Application for Air Construction Permit for the

Replacement of Four Existing Diesel Fueled Engine Driven Pumps and Generator

Alexander Orr, Jr. Water Treatment Plant Miami, Florida

Miami-Dade Water and Sewer Department

April 2002

Background Photo Courtesy of the National Weather Service

MIAMI-DADE WATER AND SEWER DEPARTMENT
4200 Salzedo Street, Coral Gables, Florida 33146 • Tel: 305-669-3700 • Fax: 669-3788

SERVE • CONSERVE

May 3, 2002

Certified Mail: 7001 0360 0001 6782 7899
Return Receipt

Mr. Alvaro Linero, P.E.
Administrator
New Source Review Section
Florida Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, FL 32399-2400

Subject: Application for Air Construction Permit for Three Natural Gas Fueled Engine Driven Pump Sets and One Diesel Fueled Engine Driven Standby Generator at the Alexander Orr, Jr. Water Treatment Plant, Miami, Florida - Facility ID No. 0250314

Dear Mr. Linero:

Enclosed, please find an application to obtain an air construction permit for the replacement of five diesel fueled engine driven pump sets with three natural gas fueled engine driven pump sets and one diesel fueled standby generator at the subject facility. The facility is operating under permit numbers 0250314-001-AC, PSD-FL-249. This application replaces the proposed construction previously permitted under DEP File No. 0250314-003-AC and includes:

1) One (1) signed and sealed filled application.
2) Three (3) additional signed and sealed signature pages.
3) Four (4) copies of the application in an electronic format.

As the designated Responsible Official of this facility, I certify this application to be true, accurate, and complete based upon information and belief formed after reasonable inquiry. Please contact me at (786) 552-8112 or Mr. Richard M. O'Rourke, P.E. at (786) 552-8123 if there are any questions regarding this submittal.

Sincerely,

Jorge S. Rodriguez, P.E.
Assistant Director Water

JSR/BMG/RMO/ro

c: Gracy Danois, EPA Region 4 (w/o encl.)
Tom Tittle, FDEP/SED
Mallika Muthiah, M-D/DERM (w/o encl.)
Gregory F. Galmin, Poole & Kent

L0225dep.doc

RECEIVED
MAY 13 2002
BUREAU OF AIR REGULATION

FLORIDA

Department of
Environmental Protection

Division of Air Resources Management

APPLICATION FOR AIR PERMIT - TITLE V SOURCE

See Instructions for Form No. 62-210.900(1)

I. APPLICATION INFORMATION

Identification of Facility

1. Facility Owner/Company Name: Miami-Dade Water and Sewer Department	
2. Site Name: Alexander Orr. Jr. Water Treatment Plant	
3. Facility Identification Number: 0250314 [ ] Unknown	
4. Facility Location: Street Address or Other Locator: 6800 S.W. 87th Avenue City: Miami County: Miami Dade Zip Code: 33133-0316	
5. Relocatable Facility? [ ] Yes [X] No	6. Existing Permitted Facility? [X] Yes [ ] No

Application Contact

1. Name and Title of Application Contact: Richard M. O'Rourke, P.E.
2. Application Contact Mailing Address: Organization/Firm: Miami-Dade Water & Sewer Street Address: P. O. Box 330316, 3071 SW 38th Avenue City: Miami State: FL Zip Code: 33233-0316
3. Application Contact Telephone Numbers: Telephone: (786) 552 - 8123 Fax: (786) 552 - 8640

Application Processing Information (DEP Use)

1. Date of Receipt of Application:	5/13/02
2. Permit Number:	0250314-005-AC
3. PSD Number (if applicable):	
4. Siting Number (if applicable):	

Purpose of Application

Air Operation Permit Application

This Application for Air Permit is submitted to obtain: (Check one)

[ ] Initial Title V air operation permit for an existing facility which is classified as a Title V source.

[ ] Initial Title V air operation permit for a facility which, upon start up of one or more newly constructed or modified emissions units addressed in this application, would become classified as a Title V source.

Current construction permit number: ____________________

[ ] Title V air operation permit revision to address one or more newly constructed or modified emissions units addressed in this application.

Current construction permit number: ____________________

Operation permit number to be revised: ____________________

[X] Title V air operation permit revision or administrative correction to address one or more proposed new or modified emissions units and to be processed concurrently with the air construction permit application. (Also check Air Construction Permit Application below.)

Operation permit number to be revised/corrected: 0250314-001-AV

[ ] Title V air operation permit revision for reasons other than construction or modification of an emissions unit.

Operation permit number to be revised:

Reason for revision:

Air Construction Permit Application

This Application for Air Permit is submitted to obtain: (Check one)

[X] Air construction permit to construct or modify one or more emissions units.

[ ] Air construction permit to make federally enforceable an assumed restriction on the potential emissions of one or more existing, permitted emissions units.

[ ] Air construction permit for one or more existing, but unpermitted, emissions units.

Owner/Authorized Representative or Responsible Official

1.	Name and Title of Owner/Authorized Representative or Responsible Official: Jorge S. Rodriguez, P.E., Assistant Director - Water
2.	Owner/Authorized Representative or Responsible Official Mailing Address: Organization/Firm: Miami-Dade Water and Sewer Department Street Address: 3071 SW 38th Avenue City: Miami State: FL Zip Code: 33146-1520
3.	Owner/Authorized Representative or Responsible Official Telephone Numbers: Telephone: (786) 552 - 8112 Fax: (786) 552 - 8626
4.	Owner/Authorized Representative or Responsible Official Statement: *I, the undersigned, am the owner or authorized representative*(check here [X], if so) or the responsible official (check here [X], if so) of the Title V source addressed in this application, whichever is applicable. I hereby certify, based on information and belief formed after reasonable inquiry, that the statements made in this application are true, accurate and complete and that, to the best of my knowledge, any estimates of emissions reported in this application are based upon reasonable techniques for calculating emissions. The air pollutant emissions units and air pollution control equipment described in this application will be operated and maintained so as to comply with all applicable standards for control of air pollutant emissions found in the statutes of the State of Florida and rules of the Department of Environmental Protection and revisions thereof. I understand that a permit, if granted by the Department, cannot be transferred without authorization from the Department, and I will promptly notify the Department upon sale or legal transfer of any permitted emissions unit.* Signature ____________ Date 5/3/02

* Attach letter of authorization if not currently on file.

Professional Engineer Certification

1.	Professional Engineer Name: Richard M. O'Rourke, P.E. Registration Number: 42683
2.	Professional Engineer Mailing Address: Organization/Firm: Miami-Dade Water & Sewer Street Address: 3071 SW 38th Avenue City: Miami State: FL Zip Code: 33146-1520
3.	Professional Engineer Telephone Numbers: Telephone: (786) 552 - 8123 Fax: (786) 552 - 8640

4. Professional Engineer Statement:

I, the undersigned, hereby certify, except as particularly noted herein, that:*

(1) To the best of my knowledge, there is reasonable assurance that the air pollutant emissions unit(s) and the air pollution control equipment described in this Application for Air Permit, when properly operated and maintained, will comply with all applicable standards for control of air pollutant emissions found in the Florida Statutes and rules of the Department of Environmental Protection; and

(2) To the best of my knowledge, any emission estimates reported or relied on in this application are true, accurate, and complete and are either based upon reasonable techniques available for calculating emissions or, for emission estimates of hazardous air pollutants not regulated for an emissions unit addressed in this application, based solely upon the materials, information and calculations submitted with this application.

If the purpose of this application is to obtain a Title V source air operation permit (check here [ ], if so), I further certify that each emissions unit described in this Application for Air Permit, when properly operated and maintained, will comply with the applicable requirements identified in this application to which the unit is subject, except those emissions units for which a compliance schedule is submitted with this application.

If the purpose of this application is to obtain an air construction permit for one or more proposed new or modified emissions units (check here [X], if so), I further certify that the engineering features of each such emissions unit described in this application have been designed or examined by me or individuals under my direct supervision and found to be in conformity with sound engineering principles applicable to the control of emissions of the air pollutants characterized in this application.

If the purpose of this application is to obtain an initial air operation permit or operation permit revision for one or more newly constructed or modified emissions units (check here [X], if so), I further certify that, with the exception of any changes detailed as part of this application, each such emissions unit has been constructed or modified in substantial accordance with the information given in the corresponding application for air construction permit and with all provisions contained in such permit.

[signature] 42683 — Signature

29 APRIL 2002 — Date

(seal)

* Attach any exception to certification statement.

Owner/Authorized Representative or Responsible Official

1.	Name and Title of Owner/Authorized Representative or Responsible Official: Jorge S. Rodriguez, P.E., Assistant Director - Water
2.	Owner/Authorized Representative or Responsible Official Mailing Address: Organization/Firm: Miami-Dade Water and Sewer Department Street Address: 3071 SW 38th Avenue City: Miami State: FL Zip Code: 33146-1520
3.	Owner/Authorized Representative or Responsible Official Telephone Numbers: Telephone: (786) 552 - 8112 Fax: (786) 552 - 8626
4.	Owner/Authorized Representative or Responsible Official Statement: *I, the undersigned, am the owner or authorized representative*(check here [X], if so) or the responsible official (check here [X], if so) of the Title V source addressed in this application, whichever is applicable. I hereby certify, based on information and belief formed after reasonable inquiry, that the statements made in this application are true, accurate and complete and that, to the best of my knowledge, any estimates of emissions reported in this application are based upon reasonable techniques for calculating emissions. The air pollutant emissions units and air pollution control equipment described in this application will be operated and maintained so as to comply with all applicable standards for control of air pollutant emissions found in the statutes of the State of Florida and rules of the Department of Environmental Protection and revisions thereof. I understand that a permit, if granted by the Department, cannot be transferred without authorization from the Department, and I will promptly notify the Department upon sale or legal transfer of any permitted emissions unit.* Signature: [signature] Date: 5/3/12

* Attach letter of authorization if not currently on file.

Professional Engineer Certification

1.	Professional Engineer Name: Richard M. O'Rourke, P.E. Registration Number: 42683
2.	Professional Engineer Mailing Address: Organization/Firm: Miami-Dade Water & Sewer Street Address: 3071 SW 38th Avenue City: Miami State: FL Zip Code: 33146-1520
3.	Professional Engineer Telephone Numbers: Telephone: (786) 552 - 8123 Fax: (786) 552 - 8640

4. Professional Engineer Statement:

I, the undersigned, hereby certify, except as particularly noted herein, that:*

(1) To the best of my knowledge, there is reasonable assurance that the air pollutant emissions unit(s) and the air pollution control equipment described in this Application for Air Permit, when properly operated and maintained, will comply with all applicable standards for control of air pollutant emissions found in the Florida Statutes and rules of the Department of Environmental Protection; and

(2) To the best of my knowledge, any emission estimates reported or relied on in this application are true, accurate, and complete and are either based upon reasonable techniques available for calculating emissions or, for emission estimates of hazardous air pollutants not regulated for an emissions unit addressed in this application, based solely upon the materials, information and calculations submitted with this application.

If the purpose of this application is to obtain a Title V source air operation permit (check here [ ], if so), I further certify that each emissions unit described in this Application for Air Permit, when properly operated and maintained, will comply with the applicable requirements identified in this application to which the unit is subject, except those emissions units for which a compliance schedule is submitted with this application.

If the purpose of this application is to obtain an air construction permit for one or more proposed new or modified emissions units (check here [X], if so), I further certify that the engineering features of each such emissions unit described in this application have been designed or examined by me or individuals under my direct supervision and found to be in conformity with sound engineering principles applicable to the control of emissions of the air pollutants characterized in this application.

If the purpose of this application is to obtain an initial air operation permit or operation permit revision for one or more newly constructed or modified emissions units (check here [X], if so), I further certify that, with the exception of any changes detailed as part of this application, each such emissions unit has been constructed or modified in substantial accordance with the information given in the corresponding application for air construction permit and with all provisions contained in such permit.

[signature] 29 APRIL 2002

Signature 42683 Date

(seal)

* Attach any exception to certification statement.

Scope of Application

Emissions Unit ID	Description of Emissions Unit	Permit Type	Processing Fee
1	Pump Engine Nos. 3, 4 (Natural Gas)	ACM1	$ 0.00
2	Pump Engine No. 5 (Natural Gas)	ACM1	$ 0.00
3	Pump Room Emergency Generator	ACM1	$ 0.00

Application Processing Fee

Check one: [ ] Attached - Amount: $________________ [X] Not Applicable

Construction/Modification Information

1. Description of Proposed Project or Alterations: This application replaces the proposed construction previously permitted under DEP File No. 0250314-003-AC. This application is for a new construction permit to remove and replace existing diesel fueled engine driven pumps and generator nos. 1, 2, 3, 4, & 5. Natural gas fueled engine driven pumps No.3 (810 bhp), No.4 (810 bhp) & No. 5 (2225 bhp) are proposed as replacements. The two (2) 810 bhp engines are proposed as a single, collectively regulated emissions unit. The 2225 bhp engine is proposed in this application as a single regulated emissions unit. A 1332 bhp (1220 bhp continuous) diesel fueled engine driven 900 KW (810KW continuous) generator set is proposed to replace the 750 KW emergency generator that engine no. 1 also drove.
2. Projected or Actual Date of Commencement of Construction: 3/1/2000
3. Projected Date of Completion of Construction: 12/31/2002

Application Comment

This application replaces the proposed construction previously permitted under DEP File No. 0250314-003-AC. The purpose of this application is to obtain construction permits to remove existing pumps & engines no. 1 and 2, replacing the (pump/generator) capacity of engine no. 1 with a diesel fueled engine driven emergency generator set and to replace existing diesel fueled engine driven pump nos. 3, 4 & 5 with three natural gas fueled engine driven pumps.

The existing units operate without restrictions. A two-year period from April 1998 to March 2000 was used to calculate the existing emissions because it was the last period in which all units (except no. 2 out of service) were operated.

The replacement emergency generator has the potential to emit over 160 tons of NOx annually when operated continuously, however this application proposes to restrict operation to only 500 hours or 33,250 gallons of fuel annually. A comparison of past actual emissions to proposed emissions with the proposed operational restrictions result in a net annual increase of 15.27 ton of NOx, 66.23 tons of CO, 0.07 tons of PM, 4.37 tons of PM10, 0.15 tons of SOx and 11.66 tons of VOC.

Information included in this construction permit application should be assimilated into the existing Title V operating permit

II. FACILITY INFORMATION

A. GENERAL FACILITY INFORMATION

Facility Location and Type

1. Facility UTM Coordinates: Zone: 17	East (km): 566.60	North (km): 2843.50	
2. Facility Latitude/Longitude: Latitude (DD/MM/SS): 25 / 42 / 30		Longitude (DD/MM/SS): 80 / 20 / 10	
3. Governmental Facility Code: 3	4. Facility Status Code: A	5. Facility Major Group SIC Code: 49	6. Facility SIC(s): 4941

7. Facility Comment (limit to 500 characters):

Facility treats up to 241.7 million gallons a day & up to 74,136 MG annually of raw water using a lime softening, filtration, recarbonation & disinfection for public water supply. Six standby generators provide standby electrical power required by the FDOH. for continuous plant operations. Engines driven pump sets are used to maintain pressure & convey water. A rotary kiln recovers the water softening process solids for conversion back in to quick lime for process reuse on site.

Facility Contact

1. Name and Title of Facility Contact:
   Tom Segars, Superintendent of Water Production
2. Facility Contact Mailing Address:
   Organization/Firm: Miami-Dade Water and Sewer Department
   Street Address: 700 W. Second Ave.
   City: Hialeah State: FL Zip Code: 33010-0006
3. Facility Contact Telephone Numbers:
   Telephone: (305) 888 - 2522 Fax: (305) 889 - 0156

Facility Regulatory Classifications

Check all that apply:

1. [ ] Small Business Stationary Source?	[ ] Unknown
2. [X] Major Source of Pollutants Other than Hazardous Air Pollutants (HAPs)?	
3. [ ] Synthetic Minor Source of Pollutants Other than HAPs?	
4. [ ] Major Source of Hazardous Air Pollutants (HAPs)?	
5. [ ] Synthetic Minor Source of HAPs?	
6. [ ] One or More Emissions Units Subject to NSPS?	
7. [ ] One or More Emission Units Subject to NESHAP?	
8. [X] Title V Source by EPA Designation?	
9. Facility Regulatory Classifications Comment (limit to 200 characters): Facility is a Publicly Owned Water Treatment and Water Supply Facility. This facility treats ground water using lime softening, filtration, recarbonation & disinfection for public water supply. The facility is a Title V source of regulated air pollutants other than hazardous air pollutants.	

List of Applicable Regulations

Chapter 62-204.240, FAC: "Ambient Air Quality Standards"	
62-296.320, FAC: "General Pollutant Emissions Limiting Standards"	
Title V Core List except: 40 CFR 61; 40 CFR 82; 62-256, 62-257, 62-281, 62-296.320	

B. FACILITY POLLUTANTS

List of Pollutants Emitted

1. Pollutant Emitted	2. Pollutant Classif.	3. Requested Emissions Cap lb/hour	tons/year	4. Basis for Emissions Cap	5. Pollutant Comment
NOX	A				No Facility Cap Requested
CO	SM				No Facility Cap Requested
PM	B				No Facility Cap Requested
SO2	SM				No Facility Cap Requested

C. FACILITY SUPPLEMENTAL INFORMATION

Supplemental Requirements

1. Area Map Showing Facility Location: [X] Attached, Document ID: A01 [ ] Not Applicable [ ] Waiver Requested
2. Facility Plot Plan: [X] Attached, Document ID: A02 [ ] Not Applicable [ ] Waiver Requested
3. Process Flow Diagram(s): [ ] Attached, Document ID: ______ [X] Not Applicable [ ] Waiver Requested
4. Precautions to Prevent Emissions of Unconfined Particulate Matter: [ ] Attached, Document ID: ______ [X] Not Applicable [ ] Waiver Requested
5. Fugitive Emissions Identification: [ ] Attached, Document ID: ______ [X] Not Applicable [ ] Waiver Requested
6. Supplemental Information for Construction Permit Application: [X] Attached, Document ID: A03 [ ] Not Applicable
7. Supplemental Requirements Comment: The Alexander Orr, Jr. WTP is a major source of air pollution and has a Title V operating permit no. 0250314-001-AV. (Chapter 62-213, FAC). This application replaces the previously proposed construction permitted under DEP File No. 0250314-003-AC. This application requests a construction permit to replace existing sources. General Preconstruction Review applies to the new construction (Chapter 62-212.300, FAC).

Additional Supplemental Requirements for Title V Air Operation Permit Applications

8. List of Proposed Insignificant Activities: [ ] Attached, Document ID:_______ [X] Not Applicable
9. List of Equipment/Activities Regulated under Title VI: [ ] Attached, Document ID:_______ [ ] Equipment/Activities On site but Not Required to be Individually Listed [X] Not Applicable
10. Alternative Methods of Operation: [ ] Attached, Document ID:_______ [X] Not Applicable
11. Alternative Modes of Operation (Emissions Trading): [ ] Attached, Document ID:_______ [X] Not Applicable
12. Identification of Additional Applicable Requirements: [ ] Attached, Document ID:_______ [X] Not Applicable
13. Risk Management Plan Verification: [X] Plan previously submitted to Chemical Emergency Preparedness and Prevention Office (CEPPO). Verification of submittal attached (Document ID: 7519) or previously submitted to DEP (Date and DEP Office:____________________) [ ] Plan to be submitted to CEPPO (Date required:____________________) [ ] Not Applicable
14. Compliance Report and Plan: [ ] Attached, Document ID:_______ [X] Not Applicable
15. Compliance Certification (Hard-copy Required): [ ] Attached, Document ID:_______ [X] Not Applicable

III. EMISSIONS UNIT INFORMATION

A separate Emissions Unit Information Section (including subsections A through J as required) must be completed for each emissions unit addressed in this Application for Air Permit. If submitting the application form in hard copy, indicate, in the space provided at the top of each page, the number of this Emissions Unit Information Section and the total number of Emissions Unit Information Sections submitted as part of this application.

A. GENERAL EMISSIONS UNIT INFORMATION
(All Emissions Units)

Emissions Unit Description and Status

1. Type of Emissions Unit Addressed in This Section: (Check one)

[ ] This Emissions Unit Information Section addresses, as a single emissions unit, a single process or production unit, or activity, which produces one or more air pollutants and which has at least one definable emission point (stack or vent).

[X] This Emissions Unit Information Section addresses, as a single emissions unit, a group of process or production units and activities which has at least one definable emission point (stack or vent) but may also produce fugitive emissions.

[ ] This Emissions Unit Information Section addresses, as a single emissions unit, one or more process or production units and activities which produce fugitive emissions only.

2. Regulated or Unregulated Emissions Unit? (Check one)

[ ] The emissions unit addressed in this Emissions Unit Information Section is a regulated emissions unit.

[X] The emissions unit addressed in this Emissions Unit Information Section is an unregulated emissions unit.

3. Description of Emissions Unit Addressed in This Section (limit to 60 characters):
Pump Engine Nos. 3, 4 (Natural Gas)

4. Emissions Unit Identification Number: [X] No ID
ID: [ ] ID Unknown

5. Emissions Unit Status Code:	6. Initial Startup Date:	7. Emissions Unit Major Group SIC Code:	8. Acid Rain Unit?
C		49	[N]

9. Emissions Unit Comment: (Limit to 500 Characters)
Pump engine nos. 2, 3 & 4 (E.U. ID Nos. 002-004) began service in August 1951 will be replaced by these new units. Permit 0250314-003-AC authorized replacement of these units with 738 bhp natural gas fired Waukesau Model 3521GL engines with a maximum heat input rate of 5.44 mmBtu/hr. This is to replace units with 810 bhp natural gas fired Caterpillar Model G3512 engines with a maximum heat input rate of 6.0 mmBtu/hr.

Emissions Unit Control Equipment

1. Control Equipment/Method Description (Limit to 200 characters per device or method):

NOx emission levels are controlled through the use of an electronic air/fuel ratio control to maintain lean combustion, electronic ignition system and a water-cooled aftercooler.

A lean (a higher air/fuel ratio) burn engine reduces thermal NOx formation in the combustion chambers because of air quenching. Caterpillar provides electronic engine controls that optimize engine operation by continually balancing power output, fuel economy and air/fuel ratio. These controls work to maintain lean combustion conditions, which result in the lowest emissions for NOx.

The Caterpillar Electronic Ignition System (EIS) system monitors engine operation and distributes power to the cylinder transformers, to provide the best engine performance at all engine speeds. It protects the engine from damage caused by detonation. EIS is capable of higher spark voltages, longer spark duration, and more precise timing control than a magneto system resulting in more complete and controlled combustion. The EIS package includes engine speed, timing, detonation, and intake manifold pressure sensors, and also an engine-mounted control module.

The water-cooled aftercooler reduces thermal NOx formation in the combustion chamber by cooling air prior to entering the combustion chamber.

PM emissions from natural gas fired engines are very low because natural gas is efficiently combusted and contains no ash. Combustion of natural gas under lean fuel conditions results in low PM and PM_{10} emissions.

2. Control Device or Method Code(s): 99

Emissions Unit Details

1. Package Unit: Manufacturer: Caterpillar	Model Number:	G3512 LE-130
2. Generator Nameplate Rating:	MW	
3. Incinerator Information:		
Dwell Temperature:		°F
Dwell Time:		seconds
Incinerator Afterburner Temperature:		°F

B. EMISSIONS UNIT CAPACITY INFORMATION
(Regulated Emissions Units Only)

Emissions Unit Operating Capacity and Schedule

1. Maximum Heat Input Rate:		105,120	mmBtu/yr
2. Maximum Incineration Rate:	lb/hr		tons/day
3. Maximum Process or Throughput Rate: Not Applicable			
4. Maximum Production Rate: Not Applicable			
5. Requested Maximum Operating Schedule:			
24	hours/day	7	days/week
52	weeks/year	8760	hours/year

6. Operating Capacity/Schedule Comment (limit to 200 characters):

Maximum Heat Input Rate is based on unrestricted operations for both units (17,520 hrs/yr)
7407 Btu/bhp-hr x 810 bhp x 1 mmBtu/100000 Btus x 2 (engines) x 8760 hrs/yr
= 105,120 mmBtu/yr.

C. EMISSIONS UNIT REGULATIONS
(Regulated Emissions Units Only)

List of Applicable Regulations

Chapter 62-4 Permits	
Rule 62-204.220 Ambient Air Quality Protection	
Rule 62-204.240 Ambient Air Quality Standards	
Rule 62-204.800 Federal Regulations Adopted by Reference	
Rule 62-210.200 Definitions	
Rule 62-210.300 Permits Required	
Rule 62-210.350 Public Notice and Comments	
Rule 62-210.370 Reports	
Rule 62-210.550 Stack Height Policy	
Rule 62-210.650 Circumvention	
Rule 62-210.700 Excess Emissions	
Rule 62-210.900 Forms and Instructions	
Rule 62-212.300 General Preconstruction Review Requirements	
Chapter 62-213 Operation Permits for Major Sources	
Rule 62-296.320 General Pollutant Emission Limiting Standards	

D. EMISSION POINT (STACK/VENT) INFORMATION
(Regulated Emissions Units Only)

Emission Point Description and Type

1. Identification of Point on Plot Plan or Flow Diagram? #3, #4 (G3512)	2. Emission Point Type Code: 3

3. Descriptions of Emission Points Comprising this Emissions Unit for VE Tracking (limit to 100 characters per point): # 3 CC, Pump Engine No. 3 (4th from north end): vertical stack outside building with silencer. # 4 CC, Pump Engine No. 4 (3rd from north end): vertical stack outside building with silencer.
4. ID Numbers or Descriptions of Emission Units with this Emission Point in Common: 003, 018, Unk – Pump Engine 3 004, 019, Unk – Pump Engine 4

5. Discharge Type Code: V	6. Stack Height: 32 feet	7. Exit Diameter: 1 feet
8. Exit Temperature: 801 °F	9. Actual Volumetric Flow Rate: 4260 acfm	10. Water Vapor: %

11. Maximum Dry Standard Flow Rate: dscfm	12. Nonstack Emission Point Height: feet

13. Emission Point UTM Coordinates:		
Zone: 17	East (km): 566.6	North (km): 2,843.5

14. Emission Point Comment (limit to 200 characters): Emission point is representative point of the two similar units

E. SEGMENT (PROCESS/FUEL) INFORMATION
(All Emissions Units)

Segment Description and Rate: Segment 1 of 1

1. Segment Description (Process/Fuel Type) (limit to 500 characters): Natural gas powered internal combustion engines (emissions related to thousand Cubic feet burned) Maximum hourly & annual fuel rates are based on brake specific fuel consumption of 7,407 BTU/bhp-hr. Annual fuel rate is for both units. Pump Engine Nos. 3 & 4 each consume 0.006348 MMCF/hr at rated capacity at 1050 MMBtu/MMScf.		
2. Source Classification Code (SCC): 1-02-006-02	3. SCC Units: Million Cubic Feet Burned (all gaseous fuels)	
4. Maximum Hourly Rate: 0.01143	5. Maximum Annual Rate: 100.11	6. Estimated Annual Activity Factor: 1.00
7. Maximum % Sulfur: 0.00	8. Maximum % Ash: 0.00	9. Million Btu per SCC Unit: 1,050
10. Segment Comment (limit to 200 characters): Maximum hourly rate of the two engines is 0.01143 MMscf/hr. The Maximum annual rate of two engines is based the hourly rate of 0.01143 MMscf/hr for 8760 hours or 100.11 MMscf/yr.		

Segment Description and Rate: Segment ___ of ___

1. Segment Description (Process/Fuel Type) (limit to 500 characters):		
2. Source Classification Code (SCC):	3. SCC Units:	
4. Maximum Hourly Rate:	5. Maximum Annual Rate:	6. Estimated Annual Activity Factor:
7. Maximum % Sulfur:	8. Maximum % Ash:	9. Million Btu per SCC Unit:
10. Segment Comment (limit to 200 characters):		

F. EMISSIONS UNIT POLLUTANTS
(All Emissions Units)

1. Pollutant Emitted	2. Primary Control Device Code	3. Secondary Control Device Code	4. Pollutant Regulatory Code
NOX	99		EL
PM			EL
CO			NS

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: NOX	2. Total Percent Efficiency of Control: 0.0
3. Potential Emissions: 7.14 lb/hour 31.3 tons/year	4. Synthetically Limited? [N]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: 2.0 g/bhp-hr Reference: Manufacturer	7. Emissions Method Code: 5
8. Calculation of Emissions (limit to 600 characters): Manufacturer Supplied NOx emissions: 2.0 g/bhp-hr NOx, each Hourly Emissions: (2 engine) x (810 bhp) x (2.0 g/bhp-hr NOx) x (1 lb/454 g) = 7.14 lbs/hr. Annual Emissions: (2 engines) x (810 bhp) x (2.0 g/bhp-hr NOx) x (1 lb/454 g) x (8,760 hr/yr) x (ton/2,000 lb) = 31.3 tpy	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters): Hourly and Annual emissions are for both units 3 and 4.	

Allowable Emissions Allowable Emissions 1 of 2

1. Basis for Allowable Emissions Code:	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units:	4. Equivalent Allowable Emissions: lb/hour tons/year
5. Method of Compliance (limit to 60 characters):	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): The emission unit is not subject to any unit specific emission limiting standard and considered "unregulated" for the purposes of Title V permitting.	

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: CO	2. Total Percent Efficiency of Control: 0.0
3. Potential Emissions: 6.42 lb/hour 31.3 tons/year	4. Synthetically Limited? [N]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ____ to ____ tons/year	
6. Emission Factor: 1.8 g/bhp-hr Reference: Manufacturer	7. Emissions Method Code: 5

8. Calculation of Emissions (limit to 600 characters):

Manufacturer Supplied NOx emissions: 1.8 g/bhp-hr CO, each
Hourly Emissions: (2 engine) x (810 bhp) x (1.8 g/bhp-hr) x (1 lb/454 g) = 6.42 lbs/hr.
Annual Emissions: (2 engines) x (810 bhp) x (1.8 g/bhp-hr) x (1 lb/454 g) x (8,760 hr/yr) x (ton/2,000 lb) = 28.12 tpy

9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters):
Hourly and Annual emissions are for both units 3 and 4.

Allowable Emissions Allowable Emissions 2 of 2

1. Basis for Allowable Emissions Code:	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units:	4. Equivalent Allowable Emissions: lb/hour tons/year

5. Method of Compliance (limit to 60 characters):

6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters):
The emission unit is not subject to any unit specific emission limiting standard and considered "unregulated" for the purposes of Title V permitting.

H. VISIBLE EMISSIONS INFORMATION
(Only Regulated Emissions Units Subject to a VE Limitation)

Visible Emissions Limitation: Visible Emissions Limitation 1 of 1

1. Visible Emissions Subtype: VE20	2. Basis for Allowable Opacity: [X] Rule [ ] Other
3. Requested Allowable Opacity: Normal Conditions: 20 % Exceptional Conditions: 40 % Maximum Period of Excess Opacity Allowed: 2 min/hour	
4. Method of Compliance: Perform Initial VE Compliance monitoring using EPA Method 9.	
5. Visible Emissions Comment (limit to 200 characters):	

I. CONTINUOUS MONITOR INFORMATION
(Only Regulated Emissions Units Subject to Continuous Monitoring)

Continuous Monitoring System: Continuous Monitor ____ of ____

1. Parameter Code:	2. Pollutant(s):
3. CMS Requirement:	[ ] Rule [ ] Other
4. Monitor Information: Manufacturer: Model Number:	Serial Number:
5. Installation Date:	6. Performance Specification Test Date:
7. Continuous Monitor Comment (limit to 200 characters):	

J. EMISSIONS UNIT SUPPLEMENTAL INFORMATION
(Regulated Emissions Units Only)

Supplemental Requirements

1. Process Flow Diagram [ ] Attached, Document ID:_______ [X] Not Applicable [ ] Waiver Requested
2. Fuel Analysis or Specification [X] Attached, Document ID: A04 [ ] Not Applicable [ ] Waiver Requested
3. Detailed Description of Control Equipment [ ] Attached, Document ID:_______ [X] Not Applicable [ ] Waiver Requested
4. Description of Stack Sampling Facilities [X] Attached, Document ID: A05 [ ] Not Applicable [ ] Waiver Requested
5. Compliance Test Report [ ] Attached, Document ID:_______ [ ] Previously submitted, Date:_______ [X] Not Applicable
6. Procedures for Startup and Shutdown [X] Attached, Document ID: A06 [ ] Not Applicable [ ] Waiver Requested
7. Operation and Maintenance Plan [ ] Attached, Document ID:_______ [X] Not Applicable [ ] Waiver Requested
8. Supplemental Information for Construction Permit Application [X] Attached, Document ID: A07 [ ] Not Applicable
9. Other Information Required by Rule or Statute [ ] Attached, Document ID:_______ [X] Not Applicable
10. Supplemental Requirements Comment:

Additional Supplemental Requirements for Title V Air Operation Permit Applications

11. Alternative Methods of Operation [ ] Attached, Document ID:_______ [X] Not Applicable
12. Alternative Modes of Operation (Emissions Trading) [ ] Attached, Document ID:_______ [X] Not Applicable
13. Identification of Additional Applicable Requirements [ ] Attached, Document ID:_______ [X] Not Applicable
14. Compliance Assurance Monitoring Plan [ ] Attached, Document ID:_______ [X] Not Applicable
15. Acid Rain Part Application (Hard-copy Required) [ ] Acid Rain Part - Phase II (Form No. 62-210.900(1)(a)) Attached, Document ID:_______ [ ] Repowering Extension Plan (Form No. 62-210.900(1)(a)1.) Attached, Document ID:_______ [ ] New Unit Exemption (Form No. 62-210.900(1)(a)2.) Attached, Document ID:_______ [ ] Retired Unit Exemption (Form No. 62-210.900(1)(a)3.) Attached, Document ID:_______ [ ] Phase II NOx Compliance Plan (Form No. 62-210.900(1)(a)4.) Attached, Document ID:_______ [ ] Phase NOx Averaging Plan (Form No. 62-210.900(1)(a)5.) Attached, Document ID:_______ [X] Not Applicable

III. EMISSIONS UNIT INFORMATION

A separate Emissions Unit Information Section (including subsections A through J as required) must be completed for each emissions unit addressed in this Application for Air Permit. If submitting the application form in hard copy, indicate, in the space provided at the top of each page, the number of this Emissions Unit Information Section and the total number of Emissions Unit Information Sections submitted as part of this application.

A. GENERAL EMISSIONS UNIT INFORMATION
(All Emissions Units)

Emissions Unit Description and Status

1. Type of Emissions Unit Addressed in This Section: (Check one)

[X] This Emissions Unit Information Section addresses, as a single emissions unit, a single process or production unit, or activity, which produces one or more air pollutants and which has at least one definable emission point (stack or vent).

[ ] This Emissions Unit Information Section addresses, as a single emissions unit, a group of process or production units and activities which has at least one definable emission point (stack or vent) but may also produce fugitive emissions.

[ ] This Emissions Unit Information Section addresses, as a single emissions unit, one or more process or production units and activities which produce fugitive emissions only.

2. Regulated or Unregulated Emissions Unit? (Check one)

[X] The emissions unit addressed in this Emissions Unit Information Section is a regulated emissions unit.

[ ] The emissions unit addressed in this Emissions Unit Information Section is an unregulated emissions unit.

3. Description of Emissions Unit Addressed in This Section (limit to 60 characters):
Pump Engine No. 5 (Natural Gas)

4. Emissions Unit Identification Number:
ID:

[ ] No ID
[X] ID Unknown

5. Emissions Unit Status Code:	6. Initial Startup Date:	7. Emissions Unit Major Group SIC Code:	8. Acid Rain Unit?
C		49	[ ]

9. Emissions Unit Comment: (Limit to 500 Characters)
Pump engine no. 5 (E.U. ID Nos. 005) began service in August 1951 will be replaced by this new unit. Permit 0250314-003-AC authorized the replacement of this unit with a 2090 bhp natural gas fired Waukesau Model SL-AT27GL engine with a maximum heat input rate of 13.70 mmBtu/hr as (E.U. ID No. 020). This is to replace unit with 2225 bhp natural gas fired Caterpillar Model G3808LE engine with a heat input rate of 15.15 mmBtu/hr.

Emissions Unit Control Equipment

1. Control Equipment/Method Description (Limit to 200 characters per device or method):
NOx emission levels are controlled through the use of an electronic air/fuel ratio control to maintain lean combustion, pre-combustion chamber, electronic ignition system and a water-cooled aftercooler. A lean (a higher air/fuel ratio) burn engine reduces thermal NOx formation in the combustion chambers because of air quenching. Caterpillar provides electronic engine controls that optimize engine operation by continually balancing power output, fuel economy and air/fuel ratio. These controls work to maintain lean combustion conditions, which result in the lowest emissions for NOx. A pre-combustion chamber allows for an appropriate air/fuel mixture for proper spark ignition and combustion in pre-combustion chamber, and a leaner air/fuel mixture in the main combustion chamber, resulting in lower NOx emissions. The Caterpillar Electronic Ignition System (EIS) system monitors engine operation and distributes power to the cylinder transformers, to provide the best engine performance at all engine speeds. It protects the engine from damage caused by detonation. EIS is capable of higher spark voltages, longer spark duration, and more precise timing control than a magneto system resulting in more complete and controlled combustion. The EIS package includes engine speed, timing, detonation, and intake manifold pressure sensors, and also an engine-mounted control module. The water-cooled aftercooler reduces thermal NOx formation in the combustion chamber by cooling air prior to entering the combustion chamber. PM emissions from natural gas fired engines are very low because natural gas is efficiently combusted and contains no ash. Combustion of natural gas under lean fuel conditions results in low PM and PM_{10} emissions.
2. Control Device or Method Code(s): 99

Emissions Unit Details

1. Package Unit: Manufacturer: Caterpillar	Model Number: G3508 LE-130	
2. Generator Nameplate Rating:	MW	
3. Incinerator Information: Dwell Temperature: Dwell Time: Incinerator Afterburner Temperature:		°F seconds °F

B. EMISSIONS UNIT CAPACITY INFORMATION
(Regulated Emissions Units Only)

Emissions Unit Operating Capacity and Schedule

1. Maximum Heat Input Rate:			132,734	mmBtu/yr
2. Maximum Incineration Rate:		lb/hr		tons/day
3. Maximum Process or Throughput Rate:				
4. Maximum Production Rate:				
5. Requested Maximum Operating Schedule:				
	24	hours/day	7	days/week
	52	weeks/year	8760	hours/year

6. Operating Capacity/Schedule Comment (limit to 200 characters):

Maximum Heat Input Rate is based on unrestricted operations.
6810 Btu/bhp-hr x 2225 bhp x 1 mmBtu/100000 Btus x 8760 hrs/yr = 132,734 mmBtu/yr.
Maximum Heat Input Rate: 16.67 mmBtu/hr is 110% of rated capacity of 15.15 mmBtu/hr

C. EMISSIONS UNIT REGULATIONS
(Regulated Emissions Units Only)

List of Applicable Regulations

Chapter 62-4 Permits	
Rule 62-204.220 Ambient Air Quality Protection	
Rule 62-204.240 Ambient Air Quality Standards	
Rule 62-204.800 Federal Regulations Adopted by Reference	
Rule 62-210.200 Definitions	
Rule 62-210.300 Permits Required	
Rule 62-210.350 Public Notice and Comments	
Rule 62-210.370 Reports	
Rule 62-210.550 Stack Height Policy	
Rule 62-210.650 Circumvention	
Rule 62-210.700 Excess Emissions	
Rule 62-210.900 Forms and Instructions	
Rule 62-212.300 General Preconstruction Review Requirements	
Chapter 62-213 Operation Permits for Major Sources	
Rule 62-296.320 General Pollutant Emission Limiting Standards	

D. EMISSION POINT (STACK/VENT) INFORMATION
(Regulated Emissions Units Only)

Emission Point Description and Type

1. Identification of Point on Plot Plan or Flow Diagram? # 5 SDR (G3608)	2. Emission Point Type Code: 3

3. Descriptions of Emission Points Comprising this Emissions Unit for VE Tracking (limit to 100 characters per point): # 5 SDR, Pump Engine No. 5 (2nd from north end): vertical stack outside building with silencer.
4. ID Numbers or Descriptions of Emission Units with this Emission Point in Common:

5. Discharge Type Code: V	6. Stack Height: 32 feet	7. Exit Diameter: 1.5 feet
8. Exit Temperature: 842 °F	9. Actual Volumetric Flow Rate: 14816 acfm	10. Water Vapor: %

11. Maximum Dry Standard Flow Rate: dscfm	12. Nonstack Emission Point Height: feet

13. Emission Point UTM Coordinates: Zone: 17 East (km): 566.6 North (km): 2,843.5
14. Emission Point Comment (limit to 200 characters):

E. SEGMENT (PROCESS/FUEL) INFORMATION
(All Emissions Units)

Segment Description and Rate: Segment 1 of 1

1. Segment Description (Process/Fuel Type) (limit to 500 characters): Natural gas powered internal combustion engines (emissions related to thousand Cubic feet burned) Maximum hourly & annual fuel rates are based on brake specific fuel consumption of 6810 BTU/bhp-hr. Pump Engine No. 5 consumes 0.01443 MMscf/hr at rated capacity or a maximum of 0.0159 MMcf/hr at 110 percent capacity at 1050 MMBtu/MMScf.		
2. Source Classification Code (SCC): 1-02-006-02	3. SCC Units: Million Cubic Feet Burned (all gaseous fuels)	
4. Maximum Hourly Rate: 0.0159	5. Maximum Annual Rate: 126.41	6. Estimated Annual Activity Factor: 1.00
7. Maximum % Sulfur: 0.00	8. Maximum % Ash: 0.00	9. Million Btu per SCC Unit: 1,050
10. Segment Comment (limit to 200 characters): Maximum hourly rate of the engine is 0.0159 MMscf/hr. The Maximum annual rate is based the nominal capacity of 0.01443 MMscf/hr and 8760 hrs/yr or 126.41 MMscf/yr		

Segment Description and Rate: Segment ___ of ___

1. Segment Description (Process/Fuel Type) (limit to 500 characters):		
2. Source Classification Code (SCC):	3. SCC Units:	
4. Maximum Hourly Rate:	5. Maximum Annual Rate:	6. Estimated Annual Activity Factor:
7. Maximum % Sulfur:	8. Maximum % Ash:	9. Million Btu per SCC Unit:
10. Segment Comment (limit to 200 characters):		

F. EMISSIONS UNIT POLLUTANTS
(All Emissions Units)

1. Pollutant Emitted	2. Primary Control Device Code	3. Secondary Control Device Code	4. Pollutant Regulatory Code
NOX	99		EL
PM			EL
CO			NS

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units -
Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: NOX	2. Total Percent Efficiency of Control: 0.0
3. Potential Emissions: 3.43 lb/hour 15.03 tons/year	4. Synthetically Limited? [N]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: 0.7 g/bhp-hr Reference: Manufacturer	7. Emissions Method Code: 5
8. Calculation of Emissions (limit to 600 characters): Manufacturer Supplied NOx emissions: 0.7 g/bhp-hr NOx Hourly Emissions: (2225 bhp) x (0.7 g/bhp-hr NOx) x (1 lb/454 g) = 3.43 lbs/hr. Annual Emissions: (2225 bhp) x (0.7 g/bhp-hr NOx) x (1 lb/454 g) x (8,760 hr/yr) x (ton/2,000 lb) = 15.03 tpy	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters):	

Allowable Emissions Allowable Emissions 1 of 2

1. Basis for Allowable Emissions Code:	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units:	4. Equivalent Allowable Emissions: lb/hour tons/year
5. Method of Compliance (limit to 60 characters):	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): The emission unit is not subject to any unit specific emission limiting standard and considered "unregulated" for the purposes of Title V permitting.	

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: CO	2. Total Percent Efficiency of Control: 0.0
3. Potential Emissions: 12.25 lb/hour 53.67 tons/year	4. Synthetically Limited? [N]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: 2.5 g/bhp-hr Reference: Manufacturer	7. Emissions Method Code: 5
8. Calculation of Emissions (limit to 600 characters): Manufacturer Supplied CO emissions: 2.5 g/bhp-hr CO Hourly Emissions: (2225 bhp) x (2.5 g/bhp-hr) x (1 lb/454 g) = 12.25 lbs/hr. Annual Emissions: (2225 bhp) x (2.5 g/bhp-hr) x (1 lb/454 g) x (8,760 hr/yr) x (ton/2,000 lb) = 53.67 tpy	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters):	

Allowable Emissions Allowable Emissions 2 of 2

1. Basis for Allowable Emissions Code:	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units:	4. Equivalent Allowable Emissions: lb/hour tons/year
5. Method of Compliance (limit to 60 characters): Initial air compliance testing	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): The emission unit is not subject to any unit specific emission limiting standard and considered "unregulated" for the purposes of Title V permitting.	

H. VISIBLE EMISSIONS INFORMATION
(Only Regulated Emissions Units Subject to a VE Limitation)

Visible Emissions Limitation: Visible Emissions Limitation 1 of 1

1. Visible Emissions Subtype: VE20	2. Basis for Allowable Opacity: [X] Rule [ ] Other
3. Requested Allowable Opacity: Normal Conditions: 20 % Exceptional Conditions: 40 % Maximum Period of Excess Opacity Allowed: min/hour	
4. Method of Compliance: Perform Initial VE Compliance monitoring using EPA Method 9.	
5. Visible Emissions Comment (limit to 200 characters):	

I. CONTINUOUS MONITOR INFORMATION
(Only Regulated Emissions Units Subject to Continuous Monitoring)

Continuous Monitoring System: Continuous Monitor _____ of _____

1. Parameter Code:	2. Pollutant(s):
3. CMS Requirement:	[ ] Rule [ ] Other
4. Monitor Information: Manufacturer: Model Number:	Serial Number:
5. Installation Date:	6. Performance Specification Test Date:
7. Continuous Monitor Comment (limit to 200 characters):	

J. EMISSIONS UNIT SUPPLEMENTAL INFORMATION
(Regulated Emissions Units Only)

Supplemental Requirements

1. Process Flow Diagram [ ] Attached, Document ID: _______ [X] Not Applicable [ ] Waiver Requested
2. Fuel Analysis or Specification [X] Attached, Document ID: A04 [ ] Not Applicable [ ] Waiver Requested
3. Detailed Description of Control Equipment [ ] Attached, Document ID: _______ [X] Not Applicable [ ] Waiver Requested
4. Description of Stack Sampling Facilities [ ] Attached, Document ID: _______ [X] Not Applicable [ ] Waiver Requested
5. Compliance Test Report [ ] Attached, Document ID: _______ [ ] Previously submitted, Date: _______ [X] Not Applicable
6. Procedures for Startup and Shutdown [X] Attached, Document ID: A06 [ ] Not Applicable [ ] Waiver Requested
7. Operation and Maintenance Plan [ ] Attached, Document ID: _______ [X] Not Applicable [ ] Waiver Requested
8. Supplemental Information for Construction Permit Application [X] Attached, Document ID: _______ [ ] Not Applicable
9. Other Information Required by Rule or Statute [ ] Attached, Document ID: A08 [X] Not Applicable
10. Supplemental Requirements Comment:

Additional Supplemental Requirements for Title V Air Operation Permit Applications

11. Alternative Methods of Operation [ ] Attached, Document ID:________ [X] Not Applicable
12. Alternative Modes of Operation (Emissions Trading) [ ] Attached, Document ID:________ [X] Not Applicable
13. Identification of Additional Applicable Requirements [ ] Attached, Document ID:________ [X] Not Applicable
14. Compliance Assurance Monitoring Plan [ ] Attached, Document ID:________ [X] Not Applicable
15. Acid Rain Part Application (Hard-copy Required) [ ] Acid Rain Part - Phase II (Form No. 62-210.900(1)(a)) Attached, Document ID:________ [ ] Repowering Extension Plan (Form No. 62-210.900(1)(a)1.) Attached, Document ID:________ [ ] New Unit Exemption (Form No. 62-210.900(1)(a)2.) Attached, Document ID:________ [ ] Retired Unit Exemption (Form No. 62-210.900(1)(a)3.) Attached, Document ID:________ [ ] Phase II NOx Compliance Plan (Form No. 62-210.900(1)(a)4.) Attached, Document ID:________ [ ] Phase NOx Averaging Plan (Form No. 62-210.900(1)(a)5.) Attached, Document ID:________ [X] Not Applicable

III. EMISSIONS UNIT INFORMATION

A separate Emissions Unit Information Section (including subsections A through J as required) must be completed for each emissions unit addressed in this Application for Air Permit. If submitting the application form in hard copy, indicate, in the space provided at the top of each page, the number of this Emissions Unit Information Section and the total number of Emissions Unit Information Sections submitted as part of this application.

A. GENERAL EMISSIONS UNIT INFORMATION
(All Emissions Units)

Emissions Unit Description and Status

1. Type of Emissions Unit Addressed in This Section: (Check one)

[X] This Emissions Unit Information Section addresses, as a single emissions unit, a single process or production unit, or activity, which produces one or more air pollutants and which has at least one definable emission point (stack or vent).

[ ] This Emissions Unit Information Section addresses, as a single emissions unit, a group of process or production units and activities which has at least one definable emission point (stack or vent) but may also produce fugitive emissions.

[ ] This Emissions Unit Information Section addresses, as a single emissions unit, one or more process or production units and activities which produce fugitive emissions only.

2. Regulated or Unregulated Emissions Unit? (Check one)

[X] The emissions unit addressed in this Emissions Unit Information Section is a regulated emissions unit.

[ ] The emissions unit addressed in this Emissions Unit Information Section is an unregulated emissions unit.

3. Description of Emissions Unit Addressed in This Section (limit to 60 characters):
Pump/Generator engine no. 1 - 900 KW emergency generator

4. Emissions Unit Identification Number:
ID:

[ ] No ID
[X] ID Unknown

5. Emissions Unit Status Code:	6. Initial Startup Date:	7. Emissions Unit Major Group SIC Code:	8. Acid Rain Unit?
C		49	[ ]

9. Emissions Unit Comment: (Limit to 500 Characters)
Pump engine no. 1 (Emission Unit ID No. 001) driving a pump and a 750 KW generator will be permanently removed from service and replaced with a 1337 bhp diesel fuel fired Caterpillar Model 3508 engine coupled to a 900 KW (820 KW prime rating) generator with a maximum heat input rate of 9.18 mmBtu/hr.

Emissions Unit Control Equipment

1. Control Equipment/Method Description (Limit to 200 characters per device or method): NOx emission levels are controlled through the use of a water-cooled aftercooler. The water-cooled aftercooler reduces thermal NOx formation in the combustion chamber by cooling air prior to entering the combustion chamber.
2. Control Device or Method Code(s): 99

Emissions Unit Details

1. Package Unit: Manufacturer: Caterpillar		Model Number: 3508	
2. Generator Nameplate Rating:	0.9	MW	
3. Incinerator Information: Dwell Temperature:			°F
Dwell Time:			seconds
Incinerator Afterburner Temperature:			°F

B. EMISSIONS UNIT CAPACITY INFORMATION
(Regulated Emissions Units Only)

Emissions Unit Operating Capacity and Schedule

1. Maximum Heat Input Rate:			9.18	mmBtu/hr
2. Maximum Incineration Rate:		lb/hr		tons/day
3. Maximum Process or Throughput Rate:				
4. Maximum Production Rate:				
5. Requested Maximum Operating Schedule:				
	24	hours/day	7	days/week
	52	weeks/year	500	hours/year

6. Operating Capacity/Schedule Comment (limit to 200 characters):

Unit will serve as an emergency standby generator for the East pump room.

Maximum heat input is based on a fuel consumption of 66.5 gal/hr and 138 mmBtu/1000gals.

C. EMISSIONS UNIT REGULATIONS
(Regulated Emissions Units Only)

List of Applicable Regulations

Chapter 62-4 Permits	
Rule 62-204.220 Ambient Air Quality Protection	
Rule 62-204.240 Ambient Air Quality Standards	
Rule 62-204.800 Federal Regulations Adopted by Reference	
Rule 62-210.200 Definitions	
Rule 62-210.300 Permits Required	
Rule 62-210.350 Public Notice and Comments	
Rule 62-210.370 Reports	
Rule 62-210.550 Stack Height Policy	
Rule 62-210.650 Circumvention	
Rule 62-210.700 Excess Emissions	
Rule 62-210.900 Forms and Instructions	
Rule 62-212.300 General Preconstruction Review Requirements	
Chapter 62-213 Operation Permits for Major Sources	
Rule 62-296.320 General Pollutant Emission Limiting Standards	

D. EMISSION POINT (STACK/VENT) INFORMATION
(Regulated Emissions Units Only)

Emission Point Description and Type

1. Identification of Point on Plot Plan or Flow Diagram? CAT 3508	2. Emission Point Type Code: 3
3. Descriptions of Emission Points Comprising this Emissions Unit for VE Tracking (limit to 100 characters per point): A single exhaust stack integral with and located directly above the unit.	
4. ID Numbers or Descriptions of Emission Units with this Emission Point in Common:	

5. Discharge Type Code: V	6. Stack Height: 18 feet	7. Exit Diameter: 0.67 feet
8. Exit Temperature: 884 °F	9. Actual Volumetric Flow Rate: 7331 acfm	10. Water Vapor: %

11. Maximum Dry Standard Flow Rate: 2473 dscfm	12. Nonstack Emission Point Height: feet
13. Emission Point UTM Coordinates: Zone: 17 East (km): 566.6 North (km): 2,843.5	
14. Emission Point Comment (limit to 200 characters):	

E. SEGMENT (PROCESS/FUEL) INFORMATION
(All Emissions Units)

Segment Description and Rate: Segment 1 of 1

1. Segment Description (Process/Fuel Type) (limit to 500 characters): Unit is fueled by diesel, no. 2 fuel oil. The maximum hourly & annual fuel rates are based on a consumption of 66.5 gal/hr.		
2. Source Classification Code (SCC): 2-02-004-01	3. SCC Units: 1000 Gallons	
4. Maximum Hourly Rate: 0.0665	5. Maximum Annual Rate: 33.25	6. Estimated Annual Activity Factor: 0.06
7. Maximum % Sulfur: 0.05	8. Maximum % Ash: 0.00	9. Million Btu per SCC Unit: 138
10. Segment Comment (limit to 200 characters): Maximum rate of the engine is 66.5 gal/hr, or 0.0665 (1000gal)/hr. The maximum annual rate is 0.0665 (1000gal)/hr x 500 hrs/yr = 33.25 (1000 gal)/yr		

Segment Description and Rate: Segment ___ of ___

1. Segment Description (Process/Fuel Type) (limit to 500 characters):		
2. Source Classification Code (SCC):	3. SCC Units:	
4. Maximum Hourly Rate:	5. Maximum Annual Rate:	6. Estimated Annual Activity Factor:
7. Maximum % Sulfur:	8. Maximum % Ash:	9. Million Btu per SCC Unit:
10. Segment Comment (limit to 200 characters):		

F. EMISSIONS UNIT POLLUTANTS
(All Emissions Units)

1. Pollutant Emitted	2. Primary Control Device Code	3. Secondary Control Device Code	4. Pollutant Regulatory Code
NOX			EL
CO			EL
PM			NS

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: NOX	2. Total Percent Efficiency of Control: 0.0
3. Potential Emissions: 37.47 lb/hour 9.37 tons/year	4. Synthetically Limited? [Y]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: 37.46 lb/hr Reference: Manufacturer	7. Emissions Method Code: 5
8. Calculation of Emissions (limit to 600 characters): Manufacturer Supplied NOx emissions: 37.46 lb/hr NOx Hourly Emissions: 37.46 lb/hr Annual Emissions: (37.46 lb/hr NOx) x (500 hr/yr) x (ton/2,000 lb) = 9.37 tpy	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters):	

Allowable Emissions Allowable Emissions 1 of 2

1. Basis for Allowable Emissions Code: RULE	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units: 4.75 lbs/mmBTU	4. Equivalent Allowable Emissions: 43.6 lb/hour 10.9 tons/year
5. Method of Compliance (limit to 60 characters): Initial air compliance testing using EPA Method 7 or 7E	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): Equivalent Allowable Emissions is based on NOx RACT Rule (4.75 lbs/mmBTU NOx) x 0.0665 (1000gals)/hr x 138 mmBTU/(1000gals) = 43.6 lbs NOx (4.75 lbs/mmBTU NOx) x 33.15 (1000gals)/hr x 138 mmBTU/(1000gals) x 1 ton/2000 lbs = 10.9 tons NOx	

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: CO	2. Total Percent Efficiency of Control:
3. Potential Emissions: 2.10 lb/hour 42.924 tons/year	4. Synthetically Limited? [Y]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ____ to ____ tons/year	
6. Emission Factor: 2.10 lb/hr Reference: Manufacturer	7. Emissions Method Code: 5
8. Calculation of Emissions (limit to 600 characters): Manufacturer Supplied CO emissions: 2.10 lb/hr CO Hourly Emissions: 2.10 lb/hr Annual Emissions: (2.10lb/hr CO) x (500 hr/yr) x (ton/2,000 lb) = 0.525 tpy	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters):	

Allowable Emissions Allowable Emissions 2 of 2

1. Basis for Allowable Emissions Code: OTHER	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units:	4. Equivalent Allowable Emissions: lb/hour tons/year
5. Method of Compliance (limit to 60 characters):	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters):	

H. VISIBLE EMISSIONS INFORMATION
(Only Regulated Emissions Units Subject to a VE Limitation)

Visible Emissions Limitation: Visible Emissions Limitation 1 of 1

1. Visible Emissions Subtype: VE20	2. Basis for Allowable Opacity: [X] Rule [ ] Other
3. Requested Allowable Opacity: Normal Conditions: 20 % Exceptional Conditions: 40 % Maximum Period of Excess Opacity Allowed: 6 min/hour	
4. Method of Compliance: Perform Initial VE Compliance monitoring using EPA Method 9.	
5. Visible Emissions Comment (limit to 200 characters):	

I. CONTINUOUS MONITOR INFORMATION
(Only Regulated Emissions Units Subject to Continuous Monitoring)

Continuous Monitoring System: Continuous Monitor _____ of _____

1. Parameter Code:	2. Pollutant(s):
3. CMS Requirement:	[ ] Rule [ ] Other
4. Monitor Information: Manufacturer: Model Number:	Serial Number:
5. Installation Date:	6. Performance Specification Test Date:
7. Continuous Monitor Comment (limit to 200 characters):	

J. EMISSIONS UNIT SUPPLEMENTAL INFORMATION
(Regulated Emissions Units Only)

Supplemental Requirements

1. Process Flow Diagram [ ] Attached, Document ID: ______ [X] Not Applicable [ ] Waiver Requested
2. Fuel Analysis or Specification [X] Attached, Document ID: A04 [ ] Not Applicable [ ] Waiver Requested
3. Detailed Description of Control Equipment [ ] Attached, Document ID: ______ [X] Not Applicable [ ] Waiver Requested
4. Description of Stack Sampling Facilities [X] Attached, Document ID: A05 [ ] Not Applicable [X] Waiver Requested
5. Compliance Test Report [ ] Attached, Document ID: ______ [ ] Previously submitted, Date: ______ [ ] Not Applicable
6. Procedures for Startup and Shutdown [X] Attached, Document ID: A06 [ ] Not Applicable [ ] Waiver Requested
7. Operation and Maintenance Plan [ ] Attached, Document ID: ______ [X] Not Applicable [ ] Waiver Requested
8. Supplemental Information for Construction Permit Application [X] Attached, Document ID: A09 [ ] Not Applicable
9. Other Information Required by Rule or Statute [ ] Attached, Document ID: ______ [X] Not Applicable
10. Supplemental Requirements Comment:

Additional Supplemental Requirements for Title V Air Operation Permit Applications

11. Alternative Methods of Operation
    [ ] Attached, Document ID:________ [X] Not Applicable

12. Alternative Modes of Operation (Emissions Trading)
    [ ] Attached, Document ID:________ [X] Not Applicable

13. Identification of Additional Applicable Requirements
    [ ] Attached, Document ID:________ [X] Not Applicable

14. Compliance Assurance Monitoring Plan
    [ ] Attached, Document ID:________ [X] Not Applicable

15. Acid Rain Part Application (Hard-copy Required)

    [ ] Acid Rain Part - Phase II (Form No. 62-210.900(1)(a))
    Attached, Document ID:________

    [ ] Repowering Extension Plan (Form No. 62-210.900(1)(a)1.)
    Attached, Document ID:________

    [ ] New Unit Exemption (Form No. 62-210.900(1)(a)2.)
    Attached, Document ID:________

    [ ] Retired Unit Exemption (Form No. 62-210.900(1)(a)3.)
    Attached, Document ID:________

    [ ] Phase II NOx Compliance Plan (Form No. 62-210.900(1)(a)4.)
    Attached, Document ID:________

    [ ] Phase NOx Averaging Plan (Form No. 62-210.900(1)(a)5.)
    Attached, Document ID:________

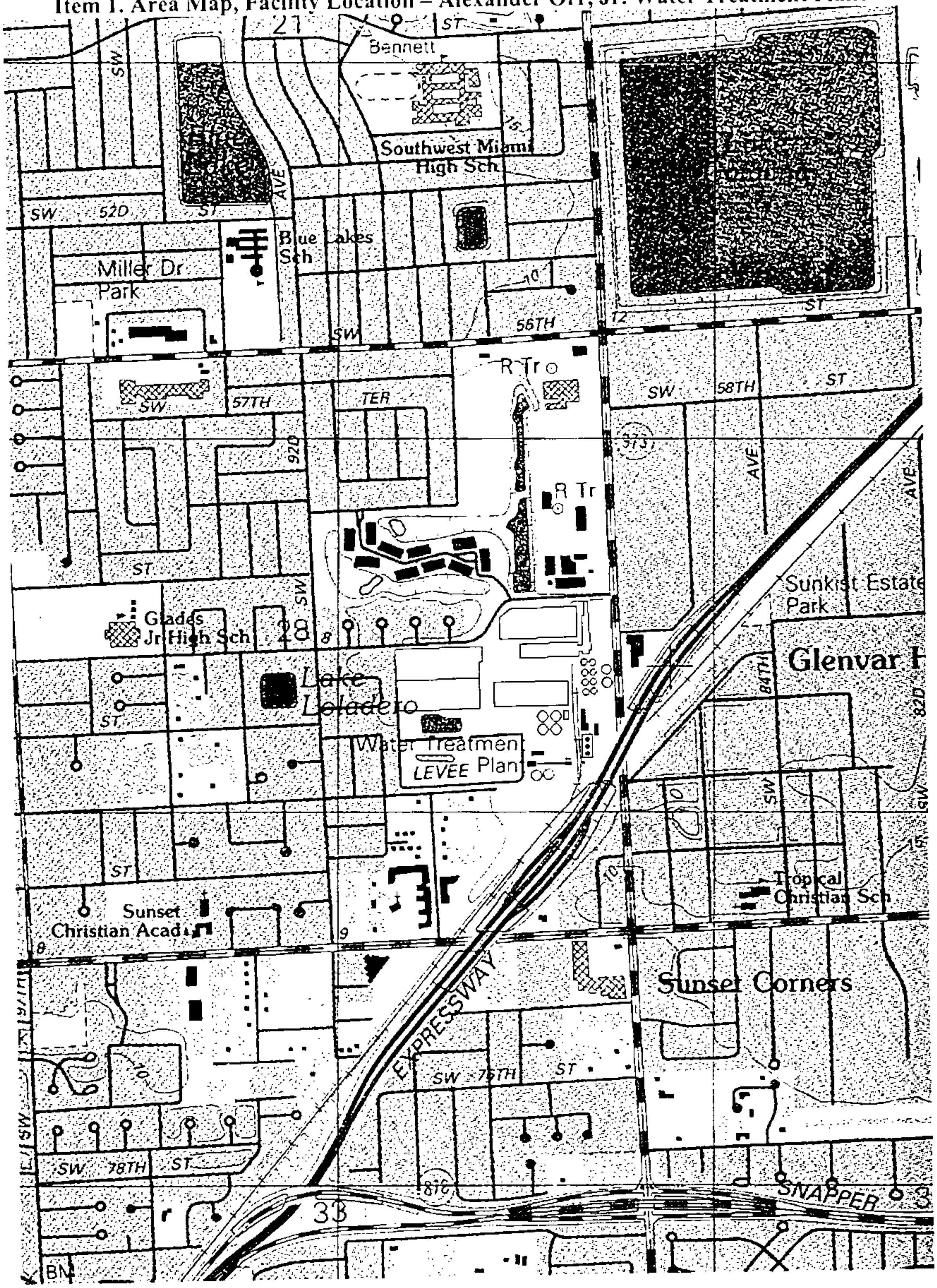
    [X] Not Applicable

Attachment 1

Area Map (USGS)
Aerial Photograph (USGS)

