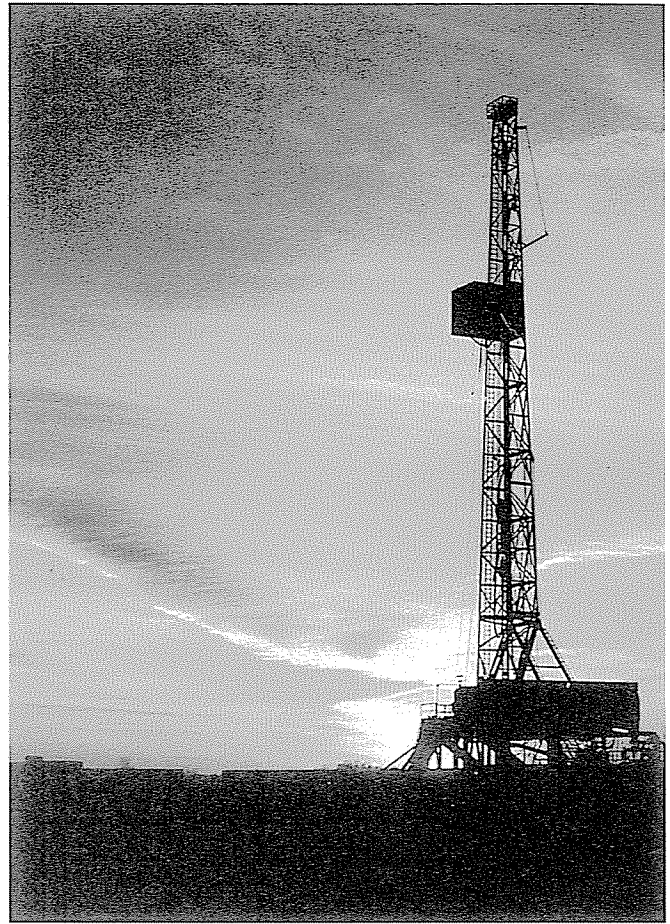
This manual is applicable to the GTA14 Spark Ignited Engines currently being produced by Cummins Natural Gas Engines, Inc. (CNGE). It contains instructions for operators that will enable them to get the best service from their engines. Before operating the engine become familiar with the procedures described.

The maintenance section is for the people who are responsible for the upkeep and availability of the engine on the job. The maintenance program is simple, realistic, easy to control and a profitable one to practice.

Repair operations on CNGE engines should be performed by specially trained personnel. Contact your local Cummins Distributor for a list of authorized CNGE repair locations in your area.

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A Cummins Company.



Section 1

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, such as the Operation & Maintenance Manual, Shop Manual, Troubleshooting & Repair Manual for the Cummins N14 Diesel Engine are available. These books 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.

Abbreviations Used in this Manual

A	Aftercooled	"G"	Gas-Spark Ignited
AFC	Air Fuel Control	Gal	Gallon
API	American Petroleum Institute	"H"	High
ASTM	American Society of Testing and Materials	Hg	Mercury
BHP	Brake Horsepower	HHV	High Heat Value
BTU	British Thermal Units	HP	Horsepower
CAC	Charge Air Core	hr.	Hour
° C	Degrees Celsius	H ₂ O	Water
CCW	Counter Clockwise	ICM	Ignition Control Module
C.I.D.	Cubic Inch Displacement	ISCV	Idle Speed Control Valve
cm	Centimeter	in.	Inch
cSt	Centistokes	in-lb	Inch Pound
CW	Clockwise	kg	Kilograms
cu.	Cubic	kPa	Kilopascal
DBTDC	Degrees Before Top Dead Center	"L"	Low
DCA	Diesel Coolant Additive	LE	Low Emission
ECM	Electronic Control Module	l	Liter
ECS	Emission Control Sensor	lb.	Pound
° F	Degrees Fahrenheit	LHV	Lower Heat Value
FCV	Fuel Control Valve	max.	Maximum
FTM	Federal Test Method	m	Meter
ft.	Feet	min.	Minimum
ft-lb	Foot Pound	mm	Millimeter
FSOV	Fuel Shut-Off Valve	Mpa	Megapascal
"G"	Ground	N	Newton
		NA	Naturally Aspirated
		NG	Natural Gas
		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
		SI	Spark Ignited
		ST	Service Tool
		T	Turbocharged
		™	Trademark
		U.S.	United States
		"VS"	Valve Set
		WB	Warranty Bulletin
		WC	Water Column
		WF	Water Filter

Safety Precautions & Warnings

Improper practices or carelessness can cause burns, cuts, mutilation, asphyxiation or other bodily injury or death.

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.*

- *Make sure that the work area surrounding the product is dry, well lit, ventilated, free of clutter, loose tools, parts, ignition sources and hazardous substances. Be aware of hazardous conditions that can exist.*
- *Always wear protective glasses and protective shoes when working.*
- *Rotating parts can cause cuts, mutilation or strangulation.*
- *Do not wear loose-fitting or torn clothing. Remove all jewelry when working.*
- *Do not work on anything that is supported ONLY by lifting jacks or a hoist. Always use blocks or proper stands to support the product before performing any service work.*
- *Disconnect the batteries negative (-) and positive (+) cables 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.*
- *Do not connect the ground cable of any welder to the ignition or governor components or leads. Attach the welder ground cables as close as possible to the part being welded.*
- *Do not connect the jumper starting or battery charging cables to any ignition or governor control wiring. This can cause electrical damage to the ignition generator or governor.*
- *The natural gas exhaust system normally operates at a higher temperature than similar diesel exhaust systems. To avoid burns, do not touch exhaust components. Do not route lines or hoses which can deteriorate from heat near the exhaust gas components.*
- *To prevent suffocation and frostbite, wear protective clothing and ONLY disconnect fuel or liquid refrigerant (freon) lines in a well ventilated area. To protect the environment, liquid refrigerant systems must be properly emptied and filled using equipment that prevents the release of refrigerant gas (fluorocarbon) into the atmosphere. Federal law requires capture and recycling refrigerant.*
- *To avoid personal injury, use a hoist or get assistance when lifting components that weigh 23 kg [50 lb] or more. Make sure hooks are positioned correctly. Always use a spreader bar when necessary. The lifting hooks must not be side-loaded.*
- *Always shutdown your CNGE Spark-Ignited engine by either using an automatically operated fuel shut-down valve as close to the engine as possible or by shutting off the manual shutoff valve upstream of the gas flow 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.*
- *Always close fuel line manual fuel shut-off valve before disassembly of engine or engine components.*
- *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 or vibration damper. This practice can cause serious personal injury, property damage, or damage to the fan blade(s), causing premature fan failure.*
- *If an engine has been operating, and the coolant is hot, allow the engine to cool before you slowly loosen the filler cap and relieve the pressure from the cooling system.*
- *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.*
- *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.*
- *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. If the eyes are contacted, immediately flood with large amounts of water for a minimum of fifteen minutes. IMMEDIATELY CALL A PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.*

Section 2

Engine & Component Identification

ENGINE DATA-PLATE

Refer to the enclosed illustration for the data-plate location.



Photo #2-01 - Engine Data-plate

Note: The engine data-plate must not be changed unless approved by CNGE.

The engine data-plate 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 used as a starting point to measure warranty for the end user customer.

How to Identify Your Engine

The model name provides the following data:

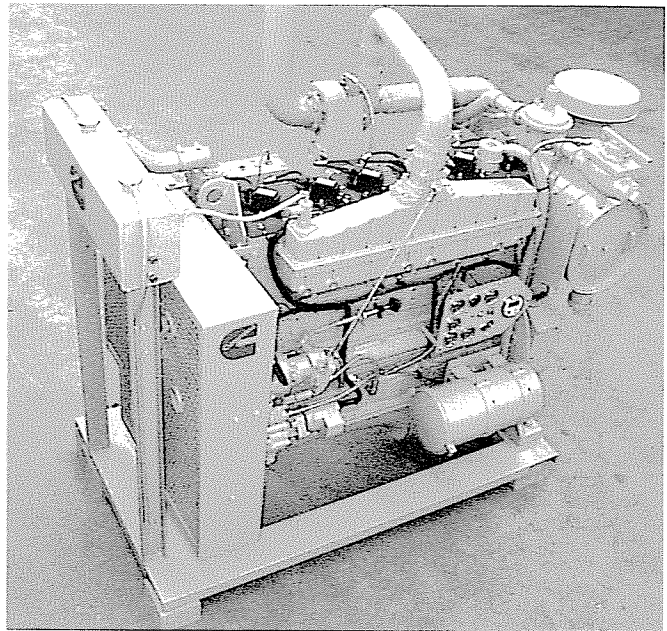
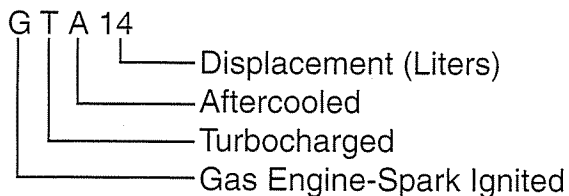


Photo #2-02 - GTA14 Engine

Turbocharger Data Plate.

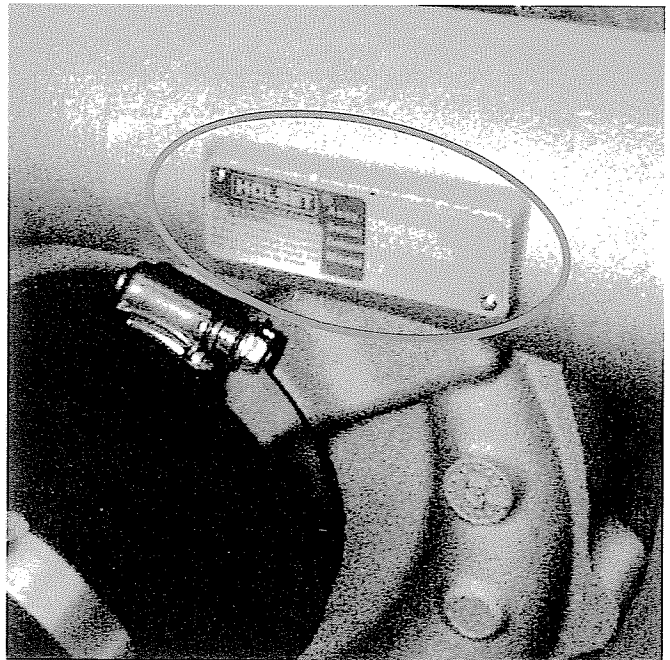


Photo #2-03 - Turbocharger Data Plate

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.

GTA14 - Aftercooler Side

1. Alternator (Not Shown).
2. Aftercooler.
3. Ignition Generator.
4. Ignition Coils.
5. Governor.
6. Throttle Butterfly.
7. Vibration Damper (Behind Wire Guard).
8. Gas Regulator.
9. Fuel Shut-off Valve.
10. By-pass Lube Oil Filter-LF750 (Not Shown).
11. Oil Pan.
12. Aftercooler Inlet.
13. Aftercooler Outlet.
14. Air Filter.
15. Engine Blow-by Hose.

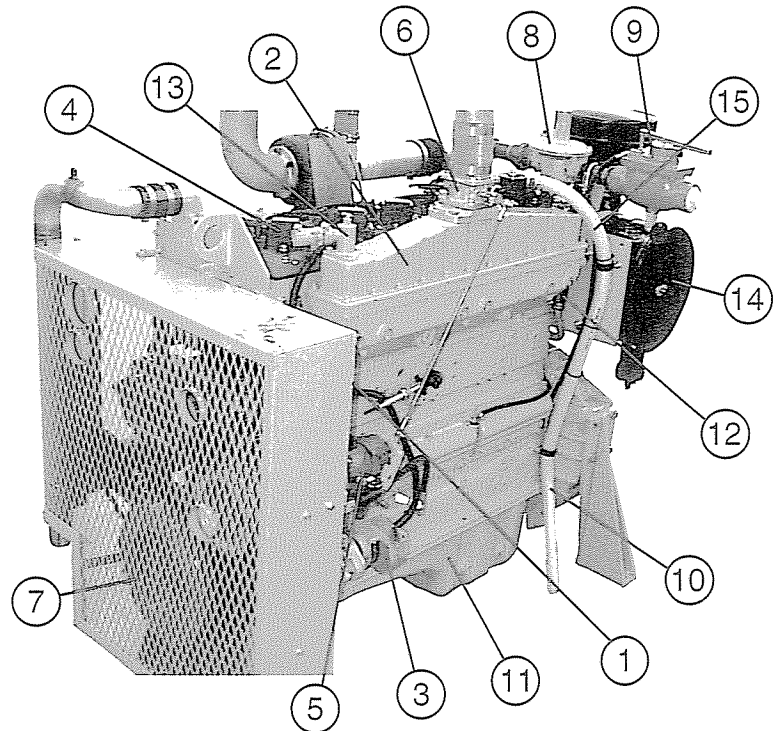


Photo #2-04 - GTA14 Aftercooler Side

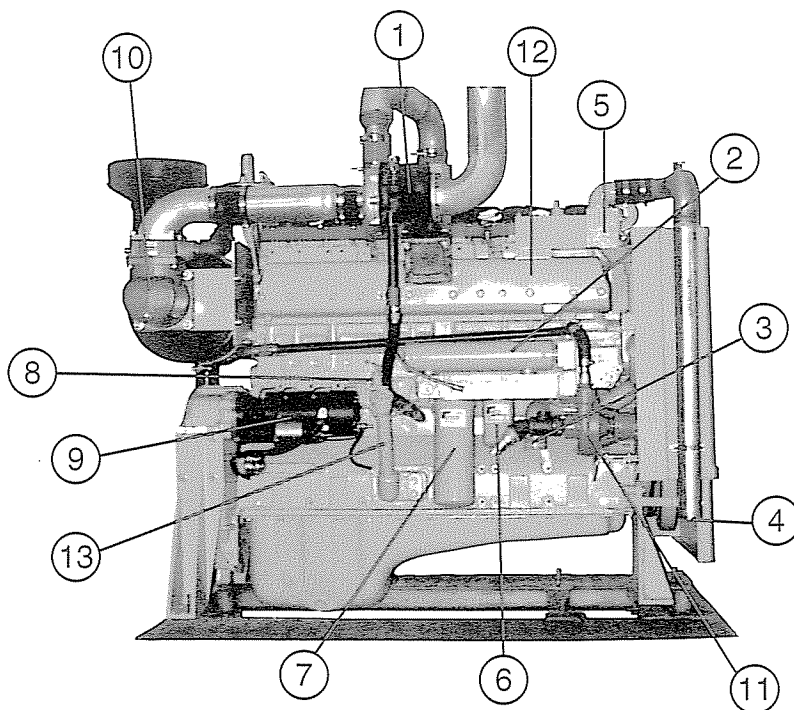


Photo #2-05 - GTA14 Exhaust Side

GTA14 - Exhaust Side

1. Turbocharger.
2. Oil Cooler.
3. Coolant Inlet.
4. Coolant Outlet.
5. Thermostat Housing.
6. Coolant Filter.
7. Lubricating Oil Combination Filter-LF3000.
8. Dipstick Location.
9. Starter.
10. Carburetor.
11. Aftercooler Pump (Auxiliary Pump).
12. Wet Exhaust Manifold.
13. Oil Fill Tube and Cap.

Section 3 Operating Principles & Systems Information

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Operating Principles & Systems Information

Operating Principles

The most satisfactory service can be expected from a Cummins Natural Gas Engine, Inc. (CNGE) spark ignited engine when the operation procedures are based upon a clear understanding of the engine working principals. Each part of the engine affects the operation of every other working part and of the engine as a whole.

The CNGE Gas Engine

CNGE Gas Engines described in this manual are four-stroke-cycle engines that burn a spark-ignited, controlled mixture of natural 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.

Caution: Different fuel gases may require a change in hardware and plumbing of the fuel system to the engine as well as physical changes in hardware on and in the engine.

The CNGE Cycle

It is easier to understand the function of the engine parts if it is known what happens in the combustion chamber during each of the four piston strokes of the cycle. The four strokes and the order in which they occur are Intake Stroke, Compression Stroke, Power Stroke, and Exhaust Stroke.

Intake Stroke

During the intake stroke, the piston travels downward permitting air and fuel mixture from the carburetor to enter the combustion chamber through the open intake valve(s).

Compression Stroke

The compression stroke starts at the end of the intake stroke. The intake valve(s) close and the piston starts upward on the compression stroke. The exhaust valves remain closed.

By the end of the compression stroke, the air and fuel mixture in the combustion chamber has been forced by the piston to occupy space significantly smaller than the volume occupied at the beginning of the stroke. This change in space is known as the compression ratio.

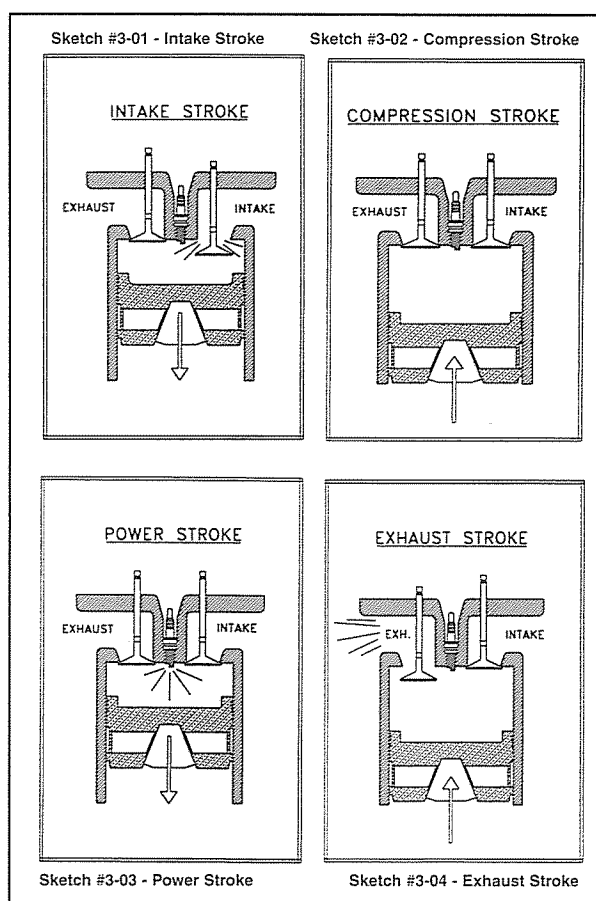
Power Stroke

Near the end of the compression stroke, the fuel is ignited by the spark plug. During the power stroke with both the intake and exhaust valve(s) closed, the burning fuel causes an increase in pressure above the piston. The increased pressure pushes the piston downward and adds impetus to the crankshaft rotation.

Exhaust Stroke

During the exhaust stroke, the intake valve(s) are closed, the exhaust valve(s) are open and the piston is on its upstroke.

Burned gases are forced out of the combustion chamber through the open exhaust valve port(s) by the upward travel of the piston.



The CNGE Cycle

Just slightly before the end of the exhaust stroke and at the very beginning of the intake stroke, the intake valve(s) open and a few degrees later the exhaust valve(s) will close. This is known as valve overlap and is required to remove the last of the remaining exhaust gases during that cycle.

The Fuel-Gas & Carburetion System

Type of Fuel-Gas

Fuel should be clean and must be free of acids, sulfur & halogen compounds, water, pipe scale and other foreign materials which could cause corrosion or abrasion of the cylinder liners, bearings and internal engine parts. Dry processed natural gas usually has the liquids removed and contains primarily methane and a small percent of ethane gases. This type of fuel gas is generally about 905 BTU/cu.ft. L.H.V. (Low Heat Value) and can be used in all CNGE engines that have been structured to run on "Dry Pipeline Natural Gas".

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

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 be run through a scrubber to remove any sulfur and other corrosive 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 lubricating oil from "blow-by" gases.

Note: All "Landfill" gas applications require factory approval.

Located between the gas supply line and the engine intake manifold are the following components that make up the fuel system for a turbocharged GTA14 engine.

Low Pressure Natural Gas System

1. Gas Filter.
2. Pipeline Flexible Connection.
3. Manual or Automatic Gas Shut-Off Valve.
4. Engine Mounted Pressure Regulator.
5. Carburetor (Before Turbocharger on TA Engine).
6. Charge Air Core (CAC) on an Air-to-Air TA System.
7. Throttle Butterfly Valve (After Turbocharger and CAC on TA Engine).

Note: On a turbocharged engine the carburetor power valve and the carburetor air mixer valve are mounted upstream on the low-pressure side of the turbocharger. Downstream of the turbocharger will be an air-to-air after-cooler with a charge air core (CAC) prior to the throttle butterfly valve. On a water-to-air system the intercooler will be after the throttle butterfly in the intake manifold.

Low Pressure Propane Gas System (Liquid) - Unique Components

1. Flexible Fuel Line
2. Engine Mounted Solenoid Shut-Off Valve.
3. Liquid Propane Filter.
4. Liquid Propane Converter.
5. Carburetor (Before Turbocharger on TA Engine).
6. Charge Air Core (CAC) on an Air-to-Air TA Engine.
7. Throttle Butterfly Valve (After Turbocharger & CAC on TA Engine).

Low Pressure Propane Gas System (Vapor) - Unique Components

1. Gas Filter.
2. Flexible Connection.
3. Engine Mounted Manual or Automatic Shut-Off Valve.
4. Engine Mounted Gas Regulator.
5. Carburetor (Before the Turbocharger on TA Engine).
6. CAC (After the Turbocharger on TA Engine).
7. Throttle Butterfly (After Turbocharger & CAC on TA Engine).

Low Pressure Natural Gas Components

Manual Gas Shut-Off Valve

This valve, on a dry pipeline natural gas system, will generally be found upstream of the main line gas flow regulator and is normally supplied by the local gas utility.

On propane systems this valve will be found at the propane supply tank and will be on the top of the tank for a propane vapor system and on the bottom of the tank for a propane liquid system.

Caution: Operators should always know the location of the manual gas shut-off valve. In cases of an emergency the operator needs to shut off the fuel-gas supply.



Photo #3-01 - Manual Gas Shut-Off Valve

Main Line Gas Flow Regulator

The main line gas flow regulator is required to reduce the gas pressure from its main line pressure down to a maximum of 125 psi or less. The minimum pressure will depend on the pressure drop between the main line gas flow regulator and the engine mounted gas flow regulator. The CNGE engine mounted gas flow regulator requires an inlet pressure between 10 to 20 inches of W.C. (water column) pressure at maximum full load operating conditions.

Note: At times there may be a requirement for a secondary gas flow regulator to be installed between the main line gas flow regulator and the on-engine gas flow regulator in order to step down the gas pressure. The maximum allowable pressure to the on-engine gas flow regulator is 20 inches of W.C. (water column) pressure.

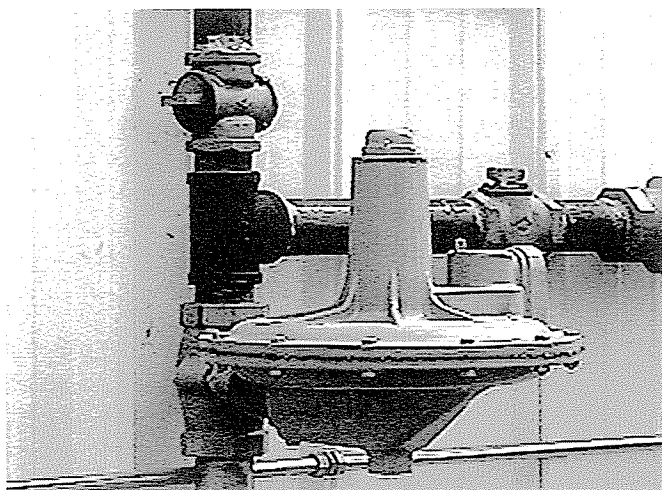


Photo #3-02 - Line Pressure Regulator

Pipeline

The pipeline must be sized so that the required maximum fuel-gas flow is supplied to the on engine gas flow regulator. The pipeline system should be capable of producing the required amount of gas flow, at a minimum of 10 inches of water column pressure under full load condition. Refer to the appropriate engine data-sheet for the correct minimum pipe size at the engine, and the maximum amount of fuel-gas required.

Note: The number of elbows, bends and long pipe runs can introduce sufficient pressure losses to effect the gas flow through the pipeline. For proper sizing contact the local gas utility and advise them on the maximum required gas flow and the minimum required gas pressure to be supplied to the engine.

Gas Filter

The CNGE gas filter is a single pass element made of fiberglass and is capable of filtering down to 10-micron particle size. The filter should be inspected on a regular basis and replaced when necessary. Refer to the appropriate maintenance chart for your respective CNGE engine model.

The 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 of the element towards the inside of the element.

CNGE recommends that the gas fuel filter be installed before the engine mounted regulator and supported by the incoming fuel line. The inlet fuel pressure should be at a maximum of 100 psi to the filter or less. CNGE also recommend that a gas flow shutoff valve (manual or electric) be installed between the line gas flow regulator and the gas filter.

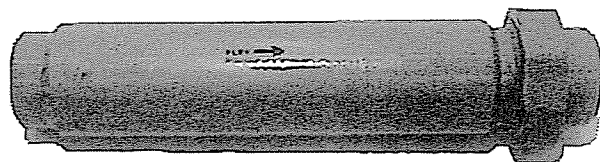


Photo #3- 03 - Gas Filter

Flexible Fuel-gas Pipeline Connection

The fuel-gas pipeline must be connected to the engine fuel inlet systems by means of a flexible, reinforced and fire resistant hose. The hose should be of the same size I.D. as the pipeline and must meet all local codes.

Manual or Automatic Gas Shut-Off Valve

A gas shut-off valve must 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 from any shutdown safety device such as low oil pressure or low water level, etc.

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

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

Warning: DO NOT OPERATE A GAS ENGINE WITHOUT A GAS SHUT-OFF VALVE.

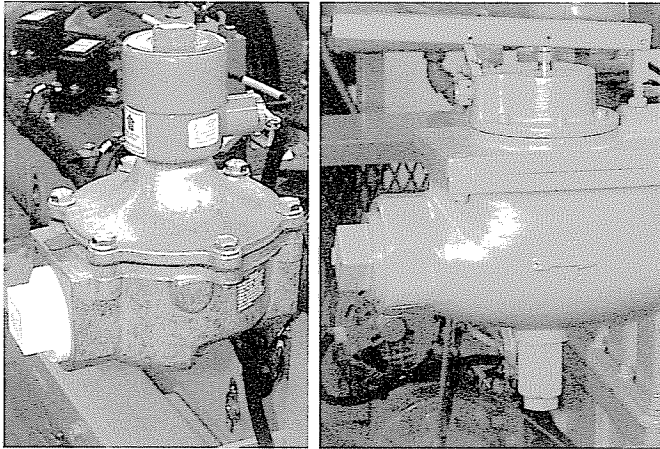


Photo #3-04 - Automatic & Manual Gas Shut-Off Valves

Engine Mounted Gas Flow Regulator

The engine mounted gas flow regulator will reduce the gas pressure at the engine down to a working pressure at the carburetor of three to six inches of W.C. (water column). Refer to Table 3 -01 Gas Pressure Regulators.

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. H₂O at full load conditions. For CNGE engines manufactured before that date, CNGE used various pressure regulators.

Table 3-01 - Gas Flow Regulators

Engine Model	Regulator	Max. Gas Flow cu ft./hr.
GTA14	RV81	3358 @ 1800 RPM

Note: All gas regulators have been sized for a gas flow with a Low Heat Value (LHV) of 905 BTU at 0.6 specific gravity @ 16° C (60° F).

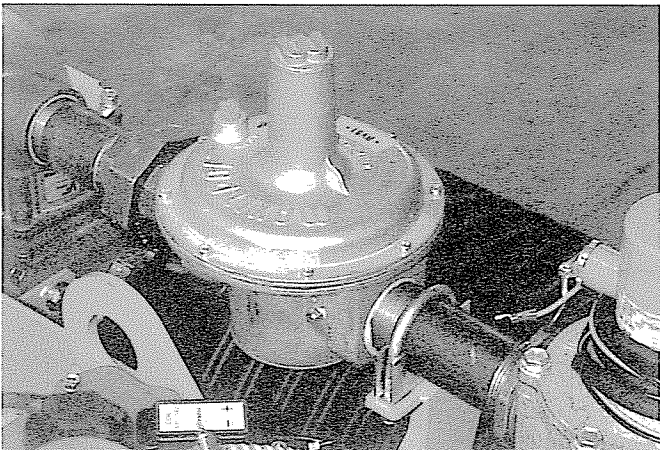


Photo #3-05 - Gas Pressure Regulator - Engine Mounted

Carburetor

The air-gas valve controls gas-flow through the carburetor. The air-gas valve meters both air and gas in proper proportions at any throttle setting. It also seals off gas flow when the engine is shut down and provides automatic choke action for starting.

The working parts consist of an Air Measuring Valve (Bullet Valve) mounted on a diaphragm. Mounted within the cup of the Air Measuring Valve is the Gas Metering Valve. A metering spring is mounted above the valve assembly. The Models # 600 & # 600 VF (vari-fuel) carburetors do not have a closed position and as such require that the engine have a shut-off valve. The shut-off valve can be either manual or automatic.

As air is drawn through the carburetor into the engine, the metering spring causes a pressure drop below the Air Measuring Valve. The pressure drop is transferred to the top of the diaphragm. The lowered pressure above the diaphragm allows the atmospheric pressure below the diaphragm to raise the assembly a distance that is directly proportional to the volume of air passing through the carburetor, thus making the assembly an Air Measuring Device. The Gas Metering Valve that is connected to the assembly will also rise and will measure the correct amount of gas for any height that the Air Measuring Valve rises.

The carburetor inlet gas pressure should be between four to six inches of WC (water column) from no load to full load condition when operating with dry processed natural gas fuel.

When operating with a propane (HD5) fuel the carburetor will be under a negative pressure from -1.5 to a -4.0 inches of water column and on a BI-fuel system the propane will go to a negative - 8.5 in. of water. column vacuum.

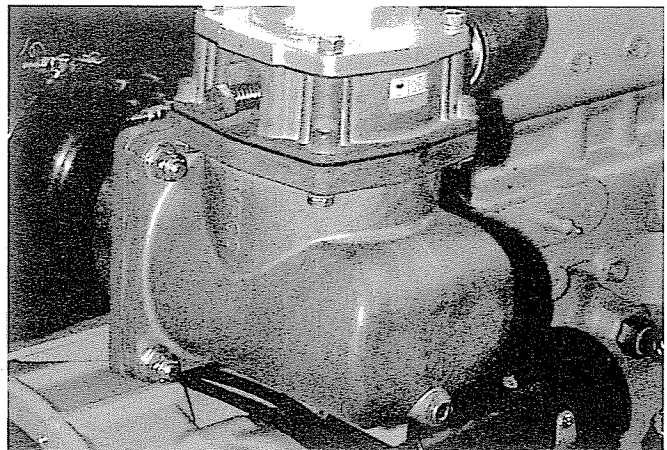


Photo #3-06 - Carburetor

Adjustment of Carburetor Air-Gas Power Valve

Impco Models # 600 & # 600VF (Vari-Fuel) Carburetors

On the model 600 & 600VF 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 rich.

The adjustment is made with the engine under a full load condition and 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.

For additional information on how to measure the excess oxygen refer to the technical specification section.

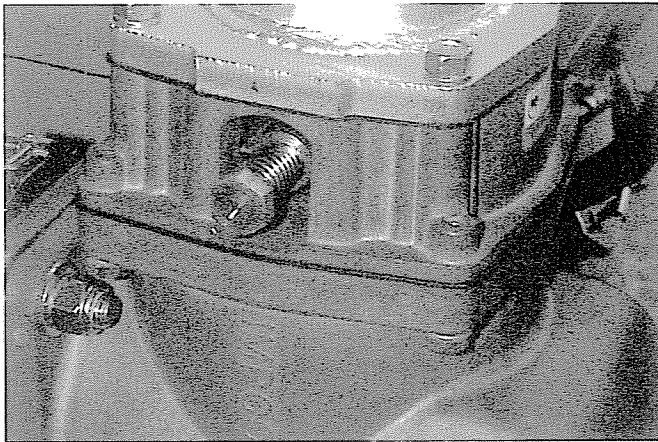


Photo #3 - 07 - Power Valve - Impco Model 600 VF (Vari-Fuel)

Throttle Butterfly

The last component of the fuel system is the throttle butterfly. This assembly consists of a flat round plate mounted on a shaft inside of a throttle body housing. The shaft is connected to a series of levers and linkages that connect to the engine governing assembly. As the engine load increases or decreases the engine governor can control the position of the butterfly causing a change in the amount of fuel gas that can enter into the intake manifold.

