MIAMI-DADE COUNTY

Carlos A. Gimenez, Mayor

Miami-Dade Water and Sewer Department
P.O. Box 330316 • 3071 SW 38th Avenue
Miami, Florida 33233-0316
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May 4, 2012

Certified Mail: 7010 0290 0000 0693 6249
CCN: 56290

Mr. Jeff Koerner
Florida Department of Environmental Protection
Division of Air Resource Management – Office of Permitting and Compliance
2600 Blair Stone Road MS 5505
Tallahassee, Florida 32399-2400

Subject: Application for Air Construction Permit for the Alexander Orr, Jr. Water Treatment Plant, Facility I.D. No. 0250314

Dear Mr. Koerner,

In accordance with Rule 62-210.300, F.A.C., enclosed please find four (4) signed and sealed applications for an Air Construction Permit for the Alexander Orr, Jr. Water Treatment Plant for the purpose of completing construction on replacement Pump Engine No. 5 (Emissions Unit ID 020) as originally permitted under expired Title V Air Construction Permit No. 0250314-005-AC incorporating Project 0250314-007-AC.

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 Richard M. O'Rourke, P.E. at (786) 552-8123 if there are any questions regarding this report.

Sincerely,

Rafael A. Terrero, P.E., BCEE, M. ASCE
Assistant Director, Water System Operations

RAT/JRP

cc: L. Anderson, FDEP/SED
J. Holtom, FDEP/TAL
M. Muthiah, MDPERA

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DIVISION OF AIR
RESOURCE MANAGEMENT

Application for Air Construction Permit for the

Replacement of Pump Engine 5
Alexander Orr, Jr. Water Treatment Plant
Miami, Florida
May, 2012

Miami-Dade Water and Sewer Department

MIAMI-DADE COUNTY

Background Photo Courtesy of the National Weather Service

Project NO: 0250 314-018-AC

Application for Title V Air Construction Permit
Alexander Orr, Jr. Water Treatment Plant
Application Technical Report

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Executive Summary

In this Title V air construction permit application, Miami-Dade Water and Sewer Department (MDWASD) seeks to repermit the replacement of one engine-driven high-service distribution pumps at its Alexander Orr, Jr. Water Treatment Plant, Facility ID No. 0250314 (AOWTP). The subject high-service pump plays a vital role in MDWASD's ability to deliver finished water to a large part of Miami-Dade County under foreseeable conditions.

Specifically, this permit application seeks to complete the installation of Pump Engine No. 5 (Emissions Unit ID No. 020), a Caterpillar Model G3608 LE, as originally permitted under Title V Air Construction Permit No. 0250314-005-AC. That permit, as subsequently extended under Permitting Project No. 0250314-007-AC, expired prior to the completion of the permitted work. This work was partially completed during the life of the permit with the installation of Emissions Units Nos. 018, 019, and 023 and their subsequent incorporation into the facility's Title V air operation permit. Work on Emissions Unit No 020 was not completed due to contractual difficulties and was suspended with the emissions unit purchased and on-site but not fully operational. At this time MDWASD is ready to complete the installation and start-up of Emissions Unit 020.

Section 1. Introduction

The Miami-Dade Water and Sewer Department (MDWASD) operates the Alexander Orr, Jr. Water Treatment Plant (AOWTP), located at 6800 SW 87th Avenue in Miami, Florida. This facility is registered with the State of Florida as a Major Source of Air Pollution, i.e. Title V source, with facility ID 0250314 and is currently permitted under Air Operation Permit No. 02540314-017-AV. Major source air emissions activity at this facility includes a natural gas-fired lime recalcination kiln (EU ID No. 007), five (5) diesel-driven standby electrical generators (EU ID Nos. 009 – 012, 24), and four (4) unregulated engine-driven water distribution high service pumps fueled by both diesel and natural-gas (EU ID Nos. 005, 006, 018, 019), along with miscellaneous facility back-up equipment, both regulated and unregulated (EU ID Nos. 021 – 023).

MDWASD is seeking an air construction permit under Chapters 62-210, and 62-212, F.A.C. for the replacement of one of the engine-driven high service pumps at the referenced facility. This pump is described in the current air operation permit as EU ID No. 005, engine driven pump rated at 1,500 hp fired with diesel fuel, or natural gas, unit No.5 and will hereafter be referred to as Pump No. 5. This existing pump has failed and is currently not operational.

High-service engine-driven pumps form an essential part of MDWASD capability to provide uninterrupted potable water to a large portion of Miami-Dade County under conceivable emergency scenarios. While these engine-driven pumps may be considered redundant capacity to the electrically-driven high-service pumps for operation of the plant under normal circumstances, these pumps maintain water distribution system pressures and volumes vital to the health and well-being of Miami-Dade residents were the AOWTP to suffer a complete or partial loss of external electrical power and be forced to rely on onsite generation. Engine-driven high-service pumps form an integral part of MDWASD's emergency backup protocol for this facility and it is vital that Pump No. 5 be returned to operational status.

Pump No. 5 was one of a number of emissions units permitted for replacement under Air Construction Permit Nos. 0250314-003-AC, -005-AC, and -007-AC (see Section 3 for expanded permitting history). The replacement Pump No. 5 is described in the Permit No. 0250314-005-AC as EU ID No. 020, 2090 brake hp natural gas fired Caterpillar Model G3608 LE engine for pump 5.

Due to construction delays and contractual issues related to the installation of the units under Permit No. 0250314-005-AC, this permit, as subsequently extended under Air Permitting Project No. 0250314-007-AC, expired without work related to Pump No. 5 having been completed and with no start-up of Pump No. 5. At the time of permit expiration, MDWASD had no contract in place to complete work on Pump No. 5 and the project was placed on hold pending funding and rebidding the project.

At this time MDWASD, seeks to repermit the installation of Pump No. 5 (EU ID No. 020), Caterpillar Model G3608 LE engine, as begun under the original Permit No. 0250314-005-AC.

Section 2. Facility description

Figure 2-1 Satellite view of the Alexander Orr, Jr. Water Treatment Plant showing location

The Alexander Orr, Jr. Water Treatment Plant is a major regional facility that processes up to 214.74 million gallons per day (MGD) and serves over one million people in southern Miami-Dade County. It was originally constructed in 1954 with a capacity of 40 MGD and has since been enlarged and upgraded a number of times. The facility is a lime softening plant with an on-site lime kiln that recovers calcium carbonate from the treatment process and converts it to lime for reuse. The facility draws its raw water from the Biscayne Aquifer via a number of onsite and offsite wells. Finished water is pumped out of the plant to the service area distribution system by a combination of electric and engine-driven high-service pumps located in two onsite pumps rooms.

The Miami-Dade Water and Sewer Department is the largest public utility in the southeast United States and the sixth largest in the country, providing direct services to approximately 410,000 retail customers. Additionally, wholesale water and/or wastewater service is provided to 18 municipalities in the county. Miami-Dade County's current population of 2.3 million is expected to reach the 2.8 million mark by the year 2030.

The facility is located at 6800 SW 87th Avenue in unincorporated Miami-Dade County, Florida. UTM coordinates are: Zone 17; 565.9 km E and 2843.3 km N.

Section 3. Permit status and history

This facility is classified as a Major or Title V Source of air pollution because emissions of at least one regulated air pollutant, such as particulate matter (PM/PM10), sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), or volatile organic compounds (VOC) exceeds 100 tons per year (TPY).

This facility is not within an industry included in the list of the 28 Major Facility Categories per Table 62-212.400-1, F.A.C. Because emissions are greater than 250 TPY for at least one criteria pollutant, the facility is also a Major Facility with respect to Rule 62-212.400, Prevention of Significant Deterioration (PSD) and currently operates under PSD-FL-249 and Title V Air Operation Permit 0250314-017-AV which expires on December 25, 2015.

Replacement of a number of engine-driven pumps in the facility's East Pump Room has been ongoing since 1999 with Air Construction Permit No. 0250314-003-AC being issued on March 5, 1999. No work was ever performed under that permit and it was superseded by Air Construction Permit No. 0250314-005-AC issued on October 30, 2002 and subsequently extended a number of times under Air Permitting Project No. 0250314-007-AC with a final expiration of October 30, 2007.

In a separate and more recent business decision, MDWASD applied for and received Air Construction Permit No. 0250314-009-AC on October 20, 2005 for the addition of two new backup standby generators rated at 2865 kW each to the existing bank of four standby generators.

Section 4. Existing emissions units

Pump No. 5 is one of the high-service distribution pumps located in one of the two pumps rooms located at the AOWTP, specifically the East Pump Room. High-service distribution pumps constitute an essential part of the water treatment plant, conveying the finished water from plant reservoirs to the distribution system with adequate pressure throughout the County-wide system. There are currently a total of four (4) permitted engine-driven pumps in the East Pump Room, Emissions Unit ID Nos. 005, 006, 018, and 019 (of which only the latter two are currently operational) along with four (4) electric motor-driven pumps not subject to air permitting. Total pumping capacity for the East Pump Room is roughly 325 MGD (million gallons per day), including the pumping capacity of the currently non-operational Pump Nos. 5 (40 MGD) and 6 (50 MGD).

Pump No. 5 has a pumping capacity of 40 MGD and is driven by a Worthington Model SW14, dual-fuel four-cycle engine. It was placed in service in the 1950's. In February of 2009, the engine failed due to pronounced loss of compression and, given its age and the limited availability of a replacement parts, was deemed beyond economical repair.

Section 5. Emissions from existing unit (baseline)

The 24-month period from November 2005 to October 2007, inclusive, was chosen to determine the baseline actual emissions as shown in Table 5-1 below . This period conforms with the requirement of Chapter 62-210 F.A.C., *Stationary Sources - General Requirements*, that the period selected to determine Baseline Actual Emissions be "within the 10-year period immediately preceding the date a complete permit application is received by the Department, except that the 10-year period shall not include any period earlier than November 15, 1990"

Table 5-1 Historical NOx Emissions
Pump Engine No. 5

Month/Year	Diesel (gal x 10^3)	NOx (tons)
November 2005	36.686	5.797
December 2005	0.000	0.000
January 2006	24.835	3.924
February 2006	36.940	5.837
March 2006	42.227	6.672
April 2006	35.538	5.615
May 2006	39.983	6.318
June 2006	21.803	3.445
July 2006	40.282	6.365
August 2006	39.745	6.280
September 2006	38.336	6.057
October 2006	40.652	6.423
November 2006	38.266	6.046
December 2006	40.503	6.400
January 2007	39.581	6.254
February 2007	37.116	5.865
March 2007	42.353	6.692
April 2007	41.731	6.594
May 2007	43.534	6.879
June 2007	42.545	6.723
July 2007	44.443	7.022
August 2007	44.042	6.959
September 2007	41.517	6.560
October 2007	42.707	6.748
Total for 24 months	895.365	141.477
Annual average	447.683	70.738

Sample calculations:
NOx (diesel fuel): NOx (tons) = Fuel (10^3 gal) x 138 MMBtu/(10^3 gal) x Factor lbs/MMBtu x ton/ 2000 lb

Emissions factors:

Pump No. 5 (diesel): Based on testing performed = 2.29 lb/MMBtu

Table 5-2 Baseline Emissions Pump Engine No. 5 Alexander Orr, Jr. Water Treatment Plant			
Average annual operations:			Nov. 2005 – Oct. 2007
Average annual fuel consumption: (diesel in 10^3 gal)			447.683
Emissions factor	Diesel	Unit	Annual Emissions (ton/yr)
Nitrogen Oxides (NOx)	See Table 5-1		70.74
Carbon Monoxide (CO)	116	lb/10^3 gal	25.97
PM10	7.85	lb/10^3 gal	1.76
Sulfur Oxides (SOx)	6.9	lb/10^3 gal	1.54
VOC	11.5	lb/10^3 gal	2.57
Notes: Emissions factors other than NOx based on USEPA WebFIRE; NOx as per Table 5-1. Emissions (ton/year) = (emissions factor [lbs/unit]) x (units) / 2000 lbs/ton			

Section 6. Proposed unit

Pump Engine Number 5 (E.U. ID No. 005) began service in 1956, driving a 40 mgd pump. This engine and pump is to be removed and replaced by Caterpillar Model G3608LE TA-130 engine and a Flowserve Model 600LNEC1150 high service pump rated at 40 million gallons per day.

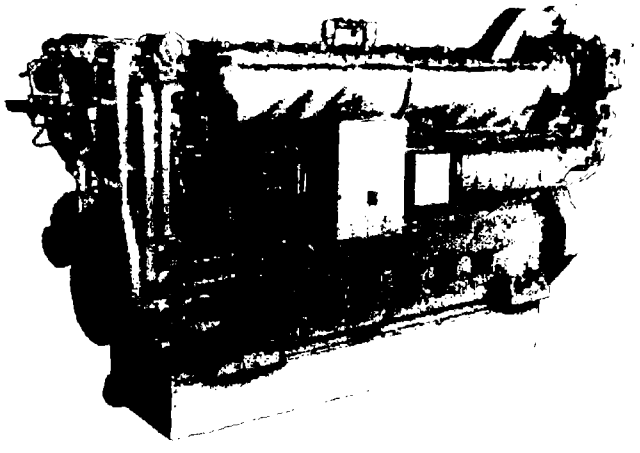


Figure 6-1 Caterpillar Model G3608LE

The Model G3608LE TA-130 engine is an eight-cylinder engine in Caterpillar's G3600 series natural gas fueled engines. Caterpillar characterizes this series as high horsepower, high torque engines that are designed for reliable operation, fuel economy and low emissions. The Model G3608LE TA-130 has an in-line cylinder arrangement, with a bore and stroke of 11.81 x 11.81 in. (300 x 300 mm) and displacement of 10,350 cu. in (169 liters). This is a turbocharged engine, and power output at the design aftercooler operating temperature of 130° F ranges from 1555 bhp to 2225 bhp at 700 rpm to 1000 rpm.

Section 7. Emissions from proposed unit

The projected emissions associated with this project are the typical pollutants from combustion of natural gas and/or diesel fuel in internal combustion reciprocating engines. The primary pollutants associated with this project are NOx and CO. Emissions for the Caterpillar Model 3608LE engine that will replace Pump No. 5 is shown in Table 7-1. This is a single-fuel engine, fired by natural gas. Based on manufacturer data, maximum emission in lb/hour occur at 100% load. Although pump calculations, not included here, indicate that the engine will normally be loaded to approximately 85% with consequent lower hourly emissions, the maximum emissions at full load are used in this application.

Table 7-1 Projected Emissions
Pump Engine No. 5 - Caterpillar Model G3608 LE
Alexander Orr, Jr. Water Treatment Plant

			Hours of Operation	8,760
			Fuel Consumption in MMscf/hr	0.016743
			Annual Fuel consumption in MMscf	146.669
			Annual Heat Input (MMBtu) based on 1050/ MMscf	154,002
	Emission Factor	Units	Source, SCC[10]	Annual Emissions in Tons
Nitrogen Oxides (NOx)	3.43	Lb/Hr	Manufacturer	15.02
Carbon Monoxide (CO)	9.32	Lb/Hr	Manufacturer	40.82
PM_{10}, Filterable	20.1	Lb/MMscf	20300201	1.47
Sulfur Oxides (SOx)	0.6	Lb/MMscf	20300201	0.04
Volatile Organic Compounds (VOC)	116	Lb/MMscf	20300201	8.51

Notes:
Emissions Factors based on Manufacturer. EPA FIRe database Source Classification Codes
Emissions (tons/yr) = (emission factor [lbs/unit]) x (units) / 2000 lbs/ton

Section 8. Emissions analysis

The existing Pump No. 5 is a dual-fuel capable internal combustion reciprocating engine that, due to its deteriorating condition, was run solely on diesel fuel. Accordingly, replacing this engines with a natural gas fired internal combustion reciprocating engine would be expected to emit much less NOx on a lb/hr basis than the existing engine. This is confirmed by the analysis conducted here, which also demonstrates that the project is not subject to the requirements of PSD. CO emissions are increased as would be expected but remain well below the 100 ton/year threshold increase for a major modification as defined in Chapter 62-210 F.A.C.

This project consists of replacing an existing engine with a new engine, therefore a Baseline Actual-to-Projected Actual Applicability Test as required under Rule 62-212.400 *Prevention of Significant Deterioration (PSD)* was performed to determine if a significant emissions increase of a PSD pollutant would result. The results are shown in Table 8-1 below. For this applicability test, the 24-month period from November 2005 to October 2007, inclusive, was chosen to determine the baseline actual emissions. This period conforms with the requirement of Chapter 62-210 F.A.C., *Stationary Sources - General Requirements*, that period selected to determine Baseline Actual Emissions be "within the 10-year period immediately preceding the date a complete permit application is received by the Department, except that the 10-year period shall not include any period earlier than November 15, 1990"

Referring to Table 5-1 and 5-2 above, the baseline actual NOx emissions for Pump Engine No. 5 is 141.477 tons in 24-months or 70.738 ton/year. As shown in Section 7, specifically Table 7-1, unrestricted usage of the replacement Pump Engine No. 5, Caterpillar natural-gas fired Model 3608LE, totals 15.02 ton/year, well under the baseline actual emissions. Unrestricted usage of the replacement Pump Engine No. 5 yields higher CO emissions than the baseline emissions of the older engine being replaced but the increase is well below the 100 ton increase that defines a major modification under Chapter 62-210 F.A.C., as shown in Table 8-1, below.

Table 8-1 NOx and CO Netting Analysis
Replacement Pump No. 5
Alexander Orr, Jr. Water Treatment Plant

Line	Description	Source	NOx emissions	CO emissions
A	Baseline emissions:	Table 5-2	70.74	25.97
Projected emissions				
B	Pump No. 5 (nat. gas)	Table 7-1	15.02	40.82
C	Net emissions change	Lines B - A	-55.72	+14.85
D	Increment allowed	Rule	40.00	100.00
E	Unused increment	Lines D - C	95.72	85.15

Notes:
1. All emissions values are in tons/year.

Section 9. Regulatory Analysis

Under Chapter 62-210 F.A.C. Stationary Sources - General Requirements, section 62-210.300(1), unless exempt from permitting pursuant to paragraph 62-210.300(3)(a) or (b), F.A.C., or Rule 62-4.040, F.A.C., an air construction permit shall be obtained by the owner or operator of any proposed new, reconstructed, or modified facility or emissions unit prior to the beginning of construction or modification of the facility or emissions unit.

Section 62-210.300(3) covers both categorical and generic exemptions, neither of which apply to this modification. Therefore this modification is subject to Chapter 62-212 F.A.C., Stationary Sources – Preconstruction Review. The preceding analysis shows that this modification is not major for the purposes of the referenced Chapter and this modification is therefore, not subject to preconstruction review under subsections 62-212.400(4) through (12), F.A.C.

A number of new regulations that could potentially impact Pump Engine No. 5 (E.U. 020) have been promulgated since the expiration of the subject permit and MDWASD addresses these below.

RICE NESHAP

For the purposes of 40 CFR Part 63 Subpart ZZZZ – *National Emissions Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines* (RICE NESHAP), replacement Pump Engine No. 5 (E.U. 020) is an existing source. Subpart ZZZZ § 63.6590(a)(1)(iii) states:

> For stationary RICE located at an area source of HAP emissions, a stationary RICE is existing if you commenced construction or reconstruction of the stationary RICE before June 12, 2006.

MDWASD entered into a contractual obligation to construct Pump Engine No. 5 (E.U. 020) along with the other units under Title V Air Construction Permit No. 0250314-003-AC, issued on March 5, 1999, and subsequent Permit No. 0250314-005-AC, issued on October 30, 2002. Pump Engine No. 5 (E.U. 020), a Caterpillar 3608LE, S/N 4WF00182, was manufactured on November 7, 2000. Accordingly, Pump Engine No. 5 (E.U. 020) is considered an existing unit for the purpose of RICE NESHAP.

Pump Engine No. 5 (E.U. 020) is a spark-ignited four-stroke lean-burn stationary rotating internal combustion engine (SI 4SLB RICE) greater than 500 brake horsepower (bhp) fueled by natural gas. It is located at an area source and is neither an emergency nor limited use unit. Under RICE NESHAP, such engines must provide initial notification, are subject to a numerical limitation on GHG emission, and are subject to certain operating limitations. MDWASD shall take all required steps to assure compliance with the RICE NESHAP including but not necessarily limited to:

- Initial notification (§ 63.6645) shall be made upon reactivation of the subject permit.
- Initial performance test/compliance demonstration (§ 63.6612) shall be performed within 30 days following successful startup of Pump Engine No. 5 (E.U. 020). Manufacturer's data indicates that it is unlikely that emissions will comply with the applicable standard of 47 ppmvd CO at 15 percent O2. In that case, an oxidation catalyst shall be fitted to the engine along with required performance monitoring equipment prior to the compliance deadline of October 19, 2013 (§ 63.6595).

- Other general requirements, monitoring, recording-keeping, and notifications required under RICE NESHAP shall be complied with prior to the compliance deadline of October 19, 2013 (§ 63.6595) and shall continue ongoing.

GHG Monitoring

Under 40 CFR Part 98 – *Mandatory Greenhouse Gas Reporting* (GHG Rule), the USEPA mandated greenhouse gas reporting requirements for owners and operators of certain facilities that directly emit GHG as well as for certain fossil fuel suppliers and industrial GHG suppliers. The first reports were due by September 30, 2011 for emissions that occurred in CY 2010.

Reportable greenhouse gasses include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs), perfluorochemicals (PFCs), and other fluorinated gases (e.g., nitrogen trifluoride, hydrofluorinated ethers [HFEs]). For reporting purposes, these gasses are all converted to a carbon dioxide equivalent (CO2e) and only CO2e is reported.

MDWASD's regional water and wastewater treatment facilities, including AOWTP, are potential sources under Subpart C – *General Stationary Fuel Combustion Sources* of the GHG Rule given their capacity to exceed the reporting threshold of 25,000 tonnes CO2e under existing permit limitations. Preliminary screening indicated that, of the referenced facilities, only AOWTP had exceeded the threshold in some, but not all, previous years and so might be subject to the reporting requirement for CY 2010. However, that was not the case for CY 2010 and reportable CO2e emissions at AOWTP totaled 22,967.6 tonnes. Accordingly, no report was required under 40 CFR Part 98 for CY 2010. Similarly, for CY 2011, reportable CO2e emissions at AOWTP totaled 20,200.2 tonnes and, again, no report was required under 40 CFR Part 98. MDWASD will continue to monitor all of its regional facilities and report under the GHG monitoring program, if and as required. Subpart C includes all fuel combusted at stationary generators, pumps, lime kilns, etc) and the emissions from replacement Pump Engine No. 5 (E.U. 020) will be a factor in future calculations of GHG emissions at AOWTP.

Section 10. Conclusion

In accordance with Chapter 62-212 Stationary Sources – Preconstruction Review Rule 62-212.400(2)(a), and based on a baseline actual-to-potential/projected applicability test in accordance with Rule 62-212.400(2)(a)3 Hybrid Test for Multiple Types of Emissions Units as described herein, no emissions increase of a PSD pollutant results from the proposed modifications and construction, and no major modification to the source facility is engendered by this application. Therefore subsections 62-212.400(4) through (12), F.A.C. do not apply to this modification.

This application to supersede existing Air Construction Permit No. 0250314-009-AC is compliant with Chapters 62-210 and 62-212 F.A.C. and will provide the Alexander Orr, Jr. Water Treatment Plant with the standby electrical generation capacity, flexibility, and redundancy to ensure that the water needs of the most populous county in the Florida can be met under all emergency conditions.

Report prepared by:

5/7/12

John R. Pardillo, E.I.
Engineer 2, MDWASD

12 MAY 2012

Richard O'Rourke, P.E.
Florida Registration No. 42683
Senior Professional Engineer, MDWASD

Department of Environmental Protection

Division of Air Resource Management

APPLICATION FOR AIR PERMIT - LONG FORM

I. APPLICATION INFORMATION

Air Construction Permit – Use this form to apply for an air construction permit:

- For any required purpose at a facility operating under a federally enforceable state air operation permit (FESOP) or Title V air operation permit;
- For a proposed project subject to prevention of significant deterioration (PSD) review, nonattainment new source review, or maximum achievable control technology (MACT);
- To assume a restriction on the potential emissions of one or more pollutants to escape a requirement such as PSD review, nonattainment new source review, MACT, or Title V; or
- To establish, revise, or renew a plantwide applicability limit (PAL).

Air Operation Permit – Use this form to apply for:

- An initial federally enforceable state air operation permit (FESOP); or
- An initial, revised, or renewal Title V air operation permit.

To ensure accuracy, please see form instructions.

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	
4. Facility Location... Street Address or Other Locator: 6800 SW 87th Avenue City: Miami County: Miami-Dade Zip Code: 33173	
5. Relocatable Facility? ☐ Yes ☒ No	6. Existing Title V Permitted Facility? ☒ Yes ☐ No

Application Contact

1. Application Contact Name: Richard O'Rourke
2. Application Contact Mailing Address... Organization/Firm: Miami-Dade Water and Sewer Department Street Address: P.O. Box 330316 City: Miami State: FL Zip Code: 33233-0316
3. Application Contact Telephone Numbers... Telephone: (786) 552 - 8123 ext. Fax: (786) 552 - 8640
4. Application Contact E-mail Address: rorou01@miamidade.gov

Application Processing Information (DEP Use)

1. Date of Receipt of Application: 5-17-12	3. PSD Number (if applicable):
2. Project Number(s): 0250314-018-AC	4. Siting Number (if applicable):

APPLICATION INFORMATION

Purpose of Application

This application for air permit is being submitted to obtain: (Check one)

Air Construction Permit

[X] Air construction permit.

[ ] Air construction permit to establish, revise, or renew a plantwide applicability limit (PAL).

[ ] Air construction permit to establish, revise, or renew a plantwide applicability limit (PAL), and separate air construction permit to authorize construction or modification of one or more emissions units covered by the PAL.

Air Operation Permit

[ ] Initial Title V air operation permit.

[ ] Title V air operation permit revision.

[ ] Title V air operation permit renewal.

[ ] Initial federally enforceable state air operation permit (FESOP) where professional engineer (PE) certification is required.

[ ] Initial federally enforceable state air operation permit (FESOP) where professional engineer (PE) certification is not required.

Air Construction Permit and Revised/Renewal Title V Air Operation Permit (Concurrent Processing)

[ ] Air construction permit and Title V permit revision, incorporating the proposed project.

[ ] Air construction permit and Title V permit renewal, incorporating the proposed project.

Note: By checking one of the above two boxes, you, the applicant, are requesting concurrent processing pursuant to Rule 62-213.405, F.A.C. In such case, you must also check the following box:

[ ] I hereby request that the department waive the processing time requirements of the air construction permit to accommodate the processing time frames of the Title V air operation permit.

Application Comment

This application is submitted to re-permit Emissions Unit No. 020, 2090 brake hp natural gas fired Caterpillar Model G3608 LE engine for Pump No. 5, as originally permitted under Title V Air Construction Permit No. 0250314-005-AC and subsequently extended under permitting action 0250314-007-AC. This permit expired without the installation of the subject emissions unit having been completed (other work under the permit was completed).

APPLICATION INFORMATION

Scope of Application

Emissions Unit ID Number	Description of Emissions Unit	Air Permit Type	Air Permit Processing Fee
020	2090 brake hp natural gas fired Caterpillar Model G3608 LE engine for Pump No. 5.*	AC1D	--
	*As previously permitted under Title V Air Construction Permit No. 0250314-005-AC		

Application Processing Fee

Check one: ☐ Attached - Amount: $_____ ☒ Not Applicable

APPLICATION INFORMATION

Owner/Authorized Representative Statement

Complete if applying for an air construction permit or an initial FESOP.

1. Owner/Authorized Representative Name :
   Rafael A. Terrero, P.E., BCEE, M. ASCE
2. Owner/Authorized Representative Mailing Address...
   Organization/Firm: Miami-Dade Water and Sewer Department
   Street Address: P.O. Box 330316
   City: Miami State: FL Zip Code: 33233-0316
3. Owner/Authorized Representative Telephone Numbers...
   Telephone: (786) 552 - 8112 ext. Fax: (786) 552 - 8639
4. Owner/Authorized Representative E-mail Address: terrero@miamidade.gov
5. Owner/Authorized Representative Statement:

   I, the undersigned, am the owner or authorized representative of the corporation, partnership, or other legal entity submitting this air permit application. To the best of my knowledge, the statements made in this application are true, accurate and complete, and any estimates of emissions reported in this application are based upon reasonable techniques for calculating emissions. I understand that a permit, if granted by the department, cannot be transferred without authorization from the department.

   Signature Date 5/7/12

APPLICATION INFORMATION

Application Responsible Official Certification

Complete if applying for an initial, revised, or renewal Title V air operation permit or concurrent processing of an air construction permit and revised or renewal Title V air operation permit. If there are multiple responsible officials, the "application responsible official" need not be the "primary responsible official."

1. Application Responsible Official Name:

2. Application Responsible Official Qualification (Check one or more of the following options, as applicable):
   - ☐ For a corporation, the president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy or decision-making functions for the corporation, or a duly authorized representative of such person if the representative is responsible for the overall operation of one or more manufacturing, production, or operating facilities applying for or subject to a permit under Chapter 62-213, F.A.C.
   - ☐ For a partnership or sole proprietorship, a general partner or the proprietor, respectively.
   - ☐ For a municipality, county, state, federal, or other public agency, either a principal executive officer or ranking elected official.
   - ☐ The designated representative at an Acid Rain source or CAIR source.

3. Application Responsible Official Mailing Address...
   Organization/Firm:
   Street Address:
   City: State: Zip Code:

4. Application Responsible Official Telephone Numbers...
   Telephone: ( ) - ext. Fax: ( ) -

5. Application Responsible Official E-mail Address:

6. Application Responsible Official Certification:

I, the undersigned, am a responsible official of the Title V source addressed in this air permit application. 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 and all other applicable requirements identified in this application to which the Title V source is subject. 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 the facility or any permitted emissions unit. Finally, I certify that the facility and each emissions unit are in compliance with all applicable requirements to which they are subject, except as identified in compliance plan(s) submitted with this application.

Signature Date

APPLICATION INFORMATION

Professional Engineer Certification

1. Professional Engineer Name: Richard M. O'Rourke
   Registration Number: 42683
2. Professional Engineer Mailing Address...
   Organization/Firm: Miami-Dade Water and Sewer Department
   Street Address: P.O. Box 330316
   City: Miami State: FL Zip Code: 33233-0316
3. Professional Engineer Telephone Numbers...
   Telephone: (786) 552 - 8123 ext. Fax: (786) 552 - 8640
4. Professional Engineer E-mail Address: rorou01@miamidade.gov
5. 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.

(3) If the purpose of this application is to obtain a Title V 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 plan and schedule is submitted with this application.

(4) If the purpose of this application is to obtain an air construction permit (check here ☒, if so) or concurrently process and obtain an air construction permit and a Title V air operation permit revision or renewal for one or more proposed new or modified emissions units (check here ☐, 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.

(5) If the purpose of this application is to obtain an initial air operation permit or operation permit revision or renewal for one or more newly constructed or modified emissions units (check here , 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 7 MAY 2012 Date

(seal)

* Attach any exception to certification statement.

II. FACILITY INFORMATION

A. GENERAL FACILITY INFORMATION

Facility Location and Type

1. Facility UTM Coordinates... Zone East (km) North (km)		2. Facility Latitude/Longitude... Latitude (DD/MM/SS) 25/42/28 Longitude (DD/MM/SS) 80/20/11	
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 : Facility treats up to 241.7 million gallons per day of raw water for public water supply using a lime softening process, which includes softening, recarbonation, disinfection, and filtration. Engine-driven high service pumps such as the subject of this permit application convey water to the consumer via the County-wide distribution system and provide redundancy and standby capacity to electric motor-driven units.			

Facility Contact

1. Facility Contact Name: Allen Tom Segars
2. Facility Contact Mailing Address... Organization/Firm: Miami-Dade Water and Sewer Department Street Address: PO Box 330316 City: Miami State: FL Zip Code: 33233-0316
3. Facility Contact Telephone Numbers: Telephone: (305) 520 - 4721 ext. Fax: (305) 889 - 5881
4. Facility Contact E-mail Address: asega@miamidade.gov

Facility Primary Responsible Official

Complete if an "application responsible official" is identified in Section I that is not the facility "primary responsible official."

1. Facility Primary Responsible Official Name:
2. Facility Primary Responsible Official Mailing Address... Organization/Firm: Street Address: City: State: Zip Code:
3. Facility Primary Responsible Official Telephone Numbers... Telephone: ( ) - ext. Fax: ( ) -
4. Facility Primary Responsible Official E-mail Address:

FACILITY INFORMATION

Facility Regulatory Classifications

Check all that would apply *following* completion of all projects and implementation of all other changes proposed in this application for air permit. Refer to instructions to distinguish between a "major source" and a "synthetic minor source."

1. ☐ Small Business Stationary Source	☐ Unknown
2. ☐ Synthetic Non-Title V Source	
3. ☒ Title V Source	
4. ☒ Major Source of Air Pollutants, Other than Hazardous Air Pollutants (HAPs)	
5. ☐ Synthetic Minor Source of Air Pollutants, Other than HAPs	
6. ☐ Major Source of Hazardous Air Pollutants (HAPs)	
7. ☐ Synthetic Minor Source of HAPs	
8. ☐ One or More Emissions Units Subject to NSPS (40 CFR Part 60)	
9. ☐ One or More Emissions Units Subject to Emission Guidelines (40 CFR Part 60)	
10. ☒ One or More Emissions Units Subject to NESHAP (40 CFR Part 61 or Part 63)	
11. ☐ Title V Source Solely by EPA Designation (40 CFR 70.3(a)(5))	

12. Facility Regulatory Classifications Comment:

This facility is classified as a Major Source of Air Pollution or Title V Source with regard to regulated air pollutants (criteria pollutants) because potential emissions of nitrogen oxides (NOx) exceed 100 tons per year.

This facility is not within an industry included in the list of the 28 Major Facility Categories per Table 62-212.400-1, F.A.C. However, because overall potential facility emissions of nitrous oxides (NOx), a regulated air pollutant, exceed 250 tons per year, it is a subject to the preconstruction review requirements of Rule 62-212.400, Prevention of Significant Deterioration (PSD).

For the purpose of 40 CFR Part 63 Subpart ZZZZ – *National Emissions Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines*, this facility is an area source of HAPs emissions.

For the purpose of 40 CFR Part 98 – *Mandatory Greenhouse Gas Reporting*, this facility has the potential under the existing Title V Air Operation Permit to emit a reportable quantity of CO2e (25,000 tonnes or above) and CO2e emissions are being tracked. In the first two reporting years, the reporting threshold was not reached.

