Maintenance And Technical Handbook

For 3600 Diesel Engines

Guidelines for

MAINTENANCE
AND
TECHNICAL
HANDBOOK

for 3600 Diesel Engines

3606 - 8RB
3608 - 6MC - 7WR - 8LL
3612 - 2NZ - 9FR - 9RC
3616 - 1FN - 1PD
3618 - 2MW

November 2001

A New Service Support Center is Available For The Products That Are Assembled At the Large Engine Center

A new Service support Center has been formed. this new Service Support Center is intended to be the starting point for Customer Service inquiries about the above engines. this new Service Support Center will primarily be for North American Dealers. Dealers that are outside of North America should contact the office of the local Marketing Profit Center with any issues that require additional information. The service support center will handle questions and issues that are related to the product after the engine commissioning has occurred. For inquiries that occur before the engine commissioning or during the engine commissioning, please contact the Application Support Group. The new Service Support Center is open Monday through Friday during normal working hours.

Customer Service inquiries should be directed to the locations that follow:

Phone: 765-448-2200
Fax: 765-448-2222
E-mail: lecservicesupport@cat.com
internet: https://lecservicesupport.cat.com

Locations For Information About Other Products

Locations For Information About Products That Are Assembled in The Griffin, Georgia Facility

For information about 3500 Generator Sets, call the phone number that follows:

Phone: 765-448-5873

For information about Power Modules and Enclosures, call the phone number that follows:

Phone: 770-233-4041

For information about Electronic Modular Control Panels, Uninterruptible Power Supplies and Automatic Transfer Switches, call the phone number that follows:

Phone: 309-578-3694

For information about 3208 Generator Sets through 3412 Generator Sets, call the phone number that follows:

Phone: 309-578-6795

Locations For Information About Custom Kato Generators

The Product Service manager for Custom 3500 Generators and Custom 3600 Generators is available at the locations that follow:

Phone: 507-345-2821
E-mail: soost.john@LSUSA.com

The Warranty and Repair Manager for Custom 3500 Generators and Custom 3600 Generators is available at the locations that follow:

Phone: 507-345-2828
E-mail: kowceun.nick@LSUSA.com

Locations For Information About Remanufactured Products

A Hotline for remanufactured products is available at the locations that follow:

Phone: 888-887-3626
E-mail: reman_help@cat.com

Locations For Information About The Application and Installation Of The Products That Are Assembled At The Large Engine Center

Information about the application and installation of the products that are assembled at the Large Engine Center is available at the locations that follow:

Phone: 765-448-2400
Fax: 765-448-2300
E-mail: applicationsupport@cat.com
internet: http://applicationsupport.cat.com

Introduction:

This Maintenance And Technical Handbook (MATH) enables dealers and their customers to benefit from cost reductions made possible through an established parts reusability and salvage program. Every effort has been made to provide the most current and relevant information known to Caterpillar Inc. Since the Company makes on going changes and improvements to its products, this Guideline must be used with the latest technical information available from Caterpillar to ensure such changes and improvements are incorporated where applicable. This booklet is a quick reference guide for service information on the 3600 Diesel Engines. This guide complements, but not replace the following Caterpillar Service Manuals:

- Standard Bolt Torque
- Specifications
- System Operation Testing & Adjusting
- Dis-assembly and Assembly
- Operation & Maintenance Guide
- Parts Book

Please see these manuals for more details on the service needs of the 3600 Diesel Engine. The ordering numbers for these manuals are in the reference publication section of this pocket guide.

3600 Engine Family

Whether your needs are marine, industrial, or electric power generation, the Caterpillar 3600 Engine Family will provide you with proven power to get the job done. The 3600 Engines are the most powerful and reliable power sources ever produced by Caterpillar. Operating economy and durability make it the logical choice; worldwide product support makes it the only choice.

The 3618 Marine Propulsion Engine is the newest addition to the 3600 Engine Family . It was specifically designed to meet the needs of our marine fast ferry customers. For more information on the new Caterpillar 3600 engine, consult your local Caterpillar Dealership.

This 3600 Series Engine "Maintenance and Technical Handbook" (MATH) Handbook & Check List will assist certified technicians, dealers and customers as a quick reference to certain engine history background, part numbers, torques, procedures, troubleshooting, conversions, and documenting the condition of engine and components during maintenance intervals and at time of overhaul. After the overhaul is completed, some pages from this document maybe copied and placed in the engine history file for future reference or this MATH book can be the engines own history book and kept close to the engine as a quick reference.

NOTE: This handbook is intended to be used as an aid to the Technician and NOT as a replacement for the Service Manuals, Parts Books or other Technical Data Books.

Table of Contents:

Ratings

Generator Set Ratings

Continuous Rating: Typical application is base load generator set, 8000 hrs/year, load factor < = 100%, 10% overload.

Prime Power: Typical application is peak shaving, 6000 hrs/year, load factor < = 60%. Rated load (100%) usage is 1 hour in 12, 10% overload.

Standby: Typical application is emergency generator set,
< 200 hrs/year, 100% during emergency outage, no overload.

Marine Ratings

Continuous Service Rating (CSR): Typical application is U.S. inland river vessel, continuous engine operation, fuel stop power equals rated power.

Maximum Continuous Rating (MCR): Typical application is tugboat, 1 hour in 12 at rated power, fuel stop power equals rated power.

Conditions

The following engine ratings are based on SAE J1995 January 1990 and ISO 3046 standard conditions of 100 kPa (99 kPa dry barometric pressure) and 25° C air. Performance and fuel consumption are based on 35 API, 16° C fuel having an LHV of 42 780 kJ/kg used at 29° C with a density of 838.9 g/L. Tolerances include -0/+5% on specific fuel consumption and ±3% on brake kilowatt power at the flywheel demonstrated at the Caterpillar production test cell. The maximum inlet air temperature to the turbocharger is 45° C before derating. Engine ratings are net power and include deduction for the following parameters: cooling water pumps, lube oil pumps, fuel pump, typical exhaust restriction, and typical air filter restriction.

3600 Engine Features

The 3600 Engine Family is a modern, highly efficient engine series consisting of in-line six and eight cylinder engines and vee engines of 12 and 16 cylinders. These are four stroke, non-reversible engines rated at speeds from 720 to 1000 rpm. They are turbocharged and aftercooled with a direct injection fuel system that uses unit fuel injectors.

Engine Model

3606	In-line 6 cylinder
3608	In-line 8 cylinder
3612	Vee 12 cylinder
3616	Vee 16 cylinder

Specifications

Bore — mm (in)	280 (11)
Stroke — mm (in)	300 (11.8)
Displacement per cyl. L (Cubic in.)	18.5 (1127)
Rotation (from flywheel end)	cw or ccw
Compression Ratio (Distillate/HFO)	13.0:1/12.4:1
Aspiration	Turbocharged Aftercooled
Rated Speed (rpm)	720–1000
Piston Speed m/s (ft/s)	7.2 (23.6) – 10.0 (32.8)

Engine blocks are made from a heavily ribbed, one piece gray iron alloy casting. Integral air intake plenums run the full length of the block, providing an even air distribution to the cylinders. The engine block is designed for four or six point mounting.

Crankshafts are forged with a continuous grain flow, induction hardened, and re-grindable. Counterweights at each cylinder are welded to the crankshaft and ultrasonically inspected to assure weld integrity. The crankshaft end flanges are identical, allowing full power to be taken from either end.

Pistons are two-piece with a forged steel crown and forged aluminum skirt. This piston construction ensures excellent strength and durability, and minimal weight. Pistons have four rings — two in hardened grooves in the piston crown, and two in the skirt. The top ring is plasma coated; this provides extra wear resistance and lowers lube oil resistance and consumption. The two middle rings are taper faced and chrome plated.
The lower oil control ring is double rail and chrome faced with a spring expander.

Main bearings are made of steel backed aluminum with a nickel bonded lead/tin/copper overlay. Rillenlager technology, which alternates stripes of aluminum and overlay on the surface, is used. This provides higher load carrying capability and reduces wear rates when compared to trimetal aluminum bearings. The bearings have no grooves in the lower bearing shell. This greatly reduces unit pressure loading when compared to grooved bearings.

Rod and camshaft bearings are made of steel backed aluminum with a copper bonded lead/tin overlay. Aluminum bearing material provides better characteristics in the areas of heat conduction, resistance against corrosion, and ability to embed small particles that may otherwise damage journal surfaces. Bearings have no grooves, greatly reducing unit pressure load on the bearings.

Cylinder liners are induction hardened. The combination of induction hardened liners, one chrome/plasma-coated piston top ring, and three chrome-coated piston rings provides the lowest wear on running surfaces. The 3600 liners are plateau honed for better oil control. Located at the top of the liner is a sleeve or “cuff” that removes carbon deposits from the top land of the piston. This sleeve prevents the loss of oil control and reduced cylinder liner life by preventing carbon deposits from accumulating and polishing the cylinder liner.

Connecting rods are forged, heat treated, and shot peened before machining. The special four-bolt design and the elimination of bearing grooves allows for an extra large bearing which reduces bearing load and extends bearing life.

Valves seat on replaceable induction-hardened inserts. Rotators on all valves maintain uniform temperature and wear pattern across the valve face and seat. The exhaust valves used in heavy fuel engines are given special attention to extend their life. The exhaust valve temperature is reduced to approximately 410° C to minimize the possibility of vanadium induced corrosion. A nimonic 80A material is used in the exhaust valve. The valve head is coated with ceramics and water-cooled valve seats are used to maintain the low valve temperatures.

Weights Of Piece Parts:

		kg.	lbs.
Engine	3606	15700	34500
	3608	20412	45000
	3612	25140	55300
	3616	30418	67000
Block	3606	4180	9200
	3608	5584	12300
	3612	6646	14620
	3616	8630	18986
Oil Pan	3606	564	1241
	3608	735	1617
	3612	628	1385
	3616	661	1457
Crankshaft	3606	1900	4185
	3608	2400	5290
	3612	2091	4600
	3616	2602	5750
Main Bearing Cap		69	152
Crankshaft Adapters		77	170
Crankshaft Gear		38	83
Damper	Narrow	228	639
	Wide	402	886
Flywheel		499	1100
Front Housing		258	569
Rear Housing		456	1005
Engine Support		64	141
Camshaft Drive Gear		44	96
Camshaft Journal		6	
Camshaft Segment		29	63
Piston		38	82
Piston Pin		20	42
Connecting Rod		61	134
Connecting Rod Cap		16	35
Piston/Rod Assembly		102	225
Cylinder Head		235	517
Cylinder Liner		128	282
Oil Pump		104	230
Water Pump		120	265
Oil Coolers		137	302
Aftercooler Housing		236	520
Aftercooler Cover		45	99
Aftercooler Core		104	232
Turbocharger		401	883

Propulsion Engine Dimensions

	3606	3608	3612	3616
Overall Length	3988 (157)	4808 (189)	4562 (180)	5482 (216)
Overall Width	1748 (69)	1748 (69)	1714 (67)	1714 (67)
C/L Crank-up	2035 (80)	2035 (80)	1850 (73)	1850 (73)
C/L Crank-down	841 (33)	841 (33)	976 (38)	976 (38)
Weight	15,700 (34,500)	19,000 (41,800)	25,100 (55,300)	30,000 (65,900)

Caterpillar Generator Set Dimensions

	3606	3608	3612	3616
Overall Length	7950 (313)	9240 (364)	8970 (353)	10,260 (404)
Overall Width	2425 (96)	2425 (96)	2515 (99)	2515 (99)
Top-Bottom	3480 (137)	3480 (137)	3710 (146)	3790 (149)
Weight (dry)	34,100 (75,000)	41,400 (91,050)	51,230 (112,700)	64,500 (141,840)

Publications:

A set of the following publications should have been sent with engine.

- Service Manual (contains):
  - Product Safety
  - Service Manual Contents Sheet
  - Torque Specifications
  - Engine Specifications
  - System Operation / Testing & Adjusting
  - Disassembly & Assembly
- The Parts Book
  (serial number specific custom parts book contains all the standard Caterpillar production parts).
- Technical Manual
  (contains all the custom iron for that specific engine(s).
- Special Instructions (any related)

How to order a "Serial Number Specific Parts Book".

- Place a Caterpillar literature order media number: SEBP3600 and specify the serial number of the engine.

How to order a "Technical Manual".

- Place a "Miscellaneous Engine Order" with the Caterpillar Subsidiary specifying the price list sales code (905.5) and the engine serial number.

Reference Publications:

SEBU6965	3600 Diesel Operation & Maintenance Manual (Distillate)
SEBU6966	3600 Diesel Operation & Maintenance Manual (Heavy Fuel)
SENR3599	System Operation Testing & Adjusting (inline)
SENR3593	System Operation Testing & Adjusting (vee)
SENR3600	Dis-assembly & Assembly Manual (inline)
SENR3594	Dis-assembly & Assembly Manual (vee)
SENR3598	Specifications Manual (inline)
SENR3592	Specifications Manual (vee)
RENR1338	UG Actuators
SENR3585	2301A Governor
SENR6473	721 Digital Governor
SENR2228	723 Plus Governor
SENR3028	3161 Governor
SENR6444	PGEV & PGE Governors (Locomotive application)
SENR4622	Heinzman Governor (Generator Set)
SENR4661	Heinzman Governor (Marine)
LECQ4021	3600 Family of Heavy Fuel Engines
LECQ4022	3600 Family of Engines
LEKM2005	3600 Marine Engines Application & Installation Guide.
LEKM9011	3600 Marine Monitoring System (MMS)
LEKX1002	3600 Generator Set Application & Installation Guide.
LEXQ7766	3600 Engine Family Pocket Guide
YEHS0201	3600 Diesel Service Pocket Guide
LEDQ8363	3600 Diesel Lube Oil Selection
LEHX5458	3600 Family Generator Sets for Heavy Fuel (spec sheet)
LEHX5459	3600 Family Generator Sets (spec sheet) Performance Data
PEHP7076	Understanding the S.O.S Oil Analysis Test
RENR1357	Diesel Plant Operation Handbook
RENR1358	3600 Diesel Service Handbook (3-Volume Set)

SEBD0640	Oil & Your Engine
SEBD0717	Diesel Fuels & Your Engine
SEBD0970	Coolant & Your Engine
SEBD9129	3600 Engine News Special Edition (all Engine News Articles from 10/85 to 10/99)
SEBU7003	3600 Fluids Recommendations for Lube Oil, Fuel & Coolants
SELU6965	Maintenance Wall Chart (distillate)
SELU6966	Maintenance Wall Chart (heavy fuel)
SENR4619	3600 Marine Propulsion Emergency Repair Procedures
LEKM9011	3600 Marine Monitoring System
SEBU7134	Marine Monitoring System (MMS) Owners Manual
RENR2458	Electric Schematic for MMS
REHS0257	Installation & Commissioning Special Instructions
LEXM8589	Product News (MMS)
RENR2225	Service Manual for Oil Mist Detector
SEBP3773	Parts Book for 3612
SEBP3768	Parts Book for 3608
SEBP3762	Parts Book for 3616
SEBP3771	Parts Book for 3616
SEBU6103	Schedules for Equipment Maintenance
SELU6121	3600 Maintenance Mgt. Recommendation
SEBR3595	Service Manual 3606-3608
SEBR3590	Service Manual 3612-3616
SEHS9031	Special Instructions Storage
NENG7002	3600 Tool Guide
LEBV0546	Maintenance and Technical Handbook (MATH)
LEKQ4028	Oil Consumption Data
SEHS9929	Turbo Wash Procedure
LEKQ6070	Blending Crankcase Oil with Fuel
RENR5851	Service Manual for 150-7700 Tachometer
RENR2493	Service Manual for Engine Control Panel
LERV0530	CD of Maintenance And Technical Handbook (Math)
REHS0285	D&A of the NAPIER NA297 Turbocharger
PELE0776	New Service Center for 3600 Engine Components
RENR2459	Electrical System Schematics for 3600 MMS II & GMS II
RENR2490	Service Manual for MMS II
RENR2491	Service Manual for GMS II

Guideline For Reusable Parts & Salvage Operations Publications:

SEBF8047	3600 Reuse Manual (contains all below)
SEBF8092	Spec's. for Turbocharger Reuse
SEBF8100	3600 Engine Components
SEBF8101	Spec's. for Cylinder Blocks
SEBF8102	Spec's. for Crankshafts
SEBF8103	Procedures for Grinding Crankshafts
SEBF8104	Spec's. for Camshafts
SEBF8105	Injector & Valve Lifter
SEBF8106	Spec's. for Cylinder Head Assemblies
SEBF8107	Spec's. for Pistons & Rings
SEBF8108	Spec's. for Connecting Rods & Bearings
SEBF8109	Spec's. for Measuring & Cleaning Cylinder Liners
SEBF8110	Spec's for Water Pumps
SEBF8129	Procedures to Salvage Cylinder Heads
SEBF8150	Procedures to Inspect, Clean, & Flush Pistons
SEBF8151	Procedures to Salvage Cylinder Block with Damaged Studs
SEBF8152	Procedures to Rebuild Vibration Dampers
SEBF8160	Procedures to Salvage Oil Pan Assemblies
SEBF8171	Recommendations for Cleaning & Inspecting Components
SEBF8302	Reusing Combustion Gaskets
SEHS9741	Cleaning Injectors

Customer / Dealership Performance Information:

1. **Name of Dealer Contact:**

   ____

2. **Contact Phone Number:**

   ____

3. **Contact Fax Number:**

   ____

4. **Name of Dealership:**

   ____

5. **Engine Serial Number:**

   ____

6. **Engine Hours:**

   ____

7. **Application**

   ___ Generator Set
   ___ Marine
   ___ Machine

8. **Detail of the request: (See separate page)**

9. **Potential root cause: (See separate page)**

10. Exhaust or performance related requests should include the following information:

A. Engine Performance Spec. (0T,2T,OK)

Factory Setting　　Current Setting

______________　______________

B. Engine Arrangement:

Factory Setting　　Current Setting

______________　______________

C. Engine Rated RPM's:

Factory Setting　　Current Setting

______________　______________

D. Engine Rated Load:

Factory Setting　　Current Setting

______________　______________

E. Injector Part No.:

Factory Setting　　Current Setting

______________　______________

F. Injector Timing:

Factory Setting　　Current Setting

______________　______________

G. Turbocharger Part No.:

Factory Setting　　Current Setting

______________　______________

11. Site Information:

A. Altitude:

____

B. Air Temperature at Inlet to Aftercooler:

________________ degrees F or C

C. Inlet Restriction:

________________ in. of H2O

D. Boost Pressure:

________________ in. Hg

E. Air Inlet Temperature after the Aftercooler:

________________ degrees F or C

F. Exhaust Temperature:

________________ degrees F or C

G. Change in Air Pressure Across Aftercooler:

________________ psi or kPa

H. Fuel Type:

____

I. Fuel Temperature:

________________ degrees F or C

J. Fuel Degrees API:

____

K. Fuel Cetane No.:

____

L. Service Hours on Injectors:

________________ hrs.

M. Filtered Fuel Pressure:

________________ psi or kPa

12. If the request is smoke related, the following should be reported in addition to the information in Step 10.

A. Describe Smoke Color:

_____ Black
_____ Gray
_____ Bluish
_____ White
_____ Other: (Describe)
____

B. Percent opacity: (using the 8T5100 Smoke Meter Group or equivalent)

______ %

C. Iron On Engine Today?

_____ Engine has been rerated since factory.
_____ Engine has been overhauled / rebuilt since factory.
_____ All engine parts are original since factory.
_____ Application change since factory.

D. Condition when smoke is occurring?

_____ Steady state.

_____ Transient

E. If smoke is transient and the engine has a Caterpillar 3161 governor:

_____ Is the Fuel Air Ratio Control operating properly? (Y or N)

_____ Is the Fuel Air Ratio Control set correctly? (Y or N)

F. Exhaust Port Temperatures:

Cyl 1. ________ F or C
Cyl 2. ________ F or C
Cyl 3. ________ F or C
Cyl 4. ________ F or C
Cyl 5. ________ F or C
Cyl 6. ________ F or C
Cyl 7. ________ F or C
Cyl 8. ________ F or C
Cyl 9. ________ F or C
Cyl 10. ________ F or C
Cyl 11. ________ F or C
Cyl 12. ________ F or C
Cyl 13. ________ F or C
Cyl 14. ________ F or C
Cyl 15. ________ F or C
Cyl 16. ________ F or C

13. When was the hour reading of the last Maintenance Interval?

________ hrs.

________ date

Engine Data Plate
Information:

S/N	
Date Delivered	
Modification Number	
Dealer Code	
Arrangement Number	
Performance Spec Number	
Max Altitude	
OEM Number	
Full Load Static Fuel	
Full Torque Static Fuel	
Power H.P. **KW**	
A/F Ratio	
Bore Engine High Idle	**RPM's**
Full Load RPM's	
Fuel Timing	

Comments or Notes:

Customer Maintenance Information:

The following charts or check-list are based on the Maintenance Schedules published by Caterpillar for the 3600 Diesel Engine.

The following charts or check-list may be used to guide the Technician so that no Maintenance Requirements are missed or forgotten. The check-list may then be placed in the history folder for the particular 3600 engine so it can be referred to at a later date.

The "3600 Diesel Operation an Maintenance Manual (Distillate Fuel)" SEBU6965 or the "3600 Diesel Operation and Maintenance (distillate) Wall Chart" SELU6965 may be used when a more in depth explanation of what may be required to perform certain maintenance task.

At the end of each requirement there enough space to write comments and notes.

When Required:

________ hrs.
________ date

_____ Centrifugal Oil Filter - Inspection
_____ Engine Air Cleaner Element - Replace
_____ Engine Crankcase Breather
_____ Engine Oil - Change
_____ Engine Oil Filter - Change
_____ Fuel Analysis - Obtain
_____ Fuel System - Prime
_____ Fuel System Primary Filter/Water Separator Element - Replace
_____ Fuel System Secondary Filter - Replaced
_____ Metal Particle Detector - Inspect
_____ Zinc Rods - Inspect/Replace

Comments or Notes:

Every Service Hour:

________ hrs.

________ date

_____ Trend Data - Record

Comments or Notes:

Daily:

________ hrs.
________ date

_____ Air Starting Motor Lubricator Oil Level - Check
_____ Air Tank Moisture and Sediment - Drain
_____ Cooling System Coolant Level - Check
_____ Driven Equipment -Inspect/Replace/Lubricate
_____ Engine Air Cleaner Service Indicator - Inspect
_____ Engine Air Pre-cleaner - Clean
_____ Engine Oil Level - Checked

Added Oil (amount): _____ gal's / liters

_____ Fuel System Primary Filter/Water Separator Element - Drain
_____ Fuel Tank Water and Sediment - Drain
_____ Governor Actuator Oil Level - Check
_____ Instrument Panel - Inspect
_____ Walk Around Inspection

Leaks: Reported Areas

____
____
____

Comments or Notes:

Every 50 Service Hours or Weekly:

________ hrs

________ date

_____ Zinc Rods - Inspect/Replace

Comments or Notes:

Every 250 Service Hours or 6 Weeks:

________ hrs
________ date

_____ Air Shutoff - Test
_____ Air Starting Motor Lines Screen - Clean
_____ Cooling System Supplement Coolant Additive (SCA) - Test/Add
_____ Engine Oil Sample - Obtain
_____ Governor Actuator Linkage - Check
_____ Oil Mist Detector - Check

Comments or Notes:

Every 500 Service Hours or 3 Months:

________ hrs

________ date

_____ Engine Mounts - Inspect

_____ Engine Protective Devices - Check

_____ Oil Mist Detector - Clean/Replace

Comments or Notes:

Every 6 Months:

________ hrs

________ date

_____ Cooling System Coolant Analysis (ELC) (Level II) - Obtain

Comments or Notes:

Initial 1000 Service Hours or 6 Months:

_________ hrs

_________ date

______ Engine Valve Lash - Inspect/Adjust, including Bridges

Cylinder No.	Intake Setting	Exhaust Setting	Bridge Adj.
1.	________	________	OK or Adj.
2.	________	________	OK or Adj.
3.	________	________	OK or Adj.
4.	________	________	OK or Adj.
5.	________	________	OK or Adj.
6.	________	________	OK or Adj.
7.	________	________	OK or Adj.
8.	________	________	OK or Adj.
9.	________	________	OK or Adj.
10.	________	________	OK or Adj.
11.	________	________	OK or Adj.
12.	________	________	OK or Adj.
13.	________	________	OK or Adj.
14.	________	________	OK or Adj.
15.	________	________	OK or Adj.
16.	________	________	OK or Adj.

______ Engine Valve Rotators - Inspect

______ Crankshaft Timing Check - Check/Adj.

______ Unit Injector (fuel) T iming - Check/Adj.

______ Unit Injector Synchronization - Check/Adj.

Comments or Notes:

Every 1000 Service Hours or 6 Months:

________ hrs
________ date

_____ Barring Device - Lubricate
_____ Engine Air Cleaner Service Indicator -Inspect
_____ Engine Mounts - Inspect
_____ Engine Oil Filter - Change
_____ Exhaust Piping - Inspect
_____ Fuel System Primary Filter/Water Separator Element - Replace
_____ Fuel System Secondary Filter - Replaced
_____ Magnetic Pickups - Clean/Inspect
_____ Pre-lube Pump - Lubricate

Comments or Notes:

Every 2000 Service Hours or 1 year:

_________ hrs

_________ date

______ Aftercooler Condensation - Drain

______ Engine Valve Lash - Inspect/Adjust, including Bridges

Cylinder No.	Intake Setting	Exhaust Setting	Bridge Adj.
1.	________	________	OK or Adj.
2.	________	________	OK or Adj.
3.	________	________	OK or Adj.
4.	________	________	OK or Adj.
5.	________	________	OK or Adj.
6.	________	________	OK or Adj.
7.	________	________	OK or Adj.
8.	________	________	OK or Adj.
9.	________	________	OK or Adj.
10.	________	________	OK or Adj.
11.	________	________	OK or Adj.
12.	________	________	OK or Adj.
13.	________	________	OK or Adj.
14.	________	________	OK or Adj.
15.	________	________	OK or Adj.
16.	________	________	OK or Adj.

______ Engine Valve Rotators - Inspect

______ Oil Mist Detector - Clean/Replace

______ Crankshaft Timing - OK or Adj.

______ Unit Injector (fuel) Timing - OK or Adj.

______ Unit Injector Synchronization - OK or Adj.

Comments or Notes:

Every Year:

________ hrs

________ date

_____ Cooling System Coolant Analysis (Level II) - Obtain

Comments or Notes:

Every 4000 Service Hours or 1 Year:

________ hrs
________ date

_____ Aftercooler Core - Clean / Test (Measure Air Side Pressure Drop)
_____ Air Starting Motor Lubricator Bowl _ Clean
_____ Starting Motor - Inspect

Comments or Notes:

Every 8000 Service Hours or 1 Year:

________ hrs

________ date

_____ Engine Protection Devices - Calibrate

Comments or Notes:

Every 8000 Service Hours or 3 Years:

________ hrs

________ date

______ Camshaft Roller Followers - Inspect

______ Cooling System Coolant (DEAC) - Change

______ Cooling System Coolant Extender (ELC) - Add

______ Crankshaft Vibration Damper - Inspect

______ Driven Equipment - Check

______ Engine Oil Temperature Regulators - Replace

______ Exhaust Shields - Inspect

______ Governor Actuator Oil - Replace

______ ABB Turbocharger - Clean & Inspect

______ Water Pump - Inspect

______ Water Temperature Regulators - Replace

______ Napier Turbocharger - Clean & Inspect

______ Thrust Bearing - Clean & Inspect

Comments or Notes:

Every 16,000 Service Hours or 6 Years:

________ hrs

________ date

_____ Cooling System Coolant (ELC) - Change

Comments or Notes:

"TOP END OVERHAUL" Between 16,000 and 24,000 Service Hours or By Fuel Consumption (See Below):

Approximate Fuel Consumption Before A
Top End Overhaul.

Engine Mode	Fuel Consumption
3606	1.5 million US gals or 5.69 million L
3608	2.0 million US gals or 7.58 million L
3612	3.0 million US gals or 11.37 million L
3616	4.0 million US gals or 15.16 million L

Remanufactured or Rebuilding of Components

Rework the following components:

- Air shutoff valve
- Cylinder Heads
- Cylinder Dowels
- Exhaust Valves
- Exhaust Valve Inserts
- Inlet Valves
- Inlet Valve Seat Inserts
- Inner Valve Springs
- Outer Valve Springs
- Turbocharger - Clean, replace bearings - inspect & Balance
- Unit Injectors
- Valve Spring Guides
- Valve Spring Locks
- Valve Rotators

  (if valves and valve seats are not replaced the valves must be ground and lapped for full face contact)

Inspection and/or Replacement of Components

Inspect the following components according to the instruction that are in the Caterpillar reusability publications. Refer to Guidelines for Reusable Parts and Salvage Operations, SEBF8029, "Index of Publications on Reusability or Salvage of Used Parts". Replace the components, if necessary.

- Cylinder Sleeves (Liners)
- Exhaust Shields
- Starting Motor
- Thermocouples

Replacement of Components

Replace the following components:

- Connecting Rod Bearings
- Cylinder Head Gasket & Seals
- Exhaust Manifold Gaskets
- Fuel Transfer Pump Seals
- Inlet Air Line Seals
- Oil Cooler Seals
- Oil Pump Bearings & Seals
- Oil Temperature Regulators & Seals
- Turbocharger Bearings, Bushings & Seals
- Valve Lubricator Pump (If equipped)
- Water Pump Bearings & Seals
- Water Temperature Regulators & Seals

Cleaning & Inspection of Components

Clean the following components. Inspect the components for good condition. Replace the components, if necessary.

- Oil Cooler Core
- Oil Suction Screen

Comments or Notes:

"MAJOR OVERHAUL" Between 36,000 and 44,000 Service Hours or By Fuel Consumption (See Below):

Approximate Fuel Consumption Before A **Major Overhaul.**

Engine Model	Fuel Consumption
3606 -----	3.0 million US gals or 11.37 million L
3608 -----	4.0 million US gals or 15.16 million L
3612 -----	6.0 million US gals or 22.74 million L
3616 -----	8.0 million US gals or 30.32 million L

Remanufactured or Rebuilding of Components

Rework the following components:

- Air Shutoff Valve
- Centrifugal filter bearings
- Cylinder Heads
- Starting Motors

Replacement of Components

Replace the following components:

- Accessory Group Bearings
- Air Intake Lines Seals
- Cylinder Head Valves
- Cylinder Head Valve Guides
- Cylinder Head Valve Spring Guides
- Exhaust Manifold Seals & Bellows
- Exhaust Shields
- Fuel Injectors
- Front Gear Train Bearings
- Grind & Lap Valves & Valve Seats
- Oil Temperature Regulators & Seals
- Water Temperature Regulators Seals

Inspection and/or Replacement of Components

Inspect the following components according to the instruction that are in the Caterpillar reusability publications. Refer to Guidelines for Reusable Parts and Salvage Operations, SEBF8029, "Index of Publications on Reusability or Salvage of Used Parts". Replace the components, if necessary.

- Aftercooler Core
- Camshafts
- Camshaft Bearings
- Connecting Rod Bearings
- Crankshafts
- Cylinder Liners
- Cylinder Sleeves (Cuff)
- Exhaust Manifolds
- Front Gear Group
- Fuel Transfer Pump Seals
- Gaskets
- Inlet Air Line Seals
- Main Bearings
- Oil Cooler Seals
- Oil Pump Bearings & Seals
- O-Ring Seals & Plugs
- Pistons
- Piston Rings
- Priority Valve
- Rear Gear Group
- Rear Gear Train Bearings
- Rocker Arm Bearings
- Seals
- Shutoff Alarms
- Shutoff Controls
- Thermocouples
- Thrust Bearings (except crankshaft)
- Turbocharger Bearings, Bushings & Seals
- Valve Lubricator Pump (If equipped)
- Valve Mechanism Group
- Water Pump Bearings & Seals

Cleaning & Inspection of Components

Clean the following components. Inspect the components for good condition. Replace the components, if necessary.

- Oil Cooler Core
- Oil Suction Screen
- Crankcase Side Covers
- Central Structure Covers
- Camshaft Front Covers
- Camshaft Drive Rear Covers
- Front Housing Group
- Gear Inspection Group
- Rear Housing Group
- Rear Structure Covers
    - Power Take-off Covers
    - Priority Valve Group
    - Crankshaft
    - Valve Mechanism Covers
    - Oil Lines
    - Water Lines
    - Oil Cooler
    - Vibration Damper
    - Fuel Lines

<u>Comments or Notes:</u>

NOTES:

Engine Start Up Procedure After an Major Repair or Overhaul

Use the following guidelines for operation and maintenance after a major repair or overhaul. This will ensure that the engine is functioning correctly. The procedure for start up requires approximately one hour and fourth five minutes.

1. Perform the procedures that are described in the Operation & Maintenance Manual "Before Starting Engine" topic (Operation Section)
   - Walk around inspection
   - Cooling System
     External leaks
     Loose connections
     Water pump leaks
     Coolant Level
   - Lube System
     External leaks
     Loose connections
     Lubrication level
     Inspect crankcase breathers & piping
   - Air Inlet System
     External leaks
     Loose connections
     Check air cleaner restriction
     Air shut off valve is open
     Air cleaner is in place
   - Fuel System
     External leaks
     Loose connections
     Open all fuel return lines
     Fuel supply
     Drain condensation & sediment
     Check hoses and clamps
   - Exhaust System
     External leaks
     Loose connections
     Check turbocharger
     Exhaust piping for restrictions
     Check cylinders for fluids (Kiene valves if equipped)

- Starting System
  - Protective guards
  - Engine control system
  - Engine starting speed at low idle
  - Drain air tanks (if equipped)
  - Check starting air pressure
  - Check air starter oil level (if equipped)
  - Barring device not engaged
- Pre-lube Engine

2. Operate the jacket water heaters & the pre-lube pump. Allow the lubricating oil to circulate for 1/2 hour.
3. During pre-lube pump operation, use the barring device to rotate the crankshaft for a minimum of four revolutions.
4. Start the engine. Operate the engine at low idle rpm's for 15 minutes. Allow the engine temperature to rise. Check for the correct temperatures and pressures. Inspect the installation for leaks.
5. DO NOT apply the load. Increase the engine rpm's to high for 5 minutes. Check for the correct temperatures & pressures. Inspect the installation for leaks.
6. Shut off the engine. Remove the side covers. Measure the temperature of the bearings with a 123-6700 Laser Infrared Thermometer. Ensure that the large end of the connecting rod bearings move freely. Visually inspect the piston skirts, cylinder liners, and bearings for any abnormal signs such as flaking and/or scuffing (engine must be rotated). If the appearance of the components is satisfactory, install the side covers.
7. Start the engine. Operate the engine at low idle rpm's for five minutes. Check for the correct temperature and pressures. Inspect the installation for leaks.
8. The temperatures will not stabilize for some time because the engine will be operating without load. To warm the engine up to "normal" operating temperature, increase the engine rpm's to high idle for five minutes. Check for the correct temperature and pressures. Inspect the installation for leaks.

NOTE: Monitor the cooling system temperatures in order to ensure that the water to the engine is being properly cooled. Observe the water temperature of the aftercooler and oil cooler system. The temperature should not exceed 50 degrees C (122 degrees F).

9 Apply 25 percent of the rated load. Operate the engine with this load for fifteen minutes. Check for the correct temperatures and pressures. Inspect the installation for leaks.

10 Increase the load to 50 percent of the rated load. Operate the engine with this load for fifteen minutes. Check for the correct temperatures and pressures. Inspect the installation for leaks.

11 Increase the load to the full rated load. Operate the engine with this load for fifteen minutes. Check for the correct temperatures and pressures. Inspect the installation for leaks.

> **NOTE:** If all temperatures and pressures are acceptable, the engine can be returned to service.

Comments or Notes:

Comments or Notes:

Maintenance Procedures After an Major Repair or Overhaul

After the initial start-up, perform the maintenance that is listed in the table below. See the maintenance procedures that are in the Operation and Maintenance Manual (Maintenance Section)

Interval	Maintenance Procedure
After the start-up procedure	1. Obtain an oil sample and analysis. 2. Remove at least one oil filter element from each oil filter housing. Cut the element open. Inspect the filter material for debris.
100 Operating Hours	Obtain an oil sample and analysis.
500 Operating Hours	1. Replace all of the oil filter elements. Cut the used elements open. Inspect the filter material for debris. 2. Perform the procedures that are described in the Operation & Maintenance Manual. "Engine Valve Lash Check/Adjust"

Comments or Notes:

Comments or Notes:

Common Filter Elements Part Numbers

Oil Filter -- 1W4136
Oil Suction Screen -------------------------------- 9Y3307
Centrifugal Oil Filter Paper Liner -------------- 7C8390*
Air Filter (Primary) --------------------------------- 105-9741
Silencer -- 159-4507
Fuel Filter
(All Distillate & Duplex Filters)(8 Reqd.) --1R0766
(4W5421 Primary Filter Gp) (2 Reqd.) ---- 4W2609
(Filter Kit includes (2) 4W2609 Filters) - 9Y6898
Soot Filter
(Primary Filter 22 in. ID) ---------------------- 4W7103
(Silencer 25 in. ID) -----------------------------137-9974
(Engine Room Air Inlet ------------------------ 125-7774
Marine only 27.8 in.)

- If you double the paper liners (1 on top of the other), it makes cleaning easier.

Comments or Notes:

Commonly Used Seals, Gaskets & O-Ring Part Numbers

A/C Core Seals (high performance 12 cyl.)	Front - 130-1300 (2 reqd.) Rear - 135-9951 (2 reqd.)
A/C Core Seals (high performance 16 cyl.)	Front - 130-1300 (2 reqd.) Rear - 130-1300 (2 reqd.)
A/C Core Seal (inline)	2W8320
A/C Core Seals (std core 12 cyl)	Front - 4W7563 (1 reqd.) Rear - 4W7563 (1 reqd.)
A/C Core Seals (std core 16 cyl)	Front - 2W4054 (1 reqd.) Rear - 2W4054 (1 reqd.)
Air Plenum Cover Gasket (inline)	9Y7083
Air Plenum Cover Gasket (vee)	121-3874
Camshaft Cover O-Ring	8T0098
Combustion Seal (diesel fuel)	See Chart
Combustion Seal (residual fuel)	See Chart
Combustion Seal (wet liner)	See Chart
Crankcase Inspection Cover O-RIng	6I4545
Fuel Connector O-Ring	8L2786
Fuel Line O-Ring	033-6033
Oil Suction Screen Cover O-Ring	5P8429
Push Rod Cover O-RIng	9X7688
Rear Cam Gear Cover O-Ring	6V5060
Rocker Base O-Ring	118-7536
Rocker Button O-Ring	6V3922
Valve Cover O-Ring	6V3602

Water Side Cover Gasket (inline)	1W0130
Water Side Cover Gasket (inline)	121-3874
Connecting Rod Bolt	1W0098
Connecting Rod Bolt Retainer	4W8344
Connecting Rod (bolt Nut	6V9801
Head Studs	7E8400 (old) 187-0450 (new)
Head Stud Nuts	1W2361
Head Stud Washer	1W2362
Main Bearing Stud	1W0121
Main Bearing Nut	1W0123
Main Bearing Washer	1W0122
Saddle Bolt	3S7079
Saddle Bolt Washer	4K0684
Stud Protectors	7W1342 (old) 185-3545 (new)
Reuse Guides	Head Stud — 20Tensions Main Bear Stud — 20Tensions Saddle Bolt — 5Tensions Rod Bolt — Do not reuse a Connecting Rod Bolt if the dimension from the underside of the bolt head to end of bolt is more than 329.00 mm (12.953 in.) Rod Bolt Nut — 5 (Replace)

3600 Combustion Seal Gasket

Seal	Combustion Gasket Thickness	Liner
Diesel/Dry Flange Liner		
1W0498-	.157±.004	
123-0247-	.165±.004	
126-5986-	.165±.004	
145-7230-	.165±.004	179-3167 or 116-1042
142-2826-	.165±.004	179-3167 Only
Diesel/Wet Flange Liner		
1W-0498-	.157±.004	
123-0247-	.165±.004	
173-2669		
HFO/Dry Flange Liner		
1W-0498-	.157±.004	
126-5986		Wet or Dry
166-7083		Dry Only
HFO/Wet Flange Liner		
1W-0498-	.157±.004	
126-5986		Wet or Dry
173-2670		Wet Only
111-1656		Wet Flange Liner
116-1042		Old Liner Cancelled (Dry Flange)
179-3167		New Liner (Dry Flange)

New and old Liners maybe used in same engine, however if both liners are being used in the same engine the 145-7230 combustion gasket should be used.

Remanufactured Part Numbers

Cross-reference production part number to Re-man part numbers:

Part	New Part No.	Reman Part No.	Application/ Comments
Injector	100-2825	OR3650	HFO
	137-4729	OR8575	Distillate
Governors	108-6484	OR4105	EPG
	108-6487	OR4106	Marine/Ind.
Lift As.	101-8201	OR9667	Unit Inj.
	101-8173	OR9668	Valve
Arm As.	7E7205	OR9709	U.I. Rocker
Arm As.	122-9578	OR9710	Valve
	128-5680	OR9711	Valve
Arm	129-4859	OR9712	Vee Rocker
Camshaft	7E7065	OR9713	Med. Overlap Hi Speed Distillate CW
Camshaft	7E7169	OR9714	CCW
Camshaft As.	7E7061	OR9715	Firing Ord/Rotation Specific
Camshaft As.	7E7163	OR9716	
Camshaft As.	7E7167	OR9717	
Cam Journal	7E7064	OR9718	Firing Ord/Rotation Specific
Cam Journal	7E7153	OR9719	
Cam Journal	7E7154	OR9720	
Cam Journal	7E8124	OR9721	
Cam Journal	7E8125	OR9722	
Cam Journal	7E8126	OR9723	
Cyl. Head	4P2334	OR3250	Distillate (all) Nimonic valves
Cyl. Head	7E1404 7W0012	OR3228	HFO
	7C0012 7E1386	OR3227	Distillate (Silchorme/

	7E9012		Nimonic Valves
Cyl. Head	111-7217 148-3043 155-4092	OR9264 & OR9265	Upgrade to New
Oil Pump	4W4598	OR2761	3606 H.S.
Oil Pump	4W4623	OR2763	3606 L.S. 3608 H.S.
Oil Pump	4W4544	OR2767	3608 L.S. 3612 H.S.
Oil Pump	4W0674	OR2770	3612 L.S. 3616 H.S.
Oil Pump	7C8538		3616 L.S. 3618 H.S.
Water Pump	1W2458 (old)* 7E3172 (new)	OR2747 (old)* OR3736	Fresh Water 3606-3608
Water Pump	2W0465 (old)* 7E8179 (new)	OR2748 (old)* OR3764 (new)	Fresh Water 3612-3616
Water Pump	7W0045 (old) 7E4358 (new)	OR2749 (old)* OR3765 (new)	Sea Water
Connecting Rod	151-5206	OR3282	Inline
Connecting Rod	151-5207	OR3283	Vee

Note: High Speed 900-1000 Low Speed Less than 899
*Old Style Bearing

Comments or Notes:

Marine Society Spares:

Qty	Description	Qty	Description
1	Cyl. Head Gp.	6	Valve Springs (in)
2	Washer	6	Valve Sprints (ex)
2	Head Stud	12	Retainer Locks
1	Cyl. Head	6	Valve Guides
1	Gasket Kit	6	Valve Seats
		2	Valves (in)
		4	Valves (ex)
		6	Rotators
		6	Valve Spring Guides
1	Piston Gp	2	Studs
1	Piston Pin	2	Washers
2	Pin Retainers	2	Head Stud Nuts
1	Set of Rings	1	Cyl. Liner
1	Con Rod As.	3	O-Rings Bottom
1	Main Bearing	1	O-Ring Top
1	Rod Bearing	2	Thrust Plate Bearings
1	Main Stud		
1	Main Stud Nut		
1	Injector		
2	Crank Gears	1	Idler Gear
1	Cam Bearing	4	Gear As.
1	Idler Gear	3	Cam Drive Gear
2	Bolt		
5	O-Rings	1	Turbo Inlet Gasket
2	Hard Washers	9	Exhaust Gaskets
1	Cover	2	Plate
1	Plug	1	O-Ring Plug

Torques for English Fasteners

Standard Torque for Inch Fasteners	
Inch Nuts and Bolts	
Thread Size Inch	**Standard Torque**
1/4	12 ± 3 N·m (9 ± 2 lb ft)
5/16	25 ± 6 N·m (18 ± 4 lb ft)
3/8	47 ± 9 N·m (35 ± 7 lb ft)
7/16	70 ± 15 N·m (50 ± 11 lb ft)
1/2	105 ± 20 N·m (75 ± 15 lb ft)
9/16	160 ± 30 N·m (120 ± 22 lb ft)
5/8	215 ± 40 N·m (160 ± 30 lb ft)
3/4	370 ± 50 N·m (275 ± 37 lb ft)
7/8	620 ± 80 N·m (460 ± 60 lb ft)
1	900 ± 100 N·m (660 ± 75 lb ft)
1 1/8	1300 ± 150 N·m (960 ± 110 lb ft)
1 1/4	1800 ± 200 N·m (1320 ± 150 lb ft)
1 3/8	2400 ± 300 N·m (1780 ± 220 lb ft)
1 1/2	3100 ± 350 N·m (2280 ± 260 lb ft)

Inch Taperlock Studs	
Thread Size Inch	**Standard Torque**
1/4	8 ± 3 N·m (6 ± 2 lb ft)
5/16	17 ± 5 N·m (13 ± 4 lb ft)
3/8	35 ± 5 N·m (26 ± 4 lb ft)
7/16	45 ± 10 N·m (33 ± 7 lb ft)
1/2	65 ± 10 N·m (48 ± 7 lb ft)
5/8	110 ± 20 N·m (80 ± 15 lb ft)
3/4	170 ± 30 N·m (125 ± 22 lb ft)
7/8	260 ± 40 N·m (190 ± 30 lb ft)
1	400 ± 60 N·m (300 ± 44 lb ft)
1 1/8	525 ± 60 N·m (390 ± 44 lb ft)
1 1/4	750 ± 80 N·m (550 ± 60 lb ft)
1 3/8	950 ± 125 N·m (700 ± 90 lb ft)
1 1/2	1200 ± 150 N·m (880 ± 110 lb ft)

Torques for Metric Fasteners

Standard Torque for Metric Fasteners	
Metric Nuts and Bolts	
Thread Size Metric	**Standard Torque**
M6	12 ± 3 N·m (9 ± 2 lb ft)
M8	28 ± 7 N·m (21 ± 5 lb ft)
M10	55 ± 10 N·m (41 ± 7 lb ft)
M12	100 ± 20 N·m (75 ± 15 lb ft)
M14	160 ± 30 N·m (120 ± 22 lb ft)
M16	240 ± 40 N·m (175 ± 30 lb ft)
M20	460 ± 60 N·m (340 ± 44 lb ft)
M24	800 ± 100 N·m (590 ± 75 lb ft)
M30	1600 ± 200 N·m (1180 ± 150 lb ft)
M36	2700 ± 300 N·m (2000 ± 220 lb ft)

Metric Taperlock Studs	
Thread Size Metric	**Standard Torque**
M6	8 ± 3 N·m (6 ± 2 lb ft)
M8	17 ± 5 N·m (13 ± 4 lb ft)
M10	35 ± 5 N·m (26 ± 4 lb ft)
M12	65 ± 10 N·m (48 ± 7 lb ft)
M16	110 ± 20 N·m (80 ± 15 lb ft)
M20	170 ± 30 N·m (125 ± 22 lb ft)
M24	400 ± 60 N·m (300 ± 44 lb ft)
M30	750 ± 80 N·m (550 ± 60 lb ft)
M36	1200 ± 150 N·m (880 ± 110 lb ft)

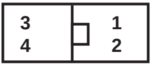
Torques & Specifications

A/C Core to Housing Scre ws (online)	30 ± 7 Nm (22 ± 5 '#)
A/C Core bolts (v ee high perf or mance aftercooler)	1/2 bolt - 120 ± 20 Nm (89 ± 30 '#) 5/8 bolt - 200 ± 40 Nm (148 ± 30 '#) 3/4 bolt - 215 ± 40 Nm (160 ± 30 '#)
A/C to Block (inline)	47 ± Nm (35 ± 7 '#)
A/C to Block (vee)	50 ± 10 Nm (37 ± 7 '#)
Air Star ter Br acket to Block	200 Nm (150 '#)
Air Star ter to Bracket	105 ± 20 Nm (75 ± 15 '#)
Barr ing De vice Br acket to Block (50:1)	105 ± 20 Nm (75 ± 15 '#)
Barr ing De vice to Block (1:1	105 ± 20 Nm (75 ± 15 '#)
Cam Follower to Block 5/8"Bolts	215 ±40 Nm (160 ±30 '#)
Cam segments to Cam Journal (thick flange)	270 ± 40 Nm (200 ± 30 '#)
Cam Segments to Cam Journal (thin flange)	135 ± 20 Nm (100 ± 15 '#)
Cam Cover to Block	47 ± 9 Nm (35 ± 7 '#)
Cam Dr ive Gear to Cam (use special dr iver)	2000 ± 275 Nm (1480 ± 200 '#)
Compression Relief Valve	275 ± 25 Nm (200 ± 18 '#)
Coupling to Flywheel	See standard bolt torque chart
Coupling to Gener ator	1300 Nm (965 '#) (16 cyl) 1050 Nm 780 '#) (12 cyl)
Crankcase Breather Clamp	3.0 ±5 Nm (27 ±4 in. #)
Crankcase Inspection Cover to Block	47 ± 9 Nm (35 ± 7 '#)
Crankshaft Seal to Block	47 ± 9 Nm (35 ± 7 '#)
Damper (23.5") to Crankshaft	1150 ± 150 Nm (850 ± 110 '#)
Damper (30") to Crankshaft	1350 ± 150 Nm (1000 ± 110 '#)
Double Damper (30" narrow) to Crankshaft	1350 ± 150 Nm (1000 ± 110 '#)
Doub le Damper (30" wide) to Crankshaft	1350 ± 150 Nm (1000 ± 110 '#)
Crankcase Breather Clamp	3.0 ± 5 Nm (27 ± 4 '#)

Engine Mounting Feet to Base Structure	900 ± 100 Nm (660 ± 75 ‘#)
Engine Mounting Feet to Block	1125 ± 100 Nm (820 ± 75 ‘#)
Exhaust Bellows to Manifold	55 ± 10 Nm (41 ± 7 ‘#)
Exhaust Bellows to Turbocharger	135 ± 20 Nm Antiseize Compound (100 ± 15 ‘#)
Exhaust Manifold to Cylinder Head	120 ± 20 Nm Antiseize Compound (85 ± 15 ‘#)
Flywheel to Crankshaft	800 ± 80 Nm plus (90 ± 15 degree turn) (540 ± 60 ‘#) plus (90 ± 15 degree turn) 2P2506 Thread Lube
Front Crankshaft Adapter	215 Nm (160 ‘#)
Front Housing to Block	215 ± 40 Nm (160 ± 30 ‘#)
Front Idler Gear Shaft to Block	105 ± 20 Nm (160 ± 30 ‘#)
Fuel Filter Cover to Filter Housing	47 ±7 Nm (35 ± 7 ‘#)
Fuel Fitting to Cylinder Head	105 ± 10 Nm (75 ± 7 ‘#)
Fuel Line to Fitting	45 ± 4 Nm (35 ± 3 ‘#)
Fuel Transfer Pump Drive to Gear Bolt	30 Nm (22 ‘#)
Fuel Transfer Pump to Front Cover	105 ± 20 Nm (75 ± 15 ‘#)
Generator Base Isolator	See standard bolt torque chart.
Generator Mounting Feet	875 Nm (645 ‘#)
Head Nuts	40,000 ± 1,500 kPa (2x) (5,800 ± 220 psi) (2x)
Head Studs to Block 20 X Reuse	100 ± 20 Nm (75 ± 7 ‘#)
Injector Hold-Down Clamp to Cylinder Head (bolts early)	47 ± 9 Nm (35 ± 7 ‘#)
Injector Hold-Down Clamp to Cylinder Head (nuts later)	35 ± 5 Nm (26 ± 4 ‘#)
Top of injector Hold-Down Clamp to Cyl. Head Distance	110.0 ± 1.0 mm (4.33 ± .04 in.)
Injector Hold-Down Clamp Stud to Cyl. Head	50 ± 5 Nm (37 ± 4 ‘#)
Main Bearing Cap Nut to Main Bearing Cap Stud	65,000 ± 2,400 kPa (2x) (9,425 ± 350 psi) (2x)

Connecting Rod Torque
(Coat Threads with 6V4876 Bolts/Nuts/Washers)

New Procedure:



1. Coat bolt threads and seating face of nut with 6V4876 Lubricant (Dow Corning Molykote GN)

a. tighten nut 1 to 105±20 Nm (75±15 lb ft)
b. tighten nut 2 to 105±20 Nm (75±15 lb ft)
c. tighten nut 3 to 105±20 Nm (75±15 lb ft)
d. tighten nut 4 to 105±20 Nm (75±15 lb ft)
e. tighten nut 1 to 340±15 Nm (250±10 lb ft)
f. tighten nut 4 to 340±15 Nm (250±10 lb ft)
g. tighten nut 2 to 340±15 Nm (250±10 lb ft)
h. tighten nut 3 to 340±15 Nm (250±10 lb ft)
i. retighten nut 2 to 340±15 Nm (250±10 lb ft)
j. retighten nut 3 to 340±15 Nm (250±10 lb ft)
k. retighten nut 1 to 340±15 Nm (250±10 lb ft)
l. retighten nut 4 to 340±15 Nm (250±10 lb ft)
m. loosen nut 1 then torque to 15±3 Nm (133±27 lb in)
n. place index mark and turn nut an additional 360±5 degrees
o. loosen nut 4 and then torque to 15±3 Nm (133±27 lb in)
p. place index mark and turn nut an additional 360±5 degrees
q. loosen nut 2 and then torque to 15±3 Nm (133±27 lb in)
r. place index mark and turn nut an additional 360±5 degrees
s. loosen nut 3 and then torque to 15±3 Nm (133±27 lb in)
t. place index mark and turn nut an additional 360±5 degrees

Main Bearing Cap Saddle Bolts to Block - 5x Reuse	1) Right Side Bolt -215 ± 40 Nm -(160 ± 30 '#) 4C5593 Thread Lube 2) Pressurize Cylinders 3) Left Side Bolt - 215 ± 40 Nm -(160 ± 30 '#) 4C5593 Thread Lube 4) Right Side Bolt - 1,825 ± 175 Nm - (1,350 ± 130 '#) **or** - 450 ± 50 Nm (330 ± 37 '#) then turn bolt 120 ± 5 degrees 5) Left Side Bolt - 1,825 ± 175 Nm - (1,350 ± 130 '#) **or** - 450 ± 50 Nm (330 ± 37 '#) then turn bolt 120 ± 5 degrees
Main Bearing Stud to Block 20x Reuse	100 ± 20 Nm (75 ± 15 '#)
Oil Filter Cover to Oil Filter Housing	47 ± 7 Nm (35 ± 7 '#)
Oil Pan to Block	120 ±20 Nm (90 ±15 '#)
Oil Pump Drive Gear to Oil Pump Drive Shaft	374 ± 48 Nm (275 ± 35 '#)
Oil Pump Mounting to Front Cover	105 ± 20 Nm (75 ± 15 '#)
Oil Suction Screen Cover to Oil Suction Tube	47 ± 9 Nm (35 ± 7 '#)
Oil Priority Valve to Front Cover	105 ± 20 Nm (75 ± 15 '#)
Piston Cooling Jets	47±9Nm 35±7 '#
Rear Crankshaft Adapter	215 Nm (160 '#)
Rear Flywheel Housing to Block	1/2 bolts 135 ± 20 Nm (100 ± 15 '#) 5/8 bolts 270 ± 40 Nm (100 ± 15 '#)
Rear Stub Shaft & Rear Idler Shaft (3/4) (vee)	160 Nm plus 45 degree turn (120 '#) plus 45 degree turn
Rocker Base to Cylinder Head	47 ± 7 Nm (35 ± 7 '#)
Rocker Arm Shaft Hold Down to Rocker Arm Base	430 ± 60 Nm (320 ± 45 '#)
Rocker Arm Adjustment Nuts	200 ± 25 Nm (150 ± 17 '#)
Rod Bolts (Reuse length bottom of head to end of bolt is more than 329.00 (12.953 in.)	300 ± 30 Nm plus 180 degree turn (220 ± 22 '#) plus 180 degree turn
Rod Bolt Nuts	5X Reuse
Tip Cool Line	50 ± 7 Nm (37 ± 7 '#)
Turbocharger Mounting	370 ± 50 Nm (275 ± 37 '#)
Turbocharger Support to Block	370 ± 50 Nm (275 ± 37 '#)

Valve to Injector RockerArm Nuts	200 ±25 Nm (150 ±17 '#)
Valve Bridge Adjustment Nuts	100 ±15 Nm (75 ±10 '#)
Valve Coverto RockerBase	47 ±9 Nm (35 ±7 '#)
Valve Lift Body to Block	215 ±40 Nm (160 ±30 '#)
Water Manifold bolts	47 ±9 Nm (35 ±7 '#)
Water Manifold to Cylinder Head	47 ±9 Nm (35 ±7 '#)
Water Pump Drive Gear	105 ±20 Nm (75 ±15 '#)
Water Pump Impeller Bolt	360 ±50 Nm (270 ±37 '#)
Water Pump to Front Cover	105 ±20 Nm (75 ±15 '#)

Comments or Notes:

Wear Limits for Liners

	Notes	Tolerances/Limits
Fire ring groove depth	1	3.50 ± 0.15 mm (0.138 ± 0.006 in)
Liner Bore Diameter (new). Allowable with any new or used piston. Allowable with original piston ONLY Top 20% Bottom 80%	 2	280.025 ± 0.025 mm (11.0246 ± 0.0010 in) 280.000 to 280.152 mm (11.0236 to 11.0296 in) 280.000 to 280.229 mm (11.0236 to 11.0326 in) 280.000 to 280.152 mm (11.0236 to 11.0296 in)
Liner flange thickness	3	33.00 ± 0.03 mm (1.299 ± 0.001 in)
Seal ring groove width	4	7.00 ± 0.13 mm (0.276 ± 0.005 in)
Cylinder liner taper	5	Maximum 0.03 mm (0.001 in) taper per 25 mm (1.0 in) length of the bore

1 Maximum variance of 0.02 mm (0.008 in)

2 The top 20% of the total length of the liner is the area at or above the upper end of the surface at the point of maximum wear.