South Miami, Florida

Item 1. Area Map, Facility Location – Alexander Orr, Jr. Water Treatment Plant

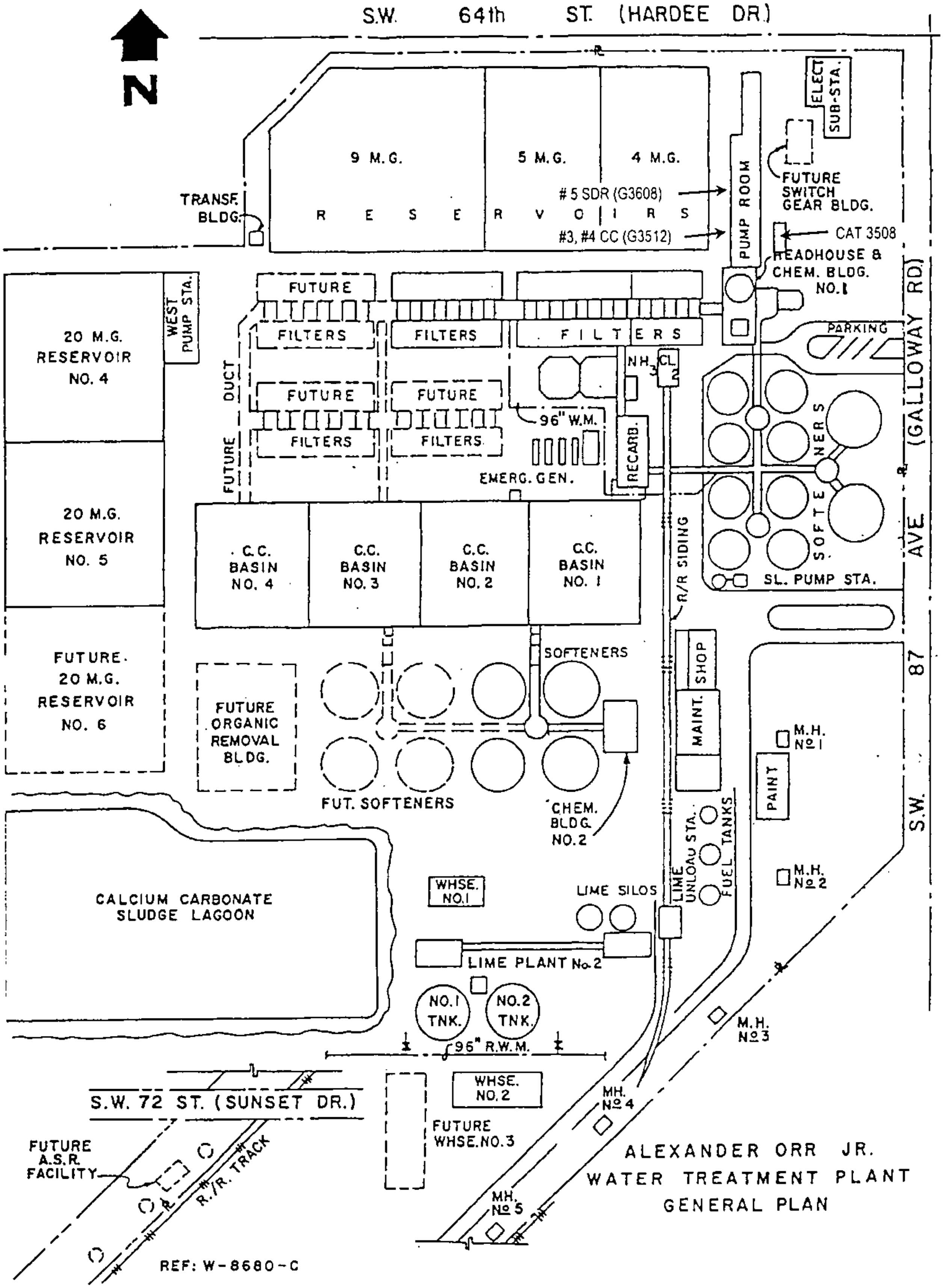


Attachment 2

Site Maps

Alexander Orr, Jr.
Water Treatment Plant

Item 2. Facility Plot Plan– Alexander Orr, Jr. Water Treatment Plant



Item 2. Facility Plot Plan– Alexander Orr, Jr. Water Treatment Plant – Aerial

Attachment 3

Emission Calculations - Nox
Replacement Sources

Alexander Orr, Jr.
Water Treatment Plant

Miami-Dade Water and Sewer Department
Alexander Orr, Jr. Water Treatment Plant --- East Pump Room - Pump Replacement Project
Replacement of Pump Diesel Engines Nos. 1, 3 & 4 and Pump Dual Fueled Engine No. 5
Calculations of Past Actual Emissions from Existing Engine Driven Pumps and Proposed Replacements

Existing Annual Pump Engine Emissions

	Pump/Gen Engine 1 - 825 bhp	Pump Engine 3 - 825 bhp	Pump Engine 4 - 825 bhp	Sum Pump Engines 3 & 4 - 825 bhp	Pump Engine 5 - 1590 bhp	Total Pump Engines 1, 3, 4 & 5
	Average Annual Operations -- April 1998 - March 2000					
Annual Average Operating Hours, 24-Month Period, April 1998 - March 2000	142.5	1,306.3	1,543.0	2,849.3	2,513.8	5,363.0
Brake Horsepower	825	825	825		1,590	
Fuel Consumption [1] gals/hr	30.1	31.0	29.5		59.2	
Average Annual Fuel consumption in gallons 10^3	4.285	40.495	45.524	86.019	148.773	234.8
MMbtus based on 138 / SCC Unit (10^3 gallons)	591	5,588	6,282	11,870.6	20,531	32,401

Annual Emissions in Tons

	Emission Factor	Units	Source or SCC[2]	Pump/Gen Engine 1 - 825 bhp	Pump Engine 3 - 825 bhp	Pump Engine 4 - 825 bhp	Sum Pump Engines 3 & 4 - 825 bhp	Pump Engine 5 - 1590 bhp	Total Pump Engines 1, 3, 4 & 5
Average Nitrogen Oxides (NOx) Emissions		Lbs/mmBTU	Tests	2.19	2.10	2.76		2.45	
Nitrogen Oxides (NOx)	-	-		0.65	5.87	8.67	14.54	25.15	**40.33**
Carbon Monoxide (CO)	1.11E+02	Lbs/1000gals	20200401	0.24	2.25	2.53	4.77	8.26	**13.27**
PM, Total	9.55E+00	Lbs/1000gals	20200401	0.02	0.19	0.22	0.41	0.71	**1.14**
PM_{10}, Total	7.85E+00	Lbs/1000gals	20200401	0.02	0.16	0.18	0.34	0.58	**0.94**
Sulfur Oxides (SOx)	6.90E+00	Lbs/1000gals	20200401	0.00	0.01	0.01	0.01	0.03	**0.04**
VOC, Total	1.37E+01	Lbs/1000gals	20200401	0.03	0.28	0.31	0.59	1.02	**1.64**

Notes:
1. Estimated rates based on usage prior to service tank change, less than full load rates.
2. EPA Source Classification Codes
3. Emissions Factors based on Emissions Testing, Manufacturer Supplied Data or EPA Source Classification Codes
4. Emissions (tons/yr) = (emission factor [lbs/unit]) x (units) / 2000 lbs/ton
5. Net Annual Increase / (Decrease) in Tons of Emissions (tons/yr) = Proposed Annual Emissions (tons/yr) - Past Annual Emissions (tons/yr)

Miami-Dade Water and Sewer Department
Alexander Orr, Jr. Water Treatment Plant --- East Pump Room - Pump Replacement Project
Replacement of Pump Diesel Engines Nos. 1, 3 & 4 and Pump Dual Fueled Engine No. 5
Calculations of Past Actual Emissions from Existing Engine Driven Pumps and Proposed Replacements

Proposed Annual Engine Emissions

Proposed Annual Operations

	900 KW GenSet	Pump Engine 3	Pump Engine 4	Sum Pump Engines 3 & 4	Pump Engine 5
Hours of Operation	500	8,760	8,760	17,520	8,760
Fuel Consumption in 1000gals/hr or MMCF/hr	0.0665	5.714	5.714		14.431
Annual Fuel consumption in 1000gals or MMCF	33.25	50.06	50.06	100.11	126.41
Annual Heat Input (mmBtus) based on 1050/ MMCF or 138 /1000 gals	4,589	52,560	52,560	105,120	132,734
Engine Brake Specific Horsepower (bhp)	1,332	810	810		2,225

Annual Emissions in Tons

	Emission Factor	Units	Source, SCC[2]	900 KW GenSet 3508	Pump Engine 3 G3512	Pump Engine 4 G3512	Σ Pump Engines 3 & 4 G3512	Pump Engine 5 G3608	Total 900 KW GenSet & Pump Engines 3,4 &	Net Annual Increase / (Decrease) in Tons
Nitrogen Oxides (NOx)	-	gr/bhp-hr	Manufacturer		2.00	2.00		0.70		
Nitrogen Oxides (NOx)	-	Lbs/Hr	Manufacturer	37.46						
Nitrogen Oxides (NOx)	-	Tons		9.40	15.60	15.60	31.20	15.00	55.60	15.27
Carbon Monoxide (CO)	-	gr/bhp-hr	Manufacturer		1.60	1.60		2.50		
Carbon Monoxide (CO)	-	Lbs/Hr	Manufacturer	3.10						
Carbon Monoxide (CO)	-	Tons		0.80	12.50	12.50	25.00	53.70	79.50	66.23
Particulate Matter (PM)	-	gr/bhp-hr	Manufacturer							
Particulate Matter (PM)	-	Lbs/Hr	Manufacturer	0.310						
PM, Filterable	1.00E+01	Lbs/MMCF	20300201		0.25	0.25		0.63		
PM	-	Tons		0.08	0.25	0.25	0.50	0.63	1.21	0.07
Particulate Matter (PM_{10})	-	gr/bhp-hr	Manufacturer		0.30	0.30				
Particulate Matter (PM_{10})	-	Lbs/Hr	Manufacturer	0.310						
PM_{10}, Filterable	1.00E+01	Lbs/MMCF	20300201					0.63		
PM_{10}	-	Tons		0.08	2.30	2.30	4.60	0.63	5.31	4.37
Sulfur Oxides (SOx)	6.00E-01	Lbs/MMCF	20300201		0.02	0.02		0.04		
Sulfur Oxides (SOx)	6.90E+00	Lbs/1000gals	20200401	0.11						
Sulfur Oxides (SOx)	-	Tons		0.11	0.02	0.02	0.04	0.04	0.19	0.15
Volatile Organic Compounds (VOC)	1.16E+02	Lbs/MMCF	20300201		2.90	2.90		7.30		
Volatile Organic Compounds (VOC)	1.37E+01	Lbs/1000gals	20200401	0.20						
Volatile Organic Compounds (VOC)	-	Tons		0.20	2.90	2.90	5.80	7.30	13.30	11.66

Notes:

1. Estimated rates based on usage prior to service tank change, less than full load rates.
2. EPA Source Classification Codes
3. Emissions Factors based on Emissions Testing, Manufacturer Supplied Data or EPA Source Classification Codes
4. Emissions (tons/yr) = (emission factor [lbs/unit]) x (units) / 2000 lbs/ton
5. Net ual Increase / (Decrease) in Tons of Emissions (tons/yr) = Proposed Annual Emissic ns/yr) - Past Annual Emissions (tons/yr)

Miami-Dade Water and Sewer Department
Alexander Orr, Jr. Water Treatment Plant --- East Pump Room - Pump Replacement Project
Replacement of Pump Diesel Engines Nos. 1, 3 & 4 and Pump Dual Fueled Engine No. 5
Calculations of Potential Emissions from Unrestricted Operations of Existing Engine Driven Pumps and Proposed Replacements

<u>*Annual Pump Engine Emissions from Permitted Unrestricted Operations.*</u>

	Annual Operations					
	Pump/Gen Engine 1 - 825 bhp	Pump Engine 3 - 825 bhp	Pump Engine 4 - 825 bhp	Sum Pump Engines 3 & 4 - 825 bhp	Pump Engine 5 - 1590 bhp	Total Pump Engines 1, 3, 4 & 5
Hours of Operation	8,760.0	8,760.0	8,760.0	17,520.0	8,760.0	26,280.0
Brake Horsepower	825	825	825		1,590	
Fuel Consumption [1] gals/hr	30.1	31.0	29.5		59.2	
Average Annual Fuel consumption in gallons 10^3	263.415	271.568	258.448	530.016	518.449	1,048.5
MMbtus based on 138 / SCC Unit (10^3 gallons)	36,351	37,476	35,666	73,142.2	71,546	144,688

	Emission Factor	Units	Source or SCC[2]	Pump/Gen Engine 1 - 825 bhp	Pump Engine 3 - 825 bhp	Pump Engine 4 - 825 bhp	Sum Pump Engines 3 & 4 - 825 bhp	Pump Engine 5 - 1590 bhp	*Total Pump* Engines 1, 3, 4 & 5
				Annual Emissions in Tons					
Average Nitrogen Oxides (NOx) Emissions		Lbs/mmBTU	Tests	2.19	2.10	2.76		2.45	
Nitrogen Oxides (NOx)	-	-		39.80	39.35	49.22	88.57	87.64	**216.02**
Carbon Monoxide (CO)	1.11E+02	Lbs/1000gals	20200401	14.62	15.07	14.34	29.42	28.77	**72.81**
PM, Total	9.55E+00	Lbs/1000gals	20200401	1.26	1.30	1.23	2.53	2.48	**6.26**
PM_{10}, Total	7.85E+00	Lbs/1000gals	20200401	1.03	1.07	1.01	2.08	2.03	**5.15**
Sulfur Oxides (SOx)	6.90E+00	Lbs/1000gals	20200401	0.05	0.05	0.04	0.09	0.09	**0.23**
VOC, Total	1.37E+01	Lbs/1000gals	20200401	1.80	1.86	1.77	3.63	3.55	**8.99**

Notes:
1. Estimated rates based on usage prior to service tank change, less than full load rates.
2. EPA Source Classification Codes
3. Emissions Factors based on Emissions Testing, Manufacturer Supplied Data or EPA Source Classification Codes
4. Emissions (tons/yr) = (emission factor [lbs/unit]) x (units) / 2000 lbs/ton
5. Net Annual Increase / (Decrease) in Tons of Emissions (tons/yr) = Proposed Annual Emissions (tons/yr) - Past Annual Emissions (tons/yr)

Miami-Dade Water and Sewer Department
Alexander Orr, Jr. Water Treatment Plant --- East Pump Room - Pump Replacement Project
Replacement of Pump Diesel Engines Nos. 1, 3 & 4 and Pump Dual Fueled Engine No. 5
Calculations of Potential Emissions from Unrestricted Operations of Existing Engine Driven Pumps and Proposed Replacements

Potential Unrestricted Annual Proposed Engine Emissions

	Unrestricted Annual Operations				
	900 KW GenSet	Pump Engine 3	Pump Engine 4	Sum Pump Engines 3 & 4	Pump Engine 5
Hours of Operation	8,760	8,760	8,760	17,520	8,760
Fuel Consumption in 1000gals/hr or MCF/hr	0.0665	5.714	5.714		14.431
Annual Fuel consumption in 1000gals or MMCF	582.54	50.06	50.06	100.11	126.41
Annual Heat Input (mmBtus) based on 1050/ MMCF or 138 /1000 gals	80,391	52,560	52,560	105,120	132,734
Engine Brake Specific Horsepower (bhp)	1,332	810	810		2,225

Annual Emissions in Tons

	Emission Factor	Units	Source, SCC[2]	900 KW GenSet 3508	Pump Engine 3 G3512	Pump Engine 4 G3512	Σ Pump Engines 3 & 4 G3512	Pump Engine 5 G3608	Total 900 KW GenSet & Pump Engines 3,4 &	Net Annual Increase / (Decrease) in Tons
Nitrogen Oxides (NOx)	-	gr/bhp-hr	Manufacturer		2.00	2.00		0.70		
Nitrogen Oxides (NOx)	-	Lbs/Hr	Manufacturer	37.46						
Nitrogen Oxides (NOx)	-	Tons		**164.10**	15.60	15.60	31.20	15.00	210.30	(5.72)
Carbon Monoxide (CO)	-	gr/bhp-hr	Manufacturer		1.60	1.60		2.50		
Carbon Monoxide (CO)	-	Lbs/Hr	Manufacturer	3.10						
Carbon Monoxide (CO)	-	Tons		**13.60**	12.50	12.50	25.00	53.70	92.30	19.49
Particulate Matter (PM)	-	gr/bhp-hr	Manufacturer							
Particulate Matter (PM)	-	Lbs/Hr	Manufacturer	0.310						
PM, Filterable	1.00E+01	Lbs/MMCF	20300201		0.25	0.25		0.63		
PM	-	Tons		1.36	0.25	0.25	0.50	0.63	2.49	(3.77)
Particulate Matter (PM_{10})	-	gr/bhp-hr	Manufacturer		0.30	0.30				
Particulate Matter (PM_{10})	-	Lbs/Hr	Manufacturer	0.310						
PM_{10}, Filterable	1.00E+01	Lbs/MMCF	20300201					0.63		
PM_{10}	-	Tons		1.36	2.30	2.30	4.60	0.63	6.59	1.44
Sulfur Oxides (SOx)	6.00E-01	Lbs/MMCF	20300201		0.02	0.02		0.04		
Sulfur Oxides (SOx)	6.90E+00	Lbs/1000gals	20200401	2.01						
Sulfur Oxides (SOx)	-	Tons		**2.01**	0.02	0.02	0.04	0.04	2.09	1.86
Volatile Organic Compounds (VOC)	1.16E+02	Lbs/MMCF	20300201		2.90	2.90		7.30		
Volatile Organic Compounds (VOC)	1.37E+01	Lbs/1000gals	20200401	4.00						
Volatile Organic Compounds (VOC)	-	Tons		**4.00**	2.90	2.90	5.80	7.30	17.10	8.11

Notes:
1. Estimated rates based on usage prior to service tank change, less than full load rates.
2. EPA Source Classification Codes
3. Emissions Factors based on Emissions Testing, Manufacturer Supplied Data or EPA Source Classification Codes
4. Emissions (tons/yr) = (emission factor [lbs/unit]) x (units) / 2000 lbs/ton
5. Net Annual Increase / (Decrease) in Tons of Emissions (tons/yr) = Proposed Annual Emissions (tons/yr) - Past Annual Emissions (tons/yr)

CATERPILLAR

Caterpillar Inc.
9701 State Road 26 East
Lafayette, IN 47905-4258

14 June 2000

Gas Engine Emissions Letter

PROJECT:	MDWASD Alexander WTP	BSFC:	7407 BTU/bhp-hr
model:	G3512	fuel pressure:	45 psi
compression ratio:	8:1	fuel LHV:	963 btu/ft3
A/C inlet temp:	130 °F	fuel MN:	72.7
J/W outlet temp:	210 °F	site altitude:	sea M ft
rating:	810 bhp @	max. ambient	110 °F
	1200 rpm	timing	31 ° BTDC

		100%
Engine Power	bhp	810
Exhaust O2	%	8.30
NOx (as NO2)	g/bhp-hr	2.00
	tons/year	15.64
CO	g/bhp-hr	1.60
	tons/year	12.51
total HC	g/bhp-hr	3.10
	tons/year	24.25
non-methane HC	g/bhp-hr	0.50
	tons/year	3.91
NMNEHC	g/bhp-hr	0.50
	tons/year	3.91
Formaldehydes	g/bhp-hr	0.27
	tons/year	2.11
PM10	lbs/bhp-hr	0.30

Emission levels are based on engine operation under steady state conditions, adjusted to the specified NOx level at 100% load. The CO, total HC, and non-methane HC values listed are 20% higher than nominal levels to allow for instrumentation, measurement, and engine-to-engine variations; these values indicate "not to exceed" levels. Tons per year values are based on 8,760 hours of operation per year. This information is valid for engine orders placed within six months of the above date. Please contact the factory if an extension of this period is required.

Sincerely,

Jeffery A. Elijah

Applications Engineer
Technical/Commercial Services
Petroleum Business Unit

Appl. Performance Engineer

Jayson Hagler

Technical Manager

Robert Masson

G3512

Engine Speed (rpm)	1200	Fuel	NAT GAS
Compression Ratio	8:1	LHV of Fuel (Btu/SCF)	920
Aftercooler Inlet Temperature (°F)	130	Fuel System	HPG IMPCO
Jacket Water Outlet Temperature (°F)	210		
Ignition System	EIS	Minimum Fuel Pressure (psig)	35
Exhaust Manifold	WATER COOLED	Methane Number at Conditions Shown	80
Combustion System Type	LOW EMISSION	Rated Altitude (ft)	5000
		at 77°F Design Temperature	

Engine Rating Data	% Load	100%	75%	50%
Engine Power (w/o fan)	bhp	810	607	405
Engine Data				
Specific Fuel Consumption (BSFC) (1)	Btu/bhp-hr	7407	7600	7937
Air Flow (Wet, @ 77°F, 28.8 in Hg)	SCFM	1668	1209	827
Air Mass Flow (Wet)	lb/hr	7395	5362	3665
Compressor Out Pressure	in. HG (abs)	69.6	62.2	46.5
Compressor Out Temperature	°F	289	261	186
Inlet Manifold Pressure	in. HG (abs)	60.8	45.9	32.3
Inlet Manifold Temperature (10)	°F	138	134	134
Timing (11)	°BTDC	33	33	33
Exhaust Stack Temperature	°F	801	786	777
Exhaust Gas Flow (Wet, @ stack temperature, 29.7 in Hg)	CFM	4260	3060	2080
Exhaust Gas Mass Flow (Wet)	lb/hr	7683	5584	3823
Engine Emissions Data				
Nitrous Oxides (NOx as NO2) (9)	g/bhp-hr	2.0	3.3	3.3
(Corr. 15% 02)	ppm	124	245	231
Carbon Monoxide (CO) (9)	g/bhp-hr	1.6	1.7	1.9
(Corr. 15% 02)	ppm	195	212	215
Total Hydrocarbons (THC) (9)	g/bhp-hr	3.1	2.8	3.2
(Corr. 15% 02)	ppm	678	604	644
Non-Methane Hydrocarbons (NMHC) (9)	g/bhp-hr	0.47	0.42	0.48
(Corr. 15% 02)	ppm	48	40	41
Exhaust Oxygen (9)	%	8.2	7.4	7.0
Lambda		1.58	1.49	1.43
Engine Heat Balance Data				
Input Energy LHV (1)	Btu/min	99992	76948	53571
Work Output	Btu/min	34365	25774	17183
Heat Rejection to Jacket (2) (6)	Btu/min	31421	26759	20465
Heat Rejection to Atmosphere (Radiated) (4)	Btu/min	3643	3036	2429
Heat Rejection to Lube Oil (5)	Btu/min	0	0	0
Total Heat Rejection to Exhaust (to 77°F) (2)	Btu/min	25965	18499	12609
Heat Rejection to Exhaust (LHV to 350°F) (2)	Btu/min	15457	10904	7330
Heat Rejection to Aftercooler (3) (7) (8)	Btu/min	4598	2880	885

CATERPILLAR

Caterpillar Inc.
Lafayette Engine Center
Lafayette, Indiana 47905

June 15, 2000

Gas Engine Emissions Letter

Project:	MDWASD Alexander WTP		
Model:	G3606 LE	Rating (note below):	2225 bhp @ 1000 rpm
Compression Ratio:	9.1	BSFC (Btu/bhp-hr):	6810 +/- 5.0%
A/C Inlet Temp. (°F):	130	J/W Outlet Temp. (°F):	190
Fuel LHV (Btu/ft3):	963	Altitude (ft):	sea level
Fuel MN:	72.7	Ambient (°F):	110

	NOx (as NO2)	CO	THC	NMHC	NMNEHC
g/bhp-hr	0.70	2.50	6.00	1.05	0.51
tons/year	15.0	53.7	128.9	22.8	11.0

Exhaust Mass Flow (lbs/hr, wet): 25,543

Exhaust Volume Flow (cfm, wet): 14,816
@ 842°F stack temp, 14.5 psia

Emission levels are based on engine operation at steady state conditions adjusted to the specified NOx level. The CO, THC, NMHC, and NMNEHC values listed are higher than nominal levels to allow for instrumentation, measurement, and engine-to-engine variations. They indicate "not to exceed" values. Tons per year values are based on 8,760 hours of operation per year.

This information is valid for engine orders placed within six (6) months of the above date. Please contact the factory after six months if an extension is required.

Sincerely,

Jeffery A. Elijah
G3600 Applications
Lafayette Engine Center

G3608 SITA 9:1 Industrial Performance

		100%	75%	50%	25%
...piration		TA	TA	TA	TA
Speed	rpm	1000	1000	1000	1000
JW Outlet Temperature (°F)		190	190	190	190
A/C Inlet Temperature (°F)		130	130	130	130
Engine Power	bhp[1]	2225	1669	1113	556
NOx (as NO_2)	g/bhp-hr[2]	0.70	0.70	0.70	1.20
CO	g/bhp-hr[2]	1.90	1.90	1.90	2.20
HC (Total)	g/bhp-hr[2]	5.95	6.30	6.50	6.00
HC (Non-Methane)	g/bhp-hr[2]	0.89	0.95	0.98	0.90
Exhaust Oxygen	% (dry)	12.3	11.7	10.7	10.2
BSFC	Btu/hp-hr	6810	7035	7550	9620
Compressor Out Pressure	in Hg abs	70.4	54.2	36.6	32.0
Compressor Out Temp (°F)		290	238	154	132
Intake Manifold Pressure	in Hg abs	69.7	53.8	38.3	23.9
Intake Manifold Temp (°F)		148	143	140	136
Air-Fuel Ratio	vol/vol	20.09	19.93	18.57	17.40
Timing	°BTDC	20.2	20.2	19	16.2
Fuel Energy	Btu/min[3]	252538	195661	139990	89185
...ust (LHV)	Btu/min[4]	97042	76771	56282	34002
...aust (to 350°F)	Btu/min[4]	58201	46698	34427	22433
A...ercooler	Btu/min[5]	16141	8285	1113	63
Radiation - Engine only	Btu/min[6]	11177	10468	9659	8740
Oil Cooler	Btu/min[7]	10325	10025	9750	9450
Jacket Water	Btu/min[4]	23467	19324	15993	13334
Air Flow	lb/hr	25760	19794	13195	7876
Air Flow (scfm @ 77°F, 13.9 psia)		6136	4715	3143	1876
Exhaust Flow	lb/hr	26537	20395	13626	8150
Exh Flow (cfm @ stack T, 14.5 psia)		14367	11610	8048	4978
Exhaust Stack Temp (°F)		847	868	918	965
Fuel Flow (scfh 4 @ 60°F, 14.7 psia)		16743	12972	9281	5913

1) Continuous output and reference conditions according to ISO 3046/1 (77°F, 14.5 psia), Natural gas LHV = 905 Btu/sft[3]. (Engine power conversion: 1 bhp = 42.42 Btu/min)
2) Emissions data shown are not to exceed values.
3) Tolerance +/-2.5%
4) Tolerance +/- 10%, jacket water heat rejection based on treated water as coolant
5) Tolerance +/- 5%, heat rejection based on treated water as coolant
...erance +/- 25%
...lerance +/- 20%, heat rejection based on treated water as coolant

PANTROPIC POWER PRODUCTS, INC.

CAT Power Systems

8205 N.W. 58th Street , Miami, FL 33166

FAX COVER

DATE: 10 - 20 - 00	FROM: Robert Butt . Project Manager
COMPANY: MIAMI DADE WASA	TEL. # (305) 592-4944 , ext 3108
ATTN : MR. RICHARD O'ROURKE	FAX # (305) - 574 - 7875
FAX # : (305 - 669 - 5749 TEL) FAX # 305 - 669 - 5717	REFERENCE : REQUEST FOR INFORMATION
PAGES : 3 (Including this page)	ALEXANDER ORR JR. WTP PROJECT GENERATOR EQUIPMENT

(PLEASE ADVISE IMMEDIATELY IF **ALL** PAGES ARE **NOT** RECEIVED)

Mr. O'Rourke :

Please find attached Caterpillar factory issued technical information pertaining to the generator set engine exhaust emissions and fuel consumption data in response to your inquiry.
This information is specific to the generator set model that is to be furnished by Pantropic Power Products , Inc. for the above referenced Project.

Response: Date:

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM
CERTIFICATION YEAR CERT AGENCY
INFO CODE 01 - GENERAL PERFORMANCE DATA *

GEN W/F EKW	PER CENT LOAD	ENG PWR BHP	ENG BMEP PSI	S FUEL CONSUM LB/BHP-HR	FUEL RATE GPH	INTAKE MANF T DEG F	INTAKE MANF P IN-HG	INTAKE AIR FL CFM	EXH MANF T DEG F	EXH STK T DEG F	EXH GAS FL CFM
900.0	100	1332	278	.350	66.5	214	78.3	2821	1262	884	7327
810.0	90	1202	251	.346	59.4	208	71.8	2691	1177	831	6695
720.0	80	1073	224	.344	52.8	203	64.5	2532	1103	787	6073
675.0	75	1009	211	.346	49.8	202	60.6	2436	1079	776	5787
630.0	70	945	197	.347	46.8	200	56.4	2334	1052	764	5484
540.0	60	817	171	.350	40.9	198	47.8	2112	1000	742	4866
450.0	50	691	144	.357	35.2	196	39.4	1886	952	723	4269
360.0	40	568	119	.368	29.9	195	31.2	1667	906	705	3708

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM
CERTIFICATION YEAR CERT AGENCY
INFO CODE 01 - GENERAL PERFORMANCE DATA *

GEN W/F EKW	PER CENT LOAD	ENG PWR BHP	ENG BMEP PSI	S FUEL CONSUM LB/BHP-HR	FUEL RATE GPH	INTAKE MANF T DEG F	INTAKE MANF P IN-HG	INTAKE AIR FL CFM	EXH MANF T DEG F	EXH STK T DEG F	EXH GAS FL CFM
270.0	30	443	93	.386	24.4	193	23.0	1441	858	686	3157
225.0	25	379	79	.400	21.6	192	19.2	1335	827	670	2888
180.0	20	315	66	.420	18.9	191	16.2	1250	780	640	2638
90.0	10	184	38	.504	13.3	189	10.8	1098	670	564	2157

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM

INFO CODE 02 - HEAT REJECTION DATA *

GEN W/F EKW	PER CENT LOAD	REJ TO JW BTU/MN	REJ TO ATMOS BTU/MN	REJ TO EXH BTU/MN	EXH RCOV TO 350F BTU/MN	FROM OIL CLR BTU/MN	FROM AFT CLR BTU/MN	WORK ENERGY BTU/MN	LHV ENERGY BTU/MN	HHV ENERGY BTU/MN
900.0	100	34804	8246	53116	28435	7621	11033	56472	142743	152070
810.0	90	31051	7166	46633	24227	6768	9327	50955	127559	135862
720.0	80	27639	6483	41231	20530	6028	7621	45496	113228	120621
675.0	75	26103	6199	38842	19222	5687	6824	42766	106915	113853
630.0	70	24511	5971	36454	17857	5346	5971	40036	100432	106972
540.0	60	21440	5573	31847	15241	4663	4322	34691	87750	93494
450.0	50	18483	5175	27525	12909	4038	2957	29288	75637	80585
360.0	40	15639	4777	23430	10805	3412	1763	24113	64035	68244

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM

INFO CODE 02 - HEAT REJECTION DATA *

GEN W/F EKW	PER CENT LOAD	REJ TO JW BTU/MN	REJ TO ATMOS BTU/MN	REJ TO EXH BTU/MN	EXH RCOV TO 350F BTU/MN	FROM OIL CLR BTU/MN	FROM AFT CLR BTU/MN	WORK ENERGY BTU/MN	LHV ENERGY BTU/MN	HHV ENERGY BTU/MN

EMISSIONS

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ EXH STK DIA 8.0 IN
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM

INFO CODE 05 - EMISSIONS DATA * * REFERENCE NOTES - NOT TO EXCEED * * * * * * *
EMISSIONS DATA MEASUREMENT IS CONSISTENT WITH THOSE DESCRIBED IN EPA CFR 40 PART 86 SUBPART D AND ISO 8178-1 FOR MEASURING HC, CO, CO2 AND NOX. THESE PROCEDURES ARE VERY SIMILAR TO THE METHODS DESCRIBED IN EPA CFR 40 PART 60 APPENDIX A METHOD 25A FOR HYDROCARBONS, METHOD 10 FOR CO, METHOD 7E FOR NOX.

DATA SHOWN IS BASED ON STEADY STATE ENGINE OPERATING CONDITIONS OF 77 DEG F, 28.42 IN HG AND NUMBER 2 DIESEL FUEL WITH 35 DEG API AND LHV OF 18,390 BTU/LB.

TO PROPERLY APPLY THIS DATA YOU MUST REFER TO PERFORMANCE PARAMETER DM1176 FOR ADDITIONAL INFORMATION, (APPLICATION GKN402, PROGRAM 03).

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ EXH STK DIA 8.0 IN
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM

* INFO CODE 05 - EMISSIONS DATA * * * * * RATED SPEED * * * * STANDARD TIMING
"NOT TO EXCEED DATA"

GEN PWR EKW	% LOAD	ENG PWR BHP	NOX (AS NO2)	CO	TOTAL HC	PART MATTER	O2 (DRY) IN EXH (VOL) %	SMOKE OPAC %	BOSCH SMOKE NO.
			* * * * * * * * *		LB/HR	* * * * * * * * *			
900.0	100	1332.2	37.46	2.10	.68	.310	9.90	1.0	1.28
675.0	75	1008.8	33.07	1.22	.77	.250	11.40	0.9	1.28
450.0	50	690.9	25.67	.83	.46	.190	12.40	1.0	1.28
225.0	25	378.9	16.92	.82	.34	.150	13.50	1.0	1.28

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ EXH STK DIA 8.0 IN
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM

INFO CODE 05 - EMISSIONS DATA * * * * * RATED CONDITIONS * * STANDARD TIMING
"NOMINAL DATA"
AT RATED:

WET EXHAUST MASS	12838 LB/HR
WET EXHAUST FLOW (884 DEG F STACK TEMP)	7331 CFM
WET EXHAUST FLOW RATE (32 DEG F AND 29.98 IN HG)...	2681 STD CFM
DRY EXHAUST FLOW RATE (32 DEG F AND 29.98 IN HG)...	2473 STD CFM
FUEL FLOW RATE	66.0 GAL/HR

Attachment 4

Fuel Specifications
Natural Gas
Diesel Fuel

Alexander Orr, Jr.
Water Treatment Plant

City Gas Company of Florida

Miami Division
955 East 25th Street
Hialeah, FL 33013-3498
Tel: (305) 691-8710
Fax: (305) 691-7112
www.nui.com

NUI Corporation (NYSE: NUI)

MIAMI - DADE
WATER AND SEWER DEPARTMENT
RECEIVED
SEP 11 1998
PLANNING

MIAMI-DADE
WATER AND SEWER DEPT.
RECEIVED
JUL 23 1998
ENGINEERING
DIVISION
(PROJECT MANAGER)

July 22, 1998

Mr. Wilfredo M. Fernandez
Miami Dade Water & Sewer Department
P.O. Box 330316
Miami, Florida 33233-0316

Re: Heating Value of natural gas

Dear Wilfredo:

Attached please find a fuel analysis provided to City Gas by Florida Gas Tmasmission Company. In it you will note that the heating value of the natural gas delivered to City Gas is 1058 Btu/cf at standard pressure and temperature

Please, call me if you have any questions or need additional information.

Sincerely,

Adrian S. Morera
Key Account Manager
Enclosure

cc: J. Pappas
M. Blanco-Pape
V. Fernandez-Cuervo
T. Chu
J. Murias
F. Sagastume
Project File (~~ES~~ WNFER 46495)
~~R. O'Rourke~~

Spot Analysis of Natural Gas for Delivery in Florida

(West Palm Beach Chromatograph)

DATE: November 17, 1997

TIME: 06:12

Component Name	Mole %
Hexane	0.094
Propane	0.865
Isobutane	0.215
n-Butane	0.175
Isopentane	0.064
n-Pentane	0.037
Nitrogen	0.387
Methane	93.317
CO2	1.029
Ethane	3.814
Totals	100.000

Dry Btu/cf @ 14.730 psia and 60°F= 1058.4

Real Relative Density= 0.6037

Total Sulfur	NA PPM
H^2S	NA PPM
H^2O	4.41 lb/MMcf

MIAMI-DADE
WATER AND SEWER DEPT.
RECEIVED
JUL 23 1998
ENGINEERING
DIVISION
(PROJECT MANAGER)

MIAMI-DADE
WATER AND SEWER DEPT.
RECEIVED
JUL 23 1998
ENGINEERING
DIVISION
(PROJECT MANAGER)

Non-Negotiable Bill of Lading

MATERIAL SAFETY DATA SHEET AVAILABLE FROM THE TERMINAL FOR THESE PRODUCTS ON REQUEST

CUSTOMER NOTICE – THE PRODUCT TRANSFER DOCUMENTS FOR THIS TRANSACTION INCLUDE OTHER DOCUMENTS WHICH MAY CONTAIN ADDITIONAL AND/OR CORRECTING REFORMULATED GASOLINE INFORMATION. IF IN CONFLICT, THE INFORMATION IN THE OTHER DOCUMENTS WILL CONTROL.

Form 50605-A Rev. 11/97

SEE REVERSE SIDE FOR HAZARD WARNING INFORMATION & NOTES

DRIVER SIGNATURE:

ALL ITEMS SUBJECT TO CONDITIONS ON REVERSE SIDE HEREOF.

TRUCK SEAL NUMBERS: SHIPMENT RECEIVED BY:

For Product Emergency
Spill, Leak, Fire, Exposure or Accident, CALL
CHEMTREC - Day or Night 800-424-9300

COPY 6

MARATHON ASHLAND PETROLEUM LLC, 539 S. MAIN STREET FINDLAY OHIO 45840 EPA 4268
*** CONVENTIONAL GASOLINES - THESE PRODUCTS DO NOT MEET THE REQUIREMENTS FOR REFORMULATED GASOLINES (RFG) AND MAY NOT USED IN ANY RFG COVERED AREA. *** SHIPPED FROM: 1601 S.E. 20TH STREET, FT. LAUDERDALE, FL 33316

DATE 08/14/01
NUMBER 549224-226
TIME IN 0940
TIME OUT 0955

SOLD TO (CONSIGNEE):
BP OIL COMPANY EX
MANSFIELD OIL CO (UNB)
FL. DEST.

SHIPPED FROM: FT LAUDERDALE TERMIN, 1601 SE 20TH ST FT LAUDERDALE FLA
LOC CODE: 0000429440

DATE SHIPPED: 08/14/01
SHIPPED VIA: BILL FREIGHT UNKNOWN, 3947 PENN TANK LINES

DESTINATION: UNKNOWN FL

CUSTOMER NUMBER: 220413496000000
ITEM NUMBER:

DRIVER	TRAILER	COMPANY	CUSTOMER P.O. AND RELEASE NUMBER	TRANSMITTED CUSTOM AND RELEASE NUMBE
11604 LOUIS EIBER	4659	0305		

CARGO TANK COMPARTMENT PRODUCT DESCRIPTIONS	GROSS GAL.	NET GAL.	TEMP./API GR.	COMMENTS
NO2 LOW SULFUR,.05% MAX SULFUR,40 CETANE MIN,DYED DIESEL FUEL, NONTAXABLE USE ONLY,PN. ENASLTY FOR TAXABLE USE				
FUEL OIL, 3, NA1993, PG III	2200 **	2172 **		Meter 19 Preset 2200 Code 07
137	2200	2172	88.1/033.6	100.0%
NO2 LOW SULFUR,.05% MAX SULFUR,40 CETANE MIN,DYED DIESEL FUEL, NONTAXABLE USE ONLY,PN. ENASLTY FOR TAXABLE USE				
FUEL OIL, 3, NA1993, PG III	2800 **	2764 **		Meter 19 Preset 2800 Code 07
137	2800	2764	88.3/033.6	100.0%
NO2 LOW SULFUR,.05% MAX SULFUR,40 CETANE MIN,DYED DIESEL FUEL, NONTAXABLE USE ONLY,PN. ENASLTY FOR TAXABLE USE				
FUEL OIL, 3, NA1993, PG III	520 **	513 **		Meter 19 Preset 520 Code 07
137	520	513	88.2/033.6	100.0%
		5449		

CONV GASOLINE / 7.8 RVP GASOLINE / CLEAR L.S. #2 / DYED L.S. #2 /
H.S. #2 (** - Batch Total)

Attachment 5

Description of Stack Sampling Facilities
Proposed Natural Gas Fueled Engine Driven Pumps
Proposed Emergency Generator

Alexander Orr, Jr.
Water Treatment Plant

Description of Stack Sampling Facilities

Alexander Orr, Jr. Water Treatment Plant
Miami-Dade Water and Sewer Department

Proposed Natural Gas Fueled Engine Driven Pumps

Diameter (in.):	12 inches (Engine Nos. 3 and 4) 18 inches (Engine No. 5)
Orientation:	Vertical
Height above structure (ft):	3.5 feet
Height above grade (ft):	32 feet
Means of access:	Portable ladder or man lift
Sampling ports:	Standard sampling ports are provided in the exhaust piping inside the East Pump Room building.

Proposed Emergency Generator

Diameter (in.):	8 inches
Orientation:	Horizontal
Height above structure (ft):	6 feet
Height above grade (ft):	18 feet
Means of access:	Portable ladder or man lift to roof.
Sampling ports:	No sampling ports are feasible given configuration. Alternate sampling procedure requested. Sampling accomplished through use of a rake probe is inserted into end of stack.

Attachment 6

Procedures for Startup

Alexander Orr, Jr.
Water Treatment Plant

Procedures for Startup
Engine Driven Pumps
Alexander Orr, Jr. Water Treatment Plant
Miami-Dade Water and Sewer Department

Normal Startup

The engine driven pumps at the Alexander Orr, Jr. WTP are started by air power. Prior to start up the starting air cylinders and compressors will be checked for adequate air supply and operation. The engine and drive gear operating fluid levels will be checked with additions made as necessary. Engine cooling water, fuel supply, starting air supply valves and pump suction valves will be aligned to the proper condition for startup. Start engine auxiliary pumps and pre-lubrication pumps if supplied. Open priming water supply valves, verify priming water supply to the main pump. To begin startup, the starting air is applied to the air motor, once the engine begins to turn over, the spark ignition will begin. After ignition, shut off the starting air, along with the engine pre-lubrication pump. The engine will be running at idle setting. Since the pump is directly coupled through the drive gears to the engine, the pump will be engaged. Let engine run for 2 to 3 minutes before putting the pump on the line. Actuate the cone valve and observe the valve open. (The pointer that indicates open or closed position is on the side of the cone valve.) After the cone valve is open and the engine loaded, shut off the main pump priming water supply. Check engine, gauges and auxiliaries to make sure there are no leaks, etc. Monitor engine exhaust and operating parameters for any abnormalities that would require shut down. Following operations at minimum speed to allow the engine to reach minimum operating temperatures, the engine speed may be increased as required. Adjust engine speed to desired operating range. The pump engines will be operating under load within 3 minutes of startup and approximately 15 minutes to before a full load is applied.

Excess Emissions

Excess emissions that occur during startup will consist of elevated hydrocarbon (HC), carbon monoxide (CO), and particulate (PM) emissions as a result of cold combustion temperatures. As the pump engine warms up and additional load, emissions of these pollutants will decrease. Emissions of nitrogen oxides (NOx) will increase as the engines warm up and reaches a fully loaded condition.

Since limitations in the permit application are based on the consumption of fuel, emissions resulting from startup of the pump engines are accounted for in monitoring, recordkeeping, and reporting.

Do not attempt to remove the valve covers when the engine is operating. The transformers are grounded to the valve covers. Personal injury or death may result and the ignition system will be damaged if the valve covers are removed during engine operation. The engine will not operate without the valve covers.

i00659904

Before Starting Engine

SMCS Code: 1000

Inspect the engine for potential hazards.

Before starting the engine, ensure that no one is on, underneath, or close to the engine. Ensure that the area is free of personnel.

Ensure that the engine is equipped with a lighting system that is suitable for the conditions. Ensure that all lights work properly.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

Do not bypass the automatic shutoff circuits. Do not disable the automatic shutoff circuits. The circuits are provided in order to help prevent personal injury. The circuits are also provided in order to help prevent engine damage.

On the initial start-up of a new engine or an engine that has been serviced, be prepared to stop the engine if an overspeed condition occurs. This may be accomplished by shutting off the fuel supply to the engine, or shutting off the ignition system.

See the Service Manual for repairs and for adjustments.

i00572000

Engine Starting

SMCS Code: 1000

If a warning tag is attached to the engine start switch or to the controls, DO NOT start the engine or move the controls. Consult with the person that attached the warning tag before the engine is started.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

Start the engine from the operator's compartment or from the engine start switch.

Always start the engine according to the procedure that is described in the Operation and Maintenance Manual, "Engine Starting" topic in the Operation Section. Knowing the correct procedure will help to prevent major damage to the engine components. Knowing the procedure will also help to prevent personal injury.

To ensure that the jacket water heater (if equipped) and/or the lube oil heater (if equipped) is working properly, check the water temperature gauge and the oil temperature gauge during the heater operation.

Engine exhaust contains products of combustion which can be harmful to your health. Always start the engine and operate the engine in a well ventilated area. If the engine is started in an enclosed area, vent the engine exhaust to the outside.

i00659907

Engine Stopping

SMCS Code: 1000

To avoid overheating of the engine and accelerated wear of the engine components, stop the engine according to the instructions in this Operation and Maintenance Manual, "Engine Stopping" topic (Operation Section).

Use the Emergency Stop Button (if equipped) ONLY in an emergency situation. Do not use the Emergency Stop Button for normal engine stopping. After an emergency stop, DO NOT start the engine until the problem that caused the emergency stop has been corrected.

On the initial start-up of a new engine or an engine that has been serviced, make provisions to stop the engine if an overspeed occurs. This may be accomplished by shutting off the fuel supply to the engine, or shutting off the ignition system.

Engine Starting

i01071463

Before Starting Engine

SMCS Code: 1000

Note: Certain procedures are required before an engine is started for the first time. See Special Instruction, SEHS9769, "Installation and Initial Start-UP Procedure for G3500 Engines".

Perform the required daily maintenance and other periodic maintenance before starting the engine. This can prevent major repairs at a later date. See this Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section).

Walk-Around Inspection

NOTICE

For any type of leak, clean up the fluid. If leaking is observed, find the source and correct the leak. If leaking is suspected, check the fluid levels more often than recommended until the leak is found or fixed, or until the suspicion of a leak is proved to be unwarranted.

To obtain maximum service life for your engine, make a thorough inspection before starting the engine. Make a walk-around inspection of the installation. Look for items such as oil or coolant leaks, loose bolts and trash buildup. Remove any trash. Make repairs, if necessary.

- The guards must be in the proper place. Repair damaged guards or replace missing guards.
- Ensure that the areas around the rotating parts are clear.

Air Inlet System

- Ensure that the air inlet piping and the air filters are in place.
- Ensure that all clamps and connections are secure.
- Inspect the air cleaner service indicator (if equipped). Service the air cleaner filter element when the yellow diaphragm enters the red zone, or the red piston locks in the visible position.

Cooling System

- Inspect the cooling system for leaks or loose connections. Inspect the condition of all the hoses and pipes for the cooling system. Ensure that the connections are properly clamped.
- Inspect the water pumps for evidence of leaks.
- Check the coolant level. Add coolant, if necessary. For information on the proper coolant to use, see this Operation and Maintenance Manual, "Cooling System Specifications" (Maintenance Section).

Driven Equipment

- If necessary, check the oil levels of the driven equipment. Perform any maintenance that is required for the driven equipment. Refer to the literature that is provided by the OEM of the driven equipment.
- If the engine is equipped with a clutch, ensure that the clutch is disengaged.
- For generator set engines, ensure that the main circuit breaker is open.

Electrical System

Inspect the wiring for the following conditions:

- Loose connections
- Wiring that is worn or frayed

Inspect the gauge panel and the control panel for good condition. Reset any shutoff or alarm components.

Fuel System

⚠ WARNING

NEVER use a flame to check for gas leaks. Use a gas detector.

An open flame can ignite mixtures of air and fuel. This will cause explosion and/or fire which could result in severe personal injury or death.

- Check the fuel lines for leaks with a gas detector.
- Inspect the fuel lines for loose fittings and leaks. Ensure that the fuel lines are properly clamped.
- Ensure that the fuel is supplied to the engine at the correct pressure for the engine.

Lubrication System

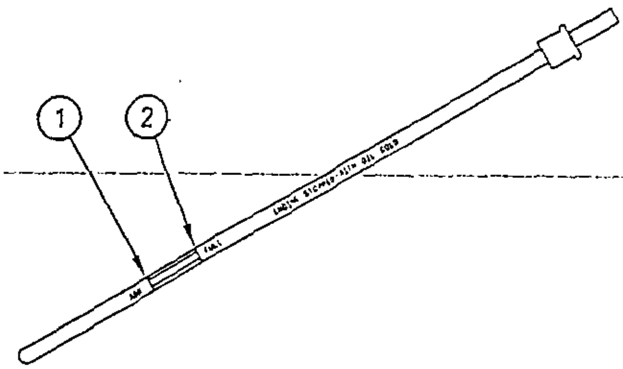


Illustration 33 g00274899

Oil level gauge (dipstick)

(1) "ADD" mark
(2) "FULL" mark

NOTICE
Excessive engine oil will increase oil consumption and result in excessive deposits in the combustion chamber. Do not overfill the engine with oil.

- Check the engine crankcase oil level. Maintain the oil level between the "ADD" and "FULL" marks on the "ENGINE STOPPED WITH OIL COLD" side of the oil level gauge. For information on the proper oil to use, see this Operation and Maintenance Manual, "Lubricant Specifications" (Maintenance Section).
- Check for leaks at the following components: crankshaft seals, crankcase, oil filters, oil gallery plugs, sensors, and valve covers.
- Inspect the tubes, tee pieces, and clamps on the crankcase breathers.

Starting System

Note: If the engine is equipped with a system for external support, prepare the system before starting the engine. Ensure that all of the systems for engine support are enabled. Perform all prestart checks for the control system.

Air Starting Motor

- Drain moisture and sediment from the air tank and from any other air piping.
- Check the oil level in the lubricator. Keep the lubricator at least half full. Add oil, if necessary. For temperatures above 0 °C (32 °F), use a nondetergent 10W oil. For temperatures below 0 °C (32 °F), use air tool oil.
- Check the air pressure for starting. The air starting motor requires a minimum of 690 kPa (100 psi). The maximum allowable air pressure is 1030 kPa (150 psi). Open the air supply valve.

Electric Starting Motor

- Disconnect any battery chargers that are not protected against the high current drain that is created when the electric starting motor engages.

Inspect the wiring, the electrical cables, and the battery for the following conditions:

- Loose connections
- Wires that are worn or frayed
- Corrosion

i00719534

Cold Weather Starting

SMCS Code: 1000; 1250

Note: Oil pan immersion heaters are not recommended for heating the lube oil. To ensure the compatibility of the components, only use equipment that is recommended by Caterpillar.

Startability will be improved at temperatures below 16 °C (60 °F) with a starting aid. A jacket water heater may be needed and/or the crankcase oil may need to be warmed.

A jacket water heater is available as an option for starting in temperatures as low as 0 °C (32 °F). The jacket water heater can maintain the water temperature at approximately 32 °C (90 °F). The heated water will help to keep the oil in the engine block warm enough to flow when the engine is started.

To start the engine at colder temperatures, a larger volume of starting air and/or a higher air pressure may be necessary.

For electric starting, extra battery capacity may be necessary.

Consult your Caterpillar dealer for more information on the starting aids that are available for cold weather starting.

i00758716

Starting the Engine

SMCS Code: 1000

WARNING

Engine exhaust contains products of combustion which may be harmful to your health. Always start and operate the engine in a well ventilated area and, if in an enclosed area, vent the exhaust to the outside.

NOTICE

For initial start-up of a new or rebuilt engine, and for start-up of an engine that has been serviced, make provision to shut the engine off should an overspeed occur. This may be accomplished by shutting off the fuel supply and/or the ignition to the engine.

Note: Using the "EMERGENCY STOP" button will shut off both the fuel and the ignition.

WARNING

Unburned gas in the inlet manifold can ignite when the engine is started. Personal injury and/or property damage can result. Clear the engine and the exhaust system of unburned gas

Before starting an engine that was stopped by terminating the ignition system, turn the gas supply OFF. Crank the engine for approximately 15 seconds in order to clear any unburned gas from the engine and the exhaust system.

Do not start the engine or move any of the controls if there is a "DO NOT OPERATE" warning tag or similar warning tag attached to the start switch or to the controls.

Ensure that no one will be endangered before the engine is started and when the engine is started.

Perform the procedures that are described in this Operation and Maintenance Manual, "Before Starting Engine" (Operation Section).

Operation of the Generator Set Control Panel

For information on operation for a specific generator set control panel, refer to the Operation and Maintenance Manual for the generator and the control panel.

Automatic Starting

WARNING

When the engine is in the AUTOMATIC mode, the engine can start at any moment. To avoid personal injury, always remain clear of the the engine when the engine is in the AUTOMATIC mode.

If the engine control switch is in the "AUTO" position, the engine will automatically start when the remote start/stop initiate contact closes. The engine will accelerate to rated rpm when the oil pressure is sufficient.

Manual Starting

1. Ensure that fuel is supplied to the engine. Ensure that no gas is leaking.

2. Ensure that the driven equipment is unloaded.

   a. For generator set engines, ensure that the main circuit breaker is open.

   b. For industrial engines, unload the compressor or pump. Disengage the clutch (if equipped). Place the transmission and/or other attachments for the power take-off in NEUTRAL.

Note: Before starting an industrial engine, move the governor control lever to the position for 1/2 of rated rpm.

NOTICE

Do not engage the starting motor when flywheel is turning. Do not start the engine under load.

If the engine fails to start within 30 seconds, release the starter switch or button and wait two minutes to allow the starting motor to cool before using it again.

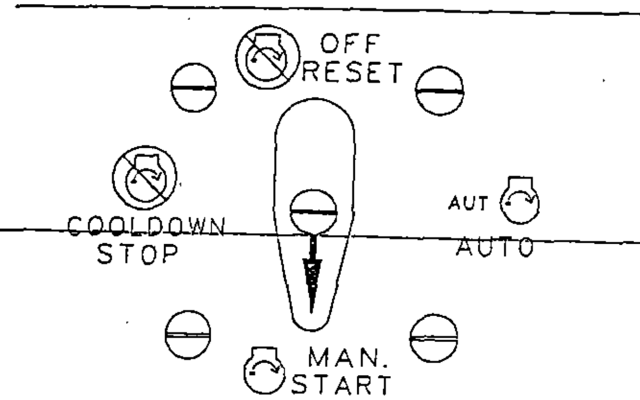


Illustration 34 g00319402

Engine control switch in the "Man. Start" position

3. Turn the engine control switch to the "Man. Start" position in order to start the engine.

Note: After starting an industrial engine, move the governor control lever to the position for low idle rpm.

4. Allow the engine to idle for three to five minutes. The engine speed should stabilize at low idle rpm. Check all of the pressure gauges. Inspect the engine for leaks and listen for unusual noises. When all systems are normal, the rpm may be increased.

Table 12

Rated RPM And Low Idle RPM					
Rated rpm	1000	1200	1400	1500	1800
Low idle rpm	700	900	1000	1000	1200

Starting Failure

Note: If the cycle crank feature is enabled, the Status Control Module (SCM) will attempt to start the engine for the programmed period. If the engine fails to start within the programmed period, the SCM will execute an overcrank fault. The "OVERCRANK" indicator on the Remote Control Panel (Status) will illuminate. The SCM must be reset before the engine can be started. Turn the engine control switch to the "OFF/RESET" position.

If the engine fails to start after cranking for 30 seconds, stop cranking. Perform the following procedure:

1. Turn the engine control switch to the "OFF/RESET" position.

2. Turn the gas supply OFF.

3. Allow the starting motor to cool for two minutes. Crank the engine for approximately 15 seconds in order to disperse any unburned gas from the engine and the exhaust system.

4. Allow the starting motor to cool for two minutes. Turn the gas supply ON. Repeat the starting procedure.

i01037941

Starting with Jump Start Cables

SMCS Code: 1000; 1401; 1402

⚠ WARNING

Improper jump start cable connections can cause an explosion resulting in personal injury.

Prevent sparks near the batteries. Sparks could cause vapors to explode. Do not allow jump start cable ends to contact each other or the engine.

If the installation is not equipped with a backup battery system, it may be necessary to start the engine from an external electrical source.

First, determine the reason that it is necessary to start with power from an external source. Refer to Special Instruction, SEHS7768, "Use of the 6V-2150 Starting/Charging Analyzer".

Many batteries which are considered unusable are still rechargeable. After jump starting, the alternator may not be able to fully recharge batteries that are severely discharged. The batteries must be charged to the proper voltage with a battery charger. For information on testing and charging, refer to the Special Instruction, SEHS7633, "Battery Test Procedure".

Attachment 7

Proposed Replacements
Engine Driven Pumps Nos. 3 & 4
G3512LE Technical Data

G3512LE Performance Data
G3512LE Emissions
G3500 Engine Basics
G3500 Ignition Systems

Alexander Orr, Jr.
Water Treatment Plant

G3512LE

PERFORMANCE DATA

CATERPILLAR®

Gas Industrial Engine

G3512

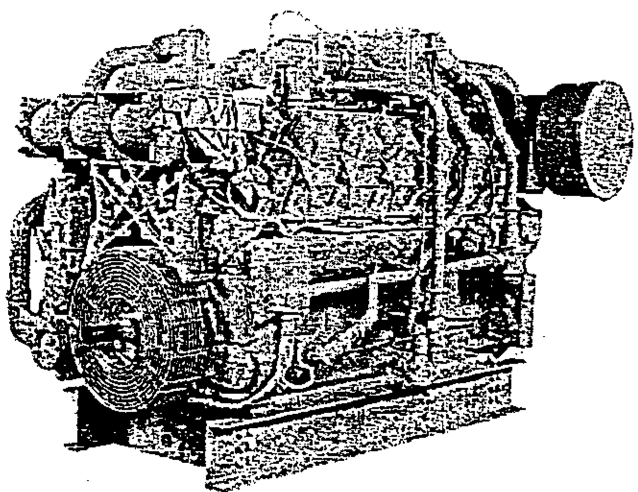
525-1005 hp

Standard and Low Emission

SPECIFICATIONS

V-12, 4-Stroke-Cycle, Spark Ignited	
Bore—in (mm)	6.7 (170)
Stroke—in (mm)	7.5 (190)
Displacement—cu in (L)	3158 (51.8)
Compression Ratio	
STD	9:1
LE	8:1
Aspiration	Naturally Aspirated or Turbocharged-Aftercooled
Lube Oil Capacity — gal (L)	
STD*	116 (493)
STD**	128 (483)
LE	81 (307)
Jacket Water System — gal (L)	
Capacity w/o Radiator	39 (148)

* Oil fill capacity with 14 elements
** Oil fill capacity without elements



Shown with Optional Equipment

FEATURES

■ DIESEL STRENGTH
All Caterpillar® gas engines are built on diesel frames which means greater service life. Caterpillar gas engines inherit more from their diesel counterparts than just strength. They are backed by the same support system recognized as one of the most sophisticated and dependable in the world.

■ APPLICATION FLEXIBILITY
Broad operating speed range and ability to burn a wide spectrum of gaseous fuels.

■ LOW EMISSIONS
Low emission engines are capable of NO(x) levels as low as 2.0 grams/hp-hr. Lower emissions may be achievable for selected applications. Consult your Caterpillar dealer.

■ CATERPILLAR® GAS ENGINES
Represent the latest technology in engine design. Engines are offered in both naturally aspirated and turbocharged/aftercooled configurations.
TA is offered as standard and low emission. These different configurations offer:
- High energy ignition systems for consistent firing
- High efficient combustion chamber for complete burning of the fuel
- Modern component design such as deep cup, oil gallery piston

■ ELECTRONIC IGNITION SYSTEM WITH DETONATION SENSITIVE TIMING
The Caterpillar electronic ignition system provides optimized spark timing for all operating conditions. Timing is automatically controlled to maintain continuous detonation protection.