CNGE carburetors will vary between engine models. Refer to Table # 3-02 for the appropriate carburetor for your specific engine.

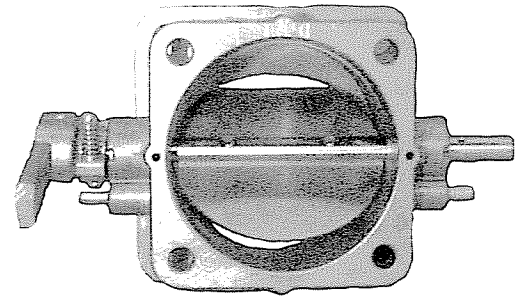


Photo #3-08 - Throttle Butterfly

Table #3-02 - CNGE Carburetors

Engine Model	Carburetors
GTA14	600 VF (Vari-Fuel)
GTA14	600

Low Pressure Propane Gas System Components (Liquid) - Unique to L.P.

Manual Liquid Gas Shut-Off Valve

On propane systems this valve will be found at the propane supply tank and will be on the top of the tank for a propane vapor system and on the bottom of the tank for a propane liquid system.

Engine Mounted Solenoid Valve

The engine mounted solenoid valve is a 2-way normally closed internal pilot-operated solenoid valve. The valve is closed when the solenoid is de-energized and open when energized. The solenoid valve is mounted on the engine, before the engine mounted pressure regulator.

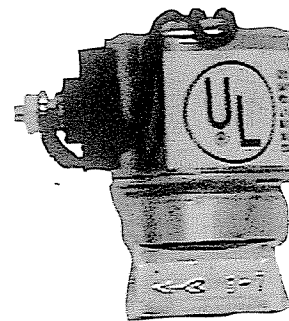


Photo #3-09 - Engine Mounted Solenoid Valve

Liquid Propane Filter

Any CNGE engine using HD-5 liquid propane fuel requires a liquid propane filter before the liquid propane converter. CNGE recommend that the filter be checked and replaced on an annual basis if necessary.

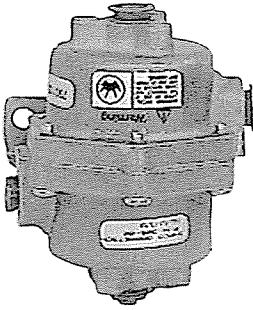


Photo #3-10 - Liquid Propane Filter

Liquid Propane Converter

When CNGE engines are using a liquid propane fuel (HD-5), a "converter" is used in order 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].

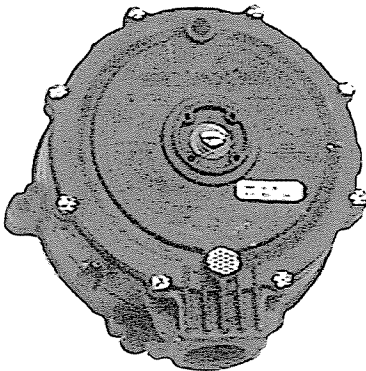


Photo #3-11 - Liquid Propane Converter

Low Pressure Propane Gas System Components [Vapor] - Unique to 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.

Propane will generally cause higher Exhaust Gas Temperatures (EGT) 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. At times, it may be necessary to reduce engine power due to elevated EGT 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.

Engine Mounted Gas Regulator

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.

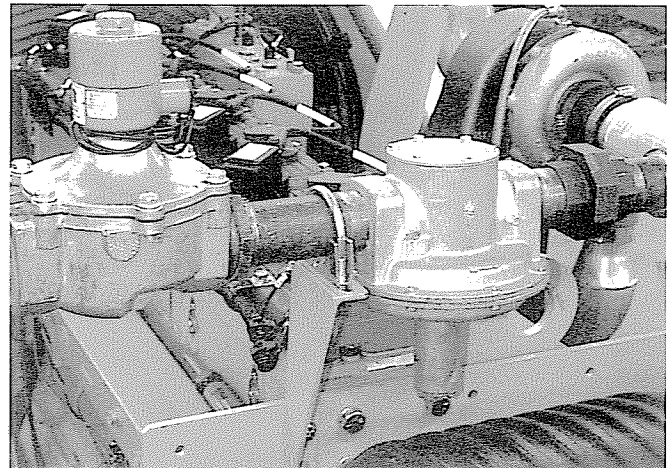


Photo #3-12 - Engine Mounted Gas Regulator - Propane Vapor

The Ignition System

CNGE uses ignition systems supplied by ALTRONIC and Fairbanks Morse.

ALTRONIC V

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

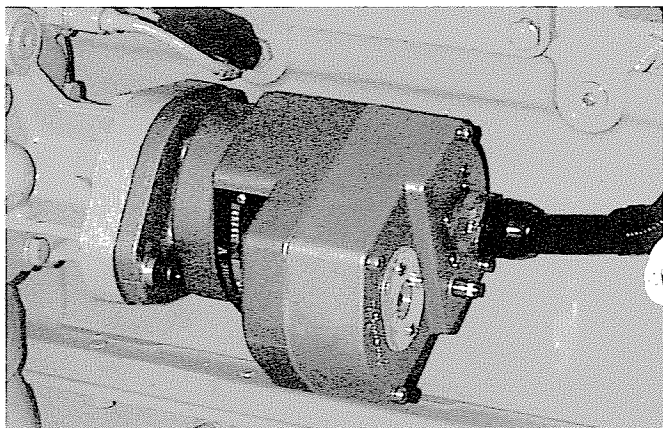


Photo #3- 13 - Altronic V

Fairbanks Morse Model 3000

Fairbanks Morse 3000 Ignition Generator is a self-contained, breaker-less, capacitor discharge ignition generator. The 3000 Ignition Generator has a negative ground (-), therefore, the primary output is positive (+) with respect to ground.

A four-pole permanent magnet rotor generates the ignition power, for the FM3000, with a four-pole stator. The unique winding design allows the four-stator coils to perform different functions. One coil furnishes high voltage for starting, two other coils provide most of the voltage for high speed running and the fourth stator coil is electrically independent from the others serving as a trigger voltage for the ignition triggering circuit.

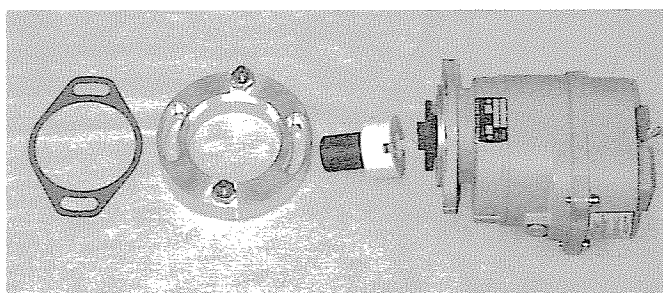


Photo #3-14-Fairbanks Morse Model FM3000

Table #3- 03 - Ignition Systems

Engine Model	ALTRONIC	Fairbanks Morse
GTA14	V	3000

Table #3- 04 - Ignition Timing Values

Engine	C.R.	Timing (DBTDC)	
		Natural Gas	Propane
GTA14	11:1	20	NA
GTA14	8.5:1	24	18

Note: The above timing is at CNGE'S plant location in Clovis, New Mexico @ 4200 ft altitude with a fuel-gas at a low heat value (LHV) of 905 BTU. Your engine may have to have the timing either retarded or advanced depending on your operating load, temperatures, LHV of your fuel-gas and your altitude. Refer to Section # 7, page 7-15 for ignition timing adjustment procedure.

The Lubrication System

CNGE engines are pressure lubricated. The pressure is supplied by a gerotor lubricating oil pump.

A pressure regulator is mounted in the lubricating oil cooler. When the regulator is open some of the oil will be by-passed to the oil pan. When the valve is closed all of the oil will be supplied to the oil cooler.

On the GTA8.3 the oil flow is through the oil cooler and on to the oil filter. The GTA8.3 uses an LF3000 full flow/by-pass combination element.

The oil then flows to the main oil rifle and throughout the various drillings and passages in the engine. Oil to the turbocharger is taken off of the top of the full flow filter directly to the turbocharger.

Some applications will also require a supplemental oil system to increase the oil capacity for extended oil drain periods.

Caution: Extension of oil drain periods should be done by using a good oil analysis program. The addition of more oil will not necessarily allow for oil drain extension.

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

Engine Lubricating Oil

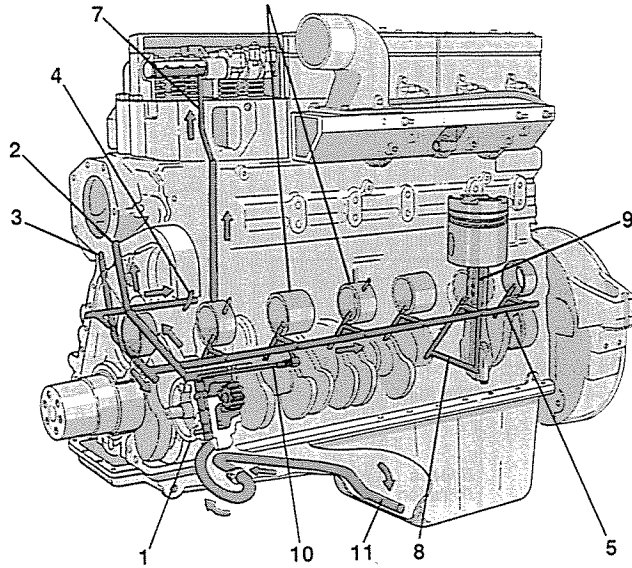
The use of a high quality lubricating oils combined with appropriate oil drain and filter change intervals is a critical factor in maintaining engine performance and durability.

Recommended Oil Specifications

Cummins Natural Gas Engines, Inc. recommends the use of a **high quality SAE 15W40 heavy duty natural gas engine oil** that meets the **American Petroleum Institute (API)** performance classification CD.

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.**

1. Oil Pump
2. To Lubricating Oil Cooler
3. From Lubricating Oil Cooler
4. Piston Cooling Nozzle
5. Main Oil Rifle
6. Cam Bushings
7. To Overhead
8. Main Bearing
9. Connecting Rod Drilling
10. Rifle Pressure Signal Line
11. Suction Tube



Lubricating Oil System Flow Diagram 1

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

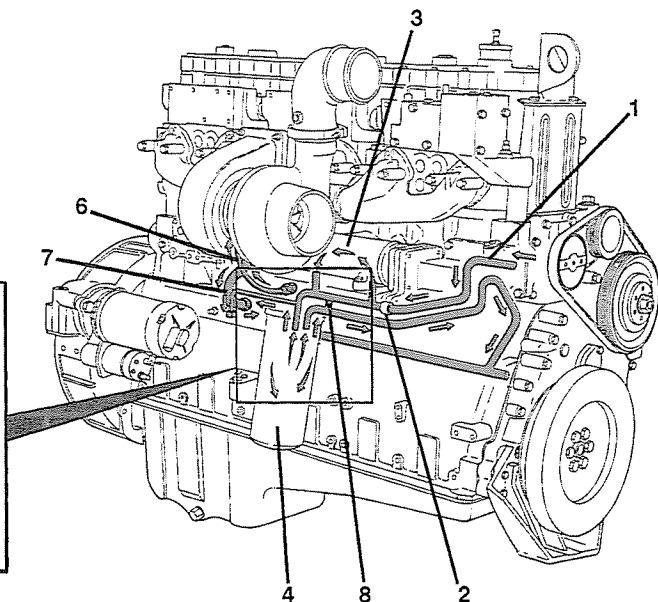
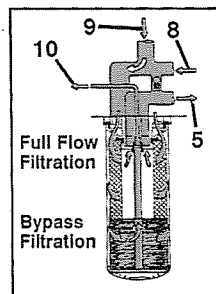
a CE/SF engine oil with adequate low temperature properties such as a synthetic 5W-20 or 5W-30.

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.

Lubricating Oil System Flow Diagram 2

1. From Oil Pump
2. Oil Cooler Thermostat
3. Oil Cooler
4. Combination Full Flow/Bypass Lube Oil Filter
5. To Main Rifle
6. Turbocharger Oil Supply
7. Turbocharger Drain
8. Oil Filter Bypass Valve
9. From Oil Cooler
10. Bypass Filter Oil to Sump



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: Operation of CNGE engines with concentrations of Sulfur above 10 PPM will require the use of high **sulfated ash oils**. Higher ash oils can cause short spark plug life; valve or piston damage, deposit buildup on electronic sensors and can lead to excessive oil consumption.

Additional information regarding lubricating oil availability 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 be ordered from:

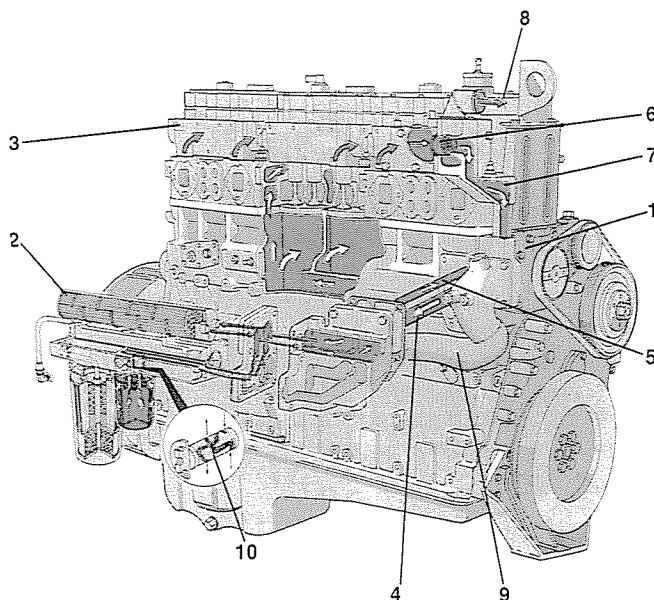
Engine Manufacturers Association
One Illinois Center
111 East Wacker Drive
Chicago, Ill. U.S.A. 60601
Telephone: (312) 644-6610

The Cooling System

On the GTA14, a belt driven centrifugal-type water pump circulates coolant. The water pump is mounted directly in the front of the cylinder block. The coolant flows past the oil cooler, past the cylinders, and on to the cylinder head. The coolant flows from the cylinder heads to the thermostat housing. At this point the coolant may be recirculated back to the water pump and to the radiator or heat exchanger as the thermostat opens.

Cooling System Flow Diagram

1. Water Pump
2. Oil Cooler
3. Water Manifold
4. Oil Cooler Supply
5. Oil Cooler Return
6. Thermostat
7. Bypass
8. To Radiator
9. Water Pump Inlet
10. Coolant Filter Head Shutoff Valve



On engines with a water-cooled exhaust manifold, the water flow is from the cylinder heads to the manifold and then to the thermostat housing.

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 concentrated mixture that is used with 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.

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 contains 50 percent 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 percent antifreeze in the mixture unless additional freeze protection is required.

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

3-11

3. Use low silicate antifreeze that meets Engineering Standard GM 6038-M or that contains no more than 0.1 percent 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.
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 antifreezes to minimize hydro-gel formation if over-concentration 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.

Irrigation Application

The cooling system on some 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. A de-aerating expansion tank is required.

Aftercooler Circuit- Water to Air

Whenever water-cooled aftercoolers are used on turbocharged Cummins Natural Gas Engines, an auxiliary water pump circulates water through the aftercooler and its separate heat exchanger or radiator core. A de-aerating expansion tank with a separate section for the aftercooler circuit is also required.

Cummins Natural Gas Engines, Inc. recommends that all cooling systems used on CNGE engines be of a design that offers a de-aerating 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.

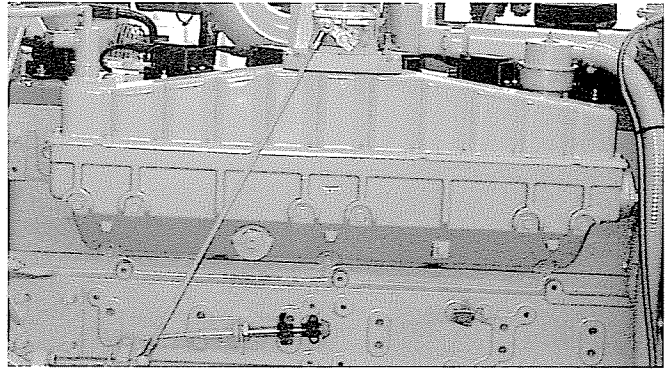


Photo #3-15 - Aftercooler Heat Exchanger - Water -to-Air

Aftercooler Circuit- Air-to-Air

Several models of CNGE engines use an aftercooler section that uses an air-to-air CHARGE AIR CORE (CAC) section of the engine radiator package.

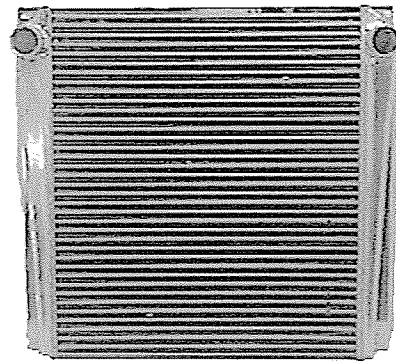


Photo #3-16 - Aftercooler Charge Air Core (CAC) -Air-to-Air

The Air Intake 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 airflow to the engine for good air-fuel mixture. Refer to your engine datasheet for allowable intake restriction and CFM of airflow.

The air cleaner is generally mounted on the engine and can be either a single stage or a two-stage dry type paper element with a safety element depending on the application.

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 and on to the cylinders.

On the turbocharged model with a low-pressure system the air will be mixed in the carburetor before the turbocharger.

Caution: Spark-Ignited gas type engines are more critical on the air cleaner restriction than diesel engines. As the air cleaner restriction increases the air-fuel mixture will become rich, increasing the combustion & exhaust gas temperature.

The Exhaust System

The GTA14 turbocharger is a top mount with front out exhaust. The turbocharger outlet stack has been provided with the necessary openings for recording excess oxygen and exhaust gas stack temperature in the exhaust gas stream.

Some locations and applications may require the use of catalytic converters, mufflers, silencers or flame arrestors.

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

Many locations will, by local code, require the use of a Catalytic Converter 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 temperature.

CNGE engines are factory set with a Stoichiometric Air/Fuel ratio toward the "lean" side of Stoichiometry for the express purpose of providing the lowest possible exhaust gas temperature required for exhaust valve durability.

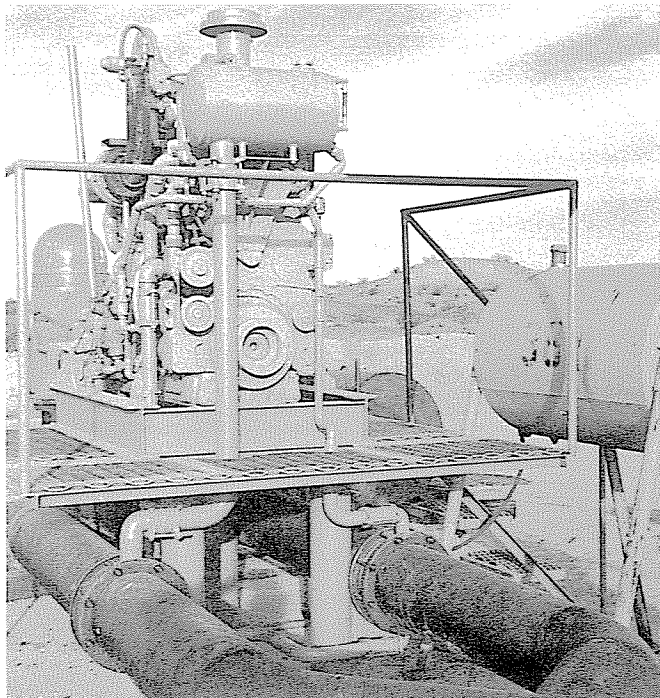
The use of a Catalytic Converter will generally require that the Air/Fuel ratio be set to the "rich" side of Stoichiometry. When this occurs the exhaust gas temperature will elevate to a higher level that may reduce exhaust valve life.

Caution: Some manufacturers of catalytic converters require that the engine oil have a sulfated ash content of no more than .5% mass of sulfated ash. In addition there may be restrictions placed on the amount of phosphorous and zinc that can be allowed in the additive packages that are used in some natural gas engine oils. Under no circumstances should the levels of zinc and phosphorous fall below the minimum required level for proper operation of the GTA14 engine.

The Electrical System

The electrical system consists of 24 VDC batteries, 24 V electrical starters, and 24 V alternators on some applications and various wiring diagrams such as;

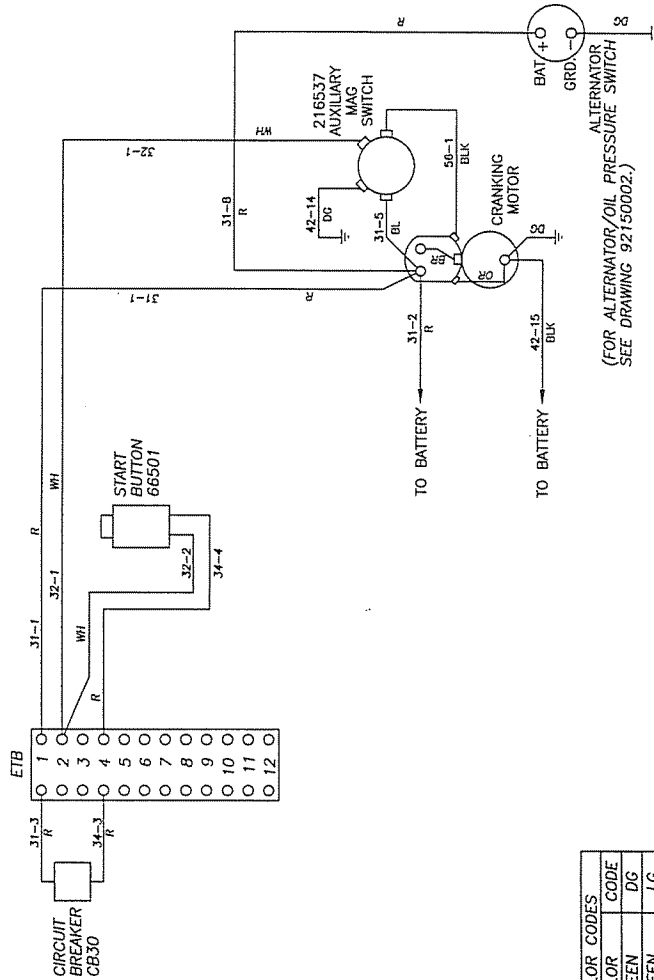
- Starter - Drawing # 10423551
- Manual Start - # 91001034
- Automatic Start - # 91001029
- Kim Hotstart - # 10900011
- Altronic V - # 90810137
- Bi-Fuel w/o Control Panel - # 90521070
- 5 Gauge Instrument Panel - # EG1025
- 6 Gauge Instrument Panel - # EG1024
- Single 6 Wiring w Options - # 11010608



Notes:

Starter - Drawing # 10423551

REVISIONS		
NO.	CORRECTIONS	ERN/EJR
A	RELEASE FOR PRODUCTION	0142 07/90
B	REVISION PER 180791	0460 07/91



WIRE COLOR	CODE
DARK GREEN	DG
LIGHT GREEN	LG
GREEN/WHITE	G/W
RED	R
WHITE	WH
BROWN	BR
BROWN/WHITE	BR/W
PURPLE/WHITE	PU/W
PURPLE	PU
DARK PURPLE	DPU
ORANGE	OR
ORANGE/WHITE	OR/W
YELLOW	YE
LIGHT YELLOW	LYE
BLUE	BL
DARK BLUE	DBL
BLUE/WHITE	BL/W
GRAY	GR
GRAY/WHITE	GR/W
DARK GRAY	DGR
BLACK	BLK

UNLESS OTHERWISE SPECIFIED, THE FOLLOWING GENERAL NOTES SHALL APPLY:
 BREAK SHARP CORNERS AND REMOVE BURRS PER INSP. STD. 16.061
 MADE FROM ROUGH CASTING/FORGING NO.
 FILLET RADIUS: REF. DRAWING NO.
 EDGE RADIUS: LAYOUT NO.
 WALL THICKNESS: USED ON: ALL
 DRAFT ANGLES: MATERIAL:
 SURFACE FINISH: PROCESS:
 FINISH STOCK: ENGR. STD.
 INSP. STD.: MFG. METHOD:
 CADD FILE: CADD DRAWING NAME:
 WD-C

CUMMINS NATURAL GAS ENGINES, INC.
 a subsidiary of Cummins Engine Co., Inc.

CUMMINS logo

CUMMINS NATURAL GAS ENGINES, INC.
 Cleveland, New Mexico 88101

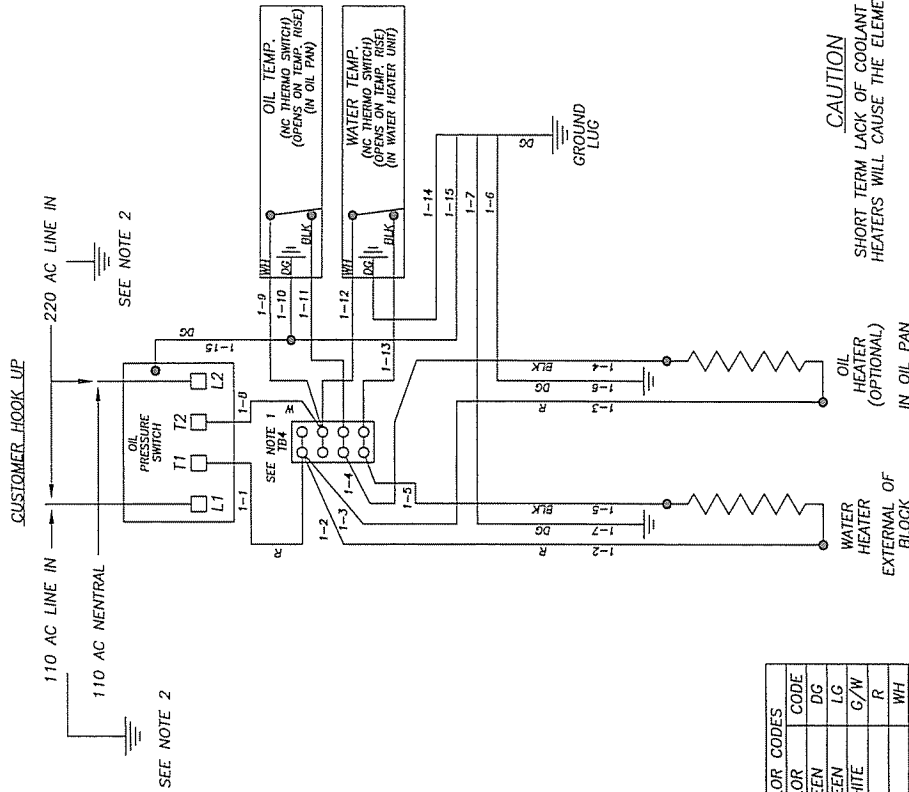
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 DRAWN: DLH 07/11/90
 CHKO: GD 07/11/90
 APPD: CAM 07/11/90
 EJR-LR 18/07/91
 SCALE: NTS
 SHEET: 1 OF 1

Kim Hotstart - # 10900011

REVISIONS		
NO.	CORRECTIONS	DATE
A	RELEASE FOR PRODUCTION	0886 04/90
B	REVISION PER 060890	0120 06/90
C	REVISION PER 071090	0138 07/90
D	REVISION PER 300491	0349 04/91
E	REVISION PER 050691	0422 06/91
F	REDRAWN AND REDESIGNED	0456 07/91



WIRE COLOR	CODE
DARK GREEN	DG
LIGHT GREEN	LG
GREEN/WHITE	G/W
RED	R
WHITE	WH
BROWN	BR
BROWN/WHITE	BR/W
PURPLE/WHITE	PU/W
PURPLE	PU
DARK PURPLE	DPU
ORANGE	OR
ORANGE/WHITE	OR/W
YELLOW	YE
LIGHT YELLOW	LYE
BLUE	BL
DARK BLUE	DBL
BLUE/WHITE	BL/W
GRAY	GR
GRAY/WHITE	GR/W
DARK GRAY	DGR
BLACK	BLK

KIM HOTSTART WATER HEATER			
CUMMINS PART NO.	SUPPLIER PART NO.	VOLTAGE	WATT
	BC110	115	1000
	E220	230	4000

LUBE OIL HEATER (OPTIONAL)			
CUMMINS PART NO.	SUPPLIER PART NO.	VOLTAGE	WATT
	OL4315	115	300
	OL4323	230	300

2. ALL GROUNDS HOOK TO JUNCTION BOX CASE.
 1. WIRE NUTS COVERED WITH ELECTRICAL TAPE CAN BE USED INSTEAD OF TBZ.

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 BREAK SHARP CORNERS AND REMOVE BURRS PER INSP. STD. 16,061
 MADE FROM ROUGH CASTING/FORGING NO.
 FILLET RADIUS: _____
 LAYOUT NO. _____
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 FINISH STOCK: _____
 INSP. STD. _____
 MFG. METHOD: _____
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 APPD: CAM 05/06/91
 APPD: EUR-LR 17/07/91

SCALE: NA
 SHEET: 1 OF: 1

TITLE: WIRING DIAGRAM
 KIM HOT START (E220)

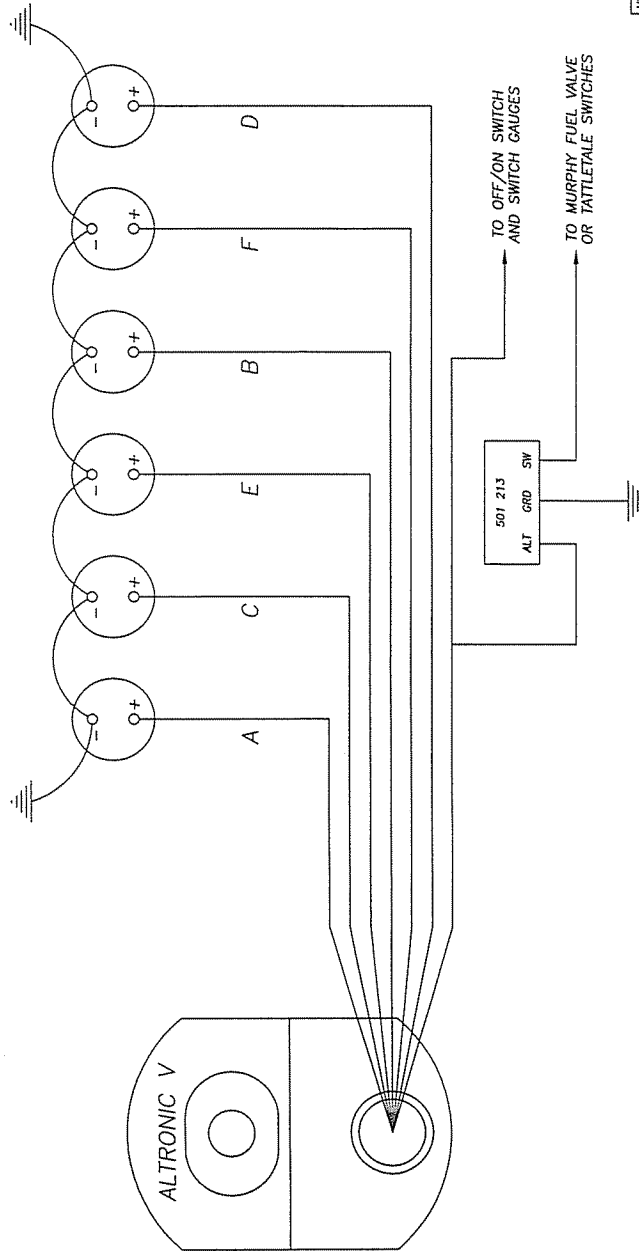
10900011


CUMMINS NATURAL GAS ENGINES, INC.
 a subsidiary of Cummins Engine Co., Inc.
 Clovis, New Mexico 88101

CAUTION
 SHORT TERM LACK OF COOLANT IN THESE HEATERS WILL CAUSE THE ELEMENT TO FAIL.