3 Dimensions must not vary more than 0.013 mm (0.0005 in)

4 Bore taper is acceptable ONLY if all of the above specifications are met.

See Specifications for Measurement and Cleaning Cylinder Liners - 3600 Family of Diesel Engines SEBF8109-01

Wear Limits for Pistons

Piston Pin Bore	Notes	Tolerances
Piston pin bore diameter	1	120.028 ± 0.008 mm (4.7255 ± 0.0003 in)
Clearance between piston pin to piston pin bore	2	0.034 ± 0.014 mm (0.0013 ± 0.0006 in)
Piston pin diameter		119.994 ± 0.006 mm (4.7242 ± 0.0002 in)
Piston pin bore taper	3	120.092 ± 0.013 mm (4.7280 ± 0.0005 in)

1 Piston pin bore diameter measured 2.00 mm (0.079 in) gauge length from the snap ring groove.
2 Clearance will vary along the piston pin bore.
3 Piston pin bore taper measured 47.00 mm (1.850 in) gauge length from the snap ring groove.

Comments or Notes:

Piston & Piston Ring Specifications

Width of Piston Ring Groove	Minimum	Maximum
Top Ring	5.150 mm (0.2027 in)	5.253 mm (0.2068 in)
2nd Ring	5.150 mm (0.2027 in)	5.253 mm (0.2068 in)
3rd Ring	5.040 mm (0.1984 in)	5.198 mm (0.2047 in)
Oil Control Ring	8.040 mm (.3165 in)	8.140 mm (0.3205 in)

Piston Ring Width	Minimum	Maximum
Top Ring	4.940 mm (0.1940 in)	4.990 mm (0.1960 in)
2nd Ring	4.940 mm (0.1940 in)	4.990 mm (0.1960 in)
3rd Ring	4.890 mm (0.193 in)	4.940 mm (0.194 in)
Oil Control Ring	7.914 mm (.3116 in)	7.936 mm (0.3124 in)

Clearance Between Grove & Piston Ring	Minimum	Maximum
Top Ring	0.16 mm (0.006 in)	0.31 mm (0.012 in)
2nd Ring	0.16 mm (0.006 in)	0.31 mm (0.012 in)
3rd Ring	0.10 mm (0.004 in)	0.31 mm (0.012 in)
Oil Control Ring	0.10 mm (0.004 in)	0.23 mm (0.009 in)

Piston Ring End Gap	**Minimum**	**Maximum**
Top Ring	0.90 mm (0.035 in)	1.30 mm (0.051 in)
2nd Ring	0.90 mm (0.035 in)	1.30 mm (0.051 in)
3rd Ring	0.90 mm (0.035 in)	1.30 mm (0.051 in)
Oil Control Ring	0.90 mm (0.035 in)	1.30 mm (0.051 in)

Note: Piston ring gap value must be taken when the ring is installed in a 280.00 mm (11.024 in) bore.

See Specifications for Pistons and Rings - 3600 Family of Diesel Engines SEBF8107-01

<u>Comments or Notes:</u>

Crankshaft Deflection for 3600 Engines

Specifications for first 300 degree rotation Specifications after returning to start (TIR)		Front 0.18 mm (0.007 in) 0.00 mm (0.000 in)	Middle 0.08 mm (0.0032 in) 0.00 mm (0.000 in)	Rear 0.18 mm (0.007 in) 0.00 mm (0.000 in)
Rear Driven	**Con Rod Journal**	**Readings**		
3606	#3			
	#6			
3608	#4			
	#8			
3612	#5			
	#6			
	#11			
	#12			
3616	#7			
	#8			
	#15			
	#16			

Front Driven	Con Rod Journal	Readings		
3606	#4			
	#1			
3608	#5			
	#1			
3612	#5			
	#6			
	#1			
	#2			
3616	#7			
	#8			
	#1			
	#2			

Crankshaft deflection check can be made when the engine is hot or cold

Crankshaft End Play .20 / .60 mm
(.008 / .024 in)

ABB Turbocharger Wear Limits

Radial End Play (up & down)	
New	.43 to 61 mm (.017 to .024 in)
Max Reuse	.87 mm (.034)
Axial End Play (in & out)	
New	.10 to .20 mm (.004 to .0086)
Max Reuse	.30 (.012 in)

Guidelines for Reuse of Studs & Bolts

All of fasteners should be thoroughly inspected before the fasteners are reused. Do not reuse a fastener that has any of the problems that follow: rust, nicks, thread damage, cracks, pits, deformations, and any other damage.

Engine	**Part No.**	**Part Name**	**Overall Length or Tension**
3600	(old) 7E8400	Cylinder Head Stud	20 Tensions
3600	(new) 187-0450	Cylinder Head Stud	20 Tensions
3618	137-4048	Cylinder Head Stud	769.50 mm (30.295 in)
3600	1W0121	Main Bearing Stud	20 Tensions
3618	137-4047	Main Bearing Stud	698.50 mm (27.500 in)
3600	1W0098	Connecting Rod Bolt	329.00 mm (12.953 in)
3618	137-0134	Connecting Rod Bolt	246.20 mm (9.693 in)
3600	357079	Main Bearing Cross Tie Bolt	5 Tensions
3618	142-0142	Main Bearing Cross Tie Bolt	280.50 mm (11.043 in)

All studs are measured total length.
All bolts are measured from bottom of head to end of bolt.
If the dimension for maximum length is exceeded replace that stud or bolts.

Alignment Tolerances (Two Bearing Generator Set)

		Laser Tool (actual)
Rough Spec.	Vertical Offset	+0.457 ± 0.254 mm (+0.018 ± 0.010 in.)
Rough Spec.	Horizontal Offset	+0.000 ± 0.254 mm (+0.000 ± 0.010 in)
Rough Spec.	Vertical Angularity*	+0.000 ± 0.127 mm (+0.000 ± 0.005 in)
Rough Spec.	Horizontal Angularity*	+0.000 ± 0.127 mm (+0.000 ± 0.005 in)
Final Spec.	Vertical Offset	+0.254 ± 0.102 mm (+0.010 ± 0.004 in.)
Final Spec.	Horizontal Offset	+0.000 ± 0.127 mm (+0.000 ± 0.005 in)
Final Spec.	Vertical Angularity*	+0.000 ± 0.178 mm (+0.000 ± 0.007 in)
Final Spec.	Horizontal Angularity*	+0.000 ± 0.178 mm (+0.000 ± 0.007 in)

		Dial Indicator (TIR)
Rough Spec.	Vertical Offset	+0.914 ± 0.508 mm (+0.036 ± 0.020 in.)
Spec.	Horizontal Offset	+0.000 ± 0.508 mm (+0.000 ± 0.020 in)
Rough Spec.	Vertical Angularity	+0.000 ± 0.254 mm (+0.000 ± 0.010 in)
Rough Spec.	Horizontal Angularity	+0.000 ± 0.254mm (+0.000 ± 0.010 in)
Final Spec.	Vertical Offset	+0.508 ± 0.204 mm (+0.020 ± 0.008 in.)
Final Spec.	Horizontal Offset	+0.000 ± 0.254 mm (+0.000 ± 0.010 in)
Final Spec.	Vertical Angularity	+0.000 ± 0.356 mm (+0.000 ± 0.014 in)
Final Spec.	Horizontal Angularity	+0.000 ± 0.356mm (+0.000 ± 0.014 in)

*The angularity values are provided for a measurement of offset at a 254 mm (10 in.) diameter. If measurements are taken at a radius other than 254 mm (10 in), the measurements must be corrected to a 254 mm (10 in) diameter)

Lubricant Specifications

Lubricant Information

Certain additives used in lubricating oils contain alkaline compounds that are formulated to neutralize acids. The measure of this reserve alkalinity in a lubricating oil is known as its "Total Base Number" (TBN). TBN values are essential to neutralize the acids from combustion gases and to minimize corrosive wear.

For more information on fuel selection and fuel properties, refer to Diesel Fuel and Your Engine, SEBD0717. For more information on oil, fuel sulfur content, etc, refer to Supplement SEBU7003, Caterpillar 3600 Diesel Engine Fluids Recommendations For Lubricants, Fuels, and Coolants or contact your Caterpillar Dealer.

Caterpillar Oil

To achieve the maximum engine life and superior performance in your diesel engine, Caterpillar recommends Caterpillar Diesel Engine Oil (DEO), API CF. Oils meeting the American Petroleum Institute (API) performance categories possess the properties to operate effectively at the higher piston temperatures.

Caterpillar DEO (certified as API CF) is blended with a diesel engine type additive with strong detergency effectiveness. This oil has a higher alkalinity (13.5 TBN) than many oils for the neutralization of wear-causing combustion products, and provides additional protection for higher fuel sulfur and an occasional extended drain period.

The primary recommendation for the 3600 Series Engines is an SAE 40 grade oil. SAE 30 and some multi-grade oils may be used. Refer to the Lubricant Viscosity chart in SEBU6965 for the proper SAE viscosity, grade and ambient temperature information.

Viscosity

The proper SAE viscosity grade oil is determined by the minimum outside temperature at cold engine start-up, and the maximum outside temperature during engine operation. Use the minimum temperature column on the Engine Oil Viscosities chart to determine the oil viscosity required for starting a "cold soaked" engine. Use the maximum temperature column on the chart to select the viscosity for operation at the highest viscosity oil available that still meets the start-up temperature requirements. SAE 40 is the preferred viscosity.
CF oils are available in single-grades and multi-grades. The CF-4 and CG-4 oils are available in multi-grades. Multi-grade oils may be used in 3600 diesel engines if the oils meet the requirements. Compared to single-grade oils, multi-grade oils provide the correct viscosity for a broad range of operating temperatures and for cold engine starts.

Lubricant Viscosities For Temperature Ranges (degrees C and degrees F)				
Oil VIscosities	**Degrees C**		**Degrees F**	
	Min	**Max**	**Min**	**Max**
SAE 5W20 (SPC)	-30	+10	-22	+50
SAE 5W40 (SPC)	-30	+40	-22	+104
SAE 10W30	-20	+40	-4	+104
SAE 15W40	-15	+50	+5	+122
SAE 20W40	-10	+40	+14	+104
SAE 30	0	+40	+32	+104
SAE 40	+5	+50	+41	+122

Engine Oil

An oil for a 3600 Series Engine must have a minimum API classification of CF or MIL-L-2104D. The oil must pass the Caterpillar Micro-Oxidation Test. API CF-4 and CG-4 oils may be acceptable if they pass the Micro-Oxidation and 7,000 Hour Field Test. **API CC oils are unacceptable in all Caterpillar diesel engines.**

Lubricant Total Base Number (TBN)

New oil for engines operating on distillate fuels must have a TBN of 10 times the percent fuel sulfur as measured by ASTM (American Society of Testing Materials) D2896 method. ASTM D2896 can normally be found at your local technological society, library or college.

Always consult with your Caterpillar dealer for the latest lubricant recommendations.

TBN for Distillate Fuel Engines

The TBN recommendation for an oil depends on the sulfur level of the fuel used. For 3600 diesel engines running on distillate diesel fuel, the minimum new oil TBN (by ASTM D2896) should be ten times the fuel sulfur level, and the minimum TBN is five regardless of sulfur level. In areas where the fuel sulfur exceeds 1.5 percent, choose an oil with the highest TBN that meets the Caterpillar performance requirements, and shorten the oil change interval based on oil analysis. The Scheduled Oil Sampling (S•O•S) analysis program should evaluate oil condition and wear metals. High TBN oils that do not meet the recommended performance requirements can produce excessive piston deposits, leading to a loss of oil control and bore polishing.

Lube Oil Experience List for 3600

Successful lube oil experiences in 3600 Series Engines are summarized in the table. Inclusion in this list indicates that the particular lube oil has been successful only in a particular application and site. This list is not an endorsement nor recommendation for any particular lube oil. Caterpillar does not recommend any lube oil for 3600 Engines other than our own branded Caterpillar DEO in distillate fuel burning applications.

When consumables such as oil, filters, additives, and similar items made by other manufacturers are used on or in Caterpillar equipment, the Caterpillar warranty is not affected simply because of such use. The Caterpillar warranty continues to cover defects caused by Caterpillar material and workmanship. Failures resulting from usage of other manufacturers' consumables are not Caterpillar factory defects and therefore are NOT covered by the Caterpillar warranty. Use of other manufacturers' consumables is at the discretion of the customer, who assumes ALL risks for the effects resulting from usage.

DISTILLATE FUEL				
SUPPLIER	**NAME**	**SAE VISCOSITY GRADE**	**TBN**	**HIGH LOAD > 85%**
Caterpillar	DEO (CF) DEO (CG-4)	40 15w-40	13.5 10.5	YES UNKNOWN
British Petroleum	Vanellus C3 (CG-4)	15w-40	11	UNKNOWN
Chevron	Delo 6170 Delo 477	40 40	17 17	UNKNOWN UNKNOWN
Exxon	DeMar Xt CM477 IOLUBE MDY 40	40 40 40	13 14 13	YES YES –
Mobil	Mobilgard ADL Delvac MX (CG-4) Mobilgard HSD (CG-4)	40 15w-40 15w-40	15 10.1 10.1	UNKNOWN UNKNOWN UNKNOWN
Shell	Rimula (North America)	40	12	YES
Valvoline	DDS 9207	40	13	UNKNOWN

YES: Lube oil has had successful experience in engines operating above 85% load factor
UNKNOWN: All documented experiences with the lube oil have been below 85% load factor
EXPECTED: A field trial is in progress and the initial results are positive

Caterpillar cannot control base stock variations and lube oil additive packages at locations around the world and therefore takes no responsibility. Differences in load cycle, fuel quality, maintenance practices, and ambient conditions further prohibit a guarantee of lube oil performance at any installation. Past performance of a particular brand does not guarantee future results due to changes in formulation and regional differences. It is the responsibility of the oil producer to verify the consistency and quality level of the product.

Oil Change Interval

Using S•O•S to Determine Oil Change Intervals that is suitable for your application. Caterpillar recommends taking an S•O•S oil analysis every 250 service throughout the life of the engine to monitor the condition and maintenance requirements. By using S•O•S program and Infrared Analysis, you will be able to achieve maximum engine lube oil life and provide optimum protection for the engine. If the analysis indicates that the oil has reached it's condemning limit, a change is necessary, regardless of the number of service hours.

Lubricant Change Intervals Without the use of S•O•S may be necessary if the service is not available. The chart below should be adhered to for oil change intervals for distillate fuel applications.

Oil Change Intervals For 3600 Engines (Distillate Fuel)		
Engine	**Lube Oil Capacity**(1)	**Oil Change Interval** (service hours) (2)
Industrial & Generator Set Engines		
3606	880 L (229 gal)	1400
3608	1112 L (289 gal)	1350
3612	1302 L (339 gal)	1000
3616	1073 L (443 gal)	1000
Marine Engines with Zero Degree Tilt Angle		
3606	731 L (190 gal)	1000
3608	795 L (207 gal)	900
3612	943 L (245 gal)	800
3612 (3)	910 L (239 gal)	750
3616	1091 L (284 gal)	600
3616 (3)	1057 L (228 gal)	500

*All (gal) are U.S. Gallons

(1) The capacity includes the oil sump plus oil filters that are installed at the factory. Engines with auxiliary oil filters will require additional oil. The capacity is approximate. The actual capacity may vary by five percent. Caterpillar recommends using the capacity that is listed and then adjusting the oil level according to the oil level gauge (dipstick).

(2) Use this oil change interval in the absence of oil analysis.

(3) Fast vessel.

Estimating Oil Consumption

Oil consumption, along with fuel consumption and maintenance information, can be used to estimate the total operating cost. Oil Consumption data may also be used to estimate the quantity of makeup oil required to accommodate maintenance intervals. Many Factors can affect oil consumption including load, oil density, oil additive packages, and maintenance practices.

The rate of oil consumption is called BSOC (brake specific oil consumption) and the unit of measure is grams per brake kilowatt hour (g/bkW-hr) or pounds per brake horsepower hour (lb/bhp-hr). The typical BSOC for ***new*** 3600 Engines operating at 100% load factor is 0.486 g/bkW-hr (0.0008 lb/bhp-hr).

NOTE: This value can vary significantly due to engine condition, load factor and maintenance practices. Also, with very low consumption, measurement methods become difficult and numbers erratic. Therefore, these values can only be used as a guide for make-up oil requirements.

Calculation of Engine BSOC

One of the following calculation formulas must be used to estimate the BSOC of an operating engine. A comparison can then be made between the operating engine and the typical value. A low hour engine may have a lower oil consumption than the typical value and a high hour engine may have higher oil consumption than the typical value, but the typical value will still provide an estimate for oil consumption.

English Units:

$$\text{Gal/hr} = \frac{\text{Engine bhp} \times \text{Load Factor (\%)} \times \text{BSOC (lb/bhp-hr)}}{\text{Density of Oil**}}$$

OR

$$\text{BSOC (lb/bhp-h)} = \frac{\text{Oil Usage (lb/h)}}{\text{Engine Power (bhp)} \times \text{Load Factor}}$$

The following **EXAMPLE** will help you through the calculation:

<u>English</u>

3616 Engine Rated at 4,500 hp.
Engine uses 110 gals of oil.
In 168 hours of operation.
Load Factor is 80%

$$\text{BSOC} = \frac{\text{110 gals of oil x 7.5 / 168 = (lb/h)}}{\text{4,500 (bhp) x .80 (\% Load Factor)}}$$

$$\text{BSCO} = \frac{\text{4.9 (lb/h)}}{\text{3600}}$$

BSCO = 0.00136 (lb/bhp-h)

<u>Metric</u>

3616 Engine Rated at 3300 kW
Engine uses 417 Liters of oil,
In 168 hours of operation.
Load Factor is 80%

$$\text{BSCO} = \frac{\text{417 Liter of oil x 899 / 168 = (g/h)}}{\text{3,300 (bkW) x .80 (\% Load Factor)}}$$

$$\text{BSCO} = \frac{\text{2,231 (g/h)}}{\text{2,640}}$$

BSOC = 0.8452 (g/bkW-h)

Oil Consumption as an Overhaul Indicator

When the oil consumption of an engine has increased to **THREE (3) TIMES the normal oil consumption** due to normal wear, the engine may need to be scheduled for overhaul. However, the 3600 Engine can easily operated with oil consumption up to 2.2 g/bkw-hr (.0036 lb/bhp-hr) without damage. The true measure of when to overhaul an engine is performance as measured by output, fuel consumption, oil consumption, blow-by and compression. If an engine is still performing at acceptable levels in all of these parameters, then it need not be overhauled. Therefore, to obtain minimum operating cost, it is helpful to keep good trend line records for the listed items.

English Example above:
BSOC = 0.001364
BSOC for typical new is 0.0008
Consumption Indicator 3 times the normal.

$$\begin{array}{r} 0.0008 \\ \underline{\times\ 3} \\ 0.0024 \end{array}$$

Since the 0.001364 calculated from our example is less than the 0.0024, then the engine should not be considered for overhaul.

Metric Example above:
BSOC = 0.8452
BSOC for typical new is 0.486
Consumption Indicator 3 times the normal.

$$\begin{array}{r} 0.486 \\ \underline{\times\ 3} \\ 1.458 \end{array}$$

Since the 0.8452 calculated from our example is less than the 1.458, then the engine should not be considered for overhaul.

Calculation for Average Oil Consumption

The equations used for calculation of the engine BSCO can be rearranged to provide an estimate of the average oil usage for the life of the engine.

Metric Units:

$$\text{Oil Usage (L/hr)} = \frac{\text{Engine Power bkW} \times \text{Load Factor} \times \text{BSOC (g/bkW-hr)}}{\text{Density of Oil**}}$$

English Units:

$$\text{Oil usage (gal/h)} = \frac{\text{Engine Power (bhp)} \times \text{Load Factor} \times \text{BSCO (lb/bhp-h)}}{\text{Density of Oil**}}$$

** Typical engine oil has density of 899 g/L (7.5 lb/gal).

Load Factor: The mathematical ratio of the actual load divided by the connected load. This ratio is expressed in a percentage (%).

. Load Factor (LF)

Assume fuel density = 838.9 g/L

$$LF\,(\%) = \left(\frac{\text{Consumed fuel per year (liters or gallons)}}{\text{Rated power fuel consumption per year (liters or gallons)}}\right) \times 100$$

$$LF\,(\%) = \frac{[(PL \times PL\ BSFC \times Time) + (PL \times PL\ BSFC \times Time) + \ldots] \times FD}{Rated\ Power \times Rated\ Power\ BSFC \times FD \times 8000\ hrs} \times 100$$

EXAMPLE

$$LF\,(\%) = \frac{[(1000 \times 260 \times 2000) + (2000 \times 220 \times 2000) + (4920 \times 200 \times 4000)] \times \frac{1}{838.9}}{4920 \times 200 \times \frac{1}{838.9} \times 8000} \times 100 = 67.78\%$$

***NOTE:** Total number of hours in the numerator must equal the total number of hours in the denominator.*

PL = Part Load Factor (bkW or ekW)
PL BSFC = Part Load Fuel Consumption (g/bkW•hr)
FD = Fuel Density (g/liter)
Time (hrs)

Air Starter Lubricator Oil & Air Prelube Pump Lubricator Oil

SAE 10W air tool oil is recommended. Diesel fuel or kerosene can be substituted.

Comments or Notes:

S•O•S Oil Analysis

Caterpillar recommends using Scheduled Oil Sampling (S•O•S) analysis at regularly scheduled intervals to compliment a good preventive maintenance program. Consult your Caterpillar dealer for complete information and assistance in establishing an S•O•S analysis program for your engine(s).

The S•O•S oil analysis tests have been developed by Caterpillar engineers and chemists to evaluate the condition of your engines rather than just the condition of the oil. Additional tests may be performed if needed. Following is a brief description of the standard oil analysis tests offered in the S•O•S program.

Wear Analysis is performed with spectrophotometer instruments. Essentially, the test monitors a given component's wear rate by identifying and measuring concentrations of wear elements in oil. Based on known normal concentration data, maximum limits of wear elements are established. After three oil samples are taken, trend lines for the various wear elements can be established for the particular engine. Impending failures can be identified when trend lines deviate from the established norm. (a base sample of new oil) Wear analysis is limited to detecting components wear and gradual dirt contamination. Failures due to component fatigue, sudden loss of lubricant or sudden ingestion of dirt occur too rapidly to be predicted by this type of test.

Chemical and Physical Test detect water, fuel and anti-freeze in the oil and determine whether or not their concentrations exceed established maximum limits. The presence and approximate amount of water is detected by a "sputter test." A drop of oil is placed on a hot plate controlled between 230 degrees and 250 degrees F. The appearance of bubbles is a positive indication (.1% to .5% is the acceptable range) with 0.5% as the maximum limit.
The presence of fuel is determined with a Setaflash Tester. The tester is calibrated to quantify the percentage of fuel dilution (4% maximum allowable fuel concentration).

The presence of antifreeze can also be determined by a chemical test. (Any indication that is positive is unacceptable.) Some new oils give a positive glycol reading. If glycol is detected, also look for an increase in sodium in the oil. Sodium compounds are used in the supplemental coolant additives. The new oil should be tested for glycol as well.

Oil Condition Analysis determines loss of the oil's lubricating properties. An infrared analysis instrument is used to compare the properties of new oil to the properties of your used oil sample. This test allows technicians to determine the extent to which the oil has deteriorated during use and to verify that the oil is performing up to specification during the entire oil change period. Oil samples for these tests are generally taken by the customer. However, your Cat dealer can do it for you as part of a customer support agreement designed to meet your needs.

The S•O•S analysis program must include infrared analysis to determine oil change intervals. Your Caterpillar dealer is the best qualified source to interpret data for the regulation of your oil change interval.

Recognizing the Causes & Effects of Contamination & Degradation.

Contamination--S•O•S identifies and measures various contaminants in the oil which cause engine failure. For example, high concentration of lead and aluminum indicates crankshaft or con-rod bearing wear. A high concentration of chromium indicates piston ring damage (with the exception of plasma coated rings.) S•O•S gives an opportunity to inspect the condition of these parts and, if necessary take action to prevent further damage. Her are some examples of typical contaminants and what effect they have on the condition of your engine.

Cause: Silicon
Effect: Above normal readings of silicon can indicate a major problem. Oil loaded with silicon becomes, in effect a grinding compound which can remove metal from any number of parts during operation. Some silicon will usually be in a new oil sample as a part of the anti-foam additive.

Cause: Sodium
Effect: A sudden increase in sodium readings indicates coolant is leaking from the cooling system into the oil. The sodium is from the coolant inhibitor. The coolant with its glycol can cause oil to thicken and become sludgy, leading to piston ring sticking and filter plugging.

Cause: Silicon, Chromium, Iron
Effect: A combination such as this signals dirt entry through the induction system, possibly causing ring and liner wear.

Cause: Silicon, Iron, Lead, Aluminum
Effect: This combination indicates dirt in the lower portion of the engine, possibly leading to crankshaft and bearing wear.

Cause: Aluminum
Effect: This can be critical. Concentrations of aluminum suggest bearing wear. Relatively small increases in the levels of this element should receive immediate attention because once rapid wear begins the crankshaft may produce large metal particles. (Aluminum can also be coming from piston skirt scuffing.)

Cause: Iron
Effect: Iron can come from any number of sources. It can also appear as rust, after engine storage. Frequently, when accompanied by a loss of oil control, increases in iron contamination indicate severe liner wear.

Cause: Soot
Effect: A high Soot content is not usually the direct cause of failure. But as an insoluble particulate, it can plug oil filters and deplete dispersant additives. Soot indicates a dirty air cleaner, engine lug, excessive fuel delivery, or repeated acceleration in the improperly set rack limited (smoke limiter). It can also indicate a poor quality fuel.

Cause: Oxidation Products
Effect: Oxidation is a chemical reaction between oil and oxygen, just as rust is a chemical reaction between iron and oxygen. Oil oxidation rate is controlled by oxidation inhibitor additives; whenever oil is in contact with air, oxidation occurs. Oxidation agents in combustion gases of diesel engines, temperature, and certain contaminants (such as copper and glycol), accelerate oxidation. As oil oxidation increases, lubricating properties in the oil decrease, resulting in thickening of the oil, formation of organic acids, plugged filters and ultimately, ring sticking, piston deposits and lacquering.

Cause: Nitration Products
Effect: Nitration occurs in all engines but only reaches problem levels in natural gas engines. Nitrogen compounds, resulting from the combustion process, cause the oil to thicken, lose its lubricating abilities and leads to filter plugging, heavy deposits and lacquering.

Cause: Water
Effect: Water combined with oil will create an emulsion which will plug the filter. Water and oil can also form a dangerous metal corroding acid. Most instances of water contamination are the result of condensation within the crankcase. More serious contamination occurs when a leak in the cooling system allows water to enter from outside the engine oil system.

Cause: Fuel
Effect: Fuel contamination decreases the oil's lubricating properties. The oil no longer has the necessary film strength to prevent metal-to-metal contact. This can lead to bearing failure and piston seizure.

Cause: Sulfur
Effect: The presence of sulfur signals danger to all engine parts. The type of corrosive wear attributed to high sulfur content can also cause accelerated oil consumption. Also, the more fuel consumed during an oil change interval the more sulfur oxides are available to form acids. Therefore, the TBN in engines working under heavy loads should be checked more often. Fuel sulfur damage can cause piston ring sticking, and corrosive wear of the metal surfaces of valve guides, piston rings and liners.

Degradation--Causes of impending failure can take forms other than contamination. These causes are potential sources of oil degradation. Let's examine each and its effect on your engine.

Cause: Low Jacket Water Temperature
Effect: Engine jacket water outlet temperature influences the formation of corrosive acids in the engine. First, even with less than 0.5% sulfur fuel, when the temperature is below 79 degree C (175 degree F), acid vapor forms easily and corrosive attack occurs. Secondly low temperature increases the water content of the oil which can react with certain additives, deplete them and reduce the oil's protection. This can cause deposits, sludge formation, lacquering, varnish and carbon build-up, which, in turn lead to increased blowby, liner bore polishing and ring sticking.

Cause: High Humidity
Effect: In applications where humidity of 85% or over is part of the operating conditions gaseous acids are most likely to form because of the additional water content in the air. This can result in more corrosive attacks.

Cause: Oil Consumption
Effect: Oil consumption rate can provide valuable information concerning the engine. Changes in consumption, whether they are gradual or sudden are signals of ring and liner wear or ring sticking. It is critical that sufficient amounts of oil (with an adequate TBN level or alkalinity reserve) are pumped up to the ring belt area in order to neutralize acid.

Cause: Incorrect Load/Speed Ratio
Effect: Engine load plays a critical role in oil degradation. Engines running at rated speed and high load will be operating at maximum efficiency for both lubrication and cooling system. If, however, the load is reduced with the engine still running at rated speed, the lubrication and cooling systems will continue to operate efficiently, but the engine can become overcooled resulting in condensation. This can effect liners, rings and cause increased blow-by.

Wear Element Sources

Oil samples from engines show abnormal readings for the basic wear elements can indicate component problems.

Copper (CU)	Oil Additives (no failure) Oil Cooler Leaching (no failure) Bushings/Bearings: - Turbochargers - Oil Pump - Wrist Pin - Rocker Arm - Cam Roller Shaft - Idler/Timing Gears - Water Pump - Oil Pump Drive - Thrust Bearings
Iron (Fe)	Cylinder Lines Gears Crankshaft Camshaft Wrist Pins Oil Pump Valve Train Cam Followers
Chrome (CR)	Roller/Ball Bearings(some) Piston Rings Exhaust Valves
Aluminum (Al)	Main Bearings Rod Bearings Camshaft Bearings Crankshaft Thrust Bearings Oil Pump Bearings Timing Gear Bearings Pistons Dirt Entry (clay soil)
Lead (Pb)	Main & Rod Bearing Overlay Camshaft Bearing Overlay
Molybdenum (Mo)	Moly Grease
Silicon (Si)	Dirt Entry Silicon Grease Anti-Foam Oil Additive
Sodium (Na)	Cooler Leak Water or Condensation Entry Oil Additive (no failure)

Classic Wear Elements Combinations

Primary Element	Secondary Element	Potential Wear	Probable Problem Area/Cause
Engine - Top End			
Silicon (dirt)	Iron Chrome Aluminum	Liners Rings Pistons	- Air Induction System/Filters - Dirt Contamination
Iron	Chrome Aluminum	Liners Rings Pistons	- Abnormal Operating Temps. - Oil Degradation - Fuel and/or Coolant - Contamination Stuck/Broken Rings
Chrome	Molybdenum Aluminum	Rings Pistons	- Blowby - Oil Consumption - Oil Degradation
Iron		Liners Gears Valve Train Crankshaft	- Abnormal Operating Temps. - Lack of Lubrication - Contamination - Storage (rust)

Engine - Bottom End			
Silicon (dirt)	Lead Aluminum	Bearings	- Dirt Contamination
Lead	Aluminum	Bearings	- Fuel Contamination - Coolant Contamination - Lack of Lubrication

Comments or Notes:

Cooling System Specifications

The cooling system is one of the most misunderstood systems of the engine and can cause the customer great expense if not maintained properly and correctly. Coolant or cooling system problems contribute to more than 50 percent of all engine failures. These failures can be due to inadequate cooling system maintenance, incorrect concentration, poor operational procedures such as extensive lugging or inadequate cool down procedures, or system problems such as stray electrical current or block heater failure. The following Caterpillar Maintenance Guidelines, if followed will help reduce cooling system cost.

Water

Distilled or deionized water is recommended because of less mineral drop out than hard or tap water and to help reduce the potential and severity of chemical insolubility. Tap water artificially softened with salt is NOT recommended for use in engine cooling systems. Mixed bed filters or reverse osmosis procedures are preferred water treatment methods.

In remote areas only, where distilled, deionized or treated water is not available, use the following guidelines:

1. Never use salt water.
2. Select the best quality fresh water available. Use water analysis to define water quality.
3. NEVER USE WATER ALONE AS A COOLANT. Supplemental coolant additives are required because water is corrosive at engine operating temperatures.

For more detailed specifications, refer to :

Know your Cooing System ………….. SEBD0518
Coolant and You Engine …………….. SEBD0970

If distilled or deionized water is NOT available, use water that meets the minimum acceptable requirements listed in the chart below.

Caterpillar Water Quality Limits	
Water Property (ASTM Test)	**Mg/L (grains/US gal.)**
Chloride (D512b or D512d or D4327)	40 (2.4) Max.
Sulfate (D516b or D516d)	100 (5.9) Max.
Total Hardness (D1126)	170 (10) Max.
Total Solids (D1888a)	340 (20) Max.
pH (D1293)	5.5 to 9.0

Water Testing

To determine water characteristics in your area, contact the city water department or an agricultural agent. Independent laboratories can also perform this testing service. Two of these companies are listed below, but there are others qualified to provide this service:

LOCC Corporation
905 Bayshore Drive
Coos Bay, Oregon
97420
(503)267-4904

Nalco Chemical Co.
Naperville Technical Center
One Nalco Center
Naperville, Illinois
60563-1198
attn: Sample Receiving
(630)305-1000

Antifreeze Content

One purpose of antifreeze is to protect the engine coolant from freezing and causing engine damage. The agent most commonly used for protection is ethylene glycol. The relative concentrations of ethylene glycol and water are crucial to determining the amount of freeze and boiling protection a mixture will give. By increasing the boiling point of the coolant helps prevent water pump cavitation.

Due to making engines lighter a change in engine component material, the industry developed an antifreeze to protect aluminum components. This new antifreeze resulted in much higher dissolved chemical solids than former antifreezes.

NOTICE

Do not use a commercial Coolant/Anti-freeze that only meets the ASTM D3306 or D4656 specification. This type of coolant/antifreeze is made for light duty automotive applications.

Unfortunately, when this new antifreeze was mixed with supplemental coolant additives as suggested in maintenance practices, an over-concentration of cooling system inhibitors could result. When an over-concentrated does occur, inhibitors can drop out of solution. This over-concentration can cause the following problems in cooling systems:

1. reduction in heat transfer due to chemical deposits, chemical precipitates and silica gel.
2. Premature water pump seal leakage or failure due to precipitates and chemical deposits on the seal face.

These problems have been linked to silicates and silicate gel, but the fundamental problem is over-concentration of silicates but of all the chemical additives used as inhibitors. To correct this problem, an overall reduction of cooling system additives is required. To accomplish acceptable performance the following is recommended:

1. For commercial antifreeze use a low silicate antifreeze meeting the GM6038M specification.
2. Follow engine manufacture's recommendations regarding the use of supplemental inhibitors.
3. If other than Caterpillar supplemental coolant additive is used, follow the supplier's recommendation for the treatment and test evaluation. Do not mix corrosion additives within a cooling system; select an effective one and then use it exclusively.
4. Use only enough antifreeze to meet freeze protection requirements. Never use over 60% by volume.
5. Never top up with pure antifreeze. Premix antifreeze and water for makeup to provide the same freeze protection that's in your cooling system.

Comments or Notes:

Conventional Antifreeze / Coolant Information

The following coolants are the primary types of coolants that are used in Caterpillar Engines:

Preferred - Caterpillar Extended Life Coolant (ELC) or a commercial extended life coolant that meets the Caterpillar EC-1 specification.

Acceptable - Caterpillar Diesel Engine Antifreeze/Coolant (DEAC) or a commercial heavy-duty coolant/antifreeze that meets "ASTM D4985" or "ASTM D5345" specifications.

Comments or Notes:

Extended Life Coolant (Preferred)

Now, worry-free maintenance of your engines coolant system is easy. With Caterpillar Extended Life Coolant (ELC), you get cooling system and engine protection that last longer than traditional coolants without the hassle of adding Supplemental Coolant Additives (SCA's).

The anti-corrosion package for Caterpillar ELC is different from the anti-corrosion package for other coolants. Caterpillar ELC is an ethylene glycol base coolant. However, Caterpillar ELC contains organic corrosion inhibitors and antifoam agents with low amounts of nitrite. Caterpillar ELC has been formulated with the correct amount of these additives in order to provide superior corrosion protection for all metals in engine cooling systems.

ELC extends the service life of the coolant to six years. The service life of coolant is also limited by use (service hours). ELC does not require frequent additions of a Supplemental Coolant Additive (SCA). An Extender is the only additional maintenance that is needed at three years or one half of the ELC service life.

A premixed solution of ELC and distilled water is available in a 1:1 concentration. The Premixed ELC provides freeze protection to -36 degree C (-33 degree F). The Premixed ELC is recommended for the initial fill and topping off of the cooling system.

ELC Concentrate is also available in mixture to lower the freezing point to -51 degree C (-60 degree F).
NOTE: Caterpillar developed the EC-1 specification as an industry standard. ELC meets the performance requirements of "ASTM D4985" and ASTM D5345" for heavy-duty low silicate coolant/antifreeze.

Protection Temperatures for Antifreeze Concentrations(1)	
Protection Temperature	**Concentration**
-15 deg. C (5 deg. F)	30% antifreeze, 70% water
-24 deg. C (-12 deg. F)	40% antifreeze, 60% water
-36 deg. C (-33 deg. F)	50% antifreeze, 50% water
-52 deg. C (-62 deg. F)	60% antifreeze, 40% water

(1) Ethylene glycol-based antifreeze.

Extended Life Coolant (ELC) Cooling System Maintenance

Caterpillar ELC Extender

Caterpillar ELC Extender is added to the cooling system halfway through the ELC service life. Treat the cooling system with ELC Extender at three years or one half of the coolant service life.

Adding Caterpillar ELC Extender

The amount of ELC Extender that is required depends on the capacity of the cooling system. Use the formula below in order to determine the proper amount of ELC Extender that is required.

Formula For Adding Extender To ELC
V x 0.02 = X V = the amount volume of the cooling system. X = the amount of ELC Extender that is required.

Comments or Notes:

Diesel Engine Antifreeze/Coolant (DEAC) (Acceptable)

If Caterpillar Extended Life Coolant (ELC) is not available Caterpillar recommends using Caterpillar Diesel Engine Antifreeze/Coolant (DEAC) for cooling systems that require a heavy-duty coolant/antifreeze. Caterpillar DEAC is an alkaline single-phase ethylene glycol type antifreeze that contains anti-foam agents and the proper amount of protection against corrosion on aluminum parts. With this protection it also has built-in corrosion protection against cylinder liner and block pitting in diesel engines, but not so much that chemicals drop out of solution and form harmful deposits. The combination of Caterpillar Antifreeze and supplemental coolant additive is a chemical system designed to work together for optimum performance. Caterpillar Antifreeze, Part Number 8C3684 (1 gallon) 8C3686 (55 gallon), is a ethylene-glycol based solution to protect against freezing.

Caterpillar DEAC was introduced specifically formulated with the correct amount of Caterpillar Supplemental Coolant Additive (SCA) to combat the problem of over-concentration of coolant inhibitors and for use in all types of heavy-duty diesel engines. Do not use SCA at the initial fill when DEAC is used. Simply add conditioner at the first 250 service hours and each successive 250 hours when needed.

If concentrated DEAC is used, Caterpillar recommends mixing the concentrate with distilled water or with deionized water. If distilled water is not available, use water that has the required properties.

Protection Temperatures for Antifreeze Concentrations(1)	
Protection Temperature	**Concentration**
-15 deg. C (5 deg. F)	30% antifreeze, 70% water
-24 deg. C (-12 deg. F)	40% antifreeze, 60% water
-36 deg. C (-33 deg. F)	50% antifreeze, 50% water
-52 deg. C (-62 deg. F)	60% antifreeze, 40% water

(1) Ethylene glycol-based antifreeze.

Supplemental Coolant Additive (SCA)

After an acceptable water has been found, it should be mixed with a corrosion inhibitor. The cooling system MUST contain supplemental coolant a additive (SCA) for proper engine protection, regardless of antifreeze concentration. SCA is necessary to inhibit rust, scale, deposits, cavitation, pitting, and corrosion of the engine parts that coolant comes in contact with. Use SCA liquid to maintain a three to six percent (3 - 6 %) SCA concentration in the coolant.

NOTE: The addition of a corrosion inhibitor in "poor" quality water will not make the water "acceptable". If poor quality water is used in the coolant mixture, the inhibitor can help, but protection against corrosion and pitting is rare.

Do not use coolant only unless Caterpillar DEAC is used. SCA is a premixed in Caterpillar DEAC. SCA is not needed for initial fill when Caterpillar DEAC is used. SCA is required on a maintenance basis, even when using Caterpillar DEAC.

SCA is required on initial fill and for subsequent maintenance when using coolant / antifreeze products which meet ASTM D4985 standards. On initial fill or refill, add .95L (1 qt) of SCA or equivalent for each 19L (5 gal) of ASTM D4985. The solution should have a three to six percent (3 - 6 %) concentration of SCA.

NOTE: This is important. Too much corrosion inhibitor in a coolant mixture will form insoluble salts which can cause wear on water pump seal surfaces.

If the salt concentration in the engine coolant mixture is more than 200 ppm because of the addition of water or evaporation in the cooling system, the corrosion inhibitor's effect will be limited. The cooling system must be drained, flushed until it is clean and then filled with new coolant.

Supplemental Coolant Additive (SCA) to Conventional Coolant/Anti-freeze at the Initial Fill.

NOTE: Caterpillar DEAC DOES NOT require an addition of SCA when the cooling system is initially filled.

Commercial heavy-duty coolant/antifreeze that meets "ASTM D4985" or "ASTM D5345" specifications MAY require an addition of SCA when the cooling system is initially filled. Read the label or the instructions that are provided by the Supplier of the product.

The size of the cooling system determines the amount of SCA that is required. Use the formula to determine the amount of SCA that may be required when the cooling system is initially filled with heavy duty coolant/antifreeze that meets "ASTM D4985" or "ASTM D5345" specifications.

Formula For Adding The SCA At The Initial Fill For Coolant/Antifreeze That Meets "ASTM D4985" or "ASTM D5345" specifications. (1)
V x 0.045 = X V = the amount volume of the cooling system. X = the amount of SCA that is required.

(1) Read the label or the instructions that are provided by the Supplier of the product.

<u>Comments or Notes:</u>

Supplemental Coolant Additive (SCA) to Conventional Coolant/Anti-freeze For Maintenance

Heavy-duty coolant/antifreeze of all types REQUIRE periodic additions of an SCA. For the interval, see the "Maintenance Interval Schedule". SCA test kits are available from your Caterpillar dealer. Test the concentration of SCA or submit a coolant sample to your local Caterpillar dealer for a complete coolant analysis.

Additions of SCA are based on the results of the test or based on the results of the coolant analysis. The size of the cooling system determines the amount of SCA that is required.

Use the formula to determine the amount of SCA that is required.

Formula For Adding The SCA To Conventional Coolant/Antifreeze That Meets "ASTM D4985" or "ASTM D5345" specifications For Maintenance. (1)
V x 0.014 = X V = the amount volume of the cooling system. X = the amount of SCA that is required.

NOTE: Specific engine applications may require maintenance practices to be periodically evaluated in order to properly maintain the engine's cooling system.

<u>Comments or Notes:</u>

Water/Supplement Coolant Additive

NOTICE

To help prevent water pump cavitation, Caterpillar recommends a minimum of 30 percent of glycol in the coolant/anti-freeze mixture.

Use a mixture that will provide protection against the lowest ambient temperature.

100 percent pure glycol will freeze at a temperature of -13 degree C (9 degree F)

NOTICE

Never use water alone without Supplemental Coolant Additives (SCA) or without inhibited coolant. Water alone is a corrosive at engine operating temperatures. Water alone does not provide adequate protection against formation of mineral deposits, cavitation, foaming, boiling or freezing.

If Caterpillar SCA is not used, select a commercial SCA. The commercial SCA must provide a minimum of 2400 mg/L or 2400 ppm (140 grains/US gal.) of nitrates in the final coolant mixture.

The quality of the water is a very important factor in this type of cooling system. Distilled water or deionized water is recommended for use in cooling systems. If distilled water or deionized water is not available, water that has the required properties may be used.

A cooling system that uses a mixture of only SCA and water requires more SCA than a cooling system that uses a mixture of glycol and water. The SCA and water requires six to eight percent of SCA.

Adding the SCA to Water at the Initial Fill

The capacity of the cooling system determines the amount of SCA that is required. Use the formula to determine the amount of SCA that is required at the initial fill of the cooling system. This formula is for a mixture of only SCA and water.

Formula For Adding SCA To Water (ONLY) At The Initial Fill
V x 0.07 = X V = the amount volume of the cooling system. X = the amount of ELC Extender that is required.

Comments or Notes:

Adding the SCA to Water for Maintenance

Test the mixture of SCA and water periodically for the concentration of SCA. Check the " Maintenance Interval Schedule" for the service interval.

Test the concentration of SCA with the 8T5296 Coolant Conditioner or with coolant analysis.

Instructions are provided with the 8T5296 Coolant Conditioner Test Kit.

Procedure for Testing Ethylene Glycol Range.

This test is designed to indicate the ratio of ethylene glycol to water. It is not a test for determining freeze or boiling protection. The 1U7297 or 5P0957 Coolant and Battery Tester (degree F) or the 1U7298 Coolant and Battery Tester (degree C) can be used to test freezing point.

This test requires the 2 ball specific gravity tester.

Step 1… Use specific gravity tester to draw coolant directly from the cooling system and discharge to rinse inside the tester.

Step 2… Draw fresh coolant slowly from the cooling system until solution reaches 3/4 level in tester.

Step 3… Tap tube to remove any air bubbles.

Step 4… Read number of balls floating to determine percent of ethylene glycol.

- a… No Balls: Less than 30 % ethylene glycol mixture.
- b… One ball: 30% to 60% ethylene glycol mixture.
- c… Two balls: Greater than 60% ethylene glycol mixture.

Procedure for Testing Coolant Conditioner Levels.

This test measures the concentration of COOLANT CONDITIONER. This test is an accurate and simple method for determining if the coolant contains an acceptable 6% to 8% concentration of COOLANT CONDITIONER.
This test requires the dropper pipet, empty scribed vial, Solution A (1U6863 Orange) and Solution B (1U6864 Red).

Step 1… Fill dropper pipet to the 1.0 ml. Mark with coolant to be tested.

Step 2… Dispense the 1.0 ml. Coolant sample from the dropper pipet into the empty vial.

Step 3… Add tap water to the vial up to the 20 ml. mark. Replace the vial cap and shake.

Step 4… Add 2 or 3 drops of **RED Solution B** to the vial and swirl to mix.

Step 5… Add 1 drop of **ORANGE Solution A** to the vial and swirl to mix. Continue this procedure of adding one drop (of Solution A) and swirling until the vial solution changes color from RED to a pale gray, green or blue. Record the number of drops (Solution A) required to cause the color to change.

NOTE: The Solution A vial should be held in a perfectly vertical plane, when adding drops, to insure most accurate test results.

Note: When the defined procedure is used, a concentration of six to eight percent will yield between 20 and 27 drops. If the number of drops is above 27, the concentration of SCA is high. Make the appropriate adjustments to the concentration of SCA.

Step 6… Compare the percent concentration of Ethylene Glycol and the number of drops counted verses the percent concentration of Ethylene Glycol and the number of drops in one of the two charts below to find out what maintenance must be performed.

Additions of SCA are based on the results of the test or based on the results of the coolant analysis. The capacity of the cooling system determines the amount of SCA that is required.

The chart below is for the Range of 0% to 30% Ethylene Glycol.

Conditioner In 0% to 30% Ethylene Glycol	Concentration of Coolant Conditioner	Maintenance Required
0 - 6 Drops	**Dangerous** NO Conditioner	**Initial Charge** Requires
7 -19 Drops	**Under** Concentrated	**Add** Conditioner
20 -28 Drops	**Recommended** (6% - 8%)	**None OK**
29 - 51 Drops	**Over** Concentrated	**Re-Check** Antifreeze Concentration
Over 52 Drops	**Dangerous - Excessive** Conditioner	**Drain 50 %** of coolant and replace with water/antifreeze. Recheck

The chart below is for the Range of 31% to 60% Ethylene Glycol.

Conditioner In 0% to 30% Ethylene Glycol	Concentration of Coolant Conditioner	Maintenance Required
0 - 10 Drops	**Dangerous** NO Conditioner	**Initial Charge** Requires
11 - 23 Drops	**Under** Concentrated	**Add** Conditioner
24 - 32 Drops	**Recommended** (3% - 6%)	**None OK**
33 - 55 Drops	**Over** Concentrated	**Re-Check** Antifreeze Concentration
Over 56 Drops	**Dangerous - Excessive** Conditioner	**Drain 50 %** of coolant and replace with water/antifreeze. Recheck

Formula For Adding SCA To Water (ONLY)
For Maintenance

$$V \times 0.023 = X$$

V = the amount volume of the cooling system.
X = the amount of ELC Extender that is required.

NOTE: Specific engine applications may require maintenance practices to be periodically evaluated in order to properly maintain the engine's cooling system.

Comments or Notes:

S•O•S Coolant Analysis

Testing the engine coolant is important to ensure that the engine is protected from internal cavitation and from corrosion. The analysis also tests the ability of the coolant to protect the engine from boiling and from freezing.

Coolant analysis can be performed at your Caterpillar dealership. Caterpillar's S•O•S coolant analysis is an excellent way to monitor the condition of your coolant and your cooling system.

The most critical aspect of coolant analysis is the interpretation of the results. Different coolants have different formulations and different condemning limits. Different commercial labs may use different methods to test for the same variable. These other considerations are also important for interpreting the results of a coolant analysis.

- The number of hours on the sample.
- The equipment that uses the coolant.
- The application of the equipment.

Analysis at Caterpillar S•O•S fluid labs are trained to determine the acceptability of coolants. These analysis have the knowledge of the equipment and applications. These qualifications enable the analysis to detect problems before damage occurs.

NOTICE

DO NOT use the same vacuum sampling pump for extracting oil samples that is used for extracting coolant samples.

A small residue of either type sample may remain in the pump and may cause a false positive analysis for the sample being taken.

Always use a designated pump for oil sampling and a designated pump for coolant sampling

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S•O•S coolant analysis is a two-level program that does more than just check the condition of your coolant. It determines the overall condition of the cooling system and can identify problems with maintenance procedures and operational practices.

Level 1: Basic Coolant Maintenance Check consists of four analytical tests and four observational parameters that not only show major problems with the coolant, but can also predict some major cooling systems problems. Level 1 results can also determine when Level 2 analysis is needed.

Level 2: Comprehensive Cooling System Analysis involves an extensive chemical evaluation of the coolant and its overall effects on the inside of your cooling system. This series of comprehensive tests can identify subtle cooling system problems, determine probable causes, and help prioritize the urgency of needed corrections.