CATERPILLAR

G3512 GAS INDUSTRIAL ENGINE

STANDARD EQUIPMENT

Air cleaners
  single stage, dry,
  with service
indicator
Breather, crankcase
Carburetor
  natural gas
Cooler
  lubricating oil
Filter
  lubricating oil, RH
Flywheel housing
  SAE No. 00
Governor
  Woodward
Ignition system
  Altronic III or
  Caterpillar E.I.S.
Instrument panel, RH
  8 gauge panel (STD)
  12 gauge panel (LE)
  oil pressure
  coolant temperature
  oil pressure
    differential
  intake manifold
    temp (TA only)
    pressure (LE)
  service meter
  exhaust pyrometer
    (LE)
Lifting eyes
Manifold, exhaust
  watercooled
Pumps, gear driven
  aftercooler water
    (TA only)
  jacket water
Rails, mounting, 10 in.
Regulator, gas
  pressure
SAE standard rotation
Thermostats and
  housing
Torsional vibration
  damper

OPTIONAL EQUIPMENT

Air to air aftercooler
  connection
Air head for 3161
Cooling systems
  high temp (LE only)
CSA ignition
Exhaust fittings
Low pressure gas
  conversion
Muffler
Power takeoffs
Starting systems
Tachometer

CONTINUOUS RATINGS (BHP)

Aspiration	1400 rpm	1300 rpm	1200 rpm	1100 rpm	1000 rpm	900 rpm
LE-90, 8:1	1005	930	860	790	720	650
LE-130, 8:1	945	875	810	740	675	610
STD TA-90, 9:1	–	–	815	745	675	610
STD TA-130, 9:1	–	–	790	725	660	595
STD NA, 9:1	–	–	525	480	440	395

PHYSICAL FACTORS

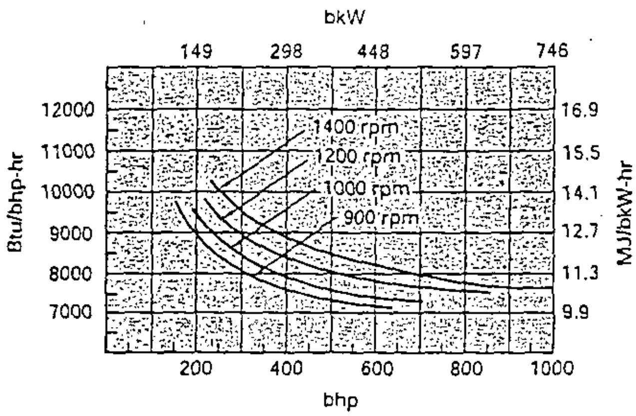
	Height in (mm)	Width in (mm)	Length in (mm)	Weight lb (kg)
LE	73.4 (1863)	67.1 (1703)	110 (2788)	14 650 (6651)
STD TA	73.4 (1863)	67.1 (1703)	110 (2788)	14 450 (6560)
STD NA	75.2 (1911)	64.7 (1642)	105 (2671)	13 400 (6084)

G3512 GAS INDUSTRIAL ENGINE

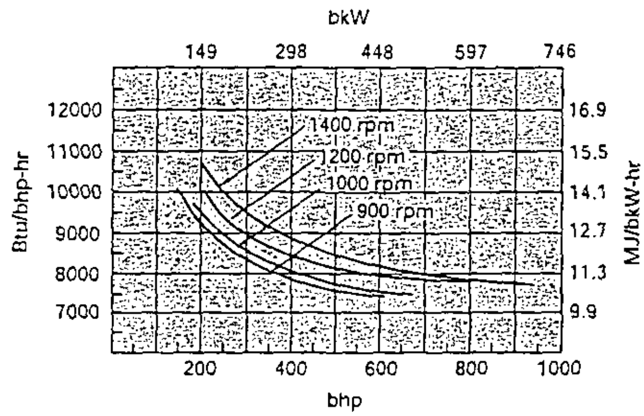
CATERPILLAR

FUEL CONSUMPTION

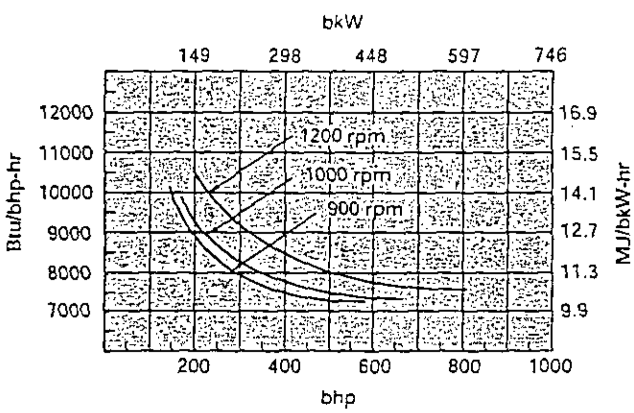
LE-90



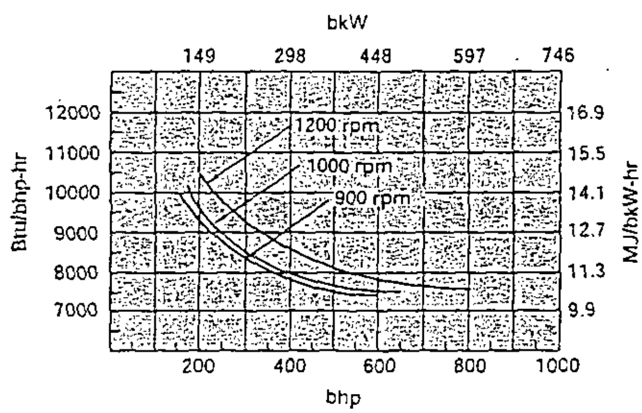
LE-130



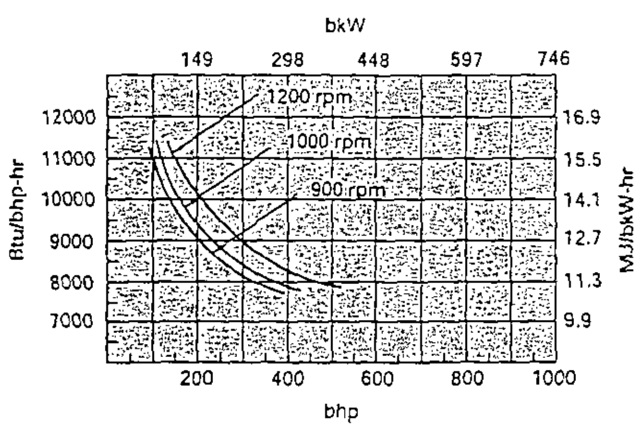
STD TA-90



STD TA-130

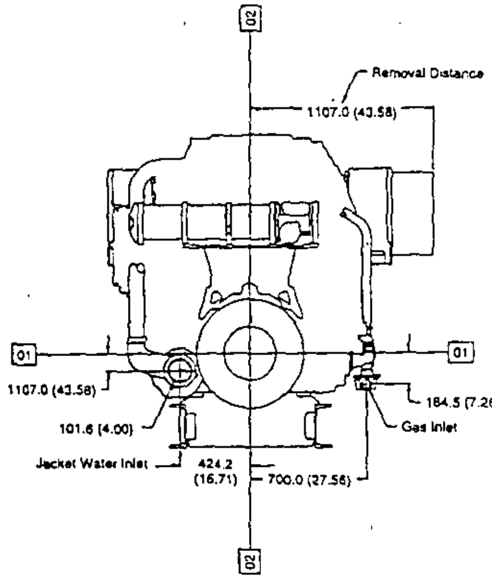


STD NA

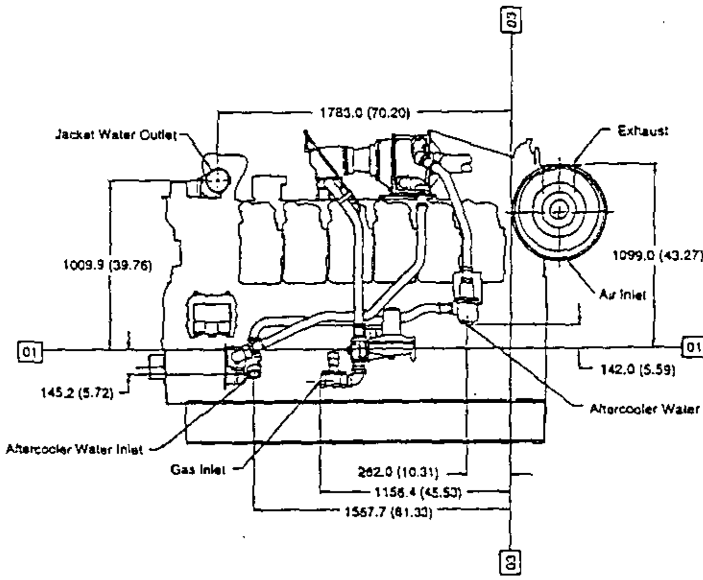


LE refers to low emission engine configuration.
STD refers to standard engine configuration.
90 refers to aftercooler water inlet temperature in 90° F (32° C).
130 refers to aftercooler water inlet temperature in 130° F (54° C).
All data is based on standard conditions. 77° F (25° C) 500 ft Alt.
These ratings do not allow for overload capability.

GAS INDUSTRIAL ENGINE



FRONT VIEW



LEFT SIDE VIEW

01	Centerline of Crankshaft
02	Centerline of Engine
03	Rear face of Cylinder Block

See general dimension drawing 119-9598 for additional Electronic Ignition System (E.I.S.) engine detail and NA information.

For magneto ignition system engines see general dimension drawing 7W-4444.

Note: General configuration not to be used for installation.

CONDITIONS AND DEFINITIONS

Ratings are based on SAE J1349 standard conditions of 29.61 in Hg (100 kPa) and 77 ° F (25° C). These ratings also apply at ISO3046, DIN6271, and BS5514 standard conditions of 29.61 in Hg (100 kPa), 81 ° F (27° C); and API 7B-11C standard conditions of 29.38 in Hg (99 kPa), 85° F (29° C).

Ratings are based on dry natural gas having a low heat value of 905 btu/ft³ (35.54 MJ/N m³). Variations in altitude, temperature, and gas composition from standard conditions may require a reduction in engine horsepower; contact your Caterpillar dealer.

Turbocharged-aftercooled ratings apply to 5000 ft (1525 m) and 77° F (25° C). **Naturally aspirated** engines apply to 500 ft (150 m) and 77° F (25° C). For applications which exceed these limits, consult your Caterpillar dealer.

Additional ratings may be available for specific customer requirements. Consult your Caterpillar representative for details.

Materials and specifications are subject to change without notice.

The International System of Units (SI) is used in this publication.

LEHQ6162 (3-96)
Supersedes LEHH0573

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G3512LE

APPLICATION & INSTALLATION

GUIDE

CATERPILLAR

Caterpillar Inc.
9701 State Road 26 East
Lafayette, IN 47905-4858

14 June 2000

Gas Engine Emissions Letter

PROJECT:	MDWASD Alexander WTP	BSFC:	7407 BTU/bhp-hr
model:	G3512	fuel pressure:	45 psi
compression ratio:	8:1	fuel LHV:	963 btu/ft3
A/C inlet temp:	130 °F	fuel MN:	72.7
J/W outlet temp:	210 °F	site altitude:	sea lvl ft
rating:	810 bhp @	max. ambient	110 °F
	1200 rpm	timing	31 ° BTDC

		100%
Engine Power	bhp	810
Exhaust O2	%	8.30
NOx (as NO2)	g/bhp-hr	2.00
	tons/year	15.64
CO	g/bhp-hr	1.60
	tons/year	12.51
total HC	g/bhp-hr	3.10
	tons/year	24.25
non-methane HC	g/bhp-hr	0.50
	tons/year	3.91
NMNEHC	g/bhp-hr	0.50
	tons/year	3.91
Formaldehydes	g/bhp-hr	0.27
	tons/year	2.11
PM10	lbs/bhp-hr	0.30

Emission levels are based on engine operation under steady state conditions, adjusted to the specified NOx level at 100% load. The CO, total HC, and non-methane HC values listed are 20% higher than nominal levels to allow for instrumentation, measurement, and engine-to-engine variations; these values indicate "not to exceed" levels. Tons per year values are based on 8,760 hours of operation per year. This information is valid for engine orders placed within six months of the above date. Please contact the factory if an extension of this period is required.

Sincerely,

Jeffrey A. Elijah

Applications Engineer
Technical/Commercial Services
Petroleum Business Unit

Appd: Performance Engineer

Jayson Wagler

Technical Manager
Robert Mason

Engine Speed (rpm)	1200	Fuel	NAT GAS
Compression Ratio	8:1	LHV of Fuel (Btu/SCF)	920
Aftercooler Inlet Temperature (°F)	130	Fuel System	HPG IMPCO
Jacket Water Outlet Temperature (°F)	210		
Ignition System	EIS	Minimum Fuel Pressure (psig)	35
Exhaust Manifold	WATER COOLED	Methane Number at Conditions Shown	80
Combustion System Type	LOW EMISSION	Rated Altitude (ft)	5000
		at 77°F Design Temperature	

Engine Rating Data	% Load	100%	75%	50%
Engine Power (w/o fan)	bhp	810	607	405
Engine Data				
Specific Fuel Consumption (BSFC) (1)	Btu/bhp-hr	7407	7600	7937
Air Flow (Wet, @ 77°F, 28.8 in Hg)	SCFM	1668	1209	827
Air Mass Flow (Wet)	lb/hr	7395	5362	3665
Compressor Out Pressure	in. HG (abs)	69.6	62.2	46.5
Compressor Out Temperature	°F	289	261	186
Inlet Manifold Pressure	in. HG (abs)	60.8	45.9	32.3
Inlet Manifold Temperature (10)	°F	138	134	134
Timing (11)	°BTDC	33	33	33
Exhaust Stack Temperature	°F	801	786	777
Exhaust Gas Flow (Wet, @ stack temperature, 29.7 in Hg)	CFM	4260	3060	2080
Exhaust Gas Mass Flow (Wet)	lb/hr	7683	5584	3823
Engine Emissions Data				
Nitrous Oxides (NOx as NO2) (9)	g/bhp-hr	2.0	3.3	3.3
(Corr. 15% 02)	ppm	124	245	231
Carbon Monoxide (CO) (9)	g/bhp-hr	1.6	1.7	1.9
(Corr. 15% 02)	ppm	195	212	215
Total Hydrocarbons (THC) (9)	g/bhp-hr	3.1	2.8	3.2
(Corr. 15% 02)	ppm	678	604	644
Non-Methane Hydrocarbons (NMHC) (9)	g/bhp-hr	0.47	0.42	0.48
(Corr. 15% 02)	ppm	48	40	41
Exhaust Oxygen (9)	%	8.2	7.4	7.0
Lambda		1.58	1.49	1.43
Engine Heat Balance Data				
Input Energy LHV (1)	Btu/min	99992	76948	53571
Work Output	Btu/min	34365	25774	17183
Heat Rejection to Jacket (2) (6)	Btu/min	31421	26759	20465
Heat Rejection to Atmosphere (Radiated) (4)	Btu/min	3643	3036	2429
Heat Rejection to Lube Oil (5)	Btu/min	0	0	0
Total Heat Rejection to Exhaust (to 77°F) (2)	Btu/min	25965	18499	12609
Heat Rejection to Exhaust (LHV to 350°F) (2)	Btu/min	15457	10904	7330
Heat Rejection to Aftercooler (3) (7) (8)	Btu/min	4598	2880	885

Engine Noise Data - at 100% load

Noise - Mechanical @ 1 m	100	dB(A)
Noise - Exhaust @ 1.5 m	111	dB(A)

Fuel Usage Guide

Derate Factor / Engine Timing vs Methane Number

<30	30	35	40	45	50	55	60	65	70	75	80
0/--	0.90/19	0.90/21	0.90/22	1.0/23	1.0/24	1.0/26	1.0/27	1.0/28	1.0/30	1.0/31	1.0/32

Altitude Deration Factors

AIR INLET TEMP. (°F) \ ALTITUDE (FEET ABOVE SEA LEVEL)	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000
130	1.00	1.00	1.00	0.98	0.94	0.91	0.88	0.84	0.81	0.78	0.75	0.72	0.70
120	1.00	1.00	1.00	1.00	0.96	0.93	0.89	0.86	0.83	0.80	0.77	0.74	0.71
110	1.00	1.00	1.00	1.00	0.98	0.94	0.91	0.87	0.84	0.81	0.78	0.75	0.72
100	1.00	1.00	1.00	1.00	1.00	0.96	0.92	0.89	0.86	0.82	0.79	0.76	0.73
90	1.00	1.00	1.00	1.00	1.00	0.98	0.94	0.91	0.87	0.84	0.81	0.78	0.75
80	1.00	1.00	1.00	1.00	1.00	0.99	0.96	0.92	0.89	0.85	0.82	0.79	0.76
70	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.94	0.90	0.87	0.84	0.81	0.77
60	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.96	0.92	0.89	0.85	0.82	0.79
50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.94	0.90	0.87	0.84	0.80

Aftercooler Heat Rejection Factors

AIR INLET TEMP. (°F) \ ALTITUDE (FEET ABOVE SEA LEVEL)	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000
130	1.38	1.45	1.52	1.59	1.67	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74
120	1.29	1.36	1.43	1.50	1.57	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
110	1.20	1.27	1.33	1.40	1.47	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54
100	1.11	1.17	1.24	1.31	1.38	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
90	1.02	1.08	1.15	1.21	1.28	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35
80	1.00	1.00	1.05	1.12	1.18	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
70	1.00	1.00	1.00	1.02	1.09	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
60	1.00	1.00	1.00	1.00	1.00	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

DM0150-03 Data is Intended to be used with Gas Engine Performance Book Parameters – DM5900-00 on page 8

CATERPILLAR®

G3500 Engine Basics

Electrical System
  Engine Electrical System
  Charging System Components
  Grounding Practices

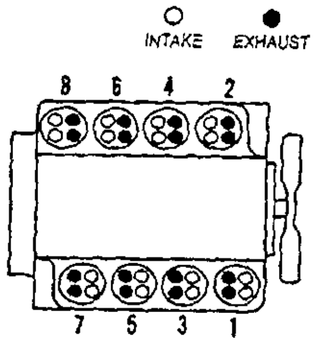
Starting Systems
  Electric
  Air Start

Engine Monitoring and Shutdown Protection
  Junction Box
  Engine Start/Stop Panel
  DC Control Panel for Gas Engine Chiller
  DC Control Panel for Gas Engine Chiller (Inside View)

Abbreviations and Symbols

Engine Design

G3508



Cylinder And Valve Location

Number And Arrangement Of Cylinders......V–8

Valves Per Cylinder......4

Bore......170 mm (6.7 in)

Stroke......190 mm (7.5 in)

Compression Ratio......refer to nameplate on engine

Type Of Combustion......spark ignited

Crankshaft Rotation (as viewed from flywheel end)......counterclockwise

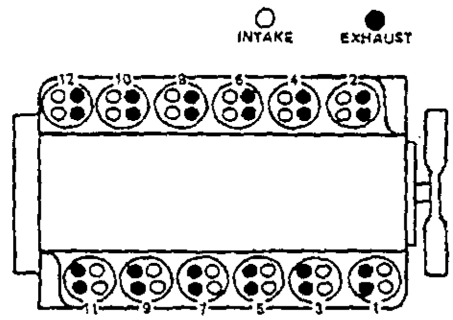
Firing Order......1-2-7-3-4-5-6-8

Compression Ratios Available......8.1:1, 9.1:1, 11.0:1

Valve Setting
- Inlet......0.51 mm (.020 in)
- Exhaust......1.27 mm (.050 in)

Note: Front of engine is opposite flywheel end. Left and right side of engine are as seen from flywheel end. No. 1 cylinder is front cylinder on right side. No. 2 cylinder is front cylinder on left side.

G3512



Cylinder And Valve Location

Number And Arrangement Of Cylinders......V–12

Valves Per Cylinder......4

Bore......170 mm (6.7 in)

Stroke......190 mm (7.5 in)

Compression Ratio......refer to nameplate on engine

Type Of Combustion......spark ignited

Crankshaft Rotation (as viewed from flywheel end)......counterclockwise

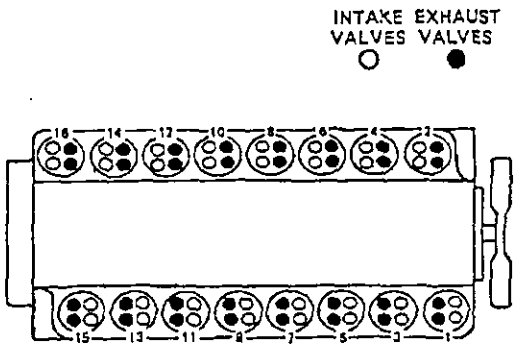
Firing Order......1-12-9-4-5-8-11-2-3-10-7-6

Compression Ratios Available......8.1:1, 9.1:1, 11.0:1, 12.0:1

Valve Setting
- Inlet......0.51 mm (.020 in)
- Exhaust......1.27 mm (.050 in)

Note: Front of engine is opposite flywheel end. Left and right side of engine are as seen from flywheel end. No. 1 cylinder is front cylinder on right side. No. 2 cylinder is front cylinder on left side.

G3516



Cylinder And Valve Location

Number And Arrangement Of Cylinders V–16

Valves Per Cylinder 4

Bore ....170 mm (6.7 in)

Stroke..190 mm (7.5 in)

Compression Ratio ....refer to nameplate on engine

Type Of Combustion....................spark ignited

Crankshaft Rotation (as viewed from flywheel end) ....counterclockwise

Firing Order 1-2-5-6-3-4-9-10-15-16-11-12-13-14-7-8

Compression Ratios Available 8.1:1, 9.1:1, 11.0:1, 12.0:1

Valve Setting
- Inlet....................................0.51 mm (.020 in)
- Exhaust ....1.27 mm (.050 in)

Note: Front of engine is opposite flywheel end. Left and right side of engine are as seen from flywheel end. No. 1 cylinder is front cylinder on right side. No. 2 cylinder is front cylinder on left side.

Electronic Ignition System (EIS)

The Caterpillar Electronic Ignition System (EIS) is designed to replace the traditional magneto ignition system. The Electronic Ignition System eliminates the magneto and other components that were subject to mechanical wear. It also provides increased engine diagnostic and troubleshooting capabilities.

The Electronic Ignition System (Figures 1) uses one control module (4) to handle many applications and many engine types. This is achieved by allowing the operator to change key parameters "on-sight". These programmable parameters are referred to as Customer Specified Parameters and may be set or changed using the Digital Diagnostic Tool (DDT). The values programmed into the system are stored in the EIS Control Module memory. This allows the operator to tailor the ignition system operation with a single service tool.

The DDT (Digital Diagnostic Tool) service tool is used to program Customer Specified Parameters, monitor engine functions, and display engine diagnostics. The DDT can monitor engine speed, engine timing and detonation levels.

For additional information on programming parameters and troubleshooting diagnostic codes, refer to Electronic Troubleshooting, G3500 Engines, SENR6413.

The EIS control module also has the ability to diagnose and store system problems and potential transformer secondary circuit problems. When a problem is detected, a diagnostic code is generated and can be displayed on the DDT.

The EIS system monitors engine operation and distributes power to the cylinder transformers, to provide the best engine performance at all engine speeds. It also protects the engine from damage caused by

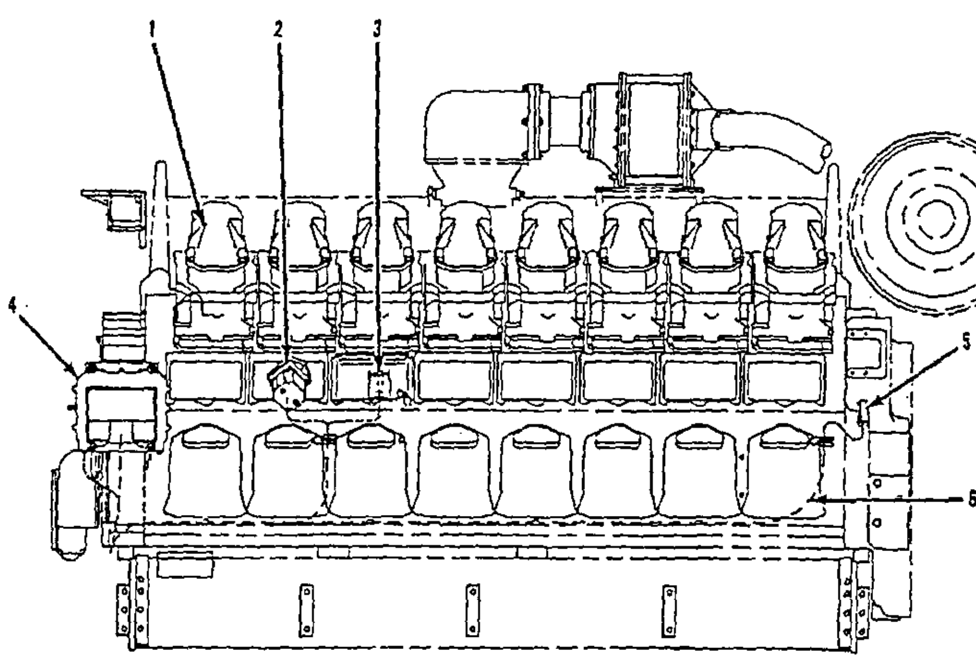


Figure 1. Component Location
(1) Ignition transformer (under valve cover). (2) Manifold air pressure sensor. (3) Detonation sensor.
(4) Electronic Ignition System control module. (5) Speed/Timing sensor. (6) Wiring harness for Speed/Timing sensor (internal).

detonation. Within specified limits, control of engine timing (retarding) is infinitely variable.

The Electronic Ignition System (Figure 3) provides detonation protection and precision spark control for each cylinder. Detonation is controlled as it occurs and timing is retarded only as much and as long as necessary to prevent engine damage. The EIS system allows improved operation, economy and lower emission levels. The system consists of three basic groups: the control module, ignition transformers(2) and sensors.

EIS Control Module

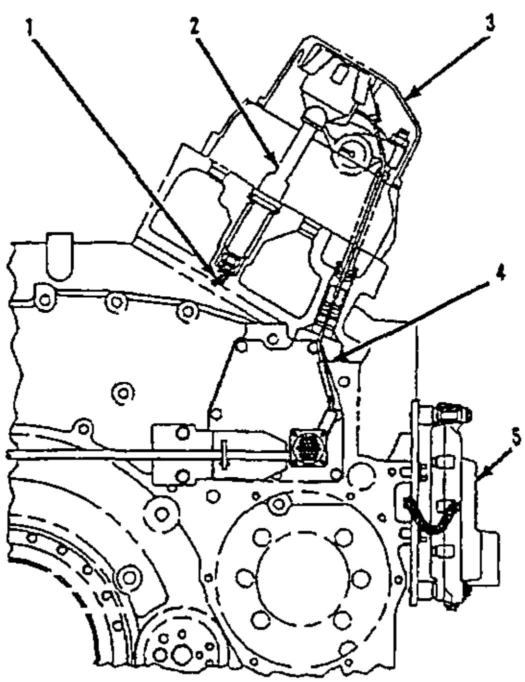


Figure 2. Ignition System Components
(1) Spark plug. (2) Ignition transformer. (3) Valve cover. (4) Wiring harness. (5) Electronic Ignition System control module.

The EIS Control Module (5) is a sealed unit with no serviceable parts (Figure 2). The control module monitors engine operation through a series of sensors. The sensors are connected to the module through wiring harnesses (4) routed inside the engine block. The control module uses input from the sensors and the control panel settings to determine ignition timing. The control module provides system diagnostics and also supplies voltage to the ignition transformers (2) which step up the voltage to fire the spark plugs (1). The valve cover (3) acts as a ground for the ignition transformer.

Engine timing is controlled by the EIS Control Module. It is based on the desired engine timing, customer specified parameters (programmed by the operator) and the conditions in which the engine operates. The engine operator can change the maximum advanced timing, the speed timing maps and load timing maps using the Digital Diagnostic Tool (DDT). The EIS Control Module automatically adjusts the engine timing according to the engine operating conditions, as determined by information from the engine speed/timing sensor, manifold air pressure sensor, and detonation sensors.

The EIS Control Module has up to 16 ignition outputs to the ignition transformers. It also uses sensors and internal circuitry to monitor the system components. If a problem develops in a component or harness, the control will sense the problem and notify the operator by creating a diagnostic code.

Ignition Transformers

Each cylinder has an ignition transformer located under the cylinder valve cover. The EIS Control Module sends a pulse to the primary coil of the ignition transformer to initiate combustion in each cylinder. The transformer steps up the voltage to create an arc across the spark plug gap. The spark created by the arc, ignites the gas in the cylinder. On engines equipped with EIS, the cylinder valve cover acts as the ground for the ignition transformer. Care should be exercised when working on the engine with a valve cover removed. *Always disconnect the primary lead to the transformer when a valve cover is removed.*

The ignition harness connects the EIS Control Module to the individual ignition transformers. The ignition harness is routed inside the engine alongside the camshaft.

Engine Sensors

Engine sensors provide information to the EIS Control Module that allow the module to control the engine as efficiently as possible over a wide range of operating conditions.

Detonation Sensors

The Detonation Sensors (RHDS and LHDS) monitor the engine for excessive detonation (vibration). One sensor is mounted in the center of each cylinder bank. The sensor produces a voltage signal proportional to engine detonation. This information is processed by the EIS Control Module to determine detonation levels and changes engine timing as needed.

Speed/Timing Sensor

The Speed/Timing Sensor provides accurate spark timing information for the control module. A speed/timing ring, mounted on the rear, left camshaft, provides the signal pattern detected by the sensor and read by the control module. The control module determines engine speed and timing position from the sensor signal.

Manifold Air Pressure Sensor (Load Sensor)

The Manifold Air Pressure Sensor provides engine load information to the EIS Control Module. The sensor is connected to the inlet manifold. The information is processed by the control module to determine engine timing and diagnostics.

Desired Timing Parameter

The Desired Timing Parameter allows the customer to electronically program the ignition spark timing of the EIS System to meet specific application/installation needs. The desired timing is programmed using the DDT Service Tool. The desired timing value can be changed while the engine is running or stopped. The value entered for the desired timing is the ignition timing when the engine is operating at rated speed, full load.

Note: Actual ignition timing at a given instance may vary from the desired timing value due to variations in engine speed, detonation activity or type of fuel being used.

Fuel, Air Inlet and Exhaust Systems

Engine Basics

On a four-stroke gas engine during the intake stroke, a change of fuel and air (mixed outside the combustion chamber in the carburetor) is drawn (NA) or forced (TA) through the intake valve (Figure 3). This mixture of fuel and air is compressed on the compression stroke and is then ignited by a spark. This spark is generated and timed by the Electronic Ignition System (EIS). The piston is then forced downward, creating the power stroke, toward bottom dead center by the expanding gases. On the exhaust stroke, the burned gases are pushed out of the cylinder through the exhaust valve as the piston travels back toward top dead center.

Diesel engines, like natural gas engines, operate in a slightly different way, although the four strokes are the same. On the intake stroke, only air is drawn or forced into the compression chamber. On the compression stroke, the air is compressed and therefore heated; just before the piston reaches top dead center, fuel is injected under high pressure. The fuel-air mixture will ignite by itself at the beginning of the power stroke.

Diesel engines are typically limited by their capabilities to carry structural load with peak pressures up to 10 335 kPa (1500 psi). Gas engines are limited by their capability to carry thermal load-high exhaust temperatures.

The gas engine runs with higher exhaust temperatures because it runs with a constant air-fuel ratio at any load. The diesel engine runs with an excess amount of air at any load. Only the amount of fuel burned increases with

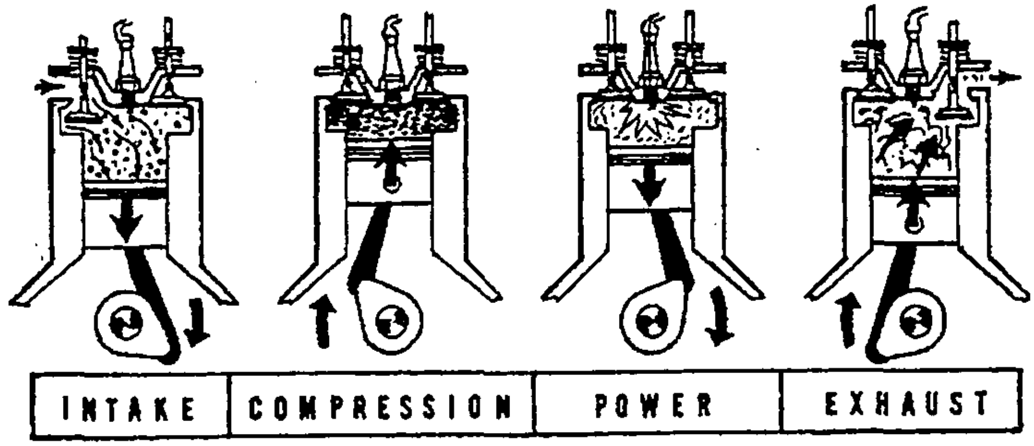


Figure 3. Four-stroke process.

the load. This additional air also cools the charge in diesel engines.

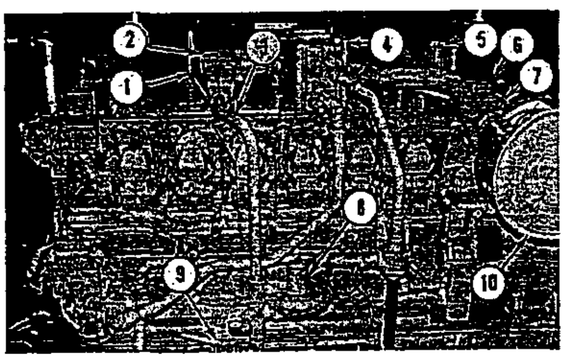


Figure 4. Fuel, Air Inlet And Exhaust System Components (G3512 Engine Shown)
(1) Balance line between carburetor and gas pressure regulator. (2) Carburetor. (3) Gas inlet line to carburetor. (4) Aftercooler. (5) Exhaust bypass valve. (6) Exhaust elbow. (7) Turbocharger. (8) Gas pressure regulator. (9) Gas shutoff valve. (10) Air cleaner.

The components of the fuel, air inlet and exhaust system (Figure 4) control the quality, temperature and amount of air/fuel mixture available for combustion. Some of these components are the gas inlet line (3), air cleaners (10), turbochargers (7), watercooled aftercooler (4), gas shutoff valve (9), gas pressure regulator (8), carburetor (2), turbulence chamber, distribution channel, an inlet manifold and the intake and exhaust valve mechanisms. Two camshafts, one on each side of the block, control the movement of the valve system components.

The inlet manifold is a series of elbows that connect the distribution channel (located in the middle of the engine) to the inlet ports (passages) of the cylinder heads.

There is a separate air cleaner, turbocharger and watercooled exhaust manifold on each side of the engine. The watercooled exhaust manifolds provide a "gas tight" connection from the cylinder heads to the turbochargers. The manifolds also serve as a water manifold by collecting coolant from each cylinder head and directing it to the regulator housing.

All installations have a shutoff valve in the gas supply line. The shutoff valves are either Energized To Run (ETR) or Energized To Shutoff (ETS). All engines with turbochargers have a balance line (1) between the gas shutoff valve and the carburetor.

In the Energized To Run system, power must be supplied to the shutoff valve to keep the fuel coming to the engine. To stop the engine, the power is removed from the shutoff valve, which interrupts the fuel to the engine.

In the Energized To Shutoff system, no power is supplied to the shutoff valve to keep the fuel coming to the engine. To stop the engine, power is supplied to the shutoff valve, which interrupts the fuel to the engine. The valve can also be manually operated to stop the engine. After the engine is stopped, manual resetting of the valve is needed to start the engine.

Fuel System

Several variations of fuel systems for G3500 Engines are available to best suit the individual customer installation. Although each installation may be different, the basic components will be the same or similar. Two different carburetor set-ups (low pressure and high pressure) are available that will determine the components of the rest of the fuel delivery system. The low pressure or high pressure carburetor set-ups may be used with either the Standard (Stoichiometric) or Low Emission engines depending on the inlet pressure of the fuel available to the engine.

Low Pressure Carburetor System

Two different gas pressure regulator arrangements are generally used on engines equipped with low pressure carburetors. Although the position and number of components may differ, both systems function in a similar manner. One arrangement uses a single gas pressure regulator (Figure 5) to supply both carburetors. The regulator will be located at the rear of the engine on a centerline between the turbochargers. The other arrangement uses two gas pressure regulators (Figure 6), one for each carburetor. A regulator will be mounted on both sides of the engine near each carburetor.

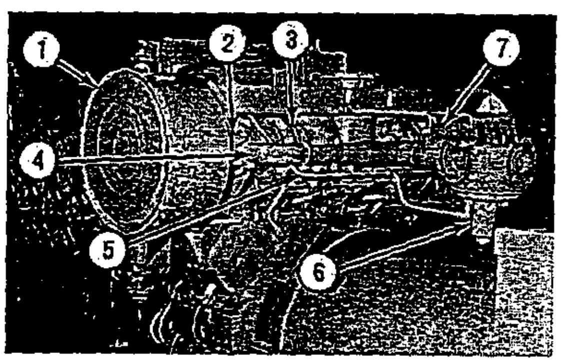


Figure 5. Single Regulator Arrangement
(1) Air cleaner. (2) Low pressure carburetor.
(3) Turbocharger. (4) Gas inlet line. (5) Balance line.
(6) Gas pressure regulator. (7) Gas pressure valve assembly.

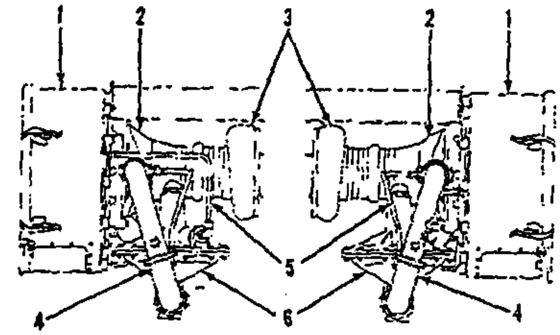


Figure 6 Dual Regulator Arrangement
(1) Air cleaner. (2) Low pressure carburetor.
(3) Turbocharger. (4) Gas inlet line. (5) Balance line.
(6) Gas pressure regulator.

From the main gas supply line, gas enters the gas pressure regulator (6). The gas pressure regulator is adjusted to provide a flow of fuel, at low pressure, to the engine gas inlet line (4). As the compressor wheels of the turbochargers (3) rotate, fuel (at low pressure) is drawn through the fuel inlet lines to the carburetors (2). The carburetors (one on each side of the engine) are located between the air cleaners (1) and the compressor side of the turbochargers. The carburetors mix the fuel with inlet air from the air cleaners. The air/fuel mixture is pulled into the turbochargers, compressed and sent to the aftercooler. The compressed, cooled air/fuel mixture flows from the aftercooler to the throttle group. The throttle group is connected by a linkage to the governor and controls the flow of the air/fuel mixture into the inlet plenum. The air/fuel mixture in the inlet plenum enters the cylinder through the cylinder inlet valves where it is compressed and ignited by the spark plug.

Turbocharged engines have a balance line (5) connected between the carburetor air inlet and the atmospheric vent of gas pressure regulator. The balance line directs carburetor inlet air pressure to the upper side of the regulator diaphragm to control gas pressure at the carburetor. The inlet air pressure added to the spring force on the diaphragm, makes sure that gas pressure to the carburetor will always be greater than inlet air pressure, regardless of load conditions. For example, under engine acceleration, the air pressure increases. A small amount of the increased air pressure is directed to the gas pressure regulator and moves the control to increase supply gas pressure to the carburetor. By this method, the correct differential pressure between the gas pressure regulator and the carburetor air inlet is controlled. A turbocharged engine will not develop full power with the balance line disconnected.

Engines equipped with a single regulator arrangement, have a gas pressure valve assembly located in the fuel inlet line. The gas pressure valve assembly is used to adjust emission levels at full load, rated speed.

High Pressure Carburetor System

On engines equipped with high pressure carburetors (Figure 7) the gas pressure regulator (4) is usually located on the side of the engine, in line with the carburetor (1) and throttle group.

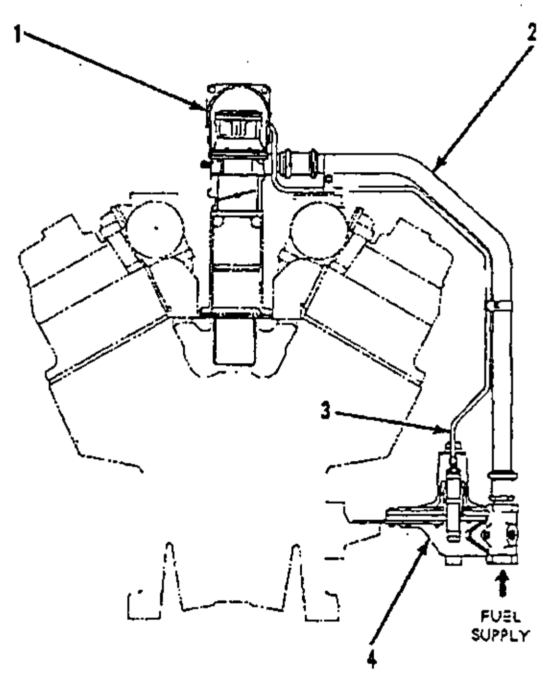


Figure 7. High Pressure Carburetor
(1) Carburetor. (2) Gas supply line to carburetor.
(3) Balance line from gas pressure regulator vent to inlet air pressure at carburetor. (4) Gas pressure regulator.

From the main fuel supply inlet, fuel enters the gas pressure regulator. The pressure regulated fuel flows through the air/fuel ratio control valve. The air/fuel ratio control valve is operated by the actuator and the control valve linkage. Gas goes from the air/fuel ratio control valve through the gas supply line (2) and then into the carburetor. Air is drawn in through the air cleaners and into the turbochargers. The turbochargers compress the air and send it to the aftercooler. The aftercooler lowers the temperature of the compressed air and the air enters the carburetor. The carburetor mixes the fuel and the air. The air/fuel mixture passes through the throttle and into the air inlet plenum. The throttle group is connected by a linkage to an EG-3P Actuator and controls the flow of the air/fuel mixture into the inlet plenum. The air/fuel mixture in the inlet plenum enters the cylinder through the cylinder intake valves where it is compressed and ignited by the spark plug.

Turbocharged engines have a balance line (3) connected between the carburetor air inlet and the atmospheric vent of the gas pressure regulator. The balance line directs carburetor inlet air pressure to the upper side of the regulator diaphragm to control gas pressure at the carburetor. The inlet air pressure added to the spring force on the diaphragm, makes sure that gas pressure to the carburetor will always be greater than inlet air pressure, regardless of load conditions. For example, under engine acceleration, the air pressure increases. A small amount of the increased air pressure is directed to the gas pressure regulator and moves the control to increase supply gas pressure to the carburetor. By this method, the correct differential pressure between the gas pressure regulator and the carburetor air inlet is controlled. A turbocharged engine will not develop full power with the balance line disconnected.

Gas Pressure Regulator

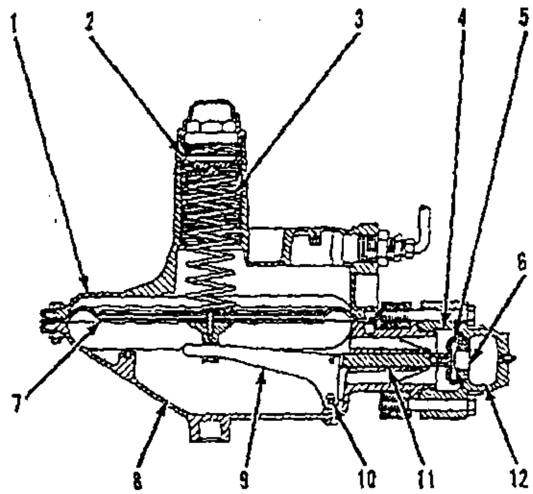


Figure 8 Regulator Operation
(1) Spring side chamber. (2) Adjustment screw. (3) Spring. (4) Outlet. (5) Valve disc. (6) Main orifice. (7) Main diaphragm. (8) Lever side chamber. (9) Lever. (10) Pin. (11) Valve stem. (12) Inlet

The function of the gas pressure regulator is to maintain a set pressure differential between the outlet of the gas pressure regulator (connected to the carburetor fuel inlet) and the carburetor air inlet. G3500 Engines can be equipped with different regulators to use a variety of fuels and a wide range of gas pressures and BTU ratings. The construction and position on the engine may vary, but all function on similiar principles and work to maintain an adjusted pressure differential. The following is a description of operation for a high pressure, high BTU content fuel regulator.

Gas goes through the inlet (12), main orifice (6), valve disc (5), and the outlet (4). Outlet pressure is felt in the chamber (8) on the lever side of diaphragm (7).

As gas pressure in chamber (8) becomes higher than the force of the diaphram spring (3) and air pressure in the spring side chamber (1) (atmosphere on naturally aspirated engines; turbocharger boost on turbocharged engines), the diaphragm is pushed against the spring. This turns the lever (9) at pin (10) and causes the valve stem (11) to move the valve disc to close the inlet orifice.

With the inlet orifice closed, gas is pulled from the lever side of chamber (8) through the outlet. This gives a reduction of pressure in the chamber (8). As a result the pressure becomes less than pressure in the spring side chamber. Force of spring and air pressure in the chamber on the spring side moves the diaphragm toward the lever. This turns (pivots) the lever and opens the valve disc, permitting additional gas flow to the carburetor.

Carburetor

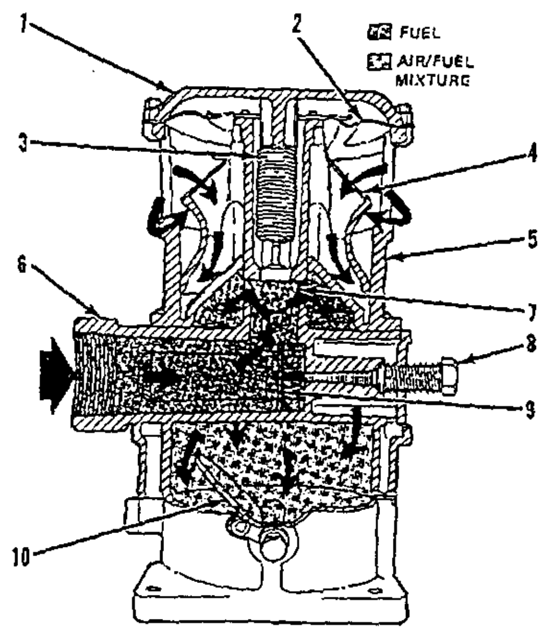


Figure 9. Carburetor Operation
(1) Cover. (2) Diaphragm. (3) Spring. (4) Air valve. (5) Air valve body. (6) Gas inlet body. (7) Gas valve. (8) Power screw. (9) Plate. (10) Throttle plate.

Note: Operation of a carburetor (Figure 9) with a single air valve is described. Operation of carburetors with dual air valves is the same.

Atmospheric air goes through the air cleaners to the air horn of the carburetor on naturally aspirated engines. On turbocharged engines, the air is pulled through the air cleaners to the turbochargers and then pushed through an aftercooler core to the carburetor air horn. In the air horn, air goes around the air valve body (5) and pushes on diaphragm (2) and then goes down through the center of air valve

(4), around gas inlet body (6), by throttle plate (10) into the engine.

Fuel goes into the carburetor at the center, through the gas inlet body. The fuel flows out the top of the gas inlet body to mix with the air and then flows around the gas inlet body, by the throttle plate into the engine. Gas valve (7) is connected to the air valve and is designed to let the correct amount of fuel into the carburetor at any opening of the air valve between idle and full load. Thus, at low idle, the gas valve keeps fuel flow to a minimum and gives a lean air fuel mixture. As the engine speed and load is increased, the gas valve lets more fuel flow to give a richer air fuel mixture. When the engine is stopped, the spring holds the gas valve down against the valve seat in the closed position and no fuel can enter the carburetor. Power screw (8) and plate (9) control fuel inlet at full load conditions when the gas valve is at a maximum distance off its seat.

As the engine is started, the intake strokes of the pistons cause a vacuum in the cylinders which causes a low pressure condition below the carburetor. Passages in air valve body (5) connect the low pressure to the upper side of the diaphragm. At this point, atmospheric pressure pushes up on the diaphragm and lifts it against the downward force of the spring. The air valve is connected to and pulled up by the diaphragm. At this point, air can push upward against the outside of the air valve to help lift it. The gas valve is connected to the air valve and is also lifted off its seat to let fuel enter the carburetor. The air pushes up on the diaphragm and at the same time goes around the outside and inside of the air valve and around the gas inlet body. As the air passes around the gas inlet body, it mixes with the fuel. The air/fuel mixture then goes down by the throttle plate, into the distribution channels, to the inlet manifolds and then into the cylinders for combustion.

2301A Electric Governor

The 2301A Electric Governor Control System consists of the components that follow: 2301A Electric Governor Control (EGC), Actuator, Magnetic Pickup.

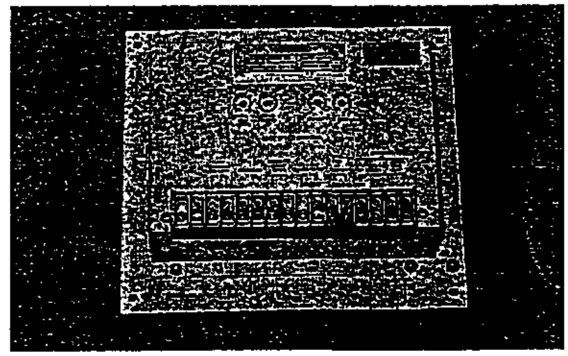


Figure 10. 2301A Electric Governor Control (EGC)

The 2301A Electric Governor System gives precision engine speed control. The 2301A control(Figure 10) measures engine speed constantly and makes necessary corrections to the engine fuel setting through an actuator connected to the fuel system.

The engine speed is felt by a magnetic pickup (Figure 11). This pickup is a single pole, permanent magnet generator made of wire coils (2) around a permanent magnet pole piece. (4). See Figure 12. As the teeth of the flywheel ring gear (5) cut through the magnetic lines of force (1) around the pickup, an AC voltage is generated. The frequency of this voltage is directly proportional to engine speed.

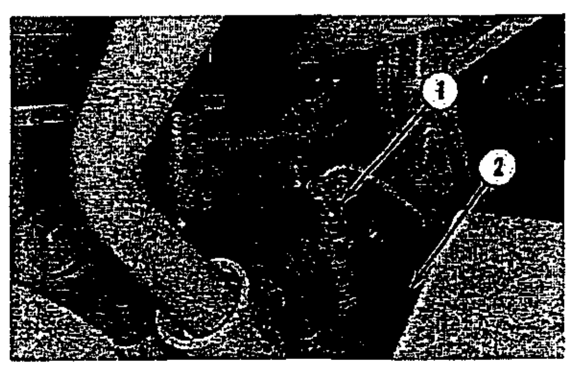


Figure 11. Magnetic Pickup Location
(1) Magnetic pickup. (2) Flywheel housing.

This engine speed frequency signal (AC) is sent to the 2301A Control Box where a conversion is made to DC voltage. The DC signal is now sent on to control the actuator, and this voltage is inversely proportional to engine speed. This means that if engine speed increases, the voltage output to the actuator decreases. When engine speed decreases, the voltage output to the actuator increases.

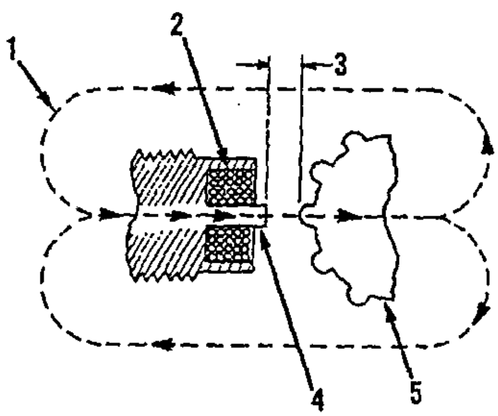


Figure 12. Schematic Of Magnetic Pickup
(1) Magnetic lines of force. (2) Wire coils. (3) Gap.
(4) Pole piece. (5) Flywheel ring gear.

The actuator ((Figure 13) changes the electrical input from the 2301A Control to a mechanical output that is connected to the fuel system by linkage. For example, if the engine speed is more than the speed setting, the 2301A Control will decrease its output and the actuator will now move the linkage to decrease the fuel to the engine.

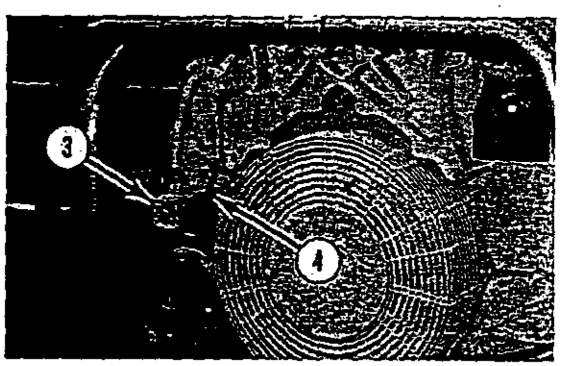


Figure 13. EG3P Actuator.
(3) Actuator. (4) Actuator lever.

Woodward PSG Governors

The Woodward PSG (Pressure compensated Simple Governor) can operate as an isochronous or a speed droop type governor. It uses engine lubrication oil, increased to a pressure of 1200 kPa (175 psi) by a gear type pump inside the governor, to give hydra/mechanical speed control.

The governor (Figure 15) is driven by the governor drive unit. This unit turns pilot valve bushing (13) clockwise as seen from the drive unit end of the governor (Figure 14). The pilot valve bushing is connected to a spring driven ballhead. Flyweights (7) are fastened to the ballhead by pivot pins. The centrifugal force caused by the rotation of the pilot valve bushing causes the flyweights to pivot out. This action of the flyweights changes the centrifugal force to axial force against speeder spring (5). There is a thrust bearing (9) between the toes of the flyweights and the seat for the speeder spring. Pilot valve (12) is fastened to the seat for the speeder spring. Movement of the pilot valve is controlled by the action of the flyweights against the force of the speeder spring.

The engine is at the governed (desired) rpm when the axial force of the flyweights is the same as the force of compression in the speeder spring. The flyweights will be in the position shown. Control ports (14) will be closed by the pilot valve.

When the force of compression in the speeder spring increases (operator increases desired rpm) or the axial force of the flyweights decreases (load on the engine increases) the pilot valve will move in the direction of the drive unit. This opens the control ports(14). Pressure oil flows through a passage in the base to chamber (B). The increased pressure in the chamber causes power piston (6) to move. The power piston pushes strut assembly (4), that is connected to output shaft lever (3). The action of the output shaft lever causes counterclockwise rotation of output shaft (2). This moves carburetor control linkage (15) in the THROTTLE OPENED direction (Figure 15).

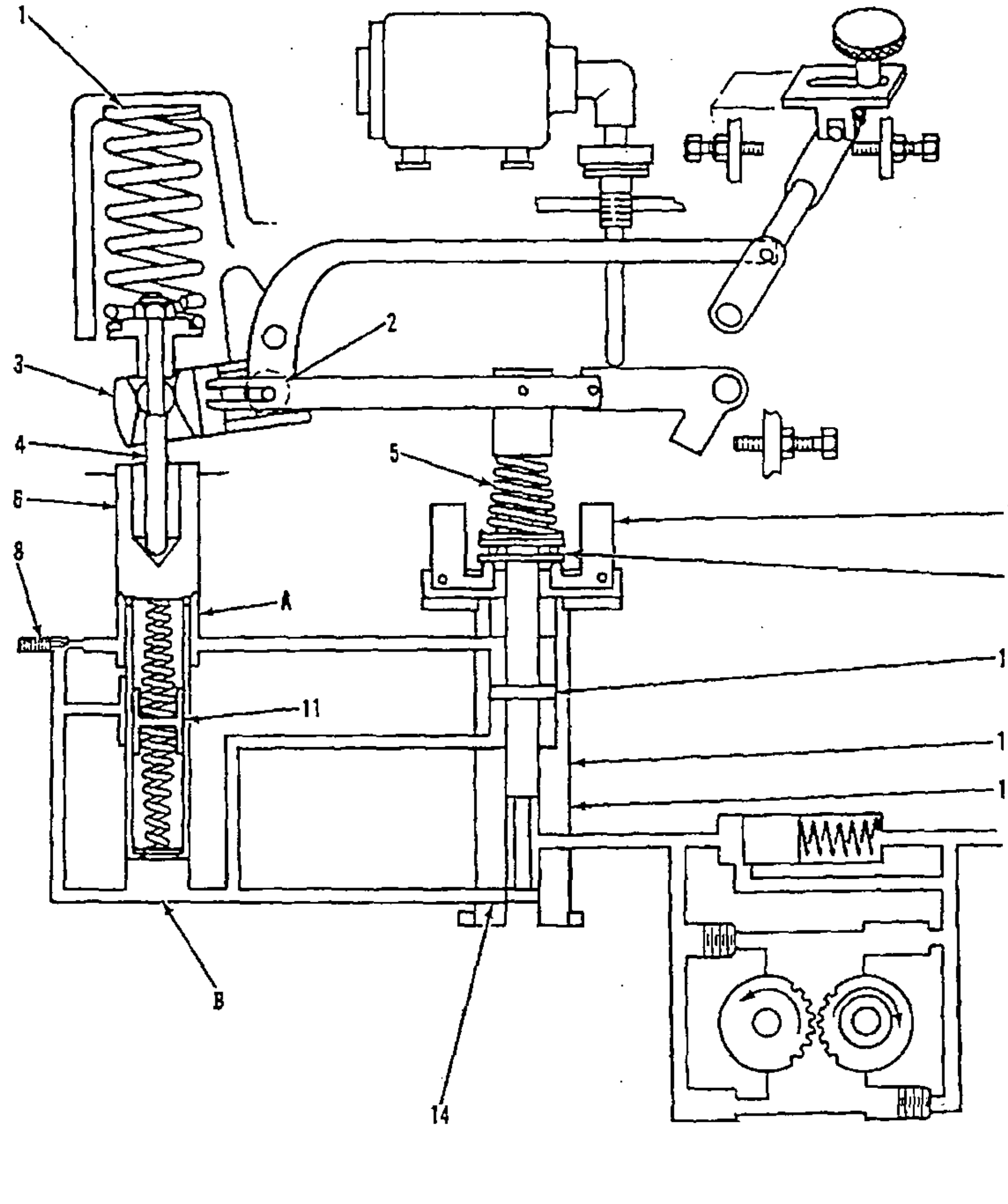


Figure 14. Schematic Of PSG Governor
(1) Return spring. (2) Output shaft. (3) Output shaft lever. (4) Strut assembly. (5) Speeder spring. (6) Power piston. (7) Flyweights. (8) Needle valve. (9) Thrust bearing. (10) Pilot valve compensating land. (11) Buffer piston. (12) Pilot valve. (13) Pilot valve bushing. (14) Control ports. (A) Chamber. (B) Chamber.

Figure 15. PSG Governor Installed
(2) Output shaft. (15) Carburetor control linkage.

As the power piston moves in the direction of return spring (1) the volume of chamber (A) increases. The pressure in the chamber decreases. This pulls the oil from the chamber inside the power piston, above buffer piston (11) into the chamber (A). As the oil moves out from above the buffer piston to fill the chamber the buffer piston moves up in the bore of the power piston. Chambers (A and B) are connected respectively to the chambers above and below the pilot valve compensating land (10). The pressure difference felt by the pilot valve compensating land adds to the axial force of the flyweights to move the pilot valve up and close the control ports. When the flow of pressure oil to chamber (B) stops so does the movement of the fuel control linkage.

When the force of compression in the speeder spring decreases (operator decreases desired rpm) or the axial force of the flyweights increases (load on the engine decreases) the pilot valve will move in the direction of the speeder spring. This opens the control ports. Oil from chamber (B) and pressure oil from the pump will dump through the end of the pilot valve bushing. The decreased pressure in chamber (B) will let the power piston move in the direction of the drive unit. The return spring pushes against the strut assembly. This moves the output shaft lever. The action of the output shaft lever causes clockwise rotation of the output shaft. This moves the carburetor control linkage in the THROTTLE CLOSED direction, (Figure 15).

On PSG governors not equipped with electric speed adjustment (Figure 16), speed can be adjusted with screw (1). When the screw is turned clockwise it pushes the link assembly (2) against speeder spring (3). This causes an increase in the force of speeder spring and pilot valve (4) will move toward governor drive unit. The engine will increase speed until it gets to the desired rpm. When the screw is turned counterclockwise the link assembly moves away from speeder spring. This causes a decrease in the force of the speeder spring and the pilot valve will move away from governor drive unit. The engine will decrease speed until it gets to the desired rpm.

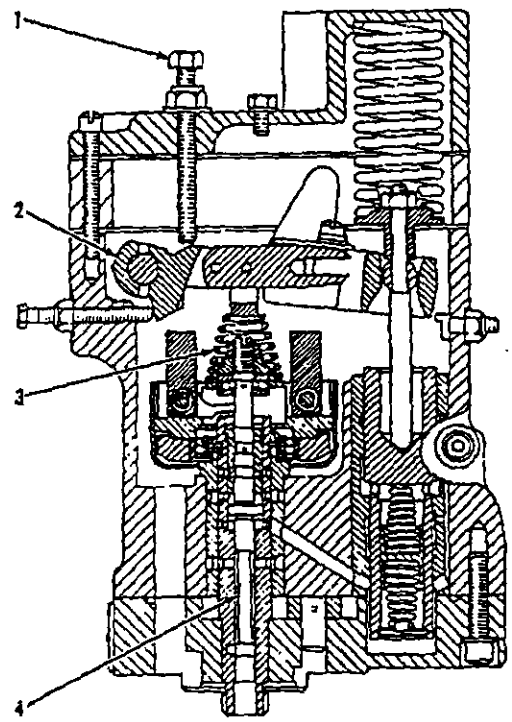


Figure 16. Non-electric PSG Governor
(1) Screw. (2) Link assembly. (3) Speeder spring.
(4) Pilot valve.

Engines with non-electric governors are also equipped with a governor control group (Figure 17) to allow easier speed adjustment.

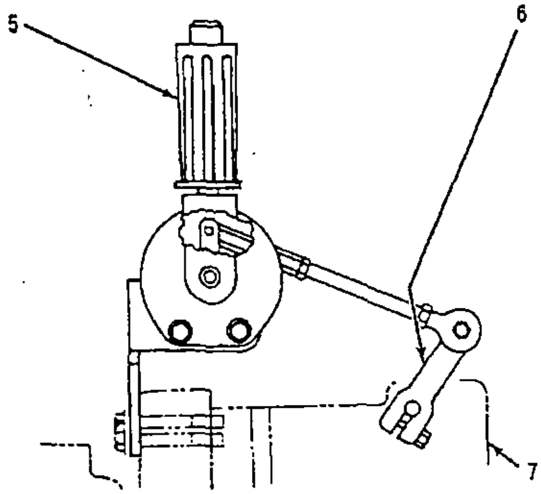


Figure 17. Governor Control Group
(5) Positive lock lever. (6) Link assembly lever.
(7) Governor.

As lever (5) is moved toward governor (7), linkage causes lever (6) to move in the same direction. The link assembly lever is clamped to the shaft of the link assambly (2). As the shaft rotates, the link assembly pushes against speeder spring (3). This causes pilot valve (4) to move toward the governor drive unit. The engine will increase speed until it gets to desired rpm.

When lever (5) is moved away from the governor, the link assembly lever moves in the same direction. This causes the link assembly to move away from the speeder spring. The pilot valve then moves away from the governor drive unit and engine speed decreases until desired rpm is reached.

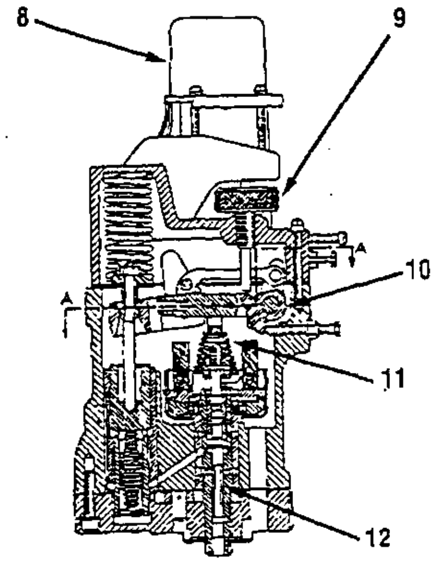


Figure 18 PSG Electric-Type Governor
(8) Synchronizing motor. (9) Clutch assembly.
(10) Link assembly. (11) Speeder spring. (12) Pilot valve.

On electric type PSG governors (Figure 18), speed adjustments are made by a 24V DC reversible synchronizing motor (8). The motor is controlled by a switch that can be put in a remote location.

The synchronizing motor drives clutch assembly (9). The clutch assembly protects the motor if it is run against the adjustment stops.

When the clutch assembly is turned clockwise it pushes link assembly (10) against speeder spring (11). The force of compression in the speeder spring is increased. This causes the pilot valve (12) to move toward the governor drive unit. The engine will increase speed, then get stability at a new desired rpm.

When the clutch assembly is turned counterclockwise the link assembly moves away from the speeder spring. The force of compression in the speeder spring is decreased. This causes the pilot valve to move away from the governor drive unit. The engine will decrease speed, then get stability at a new desired rpm.

Note: The clutch assembly can be turned manually if necessary.

Speed droop is the difference between no load rpm and full load rpm. This difference in rpm divided by the full load rpm and multiplied by 100 is the percent of speed droop.

$$\frac{\text{No load speed} - \text{Full load speed}}{\text{Full load speed}} \times 100$$

$$= \% \text{ of speed droop}$$

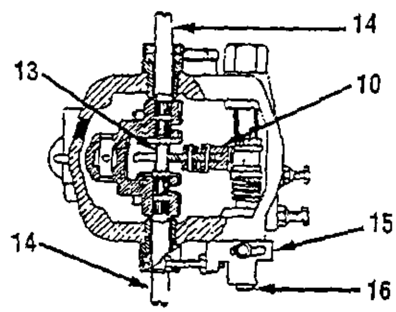


Figure 19. PSG Governor (View A-A from Figure 18)
(10) Link assembly. (13) Pivot pin. (14) Output shafts.
(15) Droop adjusting bracket. (16) Shaft assembly.