FACILITY INFORMATION

List of Pollutants Emitted by Facility

1. Pollutant Emitted	2. Pollutant Classification	3. Emissions Cap [Y or N]?
CO Carbon Monoxide	A	N
NOX Nitrogen Oxides	A	Y
PM Particulate Matter – Total	B	N
PM10 Particulate Matter – PM10	B	N
SO2 Sulfur Dioxide	B	N
VOC Volatile Organic Compounds	B	N

B. EMISSIONS CAPS

Facility-Wide or Multi-Unit Emissions Caps

1. Pollutant Subject to Emissions Cap	2. Facility-Wide Cap [Y or N]? (all units)	3. Emissions Unit ID's Under Cap (if not all units)	4. Hourly Cap (lb/hr)	5. Annual Cap (ton/yr)	6. Basis for Emissions Cap
NOX	N	009, 010, 011 012, 024		402.26	AMBIENT

7. Facility-Wide or Multi-Unit Emissions Cap Comment:

The combined fuel consumption limit and maximum NOx emission rate for the five EMD 20-645F4B generator sets is specified in Title V Air Operating Permit No. 0250314-017-AV.

B.2. "... Fuel consumption of all emission units combined shall not exceed 1,415,000 gallons of diesel fuel in any consecutive 12-month period..."

B.7. "Emissions of NOx shall not exceed 4.12 lb/MMBtu ..."

(1,415,000 gal/year)(0.138 MMBtu/gal)(4.12 lb/MMBtu)(1 ton/2000 lb)= 402.26 ton/year

The basis is "AMBIENT". Air modeling done in 1998 in conjunction with the PSD application submitted by MDWASD for increased generator usage (PSD-FL-249) established this cap to limit the impact on off-site receptors to below the PSD increment for NOx of 25 micrograms per cubic meter.

C. FACILITY ADDITIONAL INFORMATION

Additional Requirements for All Applications, Except as Otherwise Stated

1. Facility Plot Plan: (Required for all permit applications, except Title V air operation permit revision applications if this information was submitted to the department within the previous five years and would not be altered as a result of the revision being sought)
   [X] Attached, Document ID: A [ ] Previously Submitted, Date:_____

2. Process Flow Diagram(s): (Required for all permit applications, except Title V air operation permit revision applications if this information was submitted to the department within the previous five years and would not be altered as a result of the revision being sought)
   [X] Attached, Document ID: B [ ] Previously Submitted, Date:_____

3. Precautions to Prevent Emissions of Unconfined Particulate Matter: (Required for all permit applications, except Title V air operation permit revision applications if this information was submitted to the department within the previous five years and would not be altered as a result of the revision being sought)
   [X] Attached, Document ID: C [ ] Previously Submitted, Date:_____

Additional Requirements for Air Construction Permit Applications

1. Area Map Showing Facility Location:
   [ ] Attached, Document ID:_____ [X] Not Applicable (existing permitted facility)

2. Description of Proposed Construction, Modification, or Plantwide Applicability Limit (PAL):
   [X] Attached, Document ID: Report

3. Rule Applicability Analysis:
   [X] Attached, Document ID: Report

4. List of Exempt Emissions Units:
   [ ] Attached, Document ID:_____ [X] Not Applicable (no exempt units at facility)

5. Fugitive Emissions Identification:
   [ ] Attached, Document ID:_____ [X] Not Applicable

6. Air Quality Analysis (Rule 62-212.400(7), F.A.C.):
   [ ] Attached, Document ID:_____ [X] Not Applicable

7. Source Impact Analysis (Rule 62-212.400(5), F.A.C.):
   [ ] Attached, Document ID:_____ [X] Not Applicable

8. Air Quality Impact since 1977 (Rule 62-212.400(4)(e), F.A.C.):
   [ ] Attached, Document ID:_____ [X] Not Applicable

9. Additional Impact Analyses (Rules 62-212.400(8) and 62-212.500(4)(e), F.A.C.):
   [ ] Attached, Document ID:_____ [X] Not Applicable

10. Alternative Analysis Requirement (Rule 62-212.500(4)(g), F.A.C.):
    [ ] Attached, Document ID:_____ [X] Not Applicable

C. FACILITY ADDITIONAL INFORMATION (CONTINUED)

Additional Requirements for FESOP Applications

1. List of Exempt Emissions Units:
   ☐ Attached, Document ID:_____ ☐ Not Applicable (no exempt units at facility)

Additional Requirements for Title V Air Operation Permit Applications

1. List of Insignificant Activities: (Required for initial/renewal applications only)
   ☐ Attached, Document ID:_____ ☐ Not Applicable (revision application)

2. Identification of Applicable Requirements: (Required for initial/renewal applications, and for revision applications if this information would be changed as a result of the revision being sought)
   ☐ Attached, Document ID:_____
   ☐ Not Applicable (revision application with no change in applicable requirements)

3. Compliance Report and Plan: (Required for all initial/revision/renewal applications)
   ☐ Attached, Document ID:_____
   Note: A compliance plan must be submitted for each emissions unit that is not in compliance with all applicable requirements at the time of application and/or at any time during application processing. The department must be notified of any changes in compliance status during application processing.

4. List of Equipment/Activities Regulated under Title VI: (If applicable, required for initial/renewal applications only)
   ☐ Attached, Document ID:_____
   ☐ Equipment/Activities Onsite but Not Required to be Individually Listed
   ☐ Not Applicable

5. Verification of Risk Management Plan Submission to EPA: (If applicable, required for initial/renewal applications only)
   ☐ Attached, Document ID:_____ ☐ Not Applicable

6. Requested Changes to Current Title V Air Operation Permit:
   ☐ Attached, Document ID:_____ ☐ Not Applicable

C. FACILITY ADDITIONAL INFORMATION (CONTINUED)

Additional Requirements for Facilities Subject to Acid Rain, CAIR, or Hg Budget Program

1. Acid Rain Program Forms:

   Acid Rain Part Application (DEP Form No. 62-210.900(1)(a)):
   ☐ Attached, Document ID:_____ ☐ Previously Submitted, Date:_____
   ☐ Not Applicable (not an Acid Rain source)

   Phase II NO_X Averaging Plan (DEP Form No. 62-210.900(1)(a)1.):
   ☐ Attached, Document ID:_____ ☐ Previously Submitted, Date:_____
   ☐ Not Applicable

   New Unit Exemption (DEP Form No. 62-210.900(1)(a)2.):
   ☐ Attached, Document ID:_____ ☐ Previously Submitted, Date:_____
   ☐ Not Applicable

2. CAIR Part (DEP Form No. 62-210.900(1)(b)):
   ☐ Attached, Document ID:_____ ☐ Previously Submitted, Date:_____
   ☐ Not Applicable (not a CAIR source)

Additional Requirements Comment

III. EMISSIONS UNIT INFORMATION

Title V Air Operation Permit Application - For Title V air operation permitting only, emissions units are classified as regulated, unregulated, or insignificant. If this is an application for an initial, revised or renewal Title V air operation permit, a separate Emissions Unit Information Section (including subsections A through I as required) must be completed for each regulated and unregulated emissions unit addressed in this application. Some of the subsections comprising the Emissions Unit Information Section of the form are optional for unregulated emissions units. Each such subsection is appropriately marked. Insignificant emissions units are required to be listed at Section II, Subsection C.

Air Construction Permit or FESOP Application - For air construction permitting or federally enforceable state air operation permitting, emissions units are classified as either subject to air permitting or exempt from air permitting. The concept of an "unregulated emissions unit" does not apply. If this is an application for an air construction permit or FESOP, a separate Emissions Unit Information Section (including subsections A through I as required) must be completed for each emissions unit subject to air permitting addressed in this application for air permit. Emissions units exempt from air permitting are required to be listed at Section II, Subsection C.

Air Construction Permit and Revised/Renewal Title V Air Operation Permit Application – Where this application is used to apply for both an air construction permit and a revised or renewal Title V air operation permit, each emissions unit is classified as either subject to air permitting or exempt from air permitting for air construction permitting purposes, and as regulated, unregulated, or insignificant for Title V air operation permitting purposes. A separate Emissions Unit Information Section (including subsections A through I as required) must be completed for each emissions unit addressed in this application that is subject to air construction permitting and for each such emissions unit that is a regulated or unregulated unit for purposes of Title V permitting. (An emissions unit may be exempt from air construction permitting but still be classified as an unregulated unit for Title V purposes.) Emissions units classified as insignificant for Title V purposes are required to be listed at Section II, Subsection C.

If submitting the application form in hard copy, the number of this Emissions Unit Information Section and the total number of Emissions Unit Information Sections submitted as part of this application must be indicated in the space provided at the top of each page.

A. GENERAL EMISSIONS UNIT INFORMATION

Title V Air Operation Permit Emissions Unit Classification

1. Regulated or Unregulated Emissions Unit? (Check one, if applying for an initial, revised or renewal Title V air operation permit. Skip this item if applying for an air construction permit or FESOP only.)

☐ 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.

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).

☐ 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. Description of Emissions Unit Addressed in this Section:
2090 brake hp natural gas fired Caterpillar Model G3608 LE engine for pump 5. Maximum heat input rate is 13.70 MMBtu /hr. Pump has a designed 40 MGD water pumping capacity.

3. Emissions Unit Identification Number: 020

4. Emissions Unit Status Code:	5. Commence Construction Date:	6. Initial Startup Date:	7. Emissions Unit Major Group SIC Code:
C	10/2/2002		49

8. Federal Program Applicability: (Check all that apply)

☐ Acid Rain Unit

☐ CAIR Unit

9. Package Unit:
Manufacturer: Caterpillar Model Number: G3808 LE-130

10. Generator Nameplate Rating: MW

11. Emissions Unit Comment:
As previously permitted under Title V Air Construction Permits Nos. 0250314-005-AC and 0250314-007-AC. Construction on this emissions unit has remained incomplete due to delays in other aspects of the aforementioned permits and subsequent funding and procurement issue with completing this unit.

Emissions Unit Control Equipment/Method: Control N/A of N/A

1. Control Equipment/Method Description:
2. Control Device or Method Code:

B. EMISSIONS UNIT CAPACITY INFORMATION

(Optional for unregulated emissions units.)

Emissions Unit Operating Capacity and Schedule

1. Maximum Process or Throughput Rate:	
2. Maximum Production Rate:	
3. Maximum Heat Input Rate: 17.58 million Btu/hr	
4. Maximum Incineration Rate: pounds/hr tons/day	
5. Requested Maximum Operating Schedule: 24 hours/day 52 weeks/year	7 days/week 8760 hours/year

6. Operating Capacity/Schedule Comment:

Maximum Heat Input Rate is based on 100% load and the manufacturer-supplied fuel rate of 16,743 scf/hr. Although pump calculations, not included here, indicate that the engine will normally be loaded to approximately 85% with consequent lower hourly heat input rate and emissions, the maximum figures at full load are used in this application

16,743 scf/hr x 1050 Btu/scf x 10^{-6} MMBtu/Btu = 17.58 MMBtu/hr.

C. EMISSION POINT (STACK/VENT) INFORMATION

(Optional for unregulated emissions units.)

Emission Point Description and Type

1. Identification of Point on Plot Plan or Flow Diagram: Pump No. 5	2. Emission Point Type Code: 3	
3. Descriptions of Emission Points Comprising this Emissions Unit for VE Tracking: 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: 847 °F	9. Actual Volumetric Flow Rate: 14,867 acfm	10. Water Vapor: %
11. Maximum Dry Standard Flow Rate: dscfm	12. Nonstack Emission Point Height: feet	
13. Emission Point UTM Coordinates... Zone: East (km): North (km):	14. Emission Point Latitude/Longitude... Latitude (DD/MM/SS) 25/42/35 Longitude (DD/MM/SS) 80/20/08	
15. Emission Point Comment:		

D. SEGMENT (PROCESS/FUEL) INFORMATION

Segment Description and Rate: Segment 1 of 1

1. Segment Description (Process/Fuel Type): Natural gas powered internal combustion engines (emissions related to million cubic feet burned).		
2. Source Classification Code (SCC): 2-03-002-01	3. SCC Units: Million Cubic Feet Burned (all gaseous fuels)	
4. Maximum Hourly Rate: 0.0167	5. Maximum Annual Rate: 146.67	6. Estimated Annual Activity Factor: 1.00
7. Maximum % Sulfur: 0.00	8. Maximum % Ash: 0.00	9. Million Btu per SCC Unit: 1050
10. Segment Comment: Maximum Hourly Rate of the engine is 0.016743 MMscf/hr. The Maximum Annual Rate = 0.016743 MMscf/hr x 8760 hrs/yr = 146.67 MMscf/yr		

E. EMISSIONS UNIT POLLUTANTS

List of Pollutants Emitted by Emissions Unit

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

F1. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION – POTENTIAL, FUGITIVE, AND ACTUAL EMISSIONS

(Optional for unregulated emissions units.)

Complete a Subsection F1 for each pollutant identified in Subsection E if applying for an air construction permit or concurrent processing of an air construction permit and a revised or renewal Title V operation permit. Complete for each emissions-limited pollutant identified in Subsection E if applying for an air operation permit.

Potential, Estimated Fugitive, and Baseline & Projected Actual Emissions

1. Pollutant Emitted: NOX	2. Total Percent Efficiency of Control:
3. Potential Emissions: 3.43 lb/hour 15.02 tons/year	4. Synthetically Limited? ☐ Yes ☒ No
5. Range of Estimated Fugitive Emissions (as applicable): to tons/year	
6. Emission Factor: 0.70 g/bhp-hr Reference: Manufacturer	7. Emissions Method Code: 5
8.a. Baseline Actual Emissions (if required): tons/year	8.b. Baseline 24-month Period: From: To:
9.a. Projected Actual Emissions (if required): tons/year	9.b. Projected Monitoring Period: ☐ 5 years ☐ 10 years

10. Calculation of Emissions:

(0.70 gram/bhp-hour) x (2225 bhp) x (1/453.6 lb/gram) = 3.43 lb/hour

(3.43 lb/hour) x (8760 hours/year) x (1/2000 tons/lb) = 15.02 tons/year

11. Potential, Fugitive, and Actual Emissions Comment:

Based on full-load operation (maximum total emissions).

F2. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION - ALLOWABLE EMISSIONS

Complete Subsection F2 if the pollutant identified in Subsection F1 is or would be subject to a numerical emissions limitation.

Allowable Emissions Allowable Emissions N/A of N/A

1. Basis for Allowable Emissions Code:	2. Future Effective Date of Allowable Emissions:
3. Allowable Emissions and Units:	4. Equivalent Allowable Emissions: lb/hour tons/year
5. Method of Compliance:	
6. Allowable Emissions Comment (Description of Operating Method):	

F1. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION – POTENTIAL, FUGITIVE, AND ACTUAL EMISSIONS

(Optional for unregulated emissions units.)

Complete a Subsection F1 for each pollutant identified in Subsection E if applying for an air construction permit or concurrent processing of an air construction permit and a revised or renewal Title V operation permit. Complete for each emissions-limited pollutant identified in Subsection E if applying for an air operation permit.

Potential, Estimated Fugitive, and Baseline & Projected Actual Emissions

1. Pollutant Emitted: CO	2. Total Percent Efficiency of Control:
3. Potential Emissions: 9.32 lb/hour 40.82 tons/year	4. Synthetically Limited? ☐ Yes ☒ No
5. Range of Estimated Fugitive Emissions (as applicable): to tons/year	
6. Emission Factor: 1.90 g/bhp-hr Reference: Manufacturer	7. Emissions Method Code: 5
8.a. Baseline Actual Emissions (if required): tons/year	8.b. Baseline 24-month Period: From: To:
9.a. Projected Actual Emissions (if required): tons/year	9.b. Projected Monitoring Period: ☐ 5 years ☐ 10 years

10. Calculation of Emissions:

(1.90 gram/bhp-hour) x (2225 bhp) x (1/453.6 lb/gram) = 9.32 lb/hour

(9.32 lb/hour) x (8760 hours/year) x (1/2000 tons/lb) = 40.82 tons/year

11. Potential, Fugitive, and Actual Emissions Comment:

Based on full-load operation (maximum total emissions).

F2. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION - ALLOWABLE EMISSIONS

Complete Subsection F2 if the pollutant identified in Subsection F1 is or would be subject to a numerical emissions limitation.

Allowable Emissions Allowable Emissions N/A of N/A

1. Basis for Allowable Emissions Code:	2. Future Effective Date of Allowable Emissions:
3. Allowable Emissions and Units:	4. Equivalent Allowable Emissions: lb/hour tons/year
5. Method of Compliance:	
6. Allowable Emissions Comment (Description of Operating Method):	

F1. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION – POTENTIAL, FUGITIVE, AND ACTUAL EMISSIONS

(Optional for unregulated emissions units.)

Complete a Subsection F1 for each pollutant identified in Subsection E if applying for an air construction permit or concurrent processing of an air construction permit and a revised or renewal Title V operation permit. Complete for each emissions-limited pollutant identified in Subsection E if applying for an air operation permit.

Potential, Estimated Fugitive, and Baseline & Projected Actual Emissions

1. Pollutant Emitted: VOC	2. Total Percent Efficiency of Control:
3. Potential Emissions: 1.94 lb/hour 8.51 tons/year	4. Synthetically Limited? ☐ Yes ☒ No
5. Range of Estimated Fugitive Emissions (as applicable): to tons/year	
6. Emission Factor: 116 lb/MMscf Reference: SCC 2-03-002-01	7. Emissions Method Code: 3
8.a. Baseline Actual Emissions (if required): tons/year	8.b. Baseline 24-month Period: From: To:
9.a. Projected Actual Emissions (if required): tons/year	9.b. Projected Monitoring Period: ☐ 5 years ☐ 10 years

10. Calculation of Emissions:

(116 lb/MMscf) x (0.016743 MMscf/hour) = 1.94 lb/hour

(1.94 lb/hour) x (8760 hours/year) x (1/2000 tons/lb) = 8.51 tons/year

11. Potential, Fugitive, and Actual Emissions Comment:

Based on full-load operation (maximum total emissions).

F2. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION - ALLOWABLE EMISSIONS

Complete Subsection F2 if the pollutant identified in Subsection F1 is or would be subject to a numerical emissions limitation.

Allowable Emissions Allowable Emissions N/A of N/A

1. Basis for Allowable Emissions Code:	2. Future Effective Date of Allowable Emissions:
3. Allowable Emissions and Units:	4. Equivalent Allowable Emissions: lb/hour tons/year
5. Method of Compliance:	
6. Allowable Emissions Comment (Description of Operating Method):	

G. VISIBLE EMISSIONS INFORMATION

Complete Subsection G if this emissions unit is or would be subject to a unit-specific visible emissions limitation.

Visible Emissions Limitation: Visible Emissions Limitation 1 of 1

1. Visible Emissions Subtype: VE 20	2. Basis for Allowable Opacity: ☒ Rule ☐ Other
3. 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:	

H. CONTINUOUS MONITOR INFORMATION

Complete Subsection H if this emissions unit is or would be subject to continuous monitoring.

Continuous Monitoring System: Continuous Monitor N/A of N/A

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:	

I. EMISSIONS UNIT ADDITIONAL INFORMATION

Additional Requirements for All Applications, Except as Otherwise Stated

1. Process Flow Diagram: (Required for all permit applications, except Title V air operation permit revision applications if this information was submitted to the department within the previous five years and would not be altered as a result of the revision being sought)
   ☒ Attached, Document ID: B ☐ Previously Submitted, Date _____

2. Fuel Analysis or Specification: (Required for all permit applications, except Title V air operation permit revision applications if this information was submitted to the department within the previous five years and would not be altered as a result of the revision being sought)
   ☒ Attached, Document ID: D ☐ Previously Submitted, Date _____

3. Detailed Description of Control Equipment: (Required for all permit applications, except Title V air operation permit revision applications if this information was submitted to the department within the previous five years and would not be altered as a result of the revision being sought)
   ☒ Attached, Document ID: E ☐ Previously Submitted, Date _____

4. Procedures for Startup and Shutdown: (Required for all operation permit applications, except Title V air operation permit revision applications if this information was submitted to the department within the previous five years and would not be altered as a result of the revision being sought)
   ☐ Attached, Document ID: _____ ☐ Previously Submitted, Date _____
   ☒ Not Applicable (construction application)

5. Operation and Maintenance Plan: (Required for all permit applications, except Title V air operation permit revision applications if this information was submitted to the department within the previous five years and would not be altered as a result of the revision being sought)
   ☒ Attached, Document ID: F ☐ Previously Submitted, Date _____
   ☐ Not Applicable

6. Compliance Demonstration Reports/Records:
   ☐ Attached, Document ID: _____
   Test Date(s)/Pollutant(s) Tested: _____
   _____
   ☐ Previously Submitted, Date: _____
   Test Date(s)/Pollutant(s) Tested: _____
   _____
   ☐ To be Submitted, Date (if known): _____
   Test Date(s)/Pollutant(s) Tested: _____
   _____
   ☒ Not Applicable
   Note: For FESOP applications, all required compliance demonstration records/reports must be submitted at the time of application. For Title V air operation permit applications, all required compliance demonstration reports/records must be submitted at the time of application, or a compliance plan must be submitted at the time of application.

7. Other Information Required by Rule or Statute:
   ☐ Attached, Document ID: _____ ☒ Not Applicable

I. EMISSIONS UNIT ADDITIONAL INFORMATION (CONTINUED)

Additional Requirements for Air Construction Permit Applications

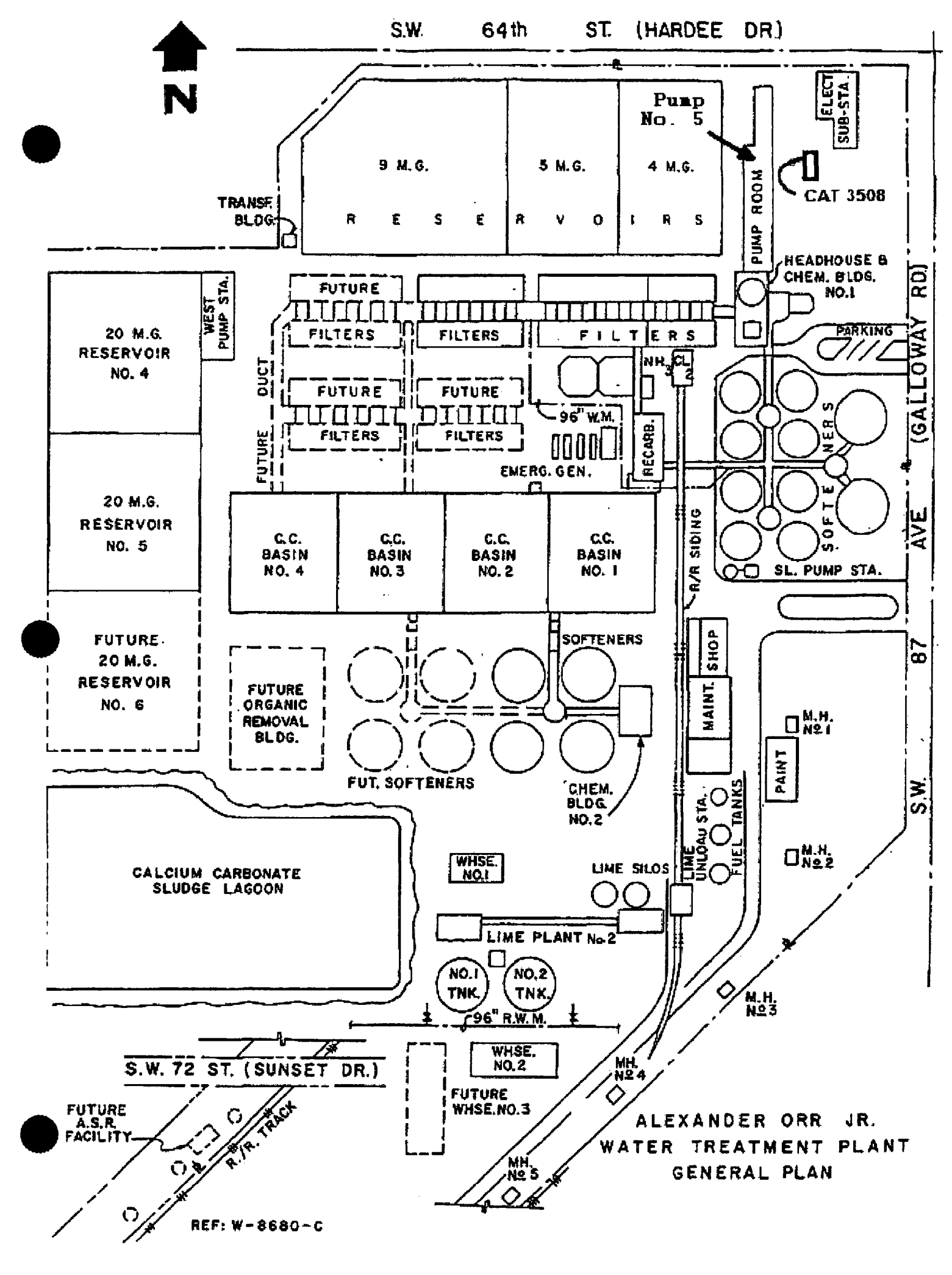
1. Control Technology Review and Analysis (Rules 62-212.400(10) and 62-212.500(7), F.A.C.; 40 CFR 63.43(d) and (e)): ☐ Attached, Document ID: _____ ☒ Not Applicable
2. Good Engineering Practice Stack Height Analysis (Rules 62-212.400(4)(d) and 62-212.500(4)(f), F.A.C.): ☐ Attached, Document ID: _____ ☒ Not Applicable
3. Description of Stack Sampling Facilities: (Required for proposed new stack sampling facilities only) ☐ Attached, Document ID: _____ ☒ Not Applicable

Additional Requirements for Title V Air Operation Permit Applications

1. Identification of Applicable Requirements: ☐ Attached, Document ID: _____
2. Compliance Assurance Monitoring: ☐ Attached, Document ID: _____ ☐ Not Applicable
3. Alternative Methods of Operation: ☐ Attached, Document ID: _____ ☐ Not Applicable
4. Alternative Modes of Operation (Emissions Trading): ☐ Attached, Document ID: _____ ☐ Not Applicable

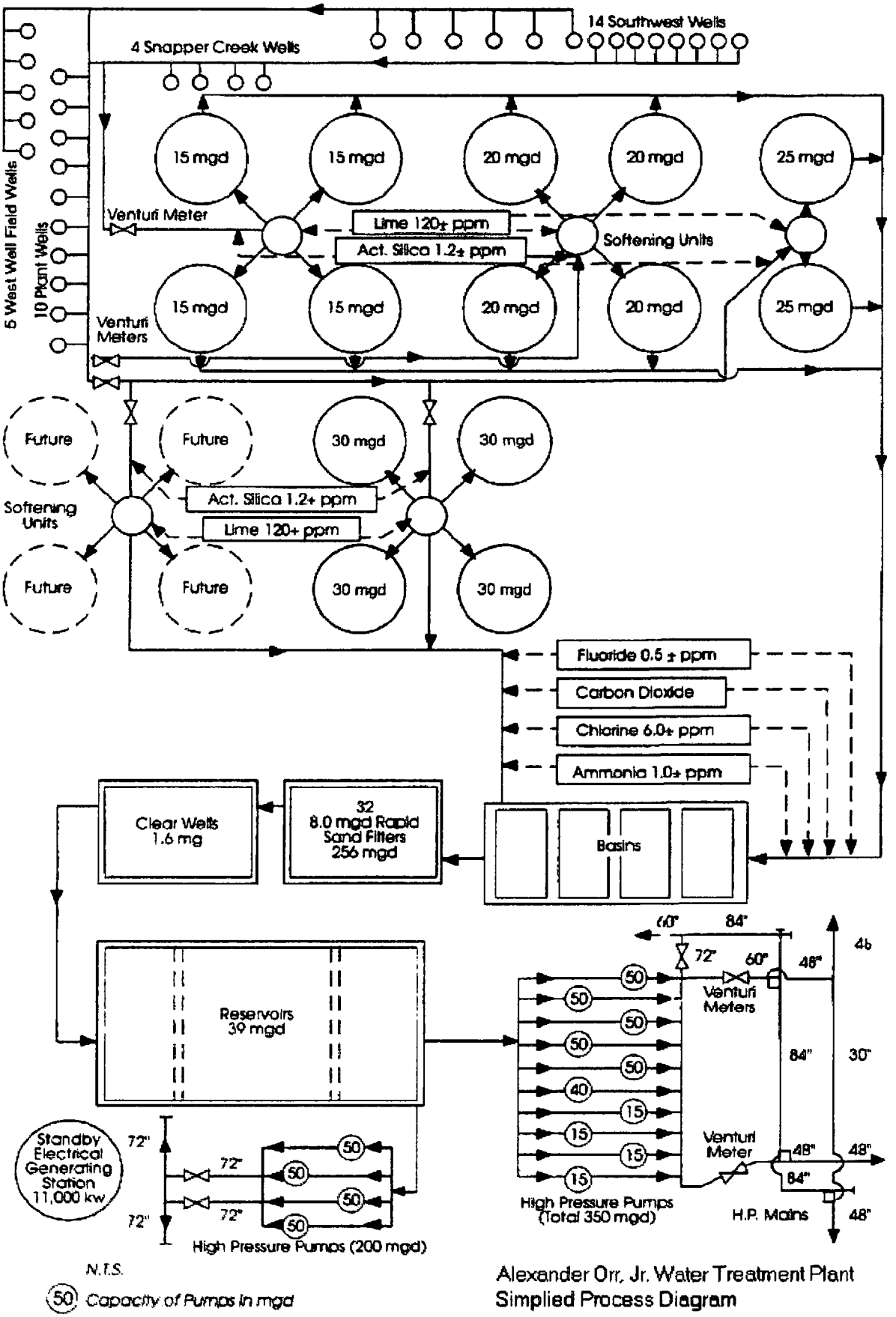
Additional Requirements Comment

Attachment A
Facility Plot Plan


S.W. 64th ST. (HARDEE DR)
N
9 M.G.
5 M.G.
4 M.G.
RESERVOIRS
Pump No. 5
CAT 3508
ELECT SUB-STA.
PUMP ROOM
TRANSF. BLDG.
HEADHOUSE & CHEM. BLDG. NO.1
PARKING
20 M.G. RESERVOIR NO. 4
WEST PUMP STA.
20 M.G. RESERVOIR NO. 5
FUTURE 20 M.G. RESERVOIR NO. 6
FUTURE FILTERS
FILTERS
FUTURE DUCT
NH3 Cl2
96" W.M.
RECARB.
EMERG. GEN.
SOFTENERS
C.C. BASIN NO. 4
C.C. BASIN NO. 3
C.C. BASIN NO. 2
C.C. BASIN NO. 1
R/R SIDING
SL. PUMP STA.
FUTURE ORGANIC REMOVAL BLDG.
FUT. SOFTENERS
CHEM. BLDG. NO.2
SHOP
MAINT.
PAINT
M.H. №1
M.H. №2
M.H. №3
M.H. №4
M.H. №5
LIME UNLOAD STA.
FUEL TANKS
CALCIUM CARBONATE SLUDGE LAGOON
WHSE. NO.1
LIME SILOS
LIME PLANT No.2
NO.1 TNK.
NO.2 TNK.
96" R.W.M.
S.W. 72 ST. (SUNSET DR.)
WHSE. NO.2
FUTURE WHSE.NO.3
FUTURE A.S.R. FACILITY
R/R TRACK
S.W. 87 AVE (GALLOWAY RD)
ALEXANDER ORR JR.
WATER TREATMENT PLANT
GENERAL PLAN
REF: W-8680-C

Attachment B
Process Flow Diagram

Attachmnet B: Process Flow – Alexander Orr, Jr. Water Treatment Plant – Water Treatment

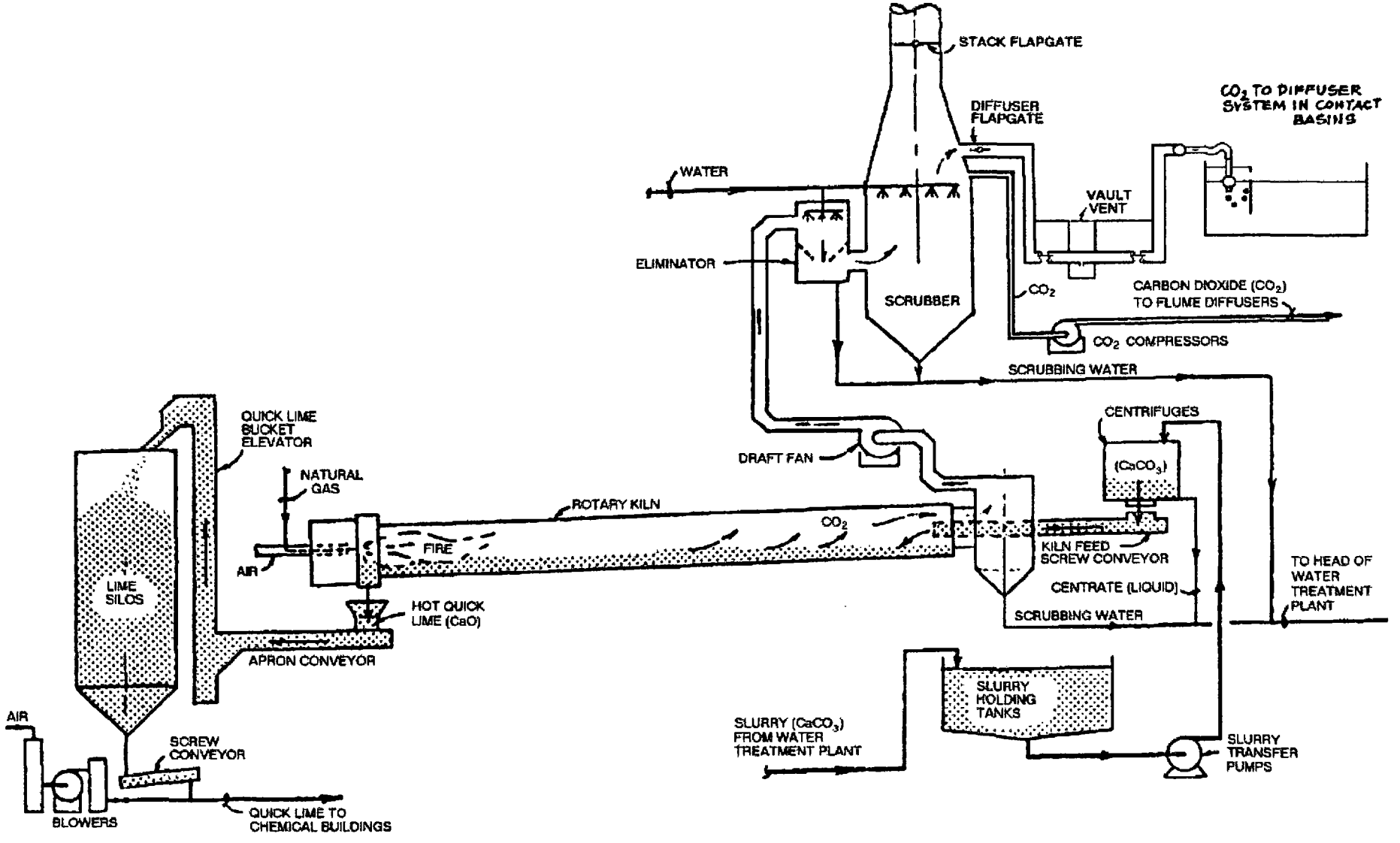


N.T.S.