Altronic V - # 90810137

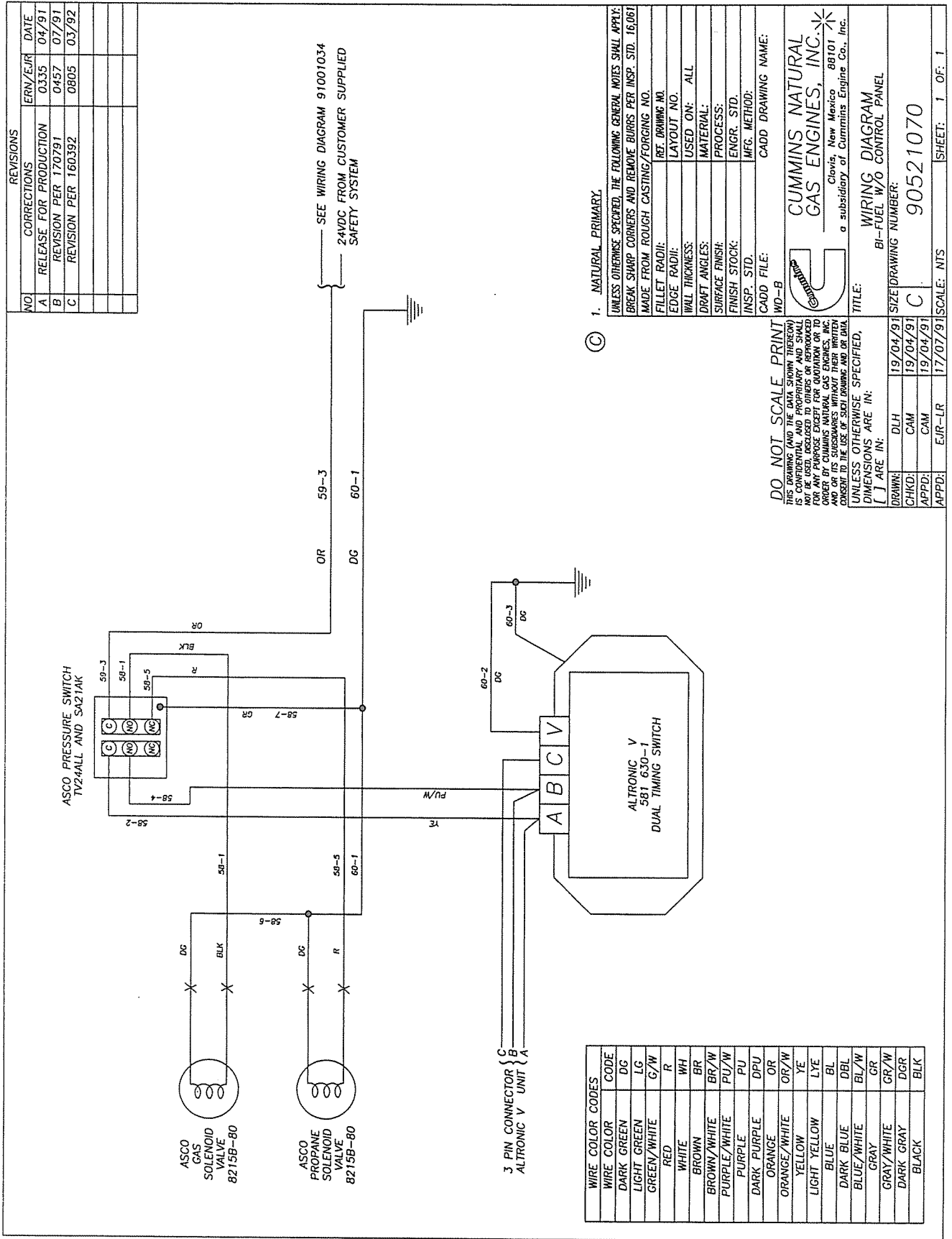
REVISIONS		
NO.	CORRECTIONS	DATE
A	RELEASE FOR PRODUCTION	04/24/91



UNLESS OTHERWISE SPECIFIED, THE FOLLOWING GENERAL NOTES SHALL APPLY: BREAK SHARP CORNERS AND REMOVE BURRS PER INSP. STD. 16.061 MADE FROM ROUGH CASTING/FORGING NO.	
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EDGE RADIUS:	LAYOUT NO.
WALL THICKNESS:	USED ON: 6 CYL
DRAFT ANGLES:	MATERIAL:
SURFACE FINISH:	PROCESS:
FINISH STOCK:	ENGR. STD.
INSP. STD.	MG. METHOD:
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 CUMMINS NATURAL GAS ENGINES, INC. Clovis, New Mexico 88701 a subsidiary of Cummins Engine Co., Inc.	
TITLE: WIRING DIAGRAM ALTRONIC V IGNITION (6A34)	
SIZE DRAWING NUMBER: 90810137	
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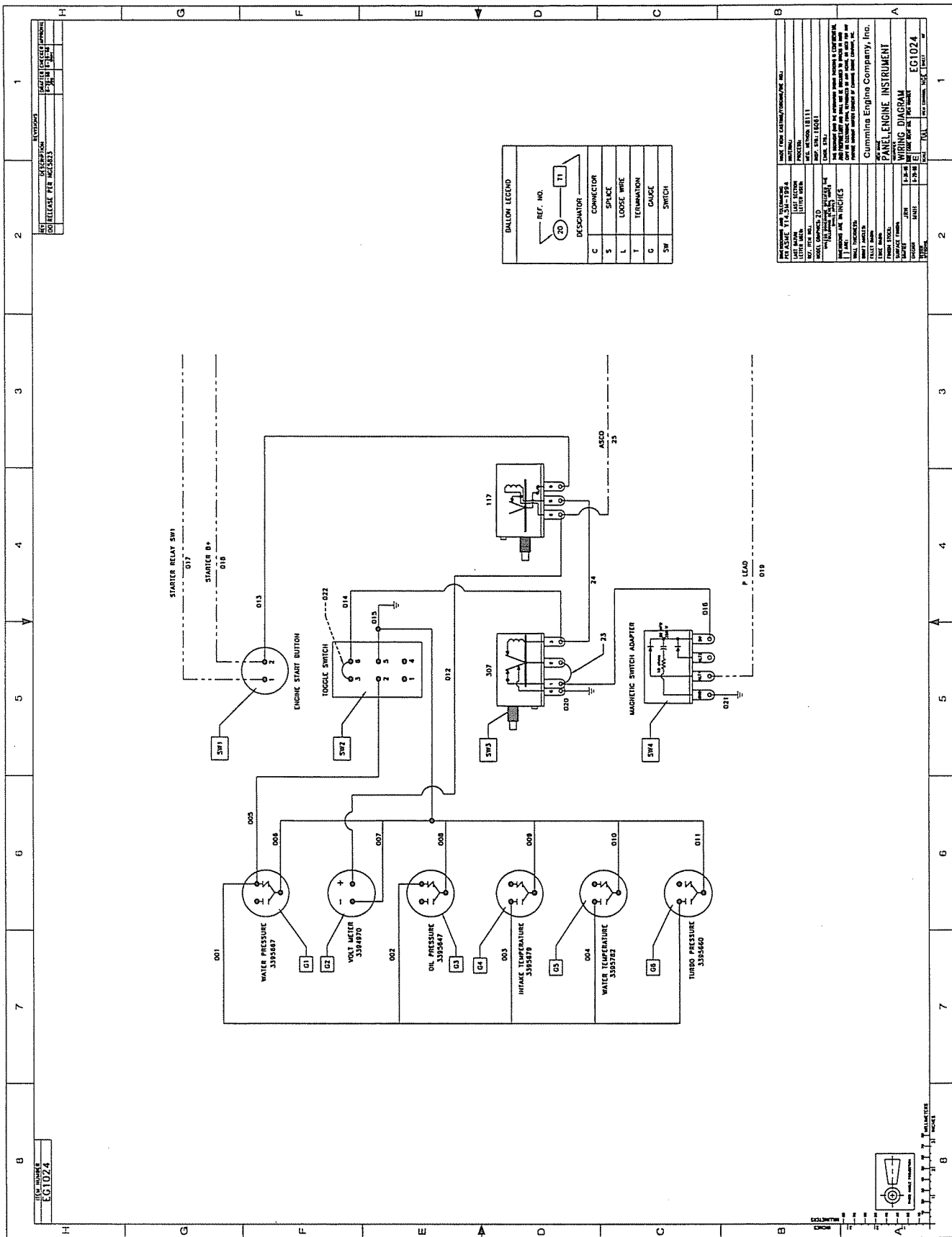
Bi-Fuel w/o Control Panel - # 90521070



Section 3

Wiring Diagrams

6 Gauge Instrument Panel - # EG1024



BALLON LEGEND

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EG1024

Section 4

Installation Instructions

Remove all tape and plastic covers from cooling, fuel, lubricating oil, exhaust and air intake connections.

Locate unit on a firm base and secure in desired position with anchor bolts and shock mounts. Check alignment of engine with driven unit; shim as necessary to obtain desired alignment. Allow for sufficient space to provide access to all sides of unit. If radiator cooled be aware of prevailing winds and position unit in the proper direction (blower fan away from prevailing winds & sucker fan facing prevailing winds).

On installations with external coolant lines, such as cooling towers and heat exchangers, install piping with flexible connections to reduce stress on rigid piping due to engine vibration. If using raw water for both engine and aftercooler system from same pipe, always plumb through aftercooler circuit first and engine circuit last if plumbing in series. If plumbing in parallel be sure to install a raw water flow control valve in order to balance the flow between the aftercooler circuit and the engine circuit.

Provide for outside venting of exhaust gas if unit is installed in an enclosed area; also, venting of radiator cooling air must be provided.

Connect your gas supply piping and observe all required local codes. Be sure to install the correct pipe size ID; if possible, consider increasing the size for the last four to six feet of pipe to help in providing sufficient gas when a sudden increase in load is required.

Install a flexible connection between your gas supply line and the engine mounted gas shut-off valve. Insure that the flexible connection meets all required local codes for gas plumbing.

Caution: Do not use rubber hose for flexible connection.

Inspect unit for damaged or missing parts. Check all bolts and nuts for tightness; replace as necessary.

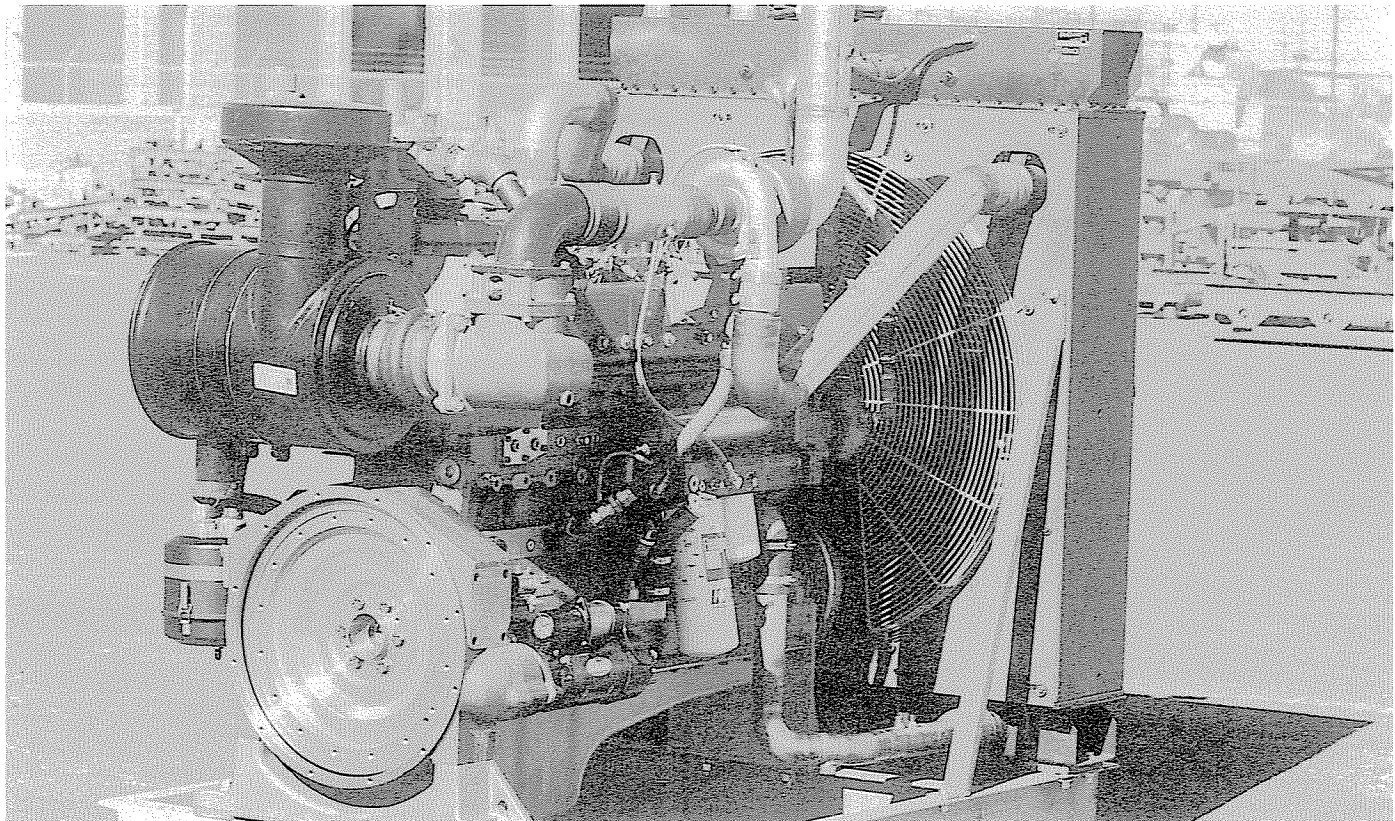
Inspect all wires for cut or frayed insulation; replace all damaged wiring.

Check the throttle control to see if you have free travel; correct as necessary.

Note: Application Engineering Bulletins, Installation Guidelines are available in the form of Installation Requirements Bulletins (IRB'S) from your local Cummins distributor.

Note: CNGE installation drawings and wiring diagrams are also available from your local Cummins Distributor.

If not sure about your installation, contact the local Cummins distributor and ask for an installation review.



Section 5

Start-Up & Operating Instructions

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Operating Instructions

General - All Applications

Correct care of your engine will result in longer life, better performance, and more economical operation.

Follow the maintenance guidelines referred to in the maintenance section 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 & exhaust gas temperature (EGT) and cause engine over-speed situations. CNGE recommends the use of safety shutdown devices such as, but not limited to: over-speed and high EGT safety devices.

Initial Inspection and Start-Up

The responsibility for an initial inspection and proper new engine start-up rests with the end user customer. CNGE recommends that all new CNGE engines have an initial inspection & start-up by either the local Cummins distributor or an authorized CNGE dealer. This presents to the end user of the CNGE engine, the opportunity to insure that the engine is properly adjusted for the on-site 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 insure that all fluids such as lubricating oil, engine coolant, aftercooler coolant, etc. are at their proper levels. All belts will be checked for proper adjustment.

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 instructions covered in this section and will make final adjustments to the engine.

5-2

Final adjustments include, but are not limited to:

1. Confirming that the on-site load is within the 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 & 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 & speed range.
5. 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 temperature at loaded conditions.
 - Intake manifold vacuum/pressure and temperature at idle and at load.
 - Excess Oxygen reading in exhaust gas at rated load and rpm.
 - Exhaust gas temperature at manifold outlet at rated load and rpm
 - Engine rpm at idle and at load.
 - Hour-meter reading.
 - Ambient temperature.
 - Altitude.
6. 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.
 - Over-speed device.

Note: All safety shutdowns are set for running at rated speed and load.

7. The Engine data-plate will be stamped with the inspection date.

At the conclusion of the inspection the service technician will supply the customer a copy of the inspection report that will later be filed with CNGE.

All end user customers should give strong consideration to having the local distributor or authorized dealer perform a new engine start-up & inspection. The cost is a minor investment when compared to the major expense from failures that are the result of either no inspection or an improper inspection.

Note: CNGE does not require an initial inspection to start the end user's warranty coverage. For warranty details refer to the warranty certificate.

New Engine Break-In

CNGE engines are run in on engine 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 require an on-site adjustment at time of installation and at the initial start-up. Refer to the Start-Up and Inspection.

In other applications, the engine can be put to work after the start-up & inspection, but the operator has an opportunity to establish conditions for optimum service life during the initial 20 hours of operation by:

1. Warm up the engine before placing it under any load.
2. Operate the unit at no more than 75% of its rated load.
3. Do not operate the engine at idle or at full load for more than 5 minutes.
4. Observe lubricating oil pressures and temperatures and engine coolant temperatures. Reduce the engine load if the oil temperature reaches 121° C [250° F] or the engine coolant temperature reaches 91° C [195° F].
5. Check oil and coolant levels frequently during the break-in period.

Starting Procedure

Priming the Lubrication System

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 dipsticks 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" (high) mark on the dipstick.
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.

Caution: Do not engage starter motor for more than 30 seconds at a time. Wait for two minutes between each start.

3. Refill crankcase to the "H" (high) 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. The GTA14 uses the engine oil to lubricate the hydraulic governor.

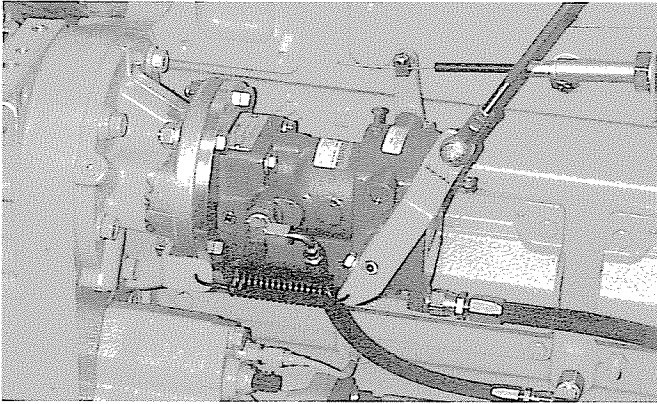


Photo #5-01 - Hydraulic Governor

Check Air Connections

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



Photo #5-02 - Air Connections

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.
2. Make a visual check for leaks and open the water filter shut-off valves.



Photo #5-03 - Radiator & Expansion Tank 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.

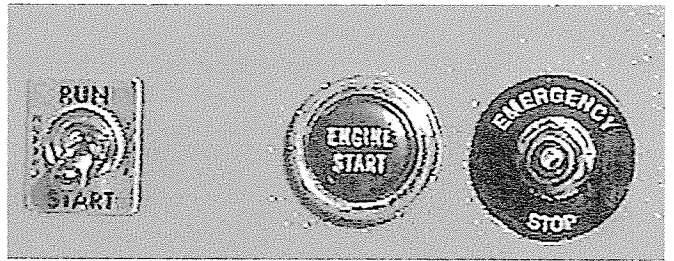


Photo #5-04 - Start-Stop Button or Switch

Normal Starting Procedure (Above 0° C [32° F])

Warning: Before starting be sure that everyone is clear of the engine and the equipment.

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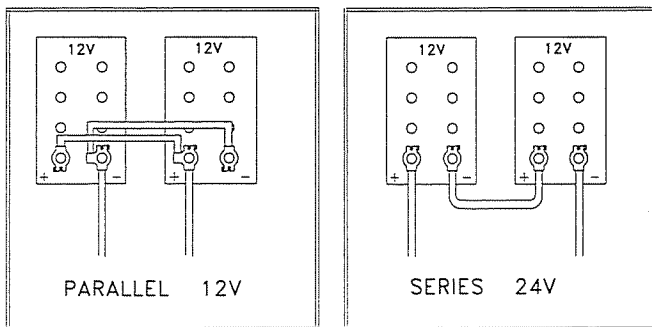
If the engine is equipped with an over-speed stop, push the “Reset” button before attempting to start the engine.

1. Check the lubricating oil and engine coolant levels.
2. Set the throttle for 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 fuel shut-off valves with a manual reset, return manual reset to open position before cranking engine. The lever will lock in the open position. After the engine starts and oil pressure begins to rise the shut-off valve will return to its normal operating position.
6. Push the “reset” button on the instrument panel.
7. Hold in the safety switch override button 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 to prevent unintentional starter engagement.

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



Sketch #5-01 - Battery Connections - Proper Hook-Up

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. If oil pressure has not registered within 15 seconds, shut off engine immediately to avoid engine damage. Check engine oil level.
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.
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 60° C (140° F). If the application permits, run the engine for the next 10 to 15 minutes or until the water temperature reaches 71° to 73.9° C (160° to 165° F) at a reduced load before applying full load.

Caution: Continuous operation with low coolant temperature below 60° C [140° F] or high coolant temperature above 100° C [212° F] can damage the engine.

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 reestablished 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 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].

Operate by the Instruments

Instrument Panels

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 a full load. Never over-ride the governor under normal operation or allow the engine to exceed the rated RPM during operation.

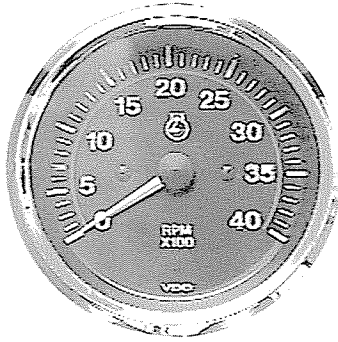


Photo #5-05 - Tachometer

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 temperature should not exceed 93° C [200° F].

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

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

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 over-heating to the maintenance department for corrections.

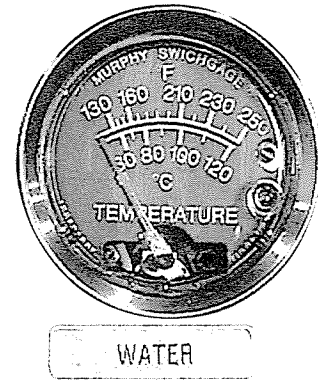


Photo #5-06 - Water Temperature Gauge - Thermostat Housing Outlet

Aftercooler Coolant Inlet Temperature

On water-to-air systems the aftercooler coolant inlet temperature to the aftercooler coolant pump must be maintained at a maximum of 32° C [90° F.] on systems with 11.0:1 compression ratio (C.R.) pistons. With a C.R. equal to 8.5:1 the water inlet temperature to the aftercooler coolant pump must be maintained at or below 54° C [130° F] at all times and during all ambient weather conditions.

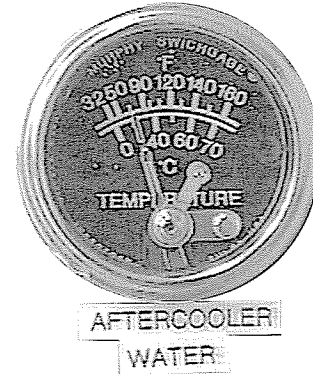


Photo #5-07 - Aftercooler Coolant Temperature Gauge

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.

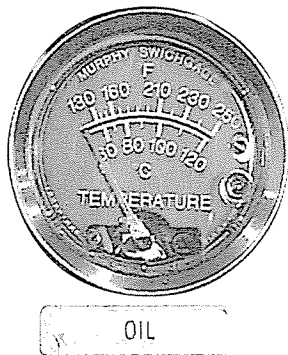
Caution: Any sudden increase in oil temperature that is not caused by an increase in load is a warning of possible mechanical failure and should be investigated at once.

During the warm-up period, apply the load gradually until the oil temperature reaches the 140° 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

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oil temperatures below 60° C [140° F] may cause water and acid formation in the crankcase that will quickly accelerate engine wear.

Photo #5-08 - Oil Temperature Gauge



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 #5-09 - Oil Pressure Gauge

Intake Manifold Air-Gas Temperature

The intake manifold air-gas temperature must be held to a temperature well below the point of detonation. For the air-to-air aftercooler system, the cooling air to the remote charge air core (CAC) must be held to 100° F or lower for engines operating with 11.0:1 compression ratio pistons and to a temperature of 130° F or lower for engines operating with 8.5:1 compression ratio pistons.

The maximum intake manifold air-gas temperature under full operating load conditions can never be higher than 125° F for engines operating with 11.0:1 compression ratio pistons and 140° F for engines operating with 8.5:1 compression ratio pistons.

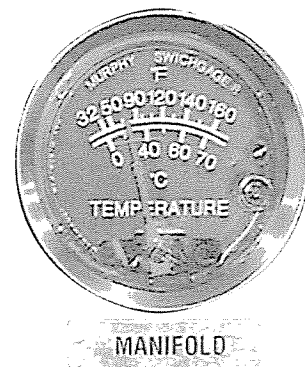


Photo #5-10 - Intake Manifold Air-Gas Temperature Gauge

Intake Manifold Boost Pressure (Turbocharged Models)

The engine intake manifold boost pressure needs to be maintained at a level below 16 psi.

Caution: As the engine fuel air ratio is leaned the turbo boost pressure will rise.



Photo #5-11 - Intake Manifold Boost Pressure Gauge

High Altitude Operation - De-Rating Requirements

Turbocharged Engines

The engine may be operated at the **MAXIMUM or EMERGENCY STAND-BY RATING** up to 914 m [3000 ft] altitude and 38° C [100° F] inlet air temperature, and at the **CONTINUOUS or PRIME POWER RATING** up to 1524 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 100° F and when altitudes are over 3000 ft.

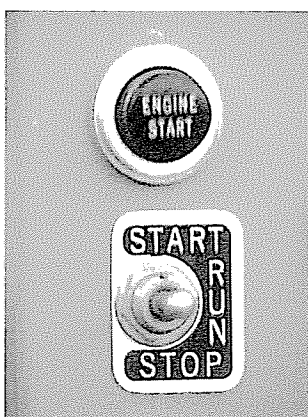


Photo #5-12 - Start-Stop Switch - "OFF" Position

Engine Shut-Down Procedure

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 "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 also will close the gas valve shutting off the gas supply to the carburetor.

Caution: Always know the location of the manual fuel shut-off valve in the event of an emergency or while servicing the engine.

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 and immediately shuts down the engine. Some changes to look for are as follows:

- Increase in oil consumption.
- Increase in fuel consumption.
- Unusual engine noise.
- Fuel gas, oil, or coolant leaks.
- Sudden changes in operating temperature or oil pressure.
- Smoke.
- Vibration.
- Engine misfires.
- Loss of power.

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

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.

If an engine is to be shut down for an extended 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 accessories if used. Open all vent cocks and all petcocks on the top and side of the engine.

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.

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

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 at start-up.

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 engine 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.

6-2

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. Reference Chart # 1 on Page 6-5.

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 high ash oil not more than .85% of sulfated ash with a high TBN number that meets a CD API specification be used to help neutralize the acid.

Digester Gas

This gas is a by-product of digester tanks where various materials are 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 quantities of methane gas. The gas is generally of a 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 to "sour gas".

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

Gas Measurement Conversion Factors

Example:

Methane Gas at 60° F

1 MCF	= 1000 Cubic feet.
1 Decatherm	= 1000 feet.
1 Decatherm	= 10 Therms.
1 Therm	= 100 cubic feet.
1 Therm	= 101,200 BTU (HHV).
1 cubic feet	= 1,012 BTU (HHV).
100 cubic feet	= 101,200 BTU (HHV).
100 cubic feet	= 91,080 BTU (LHV).

Utility companies will talk in terms of Therms of gas at HHV levels. The engines will actually use only the LHV of the gas to produce power. The balance of the energy (10%) is consumed in the removal of water from the combustion cycle (Latent heat of vaporization).

Table #6-01- Fuel Gas BTU Content

Gas	Chemical Formula	BTU per ft ³ Vapor HHV
Methane	CH ₄	1012
Ethene	C ₂ H ₄	1601
Ethane	C ₂ H ₆	1783
Propene	C ₃ H ₆	2335
Propane	C ₃ H ₈	2558
ISO-Butane	C ₄ H ₁₀	3354
Butene-1	C ₄ H ₆	3084
ISO-Butene	C ₄ H ₆	3066
N-Butene	C ₄ H ₁₀	3368
ISO-Pentane	C ₅ H ₁₂	4003
Pentene-1	C ₅ H ₁₀	3829
N-Pentane	C ₅ H ₁₂	4015
Hexane	C ₆ H ₁₄	4756
Heptane	C ₇ H ₁₆	5503
Octane	C ₈ H ₁₈	6250
Carbon Monoxide	CO	321
Carbon Dioxide	CO ₂	0
Hydrogen	H	324
Hydrogen Sulfide	H ₂ S	672
Oxygen	O ₂	0
Nitrogen	N ₂	0
Air		0
Water	H ₂ O	0

FUEL, ALTITUDE & TEMPERATURE - DE-RATING FACTORS

Cummins Natural Gas Engines, Inc. (CNGE) engines are capable of carrying standard published ratings when operated on clean "dry processed natural gas" fuels and on other combustible fuel mixtures. When low BTU content is determined, there may be a requirement to de-rate the engines.

The purpose of this Section 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

Turbocharged Engines

The engine may be operated at the MAXIMUM RATING up to 914m [3,000 ft.] altitude and 38° C [100° F] inlet air temperature, and at the CONTINUOUS RATING up to 1542m [5,000 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 914m [3000 ft.].

Fuel De-Rating Requirements

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

Inert gases such as nitrogen (N₂), carbon dioxide (CO₂) or water vapor (H₂O), 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 processed 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 & 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 should 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 economy and with an increase in exhaust gas temperature.
2. High compression ratio pistons for both naturally aspirated and turbocharged engines are extremely sensitive to fuel anti-knock characteristics, therefore a lower level of the maximum permissible percentages have 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 H₂S 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. Chlorinated hydrocarbons (halogenated hydrocarbons) can cause corrosive damage to the engine. Acceptable levels are similar to hydrogen sulfides, i.e., 10 to 24 PPM.
6. Fuel gas should be filtered to a 10-micron level to eliminate dust or 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 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 & Temperature against the amount of de-rating due to the fuel hydrocarbons and use the **HIGHER** of the two.

Notes:

Chart # 1

FUEL DE-RATING FACTORS
MAXIMUM PERMISSIBLE COMBUSTIBLES -%

		Turbocharged
Compression Ratio	8.5:1	11.0:1
Type of Gas		See Note #1
Methane (CH ₄)	100	100
Ethane (C ₂ H ₆)	100	100
Propane (C ₃ H ₈)	10	2
ISO-Butane (C ₄ H ₁₀)	7	.2
Hydrogen (H ₂)	7	TR.
Normal Butane (C ₄ H ₁₀)	3	.2
ISO-Pentane (C ₅ H ₁₂)	3	.2
Normal Pentane (C ₅ H ₁₂)	1	.1
Hexane (C ₆ H ₁₄)	1	.1
Heptane (C ₇ H ₁₆)	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.

Example Calculation

Market Application

Prime Power

Specific Conditions:

Model = GTA14
 Altitude = 6000 feet
 RPM = 1800
 Inlet Air Temperature = 107° F
 HP = 371
 C.R. = 11.0:1

A. Altitude De-Rating %

6000 - 5000 = 1000 feet subject to de-rating
 3%/1000 X 1000 ft. = 3%

B. Inlet Air Temperature

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

C. Altitude & Temperature Combined

3% + 0.7% = 3.7%

D. Fuel Analysis

Con.	Inerts (%)	Analy. (%)	Corr. (%)	Perm. prior to derate(%)	Excess (%)	Der. Fac. (%)	De-rating (%)	Hydrocarbons Max.	
N ₂	2.20	—	—	—	—	—	—		
CO ₂	1.86	—	—	—	—	—	—		
CH ₄	—	63.42	66.10	100	—	—	—		
C ₂ H ₆	—	14.56	15.18	100	—	—	—		
C ₃ H ₈	—	9.18	9.57	100	—	—	—		
C ₄ H ₁₀	—	1.71	1.78	50	—	—	—		
NC ₄ H ₁₀	—	3.61	3.76	15	—	—	—		
IC ₅ H ₁₂	—	1.05	1.10	15	—	—	—		
NC ₅ H ₁₂	1.03	1.07	0	1.07	4.0	4.28	—		
C ₇ + H ₁₆	—	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 4.7%. Use the higher of the two.

F. De-rate the engine from 200HP by 10.04 % or 21 HP to 179HP.

Chart # 3

**FUEL DE-RATING FACTORS
DE-RATE PERCENTAGE - % per %**

Turbocharged		
Compression Ratio	8.5:1	11.0:1
Type of Gas		
Methane (CH ₄)	0	0
Ethane (C ₂ H ₆)	0	0
Propane (C ₃ H ₈)	.5	0
ISO-Butane (C ₄ H ₁₀)	.5	0
Hydrogen (H ₂)	.5	0
Normal Butane (C ₄ H ₁₀)	1	0
ISO-Pentane (C ₅ H ₁₂)	1	0
Normal Pentane (NC ₅)	4	0
Hexane (C ₆ H ₁₄)	4	0
Heptane (C ₇ H ₁₆)	4	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.