Comments or Notes:

Comments or Notes:

Fuel Specifications:

CATERPILLAR DISTILLATE DIESEL FUEL SPECIFICATIONS	
Specifications (ASTM Test)	**Requirements**
Aromatics (D 1319)	35% maximum
Ash (D 482)	0.02% weight maximum
Carbon Residue on10% bottoms (D524)	1.05% weight maximum
Cetane Number (D613)	40 minimum
Cloud Point (D97)	maximum not above lowest expected ambient temperature
Copper Strip Corrosion (D130)	No. 3 maximum
Distillation (D86)	10% @ 282° C (540° F) maximum 90% @ 360° C (680° F) maximum
Flash Point (D93)	legal minimum
API Gravity (D287)	30 minimum/45 maximum
Pour Point (D97)	6° C (10° F) minimum below ambient temperature
Sulfur (D3605 or D1552)	3% maximum
Viscosity (D445) Kinematic @ 40° C (104° F)	1.4cSt minimum 20.0 cSt maximum
Water & Sediment (D1796)	0.1% maximum
Water (D1744)	0.1% maximum
Sediment (D473)	0.05% weight maximum
Gums & Resins (D381)	10 mg/100 ml maximum
Lubricity by Scuffing Load Wear Test or High Frequency Reciprocating Rig	3100 g minimum 0.45 mm maximum at 60° C (140° F) or 0.38 maximum at 25° C (77° F)

Comments or Notes:

Comments or Notes:

Adjustments:

NOTE: When using this section of the Maintenance & Technical Service Book it is only to be used as a reference guide (no pictures) to complete the procedure. The Testing and Adjusting Manual (pictures included) should be used for first time users.

Valve Lash Check

A valve lash adjustment is NOT NECESSARY if the measurement of the valve lash is in the acceptable range. The acceptable range is given in Table Below. Caterpillar Inc. recommends adjustment of the valve lash after the following intervals:

The first 1000 hours of operation

2000 hours of operation

Every 2000 hours of operation

	Tools Needed	**Qty**
4C-6594	Timing & Fuel Setting Tool	1
4C-6593	Valve Lash Tool	1
6V-3075	Dial Indicator	1
8S-3675	Indicator Contact Point	1
8T-1000	Electronic Position Indicator	1
1U-7234	Feeler Gauge (2)	1

Valve Clearance Check: Engine Stopped (1)	
Valves	**Acceptable Clearance Range**
Intake	0.52 to 0.68 mm (0.020 to 0.027 inch)
Exhaust	0.92 to 1.08 mm (0.036 to 0.042 inch)

(1) The valve lash check should only be done while the engine is stopped.

(2) The Feeler Gauge is a alternate method of checking valve adjustment. (see procedure on using gauge)

Use the procedure that follows to check the valve lash setting using the dial indicator:

1. Rotate the No. 1 piston to the Top Center position. Refer to Testing And Adjusting, "Fuel System". With the No. 1 piston at the Top Center position of the compression stroke, check the valves.

2. Adjust the valve bridges. Refer to "Bridge Adjustment".

3. Insert the 6V-3075 Dial Indicator from the timing group into the 4C-6593 Adjustment Tool. Tighten the retaining screw finger tight.

> **Note:** Make sure that the 6V-3075 Dial Indicator is used with the short contact point.

4. Use the threaded hole that is nearest to the end of the rocker arm that will be adjusted in order to install the adjustment tool on the rocker base. Position the dial indicator stem over the flat area on the end of the rocker arm. Tighten the knob. Rotate the dial indicator so that the dial indicator can be easily read. Make sure that the adjustment tool is rigid and that the dial indicator stem moves freely.

5. Lift up firmly on the end of the rocker arm that has the adjusting screw and set the dial indicator to zero.

6. Lift up firmly on the valve end of the rocker arm and read the dial indicator.

7. Try to move the rocker arm while you are lifting up on the rocker arm. The dial indicator reading will vary. Read the dial indicator when the rocker arm is positioned in the groove of normal operation. Refer to Table 17 for the specifications regarding valve lash. If the dial indicator reading is within specifications move to the next valve.

8. If the dial indicator reading is not within specifications reset the valve lash. After the adjustment is complete proceed to the next valve. Refer to "Valve Lash Adjustment ".

9. After completing all of the valve lash checks and the valve lash adjustments for this crankshaft position, remove the timing pin from the crankshaft. Rotate the crankshaft 360 degrees to the next position. Install the timing pin in the crankshaft. Repeat Steps 2 through 8.

10. Remove the timing pin from the crankshaft when all valve lash adjustments have been completed.

The following procedure, using a Feeler Gauge is an alternate method that can be used for checking the valve lash clearance:

1. Rotate the No. 1 piston to the Top Center position. Refer to Testing And Adjusting, "Fuel System". With the No. 1 piston at the Top Center position of the compression stroke, adjust the valves.

Note: Prior to making any adjustments, tap each rocker arm at the top of the adjustment screw with a soft hammer. Tapping the rocker arm ensures that the lifter roller is seated against the base circle of the camshaft.

2. Loosen the locknut for the rocker arm adjustment screw. If there is not enough clearance for the feeler gauge between the rocker arm and the bridge contact surface, turn the adjustment screw counterclockwise in order to increase the valve lash.

3. Put a feeler gauge of the correct dimension between the rocker arm and bridge contact surface. Turn the adjustment screw clockwise until the valve lash is set to the correct specification.

NOTICE

Special care must be given when sliding the feeler gauge back and forth for proper fit. The special swivel foot on the end of the rocker arm can make the adjustment feel tight thus causing the final adjustment to be loose.

4. After each check, if adjustment necessary, use the Valve Lash Adjustment procedure for proper setting and torque of the adjustment screw and locknut.

5. After completing all of the valve lash checks and the valve lash adjustments for this crankshaft position, remove the timing pin from the crankshaft. Rotate the crankshaft 360 degrees to the next position. Install the timing pin in the crankshaft. Repeat Steps 2 through 4.

6. Remove the timing pin from the crankshaft when all valve lash adjustments have been completed.

Comments or Notes:

Valve Lash Adjustment

NOTICE

The procedures for engine valve lash should be performed according to the information in the Service Manual.

Operation of Caterpillar engines with improper valve adjustments will reduce engine efficiency. This reduced efficiency could result in excessive fuel usage and/or shortened engine component life.

Note: The first interval that is recommended for the valve lash setting for a new engine or a rebuilt engine is 1000 hours and then every 2000 hours after.

	Tools Needed	Qty
4C-6594	Timing & Fuel Setting Tool	1
4C-6593	Valve Lash Tool	1
6V-3075	Dial Indicator	1
8S-3675	Indicator Contact Point	1
8T-1000	Electronic Position Indicator	1
1U-7234	Feeler Gauge (2)	1

Setting Valve Lash: (1)	
Valves	**Acceptable Clearance Range**
Intake	0.60 mm (.024 in.)
Exhaust	1.0 mm (.039 in.)

(1) The valve lash check should only be done while the engine is stopped.

(2) The Feeler Gauge is a alternate method of checking valve adjustment. (see procedure on using gauge)

Use the procedure that follows for the adjustment of the valve lash setting using a dial indicator:

1. Rotate the No. 1 piston to the Top Center position. Refer to Testing And Adjusting, "Fuel System". With the No. 1 piston at the Top Center position of the compression stroke, adjust the valves.

2. Adjust the valve bridges. Refer to "Bridge Adjustment".

3. Insert the 6V-3075 Dial Indicator from the timing group into the 4C-6593 Adjustment Tool. Tighten the retaining screw finger tight.

Note: Make sure that the 6V-3075 Dial Indicator is used with the short contact point.

4. Use the threaded hole that is nearest to the end of the rocker arm that will be adjusted in order to install the adjustment tool on the rocker base. Position the dial indicator stem over the flat area on the end of the rocker arm. Tighten the knob. Rotate the dial indicator so that the dial indicator can be easily read. Make sure that the adjustment tool is rigid and that the dial indicator stem moves freely.

5. Loosen the locknut on the rocker arm adjustment screw and turn the rocker arm adjustment screw clockwise until there is no valve lash. Loosen slightly. The valve lash should be zero. The valves should not be open any amount.

6. Set the dial indicator to zero.

7. Lift up firmly on the valve end of the rocker arm and turn the rocker arm adjustment screw until the dial indicator shows 0.60 mm (.024 inch) for the inlet valves, and 1.00 mm (.039 inch) for the exhaust valves.

8. Try to move the rocker arm while you are lifting up on the rocker arm. The dial indicator reading will vary. Read the dial indicator when the rocker arm is positioned in the groove of normal operation.

9. Tighten the locknut on the adjusting screw to a torque of 200 ± 25 N·m (150 ± 18 lb ft).

10. Recheck the valve lash setting to ensure that the valve lash is correct. Reset, as required.

11. After completing all of the valve lash checks and the valve lash adjustments for this crankshaft position, remove the timing pin from the crankshaft. Rotate the crankshaft 360 degrees to the next position. Install the timing pin in the crankshaft. Repeat Steps 2 through 10.

12. Remove the timing pin from the crankshaft when all valve lash adjustments have been completed.

The following procedure using a Feeler Gauge is an alternate method that can be used for the adjustment of the valve lash:

1. Rotate the No. 1 piston to the Top Center position. Refer to Testing And Adjusting, "Fuel System". With the No. 1 piston at the Top Center position of the compression stroke, adjust the valves.

Note: Prior to making any adjustments, tap each rocker arm at the top of the adjustment screw with a soft hammer. Tapping the rocker arm ensures that the lifter roller is seated against the base circle of the camshaft.

2. Loosen the locknut for the rocker arm adjustment screw. If there is not enough clearance for the feeler gauge between the rocker arm and the bridge contact surface, turn the adjustment screw counterclockwise in order to increase the valve lash.

3. Put a feeler gauge of the correct dimension between the rocker arm and bridge contact surface. Turn the adjustment screw clockwise until the valve lash is set to the correct specification.

NOTICE

Special care must be given when sliding the feeler gauge back and forth for proper fit. The special swivel foot on the end of the rocker arm can make the adjustment feel tight thus causing the final adjustment to be loose.

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4. After each adjustment, tighten the locknut for the adjustment screw to a torque of 200 ± 25 N·m (150 ± 18 lb ft) and check the adjustment again.

5. After completing all of the valve lash checks and the valve lash adjustments for this crankshaft position, remove the timing pin from the crankshaft. Rotate the crankshaft 360 degrees to the next position. Install the timing pin in the crankshaft. Repeat Steps 2 through 4.

6. Remove the timing pin from the crankshaft when all valve lash adjustments have been completed.

Bridge Adjustment

When the cylinder head is disassembled, keep the bridges and the respective valves together. To make an adjustment to the bridges, use the procedure that follows:

Note: The bridges can be adjusted without removal of the rocker arms and shafts. Valves must be fully closed when the adjustment is made. Refer to Testing And Adjusting, "Fuel System".

1. Lubricate bridge dowel in the cylinder head and the bore in bridge with 8T-2998 Lubricant.

2. Install bridge. The adjustment screw should be positioned toward the exhaust manifold.

3. Loosen locknut and adjustment screw for several turns.

4. Put a force of 50 ± 10 N (11 ± 2 lb) by hand straight down on top contact surface of bridge.

5. Turn adjustment screw clockwise, until the adjustment screw makes contact with the valve stem. Turn the adjustment screw clockwise for another 45 degrees in order to make bridge straight on the bridge dowel. Also, this additional rotation compensates for the clearance in the threads of the adjustment screw.

6. Hold adjustment screw in this position and tighten locknut to a torque of 100 ± 15 N·m (75 ± 11 lb ft).

7. If the bridges were removed, put clean engine oil on top contact surface at the contact point between the rocker arm and bridge.

Fuel Injector Synchronization

	Tools Needed	Qty
4C-6594	Timing and Fuel Setting Tool.	1
6V-9057	Rack Synchronizing Gauge	1

1. Loosen the locknuts on the governor rod assembly. Adjust the rod to the minimum length.

2. Remove the plugs from control housing.

3. Remove the synchronizing pin from the storage location.

4. Install synchronizing pin without the washer.

5. Turn the actuator terminal shaft to the "FUEL ON" position until the flat face of the fuel stop lever contacts synchronizing pin. This is the synchronizing position or zero reference point. Hold the control linkage in this position when the injectors are adjusted.

6. Remove the valve covers.

7. Use a screwdriver in order to pull up on each fuel control rod. This will ensure that the rods and the fuel injector racks are free.

9. Put 6V-9057 Rack Synchronizing Gauge in position on one of the injectors. This gauge sits on the round part of the injector rack bar between the trim screw and the end of the rack bar. The gauge block should make complete contact with the trim screw and the surface of the rack bar. The trim screw is provided on the injectors in order to adjust the rack's zero point. This should be done **AT THE FACTORY ONLY**. If a unit injector is found to have a loose trim screw, the unit injector must be replaced with a calibrated unit injector. If a trim screw has been moved, the unit injector must be replaced with a calibrated unit injector. The fuel injector cannot be synchronized if the trim screw has been moved.

Note: If the correct adjustment cannot be obtained by adjusting fuel control rod, loosen the locknuts on rod assembly, and adjust the rod assembly until the correct adjustment can be obtained.

9. While the fuel stop lever is against the synchronizing pin, and the 6V-9057 Rack Synchronizing Gauge is in the position use a screwdriver and make an adjustment of control rod. Turn the screw on control rod slowly. This should be done until the rack synchronizing gauge just fits between the fuel injector body (Trim Screw) and the shoulder at the end of the rack. Remove the screwdriver from control rod. This will ensure that no pressure is on the linkage while the setting is checked with rack synchronizing gauge. Any pressure on the linkage by the screwdriver will not give a correct indication when the setting is checked with rack synchronizing gauge. Move the linkage in order to ensure that the linkage is free and move the linkage in order to ensure that the linkage is giving the correct setting. Check the setting again.

10. Repeat Steps 8 and 9 for the remaining racks.

11. Install the 6V-3075 Dial Indicator. When the 5P-7263 Contact Point seats against fuel stop lever, slide the dial indicator inward or slide the dial indicator outward until the dial indicator reads 0.00 mm (0.000 inch). Tighten the 5P-4814 Collet Clamp enough to hold the indicator in the position.

12. Remove the synchronizing pin and return the synchronizing pin to the storage location.

Note: If a governor actuator linkage is used, see the subject "Adjusting The Governor Actuator Linkage ".

Adjusting The Governor Linkage On The 3161 Governor

	Tools Needed	Qty
1U-9361	Governor Torque Arm Tool	1
4C-6594	Timing & Fuel Setting Tool	1
6V-3075	Dial Indicator	1
5P-4814	Collet Clamp	1
5P-7263	Indicator Contact Point	1
8T-1000	Electronic Position Indicator	1

Note: The 8T-1000 Electronic Position Indicator maybe used in place of the 6V-3075 Dial Indicator

Note: Before the governor linkage adjustment is made, the fuel injectors must be correctly synchronized. See the subject "Fuel Injector Synchronization ".

1. Remove the two plugs and sealing washers from the governor control housing.

2. Remove synchronizing pin from the storage location in the governor control housing. Remove the spacer from the synchronizing pin and install the synchronizing pin in the governor control housing where the horizontal plug was removed. Tighten the synchronizing pin to 10 ± 2 N·m (7 ± 1 lb ft).

3. Rotate the actuator shaft in the "FUEL ON" direction until the fuel stop lever is against the synchronizing pin. Hold the actuator shaft in position by installing a 1U-8795 Governor Torque Arm Tool on the opposite end of the governor terminal shaft. The rod assembly connects to the same end.

4. Either an 4C-6594 Timing and Fuel Setting Tool or a 8T-1000 Electronic Position Indicator are acceptable to use. One of these tools will be installed in the vertical threaded hole of the governor control housing.

a. For the 4C-6594 Timing and Fuel Setting Tool, install the 5P-4814 Collet Clamp in the vertical threaded hole. Slide the 6V-3075 Dial Indicator with the 5P-7263 Indicator Contact Point into the 5P-4814 Collet Clamp. When the contact point seats against the fuel stop lever, slide the indicator inward or slide the indicator outward until the indicator dial reads +5.00 mm (+0.197 inch). Tighten the collet in order to hold the indicator in position. The indicator is now ready to be used.

b. For the 8T-1000 Electronic Position Indicator, install the 5P-4814 Collet Clamp in the vertical threaded hole. Slide the 8T-1002 Probe with the 5P-7263 Indicator Contact Point into the 5P-4814 Collet Clamp until the 8T-1002 Probe sleeve bottoms in the 5P-4814 Collet Clamp. Tighten the collet enough to hold the probe in position. Attach the probe to the 8T-1001 Electronic Indicator. Turn the indicator "ON" and set the indicator to measure millimeters. With the indicator "ON", touch the negative "-" button. Then touch the zero button. The indicator is now ready to be used.

5. Rotate governor terminal shaft toward minimum fuel until governor rig pin can be depressed. Put a 5/32 inch hex wrench in governor rig pin. Push the rig pin inward and turn the rig pin counterclockwise until the roll pin locks squarely behind the bracket.

Note: Governor rig pin is used while the governor control rod assembly is adjusted in order to stop the governor terminal shaft at a fixed position. This is done in order to synchronize the governor travel with the engine fuel control linkage travel. **Engage the pin only when the engine is off.**

6. Loosen synchronizing pin, five to six turns (out).

7. Gently rotate governor terminal shaft toward maximum fuel until contact is made with the governor rig pin. Hold shaft in place. The dead weight that is used during unit injector synchronization may also be used in order to hold the governor terminal shaft against the governor rig pin.

8. Adjust rod assembly. Use the appropriate procedure that follows.

   a. If the 4C-6594 Timing and Fuel Setting Tool is being used, adjust the rod assembly until the 6V-3075 Dial Indicator displays a reading of +5.00 mm (+0.197 inch). Secure the rod assembly in place with the locknuts. Ensure that each rod end on the rod assembly has the same amount of thread engagement.

   b. If the 8T-1000 Electronic Position Indicator is being used, adjust the rod assembly until the 8T-1001 Electronic Indicator displays a reading of 0.00 mm (0.000 inch). Secure the rod assembly in place with the locknuts. Ensure that each rod end on the rod assembly has the same amount of thread engagement.

9. Rotate governor terminal shaft toward minimum fuel. Put a 5/32 inch hex wrench in governor rig pin. Push the rig pin inward and turn the rig pin clockwise until the roll pin unlocks from the bracket. This puts the pin back into the pin's normal running position. The governor is now synchronized to the engine.

b. When the 6V-3075 Dial Indicator is used, the reading should be between -4.50 mm (-0.177 inch) and -7.00 mm (-0.276 inch). If the reading is more positive than -4.50 mm (-0.177 inch), the linkage adjustment procedure must be repeated. [-3.75 mm (-0.148 inch) is an example of a reading that is more positive than -4.50 mm (-0.177 inch)].

b. When the 8T-1001 Electronic Indicator is used, the correct reading is between -9.50 mm (-.374 inch) and -12.00 mm (-0.4724 inch). If the reading is more positive than -9.50 mm (-0.374 inch), the linkage adjustment procedure must be repeated. [(-8.75 mm (-0.344 inch)is an example of a number that is more positive than -9.50 mm (-0.374 inch)].

! WARNING !

Personal injury or death can result from flying objects generated by engine overspeed. The engine could overspeed as a result of improper linkage assembly, adjustment, or governor deadband. Be prepared to stop the engine by activating the engine air shut-off or closing the air off to the air inlets.

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10. The definition of governor deadband is the total amount of travel between the point of actual fuel shutoff and the actual "FUEL OFF" position. When the 6V-3075 Dial Indicator is used and when the reading of the maximum governor "FUEL OFF" is more positive than -4.50 mm (-0.177 inch), the governor deadband can be eliminated. (-3.75 mm (-0.148 inch) is an example of a reading that is more positive than -4.50 mm (-0.177 inch)). When the 8T-1001 Electronic Indicator is used

and when the reading of the maximum governor "FUEL OFF" is more positive than -9.50 mm (-0.374 inch), the governor deadband can be eliminated. (-8.75 mm (-0.344 inch) is an example of a reading that is more positive than -9.50 mm (-0.374 inch)). This can cause engine overspeed.

11. Tighten synchronizing pin to a torque of 10 ± 2 N·m (7 ± 1 lb ft).

12. Gently rotate the governor terminal shaft toward the maximum fuel position until the fuel stop lever makes contact with synchronizing pin.

13. When the 6V-3075 Dial Indicator is used, ensure that the dial indicator still reads +5.00 mm (+0.197 inch). When the 8T-1001 Electronic Indicator is used, ensure that the electronic indicator gives a reading of 0.00 mm (0.000 inch). If indicated reading is not correct, repeat Steps 3 through 9. If the indicated reading is correct, continue with the procedure. If the 6V-3075 Dial Indicator is used, adjust the dial indicator in order to read 0.00 mm (0.000 inch). This must be done before continuing the procedure.

14. Check the fuel setting. See the subject "Fuel Setting Check ".

15. Remove the 1U-8795 Governor Torque Arm Tool from the governor terminal shaft.

16. Remove synchronizing pin and install the sealing washer and plug. Install the spacer and synchronizing pin in the storage location.

17. Remove all tooling from the governor control housing. Install the sealing washer and plug.

18. 18.Before starting the engine, put a mark on the governor position indicator at the point of minimum governor travel. This is the engine's stopped position.

! WARNING !

The engine may overspeed due to incorrect assembly or adjustment.

Engine overspeed could result in personal injury, loss of life and/or property damage.

Be prepared to stop the engine by activating the engine shutdown system or closing the air inlet lines.

Note: It may be necessary to back off the fuel ratio control setting in order to start the engine after this adjustment. This is done by first removing the plug from the right front corner of the governor's top cover. The governor is viewed from the end of the governor output shaft. Put a 3/16 hex wrench through the hole in the top cover until the wrench engages the adjustment screw. Turn the screw in the counterclockwise direction until the engine is able to start. This will take several turns.

19. Start the engine and operate the engine at low idle. Put a mark on the governor position indicator. This is the engine running position.

20. The engine running position of the governor must be six or more degrees above the engine's stopped position.

21. Operate the engine at high idle with no load in order to ensure that the governor can control the engine.

22. The fuel ratio control setting must be readjusted even if an adjustment was required in order to start the engine.

Adjusting The Governor Actuator Linkage on the EGB

	Tools Needed	Qty
1U-9361	Governor Torque Arm Tool	1
4C-6594	Timing & Fuel Setting Tool	1
6V-3075	Dial Indicator	1
5P-4814	Collet Clamp	1
5P-7263	Indicator Contact Point	1
8T-1000	Electronic Position Indicator	1

Note: The 8T-1000 Electronic Position Indicator maybe used in place of the 6V-3075 Dial Indicator

The governor actuator linkage must be adjusted in order to synchronize the actuator travel with the fuel control linkage position.

Note: Before the adjustment of the actuator linkage is made, the fuel injectors must be correctly synchronized. Refer to Testing And Adjusting, "Fuel Injector Synchronization".

1. Remove the two plugs and sealing washers from the governor control housing.

2. Remove synchronizing pin from the storage location in the governor control housing. Remove the spacer from the synchronizing pin and install the synchronizing pin in the governor control housing where the horizontal plug was removed. Tighten the synchronizing pin to 10 ± 2 N·m (7 ± 1 lb ft).

3. Rotate shaft in the "Fuel On" direction until the flat surface of the fuel stop lever contacts synchronizing pin. Hold the shaft in position. Dead weights are recommended.

4. Either a 4C-6594 Timing and Fuel Setting Tool or an 8T-1000 Electronic Position Indicator is acceptable to use. One of these tools will be installed in the threaded hole of the fuel control housing.

a. For the 4C-6594 Timing and Fuel Setting Tool, install the 5P-4814 Collet Clamp in the vertical threaded hole. Slide the 6V-3075 Dial Indicator with the 5P-7263 Indicator Contact Point into the 5P-4814 Collet Clamp.

When the contact point seats against the fuel stop lever, slide the indicator inward or slide the indicator outward until the indicator dial reads +5.00 mm (+0.197 inch). Tighten the collet in order to hold the indicator in position. The indicator is now ready to be used.

b. For the 8T-1000 Electronic Position Indicator, install the 5P-4814 Collet Clamp in the vertical threaded hole. Slide the 8T-1002 Probe with the 5P-7263 Indicator Contact Point into the 5P-4814 Collet Clamp until the
8T-1002 Probe sleeve bottoms in the 5P-4814 Collet Clamp. Tighten the collet enough to hold the probe in position. Attach the probe to the 8T-1001 Electronic Indicator. Turn the indicator "ON" and set the indicator to measure millimeters. With the indicator "ON", touch the negative "-" button. Then touch the zero button. The indicator is now ready to be used.

5. Remove synchronizing pin from the governor control housing.

6. Remove governor control rod assembly from between the governor and actuator housing.

7. Rotate governor terminal shaft to the minimum fuel position. Then hold the governor terminal shaft in place.

8. Install lever on shaft so the centerline of the lever is 40.7 degrees from the vertical centerline.

9. Adjust rod assembly between the control housing lever and the actuator lever. Use the appropriate procedure that follows.

a. If the 4C-6594 Timing and Fuel Setting Tool is being used, adjust the rod assembly until the 6V-3075 Dial Indicator displays a reading of -4.50 mm (-0.177 inch). Secure the rod assembly in place with the locknuts. Ensure that each rod end on the rod assembly has the same amount of thread engagement.

b. If the 8T-1000 Electronic Position Indicator is being used, adjust the rod assembly until the 8T-1001 Electronic Indicator displays a reading of -9.50 mm (-0.374 inch). Secure the rod assembly in place with the locknuts. Ensure that each rod end on the rod assembly has the same amount of thread engagement.

! WARNING !

The engine may overspeed due to incorrect assembly or adjustment.

Engine overspeed could result in personal injury, loss of life and/or property damage.

Be prepared to stop the engine by activating the engine shutdown system or closing the air inlet lines.

The definition of governor deadband is the total amount of travel between the point of actual fuel shutoff and the actual "FUEL OFF" position. When the 6V-3075 Dial Indicator is used and when the reading of the maximum actuator "FUEL OFF" is more positive than -4.50 mm (-0.177 inch), the governor deadband can be eliminated. -3.75 mm (-0.148 inch) is an example of a reading that is more positive than -4.50 mm (-0.177 inch). When the 8T-1001 Electronic Indicator is used and when the reading of the maximum actuator "FUEL OFF" is more positive than -9.50 mm (-0.374 inch), the governor deadband can be eliminated. -8.75 mm

(-0.344 inch) is an example of a reading that is more positive than -9.50 mm (-0.374 inch). This can cause an engine overspeed.

11. Re-install the synchronizing pin without the spacer. When the 6V-3075 Dial Indicator is used, ensure that the indicator still reads +5.00 mm (+0.197 inch). When the 8T-1001 Electronic Indicator is used, ensure that the indicator still reads a value of 0.00 mm (0.000 inch). If the indicated reading is not correct, repeat Step 3 through Step 9. If the indicated reading is correct, continue with the procedure. If the 6V-3075 Dial Indicator is used, adjust the dial indicator in order to read 0.00 mm (0.000 inch). This must be done before continuing the procedure.

12. Check the fuel setting. See the subject Fuel Setting Check.

13. Remove the dead weight from the actuator terminal shaft.

14. Remove synchronizing pin from the synchronizing location and install the sealing washer and plug. Install the sealing washer, spacer and synchronizing pin in the storage location.

15. Remove all tooling from the governor control housing. Install the sealing washer and plug.

16. Before starting the engine, put a mark on the governor actuator's position indicator at the point of minimum governor travel. This is the engine's stopped position.

! WARNING !

The engine may overspeed due to incorrect assembly or adjustment.

Engine overspeed could result in personal injury, loss of life and/or property damage.

Be prepared to stop the engine by activating the engine shutdown system or closing the air inlet lines.

17. Start the engine and operate the engine at low idle. Put a mark on the governor actuator's position indicator. This is the engine running position.

18. The engine running position of the governor actuator must be six degrees or more above the engine's stopped position.

19. Operate the engine at high idle without a load in order to ensure that the governor actuator can control the engine.

Fuel Setting Check

	Tools Needed	Qty
1U-8795	Governor Torque Arm Tool	1
4C-6594	Timing & Fuel Setting Tool	1
6V-3075	Dial Indicator	1
4C-8753	Collet Clamp	1
5P-7263	Indicator Contact Point	1
8T-1000	Electronic Position Indicator	1

Fuel setting is the adjustment of the fuel setting screw to a specified position. The fuel setting screw limits the power output of the engine by setting the maximum travel of all the fuel injector racks.

Before the fuel setting is checked, the fuel injectors must be correctly synchronized. See the subject "Fuel Injector Synchronization ".

1. Remove the plugs from the actuator housing assembly.

2. Remove synchronizing pin and install the pin in the threaded hole without the washer. Tighten the synchronizing pin.

3. Move the actuator terminal shaft lever in the "FUEL ON" direction until the flat face of fuel stop lever contacts synchronizing pin.

4. Put 6V-3075 Dial Indicator with 5P-7263 Contact Point in 5P-4814 Collet clamp.

5. Install the dial indicator and the collet in the threaded hole. When the contact point seats against fuel stop lever, slide the dial indicator inward or slide the dial indicator outward until the dial indicator gives a reading of 0.00 mm (0.000 inch). Tighten the collet enough in order to hold the dial indicator in position.

6. Remove synchronizing pin. Slowly move the actuator terminal shaft in the "FUEL ON" direction until the flat face of fuel stop lever is against the end of the fuel setting screw. When the linkage is held in this position, the dial indicator reading will be the present fuel setting.

Note: See the information plate on the engine for the correct full load static fuel setting.

7. If the fuel setting is correct, remove the dial indicator. Return the synchronizing pin and the washer to the original locations.

8. Re-install the plugs.

9. If the fuel setting needs adjustment, go on to "Fuel Setting Adjustment ".

Fuel Setting Adjustment

NOTICE

A mechanic with governor and fuel setting training is the ONLY one to make adjustments to the engine fuel setting.

Note: Before the fuel setting adjustment is made, check the fuel setting. Refer to "Fuel Setting Check ".

1. Cut the seal wire and remove fuel setting cover and the gasket. Loosen the locknut. While the fuel stop lever is held against the end of fuel setting screw turn the fuel setting screw inward or turn the fuel setting screw outward until the correct reading is shown on the dial indicator. By moving the screw inward, decreases the desired setting and by turning the screw outward, increases in desired setting.

2. Tighten the locknut on fuel setting screw. Be sure that the fuel setting screw does not turn when the locknut is tightened.

3. Release the fuel control linkage. Again, move the linkage all the way in the "FUEL ON" direction. Check the dial indicator reading again in order to ensure that the desired fuel setting is still correct.

4. Remove the dial indicator and synchronizing pin.

5. Put fuel setting cover and the gasket in position over the fuel setting screw. Install the bolt and synchronizing pin in the cover. Install a new seal wire.

Timing Adjustments for Fuel System

If the engine operation is erratic or the operation is unsatisfactory, check the timing of the engine. Be sure that the engine fuel supply is not the problem. Several adjustments are necessary in order to ensure that the fuel is correctly delivered in accordance with the following parameters: amount, sequence and time. The following adjustments and procedures can be used to determine that the fuel system is operating correctly. Follow the procedures carefully as each procedure depends on the other procedure for good operation of the engine.

1. The camshafts must be in time with the crankshaft.

2. Fuel injectors should be adjusted to the same timing dimension in order to prevent the engine timing from advancing or retarding.

   The timing dimension is the distance from the top of the spring retainer of the fuel injector to the top of the base of the fuel injector body. If the timing dimension is longer than the setting of the gauge block, the plunger of the fuel injector must be pushed in farther before the plunger reaches the bypass opening. This point marks the start of fuel injection. This action will retard the timing. If the timing dimension is shorter than the gauge block setting, the plunger must be pushed in a shorter distance before the bypass closes. The fuel injection will start sooner in the cycle so that the timing will be advanced.

3. The fuel control linkage must be set to a reference position. This reference position is the starting point for other adjustments.

   The fuel system linkage is in the reference position when the synchronizing pin is installed. The fuel system linkage is also advanced so that the flat surface on the rack stop is against the pin.

4. The fuel injector racks must be set so that each fuel injector sends the same amount of fuel to each combustion chamber.

5. The fuel control rod for the governor and the governor linkage should be set to a reference position.

6. The fuel setting should be checked and adjusted, if necessary.

Fuel Timing

	Tools Needed	Qty
4C-6594	Timing & Fuel Setting Tool	1
6V-3075	Dial Indicator	1
8S-3675	Indicator Contact Point	1
6V-9058	Fixture Assembly	1
6V-9056	Setting Gauge	1
8T-1000	Electronic Position Indicator	1

NOTICE

The camshaft must be correctly timed with the crankshaft before an adjustment of fuel timing is made. The timing pin must be removed from the camshaft before the crankshaft is turned or damage to the cylinder block will be the result.

1. Refer to the Tables in the Crankshaft Positions For Fuel Timing And Valve Lash Adjustment Section. Ensure that the engine is in time. With the two crankshaft positions that are given, all of the fuel injectors can be checked or adjusted. This will ensure that the pushrod lifters are off the lobes and on the base circles of the camshaft.

Note: Refer to the information plate on the engine for the fuel injector's correct fuel timing dimension.

2. Before a check or an adjustment of the fuel timing can be made, the tooling must be set to the correct dimension. Use the following procedure in order to set the tooling to the correct dimension:

a. Install 8S-3675 Indicator Contact Point on the 6V-3075 Dial Indicator.

b. Install 6V-3075 Dial Indicator in the collet of 6V-9058 Fixture Assembly.

c. Install 6V-3075 Dial Indicator with 6V-9058 Fixture Assembly onto 6V-9056 Setting Gauge. Ensure that the magnetic base of the timing fixture is on the top surface and that the contact point is on the bottom step.

Note: The 6V-3075 Dial Indicator has two or three dials that register. The larger dial has marks for every 0.01mm (0.0004 inch). The red numbers on the dial are for minus readings. The black numbers on the dial are for plus readings. The smaller dial has marks for 1.00 mm (0.040 inch) (one complete revolution of the large dial).

d. Find the correct Fuel Timing Dimension on Table below and determine the setting dimension. Note whether the dimension is a plus "+" number or a minus "-" number.

Note: If the setting dimension from the chart is "0" or a plus "+" number, move the dial indicator into the collet until both dials register "0". Place the "0" on the large dial in the twelve o'clock position in order to easily read the dial when the dial is on the engine. If the setting dimension is "0" tighten the collet. If the setting dimension is not "0", move the dial indicator farther into the collet until the large dial indicates the correct plus "+" setting. Then, tighten the collet.

Note: If the setting dimension is a minus "-" number, move the dial indicator in the collet until both dials register "0". Place the "0" on the large dial in the twelve o'clock position in order to easily read the dial when the dial is on the engine. Now, move the dial indicator out of the collet until the large dial indicates the correct minus "-" setting. Then, tighten the collet.

3. Ensure that the top surface of fuel injector's retainer and shoulder are clean and dry.

4. Put 6V-3075 Dial Indicator that is installed in 6V-9058 Fixture Assembly into position on the fuel injector. Make sure that the magnetic base of the timing fixture is on the top surface of the fuel injector's retainer and that the contact point is on the top surface of shoulder.

Note: The pointer on both dials on the dial indicator must indicate 0.00 ± 0.20 mm (0.000 ± 0.008 inch).

5. If the dial indicator pointers are within the range of 0.00 ± 0.20 mm (0.000 ± 0.008 inch), no adjustment is necessary. Proceed to Step 11.

6. If the dial indicator pointers are not within the range of 0.00 ± 0.20 mm (0.000 ± 0.008 inch), complete Steps 7 through 10.

7. Loosen the rocker arm adjustment screw locknut on the fuel injector that requires adjustment.

8. Put 6V-3075 Dial Indicator that is installed in 6V-9058 Fixture Assembly into position on the fuel injector. Make sure that the magnetic base of the timing fixture is on the top surface of the fuel injector's retainer and that the contact point is on the top surface of shoulder.

9. Turn rocker arm adjustment screw until the dial indicator indicates "0".

10. Tighten rocker arm adjustment screw locknut to a torque of 200 ± 25 N·m (150 ± 18 lb ft), and check the adjustment again. If necessary, do this procedure until the adjustment is correct.

11. Remove the timing pin from the crankshaft when the fuel timing check is completed.

Dial Indicator Setting Chart (1)		
Fuel Timing Dimension on Engine Data Plate	**Minus -118.20 mm**	**Dial Indicator Setting**
(120.00 mm)	-118.20 mm	(+1.80 mm)
(119.80 mm)	-118.20 mm	(+1.60 mm)
(119.60 mm)	-118.20 mm	(+1.40 mm)
(119.50 mm)	-118.20 mm	(+1.20 mm)
(119.40 mm)	-118.20 mm	(+1.30 mm)
(119.30 mm)	-118.20 mm	(+1.10 mm)
(119.20 mm)	-118.20 mm	(+1.00 mm)
(119.10 mm)	-118.20 mm	(+0.90 mm)
(119.00 mm)	-118.20 mm	(+0.80 mm)
(118.90 mm)	-118.20 mm	(+0.70 mm)
(118.80 mm)	-118.20 mm	(+0.60 mm)
(118.70 mm)	-118.20 mm	(+0.50 mm)
(118.60 mm)	-118.20 mm	(+0.40 mm)
(118.50 mm)	-118.20 mm	(+0.30 mm)
(118.40 mm)	-118.20 mm	(+0.20 mm)
(118.30 mm)	-118.20 mm	(+0.10 mm)
(118.20 mm)	-118.20 mm	(0.00 mm)
(118.10 mm)	-118.20 mm	(-0.10 mm)
(118.00 mm)	-118.20 mm	(-0.20 mm)
(117.90 mm)	-118.20 mm	(-0.30 mm)
(117.80 mm)	-118.20 mm	(-0.40 mm)
(117.70 mm)	-118.20 mm	(-0.50 mm)
(117.60 mm)	-118.20 mm	(-0.60 mm)
(117.50 mm)	-118.20 mm	(-0.70 mm)
(117.40 mm)	-118.20 mm	(-0.80 mm)
(117.30 mm)	-118.20 mm	(-0.90 mm)
(117.20 mm)	-118.20 mm	(-1.00 mm)
(117.10 mm)	-118.20 mm	(-1.10 mm)
(117.00 mm)	-118.20 mm	(-1.20 mm)
(116.80 mm)	-118.20 mm	(-1.40 mm)
(116.60 mm)	-118.20 mm	(-1.60 mm)

(1) Refer to the engine information plate for the correct fuel timing dimension.

Crankshaft Position for Fuel Injector Timing & Valve Lash Adjustments.

Check & Adjust with Piston on the following stoke. (1)		
3606	**Top Center Compression Stroke**	**Top Center Exhaust Stroke**
SAE Standard Rotation Engine - CCW (2)		
Firing Order	1-5-3 6-2-4	
Inlet Valves	1-2-4	3-5-6
Exhaust Valves	1-3-5	2-4-6
Fuel Injectors	3-5-6	1-2-4

SAE Reverse Rotation Engine - CW (3)		
Firing Order	1-4-2 6-3-5	
Inlet Valves	1-3-5	2-4-6
Exhaust Valves	1-2-4	3-5-6
Fuel Injectors	2-4-6	1-3-5

Check & Adjust with Piston on the following stoke. (1)		
3608	**Top Center Compression Stroke**	**Top Center Exhaust Stroke**
SAE Standard Rotation Engine - CCW (2)		
Firing Order	1-6-2-5 8-3-7-4	
Inlet Valves	1-4-6-7	2-3-5-8
Exhaust Valves	1-2-4-6	3-5-7-8
Fuel Injectors	2-3-5-8	1-4-6-7

SAE Reverse Rotation Engine - CW (3)		
Firing Order	1-4-7-3 8-5-2-6	
Inlet Valves	1-2-4-6	3-5-7-8
Exhaust Valves	1-4-6-7	2-3-5-8
Fuel Injectors	3-5-7-8	1-2-4-6

Check & Adjust with Piston on the following stoke. (1)		
3612	**Top Center Compression Stroke**	**Top Center Exhaust Stroke**
SAE Standard Rotation Engine - CCW (2)		
Firing Order	1-12-9-4-5-8 11-2-3-10-7-6	
Inlet Valves	1-3-7 6-10-12	5-9-11 2-4-8
Exhaust Valves	1-5-9 4-6-12	3-7-11 2-8-10
Fuel Injectors	5-9-11 2-4-8	1-3-7 6-10-12

SAE Reverse Rotation Engine - CW (3)		
Firing Order	1-6-7-10-3-2 11-8-5-4-9-12	
Inlet Valves	1-5-9 4-6-12	3-7-11 2-8-10
Exhaust Valves	1-3-7 6-10-12	5-9-11 2-4-8
Fuel Injectors	3-7-11 2-8-10	1-5-9 4-6-12

Comments or Notes:

Check & Adjust with Piston on the following stoke. (1)		
3616	**Top Center Compression Stroke**	**Top Center Exhaust Stroke**
SAE Standard Rotation Engine - CCW (2)		
Firing Order	1-2-5-6-3-4-9-10 15-16-11-12-13-14-7-8	
Inlet Valves	1-5-7-13 2-8-12-14	3-9-11-15 4-6-10-16
Exhaust Valves	1-3-5-7 2-4-6-8	9-11-13-15 10-12-14-16
Fuel Injectors	3-9-11-15 4-6-10-16	1-5-7-13 2-8-12-14

SAE Reverse Rotation Engine - CW (3)		
Firing Order	1-8-7-14-13-12-11-16 15-10-9-4-3-6-5-2	
Inlet Valves	1-3-5-7 2-4-6-8	9-11-13-15 10-12-14-16
Exhaust Valves	1-5-7-13 2-8-12-14	3-9-11-15 4-6-10-16
Fuel Injectors	9-11-13-15 10-12-14-16	1-3-5-7 2-4-6-8

(1) SAE Standard Rotation Engines turn in the COUNTERCLOCKWISE (CCW) direction when the engines are viewed from the flywheel end.

(2) Put the No. 1 piston at the top dead center position (TDC) and identify the correct stroke. Refer to the Testing and Adjusting , "Fuel Systems". After the top center position for a particular stoke stroke is found and the adjustments are made for the correct cylinders, remove the timing pin. Turn the flywheel for 360 degrees in the direction of normal engine rotation. This will put the No. 1 piston at the top center position on the other stroke. Install the timing pin in the crankshaft and complete the adjustments for the cylinders that remain.

(3) SAE Opposite Rotation Engines turn in the CLOCKWISE (CW) direction when the engines are viewed from the flywheel end.

Camshaft Journal & Segment Installation

Use the following chart to install camshaft Journal & Segments

1. Choose engine configuration
2. Choose engine direction of rotation
3. Choose segment “anular groove” direction
4. Choose journal “anular groove” direction
5. Install journal per alfa character starting at rear of engine to front

1	2	3	4	Rear Front
3606	CCW	Rear	Front	B•B•A•C•C•A
3606	CW	Front	Front	B•B•A•C•C•A
3608	CCW	Rear	Front	E•G•E•A•D•F•D•A
3608	CW	Front	Front	E•G•E•A•D•F•D•A
3612	CCW	Front	Front	C•C•A•B•B•A
3612	CW	Rear	Front	C•C•A•B•B•A
3616	CCW	Front	Front	D•L•E•A•D•H•E•A
3616	CW	Rear	Front	D•L•E•A•D•H•E•A

Note: Standard Engine Rotation is CCW. On Vee engines (3612/3616) the alfa character is the same on both sides of the engine.

Comments or Notes:

Performance Log Sheet:

Customer Name:

Time				
% Load				
Engine Speed				
Hour Meter				
Inlet Man. Temp.				
Inlet Man Press.				
Air Restriction (R)				
Air Restriction (L)				
Jacket Water Temp. (in)				
Jacket Water Temp (out)				
Jacket Water Pressure				
Fuel Pressure				
Fuel Temp.				
Fuel Filter Diff. Pressure				
Oil Pressure				
Oil Temp.				
Oil Filter Diff. Pressure				
Exhaust Manifold Temp (R)				
Cyl. Exh. Temp (1)				
Cyl. Exh. Temp (2)				
Cyl. Exh. Temp (3)				
Cyl. Exh. Temp (4)				
Cyl. Exh. Temp (5)				
Cyl. Exh. Temp (6)				
Cyl. Exh. Temp (7)				
Cyl. Exh. Temp (8)				
Cyl. Exh. Temp (9)				
Cyl. Exh. Temp (10)				
Cyl. Exh. Temp (11)				
Cyl. Exh. Temp (12)				
Cyl. Exh. Temp (13)				
Cyl. Exh. Temp (14)				
Cyl. Exh. Temp (15)				
Cyl. Exh. Temp (16)				

Performance Log Sheet:

Customer Name:

Time				
% Load				
Engine Speed				
Hour Meter				
Inlet Man. Temp.				
Inlet Man Press.				
Air Restriction (R)				
Air Restriction (L)				
Jacket Water Temp. (in)				
Jacket Water Temp (out)				
Jacket Water Pressure				
Fuel Pressure				
Fuel Temp.				
Fuel Filter Diff. Pressure				
Oil Pressure				
Oil Temp.				
Oil Filter Diff. Pressure				
Exhaust Manifold Temp (R)				
Cyl. Exh. Temp (1)				
Cyl. Exh. Temp (2)				
Cyl. Exh. Temp (3)				
Cyl. Exh. Temp (4)				
Cyl. Exh. Temp (5)				
Cyl. Exh. Temp (6)				
Cyl. Exh. Temp (7)				
Cyl. Exh. Temp (8)				
Cyl. Exh. Temp (9)				
Cyl. Exh. Temp (10)				
Cyl. Exh. Temp (11)				
Cyl. Exh. Temp (12)				
Cyl. Exh. Temp (13)				
Cyl. Exh. Temp (14)				
Cyl. Exh. Temp (15)				
Cyl. Exh. Temp (16)				

Performance Log Sheet:

Customer Name:

Time				
% Load				
Engine Speed				
Hour Meter				
Inlet Man. Temp.				
Inlet Man Press.				
Air Restriction (R)				
Air Restriction (L)				
Jacket Water Temp. (in)				
Jacket Water Temp (out)				
Jacket Water Pressure				
Fuel Pressure				
Fuel Temp.				
Fuel Filter Diff. Pressure				
Oil Pressure				
Oil Temp.				
Oil Filter Diff. Pressure				
Exhaust Manifold Temp (R)				
Cyl. Exh. Temp (1)				
Cyl. Exh. Temp (2)				
Cyl. Exh. Temp (3)				
Cyl. Exh. Temp (4)				
Cyl. Exh. Temp (5)				
Cyl. Exh. Temp (6)				
Cyl. Exh. Temp (7)				
Cyl. Exh. Temp (8)				
Cyl. Exh. Temp (9)				
Cyl. Exh. Temp (10)				
Cyl. Exh. Temp (11)				
Cyl. Exh. Temp (12)				
Cyl. Exh. Temp (13)				
Cyl. Exh. Temp (14)				
Cyl. Exh. Temp (15)				
Cyl. Exh. Temp (16)				

Performance Log Sheet:

Customer Name:

Time				
% Load				
Engine Speed				
Hour Meter				
Inlet Man. Temp.				
Inlet Man Press.				
Air Restriction (R)				
Air Restriction (L)				
Jacket Water Temp. (in)				
Jacket Water Temp (out)				
Jacket Water Pressure				
Fuel Pressure				
Fuel Temp.				
Fuel Filter Diff. Pressure				
Oil Pressure				
Oil Temp.				
Oil Filter Diff. Pressure				
Exhaust Manifold Temp (R)				
Cyl. Exh. Temp (1)				
Cyl. Exh. Temp (2)				
Cyl. Exh. Temp (3)				
Cyl. Exh. Temp (4)				
Cyl. Exh. Temp (5)				
Cyl. Exh. Temp (6)				
Cyl. Exh. Temp (7)				
Cyl. Exh. Temp (8)				
Cyl. Exh. Temp (9)				
Cyl. Exh. Temp (10)				
Cyl. Exh. Temp (11)				
Cyl. Exh. Temp (12)				
Cyl. Exh. Temp (13)				
Cyl. Exh. Temp (14)				
Cyl. Exh. Temp (15)				
Cyl. Exh. Temp (16)				

Performance Log Sheet:

Customer Name:

Time				
% Load				
Engine Speed				
Hour Meter				
Inlet Man. Temp.				
Inlet Man Press.				
Air Restriction (R)				
Air Restriction (L)				
Jacket Water Temp. (in)				
Jacket Water Temp (out)				
Jacket Water Pressure				
Fuel Pressure				
Fuel Temp.				
Fuel Filter Diff. Pressure				
Oil Pressure				
Oil Temp.				
Oil Filter Diff. Pressure				
Exhaust Manifold Temp (R)				
Cyl. Exh. Temp (1)				
Cyl. Exh. Temp (2)				
Cyl. Exh. Temp (3)				
Cyl. Exh. Temp (4)				
Cyl. Exh. Temp (5)				
Cyl. Exh. Temp (6)				
Cyl. Exh. Temp (7)				
Cyl. Exh. Temp (8)				
Cyl. Exh. Temp (9)				
Cyl. Exh. Temp (10)				
Cyl. Exh. Temp (11)				
Cyl. Exh. Temp (12)				
Cyl. Exh. Temp (13)				
Cyl. Exh. Temp (14)				
Cyl. Exh. Temp (15)				
Cyl. Exh. Temp (16)				

Performance Log Sheet:

Customer Name:

Time				
% Load				
Engine Speed				
Hour Meter				
Inlet Man. Temp.				
Inlet Man Press.				
Air Restriction (R)				
Air Restriction (L)				
Jacket Water Temp. (in)				
Jacket Water Temp (out)				
Jacket Water Pressure				
Fuel Pressure				
Fuel Temp.				
Fuel Filter Diff. Pressure				
Oil Pressure				
Oil Temp.				
Oil Filter Diff. Pressure				
Exhaust Manifold Temp (R)				
Cyl. Exh. Temp (1)				
Cyl. Exh. Temp (2)				
Cyl. Exh. Temp (3)				
Cyl. Exh. Temp (4)				
Cyl. Exh. Temp (5)				
Cyl. Exh. Temp (6)				
Cyl. Exh. Temp (7)				
Cyl. Exh. Temp (8)				
Cyl. Exh. Temp (9)				
Cyl. Exh. Temp (10)				
Cyl. Exh. Temp (11)				
Cyl. Exh. Temp (12)				
Cyl. Exh. Temp (13)				
Cyl. Exh. Temp (14)				
Cyl. Exh. Temp (15)				
Cyl. Exh. Temp (16)				

Sea Trial:
Location Points:

900 Series Designation	Location Description
901	Jacket water outlet temperature (Before the regulators)
902	Jacket water pump outlet temperature
903	Aftercooler water inlet temperature
903A	Aftercooler water outlet temperature
904	Auxiliary water pump inlet pressure
905	Auxiliary water pump outlet pressure
906	Intake manifold air temperature
907	Inlet air restriction
908	Exhaust stack backpressure
909	Crankshaft deflection
910	Engine speed
911	Intake manifold air pressure
912	Exhaust stack temperature
913	Engine oil to bearings temperature
914	Engine oil to bearings pressure
915	Transmission oil temperature
916	Transmission oil pressure
917	Fuel Pressure
918	Jacket water outlet pressure before regulators
919	Jacket water pressure at pump outlet
920	Jacket water pump inlet pressure at pump inlet
921	Jacket water pressure from cooling system
922	Jacket water inlet temperature from cooling system
923	Aftercooler water inlet pressure
924	Aftercooler water outlet pressure
925	Transmission oil cooler inlet water temperature
926	Transmission oil cooler outlet water temperature
927	Oil filter inlet pressure
928	Oil filter outlet pressure
930	Air cleaner outlet temperature
931	Turbocharger compressor outlet temperature
932	Crankcase pressure
934	Engine oil to cooling jet pressure
935	Fuel inlet temperature
936	Fuel return line restriction
937*	A/C water temperature between front and rear housing
938	Oil cooler water outlet temperature
939	Oil cooler water outlet pressure
940*	A/C - O/C cooler water outlet mixing box temperature

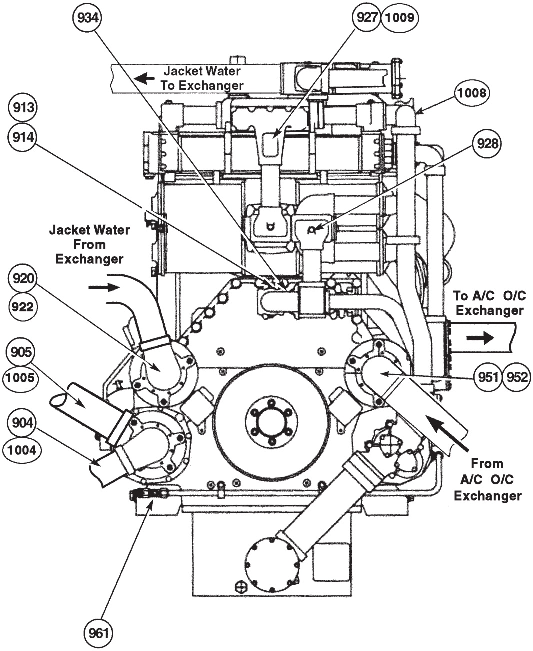
Sea Trial:
Location Points:

900 Series Designation	Location Description
941*	A/C - O/C cooler water outlet mixing box pressure
942	Jacket water pressure at block outlet (Before regulators)
943*	Water temperature to combined circuit heat exchanger
944*	Water pressure to combined circuit heat exchanger
945*	Water temperature to temperature regulator from combined circuit heat exchanger
946*	Water pressure to temperature regulator from combined circuit heat exchanger
947*	Water temperature at engine outlet to separate circuit jacket water heat exchanger
948*	Water pressure at engine outlet to separate circuit jacket water heat exchanger
949*	Water temperature to temperature regulator from single circuit jacket water heat exchanger
950*	Water pressure to temperature regulator from single circuit jacket water heat exchanger
951*	Aftercooler/Oil cooler water pump inlet temperature
952*	Aftercooler/Oil cooler water pump inlet pressure
953*	Aftercooler/Oil cooler water pump outlet pressure
954*	Raw water temperature to combined circuit heat exchanger
955*	Raw water temperature from combined circuit heat exchanger
956*	Raw water temperature to separate circuit jacket water heat exchanger
957*	Raw water temperature from separate circuit jacket water heat exchanger
958*	Raw water temperature to separate circuit aftercooler/oil cooler heat exchanger
959*	Raw water temperature from separate circuit aftercooler/oil cooler heat exchanger
960	Turbocharger compressor outlet pressure
961	Fuel pump inlet restriction
1000*	Combined Circuit Jacket Water Pump Inlet Temperature
1001*	Combined Circuit Jacket Water Pump Inlet Pressure
1002*	Combined Circuit Raw Water Pressure at Heat Exchanger Inlet.
1003*	Combined Circuit Raw Water Pressure at Heat Exchanger Outlet

To locate the proper 900 location on a particular engine consult the engine dimension drawings found in the marine propulsion engine performance manuals, or the sea trial guide manual.