(50) Capacity of Pumps in mgd

Alexander Orr, Jr. Water Treatment Plant
Simplied Process Diagram

Attachment B: Process Flow – Alexander Orr, Jr. Water Treatment Plant – Solids Recovery and Reuse, Rotary Kiln



Attachment C
Precautions to Prevent Emissions of Unconfined Particulate Matter

Attachment C

Precautions To Prevent Emissions of Unconfined Particulate Matter
Alexander Orr, Jr. Water Treatment Plant

The Alexander Orr, Jr. Water Treatment Plant will take the following reasonable precautions to control the emissions of unconfined particulate matter:

- Paving and maintenance of roads, parking areas, and yards.
- Application of water or chemicals to control emissions from such activities as demolition of buildings, grading roads, construction, and land clearing.
- Application of asphalt, water, oil, chemicals, or other dust suppressants to unpaved roads, yards, open stock piles, and similar sources.
- Removal of particulate matter from buildings or work area to prevent particulate from becoming airborne.
- Landscaping or planting of vegetation.
- Use of hoods, fans, filters, and similar equipment to contain and or vent particulate matter.
- Confining abrasive blasting, where possible.
- Enclosure or covering of conveyor systems

Attachment D
Fuel Analysis and Specification

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)

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 Trnasmission 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 (~~CO~~ WWFER 46495)
~~R. O'Rourke~~

Spot Analysis of Natural Gas for Delivery in Florida

(West Palm Beach Chromatograph)

DATE: November 17, 1997

TIME: 08:12

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)

Attachment E
Detailed Description of Control Equipment

Attachment E
Detailed Description of Control Equipment

Emissions controls for internal combustion engines fall generally into the areas of combustion control and post-combustion control.

Combustion control is incorporated in fixed engine design attributes such as bore/stroke ratio, combustion chamber shape and size, camshaft profile, etc. and in the operation of the engine though fuel/air and ignition control, usually by means of an electronic engine management system in modern engines.

A description of the combustion controls in the subject emissions unit, Pump Engine No. 5 - Caterpillar Model G3608 LE, are included in this attachment.

Post-combustion control for spark-ignition engines is usually in the form of an oxidation catalyst. Oxidation catalysts are effective for the control of carbon monoxide (CO), non-methane hydrocarbons (NMHC), volatile organic compounds (VOC), and formaldehyde (CH2O) and other EPA-classified Hazardous Air Pollutants (HAPs) from natural gas lean-burn engines.

MDWASD is currently in the planning stage of bringing its inventory of stationary RICE into compliance with 40 CFR Part 63 Subpart ZZZZ – *National Emissions Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines* (RICE NESHAP). This program involves the evaluation of the operating basis of these engines along with possible amendments to these bases, initial testing as required, and the full implementation of compliance measures including post-combustion control where required.

The proposed Pump Engine No. 5 - Caterpillar Model G3608 LE will not be operated as an emergency- or limited-use engine and will be subject to the full range of compliance measures for its category under RICE NESHAP. Accordingly, and following the issuance of this requested construction permit, initial testing will be conducted after engine start-up, and any required post-combustion control will be installed prior to application for an Air Operating Permit for the subject emissions unit.

Also included in this attachment is a description of a typical oxidation catalyst as may be installed on Pump Engine No. 5 - Caterpillar Model G3608 LE.

8/29/00 W~ 655 P.3/4
MB

CATERPILLAR®

Caterpillar Inc.
Lafayette Engine Center
Lafayette, Indiana 47906

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	+/- 3.0%	
A/C Inlet Temp. (°F):	130	JW Outlet Temp. (°F):	180		
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	2.60	6.00	1.06	0.51
tons/year	15.0	55.7	128.5	22.8	11.0

Exhaust Mass Flow (lbs/hr, wet):	28,548
Exhaust Volume Flow (cfm, wet): @ 842°F stack temp, 14.5 psia	14,816

MIAMI-DADE WATER AND SEWER DEPARTMENT
RECEIVED
SEP 12 2000
SD ENGINEERING DIVISION SD

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

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):	8810 +/- 3.0%
A/C Inlet Temp. (°F):	130	J/W Outlet Temp. (°F):	190
Fuel LHV (Btu/ft3):	953	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):	26,548
Exhaust Volume Flow (cfm, wet): @ 842°F stack temp, 14.5 psia	14,816

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

mG3600emissn\2000\00-092.xls

G3608 SITA — 9:1 Industrial Performance

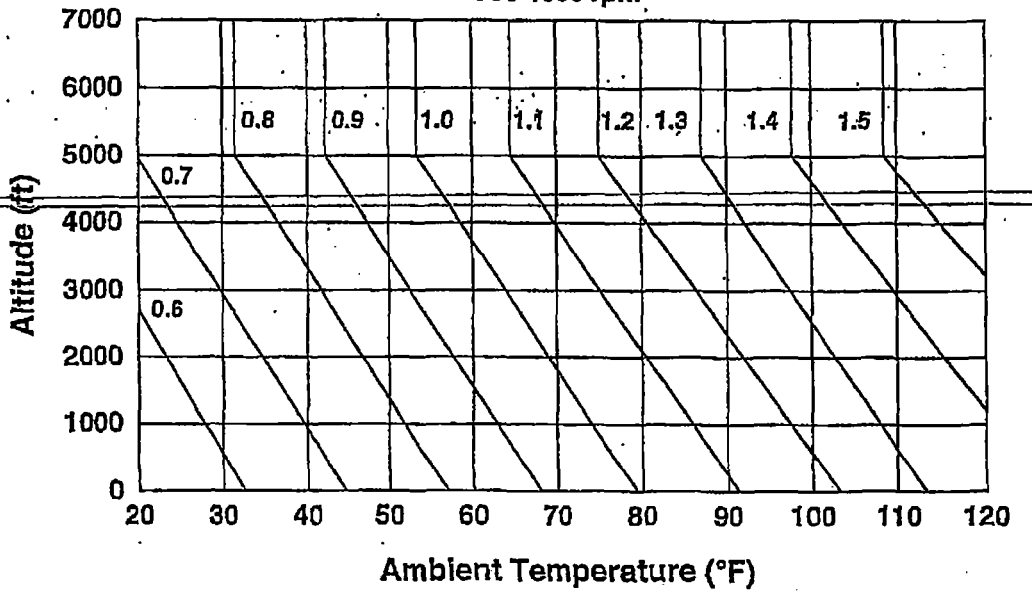
		100%	75%	50%	25%
↘ piration		TA	TA	TA	TA
Speed	rpm	1000	1000	1000	1000
JW Outlet Temperature (°F)		190	190	190	190
A/C Inlet Temperature (°F)		130	130	130	130
Engine Power	bhp[1]	2225	1669	1113	556
NOx (as NO_2)	g/bhp-hr[2]	0.70	0.70	0.70	1.20
CO	g/bhp-hr[2]	1.90	1.90	1.90	2.20
HC (Total)	g/bhp-hr[2]	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	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
[illegible]ust (LHV)	Btu/min[4]	97042	76771	56282	34002
[illegible]aust (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/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
6) [illegible]erance +/- 25%
7) [illegible]lerance +/- 20%, heat rejection based on treated water as coolant

Aftercooler Heat Rejection Factors

G3608 Industrial – 90°F SCAC

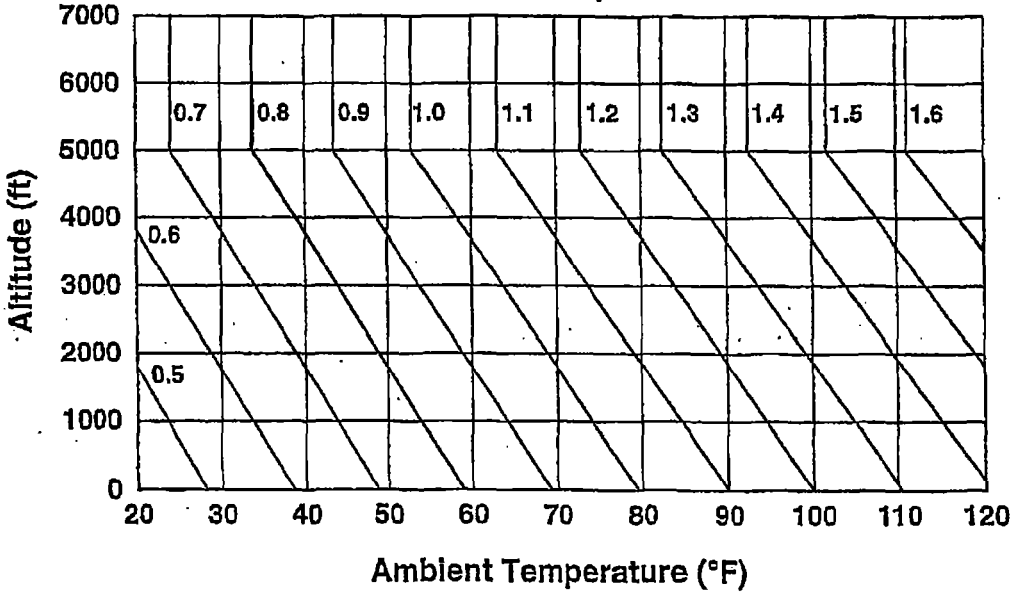
730-1000 rpm



Aftercooler Heat Rejection Factors

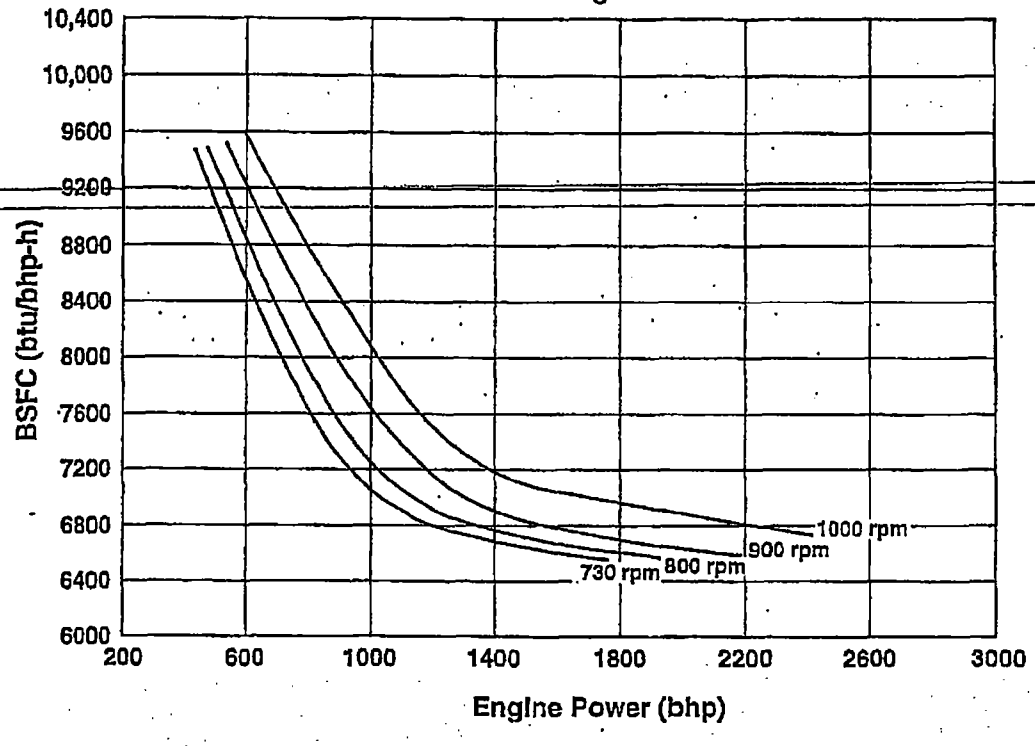
G3608 Industrial – 130°F SCAC

730-1000 rpm



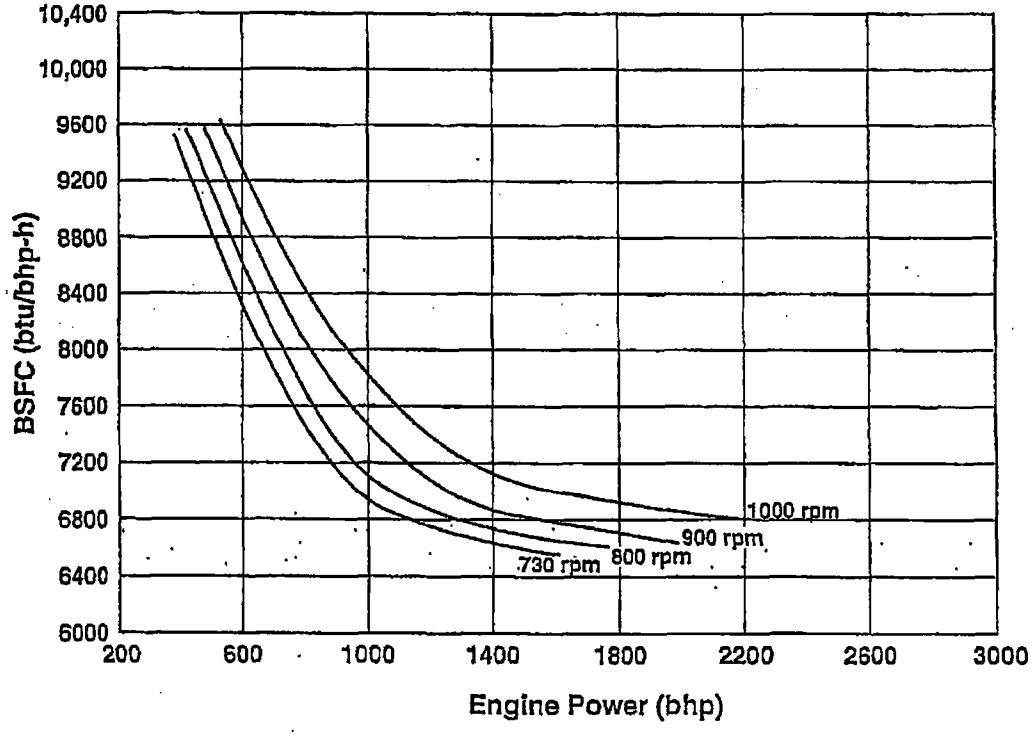
G3608 BSFC

Industrial Turbocharger 90°F SCAC



G3608 BSFC

Industrial Turbocharger 130°F SCAC



CATERPILLAR®

Gas Engine Industrial Low Emission G3608

1555-2350 HP

FEATURES

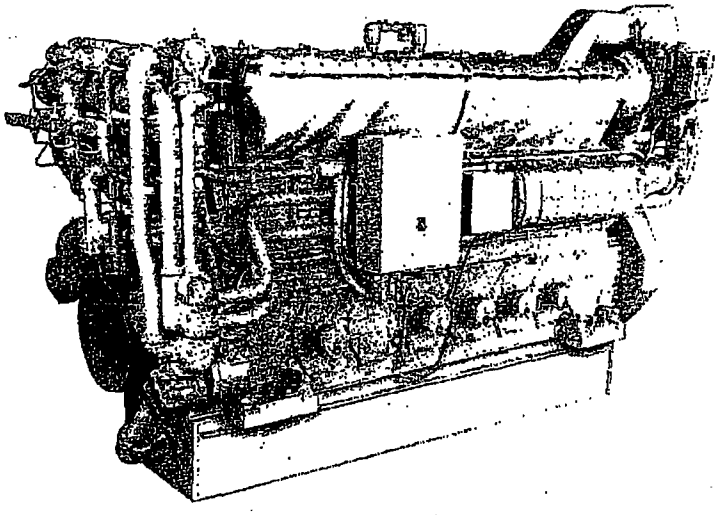
• CATERPILLAR® QUALITY THROUGHOUT
Cat gas engines incorporate many of the same proven components as their diesel counterparts – including the block, crankshaft, main bearings, camshaft and connecting rods. However, by operating at 40 to 50% lower cylinder pressure and bearing loads than diesels, they 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
1 gram/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

G3600 Product Description

The G3600 Family of Gas Engines incorporates advanced technology essential for high output, low emissions, and high thermal efficiency. Precise control of engine operating parameters allows the engine to operate at optimum performance on a wide range of fuels and ambient conditions.

Technological features include:

- Lean Burn Technology
- Precombustion Chamber
- Gas Admission Valves
- Advanced Electronic Controls
- Rugged Basic Structure

Primary applications for this engine are:

- Industrial
  air compressors and direct drive chillers
- Electric Power Generation
  load management and cogeneration
- Gas Compression
  gas gathering and gas transmission

Many electric utilities are charging substantial demand charges and time of day rates which create a significant potential for gas engine sales. The high thermal efficiency of the 3600 Engines provides early payback and the low emissions allows easy permitting for most applications.

Direct drive air compressors and air conditioning chillers are two examples of ways to save costs by avoiding high electrical usage during peak periods. On-site power generation during peak periods is another way to drastically lower utility bills. Utilities themselves represent potential as they try to decentralize or add capacity. Cogeneration, either in base load or load management applications, provides another way customers can enhance their savings. Future offerings of landfill and digester gas engine arrangements will expand this opportunity still further.

Fuel System

To ensure that each cylinder gets the correct amount of fuel at the proper air-fuel ratio, carburetors are not used. Instead, gas is admitted into the intake port, just ahead of the intake valve, see Figure 1. A unique gas admission valve, actuated by the camshaft, admits fuel into the intake port. A fuel manifold connects each cylinder and it is pressure in the manifold that meters the fuel into the intake port. By controlling the pressure in the manifold, the fuel into the engine is controlled, thereby controlling the power output of the engine. The control of the fuel pressure is the task of the electronically actuated fuel valve located on the right rear of the engine, see Figure 2. In order to admit fuel into the intake port at full load, the fuel pressure at the fuel inlet must be regulated to ±0.25 psi within a range of 43 to 47 psi. Lower pressure will result in reduced power. Separate lines from the main fuel manifold provide additional gas to each precombustion chamber. An adjustable needle valve regulates the flow. These valves are adjusted to provide precise amounts of fuel to each prechamber so that consistent ignition and power are obtained from each cylinder.

Current design limits the fuel to dry processed natural gas with a minimum methane number of 50. Propane or untreated well head gas are not permitted. Low Btu engine arrangements are not available now but are being developed for landfills and sewage treatment plants. As new arrangements with expanded fuel capabilities are developed, they will be announced and made available. Low gas pressure fuel inlet systems are not available at the present time. Regulated gas pressures of 45 ±2 psi, held to ±0.25 are required at the engine inlet. Customer mounted remote gas filter groups are available for use before the fuel inlet connection. They are designed to filter 1 micron particle size with a maximum of 2 psi pressure

G3600 Fuel System Schematic

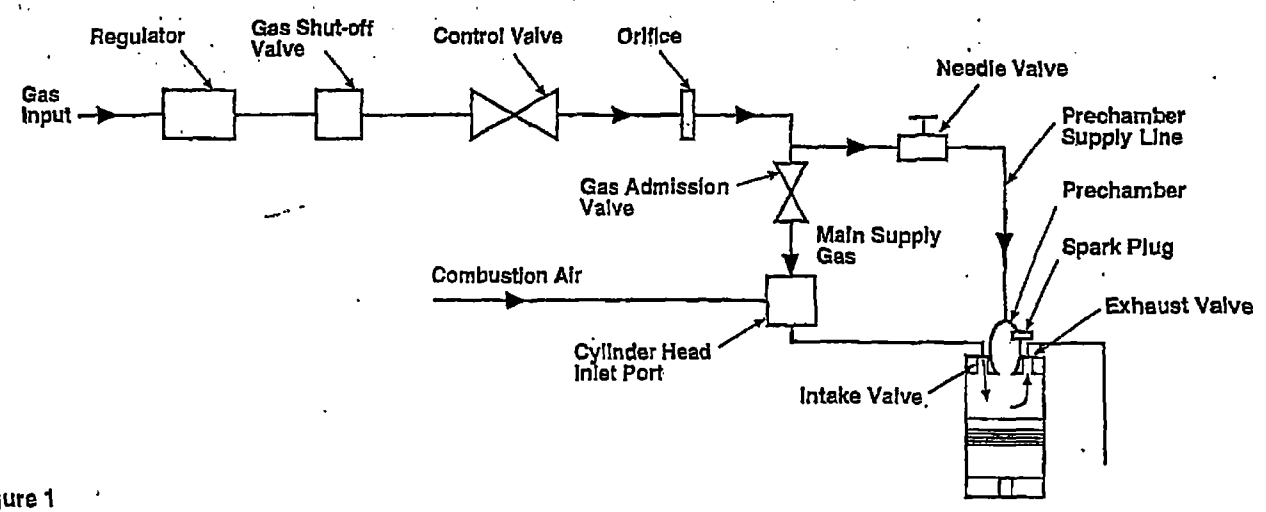


Figure 1

3600 Gas Valve

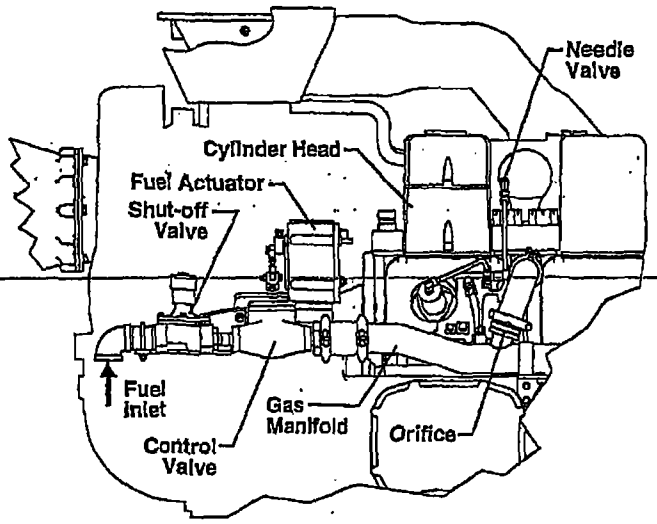


Figure 2

drop at rated flow and inlet pressures. See the *Drawings* section of this manual. Customer mounted gas pressure regulators are available to maintain gas pressure at the engine to 45 psi. They are available for gas pressures up to 150 psi.

Air System

Combustion air flows from the turbocharger, through the air inlet choke, through a water cooled plate/fin aftercooler, into the cylinder block air plenum, and then into the cylinder head inlet ports, see Figure 3. Fuel is introduced to the air in the cylinder head by the gas admission valve. Air flow is controlled by a combination of an air choke, (located downstream of the turbocharger compressor outlet) and exhaust by-pass valve or wastegate. The wastegate, which by-passes exhaust gas around the turbocharger, determines the boost level, which in turn controls the intake manifold pressure, see Figure 4. The electronic control system determines the air pressure required to maintain the correct air/fuel ratio and controls the wastegate valve and/or choke butterfly valve accordingly. At loads above approximately 40%, the air choke is in the wide open position. Below this point, the inlet air choke restricts the air flow to maintain a sufficiently rich mixture for good combustion and stability, see Figure 5. Exhaust manifolds are dry with external thermal blanket shielding for reduced radiated heat and personnel safety. The low exhaust temperatures of lean burn engines allows the use of dry manifolds. They improve engine performance and response by retaining exhaust energy to drive the turbocharger, especially for constant torque, variable speed industrial applications. Both normal and heavy duty air cleaners are available to fit specific applications. Multiple high efficiency paper elements are used. They are shipped loose and are remote-mounted by the customer at the installation site using customer supplied piping. Under normal conditions a single enclosure is used for the inlines and two for the vees. Two enclosures required for vees under heavy duty applications. See the *Drawing* section of this Manual.

Ignition System

An 18mm J-gap spark plug is connected to the ignition transformer with an teflon extender and an aluminum electrical connection inside the teflon. The J-gap offers combustion advantages, particularly at low loads, and the teflon extender prevents electrical arcing to the

G3600 Air System Schematic

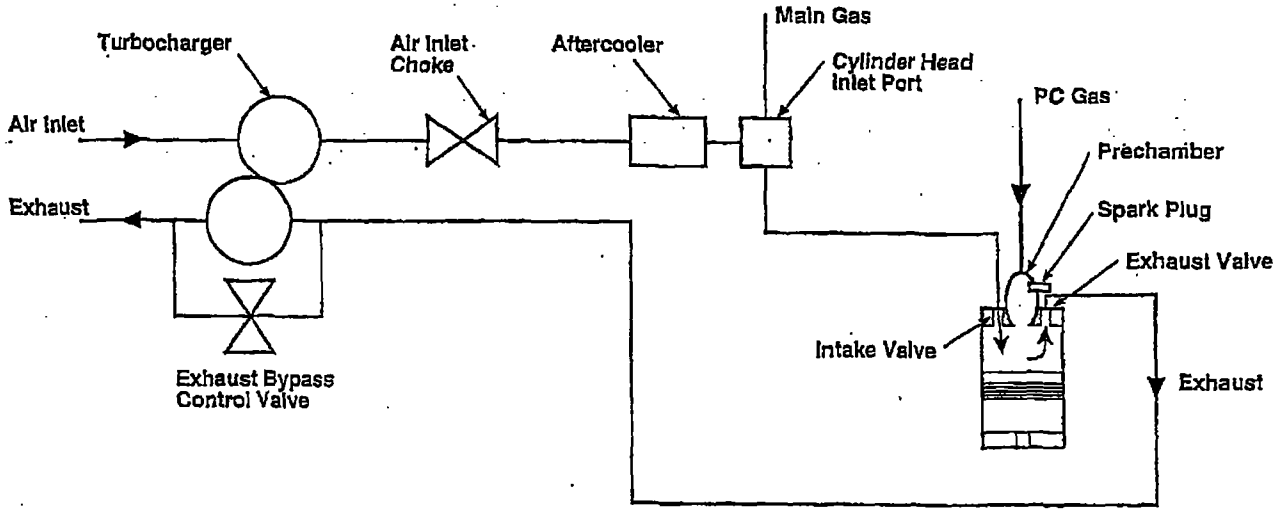


Figure 3

G3600 Exhaust Bypass

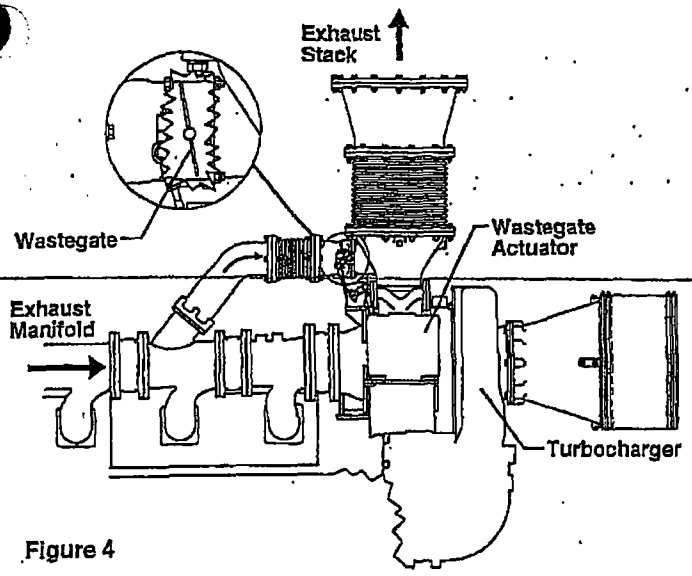


Figure 4

surrounding areas. Precious metal is used on both the center (iridium) and ground (platinum) electrodes. The metal is welded to copper cored electrodes. The copper core helps to transfer heat from the plug center.

The plug is mounted low in the prechamber to place the spark at beginning of the flame front as the enriched charge enters the main chamber. The low position allows for faster and more complete burn of the gas in the prechamber, which will provide for a positive ignition in the main chamber. This contributes to faster, more complete combustion which reduces fuel consumption. The ignition system is powered by a magneto which is driven by the camshaft at the rear of the engine.

G3600 Inlet Choke

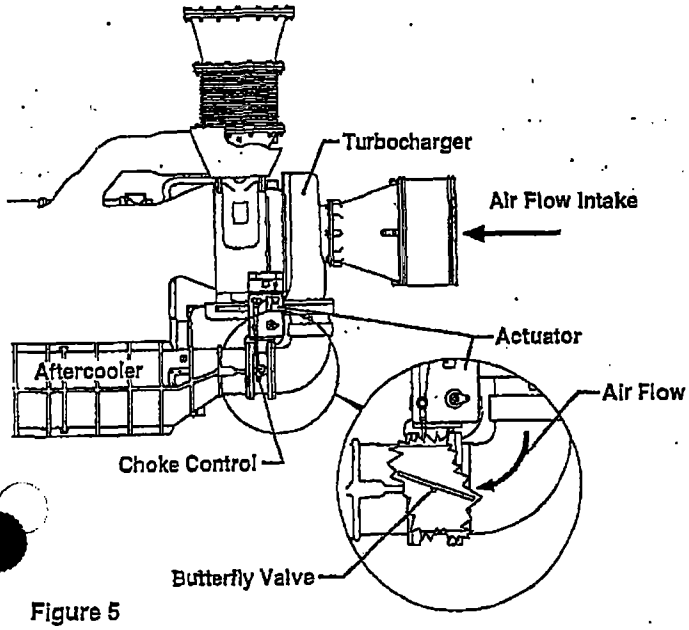


Figure 5

G3600 Engine Supervisory System

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

These subsystems include start/stop/prelube logic, engine monitoring and protection, along with governing, air/fuel ratio, and ignition control. The ESS panel is the control center for the system and houses the control modules of each sub system.

The System consists of:

- Engine Supervisory System Control Panel (ESS)
- Engine Mounted Junction Box
- Engine Mounted Sensors & Actuators
- Relays, Solenoids & Switches
- Harnesses

The System is subdivided into three interactive subsystems:

- The Start/Stop/Prelube Subsystem
  - Controls the action of the prelube pump, engine starters and gas shutoff valve.
- The Engine Monitoring and Protection Subsystem
  - Prevents engine starting or cause shutdown if vital parameters exceed acceptable limits.
  - Provides display of these parameters
  - Generates warnings when one or more parameters are outside acceptable limits.
- The Engine Control Subsystem
  - Provides Engine Governing
  - Air/Fuel Ratio Control
  - Ignition Timing Control

The Engine Supervisory System Control Panel

This panel, Figure 6, houses the control modules, switches, and potentiometers associated with the system.

- Engine Control Module (System Coordination, Governing, Air/Fuel Ratio Control)
- Timing Control Module (Ignition System Control)
- Status Control Module (Start/Stop Control)
- Computerized Monitoring System CMS (Display of System Parameters)
- Pyrometer Modules (Display of Exhaust Temperatures)
- Mode Control Switch
- Prelube Switch/Start Run ok Lamp
- Emergency Stop Switch
- Fuel Energy Adjustment Potentiometer
- Desired Speed Adjustment Potentiometer

Engine Supervisory System

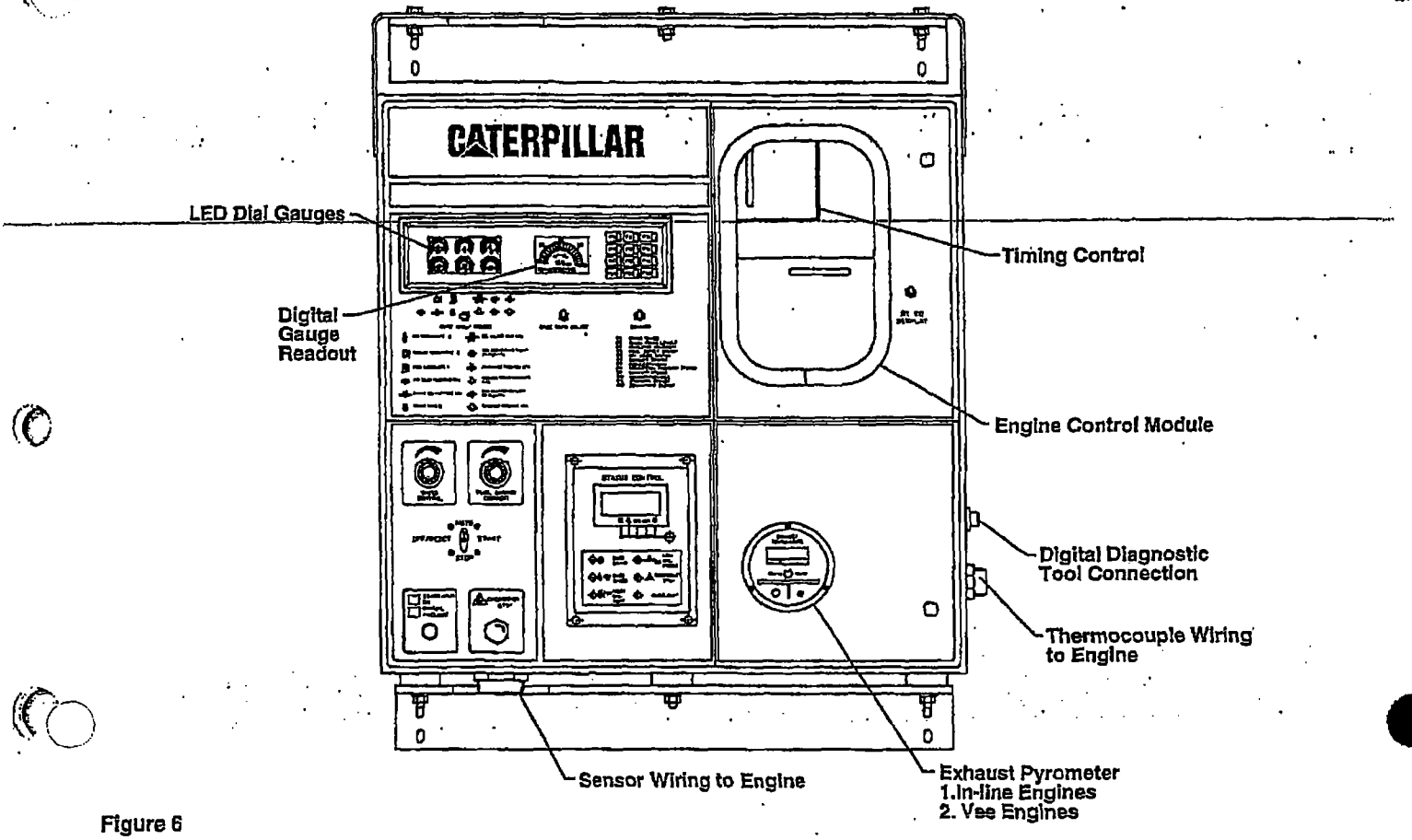


Figure 6

- Gauge Group Select Switch
- Gauge Data Select Switch
- Display Select Switch
- Dimmer Switch Diagnostics

Diagnostics

The Engine Supervisory System is self-diagnostic. Through lamps and fault codes, it directs the service technician to the system or component requiring maintenance.