Chart # 2

**FUEL DE-RATING FACTORS
STARTING POINT FOR DE-RATING - %**

Turbocharged		
Compression Ratio	8.5:1	11.0:1
Type of Gas	See Note #1	
Methane (CH ₄)	NA	NA
Ethane (C ₂ H ₆)	NA	NA
Propane (C ₃ H ₈)	5	*
ISO-Butane (C ₄ H ₁₀)	2	*
Hydrogen (H ₂)	2	*
Normal Butane (C ₄ H ₁₀)	0	*
ISO-Pentane (C ₅ H ₁₂)	0	*
Normal Pentane (NC ₅)	0	*
Hexane (C ₆ H ₁₄)	0	*
Heptane (C ₇ H ₁₆)	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.

Timing & Excess Oxygen Specifications

Ignition Timing - Checking/Adjusting

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

Therefore, it is important, that the adjustment for excess Oxygen, is made by a qualified CNGE distributor or CNGE authorized dealer service technician at the time of engine inspection and start-up.

Set initial engine timing to the appropriate value listed in Table # 6-02

Caution: CNGE sets all engines at Clovis, New Mexico conditions of 4200 feet altitude and to the limits in Table # 6-02 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 #6-02 - Initial Engine Timing
(@ 4200 ft. Clovis, N.M.)

Model	Timing Range (DBTDC)		
Engine	C.R.	Natural Gas	Propane
GTA14	11:1	20	NA
GTA14	8.5:1	24	18

Note: The above timing is at CNGE'S plant location in Clovis, New Mexico @ 4200 ft. altitude with fuel-gas at a low heat value (LHV) of 905 BTU. Your engine may have to have the timing either retarded or advanced depending on your operating load, temperatures, LHV of your fuel-gas and for your altitude. Refer to Section 7, page 7-15 For ignition timing adjustment procedure.

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 lowest intake manifold vacuum on naturally aspirated models or lowest manifold boost pressure on turbocharged models without sustaining a power or RPM loss.

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 # 6-03.

Table #6-03 - Excess Oxygen - Without Catalytic Converter

	O2 Reading - %	
	Stand-By (Maximum)	Prime (Continuous)
GTA14	4.0	4.0

Caution: When making the adjustment, it may be necessary to readjust engine ignition timing.

Caution: CNGE sets all engines at Clovis, New Mexico conditions of 4200 feet altitude.

Lubricating Oil Specifications

Functions of Lubricating Oil

The lubricating oil used in a CNGE engine must be multi-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:

- Byproducts of Engine Combustion - oxides of nitrogen, carbon, soot, acids from partially burned fuel-gas & lubricating oil.

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- 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 insoluble 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 from 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. For more information contact the API, ASTM, SAE or EMA.

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 Drive
Chicago, IL 60601/USA

This book lists commercially available oils by oil 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. CNGE does recommend for the GTA14 the use of natural gas oil that meets the following specifications.

API	CD Quality
SAE Viscosity	15W40
Sulfated Ash	Between .15 and .85%

Note: When operating with a catalytic converter the sulfated ash may have to be held to a maximum of .5%. Contact your catalytic converter manufacture for the required limits.

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 ash-less oils 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.

Viscosity Recommendations

The viscosity of oil is a measure of its resistance to flow. The Society of Automotive Engineers has classified engine oils in viscosity grades. CNGE recommends the use of a high quality SAE 15W-40 multi-viscosity heavy-duty natural gas engine oil that meets the API performance classification CD.

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

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

Caution: When the ambient temperature drops below the minimum value for the specific oil being used, drop one viscosity grade. Reference Table # 6-04.

Table #6-04 - Viscosity Grade vs Ambient Temperature

SAE Viscosity Grade	Ambient Temperature
10W-30	-25° C to 35° C [-13° F to 5° F]
15W-40	-10° C & above [14° F & above]
20W-40	0° C & above [32° F & above]

Oil Analysis Procedures

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 analyzed before being put into an engine to establish baseline data.** This oil must then be analyzed at 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 circumstance does CNGE approve 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.

The most CRITICAL TEST for Natural Gas or Propane Engines is the TAN number.

Table #6-05 - Oil Analysis Test

Property	ASTM Method	CNGE Oil Guideline Limit
Viscosity @ 40° & 100° C	D445	+ or - 1 SAE Grade
Sulfated Ash	D874	.85 % Max. .15 % Min.
Insolubles	D893/GCM359	1.0 % Max.
Total Acid Number (TAN)	D664	2.5 Number Increase above new oil.
Total Base Number (TBN)	D 664	2.5 Minimum or 50 % reduction of new oil value or equal to TAN, whichever is reached first.
Water Content	D95	.2 % Max.
Additive Reduction	AES or AAS	25 % Max. of new oil

In addition CNGE recommends that the following infrared analysis be used when measuring either Nitration or Oxidation of the Oil.

Nitration. The maximum for nitration should not exceed 25 absorbance units/cm at a wave number of 1630.

Oxidation. The maximum for oxidation should not exceed 25 absorbance units/cm at a wave number of 1710.

SPECIAL NOTE: The guideline limits specified in **Table #6-05** 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.

Oil analysis is not a low cost test 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, forming lacquer and maroon-colored deposits. In both cases the oil change interval must be lowered or the volume of oil in the engine must be increased by the addition of by-pass filters. 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 increase 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. Therefore, 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.

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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 at 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, viscosity grades and minimum additive package requirements.

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

Arctic Operations

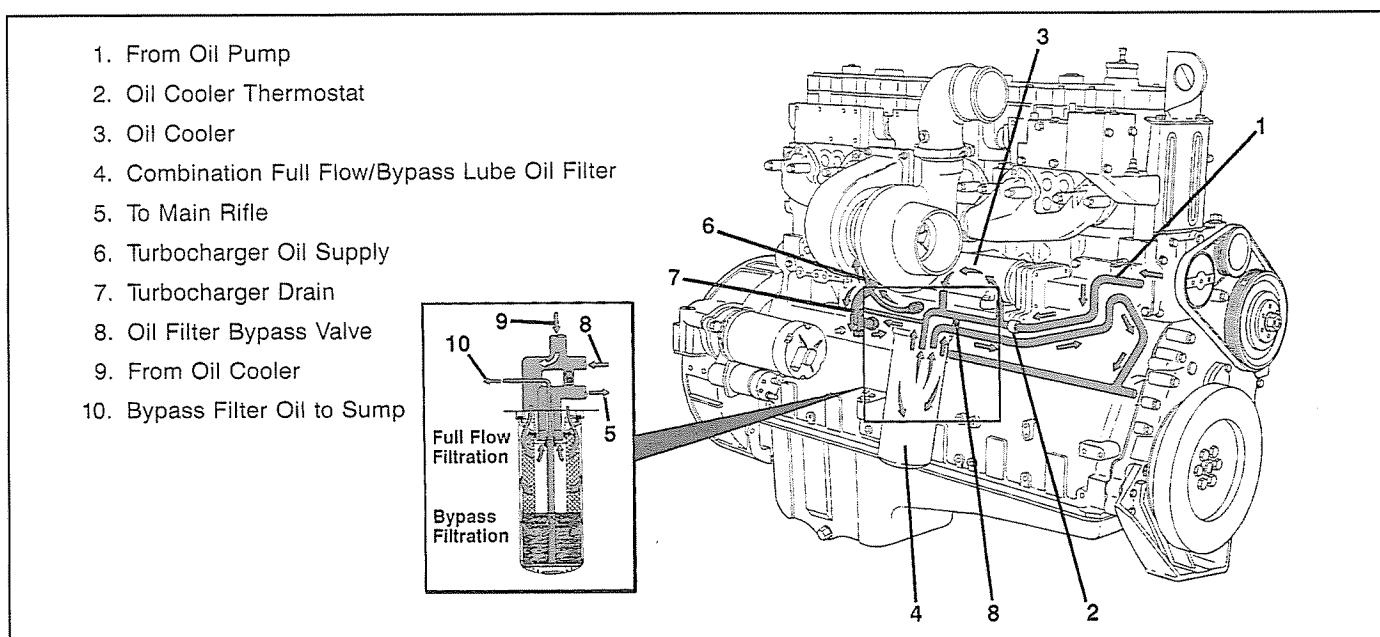
For engine operation in areas where the ambient temperature is consistently below -25°C [-13°F] and where there is no provision to keep the engine warm when it is not operating, the lubricating oil should meet the requirements in the following table.

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 100°C [212°F].

Table #6-06 - Arctic Oil Recommendations

Parameter Test Method	Specifications
Performance Quality Level	API classification CC/SC & CC/CD
Viscosity	10,000 mPa's Max. @ -35°C [-31°F] 4.1 mm ² /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 Content .15% by Weight Minimum Content

Lubricating Oil System Flow Diagram



Water Pump & Fan Hub Lubricants

Grease

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.

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.

Grease Test Specifications

Test	Test Procedure
High-Temperature Performance	
Dropping point, ° F.	ASTM D 2265 350 min.
Bearing life, hours 10,000 rpm	*FTM 331 at 300° F 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	
25 Micron+	*FTM 3005 5,000 max.
75 Micron+	1,000 max.
125 Micron+	None
Rubber Swell	
	*FTM 3603 10 max.

* Federal Test Method Standard No. 791a.

Coolant Specifications

Water should be clean and free of any corrosive chemicals such as chloride, sulfates 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.

Heavy-duty CNGE engines require a balanced coolant moisture of water and antifreeze. Drain and replace the mixture every 2 years or 6000 hours of operation (whichever occurs first) to eliminate buildup of harmful chemicals.

Antifreeze is essential in any climate. It broadens the operating temperature range by lowering the coolant freezing point and by raising its boiling point. Do **not** use more than 50 percent antifreeze in the mixture unless additional freeze protection is required. **Never** use more than 68 percent antifreeze under any condition.

Use soft water in the coolant mixture. Contaminants in 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.

Specifications - Use low-silicate antifreeze, which meets ASTM4985 test (GM6038M spec.) criteria.

Concentration - Antifreeze must be used in any climate for both freeze and boiling point protection.

CNGE recommends a 50 percent concentration level (40 percent to 60 percent range) of ethylene glycol or propylene glycol in most climates. Antifreeze at 68 percent concentration provides the maximum freeze protection and **must** never be exceeded under any condition. Antifreeze protection decreases above 68 percent.

Ethylene Glycol

40% = -23° C [-10° F]
50% = -37° C [-34° F]
60% = -54° C [-65° F]
68% = -71° C [-90° F]

Propylene Glycol

40% = -21° C [-6° F]
50% = -33° C [-27° F]
60% = -49° C [-56° F]
68% = -63° C [-82° F]

Concentration Testing - Antifreeze concentration must be checked using a refractometer (such as Fleetguard Part No. CC2800). "Floating ball" type density testers or hydrometers are not accurate enough for use with heavy duty spark ignited cooling systems.

CNGE recommends that the cooling system be maintained by using Fleetguard's™ DCA4™ Water Filter Element.

6-12

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

1. In summer or winter select an antifreeze with the proper mixture as described above.

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

2. Install or replace the DCA4™ water filter as follows.

New Engines Going into Service Equipped with DCA4™ Water Filters.

1. New engines shipped from CNGE are equipped with water filters containing a DCA4™ Recharge 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™ pre-charge element should be changed to a DCA4 service element. See Table # 6-07.
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 from a pretreated supply, such as the Fleetguard "Compleat"™.
 - b. Each time the system is drained, pre-charge per coolant specifications in Table #6-07.
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.

Table #6-07 - DCA4™ Coolant Filter Service Chart

Liters[Gallons] To Be Serviced	SCA Units			DCA4™ Filter(s)		
	250 Hrs	500 hrs	750 Hrs	250 Hrs	500 Hrs	750 Hrs
19 - 38 [6-10]	2	4	6	WF2070	WF2071	WF2072
42 - 57 [11-15]	4	6	10	WF2071	WF2072	WF2074
60 - 76 [16-20]	6	12	18	WF2072	WF2074	WF2076
79 - 114 [21-30]	10	15	20	WF2074	WF2075	WF2076
117 - 189 [31-50]	15	25	35	WF2075	WF2075(2)	WF2076(2)

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 in Table # 6-07. The mixture must be drained and replaced every two years or 6000 hours of operation, whichever first occurs.

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

Torque Specifications

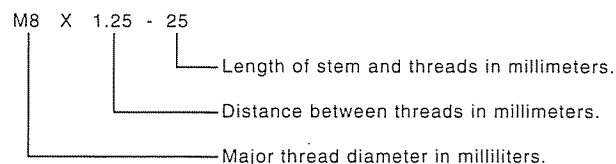
The GTA14 series engine uses parts that are U.S. Standard. The Holset turbocharger used on the GTA14 engine uses Metric cap-screw dimensions.

Always use caution to be sure that cap-screws from the engine are put back in their proper locations.

When replacing cap-screws, always use a cap-screw of the same measurement and strength as the cap-screw being replaced. Incorrect cap-screws can result in engine damage.

Metric Capscrew Nomenclature

Capscrew Markings and Torque Values - Metric



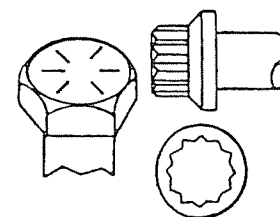
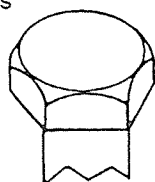
Cap-screw Markings and Torque Values – U.S. Standard

Current Usage	Much Used	Much Used	Used at Times	Used at Times
Minimum Tensile Strength PSI	To ½-69,000 [476]	To ¾-120,000 [827]	To 5/8-140,000 [965]	150,000 [1034]
Mpa	To 1-55,000 [379]	To 1-115,000 [793]	To ¾-133,000 [917]	
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]	14 [19]
15/16 — 18	11 [15]	17 [23]	19 [26]	24 [33]
— 24	13 [18]	19 [26]	27 [37]	27 [37]
3/8 — 16	18 [24]	31 [42]	34 [46]	44 [60]
— 24	20 [27]	35 [47]	49 [66]	49 [66]
7/16 — 14	28 [38]	49 [66]	55 [75]	70 [95]
— 20	30 [41]	55 [75]	78 [106]	78 [106]
1/2 — 13	39 [53]	75 [102]	85 [115]	105 [142]
— 20	41 [56]	85 [115]	120 [163]	120 [163]
9/16 — 12	.51 [69]	110 [149]	120 [163]	155 [210]
— 18	.55 [75]	120 [163]	170 [231]	170 [231]
5/8 — 11	83 [113]	150 [203]	167 [226]	210 [285]
— 18	95 [129]	170 [231]	240 [325]	240 [325]
3/4 — 10	105 [142]	270 [366]	280 [380]	375 [508]
— 16	115 [156]	295 [400]	420 [569]	420 [569]
7/8 — 9	160 [217]	395 [536]	440 [597]	605 [820]
— 14	175 [237]	435 [590]	675 [915]	675 [915]
1 — 8	235 [319]	590 [800]	660 [895]	910 [1234]
— 14	250 [339]	660 [895]	990 [1342]	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 or 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 capscrew 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.

Additional torque values can be found in Cummins N14 Series Shop manual, bulletin # 3810487.

Specialized Service Tools

Customer Tools

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

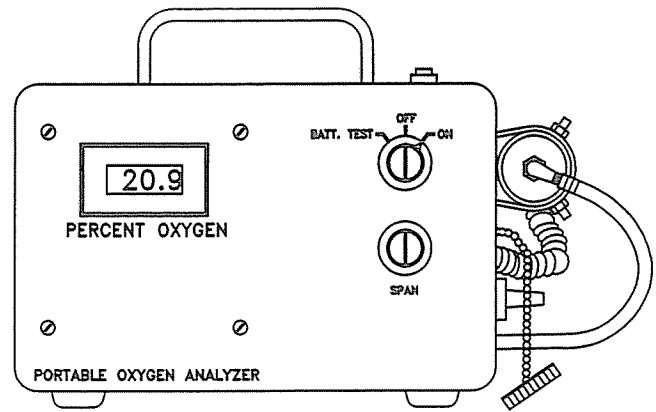
Tool	
Part Number	Description

10113858	O ₂ Meter Carrying Case
91372621	O ₂ Meter Does not include copper tubing & filter media. Recommend 10 to 15 feet of 3/8" copper or stainless tubing. Filter Media Recommend 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 Thermocouple (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 Tester
60810002	Set of Feeler Gauges
3375049	Oil Filter Wrench
3375208	DCA4™ Test Kit.
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 an engine to operate with the lowest possible exhaust gas temperatures.

91372621	Oxygen Meter - 320 P/D
91372622	Max 5 Oxygen Analyzer



Oxygen Meter Model 320 P/D

Oxygen Meter Supplemental Instructions

Operating the 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 & follow the manufacturer's manuals, 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 it if it is wet or dirty.
4. Remove the cell saver cap, check the oxygen calibration with non-tainted or polluted ambient air (20.9%) with the 320P on the high range scale. The 320P/D will auto-range. Adjust with the span dial as necessary. Then install the flow through adapter cap on the O₂ 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. Insure 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 model 320P. The model 320P/D 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 O2 cell. The CO2 in the exhaust gas will shorten the O2 cell life when run through the unit for extended periods.
- 9. The backpressure in the exhaust system may be sufficient to allow use of the 320P/D 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 O2 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 now 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.

Turbocharged Engines – Range of Excess Oxygen

Excess oxygen reading of 4.0% for standby or maximum power and 4.0% for prime or continuous power.

- 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 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 to 8.5 inches of water (negative pressure)).
- 5. All adjustments for excess Oxygen are to be made with the engine set at its published ignition timing for the appropriate model.

Notes:

Section 7

Maintenance Instructions

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Maintenance Items		Recommended Interval				Remarks
Engine Family = GTA14		Daily	250	750	1500	6000
Operating Hours		6	6	6	12	24
Calendar Months						
Check Log	X					
Operator's Report	X					
Check Cooling System	X					
Engine Coolant Level	X					
Engine Coolant DCA4™	X					
Aftercooler Coolant Level	X					
Aftercooler Coolant DCA4™	X					
Thermostat Operation			X			
Leaks & Correct	X					
Hose Wear Points	X					
Loose Band Clamps	X					
Flush Cooling System				X		
Change Antifreeze					X	
Check Fuel System	X					
Gas Leaks & Correct	X					
Gas Fuel Filter				X		
Gas Pressure to Regulator				X		
Gas Pressure to Carburetor				X		
Propane Liquid Fuel Filter				X		
Propane Converter				X		
Check Exhaust System	X					
Air/Fuel Ratio Adjustment				X		
Excess Oxygen Level in Exhaust				X		
Exh. Mnfd. Outlet Exh. Gas Temp.				X		
Exhaust Gas Back Pressure				X		
Turbocharger Radial/Axial Clearance				X		
Check Air Intake System	X					
Air Cleaner Restriction	X					
Loose Band Clamps	X					
Wear Points	X					
Intake Manifold Boost Pressure				X		
Charge Air Core Externally	X					
Check Ignition System	X					
Spark Plugs				X		
Shielded Spark Plugs				X		
Ignition Coils				X		
Ignition Generator & Voltage				X		
Wiring Harness & S.P. Wires				X		
Ignition Timing				X		

Maintenance Items		Recommended Interval				Remarks
Engine Family = GTA14		Daily	250	750	1500	6000
Operating Hours		6	6	6	12	24
Calendar Months						
Check Lubricating System	X					
Engine Lube Oil Level	X					
Change Engine Lube Oil & Filters	X					Std Lube System
Change Engine Lube Oil & Filters	X					H.C.Lube System
Leaks & Correct	X					
Check Hydraulic Governor	X					
Leaks & Correct	X					
Check Electric Governor	X					
Wear Points on Linkage	X					
Loose Wiring & Connections	X					
Adjustments				X		
Check Electrical System	X					
Clean Battery Terminals				X		
Loose Wiring & Connections	X					
Solenoid Operation				X		
Starter & Alternator Voltage				X		
Check Engine System	X					
Loose Mounts				X		
Loose Bolts & Capscrews	X					
Engine Cylinder Compression	X					
Water Pump				X		
Auxiliary Water Pump				X		
Turbocharger				X		
Vibration Damper				X		Replace 15000 hrs.
Fan Hub				X		
Valve Adjustment	X			X		1st adj. @ 250 hrs.
Crankcase Breather	X					
Cylinder Heads Replacement						As Required
Cam Followers	X					As Required
Visually Inspect Engine						
Damage, Leaks, Loose or Frayed Belts, Loose Hoses/Clamps	X					
Visually Inspect Radiator Core	X					
Spark Plugs				X		
Shielded Spark Plugs				X		
Ignition Coils				X		
Ignition Generator				X		
Wiring Harness & S. P. Wires				X		
Ignition Timing				X		

7-5

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

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.

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

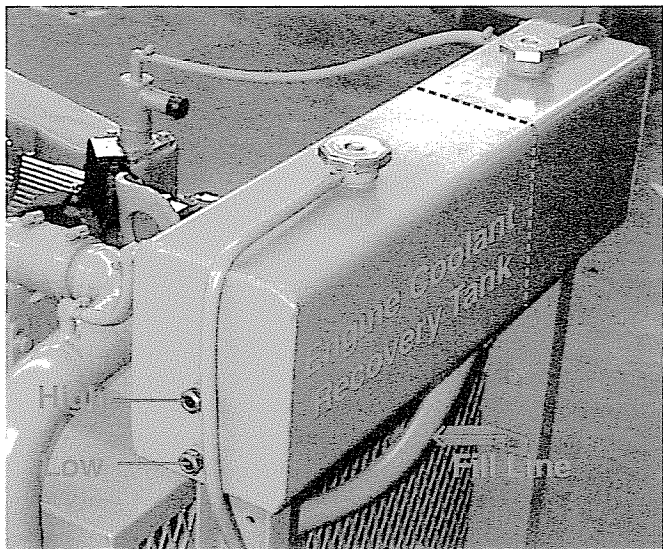


Photo # 7-02 - Sight Glass - High & Low - Engine Coolant Recovery Tank & Aftercooler Coolant Fill Line

• Aftercooler Coolant Level - Checking

On turbocharged engines with a water-to-air cooling system a separate cooling system must be maintained. Check the coolant level daily. Use the same coolant mixture as in the engine jacket systems. Add coolant as needed.

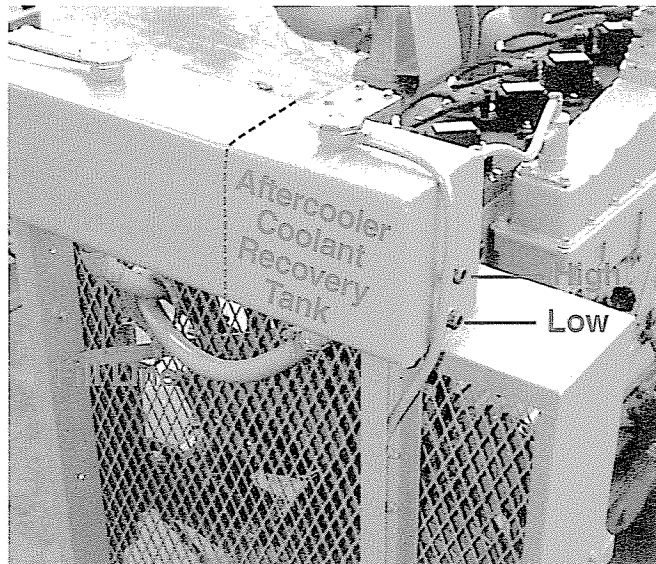


Photo # 7-03 - Sight Glass - High & Low - Aftercooler Coolant Recovering Tank & Engine Coolant Fill Line.

Check for 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 applying liquid soap.
3. On CNGE turbocharged engine models, check the throttle shaft seals for leaks with the engine at rated power.



Photo # 7-04 - Applying Liquid Soap

Check Governor

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

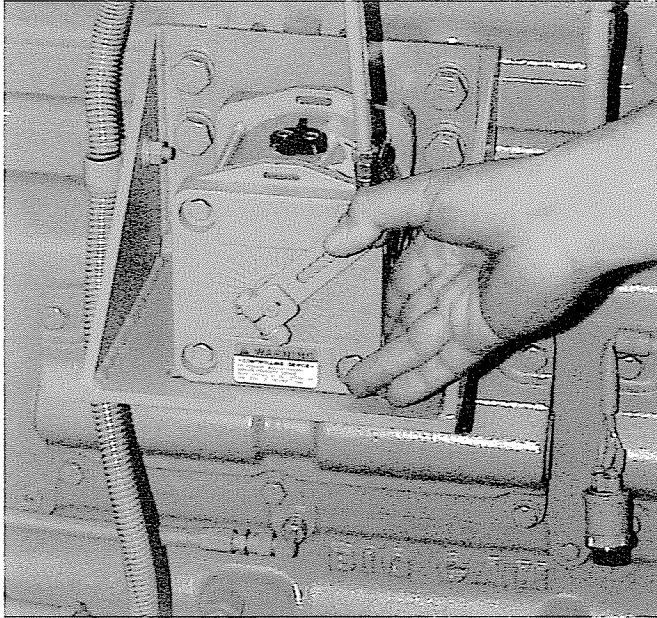


Photo #7-05 - Checking Governor

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.

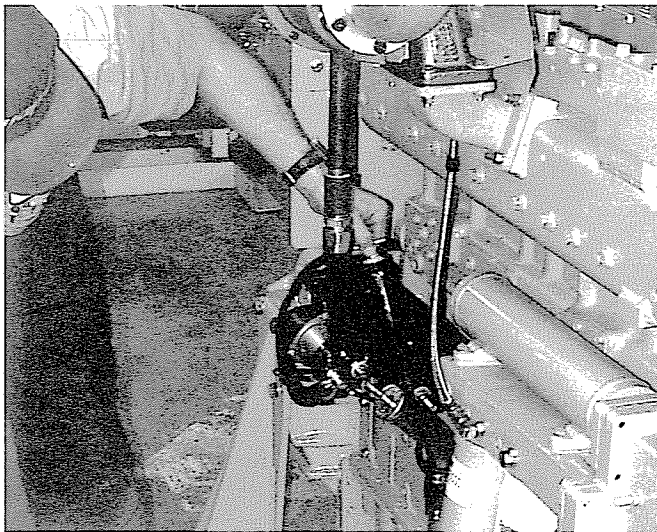


Photo #7-06 - Visual Inspection - Engine

Belt - Inspection

Visually inspect all belts. Check the belts for intersecting cracks. Transverse (across the belt width) cracks are acceptable. Longitudinal (direction of belt length) cracks that intersect with transverse cracks are not acceptable. Replace the belts if frayed or if belt material is missing.

Adjust belts that have a glazed or shiny surface, indicating belt slippage. Correctly installed and tensioned belts will show even pulley wear 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.

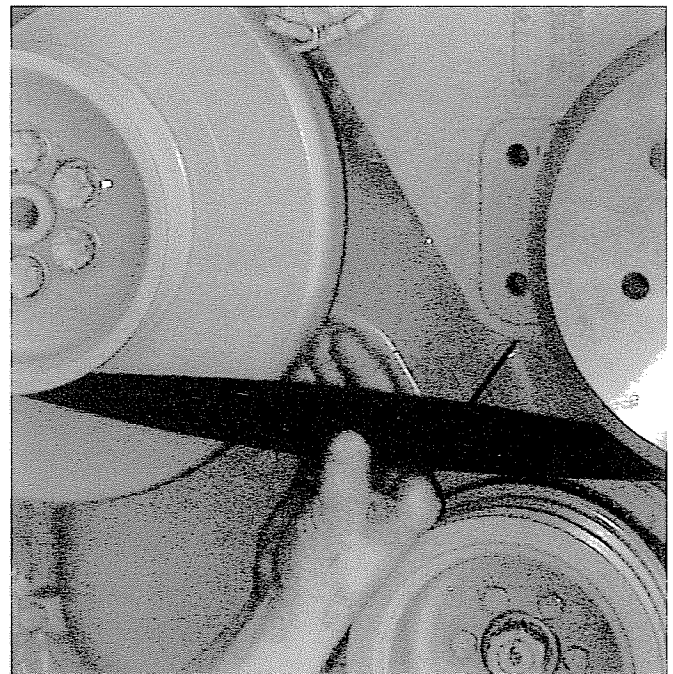


Photo #7-07 - Belt Inspection

Belt Tension - Checking

Use a belt tension gauge to measure the tension of the belt. Refer to **Table # 7-01** for the appropriate tool. An alternate method (deflection method) can be used to check belt tension by applying 110 N (25 lbs.) of force between the pulleys on the v-belts. If the deflection is more than one (1) belt thickness per foot of pulley center distance, the belt must be adjusted.

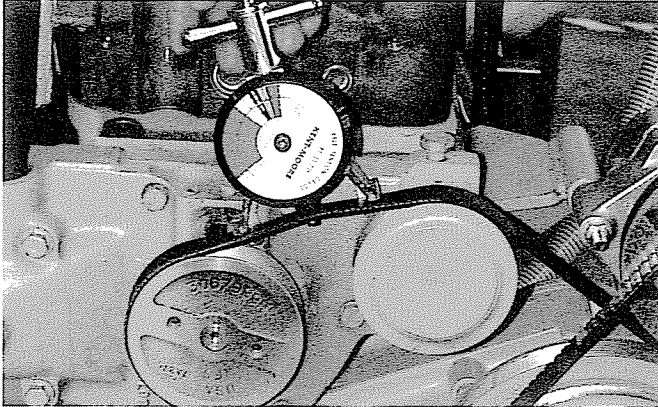


Photo # 7-08 - Belt Tension Checking

Table # 7-01 - Belt Tension Tools

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

Fan Drive Belt - Adjustment

The fan drive belt uses an automatic belt tensioner. No adjustment is required.

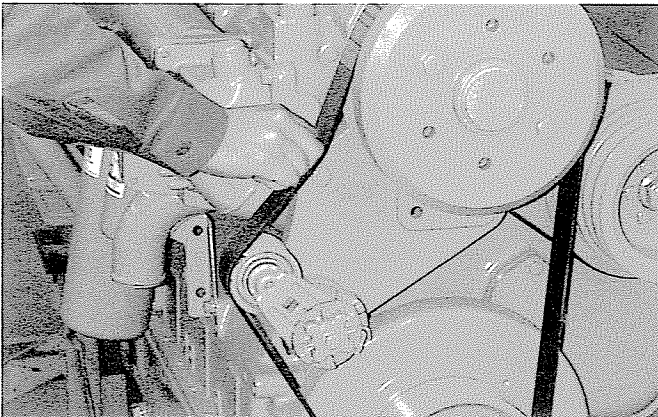


Photo # 7-09-Fan Drive Belt

Engine Water Pump Drive Belt - Adjustment

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 reduces belt and bearing life.

4. Secure the idler pulley in position by tightening the lock nut.

Torque Value: 70 N•m [50ft-lb]

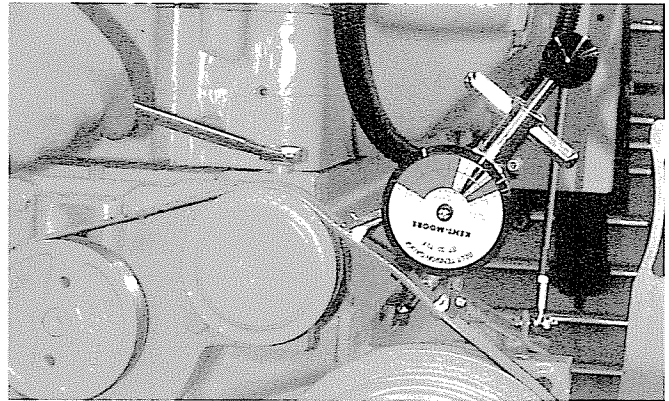


Photo # 7-10 - Engine Water Pump Drive Belt

Aftercooler Auxiliary Water Pump Drive Belt - Adjustment

Take special care when tightening the belt for the engine mounted aftercooler auxiliary 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. Over-tightening of this belt may cause aftercooler auxiliary water pump seal and bearing failures

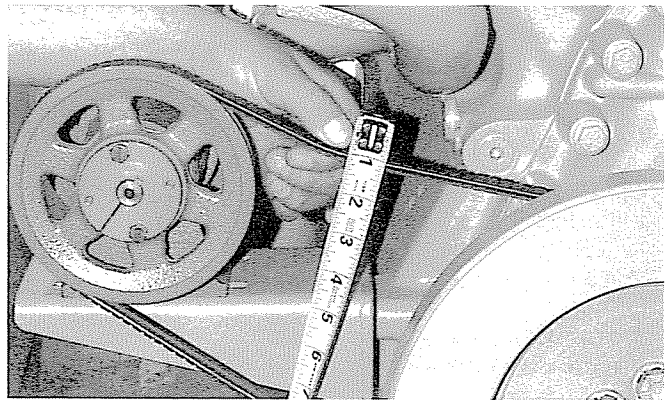


Photo # 7-11 - Aftercooler Auxiliary Water Pump Drive Belt

Alternator Drive Belt - Adjustment

Measure the belt tension. Refer to the alternator manufacturer's maintenance recommendations or refer to **Table # 7-02** for the appropriate information.