The speed droop of the PSG governor can be adjusted. The governor is isochronous when it is adjusted so that the no load and full load rpm is the same. Speed droop permits load division between two or more engines that drive generators connected in parallel or generators connected to a single shaft.

Speed droop adjustment on PSG governors (Figure 19) is made by movement of pivot pin (13). When the pivot pin is put in alignment with output shafts (14), movement of the output shaft lever will not change the force of the speeder spring. When the force of the speeder spring is kept constant, the desired rpm will be kept constant. When the pivot pin is moved out of alignment with the output shafts, movement of the output shaft lever will change the force of the speeder spring proportional to the load on the engine. When the force of the speeder spring is changed, the desired rpm of the engine will change.

An adjustment bracket (15) outside the governor connected to the pivot pin by the link assembly and shaft assembly (16) is used to adjust speed droop.

Air Inlet And Exhaust Systems

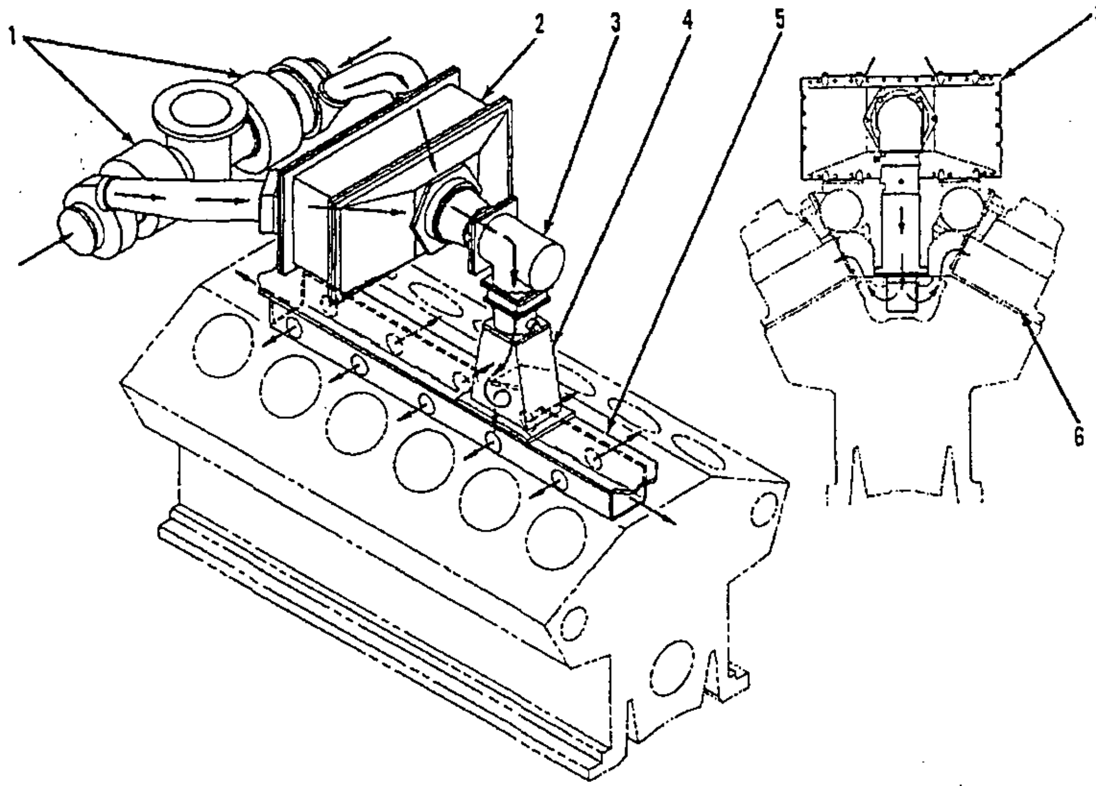


Figure 20. Air Inlet System
(1) Turbochargers. (2) Aftercooler. (3) Carburetor. (4) Turbulence chamber. (5) Distribution channel.
(6) Cylinder head.

Air flow is the same on both sides of the engine. See Figure 21. Clean inlet air from the air cleaners is pulled through the turbocharger compressor housing (1) by a compressor wheel (Figure 20). Rotation of the compressor wheel causes compression of the air and forces it through lines to the aftercooler (2). The aftercooler lowers the compressed air temperature and provides air at a constant temperature to the carburetor (3) for maximum air/fuel ratio control, independent of load on the engine. The aftercooler is usually watercooled, but air-to-air aftercooling can be used.

From the aftercooler the air goes through the carburetor (where it mixes with gas) and then into a turbulence chamber (4) which keeps the air and fuel mixed. A distribution channel (5) is located below the turbulence chamber and has holes in it to direct an equal air/fuel mixture at a constant temperature to each cylinder head (6) inlet port. Air flow from the inlet ports into the cylinder combustion chamber is controlled by the intake valves.

There are two intake and two exhaust valves for each cylinder. Make reference to *Valve System Components*. The intake valves open when the piston moves down on the intake stroke. The cooled, compressed air/fuel mixture from the inlet port is pulled into the cylinder. The intake valves close and the piston starts to move up on the compression stroke. When the piston is near the top of the compression stroke, the Electronic Ignition System control module sends voltage through a transformer to the spark plug. The transformer increases the voltage until a spark is created across the plug gap. The spark ignites the air/fuel mixture and combustion starts. The force of combustion pushes the piston down on the power stroke. When the piston moves up again it is on the exhaust stroke. The exhaust valves open and the exhaust gases are pushed through the exhaust port into the exhaust manifolds (8). See Figure 21. After the piston completes the exhaust stroke, the exhaust valves close and the cycle (intake, compression, power, exhaust) starts again.

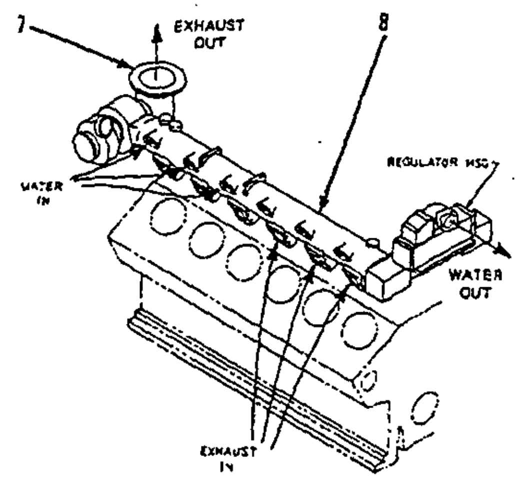


Figure 21. Exhaust System
(7) Exhaust elbow. (8) Exhaust manifold.

Exhaust gases from the exhaust manifolds go into the turbine side of each turbocharger and cause a turbine wheel to turn. The turbine wheel is connected to the shaft that drives the compressor wheel. The exhaust gases then go out the exhaust outlet through the exhaust elbow (7). Changes in engine load and fuel burned cause changes in rpm of the turbine and compressor wheels. As the turbocharger air pressure boost increases, the ratio of air to fuel can change. To increase air and gas densities equally during increased boost, a balance line is connected between the carburetor air inlet and the atmospheric vent of the gas pressure regulator.

Aftercooler

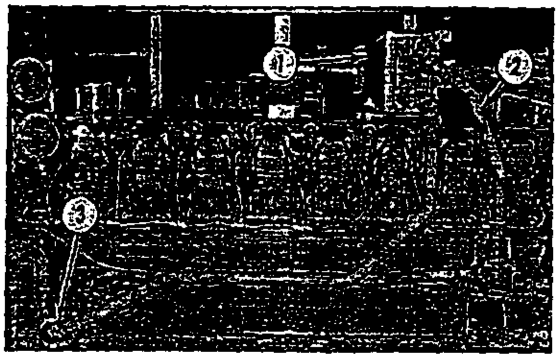


Figure 22. Engine With Watercooled Aftercooler
(1) Aftercooler. (2) Coolant return line. (3) Water pump.

The aftercooler (Figure 23) is located in the air lines between the turbochargers and the carburetor. The aftercooler is usually watercooled (Figure 22) but can be an air to air type.

Watercooled aftercoolers (1) have a separate circuit cooling system, from the engine jacket water cooling system. Coolant is supplied to the water pump (3). The water pump sends coolant through the coolant inlet line into the bottom of the aftercooler. It then flows through the core assembly and back out of the aftercooler through coolant return line (2) to the thermostatic valve that is installed in the coolant return line, to keep coolant in the aftercooler core assembly at the correct temperature.

Air flow through both cooling systems is as follows. Inlet air from the compressor side of the turbochargers flows into the aftercooler through pipes. This air then passes through the aftercooler core assembly which lowers the temperature. The cooler air (mixed with fuel on low pressure carburetor engines) goes out of the aftercooler into the carburetor. Fuel is mixed with the inlet air (on engines equipped with high pressure carburetors). The air/fuel mixture goes through the turbulence chamber and distribution channel and up through the elbows to the intake ports (passages) in the cylinder heads. The mixture goes through the intake valves into the combustion chambers.

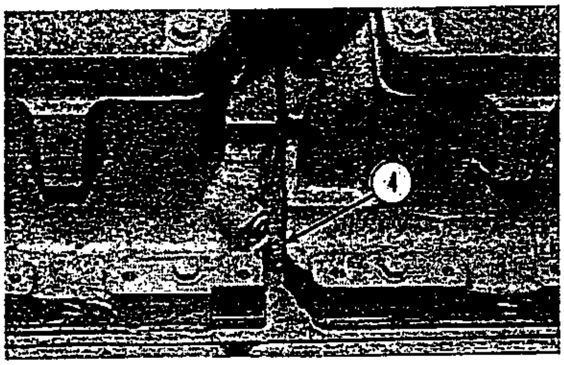


Figure 23. Distribution Channel And Air Chamber Drain
(4) Drain plug.

All engines have two drain plugs (4) installed (Figure 23). One drain plug is located between the No. 1 and No. 3 cylinder heads, and another plug is located between the last two cylinder heads on the left side of the engine. These plugs can be removed to check for water or coolant in the cylinder block air chamber.

Air to air aftercooled systems (Figures 24–26) contain a temperature controller that is pressurized to keep dirt and moisture out of it and a bypass valve which consists of an actuator and valve positioner (5). The temperature controller (12) monitors inlet air temperature and is adjusted to keep it at 43°C (110°F). If the air temperature is too cold, the temperature controller signals an actuator (with pneumatic or gas pressure) to bypass the aftercooler core so air flows from the turbochargers (8) directly into the carburetor (7).

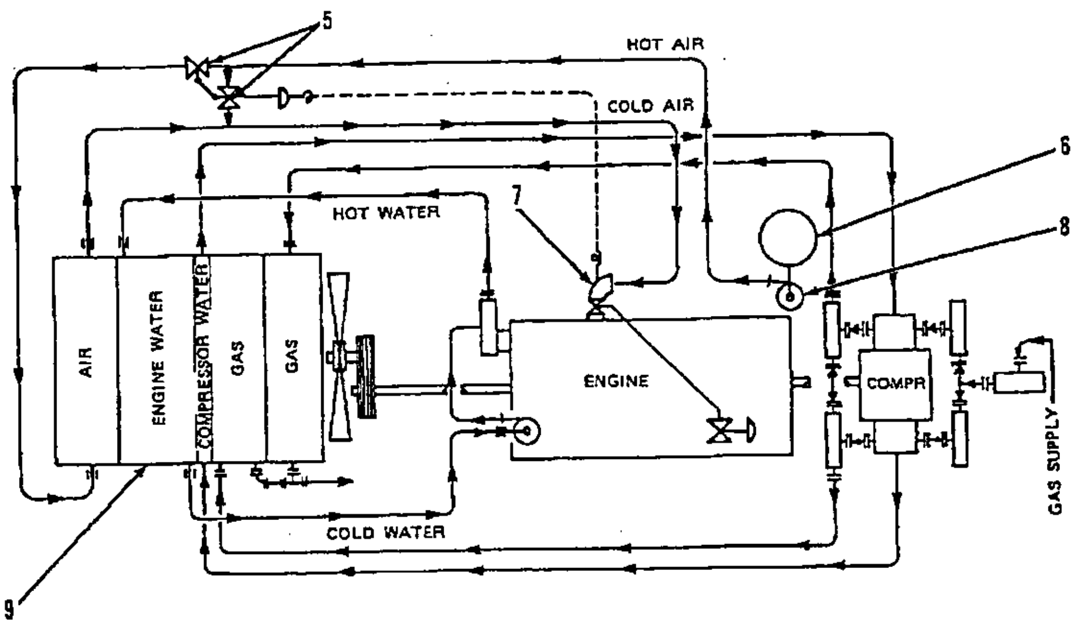


Figure 24. Schematic Of An Air To Air Aftercooler Engine
(5) Actuator with valve positioner. (6) Air cleaner. (7) Carburetor. (8) Turbocharger. (9) Cooling unit.

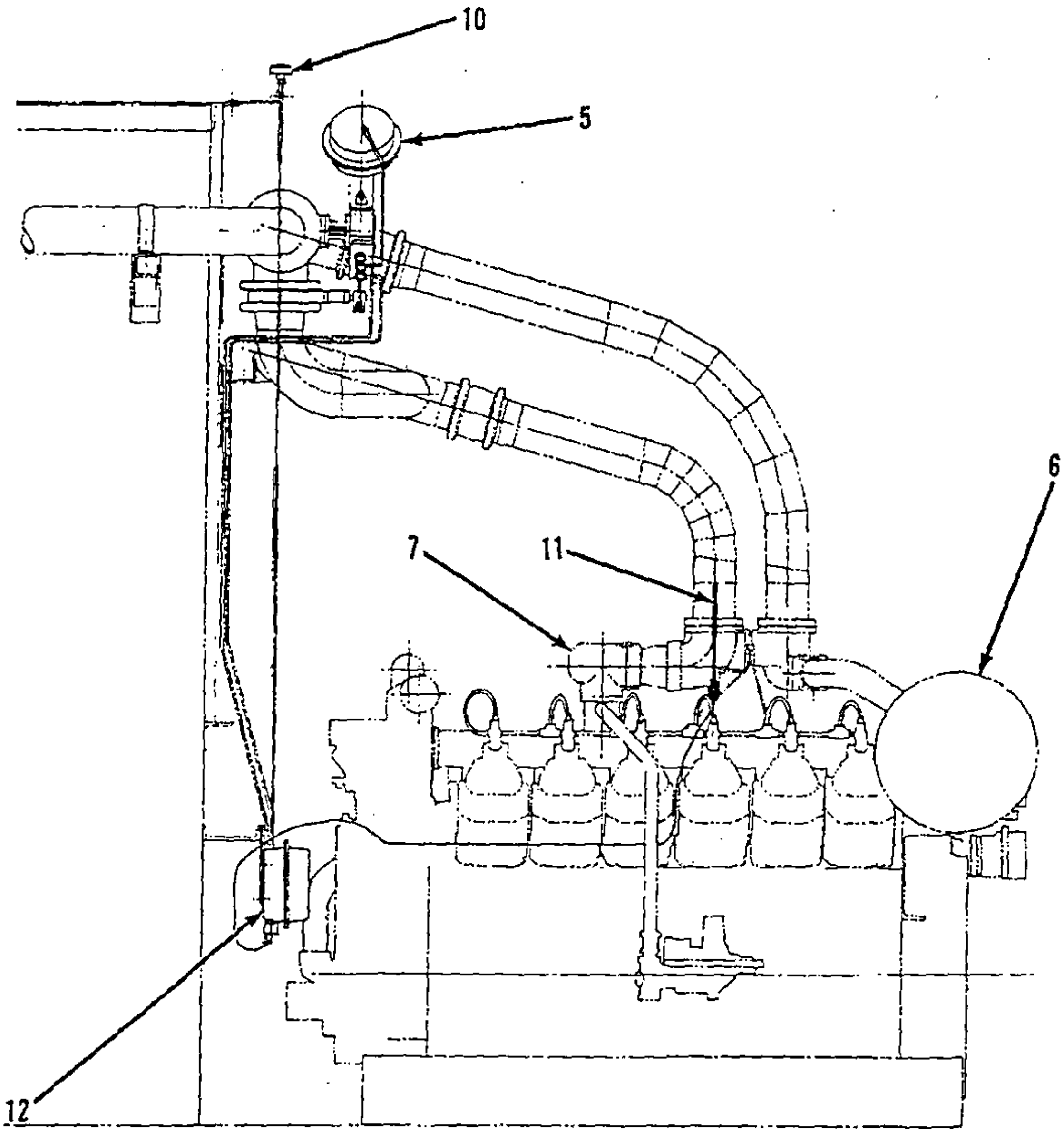


Figure 25. Typical Air To Air Aftercooled System
(5) Actuator with valve positioner. (6) Air cleaner. (7) Carburetor. (10) Vent cap for temperature controller. (11) Sensing element for temperature controller. (12) Temperature controller.

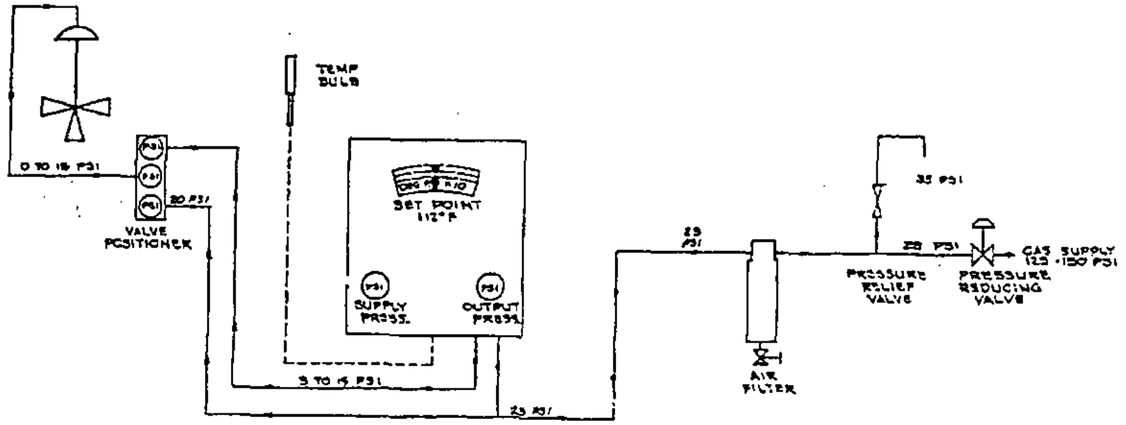


Figure 26. Schematic Of Instrument Installation For Air To Air Aftercooled Systems

Turbochargers

On turbocharged engines there are two turbochargers (Figures 27 and 28), on the rear of the engine. Each turbocharger has a turbine wheel (exhaust side) and a compressor wheel (inlet side). The two wheels are mounted on a common shaft and turn together. The turbine side of the turbochargers is fastened to the exhaust manifolds. The compressor side of the turbocharger is connected to the aftercooler.

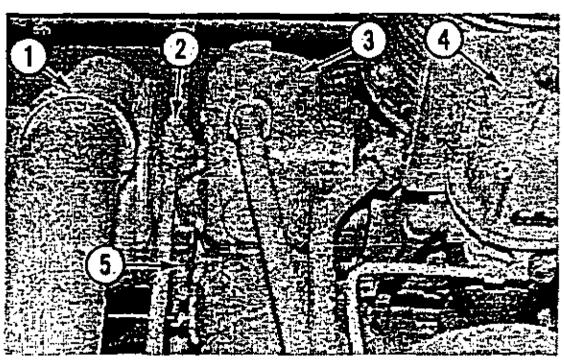


Figure 27. Turbochargers
(1) Turbocharger inlet. (2) Oil inlet line.
(3) Water cooled turbine housing. (4) Exhaust bypass valve. (5) Oil drain line.

Exhaust gases are regulated by the exhaust bypass valve (4). The exhaust gas enters the turbine housing (3) and pushes against the blades of the turbine wheel (10). The turbine wheel is connected to the same shaft as the compressor wheel. Rotation of the turbine wheel causes the compressor wheel to turn.

At high idle, the shaft can rotate at speeds up to 70,000 rpm.

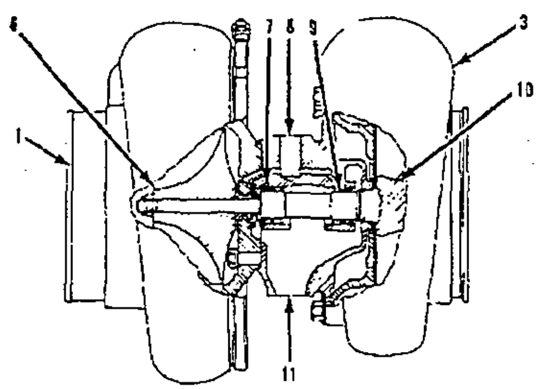


Figure 28. Turbocharger
(6) Compressor wheel. (7) Bearing. (8) Oil inlet.
(9) Bearing. (3) Turbine housing. (10) Turbine wheel.
(1) Air inlet. (11) Oil outlet.

Clean air from the air cleaners is pulled through the compressor housing air inlet (1) by rotation of compressor wheel (6). The action of the compressor wheel blades causes a compression of the inlet air. This compression gives the engine more power because it makes it possible for the engine to burn additional fuel with greater efficiency.

Maximum rpm of the turbocharger is controlled by the fuel setting, the high idle rpm setting and the height above sea level at which the engine is operated.

NOTICE

If the high idle rpm or the fuel setting is higher than given in the Fuel Setting Information Fiche (for the height above sea level at which the engine is operated), there can be damage to engine or turbocharger parts. Damage will result when increased heat and/or friction due to the higher engine output goes beyond the engine cooling and lubrication systems abilities. A mechanic that has the correct training is the only one to make the adjustment of fuel setting and high idle rpm setting.

The bearings (7 and 9) in the turbocharger use engine oil under pressure for lubrication. The oil comes in through oil inlet port (8) and goes through passages in the center section for lubrication of the bearings. Then the oil goes out oil outlet port (11) and back to the oil pan.

Exhaust Bypass Valve (Engines With Turbochargers)

G3500 Engines equipped with turbochargers are also equipped with an adjustable exhaust bypass valve (Figures 29 and 30). The bypass valve can be adjusted for altitude conditions or to adjust the throttle angle for a given load. A high throttle angle at maximum load will reduce resistance to flow by the throttle plate and minimize fuel consumption.

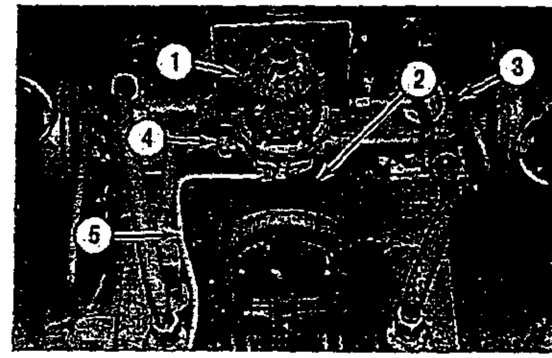


Figure 29. Exhaust Bypass Valve Location
(1) Exhaust bypass valve (2) Exhaust elbow.
(3) Turbocharger turbine housing. (4) Water cooled valve guide housing. (5) Control line from aftercooler to exhaust bypass valve.

The control line from the aftercooler to the exhaust bypass valve (5) connects the compressor side of the turbocharger (through the aftercooler) with the exhaust bypass valve. The exhaust bypass valve (1) is connected through the waste gate housing to the exhaust elbow (2). The bypass valve controls the amount of exhaust gases that enter the turbocharger turbine housing (3) and drive the turbine wheel, or bypass the turbine and go out the exhaust elbow. The guide housing (4) for the bypass valve is water cooled.

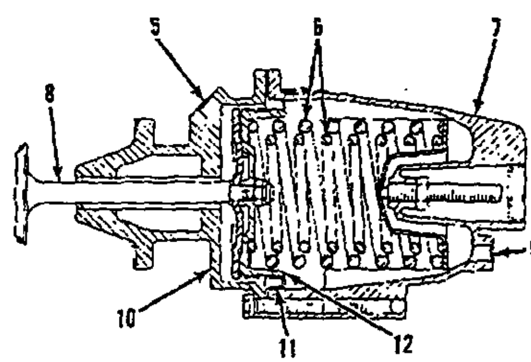


Figure 30. Exhaust Bypass Valve Operation
(5) Control line connection. (6) Springs.
(7) Cover assembly. (8) Poppet valve. (9) Breather location. (10) Guide (base) assembly. (11) Diaphragm.
(12) Diaphragm retainer.

Poppet Valve (8) is activated directly by a pressure differential between the air pressure (atmosphere) and the turbocharger compressor outlet pressure to the aftercooler.

One side of the diaphragm (11) in the regulator feels atmospheric pressure through a breather (9) in the top of the regulator. The other side of the diaphragm feels air pressure from the outlet side of the turbocharger compressor through the control line connected to the aftercooler. When outlet pressure to the aftercooler gets to the correct value, the force of the air pressure moves the diaphragm and overcomes the force of the springs (6) and atmospheric pressure. This opens the poppet valve, and allows a portion of the exhaust gases to bypass the turbine wheel. The guide (10) for the poppet valve is water cooled.

Under constant load conditions, the valve will take a set position, permitting just enough exhaust gas to go to the turbine wheel to give the correct air pressure to the aftercooler.

The Exhaust Bypass Valve is preset at the factory. Adjustments may be necessary due to altitude or changes in ambient temperature conditions.

Valve System Components

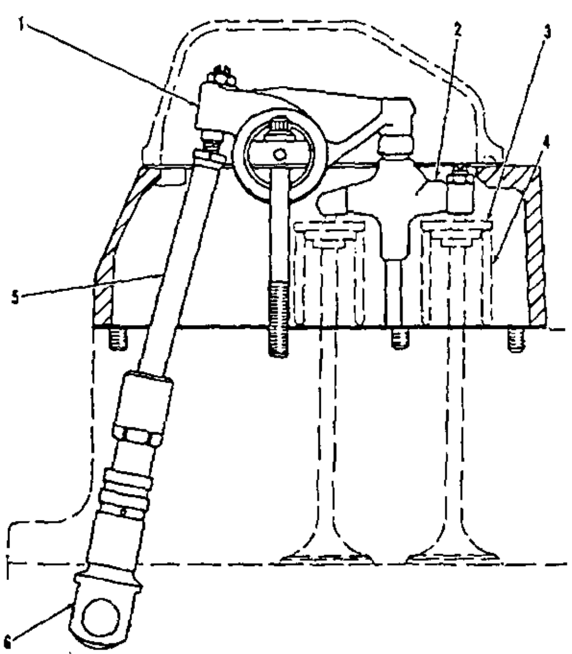


Figure 31. Valve System Components
(1) Rocker arm. (2) Bridge. (3) Rotocoil.
(4) Valve spring. (5) Push rod. (6) Lifter.

The valve system components (Figure 31) control the flow of inlet air and exhaust gases into and out of the cylinders during engine operation.

The crankshaft gear drives the camshaft gears through idlers. Both camshafts must be timed to the crankshaft to get the correct relation between piston and valve movement.

The camshafts have two cam lobes for each cylinder. The lobes operate the valves.

As each camshaft turns, the lobes on the camshafts cause lifters (6) to move up and down. This movement makes push rods (5) move rocker arms (1). Movement of the rocker arms makes bridges (2) move up and down on dowels in the cylinder head. The bridges let one rocker arm open and close two valves (intake or exhaust). There are two intake and two exhaust valves for each cylinder.

Rotocoils (3) cause the valves to turn while the engine is running. The rotation of the valves keeps the deposit of carbon on the valves to a minimum and gives the valves longer service life.

Valve springs (4) cause the valves to close when the lifters move down.

Lubrication System

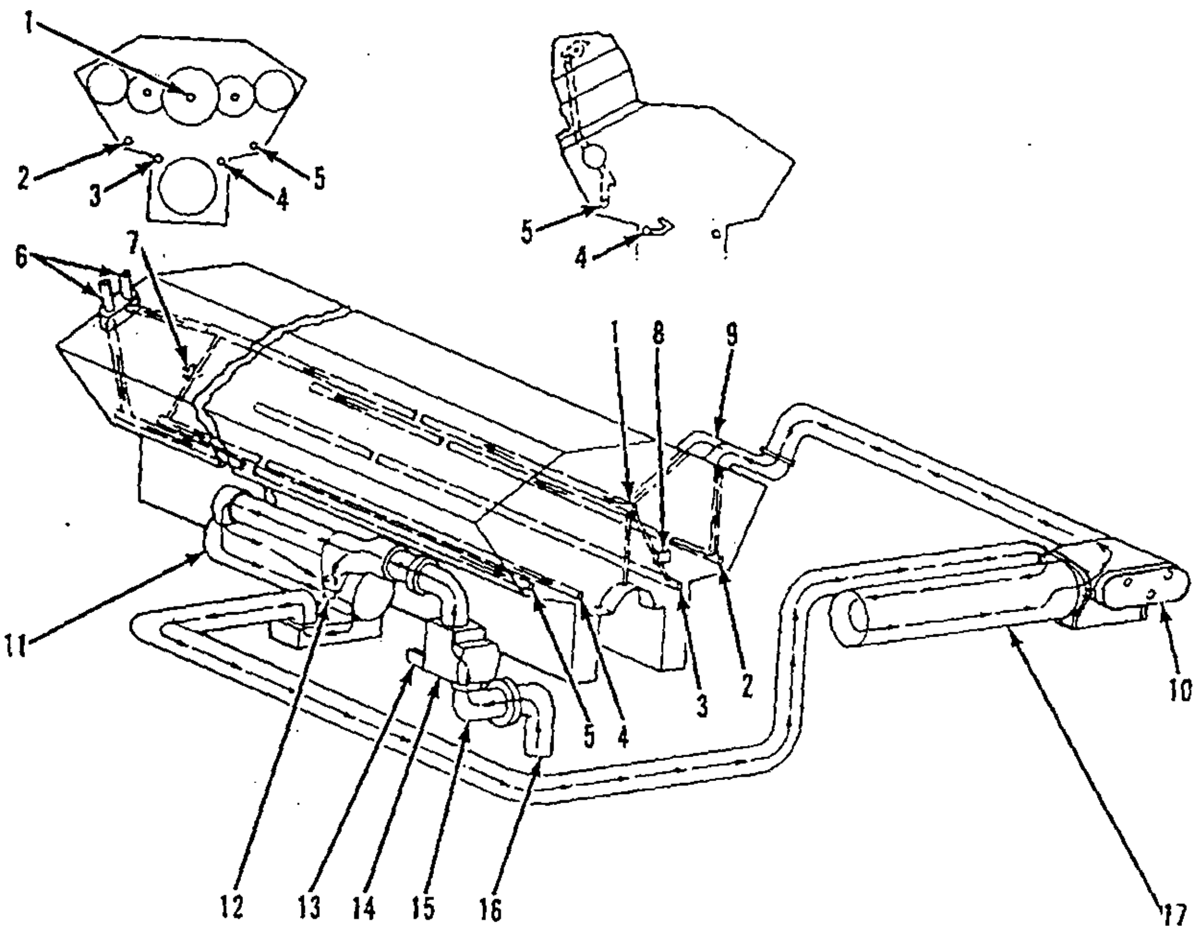


Figure 32. Lubrication System Schematic
(1) Main oil gallery. (2) Left camshaft oil gallery. (3) Piston cooling jet oil gallery. (4) Piston cooling jet oil gallery. (5) Right camshaft oil gallery. (6) Turbocharger oil supply. (7) Sequence valve. (8) Sequence valve. (9) Adapter. (10) Oil filter bypass valve. (11) Oil cooler. (12) Bypass valve. (13) Oil pump relief valve. (14) Engine oil pump. (15) Elbow. (16) Suction bell. (17) Oil filter housing.

This system (Figures 32-36) uses an oil pump (14) with three pump gears that are driven by the front gear train. Oil is pulled from the pan through suction bell (16) and elbow (15) by the oil pump. The suction bell has a screen to clean the oil.

The oil pump pushes oil through oil cooler (11) and the oil filters to oil galleries (1 and 2) in the block. The fin and tube type oil cooler lowers the temperature of the oil before the oil is sent on to the filters.

Bypass valve (12) allows oil flow directly to the filters if the oil cooler becomes plugged or if the oil becomes thick enough (cold start) to increase the oil pressure differential (cooler inlet to outlet) by an amount of 180 ± 20 kPa (26 ± 3 psi).

Note: In certain cogeneration models, with high water temperatures, an oil temperature regulator (instead of the oil cooler bypass valve) is used in the line going to the oil filter. When the oil is thick (cold start) the oil temperature regulator lets oil flow directly to the filters. When the oil temperature regulator opens (engine warm) the oil is sent through the oil cooler to the oil filters.

Cartridge type filters are located in oil filter housing (17) at the front of the engine. A single bypass valve is located in the oil filter housing.

Clean oil from the filters goes into the block through adapter (9). Part of the oil goes to the left camshaft oil gallery (2) and part goes to the main oil gallery (1).

The camshaft oil galleries are connected to each camshaft bearing by a drilled hole. The oil goes around each camshaft journal, through the cylinder head and rocker arm housing, to the rocker arm shaft. A drilled hole connects the bores for the valve lifters to the oil hole for the rocker arm shaft. The valve lifters get lubrication each time they go to the top of their stroke.

The main oil gallery is connected to the main bearings by drilled holes. Drilled holes in the crankshaft connect the main bearing oil supply to the rod bearings. Oil from the rear of the main oil gallery goes to the rear of right camshaft gallery (5).

Sequence valves (7 and 8) let oil from main oil gallery go to piston cooling jet oil galleries (3 and 4). The sequence valves open at 140 kPa (20 psi). The sequence valves will not let oil into the piston cooling jet oil galleries until there is pressure in the main oil gallery. This decreases the amount of time necessary for pressure build-up when the engine is started. It also helps hold pressure at idle speed.

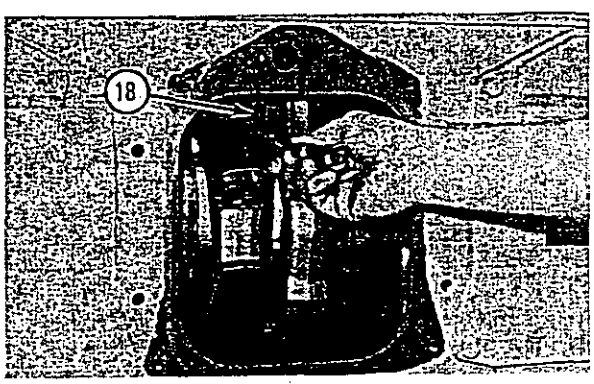


Figure 33. Piston Cooling And Lubrication
(18) Cooling jet.

There is a piston cooling jet (18) below each piston. See Figure 33. Each cooling jet has two openings directed at the center of the piston. This helps cool the piston and gives lubrication to the piston pin.

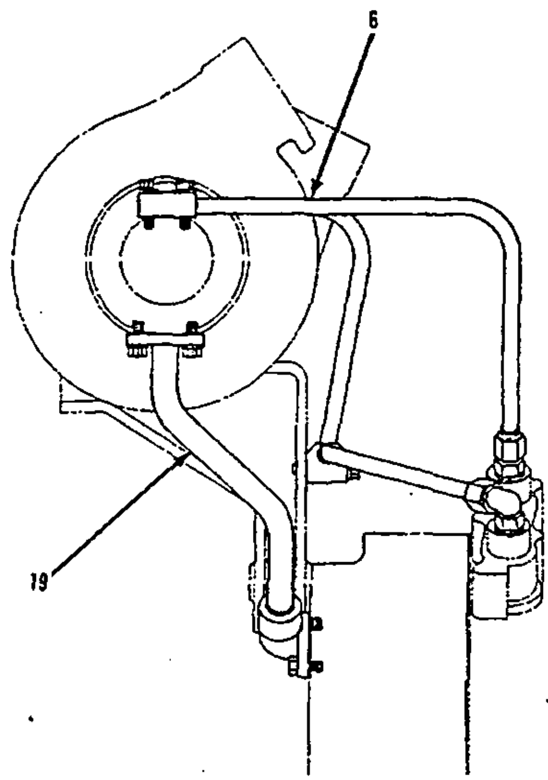


Figure 34. Turbocharger
(6) Oil supply line. (19) Oil drain lines for turbocharger.

Oil lines (6) supply oil to the turbochargers (Figure 34). The turbocharger drain lines (19) are connected to the flywheel housing on each side of the engine.

Oil is sent to the front and rear gear groups through drilled passages in the front and rear housings and cylinder block faces. These passages are connected to camshaft oil galleries (2 and 5).

After the oil for lubrication has done its work, it goes back to the engine oil pan.

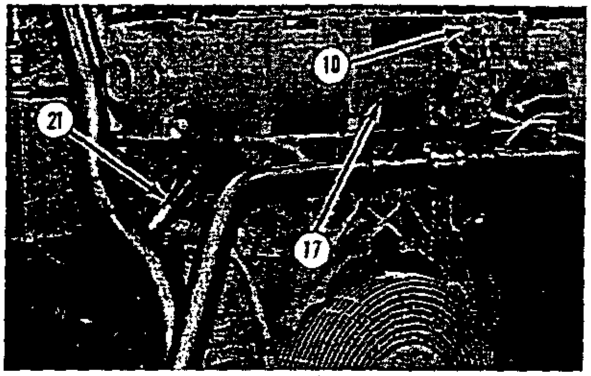


Figure 35. Right Front Side Of Engine
(10) Oil filter bypass valve. (17) Oil filter housing.
(21) Oil line to filter housing.

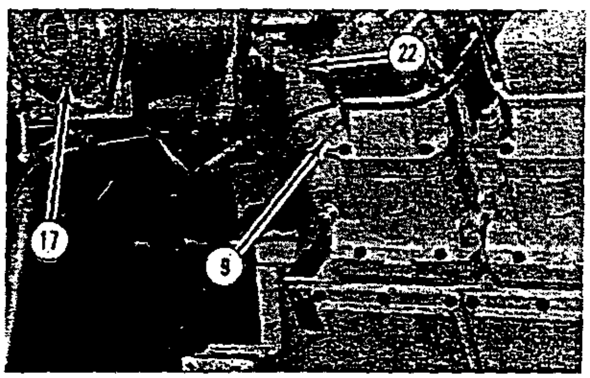


Figure 36. Left Front Of Engine
(9) Adapter. (17) Oil filter housing. (22) Oil outlet line from oil filter housing.

Cooling System

Jacket Water System

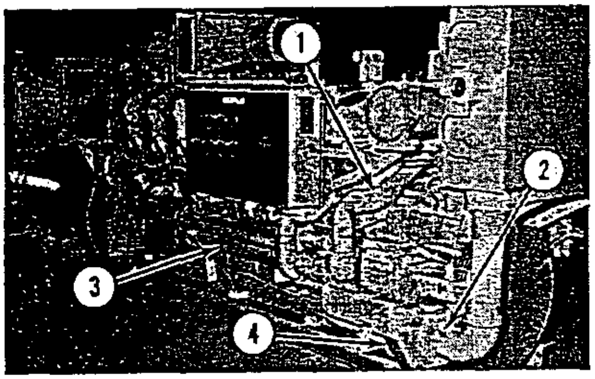


Figure 37. Right Side Of Engine
(1) Water line to front of engine cylinder block.
(2) Coolant inlet. (3) Oil cooler. (4) Water pump.

This system (Figure 37 & 38) uses a water pump (4) that is driven by the lower front right gear group. Coolant from a radiator or other heat exchanger is pulled into the coolant inlet (2) in the center of the water pump housing by the rotation of the water pump impeller. The coolant flow is then divided at the water pump outlet. Part of the coolant flow is sent through water line (1) to the front of the cylinder block and part is sent through the engine oil cooler (3).

Note: There is one opening on the pump outlet so that a remote pump can be connected to the system. The remote pump can be used if there is a failure of the water pump on the engine.

Coolant is sent through a water line to the front of the cylinder block and through a main distribution manifold to each cylinder water jacket. The main distribution manifold is located just above the main bearing oil gallery in the center of the cylinder block. Some of the coolant goes out the back of the cylinder block and into the adapter housing for the exhaust bypass valve. Flow from the exhaust bypass valve adapter housing is divided. Part of the coolant goes up through the exhaust elbow and part goes up through the turbocharger turbine housings. All coolant flow is then directed into the water cooled exhaust manifolds.

The coolant sent to the oil cooler goes through the oil cooler and flows into the water jacket of the block at the right rear cylinder. The cooler coolant mixes with the hotter coolant and goes to both sides of the block through the distribution manifolds connected to the water jacket of all the cylinders.

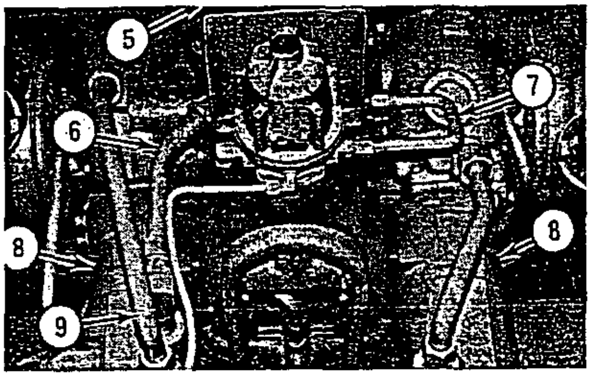


Figure 38. Coolant Flow From Rear of Engine
(5) Exhaust elbow. (6) Water line between exhaust elbow and exhaust manifold. (7) Water line between exhaust bypass valve guide and exhaust elbow.
(8) Water cooled exhaust manifold. (9) Water line between exhaust manifold and turbocharger turbine housing.

The coolant flows up through the water jackets and around the cylinder liners from the bottom to the top. Near the top of the cylinder liners, where the temperature is the hottest, the water jacket is made smaller. This shelf (smaller area) causes the coolant to flow faster for better liner cooling. Coolant from the top of the liners goes into the cylinder head which sends the coolant around the parts where the temperature in the cylinder head is the hottest. Coolant then goes to the top of the cylinder head and out through an elbow, one at each cylinder head, into the watercooled exhaust manifolds (8) (Figure 43) at each bank of cylinders. Coolant from the exhaust manifolds flows through lines (9) to cool the turbine side of the turbochargers. Coolant flows through line (6) to cool the exhaust elbow (5). Coolant flows through line (7) from the top of the cylinder block, cools the exhaust bypass valve guide and flows into the exhaust elbow. After cooling engine components the coolant flow is directed through the exhaust manifolds to the temperature regulator (thermostat) housing.

The water temperature regulator housing is located at the top, front of the engine. It has an upper and lower flow section, and uses four temperature regulators. The sensing bulbs of the four temperature regulators are in the coolant in the lower section of the housing. Before the engine reaches operating temperatures and the regulators open, cold coolant is sent through the lower section of the housing and through the bypass line back to the inlet of the water pump. As the temperature of the coolant increases enough to make the regulators start to open, coolant flow in the bypass line is stopped and coolant is sent through the outlets to the radiator or heat exchanger.

Note: The water temperature regulator is an important part of the cooling system. It divides coolant flow between the heat exchanger and internal bypass of the water pump as necessary to maintain the correct temperature. If the water temperature regulator is not installed in the system, there is no mechanical control, and most of the coolant will take the path of least resistance through the bypass. This will cause the engine to overheat in hot weather. In cold weather, even the small amount of coolant that goes through the radiator is too much, and the engine will not get to normal operating temperatures.

Total system coolant capacity will depend on the size of the heat exchanger. Use a coolant mixture of 50 percent pure water and 50 percent permanent antifreeze, then add a concentration of 3 to 6 percent corrosion inhibitor.

Separate Circuit Aftercooler (SCAC) System

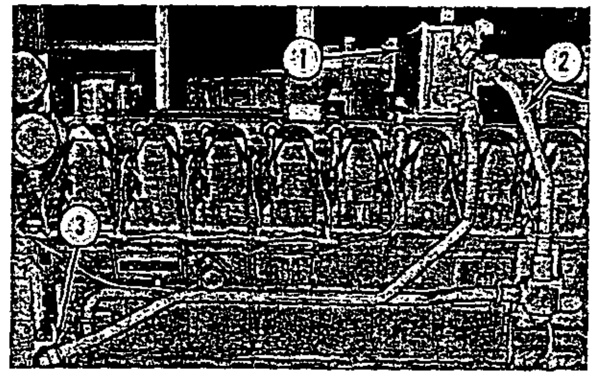


Figure 39. Left Side Of Engine
(1) Aftercooler. (2) Coolant return line. (3) Auxiliary Water pump.

Engines with a water cooled aftercooler, use a separate circuit aftercooler (SCAC) system instead of the normal jacket water circuit, to cool the air in the aftercooler. With the SCAC system, coolant is supplied from a separate radiator or heat exchanger.

With the engine running at less than operating temperature, the aftercooler coolant circuit is closed. The auxiliary water pump (3) sends coolant through a line to the aftercooler (1) at approximately 570 liter/m (150 U.S. gpm) (Figure 39). Coolant flows up through the core assembly and out of the aftercooler through the coolant return line (2), through a thermostatic valve and back to auxiliary water pump. As the coolant temperature increases, the thermostatic valve opens and coolant flow from the aftercooler core assembly is directed to a radiator or heat exchanger and then back to auxiliary water pump. The thermostatic valve will be fully open when the coolant temperature is 32°C (90°F) or 54°C (130°F) depending on the thermostat installed in the valve housing.

Note: Certain cogeneration engines do not use thermostats to control jacket water temperature. The engine temperature is controlled externally with a heat exchanger by maintaining the outlet temperature of the steam system. In high water temperature applications the oil cooler is on a separate circuit. A thermostat controls the oil temperature going to the bearings.

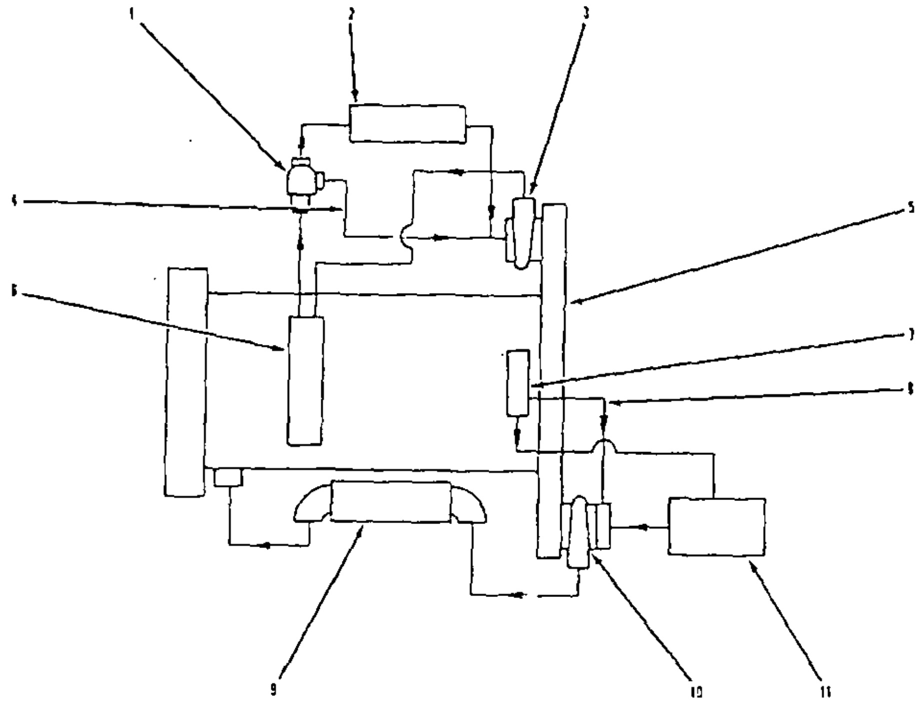


Figure 40. G3500 Cooling System Engine Schematic
Two circuit with two engine driven pumps
(1) Thermostatic valve (coolant temperature for aftercooler). (2) Heat exchanger (aftercooler). (3) Pump [aftercooler circuit (engine driven)]. (4) Bypass line (aftercooler). (5) Front housing. (6) Aftercooler. (7) Regulator housing. (8) Bypass line (jacket water). (9) Oil cooler. (10) Pump [jacket water/oil cooler circuit (engine driven)]. (11) Heat exchanger (jacket water/oil cooler).

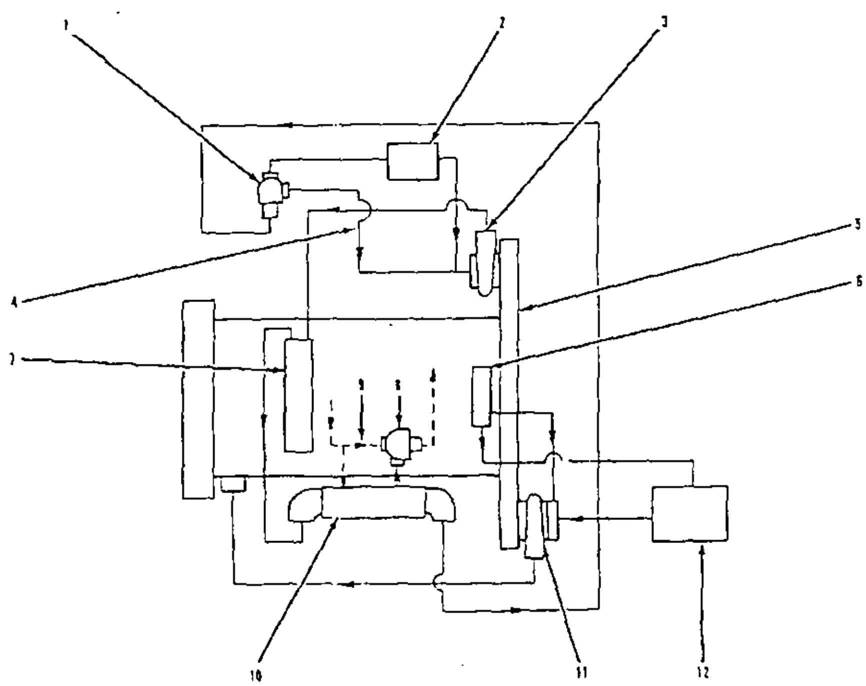


Figure 41. G3500 Landfill Cooling System Engine Schematic
Two circuit with two engine driven pumps (requires a large aftercooler/oil cooler heat exchanger).
(1) Thermostatic valve. (2) Aftercooler/oil cooler heat exchanger. (3) Pump [aftercooler/oil cooler circuit (engine driven)]. (4) Bypass line. (5) Front housing. (6) Regulator housing. (7) Aftercooler. (8) Thermostatic valve (oil temperature). (9) Bypass line. (10) Oil cooler. (11) Pump [jacket water circuit (engine driven)]. (12) Heat exchanger (jacket water).

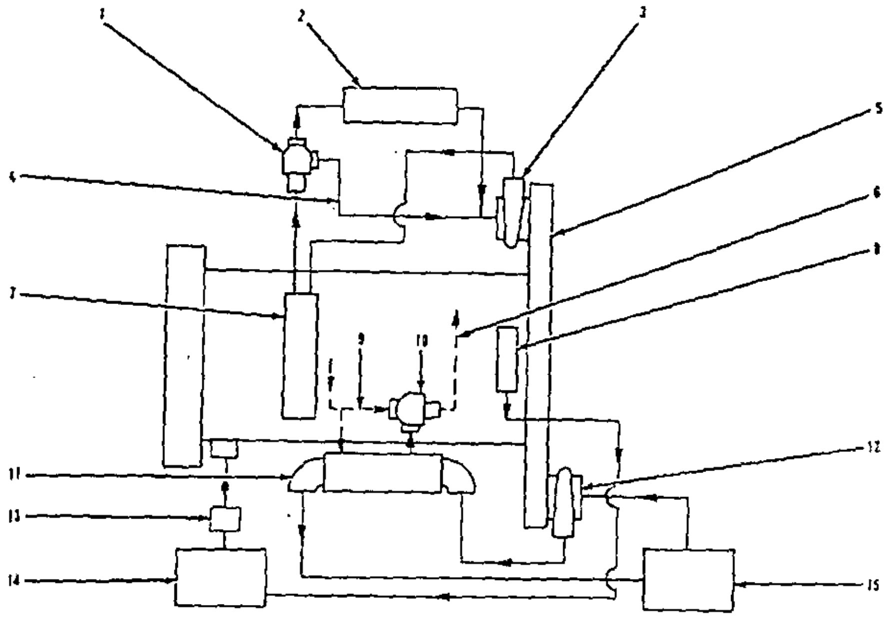


Figure 42. G3500 Cogeneration Cooling System Engine Schematic
Jacket water pump (customer supplied)
Three circuit with two engine driven pumps.
(1) Thermostatic valve. (2) Heat exchanger (aftercooler). (3) Pump [aftercooler circuit (engine driven)]. (4) Bypass line (aftercooler). (5) Front housing. (6) Oil line to oil filter. (7) Aftercooler. (8) Regulator housing. (9) Bypass line (oil cooler). (10) Thermostatic valve (oil temperature). (11) Oil cooler. (12) Pump [oil cooler circuit (engine driven)]. (13) Pump [jacket water circuit (customer supplied)]. (14) Heat exchanger (jacket water).

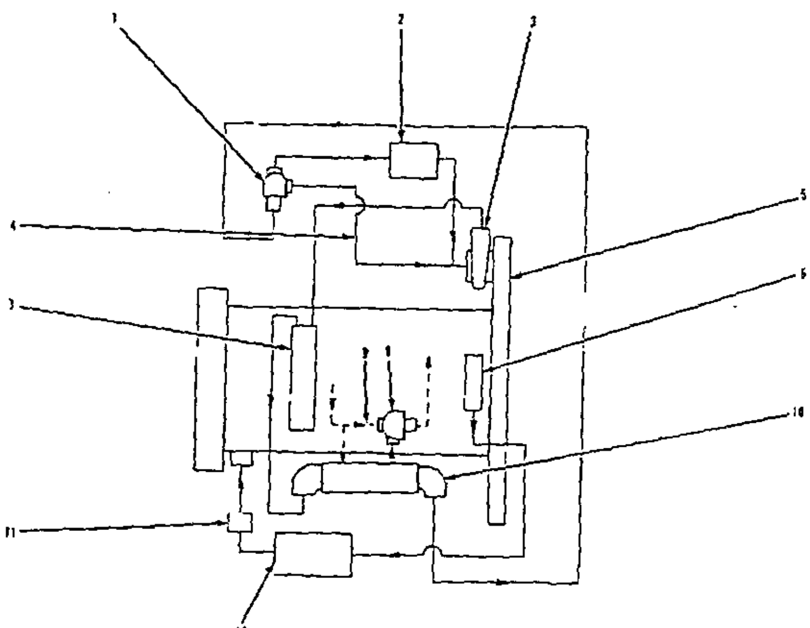


Figure 43. G3500 Cogeneration Cooling System Engine Schematic
Jacket water pump (customer supplied)
Two circuit with one engine driven pump (requires a large aftercooler/oil cooler heat exchanger).
(1) Thermostatic valve (coolant temperature for aftercooler). (2) Aftercooler/oil cooler heat exchanger. (3) Pump [aftercooler/oil cooler circuit (engine driven)]. (4) Bypass line. (5) Front housing. (6) Regulator housing. (7) Aftercooler. (8) Thermostatic valve (oil temperature). (9) Bypass line. (10) Oil cooler. (11) Pump [jacket water circuit (customer supplied)]. (12) Heat exchanger (jacket water).

Basic Block

Cylinder Block, Liners And Heads

The cylinders in the left side of the block make an angle of 60 degrees with the cylinders in the right side of the block. The main bearing caps are fastened to the block with four bolts per cap.

The cylinder liners can be removed for replacement. The top surface of the block is the seat for the cylinder liner flange. Engine coolant flows around the liners to keep them cool. Three O–ring seals around the bottom of the liner make a seal between the liner and the cylinder block. A filler band goes under the liner flange and makes a seal between the top of the liner and the cylinder block.

The engine has a separate cylinder head for each cylinder. Four valves (two intake and two exhaust), controlled by a push rod valve system, are used for each cylinder. Valve guides without shoulders are pressed into the cylinder heads. The opening for the spark plug is located between the four valves.

There is an aluminum spacer plate between each cylinder head and the block. Coolant goes out of the block through the spacer plate and into the head through eight openings in each cylinder head face. Grommets the width of the spacer plate prevent coolant leakage. Gaskets seal the oil drain passages between the head, spacer plate and block.

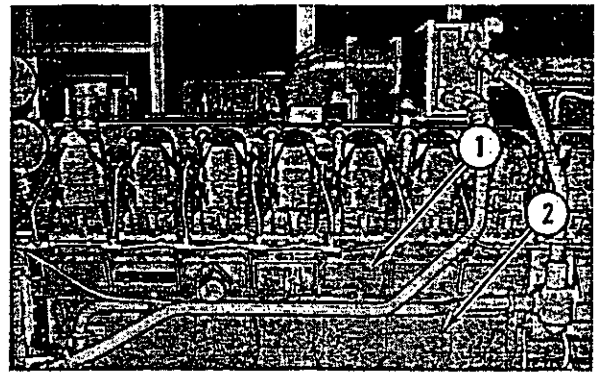


Figure 44. Left Side Of 3516 Engine
(1) Covers for camshaft and valve lifter inspection.
(2) Covers for crankshaft main and rod bearing inspection.

Covers (1) (Figures 45) allow access to the camshafts and valve lifters.

Covers (2) allow access to the crankshaft connecting rods, main bearings and piston cooling jets. With covers removed, all the openings can be used for inspection and service.

Pistons, Rings And Connecting Rods

The aluminum pistons have an iron band for the top two rings. This helps reduce wear on the compression ring grooves. The pistons have three rings; two compression rings and one oil ring. All the rings are located above the piston pin bore. The oil ring is a standard (conventional) type. Oil returns to the crankcase through holes in the oil ring groove. The top two compression rings are also the standard (conventional) type.

The connecting rod has a taper on the pin bore end. This gives the rod and piston more strength in the areas with the most load. Four bolts set at a small angle hold the rod cap to the rod. This design keeps the rod width and weight to a minimum, so that the largest possible rod bearing (and crank journal) can be used and the rod can still be removed through the top of the liner bore.

Crankshaft

The crankshaft changes the combustion forces in the cylinder into usable rotating torque which powers the engine. A vibration damper of the fluid type is used at the front of the crankshaft to reduce torsional vibrations (twist on the crankshaft) that can cause damage to the engine.

The crankshaft drives a group of gears on the front and rear of the engine. The gear group on the front of the engine drives the oil pump, water pump, fuel transfer pump, governor or governor actuator and two accessory drives. The gear group on the rear of the engine drives the camshafts.

Lip seals and wear sleeves are used at both ends of the crankshaft for easy replacement and a reduction of maintenance cost. Pressure oil is supplied to all main bearings through drilled holes in the webs of the cylinder block. The oil then flows through drilled holes in the crankshaft to provide oil to the connecting rod bearings. The crankshaft is held in place by five main bearings on the G3508, seven main bearings on the G3512, and nine main bearings on the G3516. A thrust plate at either side of the center main bearing controls the end play of the crankshaft.

Camshafts

The G3512 and G3516 have two camshafts per side that are doweled and bolted together to make a camshaft group. Each G3516 camshaft group is supported by nine bearings and is driven by the gears at the rear of the engine. Each G3512 camshaft group is supported by seven bearings and is driven by the gears at the rear of the engine. The G3508 has one camshaft per side. Each camshaft is supported by five bearings and is driven by the gears at the rear of the engine.

As the camshaft turns, each lobe moves a lifter assembly. There are two lifter assemblies for each cylinder. Each lifter assembly moves a push rod and two valves (either intake or exhaust). The camshafts must be in time with the crankshaft. The relation of the cam lobes to the crankshaft position cause the valves in each cylinder to operate at the correct time.

Engine Electrical System

The electrical system has three separate circuits: the charging circuit, the starting circuit and the low amperage circuit. Some of the electrical system components are used in more than one circuit. The battery (batteries), circuit breaker, ammeter, cables and wires from the battery are all common in each of the circuits.

The charging circuit is in operation when the engine is running. An alternator makes electricity for the charging circuit. A voltage regulator in the circuit controls the electrical output to keep the battery at full charge.

The starting circuit is in operation only when the start switch is activated.

The low amperage circuit and the charging circuit are both connected to the same side of the ammeter. The starting circuit connects to the opposite side of the ammeter.

Charging System Components

NOTICE

Never operate an alternator without a battery in the circuit. Making or breaking an alternator connection with heavy load on the circuit can cause damage to the voltage regulator.

Alternator (3T6352 & 4N3986)

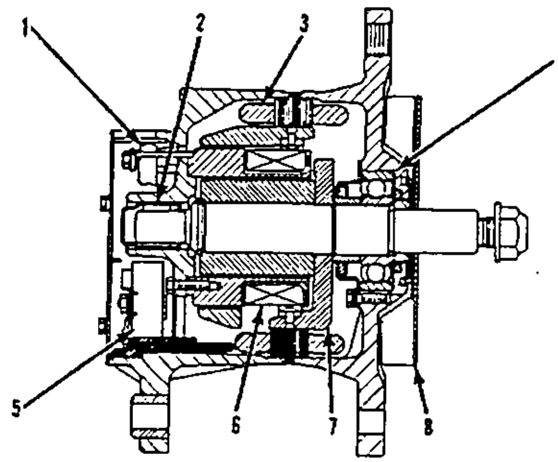


Figure 45. Alternator
(1) Regulator. (2) Roller bearing. (3) Stator winding. (4) Ball bearing. (5) Rectifier bridge. (6) Field winding. (7) Rotor assembly. (8) Fan.

The alternator (Figure 45) is driven by belts from the crankshaft pulley. This alternator is a three phase, self-rectifying charging unit, and the regulator (1) is part of the alternator.

This alternator design has no need for slip rings or brushes, and the only part that has movement is the rotor assembly (7). All conductors that carry current are stationary. The conductors are: the field winding (6), stator windings (3), six rectifying diodes, and the regulator circuit components.

The rotor assembly has many magnetic poles like fingers with air space between each opposite pole. The poles have residual magnetism (like permanent magnets) that produce a small amount of magnet-like lines of force (magnetic field) between the poles. As the rotor assembly begins to turn between the field winding and the stator windings, a small amount of alternating current (AC) is produced in the stator windings from the small magnetic lines of force made by the residual magnetism of the poles. This AC current is changed to direct current (DC) when it passes through the diodes of the rectifier bridge (5). Most of this current goes to charge the battery and to supply the low amperage circuit, and the remainder is sent on to the field windings. The DC current flow through the field windings (wires around an iron core) now increases the strength of the magnetic lines of force. These stronger lines of force now increase the amount of AC current produced in the stator windings. The increased speed of the rotor assembly also increases the current and voltage output of the alternator.

The voltage regulator is a solid state (transistor, stationary parts) electronic switch. It feels the voltage in the system, and switches on and off many times a second to control the field current (DC current to the field windings) to the alternator. The output voltage from the alternator will now supply the needs of the battery and the other components in the electrical system. No adjustment can be made to change the rate of charge on these alternator regulators.

Grounding Practices

Proper grounding for vehicle and engine electrical systems is necessary for proper vehicle performance and reliability. Improper grounding will result in uncontrolled and unreliable electrical circuit paths which can result in damage to main bearings and crankshaft journal surfaces. Uncontrolled electrical circuit paths can also cause electrical noise which may degrade vehicle and radio performance.

To insure proper functioning of the vehicle and engine electrical systems, and engine-to-frame ground strap with a direct path to the battery must be use. This may be provided by way of a starting motor, a frame to starting motor ground, or a direct frame to engine ground.

Ground wires/straps should be combined at ground studs dedicated for ground use only. The engine alternator must be battery (–) grounded with a wire size adequate to handle full alternator charging current.

NOTICE

This engine may be equipped with a 24 volt starting system. Use only equal voltage for boost starting. The use of a welder or higher voltage will damage the electrical system.