Mounting

The Control Panel is a water proof enclosure intended to be remote mounted (up to 100 ft) from the engine. It is available with separate stand-alone legs or can be customer remote mounted.

Hazardous Environments

The Engine and Engine Supervisory System have been CSA certified for use in hazardous locations (Class 1 Division 2 Group D).

Personality Module

The Personality Module attaches to the Engine Control Module and contains many of the application specific information for the system. The module contains application specific maps, protection set points, and customer defined settings. Once specified the personality module cannot be changed without removing and installing a new module. It is essential the application be clearly understood early in the order process to get the proper information in the personality module.

RS232 Computer Interface

RS232 output of system data will be available in 1994 for customer monitoring and information systems (requires a ship loose converter module).

Start/Stop/Prelube System

This Subsystem, Figure 7, consists of the following components:

- Engine Supervisory System Control Panel
  - Status Control Module
  - Engine Control Module
  - Mode Control Switch
  - Prelube Switch/Lamp
- Emergency Stop Switches
- Gas Shutoff Valve

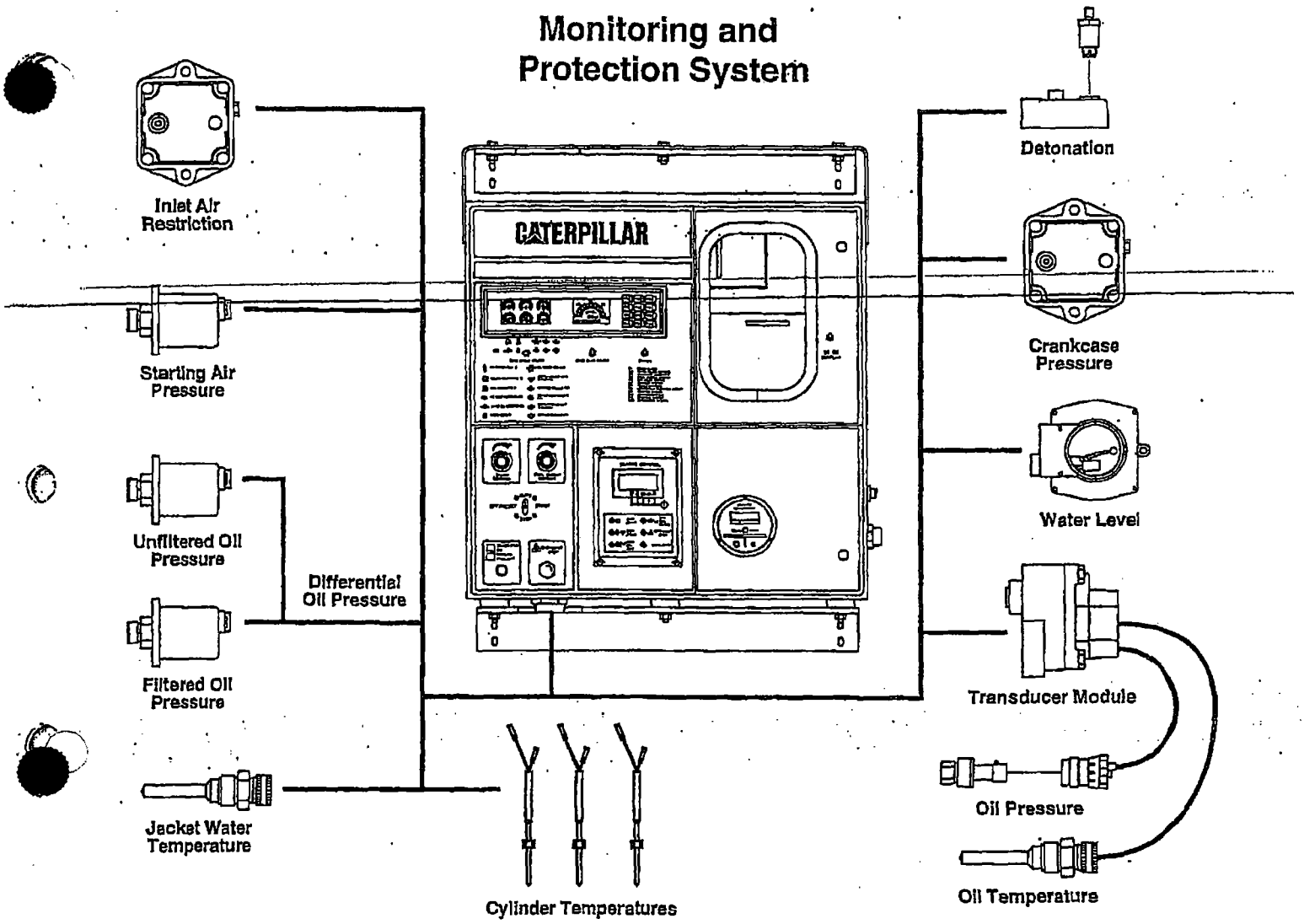


Figure 8

The system provides engine protection and monitors engine systems for vital parameters. It also provides warnings and/or inhibits engine starting or shuts down the engine when parameters are outside acceptable limits. Along with these features, it provides display/indication of engine operating parameters.

The following is a list of protection features listed by the module where the information is displayed.

Computerized Monitoring System (CMS)

The Display consists of 6 small gauges and 1 larger center gauge. The information displayed on the gauges is controlled by the gauge group select and the gauge data select switches. The gauge group select switch selects between two sets of parameters available for display on the 6 small gauges.

- Setting the switch to the left selects the first group of parameters:
  1. Manifold Air Temperature
  2. Jacket Water Temperature
  3. Fuel Correction Factor
  4. Manifold Air Pressure
  5. Engine Oil Pressure/Prelube Status
  6. Engine Load (%)
- Setting the switch to the right selects the second group of parameters:
  7. Oil Filter Differential Pressure
  8. Inlet Air Restriction (in-line engine or right bank of a vee)
  9. Crankcase Pressure
  10. Unused
  11. Inlet Air Restriction (unused for an in-line or left back of a vee)
  12. Starting Air Pressure
- The large gauge always indicates:
  13. Engine Speed

The *gauge data switch* allows the data provided on each of the gauges to be viewed on the digital read-out below the ·rge center gauge. The upper number in the gauge display indicates which parameter is being viewed (refer to above numbers in the lists of data). Each time the Gauge Data Switch is toggled the next gauge is selected (within the range of gauges currently selected by the Gauge Group Select).

If the Gauge Group Select is switched, the digital gauge will change to the gauge for the corresponding gauge position (i.e. if gauge 2 coolant temperature, was selected and the Gauge Group Select is moved the gauge data will switch to gauge 8, Inlet Air Restriction Right).

Fault Indicator Lights

The CMS has 12 lamps to indicate a fault condition has occurred. A fault is either a measured parameter outside a safe limit or a device that is malfunctioning. Each lamp indicates the system to look for to determine the exact problem.

- F1 - Check gauges
- F2 - Check fluid levels
- F3 - Auxiliary equipment
- F4 - Fuel Supply system
- F5 - Air Inlet system
- F6 - Exhaust system
- F7 - Module/wiring system
- F8 - Combustion Feedback system
- F9 - Ignition system
- F10 - Sensors/Devices
- F11 - Starting system
- F12 - Detonation system

The lamps direct the service technician to the subsystem or component with a problem. For exact information about the problem, the technician then reads the Fault Code on the module in question.

Status Control Module

The Display sequences automatically through these parameters in either English or metric units:

- Service Hours
- Engine Speed (Safety for Overspeed)
- Battery Voltage
- Engine Oil Pressure (Safety for Low Pressure)
- Engine Oil Temperature (Safety for High Temperature)

)isplayed as lamps on the front of the module:

- **Overcrank** indicates the engine did not start after cranking or cycle cranking for the entire programmed time limit.
- **Overspeed** indicates the engine has been shutdown due to excessive speed.
- **High Oil Temperature** indicates the engine has been shutdown due to excessive oil temperature.
- **Low Oil Pressure** indicates the engine has been shutdown due to insufficient oil pressure.
- **Emergency Stop** indicates the engine has been shutdown due to one of the Emergency Stop Switches being depressed.
- **Auxiliary** indicates the engine has been shutdown due to a customer requested shutdown (customer stop input).

Engine Control Module

The primary function of the Engine Control Module is to govern the speed and to control the air/fuel ratio; however, it also has the role of system coordinator. Its personality module contains many of the protection set points and it controls much of the systems operation. The display on the Engine Control Module consists of 8 characters and 8 lights.

The lights indicate:

- **Status** (Green) – The data on the 8 Character Display is status information i.e. desired engine speed, fuel energy (Btu) setting.
- **Data Link 1 Active** (Green) – When lit, this light indicates that the Engine Control Module is properly communicating with the Timing Control Module.
- **Data Link 2 Active** (Green) – When lit, this light indicates that the Engine Control Module is properly communicating with the CMS Module.
- **Caution** (Yellow) – One or more potential problems exist. The 8 Character Display will be displaying a code that indicates the exact nature of the caution condition.
- **Sensor Fault** (Red) – A problem has been detected with one of the systems sensors. The 8 Character Display will be displaying a code that indicates the exact nature of the problem.
- **Actuator Fault** (Red) – A problem has been detected with one of the actuators. The 8 Character Display will be displaying a code that indicates the exact nature of the problem.
- **System Fault** (Red) – A problem has been detected with one of the control systems. The 8 Character Display will be displaying a code that indicates the exact nature of the problem.
- **Control Module Fault** (Red) – A problem has been detected with one of the control modules. The 8 Character Display will be displaying a code that indicates the exact nature of the problem.

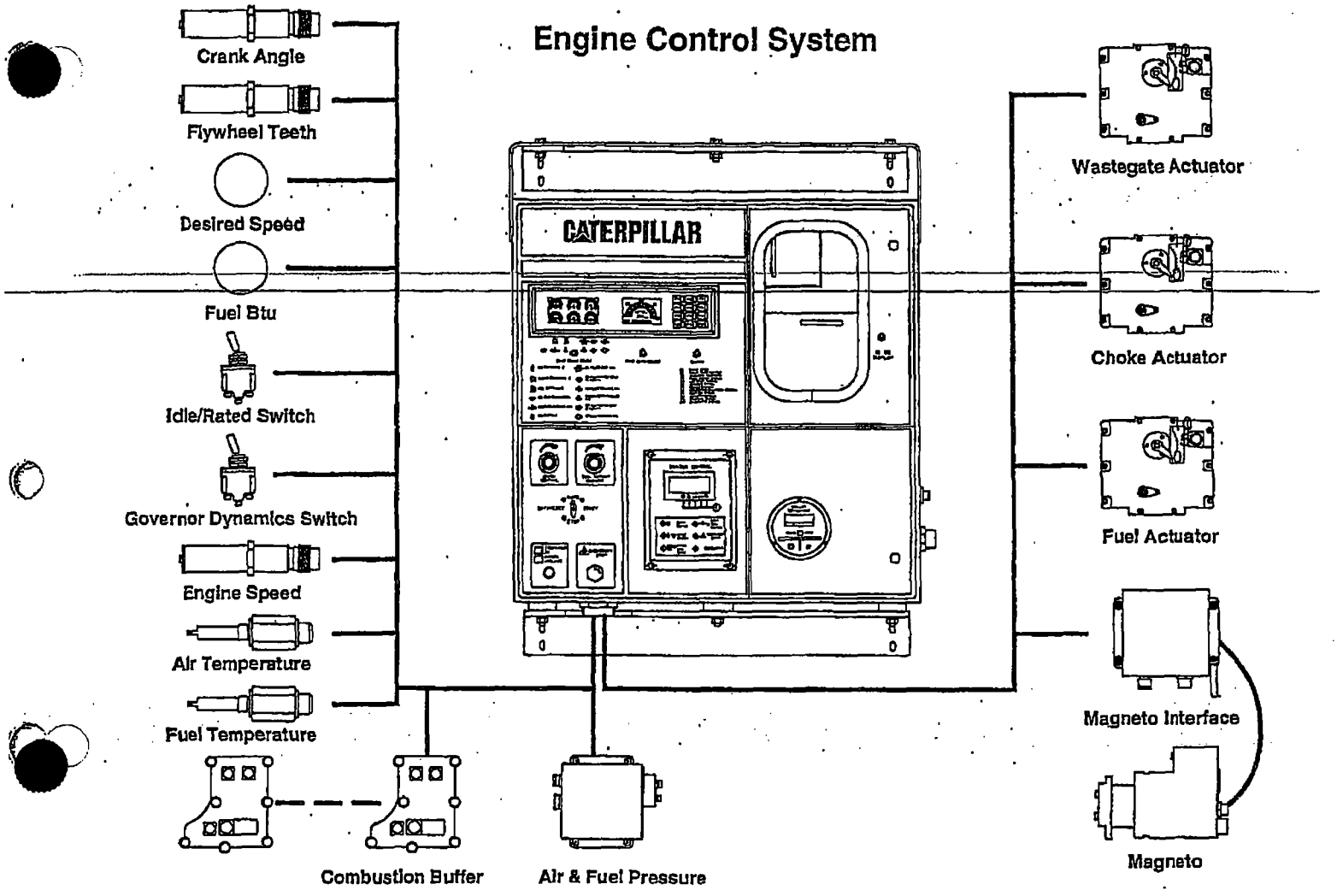


Figure 9

The Display Select Switch Allows the operator to step through the data on the Engine Control Display. Every time the switch is toggled the display steps through to the next item. Items displayed are either status or diagnostic codes (differentiated by one of the lights).

Timing Control Module

The primary function of the Timing Control Module is to maintain the ignition timing at the set point determined by the Engine Control Module. It does however measure the level of detonation or knock present in the engine. This data is used by the engine control to protect the engine from possible damage caused by detonation.

Pyrometer Modules

Each pyrometer module allows the read-out in 9 separate temperatures (in °C). The module powers up displaying the reading of channel 0 (exhaust stack temperature). To read the temperature values on the other eight channels, press the *Push to Advance* button on the front of the gauge. One of these modules is used for in-line engines two for vee engines.

The pyrometer continuously compares channel 0 (stack temperature) to a set point. If the temperature ever exceeds that set point, a contact closes instructing the system to shutdown.

Customer Inputs

- Driven Equipment Ready Contact allows the customer to stop and/or inhibit Start of the engine due to a problem with the driven equipment
- Customer Stop Contact allows the customer to request the engine to shut down for any reason needed by his equipment.

Customer Outputs

- Horn Driver annunciates that a problem has been detected in the system that may cause the engine to shutdown if it is not corrected.
- Prelube Complete annunciates that the engine is prelubed and ready to start.

- Engine Failure annunciates that the engine has shutdown with a fault. The fault needs to be reset in order to restart.
- Crank Terminate annunciates that the engine has started and is running.
- Run Relay annunciates that the fuel is turned on to the engine
- Mode Switch Position provides the position of the mode control switch (to be read by remote equipment).

Engine Control Subsystem

The Subsystem, Figure 9, consists of the following components:

- Engine Supervisory System Control Panel
  - Engine Control Module Timing Control Module
  - Desired Speed Potentiometer
  - Fuel Energy Content Potentiometer
- Engine Mounted Sensors
- Engine Mounted Actuators Engine Speed Governing

The Engine Control Module performs the governing function. The governor is more like a diesel engine governor than a typical gas engine governor. The G3600 Engine is governed by modulating the fuel valve controlling fuel flow independent of air flow. The air flow is controlled the air/fuel ratio controller in response to the asured fuel flow.

Desired Speed

Desired speed is controlled by an idle/rated switch (Open selects idle speed of 550 rpm; Closed selects the speed set by the desired speed input). The desired speed input is typically the potentiometer on the front face of the ESS panel, but may be controlled by an external module.

Droop

The Customer can select any where from 0% to 10% speed droop.

Loadshare Module

A generator set loadshare module compatible with the ESS is available as a ship loose item.

Switchable Governor Response

In order to provide optimum engine response with a generator set that operates in parallel with a utility or with other generator sets it is necessary to have two governor settings. The G3600 control system offers a dual dynamics governor. The *Governor Dynamics Switch* selects from either *Stand-alone* or *Paralleled* governor settings.

justable Governor Response

o provide optimum package response with a variety of driven equipment, the G3600 Control System offers tunable governor dynamics.

Fuel Limiting

The fuel system on the G3600 Engine does not have any carburetor or equivalent, as a result the governor is required to insure that the air/fuel mixture does not exceed the rich flammability limit (Rich Misfire). By coordinating with the Air/Fuel Ratio Control section, the governor is able to read the actual air/fuel ratio and use that information to keep the engine from getting too rich.

The governor also provides power limiting on the G3600 Engine. By reading the fuel flow and comparing against maximum allowed flow (function of engine speed) the governor protects the engine against overpower situations.

Air/Fuel Ratio Control

The G3600 Engine does not have a carburetor; instead the air flow and 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.

Desired Air Flow

The Air/Fuel Ratio Controller calculates the actual fuel flow and uses a desired air/fuel ratio combined with a fuel energy content (set on the *Energy Content* Potentiometer on the front panel of the ESS) to determine the required air flow. The desired air/fuel ratio for a given speed and load is stored in an application specific map in the Engine Control Personality Module. This map is created to achieve maximum engine performance (efficiency and emissions).

Actual Air Flow

The Engine Control reads inlet manifold air pressure and temperature combined with engine speed to estimate the actual air flow into the engine.

Air Flow Control

Once the control has calculated a desired air flow and an actual air flow, it modulates the wastegate and choke valves to make the actual match the desired.

Fuel Correction System

Combustion Measurement

Once the engine is running and the measured load exceeds a set level (typically 25%), the combustion measurement system compensates for any changes in the ambient conditions or fuel quality. The Engine Control reads the time required for the flame to propagate from the spark plug to the combustion sensor for each cylinder and creates an engine average *burn* time.

Desired Combustion Burn Rate

The Engine Control Personality Module contains application specific maps that define for any given engine speed and load the burn time that achieves maximum engine efficiency and burn proper emissions.

G3600 Engine Performance Data

The Performance section provides data for each engine. It is divided into sections depending on the engine model selected. The data for each engine model includes a rating curve, part load performance, BSFC curves, altitude deration factors and aftercooler heat rejection factors. Use the table of contents to help find the information for a specific engine. For example, the data for a G3606 Engine is organized as follows:

Part Load Data
- Gen Sets
  - 60Hz.
  - 50 Hz
- Industrial
  - 1000 rpm
  - 900 rpm

Aftercooler Heat Rejection Factors
BSFC Curves
Altitude Deration
Rating Curves

Rating Definitions

Ratings are based on SAE J1349 standard conditions of 29.61 in. Hg (100 kPa) and 77°F (25°C); ISO 3046/1, BS 5514/1 and DIN 6271/1 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) also apply.

Ratings are based on dry natural gas with a lower heating value of 905 Btu/ft^3. Variations in altitude, temperature and gas composition from standard conditions may require a reduction in engine horsepower.

Methane number is a scale to measure ignition and burning characteristics of various fuels. Representative values are shown below.

Methane	100
Ethane	44
Propane	34
n-Butane	10
Hydrogen	0

Most dry pipeline natural gas has a methane number of 67 or above. Field gas can go much lower. The engine must be operated on a gas with a methane number of 50 or above. The gas being used should have a complete analysis and the methane number determined. Consult the dealer or factory for assistance.

Part Load Data

The tabular part load data is divided into five general areas: engine configuration (including application), emissions, air system and combustion factors, heat rejection, and air/fuel and exhaust flows.

Engine Configuration

The first block of information defines the engine configuration for which the data applies. It covers aspiration, speed, jacket water temperature, aftercooler temperature, engine power, and generator output (if applicable). This data, along with the title, must be consistent with the engine being applied.

Emissions

The information in this block covers NO_x, CO, HC (total), HC (non-methane), and Exhaust Oxygen. Emissions shown are *Not to Exceed* values.

Air System and Combustion Factors

This section provides fuel consumption, turbocharger compressor pressure and temperature, intake manifold pressure and temperature, air-fuel ratio and timing.

Heat Rejection

Formula: Total heat input = work output + total exhaust heat + radiation + jacket water + oil cooler + aftercooler.

- **Total heat input** is figured by multiplying the BSFC (Btu/bhp-h) times the horsepower output to get Btu/hr. To obtain, Btu/min, divide by 60. Fuel volume consumed is obtained by dividing the total heat by the heat content of the fuel (905 Btu/ft^3).
- **Work output** is the total horsepower developed. It is expressed in Btu/min where 1 hp = 42.4 Btu/min.
- **Total exhaust heat** is the total heat available in the exhaust when it is cooled from the stack temperature down to standard conditions of 77°F. When expressed in Higher Heating Value (HHV), it includes the latent heat of vaporization. At standard conditions, 970 Btu are released as each pound of steam is condensed to water. The figures shown are in terms of low heat value and, therefore, do not included the heat of vaporization.
- **Radiation** is the amount of heat loss from the surface of the engine into the engine room or surrounding ambient.
- **Jacket water heat** is the total amount of heat picked up by the engine cooling system. It is the only source of heat on the jacket water cooling circuit, and has its own water pumps mounted on the lower right front of the engine.
- **Oil cooler heat** is the total heat rejected by the lube oil system. This cooling circuit is common with the aftercooler circuit and are the water pumps mounted on the lower left front of the engine.
- **Aftercooler heat rejection** is given for standard conditions of 77°F and 500 ft altitude. This heat rejection is increased for higher ambients and higher altitudes. We are trying to maintain a constant outlet temperature so as inlet temperature to the aftercooler goes up, so does the heat that must be removed. As

the air pressure decreases, the turbo imparts more energy to the incoming air to get up to the required boost pressure. Be sure to use the aftercooler heat rejection factor to adjust for ambient and altitude conditions. Failure to properly account for these factors could cause the engine to detonate and cause engine shutdown or failure.

- Recoverable exhaust heat is not a separate component of the heat balance equation but is the customary number used in heat recovery calculations. It represents the heat available when cooling the exhaust from the stack temperature down to 350°F. This figure, plus the jacket water heat rejection, is used in determining steam production.

  If an exhaust temperature other than 350°F is desired, the recoverable heat can be calculated by the following formula:

  $Q = CpM\ (T_1 - T_2)$

  Q = Heat Rejection in Btu/min

  Cp = Specific Heat of Exhaust Gas:
  0.258 Btu/lb/°F — Low Emission Engines
  0.278 Btu/lb/°F — Standard Engines

  $M = \text{Exhaust Mass Flow} = \frac{Ev\ (CFM) \times 41.13}{(T_1 + 460°)}$ lb/min

  T_1 = Exhaust From Engine °F

  T_2 = Exhaust Out of Heat Recovery Silencer °F

  Ev = Exhaust Flow by Volume (CFM)

In every calculation using engine data, there is a tolerance band or a deviation from norm. When using the heat balance, the following tolerance should be used.

Work Output	± 3%
Heat Input	± 2.5%
Exhaust Total	± 10%
Exhaust Recoverable	± 10%
Jacket Water	± 10%
Oil Cooler	± 20%
Aftercooler	± 5%
Radiation	± 25%

Heat rejection numbers are based on treated water as the coolant.

Air, Fuel, and Exhaust Flows

This data provides mass and volume flow information of the air, fuel and exhaust. It should be used when sizing ventilation systems, fuel piping, and exhaust equipment. The inlet air flow is based on conditions of 77°F and 13.9 psi air pressure. The exhaust flow is based on stack temperature and 13.9 psi gas pressure. Fuel flow is referenced to fuel at 60°F and 14.7 psi.

Aftercooler Heat Rejection Factors

Aftercooler heat rejection is given for standard conditions of 77°F and 500 ft altitude. Use the aftercooler heat rejection factor to adjust for ambient and altitude conditions at the installation site. Multiply the factor by the standard aftercooler heat rejection.

Altitude Deration Factors

This information is used to show altitude deration required for various ambient temperatures and altitudes. Use to determine actual engine power at the installation site.

Rating Curves

The curves of rated engine brake horsepower vs engine rpm illustrates the capability of the engine at both 90°F and 130°F aftercooler water temperatures.

Exhaust System Considerations

Natural Gas Exhaust System Considerations

If your operation requires the use of stationary natural gas reciprocating engines as a prime source of power, you need to recognize that RICE NESHAP may require some modifications of your work practices and engine(s). The ruling, issued in August 2010, covers existing non-emergency stationary natural gas engines. Compliance to the ruling is required by October 19, 2013. EPA states there are over 360,000 stationary engines in the United States that are affected by this ruling.

Though compliance is a few months away, it doesn't hurt to start planning early, especially if your operation consists of many engines. The first step is to determine your requirements to meet the ruling. The second step is to bring your engine(s) into compliance.

Exhaust System Evaluation
To begin the analysis you need to gather the following data:

1. Horsepower of the engine
2. Annual hours of operation
3. Annual hours of operation for non-emergency purposes
4. Annual hours of operation for maintenance checks and readiness purposes

This information is required to determine if your application is emergency or non-emergency, and whether you fall into a Major Source or Area Source of Hazardous Air Pollutants. A Major Source is an area that produces over 10 tons of Hazardous Air Pollutants (HAPs) annually. An Area Source is considered to be any area that is not a Major Source. Next, take this data to page 1.4 or page 1.6 or to an online RICE NESHAP calculator. There is one located on Universal's website at **www.UniversalAET.com.** The calculator will use the data to determine the steps needed to bring your engine into compliance.

There are several categories that may require attention to bring your engine into compliance. They are:

- Allowable emission levels
- Standard work practices
- Engine operating limitations
- Start-up requirements
- Compliance demonstration
- EPA reporting requirements

Study the requirements generated by the calculator with your maintenance staff. Some requirements do not require a lot of resources. Keeping maintenance and operating records may already be a part of your daily routine. However, there are other requirements that may require additional resources. Some engines may require testing, monitoring equipment and a catalyst system. Contact your engine supplier or an emission control specialist to help facilitate these needs, as their sizing and installation can be quite complex.

If you think you have the resources to handle the more complex requirements, there are some items you need to consider:

- Type of control technology
- Backpressure requirements
- Catalyst placement
- Supportive structure
- Catalyst sizing
- Service requirements
- Enclosed engines
- Compliance testing
- Compliance monitoring
- Labor time
- Air fuel ratio control

Type of Control Technology
Emission control technology that will be used is Oxidation Catalysts. See sections 2, 3, and 4. RICE NESHAP requires CO or formaldehyde reduction.

Backpressure
Engine backpressure also needs to be considered when adding a catalyst to an existing engine. Adding a catalyst will add backpressure that may exceed the engine exhaust backpressure threshold. A catalyst can add an additional 3–4" of water to engine backpressure. Replacing the silencer

Figure 1: Universal provides a combination catalyst/silencer system that causes less engine backpressure.

with a combination silencer/catalyst unit is a solution to minimize the additional backpressure. They are designed for lower backpressure by reducing the number of expansion and contractions of the exhaust gases. Another option is the catalyst itself can be designed for lower backpressure.

Catalyst Placement
Placement of the catalyst in the exhaust system is critical as the exhaust gas temperature needs to be managed so the catalyst works properly. Most catalysts need to operate above 550° F. The further the gas path is from the source, the lower the temperature. In some applications, this may require additional insulation around the exhaust system in order to maintain the proper exhaust temperature. The system should be optimized for the lowest temperature seen throughout the year. For example, colder climates may need additional insulation because of winter temperatures. Also, proper attention needs to be paid to the components upstream from the catalyst system. If you are using a packed silencer in sequence with the catalyst system, fibers may come loose that may coat or plug the catalysts element and reduce its effectiveness. In these instances, the catalyst system should be located upstream from the packed silencer.

See back cover for ordering information | www.universalAET.com

Exhaust System Considerations

Natural Gas Exhaust System Considerations

Figure 2: Proper positioning of catalyst access doors at the site is important for easy service.

Supportive Structure

Before installation of the catalyst system, the physical support structure needs to be considered. For larger catalyst systems, the connecting pipe will not be able to support the catalyst's weight. A steel ladder system may be required to support the catalyst from the package's base. The supportive structures should be fabricated before on-site installation to minimize service time.

Figure 3: This catalyst housing, offered by Universal, provides a system that eliminates exhaust bypass by forcing the catalyst against the downstream side.

Catalyst Sizing

Proper attention needs to be given to catalyst sizing. The volume of the catalyst must be properly sized for the exhaust flow rate to meet the required emissions reduction target. If it is undersized, you won't meet the emissions target. And if it is oversized, the catalyst may be overpriced and uncompetitive when selling to an end user.

Service Requirements

Catalysts require periodic servicing, typically every 8,700 hours of operation. The catalyst system needs to be placed where it can be easily accessed, whether near a service panel or open area. This design should allow easy access and removal to the catalyst element without special tools or cumbersome capture mechanisms. The quicker to remove and replace the catalyst element, the more time your technicians have for other jobs. Exhaust bypass is a common problem in some catalyst housing designs. This is where the exhaust gas is not forced through the catalyst. This issue will impact the effectiveness of the catalyst system. Seek a housing and catalyst design that includes a positive seal against the side of the housing, forcing the exhaust gas to flow through the catalyst element.

Enclosed Engines

Many engines that will be affected by the RICE NESHAP ruling will come in enclosed skid-mounted packages. Space inside the enclosures is at a premium. Finding a location to fit a catalyst can be difficult. However, by utilizing an integrated silencer/catalyst system, you may be able to place it in the same footprint as the current silencer. Also, you will need catalyst housings that have different mounting configurations, such as end-in/end-out, side-in/end-out, and high-side in/end-out.

Compliance Testing

Existing stationary engines that require the addition of a catalyst system require before and after emissions testing to validate compliance. To make this requirement easier for your organization, work with an exhaust stack testing firm that can provide the testing.

Figure 4: Enclosed packages could present space problems for a "bolt in" catalyst system.

Compliance Monitoring

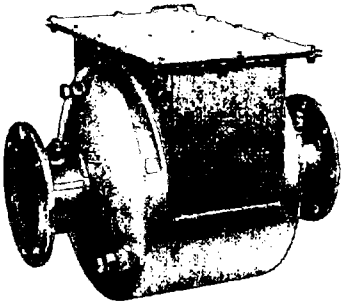
The RICE NESHAP ruling requires engines that are larger than 500 hp and are a major source of hazardous air pollutants to maintain a service log of catalyst differential pressure and temperature. See page 5.1. A continuous monitoring system can be installed to make this documentation requirement easier for your staff. Use a continuous monitoring device that allows the storage of multiple readings. Also, a monitoring device with CANBUS capabilities will allow integration into your facility's Building Automation System. Or, you may want to consider using a monitoring service that will handle the data tracking requirements for a monthly or yearly fee.

Labor Time

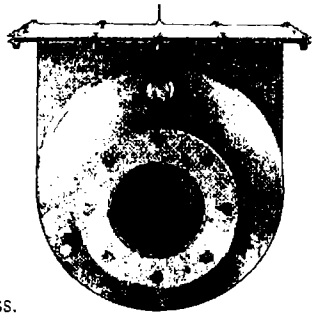
Labor time to retrofit an existing stationary engine is quite variable. One needs to consider the catalyst system's size, weight, site accessibility, lifting equipment, if the package is enclosed or open and installation complexity.

GreenShield® System

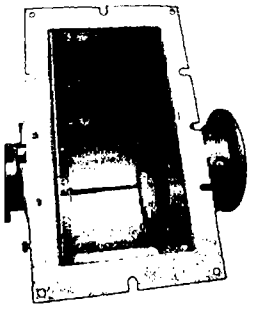
GreenShield® Serviceable Catalyst Housings contain the following features:



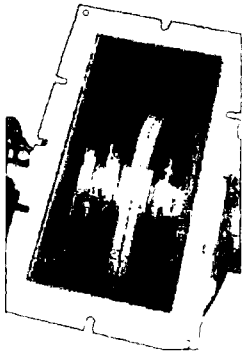
Patent pending housing design.



The axial sealing system reduces exhaust bypass.



No cumbersome fasteners or retaining bars to secure the catalyst into place—making catalyst replacements easy and safe.



Dual catalyst housing capabilities allow for future upgrades.

Universal provides a broad range of standard catalyst housings and catalytic silencers. The proper configuration of an emission control system can be quite complex. Universal has a trained staff of emission specialists to guide you through the steps.

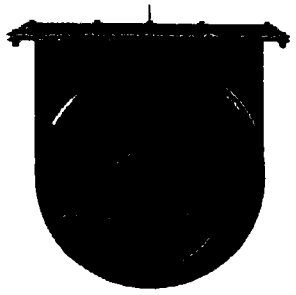
Visit www.universalAET.com, call (888) 300-4272, or complete and fax the quote form located on page 6.1.

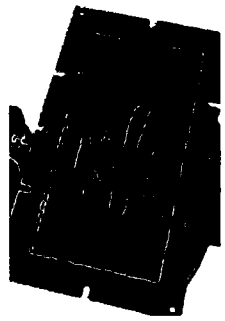
Does the system require a custom design? Universal can also design custom emission systems. Contact us about your requirements and allow our experienced staff of application engineers design an economical solution for you.