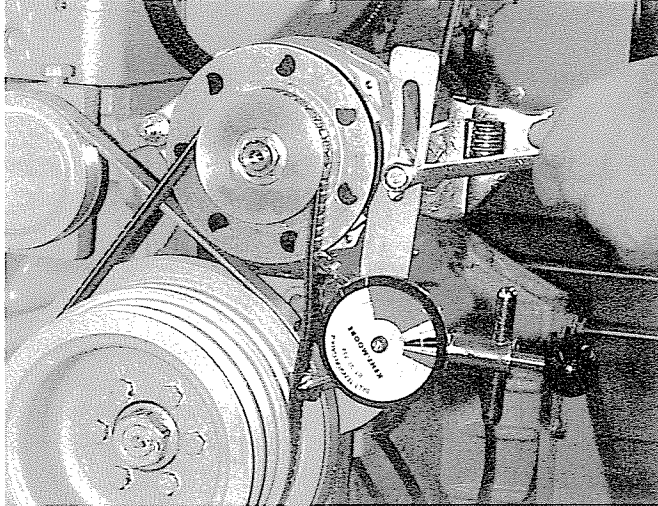


Photo # 7-12 - Alternator Drive Belt

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 **Table # 7-02 -Belt Tension Chart** to select the correct gauge and tension specifications.

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.

Table # 7-02 - 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 to 12 Rib	3822525	190 - 210	155 - 165

* Adjust used belts to the values in this column.

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

Visually Inspect Radiator & Charge Air Core Externally

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.

Caution: The aftercooler coolant temperature must be maintained below 32° C [90° F] with an 11:1 compression ratio and below 54° C [130° F] with an 8.5:1 C.R. pistons.



Photo #7-13 - Radiator & CAC (Charge Air Core) External Inspection

Visually Inspect Cooling Fan

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

Note: Manually rotate the crankshaft by using a wrench on the accessory drive pulley nut.

A visual inspection of the cooling fan is required daily. Check for cracks, loose rivets, bent or loose blades, and for contact between the fan blade tips and the fan shroud. Check the fan to make sure it is securely mounted. Tighten the cap-screws if necessary. Replace any fan that is damaged.

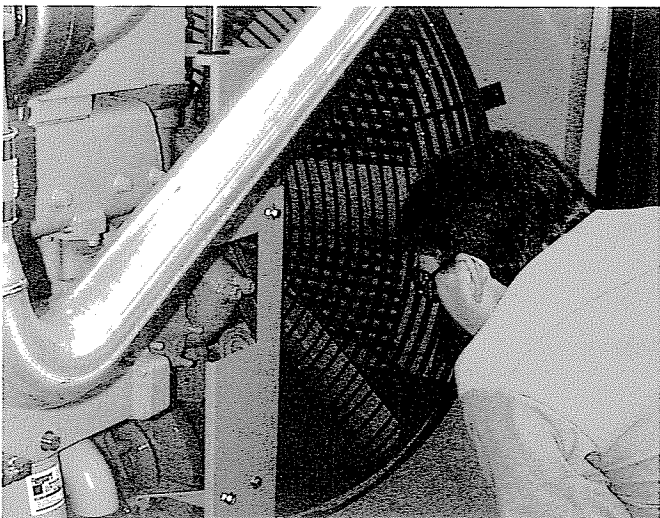


Photo #7-14 - Cooling Fan Inspection

B - Maintenance Check - 250 Hours or 6 Months

Change / Replace

- Lubricating Oil and Filter - Changing

Caution: Some state and federal agencies in the United States of America have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

Protect The Environment: Handling and disposal of used engine oil may be subject to federal, state and local law and regulation. Use authorized waste disposal facilities including civic amenity sites and garages providing authorized facilities for receipt of used oil. If in doubt, contact your state and local environmental authorities or the Environmental Protection Agency for guidance as to proper handling and disposal of used engine oil.

General Information

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 of hours or calendar time, whichever comes first as shown on 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. Lubricating 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 of 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 500 hours of operation or 6 months, whichever occurs first without the addition of more capacity and filtration.

Extended oil drain intervals can decrease engine life due to factors such as corrosion, deposits and wear.

Refer to the Specifications section for more information on oil analysis.

Lubricating Oil and Filter - Changing

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

Note: Oil for natural gas engines does not darken and look as dirty as diesel oil does. Use the recommended maintenance intervals to determine the oil change requirement, not the oil's appearance.

Note: If the engine is in service then the oil change interval of 250 hours or 6 months should be observed.

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

Note: Drain the oil only when it is hot and the contaminants are in suspension.

Caution: Hot oil can cause personal injury.

1. Operate the engine until the water temperature reaches 60° C [140° F]. Shut the engine off. Remove the oil drain plug. Use a 17-mm wrench or socket.

Note: Use a container that can hold at least 41.64 liters [44 U.S. qts.] of oil.

2. Clean the area around the lubricating oil filter head. Remove the filter using a 118 to 131 mm Filter Wrench. Clean the gasket surface on the filter head.

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

3. Make sure that the correct oil filter is installed.

Note: CNGE GTA14 engines use a LF 3000 oil filter.

4. Fill the oil filter with clean lubricating oil. The lack of lubrication during the delay until the filter is pumped full of oil is harmful to the engine.

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

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

6. Install the filter as specified by the filter manufacturer.
7. Check and clean the oil drain plug threads and sealing surface.
8. Install the oil drain plug.

Torque value is 88 N•m [65 ft-lb].

Note: Use high quality oil blended for natural gas engines. Choose the correct oil as outlined in the specifications section and in the Lubricating system section of this manual.

9. Fill the engine to the proper levels.

- Pan Capacity 36.00 litres [38.0 U.S. Quarts]
- Filter Capacity 2.70 litres [2.8 U.S. Quarts]
- Total System capacity 41.64 litres [44.0 U.S. Quarts]

Note: Capacities assume the standard oil pan. Total system capacity assumes the standard oil pan.

Some GTA14 applications use a larger oil pan capacity as well as separate by-pass filter canisters in order to increase the capacity for extended drain intervals.

10. Operate the engine to idle to inspect for leaks at the filters and drain plugs.

Note: Engine oil pressure must be indicated on the gauge within 15 seconds after starting. If oil pressure is not registered within 15 seconds after starting, shut off the engine immediately to avoid engine damage. Confirm the correct oil level in the oil pan.

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

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



Photo # 7-15 - Lube Oil & Lube Oil Filter Changing

Check Following

- Check Engine Crankcase Breather.

Inspect the crankcase breather tube for sludge or debris on or in the tube. Inspect the tube more frequently during icy conditions.

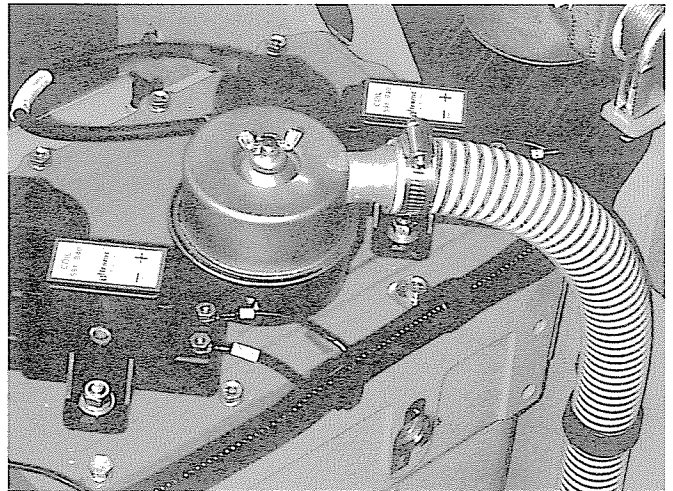


Photo # 7-16 - Crankcase Breather & Tube

7-11

• Engine Coolant DCA4™ Concentration Level.

Add makeup DCA4™ if required. Refer to **Table # 7-03** as a reference guide.

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 in **Table # 7-03**. The mixture must be drained and replaced every two years or 6000 hours of operation, whichever first occurs.

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

• Coolant Filter Replacement

General Information

Change the coolant filter at every oil change and filter change interval.

The correct coolant filter to be used is determined by the total cooling system capacity and the oil drain interval. Extended drain intervals may require a modification to the engine for dual coolant filters or a reduced change interval for the cooling system. Refer to **Table # 7-03** for the correct filter.

Table #7-03 - DCA4™ Coolant Filter Service Chart

Liters[Gallons] To Be Serviced	SCA Units			DCA4™ Filter(s)		
	250 Hrs	500 Hrs	750 Hrs	250 Hrs	500 Hrs	750 Hrs.
19 - 38 [6-10]	2	4	6	WF2070	WF2071	WF2072
42 - 57 [11-15]	4	6	10	WF2071	WF2072	WF2074
60 - 76 [16-20]	6	12	18	WF2072	WF2074	WF2076
79 - 114 [21-30]	10	15	20	WF2074	WF2075	WF2076
117 - 189 [31-50]	15	25	35	WF2075	WF2075(2)	WF2076(2)

A manual shutoff valve is provided to prevent coolant leakage while changing the coolant filter.

With the valve in a vertical position, the coolant flows to and from the coolant filter. In the horizontal position, the coolant flow is cut off to and from the coolant filter.

Warning: Do not remove the radiator cap from a hot engine. Hot steam will cause serious personal injury. Remove the coolant system pressure cap and close the coolant filter head shutoff valve before removing the coolant filter. Failure to do so can cause personal injury from heated coolant spray.

Turn the coolant shutoff valve to the "Off" position

Remove and discard the coolant filter. Clean the gasket surface on the filter head. Apply a light film of **Lubriplate® 105** or its equivalent to the coolant filter gasket sealing surface before installing the coolant filter.

Install the filter as specified by the manufacturer.

Note: Mechanical over-tightening can distort the threads or damage the filter head.

Open the shut-off valve and install the coolant system pressure cap.

Caution: Severe engine damage will result if the valve is left in the closed position.

Operate the engine until the coolant temperature is above 82° C [180° F] and check for leaks.

After the air has been purged from the system, check the coolant level.

• Air Intake System - Inspection

Every 250 hours or six months, whichever occurs first, inspect the intake piping for cracked hoses, loose clamps, or punctures that can allow dirt and debris to enter 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.

Check the Charge Air Core (CAC) piping and connections for any leakage and correct.

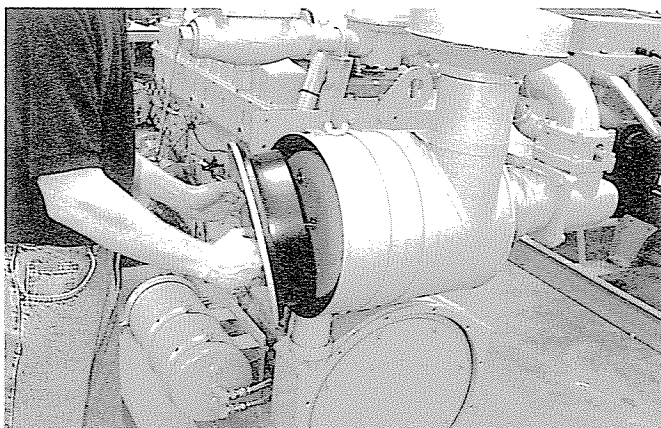


Photo # 7-17 - Air Intake System - Inspection

- **Air Cleaner Restriction - Checking**

Every 250 hours or six months, which ever occur first, check the air cleaner restriction.

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 instructions 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 for CNGE engine settings. The maximum intake air restriction with a dirty element is 635 mm H₂O [25 in H₂O].

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.

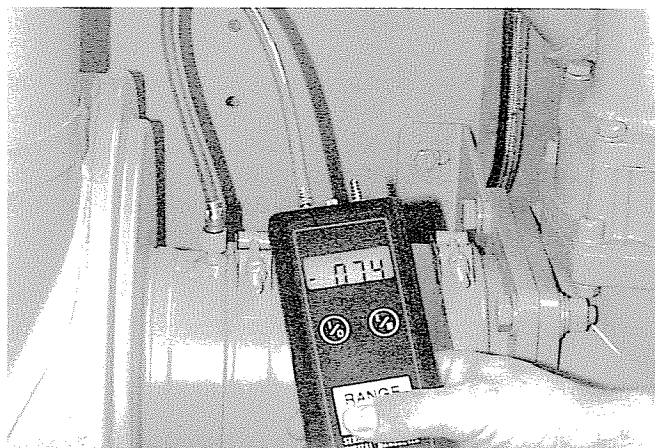


Photo # 7-18 - Air Cleaner Restriction - Checking

- **Check Governor**

- **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.

Note: When using the Woodward "Flo-Tech" governor, there will be no linkage adjustment for the throttle body.

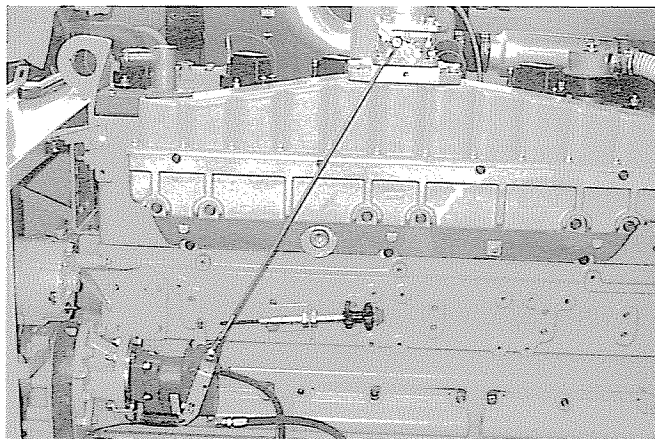


Photo # 7-19 - Governor Linkage - Non Linear

- **Governor Adjustments**

CNGE engines may be equipped with hydraulic governors. For proper operation & maintenance of the hydraulic governor, please refer to the manufacturer's manuals.

7-13

◦ Idle Speed 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. Movement of the speed droop bracket can then adjust speed droop 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.

◦ Isochronous Control of Electric Governor - Adjustments

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 then you refer to that specific manufacturer's operation & maintenance instructions for proper adjustment.

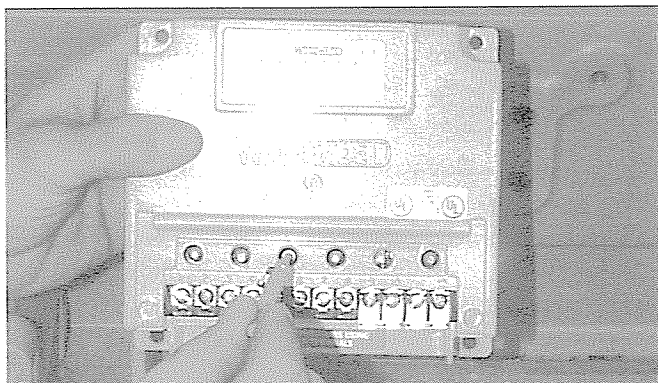


Photo # 7-20 - Controller Adjustments

◦ Woodward Flo-Tech Actuator & Flo-Tech Speed Control

CNGE also uses a Flo-Tech Actuator & Flo-Tech Speed Control governing system. The Flo-Tech Actuator is an electrically operated throttle valve. This valve operates as an air/gas control valve for gas engines. The Flo-Tech Actuator receives changes in electrical impulses from the Flo-Tech Speed Control allowing the actuator to maintain basic isochronous speed control.

Throttle linkage is not required when using the Woodward Flo-Tech Actuator and Flo-Tech Speed Control on the GTA14 engine.

Refer to the manufacturer's literature for correct installation, operation, calibration, and troubleshooting procedures.



Photo # 7-21 - Woodward Flo-Tech Actuator



Photo #7-22 - Woodward Flo-Tech Speed Control

Adjust Following

◦ Intake & Exhaust Valve Procedure

General Information

Note: The first intake & exhaust valve adjustment should take place at the 250 hour service interval. After that point check exhaust valves at the C2 check or 1500 hours or 2 years whichever comes first.

Note: Read the entire procedure for the overhead adjustment before attempting to perform this operation.

Valves must be correctly adjusted for the engine to operate efficiently. Valves must be adjusted using the values listed in this section.

Adjust the valves at the first oil change period of 250 operating hours and then at the C2 interval of 1500 hours or every 2 years whichever comes first. Check the valves after every major repair.

If the valves are checked during troubleshooting or before scheduled maintenance interval, adjustment is not required if measurements are within the recheck limits.

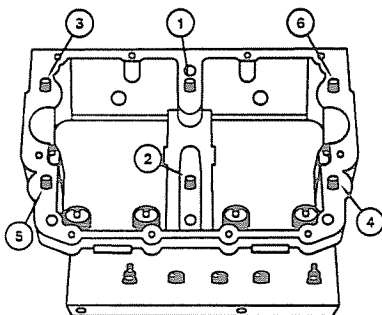
1. Disconnect the battery.
2. Remove the rocker housing covers. The rocker housing cover gaskets can be used again if they are not damaged.

Note: Do not use solvent to clean the rocker housing cover gasket. Solvent will damage the o-ring material and cause it to swell.

3. Tighten the rocker lever shaft cap-screws.

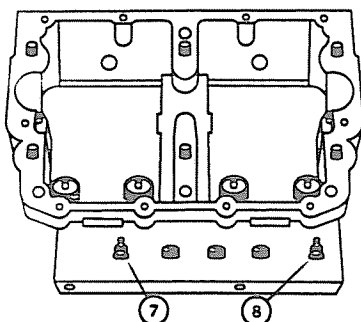
Torque Value: 156 N•m [115 ft.-lb.].

4. Tighten the rocker lever housing cap-screws in the sequence shown (1 through 6).



Torque Value: 115 N•m [85 ft.-lb.].

5. Tighten the rocker lever housing cap-screws in the sequence shown (7 and 8).



Torque Value: 47 N•m [35 ft.-lb.].

The valve set marks are located on the accessory drive pulley. The marks align with a pointer on the gear cover.

Warning: Do not pull or pry on the fan to manually rotate the engine. To do so can cause damage to the fan blades. Damaged fan blades can cause premature fan failures that can result in serious personal injury or property damage.

6. Use the accessory drive shaft nut to rotate the crankshaft. The crankshaft rotation is clockwise when viewed from the front of the engine.

The cylinders are numbered from the front of the engine. The firing order is 1-5-3-6-2-4.

Each cylinder has two rocker levers. The two levers closest to the center of each rocker housing are the intake levers. The two levers closest to the ends of the rocker housing are the exhaust levers.

7. The valve adjustment markings are on the accessory drive pulley. Two revolutions of the crankshaft are required to adjust all valves.

8. Rotate the accessory drive in the direction of engine rotation. The accessory drive will rotate clockwise on a right hand engine. Align the "1-6 VS" mark on the accessory drive pulley with the pointer on the gear cover.

9. Check the valve rocker levers on Cylinder Number 1 to see if both valves are closed.

Note: Both valves are closed when the rocker levers are loose and can be moved from side to side. If both valves are not closed, rotate the accessory drive one more complete revolution; and align the "1-6 VS" mark with the pointer again.

If the valve rocker lever adjusting screws have been loosened and not yet adjusted, watch the valve push tubes as the engine rolls upon the "1-6 VS" mark. Both valve push tubes will have moved to the downward (valve closed) position if the engine is on the correct stroke.

10. With the "1-6 VS" set mark aligned with the pointer on the gear cover and both valves closed on cylinder No. 1, loosen the lock nuts on the intake and the exhaust valve adjusting screws.

11. Select a feeler gauge for the correct valve lash specification.

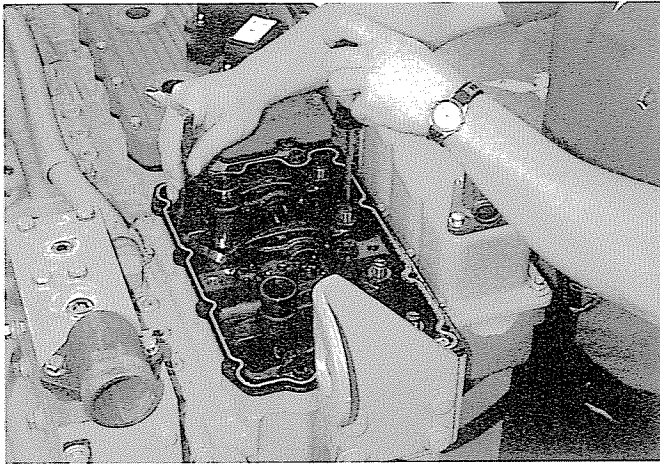


Photo # 7-23 - Valve Lash Adjustment

Intake Valve Lash -----0.35 mm [0.014 inch]
 Exhaust Valve Lash-----0.85 mm [0.033 inch]

12. Insert the feeler gauge between the top of the crosshead and the rocker lever pad.

Two different methods for establishing valve lash clearance are described below. Either method can be used; however, the torque wrench method has proven to be the most consistent.

Torque Wrench Method: Use the inch pound torque wrench, Part No. 3376592, and tighten the adjusting screw.

Torque Value: 0.56 - 0.68 N•m [5-6 in-lb]

Feel Method: Tighten the adjusting screw until a slight drag is felt on the feeler gauge.

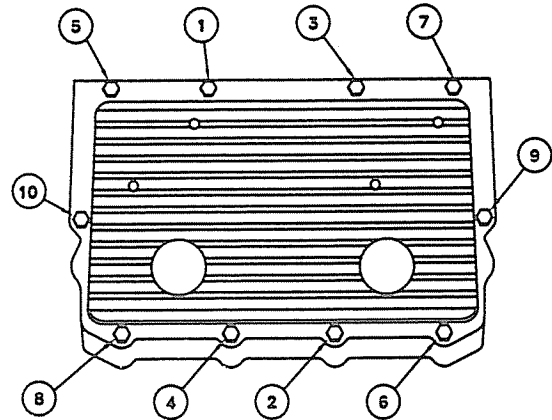
Hold the adjusting screw in this position. The adjusting screw must not turn when the lock nut is tightened.

Torque Value: With torque wrench adapter,
 Part No. ST-669 **54 N•m [40 ft-lb]**
 Without adapter **68 N•m [50 ft-lb]**

13. After tightening the lock nut to the correct torque value, check to make sure the feeler gauge will slide backward and forward between the crosshead and the rocker lever with only a slight drag.
14. If using the feel method, attempt to insert a feeler gauge that is 0.03 mm [0.001 inch] thicker between the crosshead and the rocker lever pad. The valve lash is not correct when a thicker feeler gauge will fit.
15. After adjusting the valves on Cylinder No. 1, rotate the accessory drive; and align the next valve set mark with the pointer. Repeat the process to adjust all valves in the following sequence. Set valves in order of the firing order of 1-5-3-6-2-4.

16. Install the rocker lever covers.

Torque Value: 12 N•m [105 in-lb]



C1 - Maintenance Check - 750 Hours or 6 Months

Check/Clean/Replace

Ignition Timing

All Turbocharged Natural Gas Engines are presently intended for heavy duty application and, as such, will normally operate over their RPM range of 1200 - 1800 RPM. Engine timing must be adjusted to maximize engine efficiency to the particular load and speed required at the job site.

Engine timing is **not** a fixed value but depends upon the load, type & quality of the fuel, altitude, temperature, rated speed (RPM) of the engine, and the air/fuel ratio. The air/fuel ratio is measured by the amount of excess Oxygen in the exhaust gas. The most critical of these would be the fuel and the change in altitude.

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

Timing Adjustment Procedure

- Gas Adjustment** - Install your water manometers on the on-engine gas flow regulator and at the carburetor to ensure that the gas pressures are correct. The gas pressure to the on-engine gas flow regulator should be between 10 and 20 inches of water column pressure at full load operating conditions with a gas pressure at the Carburetor of between 4 to 6 inches of water column pressure.

2. **Engine Timing** - Since engine timing is not a fixed value, it is the single most important adjustment made on each engine installation. Set the initial engine timing to the appropriate value listed in Table # 7-04 for your specific compression ratio and fuel-gas as a starting point and follow the adjustment procedures.

Caution: CNGE sets timing on all engines at Clovis, New Mexico conditions of 4200 feet altitude and to the limits in **Table # 7-04** for the initial engine timing. Your timing may need to be adjusted to a different setting due to a different altitude, operating load and temperature conditions.

Generally the timing is retarded or advanced by 4 degree for every 5000 feet of altitude change for natural gas. The change may be less when using propane gas.

Table # 7-04- Initial Engine Timing
(@ 4200 ft. Clovis, N.M.)

Model	C.R.	Timing Range (DBTDC)	
Engine	C.R.	Natural Gas	Propane
GTA14	11:1	20	NA
GTA14	8.5:1	24	18

3. Proceed to fine **Tune the Engine** as follows:

- A. Install a pyrometer in the 1/4" pipe tapped hole below the turbo mounting flange.
- B. Install a 0-30 psi gauge on the intake manifold.
- C. Install an Oxygen meter exhaust gas pickup connection in the 1/4" pipe tapped hole in the turbocharger outlet pipe
- D. Connect a low and high-tension timing light to the # 1 cylinder. (Follow the procedures for connecting the timing light and adjusting timing).
- E. With the engine running under full load conditions, adjust the power valve on the carburetor to obtain the lowest possible exhaust temperature while observing the excess Oxygen reading. This can best be obtained by turning the power valve closed (clockwise for a lean mixture) until the engine starts loosing RPM, then turn the power valve open or out (counterclockwise for a rich mixture) until the exhaust temperature reaches the lowest reading.

If the power valve is opened beyond the ultimate point, the mixture will become too rich and the exhaust temperature will start to increase. It may be necessary to perform this adjustment two or three times to obtain the proper point of air/fuel ratio which will result in the coolest possible exhaust temperatures.

- F. Retard and advance the timing by two degree increments and repeat Step E. to determine if the lowest possible exhaust temperature and lowest boost pressure has been obtained without loosing engine RPM. Repeat and confirm your readings several times.

Note: On ALTRONIC III, V, the adjustment is made by loosing the two mounting cap-screws in the ignition drive mounting slots and rotating the ignition generator in either a clockwise (advancing) or counterclockwise (retarding) direction. If the slots do not allow enough movement for adjusting the timing to the required level, contact your local CNGE distributor. The back cover plate will need to be removed and an internal adjustment will be required on the drive to driven gear. This adjustment needs to be made by a qualified ignition specialist.

Note: On the ALTRONIC CD1, the adjustment is made on the CD1 solid-state control box. The adjustments can be moved from a setting of 0 to 7. This provides for a total range of 13 degrees. Caution should be used in making a change to the settings. CNGE recommends that the adjustment be made by one number either advanced or retarded. An increase in the number will advance the timing and a decrease in the number will retard the timing.

Note: Lower BTU fuels may require higher main line pressure to obtain proper pressure to the carburetor mixer valve. Do not exceed 20 inches of water to the on-engine gas flow regulator or hard starting could result.

4. **Power Valve** - On turbocharged engines, the power valve should be turned in until the engine begins to lose power, then moved counterclockwise one turn. A more desirable method of adjustment is with the exhaust temperature pyrometer. Adjust the carburetor until the coolest exhaust temperature is reached.

Connecting the Timing Light and Adjusting the Timing

1. Connect the timing light induction pick-up clamp around the spark plug secondary wire for # 1 cylinder.
2. Connect the red power lead to the positive post (+) of the battery and the black wire to the negative post (-) of the battery.

Caution: Make sure that the voltage of the timing light has the same voltage requirement as the battery power source or you will damage the timing light.

3. Point the timing light toward the back side of the accessory drive pulley. The timing mark will light up showing the amount of degrees before top dead center (DBTDC) that the engine firing is taking place.
4. If the engine timing needs to be adjusted, loosen the two mounting cap-screws on the ignition generator. To advance the timing, rotate the ignition generator clock wise. To retard the timing, rotate the ignition generator counter-clockwise.
5. Tighten the two mounting cap-screws.

Note: The wires for the ignition generator to the ignition coils are called primary wires. The wires from the ignition coils to the spark plugs are called secondary wires.

Alternative Method for Timing the Engine

As an alternative method, one can follow the following procedure:

1. Adjust the Power Valve as described in the previous procedure searching for lowest EGT
2. Advance the timing 2 degrees at a time until the engine begins to detonate. Record the timing and retard timing until out of detonation.
3. Now retard the timing 2 degrees at a time until the engine begins to detonate. Record the timing and advance timing until out of detonation.
4. This should establish a timing window of opportunity.
5. Now adjust the timing within this window while observing the exhaust gas temperature (EGT) and the intake manifold air-gas temperature. Try and locate the lowest EGT within this timing window. This is where your engine needs to be timed.
6. Fine tune the adjustment of the Power Valve.

Caution: The engine may need to be re-timed if there is a sudden change to the ambient conditions.

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 lowest 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 in this manual.

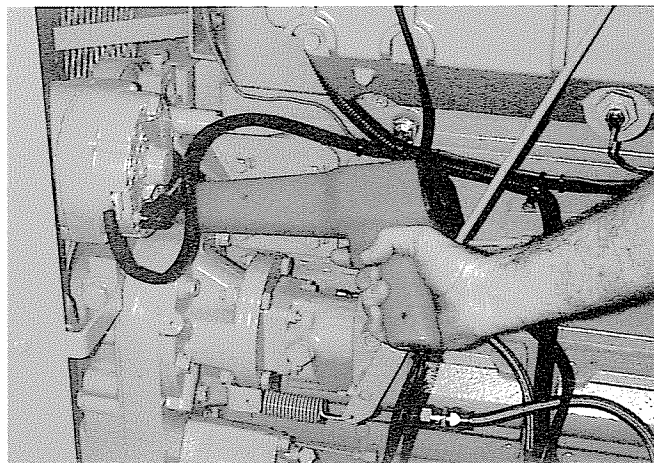


Photo # 7-24 - Timing Light

• Engine Cylinder Compression Check

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

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 ignition 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.
8. Record the reading in pounds per square inch.
9. Release the gauge pressure and remove the gauge.
10. Repeat steps 6 through 9 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 distributor or authorized CNGE dealer for further assistance.

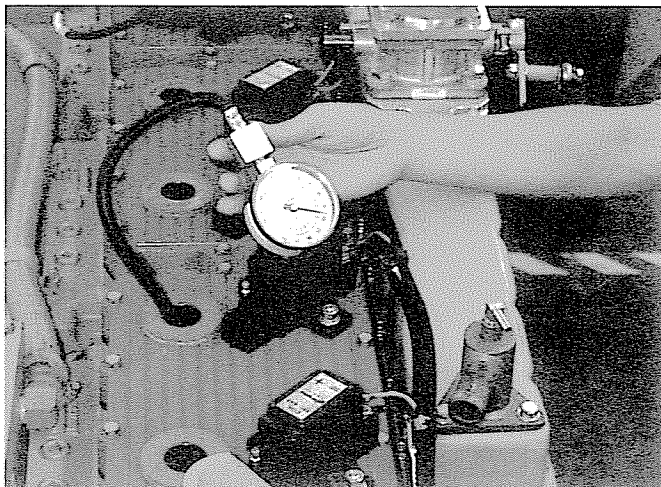


Photo # 7-25 - Compression Check Tools

• Spark Plug Wire - Inspection

Inspect the condition of the spark plug wires. Replace any damaged wires.

Visually inspect the spark plug wires for corrosion, evidence of cracking, worn spots caused by rubbing, or arcing evidenced by burnt spots. Replace as necessary.