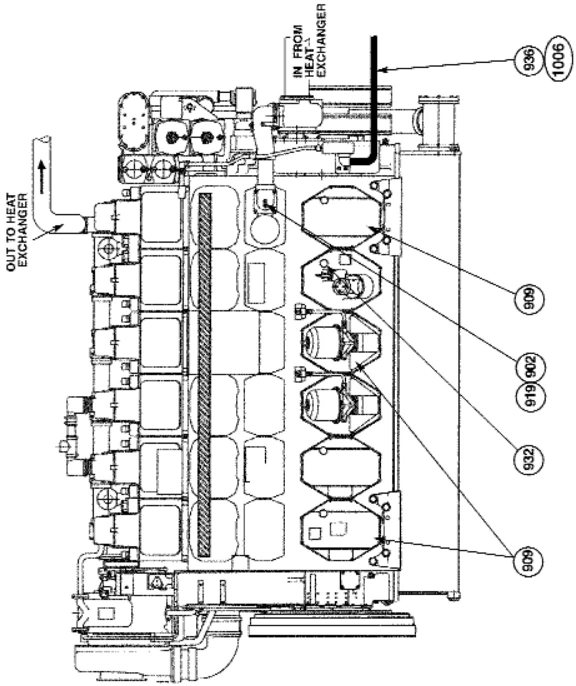
*The location pertains to the 3600 series of engines only.

900 Number Test Locations for 3600 Inline Separate Circuit



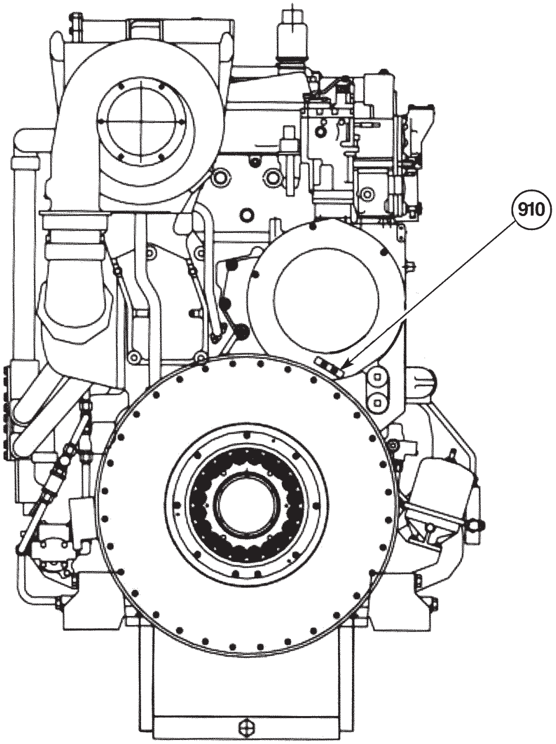
Front View

900 Number Test Locations for 3600 Inline Separate Circuit



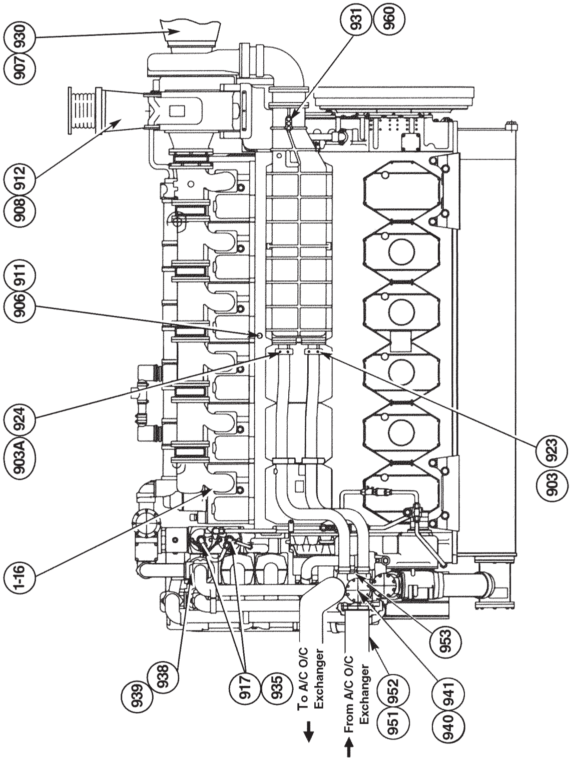
Right Side View

900 Number Test Locations for 3600 Inline Separate Circuit



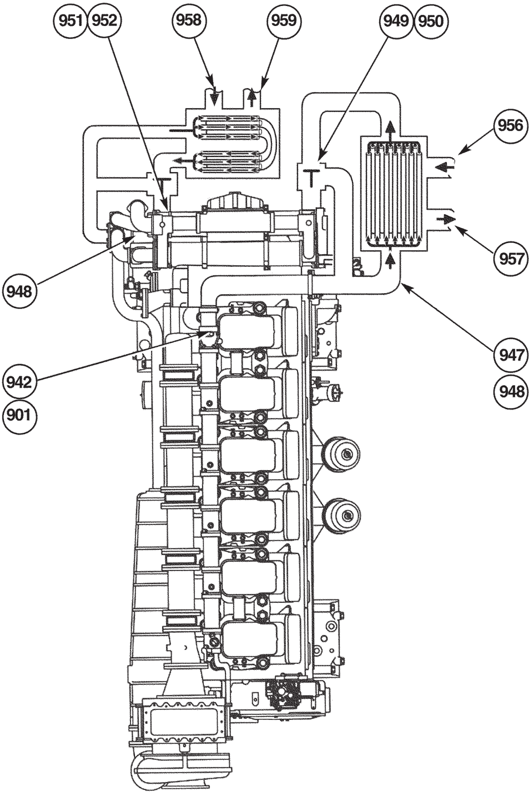
Rear View

900 Number Test Locations for 3600 Inline Separate Circuit



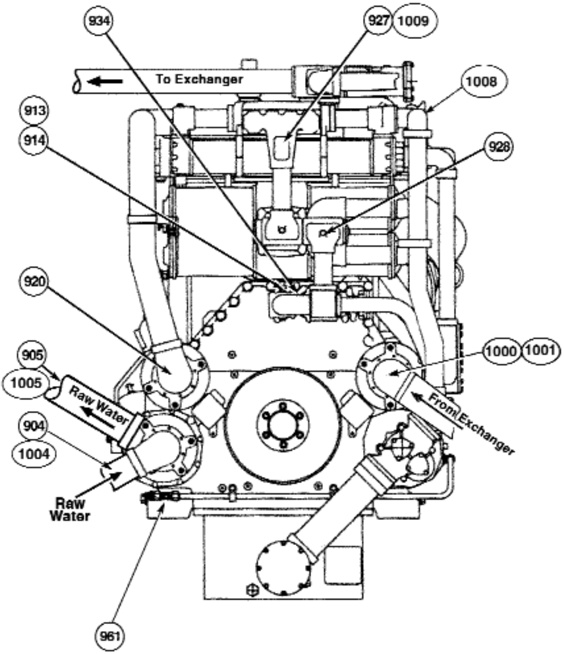
Left Side View

900 Number Test Locations for 3600 Inline Separate Circuit



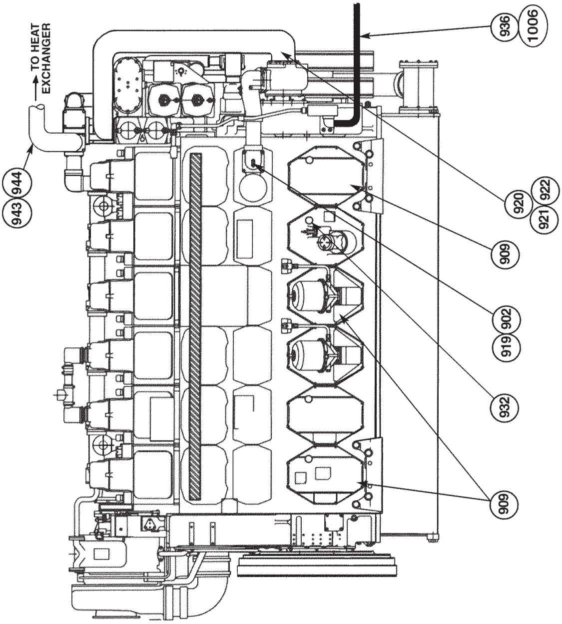
Top View

900 Number Test Locations for 3600 Inline Combined Circuit



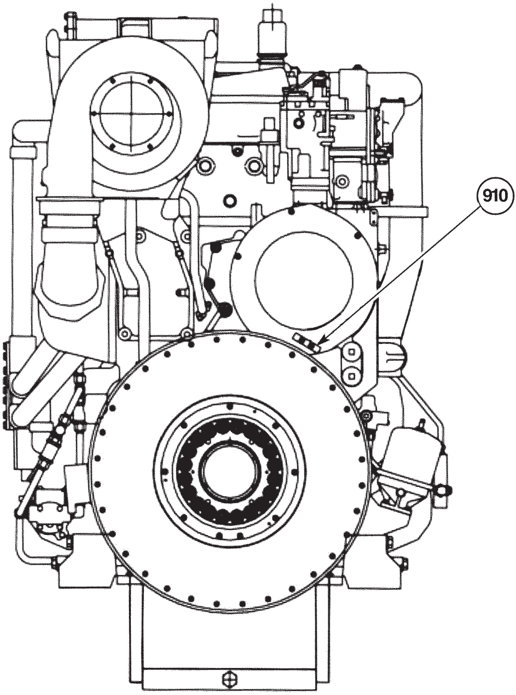
Front View

900 Number Test Locations for 3600 Inline Combined Circuit



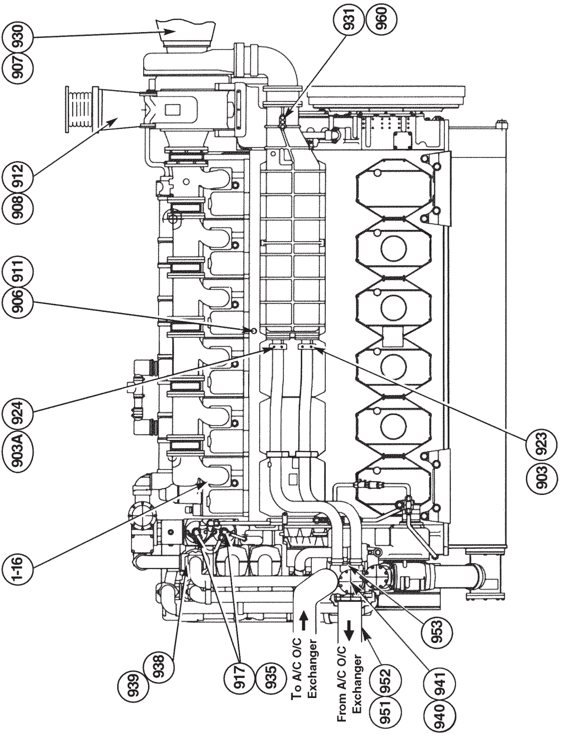
Right Side View

900 Number Test Locations for 3600 Inline Combined Circuit



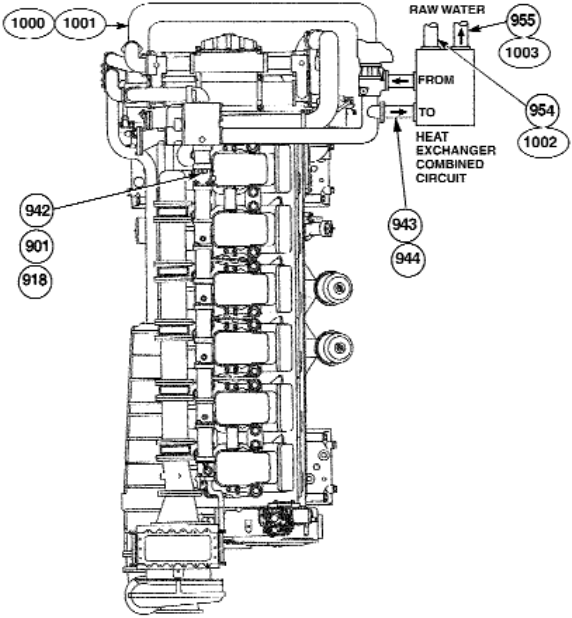
Rear View

900 Number Test Locations for 3600 Inline Combined Circuit



Left Side View

900 Number Test Locations for 3600 Inline Combined Circuit



Top View

900 Test Locations For 3600 Vee
<u>Separate Circuit</u>

Front View

900 Test Locations For 3600 Vee
Separate Circuit

Right Side View

900 Test Locations For 3600 Vee

Separate Circuit

Rear View

900 Test Locations For 3600 Vee

Separate Circuit

Left Side View

900 Test Locations For 3600 Vee
Separate Circuit

Top View

900 Test Locations For 3600 Vee
Combined Circuit

Front View

900 Test Locations For 3600 Vee
Combined Circuit

Right Side View

900 Test Locations For 3600 Vee
Combined Circuit

Rear View

900 Test Locations For 3600 Vee
Combined Circuit

Left Side View

900 Test Locations For 3600 Inline
<u>Combined Circuit</u>

Top View

Comments or Notes:

3600 Performance Analysis (Rules of Thumb) Alarms & Shutdowns

3600 Performance Analysis (Rules of Thumb) Alarms & Shutdowns for the Air Intake System:

Air Temp. at Air Cleaner ------ 49°C (120°F) Max.

Inlet Air Restriction ------------- 15"H_2O Max.
5" H_2O (New)
Alarm ----------------------------- 3.7 kPa (.53 psi)(14.8"H_2O)

Intake Manifold Air
Temp. (50°C 122°F) ------------- 65°C (150°F) Nominal
Alarm ----------------------------- 92°C (197°F) Standard
Alarm ----------------------------- 78°C (172°F) HPAC
Shutdown ----------------------- 98°C (208°F)

Intake Manifold Air
Temp. (32°C)(90°F) ------------- 65°C (150°F) Nominal
Alarm ---------------------------- 75°C (166°F) Standard
Alarm ---------------------------- 61°C (142°F) HPAC
Shutdown ----------------------- 98°C (208°F) Std. & HPAC

Intake Manifold Air
Pressure --------------------------- Nominal Values in Perf Book
Measure at part and full load
Max. Test Value ------------------ +30 kPa (4.3 psi)(22.5"H_2O)
High Inlet Manifold Pressure
Alarm --------------------------- 230 Pa (33 psi)

Crankcase Pressure/
Vacuum ---------------------------- –0.25 to +0.5 kPa
(–1 to +2"H_2O)
Alarm ---------------------------- .6 kPa (.087 psi)
63.5 mm H_2O (2.5"H_2O)
Shutdown ----------------------- 1 kPa (.15 psi)
101.6 mm H_2O (4" H_2O)

Comments or Notes:

3600 Performance Analysis (Rules of Thumb)
Alarms & Shutdowns for the Exhaust System:

Exhaust Stack Temp. ----	Nominal Temp in Perf book
Alarm ------------------	550°C (1022°F)
Individual Cyl Exhaust Port Temp.	
Std. --------------------	±42°C (±75°F)
Alarm -------------------	550°C (1022°F)
Alarm -------------------	50°C (122°F) Maximum Variation between Cyl
High Turbine Inlet Temp.	
Alarm -------------------	630°C (1300°F) Standard
Alarm -------------------	650°C (1330°F) High Output
Exhaust Back Pressure - -	2.5 kPa (.3psi)(10”H_2O) 0.8% Loss in fuel economy (increase in BSFC) for each 10”H_2O above 10”H_2O

Comments or Notes:

3600 Performance Analysis (Rules of Thumb)
Alarms & Shutdowns for the Lubrication System:

Engine Oil to Bearing
Temp. ---------------------------- 83°C (181°F) Nominal
Alarm ------------------------ 92°C (197°F)
Shutdown -------------------- 98°C (208°F)

Engine Oil to Bearing
Pressure ------------------------ 450 kPa (65 psi) Nominal
380 kPa (55 psi) Minimum
Alarm (low pressure) ------- 320 kPa (46 psi) High Speed*
Shutdown (low pressure) -- 260 kPa (38 psi) High Speed*
Alarm (low pressure) ------- 120 kPa (17 psi) Low Speed*
Shutdown (low pressure) -- 105 kPa (15 psi) Low Speed*

Oil Filter Pressure
Differential
Alarm ---------------------------- 70 kPa (10 psi)
Shutdown ----------------------- 165 kPa (24 psi)

Lube Oil Sump Level -------- 50 mm (2 ")
NOTE: Vertical distance above the oil suction inlet while operating.

* 0 - 650 rpm's low speed 650 - 1000 rpm's high speed

Comments or Notes:

3600 Performance Analysis (Rules of Thumb)
Alarms & Shutdowns for the __Fuel System__:

Fuel Pressure ----------------- 430-676 kPa (62-98 psi)
Alarm (low pressure) ------- 260 kPa (38 psi) High Speed
Alarm (low pressure) ------- 140 kPa (20 psi) Low Speed

Fuel Transfer Pump -------- - 39 kPa (-5.7 psi) Max.
Inlet Restriction (to Transfer Pump)

Fuel Return Line ------------- 350 kPa (51 psi) Max.
Restriction (Backpressure)

Fuel Supply Temperature -- *Distillate Fuel
29°C (85°F) Max. Desired
1% Power reduction for each 5.6°C (10°F) increase above 30°C (85°F)
65°C (150°F) Max. to prevent injector damage.
Maximum fuel temperature limit of 140°C (248°F) to injectors and a 130°C (266°F) to the engine regardless of fuel viscosity to prevent coking or gumming of the injectors.
Alarm -------------------------- 66°C (150°F) Distillate
Shutdown --------------------- 72°C (161°F) Distillate

Fuel Filter Pressure
Differential --------------------- 70 kPa (10 psi) Max.
Alarm -------------------------- 75 kPa (11 psi)

Unit Injector Coolant
Pressure ------------------------ 35 kPa (5 psi)
Alarm ------------------------- 276 kPa (40 psi) Gen. Set

Unit Injector Coolant
Temp. --------------------------- 73°C (163°F) Nominal
Alarm -------------------------- 75°C (167°F)

Day Tanks are desirable if main tanks are 15.25m (50 ft) from engine or 1.82m (6 ft) below engine. Total suction head must not exceed 2.6m (8.5 ft). If tanks are above fuel injectors a 20.67 kPa (3 psi) check valve must be in the supply line and a 3.45 kPa (0.5 psi) check valve in the return.

Factory installed fuel priming pump has a lift of 2.6m (8.5 ft) and a flow of 38 L / 115 rev. (10 gal / 115 rev.)
It also has a lift of 7.8m (25.5 ft) if the lines are full of fuel.

3600 Performance Analysis (Rule of Thumb) Alarms & Shutdowns for the Cooling System:

- Heat Exchanger System External Resistance (Combined & Separated Circuit)
- Measure at engine outlet and compare to heat exchanger outlet (before regulators)
- Temperature Regulators 100% OPEN (blocked)
  SPECS:
    1000 RPM 90 kPa (13psi)
    900 RPM 73 kPa (11 psi)
    720 RPM 47 kPa (7 psi)

High Jacket Water Temp.

Alarm------------------103°C (217°F) Marine
Shutdown--------------109°C (228°F) Marine
Alarm------------------100°C (212°F) Gen Set
Shutdown--------------106°C (223°F) Gen Set

Low Jacket Water Pressure

Alarm------------------ 70 kPa (10 psi)

Jacket Water Pump Inlet Temp.----------------------85°C (185°F)

Jacket Water Pump Inlet Pressure ------------------- 30 kPa (5 psi) Min.

Jacket Water Block Outlet Temp.---------------------- 85°C (185°F) + Delta T

Aftercooler Water Inlet Temp. --------------------- 50°C (122°F) Nominal
*65°C (150°F) Max. under certain special conditions

A/C & O/C Water Pump Pressure (Low)

Alarm ------------------70 kPa (10 psi)

A/C & O/C Water Pump Inlet Temp. (50°C 122°F)

Alarm------------------ 60°C (140°F) Standard
Shutdown-------------- 67°C (152°F) Standard
Alarm------------------ 66°C (150°F) High Amb.
Shutdown-------------- 69*C (156°F) High Amb.

Jacket Water to Lube Oil Differential Temp.
Alarm --------------------------- 2 degree C (3.6 degree F)

A/C & O/C Water Pump Inlet Temp. (32°C 90°F)
Alarm --------------------------- 39°C (100°F)
Shutdown ---------------------- 42°C (107°F)

A/C & O/C Water Pump
Inlet Pressure --------------- -5 kPa (-20"H_2O) Min.

Aftercooler Water Outlet
Temperature ------------------- 50°C (122°F) + Delta T

Aux./Raw Sea Water Pump Pressure
Alarm ---------------------------- 70 kPa (10.15 psi)

Low Sea Water Pump Outlet Pressure
Alarm ---------------------------- 35 kPa (5 psi) + Static Head

Comments or Notes:

3600 Performance Analysis (Rules of Thumb)
Alarms & Shutdowns for the Misc. Systems:

Starting:
Low Starting Air Pressure
Alarm --------------------------- 515 kPa (74.75 psi) Turbine
750 kPa (108.75 psi) Vane
690 kPa (100 psi) Gen. Set

Low Battery Voltage
Alarm -------------------------- 22 Volts D.C.

Speed:
High Engine Speed
Shutdown -------------------- 113% Rated Speed
Max. speed before shutdown 120% of Rated Speed.

Vibration:
High Engine Vibration
(Marine)
Alarm ------------------------- .194 mm peak to peak
31 mm/sec.
Shutdown ------------------- .216 mm peak to peak
34.3 mm/sec.
(Generator Set)
Peak to Peak disp. ½ order ------- .13 mm (5.0 mil)
Peak to Peak disp. 1st order ------ .13 mm (5.0 mil)
Overall displacement ---------------- .22 mm (8.5 mil)
Overall velocity ------------------------ 34.3mm/s (1.35 in/s)

Oil Mist Detection:
High Oil Mist Detection
Shutdown ------------------- 5 seconds

Metal Particle Detection:
High Metal Particle Detection
Shutdown -------------------- 5 seconds

Some of these specifications, alarms and shutdowns are only Rule of Thumb, Refer to T.M.I. for exact engine specifications.

Test Locations	
Engine Overspeed	Flywheel
Jacket Water Temp.	Water manifold Outlet
Oil Temp. to Bearings	Oil Temp. Regulator Housing Outlet
Oil Pressure to Bearings	Priority Valve
Crankcase Pressure	Side Cover with Oil Fill Neck
Exhaust Stack Temp.	Turbo Outlet Adapter
Low Water Level	Expansion Tank
Low Oil Level	Side Cover with Oil Fill Neck
Low Fuel Pressure	Fuel Filter Housing
Low Aux. H2O Pump psi	Aux H2O Pump Outlet
Low Air Starting Pressure	Air Supply to Starter
Low Injector Coolant Pressure	Coolant Manifold
Low Jacket Water Pressure	Cylinder Block Inlet
High Injector Coolant Temp.	Fuel Manifold Dependent
High Air Manifold Temp.	Air Manifold
Low Fuel Temp.	Fuel Inlet to Engine
High Fuel Temp.	Fuel Inlet to Engine

Quick Reference Troubleshooting

High Exhaust Temperature

- Excessive inlet air restriction.
- Usual limits
- 1.25 kPa (5 in.H2O) clean
- 3.75 kPa (15 in H2O) dirty
- Air filter too small
- Restrictive inlet air piping
- Negitive pressure in engine room when consuming engine room air
- Timing retarded
- Boost leak
- Piping
- Housing
- Air Shutoff
- Plenum
- O-ring seal at A/C inlet
- Excessive fuel
- Incorrect fuel setting
- Injector degradation
- Excessive exhaust restriction
    - Usual limit 2.5 kPa (10 in H2O)
- Exhaust leak
- Turbocharger compressor and/or turbine fouling
- Excessive A/C fouling
- Air or water side
- Excessive A/C pressure drop (air side)

Low Boost

- Excessive inlet air restriction
- Intake manifold piping leak
    - O-ring seals between compressor and aftercooler
    - Air shutoff
    - Missing plugs
    - Aftercooler core and housing gaskets
    - Gaskets at all covers
- Exhaust manifold piping leak
    - Bellows
    - Cracked manifold
    - Missing plugs
    - Gaskets
- Excessive exhaust restriction
- Compressor and/or diffuser fouling
- Damaged turbine nozzle or turbine blades
- Wrong turbocharger parts
- Damaged Turbocharger bearings
- Partially shut air shutoff
- Timing advanced
- Excessive A/C air side pressure drop
- Wrong camshaft
- Mis-adjusted valve lash
- Hot air to turbocharger inlet

High Boost
- Wrong turbocharger parts
- Timing retarded
- Wrong camshaft
- Mis-adjusted valve lash
- Cold air to turbocharger inlet
- Rack setting

Turbocharger Surge
- Excessive inlet air restriction
- High inlet manifold temperatures
- Partially shut air shut-off
- Uneven operation (bank to bank on vee engine)
- Misfire
- Unequal exhaust backpressure between banks on vee engine
- Fouled or damaged turbocharger compressor of diffuser (cold side)
- High aftercooler air side pressure drop.
- Fouled turbocharger nozzle (hot side)
- Inlet ducting with transitions too close to turbocharger
- Excessive back pressure especially on HFO engine
- Cold air temperature to the turbocharger
  - Below 0 degree C (32 degree F)
- Valve lash too tight
- Damaged valve mechanism
- Wrong turbocharger or turbocharger parts
- Operation at high load at low engine speeds

Note: It is normal for the turbocharger to surge momentarily with a rapid drop in load

Low Power
- Operating in lug condition
- Not enough fuel
- Governor limiting fuel rack movement
- API gravity of fuel
- Fuel temperature
- Fuel filter plugging
- Fuel Pressure
- Lower heating value of fuel
- Low rack (fuel setting)
- Low efficiency
- Low generator efficiency
- Low A/C effectiveness
- Retarded injector timing
- High inlet air temperature to turbo
- Misfiring
- Nozzle wear

High Oil Consumption
- Leaks
- Oil quality
- Oil change intervals
- Improper oil level
- Extended idle time
- Low operating temperatures
- Piston ring condition
- Piston top land condition
- Liner condition
- Run in time

Problem 1
The Engine Crankshaft Will Not Turn When The Start Switch Is On.

Probable Cause

1. Problem With The Air Starting Motor
   - Refer to "Problem 35 " through "Problem 40"
2. Fluid in the Cylinders
   - Open the manual valves (Kiene valves) that measure cylinder pressure on each cylinder. If the engine is not equipped with the manual valves, remove the cylinder pressure relief valve or the plug. Inspect the cylinders for fluid while the crankshaft is being turned.
3. Problem With Accessory Equipment (Hydraulic Pumps, Air Compressor, etc.)
   - Disconnect the driven equipment until the faulty accessory can be found. Make a repair or a replacement of the faulty accessory.
4. An Internal Problem Prevents The Turning Of The Engine Crankshaft.
   - If the crankshaft remains unable to be turned, the engine must be disassembled. After disassembling the engine, inspect the engine for other internal problems. Possible internal problems include the following conditions:
     - Bearing seizure
     - Piston seizure
     - Valve and piston contact

<u>Comments or Notes:</u>

Problem 2
The Engine Will Not Start. The Governor Terminal Shaft Does Not Move In Order To Open The Fuel Injector Racks

Probable Cause

1. Too Much Binding In Control Linkage
   - The Engine can start when the engine is cold. When the oil is hot the governor does not develop the oil pressure that is needed to move the linkage. Check the linkage effort and correct the linkage effort.
2. No Signal To Actuator Solenoid
   - Make reference to the "Woodward PGE Locomotive Governor Module" or the 2301A Electric Governor Service Manual, SENR3585.
3. Low Oil Pressure In The Governor
   - The governor oil pump relief valve may be stuck in the open position or the valve may be leaking. This may be corrected by disassembly and cleaning of the governor. Make reference to Caterpillar 3161 Governor Service Manual, SENR3028. Check for plugged oil supply passages from the engine.

<u>Comments & Notes</u>

Problem 3
The Engine Will Not Start. The Governor Terminal Shaft Is A Minimum Of Half Open During Cranking. This Condition Can Be Determined By Observing The Outboard Shaft Rotation.

Probable Cause

1. Slow Cranking Speed
   - Refer to "Problem 36 ".
2. Low Quality Fuel Or Water In Fuel
   - Remove the fuel from the fuel tank. Install new fuel filters. Put a good grade of clean fuel in the fuel tank. Refer to Supplement, SEBU7003, "Caterpillar 3600 Series Diesel Engine Fluids Recommendations For Lubricants, Fuels, and Coolants".
3. No Fuel To Fuel Injectors
   - Check the fuel level in the fuel tank and fill the fuel tank, if necessary. Use the priming pump in order to remove any air from the fuel system.
   - Install new fuel filters, if necessary. Fuel lines that are blocked should be cleaned and fuel lines that are broken should be replaced. Check the fuel transfer pump for damage and/or wear. Make replacements, as needed.
   - The governor linkage not connected to the internal rack linkage. This condition can exist after a governor has been assembled incorrectly during an overhaul. Ensure that the governor linkage is correctly engaged.
4. Low Fuel Pressure
   - At starting rpm, the minimum fuel pressure from the fuel transfer pump must be 415 kPa (60 psi). If the fuel pressure is less than 415 kPa (60 psi), change the fuel filters. After changing the fuel filters, inspect the fuel system for air in the fuel system. If the fuel pressure is still low, check the fuel bypass valve and the fuel transfer pump for correct operation.
5. Wrong Fuel Injection Timing
   - Make adjustment to timing. Refer to Testing And Adjusting, "Fuel System".
6. The Air Inlet Shutoff Valve Is Tripped.
   - Reset the air inlet shutoff valve.

<u>Comments & Notes</u>

Problem 4
The Engine Overspeeds On Start-up.

Probable Cause

1. Fuel Control Linkage
   - Inspect the fuel control linkage for one or more of the following conditions:
   - Incorrect assembly after overhaul
   - Bound fuel control linkage
   - Bound fuel control linkage in FUEL-ON position
   - Governor output lever to control housing lever out of adjustment.
   - Make adjustment or repair.
2. Governor Problem
   - Make reference to one of the following publications:
     - PGEV & PGE Governors Manual (Locomotive Application), SENR6444
     - 2301A Electric Governor Service Manual, SENR3585
     - 3161 Governor Service Manual, SENR3028
     - Heinzman Governor (Marine Application), SENR4661
     - Heinzman Governor Manual (Generator Set Application), SENR4622
     - 701 Digital Speed Control Manual, SENR6472
     - 705 Digital Speed Control Manual, SENR6474
     - 721 Digital Speed Control Manual, SENR6473
     - 723 Plus Digital Speed Control Manual, RENR2228
3. The Governor Actuator Is Not Engaged In The Drive Coupling.
   - Ensure that the governor is driven by the engine. If necessary, remove the governor and install the governor again in order to ensure that the engine is engaged correctly with the governor drive. Also, check for drive components in the governor and the engine that are worn or damaged.

Comments & Notes

Problem 5
The Engine Speed Does Not Have Stability.

Probable Cause

1. Engine Misfiring
    - Refer to "Problem 9 ".
2. Bound Linkage Or Worn Linkage With Flat Spots And High Clearances
    - Inspect the linkage. Repair the linkage or replace the linkage, as needed.
3. Rough Governor Drive
    - Worn splines and/or high gear clearances can cause rough governor drive. Inspect parts and replace parts whenever this is necessary.
4. Governor Problem
    - Make reference to one of the following publications:
        - PGEV & PGE Governors Manual (Locomotive Application), SENR6444
        - 2301A Electric Governor Service Manual, SENR3585
        - 3161 Governor Service Manual, SENR3028
        - Heinzman Governor (Marine Application), SENR4661
        - Heinzman Governor Manual (Generator Set Application), SENR4622
        - 701 Digital Speed Control Manual, SENR6472
        - 705 Digital Speed Control Manual, SENR6474
        - 721 Digital Speed Control Manual, SENR6473
        - 723 Plus Digital Speed Control Manual, RENR2228
5. Seized Injector
    - Replace the injector.
6. Seized Piston And/Or Stuck Piston Rings
    - Replace piston assembly and cylinder liner.

Comments & Notes

Problem 6
The Engine High Idle Speed Is Too Low.

Probable Cause

1. Speed Setting Control Shaft Is Not Against The High Idle Stop.
   - Check the speed control linkage and the pneumatic controls for restrictions. If necessary, carry out repairs or replacement.
2. Incorrect High Idle Adjustment
   - The governor speed setting shaft is against the high idle stop and the high idle is too low. Make adjustment to correct high idle. Also, check the engine fuel setting in order to ensure that the engine fuel setting is correct.
3. Speed Droop Adjustment Is Incorrect.
   - The 3161 has an internal adjustable speed droop which is set at the factory. If adjustment is necessary, see the Caterpillar 3161 Governor Service Manual, SENR3028.
4. The Speed Setting Solenoid Adjustment of the Woodward PGEV Governor is not correct.
   - Make reference to the "Woodward PGE Locomotive Governor Module".

<u>Comments & Notes</u>

Problem 7
The Engine's High Idle Declines After Start-Up.

Probable Cause

1. Loss Of Normal RPM
   - The Loss of approximately 20 rpm can be expected as the engine warms to operating temperature.
2. Incorrect High Idle Adjustment
   - If necessary, make an adjustment in order to correct high idle. Also, check the engine fuel setting in order to ensure that the engine fuel setting is correct.

Comments & Notes

Problem 8
The Engine Cannot Be Shutdown Through The Governor.

Probable Cause

1. Bad Shut Down Solenoid
   - The solenoid may have shorted wires or broken wires. The solenoid may be stuck in the open position. If necessary, inspect the solenoid and replace the solenoid.
2. Incorrect Wiring
   - The Shutdown signal is not wired correctly to the 2-pin connector. In order to achieve the correct polarity between the solenoid and the 2-pin connector, use the following method:
     - The "A" terminal is positive.
     - The "B" terminal is negative.
3. Incorrect Installation Of Governor Actuator
   - Ensure that the governor control lever or the actuator terminal shaft is engaged correctly with the fuel control linkage stop lever.
4. Governor In Need Of Repair
   - Disassemble the governor and clean the governor components. Inspect the governor components for wear and damage. Make a replacement of parts, as needed.

<u>Comments & Notes</u>

Problem 9
The Engine Is Misfiring Or The Engine Is Running Rough.

Probable Cause

1. Low Fuel Pressure
   - The fuel pressure at the outlet of the fuel filter housing must be a minimum of 450 kPa (65 psi) at 900 rpm. If fuel pressure is lower than the above pressure, check the following items:
     - Plugged fuel filters
     - Fuel transfer pump
   - Make sure that there is fuel in the fuel tank. Look for leaks or bends in the fuel line between the fuel tank and the fuel transfer pump. Look for air in the fuel system. Also look for a faulty return fuel pressure regulating valve.
2. Air In Fuel System
   - Find the air leak in the fuel system and correct the air leak. If there is air in the fuel system, the air generally enters the fuel system on the suction side of the fuel transfer pump.
3. Leakage Or Breakage In Fuel Line Between Fuel
   - Manifold And Cylinder Head
   - Install a new fuel line.
4. Defect In Fuel Injector
   - When the engine runs at rated load, the exhaust manifold port temperature can be an indication of the condition of a fuel injector. Low temperature at an exhaust manifold port is an indication of no fuel to the cylinder. This may be an indication of
     a fuel injector with a defect. Extra high temperature at an exhaust manifold port can be an indication of too much fuel to the cylinder. This may also be caused by a fuel injector with a defect. If any one cylinder varies by more than 50 °C (90 °F), a
     faulty fuel injector should be suspected.

     Note: The variance in temperature can be an increase or a decrease.

5. Faulty Inlet Or Exhaust Valve
   - When the engine runs at rated load, the temperature of an exhaust manifold port can be an indication of the condition of the inlet and exhaust valves. Extra high temperature at an exhaust manifold port can be an indication of a valve with a defect. If any one cylinder has an exhaust port temperature that is 50 °C (90 °F) higher than the average of the exhaust port

temperatures on the bank, a faulty valve should be suspected.

6. Wrong Valve Lash
   - Make adjustment to valve lash. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".
7. Wrong Fuel Injection Timing
   - Make adjustment to timing. Refer to Testing And Adjusting, "Fuel System".
8. Bent Pushrod Or Broken Pushrod
   - Make a replacement of pushrod, if necessary.
9. Fuel Has Cloud Point Higher Than Atmospheric Temperature. Cloud Point Is The Temperature When Wax Is Formed In The Fuel.
   - Drain the fuel tank, fuel lines and fuel manifolds. Change the fuel filter. Fill the tank with fuel that has the correct cloud point. Remove the air from the system with the priming pump. Some installations require the use of fuel heaters in order to ensure fuel flow. Also, the use of fuel heaters prevents filter blockage from fuel wax.
10. Excessive Engine Load
   - Lighten the load in order to observe any change in the engine operation.

<u>Comments & Notes</u>

Problem 10
The Engine Stalls At Low RPM.

Probable Cause

1. Low Fuel Pressure
   - The fuel pressure at the outlet of the fuel filter housing must be a minimum of 450 kPa (65 psi) at 900 rpm. If fuel pressure is lower than the above pressure, check the following items:
     - Plugged fuel filters
     - Fuel transfer pump
   - Make sure that there is fuel in the fuel tank. Look for leaks or bends in the fuel line between the fuel tank and the fuel transfer pump. Look for air in the fuel system. Also look for a faulty return fuel pressure regulating valve.
2. Low Engine Idle RPM
   - Make adjustment to the governor. Ensure that the idle rpm setting matches the rpm that is listed in Technical Marketing Information (TMI).
3. Defect In Fuel Injector
   - Refer to "Problem 9 ".
4. Engine Accessories
   - Check engine accessories for damage and make repair or replacement. If necessary, disconnect the accessories and test the engine.

<u>Comments & Notes</u>

Problem 11
The Engine Does Not Have Enough Power.

Probable Cause

1. Dirty Fuel Filters
   - If the pressure differential between the inlet port of the fuel filter housing and the outlet port of the fuel filter housing is 70 kPa (10 psi), a replacement of the filter is recommended.
2. Low Quality Fuel Or Water In Fuel
   - Remove the fuel from the fuel tank. Install new fuel filters. Put a good grade of clean fuel in the fuel tank. Refer to Supplement, SEBU7003, "Caterpillar 3600 Series Diesel Engine Fluids Recommendations For Lubricants, Fuels, and Coolants".
3. High Fuel Temperature
   - If the fuel supply temperature is 38 °C (100 °F) or more, a fuel cooler may be necessary.
   - Return fuel serves to remove heat from the fuel injectors. A fuel cooler is recommended in order to prevent excessive power loss and a fuel cooler is recommended in order to maintain an acceptable injector life.
4. Low Fuel Pressure
   - The fuel pressure at the outlet of the fuel filter housing must be a minimum of 450 kPa (65 psi) at full load speed. If fuel pressure is lower than the above pressure, install new fuel filter elements. If the fuel pressure is still low, check the fuel transfer pump.
   - Make sure that there is fuel in the fuel tank. Look for leaks or bends in the fuel line between the fuel tank and the fuel transfer pump. Look for air in the fuel system. Also look for a faulty return fuel pressure regulating valve.
5. Faulty Fuel Injector
   - Refer to "Problem 9 ".
6. Leaks In Air Inlet System
   - Check the pressure in the air inlet manifold (Plenum). Look for leak paths in the air cleaner pipe assemblies and the clamped joints.

7. Governor And Fuel Control Linkage
   - Ensure that the governor is moving the fuel control linkage against the fuel setting stop. Make adjustment in order to get the full travel of the linkage. Install new parts for those parts that have damage or defects. If the control linkage is not against the stop and the engine runs below rated speed under load, perform the following inspections:
     - a. Check high idle and adjust, if necessary.
     - b. The Fuel ratio control may be restricting the travel of the control linkage. Adjust, If necessary.
8. Wrong Valve Lash
   - Make adjustment to valve lash. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".
9. Wrong Fuel Injection Timing
   - Make adjustment to timing. Refer to Testing And Adjusting, "Fuel System".
10. Incorrect Fuel Setting
    - Make adjustment to timing. Refer to Testing And Adjusting, "Fuel System".
11. Ineffective Aftercooler
    - Check temperature of inlet and outlet coolant supply. Remove any external restrictions or internal restrictions.
12. Carbon Deposits On Turbocharger Or Other Causes Of Friction
    - Inspect the turbocharger. Repair the turbocharger, if necessary. Check for low boost pressure. Low boost pressure is 10 percent below initial boost pressure.
13. Not Enough Air For Combustion
    - Check the air cleaner for restrictions and check the aftercooler for restrictions.

Comments & Notes

Problem 12
The Engine Has Too Much Vibration.

Probable Cause

1. Loose Vibration Damper
   - Inspect the vibration damper for damage. Tighten the bolts, if necessary. If the vibration damper bolt holes have damage or wear, replace the vibration damper bolt holes with new parts.
2. Faulty Vibration Damper
   - Inspect the vibration damper for leakage and inspect the vibration damper for a damaged case assembly. Either of the above conditions can cause the weight to come into contact with the housing. If the weight contacts the housing, the operation of the vibration damper is affected. Your Caterpillar dealer can perform a torsional vibration measurement.
3. Engine Supports Are Loose or Faulty.
   - Tighten all mounting bolts. Install new components, if necessary.
4. Driven Equipment Is Not In Alignment Or Driven Equipment Is Not In Balance.
   - Check alignment and balance. Correct alignment and balance, if necessary.
5. The Engine Is Misfiring Or The Engine Is Running Rough.
   - Refer to "Problem 9 ".
6. External Causes of Vibration
   - Check the equipment in the engine and around the engine for the source of the vibration.

<u>Comments & Notes</u>

Problem 13
Loud Combustion Noise.

Probable Cause

1. Wrong Fuel Injection Timing
   - Make adjustment to timing. See subject, Fuel Timing.
2. Defect In Fuel Injector(s):
   Make reference to Problem 9.

<u>Comments & Notes</u>

Problem 14
The Engine Has A Valve Train Noise (Clicking).

Probable Cause

1. Damage To Valve Train Components
   - Inspect all of the following valve train components:
     - Valves
     - Springs
     - Camshafts
     - Lifters
     - Rocker arms
     - Pushrods
   - Check for worn parts or damaged parts. Replace worn parts or damaged parts, as required.
2. Not Enough Lubrication
   - Check the lubrication in the valve compartment. There must be a strong flow of oil at engine high rpm. There must be a small flow of oil at low rpm. Oil passages must be clean. The oil passages that send the oil to the cylinder head are particularly important.
3. Too Much Valve Lash
   - Make adjustment to valve lash. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".
4. Valve Recess
   - On engines that use distillate fuel, adjust the valve recess.

Comments & Notes

Problem 15
The Engine Has A Loud Valve Train Noise.

Probable Cause

1. Damage To Valve Springs
   - Replace the damaged components.
2. Damage To Camshaft
   - Replace the damaged components. Clean the engine thoroughly. If the camshaft is replaced, new valve lifters are necessary.
3. Damage To Valve Lifter
   - Clean the engine thoroughly. Replace the damaged valve lifters. Inspect the lobes of the camshaft for damage. Look for valves that do not move freely. Make adjustments to the valve lash. Refer to Testing And Adjusting, "Fuel System".

<u>Comments & Notes</u>

Problem 16
Oil Is In The Cooling System.

Probable Cause

1. Defect In Core Of Engine Oil Cooler
   - Inspect each engine oil cooler. Repair any faulty oil cooler or replace any faulty oil cooler, as required.
2. Failure Of Cylinder Head Water Seals
   - Install new cylinder head water seals in the seal plates.
3. Faulty Water Pump Seal
   - Check the water pump. If necessary, repair the water pump.

Comments & Notes

Problem 17
Mechanical Noise (Knock) Is In The Engine.

Probable Cause

1. Failure Of Bearing For Connecting Rod
   - Inspect the bearings for the connecting rods and the bearing surfaces (journals) on the crankshaft. Install new parts, as required.
2. Damaged Gears
   - Install new parts, as required.
3. Damaged Crankshaft
   - Make replacement of the crankshaft.
4. Defect In Accessory Equipment
   - Repair the faulty components or install new components.
5. Wrong Adjustment Of Fuel Injector
   - Adjust the fuel injector.
6. Wrong Adjustment Of Valve Bridge
   - Adjust valves and valve bridges.

Comments & Notes

Problem 18
Fuel Consumption Is Too High.

Probable Cause

1. Fuel System Leaks
   - Tighten or make replacement of parts at points of leakage.
2. Fuel And Combustion Noise (Knock)
   - Refer to "Problem 9 " and "Problem 13 ".
3. Wrong Fuel Injection Timing
   - Make adjustment to timing. Refer to Testing And Adjusting, "Fuel System".
4. Defect In Fuel Injectors
   - Refer to "Problem 9 ".
5. Low Quality Fuel Or Water In Fuel
   - Remove the fuel from the fuel tank. Install new fuel filters. Put a good grade of clean fuel in the fuel tank. Refer to Supplement, SEBU7003, "Caterpillar 3600 Series Diesel Engine Fluids Recommendations For Lubricants, Fuels, and Coolants".
6. Incorrect High Idle
   - Adjust high idle setting.
7. Overloaded Engine
   - Do not exceed recommended capacities.
8. Excessive Exhaust Back Pressure
   - Refer to Testing And Adjusting, "Air Inlet And Exhaust System".

Comments & Notes

Problem 19
Too Much Valve Lash Is Present.

Probable Cause

1. Not Enough Lubrication
   - Check the lubrication in the valve compartment. There must be a strong flow of oil at engine high rpm. There must be a small flow of oil at low rpm. Oil passages must be clean. The oil passages that send the oil to the cylinder head are particularly important.
2. Worn Rocker Arm
   - If the face of the rocker arm that makes contact with the valve bridge has too much wear, install new parts or rocker arms. Make adjustment to valve lash. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".
3. Worn Valve Bridges
   - Make an adjustment or replacement, as required.
4. Worn Valve Stem
   - If the end of the valve stem has too much wear, install new valves. Make adjustment to valve lash. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".
5. Worn Pushrods
   - If the pushrods have too much wear, install new pushrods. Make adjustment to valve lash. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".
6. Broken Valve Lifters Or Worn Valve Lifters
   - Install new valve lifters. Check the camshaft for wear.
   - Check for free movement of valves or bent valve stem. Clean the engine thoroughly. Make adjustment to valve lash. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".
7. Worn Camshaft
   - Check valve lash. Check for wear on camshaft lobes. Check for free movement of valves or bent valve stems. Install a new camshaft. Install new valve lifters. Make adjustment to valve lash. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".

Comments & Notes

Problem 20
The Valve Rotocoil Is Free Or Spring Lock Is Free.

Probable Cause

1. Broken Locks
   - Broken locks can cause the valve to slide into the cylinder. This will cause much damage.
2. Broken Valve Spring
   - Install a new valve spring.
3. Broken Valve
   - Replace the valve and the other damaged parts.

Comments & Notes

Problem 21
Oil Is At The Exhaust.

Probable Cause

1. Too Much Oil In The Valve Compartment
   - Be sure that the plugs are installed in the ends of the rocker arm shaft.
2. Worn Valve Guides
   - Reconditioning of the cylinder head is required.
3. Worn Piston Rings
   - Inspect piston rings and install new parts, as required.
4. Excessive Idle Time
   - Do not idle the engine for long time periods.

<u>Comments & Notes</u>

Problem 22
Little Valve Lash Or No Valve Lash Is Present.

Probable Cause

1. Worn Valve Seat Or Worn Valve Face
   - Reconditioning of the cylinder head is required. Make adjustment to valve lash. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".
2. Wrong Crankshaft/Camshaft Timing
   - Make adjustment to camshaft timing. Refer to Testing And Adjusting, "Fuel System".
3. Open Mister For Oil
   - On engines that use distillate fuel, check the delivery of oil from the mister.
4. Valve Bridge Out Of Adjustment
   - Make adjustment to the valve bridge. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".

Comments & Notes

Problem 23
The Engine Has Early Wear.

Probable Cause

Note: Internal engine components wear due to abrasion. Each of the following systems must be inspected in order to determine the source of abrasion within that system: air, oil, fuel and water. The cause must be corrected. Check the components and replace the components, as required.

1. Dirt In Lubrication Oil
   - Remove dirty lubrication oil. Clean the centrifugal oil filters. Install new filter elements. Check oil filter bypass valves for wear or broken springs. Put clean oil in the engine.
2. Lack Of Lubrication
   - Ensure that the oil is the proper viscosity. Ensure that the oil level is at the recommended capacity.
3. Air Inlet Leaks
   - Inspect all gaskets and connections. Make repairs if leaks are found.
4. Fuel Leakage Into Lubrication Oil
   - This will cause high fuel consumption and low engine oil pressure. This condition may also increase the oil level in the crankcase. Make repairs if leaks are found. Install new parts, as required.
5. Low Quality Fuel Or Water In Fuel
   - Remove the fuel from the fuel tank. Install new fuel filters. Put a good grade of clean fuel in the fuel tank. Refer to Supplement, SEBU7003, "Caterpillar 3600 Series Diesel Engine Fluids Recommendations For Lubricants, Fuels, and Coolants".

Comments & Notes

Problem 24
Coolant Is In The Lubrication Oil.

Probable Cause

1. Failure Of Any Of The Engine Oil Cooler Cores
   - Install a new core for the faulty engine oil cooler. Drain the crankcase and refill the crankcase with clean lubricant. Install new oil filters.
2. Crack Or Defect In Cylinder Head
   - Pressurize the cooling system in order to determine whether the cylinder head needs repair. While the cylinder head is removed from the engine, inspect the cylinder head in order to determine the extent of the damage. Repair the cylinder head or replace the cylinder head, as required.
3. Crack Or Defect In Cylinder Block
   - Pressurize the cooling system in order to locate the damage. Inspect the cylinder block. Repair the cylinder block or replace the cylinder block, as required.
4. Failure Of Cylinder Liner Seals
   - Replace cylinder liner seals.
5. Faulty Water Pump
   - Check the water pump for leakage.
6. Faulty Water Cooled Valve Seat Insert
   - Replace the cylinder head.

<u>Comments & Notes</u>

Problem 25
Too Much Black Smoke Or Gray Smoke Is Present.

Probable Cause

1. Not Enough Air For Combustion
   - Check the air cleaner and the aftercooler for restrictions.
2. Faulty Fuel Injectors
   - Install new fuel injectors.
3. Wrong Fuel Injection Timing
   - Make adjustment to timing. Refer to Testing And Adjusting, "Fuel System".
4. Broken Exhaust Valve
   - Replace the broken components and the damaged components, as required.
5. Overloaded Engine
   - Do not exceed recommended capacities.
6. High Fuel Rate
   - Refer to "Problem 18 ".

Comments & Notes

Problem 26
Too Much White Smoke Or Blue Smoke Is Present.

Probable Cause

1. Too Much Lubrication Oil In Engine
   - Remove extra oil. Find the source of the extra oil. Put the correct amount of oil in engine.
2. The Engine Is Misfiring Or The Engine Is Running Rough.
   - Refer to "Problem 9 ".
3. Wrong Fuel Injection Timing
   - Make adjustment to timing. Refer to Testing And Adjusting, "Fuel System".
4. Worn Valve Guides
   - Reconditioning of cylinder head is required.
5. Worn Piston Rings Or Improperly Installed Piston Rings
   - Inspect piston rings and install new parts, as required.
6. Failure Of Turbocharger Oil Seal
   - Check the air inlet manifold (Plenum) for oil and repair the turbocharger, as required.
7. Faulty Aftercooler Core
   - Check aftercooler core for leaks.
8. Faulty Valve Lubricator Pumps
   - Check the setting and the delivery of the valve lubricator pumps.
9. Worn Cylinder Liner
   - Check cylinder liners.

<u>Comments & Notes</u>

Problem 27
The Engine Has Low Oil Pressure.

Probable Cause

1. Dirty Oil Filters Or Oil Cooler
    - Check the operation of bypass valve for the oil filters. Install new oil filter elements. Clean oil cooler cores or install new oil cooler cores. Remove dirty oil from the engine. Clean centrifugal oil filters. Change engine oil.
2. Faulty Oil Pressure Gauge
    - Install new gauge.
3. Diesel Fuel In Lubrication Oil
    - Find the source of the leakage of the diesel fuel into the lubrication oil. Make repairs, as required. Remove the lubrication oil that has been contaminated with diesel fuel. Install new oil filters. Put clean oil in the engine.
4. Too Much Clearance Between Rocker Arm Shaft And Rocker Arms
    - Check lubrication in valve compartments. Install new parts, as required.
5. Faulty Oil Pump Suction Pipe
    - Replacement of oil pump suction pipe is required.
6. Oil Pump's Suction Strainer Is Fouled.
    - Clean the strainer.
7. Faulty Priority Valve
    - Inspect the priority valve and replace damaged parts or worn parts.
8. Stuck Open Oil Pressure Relief Valve
    - Clean the valve and the housing. Install new parts, as required.
9. Faulty Oil Pump
    - Repair the oil pump or replace the oil pump.
10. Too Much Clearance Between Crankshaft And Crankshaft Bearings
    - Inspect the crankshaft bearings and make replacement, as required.
11. Too Much Clearance Between Camshaft And Camshaft Bearings
    - Inspect the camshaft and the camshaft bearings. Replace the camshaft and the camshaft bearings, as required.
12. Loose Oil Plugs For Crankshaft or Missing Oil Plugs For Crankshaft
    - Check the torque of the oil plugs for the crankshaft.
13. Loose Plugs In Rocker Arm Shaft Or Missing Plugs In Rocker Arm Shaft
    - Check plugs in the ends of the rocker arm shafts.

14. Loose Oil Supply Line In Box For Lifter
    - Check the oil supply line from the cylinder block to the cylinder head behind the lifter assemblies.
15. Loose Retainer On The Idler Gear For The Rear Gear Train Or Missing Retainer On The Idler Gear For The Rear Gear Train
    - Check the retainer on the idler shafts of the rear gear train.

Comments & Notes

Problem 28
The Engine Has High Oil Pressure.

Probable Cause

1. Restriction In Engine Lubrication System
   - Use various pressure taps in order to determine the problem area and repair the problem area.
2. Faulty Priority Valve
   - Inspect the priority valve. Replace damaged parts or worn parts.
3. Faulty Oil Pressure Relief Valve
   - If necessary, inspect the oil pressure relief valve and repair the oil pressure relief valve.
4. Oil Pump Output Too High.
   - The wrong oil pump is installed. Repair the oil pump or replace the oil pump.
5. Incorrect Viscosity Oil Is Used.
   - Drain the engine oil and refill the engine with oil of the correct viscosity. Install new oil filters.

Comments & Notes

Problem 29
The Engine Uses Too Much Lubrication Oil.

Probable Cause

Notice

Use the procedure on (page 71) estimating oil consumption before the disassembly of the engine.