Starting Systems

There are two types of starting systems available for Caterpillar Engines — air and electric.

The choice of systems depends on availablility of the energy source. Availablity of space for energy of storage and ease of recharging the energy banks are considerations for determining the type of starting system to be used.

Electric

Electric starting (Figure 46) is the most convenient to use. It is least expensive and is most adaptable for remote control and automation.

Batteries

Batteries provide sufficient power to crank engines long and fast enough to start. Lead-acid types are common, have high output capabiliites, and lowest first cost. Nickel-cadmium batteries are costly, but have long shelf life and require minimum maintenance. Nickel-cadmium types are designed for long life and may incorporate thick plates which decrease high discharge capability. Consult the battery supplier for specific recommendations.

Two considerations in selecting proper battery capacity are:

- The lowest temperature at which the engine might be cranked.
- The parasitic load imposed on the engine. A good rule of thumb is to select a battery package which will provide at least four 30 second cranking periods (total of 2 minutes cranking). An engine should not be cranked continuously for more than 30 seconds or starter motors may overheat.

Ambient temperatures drastically affect battery performance and charging efficiencies. Maintain 32° C (90°F) maximum temperature to assure rated output. Impact of colder temperatures is described in Figure 47.

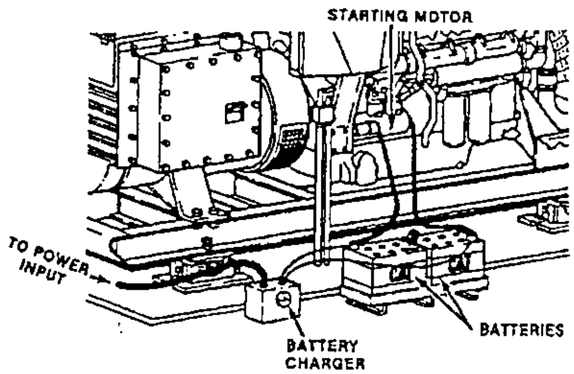


Figure 46. Electric starting system.

Temperature vs. Output		
°F	°C	27°C (80°F) Ampere Hours Output Rating
80	28	100
32	0	65
0	-18	40

Figure 47. Impact of Cold Temperatures.

Locate cranking batteries for easy visual inspection and maintence. They must be away from flame or spark sources and isolated from vibration. Mount level on nonconducting material and protect from splash and dirt. Use short slack cable lengths and minimize voltage drops by positioning batteries near the starting motor.

Disconnect the battery charger when removing or connecting battery leads. Solid-state equipment, i.e., electronic governor, speed switches, can be harmed if subjected to charger's full output.

Battery Charger

Various chargers are available to replenish a battery. Trickle chargers are designed for continuous service on unloaded batteries. They automatically shut down to milliampere current when batteries are fully charged.

Overcharging shortens battery life and is recognized by excessive water loss. Conventional lead-acid batteries require less than 2 oz. (59.2 mL) make-up water during 30 hours of operation.

Float-equalize chargers are more expensive than trickle chargers are used in applications demanding maximum battery life. These chargers include line and load regulation, and current limiting devices, which permit continuous loads at rated output.

Both trickle chargers and float equalize chargers require a source of A/C power while the engine is not running. Chargers must be capable of limiting peak currents during cranking cycles or have a relay to disconnect during cranking cycles. Where engine-driven alternators and battery chargers are both used, the disconnect relay usually disconnects the battery charger during engine cranking and running.

Engine-driven generators or alternators can be used, but have the disadvantage of charging batteries only while the engine runs. Where generator sets are subject to many starts, insufficent battery capacity could threaten dependability.

Solenoid

A solenoid (Figure 48) is a magnetic switch that does two basic operations:

a. Closes the high current starter motor circuit with a low current start switch circuit.

b. Engages the starter motor pinion with the ring gear.

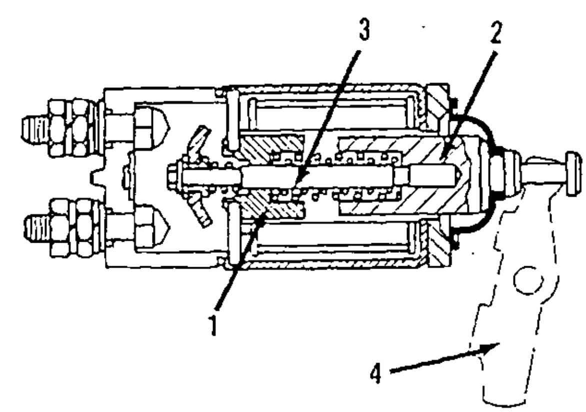


Figure 48. Solenoid Schematic.
(1) Electromagnet. (2) Hollow cylinder. (3) Plunger.
(4) Shift lever.

The solenoid switch is made of an electromagnet (one or two sets of windings) (1) around a hollow cylinder (2). There is a plunger (core) (3) with a spring load inside the cylinder that can move forward and backward. When the start switch is closed and electricity is sent through the windings, a magnetic field is made that pulls the plunger forward in the cylinder. This moves the shift lever(4) (connected to the rear of the plunger) to engage the starter pinion drive gear with the ring gear. The front end of the plunger then makes contact across the battery and motor terminals of the solenoid, and the starter motor begins to turn the flywheel of the engine.

When the start switch is opened, current no longer flows through the windings. The spring now pushes the plunger back to the original position, and, at the same time, moves the pinion gear away from the flywheel.

When two sets of windings in the solenoid are used, they are called the hold-in winding and the pull-in winding. Both have the same number of turns around the cylinder, but the pull-in winding uses a larger diameter wire to produce a greater magnetic field. When the start switch is closed, part of the current flows from the battery through the hold-in windings, and the rest flows through the pull-in windings to motor terminal, then through the motor to ground. When the solenoid is fully activated (connection across battery and motor terminal is complete), current is shut off through the pull-in windings. Now only the smaller hold-in windings are in operation for the extended period of time it takes to start the engine. The solenoid will now take less current from the battery, and heat made by the solenoid will be kept at an acceptable level.

Starter Motor

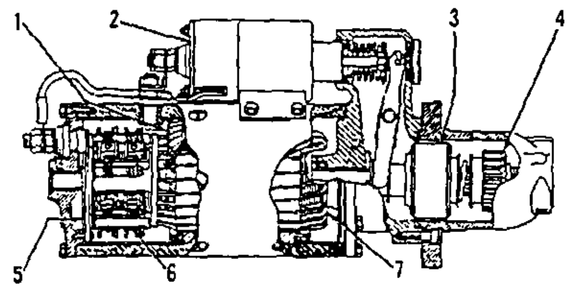


Figure 49. Starter Motor Cross Section
(1) Field. (2) Solenoid. (3) Clutch. (4) Pinion.
(5) Commutator. (6) Brush assembly. (7) Armature.

The starter motor (Figure 49) is used to turn the engine flywheel fast enough to get the engine running.

The starter motor has a solenoid(2). When the start switch is activated, the solenoid will move the starter pinion(4) to engage it with the ring gear on the flywheel of the engine. The starter pinion will engage with the ring gear before the electric contacts in the solenoid close the circuit between the battery and the starter motor. When the circuit between the battery and the starter motor is complete, the pinion will turn the engine flywheel. A clutch (3) gives protection for the starter motor so that the engine cannot turn the starter motor too fast. When the start switch is released, the starter pinion will move away from the ring gear.

Circuit Breaker

The circuit breaker (Figure 50) is a switch that opens the battery circuit (5) if the current in the electrical system goes higher than the rating of the circuit breaker.

A heat activated metal disc (4) with a contact point (3) completes the electric circuit through the circuit breaker. If the current in the electrical system gets too high, it causes the metal disc to get hot. This heat causes a distortion of metal disc which opens the contacts (2)and breaks the circuit. A circuit breaker that is open can be reset after it cools. Push the reset button (1) to close the contacts and reset the circuit breaker.

NOTICE

Find and correct the problem that causes the circuit breaker to open. This will help prevent damage to the circuit components from too much current.

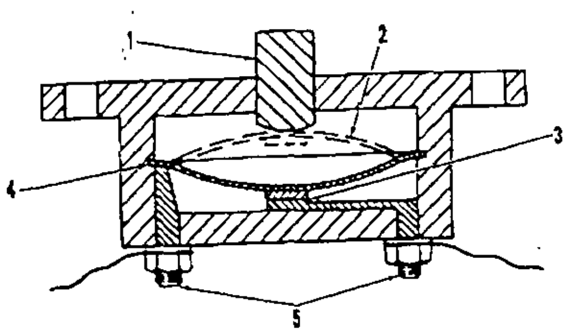


Figure 50. Circuit Breaker Cross Section
(1) Reset button. (2) Disc in open position. (3) Contacts. (4) Disc. (5) Battery circuit terminals.

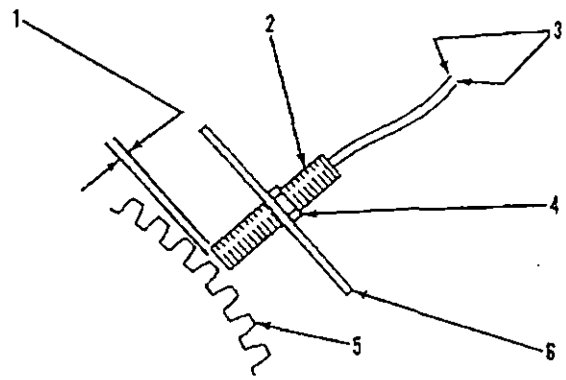


Figure 51. Magnetic Pickup
(1) Clearance dimension. (2) Pole piece. (3) Wire Coils. (4) Locknut. (5) Gear tooth. (6) Housing.

Magnetic Pickup

The magnetic pickup (Figure 51) is a single pole, permanent magnet generator made of wire coils (2) around a permanent magnet pole piece (4). As the teeth of the flywheel ring gear (5) cut through the magnetic lines of force around the pickup, an AC voltage is generated. The frequency of this voltage is directly proportional to engine speed.

Magnetic Switch

A magnetic switch (relay) is used for the starter solenoid circuit. Its operation electrically, is the same as the solenoid. Its function is to reduce the low current load on the start switch and control low current to the starting motor solenoid.

Water Temperature Connector Switch

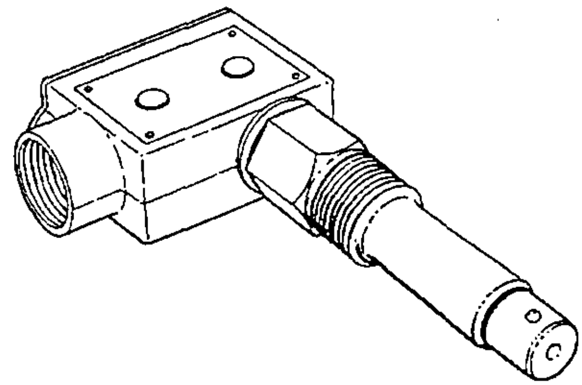


Figure 52. Water Temperature Contactor Switch

The contactor switch for water temperature (Figure 52) is installed in the regulator housing. No adjustment to the temperature range of the contactor can be made. The element feels the temperature of the coolant and then operates the micro switch in the contactor when the coolant temperature is too high. The element must be in contact with the coolant to operate correctly. If the reason for the engine being too hot is caused by low coolant level or no coolant, the contactor switch will not operate.

The contactor switch is normally connected to the electric shutoff system to stop the engine. The switch can also be connected to an alarm system. When the temperature of the coolant lowers again to the operating range, the contactor switch opens automatically.

Air Inlet Temperature Switch

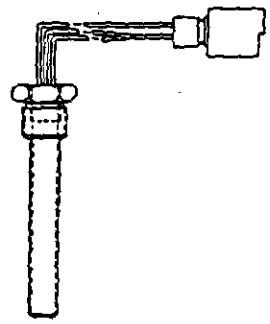


Figure 53. Air Inlet Temperature Switch.

The contactor switch for air inlet temperature (Figure 53) is installed in the inlet air manifold. No adjustment to the temperature range of the contactor can be made. The element feels the temperature of the inlet air and then operates the micro switch in the contactor when the inlet air temperature is too high. The element must be in contact with the inlet air to operate correctly.

The contactor switch is normally connected to the electric shutoff system to stop the engine. The switch can also be connected to an alarm system. When the temperature of the inlet air lowers again to the operating range, the contactor switch opens automatically.

Air Start

The air starting motor (Figures 54-56) is used to turn the engine flywheel fast enough to get the engine running.

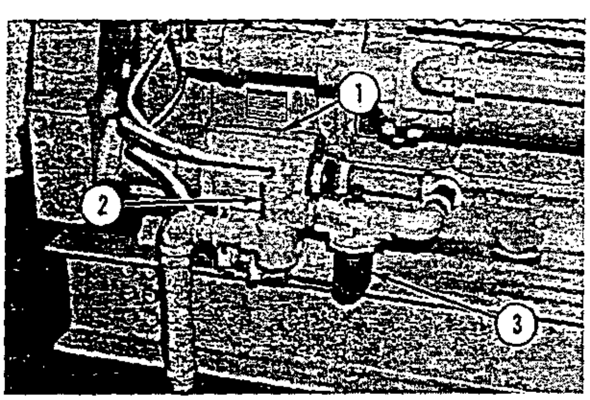


Figure 54. Typical Air Starting System
(1) Air starting motor. (2) Relay valve. (3) Oiler.

The air starting motor (1) can be mounted on either side of the engine. Air is normally contained in a storage tank and the volume of the tank will determine the length of time the engine flywheel can be turned. The storage tank must hold this volume of air at 1720 kPa (250 psi) when filled.

For engines which do not have heavy loads when starting, the regulator setting is approximately 690 kPa (100 psi). This setting gives a good relationship between cranking speeds fast enough for easy starting and the length of time the air starting motor can turn the engine flywheel before the air supply is gone.

If the engine has a heavy load which can not be disconnected during starting, the setting of the air pressure regulating valve needs to be higher in order to get high enough speed for easy starting.

The air consumption is directly related to speed; the air pressure is related to the effort necessary to turn the engine flywheel. The setting of the air pressure regulator can be up to 1030 kPa (150 psi) if necessary to get the correct cranking speed for a heavily loaded engine. With the correct setting, the air starting motor can turn the heavily loaded engine as fast and as long as it can turn a lightly loaded engine.

Other air supplies can be used if they have the correct pressure and volume. For good life of the air starting motor, the supply should be free of dirt and water. A lubricator with SAE 10 non detergent oil [for temperatures above 0°C (32°F)], or air tool oil, #1 diesel fuel or equivalent [for temperatures below 0°C (32°F)] should be used with the starting system. The maximum pressure for use in the air starting motor is 1030 kPa (150 psi).

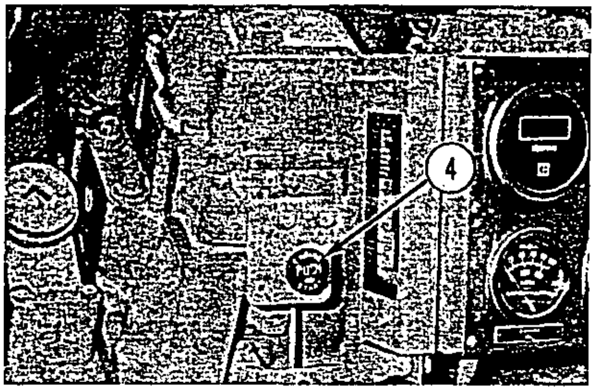


Figure 55. Typical Air Start Installation
(4) Air start control valve.

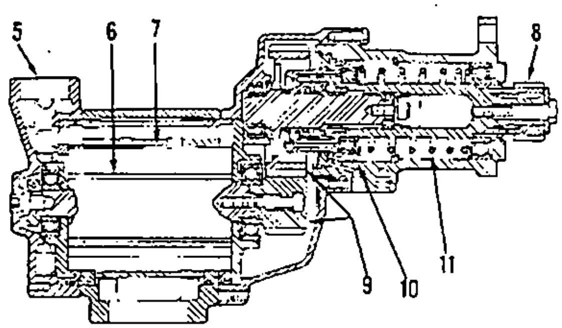


Figure 56. Air Starting Motor
(5) Air inlet. (6) Vanes. (7) Rotor. (8) Pinion. (9) Gears. (10) Piston. (11) Piston spring.

The air from the supply goes to relay valve (2). The start control valve (4) (Figure 56) is connected to the line before the relay valve. The flow of air is stopped by the relay valve until the start control valve is activated. The air from the start control valve goes to piston (10) behind pinion (8) for the starting motor. The air pressure on the piston puts spring (11) in compression and puts the pinion in engagement with the flywheel gear. When the pinion is in engagement, air can go out through another line to the relay valve. The air activates relay valve which opens the supply line to the air starting motor.

The flow of air goes through the oilerr (3) where it picks up lubrication for the air starting motor.

The air with lubrication goes into the air motor through air inlet (5). The pressure of the air pushes against vanes (6) in rotor (7), and then exhausts through the outlet. This turns the rotor which is connected by gears (9) and a drive shaft to the starting motor pinion(8) which turns the engine flywheel.

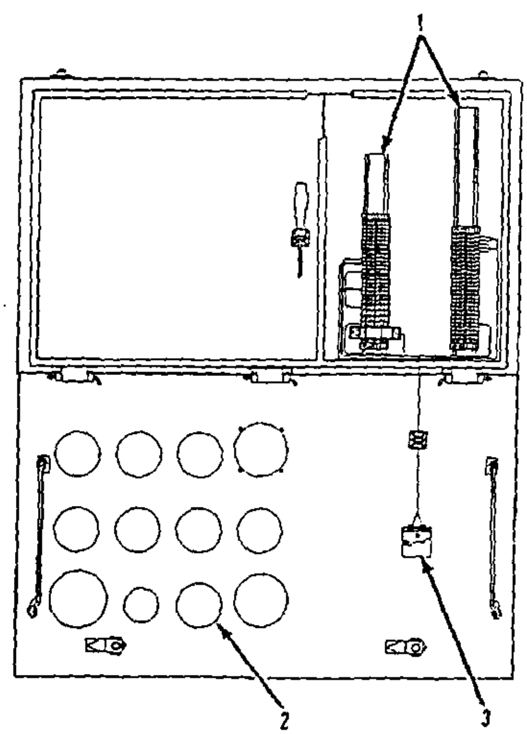
When the engine starts running, the flywheel will start to turn faster than the starting motor pinion. The pinion retracts under this condition. This prevents damage to the motor, pinion or flywheel gear.

When the start control valve is released, the air pressure and flow to the piston behind the starting motor pinion is stopped, the piston spring retracts the pinion. The relay valve stops the flow of air to the air starting motor.

Engine Monitoring and Shutdown Protection

G3500 Engines can be configured to use one of three systems to monitor engine parameters and provide engine shutdown protection: Junction Box (Energize To Shutdown), Junction Box (Energize To Run), and/or a Control Panel (Status Control). For detailed information on the operation, troubleshooting and engine control panel set-up, refer to SENR6420, Systems Operation Testing & Adjusting, Remote Control Panel (Status) For G3500 Engines (EIS).

Junction Box



Fgure 57. Junction Box (Shown With Door Open)
(1) Terminal strips. (2) Gauges. (3) Emergency stop switch.

The junction box (1) (Figure 57)provides a central location to mount the various gauges, meters, indicators and switches available for use on the engine. It also contains space for the electrical terminal strips (2) that connect the sensors, pick-ups and relays to the gauges (3). The junction box is also used to provide shutoff protection for the engine.

An Emergency Stop Push Button (ESPB) may be located on the junction box panel. When this button (3) is pressed, the fuel is shut off and the engine ignition is turned off (the ground to the shutdown switch of the Electronic Ignition System control is opened).

To restart the engine, the ESPB must be turned until it pops out.

NOTICE

The Emergency Stop Push Button (ESPB) **is not to be used for normal engine shutdown.** To avoid possible engine damage, use the Engine Control Switch (ECS) for normal engine shutdown.

If the junction box is configured for an Energized To Run (ETR) or an Energized To Shutoff (ETS) application, a gas shutoff valve will be included in the engine installation. In an Energize To Run set up, the gas shutoff valve must remain energized to operate the engine. In the most common Energized To Shutoff system, the gas shutoff valve has a mechanical (manual) latch that must be set. If a fault is detected, the gas shutoff valve will be energized to unlatch the gas shutoff valve and start a two stage shutoff sequence.

The junction box is used to monitor engine oil pressure, coolant temperature, starting motor overspeed, and engine overspeed conditions.

Note: If the junction box monitors an overspeed condition, or if the Emergency Stop Push Button is activated, a relay will be energized and cut ignition to the engine.

Note: If the junction box monitors a loss of engine oil pressure, or detects a high coolant temperature, a relay will shut the fuel off to the engine.

Engine Start/Stop Panel

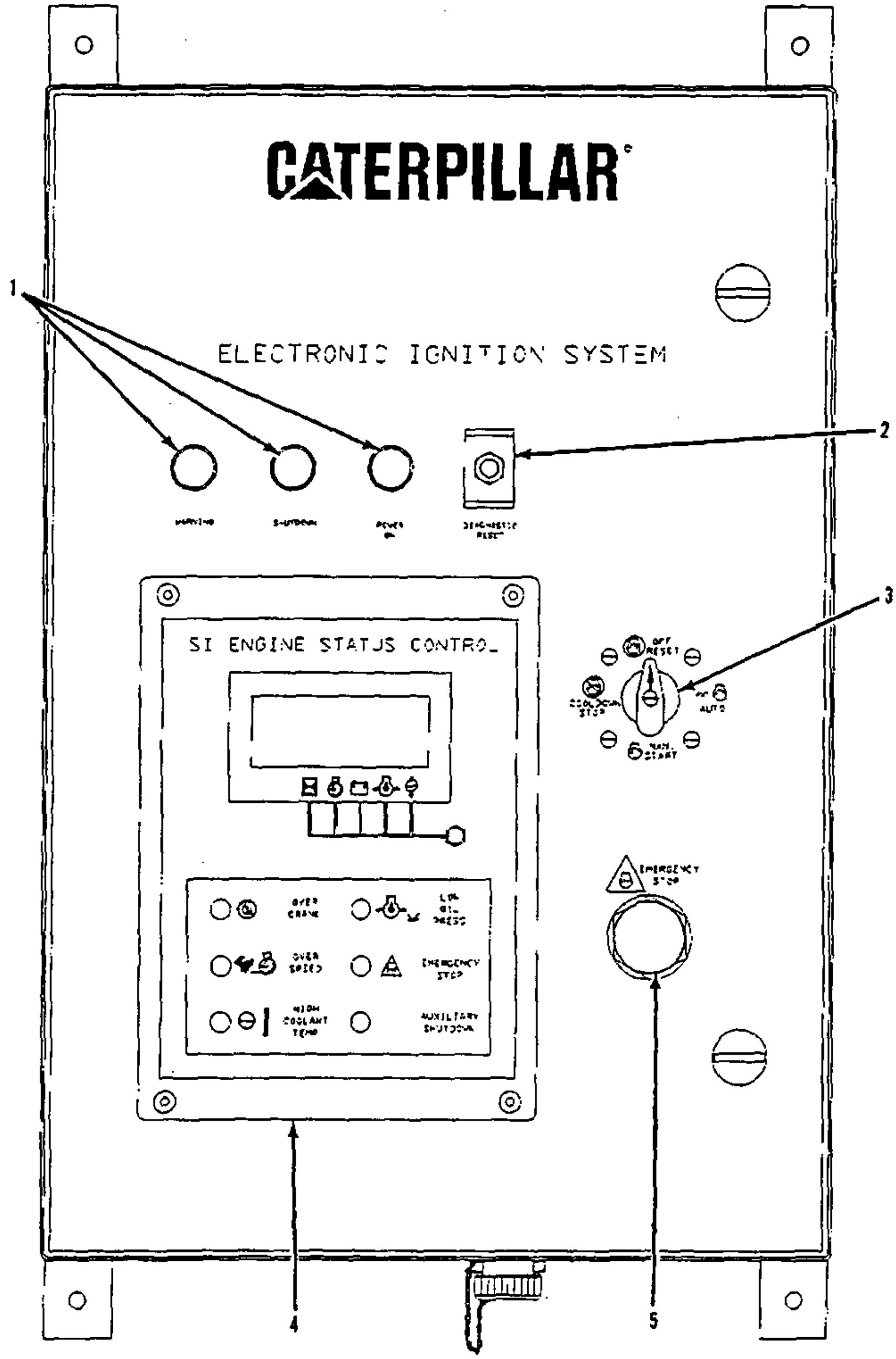


Figure 58. Engine Start/Stop Panel
(1) Indicator lights. (2) Diagnostic reset plug. (3) Engine Control Switch (ECS). (4) Status control module. (5) Emergency Stop Push Button (ESPB).

Engine Control Switch

The Engine Control Switch (ECS) (3) of the control panel has four positions - AUTO, MANUAL START, COOLDOWN/STOP, OFF/RESET. See Figure 58. If the ECS is in the AUTO position and a signal to run is received from a remote initiate contact (IC), or the ECS is placed in the MANUAL/START position, the engine will crank, terminate cranking and run. Engines equipped with electronic governors will run at low idle speed until lube oil pressure has exceeded the idle low oil pressure set point, then the relay contact of the governor control will close and the engine will accelerate to rated speed. Engines with hydra-mechanical governors will accelerate to their speed setting immediately after crank termination. The engine will run until the Engine Control Switch (ECS) is turned to COOLDOWN/STOP, OFF/RESET, or the remote initiate contact opens. Once the ECS is moved to the COOLDOWN/STOP position, or if in the AUTO position and the remote initiate contact opens, the engine will run at a lower speed for a short period of time, if the cool down feature was selected using the DDT. If the cool down feature was not programmed the engine will shut down immediately. The engine is then capable of immediate restart.

When the engine is to be shutdown, either manually (through the engine control switch) or automatically (through the engine protection system), a two stage shutdown sequence will occur. First, a relay will de-energize the gas shutoff valve, and will shut the fuel off to the engine. In the second step of the shutdown sequence the ground to the shutdown switch of the Electronic Ignition System control is opened.

Emergency Stop Push Button

An Emergency Stop Push Button (ESPB) (5) is located on the Engine Start/Stop Panel. A second Emergency Stop Push Button is located on the engine itself (junction box), when a remote start/stop panel is used. When this button is pressed, the fuel is shut off and the engine ignition is turned off (the ground to the shutdown switch of the Electronic Ignition System control is opened).

To restart the engine, the ESPB must be turned until it pops out.

NOTICE

The Emergency Stop Push Button (ESPB) **is not to be used for normal engine shutdown.** To avoid possible engine damage, use the Engine Control Switch (ECS) for normal engine shutdown.

Fuel Selector Switch

The Fuel Selector Switch (optional) is a two position switch which provides input to the Electronic Ignition System Control Module. Two selections can be made with the switch. One position is for use with propane fuel only. The other position is for any other fuel used. Use of the PROPANE position signals the EIS Control Module to increase the range of timing retard because of the heat value of propane gas.

Status Control Module

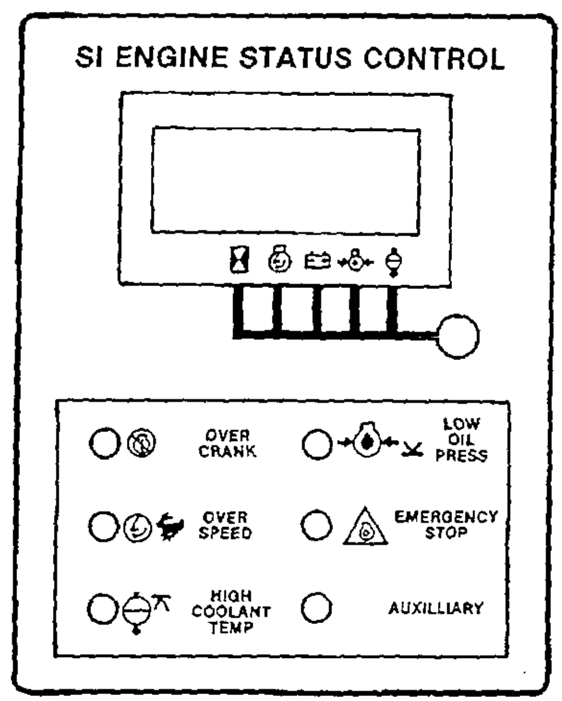
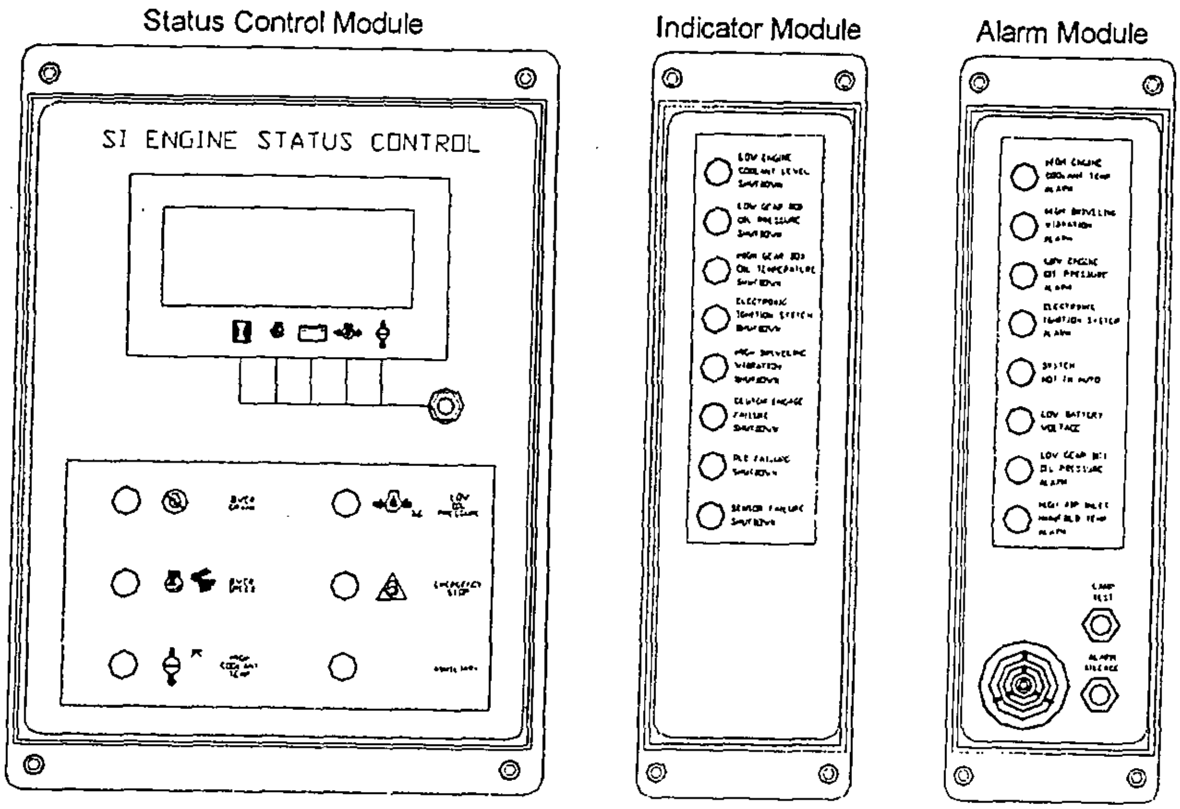


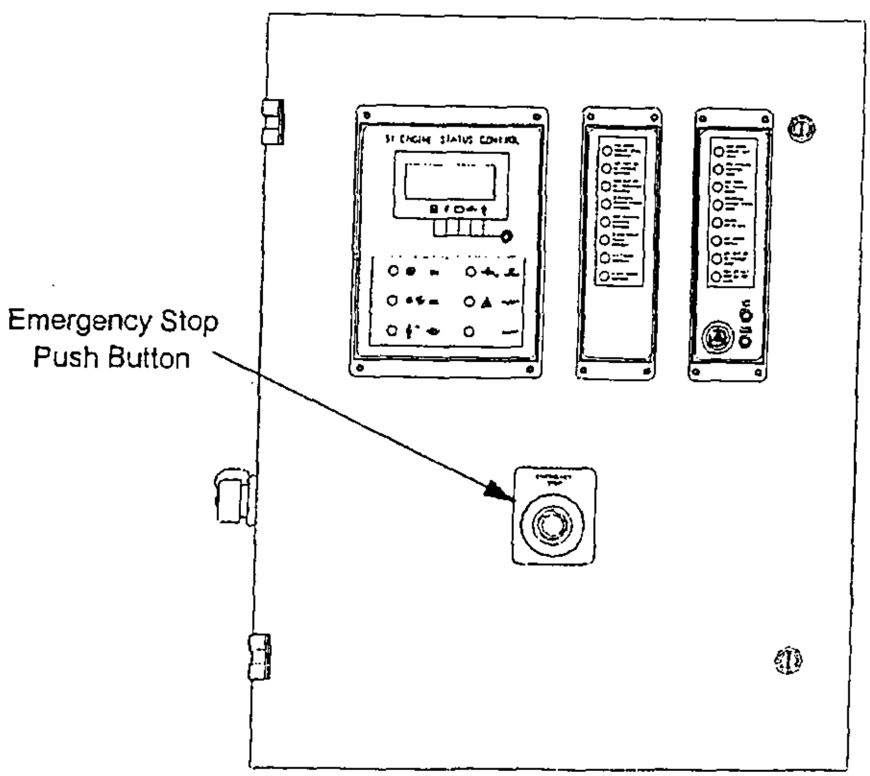
Figure 59. Status Control Module (SCM)

The Engine Status Control Module (SCM) (Figure 59) is used to monitor engine parameters (oil pressure, coolant temperature, engine overspeed and over cranking of the starter motor). It also provides an engine protection system (two stage shutdown) and controls normal start/stop functions. When a fault signal is detected, the display is also used to indicate diagnostic codes, to aid in troubleshooting.

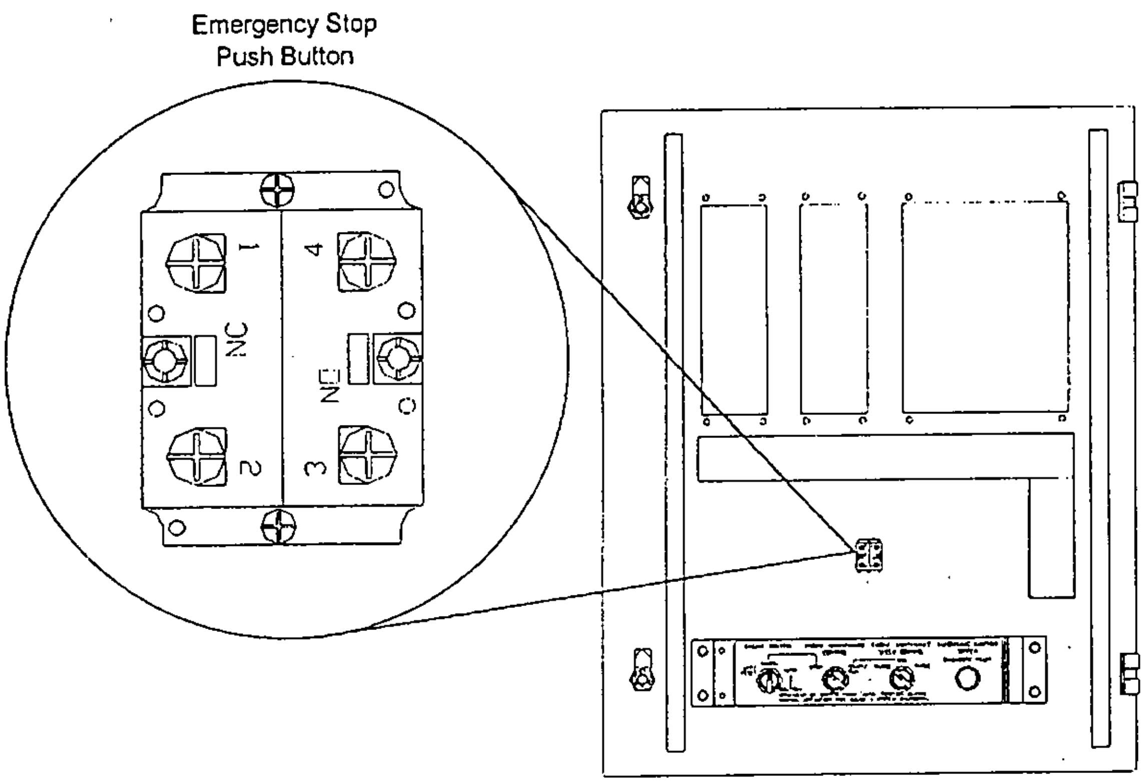
The Status Control Module contains a relay, terminal strips and overspeed verify.

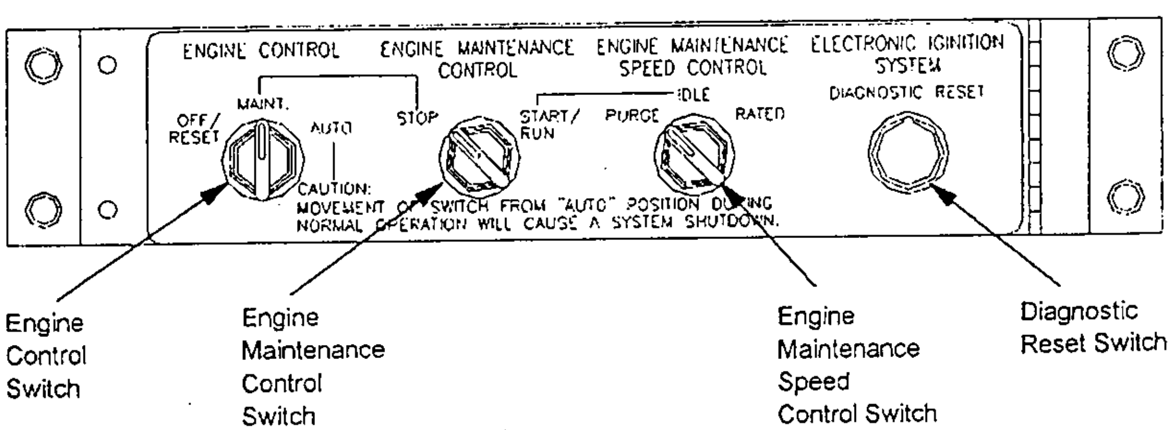
DC Control Panel for Gas Engine Chiller





DC Control Panel for Gas Engine Chiller (Inside View)





Abbreviations and Symbols

ALT	ALTERNATOR
ASSV	AIR START SOLENOID VALVE
AWG	AMERICAN WIRE GAUGE
BATT	BATTERY
C	COMMON
CAS	CRANK ANGLE SENSOR
CB	CIRCUIT BREAKER
CSPS	CUSTOMER SHUTDOWN POWER SUPPLY
CTR	CRANK TERMINATION RELAY
D	DIODE
DDTC	DIGITAL DIAGNOSTIC TOOL CONNECTOR
ECM	ENGINE CONTROL MODULE
ECS	ENGINE CONTROL SWITCH
ESPB	EMERGENCY STOP PUSH BUTTON
EXTP	COOLANT TEMPERATURE PROBE
F	FUSE
FCR	FUEL CONTROL RELAY
GSOV	GAS SHUTOFF VALVE
LHDS	LEFT HAND DETONATION SENSOR
MAN	MANUAL
MGR	MAGNETIC GROUNDING RELAY
PS	PINION SOLENOID
RHDS	RIGHT HAND DETONATION SENSOR
SCM	ENGINE STATUS CONTROL MODULE
SEC	SECOND
SIG	SIGNAL
SM	STARTING MOTOR
SMMS	STARTING MOTOR MAGNETIC SWITCH
SMR	STARTING MOTOR RELAY
XDUCER	TRANSDUCER

CONTROL PANEL TERMINAL POINT
STANDARD WIRING
OPTIONAL WIRING
CUSTOMER WIRING
PLUG IN CONNECTOR
SHIELDED WIRE
ENGINE MOUNTED COMPONENT
RELAY CONTACT (NORMALLY OPEN)
RELAY CONTACT (NORMALLY OPEN)
RELAY CONTACT (NORMALLY CLOSED)
RELAY CONTACT (NORMALLY CLOSED)
CHASSIS GROUND
EARTH GROUND
OPERATED BY TURNING
AUTOMATIC START-STOP MODE
SYSTEM NOT IN AUTOMATIC START-STOP MODE
CRANK
LOW OIL PRESSURE
OVERSPEED
EMERGENCY STOP
FAIL TO START (OVER CRANK)
HIGH COOLANT TEMPERATURE
ON
OFF
ENGINE-STOP
ENGINE RPM
LAMP/DISPLAY TEST
DIODE
DIODE
FUSE
FUSE
EMERGENCY SWITCH
RELAY COIL
RELAY COIL
CIRCUIT BREAKER
CIRCUIT BREAKER

CATERPILLAR®

G3500-G3300 Ignition Systems

Variable Timing for Dual Fuel

Ignition Systems in Hazardous Locations

Engine Shutdown

Power for Auxiliary Panels

Spark Plugs

Materials and specifications are
subject to change without notice.

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Ignition Systems

Caterpillar Gas Engines use a low tension ignition system. Individual ignition transformers are mounted near the spark plug for each cylinder. Each engine is equipped with a solid-state magneto or an Electronic Ignition System (EIS) to provide a flexible ignition system requiring less maintenance and more reliability than older breaker-point magnetos.

Figure 1 is a diagram showing the major components of the Caterpillar Electronic Ignition System (EIS). The EIS system monitors engine operation and distributes power to the cylinder transformers, to provide the best engine performance at all engine speeds. It provides detonation protection and precision spark control for each cylinder.

Gas Engines with EIS incorporate a control system that senses and reacts to combustion detonation by controlling ignition timing. An accelerometer and electronic buffer unit is mounted on each side of the cylinder block, and is used to sense the detonation level (if any). When a level of detonation is reached that might damage the engine, the electronic timing control retards the ignition timing six degrees. If the engine continues to detonate, the control will provide a signal to shut the engine down. If the retarded timing successfully stops the detonation, the timing control will begin advancing the timing at a rate of 1 degree per minute up to the original timing. The timing control will stop advancing if detonation begins again. This allows the engine to obtain optimum fuel consumption by running close to detonation without damaging the engine.

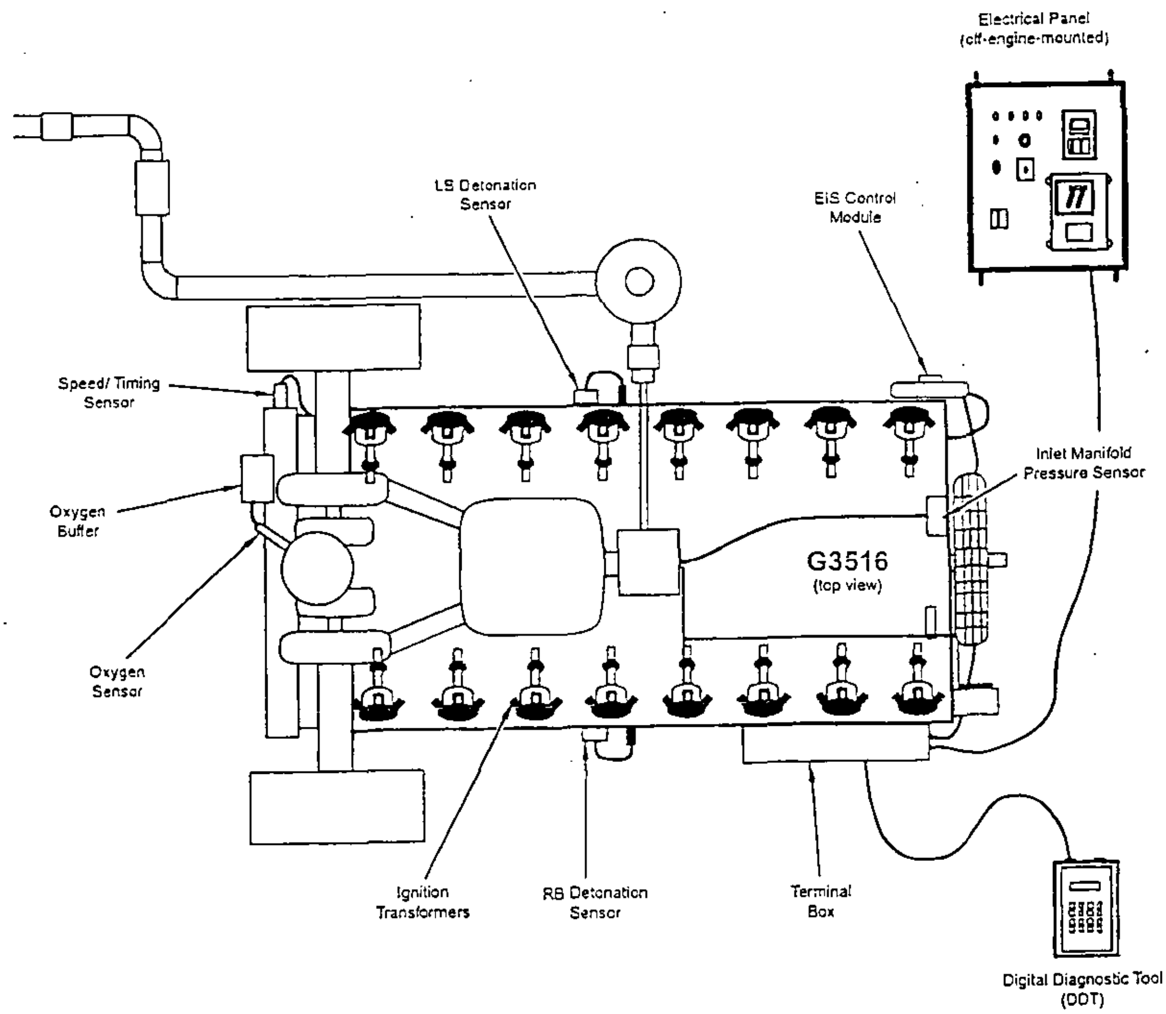

Figure 1.

The EIS control module sets engine timing according to desired engine timing, customer specified parameters, and the conditions in which the engine operates. Timing is automatically adjusted according to speed/timing maps, manifold air pressure, and any detonation. The control module also creates diagnostic codes if a problem develops in a component or harness.

EIS ignition transformers are located under the cylinder valve cover. The EIS control module sends a pulse to the primary coil of the ignition transformer to initiate combustion in each cylinder. The transformer steps up the voltage to create an arc across the spark plug gap. The cylinder valve cover acts as the ground for the ignition transformer.

Engine sensors provide information to the EIS control module. Detonation sensors are located on each side of the engine and continually monitor the engine for combustion detonation. A speed/timing sensor provides accurate spark timing and engine speed information. A special speed/timing ring is located on the rear, left camshaft on G3500 engines or on the front of G3400 camshafts. An intake manifold air pressure sensor provides engine load information.

The timing is set by connecting the Caterpillar Digital Diagnostic Tool (DDT) to the engine to electronically set the timing. The DDT is available through the price list. The DDT is also used to monitor engine speed, detonation level (if any), and diagnostic codes.

Variable Timing for Dual Fuel

The recommended timing varies with fuel composition. Serious engine damage could result if the timing is not changed when the fuel is switched for example, from natural gas to propane or digester to natural gas. To allow automatic timing adjustment when the fuel is changed, EIS offers a dual timing switch. A dual timing magneto is available as well.

The timing is automatically changed by an electrical signal, usually generated by falling pressure in the primary fuel. The customer must provide the external contacts to signal EIS or the magneto. See the "Fuel Systems" section of this guide for additional information.

Ignition Systems in Hazardous Locations

Engines installed in hazardous locations generally fall under the Class I Division 2 category of Article 500 of the National Electrical Code. It reads:

"A Class I, Division 2 location is a location:

1. in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of the ventilation equipment; or

2. in which ignitable concentrations of gases or vapors are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operation of the ventilation equipment; or

3. that is adjacent to a Class I, Division 1 location, and to which ignitible concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided."

Basic difference between Division 1 and Division 2 is:

- Division 1 – flammable gases are always present.
- Division 2 – flammable gases may be present.

When an engine is installed in such a location, shielding of the ignition system wiring or usage of approved ignition system components may be required. Many Caterpillar Gas Engines have attachments providing an ignition system that is CSA approved for Class I, Division 2,GpD, locations. CSA approval is a Canadian requirement for engines operating in hazardous locations in Canada. CSA approval is also recognized in Division 2 locations outside Canada. Consult factory for availability.

The basis for the CSA attachment design is to either prevent hazardous atmosphere from coming in contact with arcing or sparking devices or to contain an explosion, within the engine itself. This is accomplished on Caterpillar Gas Engines by special metal conduit harness assemblies for the ignition system and engine wiring harnesses. Special explosion-proof transformers and cylinder head components have been developed to contain any potential explosion in the head.

The Caterpillar EIS system is available in a CSA approved configuration. This system varies from the standard EIS system by offering special ignition coils and a terminal box located on top of the EIS control module.

With the CSA system, no shutoffs, monitoring systems, start/stop logic or gas shutoff valves are provided. The functions must be provided by the customer. The required shutoffs are jacket water temperature (104°C, 220°F), oil pressure (15 psig at low idle, 40 psig above 1000 rpm), and overspeed (lesser of 10% above maximum engine speed or maximum driven equipment speed).

The CSA terminal box contains warning, shutdown, and power lamps and a diagnostic reset switch. All of these may be remote mounted by the customer.

For magneto systems with the CSA attachment, troubleshooting can be more difficult. A standard transformer can be installed temporarily so that a timing light can be triggered from the exposed high tension lead. Detecting a misfiring cylinder is more of a problem with a shielded system. Installation of normally closed switches in the primary wiring is one method of temporarily interrupting ignition to identify a misfiring cylinder. *If devices are incorporated in the shielded system for troubleshooting purposes, the primary of the magneto must never be grounded to interrupt the ignition.* This would most likely cause failure of solid-state components within the magneto.

Engine Shutdown

Accomplish normal shutdown by shutting off the fuel supply. This allows the engine to consume the fuel trapped between the shutoff valve and cylinder. It also prevents raw fuel from being pumped into the exhaust system. Raw fuel in a hot exhaust system presents the potential for explosion. Stopping the ignition system to cause engine shutdown should be utilized only for emergencies.

Power for Auxiliary Panels

Applications not having a 24 VCD electrical power source, such as gas compressors at remote sights, must find some source of electricity to power auxiliary panels. The power source has often been magneto.

Unlike most other engines, no pin is provided on the G3500 LE magneto for auxiliary power. This engine requires all the magneto power available in order to operate the ignition system. The electronic nature of its control system requires that a 24 VDC power source be available for engine operation. The power source provided for the engine's control system can also be used to operate auxiliary panels.

Stoichiometric engines have a pin available on the magneto that can be used to provide power for auxiliary panels. This pin provides 180 VDC with a maximum current draw of 20mA. As with the low emission engine, spark plug life will be decreased if the magneto is used to power auxiliary panels.

For all engines with Caterpillar EIS, a 24 VDC power source is necessary.

Spark Plugs

Spark plugs for Caterpillar Gas Engines have been specifically developed to meet the ignition needs of a given engine. Failure to use proper spark plugs, or failure to properly maintain the park plugs will affect the engine's fuel consumption, emissions, and stability. This is why the spark plugs must be maintained according to the specified maintenance schedule. Good maintenance practices can be found in Systems Operation Testing and Adjusting Manual for your engine.

Note: The maximum ambient air temperature for magneto operation is 85°C (185°F).

Attachment 8

Proposed Replacement
Engine Driven Pump No. 5

G3608LE Technical Data

G3608LE Emissions
G3608LE Performance Data
G3600 Product Description and Specifications
G3600 Technical Data
G3600 Engine Basics
G3600 Ignition Systems

Alexander Orr, Jr.
Water Treatment Plant

CATERPILLAR

Caterpillar Inc.
Lafayette Engine Center
Lafayette, Indiana 47905

June 15, 2000

Gas Engine Emissions Letter

Project:	MDWASD Alexander WTP		
Model:	G3608 LE	Rating (note below):	2225 bhp @ 1000 rpm
Compression Ratio:	9.1	BSFC (Btu/bhp-hr):	6810 +/- 3.0%
A/C Inlet Temp. (°F):	130	J/W Outlet Temp. (°F):	190
Fuel LHV (Btu/ft3):	963	Altitude (ft):	sea level
Fuel MN:	72.7	Ambient (°F):	110

	NOx (as NO2)	CO	THC	NMHC	NMNEHC
g/bhp-hr	0.70	2.50	6.00	1.06	0.51
tons/year	15.0	53.7	128.9	22.8	11.0

Exhaust Mass Flow (lbs/hr, wet): 25,548

Exhaust Volume Flow (cfm, wet): 14,816
@ 842°F stack temp, 14.5 psia

Emission levels are based on engine operation at steady state conditions adjusted to the specified NOx level. The CO, THC, NMHC, and NMNEHC values listed are higher than nominal levels to allow for instrumentation, measurement, and engine-to-engine variations. They indicate "not to exceed" values. Tons per year values are based on 8,760 hours of operation per year.

This information is valid for engine orders placed within six (6) months of the above date. Please contact the factory after six months if an extension is required.

Sincerely,

Jeffery A. Elijah
G3600 Applications
Lafayette Engine Center

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G3608 SITA 9:1 Industrial Performance

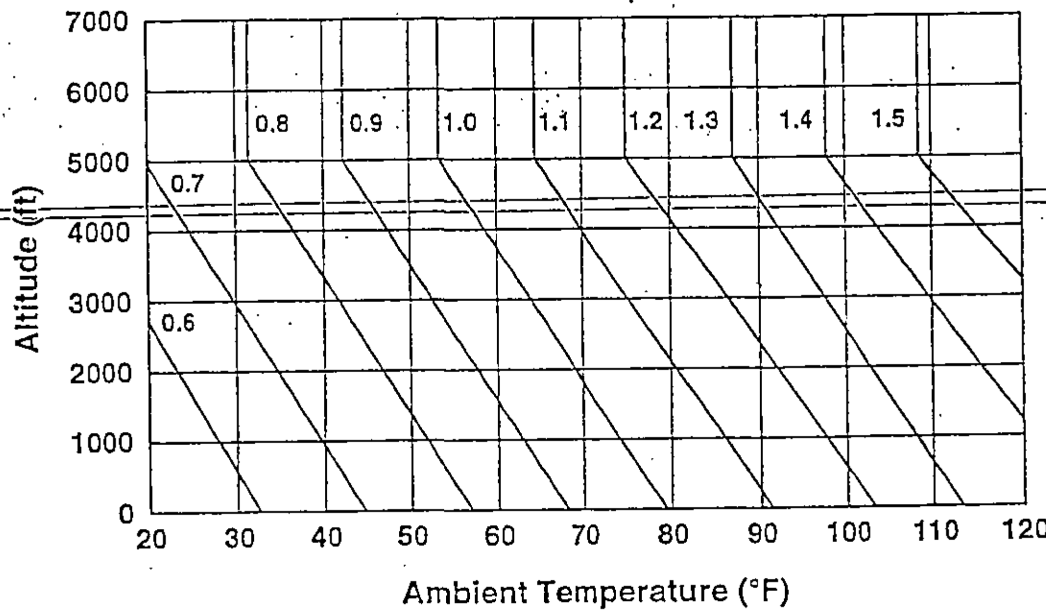
		100%	75%	50%	25%
Aspiration		TA	TA	TA	TA
Speed	rpm	1000	1000	1000	1000
JW Outlet Temperature (°F)		190	190	190	190
A/C Inlet Temperature (°F)		130	130	130	130
Engine Power	bhp[1]	2225	1669	1113	556
NOx (as NO_2)	g/bhp-hr[2]	0.70	0.70	0.70	1.20
CO	g/bhp-hr[2]	1.90	1.90	1.90	2.20
HC (Total)	g/bhp-hr[2]	5.95	6.30	6.50	6.00
HC (Non-Methane)	g/bhp-hr[2]	0.89	0.95	0.98	0.90
Exhaust Oxygen	% (dry)	12.3	11.7	10.7	10.2
BSFC	Btu/hp-hr	6810	7035	7550	9620
Compressor Out Pressure	in Hg abs	70.4	54.2	38.6	32.0
Compressor Out Temp (°F)		290	238	154	132
Intake Manifold Pressure	in Hg abs	69.7	53.8	38.3	23.9
Intake Manifold Temp (°F)		148	143	140	136
Air-Fuel Ratio	vol/vol	20.09	19.93	18.57	17.40
Timing	°BTDC	20.2	20.2	19	16.2
Fuel Energy	Btu/min[3]	252538	195661	139990	89185
Exhaust (LHV)	Btu/min[4]	97042	76771	56282	34002
Exhaust (to 350°F)	Btu/min[4]	58201	46698	34427	22433
Aftercooler	Btu/min[5]	16141	8285	1113	63
Radiation - Engine only	Btu/min[6]	11177	10468	9659	8740
Oil Cooler	Btu/min[7]	10325	10025	9750	9450
Jacket Water	Btu/min[4]	23467	19324	15993	13334
Air Flow	lb/hr	25760	19794	13195	7876
Air Flow (scfm @ 77°F, 13.9 psia)		6136	4715	3143	1876
Exhaust Flow	lb/hr	26537	20396	13626	8150
Exh Flow (cfm @ stack T, 14.5 psia)		14867	11610	8048	4978
Exhaust Stack Temp (°F)		847	868	918	965
Fuel Flow (scfh 4 @ 60°F, 14.7 psia)		16743	12972	9281	5913

1) Continuous output and reference conditions according to ISO 3046/1 (77°F, 14.5 psia),
Natural gas LHV = 905 Btu/sft³.
(Engine power conversion: 1 bhp = 42.42 Btu/min)
2) Emissions data shown are not to exceed values.
3) Tolerance +/-2.5%
4) Tolerance +/- 10%, jacket water heat rejection based on treated water as coolant
5) Tolerance +/- 5%, heat rejection based on treated water as coolant
6) Tolerance +/- 25%
7) Tolerance +/- 20%, heat rejection based on treated water as coolant

Aftercooler Heat Rejection Factors

G3608 Industrial – 90°F SCAC

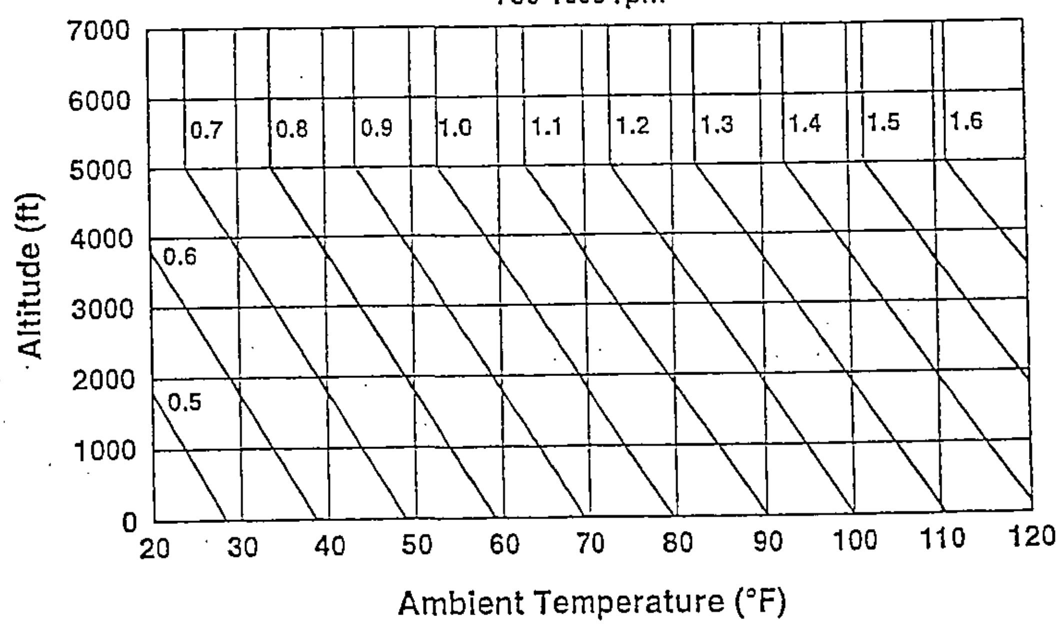
730-1000 rpm



Aftercooler Heat Rejection Factors

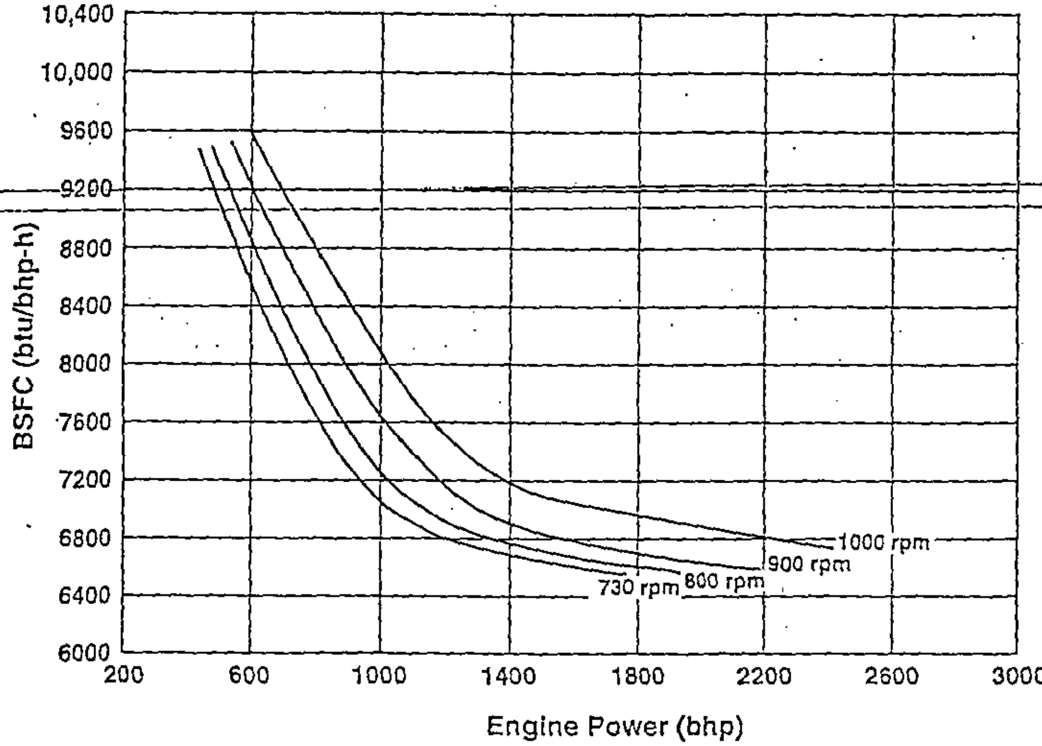
G3608 Industrial – 130°F SCAC

730-1000 rpm



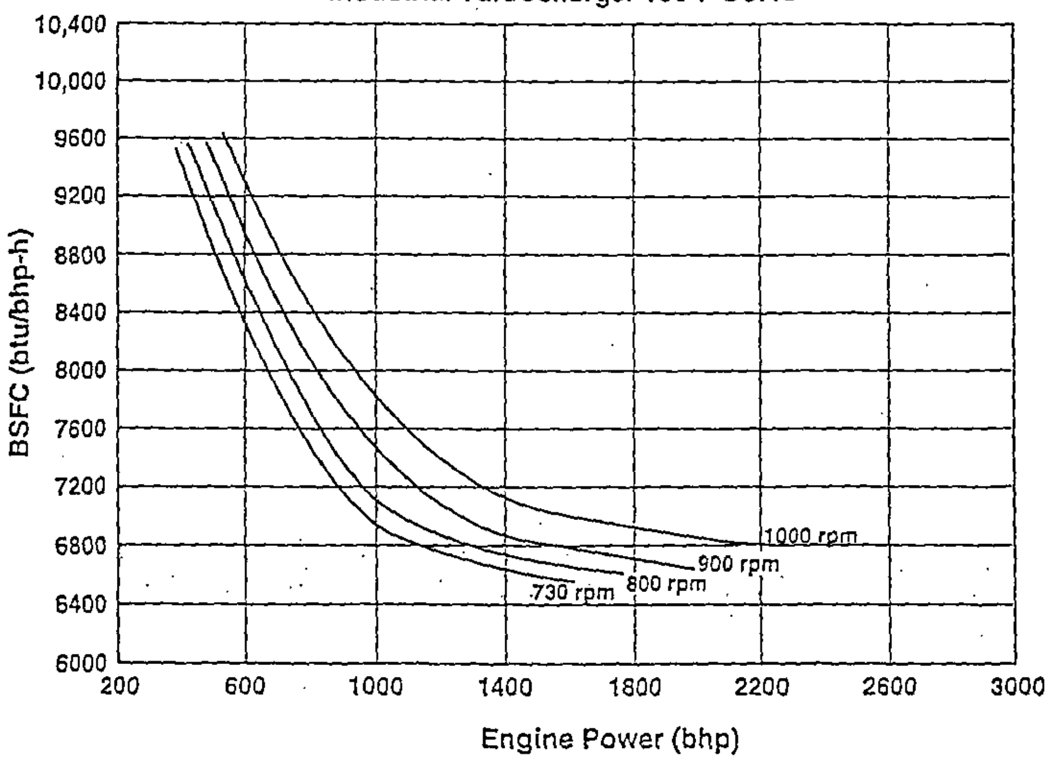
G3608 BSFC

Industrial Turbocharger 90°F SCAC



G3608 BSFC

Industrial Turbocharger 130°F SCAC



CATERPILLAR®

Gas Engine Industrial Low Emission

G3608

1555-2350 HP

FEATURES

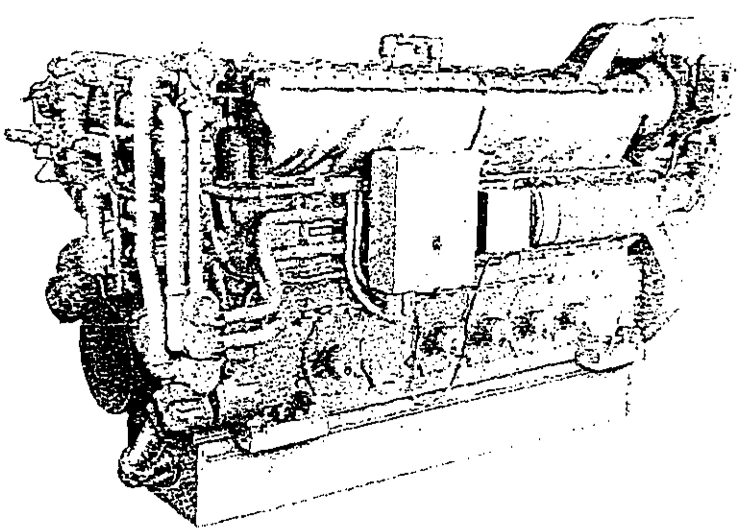
• CATERPILLAR® QUALITY THROUGHOUT
Cat gas engines incorporate many of the same proven components as their diesel counterparts – including the block, crankshaft, main bearings, camshaft and connecting rods. However, by operating at 40 to 50% lower cylinder pressure and bearing loads than diesels, they offer the extra benefit of prolonged life.
Caterpillar gas engines inherit more from their diesel counterparts than just strength. They are backed by the same support system recognized as one of the most sophisticated and dependable in the world.