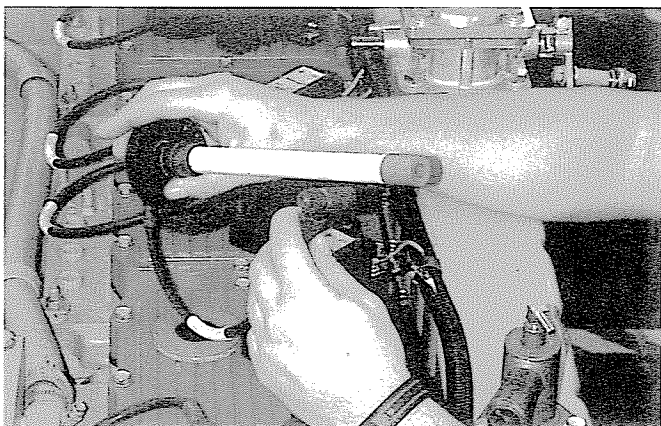


Photo # 7-26 - Spark Plug Wire - Inspection

• Spark Plug Removal

1. Disconnect the wire assembly from the ignition coil end first and then from the spark plug end.
2. Remove the rubber insert from the spark plug type sockets to prevent contamination of the spark plugs with dirt or oil.

3. Using a 15.875 mm (5/8 in.) deep-well rubber insert spark plug socket, loosen the spark plug with the extension and socket. Turn the plugs counterclockwise to loosen.
4. Continue to turn counterclockwise until the threads are no longer engaged.
5. Lift the spark plug out of the adapter, being careful not to drop the spark plug. Mark or tag the spark plugs with the cylinder number from which they are removed.
6. Visually inspect the plug wires, extenders and connections for corrosion, damage or arcing.

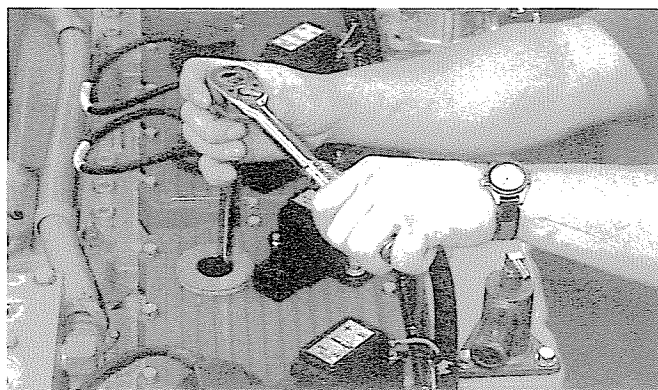


Photo # 7-27 - Spark Plug Removal

• Checking Spark Plug Well(s).

A visual inspection of the spark plug well for traces of water, oil & antifreeze should be made. If water or antifreeze is present inside the well and 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 a special tool. Contact your local Cummins Distributor or Authorized CNGE Dealer for assistance.

If oil is present in the spark plug adapter well, then replace the "O" rings on the spark plug adapter tube extension.

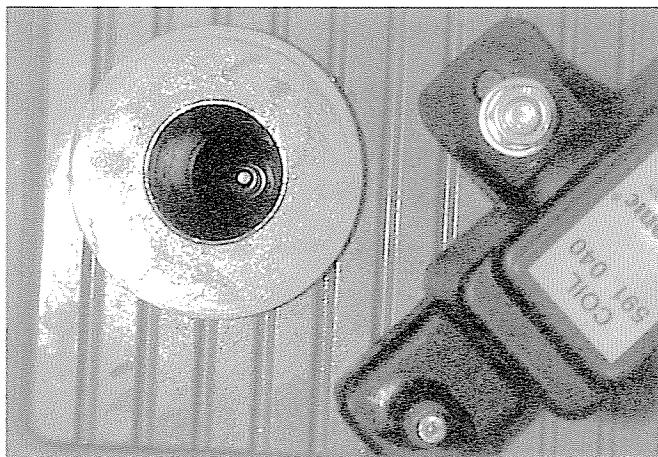


Photo # 7-28 - Spark Plug Well - Inspection

7-19

• Spark Plug(s) - 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.

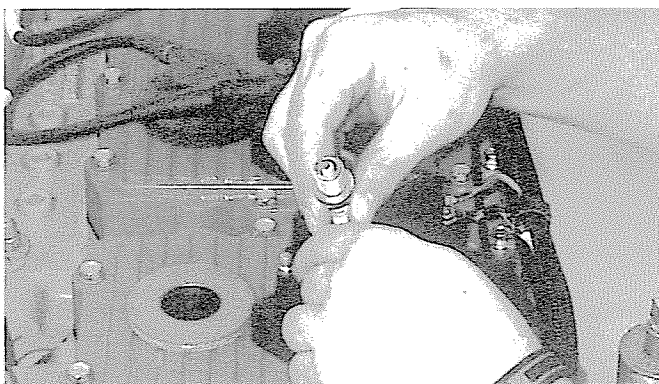


Photo # 7-29 - Spark Plug Inspection

• Spark Plug Gap - Checking

CNGE recommends that the spark plug gap of 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.

Spark Plugs used in CNGE engines should not be re-gapped.



Photo # 7-30 - Spark Plug Gap

• Spark Plug Installation

Caution: Spark plug life is largely dependent on cleanliness of the plug's porcelain. Dirt, oil and finger prints reduce the seal strength between the spark plug boot and the porcelain. Do not touch the porcelain area on the spark plug. If cleaning on porcelain is required, use rubbing alcohol and a lint free cloth.

Caution: Mechanical over-tightening can damage the spark plug and cylinder head.

Check plug socket to make sure it is not a source of dirt and oil.

Install a new spark plug in the cylinder head. Make sure that the spark plug insulator porcelain is clean. Use an extension and magnetic spark plug socket (Snap-On P.N. S971KA) and thread in by hand to make sure that the threads are smooth and the plug is not cross threaded. Turn the plug clockwise to tighten.

Use a torque wrench to complete the installation.

Torque Value: 35 to 41 N•m [26 to 30 ft-lb.]



Photo # 7-31 - Spark Plug Installation

Apply a small amount of di-electric grease inside the spark plug boot and outside of the spark plug boot.

Carefully place plug boot onto the top of the spark plug terminal. Firmly press each plug boot down until a snap is felt. This snap is the terminal clip being completely pushed over the plug terminal.

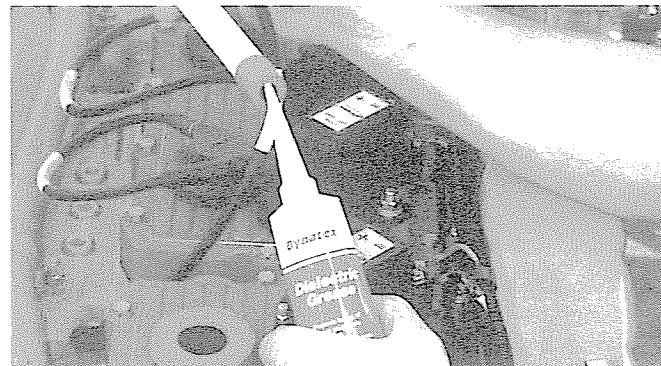


Photo # 7-32 - Di-Electric Grease

Ignition Coil Check

Preparatory Steps:

1. Turn engine to the off position and disconnect the batteries.
2. Visually check coil for cracks in the housing, carbon tracking (indication of coil arcing) and other physical damage.
3. Disconnect wiring to the coil and remove the coil wires that connect to the coil from the ignition generator.
4. Connect an ohmmeter to the positive and negative terminals of the coil.
5. Read the scale.
 - A. An infinite reading indicates an open primary winding. Replace the coil.
 - B. The correct ohmmeter reading should be .2 to .3 ohms.
6. Connect the ohmmeter to the coil positive terminal and to the high-tension coil wire terminal and read the scale of the ohmmeter.
 - A. An infinite reading indicates an open secondary winding. Replace the coil.
 - B. The correct ohmmeter resistance reading should be between 6K ohms and 11K ohms. If not, replace the coil.
7. Connect all wiring connections and reconnect the batteries.

Ignition Coil Voltage - Check - ALTRONIC CD1 Ignition System

Input Voltage

Preparatory Steps:

1. Connect the positive lead of the "Peak Hold" voltmeter to the positive terminal of the coil.
2. Disconnect and ground the coil high-tension lead wire from the ALTRONIC wiring harness to prevent the engine from starting.
3. Turn the ignition start switch to the start position and begin cranking the engine.
4. Observe the voltage while cranking.
5. The correct voltage should be 160 volts of DC pulsating voltage.
6. If the voltage is low, check the battery, starter current draw, ignition switch and ignition unit.



Photo # 7-33 - Ignition Coil Voltage Check

C2 Maintenance Check - 1500 Hours or 1 Year

Adjust Following

• Intake & Exhaust Valve Procedure

General Information

Note: The first intake & exhaust valve adjustment should take place at the 250 hour service interval. After that point check exhaust valves at the C2 check or 1500 hours or 2 years whichever comes first.

Note: Read the entire procedure for the overhead adjustment before attempting to perform this operation.

Valves must be correctly adjusted for the engine to operate efficiently. Valves must be adjusted using the values listed in this section.

Adjust the valves at the first oil change period of 250 operating hours and then at the C2 interval of 1500 hours or every 2 years whichever comes first. Check the valves after every major repair.

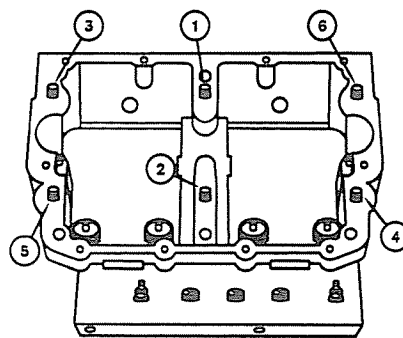
If the valves are checked during troubleshooting or before scheduled maintenance interval, adjustment is not required if measurements are within the recheck limits.

1. Disconnect the battery.
2. Remove the rocker housing covers. The rocker housing cover gaskets can be used again if they are not damaged.

Note: Do not use solvent to clean the rocker housing cover gasket. Solvent will damage the o-ring material and cause it to swell.
3. Tighten the rocker lever shaft cap-screws.

Torque Value: 156 N•m [115 ft.-lb.].

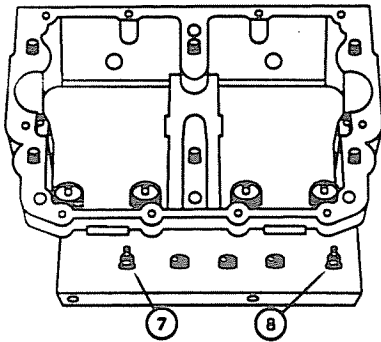
4. Tighten the rocker lever housing capscrews in the sequence shown (1 through 6).



Torque Value: 115 N•m [85 ft.-lb.].

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5. Tighten the rocker lever housing cap-screws in the sequence shown (7 and 8).



Torque Value: 47 N•m [35 ft.-lb.].

The valve set marks are located on the accessory drive pulley. The marks align with a pointer on the gear cover.

Warning: Do not pull or pry on the fan to manually rotate the engine. To do so can cause damage to the fan blades. Damaged fan blades can cause premature fan failures that can result in serious personal injury or property damage.

6. Use the accessory drive shaft nut to rotate the crankshaft. The crankshaft rotation is clockwise when viewed from the front of the engine.

The cylinders are numbered from the front of the engine. The firing order is 1-5-3-6-2-4.

Each cylinder has two rocker levers. The two levers closest to the center of each rocker housing are the intake levers. The two levers closest to the ends of the rocker housing are the exhaust levers.

7. The valve adjustment markings are on the accessory drive pulley. Two revolutions of the crankshaft are required to adjust all valves.
8. Rotate the accessory drive in the direction of engine rotation. The accessory drive will rotate clockwise on a right hand engine. Align the "1-6 VS" mark on the accessory drive pulley with the pointer on the gear cover.

9. Check the valve rocker levers on Cylinder Number 1 to see if both valves are closed.

Note: Both valves are closed when the rocker levers are loose and can be moved from side to side. If both valves are not closed, rotate the accessory drive one more complete revolution; and align the "1-6 VS" mark with the pointer again.

If the valve rocker lever adjusting screws have been loosened and not yet adjusted, watch the valve push tubes as the engine rolls upon the "1-6 VS" mark. Both valve push tubes will have moved to the downward (valve closed) position if the engine is on the correct stroke.

10. With the "1-6 VS" set mark aligned with the pointer on the gear cover and both valves closed on cylinder No. 1, loosen the lock nuts on the intake and the exhaust valve adjusting screws.
11. Select a feeler gauge for the correct valve lash specification.

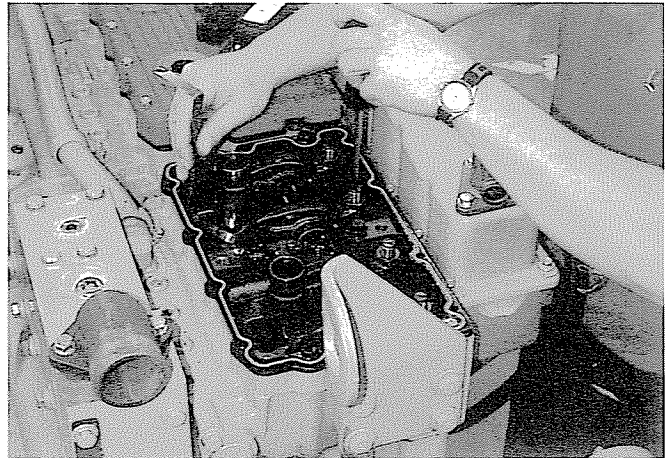


Photo # 7-34 - Valve Lash Adjustment

Intake Valve Lash	0.35 mm [0.014 inch]
Exhaust Valve Lash	0.85 mm [0.033 inch]

12. Insert the feeler gauge between the top of the crosshead and the rocker lever pad.

Two different methods for establishing valve lash clearance are described below. Either method can be used; however, the torque wrench method has proven to be the most consistent.

Torque Wrench Method: Use the inch pound torque wrench, Part No. 3376592, and tighten the adjusting screw.

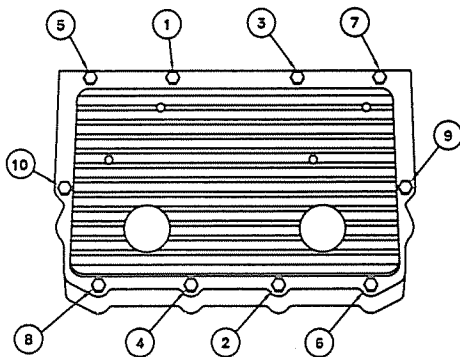
Torque Value: 0.56 - 0.68 N•m [5-6 in-lb]

Feel Method: Tighten the adjusting screw until a slight drag is felt on the feeler gauge.

Hold the adjusting screw in this position. The adjusting screw must not turn when the lock nut is tightened.

Torque Value: With torque wrench adapter, Part No. ST-669 **54 N•m [40 ft-lb]**
Without adapter **68 N•m [50 ft-lb]**

13. After tightening the lock nut to the correct torque value, check to make sure the feeler gauge will slide backward and forward between the crosshead and the rocker lever with only a slight drag.
14. If using the feel method, attempt to insert a feeler gauge that is 0.03 mm [0.001 inch] thicker between the crosshead and the rocker lever pad. The valve lash is not correct when a thicker feeler gauge will fit.
15. After adjusting the valves on Cylinder No. 1, rotate the accessory drive; and align the next valve set mark with the pointer. Repeat the process to adjust all valves in the following sequence. Set valves in order of the firing order of 1-5-3-6-2-4.
16. Install the rocker lever covers.



Torque Value: 12 N•m [105 in-lb]

Check/Clean/Replace

• Gas Fuel Filter

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 10 microns.

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.

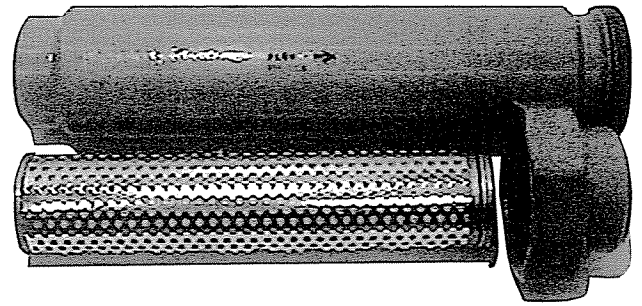


Photo # 7-35 - Gas Fuel Filter

• Gas Pressure to On Engine Gas Regulator

Every 1500 hours or 1 year, check the gas pressure to the on engine regulator. Use a water manometer or gauge that measures in inches of water column. This reading is taken on the upstream side at the on engine gas regulator and should be between 10 and 20 inches of water column pressure at full load conditions.

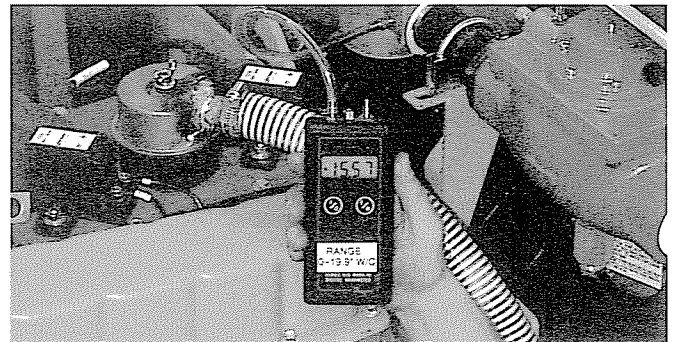


Photo # 7-36 - Gas Pressure at Gas Regulator (On Engine) - Checking

• 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. Natural gas will require 4 to 6 in. of H₂O column pressure. Propane will be under a negative pressure (vacuum), anywhere from 1.5 to 8 in. of H₂O.



Photo # 7-37 - Gas Pressure to Carburetor - Checking

• Carburetor Adjustment for Excess Oxygen

The air-gas “power valve” on the carburetor should be adjusted for the specific engine model’s excess oxygen requirement. Refer to **Table # 7-05**.

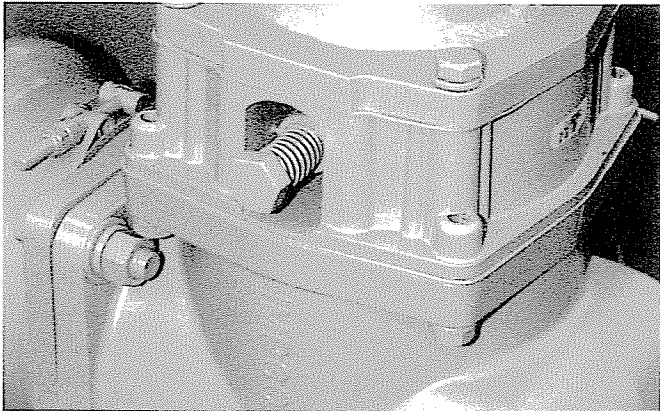


Photo # 7-38 - Power Valve - IMPCO 600 Vari-Fuel

Table # 7-05- Excess Oxygen - Without Catalytic

O ₂ Reading - %		
O ₂ Reading - %		
	Stand-By (Maximum)	Prime (Continuous)
GTA14	4.0	4.0

Caution: When making the adjustment, it may be necessary to readjust engine ignition timing.

Caution: CNGE sets all engines at Clovis, New Mexico conditions of 4200 feet altitude and to the specifications listed in Table # 7-05. Your adjustments may be slightly different due to altitude and operating load conditions.

Adjustment of Air-Gas Power Valve

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

IMPCO Model # 600 VF (Vari-Fuel)

On the model 600 VF (Vari-Fuel) 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 rich.

• Antifreeze Concentration - Checking

Use the Fleetguard® refractometer, Part No. CC-2800, to check the antifreeze concentration.

Check the antifreeze concentration. Use a mixture of 50 percent water and 50 percent ethylene-glycol base antifreeze to protect the engine to - 37° C [-34° F] year around.

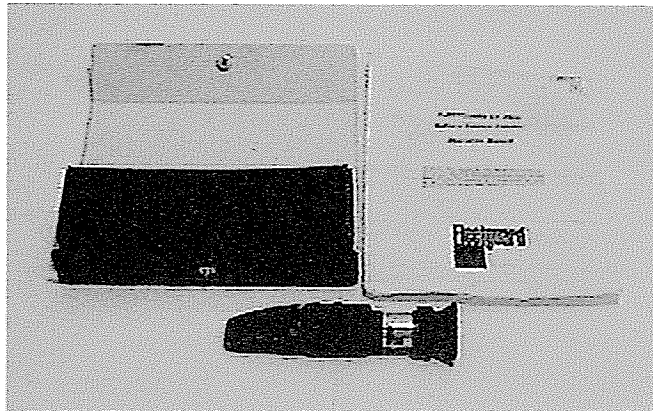


Photo # 7-39 - Fleetguard™ Refractometer
(P.N. CC-2800)

D - Maintenance Check - 6000 Hours or 2 Years

Inspect/Replace

• Spark Plug Wire - Replacement

Caution: To prevent damage to the spark plug wires during removal, do not pull on the wires.

Remove the coil end first, then remove the spark plug end.

Note: Replace the spark plug wires one cylinder at a time to prevent crossing the wires across cylinders. Move back and forth while pulling upward to remove the wire from the coil or distributor cap and spark plug.

Apply a small amount of dielectric grease inside of the spark plug boot and on the outside of the spark plug boot.

Firmly press on the boot until a snap is heard and felt as the boot seats on the spark plug. Install the coil or distributor cap end.

Exchange/Rebuild

• Engine Water Pump - Inspection and Replacement

Every 6000 hours or two years, whichever first occurs, inspect the water pump idler pulley assembly for freedom of rotation and for cracked, chipped, or broken pulley grooves. Repair or replace the idler pulley assembly if it does not rotate freely or if damage is found. Refer to the N14 Troubleshooting and Repair Manual, Bulletin No. 3666142, for removal and replacement instructions.

Inspect the water pump for seal leakage or for freedom of movement. If the water pump needs to be replaced refer to the N14 Troubleshooting and Repair Manual, Bulletin No. 3666142, for removal and replacement instructions.

Preparatory Steps

1. Drain the coolant.
2. Unplug the coolant heater (If so equipped)
3. Remove the water pump drive belt.
4. Remove the fan hub and water pump idler pulley assembly.
5. Remove the coolant inlet transfer connection from the water pump.
6. Remove the six mounting cap-screws from the water pump.
7. Remove the water pump.

Note: The water pump must be removed carefully to prevent damage to the impeller.
8. Remove the water pump out and in a downward direction to clear the dowel pin and disconnect the water transfer tube attached to the thermostat housing.
9. Clean the water pump gasket surface.

Caution: The water pump must have a dowel pin locating hole and oil cooler return passage. Engine damage will occur due to a lack of coolant flow through the oil cooler, if this oil cooler return passage does not exist.

10. Install the water transfer tube attached to the thermostat housing in the water pump.
11. Inspect the transfer tube o-ring. Replace if necessary.
12. Install the water pump to the block using the six mounting cap-screws. Tighten the cap-screws to the following torque values:

Step 1 Tighten to 15 N•m [10 ft.-lb]
Step 2 Tighten to 30 N•m [20 ft.-lb]
Step 3 Tighten to 47 N•m [35 ft.-lb]
13. Install the coolant inlet transfer connection and a new gasket on the water pump. **Tighten the cap-screws to 47 N•m [35 ft.-lb]**
14. Install the fan hub and the water pump idler assemblies.
15. Install and adjust the water pump drive belt.
16. Fill the engine with coolant, start the engine and check for leaks.

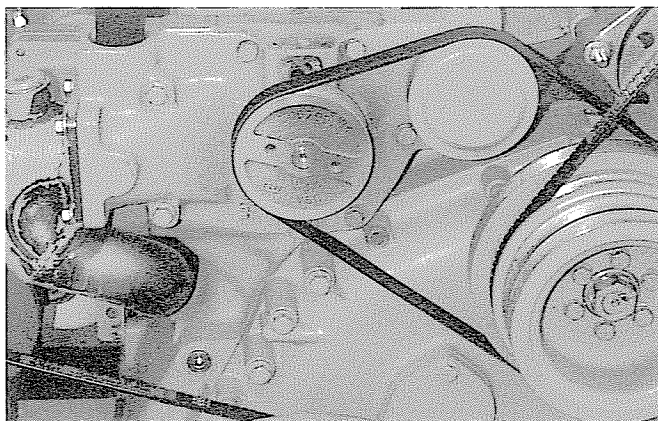


Photo # 7-40 - Water Pump

• Fan Hub (Belt Driven) - Inspection

Every 6000 hours or two years, whichever first occurs, inspect the fan hub for wobble and grease leakage. Replace with a new or rebuilt unit as necessary. Refer to the N14 Engine Series Troubleshooting and Repair Manual, Bulletin # 3666065, for removal and replacement instructions.

Preparatory Steps

1. Remove the fan.

Note: Do not discard the fan spacers. The spacers provide for the thickness needed to install the fan in the correct position.

2. Turn the adjusting screw counterclockwise to release tension. Remove the adjusting screw and remove the belts.
3. Remove the cap-screws and the fan hub.
4. Remove the fan drive belts.
5. Inspect the fan hub for the following:

Freedom of rotation.

Cracks.

Grease Seal Leakage

Note: Repair or replace the fan hub if the fan hub does not rotate freely or if there is evidence of cracks or grease seal leakage.

6. Measure the fan hub end clearance. Refer to the Troubleshooting and Repair Manual for correct specifications. The end clearance is dependent on fan hub style.
7. Install the fan hub and cap-screws.
8. Install the fan drive belts on the fan hub and the accessory drive pulley.
9. Install the fan.
10. Adjust and tighten the fan drive belts. Tighten the fan mounting cap-screws.

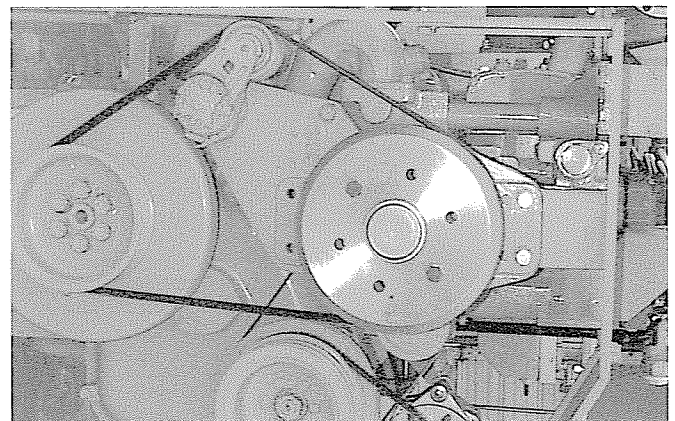


Photo # 7-41 - Fan Hub

7-25

• Aftercooler 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.

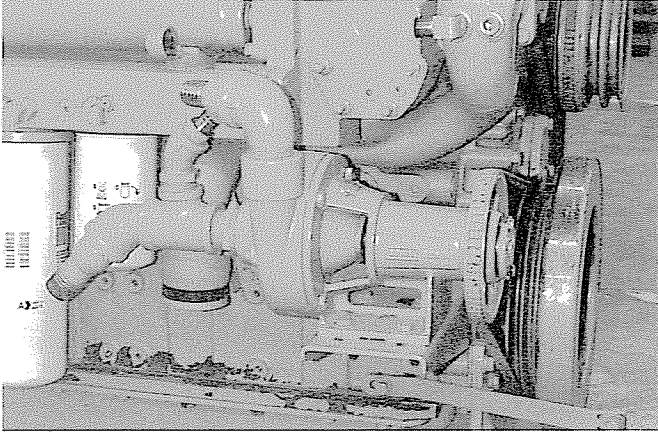


Photo # 7-42 - Aftercooler Water Pump

• Turbocharger - Inspection

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

Look for damaged or cracked compressor 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 data-plate.

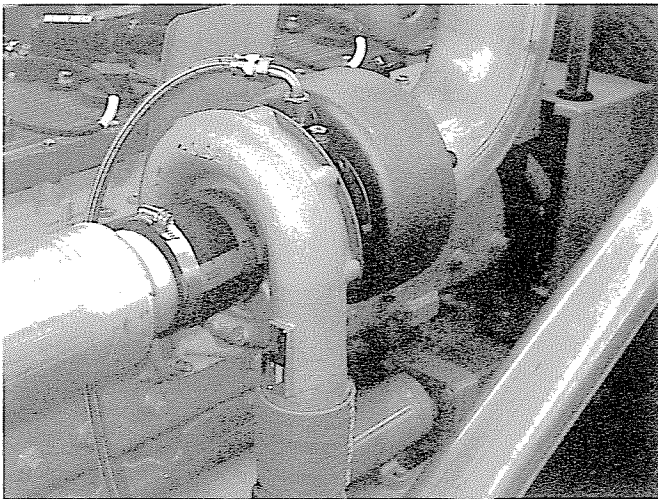


Photo # 7-43 - Turbocharger

Table #7-06- Axial Clearance (Measure end to end)

Turbocharger Model No.	Dimension	
	Min.	Max.
HZ	.03m [.001 in.]	.10mm [.004 in.]

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 Shop Manual, Bulletin # 3810321, for rebuild procedures.

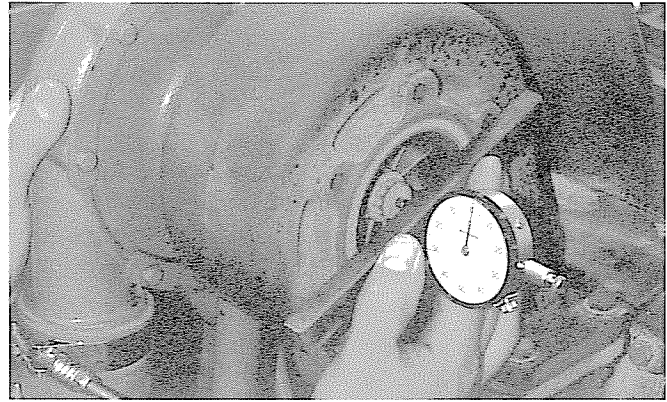


Photo # 7-44 - Axial Clearance - Checking

Measure Radial Clearance (Side to Side).

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

Table # 7-07 - Radial Clearance

Turbocharger Model No.	Dimension	
	Min.	Max.
HZ		
Compressor Wheel	.18 mm [.007 in.]	.46 mm [.018 in.]
Turbine Wheel	.25 mm [.010 in.]	.53 mm [.021 in.]

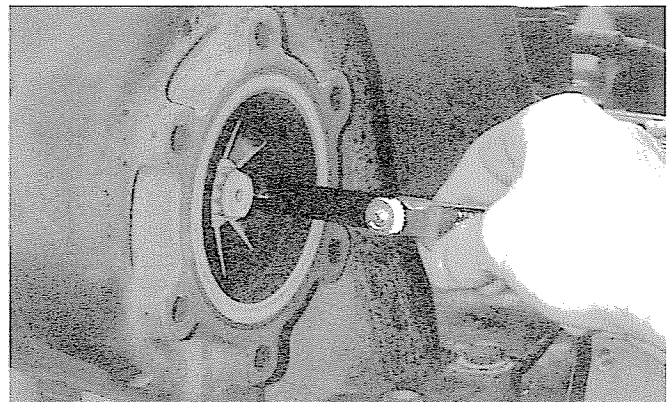


Photo # 7- 45 - Radial Clearance Checking

• Viscous Damper - Inspection

Every 4500 hours or 2 years inspect the viscous damper.

1. Clean the damper with a solvent cleaner.
2. Apply a small spray of Spotcheck developer, type SKD-NF, or equivalent on the damper. Put the damper in an oven heated to 200° F [93° C]. Let the damper reach the temperature inside the oven, and then remove the damper.
3. Inspect the damper for oil leaks. Discard the damper if any leaks are seen.
4. Remove the paint from four equally spaced areas [90 degree intervals] on both sides of the damper. Use these areas to check for movement of the damper.
5. Use a micrometer to measure the thickness at each of the four areas. Measure at approximately 0.125 inch [3.18 mm] from the outside diameter of the damper.
6. Replace the damper if the difference in measurement between any two areas is more than 0.010 inch [0.25 mm].

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



Photo # 7-46 - Vibration Damper

Check

- Cooling System Maintenance
- Coolant Draining

Caution: Avoid prolonged and repeated skin contact with used antifreeze. Such prolonged and repeated contact can cause skin disorders or bodily injury.

- Avoid excessive contact - wash thoroughly after contact.
- Keep out of reach of children.

Protect the Environment: Handling and disposal of used antifreeze can be subject to federal, state, and local law regulation. Use authorized waste disposal facilities, including civic amenity sites and garages providing authorized facilities for the receipt of used antifreeze. If in doubt, contact your local authorities or the EPA for guidance as to proper handling of used antifreeze.

Caution: 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.

Drain the cooling system by opening the radiator cap on the radiator and removing the plug in the bottom of the water inlet or in the bottom of the radiator. A drain pan with a capacity of 121 liters [32 U.S. gallons] will be adequate in most applications.