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1. Too Much Lubrication Oil In Engine
   - Remove the extra oil. Find the source of the extra oil. Put the correct amount of oil in the engine.
2. Oil Leaks
   - Find all oil leaks. Make repairs, as required. Check for dirty crankcase breathers.
3. High Oil Temperature
   - Check operation of oil cooler and oil temperature regulator. Install new parts, as required. Clean the oil cooler cores.
4. Too Much Oil In The Valve Compartment
   - Be sure that the plugs are installed in the rocker shafts.
5. Worn Valve Guides
   - Reconditioning of the cylinder head is required.
6. Failure Of Turbocharger Oil Seal
   - Check the air inlet manifold (Plenum) for oil and repair the turbocharger, as required.
7. Failure Of Crankshaft Seal
   - Replace crankshaft seals.
8. Worn Piston Rings Or Improperly Installed Piston Rings
   - Inspect piston rings and install new parts, as required.
9. Faulty Valve For Continuous Prelube
   -Check operation of continuous prelube system.
10. Defective Valve Lubricator Metering Pump(s).
    -Check setting and delivery of lubricator metering pump(s).

<u>Comments & Notes</u>

Problem 30
The Prelube Pump Is Inoperative Or Slow.

Probable Cause

1. Open Circuit Or Grounded Circuit On The Electric Motor
   - Inspect the wiring of the electric prelube pump and repair the wiring, as required.
2. Open Circuit Or Grounded Circuit On The Solenoid
   - Inspect the wiring of the electric prelube pump and repair the wiring, as required.
3. Low Air Pressure
   - Check the prelube pump's air system for air leaks.
   - Check the air compressor for correct operation.
4. No Lubrication To Air Motor
   - If necessary, repair the prelube pump's air system. If necessary, replace the air prelube pump's motor.

Comments & Notes

Problem 31
The Engine Coolant Is Too Hot.

Probable Cause

1. Restriction Of Coolant Flow Through Radiator Core Tubes
   - Clean the radiator or the heat exchanger and flush the radiator or the heat exchanger.
2. Low Coolant Level
   - Add coolant to the cooling system. Check for leaks.
3. Faulty Pressure Cap
   - Check operation of the pressure cap. Install a new pressure cap, as required.
4. Combustion Gases In Coolant
   - Find the source of the leakage of combustion gases into the cooling system. Make repairs, as required:
     - Cylinder liner
     - Water cooled valve seat insert
5. Faulty Water Temperature Regulators
   - Check water temperature regulators for correct operation. Check the water temperature gauge for correct operation. Install new parts, as required.
6. Faulty Jacket Water Pump
   - Make repairs to the jacket water pump, as required.
7. Faulty Aftercooler Pump
   - Make repairs to the aftercooler pump, as required.
8. Too Much Load On The System
   - Reduce the load on the system.
9. Wrong Fuel Injection Timing
   - Make adjustment to timing. Refer to Testing And Adjusting, "Fuel System".
10. Incorrect Coolant And/Or Flow
    - The system is not balanced correctly. Repair the system, as required.
11. Scale Buildup
    - Clean the cooling system.

Comments & Notes

Problem 32
The Exhaust Temperature Is Too High.

Probable Cause

1. Inlet Air Leakage
   - Check the following locations and the associated piping for air leakage. If necessary, make the corrections.
     - O-ring seals between the compressor and the aftercooler
     - Air inlet shutoff
     - Plugged sections
     - Gaskets within aftercooler
     - Plenum
2. Leakage At Exhaust System
   - Find the cause of the exhaust leak. Make repairs, as required.
3. Excessive Exhaust Restriction
   - Ensure that the pressure drop between the outlet of the turbocharger and the atmosphere is less than 2.5 kPa (10 inches of H2O).
4. Insufficient Air Passage Through Filters Or Inlet Air Piping
   - Ensure that the pressure drop between the inlet of the filters to the inlet of the turbocharger is less than 1.5 kPa (5.00 inches of H2O) when the filters and the piping is clean.
   - Ensure that the pressure drop between the inlet of the filters to the turbocharger inlet is less than 3.75 kPa (15 inches of H2 0) when the filters and the piping is dirty.
5. Wrong Fuel Injection Timing
   - If necessary, make adjustments to timing. Refer to Testing And Adjusting, "Fuel System".
6. Faulty Exhaust Valve
   - Check exhaust valves for damage and replace exhaust valves, as required.
7. Faulty Turbocharger
   - Inspect the turbocharger. Repair the turbocharger, if necessary. Check for low boost pressure. Low boost pressure is 10 percent below initial boost pressure.
8. Fouled Turbocharger
   - Ensure that both the compressor side and the turbine side of the turbocharger are not fouled.
9. The Air Inlet Temperature Is Too High.
   - Refer to "Problem 34 ".

10. Excessive Pressure Drop Through The Aftercooler (Air Side)
   - Ensure that the air side of the aftercooler is not restricted or too contaminated with soot and debris.

Use the following guidelines in order to determine if a rise in exhaust temperatures is the result of a change in ambient conditions.

1. The exhaust manifold temperature will increase approximately 1.6 °C (2.90 °F) for every 1.0 °C (1.80 °F) increase in the inlet air temperature.
2. The exhaust manifold temperature will increase approximately 0.2 °C (0.36 °F) for every 1.0 °C (1.80 °F) increase in the aftercooler inlet water temperature.

Comments & Notes

Problem 33
The Engine Oil Temperature Is Too High.

Probable Cause

1. Faulty Oil Temperature Regulators
   - Check the oil temperature regulators for correct operation. Check the oil temperature gauge for correct operation. Install new parts, as required.
2. Restriction Of Oil Flow Through The Engine Oil Cooler
   - Clean the engine oil cooler and flush the engine oil cooler.
3. Engine Coolant Temperature Is Too High.
   - Refer to "Problem 31 ".
4. Low Coolant Flow
   - Refer to "Problem 31 ".
5. Crankcase Pressure Is Too High.
   - Check for faulty main bearings and connecting rod bearings.

<u>Comments & Notes</u>

Problem 34
The Air Inlet Temperature Is Too High.

Probable Cause

Note: Inlet air temperatures should be compared to trends in the performance data in addition to data that is supplied by the factory. Do not rely on the setpoint of the alarm only. High inlet manifold temperature may occur on only the front half or the back half of the engine. This is due to a blockage that is only in one part of the water side of the aftercooler. When the inlet manifold temperature is being measured at the middle of the aftercooler, a hot front section or a hot back section can be undetected. This occurs because the temperature is taken at a point that yields an average temperature. Additional temperature measurements must be made at the ends of the inlet manifold. Drilling of the covers will be required.

1. Restriction Of Coolant Flow Through Aftercooler Cores
   - Clean the aftercooler cores and flush the aftercooler cores.
2. Engine Coolant Temperature Is Too High.
   - Refer to "Problem 31 ".

Comments & Notes

Problem 35
The Air Starting Motor Does Not Turn.

Probable Cause

1. Low Air Pressure
   - Check the system for leaks. Check the operation of the air compressor.
2. Faulty Oil Pressure Valve (Intermittent Operation)
   - Check the operation of the oil pressure valve. Set the oil pressure valve to open at 7 kPa (1 psi). Replace the oil pressure valve, as required.
3. Inoperative Relay Valve
   - Check the operation of the relay valve. Repair the relay valve or replace the relay valve, as required.
4. Faulty Air Start Control Valve
   - Repair the air start control valve or replace the air start control valve, as required.
5. Faulty Air Starting Motor
   - Repair the air starting motor or replace the air starting motor, as required.
6. The Pinion Is Not Engaged.
   - Ensure that the pinion is engaged with the flywheel ring gear.
7. The Manual Barring Group Is Engaged.
   - Check the manual barring group and the switches.
8. Fluid In the Cylinders
   - Open the manual valves (Kiene valves) that measure cylinder pressure on each cylinder. If the engine is not equipped with the manual valves, remove the cylinder pressure relief valve or plug. Inspect the cylinders for fluid while the crankshaft is being turned.

Comments & Notes

Problem 36
The Air Starting Motor Turns Slowly Or The Air Starting Motor Has A Loss Of Power.

Probable Cause

1. Low Air Pressure
   - Check the system for leaks. Check the operation of the air compressor.
2. Malfunctioning Lubricator
   - Check the lubricator for correct operation. Fill the lubricator and adjust the drip rate.
3. Worn Motor Parts
   - Disassemble the air starting motor and inspect the parts. The following guideline should be used for determining the reusability of the motor parts:
     a. Install a set of new vanes if any vane is cracked or damaged. Also, install a set of new vanes if any vane's width is 32 mm (1.25 inch) at either end.
     b. Replace rotor bearings if any roughness or looseness is apparent in the bearings.
     c. Replace the rotor if the body has deep scoring that cannot be removed with the use of emery cloth.
     d. Replace the air cylinder if there are any cracks or deep scoring.
     e. Clean up end plate scoring with emery cloth that is placed on a flat surface.
4. Air Leakage
   - Check the air starting motor for worn seals. Plug the exhaust. Apply 205 kPa (30 psi) air to the inlet and put the unit in nonflammable fluid for 30 seconds. If bubbles appear, replace the motor seals.
5. External Resistance
   - Disconnect driven equipment.

Comments & Notes

Problem 37
The Air Starting Motor's Pinion Does Not Engage With The Flywheel.

Probable Cause

1. Broken Clutch Jaws Or Other Broken Parts
   - Replace the parts, as required.
2. Worn Pinion Engagement Piston
   - Replace the pinion engagement piston and the seal.

<u>Comments & Notes</u>

Problem 38
The Air Starting Motor Runs And The Pinion Engages. After The Pinion Engages, The Air Starting Motor Does Not Turn The Flywheel.

Probable Cause

1. Broken Shafts, Gears Or Clutch Jaws
Replace the parts, as required.

<u>Comments & Notes</u>

Problem 39
The Air Starting Motor's Pinion Does Not Engage Correctly With The Flywheel.

Probable Cause

1. Dry Pinion Shaft
   - Remove the drive pinion. Put clean grease on the drive shaft splines and the drive pinion.
2. The Manual Barring Group Is Engaged.
   - Check the manual barring group and the switches.
3. Fluid In The Cylinders
   - Open the manual valves (Kiene valves) that measure cylinder pressure on each cylinder. If the engine is not equipped with the manual valves, remove the cylinder pressure relief valve or plug. Inspect the cylinders for fluid while the crankshaft is being turned.
4. Improperly Installed Pinion
   - Ensure that the pinion is installed for the correct rotation.

<u>Comments & Notes</u>

Problem 40
The Air Starting Motor's Pinion Does Not Disengage From The Flywheel.

Probable Cause

1. High Air Pressure
   - Check air supply pressure and the air pressure regulator.
2. Incorrect Timing Of Crank Termination
   - Check the controls of the air starting motor for the correct setting for crank termination.
3. Faulty Bearing In Air Starting Motor
   - Check the condition of the bearings in the air starting motor. Replace the bearings, as required.

Comments & Notes

Problem 41
The Electric Starter Motor Does Not Turn.

Probable Cause

1. Low Voltage To Starter Motor
   - Check power supply to the starter motor. If necessary, make repairs.
2. The Wiring Is Faulty Or The Switch Is Faulty.
   - If necessary, make repairs or replacement.
3. Starter Motor's Solenoid Is Faulty.
   - Install a new solenoid.
4. The Starter Motor Is Faulty.
   - If necessary, repair the starter motor or replace the starter motor.

<u>Comments & Notes</u>

Problem 42
The Engine's Crankcase Pressure Is Too High.

Probable Cause

1. Engine Oil Level Is Too High.
   - Remove extra oil. Find the source of the extra oil. Put the correct amount of oil in the engine.
2. Restricted Crankcase Breathers
   - Check and clean crankcase breather elements and tubes.
3. Seized Piston And/Or Stuck Piston Rings
   - Replace piston assembly and cylinder liner.
4. Loose Fuel Injector
   - Ensure that all fuel injectors are tight.
5. Faulty Turbocharger Seal
   - Replace the turbocharger seal.

Comments & Notes

Problem 43
Turbocharger Surge

Note: A rapid drop in load will cause the turbocharger to surge. This is normal.

Probable Cause

1. Insufficient Air Passage Through Filters Or Inlet Air Piping
   - Ensure that the filters are sized properly for the engine. Ensure that the air passages are clean and that the air passages are free of obstructions.
2. Negative Pressure In Engine Space
   - Increase air pressure in engine space.
3. The Inlet Manifold Temperature Is Too High.
   - Refer to "Problem 34 ".
4. Partially Closed Air Shutoff
   - Ensure that the air shutoff is in the open position.
5. Unequal Operation Between Cylinder Banks
   - Ensure that the cylinder banks are operating evenly. Look for any cylinders that are misfiring. This may be the cause of uneven operation. Refer to "Problem 9 ".
6. Unequal Exhaust Back Pressure Between Cylinder Banks
   - Ensure that the difference in the back pressures of the banks is within 0.5 kPa (2.00 inch of H_2O).
7. Fouled Turbocharger Compressor Or A Fouled Turbocharger Diffuser (Air Side)
   - Ensure that the passages are free of debris. Ensure that there is not excessive soot in the passages.
8. Damaged Turbocharger Compressor Or A Damaged Turbocharger Diffuser
   - Ensure that the components are not damaged. If necessary, replace the components or repair the components.
9. Incorrect Turbocharger Or Associated Parts
   - Ensure that the installed turbocharger has the proper rating. Ensure that the parts that are used are intended for the turbocharger that is being used.
10. High Pressure Drop In Aftercooler (Air Side)
    - Ensure that the pressure drop between the compressor outlet and the intake manifold is not excessive.
11. Fouled Turbocharger Nozzle (Turbine Side)
    - On engines that use heavy fuel oil, ensure that the proper water wash intervals are followed.

12. Excessive Turbulence At Turbocharger Air Inlet
    - Ensure that transitions within the ducting to the turbocharger air inlet are not too close to the turbocharger. Use a Caterpillar supplied air inlet elbow or follow the guidelines that are given in the "Application and Installation Guide".

Note: Inlet Air Piping that is common to two turbochargers should receive special attention.

13. Excessive Back Pressure
    - On engines that use heavy fuel oil and high overlap camshafts, ensure that there is not excessive back pressure.
14. Low Inlet Air Temperature To Turbocharger
    - Ambient Air temperature that is below 0 °C (32 °F) should be noted in the rating request. This will allow proper selection of a turbocharger. Contact your local Caterpillar dealer.
15. Too Little Valve Lash (Unlikely Cause)
    - Make adjustment to valve lash. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".
16. Damage To Valve Train Components
    - Inspect all of the following valve train components:
        - Valves
        - Springs
        - Camshafts
        - Lifters
        - Rocker arms
        - Pushrods
    - Check for worn parts or damaged parts. Replace worn parts or damaged parts, as required.
17. Incorrect Camshaft Installation
    - Ensure that the camshafts are installed correctly. Refer to Testing And Adjusting, "Fuel System".
18. High Load Operation At Low Engine Speed
    - Ensure that engine speed is not below 85% rated speed on engines that are not used as gensets during high load operation.

Comments & Notes

Problem 44
Low Boost Pressure

Probable Cause

1. Insufficient Air Passage Through Filters Or Inlet Air Piping
   - Ensure that the pressure drop between the inlet of the filters to the inlet of the turbocharger is less than 1.5 kPa (5.00 inch of H_2O) when the filters and the piping is clean.
   - Ensure that the pressure drop between the inlet of the filters to the turbocharger inlet is less than 3.75 kPa (15 inch of H_2O) when the filters and the piping is dirty.
2. Inlet Air Leakage
   - Check the following locations and the associated piping for air leakage. If necessary, make corrections.
     - O-ring seals between the compressor and the aftercooler
     - Air inlet shutoff
     - Plugged sections
     - Gaskets within aftercooler
     - Plenum
3. Excessive Exhaust Restriction
   - Ensure that the pressure difference between the outlet of the turbocharger and the atmosphere is less than 2.5 kPa (10 inch of H_2O).
4. Damaged Turbine Nozzle Or Damaged Turbine Blades
   - Ensure that the components of the turbine are not damaged.
5. Incorrect Turbocharger Or Associated Parts
   - Ensure that the installed turbocharger has the proper rating. Ensure that the parts that are used are intended for the turbocharger that is being used.
6. The Turbocharger Bearings Are Damaged Or The Turbocharger Bearings Are Not Functioning Correctly.
   - Ensure that the bearings are operating correctly and that the bearings are not causing excessive drag.
7. Damaged Turbocharger Compressor Or Turbocharger Diffuser
   - Ensure that the components are not damaged. If necessary, replace the components or repair the components.
8. Partially Closed Air Shutoff
   - Ensure that the air shutoff is in the open position.
9. The Timing Is Advanced Too Far.
   - This will be only a minor influence. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".

10. High Pressure Drop In Aftercooler (Air Side)
    - Ensure that the pressure drop between the compressor outlet and the intake manifold is not excessive.

11. Wrong Camshaft (High Overlap Camshaft)
    - Ensure that the correct camshafts are installed in the engine.
12. Incorrect Valve Lash (Minor Influence)
    - Make adjustment to valve lash. Refer to Testing And Adjusting, "Air Inlet And Exhaust System".
13. High Ambient Temperature
    - Inlet manifold pressure decreases approximately 0.3% for every 1 °C increase of the temperature of the air to the turbocharger compressor.

<u>Comments & Notes</u>

Problem 45
Low Efficiency

Probable Cause

1. Ineffective Aftercooler
   - Check temperature of inlet and outlet coolant supply. Remove any external restrictions or internal restrictions.
2. Late Fuel Injection Timing
   - Make adjustment to timing. Refer to Testing And Adjusting, "Fuel System".
3. High Ambient Temperature
   - Inlet manifold pressure decreases approximately 0.3% for every 1 °C increase of the temperature of the air to the turbocharger compressor.
4. Excessive Back Pressure
   - On engines that use heavy fuel oil and high overlap camshafts, ensure that there is not excessive back pressure.
5. Engine Misfiring
   - Refer to "Problem 9 ".
6. A Damaged Turbine Nozzle And Turbine Blades
   - Ensure that the components of the turbine are not damaged.
7. A Worn Turbine Nozzle And Turbine Blades
   - Ensure that the components of the turbine are not worn.
8. Generator's Efficiency Is Low.
   - An engine may appear to be operating with low efficiency. Ensure that the driven generator is operating at the correct efficiency.
9. Improper Conditions Of Fuel
   - Ensure that the following fuel requirements are being met.
     - Temperature
     - Heating value
     - Pressure
     - API gravity
     - Governor limiting rack setting
   - Refer to Supplement, SEBU7003, "Caterpillar 3600 Series Diesel Engine Fluids Recommendations For Lubricants, Fuels, and Coolants".

<u>Comments & Notes</u>

Changing a Standard Rotation Engine to a Reverse Rotation Engine

SAE STANDARD ROTATION TO SAE REVERSE ROTATION		
	Inline	Vee
Crankshaft	No Change No End to End No Thrust Change	Same Same Same
Camshaft	Cam Segment Change Cam Journals Same	Cam Segment Change Bank to Band and End to End
Oil Pump	Rotate 180°	Same
Fuel Transfer Pump	Rotate 180°	Same
Governors 3161	Internal Oil Pump is Rotated 180°	Same
EGB 29P	Same	Same
EGB 13P	Same	Same
UG	Internal Oil Pump	Same
Heinzeman	Same	Same
Crankseal	End to End	Same
Air Starter	New Starter & Ring Gear	Same
Water Pump	Same	Same
Oil Mister Pump	Same	Same

Comments & Notes:

Conversion Factors
Handy Multipliers for Engineers

English measures— unless otherwise designated, are those used in the United States, and the units of weight and mass are avoirdupois units.

Gallon— designates the U.S. gallon. To convert into the Imperial gallon, multiply the U.S. gallon by 0.83267. Likewise, the word designates a short ton, 2,000 pounds.

Exponents— the figures 10 -1 , 10 -2 , 10 -3 , etc. denote 0.1, 0.01, 0.001, etc. respectively.
The figures 10+1 , 10+2 , 10+3 , etc. denote 10, 100, 1000, etc. respectively.

Properties of water— it freezes at 32°F, and is at its maximum density at 39.2°F. In the multipliers using the properties of water, calculations are based on water at 39.2°F in a vacuum, weighing 62.427 pounds per cubic foot, or 8.345 pounds per U.S. gallon.

Parts Per Million— designated as P.P.M., is always by weight and is simply a more convenient method of expressing concentration, either dissolved or undissolved material. Usually P.P.M. is used where percent-age would be so small as to necessitate several ciphers after the decimal point, as one part per million is equal to 0.0001 percent. As used in the sanitary field, P.P.M. represents the number of pounds of dry solids contained in one million pounds of water, including solids. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U.S. gallons of water. In the Metric system, one part per million may be expressed as one gram of dry solids to one million grams of water, or one milligram per liter.
In arriving at parts per million by means of pounds per million gallons or milligrams per liter, it may be mentioned that the density of the solution or suspension has been neglected and if this is appreciably different from unity, the results are slightly in error.

Multiply	By	To Obtain
Acres	43,560	Square feet
Acres	4047	Square meters
Acres	1.562x10-3	Square miles
Acres	4840	Square yards
Acre – feet	43,560	Cubic feet
Acre – feet	325,851	Gallons
Acre – feet	1233.48	Cubic meters
Atmospheres	76.0	Cms of mercury
Atmospheres	29.92	Inches of mercury
Atmospheres	33.90	Feet of water
Atmospheres	10,332	Kgs/sq meter
Atmospheres	14.70	Lbs/sq inch
Atmospheres	1.058	Tons/sq ft
Barrels - oil	42	Gallons - oil
Barrels - cement	376	Pounds - cement
Bags or sacks - cement	94	Pounds - cement
Board feet	144 sq in X 1 in	Cubic inches
British Thermal Units	0.2520	Kilogram-calories
British Thermal Units	777.6	Foot-lbs
British Thermal Units	3.927x10 -4	Horsepower-hrs
British Thermal Units	107.5	Kilogram-meters
British Thermal Units	2.928x10-4	Kilowatt-hrs
BTU/min	12.96	Foot-lbs/sec
BTU/min	0.02356	Horsepower
BTU/min	0.01757	Kilowatts
BTU/min	17.	Watts
Centares (Centiares)	1	Square meters
Centigrams	0.01	Grams
Centiliters	0.01	Liters
Centimeters	0.3937	Inches
Centimeters	0.01	Meters
Centimeters	10	Millimeters
Centimeters of mercury	0.01316	Atmospheres
Centimeters of mercury	0.4461	Feet of water
Centimeters of mercury	136.0	Kgs/sq meter
Centimeters of mercury	27.85	Lbs/sq ft
Centimeters of mercury	0.1934	Lbs/sq inch
Centimeters/sec	1.969	Feet/min
Centimeters/sec	0.03281	Feet/sec
Centimeters/sec	0.036	Kilometers/hr
Centimeters/sec	0.6	Meters/min

Multiply	By	To Obtain
Centimeters/sec	0.02237	Miles/hr
Centimeters/sec	3.728x10-4	Miles/min
Cms/sec/sec	0.03281	Feet/sec/sec
Cubic centimeters	3.531x10-5	Cubic feet
Cubic centimeters	6.102x10-2	Cubic inches
Cubic centimeters	10-6	Cubic meters
Cubic centimeters	1.308210-6	Cubic yards
Cubic centimeters	2.642x10-4	Gallons
Cubic centimeters	9.999x10-4	Liters
Cubic centimeters	2.113x10-3	Pints (liq)
Cubic centimeters	1.057x10-3	Quarts (liq)
Cubic feet	2.832x10+4	Cubic cms
Cubic feet	1728	Cubic inches
Cubic feet	0.02832	Cubic meters
Cubic feet	0.03704	Cubic yards
Cubic feet	7.48052	Gallons
Cubic feet	28.32	Liters
Cubic feet	59.84	Pints (liq)
Cubic feet	29.92	Quarts (liq)
Cubic feet/min	472.0	Cubic cms/sec
Cubic feet/min	0.1247	Gallons/sec
Cubic feet/min	0.4719	Liters/sec
Cubic feet/min	62.43	Pounds of water/min
Cubic feet/sec	0.646317	Millions gals/day
Cubic feet/sec	448.831	Gallons/min
Cubic inches	16.39	Cubic centimeters
Cubic inches	5.787x10-4	Cubic feet
Cubic inches	1.639x10-5	Cubic meters
Cubic inches	2.143x10-5	Cubic yards
Cubic inches	4.329x10-3	Gallons
Cubic inches	1.639x10-2	Liters
Cubic inches	0.03463	Pints (liq)
Cubic inches	0.01732	Quarts (liq)
Cubic meters	10+6	Cubic centimeters
Cubic meters	35.31	Cubic feet
Cubic meters	61023	Cubic inches
Cubic meters	1.308	Cubic yards
Cubic meters	264.2	Gallons
Cubic meters	999.97	Liters
Cubic meters	2113	Pints (liq)
Cubic meters	1057	Quarts (liq)
Cubic yards	764,554.86	Cubic centimeters

Multiply	By	To Obtain
Cubic yards	27	Cubic feet
Cubic yards	46,656	Cubic inches
Cubic yards	0.7646	Cubic meters
Cubic yards	202.0	Gallons
Cubic yards	764.5	Liters
Cubic yards	1616	Pints (liq)
Cubic yards	807.9	Quarts (liq)
Cubic yards/min	0.45	Cubic feet/sec
Cubic yards/min	3.366	Gallons/sec
Cubic yards/min	12.74	Liters/sec
Decigrams	0.1	Grams
Deciliters	0.1	Liters
Decimeters	0.1	Meters
Degrees (angle)	60	Minutes
Degrees (angle)	0.01745	Radians
Degrees (angle)	3600	Seconds
Degrees/sec	0.01745	Radians/sec
Degrees/sec	0.1667	Revolutions/min
Degrees/sec	0.002778	Revolutions/sec
Dekagrams	10	Grams
Dekaliters	10	Liters
Dekameters	10	Meters
Drams	27.34375	Grains
Drams	0.0625	Ounces
Drams	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
Feet	12	Inches
Feet	0.3048	Meters
Feet	1/3	Yards
Feet of water	0.0295	Atmospheres
Feet of water	0.8826	Inches of Hg
Feet of water	304.8	Kgs/sq meter
Feet of water	62.43	Lbs/sq ft
Feet of water	0.4335	Lbs/sq inch
Feet/min	0.5080	Centimeters/sec
Feet/min	0.01667	Feet/sec
Feet/min	0.01829	Kilometers/hr
Feet/min	0.3048	Meters/min
Feet/min	0.01136	Miles/hr
Feet/sec	30.48	Centimeters/sec
Feet/sec	1.097	Kilometers/hr
Feet/sec	0.5924	Knots

Multiply	By	To Obtain
Feet/sec	18.29	Meters/min
Feet/sec	0.6818	Miles/hr
Feet/sec	0.01136	Miles/min
Feet/sec/sec	30.48	Cms/sec/sec
Feet/sec/sec	0.3048	Meters/sec/sec
Foot – pounds	1.286x10-3	BTU's
Foot – pounds	5.050x10-7	Horsepower-hrs
Foot – pounds	3.240x10-4	Kilogram-calories
Foot – pounds	0.1383	Kilogram-meters
Foot – pounds	3.766x10-7	Kilowatt-hours
Foot – pounds/min	2.140x10-5	BTU/sec
Foot – pounds/min	0.01667	Foot-pounds/sec
Foot – pounds/min	3.030x10-5	Horsepower
Foot – pounds/min	5.393x10-3	Gm-calories/sec
Foot – pounds/min	2.260x10-5	Kilowatts
Foot – pounds/sec	7.704x10-2	BTU/min
Foot – pounds/sec	1.818x10-3	Horsepower
Foot – pounds/sec	1.941x10-2	Kg-calories/min
Foot – pounds/sec	1.356x10-3	Kilowatts
Gallons	3785	Cubic cm
Gallons	0.1337	Cubic feet
Gallons	231	Cubic inches
Gallons	3.785x10-3	Cubic meters
Gallons	4.951x10-3	Cubic yards
Gallons	3.785	Liters
Gallons	8	Pints (liq)
Gallons	4	Quarts (liq)
Gallons-Imperial	1.20095	US gallons
Gallons-US	0.83267	Imperial gallons
Gallons water	8.345	Pounds of water
Gallons/min	2.228x10-3	Cubic feet/sec
Gallons/min	0.06308	Liters/sec
Gallons/min	8.0208	Cu ft/hr
Grains (troy)	0.06480	Grams
Grains (troy)	0.04167	Pennyweight (troy)
Grains (troy)	2.0833x10-3	Ounces (troy)
Grains/US gal	17.118	Parts/million
Grains/US gal	142.86	Lbs/million gal
Grains/Imp gal	14.254	Parts/million
Grams	980.7	Dynes
Grams	15.43	Grains

Multiply	By	To Obtain
Grams	.001	Kilograms
Grams	1000	Milligrams
Grams	0.03527	Ounces
Grams	0.03215	Ounces (troy)
Grams	2.205x10-3	Pounds
Grams/cm	5.600x10-3	Pounds/inch
Grams/cu cm	62.43	Pounds/cubic foot
Grams/cu cm	0.03613	Pounds/cubic inch
Grams/liter	58.416	Grains/gal
Grams/liter	8.345	Pounds/1000 gals
Grams/liter	0.06242	Pounds/cubic foot
Grams/liter	1000	Parts/million
Hectares	2.471	Acres
Hectares	1.076x10+5	Square feet
Hectograms	100	Grams
Hectoliters	100	Liters
Hectometers	100	Meters
Hectowatts	100	Watts
Horsepower	42.44	BTU/min
Horsepower	33,000	Foot-lbs/min
Horsepower	550	Foot-lbs/sec
Horsepower	1.014	HP (metric)
Horsepower	10.547	Kg-calories/min
Horsepower	0.7457	Kilowatts
Horsepower	745.7	Watts
Horsepower (boiler)	33,493	BTU/hr
Horsepower (boiler)	9.809	Kilowatts
Horsepower-hours	2546	BTU
Horsepower-hours	1.98x10+6	Foot-lbs
Horsepower-hours	641.6	Kilogram-calories
Horsepower-hours	2.737x10+5	Kilogram-meters
Horsepower-hours	0.7457	Kilowatt-hours
Inches	25.40	Millimeters
Inches of mercury	0.03342	Atmospheres
Inches of mercury	1.133	Feet of water
Inches of mercury	345.3	Kgs/sq meter
Inches of mercury	70.73	Lbs/sq ft
Inches of mercury (32°F)	0.491	Lbs/sq inch
Inches of mercury	3.38	Kilopascal
Inches of water	0.002458	Atmospheres
Inches of water	0.07355	Inches of Hg
Inches of water	25.40	Kgs/sq meter

Multiply	By	To Obtain
Inches of water	0.578	Ounces/sq inch
Inches of water	5.202	Lbs/sq foot
Inches of water	0.03613	Lbs/sq inch
Inches of water	.249	Kilopascal
Kilograms	980,665	Dynes
Kilograms	2.205	Lbs
Kilograms	1.102x10-3	Tons (short)
Kilograms	10+3	Grams
Kilograms-cal/sec	3.968	BTU/sec
Kilograms-cal/sec	3086	Foot-lbs/sec
Kilograms-cal/sec	5.6145	Horsepower
Kilograms-cal/sec	4186.7	Watts
Kilogram-cal/min	3085.	Foot-lbs/min
Kilogram-cal/min	0.09351	Horsepower
Kilogram-cal/min	69.733	Watts
Kgs/meter	6.720	Lbs/foot
Kgs/sq meter	9.678x10-5	Atmospheres
Kgs/sq meter	3.281x10-3	Feet of water
Kgs/sq meter	2.896x10-3	Inches of Hg
Kgs/sq meter	0.2048	Lbs/sq foot
Kgs/sq meter	1.422x10-3	Lbs/sq inch
Kgs/sq millimeter	10+6	Kgs/sq meter
Kiloliters	10+3	Liters
Kilometers	10+5	Centimeters
Kilometers	3281	Feet
Kilometers	10+3	Meters
Kilometers	0.6214	Miles
Kilometers	1094	Yards
Kilometers/hr	27.78	Centimeters/sec
Kilometers/hr	54.68	Feet/min
Kilometers/hr	0.9113	Feet/sec
Kilomteters/hr	.5399	Knots
Kilometers/hr	16.67	Meters/min
Kilometers/hr	0.6214	Miles/hr
Kilopascal (kPa)	4.0	Inch of Water
Kilopascal (kPa)	.30	Inch of Mercury
Kilopascal (kPa)	.145	PSI
Kms/hr/sec	27.78	Cms/sec/sec
Kms/hr/sec	0.9113	Ft/sec/sec
Kms/hr/sec	0.2778	Meters/sec/sec
Kilowatts	.948	BTU's
Kilowatts	56.907	BTU/min
Kilowatts	4.425x10+4	Foot-lbs/min

Multiply	By	To Obtain
Kilowatts	737.6	Foot-lbs/sec
Kilowatts	1.341	Horsepower
Kilowatts	14.34	Kg-calories/min
Kilowatts	10+3	Watts
Kilowatt-hours	3414.4	BTU
Kilowatt-hours	2.655x10+6	Foot-lbs
Kilowatt-hours	1.341	Horsepower-hrs
Kilowatt-hours	860.4	Kilogram-calories
Kilowatt-hours	3.671x10+5	Kilogram-meters
Liters	10+3	Cubic centimeters
Liters	0.03531	Cubic feet
Liters	61.02	Cubic inches
Liters	10-3	Cubic meters
Liters	1.308x10-3	Cubic yards
Liters	0.2642	Gallons
Liters	2.113	Pints (liq)
Liters	1.057	Quarts (liq)
Liters/min	5.886x10-4	Cubic ft/sec
Liters/min	4.403x10-3	Gals/sec
Lumber Width (in) x $\frac{\text{Thickness (in)}}{12}$	Length (ft)	Board feet
Meters	100	Centimeters
Meters	3.281	Feet
Meters	39.37	Inches
Meters	10-3	Kilometers
Meters	10+3	Millimeters
Meters	1.094	Yards
Meters/min	1.667	Centimeters/sec
Meters/min	3.281	Feet/min
Meters/min	0.05468	Feet/sec
Meters/min	0.06	Kilometers/hr
Meters/min	0.03728	Miles/hr
Meters/sec	196.8	Feet/min
Meters/sec	3.281	Feet/sec
Meters/sec	3.6	Kilometers/hr
Meters/sec	0.06	Kilometers/min
Meters/sec	2.237	Miles/hr
Meters/sec	0.03728	Miles/min
Microns	10-6	Meters
Miles	1.609x10+5	Centimeters
Miles	5280	Feet
Miles	1.609	Kilometers

Multiply	By	To Obtain
Miles	1760	Yards
Miles/hr	44.70	Centimeters/sec
Miles/hr	88	Feet/min
Miles/hr	1.467	Feet/sec
Miles/hr	1.609	Kilometers/hr
Miles/hr	0.8689	Knots
Miles/hr	26.82	Meters/min
Miles/min	2682	Centimeters/sec
Miles/min	88	Feet/sec
Miles/min	1.609	Kilometers/min
Miles/min	60	Miles/hr
Milliers	10+3	Kilograms
Milligrams	10-3	Grams
Milliliters	10-3	Liters
Millimeters	0.1	Centimeters
Millimeters	0.03937	Inches
Milligrams/liter	1	Parts/million
Million gals/day	1.54723	Cubic ft/sec
Miner's inches	1.5	Cubic ft/min
Minutes (angle)	2.909x10-4	Radians
Newton meter (N.m)	8.9	Pound inch ("#)
Newton meter (N.m)	.74	Pound feet ('#)
Ounces	16	Drams
Ounces	437.5	Grains
Ounces	0.0625	Pounds
Ounces	28.3495	Grams
Ounces	0.9115	Ounces (troy)
Ounces	2.790x10-5	Tons (long)
Ounces	2.835x10-5	Tons (metric)
Ounces (troy)	480	Grains
Ounces (troy)	20	Pennyweights (troy)
Ounces (troy)	0.08333	Pounds (troy)
Ounces (troy)	31.10348	Grams
Ounces (troy)	1.09714	Ounces (avoir.)
Ounces (fluid)	1.805	Cubic inches
Ounces (fluid)	0.02957	Liters
Ounces/sq inch	0.0625	Lbs/sq inch
Parts/million	0.0584	Grains/US gal
Parts/million	0.07015	Grains/Imp gal
Parts/million	8.345	Lbs/million gal
Pennyweights (troy)	24	Grains
Pennyweights (troy)	1.55517	Grams

Multiply	By	To Obtain
Pennyweights (troy)	0.05	Ounces (troy)
Pennyweights (troy)	4.1667x10-3	Pounds (troy)
Pounds	16	Ounces
Pounds	256	Drams
Pounds	7000	Grains
Pounds	0.0005	Tons (short)
Pounds	453.5924	Grams
Pounds	1.21528	Pounds (troy)
Pounds	14.5833	Ounces (troy)
Pounds (troy)	5760	Grains
Pounds (troy)	240	Pennyweights (troy)
Pounds (troy)	12	Ounces (troy)
Pounds (troy)	373.2417	Grams
Pounds (troy)	0.822857	Pounds (avoir.)
Pounds (troy)	13.1657	Ounces (avoir.)
Pounds (troy)	3.6735x10-4	Tons (long)
Pounds (troy)	4.1143x10-4	Tons (short)
Pounds (troy)	3.7324x10-4	Tons (metric)
Pound inch	.113	Newton meter
Pound foot	1.36	Newton meter
Pounds of water	0.01602	Cubic feet
Pounds of water	27.68	Cubic inches
Pounds of water	0.1198	Gallons
Pounds of water/min	2.670x10-4	Cubic ft/sec
Pounds/cubic foot	0.01602	Grams/cubic cm
Pounds/cubic foot	16.02	Kgs/cubic meters
Pounds/cubic foot	5.787x10-4	Lbs/cubic inch
Pounds/cubic inch	27.68	Grams/cubic cm
Pounds/cubic inch	2.768x10+4	Kgs/cubic meter
Pounds/cubic inch	1728	Lbs/cubic foot
Pounds/foot	1.488	Kgs/meter
Pounds/inch	178.6	Grams/cm
Pounds/sq foot	0.01602	Feet of water
Pounds/sq foot	4.882	Kgs/sq meter
Pounds/sq foot	6.944x10-3	Pounds/sq inch
Pounds/sq inch	0.06804	Atmospheres
Pounds/sq inch	2.307	Feet of water
Pounds/sq inch	2.036	Inches of Hg
Pounds/sq inch	703.1	Kgs/sq meter
Pound/sq inch (psi)	6.89	Kilopascal
Quadrants (angle)	90	Degrees
Quadrants (angle)	5400	Minutes

Multiply	By	To Obtain
Quadrants (angle)	1.571	Radians
Quarts (dry)	67.20	Cubic inches
Quarts (liq)	57.75	Cubic inches
Quintal, Argentine	101.28	Pounds
Quintal, Brazil	129.54	Pounds
Quintal, Castile, Peru	101.43	Pounds
Quintal, Chile	101.41	Pounds
Quintal, Mexico	101.47	Pounds
Quintal, Metric	220.46	Pounds
Quires	25	Sheets
Radians	57.30	Degrees
Radians	3438	Minutes
Radians	0.637	Quadrants
Radians/sec	57.30	Degrees/sec
Radians/sec	0.1592	Revolutions/sec
Radians/sec	9.549	Revolutions/min
Radians/sec/sec	573.0	Revs/min/min
Radians/sec/sec	0.1592	Revs/sec/sec
Reams	500	Sheets
Revolutions	360	Degrees
Revolutions	4	Quadrants
Revolutions	6.283	Radians
Revolutions/min	6	Degrees/sec
Revolutions/min	0.1047	Radians/sec
Revolutions/min	0.01667	Revolutions/sec
Revolutions/min/min	1.745x10-3	Radians/sec/sec
Revolutions/min/min	2.778x10-4	Revs/sec/sec
Revolutions/sec	360	Degrees/sec
Revolutions/sec	6.283	Radians/sec
Revolutions/sec	60	Revolutions/min
Revolutions/sec/sec	6.283	Radians/sec/sec
Revolutions/sec/sec	3600	Revs/min/min
Seconds (angle)	4.848x10-6	Radians
Square centimeters	1.076x10-3	Square feet
Square centimeters	0.1550	Square inches
Square centimeters	10-4	Square meters
Square centimeters	100	Square millimeters
Square feet	2.296x10-5	Acres
Square feet	929.0	Square centimeters
Square feet	144	Square inches
Square feet	0.09290	Square meters
Square feet	3.587x10-8	Square miles

Multiply	By	To Obtain
Square feet	1/9	Square yards
1 / Sq ft/gal/min	8.0208	Overflow rate (ft/hr)
Square inches	6.452	Square centimeters
Square inches	6.944x10-3	Square feet
Square inches	645.2	Square millimeters
Square kilometers	247.1	Acres
Square kilometers	10.76x10+6	Square feet
Square kilometers	10+6	Square meters
Square kilometers	0.3861	Square miles
Square kilometers	1.196x10+6	Square yards
Square meters	2.471x10-4	Acres
Square meters	10.76	Square feet
Square meters	3.861x10-7	Square miles
Square meters	1.196	Square yards
Square miles	640	Acres
Square miles	27.88x10+6	Square feet
Square miles	2.590	Square kilometers
Square miles	3.098x10+6	Square yards
Square millimeters	0.01	Square centimeters
Square millimeters	1.550x10-3	Square inches
Square yards	2.066x10-4	Acres
Square yards	9	Square feet
Square yards	0.8361	Square meters
Square yards	3.228x10-7	Square miles
Temp (°C) + 273	1	Abs temp (°C)
Temp (°C) + 17.78	1.8	Temp (°F)
Temp (°F) + 460	1	Abs temp (°F)
Temp (°F) – 32	5/9	Temp (°C)
Tons (long)	1016	Kilograms
Tons (long)	2240	Pounds
Tons (long)	1.12000	Tons (short)
Tons (metric)	10+3	Kilograms
Tons (metric)	2205	Pounds
Tons (short)	2000	Pounds
Tons (short)	32,000	Ounces
Tons (short)	907.1848	Kilograms
Tons (short)	2430.56	Pounds (troy)
Tons (short)	0.89287	Tons (long)
Tons (short)	29166.66	Ounces (troy)
Tons (short)	0.90718	Tons (metric)

Multiply	By	To Obtain
Tons of water/24 hrs	83.333	Pounds water/hr
Tons of water/24 hrs	0.16643	Gallons/min
Tons of water/24 hrs	1.3349	Cu ft/hr
Watts	0.05686	BTU/min
Watts	44.25	Foot-lbs/min
Watts	0.7376	Foot- lbs/sec
Watts	1.341x10-3	Horsepower
Watts	0.01434	Kg-calories/min
Watts	10-3	Kilowatts
Watt-hours	3.414	BTU
Watt-hours	2655	Foot-lbs
Watt-hours	1.341x10-3	Horsepower-hrs
Watt-hours	0.8604	Kilogram-calories
Watt-hours	367.1	Kilogram-meters
Watt-hours	10-3	Kilowatt-hours
Yards	91.44	Centimeters
Yards	3	Feet
Yards	36	Inches
Yards	0.9144	Meters

CONVERSIONS

English > SI

Millimeter (mm) = inch x 25.4
Liter (L) = inch³ x 0.016
Liter (L) = gallon x 3.79
Gram (g) = ounce x 28.3
Kilogram (kg) = pound x 0.454
Kilonewton (kN) = pound x 0.00445
Newton meter (N•m) = lb•ft X 1.36
Kilopascal (kPa) = psi x 6.89
Kilowatt (kW) = hp x 0.746
Kilowatt (kW) = Btu/min x 0.01758
Kilojoule (kJ) = Btu x 1.055
°Celsius (°C) = (°F -32) /1.8

SI > English

Inch = 0.03937 x mm
inch³ = liter x 61
Gallon = liter x 0.26
Ounce = gram x 0.035
Pound = kg x 2.2
Pound = kN x 225
Lb-ft = N•m x 0.74
psi = kPa x 0.145
hp = kW x 1.34
Btu = kJ x 0.948
Btu/min = kW x 56.869
°Fahrenheit = (°C x 1.8) + 32

SI Prefixes

1 000 000 000	G	giga
1 000 000	M	mega
1 000	k	kilo
100	h	hecto
10	da	deca
0.1	d	deci
0.01	c	centi
0.001	m	milli
0.000 001	μ	micro
0.000 000 001	n	nano

Unit of Measure

Linear Measurements

Nautical measurements

1 cable	=	608 feet (British measure)
1 cable	=	185 meters (British measure)
1 cable	=	10.1 nautical mile
10 cables	=	1 nautical mile
1 fathom	=	6 feet, 2 yards
1 fathom	=	1.83 meters
1 nautical mile	=	1.15 statute mile
1 nautical mile	=	1.852 kilometers
1 nautical mile	=	2,025 yards
1 nautical mile	=	6,076.1155 feet
1 knot	=	1 nautical mile/hour
1 knot	=	1.15 statute mile/hour

U.S. Customary System

1 statute mile	=	5,280 feet
1 statute mile	=	1,760 yards
1 nautical mile	=	6,076.1155 feet
1 nautical mile	=	2,026 yards
1 inch	=	2.54 centimeters
1 inch	=	25.4 millimeters
1 foot	=	0.3048 meter
1 foot	=	0.17 fathoms
1 yard	=	0.91 meters
1 statute mile	=	1.61 kilometers
1 statute mile	=	0.87 nautical mile

Metric System

1 millimeter	=	0.04 inch
1 meter	=	3.28 feet
1 meter	=	0.55 fathoms
1 kilometer	=	0.54 nautical mile
1 kilometer	=	0.62 statute mile

Mass & Weight

16 ounces	=	1 pound
1 pound	=	0.45 kilogram
1 short ton	=	2,000 pounds
1 long ton	=	2,240 pounds
1 kilogram	=	35.24 ounces
1 kilogram	=	2.20 pounds

Liquid Measure

U.S. Customary system

1 gallon	=	8.33 pounds
1 pint	=	0.47 liters
1 quart	=	0.95 liters
1 gallon	=	3.78 liters

Metric System

1 liter	=	33.8 ounces
1 liter	=	2.1 pints
1 liter	=	1.1 quart
1 liter	=	0.264 gallons
1 liter	=	0.0351 cubic feet
1 cubic meter	=	264 gallons
1 cubic meter	=	35.3 cubic feet
1 cubic meter	=	1.35 cubic yards

Miscellaneous

1 cubic foot	=	62.4 pounds fresh water
1 cubic foot	=	64 pounds sea water
1 long ton	=	35 cubic feet fresh water
1 cubic foot	=	56 pounds ice
1 long ton	=	35 cubic feet salt water
1 ton (measurement)	=	40 cubic feet
1 ton register	=	100 cubic feet
1 barrel (oil)	=	42 gallons
1 ton (oil)	=	269 gallons
1 ton (oil)	=	6.4 barrels

Barometric Pressure

Inch of mercury	=	33.864 millibars
1 millibar	=	0.030 inches of mercury

Volume Conversion:

	cc	cu in	quarts
cc	1.0	.06102	.001056
cu in	16.387	1.0	.0173
quarts	946.3	57.75	1.0
liters	.1000	61.02	1.056
gallons	3785.4	231	4
cu ft	28314.8	1728	29.92

	liters	gallons	cu ft
cc	.001	.000264	.0000353
cu in	.016387	.00433	.000578
quarts	.9464	.250	.0334
liters	1.0	.264	.0353
gallons	3.785	1.0	.1337
cu ft	28.315	7.4805	1.0

	drops	tsp.	tbsp.	cup
drops	1.0	.01666	.00555	.000347
tsp.	60	1.0	.333	.02083
tbsp.	180	3.0	1.0	.0625
cup	.2880	48.0	16	1.0
quart	.11520	192	64	4.0
gallon	.46080	768	256	16.0
ounces	.360	.6	.2	.125

	quart	gallons	ounces
drops	.0000866	.000216	.00277
tsp.	.0052	.0013	.166
tbsp.	.0156	.0039	.5
cup	.25	.0625	8
quart	1.0	.25	32
gallon	4.0	1.0	128
ounces	.03125	.00107	1.0

12 drops / ml
12,172 drops / l
29.576 ml / oz
.03381 oz / ml

Approximate Conversions

Multiply		By		To Get or Multiply		By		To Get
SI Unit		**Conv Factor**		**Non-SI Unit**		**Conv Factor**		**SI Unit**
				LENGTH				
millimeter (mm)	×	0.03937	=	inch	×	25.4	=	mm
(1 inch = 25.4 mm exactly)								
centimeter (cm) 10 mm	×	0.3937	=	inch	×	2.54	=	cm
meter (m) 1000 mm	×	3.28	=	foot	×	0.305	=	m
meter (m)	×	1.09	=	yard	×	0.914	=	m
kilometer (km) 1000 m	×	0.62	=	mile	×	1.61	=	km
				AREA				
millimeter^2 (mm^2)	×	0.00155	=	inch^2	×	645	=	mm^2
centimeter^2 (cm^2)	×	0.155	=	inch^2	×	6.45	=	cm^2
meter^2 (m^2)	×	10.8	=	foot^2	×	0.0929	=	m^2
meter^2 (m^2)	×	1.2	=	yard^2	×	0.836	=	m^2
hectare (ha) 10 000 m^2	×	2.47	=	acre	×	0.405	=	ha
kilometer (km) 1000 m	×	0.39	=	mile^2	×	2.59	=	km^2
				VOLUME				
centimeter^2 (cm^2)	×	0.061	=	inch^3	×	16.4	=	cm^3
liter	×	61	=	inch^3	×	0.016	=	L
milliliter (mL)	×	0.034	=	oz.-liq	×	29.6	=	mL
(1 mL = 1 cm^3)								
liter (L) 1000 mL	×	1.06	=	quart	×	0.946	=	L
liter (L)	×	0.26	=	gallon	×	3.79	=	L
meter^3 (m^3) 1000 L	×	1.3	=	yard^2	×	0.76	=	m^2
				MASS				
gram (g)	×	0.035	=	ounce	×	28.3	=	g
kilogram (kg) 1000 g	×	2.2	=	pound	×	0.454	=	kg
metric ton (t) 1000 kg	×	1.1	=	ton (short)	×	0.907	=	t
				FORCE (N = Kg – m/s^2)				
newton (N)	×	0.225	=	pound	×	4.45	=	N
kilonewton (kN)	×	225	=	pound	×	0.00445	=	kN

Working in SI will reveal its simplicity –
Try it you'll like it.

01-085464-01 (11.00)

Making Metric Parts – Use Metric Tools

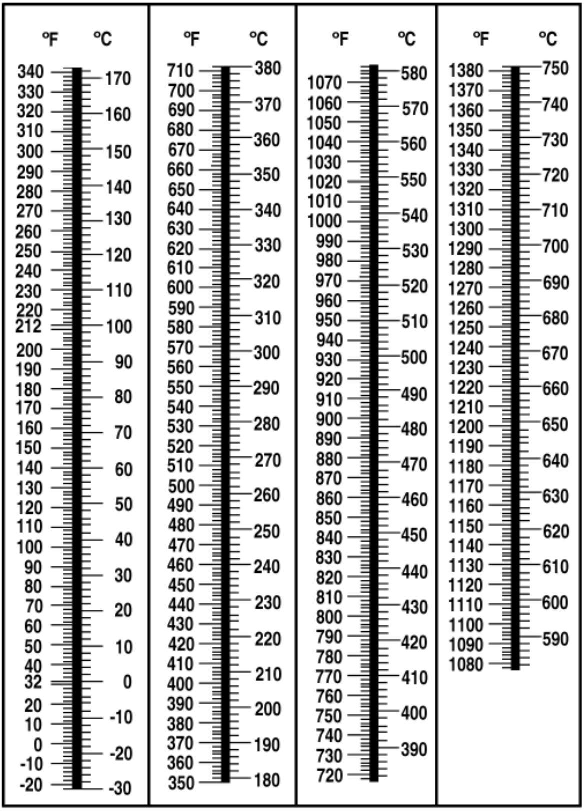
Approximate Conversions

Multiply	By	To Get or Multiply	By	To Get
SI Unit	Conv Factor	Non-SI Unit	Conv Factor	SI Unit
TORQUE				
newton meter (N•m)	× 8.9	= lb in	× 0.113	= N•m
newton meter (N•m)	× 0.74	= lb ft	× 1.36	= N•m
PRESSURE (Pa = N/m²)				
kilopascal (kPa)	× 4.0	= in H_2O	× 0.249	= kPa
kilopascal (kPa)	× 0.30	= in Hg	× 3.38	= kPa
kilopascal (kPa)	× 0.145	= psi	× 6.89	= kPa
STRESS (Pa = N/m²)				
megapascal (MPa)	× 145	= psi	× 0.00689	= MPa
POWER (W = J/s)				
kilowatt (kW)	× 1.34	= hp	× 0.746	= kW
kilowatt (kW)	× 0.948	= Btu/s	× 1.055	= kW
watt (W)	× 0.74	= ft lb/s	× 1.36	= W
ENERGY (J = N•m)				
kilojoule (kJ)	× 0.948	= Btu	× 1.055	= kJ
joule (J)	× 0.239	= calorie	× 4.19	= J
VELOCITY AND ACCELERATION				
meter per sec² (m/s²)	× 3.28	= ft/s²	× 0.305	= m/s²
meter per sec (m/s)	× 3.28	= ft/s	× 0.305	= m/s
kilometer per hour (km/h)	× 0.62	= mph	× 1.61	= km/h
TEMPERATURE				
° C = (° F – 32) ÷ 1.8	° F = (° C × 1.8) + 32			

SI is a System of Tens like our Money System.