• APPLICATION FLEXIBILITY
Broad operating speed range and the ability to burn a wide spectrum of fuels.

• LOW EMISSIONS
1gram/hp hr NOx level at 1000 RPM.

• SUPERIOR TECHNOLOGY
Represent the latest technology in engine design. The engine is offered in a low emission turbocharged and aftercooled configuration only. This configuration offers:
– High energy ignition systems for consistent firing
– Highly efficient enriched prechamber design for complete combustion
– Modern component design such as deep cup, oil gallery piston
– Electronic controls to optimize performance.

• RESULT
Low emissions and BSFC under all operating conditions.



Arrangement may be shown with optional equipment

STANDARD PACKAGE ARRANGEMENT

GENERAL
Flywheel and Ring Gear
Crankcase Explosion Doors
High Efficiency Turbos
Aftercooler
Engine Barring Device
Torsional Vibration Damper
Industrial Engine Supports
Protective Guards

COOLING SYSTEM
Jacket Water Pump
Water Regulators, 189° F
Separate Circuit Gear Driven Pump For Aftercooler/Oil Cooler Circuit

IGNITION SYSTEM
Altronic III Ignition with Variable Timing

CONTROLS
Electronic Supervisory System:
- Governing
- Air/Fuel Ratio Control
- Timing Optimization

Instrument Panel to Monitor:
- Oil Pressure and *Temperature*
- Oil Pressure Differential
- Intake Manifold Pressure
- Intake Manifold Temperature
- Crankcase Pressure
- Water Temperatures
- Exhaust Temperatures
- Service Meter Hours
- Engine Speed

FUEL SYSTEM
Fuel Filter
Shipped Loose Gas Pressure Regulator

PROTECTION
Misfire Sensing
Detonation Sensing and Compensation
Energized to Run Shutdowns for:
- Engine Overspeed
- Oil Pressure
- Water Pressure
- Crankcase Pressure

LUBE OIL SYSTEM
Gear Driven Lube Oil Pump
Engine Mounted Lube Oil Filters
Engine Mounted Lube Oil Cooler
Prelube/Postlube System
Sump Pump Connections

AIR INTAKE SYSTEM
Shipped Loose Air Cleaners
Installed Turbo Air Inlet Adapters

ATTACHMENTS
Custom Industrial Base
Expansion Tank

G3608 INDUSTRIAL GAS ENGINE GENERAL SPECIFICATIONS

Continuous Ratings (BHP)

	1000 rpm	900 rpm	800 rpm	700 rpm
LE TA-90	2350	2120	1880	1645
LE TA-130	2225	2000	1775	1555

Physical Factors

	Height	Width	Length	Weight
LE TA	129.2 in	64.7 in	213.5 in	48,800 lbs

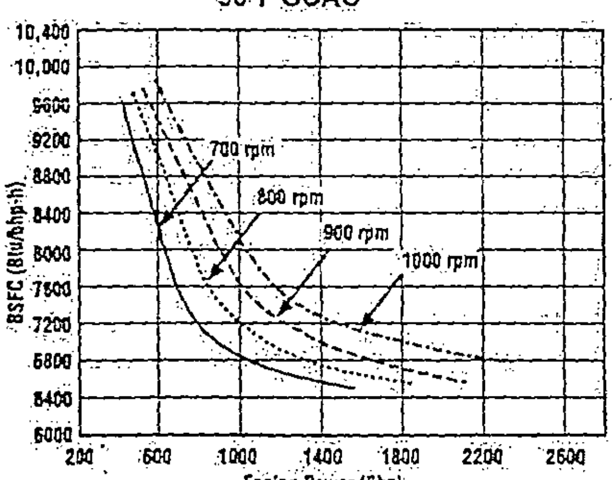
General Specifications

CAT 3608 ENGINE

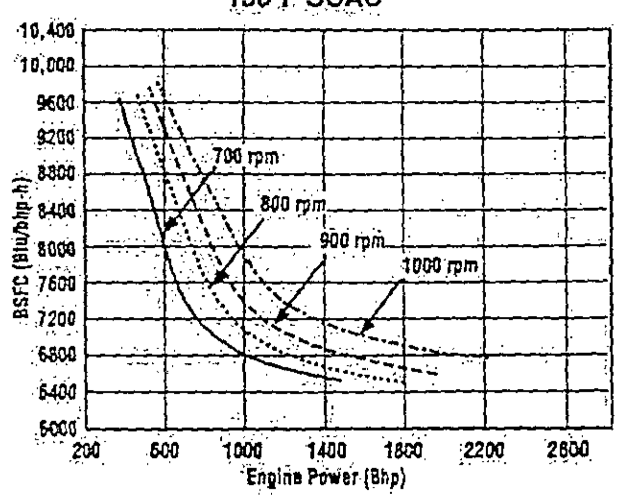
Type — Spark Ignited
Displacement — 10,350 cu in
Compression Ratio — 9.2:1
Lube oil capacity — 341 gal
Jacket water system — 140 gal

No. of Cylinders — 8
Bore — 300 mm
Stroke — 300 mm

90°F SCAC

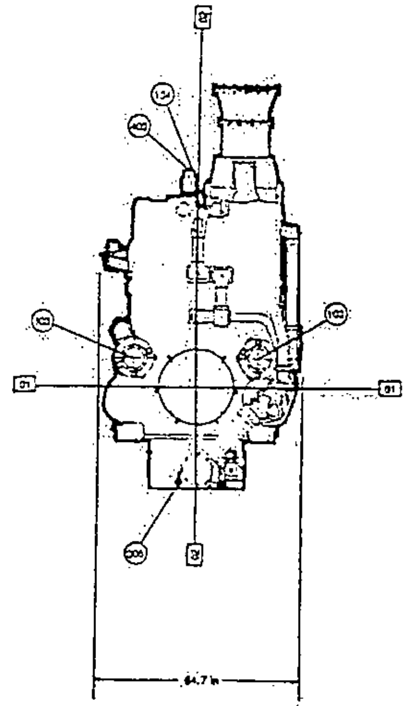


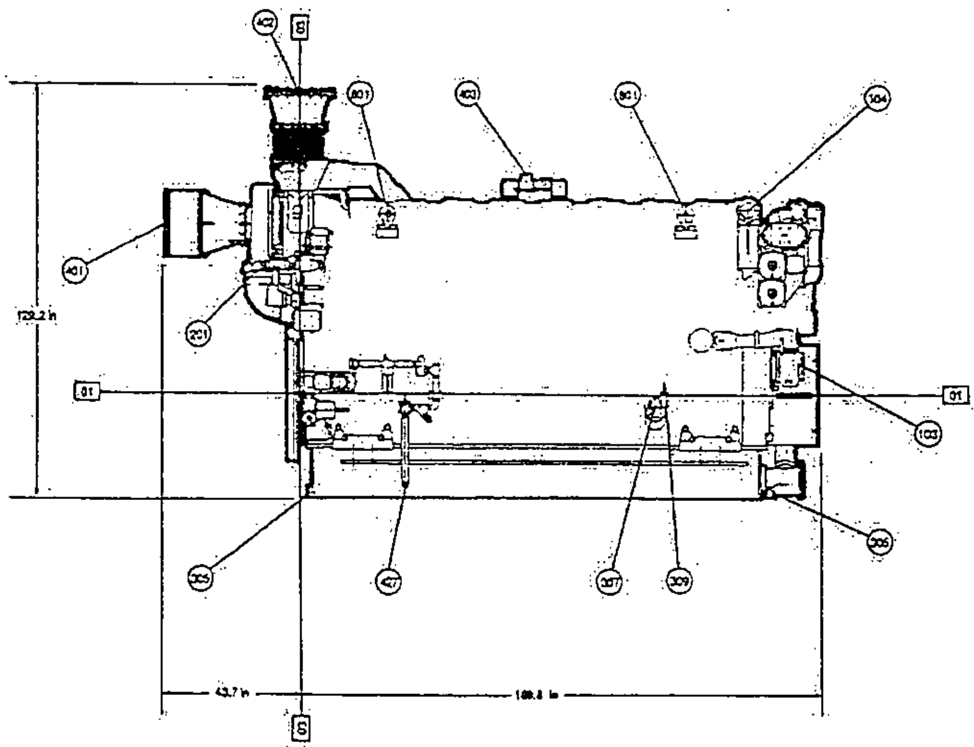
130°F SCAC



G3608 INDUSTRIAL GAS ENGINE CONFIGURATION

- 01 - CENTERLINE OF CRANKSHAFT
- 02 - CENTERLINE OF ENGINE
- 03 - REAR FACE OF CYL BLOCK
- 103 WATER INLET
- 104 WATER OUTLET
- 201 FUEL INLET
- 305 OIL DRAIN
- 307 OIL FILLER
- 309 OIL LEVEL GAUGE
- 401 AIR INLET
- 402 EXHAUST
- 403 BREATHER OUTLET
- 427 AIR STARTING MOTOR INLET
- 801 LIFTING EYE





Note: General Configuration not to be used for installation.

CONDITIONS & DEFINITIONS

Ratings are based on SAE J1349 standard conditions of 100 kPa (29.61 in)Hg and 25°C (77°F); ISO 3046, DIN 6271, BS 5514 standard conditions of 100 kPa (29.61 in)Hg, 27°C (81°F); and API 7B-11C standard conditions of 99 kPa (29.38 in)Hg, 29°C (85°F) also apply.

Ratings are based on dry natural gas having a low heat value of 35.22 MJ/m³ (905 btu/ft³). Variations in altitude, temperature and gas composition from standard conditions may require a reduction in engine horsepower.

Turbocharged-aftercooled ratings apply to 1525 m (5,000 ft) and 25°C (77°F). For applications which exceed these limits contact your Caterpillar Dealer.

Materials and specifications are subject to change without notice.
The International System of Units (SI) is used in this publication.

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G3600 Engine Basics

Engine Design Specifications

G3606

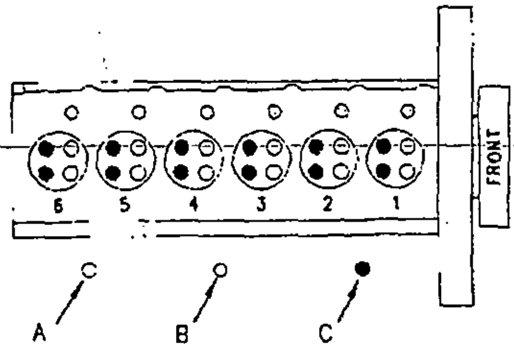

Illustration 1
G3606 Engine Design
(A) Inlet. (B) Gas admission. (C) Exhaust.

Number and arrangement of cylinders ....In-line 6

Valves per cylinder

- Inlet valves 2
- Exhaust valves 2
- Gas inlet valve 1

Displacement ....127.2 L (7762 cu in.)

Bore ....300 mm (11.8 in.)

Stroke ....300 mm (11.8 in.)

Compression ratio 9.2:1

Combustion ....Spark Ignited

Firing order

- Standard rotation CCW 1-5-3-6-2-4

Valve lash

- Inlet ....0.50 mm (.020 in.)
- Exhaust ....1.27 mm (.050 in.)
- Gas admission ....0.64 mm (.025 in.)

When the crankshaft is viewed from the flywheel end the crankshaft rotates in the following direction . ...Counterclockwise

Note: The front end of the engine is opposite the flywheel end of the engine. The left and the right side of the engine are determined from the flywheel end. The number 1 cylinder is the front cylinder.

G3608

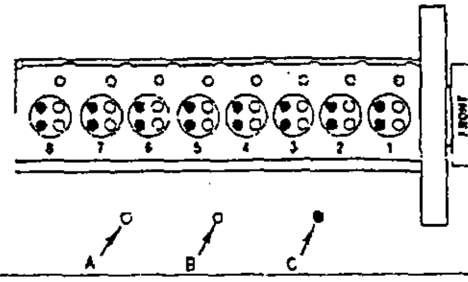

Illustration 2
G3608 Engine Design
(A) Inlet. (B) Gas admission. (C) Exhaust.

Number and arrangement of cylinders ....In-line 8

Valves per cylinder

- Inlet valves 2
- Exhaust valves 2
- Gas admission valve 1

Displacement ....170 L (10,352 cu in.)

Bore ....300 mm (11.8 in.)

Stroke ....300 mm (11.8 in.)

Compression ratio 9.2:1

Combustion ....Spark Ignited

Firing order

- Standard rotation CCW 1-6-2-5-8-3-7-4

Valve lash

- Inlet ....0.50 mm (.020 in.)
- Exhaust ....1.27 mm (.050 in.)
- Gas admission ....0.64 mm (.025 in.)

When the crankshaft is viewed from the flywheel end the crankshaft rotates in the following direction . ...Counterclockwise

Note: The front end of the engine is opposite the flywheel end of the engine. The left and the right side of the engine are determined from the flywheel end. The number 1 cylinder is the front cylinder.

G3612

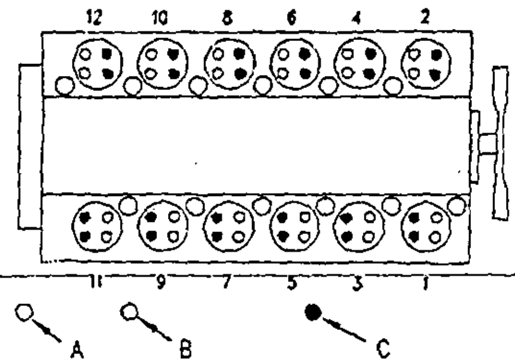

Illustration 3
G3612 Engine Design
(A) Inlet. (B) Gas admission. (C) Exhaust.

Number and arrangement of cylinders ....Vee 12

Valves per cylinder

Inlet valves 2
Exhaust valves 2
Gas admission valve 1

Displacement ....254.5 L (15,525 cu in.)

Bore ....300 mm (11.8 in.)

Stroke ....300 mm (11.8 in.)

Compression ratio 9.2:1

Compression ratio 10.5:1

Combustion ....Spark Ignited

Firing order

Standard rotation
CCW 1- 12-9-4-5-8-11-2-3-10-7-6

Valve lash

Inlet ....0.50 mm (.020 in.)
Exhaust ....1.27 mm (.050 in.)
Gas admission ....0.64 mm (.025 in.)

When the crankshaft is viewed from the flywheel end the crankshaft rotates in the following direction . ...Counterclockwise

Note: The front end of the engine is opposite the flywheel end of the engine. The left and the right side of the engine are determined from the flywheel end. The number 1 cylinder is the front cylinder.

G3616

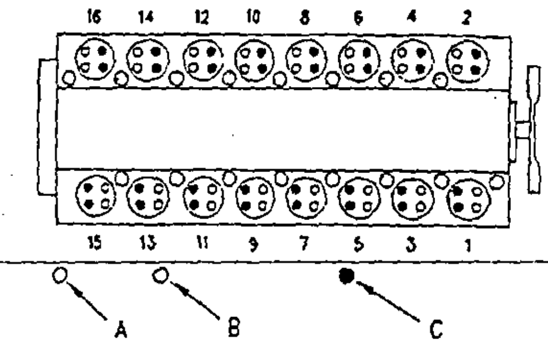

Illustration 4
G3616 Engine Design
(A) Inlet. (B) Gas admission. (C) Exhaust.

Number and arrangement of cylinders ....Vee 16

Valves per cylinder

Inlet valves 2
Exhaust valves 2
Gas admission valve 1

Displacement ....339.3 L (20,700 cu in.)

Bore ....300 mm (11.8 in.)

Stroke ....300 mm (11.8 in.)

Compression ratio 9.2:1

Compression ratio 10.5:1

Combustion ....Spark Ignited

Firing order

Standard rotation CCW
...... 1-2-5-6-3-4-9-10-15-16-11-12-13-14-7-8

Valve lash

Inlet ....0.50 mm (.020 inch)
Exhaust ....1.27 mm (.050 inch)
Gas admission ....0.64 mm (.025 inch)

When the crankshaft is viewed from the flywheel end the crankshaft rotates in the following direction . ...Counterclockwise

Note: The front end of the engine is opposite the flywheel end of the engine. The left and the right side of the engine are determined from the flywheel end. The number 1 cylinder is the front cylinder.

Engine Supervisory System

The Engine Supervisory System (ESS) is specifically designed for the Caterpillar G3600 Engines. The ESS integrates several control systems that are installed on the engine. With the ability to communicate with the various systems, the ESS optimizes each controlled parameter in order to ensure maximum engine performance.

The ESS communicates with the following systems:

- Start/Stop/Prelube Logic
- Engine Monitoring And Protection
- Governing
- Air/Fuel Ratio
- Ignition Control

The control panel for the ESS is the center of control for the systems. The control panel for the ESS contains the control modules of each system.

The Engine Supervisory System consists of the following components:

- Control Panel For The Engine Supervisory System (ESS)
- Engine Mounted Junction Box
- Engine Mounted Sensors And Actuators
- Relays, Solenoids And Switches
- Harness

The Engine Supervisory System (ESS) is divided into the following three interactive systems:

Start/Stop/Prelube System – This system controls the starting of the engine, the stopping of the engine, and the prelube pump.

Engine Monitoring And Protection System – This system provides a display of parameters of engine operation. The system generates warnings when one or more parameters are outside acceptable limits. The system can stop the engine if the engine operation reaches a setpoint that is programmed for shutdown. The system can prevent the engine from starting if certain parameters are outside of acceptable limits.

Engine Control System – This system governs the engine. This system controls the air/fuel ratio, the ignition timing, and the limiting of power.

Note: Some of the components within the ESS perform more than one function. For example, the Engine Control Module (ECM) is involved with starting the engine, stopping the engine, monitoring the engine, and controlling the engine.

Engine Mounted Sensors

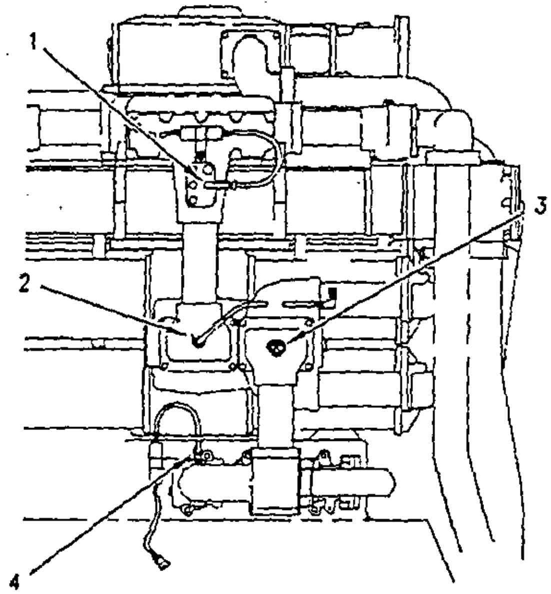

Illustration 5
Engine Mounted Sensors Front View
(1) CMS unfiltered engine oil pressure sensor. (2) SCM engine oil temperature sensor. (3) SCM filtered engine oil pressure sensor. (4) CMS filtered engine oil pressure sensor.

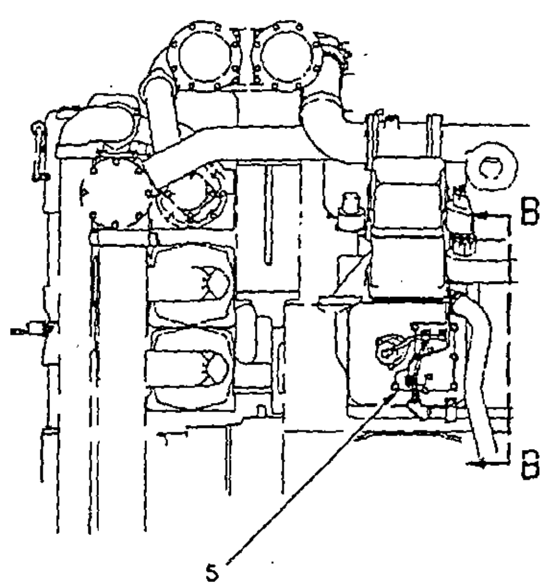

Illustration 6
Engine Mounted Sensors Left Side View
(5) Combustion buffer.

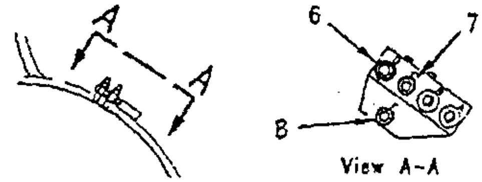

Illustration 7
Engine Mounted Sensors Rear View
(6) Timing control speed sensor. (7) Engine control speed sensor. (8) Timing control crank angle sensor.

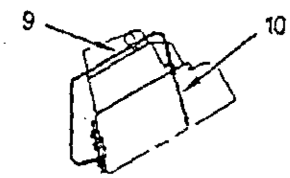

Illustration 8
Engine Mounted Sensors View B-B
(9) Combustion feedback cable. (10) Combustion feedback extension and probe.

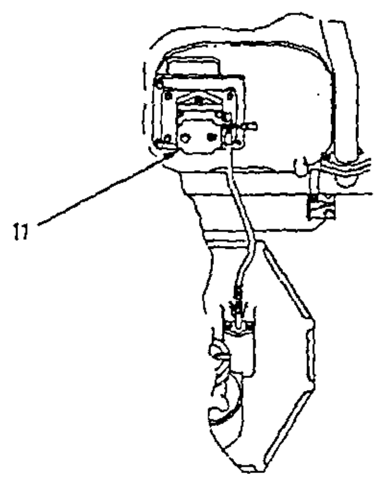

Illustration 9
Engine Mounted Sensors Right Side View
(11) Crankcase pressure sensor.

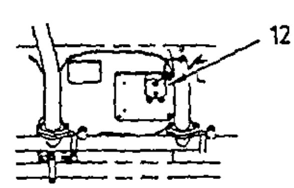

Illustration 10
Detonation Sensors
(12) Detonation sensors.

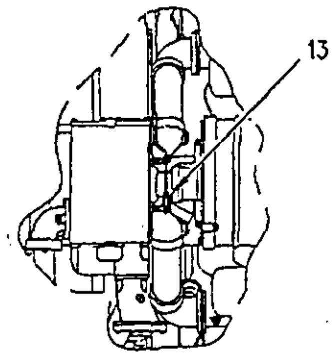

Illustration 11
Engine Mounted Sensors Top View
(13) Jacket water temperature sensor.

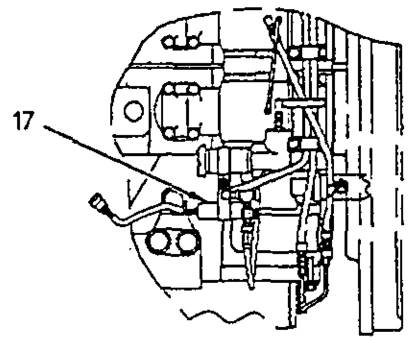

Illustration 14
Engine Mounted Sensors Left Side View
(17) Starting air pressure sensor.

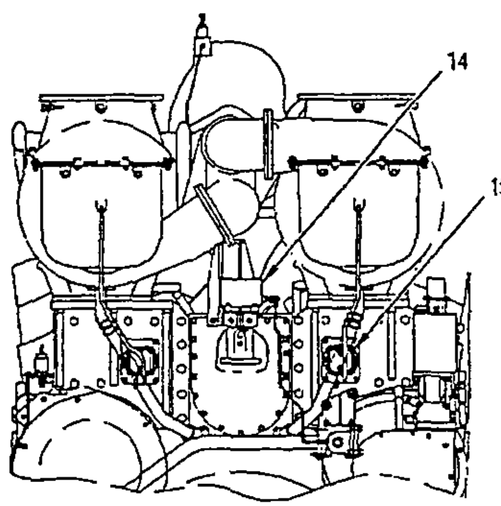

Illustration 12
Engine Mounted Sensors Rear View
(14) Fuel and air Pressure module. (15) Inlet air restriction.

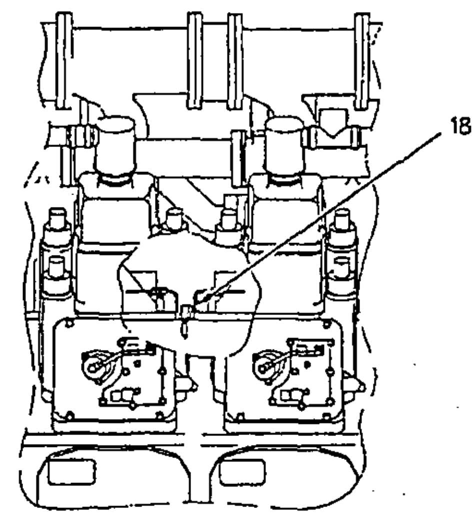

Illustration 15
Engine Mounted Sensors Right Side View
(18) Inlet air temperature sensor.

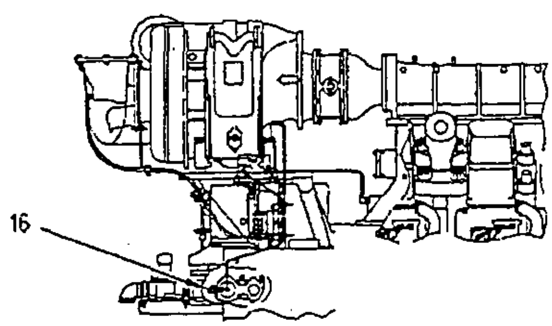

Illustration 13
Engine Mounted Sensors Right Side View
(16) Fuel temperature sensor.

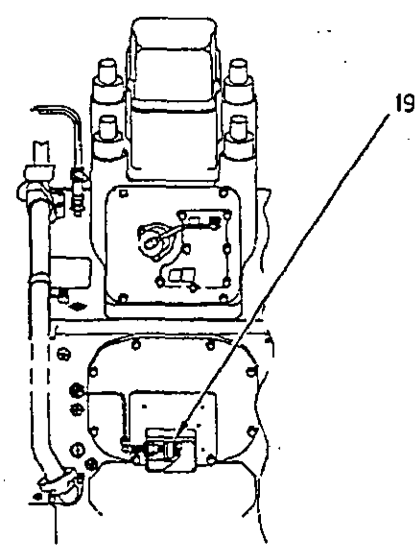

Illustration 16
Engine Mounted Sensors Right Side View
(19) Prelube pressure switch.

Control Panel For The Engine Supervisory System (ESS)

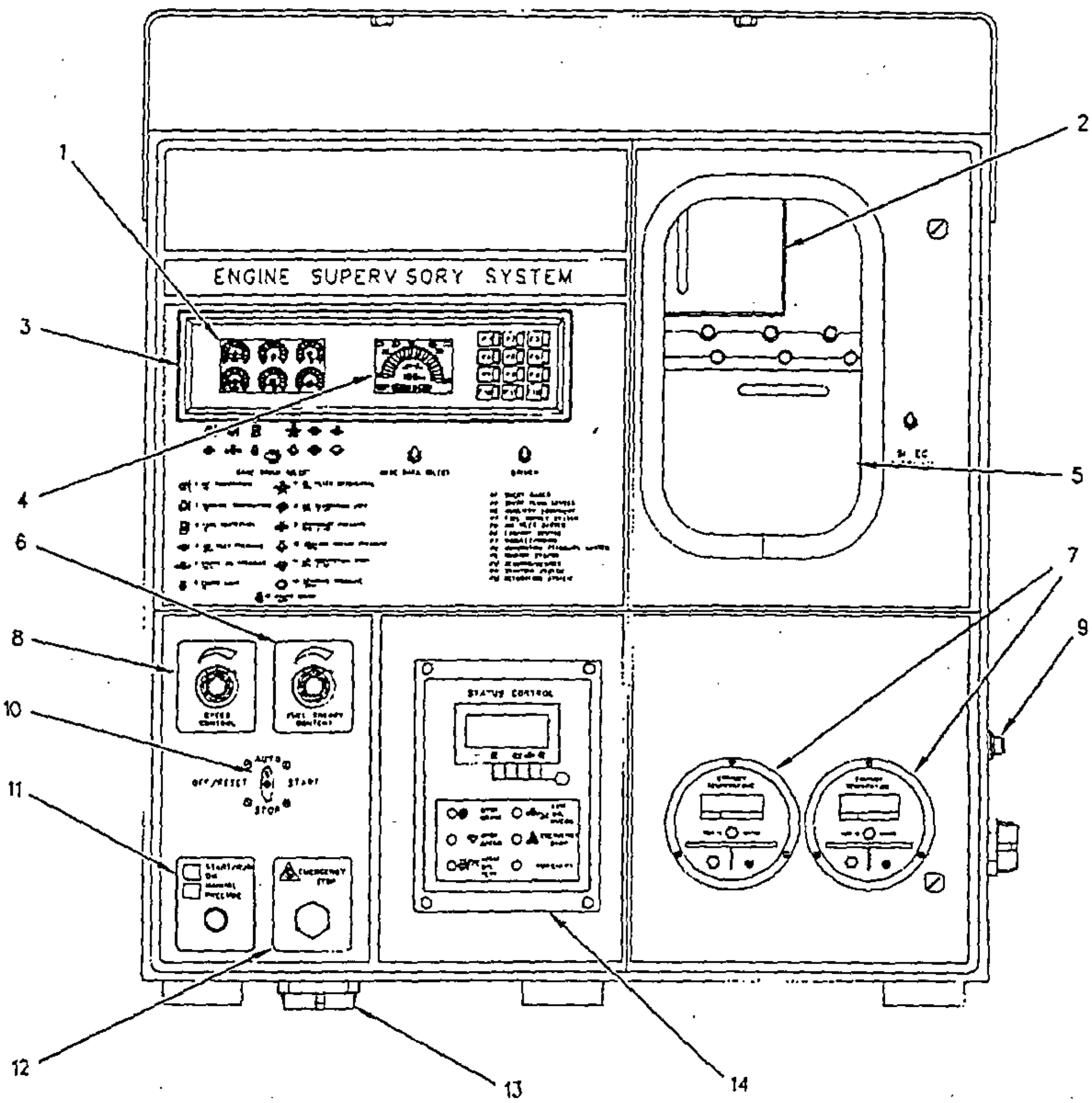

Illustration 17
(1) LED Dial gauges. (2) Timing Control Module (TCM). (3) CMS Gauge panel. (4) Digital gauge readout. (5) Engine Control Module (ECM). (6) Fuel energy adjustment dial. (7) Exhaust pyrometer. (8) Engine speed adjustment dial. (9) Digital Diagnostic Tool (DDT) connection. (10) Mode control switch. (11) Prelube switch. (12) Emergency stop push button. (13) Sensor wiring to the engine. (14) Status Control Module (SCM).

This panel contains the control modules, the switches, and the potentiometers that are associated with the system.

- Engine Control Module (ECM) (System Coordination, Governing, Air/Fuel Ratio Control)
- Timing Control Module (TCM) (Ignition System Control)
- Status Control Module (SCM) (Start/Stop Control)
- Computerized Monitoring System (CMS) (Gauge Panel Display of System Parameters)
- Pyrometer Module (Display of Exhaust Temperatures)
- Mode Control Switch (MCS)
- Prelube Switch/Start Run Okay Lamp
- Emergency Stop Switch
- Fuel Energy Adjustment Potentiometer
- Desired Speed Adjustment Potentiometer
- Gauge Group Select Switch
- Gauge Data Select Switch
- Display Select Switch
- Dimmer Switch Diagnostics

Diagnostics

The Engine Supervisory System is self-diagnostic. Through lights and fault codes, the ESS directs the service technician to the system or the component that requires maintenance.

Mounting

The control panel for the ESS is a waterproof enclosure. The control panel is intended to be mounted at a remote location. The control panel can be mounted up to 30.5 m (100 ft) from the engine.

Hazardous Environments

The engine and the Engine Supervisory System have been Canadian Standards Association (CSA) certified for use in hazardous locations Class 1, Division 2, Group D.

Customer Interface Connections

Refer to Installation And Initial Start-up Procedures, SEHS9549, for information regarding customer input and output connection points.

RS232 Computer Interface

RS232 output of system data is available for customer monitoring and information systems. This output requires a ship loose converter module.

Start/Stop/Prelube System

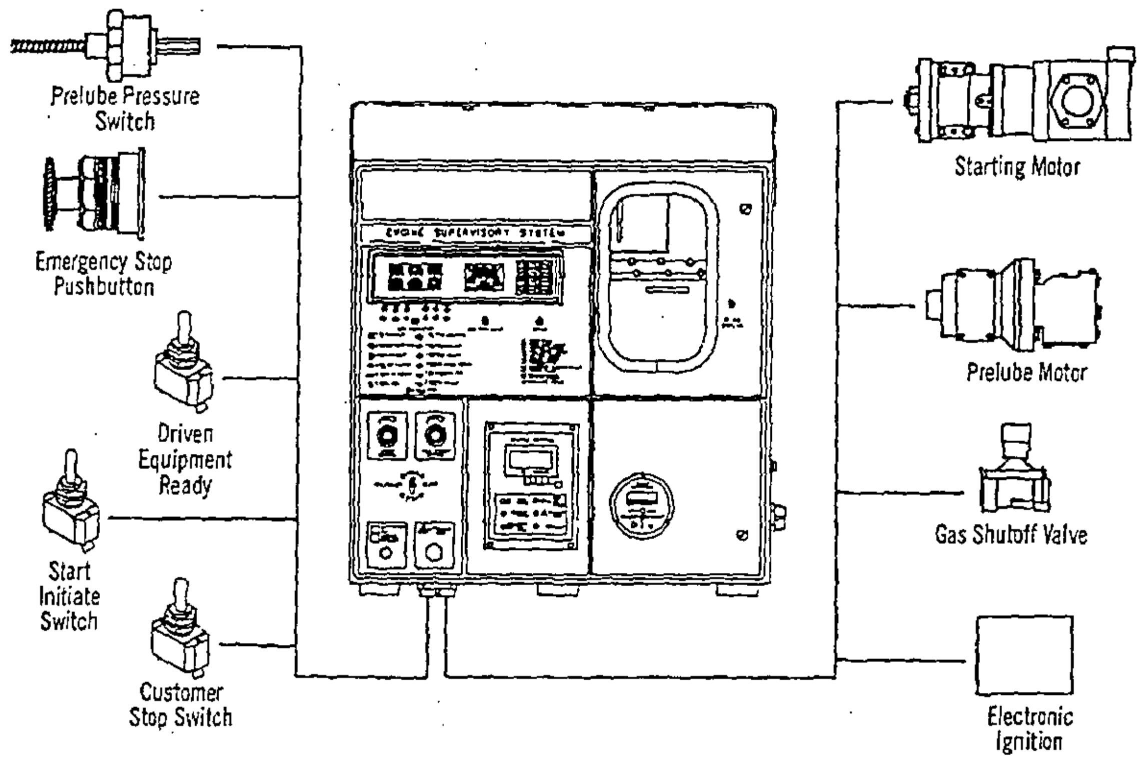

Illustration 18

The system consists of the following components:

1. The Control Panel For The Engine Supervisory System (ESS). The control panel consists of the following components:
   - Mode Control Switch (MCS)
   - Status Control Module (SCM)
   - Engine Control Module (ECM)
   - Prelube Switch/Lamp
   - Speed Control Dial
   - Fuel Energy Content Dial
   - Emergency Stop Push Button
2. Gas Shutoff Valve (GSOV)
3. Ignition System
4. Fuel Actuator
5. Prelube Pump System (Pump And Solenoid)
6. Engine Cranking System (Starting Motors And Solenoids)

The controls for the Start/Stop/Prelube and the Status Control Module perform the automatic start/ stop functions. The Status Control Module monitors certain engine functions that are required for operation. The Status Control Module monitors and provides an automatic shutdown of the engine under normal operating conditions.

The Speed Control Potentiometer will allow the operator the ability to select the engine speed that is needed for a particular application. Low idle speed is 550 rpm. Rated speed can be as high as 1000 rpm.

The Fuel Energy Content Potentiometer is used in order to adjust the setting for the Lower Heat Value of the fuel. The Fuel Energy Content Potentiometer setting should be adjusted in order to display a Btu value on the ECM that is equal to the Lower Heating Value of the fuel supply in terms of Btu/ft^3. The Lower Heating Value Btu is based on the data from a fuel analysis that is input into the Caterpillar Methane Number Program, 5.0, LEKQ6378-01.

The major functions of this system are controlled by the following components:

- Mode Control Switch (MCS)
- Prelube Push Button

The MCS has the following four positions and operations:

- AUTO
- START
- STOP
- OFF/RESET

AUTO – When the mode control switch is in the AUTO position, the system is configured for remote operation. When the remote start/stop initiate contact closes, the prelube system will operate and the engine will start. When the remote start/stop initiate contact opens, the engine will shut off. If the cool down cycle is programmed, the engine will operate for the cool down period before the engine stops. The cool down cycle can be programmed for a 0 to 30 minute period. A cool down period is not recommended for G3600 engines.

START – When the mode control switch is turned to the START position, the prelube system will operate. When the prelube pressure is sufficient, the engine will start. The engine will operate until the ESS receives a shut down signal.

STOP – When the mode control switch is turned to the STOP position, the engine will shut off. After the engine stops, a postlube cycle will operate. The power to the control panel is maintained when the mode control switch is in the STOP position. The "STOP" mode can be used to troubleshoot some problems without starting the engine.

OFF/RESET – When the mode control switch is turned to the OFF/RESET position, the engine is immediately shut off and the diagnostic lights of the status control module are reset. Power is removed from the control panel and the actuators after the engine completes the postlube cycle.

MANUAL PRELUBE button enables the operator to prelube the engine. All G3600 Family Engines should be lubricated before the crankshaft is rotated. This includes crankshaft rotation in order to service the engine. Rotating the crankshaft before prelube may cause damage to the crankshaft bearings if the surfaces of the bearings are dry.

All G3600 Family Engines require lubrication prior to start-up. The ESS will not permit the engine to start until sufficient prelube pressure has been achieved. The actuators will be powered up after the engine has been prelubed.

Note: The ECM is programmed to provide engine lubrication after the engine is shut off. The typical duration of the postlube is 60 seconds.

The EMERGENCY STOP push button immediately de-energizes the Gas Shutoff Valve and grounds the CIS in order to stop the engine (no cool down). The engine may not be restarted until the Status Control Module has been reset by turning the MCS to the OFF/RESET position. More than one EMERGENCY STOP push button may be used, depending on the engine installation.

NOTICE

The EMERGENCY STOP push button is not to be used for normal engine shutdown. To avoid possible engine damage, use the Mode Control Switch (or Start Initiate Contact for remote operation) for normal engine shutdown.

These engines require a prelube cycle prior to start-up. The engine will not start until the Status Control Module tells the Engine Supervisory System that the minimum requirement for oil lubrication has been reached.

The Engine Control Module is programmed to provide a period of engine lubrication (postlube) after shutdown. The time that is required for postlube is typically 60 seconds.

Sequence Of Operation

The Mode Control Switch (MCS) of the remote control panel has four positions: AUTO, START, STOP, OFF/RESET. If the MCS is in the AUTO position and a signal to run is received from a remote initiate contact (IC), or when the MCS is placed in the START position, the engine will prelube, crank, terminate cranking and run. The engine may cycle crank if the feature for cycle crank is utilized. The engine will run until the signal to run is removed by either turning the Mode Control Switch (MCS) to STOP, OFF/RESET, or opening the remote initiate contact with the MCS in the AUTO position. Once the MCS is moved to the STOP position, or if in the AUTO position and the remote initiate contact opens, the engine will run for a short period of time in the cool down mode, if the cool down feature was utilized, If the cool down feature was not utilized the engine will shut down immediately. The engine will then start the postlube cycle. The engine is then capable of immediate restart.

Sequence Of Operation (Normal Start/ Stop)

When the MCS is placed in the START position or the AUTO position and the remote initiate contact is closed:

1. A signal is sent to the prelube relay.
2. The prelube pump will run.
3. The prelube switch will close to indicate that 6.9 kPa (1 psi) of oil pressure is at the switch.
4. After a preprogrammed period of time (typically 30 seconds), the ECM will send a signal in order to energize the prelube pump switch relay The green prelube light will turn on. CMS Gauge No. 5 will stop flashing. A start signal is sent to the SCM.

Upon receipt of a signal to start, the SCM will check in order to ensure that the following conditions are met:

1. An emergency stop signal is not present.
2. All faults have been reset.
3. All sensors are connected and operating properly.
4. No abnormal mode control switch signals are present.
5. The engine is not already running.
6. The SCM microprocessor is functioning properly.
7. The SCM is not in the programming mode.

The SCM will not allow the start sequence to begin. The SCM will display the proper diagnostic code when applicable, if an above fault condition exists. However, once the SCM is satisfied that conditions are normal, the SCM will energize the Starting Motor Relay (SMR) and the Run Relay (RR). The SCM will also signal for fuel to be turned on by energizing the Fuel Control Relay (FCR) and the Run Relay (RR). The fuel actuator will begin to open at 50 rpm. The Ignition Shutoff Relay will be energized in order to begin the ignition system functioning.

If the feature for cycle crank is enabled, the SCM will automatically crank/rest/crank the engine for adjustable time periods. If the engine fails to start within the selected total crank time, the SCM will execute an overcrank fault. If a fault condition occurs while the engine is cranking, the SCM will terminate and lock out cranking. The SCM will display the applicable diagnostic code, or the SCM will light the appropriate LED.

After the engine starts and has achieved the crank termination speed (typically 250 rpm), the SCM will de-energize the starting motor by de-energizing the SMR. The SCM will energize the Crank Termination Relay (CTR). Once the correct low idle oil pressure is achieved, the SCM will signal for the ECM to accelerate the engine to rated speed.

The engine will run if the operating conditions remain normal and a signal to run is being received by the SCM. The SCM will sequentially display each of the following for a two second period: the engine oil pressure, the oil temperature, the rpm, the service hours, and the system DC volts. This is done via the digital display prior to or while the engine is operating. As well as monitor for any fault or abnormal conditions that may occur.

Upon loss of the run signal, the engine will continue to run for an adjustable cool down period if the cool down feature is utilized. However, if the cool down feature is not used or if the SCM receives an off/reset signal, the SCM will immediately de-energize the Run Relay. The fuel circuitry will be de-energized. If the signal to run returns before the engine stops, the SCM will immediately go back to the running state. This means, the fuel will be turned back on, but the starting motor will not energize. However, if a restart does not occur and the rpm continues to drop, then the SCM will initiate cranking upon reaching zero rpm, Assuming that the run signal does not return and the engine speed continues to diminish until zero rpm is reached, then the Crank Termination Relay (CTR) will be de-energized and the SCM will be ready for an instant restart. The Fuel Control Relay will be ready for an instant restart. The Fuel Control Relay (FCR) of the SCM will de-energize in two seconds after zero rpm.

Sequence Of Operation (Fault Conditions)

If a fault condition occurs prior to starting the engine, the SCM will:

1. De-energize and lock out the starting motor circuit.

2. Ensure that fuel is shut off.

3. De-energize the Run Relay Circuit.

4. Energize the fault shutdown circuitry (Engine Failure Relay).

If a fault condition occurs while the engine is running, then the SCM will respond in the following manner:

1. Fuel control circuitry will be de-energized for energized to run engines.

2. Ignition Shutoff Relay will be de-energized, for an overspeed, emergency stop, or diagnostic codes 01, 04, 06 or if all six LEDs are on. The relay will also de-energize if the engine has not shut down within five seconds after the FCR commanded it to do so. This would be the result of a fault condition. The relay circuitry shall be re-energized for 10 to 15 seconds after the engine reaches zero rpm. The relay shuts off the ignition system.

3. The Starting Motor Relay (SMR) circuitry shall be locked in the de-energized state.

4. The Run Relay (RR) circuitry shall be de-energized.

5. The Fault Shutdown Circuitry shall be energized, including the Engine Failure Relay (ENFR).

If a fault occurs before or after the engine starts, then the appropriate fault indicating LED shall flash at two Hertz or a diagnostic code shall be displayed to indicate the nature of the problem. The indicators shall remain on. The SCM shall remain in the fault mode until it receives a reset signal.

Engine Monitoring And Protection System

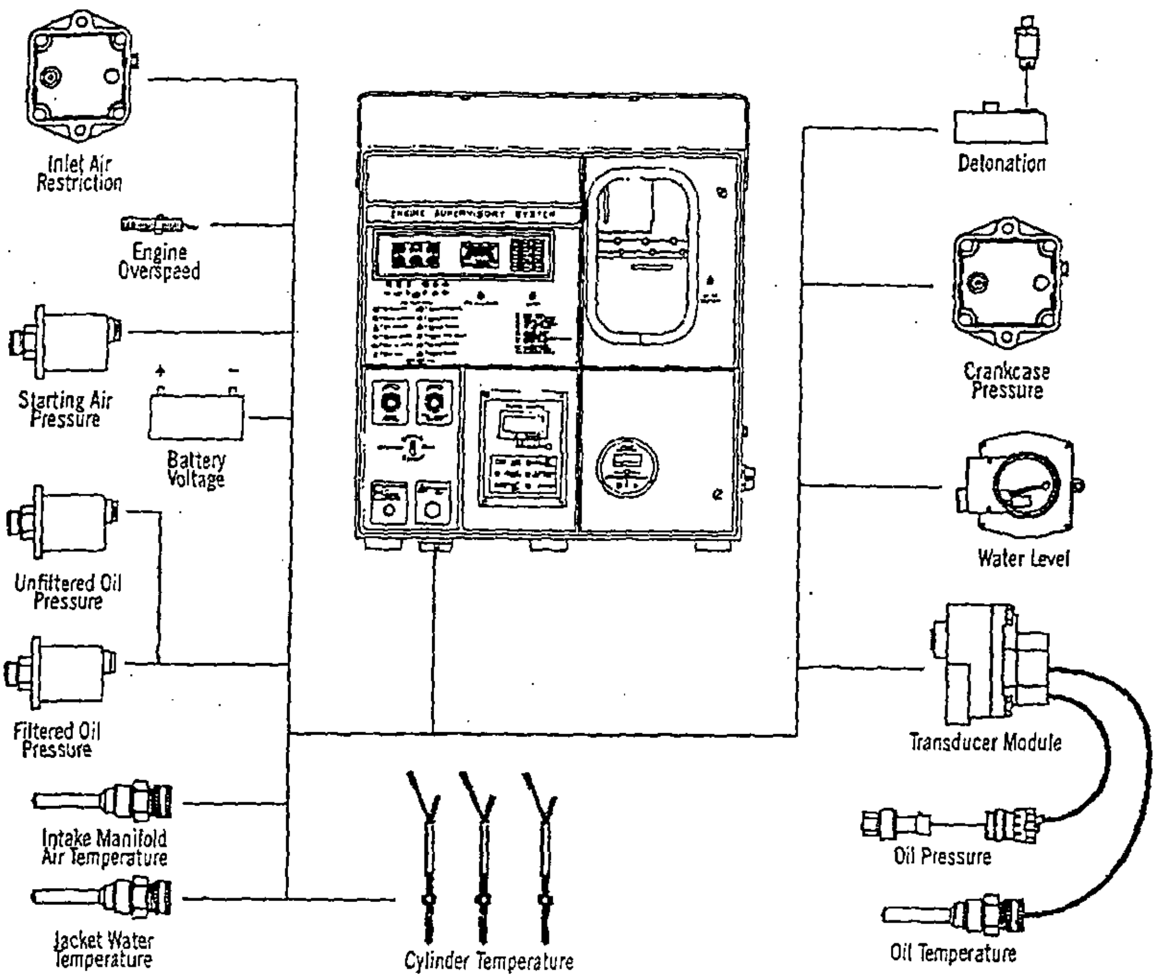

Illustration 19

The system provides engine protection and monitors engine systems for vital parameters. The system provides warnings and/or inhibits the engine from starting. The system shuts down the engine when the parameters are outside acceptable limits. Along with these features, the system provides display/ indication of the engine operating parameters.

Engine Shutdown And Start Inhibiting Functions

The engine shutdown features provide engine protection by shutting down the engine when certain operating parameters are beyond acceptable limits. The engine shutdown features provide engine protection when the driven equipment sense a shutdown signal to the control panel for the ESS.

The start inhibiting features provide protection to the engine and the driven equipment by preventing the engine from cranking when the engine parameters are not within acceptable limits or the driven equipment has indicated that the driven equipment is not ready to start.

Engine shutdown and start inhibiting problems will be indicated by the CMS panel display, the Engine Control Module (ECM) or the Status Control Module (SCM). The CMS panel display will provide a diagnostic indication when the lights are ON. The ECM will display a FLASHING diagnostic code to indicate that engine shutdown due to a specific problem that was encountered. The ECM will display a SOLID diagnostic code in order to indicate that a warning condition has occurred due to a specific problem that was encountered. For additional information on troubleshooting the displayed information, refer to Troubleshooting, SENR6510, for G3600 Engines.

Computerized Monitoring System (CMS)

The display consists of six small gauges (left side) and one larger gauge (center). The information that is displayed on the gauges is controlled by the GAUGE GROUP SELECT switch and the GAUGE DATA SELECT switch. The GAUGE GROUP SELECT switch selects between two sets of parameters that are available for display on the six small gauges.

The GAUGE GROUP SELECT switch allows the data that is provided on each of the gauges to be viewed on the digital readout. The digital readout is located below the large center gauge. The upper number in the gauge display will indicate which parameter is being viewed. Each time that the GAUGE DATA SELECT switch is toggled, the next gauge is selected. This is within the range of gauges currently selected by the GAUGE GROUP SELECT switch.

If the GAUGE GROUP SELECT switch is switched, then the digital gauge will change to the gauge for the corresponding gauge position, If gauge 2 coolant temperature was selected and the GAUGE GROUP SELECT switch is moved the gauge data will switch to gauge 8, AIR RESTRICTION LEFT.

CMS Gauge Display

The film on the control panel for the ESS is either in English Units or Metric Units. Depending on the application, the readouts will be in either English Units or Metric Units. By setting the "GAUGE GROUP SELECT" switch to the left, the following engine functions are displayed on the gauge and the digital readout.

Gauge 1 AIR TEMPERATURE – The temperature of the air inlet manifold is displayed in °C or °F. The temperature is displayed within one degree.

Gauge 2 COOLANT TEMPERATURE – Temperature is displayed in °C or °F. The temperature is displayed within one degree.

Gauge 3 FUEL CORRECTION – The display shows a percent value. This is a ratio of the difference between the adjusted setting of the fuel energy content Btu potentiometer and the Btu energy content of the fuel that the engine is burning.

Note: When the red limit bars on this gauge are turned off, the air/fuel ratio is not being automatically controlled and the fuel correction factor is fixed at 100%. When the red bars are present, the air/fuel ratio control is based on the in cylinder measured combustion burn time.

Gauge 4 AIR INLET PRESSURE – Air inlet manifold pressure (absolute) is displayed in kPa or psi/10.

Gauge 5 ENGINE OIL PRESSURE – Pressure is displayed (gauge) in kPa or psi.

Note: Prelube oil pressure is indicated by a bar around the display for the oil pressure gauge. A solid bar indicates that the prelube pressure is OKAY. A flashing bar indicates that the prelube pressure is NOT OKAY.

Gauge 6 ENGINE LOAD – Load is displayed as a percentage of the full rated power output of the engine. The calculation of the percentage is based on the following factors: flow of fuel, engine rpm, and fuel energy content.

By setting the "GAUGE GROUP SELECT" switch to the right, the following engine functions are displayed on the gauge and the digital readout.

Gauge 7 OIL FILTER DIFFERENTIAL – The amount of pressure drop between the inlet and the outlet of the oil filter housing is displayed in kPa or psi.

Gauge 8 AIR RESTRICTION LEFT – The amount of pressure drop between the inlet (unfiltered) and outlet (filtered) sides of the air cleaner, displayed in kPa/10 or inches of $H_2O/10$.

Gauge 9 CRANKCASE PRESSURE – This gauge indicates the pressure that is inside the crankcase. This is displayed in kPa/10 or inches of $H_2O/10$

Gauge 10 COOLANT OUTLET PRESSURE – This gauge is not used.

Gauge 11 AIR RESTRICTION RIGHT – This gauge is not used with the G3600 engines.

Gauge 12 STARTING PRESSURE – This gauge indicates the air pressure that is available for starting the engine. This is displayed in kPa or psi.

The large gauge (center) always indicates the engine speed.

Gauge 13 ENGINE SPEED – This gauge displays engine speed in rpm (within 10 rpm).

CMS Fault Indicator Lights

The CMS has 12 lights that indicate a fault condition has occurred. A fault is either a measured parameter outside a safe limit or a malfunctioning device. Each light indicates the system to look for in determining the exact problem.

F1 CHECK GAUGES – One or more gauges indicate that a parameter is outside of the normal operating range. Check gauges.

F2 CHECK FLUID LEVELS – One or more fluid levels are below an acceptable limit. Observe the diagnostic code(s). Refer to Troubleshooting, SENR6510 for G3600 Engines.

F3 AUXILIARY EQUIPMENT – One or more problems exist in the interface for the driven equipment. Observe the diagnostic code(s). Refer to Troubleshooting, SENR6510 for G3600 Engines.

F4 FUEL SUPPLY SYSTEM – One or more problems exist in the system that controls the fuel. Observe the diagnostic code(s). Refer to Troubleshooting, SENR6510 for G3600 Engines.

F5 AIR INLET SYSTEM – One or more problems exist in the system that controls the inlet air. Observe the diagnostic code(s). Refer to Troubleshooting, SENR6510 for G3600 Engines.

F6 EXHAUST SYSTEM – One or more problems exist in the exhaust system. Observe the diagnostic code(s). Refer to Troubleshooting, SENR6510 for G3600 Engines.

F7 MODULES/WIRING – One or more problems exist with specific control modules and/or the wiring. Observe the diagnostic code(s). Refer to Troubleshooting, SENR6510 for G3600 Engines.

F8 COMBUSTION FEEDBACK SYSTEM – One or more problems exist in the controls for the feedback from the combustion system. Observe the diagnostic code(s). Refer to Troubleshooting, SENR6510 for G3600 Engines.

F9 IGNITION SYSTEM – One or more problems exist in the ignition system. Observe the diagnostic code(s). Refer to Troubleshooting, SENR6510 for G3600 Engines.

F10 SENSORS/DEVICES – One or more problems exist on specific control devices. This includes sensors, actuators, etc. Observe the diagnostic code(s). Refer to Troubleshooting, SENR6510 for G3600 Engines.

F11 STARTING SYSTEM – One or more problems exist in the engine starting system. Observe the diagnostic code(s). Refer to Troubleshooting, SENR6510 for G3600 Engines.

F12 DETONATION SYSTEM – One or more problems exist in the system that detects detonation. Observe the diagnostic code(s). Refer to Troubleshooting, SENR6510 for G3600 Engines.

Status Control Module (SCM)

The bottom of the control panel for the ESS contains the Status Control Module (SCM). This displays fault conditions and key engine parameters. The Status Control Module (SCM) accepts information from the operator, magnetic speed pickup (MPU), pressure/temperature module and the Engine Supervisory System (ESS). This information is used to determine the "on/off" state of the engine's fuel and ignition system.

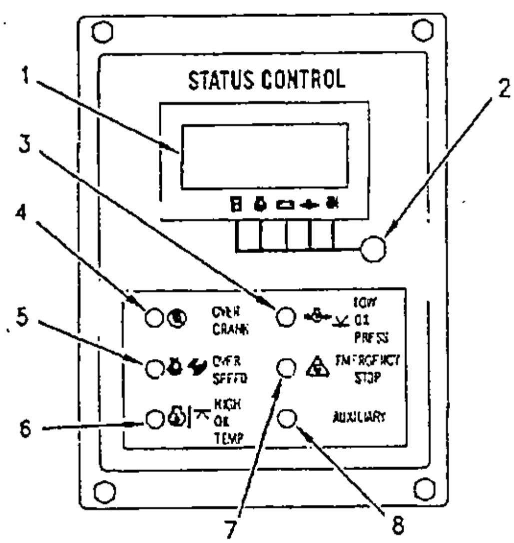

Illustration 20
Status Control Module (SCM)
(1) Liquid Crystal Display (LCD). (2) Switch (display hold switch). (3) Low Oil Pressure Light Emitting Diode (LED). (4) Overcrank LED. (5) Overspeed LED. (6) High Oil Temperature LED. (7) Emergency stop LED. (8) Auxiliary LED (shutdown).

The SCM receives a signal that instructs the SCM to start the engine. The SCM activates the fuel system and the starting motor. When the engine rpm reaches the crank termination speed, the starting motor is disengaged. When the SCM receives a signal to stop the engine, the fuel system is shut off.

The SCM has the following features:

Cycle Crank – The SCM can be programmed to crank-rest-crank for adjustable time periods.

Speed Control – When the engine oil pressure increases past the low oil pressure set point, the SCM will inform the ECM that the ECM should increase the engine speed from idle to rated.

Cooldown – After the SCM receives a signal to perform a normal shut down, the SCM will wait for a preprogrammed amount of time before shutting the engine off via the gas shutoff valve.

Automatic Operation – While in the automatic mode, the SCM can be started by a remote initiate signal. This signal is when the initiate contact (IC) closes. Upon the loss of the signal, the SCM will perform a normal shut down.

Power Down – The ESS system is designed to remove power when in the *off/reset* mode once the postlube cycle is complete. The SCM will not allow the engine to power down until the *Crank Termination Relay* and the *Fuel Control Relay* are both off. Both relays turn off two seconds after zero rpm.

Fuel Solenoid Type – The SCM can be programmed to work with either an Energize To Run (ETR) fuel system or an Energize To Shutdown (ETS) fuel system. In G3600 applications this must be an ETR system.

LED Display – Six LEDs are located on front of the SCM to annunciate overcrank shutdown, overspeed shutdown, low oil pressure shutdown, high oil temperature shutdown, emergency stop and auxiliary shutdown.

Emergency Stop – LED (7) will flash if the *Emergency Stop* button is used to stop the engine.

Pressure/Temperature Module Malfunction – If the signal from the engine mounted oil pressure/temperature transducer module is lost or unreadable, the engine will be shut down via the fuel control. A diagnostic code will be displayed. The SCM can be programmed to ignore the malfunction of the transducer module.

Speed Pickup Malfunction – If the SCM loses the magnetic pickup signal, the engine will be shut down via the ignition system and the fuel control. A diagnostic code will be displayed.

Overcrank Protection – If the engine fails to start within a programmed amount of time, the SCM will cause the starting sequence to cease. LED (4) will flash. The mode control switch must be turned to the *Off/Reset* position before another attempt to start the engine can be made.

Liquid Crystal Display (1) – Service hours, engine speed, system battery voltage, engine oil pressure and engine oil temperature are sequentially displayed in either English or Metric Units. Pressing switch (2) on the front of the SCM will cause the display to lock (stop) on one of the engine parameters. Pressing the switch again will resume the display to normal sequencing. When a fault signal is detected, the display is also used to indicate diagnostic codes. This is to aid in troubleshooting. Refer to Systems Operation, Testing And Adjusting, Status Control Module (SCM), SENR6515, *Troubleshooting Section, Diagnosed Problems*.

Note: All diagnostic lights should turn on briefly when the panel is powered up. This is a light test.

Overspeed Protection – If the engine speed exceeds the set point for the overspeed, then the engine will be shut down via the ignition control and the fuel control. LED (5) will flash. The set point for the overspeed is lowered to 75 percent of the original value while the *Overspeed Verify* switch is depressed. This will allow the overspeed circuit to be tested while the engine is operating at rated speed.

Low Oil Pressure Protection – If the engine oil pressure drops below the low oil pressure set point, it will be shut down by means of the fuel control. LED (3) will flash. There are two set points for the low oil pressure. One set point is for when the engine speed is below the oil step speed. The another set point is for when the engine speed is above the oil step speed.

High Oil Temperature Protection – If the engine oil temperature exceeds the set point, the fuel will be shut off. LED (6) will flash. Refer to the Testing And Adjusting section of *G3612 and G3616 Engines Systems Operation and Testing & Adjusting Manual*, SENR5528, for status control module service procedure for information about testing and programming of the SCM.

Note: If a fault occurs and the control for the fuel does not shut down the engine, the ignition is shut off five seconds after the fault has occurred.

Engine Control Module (ECM)

The ECM monitors the fuel energy content for the air/fuel ratio control and for limiting the power. The ECM also has the function of system coordinator. The personality module of the ECM contains many of the protection set points. The personality module controls much of the systems operation. The display on the ECM consists of eight characters and eight lights.

The lights indicate:

STATUS (Green) – When this light is on, this light is for status information. Status information is the desired engine speed, fuel energy (Btu) setting, etc.

COMMUNICATION LINK 1 ACTIVE (Green) – When this light is on, this light will indicate that the ECM is properly communicating with the Timing Control Module (TCM).