Check for damaged hoses and loose or damaged hose clamps. Replace as required. Check the radiator for leaks, damage and build up of dirt. Clean and repair as required.

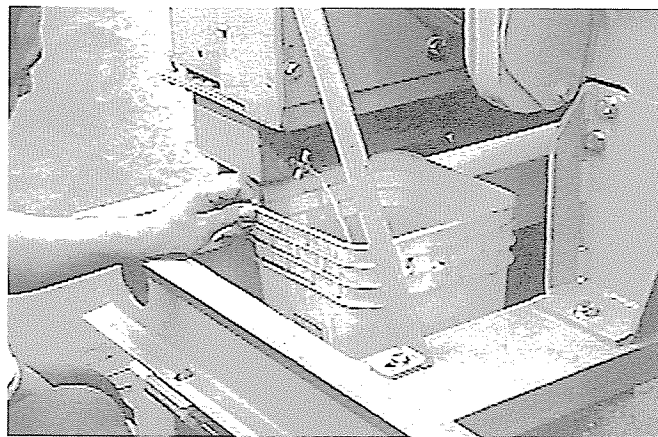


Photo # 7-47 - Draining Cooling System

• Cooling System Flushing

Caution: During filling, air must be vented from the engine coolant passages. The system must be filled slowly to prevent air locks. Wait 2 to 3 minutes to allow air to be vented, then add mixture to bring the level to the top.

Fill the system with a mixture of sodium carbonate and water or a commercially available equivalent.

Note: Use 0.5 kilograms [1.0 lb.] of sodium carbonate for every 23 liters [6.0 U.S. Gallons] of water.

Caution: Do not install the radiator cap. The engine is to be operated without the cap for this process.

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

Operate the engine for 5 minutes with the coolant temperature above 80° C [176° F].

Shut the engine off and drain the cooling system.

Fill the cooling system with clean water.

7-27

Note: Be sure to allow the engine to vent for complete filling. Do not install the radiator cap or a new filter if equipped.

Operate the engine for 5 minutes with the coolant temperature above 80° C [176° F].

Shut the engine off and drain the cooling system.

Note: If the water being drained is still dirty, the system must be flushed again until the water is clean.



Photo # 7-48 - Flushing Cooling System

• Coolant System Filling

The system has a maximum fill rate of 14 liters/min. [3.5 US. Gal./min.]. Do not exceed this fill rate.

Caution: The system must be filled slowly to prevent air locks. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented, then add mixture to bring the level to the top.

Caution: Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant.

Use a mixture of 50 percent water and 50 percent ethylene glycol antifreeze to fill the cooling system.

The system capacity for the engine is 19 liter [20 U.S.qt]

Install the pressure cap. Operate the engine until it reaches a temperature of 80° C [176° F].

Check the coolant level again to make sure the system is full of coolant, or that the coolant level has risen to the hot level in the recovery bottle on the system, if so equipped.

Warning: Before removing the pressure cap, wait until the coolant temperature is below 50° C [120° F]. Failure to do so can cause personal injury from heated coolant spray.



Photo # 7-49 - Filling Cooling System

Annual

• Steam Clean Engine

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.

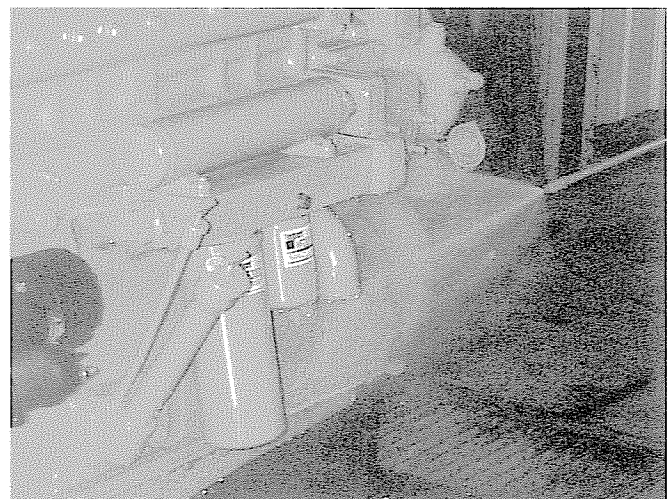


Photo # 7-50 - Steam Clean Engine

• Turbocharger Mounting Nuts - Check Torque

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

Tighten the mounting nuts.

Torque Value: 68 N•m [50 ft.-lb.]

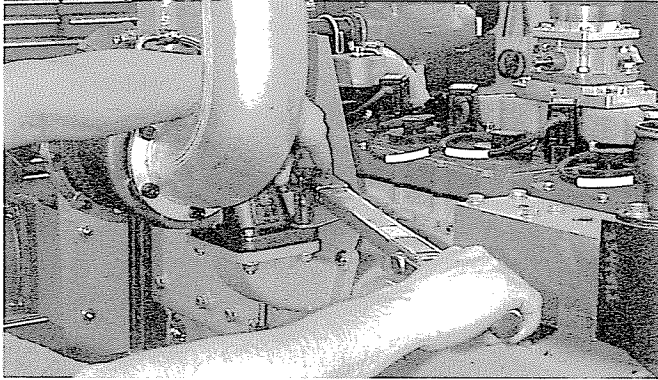


Photo # 7-51 - Turbocharger Mounting Nuts - Checking Torque

◦ **Engine Mounting Bolts - Check Torque**

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 # 7-52 - Engine Mounting Bolts - Checking Torque

◦ **Hoses - Checking and Replacement**

Hoses & 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.

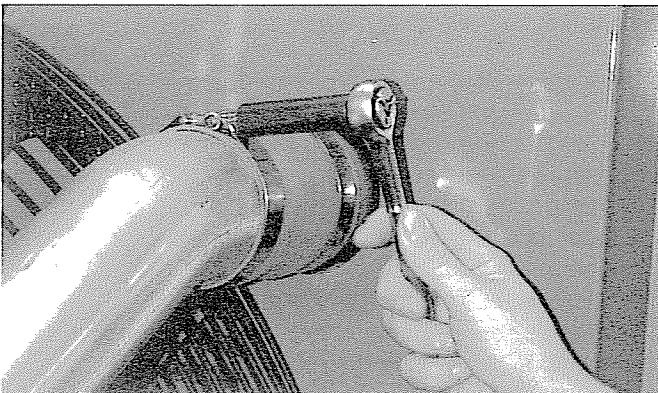


Photo # 7-53 - Hose Inspection

Inspect/Replace All Drive Belts

Maintenance Check

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

Belt damage can be caused by:

- Incorrect tension
- Incorrect size or length
- Pulley misalignment
- Incorrect installation
- Severe operating environment
- Oil or grease on the belts
- Clean Cooling System (Internally and Externally)

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.

◦ **Change Coolant and Antifreeze (Every 2 Years)**

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 the 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 Cummins Engine Co.

7-29

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 cap-screws to the recommended cap-screw torque as listed in the Technical Specifications in this manual. Replace any fan that is damaged.

• Shutterstats and Thermatic Fans - Checking

Check the shutterstats and the thermatic fans annually.

- Shutterstats and the thermatic fan controls must operate in the same temperature range as the thermostat with which they are used.

• Thermostats and Seals - Checking/ Replacing

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.

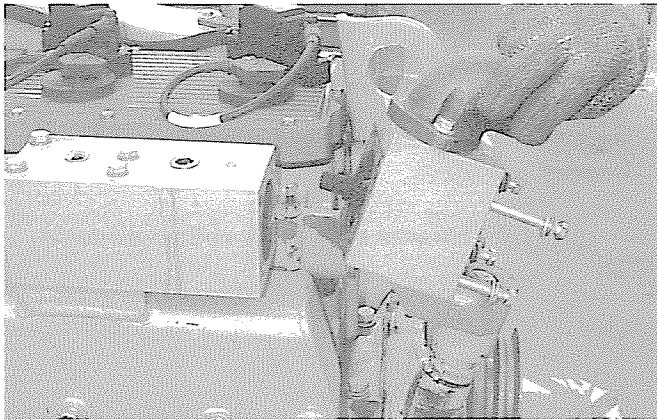


Photo # 7-54 - Thermostat & Seal

Thermal Control Settings

Table # 7-08 - Thermal Control Settings

	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	

Special Notes

1. The maintenance interval may be adjusted based on a good oil analysis program.
2. At each scheduled maintenance interval, perform 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, alternator, generator, batteries, electrical connections, magnetos or Ignition generators, carburetors, gas regulators, 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.
6. **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 or CNGE authorized Repair Location, or consult the Cummins Engine Shop Manual for information concerning engine storage procedures

Flame Retarder

Flame Retarders are special components that are mounted between the intake manifold and the cylinder head at each intake port opening. The purpose of the Flame Retarder is to assist in stopping any backfire from entering the intake system and beyond. This device is made of a special honeycomb material with a finite number of small openings that will tend to snuff out the flame and prevent it from entering the intake manifold.

Backfire relief valves are not required when using Flame Retarders

Adjustment, Replacement & Repair Procedure

• Air System Repair

Turbocharger Replacement

Preparatory Steps

1. Remove the oil supply and the oil drain connections from the turbocharger.
2. Remove the exhaust pipe from the turbocharger.
3. Remove the CAC piping from the turbocharger.
4. Remove the four mounting nuts.
5. Remove the turbocharger and gasket.
6. Install a new gasket and apply anti-seize compound, Part No. 3823097 to the mounting studs.
Note: Use only anti-seize compound compatible with oxygen sensors.

9. Install the turbocharger and a new gasket.
Torque Value: 68 N•m [50 ft-lb]
10. Install the drain tube and gasket on the turbocharger.
Torque Value: 44 N•m [32 ft-lb].

Caution: To prevent bearing damage, new turbochargers must be pre lubricated before start-up.

Pour 50 to 60 cc [2 to 3 ounces] of clean engine oil into the supply fitting. Rotate the turbine wheel to allow the oil to enter the bearing housing.

11. Install the oil supply line.
Torque Value: 30 N•m [22 ft-lb]
12. Install the charge air core and exhaust piping.
13. Operate the engine and check for leaks.

• Cooling System Repair

Drive Belt - Replacement

1. Remove the fan drive belt.
2. Loosen the idler pulley shaft lock nut.
3. Turn the adjusting screw counterclockwise to release tension and remove the water pump belt.
4. Visually inspect the idler and the water pump pulleys for cracks or broken grooves. Replace if necessary.
5. Visually inspect and replace the belt for the following characteristics:
 - Cracks
 - Glazing
 - Tears or cuts.
6. Visually inspect the pulley alignment. Pulley misalignment must not exceed 0.5 mm per cm [1/16 inch per foot] of distance between the pulley centers.
7. Replace the idler pulley or the water pump if they are not in alignment.
8. Install a new belt on the pulleys.
9. Turn the adjusting screw to adjust belt tension.
Note: Belt tension can increase when the lock nut is tightened. Do not adjust belt tension to full value with the adjusting screw.
10. Use Part No. ST 1293 (Borroughs) or 3822525 (Click-Type) Belt Tension Gauge to measure six rib belt tension.
New Belt Tension 710 N [160 lb]
Used Belt Tension 290 to 580 N [65 to 130 lb]
A belt is considered used if it has operated for 10 minutes or longer.
If used belt tension is below the minimum, tighten to the maximum value.
11. Tighten the idler pulley shaft lock nut to **68 N•m [50 ft-lb].**
12. Loosen the adjusting screw 1/2 turn to prevent breakage.
13. Measure the belt tension again. Adjust if necessary.

Thermostat Replacement

Preparatory Steps

1. Disconnect the negative battery cable.
2. Drain the cooling system to a level just below the thermostat housing.
3. Remove the four capscrews that attach the thermostat housing to the rocker housing.
4. Remove the thermostat housing from the water transfer tube.
5. Remove the four thermostat cover cap-screws and disassemble the thermostat housing.
6. Remove the thermostat from the cover.
7. Inspect the thermostat seal and the cover gasket.
8. Install the thermostat in the cover.
9. Clean the gasket surfaces. Install a new gasket on the thermostat housing.
10. Install the thermostat cover and four mounting cap-screws.
11. Tighten all cap-screws.
Torque Value: 47 N•m [35 ft-lb].
12. Install the thermostat housing assembly and mounting gasket on the rocker lever housing and onto the water transfer tube.
13. Inspect the transfer tube o-ring. Replace if necessary.
14. Install the four mounting cap-screws and washers. Tighten the cap-screws.
Torque Value: 47 N•m [35 ft-lb].
15. Install the upper radiator hose and tighten all hose clamps.
16. Fill the engine with coolant, start the engine and check for leaks.

Aftercooler Pump - Replacement

Preparatory Steps:

1. Disconnect battery ground cable from engine to prevent starting of the engine.
2. Drain all coolant from the aftercooler cooling system.
3. Disconnect both the pressure line and the suction line from the auxiliary aftercooler water pump.
4. Remove both inlet and outlet fittings.
5. Loosen and remove the 4 mounting bolts and nuts.
6. Remove the drive belt.
7. Remove the auxiliary aftercooler drive pulley from the pump.
8. Install a new pump.
9. Install the 4 mounting bolts and nuts and do not tighten at this time.
10. Install the inlet and out let fittings. Use a thread sealant on the pipe threads.
11. Install drive pulley and belt.
12. Align the drive pulley and belt to the engine front crankshaft pulley. And tighten the mounting bolts.
Torque Value: 44 N•m (32 ft-lb).

Section 8

Compressed Air/Gas System

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 temperatures than electric storage batteries.

Air-Gas Starters

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

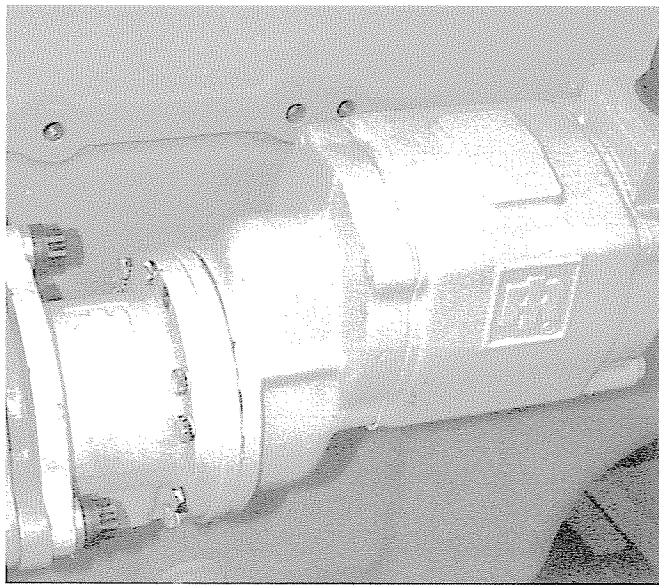


Photo # 8-01 - Air-Gas Starter

Air Starters - Maintenance

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

Air-Gas Starters - Maintenance

Do not operate air-gas starting motors with air-gas pressure lower than 490 kPa (70 psi).

Special Note:

Refer to the original equipment manufacturers and starting motor manufacturer 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 lubricant, preferable an SAE 10 (90SSU), or lighter. The rate of oil delivery is adjusted by turning the adjusting screw either clockwise for less oil or counter-clockwise for more oil delivery.

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

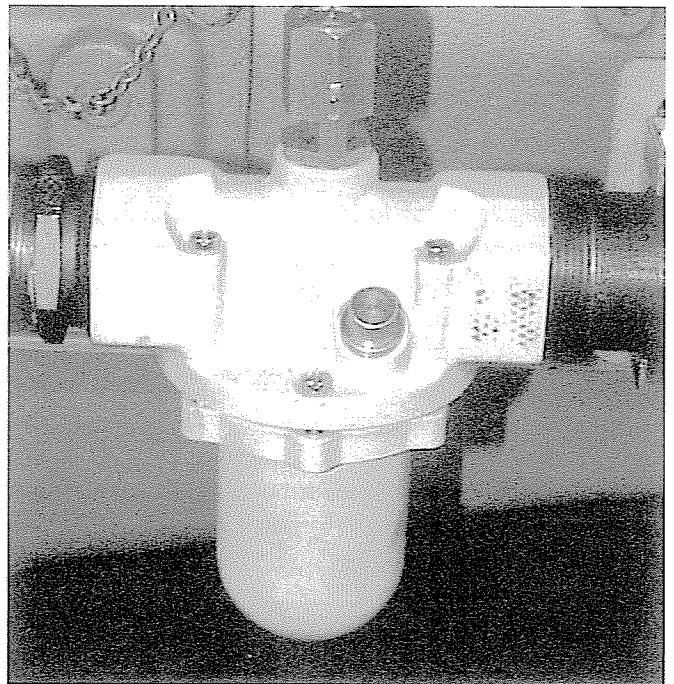
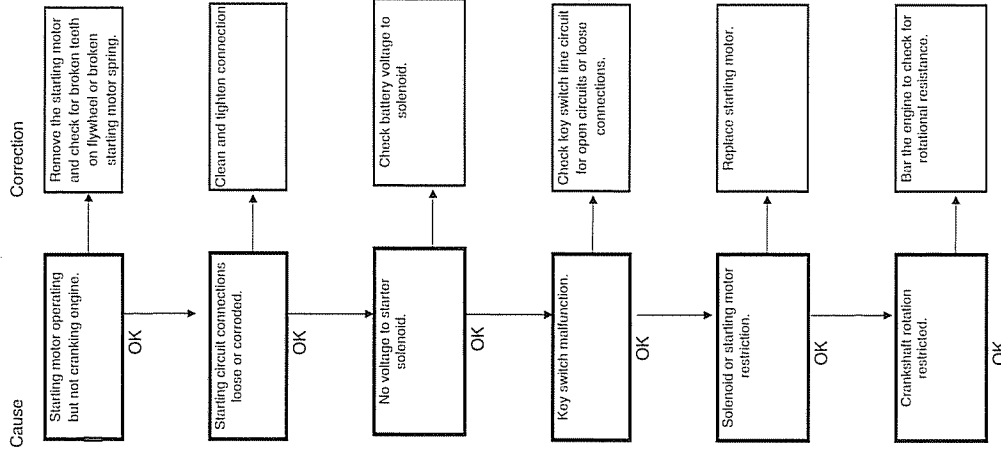
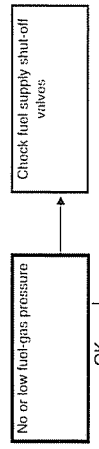


Photo # 8-02 - Economist Lubricator

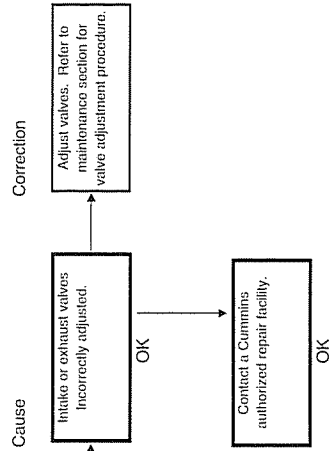
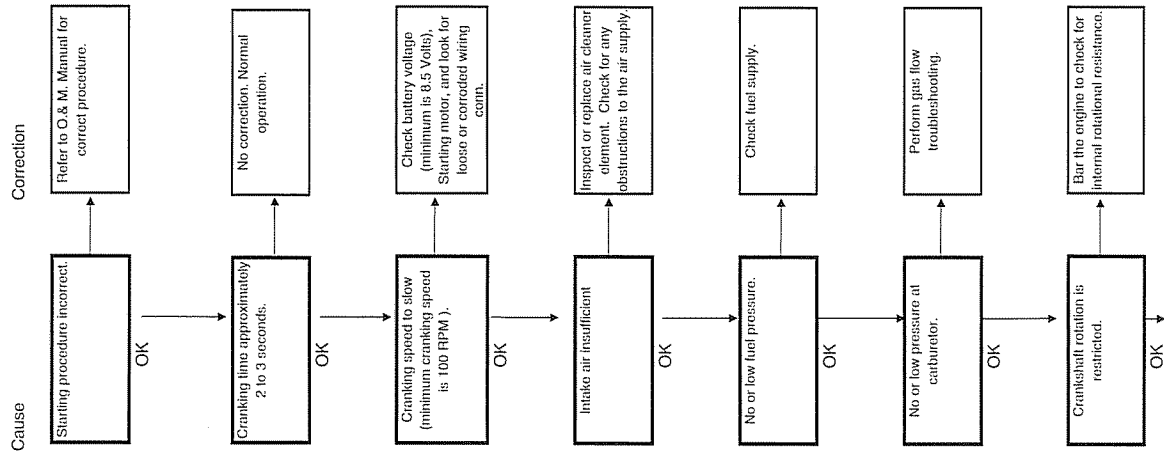
Engine Will Not Crank



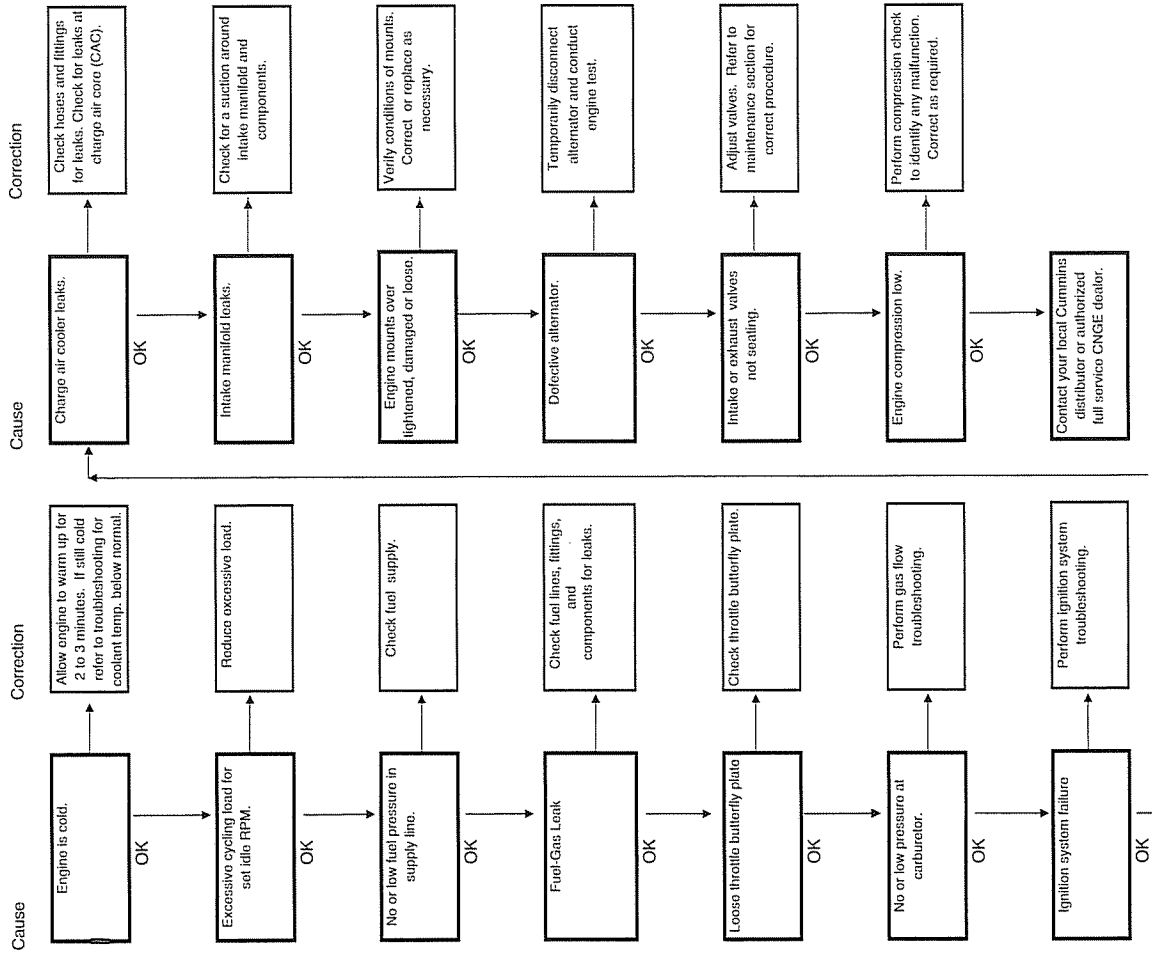
Engine Cranks But Will Not Start



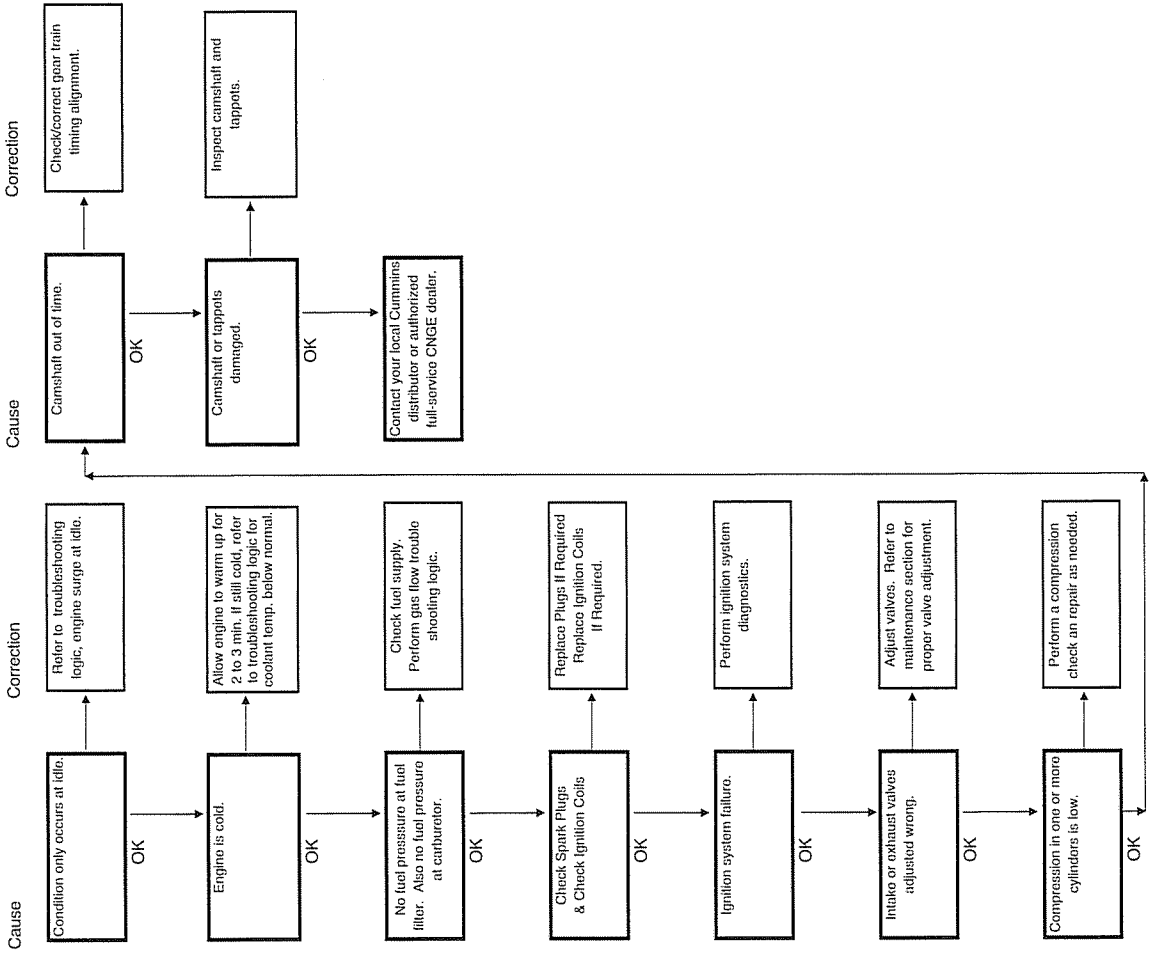
Hard to Start - Long Cranking Time



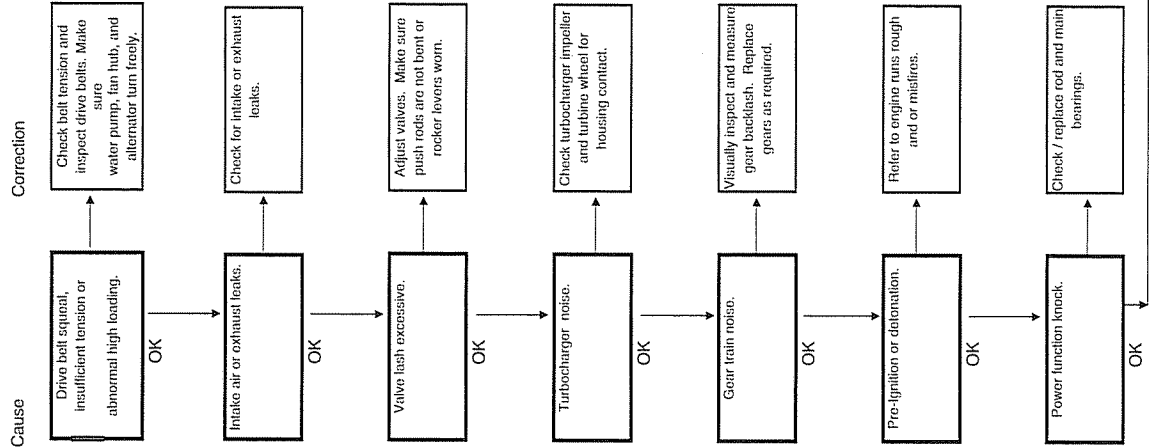
Engine Surge at Low Idle , Engine Shaking or Rough Idle