Conversions

Temperature Conversion



Celcius (Centigrade) Fahrenheit Conversion Table

C	C or F	F	C	C or F	F	C	C or F	F	C	C or F	F
–73.33	**–100**	–148.0	–6.11	**21**	69.8	16.1	**61**	141.8	43	**110**	230
–70.56	**– 95**	–139.0	–5.56	**22**	71.6	16.7	**62**	143.6	49	**120**	248
–67.78	**– 90**	–130.0	–5.00	**23**	73.4	17.2	**63**	145.4	54	**130**	266
–65.00	**– 85**	–121.0	–4.44	**24**	75.2	17.8	**64**	147.2	60	**140**	284
–62.22	**– 80**	–112.0	–3.89	**25**	77.0	18.3	**65**	149.0	66	**150**	302
–59.45	**– 75**	–103.0	–3.33	**26**	78.8	18.9	**66**	150.8	71	**160**	320
–56.67	**– 70**	– 94.0	–2.78	**27**	80.6	19.4	**67**	152.6	77	**170**	338
–53.89	**– 65**	– 85.0	–2.22	**28**	82.4	20.0	**68**	154.4	82	**180**	356
–51.11	**– 60**	– 76.0	–1.67	**29**	84.2	20.6	**69**	156.2	88	**190**	374
–48.34	**– 55**	– 67.0	–1.11	**30**	86.0	21.1	**70**	158.0	93	**200**	392
–45.56	**– 50**	– 58.0	–0.56	**31**	87.8	21.7	**71**	159.8	99	**210**	410
–42.78	**– 45**	– 49.0	0	**32**	89.6	22.2	**72**	161.6	100	**212**	413
–40.00	**– 40**	– 40.0	0.56	**33**	91.4	22.8	**73**	163.4	104	**220**	428
–37.23	**– 35**	– 31.0	1.11	**34**	93.2	23.3	**74**	165.2	110	**230**	446
–34.44	**– 30**	– 22.0	1.67	**35**	95.0	23.9	**75**	167.0	116	**240**	464
–31.67	**– 25**	– 13.0	2.22	**36**	96.8	24.4	**76**	168.8	121	**250**	482
–28.89	**– 20**	– 4.0	2.78	**37**	98.6	25.0	**77**	170.6	127	**260**	500
–26.12	**– 15**	5.0	3.33	**38**	100.4	25.6	**78**	172.4	132	**270**	518
–23.33	**– 10**	14.0	3.89	**39**	102.2	26.1	**79**	174.2	138	**280**	536
–20.56	**– 5**	23.0	4.44	**40**	104.0	26.7	**80**	176.0	143	**290**	554
–17.80	**0**	32.0	5.00	**41**	105.8	27.2	**81**	177.8	149	**300**	572
–17.20	**1**	33.8	5.56	**42**	107.6	27.8	**82**	179.6	154	**310**	590
–16.70	**2**	35.6	6.11	**43**	109.4	28.3	**83**	181.4	160	**320**	608
–16.10	**3**	37.4	6.67	**44**	111.2	28.9	**84**	183.2	166	**330**	626
–15.60	**4**	39.2	7.22	**45**	113.0	29.4	**85**	185.0	171	**340**	644
–15.00	**5**	41.0	7.78	**46**	114.8	30.0	**86**	186.8	177	**350**	662
–14.40	**6**	42.8	8.33	**47**	116.6	30.6	**87**	188.6	182	**360**	680
–13.90	**7**	44.6	8.89	**48**	118.4	31.1	**88**	190.4	188	**370**	698
–13.30	**8**	46.4	9.44	**49**	120.2	31.7	**89**	192.2	193	**380**	716
–12.80	**9**	48.2	10.00	**50**	122.0	32.2	**90**	194.0	199	**390**	734
–12.20	**10**	50.0	10.60	**51**	123.8	32.8	**91**	195.8	204	**400**	752
–11.70	**11**	51.8	11.10	**52**	125.6	33.3	**92**	197.6	210	**410**	770
–11.10	**12**	53.6	11.70	**53**	127.4	33.9	**93**	199.4	216	**420**	788
–10.60	**13**	55.4	12.20	**54**	129.2	34.4	**94**	201.2	221	**430**	806
–10.00	**14**	57.2	12.80	**55**	131.0	35.0	**95**	203.0	227	**440**	824
– 9.44	**15**	59.0	13.30	**56**	132.8	35.6	**96**	204.8	232	**450**	842
– 8.89	**16**	60.8	13.90	**57**	134.6	36.1	**97**	206.6	238	**460**	860
– 8.33	**17**	62.6	14.40	**58**	136.4	36.7	**98**	208.4	243	**470**	878
– 7.78	**18**	64.4	15.00	**59**	138.2	37.2	**99**	210.2	249	**480**	896
– 7.22	**19**	66.2	15.60	**60**	140.0	37.8	**100**	212.0	254	**490**	914
– 6.67	**20**	68.0							260	**500**	932

The bold face numbers refer to temperatures in either Centigrade or Fahrenheit degrees. If used to represent Centigrade degrees, the equivalent temperature in Fahrenheit is listed in the “F” column. If used to represent Fahrenheit the equivalent is listed in the “C” column.

Comments & Notes:

Physics Formulas

$$\textbf{Velocity} = \frac{\text{Distance}}{\text{Time}}$$

Distance = (Velocity) x (Time)

$$\textbf{Time} = \frac{\text{Distance}}{\text{Velocity}}$$

$$\textbf{Acceleration} = \frac{\text{Difference in Velocity}}{\text{Difference in Time}}$$

Force = (Mass x (Acceleration)

$$\textbf{Mass} = \frac{\text{Force}}{\text{Acceleration}}$$

$$\textbf{Acceleration} = \frac{\text{Force}}{\text{Mass}}$$

Momentum = (Mass) x (Velocity)

Work = (Force) x (Distance)

$$\textbf{Power} = \frac{\text{Work}}{\text{Time}}$$

Heat = (Mass) x (Specific Heat) x (Temperature Change)

Or

Heat = (M) x (C) x (•T)   M=

Where: **M = Mass**
C = Specific Heat
ΔT Change in Temperatur

Btu = Heat required to raise 1 pound of water 1° F.

Calorie = Heat required to raise 1 gram of water 1°C.

Absolute Zero is the temperature at which matter has given up all thermal energy.

Absolute Zero = 0° K (Kelvin) or -273° C (Centigrade) or -459° F (Fahrenheit)

Speed Droop: Droop, Speed Droop, or regulation terms used interchangeably to describe relationship of engine speed and load in steady-state operation.

$$\%\ \text{Speed Droop} = \frac{\text{Speed @ Zero Load} - \text{Speed @ Full Load}}{\text{Speed @ Full Load}} \times 100$$

Isochronous: 0% droop, i.e., speed unchanged from zero to full load. This demanding precise frequency control or automatic paralleling.

Formula for Calculating Horsepower

                              2Лr X TORQUE X RPM
Horsepower = --------------------------------------
                                        33,000

This formula was established by James Watt in the 1800's and requires some known values:

- Average horse walks at 2 1/2 MPH.
- Average horse pulls with a force of 150 pounds.
- 1 mile = 5,280 feet
- r = distance from center line of shaft, usually 1 foot

With this background, we will be able to establish the Horsepower formulas used today.

5,280 feet X 2 ½MPH = 13,200 FEET per HOUR

13200 FT/HR
------------------ = 220 FEET per MINUTE
60 Minutes

220 FT/MIN x 150 POUNDS = 33,000 FT. LBS/per MIN

220 Л r = 6.2831853

33,000
--------------   = 5252
6.2831853

Thus we get the familiar formula used today in calculating
Hp.

            Torque X RPM
HP = ----------------------- or expressed another way as
                5252

            HP X 5252
Torque = ---------------------
                RPM

CALCULATIONS — ENGLISH

1. Fuel Rate (gallon/min)

Assume 35 API distillate fuel, fuel density = 7.001 lb/gal

$$\frac{\text{grams}}{\text{bkW-hr}} \times \frac{\text{bkW}}{1} \times \frac{1\ \text{hr}}{60\ \text{min}} \times \frac{2.205\ \text{lb}}{1000\ \text{g}} \times \frac{1\ \text{U.S. gal}}{7.001\ \text{lb}} = \frac{\text{U.S. gallon}}{\text{minute}}$$

REDUCED EQUATION

$$(\text{g/bkW-hr})(\text{bkW})(0.000005293) = \frac{\text{U.S. gallon}}{\text{minute}}$$

EXAMPLE

$$(200\ \text{g/bkW})(1850\ \text{bkW})(0.000005293) = 1.9\ \frac{\text{U.S. gallon}}{\text{minute}}$$

1.1

$$\frac{\text{lb}}{\text{hp-hr}} \times \frac{\text{hp}}{1} \times \frac{\text{hr}}{60\ \text{min}} \times \frac{1\ \text{gal}}{7.001\ \text{lb}} = \frac{\text{U.S. gallon}}{\text{minute}}$$

REDUCED EQUATION

$$(\text{lb/hp-hr})(\text{hp})(0.002381) = \frac{\text{U.S. gallon}}{\text{minute}}$$

EXAMPLE

$$(0.329\ \text{lb/hp-hr})(2480\ \text{hp})(0.002381) = 1.9\ \frac{\text{U.S. gallon}}{\text{minute}}$$

Heat Rate (BTU/ekW•hr)

Assume fuel with a LHV of 42 780 kJ/kg, 96.5% efficient generator

$$\frac{g}{bkW \cdot hr} \times \frac{1\ bkW}{0.965\ ekW} \times \frac{1\ kg}{1000\ g} \times \frac{42\ 780\ kJ}{kg} \times \frac{BTU}{1.055\ kJ} = \frac{BTU}{ekW \cdot hr}$$

REDUCED EQUATION

$$(g/bkW \cdot hr)(42.02) = \frac{BTU}{ekW \cdot hr}$$

EXAMPLE

$$(200\ g/bkW \cdot hr)(42.02) = 8404 \frac{BTU}{ekW \cdot hr}$$

Power (hp)

$$POWER\ (hp) = \frac{BMEP\ (psi) \times SPEED\ (rpm) \times DISP\ (in^3)}{792\ 000}$$

$$= \frac{BMEP\ (psi) \times SPEED\ (rpm)}{K}$$

$$K = \frac{792\ 000}{DISPLACEMENT\ (in^3)}$$

EXAMPLE

$$\frac{291\ (psi) \times 1000\ (rpm) \times 6763.8\ (in^3)}{792\ 000} = 2485\ hp$$

Power (hp)

$$\text{POWER (hp)} = \frac{\text{TORQUE (lb}\cdot\text{ft) x SPEED (rpm)}}{5252}$$

Torque (lb•ft)

$$TORQUE\ (lb \cdot ft) = \frac{BMEP\ (psi) \times DISPLACEMENT\ (in^3)}{150.797}$$

$$= BMEP \times C$$

$$C = \frac{DISPLACEMENT}{150.797}$$

1 Torque (lb•ft)

$$\text{TORQUE (lb•ft)} = \frac{\text{POWER (hp)} \times 5252}{\text{SPEED (rpm)}}$$

EXAMPLE

$$13\,051 \text{ (lb•ft)} = \frac{2480 \text{ (hp)} \times 5252}{1000 \text{ (rpm)}}$$

Comments & Notes:

Atlantic Distance Table

Azores to

Bermuda 2,201	Cape Horn 6,282	Cape Town 5,040	Fastnet 1,377
Gibraltar 946	Halifax 1,785	Miami 2,900	New York 2,246
Norfolk 2,401	Panama 3,439	Rio 3,875	St.Thomas 2,393

Bermuda to

Azores 2,201	Cape Horn 6,300	Cape Town 6,269	Fastnet 2,651
Gibraltar 2,903	Halifax 756	Miami 956	New York 697
Norfolk 683	Panama 1,702	Rio 4,110	St.Thomas 872

Cape Horn to

Azores 6,282	Bermuda 6,300	Cape Town 4,731	Fastnet 7,151
Gibraltar 6,452	Halifax 6,800	Miami 6,882	New York 6,920
Norfolk 6,900	Panama 4,093	Rio 2,338	St.Thomas 5,886

Cape Town to

Azores 5,040	Bermuda 6,269	Cape Horn 4,731	Fastnet 5,880
Gibraltar 5,072	Halifax 6,492	Miami 6,800	New York 6,786
Norfolk 6,790	Panama 6,508	Rio 3,273	St.Thomas 5,904

Fastnet to

Azores 1,377	Bermuda 2,651	Cape Horn 7,151	Cape Town 5,880
Gibraltar 977	Halifax 2,364	Miami 3,578	New York 2,815
Norfolk 2,979	Panama 4,247	Rio 4,873	St.Thomas 3,279

Gibraltar to

Azores 946	Bermuda 2,903	Cape Horn 6,452	Cape Town 5,072
Fastnet 977	Halifax 2,708	Miami 3,800	New York 3,180
Norfolk 3,335	Panama 4,351	Rio 4,180	St.Thomas 3,323

Halifax to

Azores 1,785	Bermuda 756	Cape Horn 6,800	Cape Town 6,492
Fastnet 2,364	Gibraltar 2,708	Miami 1,413	New York 600
Norfolk 790	Panama 2,338	Rio 4,630	St.Thomas 1,595

iami to

Azores 2,900	Bermuda 956	Cape Horn 6,882	Cape Town 6,800
Fastnet 3,578	Gibraltar 3,800	Halifax 1,413	New York 1,100
Norfolk 698	Panama 1,249	Rio 4,879	St.Thomas 991

New York to

Azores 2,246	Bermuda 697	Cape Horn 6,920	Cape Town 6,786
Fastnet 2,815	Gibraltar 3,180	Halifax 600	Norfolk 271
Miami 1,100	Panama 2,016	Rio 4,770	St.Thomas 1,434

Norfolk to

Azores 2,401	Bermuda 683	Cape Horn 6,900	Cape Town 6,790
Fastnet 2,979	Gibraltar 3,335	Halifax 790	New York 271
Miami 698	Panama 1,825	Rio 4,723	St.Thomas 1,296

Panama to

Azores 3,439	Bermuda 1,702	Cape Horn 4,093	Cape Town 6,508
Fastnet 4,247	Gibraltar 4,351	Halifax 2,338	New York 2,016
Miami 1,249	Norfolk 1,825	Rio 4,284	St.Thomas 1,072

Rio de Janeiro to

Azores 3,875	Bermuda 4,110	Cape Horn 2,338	Cape Town 3,273
Fastnet 4,873	Gibraltar 4,180	Halifax 4,630	Miami 4,879
New York 4,770	Norfolk 4,723	Panama 4,284	St.Thomas 3,542

St.Thomas to

Azores 2,323	Bermuda 872	Cape Horn 5,886	Cape Town 5,904
Fastnet 3,279	Gibraltar 3,323	Halifax 1,595	Miami 991
New York 1,434	Norfolk 1,296	Rio 3,542	Panama 1,072

Pacific Distance Table

Auckland to

Cape Horn 6,232	HongKong 5,060	Honolulu 3,820	LosAngeles 5,658
PagoPago 1,565	Panama 6,516	Papeete 2,216	SanFrancisco 5,680
Sitka 6,176	Sydney 1,280	Vancouver 6,191	Yokohama 4,789

Cape Horn to

Auckland 6,232	HongKong 10,404	Honolulu 6,644	LosAngeles 6,100
PagoPago 5,381	Panama 4,162	Papeete 4,333	SanFrancisco 6,458
Sitka 7,705	Sydney 7,301	Vancouver 7,248	Yokohama 9,642

Hong Kong to

Auckland 5,060	Cape Horn 10,404	Honolulu 4,857	LosAngeles 6,380
PagoPago 4,948	Panama 9,195	Papeete 6,132	SanFrancisco 6,044
Sitka 5,136	Sydney 4,086	Vancouver 6,361	Yokohama 1,585

Honolulu to

Auckland 3,820	Cape Horn 6,644	HongKong 4,857	LosAngeles 2,228
PagoPago 2,276	Panama 4,685	Papeete 2,381	SanFrancisco 2,091
Sitka 2,386	Sydney 4,420	Vancouver 2,423	Yokohama 3,395

Los Angeles to

Auckland 5,658	Cape Horn 6,100	HongKong 6,380	Honolulu 2,228
PagoPago 4,163	Panama 2,913	Papeete 3,571	SanFrancisco 349
Sitka 1,640	Sydney 6,511	Vancouver 1,091	Yokohama 4,836

Pago Pago to

Auckland 1,565	Cape Horn 5,381	HongKong 4,948	Honolulu 2,276
LosAngeles 4,163	Panama 5,656	Papeete 1,236	SanFrancisco 4,151
Sitka 4,635	Sydney 2,377	Vancouver 4,549	Yokohama 4,135

Panama to

Auckland 6,516	Cape Horn 4,162	HongKong 9,195	Honolulu 4,685
LosAngeles 2,913	PagoPago 5,656	Papeete 4,493	SanFrancisco 3,245
Sitka 4,524	Sydney 7,674	Vancouver 4,032	Yokohama 7,682

Papeete to

Auckland 2,216	Cape Horn 4,333	HongKong 6,132	Honolulu 2,381
LosAngeles 3,571	PagoPago 1,236	Panama 4,493	SanFrancisco 3,663
Sitka 4,537	Sydney 3,308	Vancouver 4,396	Yokohama 5,140

San Francisco to

Auckland 5,680	Cape Horn 6,458	HongKong 6,044	Honolulu 2,091
LosAngeles 349	PagoPago 4,151	Panama 3,245	Pepeete 3,663
Sitka 1,302	Sydney 6,448	Vancouver 812	Yokohama 4,536

Sitka to

Auckland 6,176	Cape Horn 7,705	HongKong 5,136	Honolulu 2,386
LosAngeles 1,640	PagoPago 4,635	Panama 4,524	Pepeete 4,537
SanFrancisco 1,302	Sydney 6,595	Vancouver 823	Yokohama 3,640

Sydney to

Auckland 1,280	Cape Horn 7,301	HongKong 4,086	Honolulu 4,420
LosAngeles 6,511	PagoPago 2,377	Panama 7,674	Pepeete 3,308
SanFrancisco 6,448	Sitka 6,595	Vancouver 6,814	Yokohama 4,330

Vancouver to

Auckland 6,191	Cape Horn 7,248	HongKong 6,361	Honolulu 2,423
LosAngeles 1,091	PagoPago 4,549	Panama 4,032	Pepeete 4,396
SanFrancisco 812	Sitka 823	Sydney 6,814	Yokohama 4,262

Yokohama to

Auckland 4,789	Cape Horn 9,642	HongKong 1,585	Honolulu 3,395
LosAngeles 4,839	PagoPago 4,135	Panama 7,682	Pepeete 5,140
SanFrancisco 4,536	Sitka 3,640	Sydney 4,330	Vancouver 4,262

Geographic Range Table

Them following table gives the approximate geographic range of visibility for an object that may be seen by an observer at sea level. It also provides the approximate distance to the visible horizon for various heights of eye. To determine the geographic range of an object, you must add the range for the observer's height of eye and the range for the object's height. For instance, if the object seen is 65 feet, and the observer's height of eye is 35 feet above sea level, then the object will be visible at a distance of no more than 16.3 miles:

Height of eye: 35 feet Range = 6.9 nm
Object height: 65 feet Range = 9.4 nm
Computed geographic range = 16.3 nm

The standard formula is d =1.17 x square root of H + 1.17 x square root of h. Where d = visible distance, H = height of the object, and h the height of eye of the observer.

HEIGHT		DISTANCE
Feet	Meters	International Nautical Miles = 1.152 Nautical Mile/Mile
5	1.5	2.6
10	3.0	3.7
15	4.6	4.5
20	6.1	5.2
25	7.6	5.9
30	9.1	6.4
35	10.7	6.9
40	12.2	7.4
45	13.7	7.8
50	15.2	8.3
55	16.8	8.7
60	18.3	9.1
65	19.8	9.4
70	21.3	9.8
75	22.9	10.1
80	24.4	10.5
85	25.9	10.8
90	27.4	11.1
95	29.0	11.4
100	30.5	11.7
110	33.5	12.3
120	36.6	12.8
130	39.6	13.3
140	42.7	13.8
150	45.7	14.3
200	61.0	16.5
250	76.2	18.5
300	91.4	20.3
350	106.7	21.9
400	121.9	23.4
450	137.2	24.8
500	152.4	26.2
550	167.6	27.4
600	182.9	28.7
650	198.1	29.8
700	213.4	31
800	243.8	33.1
900	274.3	35.1
1000	304.8	37

Comments & Notes:

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G L O S S A RY O F T E R M

A *Ampere*
ABDC *After Bottom Dead Center*
ABS *American Bureau of Shipping Absolute*
Abrasion – Wearing or rubbing away of a part.
Absolute Humidity – Amount of moisture in the air, indicated in grains per cubic foot.
Absolute Pressure – Gauge pressure plus atmospheric pressure (14.7 lb per in 2).
Absolute Temperature – The temperature measured using absolute zero as a reference. Absolute zero is -469.69° F (-273.16° C) and is the lowest point of temperature known.
AC *Alternating Current*
A/C *Aftercooler*
Acceleration – The rate of increase of velocity per time unit (example: feet per second).
Accommodation Ladder– The stairs used to go aboard a ship.
Accumulator – A device used for storing liquid under pressure (sometimes used to smooth out pressure surges in a hydraulic system).
Active Power – The real power supplied by the generator set to the electrical load. Active power creates a load on the set's engine and is limited by the horsepower of the engine. Active power does the work of heating, turning motor shafts, etc., and is measured in watts, kilowatts, and megawatts.
Actuator – A device which uses fluid power to produce mechanical force and motion.
Additive – 1. A compound which is added to improve fuel. 2. A substance added to oil to give it certain properties. For example, a material added to engine oil to lessen its tendency to congeal or thicken at low temperatures.
Advance – To move the timing of the injection pump or injectors to an earlier injection point.
Advanced Diesel Engine Management (ADEM) – The name for current generation of the electronic engine control system.
AFRC *Air-Fuel Ratio Control*
AFTS *Automatic Fuel Transfer System*
A/F Dynamic Setting – The dynamic (engine running) setting of a device on the engine which limits the amount of fuel injected per stroke as a function of the boost.
Aft – Toward, at, or near the stern.
Aftercooler – A heat exchanger inserted into the induction system of an engine after any device used to compress combustion air.
Ah *Ampere-hour*
AIMS *A (cluster) – Information Management System*
Air Bleeder – A device used to remove air from a hydraulic system. Types include a needle valve, capillary tubing to the reservoir, and a bleed plug.
Air Cleaner – A device (filter) for removing unwanted solid impurities from the air before the air enters the intake manifold.
Air Compressor – A device used to increase air pressure.
Air Conditioning – The simultaneous control of all or at least the first three of the following factors affecting the physical and chemical conditions of the atmosphere within a structure: temperature, humidity, motion, distribution, dust, bacteria, odors, toxic gases and ionization — most of which affect, in

Air Cooled Condenser – Heat of compression is transferred from condensing coils to surrounding air. This may be done either by convection or by a fan or blower.
Air Diffuser – Air distribution outlet designed to direct airflow into desired patterns.
Air-Fuel Ratio – The ratio (by weight or by volume) between fuel and air.
Air-Fuel Ratio Control (AFRC) – A feature on Cat engines which measures actual engine speed and boost pressure to reduce smoke and lower fuel consumption.
Air Gap – The distance between two components; clearance between internal rotating member and stationary outside member. Refers to gap per side.
Air Inlet Shutoff – An engine protection measure used to supplement the fuel shutoff, when blocking the air supply is the quickest way to stop the engine. Often this approach is used on larger engines when operating in combustible environments or to achieve fast shutdowns. Air shutoffs are not used for routine shutdowns.
Air Pollution – Contamination of the earth's atmosphere by pollutants such as smoke, -harmful gases, etc.
Air (Specific Heat of) – The quantity of heat absorbed by a unit weight of air per unit temperature rise.
Air (Standard) – Air with a density of 0.075 lb per ft 3 and an absolute viscosity of 0.0379 x 10-5 lb mass per (ft) (sec). This is substantially equivalent to dry air at 70° F and 29.92 in. Hg barometric pressure.
Air Starting Valve – A valve which admits compressed air to the air starter for starting purposes.
Air-to-Air Aftercooler (ATAAC) – A means of cooling intake air after the turbocharger, using ambient air for cooling. The intake air is passed through an aftercooler (heat exchanger) mounted in front of the radiator before going to the intake manifold.
Aldehydes – A chemical compound formed by incomplete combustion.
Align – To bring two or more components of a unit into the correct positions with respect to one another.
Allowance – The difference between the minimum and the maximum dimensions of proper functioning.
Alloy – A mixture of two or more different metals, usually to produce improved characteristics.
Alternating Current (AC) – An electric current that reverses its direction at regularly recurring intervals such as 50 or 60 times per second in 50 Hz and 60 Hz, respectively.
Alternating Current (AC) Metering Module – An apparatus which displays generator set volts, amps, and frequency.
Alternator – An electromechanical device which produces alternating current.
Ambient – The surrounding atmosphere; encompassing on all sides; the environment surrounding a body but undisturbed or unaffected by it.
Ambient Temperature – Temperature of fluid (usually air) which surrounds object on all sides.
AMD *Authorized Marine*
Ammeter – An instrument used to indicate, in amperes, the current flowing through the phases from a generator to the load.
Ammonia – Chemical combination of nitrogen and hydrogen (NH 3). Ammonia refrigerant is identified by R-117.

Amortisseur Windings – Apparatus formed by copper rotor end plates and damper bars to help stabilize a generator set during parallel operation.
Amperage – A measure of the current or number of electrons passing a given point per unit of time.
Ampere (A) – A unit of measurement defined as the current that 1 V can send through 1W resistance.
Ampere-hour Capacity (Ah) – A measurement of the battery's capacity to deliver a specified current over a specified length of time.
Analog – A continuous performance signal representing the value of an engine performance characteristic.
Aneroid – A pressure-measuring device containing no liquid.
Angle – Inclination of two lines to each other.
Angularity – Having or being at an angle.
Anneal – To toughen metals by heating and then cooling.
Annular – In the form of an annulus; ring-shaped.
Annulus – A figure bounded by concentric circles or cylinders (e.g., a washer, ring, sleeve, etc.).
Annunciator – An alarm which produces audible and/or visual signals to give warnings of shutdown or fault conditions. Annunciators are typically used in applications where the equipment monitored is not located in a portion of the facility that is normally attended.
Dealers
***ANSI** American National Standards Institute*
Antifreeze – A chemical such as alcohol, glycerin, etc., added to the coolant in order to lower its freezing point.
Antifriction Bearing – A bearing constructed with balls, rollers or the like between the journal and the bearing surface to provide rolling instead of sliding friction.
API Gravity – Gravity expressed in units of standard API (hydrometer).
Arc – Portion of a curved line or of the circumference of a circle.
Air Gap – The clearance between internal rotating member and stationary outside member. Refers to gap per side.
Air Welding – A method of utilizing the heat of an electric current jumping an air gap to provide heat for welding metal.
***API** American Petroleum Institute*
***APU** Auxiliary Power Unit*
Armature – The movable part of a relay, regulator, or horn, or the rotating part of a generator or starter.
***AS** Air Shut-off (Solenoid)*
Asbestos – A heat-resistant and nonburning organic mineral.
***ASME** American Society of Mechanical Engineers*
***asp** Engine aspiration*
Asphalt Epoxy – Additional protective coating on winding coil heads on the intake end of a generator.
Aspirate – To breathe (to draw out gas by suction).
Aspiration – The method used to move inlet air into the combustion chamber; e.g. Naturally Aspirated (NA), Turbocharged (T), and Turbocharged-Aftercooled (TA).
***ASTM** American Society of Testing Materials*
***ATAAC** Air-To-Air AfterCooling*

ATA Link – An analog terminal adapter that allows a Northern Transcom Norstar digital phone system to use analog devices such as a fax, answering machine, or modem.
ATDC *After Top Dead Center*
Athwartship – Across the ship, at right angles to the fore-and-aft center line of the ship.
Atmosphere – The mass or blanket of gases surrounding the earth.
Atmospheric Pressure (Barometric Pressure) – The pressure exerted by the atmosphere, averaging 14.7 psi at sea level with a decrease of approximately 1/2 lb per 1,000 ft of altitude gained.
Atom – The smallest particle of an element.
Atomizer – A device which disperses liquid (e.g. fuel) into fine particles (pulverized spray).
ATS *Automatic Transfer Switch*
Attrition – Wearing down by rubbing or by friction: abrasion.
Austempering – A method of hardening steel by quenching from the austenitizing temperature into a heat extracting medium (usually salt) which is maintained at some constant temperature level between 400° F and 800° F (usually near the higher temperature) and holding the steel in this medium until transformation is substantially complete and then cooling to room temperature.
Automatic Defrost – System of removing ice and frost from evaporators automatically.
Automatic Synchronizer – A magnetic-type control relay which will automatically close the generator switch/circuit breaker when the conditions for paralleling are satisfied.
Automatic Transfer Switch (ATS) – Automatically switches electrical load from the normal (or preferred) power source to an alternate supply, should normal voltage fail or be substantially reduced. It retransfers load to the normal source when voltage has been restored.
Automatic Valve –A valve assisted by a spring, which is opened by a difference of pressure acting in one direction and closed by a difference in pressure acting in the opposite direction.
Automatic Voltage Regulator – Controls the output voltage produced by a generator by controlling excitation.
AUX GEN *Auxiliary Generator*
Auxiliary – An aid to the main device which may only be used occasionally.
Avoided Costs – The decremental cost for the electric utility to generate or purchase electricity that is avoided through the purchase of power from a cogeneration facility.
AVR *Automatic Voltage Regulator*
Axial Fan –A shaft mounted fan on some designs between bearing and revolving field assembly to provide additional air movement within the unit for cooling; also used for balancing.
Avoided Cost (Regulatory) – The amount of money that an electric utility would need to spend for the next increment of electric generation production to produce or purchase elsewhere the power that it instead buys from a cogenerator or small power producer.
Babbitt – An antifriction metal used to line bearings, thereby reducing the friction of the moving components.
Backfire – Ignition of the mixture in the intake manifold by flame from the cylinder such as might occur from a leaking inlet valve.

Backlash – The distance (play) between two movable components such as meshed gears.
Backpressure – A pressure exerted contrary to the pressure producing the main flow. Also called suction pressure or low side pressure.
Back-Up Power – Electric energy available from or to an electric utility during an unscheduled outage to replace energy ordinarily generated by the facility or the utility. Frequently referred to as standby power.
Baffle or Baffle Plate – A device which slows down or diverts the flow of gases, liquids, sound, etc.
Bainite – The structure that is obtained when steel is quenched at a constant subcritical temperature.
Ball Bearing – A bearing using steel balls as its rolling element between the inner and outer ring (race).
Ball Check Valve –A valve consisting of a ball held against a ground seat by a spring. It is used to check the flow or to limit the pressure.
Ballast – Weight added in a ship's inner bottom to balance her topside weight, or to keep her down in the water under light loads. some ships carry permanent concrete ballast. Others pump salt water into the tanks for the same purpose.
Barometer – An instrument which measures atmospheric pressure.
Bars – The term "bars" includes rounds, squares, hexagons, etc.; small standard shapes (angles, channels, tees, etc.) under 3"; flats 6" or under in width and 13/64" or over in thickness.
Base Load – The lowest level of power production needs during a season or year.
Base Load Unit – A power generating facility that is intended to run constantly at near capacity levels, as much of the time as possible.
Base Loading – Use of on-site generating equipment to supply a set amount of power for a specific time period — usually on a daily basis.
Baseline Forecast – A prediction of future energy needs which does not take into account the likely effects of new conservation programs that have not yet been started.
Basic Size –The theoretical or nominal standard size from which all variations are made.
BAT *Battery*
Battery – A connected group of cells storing an electrical charge and capable of furnishing a current from chemical reactions.
BBDC *Before Bottom Dead Center*
BDC *Bottom Dead Center*
Beam – An athwartship horizontal member supporting a deck or flat. Also, the extreme width of a ship.
Bearing – The contacting surface on which a revolving part rests.
Bearing Clearance – The distance between the shaft and the bearing surface.
Bell Housing (Clutch Housing) – The metal covering around the clutch or torque converter assembly.
Below Deck/Go Below – To move to a deck located under the main deck.
Bendix-Type Starter Drive (Inertia Starter Drive) – A type of starter drive that causes the gear to engage when the armature starts rotating and to automatically disengage when it stops.
Bernoulli's Principle – Given a fluid flowing through a tube, any constriction or narrowing of the tube will create an increase in that fluid's velocity and a decrease in pressure.

Bernoulli's Theorem – In a stream of liquid, the sum of elevation head, pressure head, and velocity remains constant along any line of flow provided no work is done by or upon the liquid in its course of flow, and decreases in proportion to energy lost in the flow.
BES *Brushless Excitation System*
Bessemer Process – A process for making steel by blowing air through molten pig iron contained in a suitable vessel. The process is one of rapid oxidation mainly of silicon and carbon.
bhp *Engine brake horsepowerwithout fan*
Bilge – Curved section between the bottom and the side of a ship; the recess into which all water drains.
Bilge Keels – Long, narrow fins fitted to both side of the hull at the turn of the bilge to prevent the ship from rolling.
Bimetal Strip – Temperature regulating or indication device which works on the principle that two dissimilar metals with unequal expansion rates, welded together, will bend as temperatures change.
bkW *Engine brake kilowatts without fan*
Black Smoke –A soot-like substance emitted by engines resulting from incomplete combustion.
Black Start – Refers to the starting of a power system with its own power sources, without assistance from external power supplies.
Blended or Heavy Fuel – A mixture of residual fuel and a lighter fuel. This fuel type tends to create more combustion chamber deposit formations which can cause increased cylinder and ring wear, especially in smaller, higher-speed engines.
Blister – A defect in metal produced by gas bubbles either on the surface or formed beneath the surface.
Block Rate Schedules – Utility rate schedules that charge different rates for certain increments of energy consumed. For example: 3 cents for the first 1000 kW-hr, 4 cents for the next 1000 kW-hr, 5 cents for the next 1000 kW-hr, etc.
Block Wall – A concrete structure which is sometimes used to muffle the noise from an operating generator set.
Blowby – Combustion gas leakage into the engine crankcase. The leakage is normally from the combustion chamber past the piston rings or through the valve guides. Specific blowby is the volume of blowby at atmospheric pressure divided by the engine power.
Blower – A low-pressure air pump, usually of one rotary or centrifugal type.
Blowhole – A hole produced during the solidification of metal by evolved gas which, in failing to escape, is held in pockets.
Blue Brittleness – Brittleness occurring in steel when worked in the temperature range of 300-700° F or when cold after being worked within this temperature range.
B/M *Bill of Material*
BMEP *Brake Mean Effective Pressure*
Boiling Point – The temperature at which bubbles or vapors rise to the surface of a liquid and escape.
Boiling Temperature – Temperature at which a fluid changes from a liquid to a gas.
Bond – The holding together of different parts.
Boost – The gauge pressure as measured in the inlet manifold of a diesel engine. Adjusted boost is the calculated value of boost that would exist if an

engine were running at nominal power. Boost is not synonymous with inlet manifold pressure.
Bore – The diameter of each cylinder in an engine.
Boring – Enlarging the cylinders by cutting or honing them to a specified size.
Boring Bar (Cylinder) – A tool used to machine the cylinders to a specific size.
Bosch Metering System – A metering system with a helical groove in the plunger which covers or uncovers ports in the pump barrel.
Bottom Dead Center (BDC) – The lowest point a piston reaches in its movement within a cylinder.
Bottoming Cycle – A means to increase the thermal efficiency of a steam electric generating system by converting some waste heat from the condenser into electricity rather than discharging all of it into the environment.
Bound Electrons – The inner-orbit electrons around the nucleus of the atom.
Bow – The front part of a ship, where the two sides meet. To move in that direction is to go forward.
Boyle's Law of Physics – The absolute pressure which a given quantity of gas at constant temperature exerts against the walls of the containing vessel is inversely proportional to the volume occupied. Examples: If pressure is doubled on the quantity of gas, volume becomes one-half. If volume becomes doubled, gas has its pressure reduced by one-half.
Brake Horsepower (bhp) – A measurement of the power developed by an engine in actual operation. It subtracts the F.H.P. (friction losses) from the I.H.P. (pure horsepower).
Brake Mean Effective Pressure (BMEP) – Mean effective pressure acting on the piston which would result in the given brake horsepower output, if there were no losses due to friction, cooling, and exhaustion. Equal to mean indicated pressure times mechanical efficiency.
Brake Specific Fuel Consumption (BSFC) – The quantity of fuel burned to produce one horsepower for one hour.
Brake Thermal Efficiency – Ratio of power output in the form of brake horsepower to equivalent power input in the form of heat from fuel.
Braze – To join two pieces of metal using a comparatively high-melting-point material. An example is to join two pieces of steel by using brass or bronze as a solder.
Break-in – The process of wearing in to a desirable fit between the surfaces of two new or reconditioned parts.
Breather – A device that allows fumes to escape from the crankcase.
Breather Pipe – A pipe opening into the crankcase to assist ventilation.
Bridge – A crosswise platform above the main deck of a ship from which the ship is controlled.
Brine – Water saturated with chemical such as salt.
Brinell Hardness – The surface hardness of a metal, alloy, or similar material according to J.A. Brinell's method of measurement. A metal's surface is struck at a given force by a rigid steel ball of given diameter, and the indentation is measured.
British Gallon (Imperial Gallon, gal [Imp.]) – A gallon measurement of 277.4 in ^{3}.
British Thermal Unit (Btu) – Approximate definition: The amount of heat required to raise 1 lb of water 1° F. Exact definition: The amount of heat required to raise 1 lb. of water from freezing to boiling at standard atmospheric pressure.

Broad Voltage – A term used to denote 12-lead unit, which allows low and high voltage connections by customer.
Brownout – A controlled power reduction in which the utility decreases the voltage on the power lines, so customers receive weaker electric current.
Brush – The pieces of carbon or copper that make a sliding contact against the commutator or slip rings.
Brushless – A synchronous machine having a brushless exciter with its rotating armature and semiconductor devices on a common shaft with the field of the main machine.
BSFC *Brake Specific Fuel Consumption*
BSOC *Brake Specific Oil Consumption*
BTDC *Before Top Dead Center*
Btu *British thermal unit*
Bulkheads – This refers to inner walls of a ship, also called partitions.
Bulwarks – Vertical extensions above the deck edge of the shell plating. Bulwarks are built high enough to keep men and equipment from going overboard.
Buoyancy – The upward or lifting force exerted on a body by a fluid.
Burning – The heating of a metal to temperatures sufficiently close to the melting point to cause permanent damage to the metal.
Burnish – To polish or shine a surface with a hard, smooth object.
Bursts – Ruptures made in forging or rolling.
Bus – An electrical conductor that serves as a common connection for two or more electrical circuits.
Bus – Refers to the devices that connect the generators and loads in a paralleling system, or any point fed by multiple sources and/or supplying multiple loads.
Bus Bars – A set of common conductors on the load side of a circuit breaker used to conduct generator output to the distribution system.
Bus Capacity – The maximum load that can be carried on a system without causing degradation of the generator frequency. In other words, the full load capacity of the system.
Bushing – A metallic or synthetic lining for a hole which reduces or prevents abrasion between components.
Butane – A hydrocarbon gas formed synthetically by the action of zinc or ethyl iodide. This gas becomes a liquid when under pressure.
Butterfly Valve – A valve in the venturi to control the airflow.
Bypass Filter – An oil filter that only filters a portion of the oil flowing through the engine lubrication system.
Bypass Valve – A valve that opens when the set pressure is exceeded. This allows the fluid to pass through an alternative channel.
CAC *Charge Air Cooler*
CACo *Caterpillar Americas Company*
Cage – A housing in which a valve operates and seats.
Calcium Sulfate – Chemical compound ($CaSO_4$) which is used as a drying agent or desiccant in liquid line driers.
Calibrate – To make an adjustment to a meter or other instrument so that it will accurately indicate its input.
Caliper – A tool for measuring diameter, usually having curved legs and resembling a pair of compasses.
Calorie – Heat required to raise temperature of one gram of water one degree centigrade.

Calorific Value – The amount of heat produced by burning one pound of fuel. (See *Heating Value*.)
Calorimeter – Device used to measure quantities of heat or determine specific heats.
Cam – A component of irregular shape. It is used to change the direction of the motion of another part moving against it, e.g., rotary into reciprocating or variable motion.
Cam Follower (Valve Lifter) – A part which is held in contact with the cam and to which the cam motion is imparted and transmitted to the pushrod.
Cam-Ground Piston – A piston ground to a slightly oval shape which under the heat of operation becomes round.
Cam Nose – That portion of the cam that holds the valve wide open. It is the high point of the cam.
CAMPAR *Computer Aided Marine PAR*
Camshaft – The shaft containing lobes or cams to operate the engine valves.
Camshaft Gear – The gear that is fastened to the camshaft.
Capability – The maximum load which a generating unit, generating station, or other electrical apparatus can carry under specified conditions for a given period of time, without exceeding approved limits of temperature and stress.
Capacitor – An arrangement of insulated conductors and dielectrics for the accumulation of an electric charge with small voltage output.
Capacity (electric utility) – The maximum amount of electricity that a generating unit, power plant, or utility can produce under specified conditions. Capacity is measured in megawatts and is also referred to as the nameplate rating.
Capacity Credits – The value incorporated into the utility's rate for purchasing energy, based upon the savings due to the reduction or postponement of new generation capacity resulting from the purchase of power from cogenerators.
Capacity Factor – The ratio of the actual annual plant electricity output to the rated plant output.
Capacity-Net Cooling – The cooling capacity of an air-conditioning system or heat pump on the cooling cycle is the amount of Sensible and Latent heat (total heat) removed from the inside air.
Capstan – A revolving device with a vertical axis, used for heaving-in mooring lines.
CARB *California Air Resources Board*
Carbon – One of the nonmetallic elements constituting fuel and lubricating oil.
Carbon Dioxide (CO_2) – A "greenhouse" gas produced as a result of combustion of any hydrocarbon fueled engine, including a human. The highest efficiency engines produce the least CO_2.
Carbon Monoxide (CO) – A poisonous gas formed by combustion taking place with a shortage of oxygen. Measured in parts per million by volume.

$$\text{CO Concentration (ppm)} = \frac{1034 \times \text{CO mass emissions (g/hr)}}{\text{Exhaust mass flow (kg/hr)}}$$

Carbon Pile – Carbon disks or plates capable of carrying high current.
Carbon Tetrachloride – A colorless liquid, the fumes of which are toxic. Used in fire extinguishers and for cleaning.
Carbonize – The process of carbon formation within an engine, such as on the spark plugs and within the combustion chamber.

Carburetor – A device for automatically mixing gasoline fuel in the proper proportion with air to produce a combustible vapor.
Carburetor "Icing" – A term used to describe the formation of ice on a carburetor throttle plate during certain atmospheric conditions.
Carburizing (cementation) – Adding carbon to the surface of iron-base alloys by heating the metal below its melting point in contact with carbonaceous solids, liquids, or gases.
Cat Data Link – A communication data link which displays status of various engine parameters on the Computerized Monitoring System.
CAT PC *Caterpillar Engine Power Connection*
CB *Circuit Breaker*
CDL *Cat Data Link*
Ceiling – The absolute maximum to which the high limit of an engine performance specification may rise.
Cementite – A compound of iron and carbon always containing 6.68% carbon and 93.32% iron.
Central Cooling – Same as central heating except that cooling (heat removal) is supplied instead of heating; usually a chilled water distribution system and return system for air conditioning.
Central Heating – Supply of thermal energy from a central plant to multiple points of end-use, usually by steam or hot water, for space and/or service water heating. Central heating may be large-scale as in plants serving central business districts, university campuses, medical centers, and military installations or in central building systems serving multiple zones; also district heating.
cemf *counterelectromotive force*
Cetane – Measure of ignition quality of diesel fuel — at what pressure and temperature the fuel will ignite and burn.
Chamfer –A bevel or taper at the edge of a hole.
Charge Air Cooler (CAC) – An air-to-air or water-to-air heat exchanger to cool turbocharged combustion air.
Chase – To straighten up or repair damaged threads.
Choke – A device such as a valve placed in a carburetor air inlet to restrict the volume of air admitted.
CHP *Combined Heat and Power (also referred to as cogeneration)*
CIM *Customer Interface Module*
CIPS *Caterpillar International Power Systems*
Circuit – The complete path of an electric current including, usually, the source of electrical energy.
Circuit Breaker – A device used to open and close a circuit by nonautomatic means, and to open the circuit automatically on a predetermined overload of current.
CIS *Corporate Information Services*
Closing Rating – The maximum fault current into which an automatic transfer switch of a generator set can close.
CLS *Caterpillar Logistics Services*
CMS *Computerized Monitoring System*
Coefficient of Expansion – The change in length per unit length or the change in volume per unit volume per degree change in temperature.
Coefficient of Performance (COP) – The ratio of the rate of heat removal to the rate of energy input in consistent units.

Cofferdam – A narrow empty space between two bulkheads that prevents leakage into the adjoining compartments.
Cogeneration – Utilizing a prime power generator set, this process involves harnessing "free" heat energy from engine cooling and exhaust systems for heating or steam generation, or to power air conditioning, absorption chillers, or other equipment.
Cohesive Strength – The strength property of a metal that resists the tensile, disruptive stress across a plane at right angles to the load applied.
Coil Spring – A spring-steel wire wound in a spiral pattern.
Coil Wedge – A mechanical device which prevents coil bundle from coming out of rev. field slot passage during rotation of rev. field. Two types: expansion wedges — 360, 440, and 580, 680 frames; compression wedges — 800 frame.
Cold – Cold is the absence of heat; a temperature considerably below normal.
Cold Drawing – The process for finishing a hot rolled rod or bar at room temperature by pulling it through the hole of a die of the same shape but smaller in size.
Cold Finishing – The process of reducing the cross sectional area without heating by cold rolling, cold drawing, cold drawing and grinding, turning and polishing, or turning and grinding.
Cold Rolling – The cold working of hot rolled material by passing it between power-driven rolls. The process applies to flat bars of such a size that they cannot be pulled through a die.
Cold Working – Plastic deformation of a metal at a temperature low enough to ensure strain hardening.
Color Code – Colored markings or wires to identify the different circuits.
Combustion – The process of burning.
Combustion Chamber – The chamber in reciprocating engines between the cylinder head and piston, in which combustion occurs.
Combustion-Chamber Volume – The volume of the combustion chamber (when the piston is at TDC) measured in cubic centimeters.
Combustion Cycle – A series of thermodynamic processes through which the working gas passes to produce one power stroke. The cycle is: intake, compression, power, and exhaust.
Comfort Air-Conditioning – A simultaneous control of all, or at least the first three, of the following factors affecting the physical and chemical conditions of the atmosphere within a structure of the purpose of human comfort; temperature, humidity, motion, distribution, dust, bacteria, odors, toxic gases, and ionization, most of which affect in greater or lesser degree human health or comfort.
Commutator – A number of copper bars connected to the armature windings but insulated from each other and from the armature. Rotation of the armature will, in conjunction with fixed brushes, result in unidirectional current output.
Compartment – A subdivision of space or room in a ship.
Compound – A combination of two or more elements that are mixed together.
Compressed Air – Air that at any pressure in excess of atmospheric pressure is considered to be compressed.
Compressibility – The property of a substance (e.g., air) by virtue of which its density increases with increase in pressure.

Compression – The process by which a confined gas is reduced in volume through the application of pressure.
Compression Check – A measurement of the compression of each cylinder at cranking speed or as recommended by the manufacturer.
Compression Gauge – A test instrument used to test the cylinder compression.
Compression Ignition – The ignition of fuel through the heat of compression.
Compression Pressure – Pressure in the combustion chamber at the end of the compression stroke, but without any of the fuel being burned.
Compression Ratio – Compares the minimum and maximum volumes between the piston crown and the cylinder head.
Compression Release – A device to prevent the intake or exhaust valves from closing completely, thereby permitting the engine to be turned over without compression.
Compression Ring – The piston rings used to reduce combustion leakage to a minimum.
Compression Stroke – That stroke of the operating cycle during which air is compressed into a smaller space, creating heat by molecular action.
Compressor – A mechanical device to pump air, and thereby increase the pressure. The pump of a refrigerating mechanism which draws a vacuum or low pressure eon cooling side of refrigerant cycle and squeezes or compresses the gas into the high pressure or condensing side of the cycle.
Compressor-Brake Horsepower – A function of the power input to the ideal compressor and to the compression, mechanical, and volumetric efficiency of the compressor.
Compressor Efficiency – A measure of the deviation of the actual compression from the perfect compression cycle. Is defined as the work done within the cylinders.
Compressor, Open-Type – Compressor in which the crankshaft extends through the crankcase and is driven by an outside motor.
Compressor Outlet Pressure – Gauge pressure of the combustion air at the turbocharger compressor outlet of a spark ignited engine.
Compressor, Reciprocation – Compressor which uses a piston and cylinder mechanism to provide pumping action.
Compressor, Rotary – Compressor which uses vanes, eccentric mechanisms, or other rotating devices to provide pumping action.
Computerized Monitoring System (CMS) – An electronic display for marine or industrial engines to display engine parameters and diagnostics.
Concentric – Having the same center.
Conceptual Design – The specification of the major components of a system and their operating characteristics, layout, space needs, and operating and maintenance requirements.
Condensate – Fluid which forms on an evaporator.
Condensate Pump – Device used to remove fluid condensate that collects beneath an evaporator.
Condensation – Liquid or droplets which form when a gas or vapor is cooled below its dew point.
Condense – Action of changing a gas or vapor to a liquid.
Condenser, Air-Cooled – A heat exchanger which transfers heat to surrounding air.
Condenser, Electrical – An arrangement of insulated conductors and dielectrics for the accumulation of an electric charge.

Condenser, Evaporative – A condenser in which heat is absorbed from the surface by the evaporation of water sprayed or flooded over the surface.
Condenser, Thermal – The part of a refrigeration mechanism which receives hot, high pressure refrigerant gas from the compressor and cools gaseous refrigerant until it returns to liquid state.
Condenser, Water-Cooled – Heat exchanger which is designed to transfer heat from hot gaseous refrigerant to water.
Condensing Unit – The part of the refrigerating mechanism which pumps vaporized refrigerant from the evaporator, compresses it, liquifies it in the condenser, and returns the liquid refrigerant to refrigerant control.
Conduction, Thermal – The process of heat transfer through a material medium in which kinetic energy is transmitted by the particles of the material from particle to particle without gross displacement of the particles.
Conductivity, Thermal – "k" factor — The time rate of heat flow through unit area of a homogeneous material under steady conditions when a unit temperature gradient is maintained in the direction perpendicular to the area. In English units its value is usually expressed in Btu per (hour) (square foot) (Fahrenheit degree per inch of thickness). Materials are considered homogeneous when the value of "k" is not affected by variation in thickness or in size of sample within the range normally used in construction.
Conductor – Any material whose properties allow electrons to move with relative ease. Typical examples are copper and aluminum.
Connecting Rod – A reciprocating rod connecting the crankshaft and piston in an engine.
Conservation – Steps taken to cause less energy to be used than would otherwise be the case.
Constant-pressure Combustion – Combustion which occurs without a change in pressure. In an engine, this is obtained by a slower rate of burning than with constant-volume combustion.
Contaminant – A substance (dirt, moisture, etc.) foreign to refrigerant or refrigerant oil in system.
Contamination – The presence of harmful foreign matter in a fluid or in air.
Continuous Cycle Absorption System – System which has a continuous flow of energy input.
Continuous Power – Output available without varying load for an unlimited time. Continuous power in accordance with ISO8528, ISO3046/1, AS2789, DIN6271, and BS5514.
Contour – Outline.
Contract – To reduce in mass or dimension; to make smaller.
Control – To regulate or govern the function of a unit.
Control Voltage Terminal Strip – Strips provided to allow easy customer connections of generator sets to regulators, space heaters, or other devices.
Convection – Transfer of heat by means of movement or flow of a fluid or gas.
Convection, Forced – Transfer of heat resulting from forced movement of liquid or gas by means of fan or pump.
Convection, Natural – Circulation of a gas or liquid due to the difference in density resulting from temperature difference.
Conventional – According to the most common or usual mode.
Converge – To incline to or approach a certain point; to come together.
Converter –As used in connection with LP gas, a device which converts or changes LP gas from a liquid to a vapor for use by the engine.

Convolution – One full turn of a screw.
Coolant – A liquid used as a cooling medium.
Cooling Load – The rate of heat removed from the chilled water passing through the evaporator — measured in tons.
Cooling System – The complete system for circulating coolant.
Cooling Tower – Device which cools water by water evaporation in air. Water is cooled to wet bulb temperature of air.
Cooperative (electric utility) – A joint venture organized by consumers to make electric utility service available in their area.
COP *Coefficient of Performance*
Coproduction – The conversion of energy from a fuel (possibly including solid or other wastes) into shaft power (which may be used to generate electricity) and a second or additional useful form. The process may entail a series topping and bottoming arrangement for conversion to shaft power and either process or space heating. Cogeneration is a form of coproduction; however, the concept also includes a single heat producer serving several different mechanical and/or thermal requirements in parallel.
Core – The central or innermost part of an object.
Correction Factor – A number by which an engine performance characteristic is multiplied to show the value which would have been obtained if the engine were operating under some other set of conditions.
Corrosion – The slow destruction of material by chemical agents and electromechanical reactions.
Counterbalance – A weight, usually attached to a moving component, that balances another weight.
Counterbore – A cylindrical enlargement of the end of a cylinder bore or bore hole.
Counterelectromotive Force (cemf) – The electromotive force (voltage) that opposes the applied voltage.
Countersink – To cut or shape a depression in an object so that the head of a screw may set flush or below the surface.
Counterweight – Weights that are mounted on the crankshaft opposite each crank throw. These reduce the vibration caused by putting the crank in practical balance and also reduce bearing loads due to inertia of moving parts.
Coupling – A device used to connect two components.
CPS *Cycles Per Second*
C/R *Compression Ratio*
Crankcase – The lower housing in which the crankshaft and many other parts of the engine operate.
Crankcase Dilution – When unburned fuel finds its way past the piston rings into the crankcase oil, where it dilutes or "thins" the engine lubricating oil.
Crankcase Scavenging – Scavenging method using the pumping action of the power piston in the crankcase to pump scavenging air.
Cranking – Rotating an engine with a source of power external to the engine.
Crankpin – The portion of the crank throw attached to the connecting rod.
Crankshaft – The main drive shaft of an engine which takes reciprocating motion and converts it to rotary motion.
Crankshaft Counter-Balance – A series of weights attached to or forged integrally with the crankshaft to offset the reciprocating weight of each piston and rod.

Crank Throw – One crankpin with its two webs (the amount of offset of the rod journal).
Crank Web – The portion of the crank throw between the crankpin and main journal. This makes up the offset.
Crest – The top surface joining the two sides of a thread.
Crest Clearance – Defined on a screw form as the space between the top of a thread and the root of its mating thread.
Critical Compression Ratio – Lowest compression ratio at which any particular fuel will ignite by compression under prescribed test procedure. The lower the critical compression ratio the better ignition qualities the fuel has. (Gasoline engine, 4:1; oil engine, 7:1; diesel engine, 12.5:1.)
Critical Pressure – Condition of refrigerant at which liquid and gas have the same properties.
Critical Speeds – Speeds at which the frequency of the power strokes synchronize with the crankshaft's natural frequency or torsional damper. If the engine is operated at one of its critical speeds for any length of time, a broken crankshaft may result.
Critical Temperature – Temperature at which vapor and liquid have the same properties.
Crocus Cloth – A very fine abrasive polishing cloth.
Cross Current Compensating Transformer – A unit which senses circulating currents between generators in parallel operation.
Cross Current Compensation – Method of controlling the reactive power supplied by generators in a paralleling system so that they equally share the total reactive load on the bus, without significant voltage droop.
Crowned – A very slight curve in a surface (e.g. on a roller or raceway).
Crude Oil – Petroleum as it comes from the well (unrefined).
Crush – A deliberate distortion of an engine's bearing shell to hold it in place during operation.
Cryogenic Fluid – Substance which exits as a liquid or gas at ultra-low temperatures (-250° F or lower).
Cryogenics – Refrigeration which deals with producing temperatures at -250° F and lower.
CSFC *Corrected Specific Fuel Consumption*
CSTG *Caterpillar Service Technology Group*
CT *Current Transformer, Crank Terminate (ESS)*
cu in *cubic inch*
Current – A flow of electric charge and the rate of such a flow measured in amperes.
Current Transformer – An auxiliary instrument used to reduce generator current to that of the instruments and apparatus. Current transformers are used to step down the higher line current to the lower currents that the control system is designed for. These signals are utilized by AC meters, protective relays, and control devices.
Custom Alarm Module (CAM) – A Cat unit which provides flexible annunciation capabilities for engines.
Customer Communication Module (CCM) – Apparatus which allows users of electronic engines to monitor up to eight Cat power systems remotely, perform system diagnostics, and receive parameter readouts in real time.
Customer Interface Module (CIM) – A device which decodes Cat electronic engine monitoring information and provides a link to remote alarms and annunciators.