COMMUNICATION LINK 2 ACTIVE (Green) – When this light is on, this light will indicate that the ECM is properly communicating with the Computerized Monitoring System (CMS Gauges), the Digital Diagnostic Tool (DDT) ports, and the optional Customer Communication Module (CCM).

CAUTION MODE (Yellow) – One or more problems exist. The code that indicates the exact nature of the condition will be displayed.

SENSOR FAULT (Red) – A problem with one of the sensors has been detected. One or more problems exist. The code that indicates the exact nature of the condition will be displayed.

ACTUATOR FAULT (Red) – A problem with one of the actuators has been detected. The code that indicates the exact nature of the problem will be displayed.

SYSTEM FAULT (Red) – A problem with one of the control systems has been detected. The code that indicates the exact nature of the problem will be displayed.

CONTROL MODULE FAULT (Red) – A problem with one of the control modules has been detected. The code that indicates the exact nature of the problem will be displayed.

The DISPLAY SELECT switch that is located on the right hand side of the ESS control panel door will allow the operator to step through the data on the Engine Control Module display. Every time the switch is toggled, the display steps through to the next item. Items displayed are either status codes or diagnostic codes. These codes are differentiated by one of the lights.

ECM Timing Control Module (TCM)

The Timing Control Module (TCM) maintains the ignition timing that is determined by the ECM. The TCM also protects the engine from unacceptable levels of detonation.

The TCM provides the ECM with information about detonation. The ECM sends a signal to the TCM for the engine timing that is desired. The signal can be retarded up to six crankshaft degrees if detonation is sensed. The engine will be shut down if high levels of detonation persist.

ECM Pyrometer Module

The pyrometer module allows the read out in nine separate temperatures in °C. The module powers up and displays the reading on channel zero (exhaust stack temperature). In order to read the temperature values on the other eight channels, press the *Push To Advance* button on the front of the gauge.

The pyrometer continuously compares channel zero (exhaust stack temperature) to a set point. If the exhaust stack temperature ever exceeds the set point, a contact closes. The ECM shuts down the engine.

Engine Control System

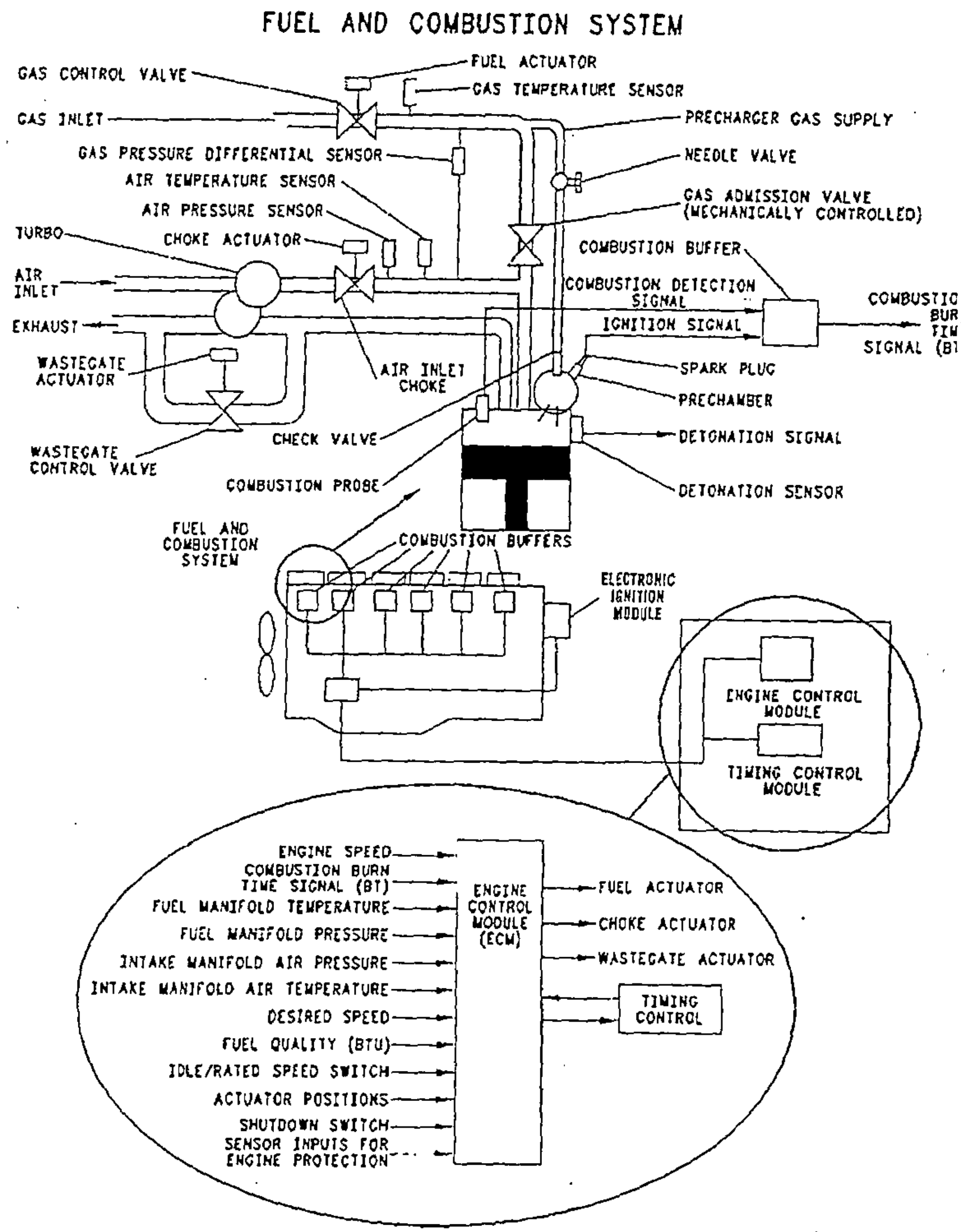

Illustration 21

The Engine Control System consists of the following components:

1. Engine Supervisory System (ESS) Control Panel
   - Engine Control Module (ECM)
   - Timing Control Module (TCM)
   - Desired Speed Potentiometer
   - Fuel Energy Content Potentiometer
2. Engine Mounted Sensors
3. Engine Mounted Actuators
   - Fuel
   - Wastegate
   - Choke

Governor

The Electronic Control Module (ECM) performs the governing function. The governor resembles a diesel engine governor more than a typical gas engine governor. The G3600 Engine is governed by modulating the fuel valve that controls the fuel flow independent of the air flow. The command signal that is sent from the ECM to the fuel actuator is based on the difference between the actual engine speed (as measured by the ECM magnetic pickup) and the desired engine speed.

Speed Droop

A setting from 0 to 10 percent speed droop can be selected by using the *Customer Selectable Parameter Screen, Number 31*, on the Digital Diagnostic Tool.

Switchable Governor Response

In order to provide a optimum engine response, with a generator set that operates in parallel with a utility or that operates with other generator sets, there must be two governor settings. The G3600 control system offers a dual dynamics governor. The *Governor Dynamics Switch* will select from either *Stand Alone* or *Paralleled* governor settings. Refer to Installation And Initial Start-up Procedures, SEHS9549, for information regarding switching from *OFF-GRID* to *ON-GRID* governor dynamics.

Desired Speed Control

Desired speed is controlled by an idle/rated switch. Open selects the idle speed of 550 rpm, closed selects the speed set by the desired speed potentiometer. The desired speed input is typically the potentiometer on the front face of the ESS panel. The desired speed may be controlled by an external input to the ECM. Refer to Installation And Initial Start-up Procedures, SEHS9549, for information regarding customer input.

Fuel Limiting

The governor provides the limiting of power on the G3600 Engine. The governor calculates the fuel flow. The governor compares the fuel flow against the maximum allowed flow. The governor protects the engine against over power situations.

Transient Fuel Limiting

In order to prevent the engine from operating at an air/fuel ratio that is excessively rich, the command signal that is sent to the fuel actuator may be limited. This will limit the amount of fuel flow into the engine during engine starting, engine acceleration or variable load operating conditions.

Personality Module

The Engine Control System contains a Personality Module. The Personality Module provides the engine application control maps. The Personality Module attaches to the ECM and the Personality Module communicates with the ECM. The Personality Module receives input from the engine control system sensors. The Personality Module monitors and controls the engine according to the parameters that are within the Personality Module. The Personality Module contains application specific engine control maps, protection set points and customer defined settings.

Air/Fuel Ratio Control

The G3600 Engine does not have a carburetor. The air flow and the fuel flow are independently controlled. The governor has complete control of the fuel flow. This leaves the air flow as the only parameter for adjusting the air/fuel ratio. The air flow is controlled by the exhaust wastegate system in order to maintain the desired air/fuel ratio or the desired combustion burn time (BT).

Fuel Flow

The ECM will calculate the fuel flow by using the following inputs:

- measured fuel manifold pressure
- measured fuel manifold temperature
- measured air inlet manifold pressure
- measured air inlet manifold temperature
- engine speed
- Btu setting

Air Flow

The ECM calculates the air flow based on the measured inlet manifold air pressure, the measured inlet manifold temperature, and the engine speed.

Desired Air/Fuel Ratio

The desired air/fuel ratio varies depending on engine speed and load. These values are stored in application specific maps in the Personality Module. These maps were created to achieve optimum engine performance (efficiency and emissions) as the engine speed and load varies.

Combustion Burn Time (BT)

Combustion Burn Time is the time measured for combustion flame propagation from the ignition spark in the precombustion chamber to the combustion sensing probe. The probe is mounted in the main combustion chamber.

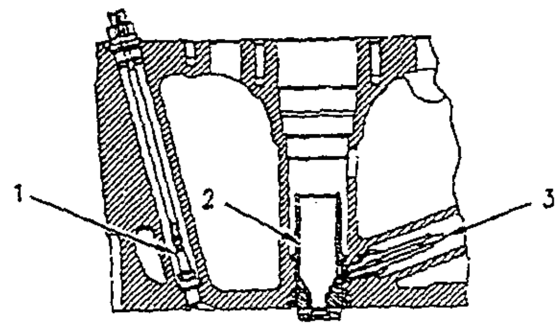

Illustration 22
Cylinder Ignition and Sensor
(1) Combustion sensor. (2) Precombustion chamber. (3) Gas ignition spark plug.

In-cylinder combustion sensing for each cylinder, allows the engine to respond rapidly to changes in ambient conditions, fuel quality or speed and load changes. This results in a more precise control of the engine emissions and the fuel consumption. The combustion sensor is a nonconventional 14 mm (.55 in.) spark plug. The spark plug operates in conjunction with an electronic combustion buffer. This measures the actual time between the spark and the passage of the flame across the sensor. This information is averaged and compared with a desired map setting in the personality module. Corrections for variations in fuel quality, temperatures, etc. are made automatically as well as more quickly and accurately than manual adjustments.

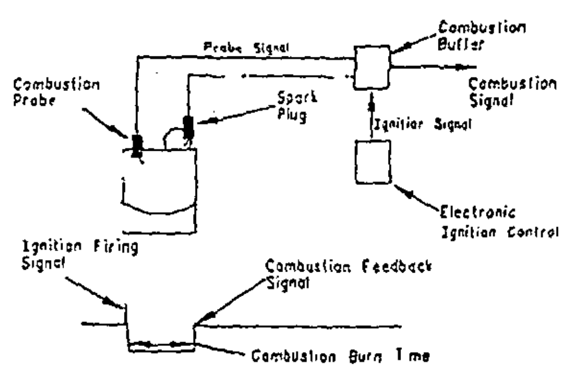

Illustration 23
Basic Combustion Probe System Diagram

The measured combustion burn time signals are sent to the ECM on two separate circuits. One circuit is dedicated to the Cylinder No. 1.

Another circuit sends the signals for the remaining cylinders to the ECM. The signals are received by the ECM in the firing order sequence.

Air Flow Control

Once the ECM has determined a desired air flow, the ECM modulates the exhaust bypass valve by changing the position of the wastegate actuator.

When the engine is operating in a normal operation mode, at an engine load that is typically greater than 50 percent, the air/fuel ratio is automatically controlled based on the average Combustion Burn Time (BT).

The position command signal that is sent from the ECM to the wastegate actuator is based on the difference between the average BT that is measured from the cylinders and the desired BT that is programmed into the personality module. Maintaining the desired BT ensures optimum engine performance and stable engine operation even when the quality of the fuel changes or when ambient conditions change.

When the engine is operating in precombustion chamber calibration mode or at an engine load that is typically less than 50 percent, the position command signal that is sent from the ECM to the wastegate actuator is the difference between the measured air/fuel ratio and the desired air/fuel ratio. The measured air/fuel ratio is a calculated value that is based on sensor inputs from the engine to the ECM. The inputs to the ECM that are required to calculate the air/fuel ratio are fuel manifold pressure, fuel manifold temperature, inlet manifold air pressure, inlet manifold air temperature, engine speed and fuel quality (Fuel Energy Content potentiometer setting). At start-up, the fuel energy content (Btu) is adjusted in order to agree with the fuel analysis by using the Fuel Energy Content potentiometer on the ESS control panel. When the engine is operating at greater than 50 percent load, the engine control overrides the manual fuel setting and provides fuel quality information. This is based upon the actual combustion burn time measurements that are taken during the combustion process. The manual setting of the Btu potentiometer will provide a starting point for the Air/Fuel Ratio Control system until the BT information is available from the combustion sensors.

Fuel Correction Factor

The fuel correction system will use the desired burn time along with the measured burn time in order to compute a fuel correction factor.

The percent fuel correction factor represents the difference in the actual energy content (Btu/ft^3) and the setting of the *Fuel Energy Content* potentiometer. The potentiometer is located on the front control panel of the ESS.

For example: the engine air/fuel ratio had been properly adjusted using a Btu dial setting of 900 Btu. After the engine has been running for a period of time, the quality of the fuel that is supplied to the engine will change from 900 to 990 Btu/ft^3. The result would be that the combustion flame would be faster. The ECM would slow down the combustion time by changing the air/fuel ratio to a leaner setting. The ECM would display a calculated fuel correction factor of 110 percent (990/900 times 100).

Fuel System

To ensure precise regulation of fuel flow on G3600 engines, carburetors are not used. Fuel flow is controlled electronically in order to maintain precise control of fuel delivery to the engine. The fuel system contains the following components: a gas shutoff valve, a fuel control valve, a electronic actuator, a fuel manifold, a gas admission valve, a needle valve, a check valve, and a precombustion chamber.

Gas is delivered to the engine through a customer supplied regulator (2). Fuel pressure must be 310 ± 14 kPa (45 ± 2 psi) and the fuel pressure must be regulated to 1.7 kPa (.25 psi). Lower fuel pressure may result in reduced power. The regulator is connected to a gas shutoff valve (3), which is controlled by the Engine Control Module (ECM).

Control valve (4), which is controlled by the electronic actuator (10) regulates the gas pressure in the fuel manifold (5). The electronic actuator controls the fuel manifold pressure. This control is based on a signal that was received from the engine control module. The engine control module determines the signal. The signal is based on the difference between the actual engine rpm and the desired engine rpm. Engine speed is controlled by the fuel manifold pressure. The fuel manifold (5) supplies gas to all cylinders.

Each cylinder has an orificed fuel line that is connected to the fuel manifold. The fuel line delivers gas to the gas admission valve (11) and from the gas admission valve on to the main combustion chamber. A separate fuel line (8) and adjustable needle valve (7) provide a new supply of gas to the precombustion chamber (12).

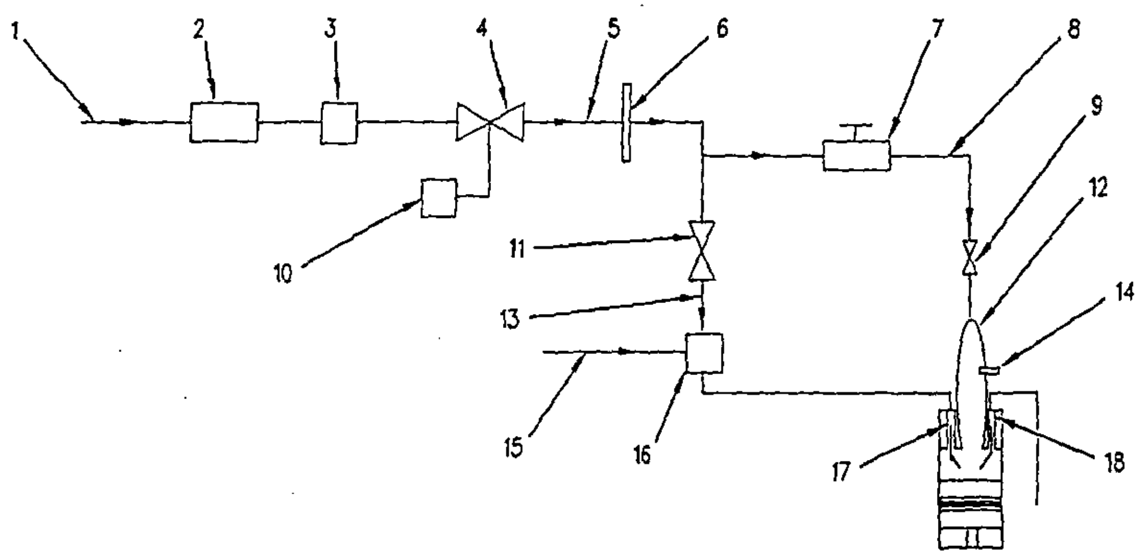

Illustration 24
Fuel System Schematic Diagram
(1) Gas input. (2) Customer supplied regulator. (3) Gas shutoff valve. (4) Control valve. (5) Fuel manifold. (6) Orifice. (7) Needle valve. (8) Precombustion chamber supply line. (9) Precombustion chamber check valve. (10) Electronic actuator. (11) Gas admission valve. (12) Precombustion chamber. (13) Main gas supply. (14) Spark plug. (15) Combustion air. (16) Cylinder head inlet port. (17) Inlet valve. (18) Exhaust valve.

Main Combustion Chamber

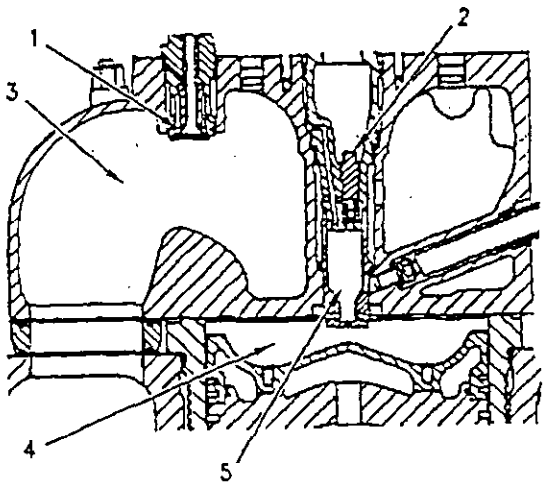

Illustration 25
(1) Gas admussion valve. (2) Check valve. (3) Inlet air.
(4) Main combustion chamber. (5) Precombustion chamber.

The gas admission valve (1) is mounted in the inlet port and is actuated by the camshaft. As the gas admission valve is opened, gas is admitted into the inlet port. The gas mixes with the combustion air in the inlet port. The gas and combustion air mix and flow into the cylinder.

Combustion air flow into the cylinder head is regulated (depending on the engine load) by the exhaust bypass valve (wastegate) and inlet air choke. As air flows into the cylinder head inlet valve chamber, the cam operated gas admission valve (1) admits gas to the air flow as the inlet valve opens. At the same time, an additional, separate, new gas supply is added to the precombustion chamber (5) through a ball type check valve (2).

Precombustion Chamber

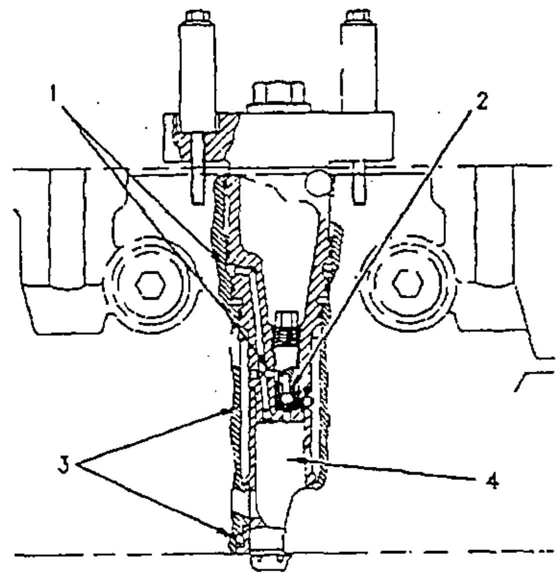

Illustration 26
PC Check Valve and Fuel Supply Path
(1) Fuel inlet passage. (2) Check valve. (3) Passageways for the jacket water coolant. (4) Precombustion chamber.

The new gas supply for the precombustion chamber (4) comes from the manifold. The new gas goes through a separate line and an adjustable needle valve. The new gas flows through the fuel inlet passage (1) into a ball type check valve (2). The check valve is located at the top of the precombustion chamber (4). The main charge of the air/fuel mixture flows through the inlet valves and into the cylinder. The check valve opens. The check valve adds new gas supply to the precombustion chamber. The gas in the precombustion chamber is ignited by the spark plug. The ignited gas in the precombustion chamber ignites the gas mixture in the cylinder in order to ensure consistent combustion and complete combustion.

Adjustment of the needle valve settings is a calibration procedure that is done by using the Digital Diagnostic Tool (DDT). The needle valve settings are adjusted in order to provide the desired combustion burn time. This depends on the engine speed and the engine load.

The need for low emissions and consistent combustion requires the use of an enriched precombustion chamber. To further enhance the overall effectiveness of this system, the side mounted spark plug is installed low in the precombustion chamber. With this design, the initiation of the flame front in the precombustion chamber is near the outlet to the main combustion chamber. This ensures that the rich fuel mixture is more completely burned prior to entering the main chamber than the fuel mixture would be burned if the ignition source was at the top of the precombustion chamber. Mixing of the fuel in the precombustion chamber with the lean combustion air from the main chamber during cylinder compression, yields an optimum air/fuel mixture for initiation of combustion.

Ignition System

The components of the gas engine ignition group and the fully shielded ignition system wiring are used with the magneto in order to provide spark ignition.

Ignition Transformer

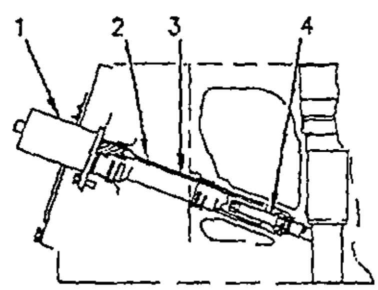

Illustration 27
Components of the Gas Engine Ignition Group
(1) High energy ignition transformer. (2) Tube.
(3) Extension with a spring loaded rod. (4) Spark plug.

The ignition transformer causes an increase of the primary voltage. The increased voltage is needed to send a spark (secondary electrical impulse) across the electrodes of the spark plugs. For good operation, the connections (terminals) must be clean and tight. The negative transformer terminals for each transformer are connected together and the terminals are connected to ground.

Timing Control System

The Caterpillar Detonation Sensitive Timing Control (DSTC) system provides detonation protection for the engine and electronic adjustment of ignition timing with a variable timing.

Timing Control System

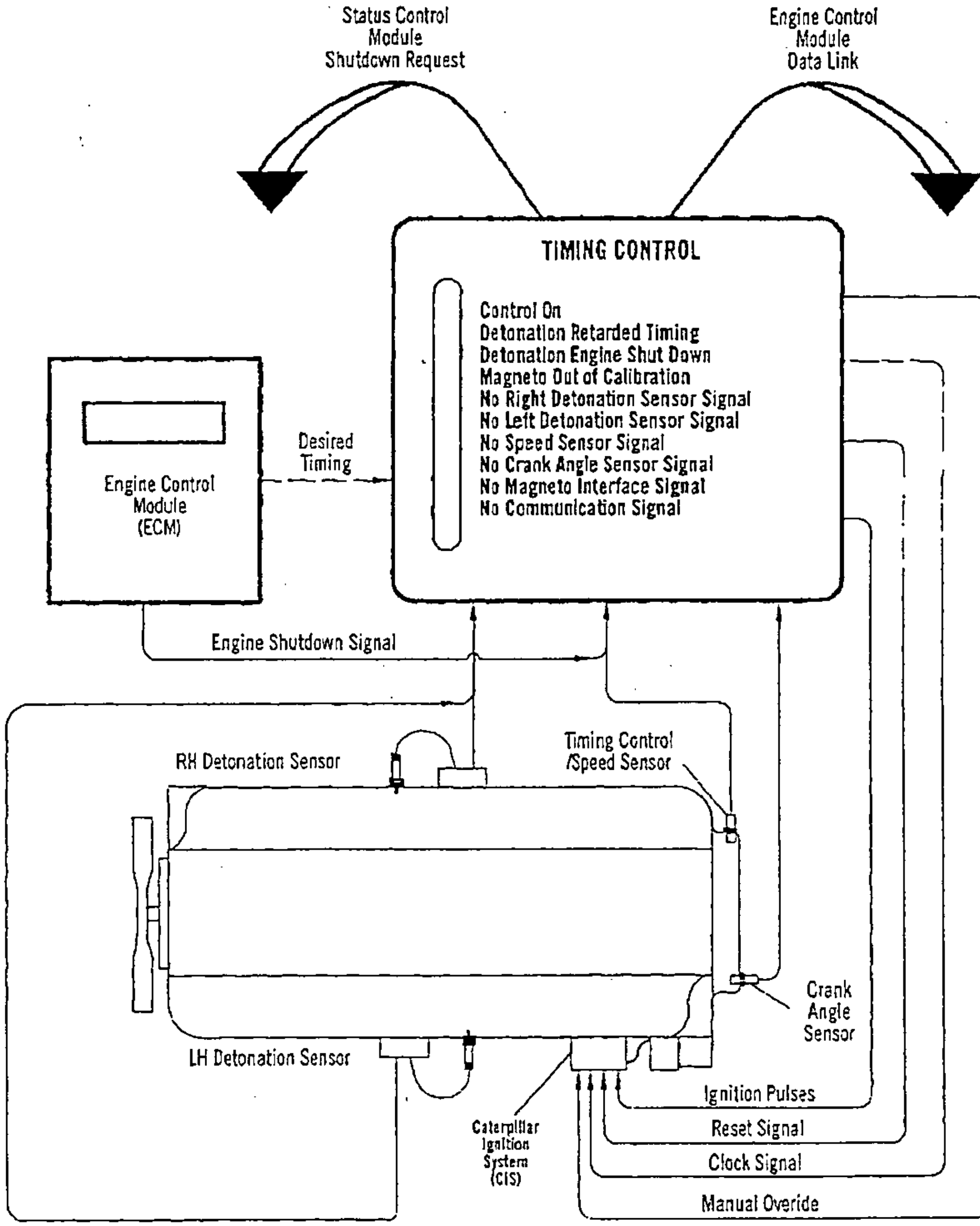

Illustration 28

Timing Control Module (TCM)

The TCM determines the ignition timing. The TCM communicates the ignition timing with the Caterpillar Ignition System (CIS). The TCM provides the system diagnostics.

Engine timing, controlled by the TCM, is based upon the desired timing signal received from the ECM. The desired timing signal from the ECM varies depending on engine speed, engine load and engine detonation.

The ignition timing is controlled by three signals that are sent from the TCM to the CIS. The CIS sends a signal that indicates that the plug is firing to the TCM. The TCM uses this signal to calculate actual engine timing.

Timing Control Sensors

The TCM uses two sensor signals for the ignition timing control. The TCM uses the detonation sensors for detonation protection. The Crank Angle Sensor (CAS) and the Speed Sensor (TCMPU) provide top center (TC) and rotational position needed to control timing. The detonation sensors provide an electrical signal of the engine's mechanical vibrations that are used in order to calculate the detonation levels.

Crank Angle Sensor (CAS)

This passive magnetic speed sensor indicates the crankshaft angle to the TCM. The crank angle sensor provides the TC signal used to control timing and calculate actual timing. The signal is generated when the TC hole (for the No. 1 piston) in the flywheel face passes the sensor.

Speed Sensor (TCMPU)

This passive magnetic speed sensor indicates engine speed to the TCM. The speed sensor produces a signal whenever a ring gear tooth on the flywheel passes the sensor. The signal is used to calculate engine speed, to monitor the crankshaft angle between TC pulses and to clock the MIB electronics.

Detonation Sensors

The detonation sensor is a powered device that outputs a filtered electrical signal and a amplified electrical signal of the engine's mechanical vibrations. When increased levels of vibration are occurring, the ECM calculates the engine detonation. If necessary, the ECM will adjust the ignition timing in order to control detonation. This is done by sending a desired timing signal that is retarded as much as six crank degrees to the TCM, When the level of vibration has returned to normal, the ECM will adjust the desired timing signal in order to gradually allow the ignition timing to return to operation. This adjustment is based on the desired timing map that is part of the personality module.

G3600 Ignition Timing System

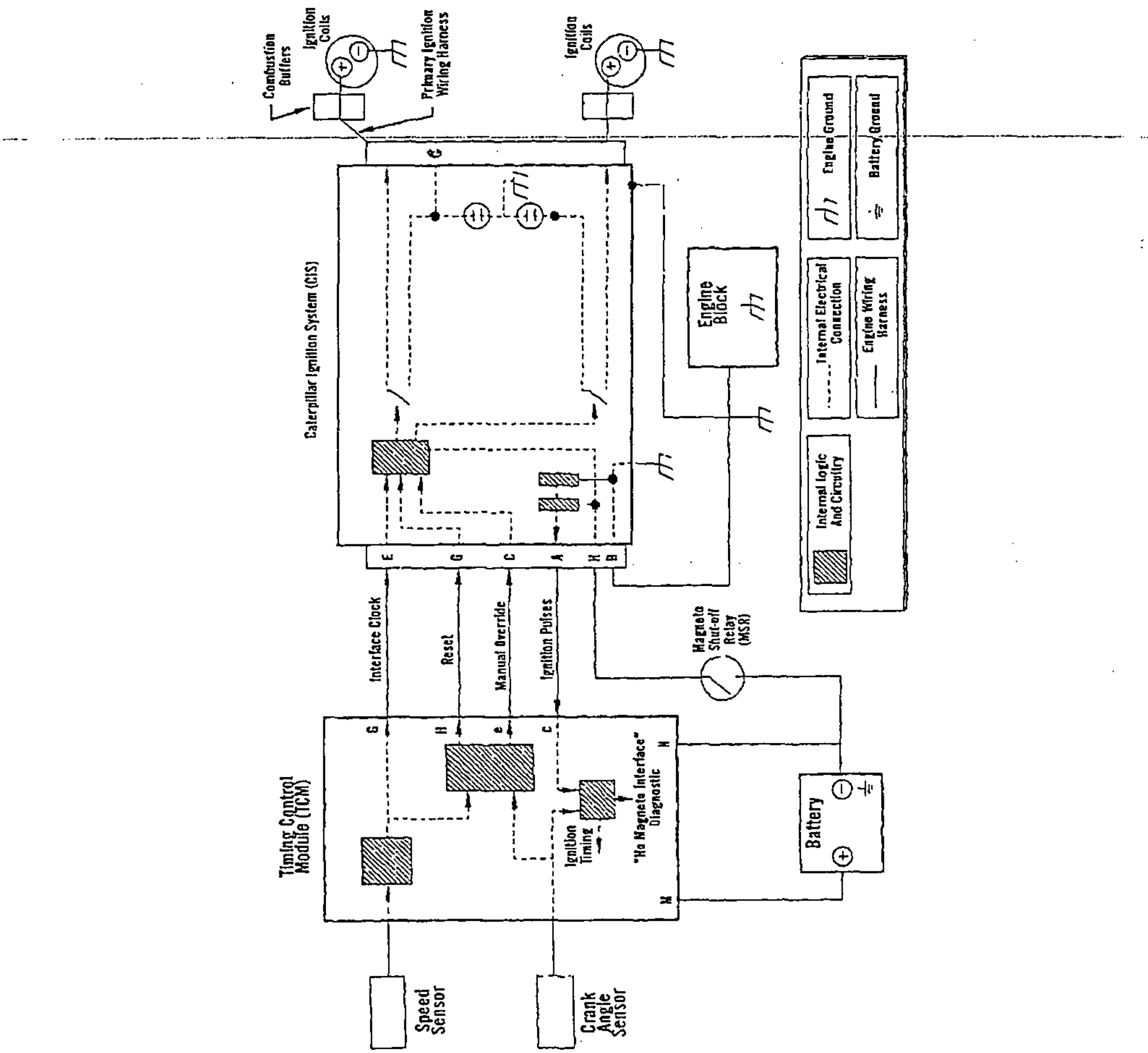

Illustration 29

The Timing Control provides three signals to the Caterpillar Ignition System (CIS) in order to communicate the desired ignition timing. These signals are the Ignition Interface Clock, the Reset Pulse signal, and the Manual Override signal. The CIS returns the Ignition Pulses to the Timing Control. The Timing Control calculates the Actual Engine Timing. The Timing Control performs some ignition diagnostics from this signal.

Ignition Interface Clock

The Ignition Interface Clock signal is a square wave version of the speed sensor signal. This signal provides a timing clock for the CIS.

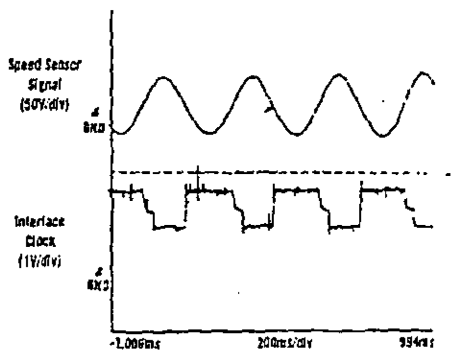

Illustration 30
Relationship Between Speed Sensor and Clock Signals

Sent from Timing Control (pin-G) to CIS (pin-E, 10 pin Connector).

The waveform is a square wave version of the speed sensor signal, with peak voltage of 2.5 V and minimum voltage of 1 V. The positive-going edge of the clock signal should align with the negative-going zero-crossing of the speed sensor signal.

Reset Pulse

The Reset Pulse signal indicates to the CIS the ignition timing desired by the Timing Control. The pulse is sent once from TC to TC.

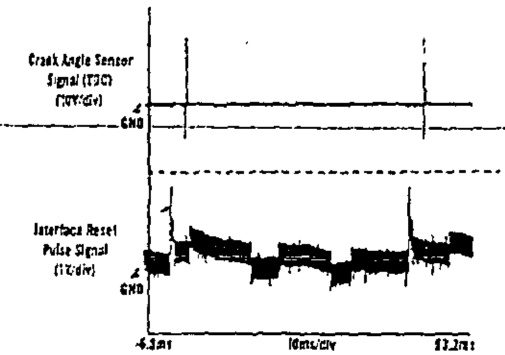

Illustration 31
Interface Reset Pulse Signal Relative to Crank Angle TC Signal

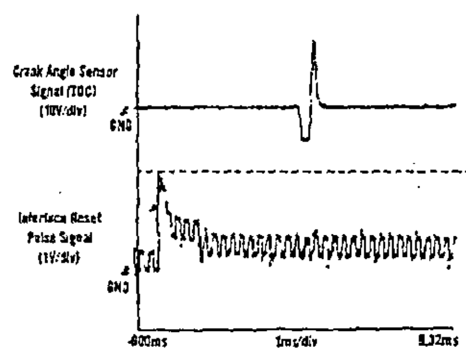

Illustration 32
Close Up of Interface Reset Pulse Signal Relative to Crank Angle TC Signal

Sent from Timing Control (pin-H) to CIS (pin-G, 10 pin Connector).

The Interface Reset Pulse signal is normally below 1 V. The Reset Pulse goes high to about 2.5 V. This signal should go high once from Top Center (TC) to TC.

Manual Override ("Mag Cal" Mode As Seen In DDT)

The Manual Override signal tells the CIS to control fully advanced ignition timing.

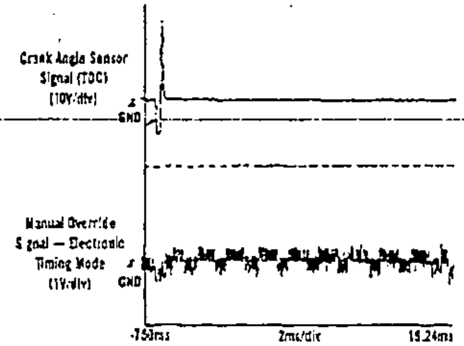

Illustration 33
Manual Override Signal, Timing Control in Electronic Timing Mode

Sent from Timing Control (pin-E) to CIS (pin-C, 10 pin Connector).

The manual override signal should remain below 1 V when the system is in Electronic Timing Control mode. A 5 V signal on this line will tell the CIS to run the ignition at fully advanced timing.

Ignition Pulses

The Ignition Pulse signal is the odd number bank's capacitor charge. The signals waveform indicates the discharge of the CIS and firing of cylinders. One pulse is shown for each number cylinder. This signal is used by the TCM to calculate ignition timing and some ignition diagnostics.

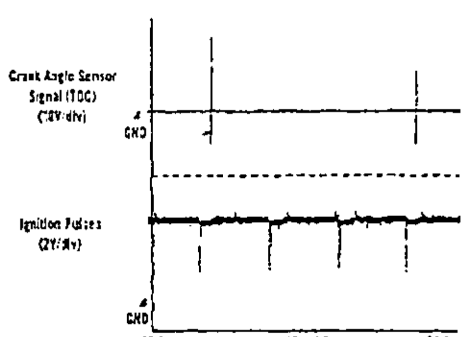

Illustration 34
Ignition Pulses Relative to Crank Angle TC Signal (Six Cylinder Engine)

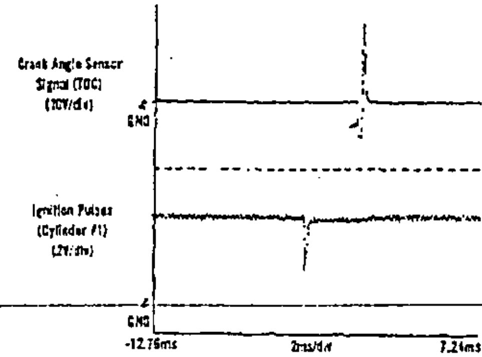

Illustration 35
Close Up of Ignition Pulses Relative to Crank Angle TC Signal (Six Cylinder Engine)

Sent from CIS (pin-A, 10 pin Connector) to Timing Control (pin-C).

From TC to TC, this waveform should show one pulse for each number cylinder. The pulse is normally at 5 V and goes below 2 V when the MIB detects the ignition firing.

Interaction Of The Interface Signals

The manual override signal is held below one volt, the CIS is placed in *Mag Cal* Mode. The TCM generates the Clock signal by squaring the Speed Sensor (TCMPU) signal. This clock signal is used by the CIS electronics in order to keep track of the rotational position. When the the Reset pulse is received from the TCM, the CIS counts nine Clock signal edges. The CIS will then signal to fire Cylinder Number One. The CIS continues to monitor the Clock. The CIS signals to fire the remaining cylinders through the rotation. When the CIS discharges to fire the cylinder, an ignition pulse is generated. The Ignition Pulse signal is a reduced voltage signal of the odd number bank's capacitor voltage. Ignition Timing is calculated by comparing the timing offset between TC from the Crank Angle Sensor and the Ignition Pulse for Cylinder Number One.

When the Manual Override signal goes above one volt, the CIS operates in Manual (Standard) Mode. The CIS will no longer control ignition firing. The CIS will generate an ignition pulse at the most advanced ignition timing. The Ignition Timing is calculated in the same manner as in Electronic Timing Mode.

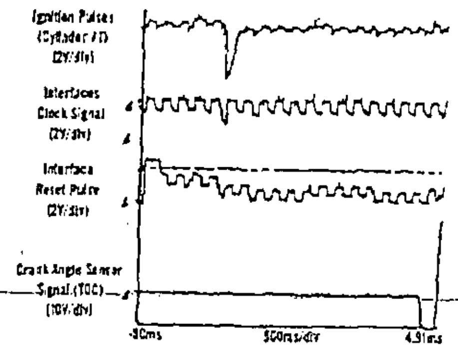

Illustration 36
Interaction of Reset, Clock, Ignition Pulse and TC Signal

When the CIS receives the Reset Pulse, the CIS generates a ignition pulse after 9 Clock Signal edges (both rising and falling edges). The CIS generates the Ignition Pulse for Cylinder Number One. This should occur before the TC signal of the engine.

Ignition Pulse Firings

From TC to TC, this waveform should show one pulse for each cylinder. The pulses should go from 190 V to ground when the cylinder is signaled to fire.

Engine Start-up

At engine start-up, the Timing Control performs some system checks not done once the engine is running. The Manual Override signal places the CIS in Manual Mode until the engine speed is above 500 rpm. Once the engine speed increases between 300 and 500 rpm, the Timing Control will compare the timing of Cylinder No. 1 firing to the *Mag Cal* Timing stored in internal memory. If the two timing values do not match, the Timing Control will display the "Magneto Out Of Calibration" fault.

CATERPILLAR®

G3600 Ignition System

General Information
- System Operation
- Digital Diagnostic Tool (DDT) Service Tool
- Engine Timing Reference
- Engine Rotation
- Hazardous Location (CSA)
- Power for Auxiliary Panels
- Electrical Schematics

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- Spark Plug Extenders
- Ignition Transformers
- Magneto
- Magneto Interface Box
- Crank Angle Sensor
- Speed Sensor
- Detonation Sensor

Components-Remote Mounted
- Timing Control Module

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Timing Control Module (TCM) Control Signals
Ignition Timing Control Logic

Customer Connections

Reference Material

Ignition System

General Information

System Operation

Caterpillar Gas Engines use a low tension ignition system. The low tension ignition system provides dependable firing with low maintenance. An ignition transformer is mounted near the spark plug for each cylinder. The ignition transformer converts the low level primary voltage to the high level secondary voltage required to arc across the J-gap spark plug. An extension piece connects the spark plug to the ignition transformer secondary.

The low level primary voltage (approximately 200 volts) is generated by a magneto. The magneto is mounted at the rear of the engine and driven by the camshaft. The variable timing magneto contains a permanent magnet alternator and solid-state electronic switches to control ignition firing.

The Timing Control System provides electronic control of the engine timing. This system controls the variable timing magneto to provide optimum engine timing during steady-state and transient operating conditions. Timing accuracy is controlled to within ±0.7 degrees of crank angle. This system also provides detonation sensitive timing. The Timing Control System will retard engine timing when a level of detonation is reached that might damage the engine.

A normal engine shutdown is accomplished by shutting off the fuel supply. The ignition system continues to operate until the engine is below 50 rpm. This allows the engine to consume the fuel that is trapped between the shutoff valve and the cylinder. The ignition system is disabled for engine overspeed and emergency stop shutdowns.

Digital Diagnostic Tool (DDT) Service Tool

A DDT service tool can be used to read the actual and desired engine timing. The DDT is also used to set the ignition system into the magneto calibration "MAG CAL" mode. The "MAG CAL" mode allows the magneto to be manually adjusted to the magneto calibration setting of 28 ± 1 degree. The DDT does not display a desired timing in the "MAG CAL" mode but does display the actual engine timing.

Engine Timing Reference

Many procedures on the engine require a timing reference. The G3600 Gas Engines are considered "in time" when the number 1 cylinder is at top-dead-center position on the compression stroke, the crankshaft timing pin is engaged in the bracket attached to the crankshaft and the camshaft timing pin is engaged in the hole in the camshaft assembly.

Engine Rotation

SAE standard engine rotation is counterclockwise as seen from the flywheel end of the engine.

Note: The front end of the engine is opposite the flywheel end. Left side and right side are as seen from the flywheel end of the engine. The number 1 cylinder on the G3606 and G3608 engines is the front cylinder. The number 1 cylinder on the G3612 and G3616 engines is the front right cylinder.

Hazardous Location (CSA)

Factory certification by the Canadian Standards Association (CSA) is available. With an attachment design, the G3600 Gas Engine is approved for use in Class 1, Division 2, Group D hazardous locations. CSA approval is required for engines operating in hazardous locations in Canada. CSA certification is recognized by many authorities outside of Canada as well.

Power for Auxiliary Panels

The G3600 Engine Supervisory System control panel requires 24 VDC for operation. The power source for this system can also be used to power auxiliary panels. The magneto should not be used to power auxiliary panels. All magneto power is required to provide optimum engine operation and maximum spark plug life.

Electrical Schematics

Electrical schematics are shipped with the engine and should be kept with the service manual. All ignition system components, wiring, and terminal connections are shown in the schematic.

Components–Engine Mounted

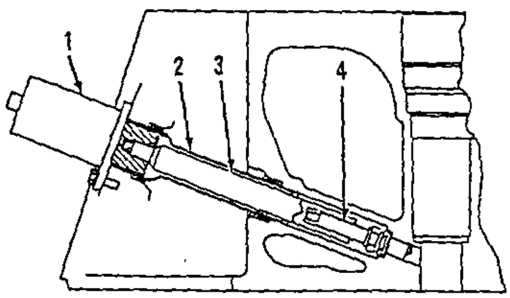


Figure 1: Ignition Group Components
(1) High energy ignition transformer. (2) Tube.
(3) Extender with spring loaded aluminum rod.
(4) Spark plug.

Spark Plugs

An 18 mm J-gap type spark plug (4) is mounted in each cylinder head with the firing end extending into and positioned low in the prechamber insert (see Figure 1). The spark plugs include precious metal electrodes for durability and resistance to electrical erosion. Other features developed for this application include copper-cored electrodes for better heat transfer, and a ceramic resistor for electrical noise suppression.

Failure to use recommended plugs, or failure to properly maintain the spark plugs will affect the engines fuel consumption, emissions, and steady-state stability.

Spark Plug Extenders

The spark plug extenders (3) provide the high voltage electrical connection from the ignition transformer secondary to the spark plug terminal. The one piece extender consists of a brass center electrode and spring-loaded tip within a Teflon insulator.

Ignition Transformers

An ignition transformer (1) is mounted on each cylinder head side cover. The ignition transformer converts the low level primary voltage (approximately 200 Volts) from the magneto to the high level secondary voltage (3,000-30,000 Volts) required to arc across the spark plug J-gap.

There is a separate pin on the magneto output connector for each ignition transformer. The ignition transformers are connected to the magneto output connector by wiring that is installed in a metal conduit assembly. Each ignition transformer primary coil positive terminal is connected to a solid-state electronic switch in the magneto. The wires from the primary coil negative terminals are connected together and attached to the engine block near the magneto.

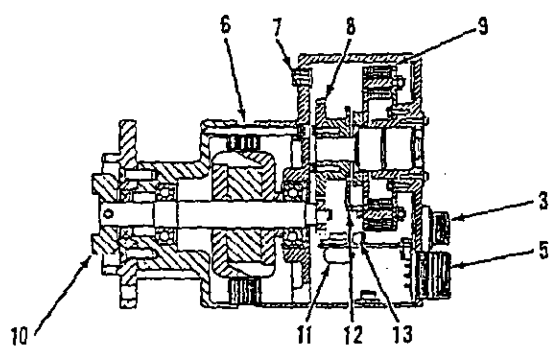


Figure 2. Cross Section Of Solid State Magneto
(3) Magneto interface box input connector.
(5) Magneto output connector. (6) Magneto alternator.
(7) Vent. (8) Speed reduction gears. (9) Pick-up coil.
(10) Drive tang. (11) Energy storage capacitor. (12) Rotating timer arm. (13) SCR solid state switch.

Magneto

The variable timing magneto (Figures 2 and 3) contains a permanent magnet alternator and solid-state electronic switches to control ignition firing. The magneto is mounted at the rear of the engine on the camshaft cover.

A drive gear from the camshaft turns the magneto drive tang (10). The drive tang turns the permanent magnet alternator (6), speed reduction gears (8), and the rotating timer arm (12). As the alternator is turned, it provides power to charge the storage capacitor (11). The G3612 and G3616 magnetos contain two storage capacitors, one stores the charge to fire the right bank (odd numbered) cylinders and the other fires the left bank (even numbered) cylinders. There are separate stationary pick-up coils (9) and solid-state switches (13) for each cylinder.

Two conditions must be met before the storage capacitor will discharge across an ignition transformer primary. The switch in the Magneto Interface Box (MIB) and a solid-state switch in the magneto must be closed. The voltage from the storage capacitor is sent to the MIB and then back to the solid-state switches in the magneto through the magneto interface box connector (3). The switch in the MIB is controlled by signals from the Timing Control System. While the rotating timer arm is over a pick-up coil, the solid-state switch in the magneto paired with that pick-up coil is closed.

Note: The maximum ambient air temperature for magneto operation is 85°C (185°F).

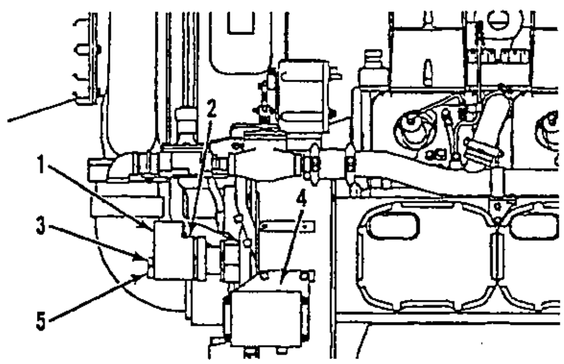


Figure 3: Solid State Magneto
(1) Electronic firing section of magneto. (2) Alternator section of magneto. (3) Magneto interface box input connector. (4) Magneto interface box. (5) Magneto output connector.

Magneto Interface Box

The Magneto Interface Box (MIB) is mounted near the magneto at the rear of the engine. The MIB is an interface between the Timing Control System and the magneto. The Timing Control Module sends signals to the MIB that control when the spark plugs fire. The MIB returns a signal to the Timing Control Module when the spark plugs fire.

Crank Angle Sensor

The crank angle sensor is mounted in a bracket above the flywheel. This passive magnetic pick-up indicates crankshaft angle to the Timing Control Module. A pulse is generated when the Top-Dead-Center (TDC) hole in the flywheel passes beneath the sensor. The TDC pulse is required to calculate actual engine timing.

Speed Sensor

The speed sensor is mounted in a bracket above the ring gear. This passive magnetic pick-up generates a pulse whenever a ring gear tooth on the flywheel passes beneath the sensor. There are 255 teeth on the ring gear. The pulses are used to calculate engine speed, monitor crankshaft angle between the crank angle sensor pulses, and provide a clock signal for the magneto interface box.

Detonation Sensor

The detonation sensor consists of an accelerometer body with a short steel jacketed wiring connection to an electronic buffer unit. The accelerometer body is threaded into the cylinder block and the buffer unit is mounted on a plate nearby. The detonation sensor outputs a filtered and amplified electrical signal that represents the engine's mechanical vibration. This signal is processed by the Timing Control System and used to provide detonation protection.

Components-Remote Mounted

Timing Control Module

The Timing Control Module (TCM) is located inside the ESS control panel and is visible through the window on the front of the panel. The TCM receives information from the Crank Angle Sensor, Speed Sensor, Detonation Sensors, and the Engine Control Module. This information is used to control engine timing.

The TCM controls the engine timing based upon the set point determined by the Engine Control Module (ECM). This is accomplished by receiving the desired timing set point from the ECM over a dedicated data link and generating the proper control signals for the magneto interface box. The TCM returns its status (caution and fault codes) along with the

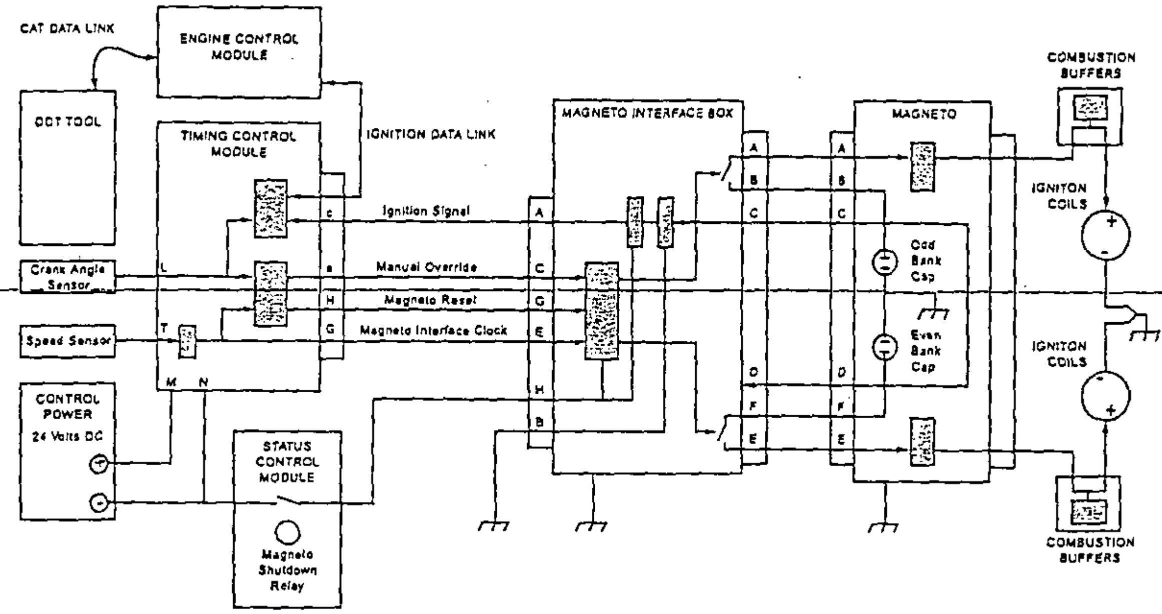


Figure 4: G3600 Ignition Timing System.

actual timing and the detonation level to the ECM for processing.

Ignition Timing System

System Operation

The Engine Supervisory System (ESS) integrates several control subsystems installed on the engine. With the ability to communicate with the various subsystems, the ESS optimizes each controlled parameter to ensure maximum engine performance. The subsystems include start/stop/prelube logic, engine monitoring and protection, and engine control which includes the Ignition Timing System (Figure 4). The ESS panel is the control center for the Engine Supervisory System and houses the control modules of each subsystem. The Timing Control Module (TCM) (Figure 5) maintains the ignition timing at the set point determined by the Engine Control Module (ECM). This is accomplished by receiving the desired timing set point from the ECM across a dedicated data link and generating the proper control signals for the magneto interface box.

Timing Control Module (TCM) Control Signals

When the manual override signal is held below 1 volt and engine speed is greater than 500 rpm, the ignition system operates in the electronic timing mode. The Timing Control Module (TCM) generates the magneto interface clock signal which the Magneto Interface Box (MIB) uses to keep track of the engines rotational position. The magneto interface clock signal is a square wave version of the speed sensor signal. The TCM sends a magneto reset pulse once per crankshaft revolution. When the MIB receives the magneto reset pulse, it counts 9 magneto interface clock signal edges and then closes the switch in the MIB which fires a cylinder. The MIB continues to monitor the magneto interface clock signal and fires the remaining cylinders in the rotation. When the magnetos odd bank capacitor discharges to fire a cylinder an ignition pulse is generated. The ignition signal is a reduced voltage version of the ignition pulse.

The TCM calculates the engine timing by comparing the timing offset between the ignition signal for cylinder 1 and the Top-Dead-Center (TDC) pulse from the crank angle sensor.

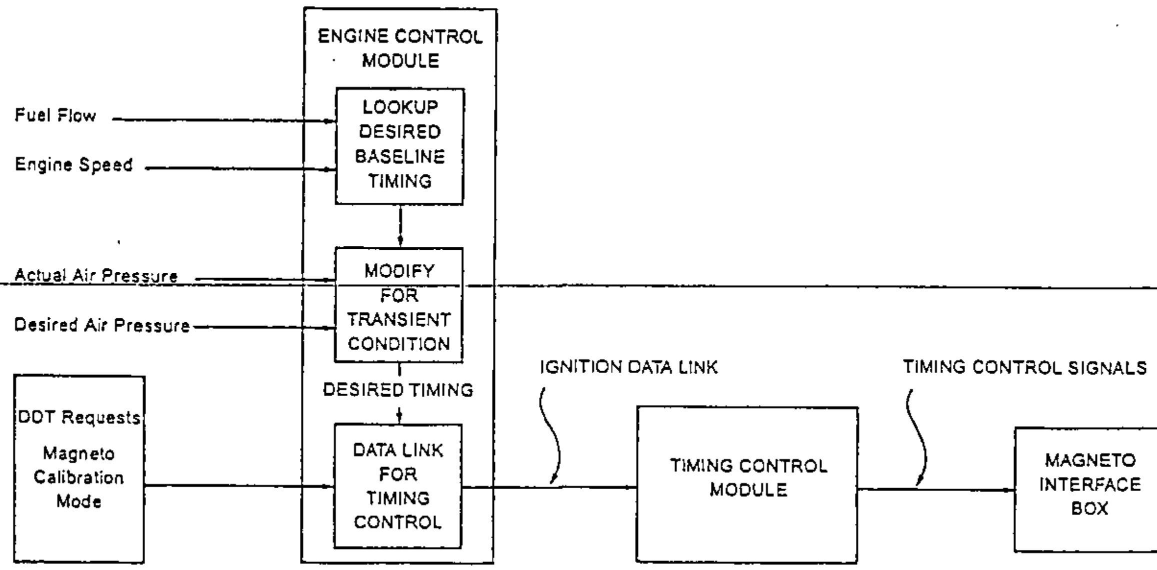


Figure 5: G3600 Ignition Timing Control Logic

When the manual override signal is above 1 volt, the ignition system operates in the magneto calibration "MAG CAL" mode. A DDT service tool is used to request the "MAG CAL" mode. In the "MAG CAL" mode, electronic timing is disabled. The solid-state switches in the MIB are always closed and ignition timing is fully advanced to 28 ± 1 degree. In "MAG CAL" mode, a spark plug will fire as soon as the timing arm in the magneto enters the pick-up coil field associated with that plug. The ignition timing is calculated in the same manner as it is in the electronic timing mode.

At engine start-up the Ignition System operates in the "MAG CAL" mode until the engine is above 500 rpm. The TCM checks for the ignition pulse firing signal from cylinder 1 between 120 and 300 rpm. The TCM will display the "No Magneto Interface Signal" fault if this ignition pulse is not detected for 0.3 seconds. Between 300 and 500 rpm the TCM compares the current timing of cylinder 1 with the "MAG CAL" timing stored in internal memory. The "Magneto Out of Calibration" fault will be displayed if the two values do not match.

Ignition Timing Control Logic

The primary function of the Engine Control Module (ECM) is to govern the engine speed and control the air/fuel ratio. It also has the role of systems coordinator. The software to operate the ECM is stored in a personality module that is mounted on the front of the ECM. The personality module contains many of the protection set points and stores the maps that are used for engine control. The map to control the ignition timing is stored in the personality module.

A DDT service tool connected to the Cat Data Link can be used to read the actual and the desired engine timing. The information on the Cat Data Link is sent from the ECM. The DDT is also used to place the ignition system in the magneto calibration "MAG CAL" mode. The ECM receives the request from the DDT and flags the Timing Control Module (TCM) to operate in the "MAG CAL" mode. In "MAG CAL" mode, the solid-state switches in the MIB are always closed and the ignition timing is fully advanced to 28 ± 1 degree.

If the DDT is not requesting "MAG CAL" mode, the ECM flags the TCM to operate in electronic timing mode. In electronic timing mode the ECM sends the desired timing set point to the TCM over a dedicated data link. The desired timing set point is selected from the ignition timing map based on fuel flow and engine speed. The set point value is modified during transient conditions based on the actual and desired inlet manifold air pressure.

The ECM also uses the detonation level from the TCM to retard the engine timing if excessive levels of detonation are measured. The retarded timing essentially reduces the peak cylinder pressure.

Customer Connections

The only customer connections required to complete the ignition system are control power for the ESS panel and interconnect wiring between the ESS panel and the engine mounted junction box.

Two interconnect harnesses are available from Caterpillar to complete the wiring from the ESS panel to the junction box. One harness contains all wiring required for the start/stop/prelube systems, monitoring and protection system, and control systems which includes the ignition wiring. The other harness connects the engine thermocouples to the pyrometer(s) in the ESS panel. The harnesses are available in lengths of 20, 50, and 100 feet.

Reference Material

Special Instruction - *Installation and Initial Start-Up*. SEHS9708 for G3608 and G3606. SEHS9549-01 for G3616 and G3612.

This publication provides the information required to install the interconnect wiring between the ESS panel and the engine mounted junction box and completes the initial engine start-up.

Electrical Schematics – Wiring schematics are shipped with the engine and should be kept with the service manual. All ignition system components, wiring, and terminal connections are shown in the schematic.

Service Manual - *Systems Operation Testing and Adjusting*. SENR4258-03 for G3608 and G3606. SENR5528-03 for G3616 and G3612.

Attachment 9

Proposed Replacement
Engine Driven Pump and Generator No. 1

3508 Prime Power Generator Set
820 kW Power Rating
Emissions
Systems Operation

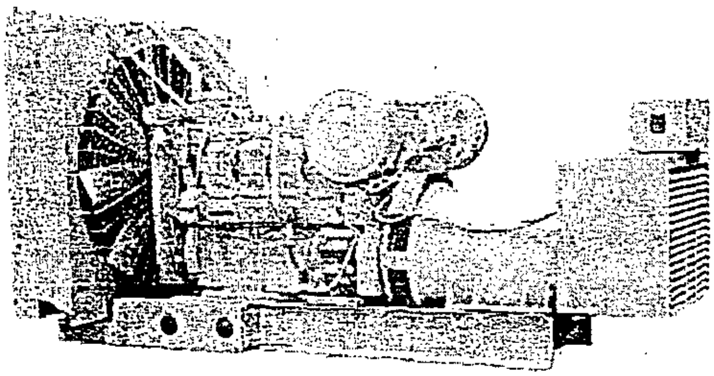
Alexander Orr, Jr.
Water Treatment Plant

CATERPILLAR®

Generator Set

3508
Prime Power

650-820 kW 60 Hz



Shown with
Optional Equipment

SPECIFICATIONS

V-8, 4-Stroke-Cycle Watercooled Diesel

Bore—mm (in)	170 (6.7)
Stroke—mm (in)	190 (7.5)
Displacement—L (cu in)	34.5 (2,105)
Compression Ratio	13.5:1

FEATURES

■ **CAT® DIESEL GENERATOR SETS**
Factory designed, certified prototype tested with torsional analysis. Production tested and delivered to you in a package that is ready to be connected to your fuel and power lines. EPG Designer computer sizing available. Supported 100% by your Caterpillar dealer with warranty on parts and labor. Extended warranty available in some areas. The generator set was designed and manufactured in an ISO 9001 compliant facility. Generator set and components meet or exceed the following specifications: AS1359, AS2789, ABGSM TM3, BS4999, DIN6271, DIN6280, EGSA101P, JEM1359, IEC 34/1, ISO3046/1, ISO DIS8528, NEMA MG1-22

■ **RELIABLE, FUEL EFFICIENT DIESEL**
The compact, four-stroke-cycle diesel engine combines durability with minimum weight while providing dependability and economy. The fuel system operates on a variety of fuels.

■ **CATERPILLAR® SR4 GENERATOR**
Single bearing, wye connected, static regulated, brushless permanent magnet excited generator designed to match the performance and output characteristics of the Caterpillar diesel engine that drives it.