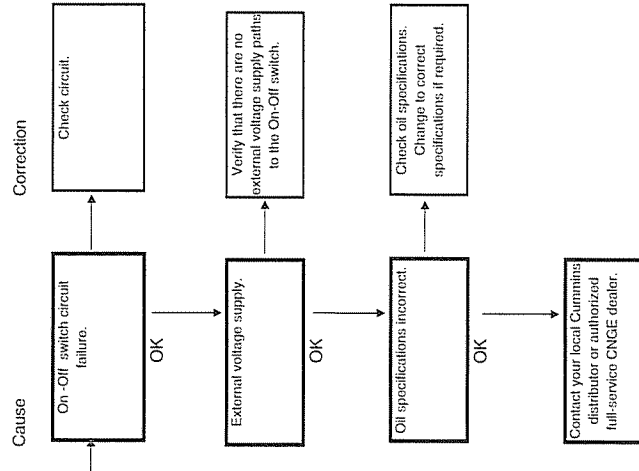
Engine Runs Rough or Misfires



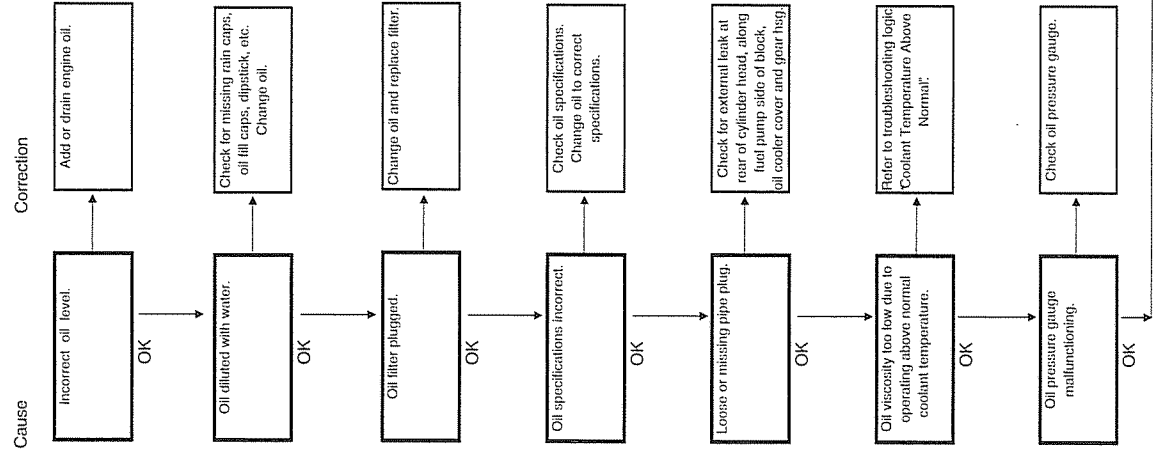
Engine Noise Excessive



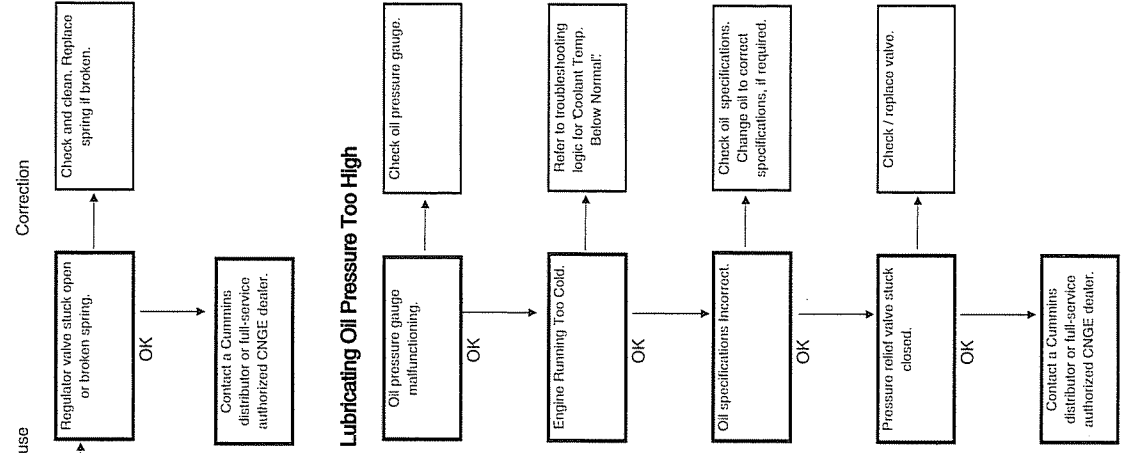
Engine Will Not Shut Off



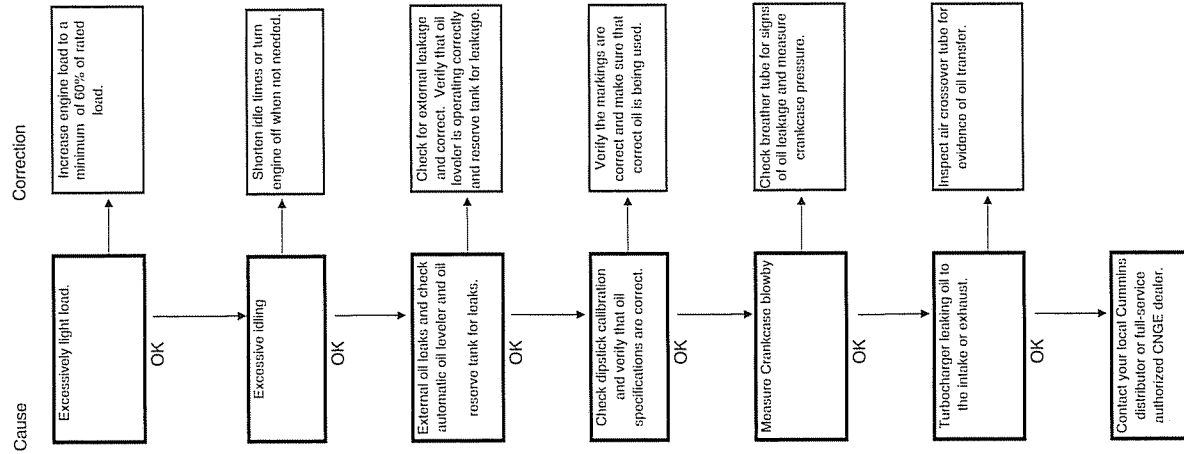
Lubricating Oil Pressure Low



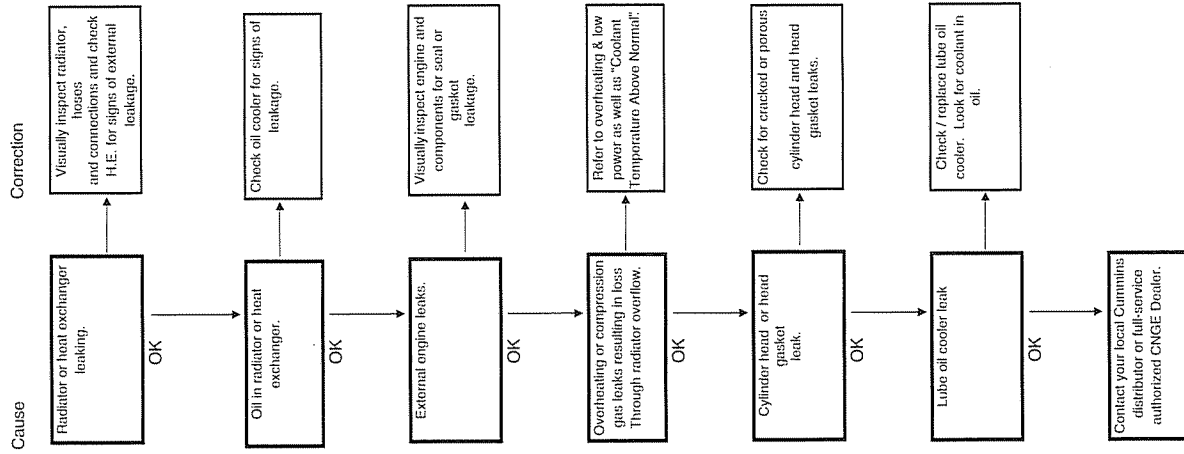
Lubricating Oil Pressure Too High



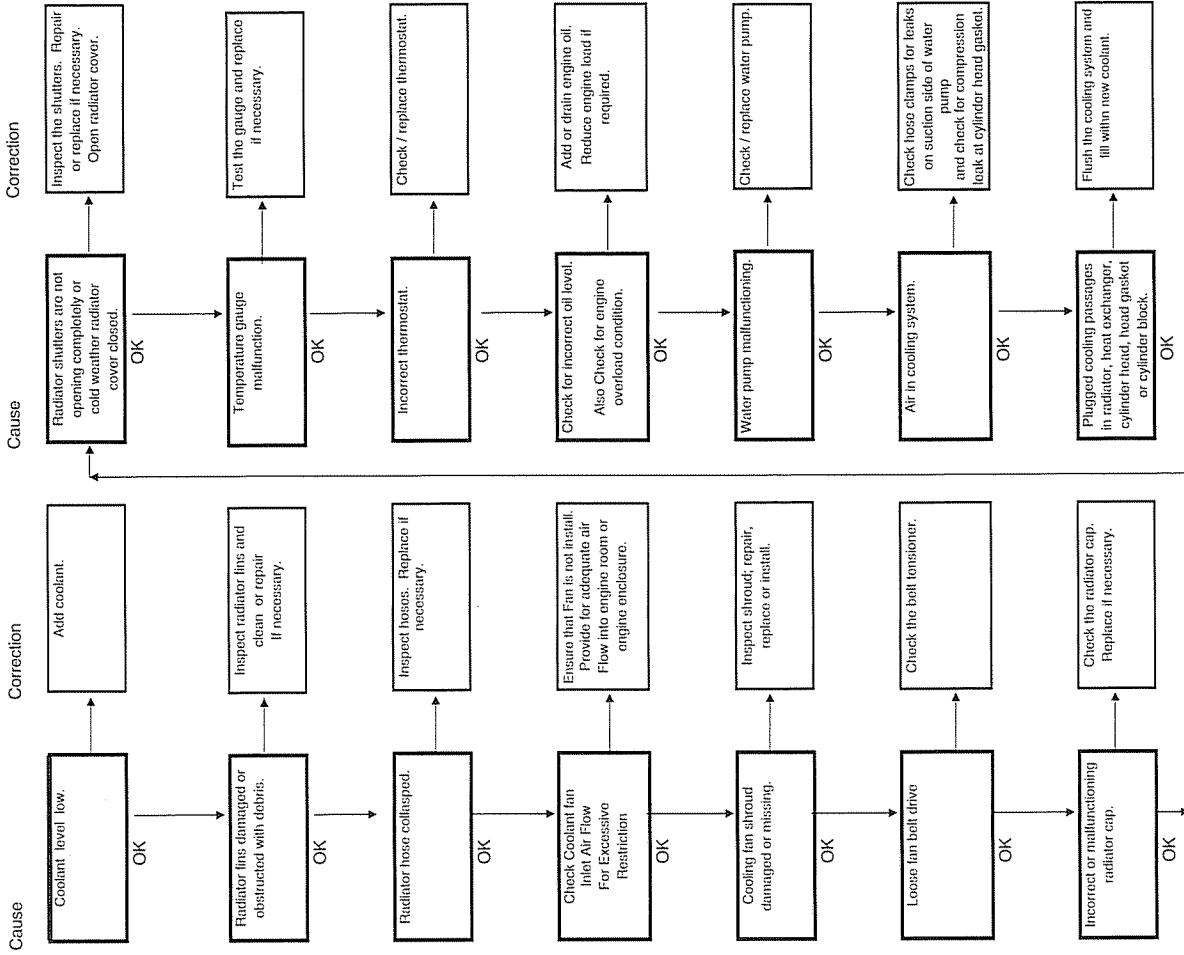
Lubricating Oil Consumption Excessive



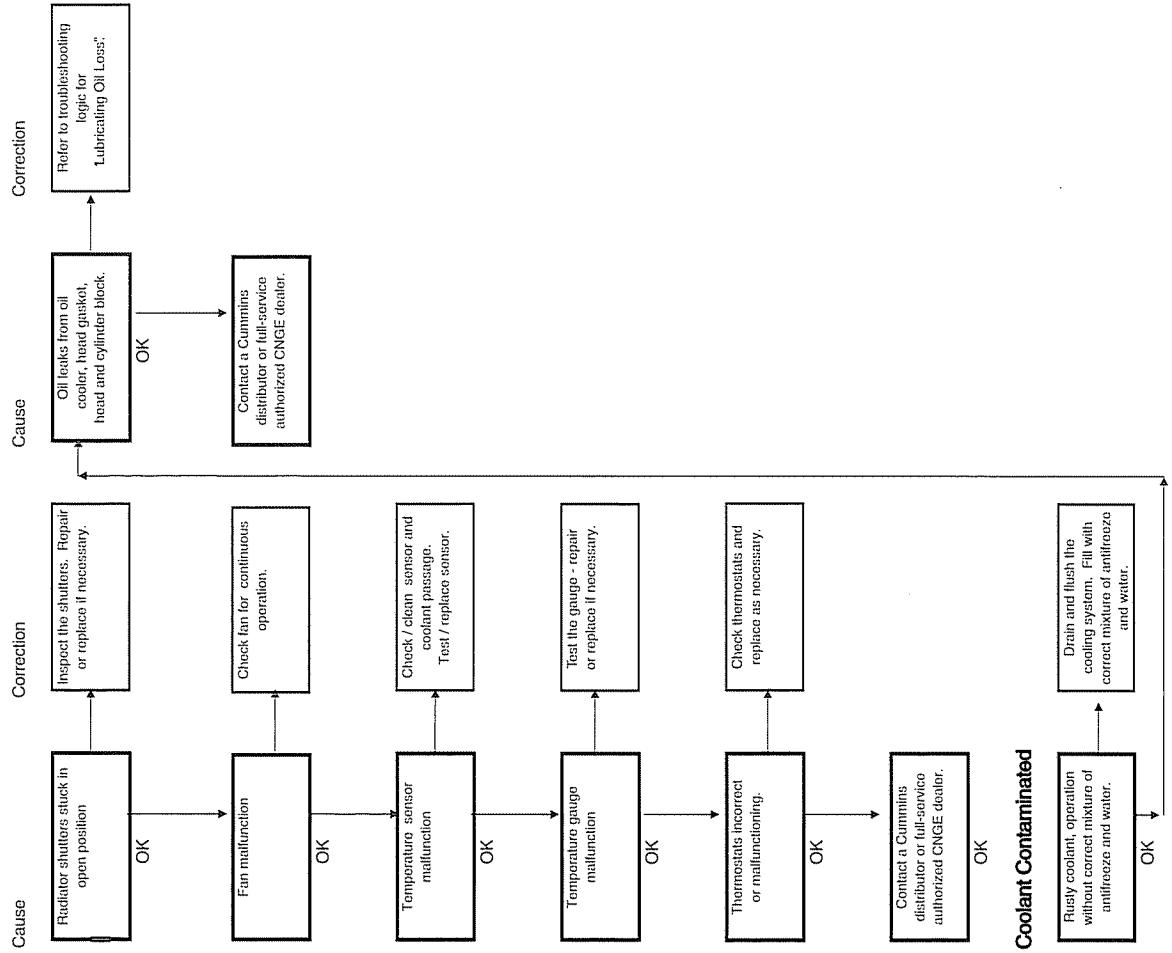
Coolant Loss



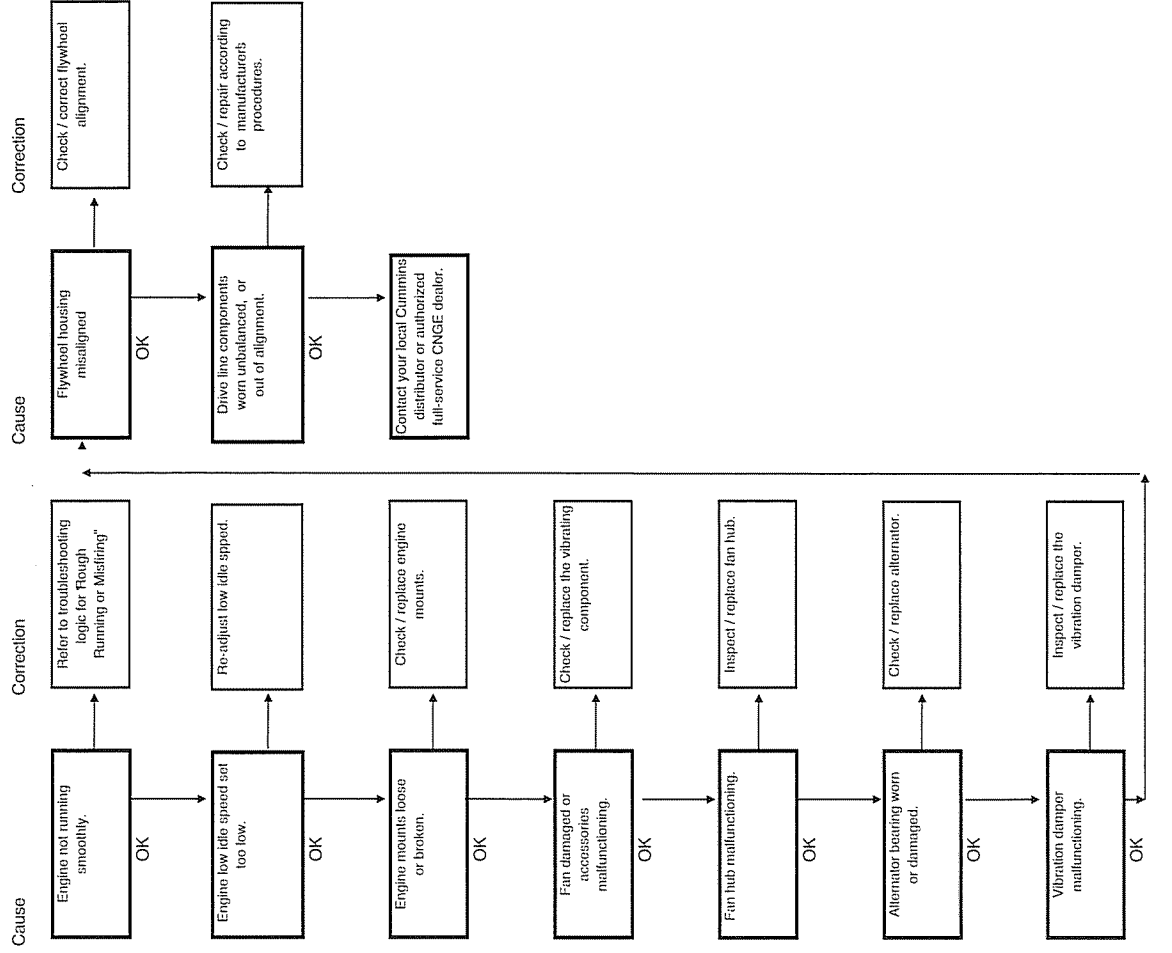
Coolant Temperature Above Normal



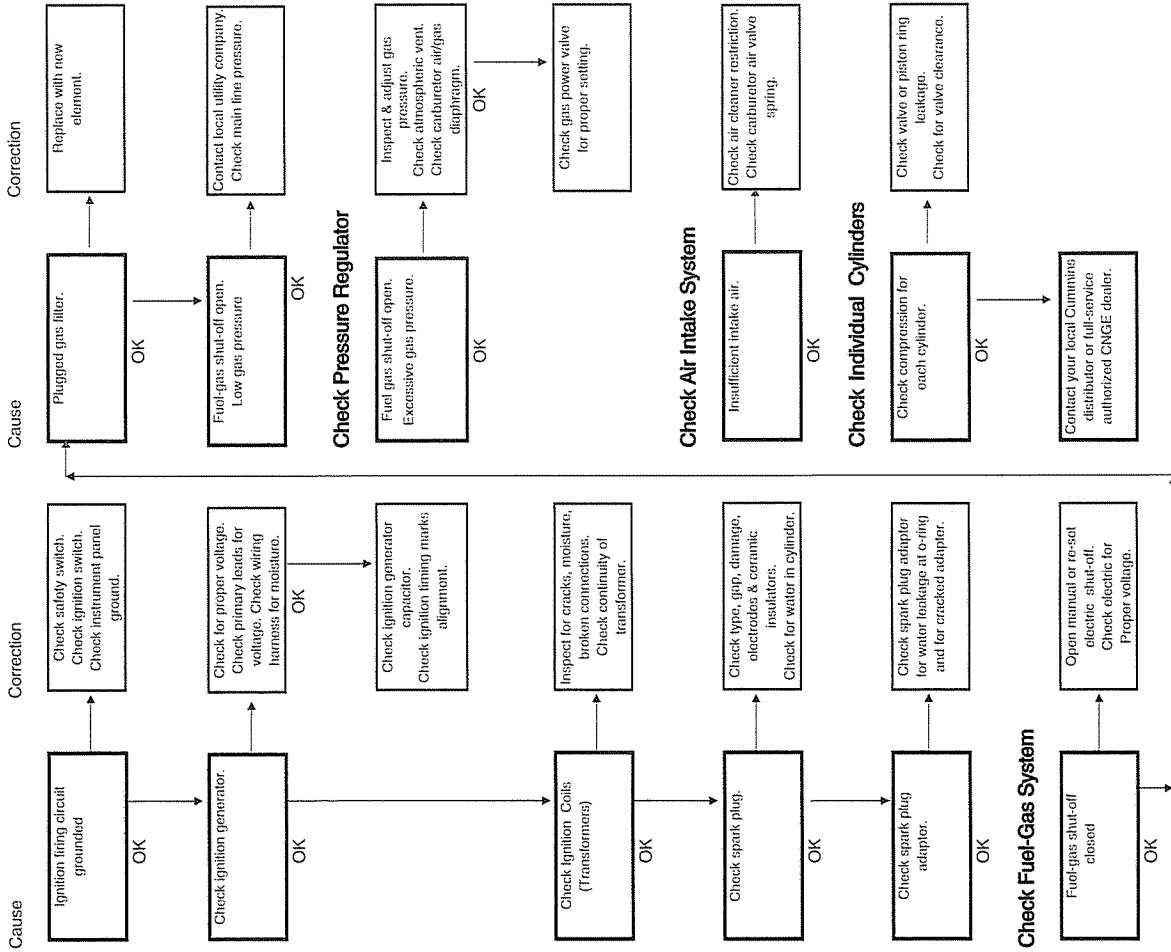
Coolant Temperature Below Normal



Engine Vibration Excessive

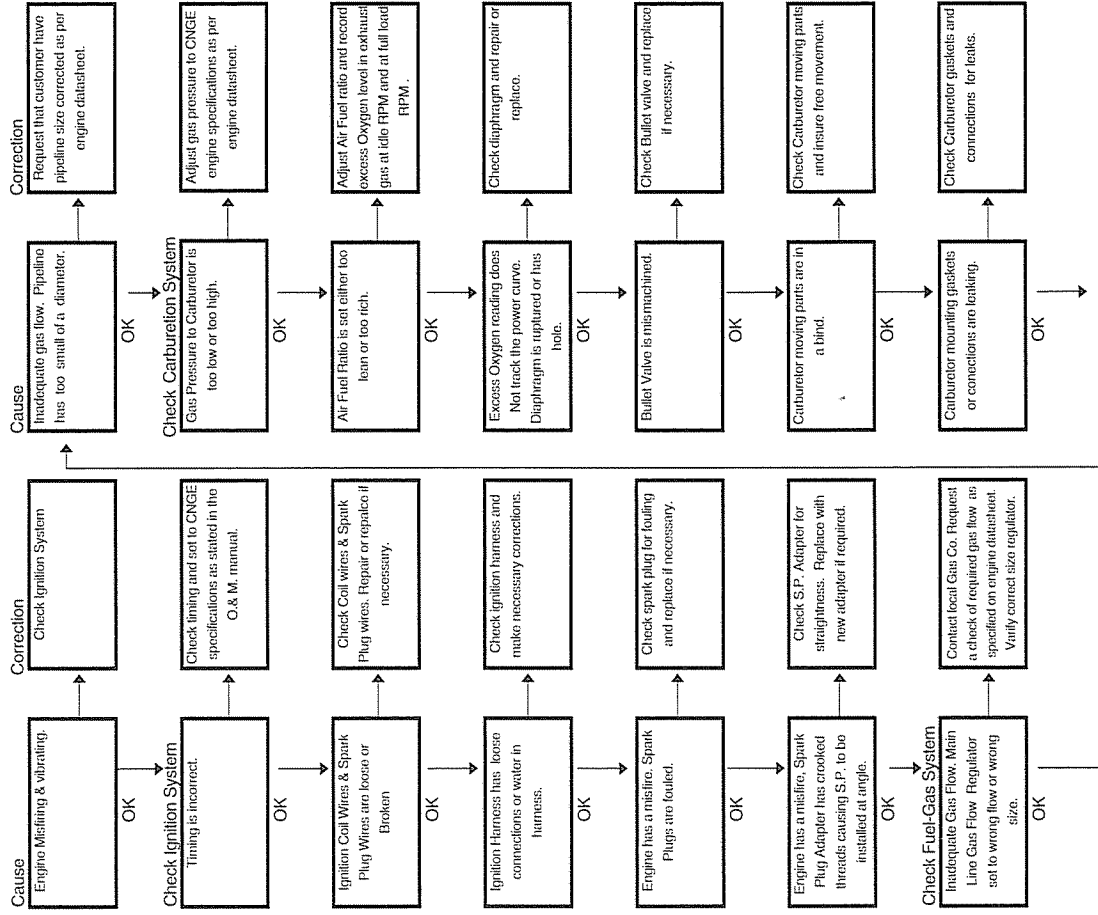


Check Ignition System



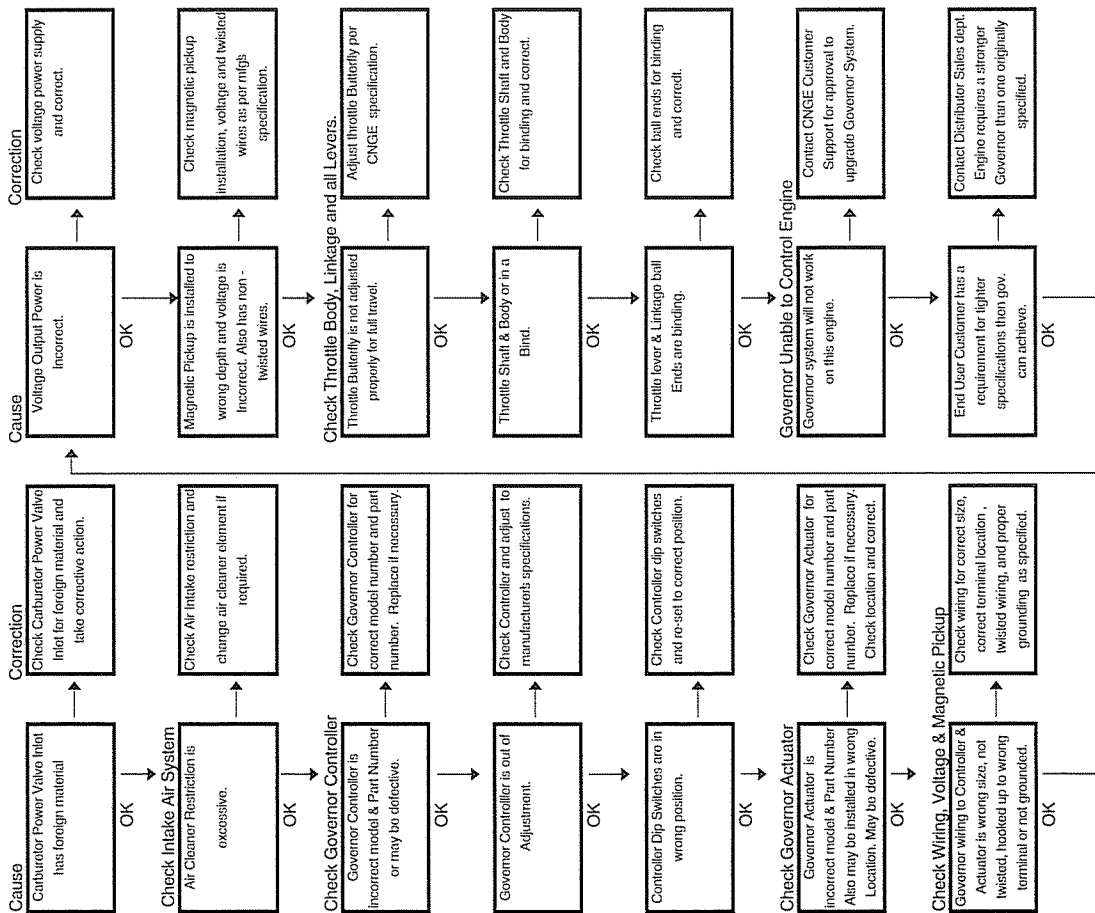
Governor Instability

Governor - Unstable - Engine Surges Fuel System - Dry Processed Natural Gas



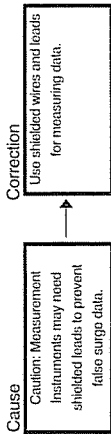
Governor Instability

Fuel System - Dry Processed Natural Gas



Governor Instability

Fuel System - Dry Processed Natural Gas



OK

If you are unable to resolve this problem, then contact the Customer Support department for Technical Assistance.

Note: On older engines the Turbo boost Limiter may need to be moved out of the governor range so that it does not interfere with Governor operation.

Caution: In some cases the generator voltage regulator may have to be adjusted first before the engine governor error can be adjusted. Refer to the generator voltage regulator manufacturer's literature for proper adjustment procedures.

Section 10

Component Manufacturers

Note: The following list contains addresses and telephone numbers of suppliers of accessories used on Cummins Natural Gas Engines, Inc. engines. Suppliers may be contacted directly for any specifications not covered in this manual.

Air Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone - (931) 526-9551
Telephone - (800) 223-4583
FAX - (800) 999-8664

Air Starting Motors

Ingersoll-Rand Engine
Starting Systems
888 Industrial Drive
Elmhurst, IL 60126
Telephone - (615) 672-7664
FAX - (615) 672-0805

Air-Gas Starting Motors

Ingersoll-Rand Engine
Starting Systems
888 Industrial Drive
Elmhurst, IL 60126
Telephone - (615) 672-7664
FAX - (615) 672-0805

Alternators

Delco-Remy
P.O. Box 2439
Anderson, IN 46018
Telephone - (765) 778-6588
FAX - (765) 778-6566

Robert Bosch Ltd.
P.O.Box 96
Broadway Park
North Orbital Road
Denham
Uxbridge
Middlesex
UD9 5H6
England
Telephone - (01895) 833633

Auxiliary Water Pumps

Crane Deming
TP Pump
Telephone - (505) 247-4036
Fax - (505) 243-0308

Belts

Dayco Mfg.
Belt Tech. Center
1955 Enterprise
Rochester Hills, MI 48309
Telephone - (800) 848-7902
FAX - (704) 452-9777

Carburetors

Impco Technologies Inc.
16804 Gridley Place
Cerritos, CA. 90701
Telephone - (562) 860-6666
FAX - (562) 860-3088

Coolant Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone - (800) 223-4583
FAX - (800) 999-8664

Kim Hotstart, Inc.
E. 5724 Broadway
Spokane, WA. 99212
Telephone - (509) 534-6171
FAX - (800) 224-5550

Electric Starting Motors

Delco-Remy
P.O.BOX 2439
Anderson, IN 46018
Telephone - (765)778-6588
FAX - (765) 778-6566

Fans

Hayes-Albion
1999 Wildwood Avenue
Jackson, MI 49202
Telephone - (517) 782-9421

Brookside
P.O. Box 30
McCordsville, IN 46055
Telephone - (317) 335-2014

Filters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone - (800)223-4583
FAX - (800) 999-8664

Gas Regulators

Fisher Mfg.
Silver Star Supply
14004 Canyon Dr.
Amarillo, TX 79110
Telephone - (806) 622-2166
FAX - (806) 622-2057

Maxitrol Co.
P.O.Box 2230
Southfield, MI 48037
Telephone - (248) 356-1400
FAX - (248) 356-0829

Gauges

Frank W. Murphy Mfg.
P.O.Box 470248
Tulsa, OK 74147
Telephone - (918) 627-3550
FAX - (918) 664-6146

The Nasson Co.
P.O.Box 505
West Union, SC 29696
Telephone - (864) 638-9521
FAX - (864) 838-7903

Governors

Woodward Governor Co.
1000 E. Drake Road
P.O.Box 1519
Fort Collins, CO 80522
Telephone - (970) 498-3539
FAX - (970) 498-3086

Barber Colman Co.
1354 Clifford Ave.
Rochford, IL 61132
Telephone - (815) 877-0241
FAX - (815) 877-0150

Heat Exchangers

Modine Mfg. Co.
1500 DeKoven Ave.
Racine, WI 53401
Telephone - (414) 636-1200
FAX - (414) 636-1424

Young Radiator Co.
2825 4 Mile Road
Racine, WI 53404
Telephone - (414) 639-1011
FAX - (414) 639-1013

Ignition Systems

Altronic, Inc.
1200 Stambaugh Bldg
Youngston, OH 44501
Telephone - (330) 545-9768
FAX - (330) 545-4446

Fairbanks Morse
Engine and Accessory Operations
6402 Rockton Road
Bosco, IL 61073
Telephone - (815) 389-4906
FAX - (815) 389-1770

Oil & Coolant Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone - (800) 223-4583
FAX - (800) 999-8664

Kim Hotstart Co.
West 917 Broadway
Spokane, WA 99210
Telephone - (509) 534-6171
FAX - (800) 224-5550

Radiators

GTI
General Thermodynamics Inc.
190 W. Marquette Ave.
Oak Creek, WI 53154
Telephone - (414) 764-5600
FAX - (414) 764-5630

Radiator Specialties
P.O.Box 28698
Sacramento, CA 95828
Telephone - (916) 381-4790
FAX - (916) 381-8943

G. & O.
160 Gando Drive
New Haven, CT 06513
Telephone - (203) 562-5121
FAX - (203) 789-8760

Spark Plugs

Champion Spark Plug Co.
910 Upton Ave.
Toledo, OH 43607
Telephone - (419) 535-2458

Stitt Spark Plug Co.
P.O.Box 327
Conroe, TX 77305
Telephone - (409) 756-7796
FAX - (409) 539-9762

Shut -Off Valves

Automatic Switch Co.
P.O.Box 13681
Newark, NJ 07188
Telephone - (714) 937-0811
FAX - (714) 937-1390

L.P.Gas & Equipment Co.
3216 S. Nordic Road
Arlington Heights, IL 60005
Telephone - (708) 437-2345

Tachometers

Altronic, Inc.
1200 Stambaugh Bldg.
Youngston, Ohio 44501
Telephone - (330) 545-9768
FAX - (330) 545-4446

Section 11

Service Assistance

Service Assistance

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 800-343-7357. In Alaska, Hawaii, and Canada, call collect 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 been 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 number of hours of operation.
- E. Nature of problem.
- F. Summary of the current problem arranged in the order of occurrence.

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

Representatives for the following regions are located at CNGE Headquarter Office in Fort Worth, TX, 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, TX 76180
Telephone (817) 581-7575
Fax: (817) 581-4548

Cummins Natural Gas Engines, Inc
Parts Distribution Center
409 South Norris Street
Clovis, NM 88109
Telephone: (505) 769-2173
Fax: (505) 762-4203

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