∴ See back cover for ordering information | www.universalAET.com

See back cover for ordering information | www.universalAET.com

Oxidation Catalyst for Lean-Burn Engines





Benefits

- High CO (Carbon Monoxide), H2CO (Formaldehyde) and NMNEHC (Non-Methane, Non-Ethane HydroCarbon) reduction efficiency in a compact package
- Low leak housing design
- Robust, positive catalyst sealing design ensures maximum exhaust gas treatment
- Stainless Steel catalyst substrates built for superior durability
- Dual substrate housing provides option to upgrade emission performance with same housing
- Easy to service—no internal clips or fasteners
- Available with or without integrated silencing. Catalytic Silencers available in four silencer grades: Industrial, Residential, Critical and Hospital
- Available with various optional mounting brackets

Specifications

Fuel	Pipeline quality natural gas with less than 0.5 g/100 scf sulfur and less than 0.25 g/100 scf of hydrogen sulfide.	
Flow-rate	Up to 9,639 SCFM (23,406 ACFM at 800° F) with dual catalysts.	
Emissions Reduction	CO:	< 93% above 900° F
	NMNEHC:	< 80% above 900° F
	H2CO:	< 93% above 900° F
Temperature Range	482–1200° F	
Housing Material	Painted carbon steel using high temperature aluminum paint. Optional stainless steel also available.	
Sensor Ports	Inlet:	(2) ¾" female NPT and (1) female M18 fittings located on inlet nozzle
	Outlet:	(2) ¾" female NPT and (1) female M18 fittings located on outlet nozzle

Selection

1 Determine the approximate emissions reduction required (Table 1b).

2 Determine the engine's max exhaust flow rate (SCFM).

3 Use Table 1b to determine your catalyst element size code.

4 Determine inlet/outlet configuration and insertion loss then refer to the corresponding section:

A	End-in, End out, 0–12 dB	Section 2.4
B	End-in, End out, 12–18 dB	Section 2.5
C	End-in, End out, 18–25 dB	Section 2.6
D	End-in. End out, 25–35 dB	Section 2.7
E	End-in. End out, 35–42 dB	Section 2.8
F	Side-in, End out, 12–18 dB	Section 2.9
G	Side-in, End out, 18–25 dB	Section 2.10
H	Side-in, End out, 25–35 dB	Section 2.11
I	Side-in, End out, 35–42 dB	Section 2.12

5 Determine inlet size.

6 Select part number and place order.

Oxidation Catalyst

1b

Max. Exhaust Flow Rate (scfm)	Below 900° F	Max. Exhaust Flow Rate (scfm)	At or Above 900° F
	Emissions Reduction Efficiency		Emissions Reduction Efficiency
	CO 90%		CO 93%
	NMNEHC 75%		NMNEHC 80%
	H_2CO 90%		H_2CO 93%
	Catalyst Size Code		Catalyst Size Code
903	E-1	903	E-1
1241	E-2	1241	E-2
1633	E-3	1633	E-3
1985	E-4	1985	E-4
2372	E-5	2372	E-5
2684	E-6	2684	E-6
3016	E-7	3016	E-7
3930	E-8	3930	E-8
4820	E-9	4820	E-9
6021	*Contact Tech Support*	6021	*Contact Tech Support*
7857	*Contact Tech Support*	7857	*Contact Tech Support*
9639	*Contact Tech Support*	9639	*Contact Tech Support*

2b

Element Size Code	Cat O.D. × 3.5" Depth (in.)	Oxidation Catalyst P/N	Catalyst Weight (lbs.)	Catalyst Spacer P/N	Spacer Weight (lbs.)
E-1	14.5	18-7000019	25	18-7000028	15
E-2	17	18-7000020	35	18-7000029	17
E-3	19.5	18-7000021	40	18-7000030	20
E-4	21.5	18-7000022	50	18-7000031	22
E-5	23.5	18-7000023	55	18-7000032	23
E-6	25	18-7000024	60	18-7000033	25
E-7	26.5	18-7000025	65	18-7000034	26
E-8	30.25	18-7000026	80	18-7000035	30
E-9	33.5	18-7000027	95	18-7000036	33

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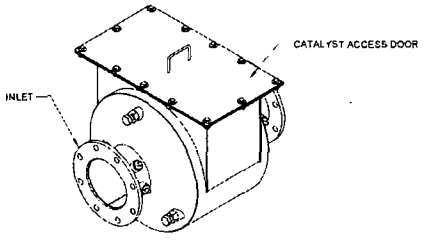
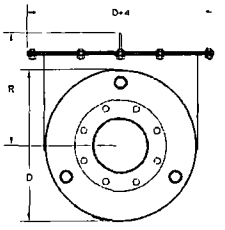
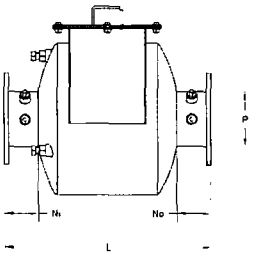
Oxidation Catalyst

None or < 12 (dB) Insertion Loss, End-In, End-Out







Catalyst Element Size Code	P	D	L	Ni	No	R	Housing Part Number	Estimated Housing Weight (lbs.)	Complete System, Single Catalyst	
									Part Number	Estimated Weight (lbs.)
E-1	6	18.2	28	4.5	4.5	14	18-510001	140	18-510001C	180
E-1	8	18.2	32	9.5	4.5	14	18-510002	150	18-510002C	190
E-1	10	18.2	32	10.5	4.5	14	18-510003	160	18-510003C	200
E-2	6	20.2	29	4.5	4.5	15	18-510004	150	18-510004C	202
E-2	8	20.2	29	4.5	4.5	15	18-510005	160	18-510005C	212
E-2	10	20.2	33	10.5	4.5	15	18-510006	180	18-510006C	232
E-2	12	20.2	32	10.5	4.5	15	18-510007	200	18-510007C	252
E-3	8	22.2	29	4.5	4.5	16	18-510008	180	18-510008C	240
E-3	10	22.2	29	4.5	4.5	16	18-510009	190	18-510009C	250
E-3	12	22.2	33	10	4.5	16	18-510010	220	18-510010C	280
E-3	14	22.2	32	12.5	4.5	16	18-510011	230	18-510011C	290
E-4	8	24.2	30	4.5	4.5	17	18-510012	210	18-510012C	282
E-4	10	24.2	29	4.5	4.5	17	18-510013	210	18-510013C	282
E-4	12	24.2	29	4.5	4.5	17	18-510014	240	18-510014C	312
E-4	14	24.2	33	11	4.5	17	18-510015	250	18-510015C	322
E-4	16	24.2	32	11.5	4.5	17	18-510016	270	18-510016C	342
E-5	8	26.2	30	4.5	4.5	18	18-510017	220	18-510017C	298
E-5	10	26.2	30	4.5	4.5	18	18-510018	230	18-510018C	308
E-5	12	26.2	30	4.5	4.5	18	18-510019	250	18-510019C	328
E-6	10	28.2	31	4.5	4.5	19	18-510020	250	18-510020C	335
E-6	12	28.2	30	4.5	4.5	19	18-510021	270	18-510021C	355
E-6	14	28.2	30	4.5	4.5	19	18-510022	280	18-510022C	365
E-6	16	28.2	33	11	4.5	19	18-510023	300	18-510023C	385
E-6	18	28.2	33	12	4.5	19	18-510024	310	18-510024C	395
E-7	10	30.2	31	4.5	4.5	20	18-510025	270	18-510025C	361
E-7	12	30.2	31	4.5	4.5	20	18-510026	300	18-510026C	391
E-7	14	30.2	31	4.5	4.5	20	18-510027	310	18-510027C	401
E-8	8	36.2	34	4.5	4.5	23	18-510028	390	18-510028C	500
E-8	10	36.2	33	4.5	4.5	23	18-510029	400	18-510029C	510
E-8	12	36.2	33	4.5	4.5	23	18-510030	420	18-510030C	530
E-8	14	36.2	33	4.5	4.5	23	18-510031	430	18-510031C	540
E-8	16	36.2	32	4.5	4.5	23	18-510032	440	18-510032C	550
E-9	8	36.2	34	4.5	4.5	23	18-510033	380	18-510033C	508
E-9	10	36.2	33	4.5	4.5	23	18-510034	390	18-510034C	518
E-9	12	36.2	33	4.5	4.5	23	18-510035	410	18-510035C	538
E-9	14	36.2	33	4.5	4.5	23	18-510036	420	18-510036C	548
E-9	16	36.2	32	4.5	4.5	23	18-510037	430	18-510037C	558
E-9	18	36.2	32	4.5	4.5	23	18-510038	440	18-510038C	568

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GreenShield® Catalyst Monitor

For RICE NESHAP Compliance

The GreenShield® Catalyst Monitor displays and records exhaust gas temperature and catalyst differential pressure, a requirement for RICE NESHAP compliance. Pressure and temperature signals are received from sensors located upstream and downstream from the catalyst. Catalyst inlet temperature and differential pressure are displayed textually on the monitor screen and logged on a microSD memory card. If the catalyst temperature or differential pressure is out of recommended ranges, warnings and alarms will be displayed textually and with external lights. An "Attention required" signal output is also available.

Features:

1. Programmable Logic Controller (PLC) with integral Human Machine Interface (HMI)
2. Orange light to indicate temperature or pressure warning
3. Red light to indicate temperature or pressure alarm
4. "Attention required" Form C dry contact set (internal)
5. Circuit breaker protected power lines
6. Ability to mount remotely from engine
7. microSD card to for easy access to thousands of hours of logged data

Specifications:

Monitor:
- Dimensions: 300 X 300 X 150 mm NEMA 4 rated enclosure
  100-240 V AC power supply

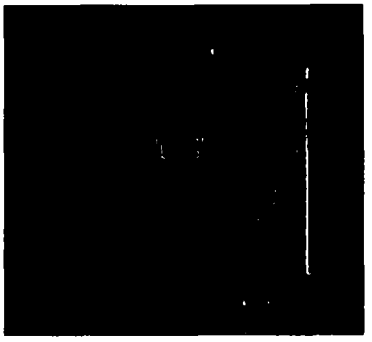
Environmental requirements:
- PLC must be protected from UV degradation (optional internally mounted PLC with view port door available).
- The Monitor enclosure must be located in an operational environment of 0° to 50°C (32° to 122° F). If the minimum temperature cannot be ensured an optional enclosure heater or cooler may be requested.

Weight:
- 7.7 kg (17 lb)

Mounting interface:
- (4) 8.2 mm diameter holes
- Horizontal spacing = 260 mm
- Vertical spacing = 320 mm

Part Number: 18-7000079
Delivery Time: 2–4 weeks

- These specifications represent Universal Emission Technologies' standard design. Universal Emission Technologies can provide custom designs to meet your specific system performance requirements.



The GreenShield® Catalyst Monitor provides data logging, text readouts and color coded visual alarms.

See back cover for ordering information | www.universalAET.com

Attachment F
Operation and Maintenance Plan

G3608TA

TECHNICAL DATA

8/29/00 WR P.3/4
MB

CATERPILLAR

Caterpillar Inc.
Lafayette Engine Center
Lafayette, Indiana 47906

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	+/- 3.0%	
A/C Inlet Temp. (°F):	130	J/W Outlet Temp. (°F):	180		
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	2.60	6.00	1.06	0.51
tons/year	15.0	53.7	123.9	22.8	11.0

Exhaust Mass Flow (lbs/hr, wet):	28,548
Exhaust Volume Flow (cfm, wet): @ 842°F stack temp, 14.5 psia	14,816

MIAMI-DADE WATER AND SEWER DEPARTMENT
RECEIVED
SEP 12 2000
SD ENGINEERING DIVISION SD

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

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):	26,548
Exhaust Volume Flow (cfm, wet): @ 842°F stack temp, 14.5 psia	14,816

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

M:\G3600\emi\sir\2000\00-092.xls

G3608 SITA — 9:1 Industrial Performance

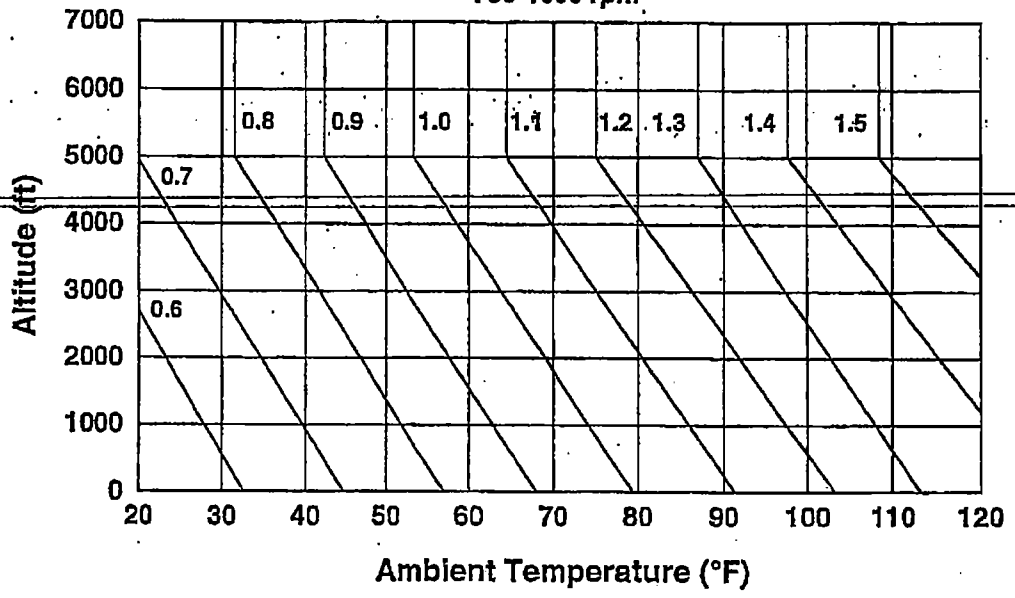
		100%	75%	50%	25%
↘piration		TA	TA	TA	TA
Speed	rpm	1000	1000	1000	1000
JW Outlet Temperature (°F)		190	190	190	190
A/C Inlet Temperature (°F)		130	130	130	130
Engine Power	bhp[1]	2225	1669	1113	556
NOx (as NO_2)	g/bhp-hr[2]	0.70	0.70	0.70	1.20
CO	g/bhp-hr[2]	1.90	1.90	1.90	2.20
HC (Total)	g/bhp-hr[2]	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	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
F ust (LHV)	Btu/min[4]	97042	76771	56282	34002
aust (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) erance +/- 25%
7) lerance +/- 20%, heat rejection based on treated water as coolant

Aftercooler Heat Rejection Factors

G3608 Industrial – 90°F SCAC

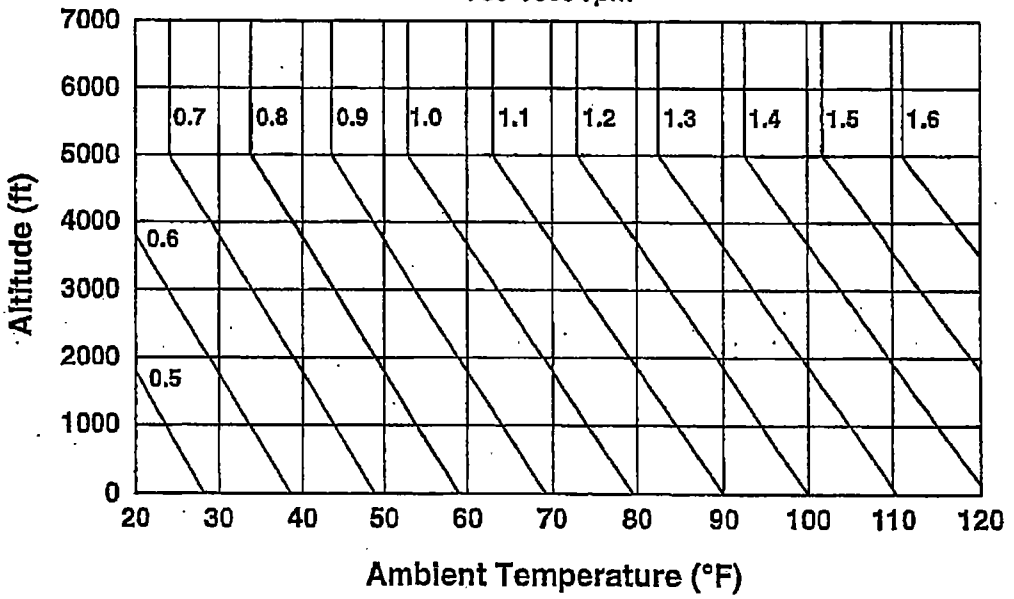
730-1000 rpm



Aftercooler Heat Rejection Factors

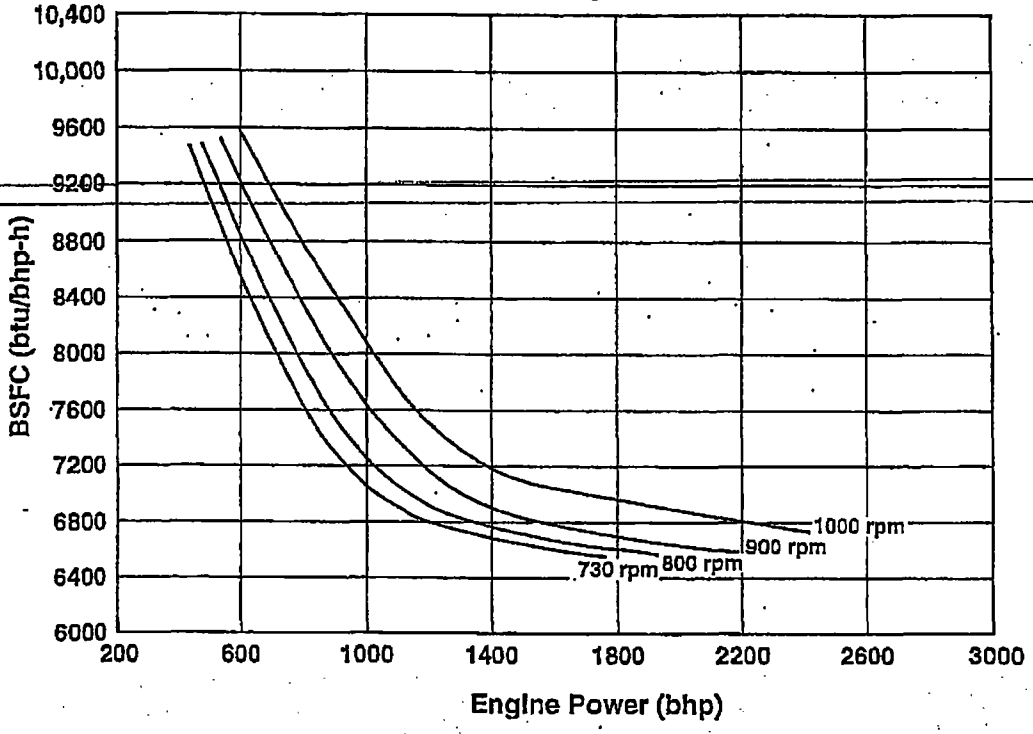
G3608 Industrial – 130°F SCAC

730-1000 rpm



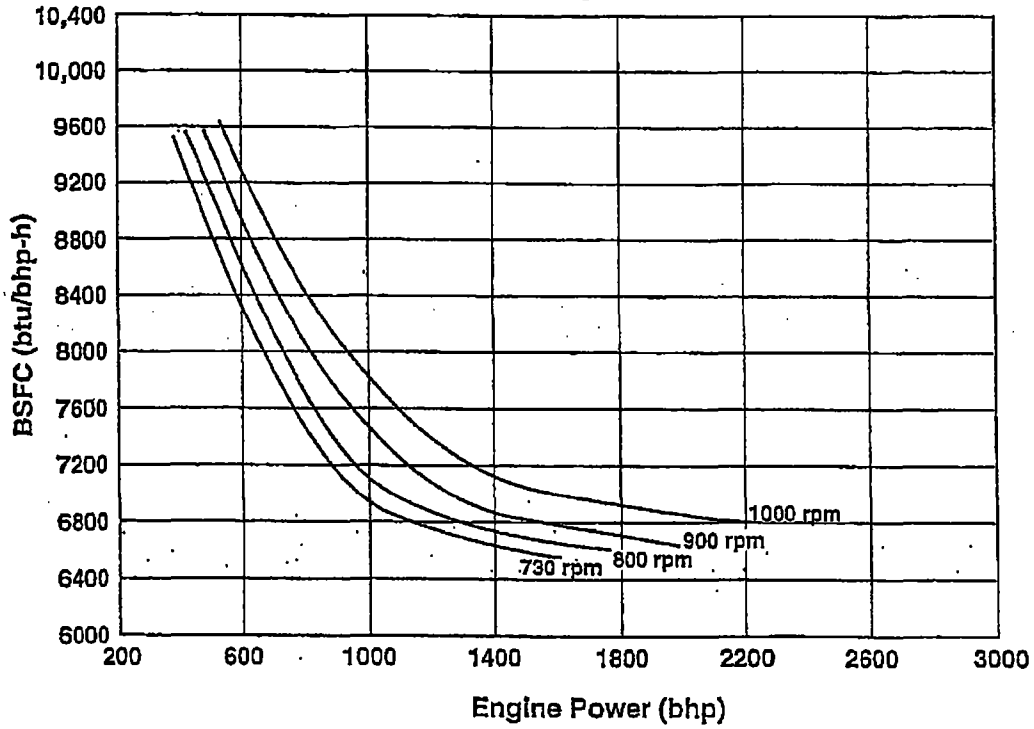
G3608 BSFC

Industrial Turbocharger 90°F SCAC



G3608 BSFC

Industrial Turbocharger 130°F SCAC



CATERPILLAR®

Gas Engine Industrial Low Emission G3608

1555-2350 HP

FEATURES

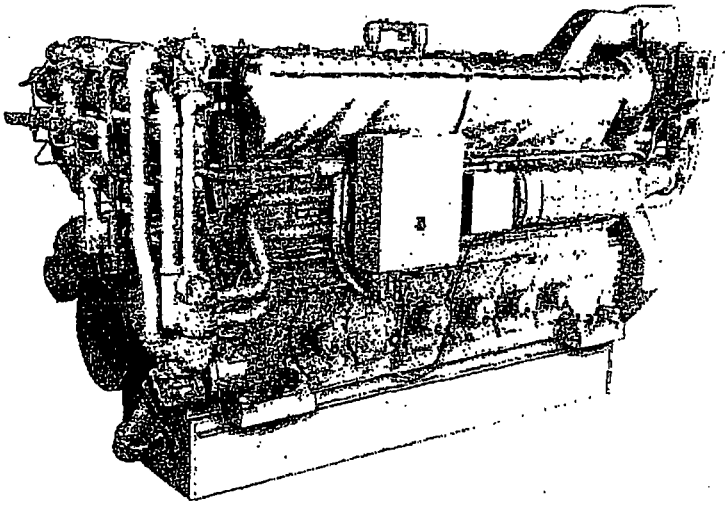
• CATERPILLAR® QUALITY THROUGHOUT
Cat gas engines incorporate many of the same proven components as their diesel counterparts – including the block, crankshaft, main bearings, camshaft and connecting rods. However, by operating at 40 to 50% lower cylinder pressure and bearing loads than diesels, they 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
1 gram/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

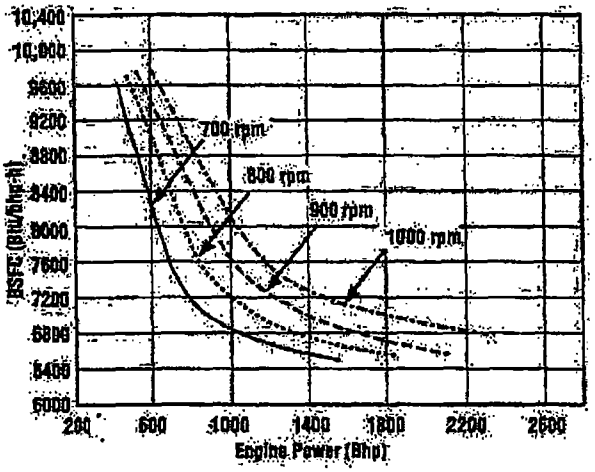
	Height	Width	Length	Weight
LE TA	129.2 in	64.7 in	213.5 in	48,800 lbs

General Specifications

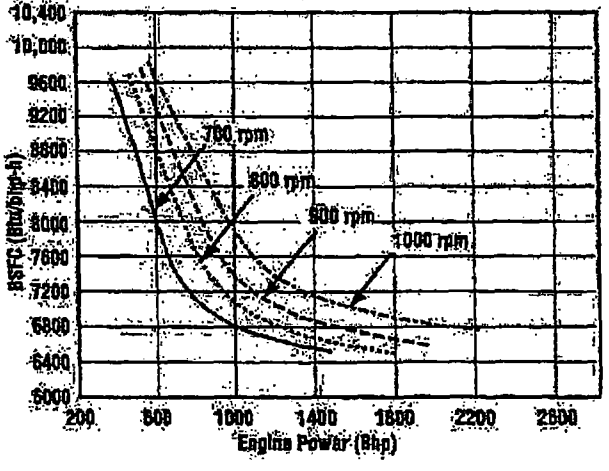
CAT 3608 ENGINE
Type — Spark ignited
Displacement — 10,350 cu in
Compression Ratio — 9.2:1
Lube oil capacity — 241 gal
Jacket water system — 140 gal

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

90°F SCAC

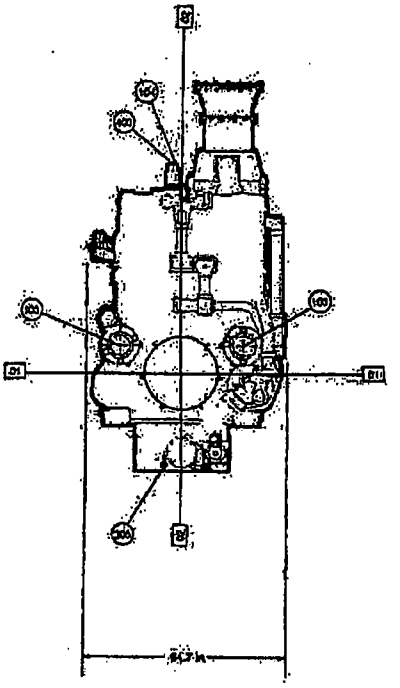


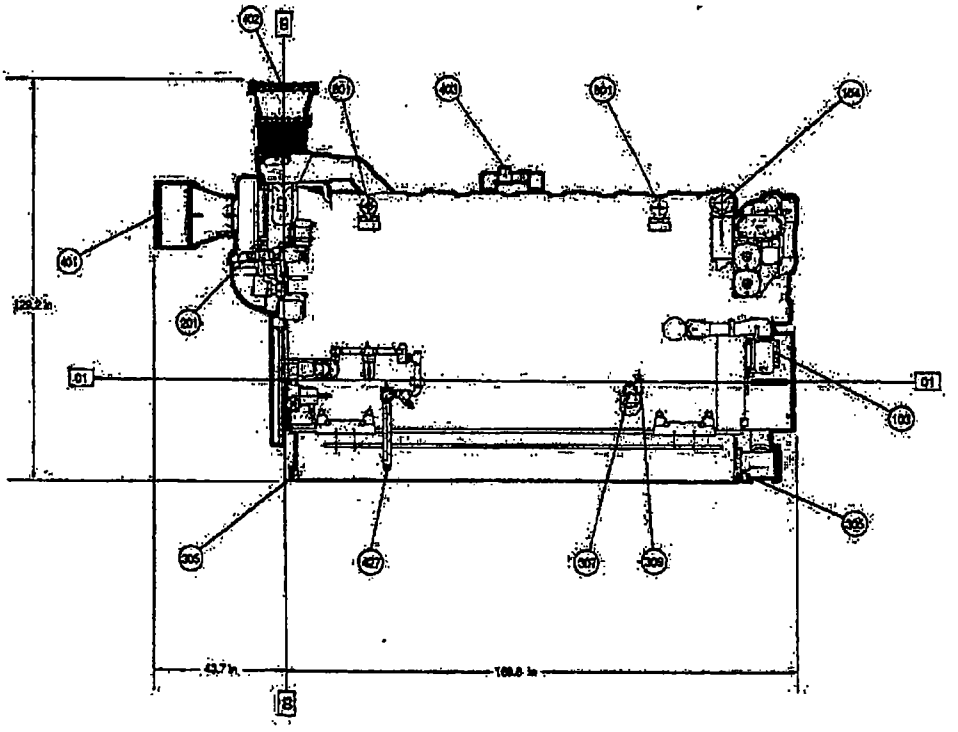
130°F SCAC



G3600 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 3045, 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.

CATERPILLAR®

LEHH9119

Printed in U.S.A.

G3608TA

PRODUCT BROCHURE

G3608TA

PRODUCT DESCRIPTION

G3608TA

APPLICATION & INSTALLATION GUIDE

G3600 Family of Engines

Product Description and Specifications

CATERPILLAR®

Engine Specifications

Engine Models		G3606	G3608	G3612	G3616
Configuration		6 Cylinder In-line	8 Cylinder In-line	12 Cylinder Vee	16 Cylinder Vee
Combustion System		*	*	*	*
Air Aspiration		TA	TA	TA	TA
Emissions	NO_X	1.0	1.0	0.7	0.7
(g/hp-hr)	CO	1.9	1.9	1.9	1.9
	THC	5.4	5.4	5.3	5.3
Mech Efficiency		38%	38%	38%	38%
Gas Pressure (psi)		45	45	45	45
Bore/Stroke	mm	300/300	300/300	300/300	300/300
	in.	11.81/11.81	11.81/11.81	11.81/11.81	11.81/11.81
Displacement	L	127.2	169.6	254.4	339.2
	cu in.	7764	10,352	15,528	20,704
Compression Ratio		9.2:1	9.2:1	9.2:1	9.2:1
Fuel Type					
Minimum Methane No.		50	50	50	50

* Spark Ignited, Lean Burn, Precombustion Chamber, Gas Admission

Engine Ratings

Generator Set – Ratings in ekW (generator output)

Engine Model	A/C Temp	50 Hz 1,000 rpm	60 Hz 900 rpm
3606	90°F	1265	1135
	130°F	1195	1075
3608	90°F	1685	1515
	130°F	1590	1430
3612	90°F	2540	2285
	130°F	2400	2160
3616	90°F	3385	3050
	130°F	3195	2880

Assumes 96% generator on 3606 and 3608, 96.5% on the 3612 and 3616.

Industrial – Ratings in hp

Engine Model	A/C Temp	1,000 rpm	900 rpm	800 rpm	700 rpm
3606	90°F	1765	1590	1410	1160
	130°F	1665	1500	1335	1110
3608	90°F	2350	2120	1880	1510
	130°F	2220	2000	1780	1410
3612	90°F	3530	3175	2825	2360
	130°F	3335	3000	2665	2215
3616	90°F	4705	4235	3765	2490
	130°F	4445	4000	3555	2230

G3600 Product Description

The G3600 Family of Gas Engines incorporates advanced technology essential for high output, low emissions, and high thermal efficiency. Precise control of engine operating parameters allows the engine to operate at optimum performance on a wide range of fuels and ambient conditions.

Technological features include:

- Lean Burn Technology
- Precombustion Chamber
- Gas Admission Valves
- Advanced Electronic Controls
- Rugged Basic Structure

Primary applications for this engine are:

- Industrial
  air compressors and direct drive chillers
- Electric Power Generation
  load management and cogeneration
- Gas Compression
  gas gathering and gas transmission

Many electric utilities are charging substantial demand charges and time of day rates which create a significant potential for gas engine sales. The high thermal efficiency of the 3600 Engines provides early payback and the low emissions allows easy permitting for most applications.

Direct drive air compressors and air conditioning chillers are two examples of ways to save costs by avoiding high electrical usage during peak periods. On-site power generation during peak periods is another way to drastically lower utility bills. Utilities themselves represent potential as they try to decentralize or add capacity. Cogeneration, either in base load or load management applications, provides another way customers can enhance their savings. Future offerings of landfill and digester gas engine arrangements will expand this opportunity still further.

Fuel System

To ensure that each cylinder gets the correct amount of fuel at the proper air-fuel ratio, carburetors are not used. Instead, gas is admitted into the intake port, just ahead of the intake valve, see Figure 1. A unique gas admission valve, actuated by the camshaft, admits fuel into the intake port. A fuel manifold connects each cylinder and it is pressure in the manifold that meters the fuel into the intake port. By controlling the pressure in the manifold, the fuel into the engine is controlled, thereby controlling the power output of the engine. The control of the fuel pressure is the task of the electronically actuated fuel valve located on the right rear of the engine, see Figure 2. In order to admit fuel into the intake port at full load, the fuel pressure at the fuel inlet must be regulated to ±0.25 psi within a range of 43 to 47 psi. Lower pressure will result in reduced power. Separate lines from the main fuel manifold provide additional gas to each precombustion chamber. An adjustable needle valve regulates the flow. These valves are adjusted to provide precise amounts of fuel to each prechamber so that consistent ignition and power are obtained from each cylinder.

Current design limits the fuel to dry processed natural gas with a minimum methane number of 50. Propane or untreated well head gas are not permitted. Low Btu engine arrangements are not available now but are being developed for landfills and sewage treatment plants. As new arrangements with expanded fuel capabilities are developed, they will be announced and made available. Low gas pressure fuel inlet systems are not available at the present time. Regulated gas pressures of 45 ±2 psi, held to ±0.25 are required at the engine inlet. Customer mounted remote gas filter groups are available for use before the fuel inlet connection. They are designed to filter 1 micron particle size with a maximum of 2 psi pressure

G3600 Fuel System Schematic

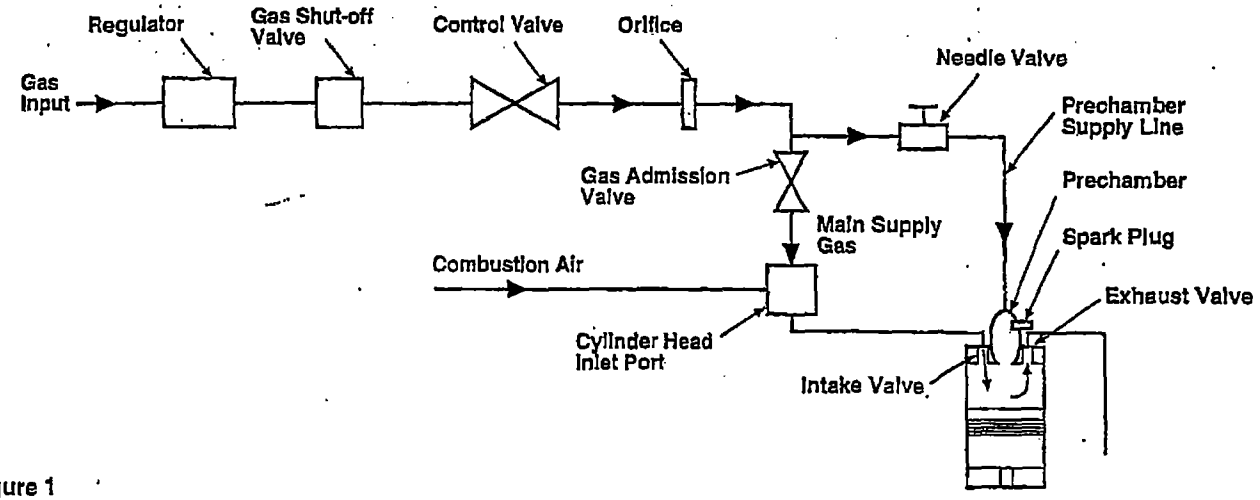


Figure 1

3600 Gas Valve

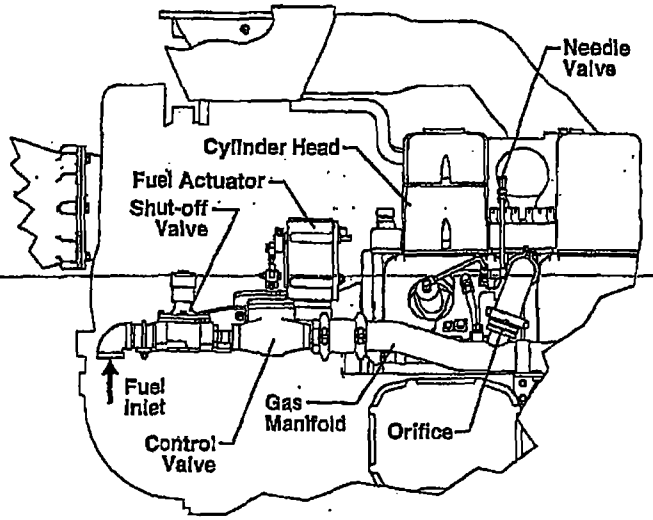


Figure 2

drop at rated flow and inlet pressures. See the *Drawings* section of this manual. Customer mounted gas pressure regulators are available to maintain gas pressure at the engine to 45 psi. They are available for gas pressures up to 150 psi.