■ **EXCLUSIVE CATERPILLAR VOLTAGE REGULATOR**
Three-phase sensing and Volts-per-Hertz regulation give precise control, excellent block

CATERPILLAR® SR4 GENERATOR

Type	Brushless, revolving field, solid-state exciter
Construction	Single bearing, close coupled
Three phase	Wye connected
Insulation	Class F with tropicalization and antiabrasion
Enclosure	Drip proof IP 22
Alignment	Pilot shaft
Overspeed capability	150%
Wave form	Less than 5% deviation
Paralleling capability	Standard with adjustable voltage droop
Voltage regulator	3-phase sensing with Volts-per-Hertz
Voltage regulation	Less than ± 1/2%
Voltage gain	Adjustable to compensate for engine speed droop and line loss
TIF	Less than 50
THF	Less than 3%

CATERPILLAR CONTROL PANEL

24 Volt DC Control
Vibration isolated
NEMA 1, IP 22 enclosure
Dead front
Lockable hinged door
Generator instruments meet ANSI C-39-1

Voltages Available
60 Hz
139/240, 227/480
346/600, 380, 4160

(Adjustable a minimum of ±10%)
Other voltages available–consult your Caterpillar dealer.

STANDARD EQUIPMENT

Engine
Aftercooler
Air cleaner
Breather, crankcase
Cooler, lubricating oil
Exhaust fitting and flange
Filters, right hand
  fuel, full flow
  lubricating oil, full flow
Flywheel housing
Governor
  2301A, speed control
Lifting eyes
Manifold, exhaust, dry
Pumps,
  fuel transfer, gear driven
  lubricating oil – gear driven
  jacket water – gear driven
Rails, mounting
Shutoff, manual
Starting, electric, 24 Volt DC
Turbochargers
Vibration damper

Generator
SR4 brushless with VR3 voltage regulator

ELECTRONIC MODULAR CONTROL PANEL (EMCP)

Standard Generator Controls and Monitoring:
Ammeter/voltmeter phase selector switch
Digital ammeter, voltmeter, and frequency meter
Voltage adjust rheostat

Standard Engine Controls and Monitoring:
Automatic/manual start-stop control
Engine control switch for:
  off/reset, auto start,
  manual start, stop,
  cooldown timer,
  cycle cranking,
  emergency stop pushbutton

Safety shutoff protection and LED indicators for:
High coolant temperature
Low oil pressure
Overcrank
Overspeed

OPTIONAL EQUIPMENT

Engine
Air cleaner, heavy duty
Charging alternator
Cooling systems
Exhaust fittings
Governor, Woodward 3161, 2301A load share
Protection devices
Tachometer drive

Generator
Extension terminal box
Manual voltage control
Permanent magnet excitation
RFI Filters –
  N level (VDE 875), BS800
  MIL Std 461B
Space heater
Temperature rise detectors

Switchgear
Automatic start-stop
Battery charger
Circuit breaker
Manual
Electric operated

Switchgear
Enclosure — floor standing NEMA 1
Main load buss
Paralleling
  manual
  permissive
Protective relays

Control Panel
Annunciator panel and prealarm module (meets NFPA 99/110 requirements)
Enclosure, NEMA 12/IP 23
Provision for:
  auxiliary relay
  charging voltmeter
  cycle cranking
  governor speed switch
  manual start-stop module
  prealarm module
  starting aid switch
  synchronizing lights

Caterpillar® EMCP II

Electronic Modular Control Panel

The Electronic Modular Control Panel (EMCP) is a generator-mounted control panel, available on all Caterpillar packaged generator sets. It utilizes environmentally sealed, solid-state, micrprocessor-based modules for engine control and AC metering. This new application of mature, high-tech electronics to generator monitoring provides more features, accuracy and reliability than present electro-mechanical and many competitive panel systems.

The EMCP provides these standard control and monitoring features, many of which are options on other panels:

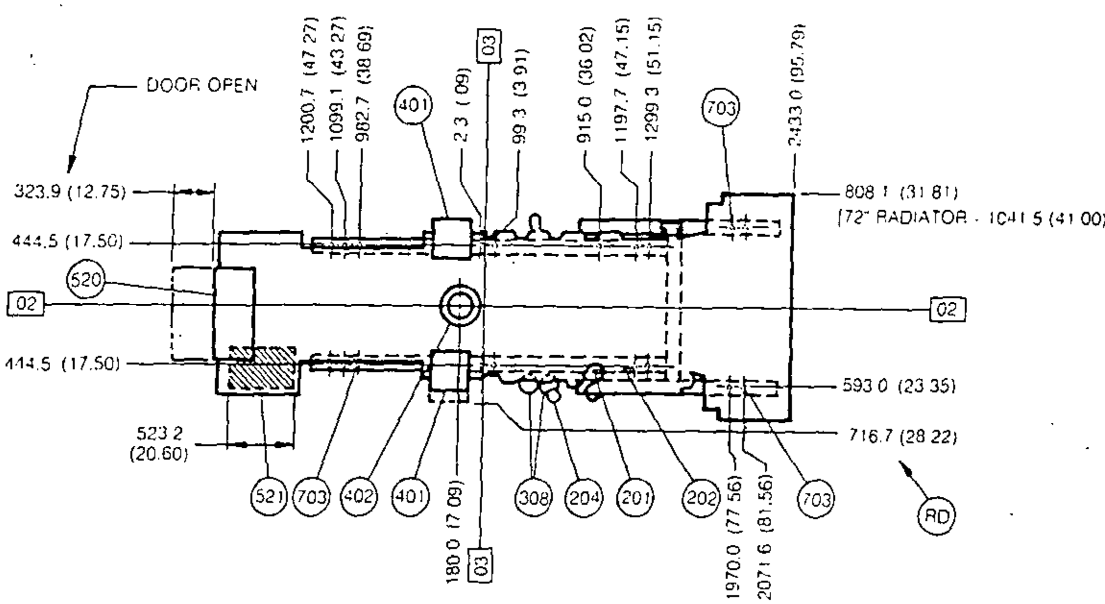
- Automatic/manual start-stop engine control with programmable safety shutdowns and associated flashing LED indicators for low oil pressure, high coolant temperature, overspeed, overcrank and emergency stop
- Cycle cranking–adjustable 1-60 second crank/rest periods
- Cooldown timer–adjustable 0-30 minutes
- Energized to run or shutdown fuel control systems
- LCD digital readout for: Engine oil pressure; coolant temperature; engine rpm; system DC volts; .... engine running hours; system diagnostic codes; generator AC volts; generator AC amps; and generator frequency
- Engine control switch
- Ammeter-voltmeter phase selector switch
- Emergency stop pushbutton
- Indicator/display test switch
- Voltage adjust potentiometer

CATERPILLAR®

TECHNICAL DATA

3508 Prime Power Generator Sets			60 Hz–1800 RPM			
Rating Information	Power Rating @ 0.8 PF with Fan	kW	650	680	725	820
		kV•A	812	850	906	1025
	Engine Bhp without Fan		962	1014	1089	1220
Physical Factors	Length	mm	4471	4449	4449	4583
		in	176.0	175.2	175.2	180.4
	Width	mm	1703	1703	1703	2092
		in	67.0	67.0	67.0	82.4
	Height	mm	2361	2361	2361	2459
		in	93.0	93.0	93.0	96.8
	Weight	kg	7855	8210	8210	8490
		lb	17,320	18,100	18,100	18,720
	Generator Frame Size		589	681	681	685
Lubrication & Cooling Systems	Engine Lubricating Oil Capacity	L	227	227	227	227
		qts	240	240	240	240
	Engine Coolant Capacity with Radiator	L	225	225	225	280
		gal	59	59	59	75
	Standard Radiator Arrangement Data: Air Flow (Max @ Rated Speed)	m³/min	1178	1253	1432	1594
		cfm	41,595	44,243	50,564	56,284
	Air Flow Restriction (after radiator)	kPa	0.12	0.12	0.12	0.12
		in water	0.5	0.5	0.5	0.5
	Ambient Air Capability (TMI)	Deg. C	45	44	43	52
		Deg. F	113	111	110	126
	Radiator Size		60/13	60/13	60/13	72/25
Exhaust System	System Backpressure (Max Allowable)	kPa	6.7	6.7	6.7	6.7
		in water	27	27	27	27
	Exhaust Flange Size (Internal Diameter)	mm	203	203	203	203
		in	8.0	8.0	8.0	8.0
Performance Data @ Rated Conditions	Fuel Consumption (100% load) with Fan per ISO3046/1: +5%, -0% tolerance	L/Hr	183.7	192.8	208.2	233.9
		gph	48.5	50.9	55.0	61.8
	Fuel Consumption (75% load) with Fan	L/Hr	139.2	144.7	157.5	177.7
		gph	36.8	38.5	41.6	46.9
	Fuel Consumption (50% load) with Fan	L/Hr	98.9	102.7	110.7	124.4
		gph	26.1	27.2	29.2	32.9
	Combustion Air Inlet Flow Rate	m³/min	62.1	64.3	67.9	74.9
		cfm	2193	2270	2398	2645
	Exhaust Gas Flow Rate	m³/min	165	173	185	208
		cfm	5819	6091	6536	7362
	Heat Rejection to Coolant (total)	kW	441	463	501	566
		BTU/min	25,080	26,331	28,492	32,188
	Heat Rejection to Exhaust (total)	kW	750	790	857	981
		BTU/min	42,652	44,927	48,737	55,789
	Heat Rejection to Atmosphere from Engine	kW	103	104	106	109
		BTU/min	5858	5914	6028	6199
	Heat Rejection to Atmosphere from Generator	kW	45.9	48.1	52.9	48.6
		BTU/min	2610	2735	3010	2765
	Exhaust Gas Stack Temperature	Deg. C	515	523	536	552
		Deg. F	958	973	997	1026
	Deration for Engine Altitude–3% per 305m (1000 ft) above	m	2175	1675	950	725
		ft	7136	5495	3117	2379

PRIME GEN SET PACKAGE — TOP VIEW



02	Centerline of Engine	204	Fuel Filter	520	Control and Power Panel
03	Rear Face of Cylinder Block	308	Oil Filter	521	Conduit Entrance
201	Fuel Inlet	401	Air Inlet	703	Customer Mounting Holes
202	Excess Fuel Return	402	Exhaust	RD	Removal Distance

For overall length see technical data section (page

Note: General configuration not to be used for installation. See general dimension drawings for detail.

CONDITIONS AND DEFINITIONS

Prime — Output available with varying load for an unlimited time. Prime power in accordance with ISO8528. 10% overload power in accordance with ISO3046/1, AS2789, DIN6271, and BS5514 available on request.
Standby — Output available with varying load for the duration of the interruption of the normal source power. Fuel stop power in accordance with ISO3046/1, AS2789, DIN6271, and BS5514.
Continuous — Output available without varying load for an unlimited time. Continuous power in accordance with ISO8528, ISO3046/1, AS2789, DIN6271 and

Ratings are based on SAE J1349 standard conditions. These ratings also apply at ISO3046/1, DIN6271 and BS5514 standard conditions.
Fuel rates are based on fuel oil of 35° API (16° C or 60° F) gravity having an LHV of 42 780 kJ/kg (18,390 Btu/lb) when used at 29° C (85° F) and weighing 838.9 g/L (7.001 lbs/U.S. gal.).

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PANTROPIC POWER PRODUCTS, INC.

8205 N.W. 58th Street , Miami, FL 33166

FAX COVER

DATE: 10 - 20 - 00	FROM: Robert Butt , Project Manager
COMPANY: MIAMI DADE WASA	TEL. # (305) 592-4944 , ext 3108
ATTN : MR. RICHARD O'ROURKE	FAX # (305) – 574 - 7875
FAX # : (305 – 669 - 5749 TEL) FAX # 305-669-5717	REFERENCE : REQUEST FOR INFORMATION
PAGES : 3 (Including this page)	ALEXANDER ORR JR. WTP PROJECT GENERATOR EQUIPMENT

(PLEASE ADVISE IMMEDIATELY IF ALL PAGES ARE NOT RECEIVED)

Mr. O'Rourke :

Please find attached Caterpillar factory issued technical information pertaining to the generator set engine exhaust emissions and fuel consumption data in response to your inquiry.
This information is specific to the generator set model that is to be furnished by Pantropic Power Products , Inc. for the above referenced Project.

Response: Date:

EMISSIONS

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ EXH STK DIA 8.0 IN
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM

INFO CODE 05 - EMISSIONS DATA * * REFERENCE NOTES - NOT TO EXCEED * * * * * * *
EMISSIONS DATA MEASUREMENT IS CONSISTENT WITH THOSE DESCRIBED IN EPA CFR 40 PART 86 SUBPART D AND ISO 8178-1 FOR MEASURING HC, CO, CO2 AND NOX. THESE PROCEDURES ARE VERY SIMILAR TO THE METHODS DESCRIBED IN EPA CFR 40 PART 60 APPENDIX A METHOD 25A FOR HYDROCARBONS, METHOD 10 FOR CO, METHOD 7E FOR NOX.

DATA SHOWN IS BASED ON STEADY STATE ENGINE OPERATING CONDITIONS OF 77 DEG F, 28.42 IN HG AND NUMBER 2 DIESEL FUEL WITH 35 DEG API AND LHV OF 18,390 BTU/LB.

TO PROPERLY APPLY THIS DATA YOU MUST REFER TO PERFORMANCE PARAMETER DM1176 FOR ADDITIONAL INFORMATION, (APPLICATION GKN402, PROGRAM 03).

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ EXH STK DIA 8.0 IN
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM

* INFO CODE 05 - EMISSIONS DATA * * * * * RATED SPEED * * * * STANDARD TIMING
"NOT TO EXCEED DATA"

GEN PWR EKW	% LOAD	ENG PWR BHP	NOX (AS NO2)	CO	TOTAL HC LB/HR	PART MATTER	O2 (DRY) IN EXH (VOL) %	SMOKE OPAC %	BOSCH SMOKE NO.
900.0	100	1332.2	37.46	2.10	.68	.310	9.90	1.0	1.28
675.0	75	1008.8	33.07	1.22	.77	.250	11.40	0.9	1.28
450.0	50	690.9	25.67	.83	.46	.190	12.40	1.0	1.28
225.0	25	378.9	16.92	.82	.34	.150	13.50	1.0	1.28

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ EXH STK DIA 8.0 IN
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM

INFO CODE 05 - EMISSIONS DATA * * * * * RATED CONDITIONS * * STANDARD TIMING
"NOMINAL DATA"
AT RATED:

WET EXHAUST MASS	12838 LB/HR
WET EXHAUST FLOW (884 DEG F STACK TEMP)	7331 CFM
WET EXHAUST FLOW RATE (32 DEG F AND 29.98 IN HG)...	2681 STD CFM
DRY EXHAUST FLOW RATE (32 DEG F AND 29.98 IN HG)...	2473 STD CFM
FUEL FLOW RATE	66.0 GAL/HR

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM
CERTIFICATION YEAR CERT AGENCY
INFO CODE 01 - GENERAL PERFORMANCE DATA *

GEN W/F EKW	PER CENT LOAD	ENG PWR BHP	ENG BMEP PSI	S FUEL CONSUM LB/BHP-HR	FUEL RATE GPH	INTAKE MANF T DEG F	INTAKE MANF P IN-HG	INTAKE AIR FL CFM	EXH MANF T DEG F	EXH STK T DEG F	EXH GAS FL CFM
900.0	100	1332	278	.350	66.5	214	78.3	2821	1262	884	7327
810.0	90	1202	251	.346	59.4	208	71.8	2691	1177	831	6695
720.0	80	1073	224	.344	52.8	203	64.5	2532	1103	787	6073
675.0	75	1009	211	.346	49.8	202	60.6	2436	1079	776	5787
630.0	70	945	197	.347	46.8	200	56.4	2334	1052	764	5484
540.0	60	817	171	.350	40.9	198	47.8	2112	1000	742	4866
450.0	50	691	144	.357	35.2	196	39.4	1886	952	723	4269
360.0	40	568	119	.368	29.9	195	31.2	1667	906	705	3708

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM
CERTIFICATION YEAR CERT AGENCY
INFO CODE 01 - GENERAL PERFORMANCE DATA *

GEN W/F EKW	PER CENT LOAD	ENG PWR BHP	ENG BMEP PSI	S FUEL CONSUM LB/BHP-HR	FUEL RATE GPH	INTAKE MANF T DEG F	INTAKE MANF P IN-HG	INTAKE AIR FL CFM	EXH MANF T DEG F	EXH STK T DEG F	EXH GAS FL CFM
270.0	30	443	93	.386	24.4	193	23.0	1441	858	686	3157
225.0	25	379	79	.400	21.6	192	19.2	1335	827	670	2888
180.0	20	315	66	.420	18.9	191	16.2	1250	780	640	2638
90.0	10	184	38	.504	13.3	189	10.8	1098	670	564	2157

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM

INFO CODE 02 - HEAT REJECTION DATA *

GEN W/F EKW	PER CENT LOAD	REJ TO JW BTU/MN	REJ TO ATMOS BTU/MN	REJ TO EXH BTU/MN	EXH RCOV TO 350F BTU/MN	FROM OIL CLR BTU/MN	FROM AFT CLR BTU/MN	WORK ENERGY BTU/MN	LHV ENERGY BTU/MN	HHV ENERGY BTU/MN
900.0	100	34804	8246	53116	28435	7621	11033	56472	142743	152070
810.0	90	31051	7166	46633	24227	6768	9327	50955	127559	135862
720.0	80	27639	6483	41231	20530	6028	7621	45496	113228	120621
675.0	75	26103	6199	38842	19222	5687	6824	42766	106915	113853
630.0	70	24511	5971	36454	17857	5346	5971	40036	100432	106972
540.0	60	21440	5573	31847	15241	4663	4322	34691	87750	93494
450.0	50	18483	5175	27525	12909	4038	2957	29288	75637	80585
360.0	40	15639	4777	23430	10805	3412	1763	24113	64035	68244

3508 DI TA JW DRY MANF TURBO QTY WDWRD GOV
TM4516-09 PGS STANDBY 60 HERTZ
GEN 900.0 W/F EKW 930.0 W/O F EKW W/F BHP 1337 W/O F BHP @ 1800 RPM

INFO CODE 02 - HEAT REJECTION DATA *

GEN W/F EKW	PER CENT LOAD	REJ TO JW BTU/MN	REJ TO ATMOS BTU/MN	REJ TO EXH BTU/MN	EXH RCOV TO 350F BTU/MN	FROM OIL CLR BTU/MN	FROM AFT CLR BTU/MN	WORK ENERGY BTU/MN	LHV ENERGY BTU/MN	HHV ENERGY BTU/MN

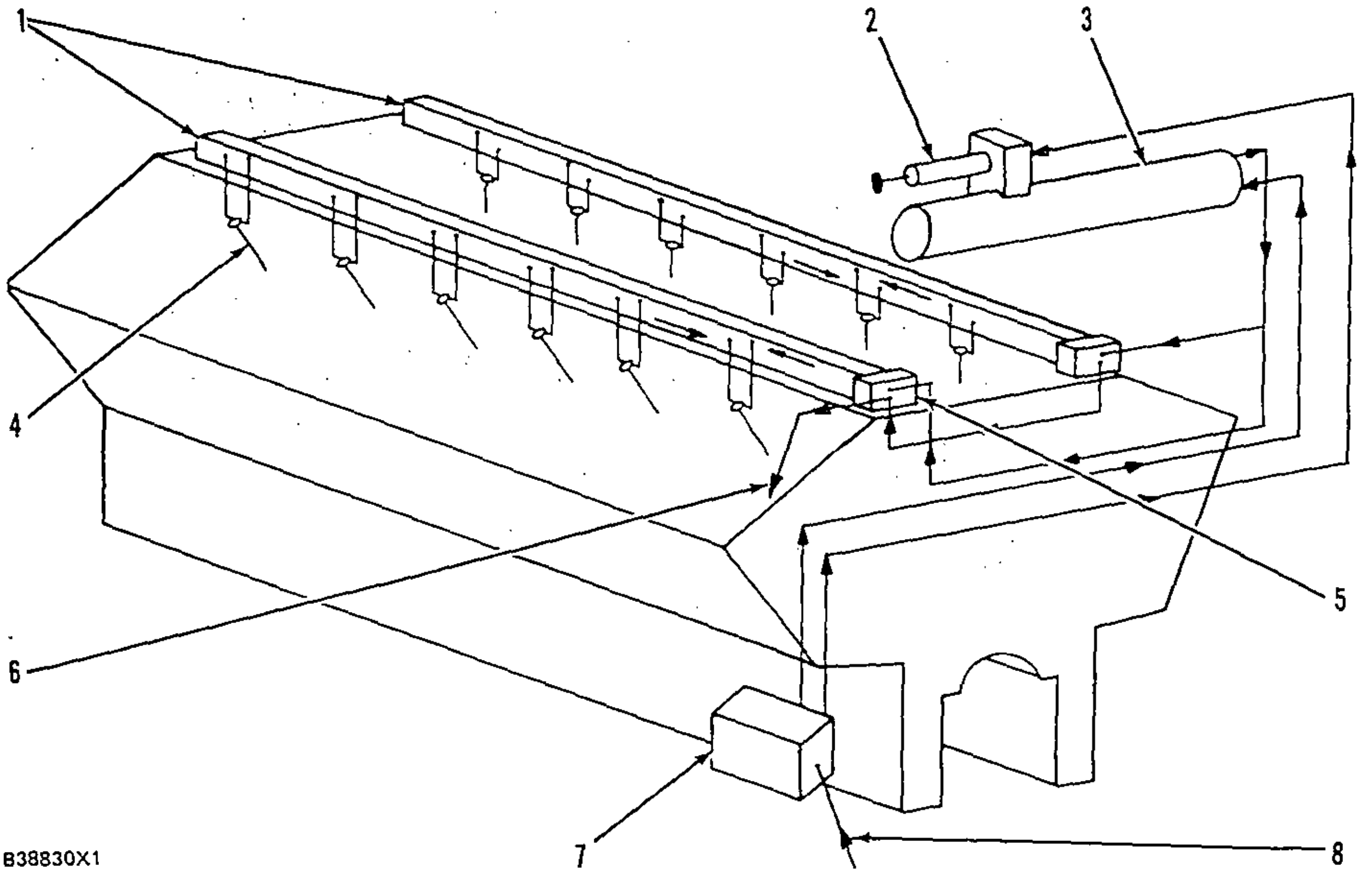
?ANSMISSION VERIFICATION REPORT

TIME : 10/20/2000 11:03

DATE,TIME	10/20 11:01
FAX NO./NAME	3056695717
DURATION	00:01:14
PAGE(S)	03
RESULT	OK
MODE	FINE ECM

FUEL SYSTEM

GENERAL

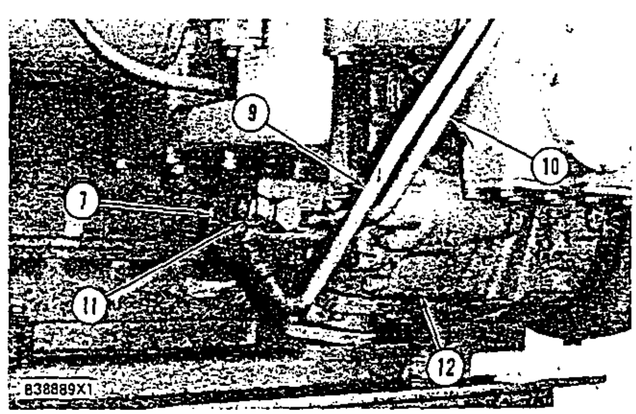


FUEL FLOW SCHEMATIC
(3512 Illustrated)

1. Fuel manifolds. 2. Fuel priming pump. 3. Fuel filter housing. 4. Fuel injectors. 5. Pressure regulating valve. 6. Fuel return to supply. 7. Fuel transfer pump. 8. Fuel from supply.

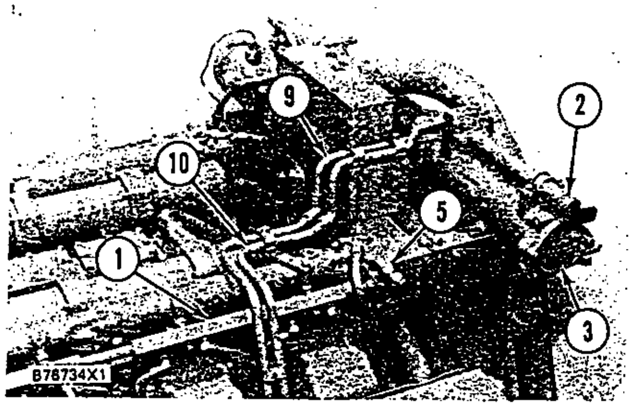
Fuel transfer pump (7) is located on the right side of the engine. The lower shaft of engine oil pump (12) drives the gear type transfer pump. Fuel from the supply tank is pulled through a primary fuel filter by the transfer pump and sent to the fuel filter housing.

The transfer pump has a check valve and a bypass valve. The check valve is located in the pump head assembly located behind where line (9) is connected. The check valve prevents fuel flow back through the transfer pump when priming pump (2) is used. The bypass valve is located behind a cap (plug) in the drive end of the pump. The bypass valve limits the maximum pressure of the fuel. It will open the outlet side of the pump to the pump inlet if the fuel pressure goes up to 860 kPa (125 psi). This helps prevent damage to fuel system components caused by too much pressure.



RIGHT SIDE OF ENGINE

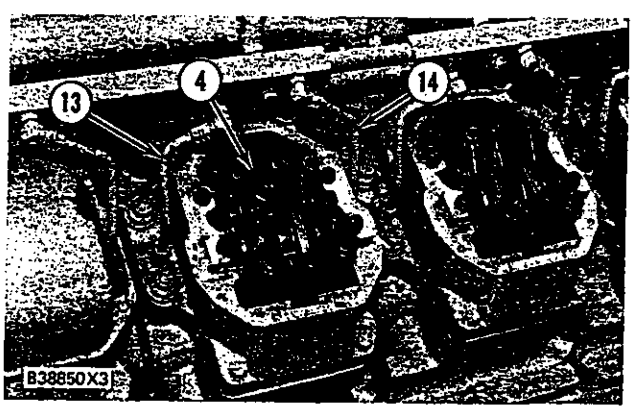
7. Fuel transfer pump. 9. Fuel line to filter housing. 10. Fuel line to priming pump. 11. Elbow (fuel supply). 12. Engine oil pump.



RIGHT SIDE OF ENGINE

1. Fuel manifold (right hand). 2. Priming pump. 3. Fuel filter housing. 5. Pressure regulating valve. 9. Fuel line to filter housing (from transfer pump). 10. Fuel line to priming pump (from transfer pump).

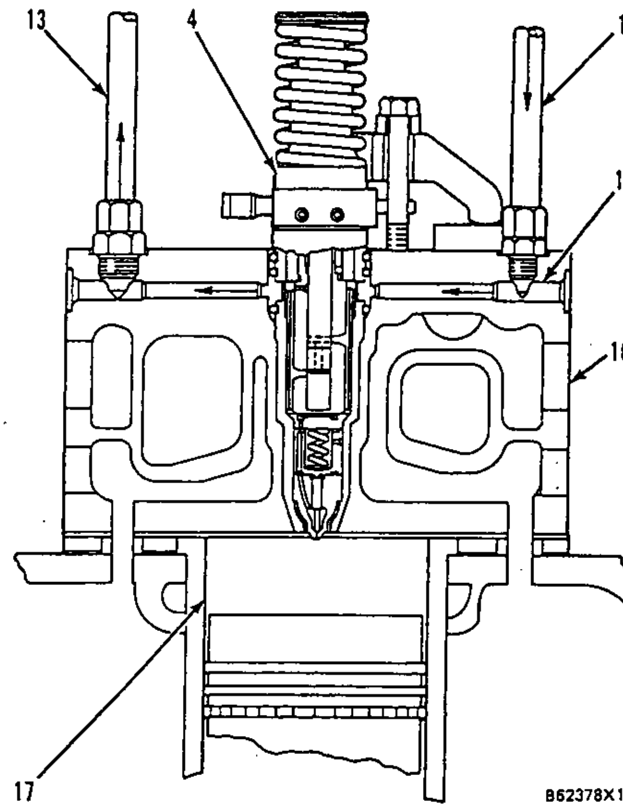
The transfer pump pushes fuel through fuel filter housing (3) to fuel manifolds (1). The fuel manifolds have two sections. The fuel flows through the top section of the manifold to inlet fuel line (14) connected to the right side of each cylinder head. On earlier engines, filter screens are located in the fittings where fuel goes into each cylinder head. On later engines, the filter screens are located in the ports of the unit injector. A drilled passage (15) in cylinder head (16) takes fuel to a circular (shape of a circle) chamber around the injector. The chamber is made by O-rings on the outside diameter of injector (4) and the injector bore in the cylinder head.



CYLINDER HEADS

4. Injector. 13. Outlet fuel line. 14. Inlet fuel line.

Only part of the fuel in the chamber is used for injection. Approximately 4 1/2 times as much fuel as needed for normal combustion flows through the chamber to a drilled passage in the left side of the cylinder head. This passage is connected by outlet fuel line (13) to the bottom section of the fuel manifold. This constant flow of fuel around the injectors helps to cool them.



FUEL FLOW THRU INJECTOR

4. Injector. 13. Outlet fuel line. 14. Inlet fuel line. 15. Drilled passage. 16. Cylinder head. 17. Cylinder.

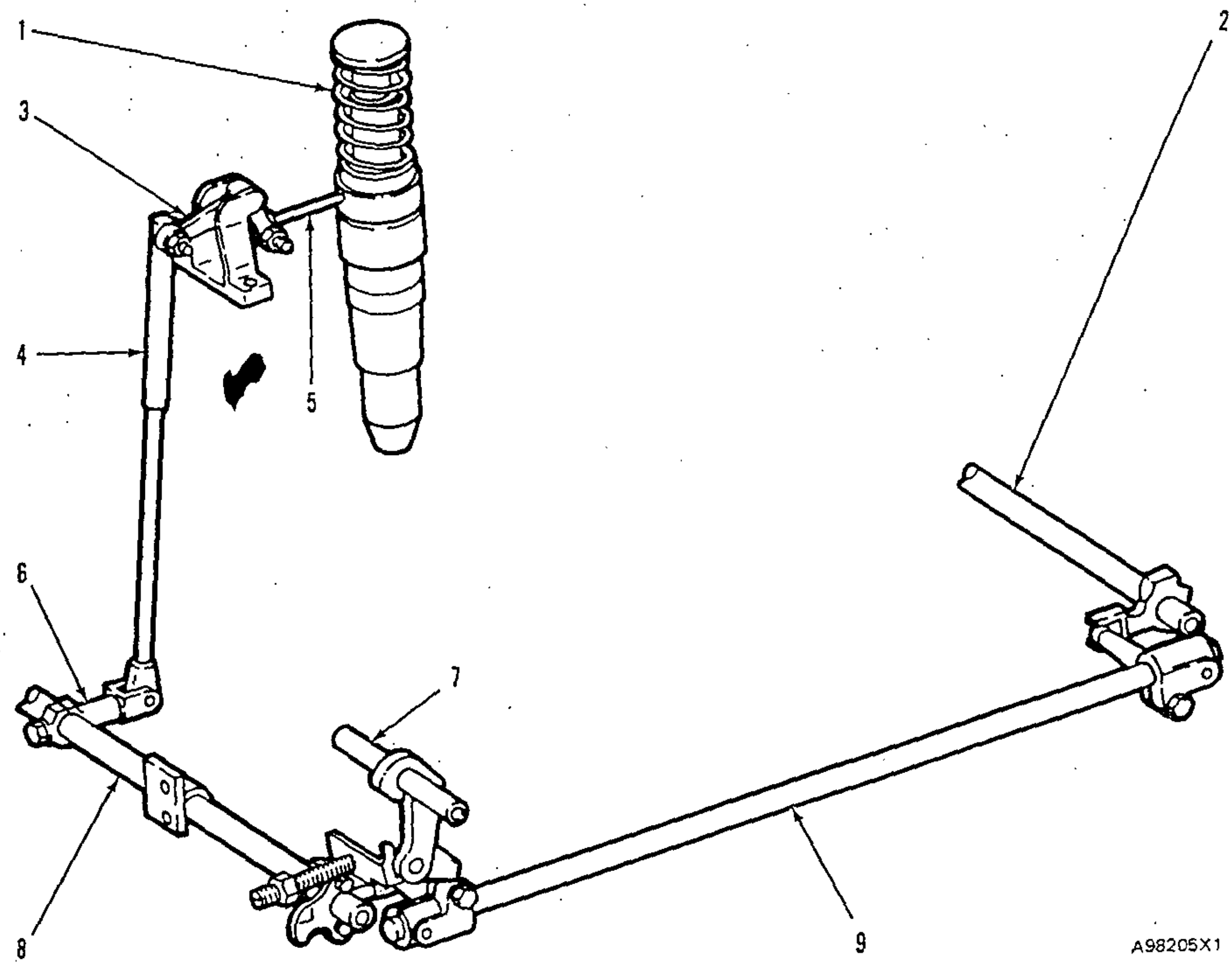
The fuel flows back through the bottom section of each fuel manifold to pressure regulating valve (5), on the front of the right fuel manifold. The fuel flows through this valve and then back to the tank.

Check each engine installation for an excess fuel flow based on fuel consumed (used for combustion). Minimum flow is three times the amount of fuel consumed. Excess fuel is then returned to the fuel tank, not back to the pump inlet. This will make sure that any air in the system will be removed before the fuel is sent back to the injectors.

Pressure regulating valve (5) has a spring and plunger arrangement between the bottom section of the fuel manifolds and the line that returns fuel to the tank. The valve keeps the pressure of the fuel between 415 to 450 kPa (60 to 65 psi).

A syphon break (small orifice) between the inlet and outlet passages in the regulator valve adapter is used when the filters are changed to remove the air from the system. Normally it will not be necessary to use priming pump (2) to force air from the system after the filters are changed. The priming pump must be used when the lines are dry. For example: af[illegible] overhaul or other major fuel system work.

FUEL INJECTION CONTROL LINKAGE



FUEL INJECTOR CONTROL LINKAGE

1. Injector. 2. Control shaft (left side). 3. Bellcrank. 4. Control rod. 5. Rack. 6. Lever. 7. Governor shaft. 8. Control shaft (right side). 9. Cross shaft.

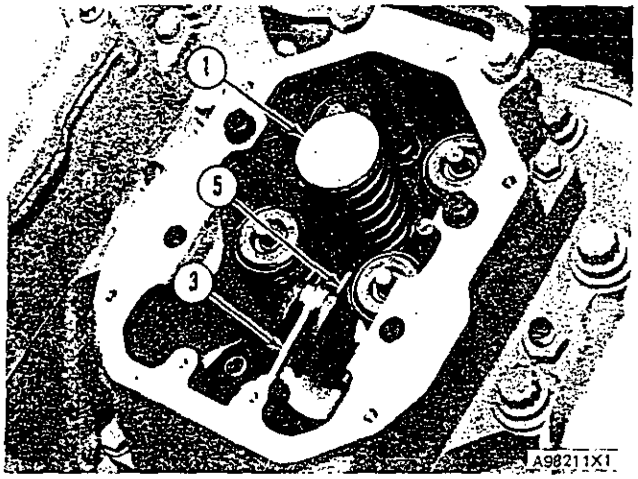
A fuel injector (1) is located in each cylinder head. The position of rack (5) controls the amount of fuel injected into the cylinder. Pull the rack out of the injector for more fuel, push it in for less fuel.

Rack position is changed by bellcrank (3). The bellcrank is moved by control rod (4). The control rods have an adjustment screw on the top. The adjustment screw is used to synchronize the injectors. The control rods are spring loaded. If the rack of one injector sticks (will not move), it will still be possible for the governor to control the other racks so the engine can be shutdown. Each control rod on the right side of the engine is connected by a lever (6) to control shaft (8).

When the rotation of governor shaft (7) is clockwise, as seen from in front of the engine, the action of the governor linkage moves control shaft (8) counterclockwise. That is, in the fuel "ON" direction.

Right control shaft (8) and left control shaft (2) are connected by cross shaft (9). The linkage between the injectors on the left side of the engine and control shaft (2) is similar to the linkage on the right side.

Should the linkage become disconnected from the governor, the weight of the control linkage will move the fuel injector racks to the fuel "SHUTOFF" position, and the engine will stop.



CYLINDER HEAD
(Rocker Shaft Removed for Photo Illustration)
1. Injector. 3. Bellcrank. 5. Rack.

FUEL INJECTOR

The injector is held in position by clamp (3). Fuel is injected when rocker arm (2) pushes the top of the injector down. The movement of the rocker arm is controlled by the camshaft through lifter assembly (7) and push rod (4). The amount of fuel injected is controlled by rack (5). Movement of the rack causes rotation of a gear fastened to plunger (6). Rotation of the plunger changes the effective stroke (that part of the stroke during which fuel is actually injected) of the plunger.

Injection timing is a product of two factors; the angular location of camshaft (8) and the location of plunger (6). The angular location of the camshaft is controlled by the camshaft drive gears at the rear of the engine. The location of the plunger can be adjusted with screw (1).

Injection Cycle

When the plunger is at the top of its stroke, fuel flows from the fuel supply chamber, around the injector and through both the lower and upper ports of the barrel. As plunger (6) is moved down by rocker arm (2), fuel is pushed back into the supply chamber through the lower port. The fuel can now go up through a passage in the center of the plunger and out through the upper port of the barrel. As the lower port is closed by the lower scroll on plunger (6), fuel can still flow through the upper port until it is closed by the upper scroll on plunger (6). At this point, injection starts and the effective stroke begins. During the effective stroke, fuel is injected into the cylinder until the downward movement of plunger (6) causes the lower scroll to open the lower port and release the fuel pressure.

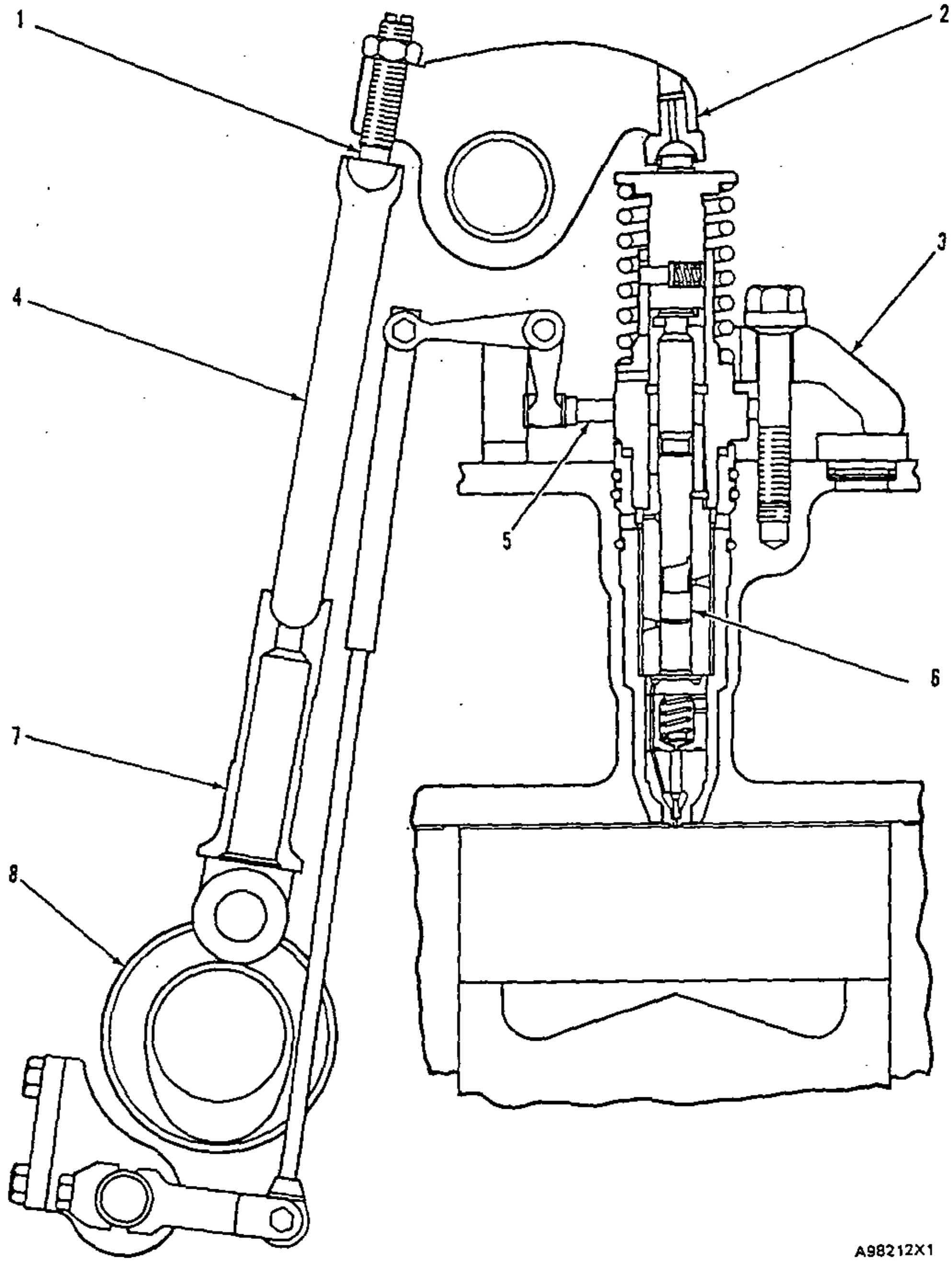
Fuel then goes through the center passage (plunger (6) and the lower port during the remaind of the downstroke. This sudden release of press ε the lower port is opened causes the fuel to hit th deflector with a high force. The spill deflector give protection to the injector housing (nut) from erosio (wear) because of the force of the released fuel. O the return (UP) stroke, the chamber inside the injec tor barrel is filled with fuel again.

The plunger can be turned by rack (5) at the sam time it is moved up and down by rocker arm (2). Th upper section of the plunger has a flat side that fits ir the gear, which is engaged with the rack. The plunge slides up and down in the gear, which also has a fla side on its inside diameter. The flat sides let the parts turn together. The rack is engaged with the gear. When the rack moves, it turns the plunger through the gear. The rotation of plunger (6) controls injection timing and the fuel output of the injector. Rotation of the plunger changes the relation of the plunger scrolls to the ports in the barrel, and this increases or decreases the length of the effective stroke and the point at which injection takes place.

When rack (5) is moved all the way in against the injector body, no injection takes place during the downstroke of the plunger. This is the fuel "SHUTOFF" position. A small amount of rack mover nt "OUT" from the injector body is used as a) FUEL" movement or "SHUTOFF" position for governing purposes. This "NO FUEL" distance starts at the "ALL-THE-WAY-IN" position of the rack, and ends when the lower scroll opens the lower port and the upper scroll closes the upper port. Movement of the rack "OUT" from this point in the fuel "ON" direction, gives an interval in the plunger stroke when both ports are closed by the scrolls and injection takes place. As the rack is moved farther "OUT" in the fuel "ON" direction, the quantity of fuel during the injection stroke increases until a maximum is available at full rack movement.

The scrolls on plunger (6) are used to time the start of injection and set the amount of fuel per injection stroke. The scrolls can change the start of injection in relation to the engine piston position and the length of the effective stroke in relation to the different engine loads. The start of injection can be retarded (made later) with a decrease or increase in injector output according to the engine needs.

During the fuel injection stroke, fuel passes from the barrel chamber through a valve assembly. The valve assembly has a spring-loaded needle valve with a cone shaped end which operates against a seat angle of the valve is slightly larger than that ι ne



FUEL INJECTOR OPERATION

1. Screw. 2. Rocker arm. 3. Clamp. 4. Control rod. 5. Rack. 6. Plunger. 7. Lifter assembly. 8. Camshaft.

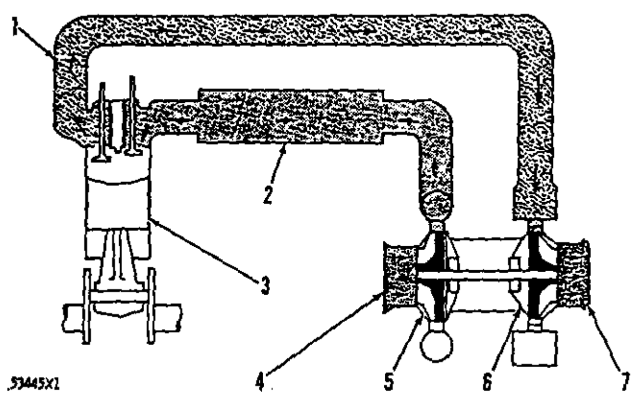
seat to give line contact. The valve opens at approximately 20 000 to 23 300 kPa (2800 to 3400 psi) and closes at approximately 10 300 kPa (1500 psi). The fuel flows from the chamber inside the barrel through drilled passages and grooves in the spring cage, and then through passages around the guide section of the valve to the valve chamber. Here the fuel pressure lifts the needle valve off its seat, and the fuel now flows through the spray tip and out the orifices into the combustion chamber.

A flat check valve is used above the needle valve to keep the high pressure combustion gases out of the injector. If the needle valve is held open by small foreign particles for a moment between injection cycles, combustion gases can come into the injector and cause damage. The injector operates with the flat check valve until the foreign particle has washed on through and normal operation takes place.

The spray tip of the injector extends a short distance below the cylinder head into the combustion chamber. The spray tip has several small orifices spaced evenly around the outside diameter. The tip sprays fuel into the combustion chamber. The top surface of the piston has a shaped (mexican hat-type) crater. The design of the piston causes rotation of the air as it comes through the valves into the combustion chamber, which improves the mixture of the fuel and air.

AIR INLET AND EXHAUST SYSTEM

The components of the air inlet and exhaust system control the quality and amount of air available for combustion. There is a separate turbocharger and exhaust manifold on each side of the engine. A common aftercooler is located between the cylinder heads in the center of the engine. The inlet manifold is a series of elbows that connect the aftercooler chamber to the inlet ports (passages) of the cylinder heads. Two camshafts, one in each side of the block, control the movement of the valve system components.



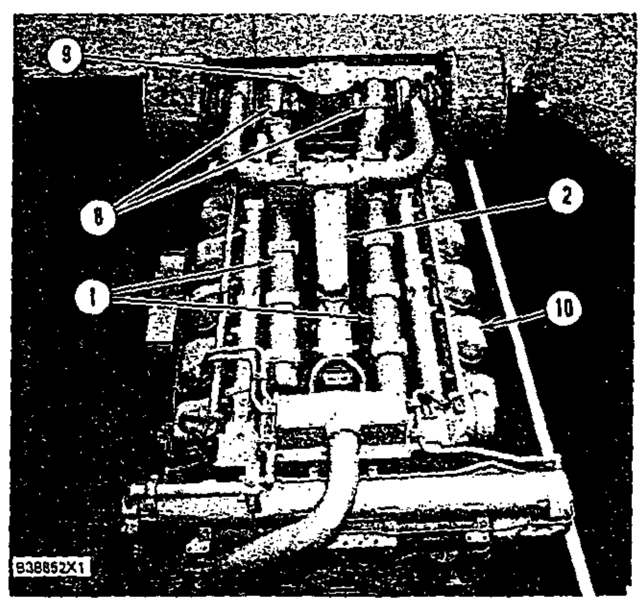
AIR INLET AND EXHAUST SYSTEM

1. Exhaust manifold. **2.** Aftercooler. **3.** Engine cylinder. **4.** Air inlet. **5.** Turbocharger compressor wheel. **6.** Turbocharger turbine wheel. **7.** Exhaust outlet.

Air flow is the same on both sides of the engine. Clean inlet air from the air cleaners is pulled through air inlet (4) by compressor wheel (5). The rotation of the compressor wheel causes compression of the air and forces it through a tube to aftercooler (2). The aftercooler lowers the temperature of the compressed air before it goes into the inlet chambers in each cylinder head. This cooled, compressed air fills the inlet chambers in the cylinder heads. Air flow from the inlet chamber into the cylinder is controlled by the intake valves.

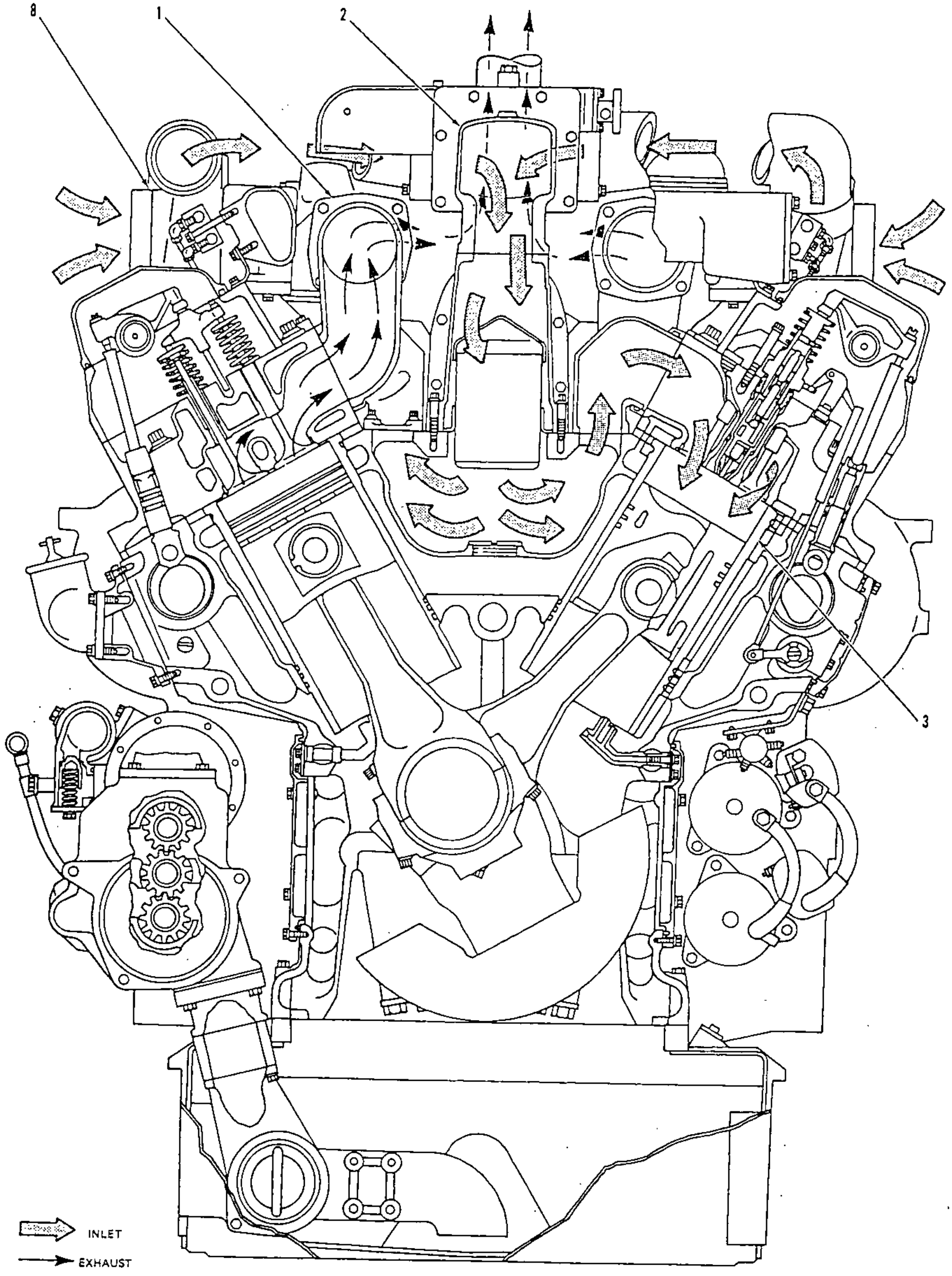
There are two intake and two exhaust valves for each cylinder. Make reference to Valve System Components. The intake valves open when the piston moves down on the inlet stroke. Cooled, compressed air from the inlet chamber is pulled into the cylinder. The intake valves close and the piston starts to move up on the compression stroke. When the piston is near the top of the compression stroke, fuel is injected into the cylinder. The fuel mixes with the air and combustion starts. The force of combustion pushes the piston down on the power stroke. When the piston moves up again it is on the exhaust stroke. The exhaust valves open and the exhaust gases are pushed through the exhaust port into exhaust manifold (1). After the piston makes the exhaust stroke, the exhaust valves close and the cycle (inlet, compression, power, exhaust) starts again.

Exhaust gases from the exhaust manifold go into the turbine side of the turbocharger (8) and cause turbine wheel (6) to turn. The turbine wheel is connected to the shaft that drives compressor wheel (5). The exhaust gases then go out the exhaust outlet (7) through exhaust elbow (9).



AIR SYSTEM COMPONENTS
(3512 Engine Shown)

1. Exhaust manifolds. **2.** Aftercooler. **8.** Turbochargers. **9.** Exhaust elbow. **10.** Cylinder head.



AIR FLOW SCHEMATIC

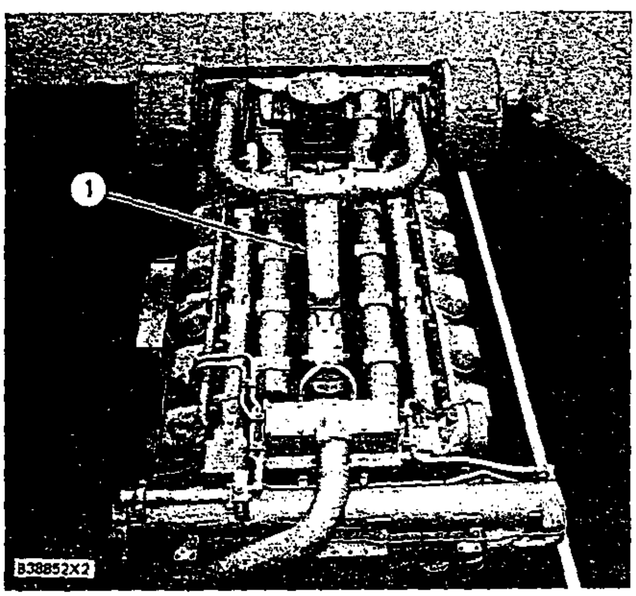
1. Exhaust manifold. 2. Aftercooler. 3. Cylinder. 8. Turbocharger.

AFTERCOOLER

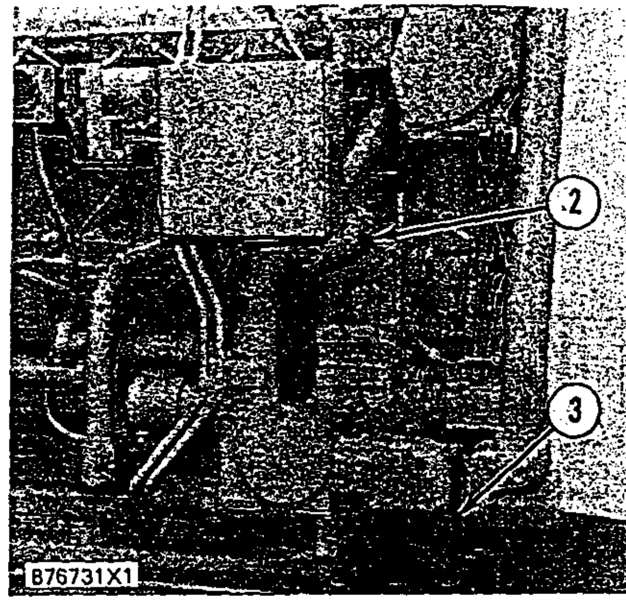
The aftercooler is located at the center of the vee, and has a coolant charged core assembly. The 3516 can have two core assemblies. Coolant from water pump (3) flows through pipe (2) into the aftercooler. It then flows through the core assembly (assemblies) and back out of the aftercooler through a different pipe into the rear of the cylinder block.

There is a connector (tube) that connects the bottom rear of each core assembly to the cylinder block. This is used to drain the core assembly (assemblies) when the coolant is drained from the engine.

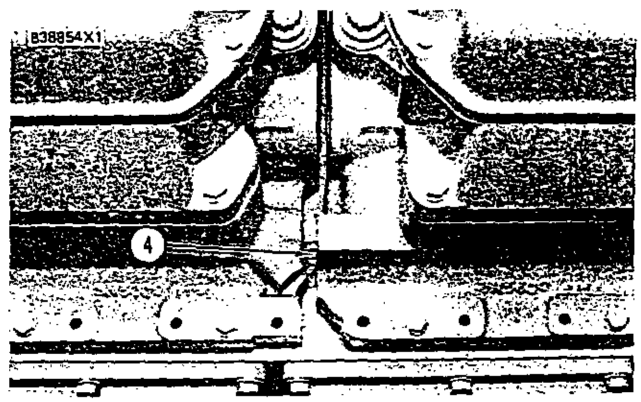
Inlet air from the compressor side of the turbochargers flows into the aftercooler through pipes. This air then passes through the fins of the core assembly (assemblies) which lowers the temperature. The cooler air goes out the bottom of the aftercooler into the air chamber, and then up through the elbows to the inlet ports (passages) in the cylinder heads.



TOP OF ENGINE
1. Aftercooler housing.



RIGHT FRONT OF ENGINE
2. Pipe. 3. Water pump.

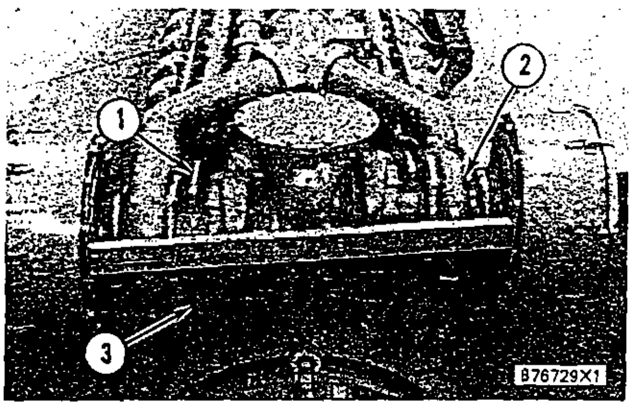


AFTERCOOLER AIR CHAMBER DRAIN
4. Drain plug.

One drain plug is located between the No. 1 and No. 3 cylinder heads, and another plug is located between the last two cylinder heads on the left side of the engine. These plugs can be removed to check for water or coolant in the aftercooler air chamber.

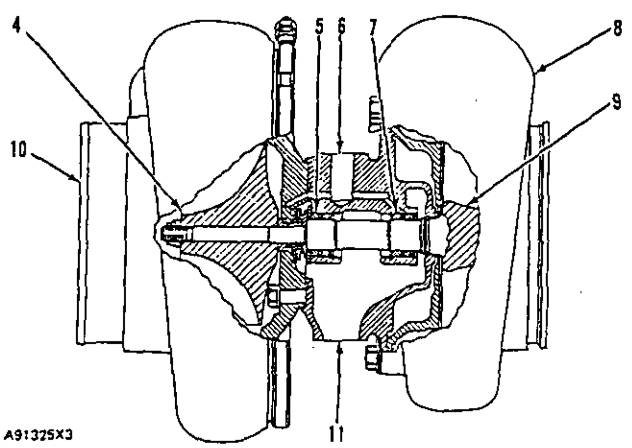
TURBOCHARGERS

There are two turbochargers, on the rear of the engine. The turbine side of the turbochargers is fastened to the exhaust manifolds. The compressor side of the turbocharger is connected to the aftercooler.



TURBOCHARGERS
1. Oil supply line. 2. Turbocharger. 3. Oil drain line.

The exhaust gases go into turbine housing (8) and push the blades of turbine wheel (9). This causes the turbine wheel and compressor wheel to turn at up to 70,000 rpm.



TURBOCHARGER
(3512 SHOWN)
4. Compressor wheel. 5. Bearing. 6. Oil inlet. 7. Bearing. 8. Turbine housing. 9. Turbine wheel. 10. Air inlet. 11. Oil outlet.

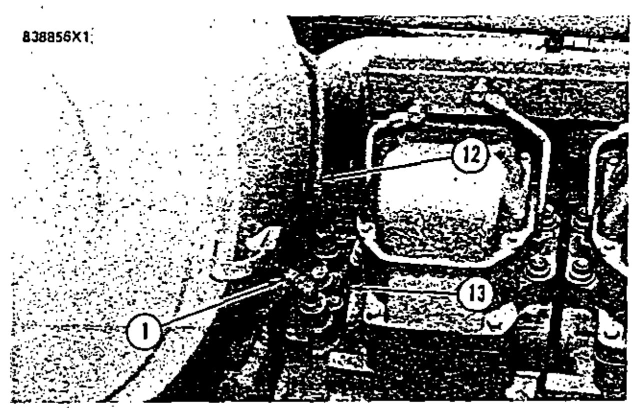
Clean air from the air cleaners is pulled throu the compressor housing air inlet (10) by rotation compressor wheel (4). The action of the comp wheel blades causes a compression of the inle. This compression gives the engine more power cause it makes it possible for the engine to bu additional fuel with greater efficiency.

Maximum rpm of the turbocharger is controlle by the fuel setting, the high idle rpm setting and th height above sea level at which the engine operated.

NOTICE

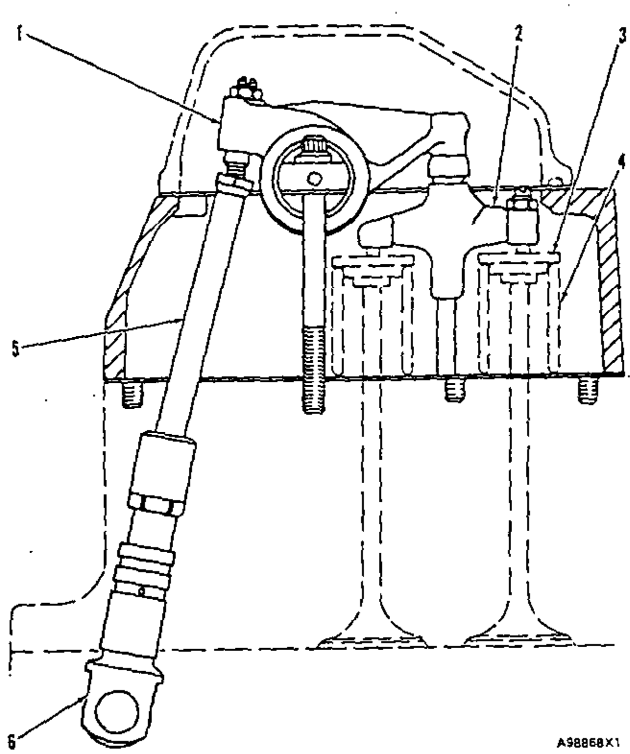
If the high idle rpm or the fuel setting is highe than given in the Fuel Setting Information (fo the height above sea level at which the engine is operated), there can be damage to engine o turbocharger parts. Damage will result when increased heat and/or friction, due to the higher engine output, goes beyond the engine cooling and lubrication systems abilities. A mechanic that has the proper training is the only one to make the adjustment of fuel setting and high idle rpm setting.

The bearings (5 and 7) in the turbocharge e engine oil under pressure for lubrication. The oil comes in through oil inlet port (6) and goes through passages in the center section for lubrication of the bearings. Then the oil goes out oil outlet port (11) and back to the oil pan.



TURBOCHARGER OIL LINES
1. Oil supply line to left turbocharger. 12. Oil supply line to right turbocharger. 13. Oil manifold.

VALVE SYSTEM COMPONENTS



VALVE SYSTEM COMPONENTS

1. Rocker arm. 2. Bridge. 3. Rotocoil. 4. Valve spring. 5. Push rod. 6. Lifter.

The valve system components control the flow of inlet air and exhaust gases into and out of the cylinders during engine operation.

The crankshaft gear drives the camshaft gears through idlers. Both camshafts must be timed to the crankshaft to get the correct relation between piston and valve movement.

The camshafts have three cam lobes for each cylinder. Two lobes operate the valves and one operates the fuel injector.

As each camshaft turns the lobes of the camshafts, they cause lifters (6) to go up and down. This movement makes push rods (5) move the rocker arms (1). Movement of the rocker arms makes the bridges (2) move up and down on dowels in the cylinder head. The bridges allow one rocker arm to open or close two valves (intake or exhaust) at the same time. There are two intake and two exhaust valves for each cylinder.

Rotocoils (3) cause the valves to turn while the engine is running. The rotation of the valves keeps the deposit of carbon on the valves to a minimum and gives the valves longer service life.

Valve springs (4) cause the valves to close when the lifters move down.