Cut-In – Temperature or pressure valve which closes control circuit.
Cutless Bearing – The bearing used in conjunction with the "stern strut" to support the propeller and or propeller shaft. This bearing usually water lubricated.
Cut-Out – Temperature or pressure valve which opens the control circuit.
Cyaniding – Surface hardening by carbon and nitrogen absorption of an iron-base alloy article or portion of it by heating at a suitable temperature in contact with a cyanide salt, followed by quenching.
Cycle – One complete rise and fall of the voltage of alternating current, from zero to maximum positive/back to zero and from zero to maximum negative and back to zero again.
Cyclic – Variation in the performance characteristics which vary as the engine runs; especially, but not exclusively, those characteristics which vary in a repetitive fashion.
Cyclic Irregularity – A nondimensional ratio describing the degree of crankshaft twist occurring between two successive firings of cylinders of an engine during steady-state operation.

$$\text{Cyclic Irregularity} = \frac{\text{rpm (maximum) - rpm (minimum)}}{\text{rpm (average)}}$$

Cylinder – The chamber in which a piston moves in a reciprocating engine.
Cylinder Block – The largest single part of an engine. The basic or main mass of metal in which the cylinders are bored or placed.
Cylinder Head – The replaceable portion of the engine fastened securely to the cylinder block that seals the cylinder at the top. It often contains the valves, and in some cases, it is part of the combustion chamber.
Cylinder Hone – A tool used to bring the diameter of a cylinder to specification and at the same time smooth its surface.
Cylinder Liner – A sleeve or tube interposed between the piston and the cylinder wall or cylinder block to provide a readily renewable wearing surface for the cylinder.
Cylinder, Refrigerant – Cylinder in which refrigerant is purchased and dispensed. The color code painted on cylinder indicates the kind of refrigerant the cylinder contains.
D – Diode; Distance from plane of reference to assembled unit center of gravity location.
D1 – Distance from plane of reference aft to generator center of gravity.
D2 – Distance from plane of reference forward to engine center.
Dalton's Law – Vapor pressure exerted on container by a mixture of gasses is equal to sum of individual vapor pressures of gasses contained in mixture.
Davit – Any of various small cranes used on ships to hoist boats, anchors and cargo.
DC *Direct Current*
DDT *Digital Diagnostic Tool*
Dead Bus – The de-energized state of the power connections between outputs of paralleled generator sets.
Dead Center – Either of the two positions when the crank and connecting rod are in a straight line at the end of the stroke.
Dead Front– A term to used to describe the lack of accessibility of bare connections or apparatus on the panel face of controls or switchgear.

Decarburization – The removal of carbon (usually refers to the surface of solid steel) by the (normally oxidizing) action of media which react with carbon.
Deceleration – Opposite of acceleration; that is, implying a slowing down instead of a speeding up. Also called *negative acceleration.*
Decibel – Unit used for measuring relative loudness of sounds. One decibel is equal to the approximate difference of loudness ordinarily detectable by the human ear, the range of which is about 103 decibels on a scale beginning with one for faintest audible sound.
Deck – The floor. There may be several decks to a ship. The main deck is the deck exposed (open) to atmosphere.
Deferrable or Scheduled Loads – Loads which can be disconnected for extended periods of time and restarted later without a great effect on a facility's operation. Delaying energy use to a time of lower demand is effective in minimizing peak demand.
Deflection – Bending or movement away from the normal position, due to loading.
Deglazer – A tool used to remove the glaze from cylinder walls.
Degree, Circle – 1/360 of a circle.
Degree-Day – Unit that represents one degree of difference from given point in average outdoor temperature of one day and is often used in estimating fuel requirements for a building. Degree-days are based on average temperature over a 24-hour period. As an example, if an average temperature for a day is 50° F, the number of degree-day for that day would be equal to 65° F minus 50° F or 15 degree-days (65-15 = 50) Degree-days are useful when calculating requirements for heating purposes.
Degree Wheel – A wheel marked in degrees to set the lifter height.
Dehumidify – To remove water vapor from the atmosphere. To remove water or liquid from stored goods.
Dehumidifying Effect – The difference between the moisture contents, in pounds per hour, of the entering and leaving air, multiplied by 1.060.
Dehydrate – To remove water in all forms from matter. Liquid water, hygroscopic water, and water of crystallization or water of hydration are included.
Dehydrated Oil – Lubricant which has had most of water content removed (a dry oil).
Dehydration – The removal of water vapor from air by the use of absorbing or absorbing materials; the removal of water from stored goods.
Delta Connection – The connection of the three windings of a generator into a triangular or delta configuration. Most commonly used by utility companies. Has no neutral point.
Delta-T – The temperature rise of the engine coolant from the jacket water pump inlet to the engine coolant outlet.
Demand (Utility) – The level at which electricity or natural gas is delivered to users at a given point in time. Electric demand is expressed in kilowatts.
Demand, Annual – The greatest of all demands which occurred during a prescribed demand interval in a calendar year.
Demand Charge – The sum to be paid by a large electricity consumer for its peak usage level.
Demand, Coincident – The sum of two or more demands which occur in the same demand interval.

Demand, Instantaneous Peak – The maximum demand at the instant of greatest load.
Dendrites – A crystal formed by solidification, or in any other way, having many branches and a tree-like pattern; also termed “pine tree” and “fir tree” crystals.
Density (Fuel) – The mass of fuel per unit volume. The units of density used in this specification are degrees API at 60 degrees Fahrenheit.
(API = American Petroleum Institute)
DEO *Diesel Engine Oil*
Depth of Engagement – The depth of a thread in contact with two mating parts measured radially. It is the radial distance by which their thread forms overlap each other.
Design Voltage – The nominal voltage for which a line or piece of equipment is designed. This is a reference level of voltage for identification and not necessarily the precise level at which it operates.
Detergent – A compound of a soap-like nature used in engine oil to remove engine deposits and hold them in suspension in the oil.
Detonation – Burning of a portion of the fuel in the combustion chamber at a rate faster than desired (knocking).
Dew Point – Temperature at which vapor (at 100 percent humidity) begins to condense and deposit as liquid.
DFD *Diode Fault Detector*
DI *Direct Injection*
Diagnosis – In engine service, the use of instruments to troubleshoot the engine parts to locate the cause of a failure.
Dial Indicator (dial gauge) – A precision measuring instrument.
Diaphragm – Any flexible dividing partition separating two compartments.
Dichlorodifluoromethane – Refrigerant commonly known as R-12. Chemical formula is CCl_2F_2. Cylinder color code is white. Boiling point at atmospheric pressure is -21.62° F.
Die, Thread – A thread-cutting tool.
Dielectric – A nonconductor of direct electric current.
Diesel Engine – A type of internal combustion engine that burns fuel oil; the ignition is brought about by heat resulting from air compression, instead of by an electric spark, as in a gasoline engine.
Diesel Index – A rating of fuel according to its ignition qualities. The higher the diesel index number, the better the ignition quality of the fuel.
Differential – As applied to refrigeration and heating, the difference between cut-in and cut-out temperature or pressure of a control.
Differential Fuel Pressure – The gas pressure supplied to the carburetor of a spark ignited engine minus the carburetor inlet pressure.
Differential Pressure Fuel Valve – A closed fuel valve with a needle or spindle valve which seats onto the inner side of the orifices. The valve is lifted by fuel pressure.
Differential Protection (Line) – Leads pass through current transformers for the purpose of sensing current imbalance between line-leads.
Digital – A numeric value representing the value of an engine performance characteristic.
Digital Voltage Regulator (D.V.R.) – A microprocessor-based unit which regulates voltage output of a generator.
Dilution – Thinning, such as when fuel mixes with the lubricant.
DINA *Direct Injection Naturally Aspirated*

Diode – A device which allows current to pass but only in one direction.
Dip and Bake – The process of treating a wound electrical element with varnish to provide protection/insulation, and to secure the winding insulation in place.
Dipstick – A device to measure the quantity of oil in the reservoir.
Direct Current (DC) – An electric current flowing in one direction only.
Direct-cooled Piston – A piston which is cooled by the internal circulation of a liquid.
Directional Control Valve – A valve which selectively directs or prevents flow to or from specific channels. Also referred to as *selector valve, control valve, or transfer valve.*
Discharge – A draw of current from the battery.
Displacement – The total weight of the ship when afloat, including everything aboard, equals the weight of water displaced. Displacement may be expressed in either cubic feet or long tons. A cubic foot of sea water weighs 64 pounds and one of fresh water weighs 62.5 pounds; consequently, one long ton is equal to 35 cubic feet of sea water or 35.9 cubic feet of fresh water. One long ton equals 2,240 pounds.
Displacement or Swept Volume – In a single-acting engine, the volume swept by all pistons in making one stroke each. The displacement on one cylinder in cubic inches is the circular area (in square inches) times the stroke (in inches) times the number of cylinders.
DISTA *Direct Injection Series Turbocharged-Aftercooled*
Distillation – Heating a liquid and then condensing the vapors given off by the heating process.
Distilling Apparatus – Fluid reclaiming device used to reclaim used refrigerants. Reclaiming is usually done by vaporizing and then recondensing refrigerant.
Distortion – A warpage or change in form from the original shape.
Distribution Circuit Breaker – A device used for overload and short circuit protection of loads connected to a main distribution device.
Distribution Switchgear – May include automatic transfer switches, circuit breakers, fusible switches, or molded case breakers. This equipment distributes utility or generator power to the site electrical loads.
DIT *Direct Injection Turbocharged*
DITA *Direct Injection Turbocharged-Aftercooled*
DITA-JW *Direct Injection Turbocharged-Aftercooled Jacket Water*
DITT *Direct Injection Turbocharged (Dual Turbo)*
DITTA *Direct Injection Turbocharged-Aftercooled (Dual Turbo)*
Division Plate – A diaphragm surrounding the piston rod of a crosshead-type engine, usually having a wiper ring to remove excess oil from the piston rod as it slides through. It separates the crankcase from the lower end of the cylinder.
D/N *Dealer/Net*
Dog-Leg – A colloquialism applied to the shape of a torque curve which has been modified to provide a steep torque rise at a speed just above the full load point to prevent excessive shifting of transmissions.
Double Acting – An actuator producing work in both directions.
Double Flare – A flared end of the tubing having two wall thicknesses.
Dowel – A pin, usually of circular shape like a cylinder, used to pin or fasten something in position temporarily or permanently.

Down Draft –A type of carburetor in which the fuel-air mixture flows downward to the engine.
Draft – The vertical distance from the waterline to the keel. Draft is measured in feet and inches, by scaled marked on the hull at the stem and stern post. Draft numbers are six inches high and spaced six inches apart. The bottom of each number indicates foot marks, the top indicates half-foot marks.
Draw-Out Relay –An AC protective relay that is door mounted, and can be removed from its case without disturbing the wiring to the case, or interrupting the connected circuits. This allows for easy testing and calibration of the relay.
Draw-Out Unit – A structure that holds a circuit breaker in an enclosure. It has a movable carriage and contact structures that permit the breaker to be removed from the enclosure without manually disconnecting power cables and control wires.
Drawbar Horsepower – Measure of the pulling power of a machine at the drawbar hitch point.
Dribbling – Unatomized fuel running from the fuel nozzle.
Drill – A tool used to bore holes.
Drill Press – A fixed machine to drive a tool in rotary motion.
Drive Flange – Presses on shaft of revolving field rabbet pilot and mounting bolt pattern for mounting to engine drive discs.
Drive-fit – A fit between two components, whose tolerance is so small that the two parts must be pressed or driven together.
Droop Load Sharing – A method of making two or more parallel generator sets share a system kW load. This is accomplished by having each governor control adjusted so that the sets have the same droop (reduction of speed).
Droop (or Speed Droop) – The decrease from no load speed to full load speed when full load is applied to a generator set, expressed as a percentage of the full load speed.
Droop Transfer – A small transformer provided for mounting current flow through output line leads. A loop of one or two turns of one of the line leads passes through the coil/plane of the transformer to produce sensing.
Drop-forged – Formed by hammering or forced into shape by heat.
Dry Bulb – An instrument with a sensitive element which measures ambient (moving) air temperature.
Dry Bulb Temperature – Air temperature as indicated by an ordinary thermometer.
Dry Cell, Dry Battery – A battery that uses no liquid electrolyte.
Dry-Charged Battery – A battery in a pre-charged state but without electrolyte. The electrolyte is added when the battery is to be placed in service.
Dry Sleeve – A cylinder sleeve (liner) where the sleeve is supported over its entire length. The coolant does not touch the sleeve itself.
***DST** Detonation Sensitive Timing*
***DSU** Data Sending Unit*
Dual Element (DE) – Number of elements in an assembly, especially filters.
Dual Fuel – A term used to describe an engine which starts on one type of fuel and runs on another type.
Dual Service – Utilizing a prime power generator set for a regular, but noncritical load. When a utility outage occurs, the unit automatically switches to provide emergency power immediately.

Dual Valves – Refers to cylinders having two valves performing one function, e.g. two intake valves, two exhaust valves.
Dual Voltage – The term used to denote 10-lead machine — 240/480, 300/600.
Ductility – The ability of a metal to withstand plastic deformation without rupture.
D.V.R. *Digital Voltage Regulator*
Dynamic Balance – Condition when the weight mass of a revolving object is in he same plane as the centerline of the object.
Dynamic Pressure – The pressure of a fluid resulting from its motion, equal to one-half the fluid density times the fluid velocity squared. In incompressible flow, dynamic pressure is the difference between total pressure and static pressure.
Dynamometer – A device for absorbing the power output of an engine and measuring torque or horsepower so that it can be computed into brake horsepower.
Ebullient Cooled Engine – An engine cooled by boiling water. The cooling is accomplished by turning water into steam. The latent heat of evaporation absorbed in this process cools the engine.
Ebullient System – A type of high temperature heat recovery system. Also known as solid water system.
ECAP *Electronic Control Analyzer Programmer*
Eccentric – One circle within another circle but with different center of rotation. An example of this is a driving cam on a camshaft.
ECM *Electronic Control Module*
ECS *Electronic Control System*
ECU *Electronic Control Unit*
Economizer – A device installed in a carburetor to control the amount of fuel used under certain conditions.
Edge Filter – A filter which passes liquid between narrowly separated disks or wires.
EDS *Engine Data System*
Efficiency – In general, the proportion of energy going into a machine which comes out in the desired form, or the proportion of the ideal which is realized.
EFH *Engine Front Horizontal*
EFV *Engine Front Vertical*
EIS *Electronic Ignition System, Engine Information System, Environmental Impact Statement*
EkW *Electrical kilowatts with fan*
Elapsed Time Meter – Totals the hours of generator set operation.
Elastic Limit – The greatest stress which a material is capable of developing without a permanent deformation remaining upon complete release of the stress.
Electric Power Generation (EPG) – Producing energy through the use of a generator set.
Electric Power Generation Designer (EPG Designer) – A Cat software program which guides Cat dealers and consulting engineers through “specing” and installing generator set packages.
Electrical Operator – The electric motor-driven closing and tripping (opening) devices that permit remote control of a circuit breaker.
Electrolyte – A solution of sulfuric acid and water.
Electromotive Force (emf) – Forces that move or tend to move electricity.

Electronic Control Analyzer Programmer (ECAP) – An electronic service tool developed by Caterpillar used for programming and diagnosing a variety of Caterpillar electronic controls using a data link.
Electronic Control Module (ECM) – The engine control computer that provides power to the truck engine electronics. It accepts inputs that monitor and outputs that control or change to act as a governor to control engine rpm.
Electronic Modular Control Panel (EMCP) – A microprocessor-based feature on all Cat generator sets which provides improved reliability through precise engine control.
Electronic Technician (ET) – A software program to run on a service tool like a personal computer (PC). This program will supplement and eventually replace ECAP.
Element, Battery – A group of plates — negative and positive.
Elongation – The amount of permanent extension in the vicinity of the fracture in the tension test, usually expressed as a percentage of the original gauge length, such as 25 percent in two inches.
Embedded Stator Temperature Detector – Thermocouple embedded in a generator's stator winding.
***EMCP** Electronic Modular Control Panel*
Emergency System – Independent power generation equipment that is legally required to feed equipment or systems whose failure may present a hazard to persons or property.
***emf** electromotive force*
Emission Standard – The maximum amount of a pollutant legally permitted to be discharged from a single source.
Emissions – The gaseous products emitted in engine exhaust.
***EMS** Engine Monitoring System, Equipment Management System*
Emulsify – To suspend oil in water in a mixture where the two do not easily separate.
Encapsulation – An impervious material to surround and protect an item from the environment.
End Mounted Terminal Box (EMTB) – The latest design on very large generators; 580, 680, and 800 frames; for covering customer line lead connections (bus bars or circuit breakers) and regulator assemblies.
End Play – The amount of axial movement in a shaft that is due to clearance in the bearings or bushings.
Endurance Limit – A limiting stress, below which metal will withstand without fracture an indefinitely large number of cycles of stress.
Energize – To make active.
Energized Systems – A system under load (supplying energy to load) or carrying rated voltage and frequency, but not supplying load.
Energy – Capacity for doing work.
Energy Charge – That portion of the billed charge for electric service based upon the electric energy (kilowatt-hours) supplied, as contrasted with the demand charge.
Energy Consumption – The amount of energy consumed in the form in which it is acquired by the user (excluding electrical generation and distribution losses).
Energy Efficiency Ratio (EER) – The heat transfer ability of the refrigeration system, expressed in Btu/h, compared to watts of electrical energy necessary to accomplish the heat transfer. This comparison is expressed in Btu/h/Watt of electrical energy.

Engine – The prime source of power generation used to propel the machine.
Engine Coolant Level – On the EMS II module, a flashing red light and horn annunciate when a customer-provided coolant level switch is activated. This information is provided to EMS II directly and then sent on the datalink. In the event that coolant level input is not provided, the input will be shorted on the terminal strip.
Engine Displacement – The volume each piston displaces when it moves from BDC to TDC times the number of cylinders. *(Also see Displacement.)*
Engine Load – The engine power is determined as a function of manifold pressure and speed from dynamometer test data.
Engine Monitoring System (EMS) – An electronic display for marine or industrial engines to display engine parameters and diagnostics.
Engine Mounting Ring – A rabbet fit ring with mounting holes on end of the stator frame for engine mounting.
Ensign Staff – A flagstaff at the stern of a vessel from which the national ensign maybe flown.
Enthalpy – Total amount of heat in one pound of a substance calculated from accepted temperature base. Temperature of 32° F is the accepted base for water vapor calculation. For refrigerator calculations, the accepted base is -40° F.
Environmental Protection Agency (EPA) – A Federal agency.
EPA *Environmental Protection Agency*
EPG *Electric Power Generation*
ERH *Engine Rear Horizontal*
Erode – To wear away.
ERR *Engine Rear Roll*
ERV *Engine Rear Vertical*
ESC *Extended Service Coverage, Energy Service Company*
ESS *Electronic Speed Switch, Engine Supervisory System*
ET *Engine Test, Electronic Technician*
Etching – A process which determines the structure and defects in metals.
ETDS *Engine Technical Data System (TMI)*
Ether – A volatile, colorless, and highly flammable chemical compound which is used as a starting aid.
Ethylene Glycol – A compound added to the cooling system to reduce the freezing point.
ETR *Energize To Run*
EUI *Electronic Unit Injector*
Eutectoid – Nearly all iron contains some carbon. In annealed steel, iron carbide mixes with iron (ferrite) in alternate thin layers and is called pearlite. As the carbon content increases, it causes an increase in pearlite and a decrease in ferrite. At the point of increase where all the ferrite is in combination with carbon, the structure will be entirely of pearlite. This is called the eutectoid, and the structure is the eutectoid composition.
Evaporation – The process of changing from a liquid to a vapor, such as boiling water to produce steam. Evaporation is the opposite of condensation.
Evaporative Cooling System – A cooling system in which the heat finally passes to the atmosphere by evaporation. This system may be either open or closed.
Evaporator – Part of a refrigerating mechanism in which the refrigerant vaporizes and absorbs heat.

Evaporator, Dry Type – An evaporator into which refrigerant is fed from a pressure reducing device. Little or no liquid refrigerant collects in the evaporator.
Evaporator, Flooded – An evaporator containing liquid refrigerant at all times.
Excess Air – Air present in the cylinder over and above that which is theoretically necessary to burn the fuel.
Excess Oxygen – The amount of free oxygen in the products of combustion. It may be expressed as a percentage of either volume or mass.
Excitation – The power required to energize the magnetic field of generators in an electric generating station.
Excitation Current – Amperage required by the exiter to produce a magnetic field.
Excite – To pass current through a coil or starter.
Exciter –A generator or static rectifier assembly that supplies the electric current used to produce the magnetic field in another generator.
Exhaust – Air removed deliberately from a space by fan or other means, usually to remove contaminates from a location near their source.
Exhaust Analyzer (Smoke Meter) – A test instrument used to measure the density of the exhaust smoke to determine the combustion efficiency.
Exhaust Fan – Normally shipped with MCE generators, designed to mount on engine drive disc to run inside of generator exhaust opening.
Exhaust Gas – The products of combustion in an internal-combustion engine.
Exhaust Gas Analyzer – An instrument for determining the efficiency with which an engine is burning fuel.
Exhaust Manifold – The passages from the engine cylinders to the muffler which conduct the exhaust gases away from the engine.
Exhaust Port – The opening through which exhaust gas passes from the cylinder to the manifold.
Exhaust Valve – The valve which, when opened, allows the exhaust gas to leave the cylinder.
Expansion – An increase in size. For example, when a metal rod is heated it increases in length and perhaps also in diameter. Expansion is the opposite of contraction.
Expansion Ratio – Ratio of the total volume when the piston is at BDC to the clearance volume when the piston is at TCD. (Nominally equal to compression ratio.)
Expansion Valve – A device in a refrigerating system which maintains a pressure difference between the high side and low side and is operating by pressure.
Extended Service Coverage (ESC) – A Cat service offering maintenance and or repair (up to five years) beyond that offered in a particular product's warranty.
Eye Bolt – A bolt threaded at one end and bent to a loop at the other end.
Fahrenheit (°F) – A designated temperature scale in which the freezing temperature of water is 32° F and boiling point 212° F (when under standard atmospheric pressure).
Fantail – The rear portion of the main deck.
Fathom – A measure of length, equivalent to 6 linear feet, used for depths of water and lengths of rope or chain.
Fatigue – Deterioration of material caused by constant use.

Fault – (1) The failure of an operating piece of equipment, and the specific reason for the failure, or (2) an electrical distribution system failure, where there is a line-to-ground or line-to-line short circuit.
Federal Energy Regulatory Commission (FERC) – An independent regulatory commission within the U.S. Department of Energy that has jurisdiction over energy producers that sell or transport fuels for resale in interstate commerce; the authority to set oil and gas pipeline transportation rates and to set the value of oil and gas pipelines for rate making purposes; and regulates wholesale electric rates and hydroelectric plant licenses.
Feeder – An electric line for supplying electric energy within an electric service area or sub-area.
Feeler Gauge – A strip of steel ground to a precise thickness used to check clearance.
FERC *Federal Energy Regulatory Commission*
Ferrite – Solid solutions in which alpha iron (or delta iron) is the solvent.
FGR *Flue Gas Recirculation*
fhp *friction horsepower*
FID *Flame Ionization Detector*
Field – A space or region where magnetism exists.
Field Coil – An insulated wire wound around an (iron) pole piece.
Fillet – A curved joint between two straight surfaces.
Filter: Oil, Water, Gasoline, etc. – A unit containing an element, such as a screen of varying degrees of fineness. The screen or filtering element is made of various materials depending upon the size of the foreign particles to be eliminated from the fluid being filtered.
Fin (Flash) – A thin fin of metal formed at the sides of a forging or weld where a small portion of the metal is forced out between the edges of the forging or welding dies.
Finishing Stone (hone) – A honing stone with a fine grid.
Fire Point – Lowest temperature at which an oil heated in standard apparatus will ignite and continue to burn.
Firing Order – The order in which the cylinders deliver their power stroke.
Firing Pressure – The highest pressure reached in the cylinder during combustion.
Firm Energy – Power supplies that are guaranteed to be delivered under terms defined by contract.
Fit – The closeness of contact between machined components.
Fixed Displacement Pump – A type of pump in which the volume of fluid per cycle cannot be varied.
Flake – Internal fissures in large steel forgings or massive rolled shapes. In a fractured surface or test piece, they appear as sizeable areas of silvery brightness and coarser grain size than their surroundings. Sometimes known as “chrome checks” and (when revealed by machining) “hairline cracks.” Not to be confused with “woody fracture.”
Flame Hardening (Shorterizing) – A method for hardening the surface without affecting the remainder of the part, used mainly for gears or other parts where only a small portion of the surface is hardened and where the part might distort in a regular carburizing or heat-treating operation. The operation consists of heating the surface to be hardened by an acetylene torch to the proper quenching temperature followed immediately by a water-quench and proper tempering. A special tool is required, and either the torch or part may be rotated so that the flame passes over the surface at a speed

that will produce the proper quenching temperature. Water quenching follows immediately, and the part is neither scaled nor pitted by the operation.
Flange – A metal part which is spread out like a rim; the action of working a piece or part spread out.
Flank, Side or Thread– The straight part of the thread which connects the crest with the root.
Flank Angles – The angle between a specified flank of a thread and the plane perpendicular to the axis (measured in an axial plane).
Flare – To open or spread outwardly.
Flaring Tool – A tool used to form a flare on a tubing.
Flash Point – The temperature at which a substance, usually a fluid, will give off a vapor that will flash or burn momentarily when ignited.
Flat Crank – A crankshaft in which one of the bearing journals is not round.
Floating Piston Pin – A piston pin which is not locked in the connecting rod or the piston, but is free to turn or oscillate in both the connecting rod and the piston.
Flooding – Act of filling a space with a liquid.
Floor – The absolute minimum to which the low limit of an engine performance specification may fall.
Flow Control Valve – A valve which is used to control the flow rate of fluid in a fluid power system.
Flowmeter – An instrument used to measure the quantity or flow rate of a fluid in motion.
FLSFS *Full Load Static Fuel Setting*
Fluctuating –Wavering, unsteady, not constant.
Fluid – A liquid, gas, or mixture thereof.
Fluid Flow – The stream or movement of a fluid; the rate of a fluid's movement.
Fluid Power – Power transmitted and controlled through the use of fluids, either liquids or gases, under pressure.
Flush – An operation to remove any material or fluids from refrigeration system parts by purging them to the atmosphere using refrigerant or other fluids.
Flute – The grooves of a tap that provide the cutting rake and chip clearance.
Flutter or Bounce – In engine valves, refers to a condition where the valve is not held tightly on its seat during the time the cam is not lifting it.
Flyball Governor - (Flyweight Governor)– Conventional type of centrifugal governor commonly called a *mechanical governor.*
Flywheel – A device for storing energy in order to minimize cyclical speed variations.
Flywheel Ring Gear – A circular steel ring having gear teeth on the outer circumference.
Foaming – Formation of a foam in an oil-refrigerant mixture due to rapid evaporation of refrigerant dissolved in the oil. This is most likely to occur when the compressor starts and the pressure is suddenly reduced.
Foot-pound (ft-lb) – The amount of work accomplished when a force of 1 lb produces a displacement of 1 ft.
Force – The action of one body on another tending to change the state of motion of the body acted upon. Force is usually expressed in pounds (kilograms).
Force Convection – Movement of fluid by mechanical force such as fans or pumps.

Force-Feed Lubrication – A lubricating system in which oil is pumped to the desired points at a controlled rate by means of positive displacement pumps.
Forecastle – (Foc'sle) The forward portion of the main deck, contains anchor windlass, etc.
Forged – Shaped with a hammer or machine.
Fossil Fuel – Oil, coal, natural gas, or their by-products. Fuel that was formed in the earth in prehistoric times from remains of living-cell organisms.
Foundation – The structure on which an engine is mounted. It performs one or more of the following functions: holds the engine in alignment with the driven machine, adds enough weight to the engine to minimize vibration, adds to rigidity of the bed plate.
Four-cycle Engine – Also known as Otto cycle, where an explosion occurs every other revolution of the crankshaft, a cycle being considered as 1/2 revolution of the crankshaft. These strokes are (1) intake stroke, (2) compression stroke, (3) power stroke, (4) exhaust stroke.
Four-Stroke Cycle – Cycle of events which is completed in four strokes of the piston, or two crankshaft revolutions.
Frame – The main structural member of an engine.
frame *Generator frame size*
FRC *Fuel Ratio Control*
Freeboard – The vertical distance from the waterline to the weather deck.
Free Electrons – Electrons which are in the outer orbit of the atom's nucleus.
Free Flow – Flow which encounters little resistance.
Freon – Trade name for a family of synthetic chemical refrigerants manufactured by DuPont, Inc.
Frequency – The number of cycles completed within a one-second period, expressed as hertz.
Frequency Meter – A unit which monitors a generator set's output frequency.
Frequency Relay – This relay can be configured to operate when the monitored frequency is above or below a given setpoint.
Friction – The resistance to motion due to the contact of two surfaces, moving relatively to each other.
Friction Horsepower (FHP) – A measure of the power lost to the engine through friction or rubbing of parts.
FS *Fuel Solenoid*
FSS *Floor Standing Switchgear*
ft-lb *foot-pound*
FTSFS *Full Torque Static Fuel Setting*
Fuel Cell – A device or an electrochemical engine with no moving parts that converts the chemical energy of a fuel, such as hydrogen, and an oxidant, such as oxygen, directly into electricity. The principal components of a fuel cell are catalytically activated electrodes for the fuel (anode) and the oxidant (cathode) and an electrolyte to conduct ions between the two electrodes, thus producing electricity.
Fuel-Flow Oil Filter – All engine oil passes through this oil filter before entering the lubrication channels.
Fuel Knock – See *Detonation.*
Fuel Level – On the EMS II module, a flashing red light and horn annunciate when a customer provided fuel level switch is activated. This information is provided to EMS II directly and then sent on the datalink. In the event that coolant level input is not provided, the input will be shorted on the terminal strip.

Fuel Mixture – A ratio of fuel and air.
Fuel Pressure – The fuel pressure supplied to the injection pumps of a diesel engine.
Fuel Rate (Diesel) – The mass of fuel burned by an engine in a specified time. Corrected fuel rate is the actual or observed fuel rate corrected for fuel density.
Fuel Rate (Spark Ignited) – The volume of fuel burned by an engine in a specified time at the pressure and temperature being supplied to the engine. Corrected fuel rate is the volume of fuel at standard conditions multiplied by the lower heating value of the fuel.
Fuel Transfer Pump – A mechanical device used to transfer fuel from the tank to the injection pump.
Fuel Valve – A valve admitting fuel to the combustion chamber. In a more general sense, this term may also apply to any manual or automatic valve controlling flow of fuel.
Fulcrum – The pivot point of a lever.
Full-Floating Piston Pin – A piston pin free to turn in the piston boss of the connecting-rod eye.
Full Load – The maximum power an engine can develop when running at rated speed with the fuel system opened to its maximum specified condition.
Gallery – Passageway inside a wall or casting.
Galley – The kitchen of a ship.
Galvanic Action – When two dissimilar metals are immersed in certain solutions, particularly acid, electric current will flow from one to the other.
Gas – A substance which can be changed in volume and shape according to the temperature and pressure applied to it. For example, air is a gas which can be compressed into smaller volume and into any shape desired by pressure. It can also be expanded by the application of heat.
Gasket – A layer of material used between machined surfaces in order to seal against leakage.
Gassing – Hydrogen bubbles rising from the electrolyte when the battery is being charged.
Gate Valve – A common type of manually operated valve in which a sliding gate is used to obstruct the flow of fluid.
Gauge Construction – Shell is a cosmetic wrapper. Only advantage — no varnish clean-up of shell required.
Gauge, Low Pressure – Instrument for measuring pressures in range of 0 psig and 50 psig.
Gauge, High Pressure – Instrument for measuring pressures in range of 0 psig to 500 psig.
Gauge Pressure – Pressure above atmospheric pressure.
Gauge Snubber – A device installed in the fuel line to the pressure gauge used to dampen pressure surges and thus provide a steady reading. This helps protect the gauge.
GCCS *landfill Gas Collection and Control Systems*
GCM *Generator Control Module*
Gear Ratio – The number of revolutions made by a driving gear as compared to the number of revolutions made by a driven gear of different size. For example, if one gear makes three revolutions while the other gear makes one revolution, the gear ratio would be 3 to 1.
Gear-type Pump – A pump which uses the spaces between the adjacent teeth of gears for moving the liquid.

Generator, Electrical – An electromagnetic device used to generate electricity.
Generator, Cooling – A device used in absorption-type refrigeration systems to heat the absorbing liquid to drive off the refrigerant vapor for condensing to a liquid before entering the evaporator.
Generator Power System (GPS) – EPG power system that uses energy off an electric generator.
Ghost (Ferrite Ghost) – A faint band of ferrite.
Gland – A device to prevent the leakage of gas or liquid past a joint.
Glaze – As used to describe the surface of the cylinder, an extremely smooth or glossy surface such as a cylinder wall highly polished over a long period of time by the friction of the piston rings.
Glaze Breaker – A tool for removing the glossy surface finish in an engine cylinder.
Glow Plug – A heater plug for the combustion chamber. It has a coil of resistance wire heated by a low voltage current.
GMM *Generator Monitoring System*
gov *governor*
Governor – A device that maintains a constant engine speed under various load conditions. The governor must have provision for adjustment of speed (which controls generator frequency) and of the amount of speed droop from no load to full load.
GPD *Gallons Per Day*
gpm *gallons per minute*
GPS *Generator Power System*
GRA *Generator Rear Axial*
Grain – A unit of weight equal to one 7000th of a pound. It is used to indicate the amount of moisture in the air.
Grain Size – There are two types of grains in steel which affect the physical properties of steel; the austenite grain and the ferrite grain. The ferrite grain tends to remain stable in size at temperatures below the transformation range unless the steel is cold worked a critical amount, in which case the grains grow rapidly. When steel is heated above the transformation range, the newly formed austenite grain is small but tends to grow in size with increasing temperature and time at temperature. Grain size, as commonly used, is the size of the grain that is developed in the austenite at the final heat treating temperature and does not refer to the ferrite grain. Except for the austenitic steels, the austenite grain size does not exist at room temperature; but its pattern can be developed by special methods.
Gravity – The force which tends to draw all bodies toward the center of the earth. The weight of a body is the result of all gravitational forces on the body.
Gravity, Specific – The specific gravity of a solid or liquid is the ratio of the mass of the body to the mass of an equal volume of water at some standard temperature. At the present time a temperature of a 4° C (39° F) is commonly used by physicists, but the engineer uses 16° C (60° F). The specific gravity of a gas is usually expressed in terms of dry air at the same temperature and pressure as the gas.
GRH *Generator Rear Horizontal*

Grid – The electric utility companies' transmission and distribution system that links power plants to customers through high power transmission line service (110 kilovolt [kV] to 765 kV); high voltage primary service for industrial applications and street rail and bus systems (23 kV to 138 kV); medium voltage primary service for commercial and industrial applications (4 kV to 35 kV); and secondary service for commercial and residential customers (120 V to 480 V). Grid can also refer to the layout of a gas distribution system of a city or town in which pipes are laid in both directions in the streets and connected at intersections.
Grid, Battery – The lead frame to which the active material is affixed.
Grid Interconnection – The intertie of a cogeneration plant to an electric utility's system to allow electricity flow in either direction.
Grinding – Removing metal from an object by means of a revolving abrasive wheel, disk, or belt.
Grinding Compound – Abrasive for resurfacing valves, etc.
Ground, Battery – The battery terminal that is connected to the engine of the framework.
Ground Fault Protection – This function trips (opens) a circuit breaker or sounds an alarm in the event that there is an electrical fault between one or more of the phase conductors and ground (earth). This ground fault protection function may be incorporated into a circuit breaker.
Grounding Bar – A copper or aluminum bar that electrically joins all the metal sections of the switchgear. This bar is connected to the earth or ground connection when the system is installed. The grounding or earthing protects personnel.
Growler – A test instrument used for testing the armature of a starter or generator for open, short, and grounded circuits.
GRV *Generator Rear Vertical*
GSC *Genset Status Control*
GSC + (S)ynchronizing – General Status Control plus Synchronizing
GSE *Generator Set Engine*
Half-moon Key – A fastening device in a shape somewhat similar to a semicircle. (See *Key*.)
Hardenability – This relates to the ability of steel to harden deeply upon quenching and takes into consideration the size of the part and the method of quenching. In testing for hardenability, standards are established governing the method of quenching and the quenching medium which makes it possible to compare the hardenability of steels of various analysis and grain size.
Hardness – The ability of a metal to resist penetration. The principal methods of hardness determination are described under hardness testing and the correlation of these determinations with the other mechanical properties are described under physical properties.
Hardness Testing – The determination of the ability of a metal to resist penetration; the hardness of the metal may be determined by several methods (i.e. Brinell, Rockwell, Superficial).
Harmonics – Waveforms whose frequencies are multiples of the fundamental (60 Hz) wave. The combination of harmonics and fundamental waves causes a non-sinusoidal, periodic wave. Harmonics in power systems are the result of non-linear effects. Typically, harmonics are associated with rectifiers and inverters, arc furnaces, arc welders, and transformer magnetizing current. There are both voltage and current harmonics.

Hatch – An opening in the deck of a ship leading to the "hold". Any small door or opening.
Hawser Pipe – Casting extending through deck and side of a ship for passage of anchor chain, for storage of anchor in most cases.
HCR *High Compression Rating*
HD *Heavy Duty*
Head – The toilet facilities aboard a ship.
Head Pressure – Pressure which exists in the condensing side of a refrigerating system.
Head, Static – Pressure of fluid expressed in terms of height of column of the fluid, such as water or mercury.
Head, Velocity – In flowing fluid, heat of fluid equivalent to its velocity pressure.
Head-Pressure Control – Pressure operating control which opens electrical circuit if high side pressure becomes excessive.
Heat – Form of energy the addition of which causes substances to rise in temperature; energy associated with random motion of molecules.
Heat Balance – Energy flow in a power generating system.
Heat Coil – A heat transfer device which releases heat.
Heat Exchanger – Device used to transfer heat from a warm or hot surface to a cold or cooler surface. Evaporators and condensers are heat exchangers.
Heat, Latent – Heat characterized by a change of state of the substance concerned, for a given pressure and always at a constant temperature for a pure substance, i.e., heat of vaporization or of fusion.
Heat Load – Amount of heat, measured in Btu, which is removed during a period of 24 hours.
Heat of Compression – Mechanical energy of pressure transformed into energy of heat.
Heat of Fusion – The heat released in changing a substance from a liquid state to a solid state. The heat of fusion of ice is 144 Btu per pound.
Heat Pump – A name given to an air-conditioning system that is reversible so as to be able to remove heat from or add heat to a given space or material upon demand.
Heat Pump — Air Source – A device that transfers heat between two different air quantities, in either direction, upon demand.
Heat Pump — Water Source – A device that uses a water supply as a source of heat or for disposal of heat depending upon the operational demand.
Heat Rate – A measure of generating station thermal efficiency, generally expressed in Btu (per net kilowatt-hour).
Heat Recovery – The capture and utilization of heat energy which is normally wasted as a by-product of a diesel or gas engine.
Heat, Sensible – A term used in heating and cooling to indicate any portion of heat which changes only the temperature of the substances involved.
Heat Sink – An aluminum plate or extrusion under the rectifier assembly which dissipates heat generated by the rectifier.
Heat Source – The material from which the refrigeration system extracts heat.
Heat, Specific – The heat absorbed (or given up) by a unit mass of a substance when its temperature is increased (or decreased) by 1-degree Common Units: Btu per (pound)

(Fahrenheit degree), calories per (gram) (Centigrade degree). For gasses, both specific heat at constant pressure (cp) and specific heat at constant volume (cv) are frequently used. In air-conditioning, cp is usually used.
Heat Transfer – Movement of heat from one body or substance to another. Heat may be transferred by radiation, conduction, convection, or a combination of these three methods.
Heat Treatment – A combination of heating and cooling operations timed and applied to a metal in a solid state in a way that will produce desired properties.
Heating Value – The amount of heat produced by burning 1 lb of fuel.
Helical Gear – A gear wheel of a spiraling shape. (The teeth are cut across the face at an angle with the axis.)
Hermetically Sealed Unit – A sealed hermetic-type condensing unit is a mechanical condensing unit in which the compressor and compressor motor are enclosed in the same housing with no external shaft or shaft seal, the compressor motor operating in the refrigerant atmosphere. The compressor and compressor motor housing may be of either the fully welded or brazed type, or of the service-sealed type. In the fully welded or brazed type, the housing is permanently sealed and is not provided with means of access of servicing internal parts in the field. In the service-sealed type, the housing is provided with some means of access of servicing internal parts in the field.
Hermetic Motor – Compressor drive motor sealed within same casing which contains compressor.
Hermetic System – Refrigeration system which has a compressor driven by a motor contained in compressor dome or housing.
Hertz (Hz) – A unit of frequency equal to one cycle per second.
HEUI *Hydraulically actuated Electronically controlled Unit Injector*
Hg (Mercury) – Heavy silver-white metallic element; only metal that is liquid at ordinary room temperature.
HHV *High Heat Value*
High Coolant Temperature – On the EMS II module, a flashing red light and a horn will indicate the engine has started a high coolant temp. derate. If the ECM triggers an engine shutdown due to high coolant temperature, the light and horn will continue, and the system shutdown light will also begin flashing.
High Heat Value (HHV) – The total energy content of a fuel available by complete combustion and all products of combustion at 60° F and water in a vapor state. Equals to the High Heat Value less the latent heat of vaporization.
High Idle Setting – The maximum speed at which an engine will run with the governor wide open at no load condition.
High Side – Parts of a refrigerating system which are under condensing or high side pressure.
High Voltage – Any AC voltage above 15000V.
Hold – The interior of a ship below decks where cargo is stored.
Hone – A tool with an abrasive stone used for removing metal, such as correcting small irregularities or differences in diameter in a cylinder.
Horsepower (hp) – A unit used to measure power of an engine. An electric motor develops one horsepower by lifting weight of 550 pounds through a distance of one foot in one second. It represents the product of force and rate of motion. (See *Brake Horsepower and Indicated Horsepower*.)
Horsepower-hour (hp-h) – A unit of energy equivalent to that expended in 1 hp applied for 1 hour. Equal to approximately 2,545 Btu.

Hot Shortness – Brittleness in metal when hot.
Hot Spot – Refers to a comparatively thin section or area of the wall between the inlet and exhaust manifold of an engine, the purpose being to allow the hot exhaust gases to heat the comparatively cool incoming mixture. Also used to designate local areas of the cooling system which have attained above average temperatures.
Hot Well (expansion tank) – A system used when static head exceeds 17.4 m (57 ft), or a boost pump imposes excessive dynamic head.
HP *High Performance*
hp *Horsepower*
Hull – The outer walls of the ship, the outer skin of the ship that is exposed to the water.
Humidifier – Device used to add to and control the humidity in a confined space.
Humidistat – An electrical control which is operated by changing humidity.
Humidity – Moisture; dampness. Relative humidity is a ratio of quantity of vapor present in air to the greatest amount possible at given temperature.
Hunting – Alternate overspeeding and underspeeding of the engine caused by governor instability.
HV *High Voltage*
HWTS *High Water Temperature Switch*
Hybrid – An engine which combines the features of reciprocating and rotating engines.
Hydraulic Governor – A governor which uses a control valve to allow oil pressure to work directly on the terminal shaft through a power piston.
Hydraulically Actuated Electronically Controlled Unit Injector (HEUI) – A Cat system which manages precise injection of fuel in an engine to achieve optimal efficiency and performance.
Hydraulics – That branch of mechanics or engineering which deals with the action or use of liquids forced through tubes and orifices under pressure to operate various mechanisms.
Hydrocarbons (HC) – Emissions consisting of unburned fuel or lubricating oil, which cause eye irritation and unpleasant odors. Measured in parts per million by volume.

$$\text{HC concentration (ppm)} = \frac{2067 \text{ x HC mass emissions (g/hr)}}{\text{Exhaust mass flow (kg/hr)}}$$

Hydrogen – One of the elements constituting fuel and lubricating oil.
Hydromechanical Governor – A governing system which uses engine or it's own lubricating oil pressure to support the action of a mechanical control — any mechanical governor assisted by a hydraulic servo valve.
Hydrometer – A test instrument for determining the specific gravities of liquids.
Hz *Hertz*
IAPCV *Injector Actuation Pressure Control Valve*
ID *Inside Diameter*
Idle – To operate (an engine) without transmitting power.
Idling – Refers to the engine operating at its slowest speed with a machine not in motion. An engine running without load.
IEC *International Electromechanical Commission*
Ignition – The start of combustion.

Ignition Delay – The period between when fuel injection begins and when fuel actually starts to burn.
Ignition Lag – The time between start of injection and ignition.
ihp *indicated horsepower*
Immersed – To be completely under the surface of a fluid.
Impact Testing – Method to determine the tendency of a metal toward brittleness. Samples are mounted and struck with a single pendulum-type blow of such force as to fracture the
specimen. The energy required is measured in foot-pounds and is affected by the striking velocity, temperature, form, and size of sample. If the sample resists fracture in the test, it is described as tough; if it fractures easily, it is brittle or notch sensitive. See *Cohesive Strength.*
Import/Export Control – Requires varying generator set power output with site load to keep the amount of power "imported" from or "exported" to the utility near constant. The generator sets operate in parallel with the utility, and their output is raised and lowered to match changes in the site load. This scheme requires a monitoring device at the point in the system to be kept near constant and is typically accomplished with a programmable logic controller (PLC).
in *inch*
Inboard – Inside the ship; toward the center line.
Inboard Exciter – Exciter components are physically inboard of ball bearing. This design is okay where shaft deflection between bearing center and engine drive flange mounting is not a problem.
Inclusions – Particles of impurities, usually oxides, sulphides, silicates, and such, which are mechanically held during solidification or which are formed by subsequent reaction of the solid metal. These impurities are called nonmetallic inclusions and may or may not be harmful depending on their type, size, distribution, and the end product to be manufactured.
Indicated Horsepower (ihp) – An elevated engine power measurement which includes the entire amount of horsepower developed in the combustion chamber, before any is lost through friction or operation of satellite systems.
Indicated Thermal Efficiency – The ratio of indicated horsepower to equivalent power input in the form of heat from fuel.
Indicator – An instrument for recording the variation of cylinder pressure during the cycle.
Indicator Card – A graphic record of the cylinder pressures made by an indicator.
Indirectly Cooled Piston – A piston cooled mainly by the conduction of heat through the cylinder walls.
Induction Generator – A nonsynchronous AC generator similar in construction with an AC motor, and which is driven above synchronous speed by external sources of mechanical power.
Induction Hardening – A method of hardening the surface of a part electrically. A high frequency current, varying from a few thousand cycles to several million cycles per second, is passed through a coil that is held very close to the surface to be hardened. This induces eddy currents into the surface of the part which, together with hysteresis effect of the rapid reversals, heats the surface, and by conduction may through heat the part, if desired. Quenching may be done immediately in water, or in some cases the cold core of the steel itself may be the quenching medium. The surface finish is in no way affected by this method nor is the part distorted.

Induction Motor – An AC motor which operates on the principle of rotating magnetic field. The rotor has no electrical connection, but receives electrical energy by transformer action from field windings.
Induction System – Those components of an engine involved in providing combustion air to an engine.
Inductor – An apparatus formed by wrapping a number of turns of insulated wire around a form; used to introduce inductance into an electric circuit.
Industrial Air Conditioning – Air-conditioning for uses other than comfort.
Industrial Grade Relay – An AC protective relay that is installed within the switchgear enclosure and cannot be easily removed for testing and calibration.
Inertia – That property of matter which causes it to tend to remain at rest if already motionless or to continue in the same straight line of motion if already moving.
Inhibitor – Any substance which retards or prevents such chemical reactions as corrosion or oxidation.
Injection Pump – A high-variable pressure pump delivering fuel into the combustion chamber.
Injection System – The components necessary for delivering fuel to the combustion chamber in the correct quantity, at the correct time, and in a condition satisfactory for efficient burning.
Injector – A device used to bring fuel into the combustion chamber.
Injector Actuation Pressure Control Valve (IAPCV) – A component of the Cat HEUI fuel system that controls the pressure of the oil which actuates the unit injector.
Inlet Air Pressure – The dry air pressure supplied to the inlet of an engine. This is normally barometric pressure minus water vapor pressure minus inlet air restriction.
Inlet Air Restriction – The pressure drop of the combustion air from atmospheric pressure to the compressor inlet of a supercharged engine or to the inlet manifold of a naturally aspirated engine.
Inlet Fuel Pressure – The fuel pressure supplied to the fuel inlet of a diesel engine.
Inlet Fuel Pressure (ABS) – The gas pressure supplied to the fuel inlet of a spark ignited engine.
Inlet Fuel Temperature – The temperature of the fuel supplied to the fuel inlet of either a diesel or spark ignited engine.
Inlet Manifold Pressure – Absolute pressure in the inlet manifold of a spark ignited engine.
Inline – A type of cylinder arrangement in an engine where the cylinders are aligned in a row.
Input Shaft – The shaft carrying the driving gear, such as in a transmission by which the power is applied.
Insert Bearing – A removable, precision-made bearing.
Insulated Case Circuit Breaker – A power circuit breaker that is provided in a preformed case, similar to a molded case breaker.
Insulator – Materials or substances that effectively block the movement of electrons. An example is glass.
Intake Manifold – A connecting casting between the air filter or turbocharger and the port openings to the intake valves.
Intake Valve – The valve which allows air to enter into the cylinder and seals against exit.

Integral – The whole, made up of parts.
Intercooler – Heat exchanger for cooling the air between stages of compression.
Internal Rate of Return – Discount rate at which the present value of an investment is equal to the investment.
Internal-Combustion Engine – An engine that burns fuel within itself as a means of developing power.
Interrupted Quenching – Refers to the use of two or more quenching media to obtain the final structure required. The part may be removed after a definite time in the original quenching medium and then finish cooled in another medium. Several methods have been developed. See *Austempering, Isothermal Quenching, Martempering.*
Interruptible – This refers to the practice of operating on-site power systems, at the request of a utility, to reduce electrical demand on the utility grid during periods of high consumption.
Interruptible Loads – Loads which can be temporarily disconnected without damage or any apparent reduction in facility performance. Such loads may include electric motors, driving pumps and fans, or lighting circuits.
Interruptible Power – Electric energy supplied by an electric utility subject to interruption by the electric utility under specified conditions.
Interrupting Capacity – The magnitude of electrical current that a device can safely interrupt (open against), without failure of the component.
Interrupting Rating – The maximum current allowed by the normal source protective device on a generator set, that the automatic transfer switch is capable of interrupting. It applies when line voltage falls below the preset value of the voltage sensing relay, and the standby source is present. The switch then could transfer before the normal service protective device clears the fault.
Inverter – An electromechanical or electronic device for converting direct current into alternating current.
IR *Infrared*
Irregular Straighteners – Used to straighten hexagons, flats, and squares. Essentially consisting of two groups of rolls placed at right angles to each other. Each group of rolls consists of five or more rolls set in the same plane and adjusted to provide reciprocate bending of the steel in the same plane.
ISO *Independent System Operator, International Standards Organization*
Isochronous – The condition of maintaining constant speed, regardless of load, at steady-state conditions, for constant electrical frequency output.
Isochronous Governor – A governor having zero speed droop.
Isochronous Load Sharing – A method of controlling the speed of paralleled generator sets so that all sets share the load equally, without any droop in frequency.
Isolators – Materials used between the foundation of a generator set and its mounting surface.
Isothermal Quenching – A method of hardening steel by quenching from the austenitizing temperature into an agitated salt bath which is maintained at a constant temperature level above the point at which martensite is formed (usually 450° F or higher), holding in this for sufficient time to permit transformation, transferring the steel immediately to some medium maintained at some higher temperature level for tempering and cooling in air. The advantages of this method of interrupted quenching are a minimum of

distortion and residual strains with higher hardness which can be tempered to produce the needed physical properties. Larger sections can be hardened by this method than by austempering.
Jacket – A covering used to isolate or insulate, especially engine heat.
Jacket Water – Cooling water which circulates through the engine.
Jack Staff – A flagpole at the bow of a vessel, from which the union jack maybe displayed.
Jet Cooling – A method of passing cooling oil below the piston by means of a jet or nozzle.
JIT *Just-in-Time (Juran lingo)*
Joiminy Hardenability Test – A test used to determine the hardenability of any grade of steel. It is based on the premise that (1) irrespective of their chemistry, steel bars of the same size loose heat at a predetermined number of degrees per second under fixed conditions and (2) that the structure and physical properties vary with the rate of cooling. See *Hardenability* and *Quenching.*
Journal – The portion of a shaft, crank, etc., which turns in a bearing.
JW *Jacket Water*
JWAC *Jacket Water After-Cooling*
JWH *Jacket Water Heater*
kAIC *k Amps Interrupting Capacity*
Keel – The principal structural member of a ship, extending from bow to stern and forming the backbone of the ship.
Kelvin Scale (K) – A temperature scale having the same size divisions as those between Celsius degrees, but having the zero point at absolute zero.
Key – A fastening device wherein two components each have a partially cut groove, and a single square is inserted in both to fasten them together such as between the shaft and hub to prevent circumferential movement.
Keyway or Keyseat – The groove cut in a component to hold the key.
Killed Steel – A steel sufficiently deoxidized to prevent gas evolution during solidification. The top surface of the ingot freezes immediately and subsequent shrinkage produces a central pipe. A semikilled steel, having been less completely deoxidized, develops sufficient gas evolution internally in freezing to replace the pipe by a substantially equivalent volume of rather deep-seated blow holes.
Kilometer (km) – A metric measurement of length equal to 0.6214 mi.
Kilovolt (kV) – 1000 volts.
Kilowatt (kW) – 1000 watts. A term for rating electrical devices. Generator sets in the United States are usually rated in kW. Sometimes called active power, kW loads the generator set engine.
Kilowatt-Hour (kW-h) – The most commonly used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour.
Kinetic Energy – The energy which an object has while in motion.
Knock – A general term used to describe various noises occurring in an engine; may be used to describe noises made by loose or worn mechanical parts, preignition, detonation, etc.
Knot – A speed measurement of one nautical mile per hour, a nautical mile being about 1 1 /7 land miles (6,080 feet or 1 /60 of a degree at the equator.)
Knurling – A method of placing ridges in a surface, thereby forcing the areas between these ridges to rise.

kV•A – The abbreviation for Kilo-Volt-Amperes, a common term for rating electrical devices. A device's kV•A rating is equal to its rated output in amps multiplied by its rated operating voltage.
kVAR – The abbreviation for Kilo-Volt-Amperes Reactive. It is associated with the reactive power that flows in a power system. Reactive power does not load the set's engine but does limit the generator thermally.
kW *Kilowatt*
L *Liter*
Lacquer – A solution of solids in solvents which evaporate with great rapidity.
Ladders – Any stairway aboard a ship.
Lag – To slow down or get behind; time interval, as in *ignition lag.*
Land – The projecting part of a grooved surface; for example, that part of a piston on which the rings rest.
Lap – A surface defect appearing as a seam caused from folding over hot metal, fins, or sharp corners and then rolling or forging, but not welding them into the surface.
Lap (lapping) – A method of refinishing (grinding and polishing) the surface of a component.
Latent Heat – Heat energy absorbed in process of changing form of substance (melting, vaporization, fusion) without change in temperature or pressure.
LCD *Liquid Crystal Display*
LCR *Low Compression Rating*
Length Over All – The length of a ship from the forward most point of the stem to the after most point of the stern.
Letter Drills – Drills on which the size is designated by a letter.
LFG *Landfill Gas*
LFGTE *Landfill Gas-To-Energy*
LH *Left Hand*
L-Head Engine – An engine design in which both valves are located on one side of the engine cylinder.
LHV *Low Heat Value*
Lifelines – Light wire ropes supported on stanchions. They serve the same purpose as bulwarks.
Line – A tube, pipe, or hose which is used as a conductor of fluid.
Linear – Moving in one direction only.
Liner – The sleeve forming the cylinder bore in which the piston reciprocates.
Linkage – A movable connection between two units.
Liquid – Matter which has a definite volume but takes the shape of any container.
Liquid Absorbent – A chemical in liquid form which has the property to "take on" or absorb moisture.
Liquid Crystal Display (LCD) – A device for alphanumeric displays using a pattern of tiny sealed capsules which contain a transparent liquid crystal that becomes opaque when an electric field is applied to it; the contrast between the transparent and opaque areas forms letters or numbers.
Liquefied Natural Gas (LNG) – Natural gas that has been condensed to a liquid, typically by cryogenically cooling the gas to -327.2° F (below zero).
Liquefied Petroleum Gas (LPG) – A mixture of gaseous hydrocarbons, mainly propane and butane that change into liquid form under moderate pressure.