Air System

Combustion air flows from the turbocharger, through the air inlet choke, through a water cooled plate/fin aftercooler, into the cylinder block air plenum, and then into the cylinder head inlet ports, see Figure 3. Fuel is introduced to the air in the cylinder head by the gas admission valve. Air flow is controlled by a combination of an air choke, (located downstream of the turbocharger compressor outlet) and exhaust by-pass valve or wastegate. The wastegate, which by-passes exhaust gas around the turbocharger, determines the boost level, which in turn controls the intake manifold pressure, see Figure 4. The electronic control system determines the air pressure required to maintain the correct air/fuel ratio and controls the wastegate valve and/or choke butterfly valve accordingly. At loads above approximately 40%, the air choke is in the wide open position. Below this point, the inlet air choke restricts the air flow to maintain a sufficiently rich mixture for good combustion and stability, see Figure 5. Exhaust manifolds are dry with external thermal blanket shielding for reduced radiated heat and personnel safety. The low exhaust temperatures of lean burn engines allows the use of dry manifolds. They improve engine performance and response by retaining exhaust energy to drive the turbocharger, especially for constant torque, variable speed industrial applications. Both normal and heavy duty air cleaners are available to fit specific applications. Multiple high efficiency paper elements are used. They are shipped loose and are remote-mounted by the customer at the installation site using customer supplied piping. Under normal conditions a single enclosure is used for the inlines and two for the vees. Two enclosures required for vees under heavy duty applications. See the *Drawing* section of this Manual.

Ignition System

An 18mm J-gap spark plug is connected to the ignition transformer with an teflon extender and an aluminum electrical connection inside the teflon. The J-gap offers combustion advantages, particularly at low loads, and the teflon extender prevents electrical arcing to the

G3600 Air System Schematic

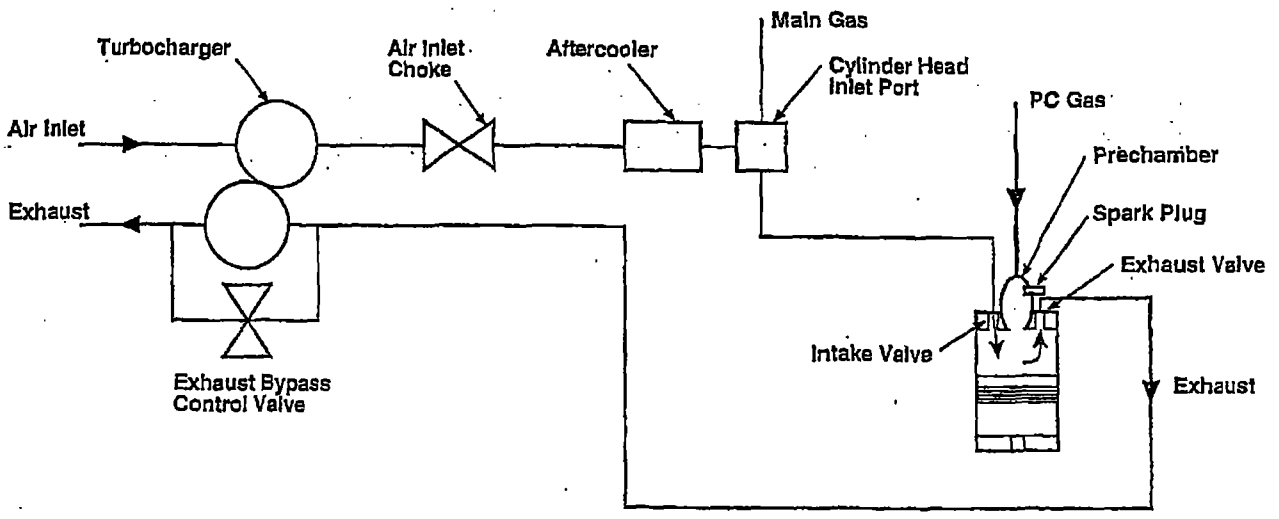


Figure 3

G3600 Exhaust Bypass

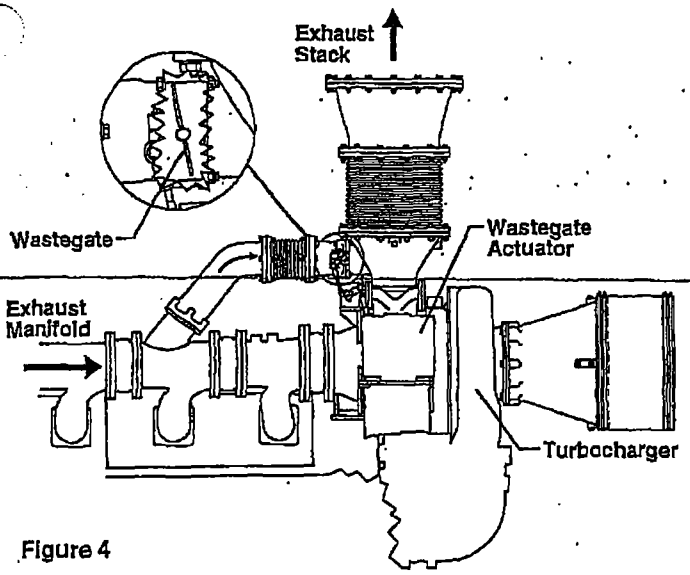


Figure 4

surrounding areas. Precious metal is used on both the center (iridium) and ground (platinum) electrodes. The metal is welded to copper cored electrodes. The copper core helps to transfer heat from the plug center.

The plug is mounted low in the prechamber to place the spark at beginning of the flame front as the enriched charge enters the main chamber. The low position allows for faster and more complete burn of the gas in the prechamber, which will provide for a positive ignition in the main chamber. This contributes to faster, more complete combustion which reduces fuel consumption. The ignition system is powered by a magneto which is driven by the camshaft at the rear of the engine.

G3600 Inlet Choke

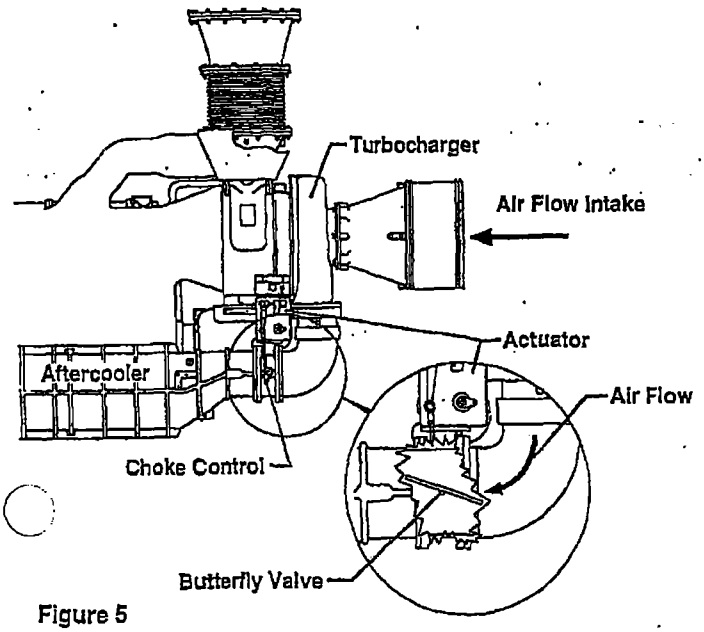


Figure 5

G3600 Engine Supervisory System

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

These subsystems include start/stop/prelube logic, engine monitoring and protection, along with governing, air/fuel ratio, and ignition control. The ESS panel is the control center for the system and houses the control modules of each sub system.

The System consists of:

- Engine Supervisory System Control Panel (ESS)
- Engine Mounted Junction Box
- Engine Mounted Sensors & Actuators
- Relays, Solenoids & Switches
- Harnesses

The System is subdivided into three interactive subsystems:

- The Start/Stop/Prelube Subsystem
  - Controls the action of the prelube pump, engine starters and gas shutoff valve.
- The Engine Monitoring and Protection Subsystem
  - Prevents engine starting or cause shutdown if vital parameters exceed acceptable limits.
  - Provides display of these parameters
  - Generates warnings when one or more parameters are outside acceptable limits.
- The Engine Control Subsystem
  - Provides Engine Governing
  - Air/Fuel Ratio Control
  - Ignition Timing Control

The Engine Supervisory System Control Panel

This panel, Figure 6, houses the control modules, switches, and potentiometers associated with the system.

- Engine Control Module (System Coordination, Governing, Air/Fuel Ratio Control)
- Timing Control Module (Ignition System Control)
- Status Control Module (Start/Stop Control)
- Computerized Monitoring System CMS (Display of System Parameters)
- Pyrometer Modules (Display of Exhaust Temperatures)
- Mode Control Switch
- Prelube Switch/Start Run ok Lamp
- Emergency Stop Switch
- Fuel Energy Adjustment Potentiometer
- Desired Speed Adjustment Potentiometer

Engine Supervisory System

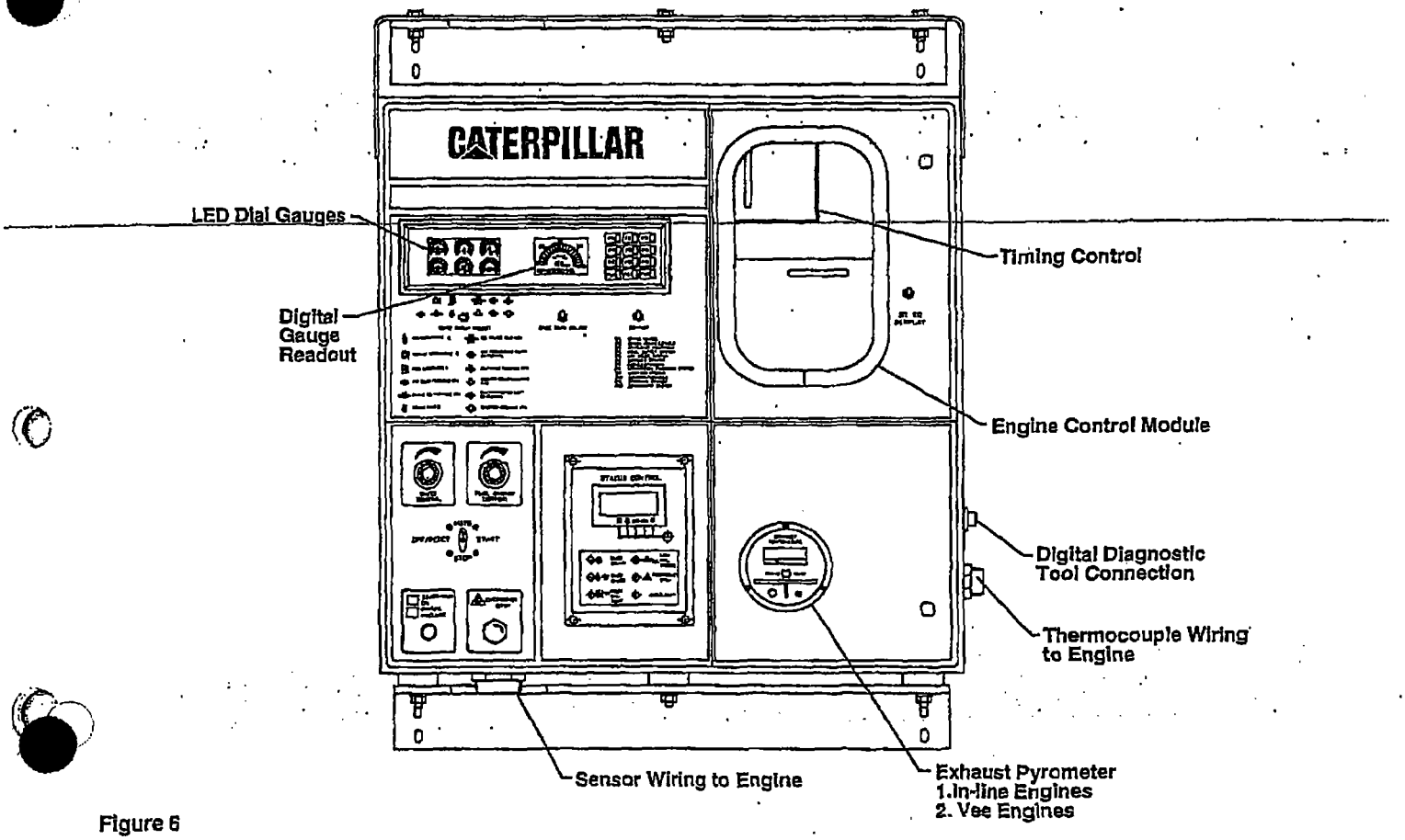


Figure 6

- Gauge Group Select Switch
- Gauge Data Select Switch
- Display Select Switch
- Dimmer Switch Diagnostics

Diagnostics

The Engine Supervisory System is self-diagnostic. Through lamps and fault codes, it directs the service technician to the system or component requiring maintenance.

Mounting

The Control Panel is a water proof enclosure intended to be remote mounted (up to 100 ft) from the engine. It is available with separate stand-alone legs or can be customer remote mounted.

Hazardous Environments

The Engine and Engine Supervisory System have been CSA certified for use in hazardous locations (Class 1 Division 2 Group D).

Personality Module

The Personality Module attaches to the Engine Control Module and contains many of the application specific information for the system. The module contains application specific maps, protection set points, and customer defined settings. Once specified the personality module cannot be changed without removing and installing a new module. It is essential the application be clearly understood early in the order process to get the proper information in the personality module.

RS232 Computer Interface

RS232 output of system data will be available in 1994 for customer monitoring and information systems (requires a ship loose converter module).

Start/Stop/Prelube System

This Subsystem, Figure 7, consists of the following components:

- Engine Supervisory System Control Panel
  - Status Control Module
  - Engine Control Module
  - Mode Control Switch
  - Prelube Switch/Lamp
- Emergency Stop Switches
- Gas Shutoff Valve

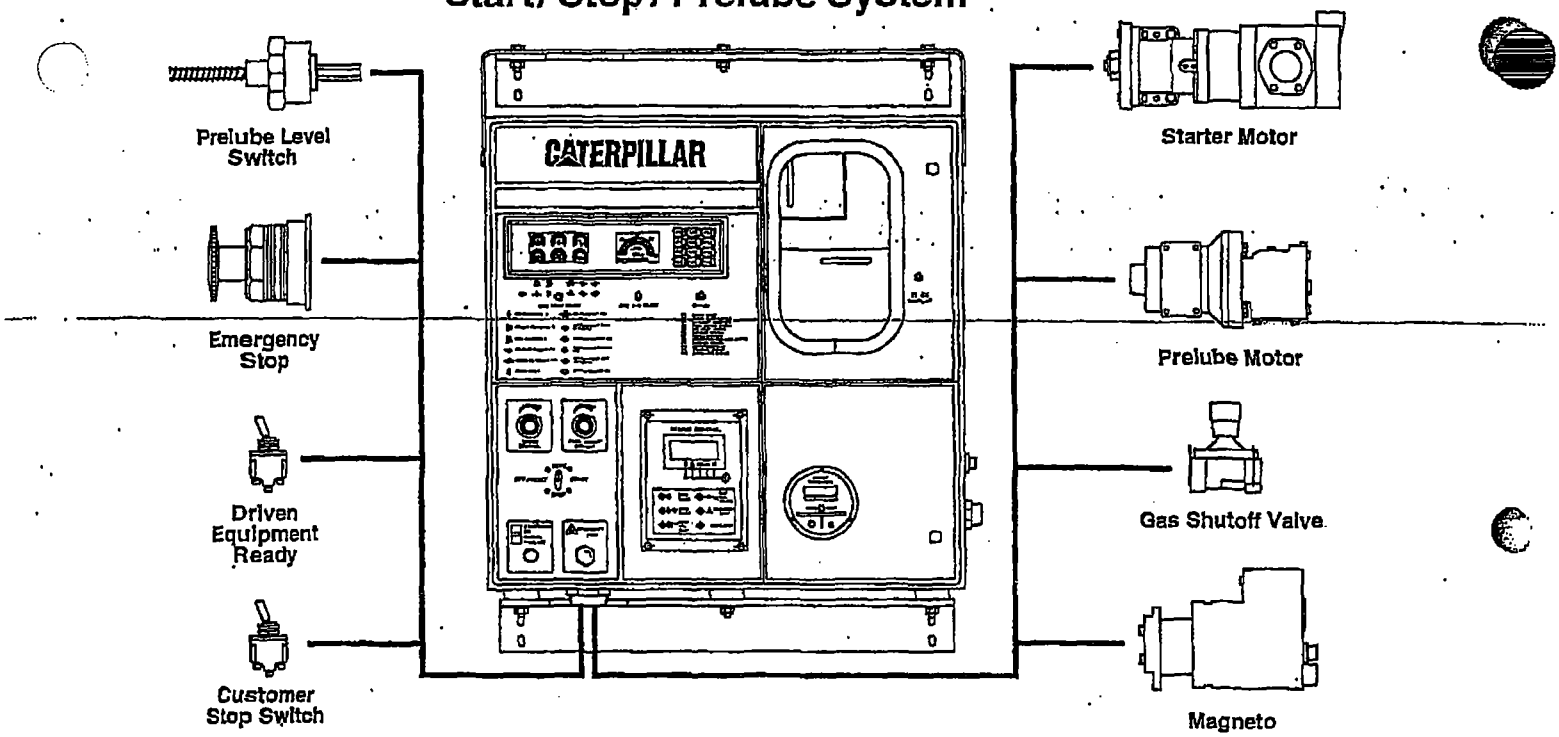


Figure 7

- Prelube pump system (Pump and Solenoids)
- Engine cranking system (Starters and Solenoids)

The Major Functions of this system are controlled by the Mode Control switch and Prelube push button. The Mode Control switch has 4 positions/operations:

Off/Reset

In Off/Reset the System Diagnostic Codes are reset. If the engine is running it will go through a sequenced shutdown; and once the post-lube cycle is complete the system power is turned off.

Stop

In Stop if the engine is running it will go through a sequenced shutdown and a post-lube cycle. All Control Modules will remain powered up.

Start

In Start the Engine Supervisory System will prelube the engine, crank, and run until the switch is moved from this position.

Auto

In Auto the system is configured for remote operation and becomes dependent on the remote Start Initiate Contact. If the contact is *Open* the system functions as if were the Stop position. If the contact is *Closed*, the stem operates as if it were in the Start position.

The Prelube Switch located on lower left of the ESS Panel can be used to manually run the prelube pump. The pump runs as long as the switch is depressed and until prelube conditions are achieved (indicated by the prelube complete contact closing).

There are Emergency Stop switches located on the ESS Panel and on the Engine Mounted Junction Box as well as an input the customer provided switches at other locations. Closing any one of the switches will immediately initiate an emergency shutdown of the engine. These switches are not intended for routine use and should only be used in an emergency.

The Engine Monitoring and Protection Subsystem

This Subsystem, Figure 8, consists of the following components:

- Engine Supervisory System Control Panel
  - Computerized Monitoring System (CMS)
  - Status Control Module
  - Engine Control Module
  - Timing Control Module
  - Pyrometer Modules
  - Gauge Group Select Switch
  - Gauge Data Select Switch
  - Display Select Switch
  - Dimmer Switch
- Engine Mounted Sensors
- Customer Inputs
- Customer Outputs

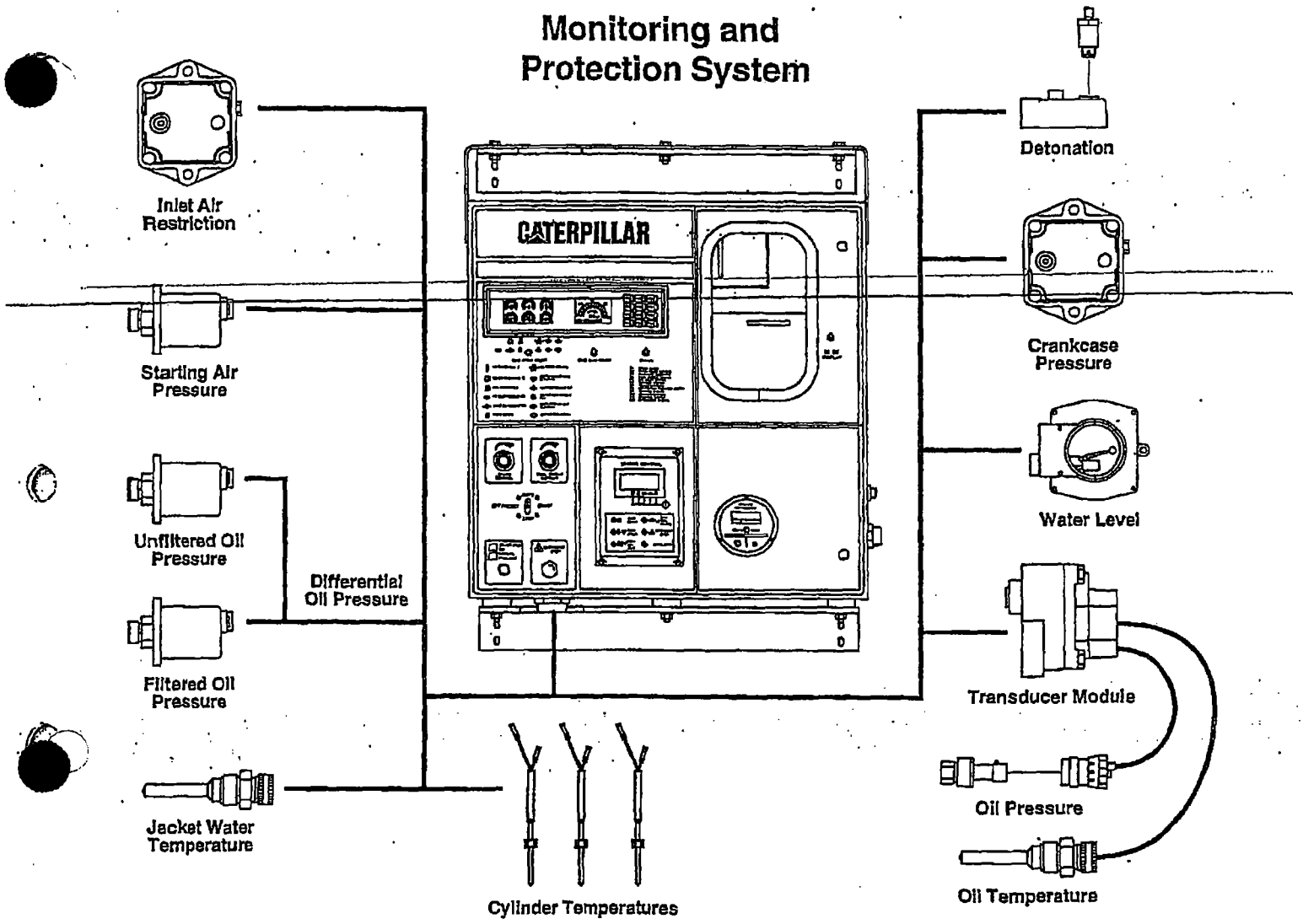


Figure 8

The system provides engine protection and monitors engine systems for vital parameters. It also provides warnings and/or inhibits engine starting or shuts down the engine when parameters are outside acceptable limits. Along with these features, it provides display/indication of engine operating parameters.

The following is a list of protection features listed by the module where the information is displayed.

Computerized Monitoring System (CMS)

The Display consists of 6 small gauges and 1 larger center gauge. The information displayed on the gauges is controlled by the gauge group select and the gauge data select switches. The gauge group select switch selects between two sets of parameters available for display on the 6 small gauges.

- Setting the switch to the left selects the first group of parameters:
  1. Manifold Air Temperature
  2. Jacket Water Temperature
  3. Fuel Correction Factor
  4. Manifold Air Pressure
  5. Engine Oil Pressure/Prelube Status
  6. Engine Load (%)
- Setting the switch to the right selects the second group of parameters:
  7. Oil Filter Differential Pressure
  8. Inlet Air Restriction (in-line engine or right bank of a vee)
  9. Crankcase Pressure
  10. Unused
  11. Inlet Air Restriction (unused for an in-line or left back of a vee)
  12. Starting Air Pressure
- The large gauge always indicates:
  13. Engine Speed

The *gauge data switch* allows the data provided on each of the gauges to be viewed on the digital read-out below the large center gauge. The upper number in the gauge display indicates which parameter is being viewed (refer to above numbers in the lists of data). Each time the Gauge Data Switch is toggled the next gauge is selected (within the range of gauges currently selected by the Gauge Group Select).

If the Gauge Group Select is switched, the digital gauge will change to the gauge for the corresponding gauge position (i.e. if gauge 2 coolant temperature, was selected and the Gauge Group Select is moved the gauge data will switch to gauge 8, Inlet Air Restriction Right).

Fault Indicator Lights

The CMS has 12 lamps to indicate a fault condition has occurred. A fault is either a measured parameter outside a safe limit or a device that is malfunctioning. Each lamp indicates the system to look for to determine the exact problem.

- F1 - Check gauges
- F2 - Check fluid levels
- F3 - Auxiliary equipment
- F4 - Fuel Supply system
- F5 - Air Inlet system
- F6 - Exhaust system
- F7 - Module/wiring system
- F8 - Combustion Feedback system
- F9 - Ignition system
- F10 - Sensors/Devices
- F11 - Starting system
- F12 - Detonation system

The lamps direct the service technician to the subsystem or component with a problem. For exact information about the problem, the technician then reads the Fault Code on the module in question.

Status Control Module

The Display sequences automatically through these parameters in either English or metric units:

- Service Hours
- Engine Speed (Safety for Overspeed)
- Battery Voltage
- Engine Oil Pressure (Safety for Low Pressure)
- Engine Oil Temperature (Safety for High Temperature)

Displayed as lamps on the front of the module:

- **Overcrank** indicates the engine did not start after cranking or cycle cranking for the entire programmed time limit.
- **Overspeed** indicates the engine has been shutdown due to excessive speed.
- **High Oil Temperature** indicates the engine has been shutdown due to excessive oil temperature.
- **Low Oil Pressure** indicates the engine has been shutdown due to insufficient oil pressure.
- **Emergency Stop** indicates the engine has been shutdown due to one of the Emergency Stop Switches being depressed.
- **Auxiliary** indicates the engine has been shutdown due to a customer requested shutdown (customer stop input).

Engine Control Module

The primary function of the Engine Control Module is to govern the speed and to control the air/fuel ratio; however, it also has the role of system coordinator. Its personality module contains many of the protection set points and it controls much of the systems operation. The display on the Engine Control Module consists of 8 characters and 8 lights.

The lights indicate:

- **Status** (Green) – The data on the 8 Character Display is status information i.e. desired engine speed, fuel energy (Btu) setting.
- **Data Link 1 Active** (Green) – When lit, this light indicates that the Engine Control Module is properly communicating with the Timing Control Module.
- **Data Link 2 Active** (Green) – When lit, this light indicates that the Engine Control Module is properly communicating with the CMS Module.
- **Caution** (Yellow) – One or more potential problems exist. The 8 Character Display will be displaying a code that indicates the exact nature of the caution condition.
- **Sensor Fault** (Red) – A problem has been detected with one of the systems sensors. The 8 Character Display will be displaying a code that indicates the exact nature of the problem.
- **Actuator Fault** (Red) – A problem has been detected with one of the actuators. The 8 Character Display will be displaying a code that indicates the exact nature of the problem.
- **System Fault** (Red) – A problem has been detected with one of the control systems. The 8 Character Display will be displaying a code that indicates the exact nature of the problem.
- **Control Module Fault** (Red) – A problem has been detected with one of the control modules. The 8 Character Display will be displaying a code that indicates the exact nature of the problem.

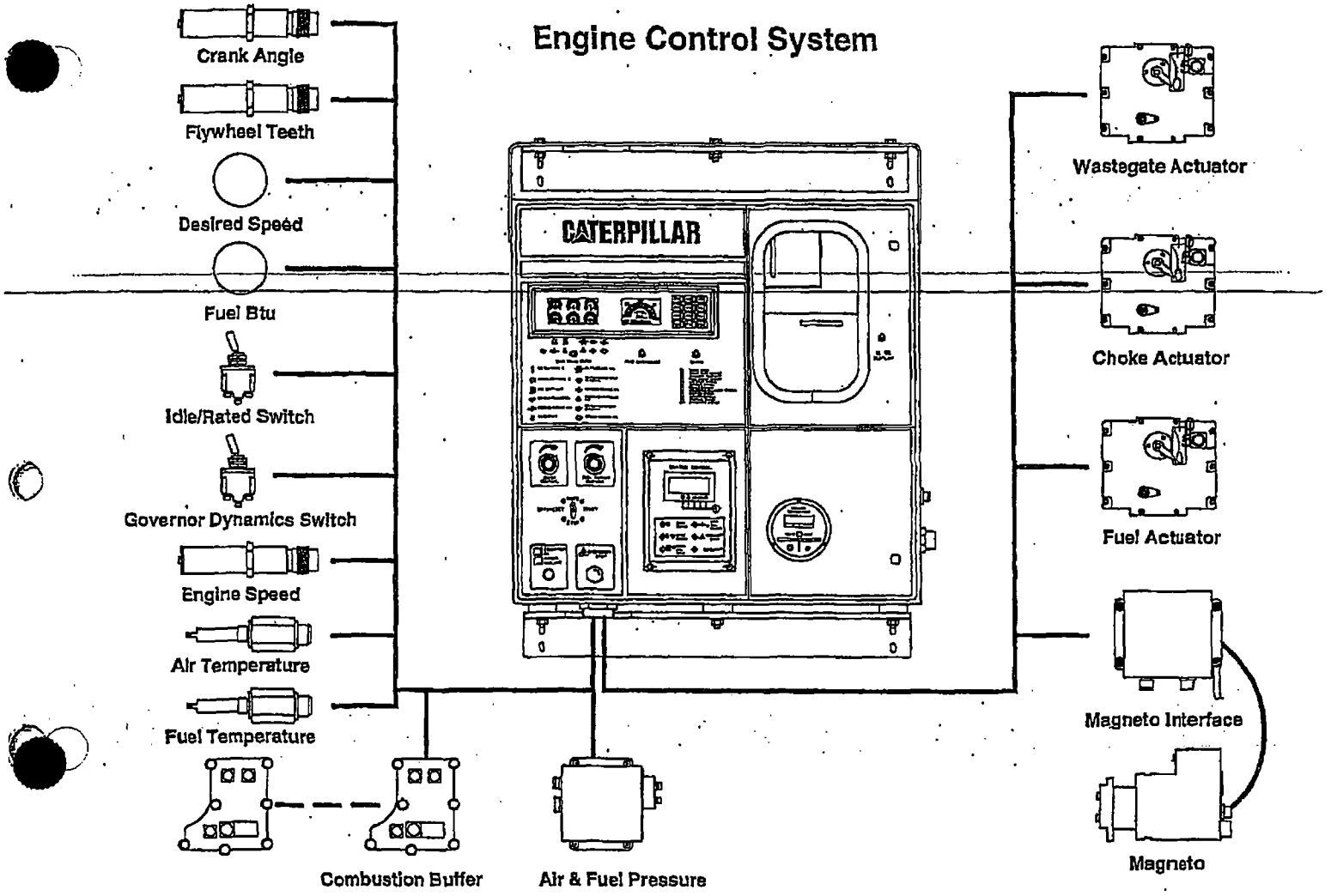


Figure 9

The Display Select Switch Allows the operator to step through the data on the Engine Control Display. Every time the switch is toggled the display steps through to the next item. Items displayed are either status or diagnostic codes (differentiated by one of the lights).

Timing Control Module

The primary function of the Timing Control Module is to maintain the ignition timing at the set point determined by the Engine Control Module. It does however measure the level of detonation or knock present in the engine. This data is used by the engine control to protect the engine from possible damage caused by detonation.

Pyrometer Modules

Each pyrometer module allows the read-out in 9 separate temperatures (in °C). The module powers up displaying the reading of channel 0 (exhaust stack temperature). To read the temperature values on the other eight channels, press the *Push to Advance* button on the front of the gauge. One of these modules is used for in-line engines two for vee engines.

The pyrometer continuously compares channel 0 (stack temperature) to a set point. If the temperature ever exceeds that set point, a contact closes instructing the system to shutdown.

Customer Inputs

- Driven Equipment Ready Contact allows the customer to stop and/or inhibit Start of the engine due to a problem with the driven equipment
- Customer Stop Contact allows the customer to request the engine to shut down for any reason needed by his equipment.

Customer Outputs

- Horn Driver annunciates that a problem has been detected in the system that may cause the engine to shutdown if it is not corrected.
- Prelube Complete annunciates that the engine is prelubed and ready to start.

- Engine Failure annunciates that the engine has shutdown with a fault. The fault needs to be reset in order to restart.
- Crank Terminate annunciates that the engine has started and is running.
- Run Relay annunciates that the fuel is turned on to the engine
- Mode Switch Position provides the position of the mode control switch (to be read by remote equipment).

Engine Control Subsystem

The Subsystem, Figure 9, consists of the following components:

- Engine Supervisory System Control Panel
  - Engine Control Module Timing Control Module
  - Desired Speed Potentiometer
  - Fuel Energy Content Potentiometer
- Engine Mounted Sensors
- Engine Mounted Actuators Engine Speed Governing

The Engine Control Module performs the governing function. The governor is more like a diesel engine governor than a typical gas engine governor. The G3600 Engine is governed by modulating the fuel valve controlling fuel flow independent of air flow. The air flow is controlled the air/fuel ratio controller in response to the asured fuel flow.

Desired Speed

Desired speed is controlled by an idle/rated switch (Open selects idle speed of 550 rpm; Closed selects the speed set by the desired speed input). The desired speed input is typically the potentiometer on the front face of the ESS panel, but may be controlled by an external module.

Droop

The Customer can select any where from 0% to 10% speed droop.

Loadshare Module

A generator set loadshare module compatible with the ESS is available as a ship loose item.

Switchable Governor Response

In order to provide optimum engine response with a generator set that operates in parallel with a utility or with other generator sets it is necessary to have two governor settings. The G3600 control system offers a dual dynamics governor. The *Governor Dynamics Switch* selects from either *Stand-alone* or *Paralleled* governor settings.

justable Governor Response

o provide optimum package response with a variety of driven equipment, the G3600 Control System offers tunable governor dynamics.

Fuel Limiting

The fuel system on the G3600 Engine does not have any carburetor or equivalent, as a result the governor is required to insure that the air/fuel mixture does not exceed the rich flammability limit (Rich Misfire). By coordinating with the Air/Fuel Ratio Control section, the governor is able to read the actual air/fuel ratio and use that information to keep the engine from getting too rich.

The governor also provides power limiting on the G3600 Engine. By reading the fuel flow and comparing against maximum allowed flow (function of engine speed) the governor protects the engine against overpower situations.

Air/Fuel Ratio Control

The G3600 Engine does not have a carburetor; instead the air flow and 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.

Desired Air Flow

The Air/Fuel Ratio Controller calculates the actual fuel flow and uses a desired air/fuel ratio combined with a fuel energy content (set on the *Energy Content* Potentiometer on the front panel of the ESS) to determine the required air flow. The desired air/fuel ratio for a given speed and load is stored in an application specific map in the Engine Control Personality Module. This map is created to achieve maximum engine performance (efficiency and emissions).

Actual Air Flow

The Engine Control reads inlet manifold air pressure and temperature combined with engine speed to estimate the actual air flow into the engine.

Air Flow Control

Once the control has calculated a desired air flow and an actual air flow, it modulates the wastegate and choke valves to make the actual match the desired.

Fuel Correction System

Combustion Measurement

Once the engine is running and the measured load exceeds a set level (typically 25%), the combustion measurement system compensates for any changes in the ambient conditions or fuel quality. The Engine Control reads the time required for the flame to propagate from the spark plug to the combustion sensor for each cylinder and creates an engine average *burn* time.

Desired Combustion Burn Rate

The Engine Control Personality Module contains application specific maps that define for any given engine speed and load the burn time that achieves maximum engine efficiency and burn proper emissions.

G3600 Family of Engines

Technical Data

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G3600 Engine Performance Data

The Performance section provides data for each engine. It is divided into sections depending on the engine model selected. The data for each engine model includes a rating curve, part load performance, BSFC curves, altitude deration factors and aftercooler heat rejection factors. Use the table of contents to help find the information for a specific engine. For example, the data for a G3606 Engine is organized as follows:

Part Load Data
- Gen Sets
  - 60Hz.
  - 50 Hz
- Industrial
  - 1000 rpm
  - 900 rpm

Aftercooler Heat Rejection Factors
BSFC Curves
Altitude Deration
Rating Curves

Rating Definitions

Ratings are based on SAE J1349 standard conditions of 29.61 in. Hg (100 kPa) and 77°F (25°C); ISO 3046/1, BS 5514/1 and DIN 6271/1 standard conditions of 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) also apply.

Ratings are based on dry natural gas with a lower heating value of 905 Btu/ft³. Variations in altitude, temperature and gas composition from standard conditions may require a reduction in engine horsepower.

Methane number is a scale to measure ignition and burning characteristics of various fuels. Representative values are shown below.

Methane	100
Ethane	44
Propane	34
n-Butane	10
Hydrogen	0

Most dry pipeline natural gas has a methane number of 67 or above. Field gas can go much lower. The engine must be operated on a gas with a methane number of 50 or above. The gas being used should have a complete analysis and the methane number determined. Consult the dealer or factory for assistance.

Part Load Data

Tabular part load data is divided into five general areas: engine configuration (including application), emissions, air system and combustion factors, heat rejection, and air/fuel and exhaust flows.

Engine Configuration

The first block of information defines the engine configuration for which the data applies. It covers aspiration, speed, jacket water temperature, aftercooler temperature, engine power, and generator output (if applicable). This data, along with the title, must be consistent with the engine being applied.

Emissions

The information in this block covers NO_x, CO, HC (total), HC (non-methane), and Exhaust Oxygen. Emissions shown are *Not to Exceed* values.

Air System and Combustion Factors

This section provides fuel consumption, turbocharger compressor pressure and temperature, intake manifold pressure and temperature, air-fuel ratio and timing.

Heat Rejection

Formula: Total heat input = work output + total exhaust heat + radiation + jacket water + oil cooler + aftercooler.

- **Total heat input** is figured by multiplying the BSFC (Btu/bhp-h) times the horsepower output to get Btu/hr. To obtain, Btu/min, divide by 60. Fuel volume consumed is obtained by dividing the total heat by the heat content of the fuel (905 Btu/ft³).
- **Work output** is the total horsepower developed. It is expressed in Btu/min where 1 hp = 42.4 Btu/min.
- **Total exhaust heat** is the total heat available in the exhaust when it is cooled from the stack temperature down to standard conditions of 77°F. When expressed in Higher Heating Value (HHV), it includes the latent heat of vaporization. At standard conditions, 970 Btu are released as each pound of steam is condensed to water. The figures shown are in terms of low heat value and, therefore, do not included the heat of vaporization.
- **Radiation** is the amount of heat loss from the surface of the engine into the engine room or surrounding ambient.
- **Jacket water heat** is the total amount of heat picked up by the engine cooling system. It is the only source of heat on the jacket water cooling circuit, and has its own water pumps mounted on the lower right front of the engine.
- **Oil cooler heat** is the total heat rejected by the lube oil system. This cooling circuit is common with the aftercooler circuit and are the water pumps mounted on the lower left front of the engine.
- **Aftercooler heat rejection** is given for standard conditions of 77°F and 500 ft altitude. This heat rejection is increased for higher ambients and higher altitudes. We are trying to maintain a constant outlet temperature so as inlet temperature to the aftercooler goes up, so does the heat that must be removed. As

the air pressure decreases, the turbo imparts more energy to the incoming air to get up to the required boost pressure. Be sure to use the aftercooler heat rejection factor to adjust for ambient and altitude conditions. Failure to properly account for these factors could cause the engine to detonate and cause engine shutdown or failure.

- **Recoverable exhaust heat** is not a separate component of the heat balance equation but is the customary number used in heat recovery calculations. It represents the heat available when cooling the exhaust from the stack temperature down to 350°F. This figure, plus the jacket water heat rejection, is used in determining steam production.

  If an exhaust temperature other than 350°F is desired, the recoverable heat can be calculated by the following formula:

  $Q = CpM\ (T_1 - T_2)$

  Q = Heat Rejection in Btu/min

  Cp = Specific Heat of Exhaust Gas:
  0.258 Btu/lb/°F — Low Emission Engines
  0.278 Btu/lb/°F — Standard Engines

  $M = \text{Exhaust Mass Flow} = \frac{Ev\ (CFM) \times 41.13}{(T_1 + 460°)}\ lb/min$

  T1 = Exhaust From Engine °F

  T2 = Exhaust Out of Heat Recovery Silencer °F

  Ev = Exhaust Flow by Volume (CFM)

In every calculation using engine data, there is a tolerance band or a deviation from norm. When using the heat balance, the following tolerance should be used.

Work Output	± 3%
Heat Input	± 2.5%
Exhaust Total	± 10%
Exhaust Recoverable	± 10%
Jacket Water	± 10%
Oil Cooler	± 20%
Aftercooler	± 5%
Radiation	± 25%

Heat rejection numbers are based on treated water as the coolant.

Air, Fuel, and Exhaust Flows

This data provides mass and volume flow information of the air, fuel and exhaust. It should be used when sizing ventilation systems, fuel piping, and exhaust equipment. The inlet air flow is based on conditions of 77°F and 13.9 psi air pressure. The exhaust flow is based on stack temperature and 13.9 psi gas pressure. Fuel flow is referenced to fuel at 60°F and 14.7 psi.

Aftercooler Heat Rejection Factors

Aftercooler heat rejection is given for standard conditions of 77°F and 500 ft altitude. Use the aftercooler heat rejection factor to adjust for ambient and altitude conditions at the installation site. Multiply the factor by the standard aftercooler heat rejection.

Altitude Deration Factors

This information is used to show altitude deration required for various ambient temperatures and altitudes. Use to determine actual engine power at the installation site.

Rating Curves

The curves of rated engine brake horsepower vs engine rpm illustrates the capability of the engine at both 90°F and 130°F aftercooler water temperatures.

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G3600 Engine Basics

Engine Design Specifications

G3606

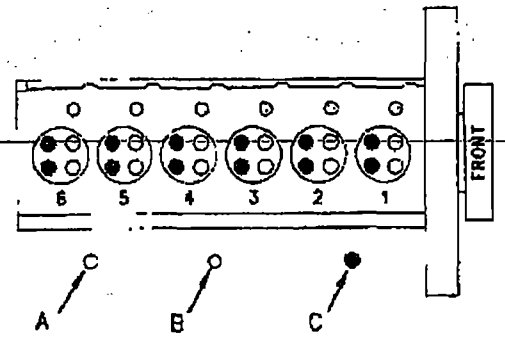


Illustration 1
G3606 Engine Design
(A) Inlet. (B) Gas admission. (C) Exhaust.

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

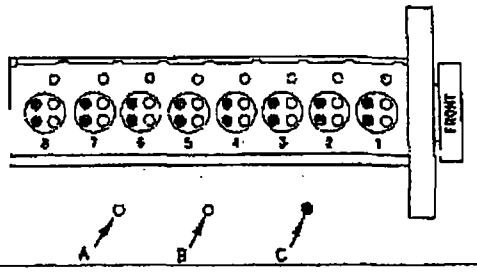


Illustration 2
G3608 Engine Design
(A) Inlet. (B) Gas admission. (C) Exhaust.

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

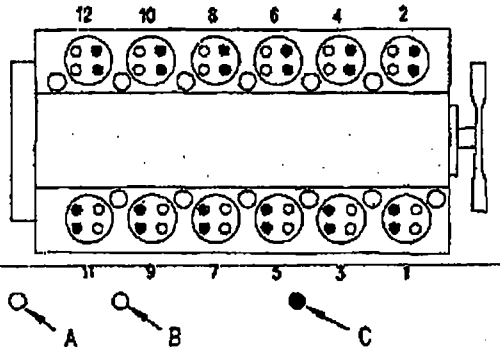


Illustration 3
G3612 Engine Design
(A) Inlet. (B) Gas admission. (C) Exhaust.

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

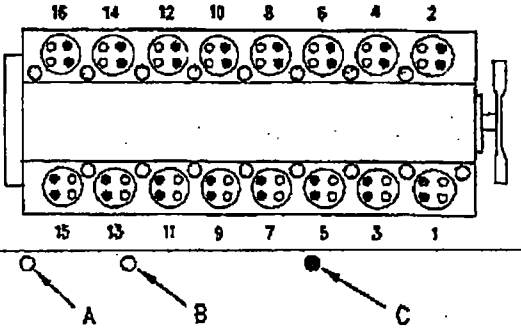


Illustration 4
G3616 Engine Design
(A) Inlet. (B) Gas admission. (C) Exhaust.

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

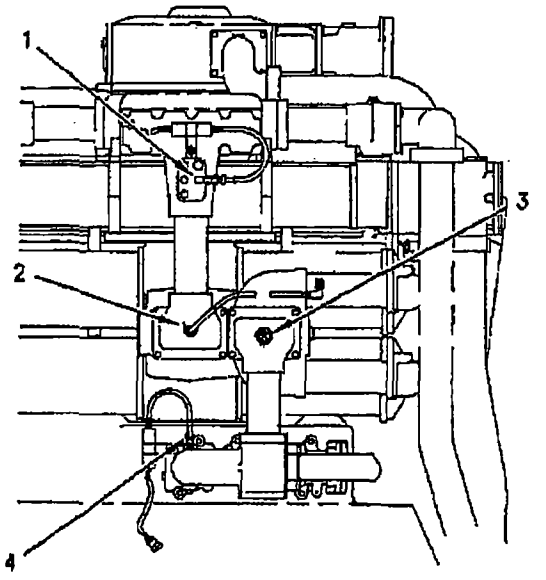


Illustration 5
Engine Mounted Sensors Front View
(1) CMS unfiltered engine oil pressure sensor. (2) SCM engine oil temperature sensor. (3) SCM filtered engine oil pressure sensor. (4) CMS filtered engine oil pressure sensor.

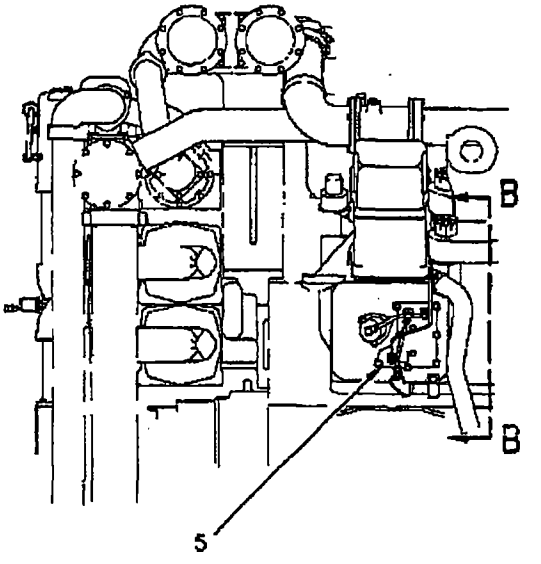


Illustration 6
Engine Mounted Sensors Left Side View
(5) Combustion buffer.

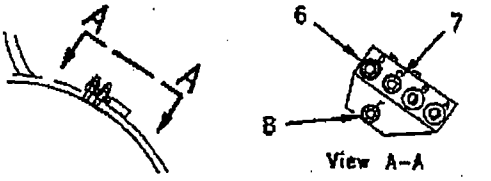


Illustration 7
Engine Mounted Sensors Rear View
(6) Timing control speed sensor. (7) Engine control speed sensor. (8) Timing control crank angle sensor.

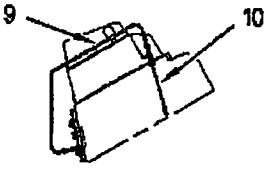


Illustration 8
Engine Mounted Sensors View B-B
(9) Combustion feedback cable. (10) Combustion feedback extension and probe.

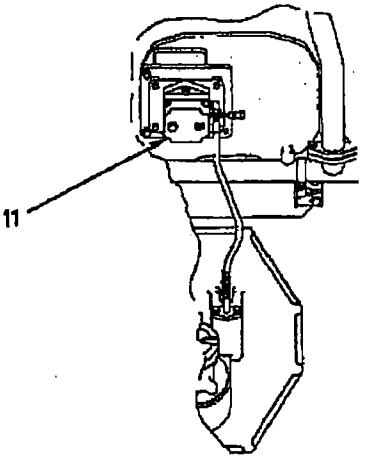


Illustration 9
Engine Mounted Sensors Right Side View
(11) Crankcase pressure sensor.

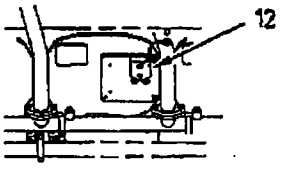


Illustration 10
Detonation Sensors
(12) Detonation sensors.

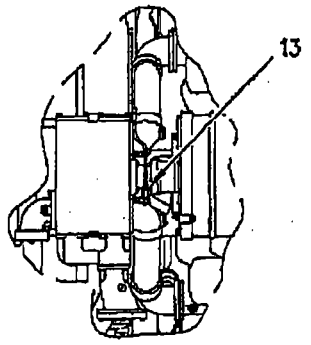


Illustration 11
Engine Mounted Sensors Top View
(13) Jacket water temperature sensor.

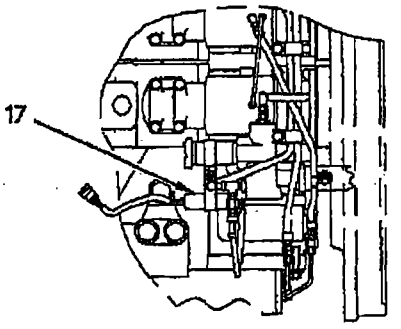


Illustration 14
Engine Mounted Sensors Left Side View
(17) Starting air pressure sensor.

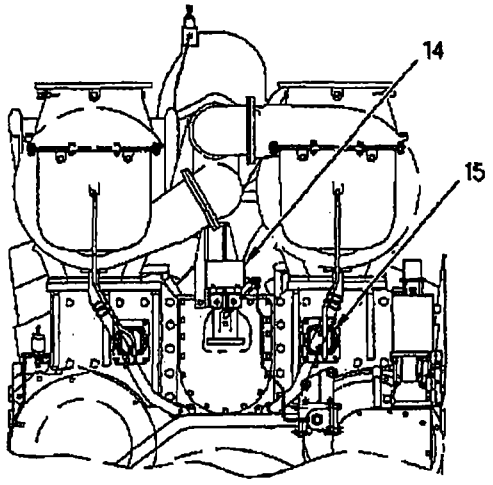


Illustration 12
Engine Mounted Sensors Rear View
(14) Fuel and air Pressure module. (15) Inlet air restriction.

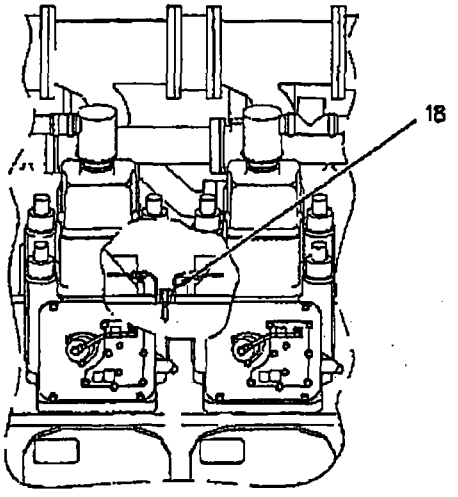


Illustration 15
Engine Mounted Sensors Right Side View
(18) Inlet air temperature sensor.

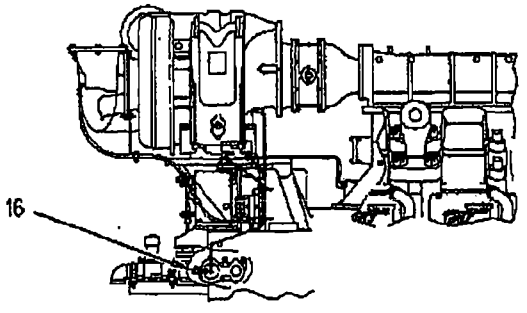


Illustration 13
Engine Mounted Sensors Right Side View
(16) Fuel temperature sensor.

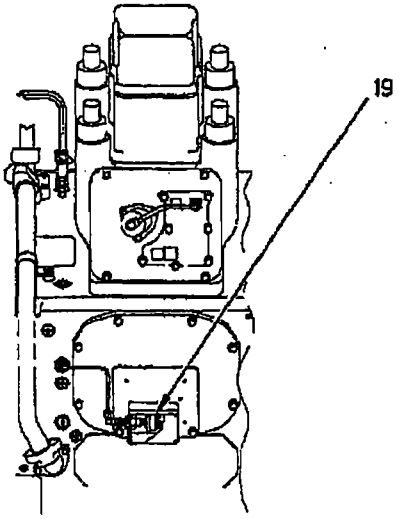


Illustration 16
Engine Mounted Sensors Right Side View
(19) Prelube pressure switch.

Control Panel For The Engine Supervisory System (ESS)

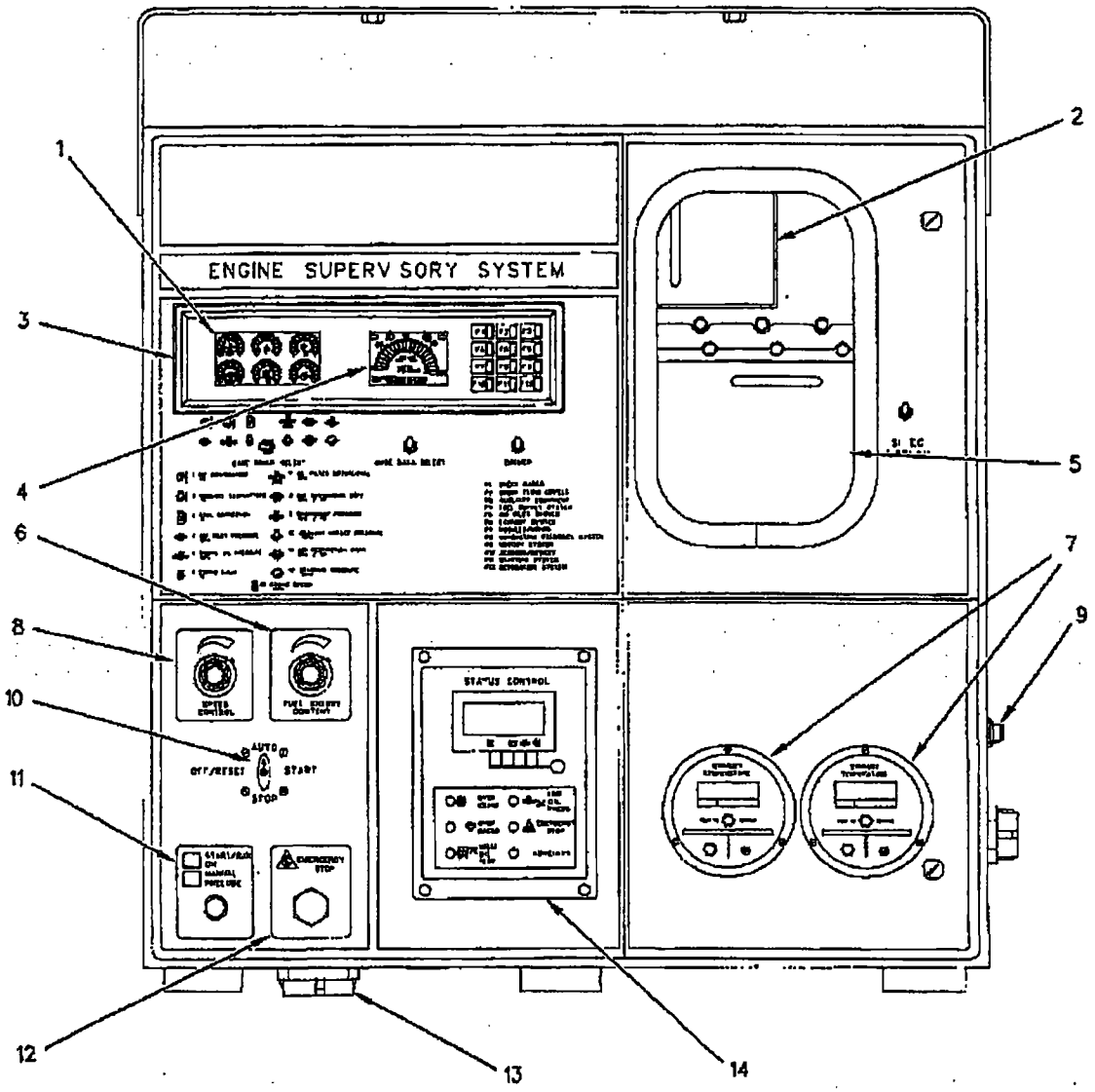


Illustration 17
(1) LED Dial gauges. (2) Timing Control Module (TCM). (3) CMS Gauge panel. (4) Digital gauge readout. (5) Engine Control Module (ECM). (6) Fuel energy adjustment dial. (7) Exhaust pyrometer. (8) Engine speed adjustment dial. (9) Digital Diagnostic Tool (DDT) connection. (10) Mode control 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

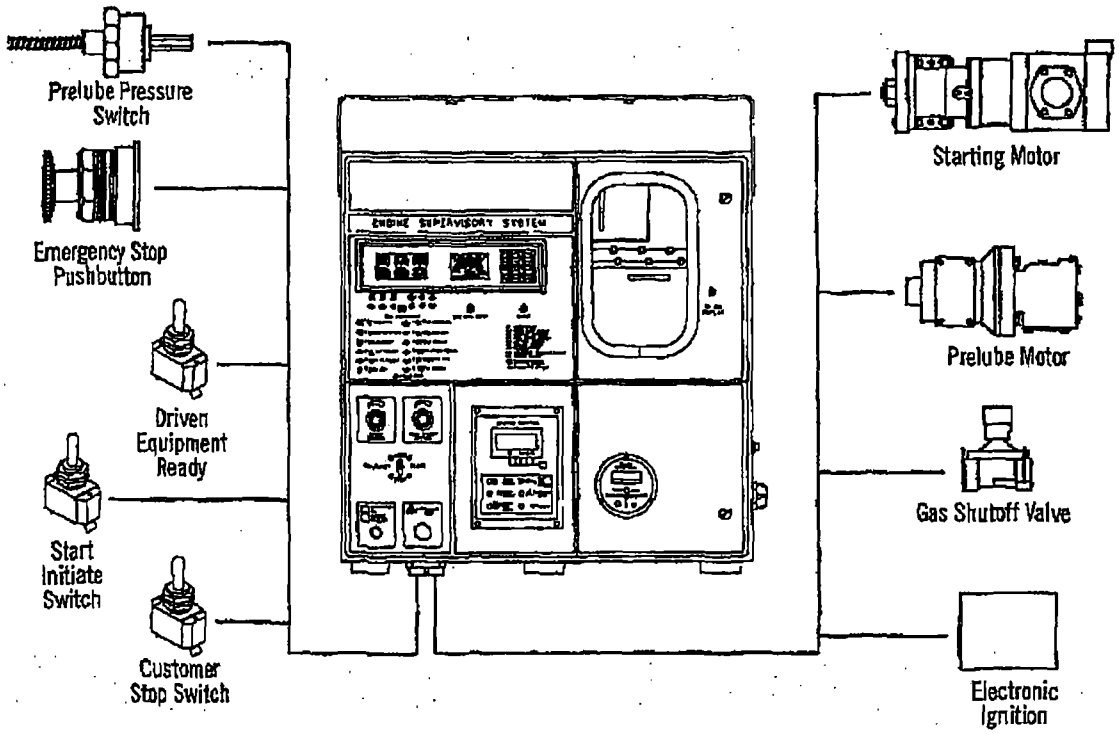


Illustration 18

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

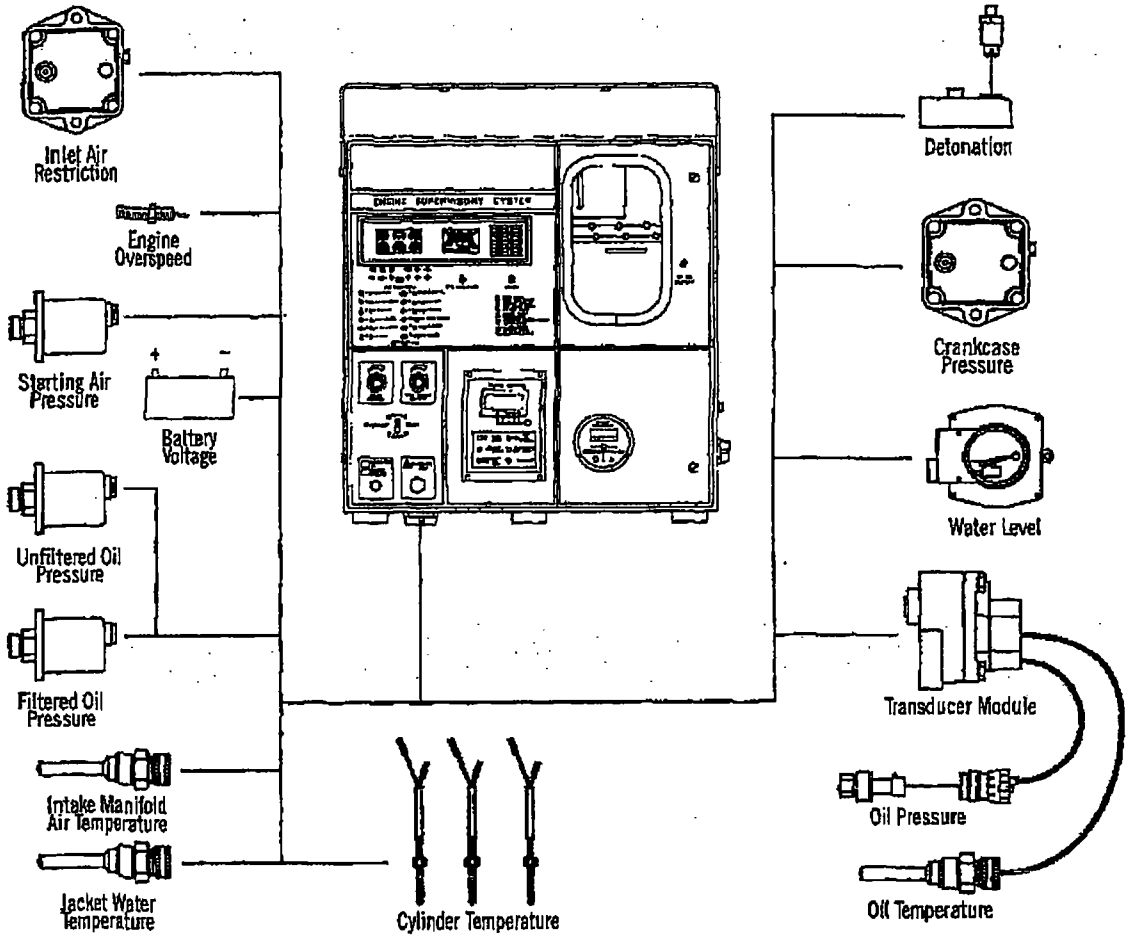


Illustration 19

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 $H_20/10$.

Gauge 9 CRANKCASE PRESSURE – This gauge indicates the pressure that is inside the crankcase. This is displayed in kPa/10 or inches of $H_20/10$

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.

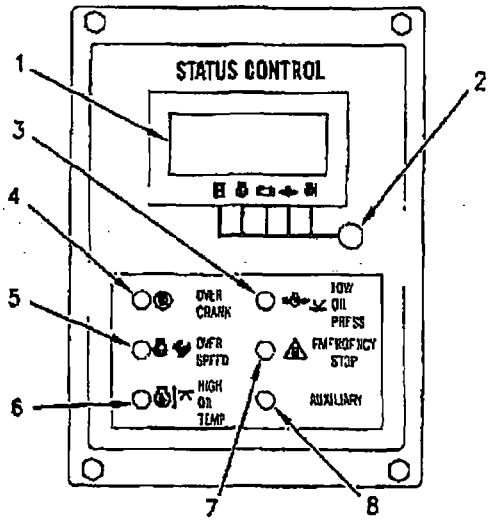


Illustration 20
Status Control Module (SCM)
(1) Liquid Crystal Display (LCD). (2) Switch (display hold switch). (3) Low Oil Pressure Light Emitting Diode (LED). (4) Overcrank LED. (5) Overspeed LED. (6) High Oil Temperature LED. (7) Emergency stop LED. (8) Auxiliary LED (shutdown).

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

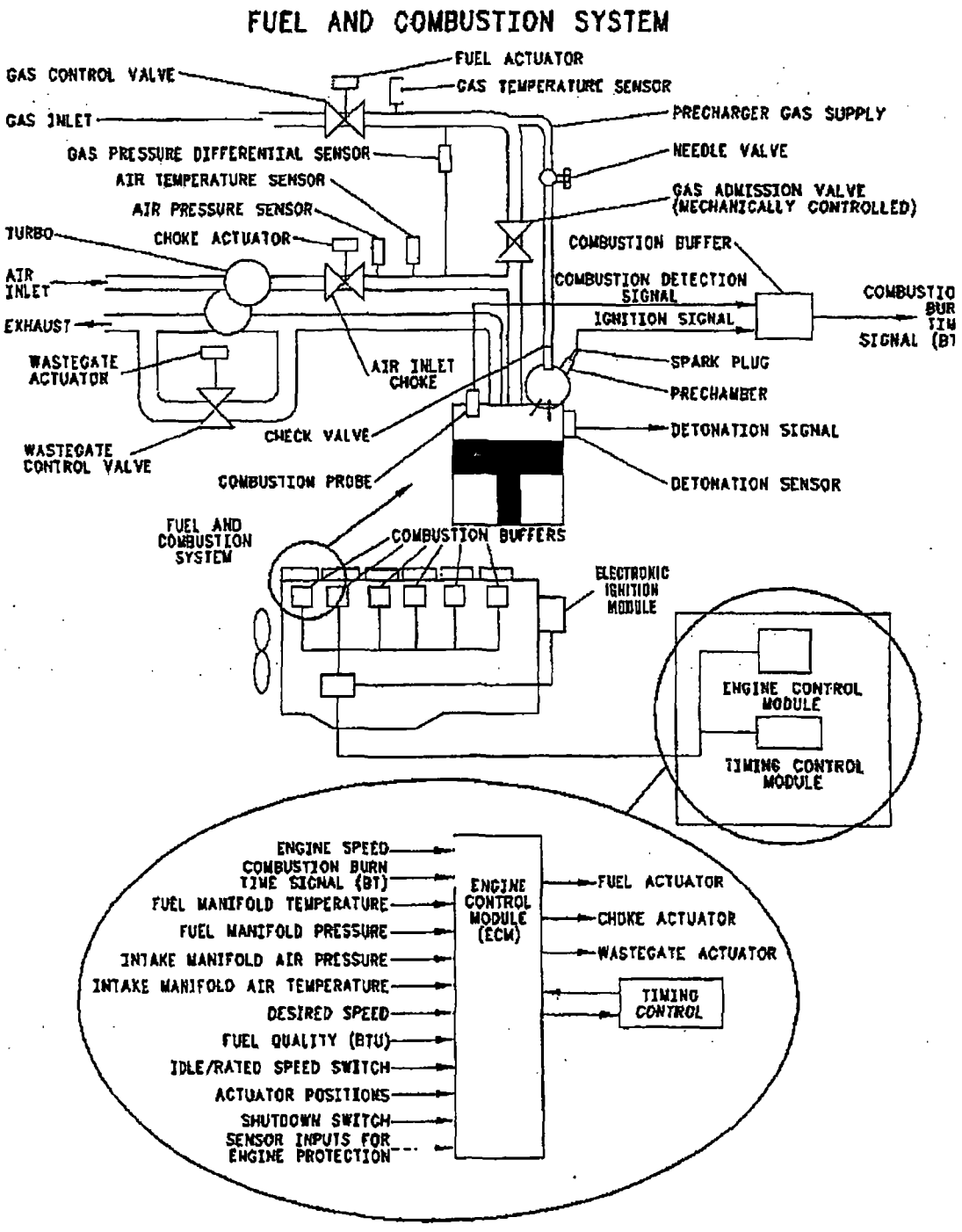


Illustration 21

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.

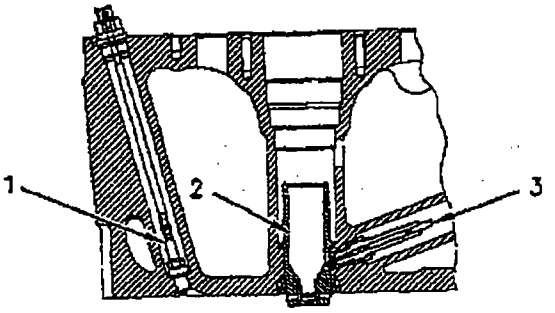


Illustration 22
Cylinder Ignition and Sensor
(1) Combustion sensor. (2) Precombustion chamber.
(3) Gas ignition spark plug.

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.

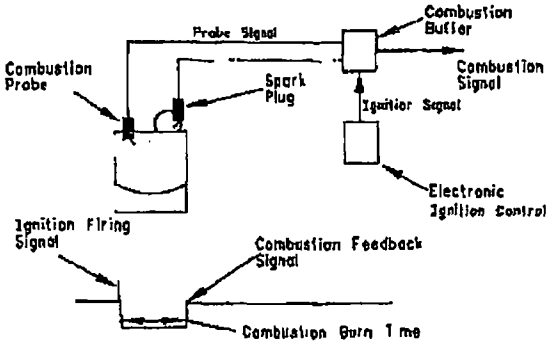


Illustration 23
Basic Combustion Probe System Diagram

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).

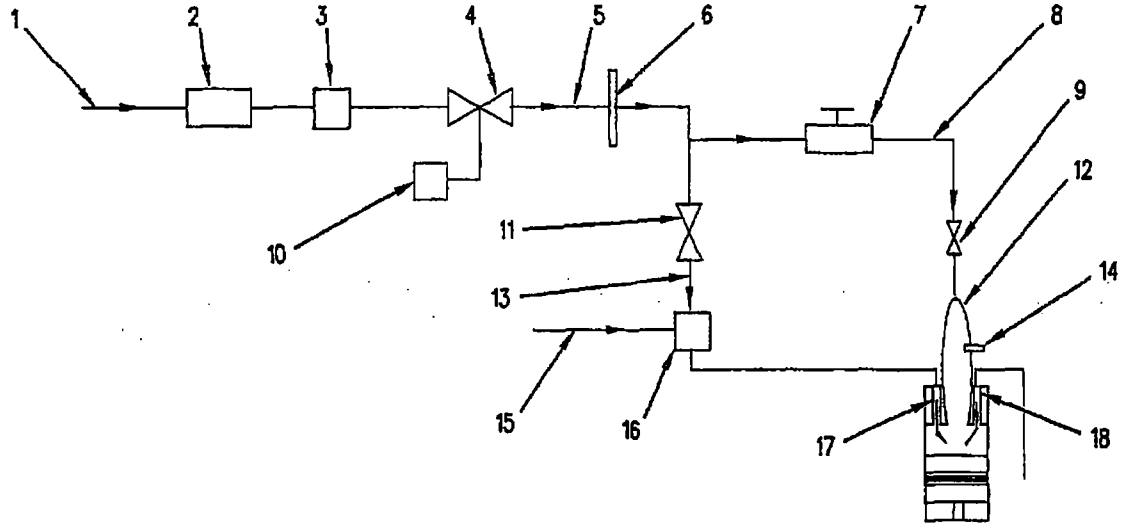


Illustration 24
Fuel System Schematic Diagram
(1) Gas input. (2) Customer supplied regulator. (3) Gas shutoff valve. (4) Control valve. (5) Fuel manifold. (6) Orifice. (7) Needle valve. (8) Precombustion chamber supply line. (9) Precombustion chamber check valve. (10) Electronic actuator. (11) Gas admission 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

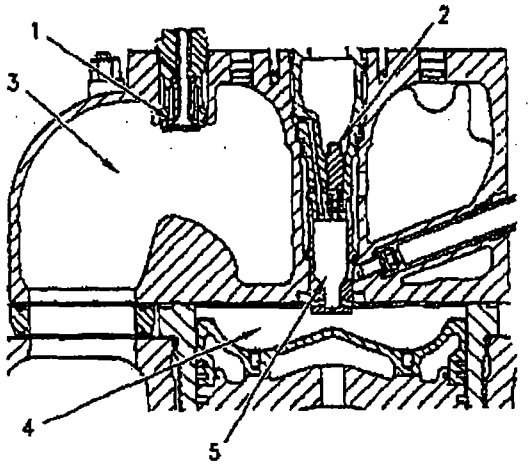


Illustration 25
(1) Gas admission valve. (2) Check valve. (3) Inlet air.
(4) Main combustion chamber. (5) Precombustion chamber.

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

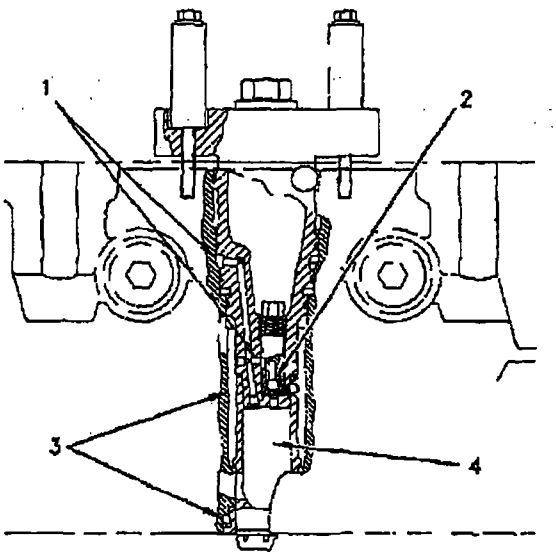


Illustration 26
PC Check Valve and Fuel Supply Path
(1) Fuel inlet passage. (2) Check valve. (3) Passageways for the jacket water coolant. (4) Precombustion chamber.

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

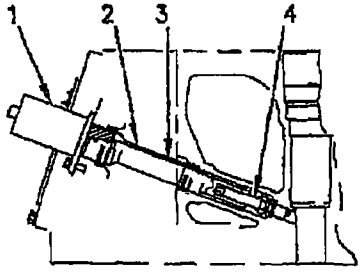


Illustration 27
Components of the Gas Engine Ignition Group
(1) High energy ignition transformer. (2) Tube.
(3) Extension with a spring loaded rod. (4) Spark plug.

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

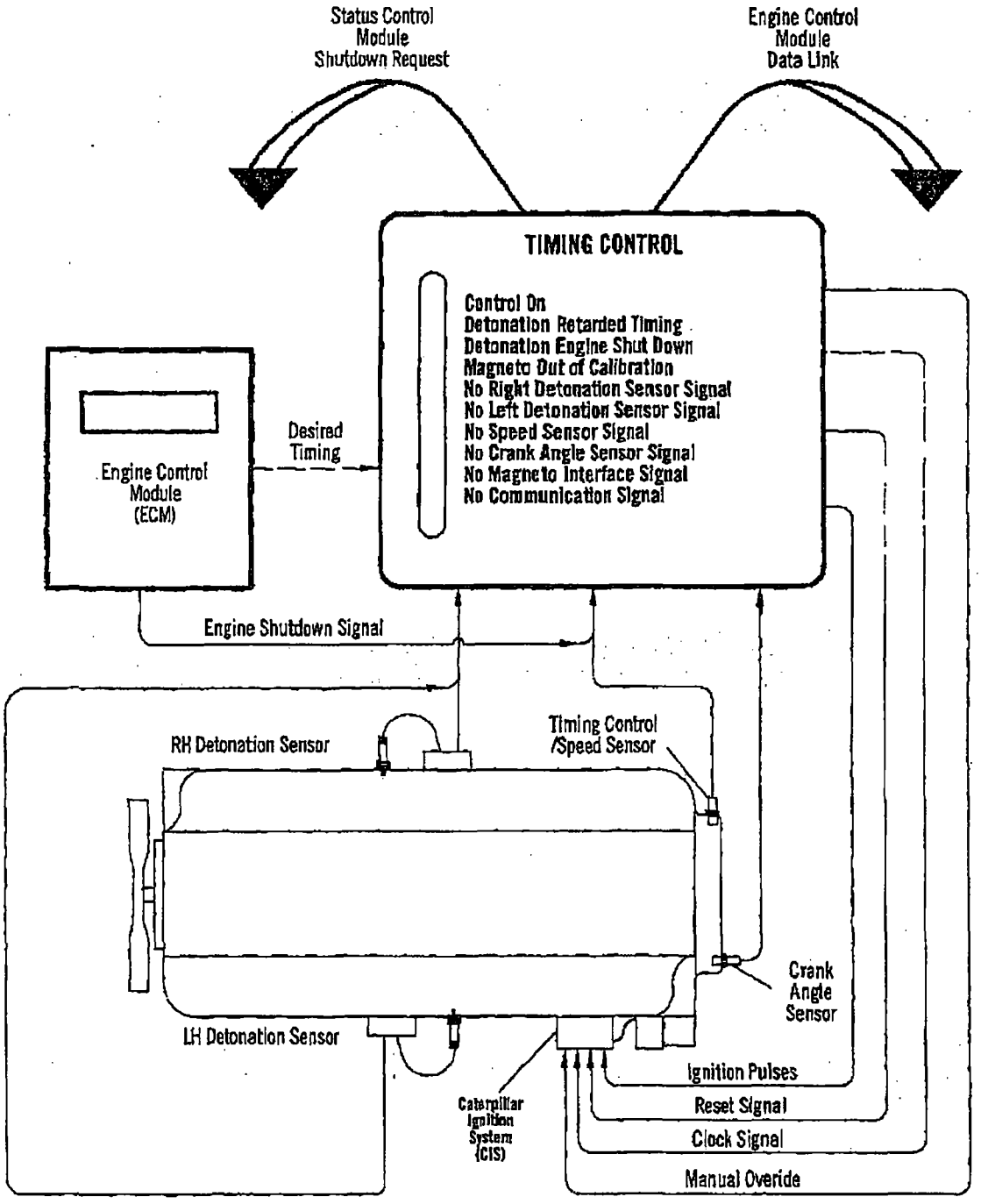


Illustration 28

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

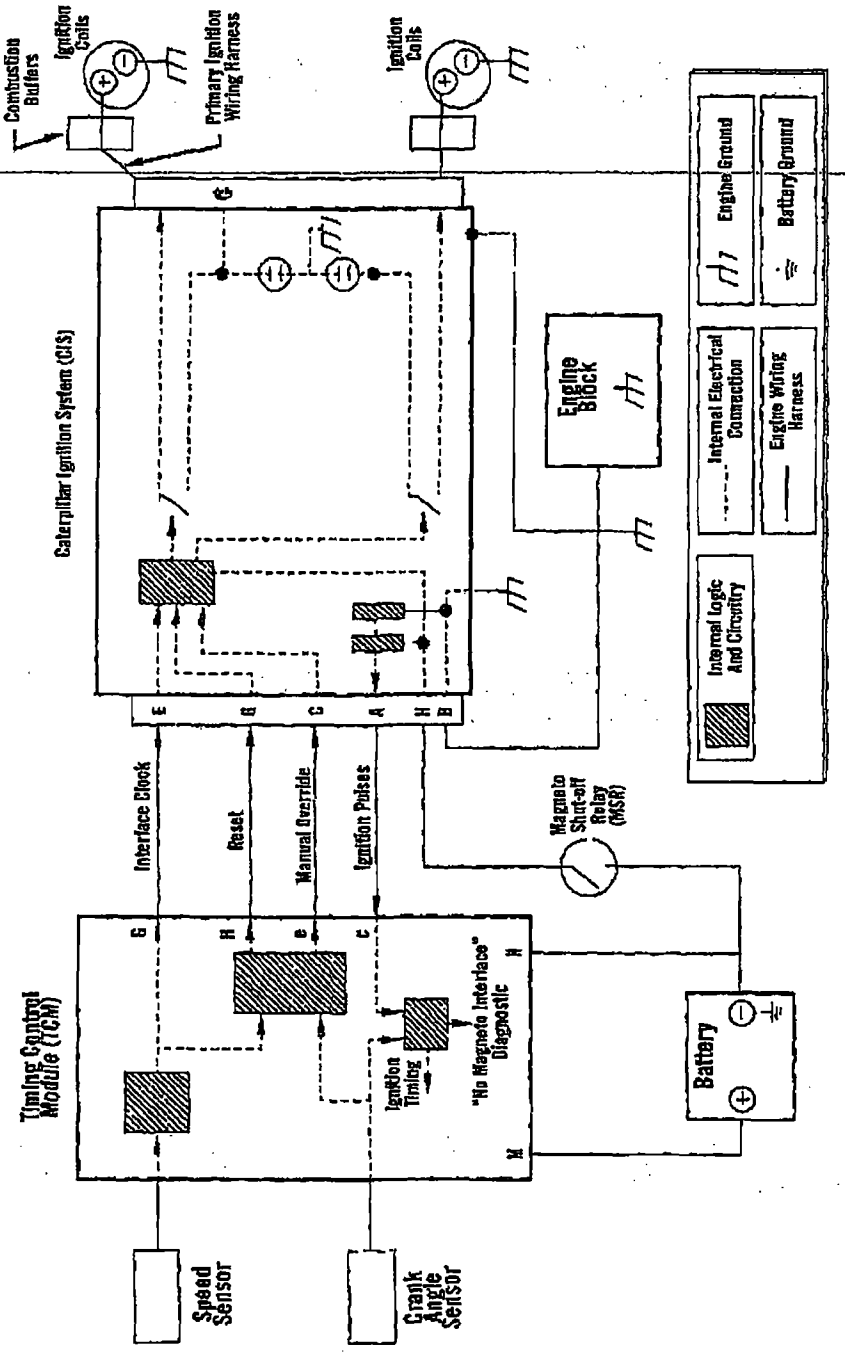


Illustration 29

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.

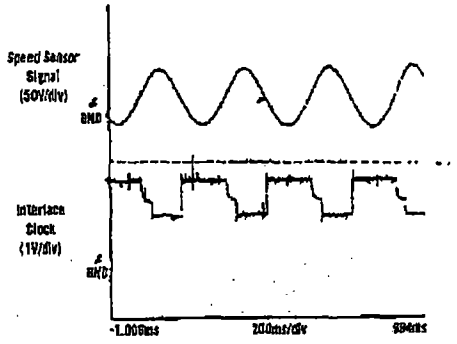


Illustration 30
Relationship Between Speed Sensor and Clock Signals

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.

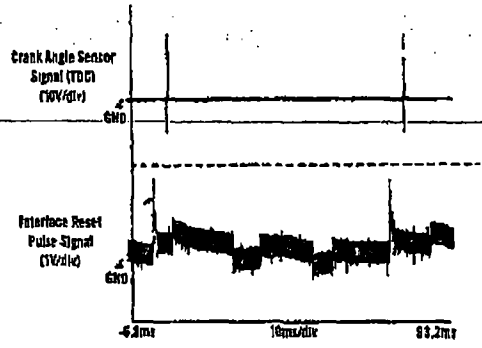


Illustration 31
Interface Reset Pulse Signal Relative to Crank Angle TC Signal

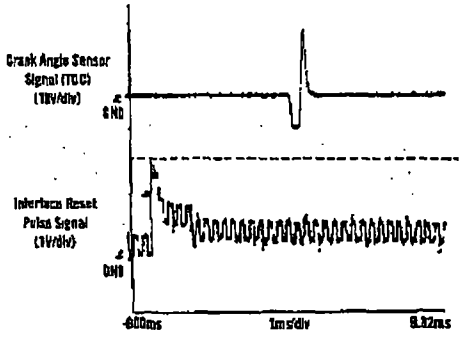


Illustration 32
Close Up of Interface Reset Pulse Signal Relative to Crank Angle TC Signal

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.

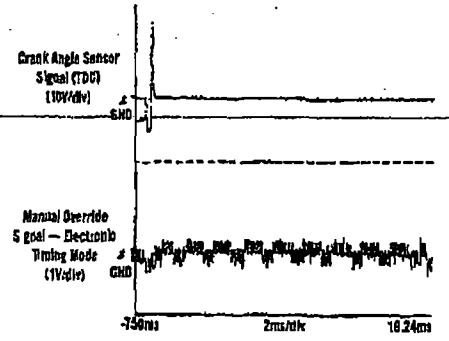


Illustration 33
Manual Override Signal, Timing Control In Electronic Timing Mode

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.

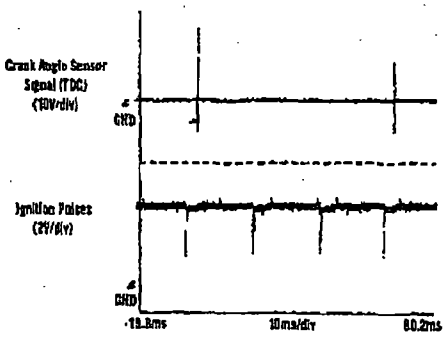


Illustration 34
Ignition Pulses Relative to Crank Angle TC Signal (Six Cylinder Engine)

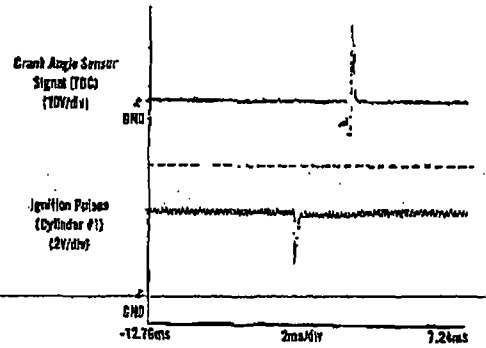


Illustration 35
Close Up of Ignition Pulses Relative to Crank Angle TC Signal (Six Cylinder Engine)

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.

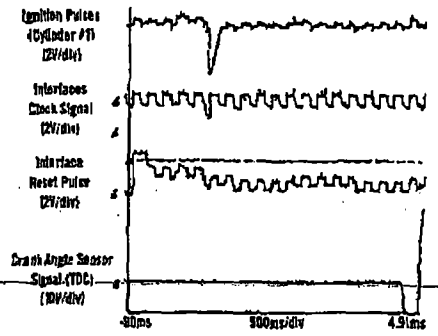


Illustration 36
Interaction of Reset, Clock, Ignition Pulse and TC Signal

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

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

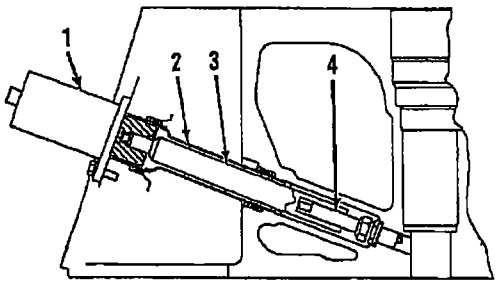


Figure 1: Ignition Group Components
(1) High energy ignition transformer. (2) Tube.
(3) Extender with spring loaded aluminum rod.
(4) Spark plug.

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.

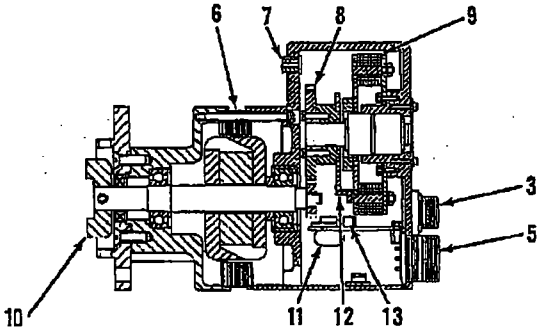


Figure 2. Cross Section Of Solid State Magneto
(3) Magneto interface box input connector.
(5) Magneto output connector. (6) Magneto alternator.
(7) Vent. (8) Speed reduction gears. (9) Pick-up coil.
(10) Drive tang. (11) Energy storage capacitor. (12) Rotating timer arm. (13) SCR solid state switch.

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).

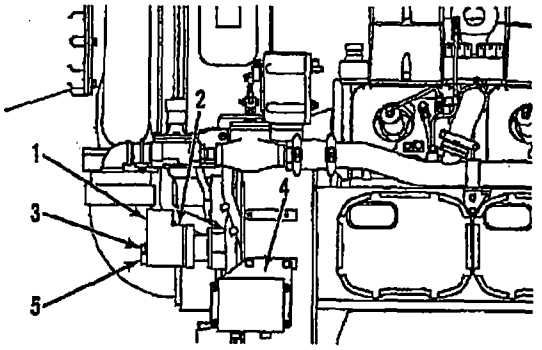


Figure 3: Solid State Magneto
(1) Electronic firing section of magneto. (2) Alternator section of magneto. (3) Magneto interface box input connector. (4) Magneto interface box. (5) Magneto output connector.

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

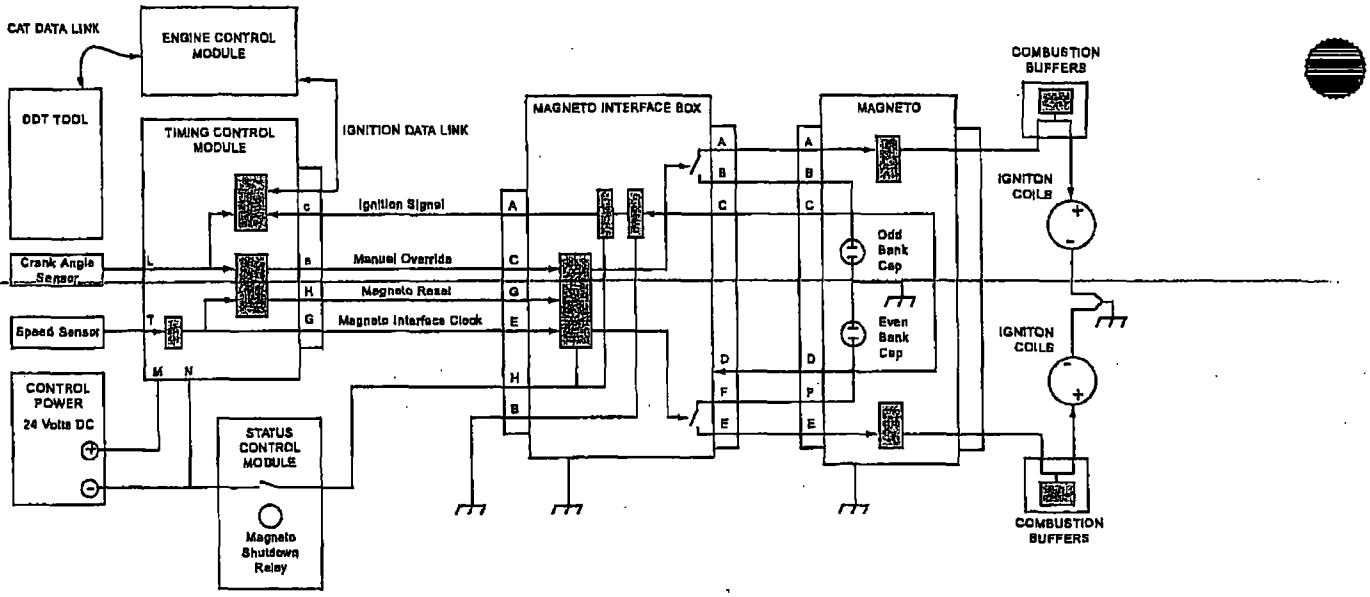


Figure 4: G3600 Ignition Timing System.

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.

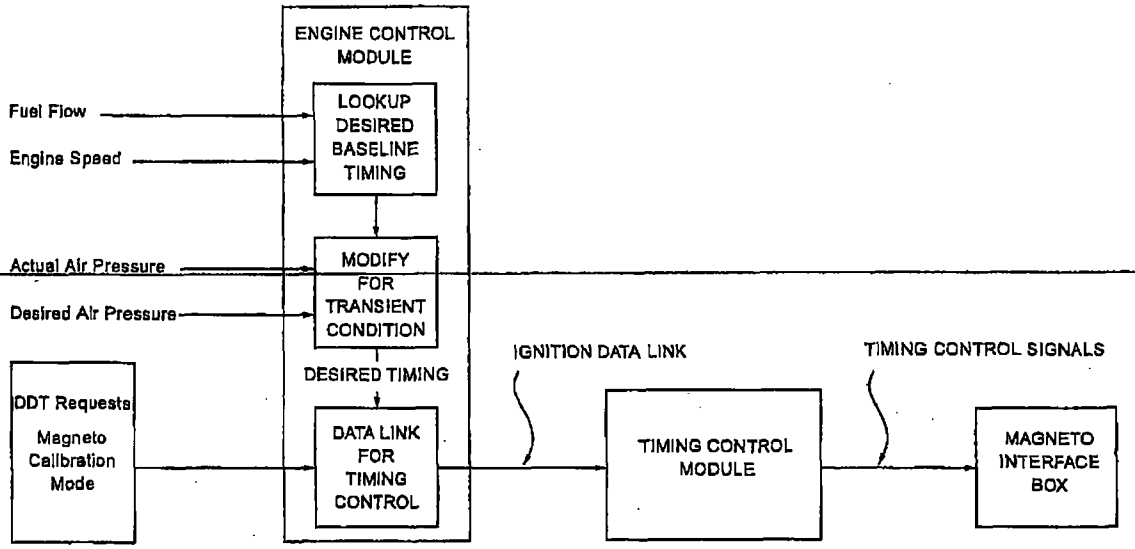


Figure 5: G3600 Ignition Timing Control Logic

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.

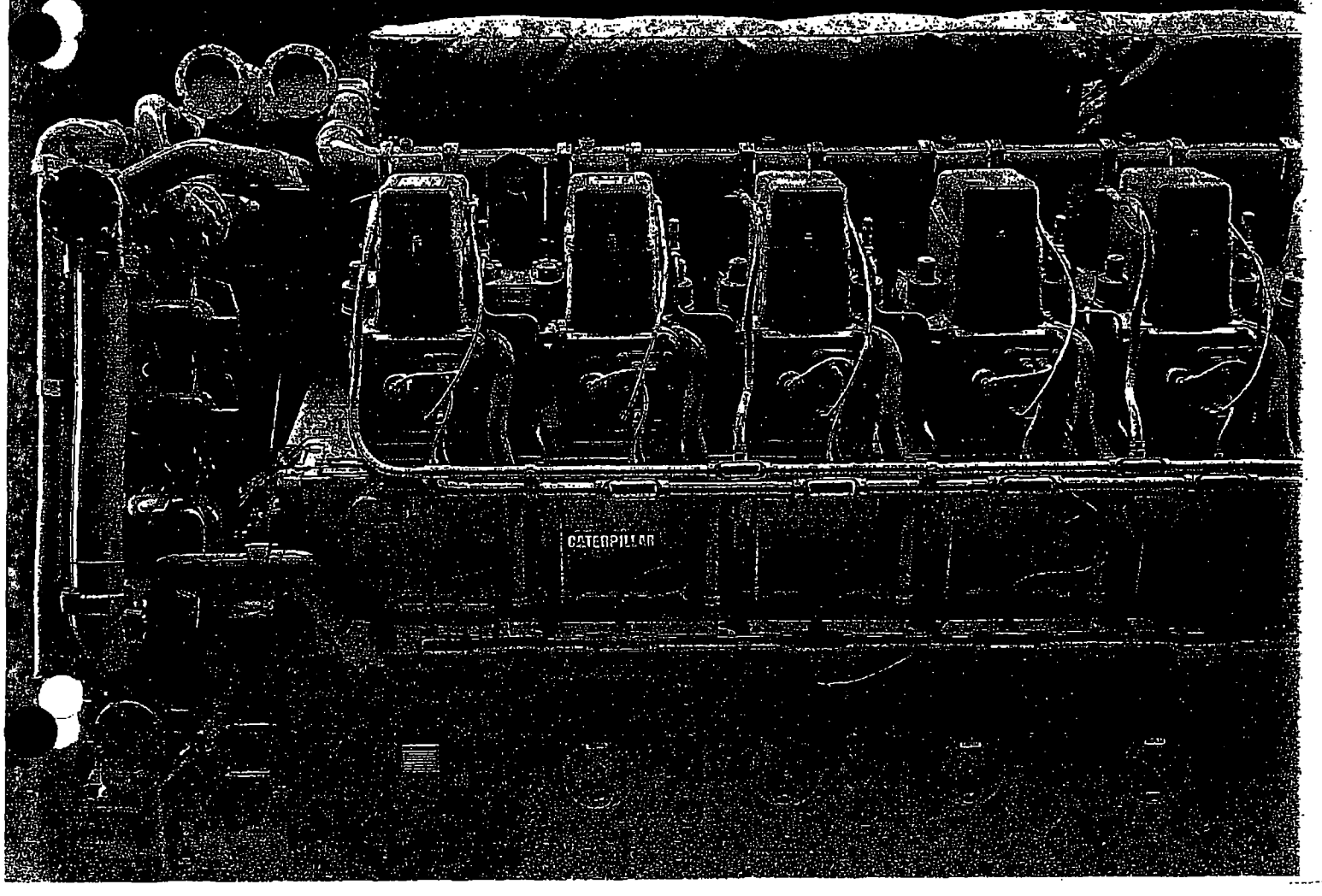
Service Manual - *Systems Operation Testing and Adjusting*. SENR4258-03 for G3608 and G3606. SENR5528-03 for G3616 and G3612.

CATERPILLAR®

G3600

Family Of Gas Engines

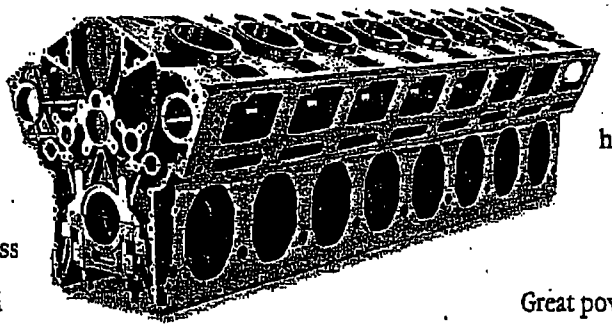
**Lower Speeds,
Higher Horsepower,
Lower Emissions.**



Cat® G3600 Family of Natural Gas Engines are the biggest, most powerful, most sophisticated gas engines ever built by Caterpillar. Ten years in development, the goal was to create a new engine that would run longer, and be more reliable than anything else on the market.

The Ultimate Po

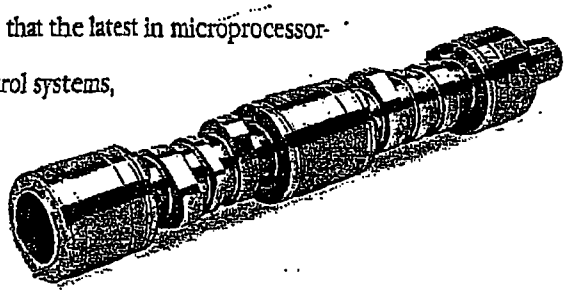
What resulted was an engine able to do more work in more applications. An engine that thinks for itself, allowing more unsupervised uptime with a minimum of 45,000 hours between major overhauls. An engine that burns less fuel, uses less oil, yet can meet or exceed almost any emissions standard anywhere in the world.



A Powerhouse of Technologies.

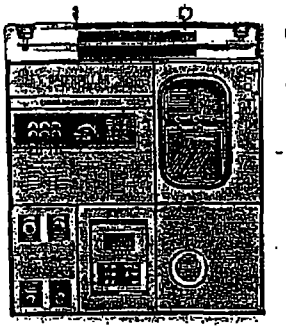
The G3600s get their strength from a foundation that is pure diesel, and therefore pure Caterpillar. Built for pressures that far exceed gas combustion, the block, crankshaft, rods, bearings, pistons, and other major components, are all the products of the latest innovations in over 60 years of diesel engine technology and design.

Add to that the latest in microprocessor-driven control systems, computer controlled ignition and combustion, and electronic sensing and monitoring devices, and you begin to get the picture. The G3600s clearly deliver all and more of what Caterpillar has always been known for—reliable, heavy-duty power.



G3600 Electronics.

Great power requires great control. And the brains behind all the brawn is the Cat Engine Supervisory System. The ESS control system greatly enhances engine power and flexibility by constantly monitoring operations and making adjustments to optimize performance.



Through ESS, key parameters like timing, detonation margin, and air/fuel ratios are precisely controlled, adding power, fuel efficiency, and reducing emissions.

In addition, it's through the ESS that the G3600s get their ability to self-diagnos and self-adjust before problems occur, thereby assuring great performance and reliability.

G3600 Mechanicals.

Engineered into every component of the G3600s is the Caterpillar drive for durability. Durability that translates directly into lower owning and operating costs. Some of the major mechanical innovations that make these gas engines the ultrareliable powerhouses they are include: one-piece cylinder block casting; press-forged crankshaft; steel-backed aluminum bearings with a lead-tin overlay; forged, heat treated, shot peened connecting rods; high-alloy, cast iron cylinder liners; and steel crowned, forged aluminum, deep cup pistons.

ver Tool.

Caterpillar. Powering The Way Worldwide.

From offshore oil rigs, to natural gas fields, from wide open spaces, to the confines of an urban city. Whether it's powering a generator, a compressor or a pump. No matter what the available gaseous fuel. Wherever the need is for efficient, reliable, durable power, and in a big way, there's a G3600 configuration to answer the call.

And because reliable power also means reliable support, count on the 1,200 strong worldwide Cat dealer facilities network to deliver all the customer and product support you need to keep your power up and costs down. From application matching, to maintenance, to financing, your local Cat dealer has all the engine power and manpower required to ensure that everything Caterpillar put into the G3600s is everything you get out.