List – Refers to athwartships balance. A ship with one side higher than the other side has a starboard list or port list. List is measured in degrees by an inclinome-ter, mounted on the bridge, exactly on the center line of the ship. Also called "Heeling".
Liter (L) – A metric measurement of volume equal to 0.2642 gal (U.S.).
Live Wire – A conductor which carries current.
LLDPE *Liner Low Density Polyethylene*
Load – The power that is being delivered by any power-producing device. The equipment that uses the power from the power-producing device. (Also see *Cooling Load and Engine Load.)*
Load Current – Amperage required by the load that is supplied by an electrical power source.
Load Curve – A curve on a chart showing power (kilowatts) supplied, plotted against time of occurrence, and illustrating the varying magnitude of the load during the period covered.
Load Factor – The mathematical ratio of the actual load divided by the connected load.
Load Following – Operation of equipment to match production to demand.
Load Line – A center line indicating the points of contact where the load passes within the bearing.
Load Management – The utilization of generator sets in order to control the amount of electrical power purchased from a utility. This can be accomplished by switching specific loads from utility power to generator power, or operating generator(s) in parallel with the utility.
Load Sense Demand – A paralleling system operating mode in which the system monitors the total kW output of the generator sets, and controls the number of operating sets as a function of the total load on the system. The purpose of load demand controls is to reduce fuel consumption and limit problems caused by light load operation of reciprocating diesel generator sets.
Load Shedding – The process by which the total load on a paralleling system is reduced, on overload of the system bus, so that the most critical loads continue to be provided with reliable electrical service. Overload is typically determined as a bus underfrequency condition.
Load-Line Angle – The angle of a load line with respect to the shaft center or bearing radial centerline.
Load Water Line – Line of the surface of water on a ship when loaded to maximum allowance in slat water in the summertime.
Lobe – The projecting part, usually rounded, on a rotating shaft.
LOPS *Low (rev/min) Oil Pressure Switch*
Low Coolant Temperature – On the EMS II module, a flashing red light and horn annunciate when the coolant temperature falls below a value programmed within EMS II.
Low Heat Value (LHV) – The total heat produced by burning a given mass of fuel minus the latent heat of evaporation of water produced by the combustion process.
Low Voltage – Any AC voltage between 120V and 600V.
LP-Gas, Liquefied Petroleum Gas – Made usable as a fuel for internal combustion engines by compressing volatile petroleum gases to liquid form. When so used, must be kept under pressure or at low temperature in order to remain in liquid form, until used by the engine.

Lubricant – A substance to decrease the effects of friction, commonly a petroleum product (grease, oil, etc.).
Lubricator – A mechanical oiler which feeds oil at a controlled rate.
Lug – Condition when the engine is operating at or below its maximum torque speed, or slowing the speed of an engine by adding load.
LWLS *Low Water Level Switch*
Machinability – The factors involved in determining machinability are cutting speed and feed, resultant surface produced, and tool life. There are, however, many variables involved in each of these factors such as hardness, grain size, structure, inclusions, size and shape of tool, coolant, etc. The standard for machinability ratings is SAE 1112 (AISI B.1112) Bessemer screw stock rated as 100% although other materials may be used.
Magnaflux – A method used to check components for cracks.
Magnaflux Testing – A method of inspection used to locate cracks, cavities or seams in steel bars at or very close to the surface. Special equipment has been developed for this test and several methods are used. In principle the part is magnetized and magnetic powder is applied, wet or dry. Flaws that are not otherwise visible will be indicted by the powder clinging to them. Due to many variables that may be present in this test, considerable experience is needed for uniform interpretation or results.
Magnetic Field – The affected area of the magnetic lines of force.
Magnetizing Current – Transformers, motors and other electromagnetic devices containing iron in the magnetic circuit must be magnetized in order to operate. It is customary to speak of the lagging inductive current as a magnetizing current.
Main Bearing – A bearing supporting the crankshaft on its axis.
Main Breaker – A circuit breaker at the input or output of the bus, through which all of the bus power must flow. The generator main breaker is the device that interrupts the set's power output. Main breakers provide overcurrent protection and a single disconnect point for all power in a switchboard or device.
Maintenance Costs – The cost of servicing and repair of equipment, including parts and labor.
Maintenance Power – Electric energy supplied by an electric utility during scheduled outages of the cogenerator.
Makeup Water – The water required to replace the water lost from a cooling tower by evaporation, drift, and bleedoff.
Mandrel – A mounting device for a stone, cutter, saw, etc.
Manifold – A pipe with one inlet and several outlets, used to collect and direct fluids and gases.
Manometer – A device for measuring a vacuum. It is a U-shaped tube partially filled with fluid. One end of the tube is open to the air and the other is connected to the chamber in which the vacuum is to be measured. A column of Mercury 30 in. high equals 14.7 lbs. per square in., which is atmospheric pressure at sea level. Readings are given in terms of inches of Mercury.
Manual Control – A device which allows manual control of output voltage.
Manual Valve – A valve which is opened, closed, or adjusted by hand.
Marine Duty – A generator with features to meet marine duty certification. PM, thermocouples in winding for heat sensing, green paint, and space heaters.
Marine Power System (MPS) Software – A Cat computer program which automatically sizes marine engines, gears, and propellers, based on desired

vessel performance. A complete report is compiled for buyers to reference comparisons between various system configurations.
Marmon Clamps – Circular clamps used for air pipe connection. They include metal rings to aid in sealing.
Martempering – A method of hardening steel by quenching from the austenitizing temperature into some heat extracting medium (usually salt) which is maintained at some constant temperature level above the point at which martensite starts to transform (usually about 450° F), holding the steel in this medium until the temperature is uniform throughout, cooling in air for the formation of martensite and tempering by the conventional method. The advantages of this method of interrupted quenching are a minimum of distortion and residual strains. The size of the part can be considerably larger than for austempering.
Martensite – A microconstituent or structure in quenched steel characterized by an acicular or needle-like pattern on the surface polished and etched. It has the maximum hardness of any of the decomposition products of austenite. It is a transition lattice formed by the partial transformation of austenite.
MASH *Machine Sales History, Marine Analyst Service Handbook*
Mass Elastic System – Pistons, rods, crankshaft, flywheel, coupling, driven equipment, and associated shafting.
MATH *Maintenance & Technical Handbook*
Matter – Any substance which occupies space and has weight. The three forms of matter are solids, liquids, and gases.
MBH *1000 Btu/hour*
MD *Medium Duty*
Mean Effective Pressure (mep) – The calculated combustion in pounds per square inch (average) during the power stroke, minus the pounds per square inch (average) of the remaining three strokes.
Mean Indicated Pressure (mip) – Net mean gas pressure acting on the piston to produce work.
Mechanical Advantage – The ratio of the resisting weight to the acting force. The distance through which the force is exerted divided by the distance the weight is raised.
Mechanical Efficiency – (1) The ratio of brake horsepower to indicated horsepower, or ratio of brake mean effective pressure to mean indicated pressure. (2) An engine's rating which indicates how much of the potential horsepower is wasted through friction within the moving parts of the engine.
Mechanical Governor – A simple type of governor using flyweights for speed sensing and throttle control.
Mechanical Injection – Mechanical force pressurizing the metered fuel and causing injection.
Mechanical Properties – Those properties that reveal the reaction, elastic and inelastic, of a material to an applied force or that involve the relationship between stress and strain; for example, Young's modulus, tensile strength, fatigue limit. These properties have often been designated as physical properties, but the term mechanical properties is much to be preferred. See *Physical Properties.*
Mechanically Operated Valve – A valve which is opened and closed at regular points in a cycle of events by mechanical means.
Medart – Equipment developed for straightening cold drawn bars measuring from about 1/2" to 2-7/8" in diameter. These straighteners have one concave

and one straight roll which revolve the bar as it passes between them. Much of the sizing of the bar and the brightness of the finish is accomplished in this operation.
Medium Voltage – Any AC voltage between 1000 and 15,000 VAC.
Megawatt (MW) – One million watts
Megawatt Hour (MWh) – One thousand kilowatt-hours, or an amount of electricity that would supply the monthly power needs of a typical home having an electric hot water system.
***MEP** Mean Effective Pressure*
***MEPS** Marine Engine Power Systems*
Metal Fatigue – When metal crystallizes and is in jeopardy of breaking because of vibration, twisting, bending, etc.
Metering Fuel Pump – A fuel pump delivering a controlled amount of fuel per cycle.
Methyl Chloride (R-40) – A chemical once commonly used as a refrigerant. The chemical formula is CH3Cl. Cylinder color code is orange. The boiling point at atmospheric pressure is -10.4° F.
Metric Size – Size of a component, part, etc., in metric units of measurement (e.g., meters, centimeters).
***Mg** Million megagrams*
***MHA** Material Handling Arrangement*
Micrometer (m) – One one-millionth of a meter or 0.000039 in.
Micrometer (mike) – A precision measuring tool that is accurate to within one one-thousandth of an inch or one one-hundredth of a millimeter.
Millimeter (mm) – One one-thousandth of a meter or 0.039370 in.
Milling Machine – A machine used to remove metal, cut splices, gears, etc., by the rotation of its cutter or abrasive wheel.
Minimum Generation – Generally, the required minimum generation level of a utility system's thermal units. Specifically, the lowest level of operation of oil-fired and gas-fired units at which they can be currently available to meet peak load needs.
***MIP** Mean Indicated Pressure, Membrane Interface Probe*
Misfiring – When the pressure of combustion of one or more cylinders is lower than the remaining cylinders, one or more cylinders have an earlier or later ignition than the others.
Mixed Cycle – Where fuel burns partly at constant volume and partly at constant pressure. Sometimes applied to the actual combustion cycle in most high-speed internal combustion engines.
Mixture Control – A screw or adjustable valve to regulate the air/fuel provided by a carburetor.
***mm** millimeter*
MMS Marine Monitoring System
Modulus of Elasticity – The ratio, within the limit of elasticity, of the stress to the corresponding strain. The stress in pounds per square inch is divided by the elongation in fractions of an inch for each inch of the original gage length of the specimen.
Molded Case Circuit Breaker – Automatically interrupts the current flowing through it when the current exceeds the trip rating of the breaker. Molded case refers to the use of molded plastic as the medium of electrical insulation for enclosing the mechanisms, and for separating conducting surfaces from one another and from grounded metal parts.

Monochlorodifluoromethane – A refrigerant better known as Freon 12 or W-22. The chemical formula is CHCIF2. Cylinder color code is green.
Monocoque Construction – Integral construction of stator assembly where outside shell provides a major portion of construction strength.
Motor –An actuator which converts fluid power or electric energy to rotary mechanical force and motion. This term should be used in connection with an electric motor and should not be used when referring to the *engine* of a machine.
Motor Inrush Current – The current required to start an electric motor at rest. This current is equal to the current that would be drawn by the motor if the rotor were not allowed to turn.
mph *miles per hour*
MPS *Marine Power System*
MPU *Magnetic Pick-Up*
MR *Medium Range, Mid-Range*
MT *Multi-Torque*
Muffler – A chamber attached to the end of the exhaust pipe which allows the exhaust gases to expand and cool. It is usually fitted with baffles or porous plates and serves to subdue much of the noise created by the exhaust.
MUI *Mechanical Unit Injector*
Multifuel – A term used to describe an engine which can burn a variety of different fuels.
Multimegawatt – Many million watts.
Multiple Rating Engine – An engine which has a variable full load fuel setting to provide more than one full load power.
Multiviscosity Oil – An oil meeting SAE requirements.
MW *Megawatt*
MWh *Megawatt Hour*
NA *Naturally Aspirated*
National Electrical Manufacturers Association (NEMA) – A non-profit U.S. trade association of manufacturers of electrical apparatus and supplies. This organization facilitates understanding between manufacturers and users of electrical products.
Natural Convection – Movement of a fluid caused by temperature differences (density changes).
Natural Gas – Hydrocarbon gas found in the earth, composed of methane, ethane, butane, propane and other gases.
Naturally Aspirated – A term applied to an engine which has no method of compressing air supplied to the inlet manifold.
Needle Bearing – A roller-type bearing in which the rollers are smaller in diameter than in length proportional to the race.
Negative Terminal – A terminal from which the current flows back to its source.
NEMA 1 Enclosure – This enclosure designation is for indoor use only when dirt, dust, and water are not a consideration. Personnel protection is the primary purpose of this type of enclosure.
Neoprene – A synthetic rubber highly resistant to oil, light, heat, and oxidation.
Network – A system of transmission or distribution lines so cross-connected and operated as to permit multiple power supply to any principal point on it.
Neutron – A neutral charged particle of an atom.

New Material Release – Announces new or different items of interest that would be of value to dealers and sales representatives.
Newton's Third Law – For every action there is an equal, opposite reaction.
Nitrogen Oxide (NO) – The combination of nitrogen and oxygen that occurs during the combustion process.
Nominal – The specified or target value of an engine performance characteristic. The nominal value is usually accompanied by tolerances defining the acceptable range of the characteristic relative to the nominal.
Nonferrous Metals – Any metals not containing iron.
Non-Interruptible Loads – Loads which cannot tolerate even a momentary power outage without causing damage or severe functional loss to a facility. A computer is a noninterruptible load, as any power lapse could result in loss of vital data or computer-controlled action.
Nonlinear Loads – Any load for which the relationship between voltage and current is not a linear function. Some common nonlinear loads are fluorescent lighting, SCR motor starters, and UPS systems. Nonlinear loads cause abnormal conductor heating and voltage distortion.
Not In Auto (EPG only) – On the EMS II module, a flashing red light annunciates when the engine control switch is not in auto. The engine control switch information will be available on the datalink.
Notching – A method of producing stator laminations by indexing and punching stator slots one at a time.
NO x [combination of nitric oxide (NO) and nitrogen dioxide (NO_2)] – A harmful chemical present in combustion air formed by decomposition and recombination of molecular oxygen and nitrogen. Measured in parts per million by volume.

$$\text{NO x Concentration (ppm)} = \frac{\text{629 x NO x mass emissions (g/hr)}}{\text{Exhaust mass flow (kg/hr)}}$$

NO x RACT – Reasonable Available Control Technology being applied to NO x on existing stationary sources in nonattainment areas.
Nozzle – The component containing the fuel valve and having one or more orifices through which fuel is injected.
Number Drills – Drills on which the size is designated by a number.
OA *Outside Air*
Octane – Measurement which indicates the tendency of a fuel to detonate or knock.
OD *Outside Diameter*
OEM *Original Equipment Manufacturer*
Off-Peak – Time periods when power demand are below average. For electric utilities, generally nights and weekends; for gas utilities, summer months.
Ohm (**W)** – A unit used to measure the opposition or resistance to flow of electric current in a circuit.
Ohmmeter – An instrument for measuring the resistance in a circuit or unit in ohms.
Ohm's Law – The number of amperes flowing in a circuit is equal to the number of volts divided by the number of ohms.
Oil Cooler – A heat exchanger for lowering the temperature of oil.
Oil Filter – A device for removing impurities from oil.

Oil Gallery – A pipe-drilled or cast passage in the cylinder-head block and crankcase that is used to carry oil from the supply to an area requiring lubrication or cooling.
Oil Pressure – The engine oil pressure at full load at a specified location on the engine.
Oil Pump – A mechanical device to pump oil (under pressure) into the various oil galleries.
Oil Pumping – An engine condition wherein excessive oil passes by the piston rings and is burned during combustion.
Oil, Refrigeration – Specifically prepared oil used in refrigerator mechanism circulates to same extent with refrigerant. The oil must be dry (entirely free of moisture), otherwise, moisture will condense out and freeze in the refrigerant control and may cause refrigerant mechanism to fail. An oil classified as a refrigerant oil must be free of moisture and other contaminants.
Oil Seal – A mechanical device used to prevent oil leakage, usually past a shaft.
Oil Separator – Device used to remove oil from gaseous refrigerant.
Oil Slinger – A special frame disk fastened to a revolving shaft. When the shaft rotates and oil contacts the disk, it is thrown outward away from the seal, and thus reduces the force on the seal.
Oil-Bath Air Cleaner – An air filter that utilizes a reservoir of oil to remove the impurities from the air before it enters the intake manifold or the compressor of the turbine.
Open Circuit – A circuit in which a wire is broken or disconnected.
Open-Type System – A refrigerating system which uses a belt-driven compressor or a coupling-driven compressor.
Opposed – A type of cylinder arrangement in an engine where the cylinders are placed opposite one another.
Opposed Piston Engine – An engine having two pistons operating in opposite ends of the same cylinder, compressing air between them.
***OPSS** Oil Pressure Step Switch (ESS)*
Orderly Turbulence – Air motion which is controlled as to direction or velocity.
Orifice – Accurate size openings for controlling fluid flow.
***OS** Overspeed (ESS)*
Oscillate – To swing back and forth like a pendulum; to vibrate.
Oscilloscope – A device for recording wave forms on a fluorescent screen, proportional to the input voltage.
***OSHA** Occupational Safety and Health Administration*
Otto Cycle – Also called four-stroke cycle. Named after the man who adopted the principle of four cycles of operation for each explosion in an engine cylinder. They are (1) intake stroke, (2) compression stroke, (3) power stroke, (4) exhaust stroke.
Outboard Exciter – Exciter components are physically located outboard of the ball bearing. This design is used to keep shaft deflection between the bearing center and the engine drive flange mounting to a minimum.
Outage (electric utility) – An interruption of electric service that is temporary (minutes or hours) and affects a relatively small area (buildings or city blocks).
Output Shaft – The shaft which delivers the power.
Overcrank (EPG only) – On the EMS II module, a flashing red light and a horn annunciate when an overcrank has occurred. The ECM will determine

when an overcrank has occurred and will provide the information on the datalink.
Overcurrent Relay – Operates when the monitored current exceeds the relay setpoint. Overcurrent protection usually consists of an instantaneous setting and a timed setting. Low voltage circuit breakers usually include a trip unit that incorporates these functions.
Overhead Camshaft – A camshaft which is mounted above the cylinder head.
Overheads – The ceilings aboard a ship.
Overrunning Clutch – A clutch mechanism that transmits power in one direction only.
Overrunning-Clutch Starter Drive – A mechanical device that locks in one direction but turns freely in the opposite direction.
Overspeed – Engine running higher than the operational speed range. A dangerous engine condition where the combustion system is receiving more fuel than the engine load demands. On the EMS II module, a flashing red light and a horn annunciate when an engine overspeed has occurred. The ECM will determine when an engine overspeed has occurred and will shut down the engine by shutting off the fuel to the engine and tripping the air shutoffs (if provided).
Overspeed Governor – A governor that shuts off the fuel or stops the engine only when excessive speed is reached.
Oversquare Engine – An engine that has a larger bore diameter than the length of its stroke.
Overvoltage Relay – Operates when the monitored voltage exceeds the relay setpoint. If monitoring a generator set the generator set's circuit breaker is typically tripped open and the generator set is shut down.
Oxidation – That process by which oxygen unites with some other substance causing rust or corrosion.
Packing Gland – The seal used to keep sea water from entering the ship through the stern tube from around the prop shaft.
Paper Air Cleaner–An air filter with a special paper element through which the air is drawn.
PAR *Performance Analysis Report*
Parallel Circuit – An electric circuit with two or more branch circuits. It is wired to allow current to flow through all branches at the same time.
Paralleling – Two or more AC generator sets (or one generator set and the utility) supplying power to a common load. Connection of the power sources is made so that the sources electrically function as a single source of power. Parallel operation requires that the two sources of electrical power match in voltage, frequency, and number of phases.
Particle Emissions – Emitted substances including soot (unburned carbon), soluble organic fraction (SOF), and sulfates.
Pascal's Law – Pressure applied anywhere to a body of confined fluid is transmitted undiminished to every portion of the surface of the containing vessel.
Passageways – Aisle ways through the ship for personnel to walk, also referred to as corridors.
Payback Period - The time required to completely recover the original capital investment.
PC *Personal Computer, Pre-Combustion Chamber*
PCNA *Pre-chambered Naturally Aspirated*

PCT *Pre-chambered Turbocharged*
PCTA *Pre-chambered Turbocharged Aftercooled*
Peak Demand – The maximum electrical power (kilowatt) demand for a given facility for a given time.
Peak Load – The highest electrical demand within a particular period of time. Daily electric peaks on weekdays occur in late
afternoon and early evening. Annual peaks occur on hot summer days.
Peak Load Power Plant – A power generating station that is normally used to produce extra electricity during peak load times.
Peak Sharing – Power customers directly assisting utilities by generating electricity during times of peak demand on the utility system.
Peak Shaving – The process by which loads in a facility are reduced for a short time to limit maximum electrical demand in a facility and to avoid a portion of the demand charges from the local utility. This is typically accomplished by turning off low priority loads, transferring specific loads to generator power, or generating electrical power in parallel with the utility.
Peak-to-Peak Voltage – Measurement of voltage from the maximum value of one polarity to the maximum of the opposite polarity.
Peak Voltage – Measurement of voltage at the maximum points of the waveform.
Peaking Unit – A power generator used by a utility to produce extra electricity during peak load times.
Pearlite – The lamellar aggregate of ferrite and carbide resulting from the direct transformation of austenite at Arl. It is recommended that this word be reserved for the microstructures consisting of thin plates of lamellae; that is, those that may have a pearly luster in white light.
PEEC *Programmable Electronic Engine Control*
Peen – The thin end of a hammer head (opposite to the face).
Peening – Flattening the end of a rivet, etc., using the force of a hammer.
Penetrating Oil – A special oil that aids the removal of rusted parts.
Perforate – To make full of holes.
Periphery – The external boundary or circumference.
Permissive Paralleling – A feature of manual and automatic paralleling switchboards that prevents out-of-phase manual paralleling. A synchronizing check relay prevents the electrical closing of the electrically operated circuit breaker if the incoming set is outside of the frequency or phase angle limits required for proper paralleling to a bus.
Personality Module (PM) – The apparatus which houses the software in a Cat electronic engine's ECM.
Petroleum – An oil-liquid mixture made up of numerous hydrocarbons chiefly of the paraffin series.
Phase – The relationship in time between two waveforms of the same frequency. For practical use, refer to single- and three-phase.
Phase Rotation – (Or phase sequence) describes the order (A-B-C, R-S-T, or U-V-W) of the phase voltages at the output terminals of a three-phase generator. The generator phase rotation must match the facility phase rotation.
Phase Selector Switch – Allows one meter to supply power to the voltage regulator and main exciter.
Phosphor-Bronze – A bearing material composed of tin, lead, and copper.
Physical Change – A change which does not alter the composition of the molecules of a substance.

Physical Properties – It has been established that fully hardened steels have the same mechanical properties when tempered to the same hardness, regardless of composition. Any one of several compositions having the desired hardenability would produce the same results. Since service stresses determine tensile strength requirements, a knowledge of this factor will permit the determination of the other properties of hardness, tempering temperature, elongation, reduction of area and yield. See *Mechanical Properties.*
Pickling – A treatment given hot rolled rods prior to cold drawing. Its purpose is to remove hot rolled scale and other foreign matter from the rod; and this is commonly done by immersing in a hot acid, generally a sulfuric acid solution. The rolls are then rinsed in cold water, followed most generally by lime coating by dipping in a vat of lime emulsion, and are then heated to dry the lime and remove acid embrittlement.
Pilot Shaft – A shaft position in or through a hole of a component as a means of aligning the components.
Pilot Valve – A valve used to control the operation of another valve.
Pinion – A small gear having the teeth formed in the hub.
Pintle-Type Nozzle – A closed-type nozzle having a projection on the end of the fuel valve which extends into the orifice when the valve is closed.
Pipe – In diesel applications, that type of fluid line, the dimensions of which are designated by nominal (approximate) inside diameter.
Pipe (steel defect) –A cavity formed in metal (especially ingots) during the solidification of the last portion of liquid metal. Contraction of the metal causes the cavity pipe.
Piston – A cylindrical part closed at one end which is connected to the crankshaft by the connecting rod. The force of the expansion in the cylinder is exerted against the closed end of the piston, causing the connecting rod to move the crankshaft.
Piston Boss – The reinforced area around the piston-pin bore.
Piston Collapse – A condition describing a collapse or a reduction in diameter of the piston skirt due to heat or stress.
Piston Displacement – The volume of air moved or displaced by a piston when moved from BDC to TDC.
Piston Head – The portion of the piston above the top ring.
Piston Lands – That space of the piston between the ring grooves.
Piston Pin (wrist pin) – A cylindrical alloy pin that passes through the piston bore and is used to connect the connecting rod to the piston.
Piston Ring – A split ring of the expansion type placed in a groove of the piston to seal the space between the piston and the wall.
Piston Ring End Cap – The clearance between the ends of the ring (when installed in the cylinder).
Piston Ring Expander – A spring placed behind the piston ring in the groove to increase the pressure of the ring against the cylinder wall.
Piston Ring Gap – The clearance between the ends of the piston ring.
Piston Ring Groove – The grooves cut in the between the sides of the ring and the ring lands.
Piston Skirt – The portion of the piston which is below the piston bore.
Piston Speed – The total distance traveled by each piston in 1 minute. The formula is:

$$\text{Piston speed} = \frac{(\text{stroke (ft)} \times \text{rpm} \times 2) \text{ or } (\text{stroke (in)} \times \text{rpm})}{6}$$

Pivot – The pin or shaft on which a component moves.
Plate (battery) – A flat, square, rigid body of lead peroxide or porous lead.
Play – The movement or slack between two components.
Plenum Chamber – Chamber or container for moving air or other gas under a slight positive pressure.
***PLC** Programmable Logic Controller*
Plunger Pump – A pump which displaces fluid by means of a plunger.
***PM** Personality Module, Preventive Maintenance*
***PMS** Problem Monitoring System*
Pneumatics – That branch of physics pertaining to the pressure and flow of gases.
Polar Timing Diagram – A graphic method of illustrating the events of an engine cycle with respect to crankshaft rotation.
Polarity – Refers to the grounded battery terminal or to an electric circuit or to the north and south pole of a magnet.
Polarizing – To develop polarization of the pole shoes in respect to battery polarity.
Pole (magnet) – The pole from which the lines of force emanate (thereafter entering the south pole).
Port – The left side of a ship, when facing the front of the ship.
Port Bridge – The portion of a cylinder or liner between two exhaust or scavenging ports.
Port Scavenging – Introducing scavenging air through ports in the cylinder wall when they are uncovered by the power piston near the end of the power stroke.
Ports – Openings in the cylinder block and cylinder head for the passage of oil and coolant. (Also exhaust-intake connection and valve openings.)
Positive Terminal – The terminal which has a deficiency of electrons.
Potential Energy – The energy possessed by a substance because of its position, its condition, or its chemical composition.
Potential Transformer (PT) – An instrument used to reduce the voltage to be measured by a known ratio to a level suitable for the meter movement.
Pounds per Square Inch (psi) – A unit of measurement for pressure.
Pour Point – The lowest temperature at which an oil will flow.
Power – The rate of doing work. Power is the actual or observed power corrected to standard conditions of atmospheric pressure, inlet air temperature, and fuel density.
Power, Apparent – A quantity of power proportional to the mathematical product of the volts and amperes of a circuit. This product is generally designated in kilovoltamperes (kV•A), and is comprised of both real and reactive power.
Power Conditioner – A device which removes undesirable transients and distortion from a power source.
Power Factor – A correction factor used to figure the actual power being consumed. It is defined as the ratio of the actual power to the apparent power (current/voltage):

$$\text{Power Factor} = \frac{\text{Actual Power (watts)}}{\text{Apparent Power (kV•A)}}$$

Power Factor Meter – Indicates the ratio between true power (kW) and apparent power (kV•A).

Power Factor/VAR Controller – A device to maintain constant generator set reactive power output while operating in parallel with a utility or other large source. The controller interfaces with the generator automatic voltage regulator and can usually be set to maintain a constant power factor or constant kVAR output.
Power Pool – Two or more interconnected electric systems planned and operated to supply power in the most reliable and economical manner for their combined load requirements and maintenance program.
Power, Real – The energy or work-producing part of "apparent power." It is the rate of supply of energy, measured commercially in kilowatts.
Power Take-Off (PTO) – Accessory engine drive which is used to power auxiliary equipment.
ppm *parts per million*
PRCM *Programmable Relay Control Module*
Precision Insert Bearing – A precision type of bearing consisting of an upper and lower shell and a replaceable wear surface.
Pre-combustion Chamber – A portion of the combustion chamber connected to the cylinder through a narrow port. Fuel is injected into and is partly burned in the pre-combustion chamber. Heat released by the burning causes the CO in the pre-combustion chamber to be ejected into the cylinder with considerable turbulence.
Pre-ignition – Ignition occurring earlier than intended. For example, the explosive mixture being fired in a cylinder as by a flake of incandescent carbon before the electric spark occurs.
Pre-loading – Adjusting taper roller bearings so that the rollers are under mild pressure.
Pre-rotation Vanes (PRVs) – Vanes which are located at the compressor inlet. These vanes can be rotated through the use of an actuator to vary the load.
Press-Fit – Also known as a force-fit or drive-fit. This term is used when the shaft is slightly larger than the hole and must be forced into place.
Press-Fit Pressure – Force exerted per unit of area. (See *Drive-fit*.)
Pressure – An energy impact on a unit area; force or thrust exerted on a surface.
Pressure Cap – A special radiator cap with a pressure-relief and vacuum valve.
Pressure Differential – The difference in pressure between any two points of a system or a component.
Pressure Drop – The pressure difference at two ends of a circuit, part of a circuit, or the two sides of a filter, or the pressure difference between the high side and low side in a refrigerator mechanism.
Pressure Lubrication – A lubricating system in which oil at a controlled pressure is brought to the desired point.
Pressure Regulator, Evaporator – An automatic pressure regulating valve. Mounted in suction line between evaporator outlet and compressor inlet. Its purpose is to maintain a pre-determined pressure and temperature in the evaporator.
Pressure Time (PT) Curve –Avisual representation of the pressure within the combustion chamber during an engine's working cycle.
Pressure-Relief Valve – A valve that limits the maximum system pressure.
Primary Distribution Feeder – An electric line supplying power to a distribution circuit, usually considered to be that portion of the primary

conductors between the substation or point of supply and the center of distribution.
Prime Mover – The engine, turbine, water wheel, or similar machine which drives an electric generator.
Prime Power – An application where the generator set(s) must supply power on a continuous basis and for long periods of time between shutdowns. No utility service is present in typical prime power applications.
Printed Circuit – An electric circuit where the conductor is pressed or printed in or on an insulating material (panel) and at the same time is connected to the resistor, diodes, condenser, etc.
Probability of On-Site Power Economic Test (PROSPECT) – A Cat menu-driven personal computer software package which quickly analyzes peak shaving economic feasibility and return on investment.
Product Information – A book designed to educate dealers on a product or product line, and serve as a resource guide to aid in the sales process. It is comprehensive, yet quickly read, with a bulleted text format. Product features, benefits, and diagrams; servicing information; maintenance schedules; performance and competitive data; schematics; and other material may be included.
Product News – A publication used to update dealers on the development and availability of a new product, product update, product change, or feature. In addition to a basic description of the new item, among the contents may be specifications, detailed feature breakdown, performance data, schematics, pricing and shipping information, product contacts, and any other pertinent statistics.
Prognostics – Predict failure or potential problems before occurrence.
Progressive – Normally refers to a compound die where all slots are gang punched at one time.
Proof Stress – The load per unit area which a material is capable of withstanding without resulting in a permanent deformation of more than a specified amount per unit of cage length after complete release of load; i.e., the stress that will produce a very small permanent deformation, generally specified as 0.01% of the original gauge length. Because this is difficult to determine by the alternate loading and releasing which is generally prescribed, the offset method is frequently employed.
Propeller – The device used to propel the ship through the water.
Propeller Guards – Steel braces at the stern, directly above the propellers. They prevent the pro-pellers from striking a dock, pier or other ship.
Proton – The positively charged particle in the nucleus of an atom.
Prussian Blue – A blue pigment, obtainable in tubes, which is used to find high spots in a bearing.
PS — Pferdestarke (horsepower) – German designation for metric horsepower.
PSA *Power Systems Associates*
PSD *Power Systems Distributor* ***psi*** *pounds per square inch*
psig *pounds per square inch gauge*
Psychrometric Chart – A chart that shows the relationship between the temperature, pressure, and moisture content of the air.
PT *Pressure Time, Potential Transformer*
PTO *Power Take-Off*
PUC *Public Utility Commission*

Pull Down – An expression indicating action of removing refrigerant from all or a part of a refrigerating system.
Pulsate – To move with rhythmical impulse.
Pulse Width Modulation (PWM) – A signal consisting of variable width pulses at fixed intervals, whose ratio of "TIME ON" versus total "TIME OFF" can be varied. (Also referred to as "duty cycle.")
Pulverize – To reduce or become reduced to powder or dust.
Pump – A device for moving fluids.
Pump Down – The act of using a compressor or a pump to reduce the pressure in a container or a system.
Pump Scavenging – Using a piston-type pump to pump scavenging air.
Pumping Loss – The power consumed by replacing exhaust gas in the cylinder with fresh air.
Punch Press – A method of straightening which employs a punch press, "V" block supports, a dial gauge, and a straightedge. The bar to be straightened in placed on "V" blocks under the punch and rotated against a dial gauge or straightedge. The punch is then used to straighten the bar by deflecting the bar in the direction indicated by the gauge or straightedge. Neither the size nor finish is affected by this operation.
Purging – Releasing compressed gas to the atmosphere through some part of parts for the purpose of removing contaminants from the part or parts.
Push Fit – The part of the bearing that can be slid into place by hand if it is square with its mounting.
Push Rod – A connecting link in an operating mechanism, such as the rod interposed between the valve lifter and rocker arm on an overhead valve engine.
PVC *Polyvinyl Chloride*
PWM *Pulse Width Modulated*
Pyrometer – A temperature indicator used for indicating exhaust temperature.
Qualified Facility – A cogeneration facility which has been granted a "qualified" status by the FERC. To obtain the qualified status a facility must meet the ownership requirements (i.e., less than 50% electric utility ownership) and operating efficiency standards as outlined in the Public Utility Regulatory Policies Act of 1978 PURPA).
Qualifying Facility – A cogenerator or small power producer which, under federal law, has the right to sell its excess power output to the public utility.
Quarterdeck – The deck on which you go aboard a ship.
Quenching – The rapid cooling by immersion in liquids or gases or by contact with metal. The operation of hardening steel consists of slowly and uniformly heating to the proper austenitizing temperature above the upper critical (AC3), holding for sufficient time for through heating, and then quickly cooling by plunging the part into the quenching medium.
Quicksilver – Metallic mercury.
R-11,Trichloromonofluoromethane – Low pressure, synthetic chemical refrigerant which is also used as a cleaning fluid.
R-113, Trichlorotrifluoroethane – Synthetic chemical refrigerant.
R-12, Dichlorodifluoromethane – A popular refrigerant known as Freon 12.
R-134a – A commercially available, environmentally friendly hydrofluorocarbon (HFC) refrigerant for use as a long-term replacement for R-12 in new equipment and for retrofitting medium temperature CFC-12 systems.

R-160, Ethyl Chloride – Refrigerant which is seldom used at the present time.
R-170, Ethane – Low temperature application refrigerant.
R-22, Monochlorodifluoromethane – Synthetic chemical refrigerant.
R-290, Propane – Low temperature application refrigerant.
R-40, Methyl Chloride – Refrigerant which was used extensively in the 1920s and 1930s.
R-500 – Refrigerant which is azeotropic mixture of R-12 and R-152A
R-502 – Refrigerant which is azeotropic mixture of R-22 and R-115.
R-503 – Refrigerant which is azeotropic mixture of R-23 and R-13.
R-504 – Refrigerant which is azeotropic mixture of R-32 and R-115.
R-600, Butane – Low temperature application refrigerant, also used as a fuel.
R-611, Methyl Formate – Low pressure refrigerant.
R-717, Ammonia – Popular refrigerant for industrial refrigerating systems; also a popular absorption system refrigerant.
R-764, Sulphur Dioxide – Low pressure refrigerant used extensively in the 1920s and 1930s. Not in use at present; chemical is often used as an industrial bleaching agent.
Race (bearing) – A finished inner and outer surface in which or on which balls or rollers operate.
Raceway – The surface of the groove or path which supports the balls or rollers of a bearing roll.
Rack Shutoff – An engine protection measure involving a hydraulic fuel rack actuator installed on an engine's injection pump housing. When activated, the piston of the actuator moves the rack to the fuel "off " position.
Radial – A type of cylinder arrangement in an engine where the cylinders are placed radially like wheel spokes.
Radial Clearance (radial displacement) – The clearance within the bearing and between the balls and races, perpendicular to the shaft.
Radial Load – A "round-the-shaft" load; that is, one that is perpendicular to the shaft through the bearing.
Radiator – A heat exchanger in which cooling water gives up heat to the air without coming into direct contact with it.
Radiator Cooling – A type of cooling system used on generator sets which involves a fan forcing air through an engine's radiator, lowering the temperature of the coolant.
Radius – The distance from the center of a circle to its outer edge or the straight line extending from the center to the edge of a circle.
Random Wound – The type of winding style which refers to flexible bundles of main stator winding with round wire.
Rate Schedule – Price list showing how the utility will bill a class of customers.
Rated – The advertised value of an engine when full load is removed, expressed as a percentage of full load speed.
Rated Horsepower – Value used by the engine manufacturer to rate the power of his engine, allowing for safe loads, etc.
Ratio – The relation or proportion of one number or quantity to another.
Reactive Droop Compensation – One method used in paralleled generator sets to enable them to share reactive power supplied to a load. This system causes a drop in the internal voltage of a set when reactive currents flow from that generator. Typically, at full load, 0.8 PF, the output voltage of a set is

reduced by 4% from that at no load when reactive droop compensation is used.
Reactive Power – Power that flows back and forth between the inductive windings of the generator and the inductive windings of motors, transformers, etc., which are part of the electrical load. This power does no useful work in the electrical load nor does it present load to the engine. It does apply load to the generator and limits the capacity of the generator.
Ream – To finish a hole accurately with a rotating fluted tool.
Rebore – To bore a cylinder to a size slightly larger than the original.
Reciprocating Action (motion) – A back-and-forth (alternating) movement.
Reciprocating Engine – A type of engine where pistons with pressurized gas move back and fourth (reciprocate) within the cylinders).
Rectifier – A device which exhibits a very high resistance to the flow of current in one direction and a very low resistance to flow in the opposite direction. Rectifiers are used to change AC voltages to DC before applying it to the generator field.
Reduction of Area – The difference between the original cross sectional area and that of the smallest area at the point of rupture. It is usually stated as a percentage of the original area, also called "contraction of area."
Rectifier Assembly – An electronic device which rectifies AC current (produced by exciter rotor winding) to DC current and applies it to the revolving field winding.
Refrigerant – Substance used in refrigerating mechanism to absorb heat in evaporator coil by change of state from a liquid to a gas, and to release its heat in a condenser as the substance returns from the gaseous state back to a liquid state.
Refrigerant Charge – Quantity of refrigerant in a system.
Refrigerating Effect – The amount of heat in Btu/h or Cal/hr the system is capable of transferring.
Refrigeration – The process of transferring heat from one place to another by the change in state of a liquid.
Refrigeration System – A system composed of parts necessary to accomplish heat transfer by the change in state of the refrigerant.
Refrigeration-Absorption – Refrigerating effect produced by the change in pressure in the system produced by the changes in the ability of a substance to retain a liquid dependent upon the temperature of the substance.
Refrigeration-Mechanical – Refrigerating effect produced by the changes in pressure in the system produced by mechanical action of a compressor.
Regulator – An electronic device which senses AC current, compares current to a set value, rectifies AC to DC and applies it to the exciter stator winding in order to maintain constant output voltage in the main stator winding. *(See VR1, 2, 3, 4)*
Regulator, Electrical – An electromagnetic or electronic device used to control generator voltage.
Relative Humidity – Ratio of the amount of water vapor present in air to the greatest amount possible at the same temperature.
Relay – An electromagnetic switch which utilizes variation in the strength of an electric circuit to affect the operation of another circuit.
Relief Valve – An automatic valve which is held shut by a spring of correct strength. Excess pressure opens the valve and releases some of the gas or liquid. This valve is for protecting filters, air tanks, etc. from dangerous pressures.

REMAN *Remanufactured*
Remanufactured Extended Coverage – A Caterpillar program which protects buyers from repair expenditures beyond the standard warranty period on remanufactured truck engines.
Residual Fuel – A fuel resembling tar and containing abrasive and corrosive substances. It is composed of the remaining elements from crude oil after the crude has been refined into diesel fuel, gasoline, or lubricating oil.
Resistance, Electrical – The opposition offered by a body when current passes through it.
Resistor – A device placed in a circuit to lower the voltage, to reduce the current, or to stabilize the voltage.
Response Check – A measure of the engine's ability to develop increasing torque at constant speed.
Response Check Idle Speed – The engine speed specified for the cool-down portion of the response check.
Response Check Speed – The constant engine speed at which the engine is loaded to determine the time to develop a specified torque.
Response Time – A measure of the time required for an engine to develop a specified torque or power.
Retard (injection timing) – To set the timing so that injection occurs later than TDC or fewer degrees before TDC.
Reverse Flush – To pump water or a cleaning agent through the cooling system in the opposite direction to normal flow.
Reverse Power Relay – A device which is sensitive to the current flow direction. Reverse currents trip the relay, activating auxiliary switches that control the circuit breaker and/or alarm devices.
Reverse Rotation – An engine condition caused by a transmission shift from forward to reverse, or vice versa, when sufficient engine torque is not available at idle speed to overcome propeller and driveline inertia. It causes the engine to stall or reverse itself.
Reverse VAR Relay – Detects VAR flow into generator set (leading power factor). This condition occurs in a paralleled generator set if the system is not adjusted properly or a failure has occurred in the excitation system.
Revolutions per Minute (rpm) – The number of revolutions an engine's crankshaft makes in one minute.
RFI *Radio Frequency Interference*
RH *Right Hand*
Rheostat – A device to regulate current flow by varying the resistance in the circuit.
Rimmed Steel – An incompletely deoxidized steel normally containing less than 0.25 % carbon and having the following characteristics: (a) During solidification an evolution of gas occurs sufficient to maintain a liquid ingot top ("open" steel) until a side and bottom rim of substantial thickness has formed. If the rimming action is intentionally stopped shortly after the mold is filled, the product is termed capped steel. (b) After complete solidification, the ingot consists of two distinct zones: a rim somewhat purer than when poured and a core containing scattered blowholes with a minimum amount of pipe and having an average metalloid content somewhat higher than when poured and markedly higher in the upper portion of the ingot.
Ring Groove – A groove machined in the piston to receive the piston ring.
Ring Job – The service work on the piston and cylinder including the installation of new piston rings.

Risers – Bus bars that connect circuit breakers to the system bus.
Rivet – A soft-metal pin having a head at one end.
Rocker Arm – A first-class lever used to transmit the motion of the pushrod to the valve stem.
Rocker Arm Shaft – The shaft on which the rocker arms pivot.
Rockwell Hardness – A measurement of the degree of surface hardness of a given object by pressing a steel ball or diamond cone into a sample and using scales which indicate differences between depths penetrated by major and minor loads.
Rod – Refers to a connecting rod.
Roller Bearing – An antifriction bearing using straight (cupped or tapered) rollers spaced in an inner and outer ring.
Roller Tappets (Roller Lifters) – Refers to valve lifters having a roller at one end which is in contact with the camshaft and is used to reduce friction.
Roots Blower – An air pump or blower similar in principle to a gear-type pump.
Rope Brake – A friction brake used for engine testing.
Rotary Blower – Any blower in which the pumping element follows rotary motion, centrifugal blowers being the exception.
Rotary Compressor – Mechanism which pumps fluid by using rotating motion.
Rotary Motion – A circular movement, such as the rotation of a crankshaft.
Rotating Engine or Turbine – An engine which sends pressurized gas through a wheel, forcing it to turn.
Rotation of Engine – The direction of rotation of the engine flywheel as viewed from the rear of an engine, usually expressed as clockwise or counterclockwise. The rotation of an engine is normally counterclockwise.
Rotor – Rotating valve or conductor for carrying fluid or electrical current from a central source to the individual outlets as required.
Roughing Stone (hone) – A coarse honing stone.
rpm *Revolutions per minute*
Rudder – A vertically hinged plate mounted at the rear of a vessel used for directing or altering its course.
Runbacks – Bus extensions from the circuit breaker that provided a location for connection of the cables coming from a generator set.
Running-fit – A machine fit with sufficient clearance to provide for expansion and lubrication.
S *Single turbocharger*
SAE *Society of Automotive Engineers*
SAE Horsepower (Rated Horsepower) – Formula to determine power: bore diameter ^{2} x number of cylinders/2.5 = hp
SAE Viscosity Numbers – Simplified viscosity ratings of oil based on Saybolt viscosity.
Safety Factor – Providing strength beyond that needed as an extra margin of insurance against parts failure.
Sand Blast (Glass Blast) – A cleaning method using an air gun to force the sand at low pressure (about 150 psi) against the surface to be cleaned.
Saturation – A condition existing when a substance contains the maximum of another substance for that temperature and pressure.
SC *Speed Control*
SCA *Supplemental Coolant Additives*

Scab – A rough projection on a casting caused by the mold breaking or being washed by the molten metal or occurring where the skin from a blowhole has partly burned away and is not welded.
Scale – A flaky deposit occurring on steel or iron. Ordinarily used to describe the accumulation of minerals and metals accumulating in an engine cooling system.
Scavenging – The displacement of exhaust gas from the cylinder by fresh air.
Scavenging Air – The air which is pumped into a cylinder to displace exhaust gas.
Scavenging Blower – A device for pumping scavenging air.
Scavenging Pump – A piston-type pump delivering scavenging air to an engine.
Scheduled Oil Sampling (S•O•S) – A Cat service which offers insight into engine wear through periodic analysis of oil samples.
Score – A scratch, ridge or groove marring a finished surface.
Scraper Ring – An oil control ring.
Screw – Another name for the propeller.
Screw Extractor – A device used to remove broken bolts, screws, etc. from holes.
S-Curve – The curve that results from plotting the time for austenite transformation against the temperature at which the transformation takes place. These curves were originally developed by Davenport & Bain and reported in their paper entitled "Transformation of Austenite and Constant Subcritical Temperatures."
SE (Excitation Type) – A self-excited generator where residual magnetism found in the revolving field lamination initiates current flow in the main stator winding.
Sealed Bearing – A bearing which is lubricated and sealed at the factory and which cannot be lubricated during service.
Sealed Unit – (See *Hermetic System)* A motor-compressor assembly in which motor and compressor operate inside a sealed dome or housing.
Seam – A crack on the surface of metal which has been closed but not welded, usually produced by blowholes which have become oxidized. If very fine, a seam may be called a hair crack or hair seam.
Seat – A surface, usually machined, upon which another part rests or seats. For example, the surface upon which a valve face rests.
Seat (Rings) – Rings fitted or seated properly against the cylinder wall.
Second Law of Thermodynamics – Heat will flow only from material at certain temperature to material at lower temperature.
Secondary Distribution System – A low-voltage, alternating-current system which connects the secondaries of distribution transformers to the customer's services.
Sediment – Solid impurities in a liquid.
Segregation – Steel is a mixture of compounds and elements which, when cooled from the molten state, solidify at different temperatures. Segregation is the resulting concentration of the various ingredients in different parts of the ingot with the maximum concentration generally found at the base of the pipe.
Selective Energy System – The name previously used to describe a form of cogeneration in which part, but not all of the site's electrical needs were met

with on-site generation with additional electricity purchased from a utility as needed.
Self Excited (SE) – Excitation Type — Generator where residual magnetism found in the revolving field lamination initiates current flow in the main stator winding.
Semiconductor – An element which is neither a good conductor nor a good insulator.
Semifloating Piston Pin – A piston pin which is clamped either in the connecting rod or piston bosses.
Sensible Heat – Heat which causes a change in temperature of a substance.
Separate Circuit AfterCooled (SCAC) – Removal of the aftercooler from the jacket water circuit, and provision of cooling from an independent source. It is necessary on all turbocharged engines and high temperature jacket water systems used in heat recovery applications.
Separate Circuit Aftercooler – A heat exchanger for cooling combustion air cooled by a source of water external to the engine.
Separator, Battery – A porous insulation material placed between the positive and negative plates.
Separator, Oil – A device used to separate refrigerant oil from refrigerant gas and return the oil to the crankcase of the compressor.
Series Boost – An additional electronic device added into the generator power system which provides a power source for approximately 10 seconds after a short occurs to allow protective trip devices to function correctly.
Series Circuit – An electric circuit wired so that the current must pass through one unit before it can pass through the other.
Series-Parallel Circuit – A circuit with three or more resistance units in a combination of a series and a parallel circuit.
Service Area – Territory in which a utility system is required or has the right to supply electric service to ultimate customers.
Serviceable Hermetic – Hermetic unit housing containing motor and compressor assembled by use of bolts or threads.
Shaft – The shaft that connects the reduction gear, marine transmission, to the propeller
Shaft Alley – A watertight casing covering propeller shaft, large enough to walk in, extending from the engine room to after peak bulkhead, to provide access and protection to shaft in way of after cargo holds.
Shaft Horsepower – Power delivered at the engine crankshaft. This term is commonly used instead of *brake horsepower* to express output of large marine engines.
Shell-Type Condenser – Cylinder or receiver which contains condensing water coils or tubes.
Shell-and-Tube Flooded Evaporator – Device which flows water through tubes built into cylindrical evaporator or vice-versa.
Shim – A thin, flat piece of brass or steel used to increase the distance between two components.
Short Circuit – A circuit whose resistance is reduced in power owing to one or more coil layers contacting one another.
Shrink-Fit – A fit between two components made by heating the outer component so that it will expand and fit over the inner component. As the outer component cools, it shrinks and thereby fits tight to the inner component.

Shroud – The enclosure around the fan, engine, etc., which guides the airflow.
Shunt – A parallel circuit where one resistance unit has its own ground.
Shunt Trip – Feature modification allows for tripping the breakers with an electrical signal from a remote location.
Shunt Winding – A resistance coil with its own ground.
Shutoff Valve – A valve which opens and thereby stops the flow of a liquid, air, or gas.
SI *Spark Ignited*
Significant Figures – The number of digits in a number defining the precision of the number.
Silencer – A device for reducing the noise of intake or exhaust.
Silica Gel – Chemical compound used as a drier, which has the ability to absorb moisture when heated. Moisture is released and the compound may be reused.
Silicon-Controlled Rectifier (SCR) – A device that passes current in one direction only, like an ordinary rectifier, but includes a switch to control the current flow.
Single Element (SE) – Number of elements in an assembly, especially filters.
Single Phase – An AC system having one voltage of given frequency.
Single Voltage – Term used to denote 4-lead unit — 480V or 600V.
Single-Acting Cylinder – An actuating cylinder in which one stroke is produced by pressurized fluid, and the other stroke is produced by some other force, such as gravity or spring tension.
Sliding-Fit – Where sufficient clearance has been allowed between the shaft and journal to allow free running without overheating.
Slip-In Bearing – A liner made to precise measurements which can be used for replacement without additional fitting.
Slobber – Unburned lubricating oil or fuel discharged into the exhaust system along with exhaust gasses.
Slot Cell – Passage into which magwire is inserted. Either in stator lamination or revolving field lamination.
Slot Fill – Calculated and actual percentage area of the wire. Compared to the available slot area in the lamination minus the slot and coil insulation.
Slot Liners – Insulation between top and bottom magwire coil in slot passage.
Slot Separator – The insulation between top and bottom magwire coil in the slot passage.
Sludge – A composition of oxidized petroleum products along with an emulsion formed by the mixture of oil and water. This forms a pasty substance and clogs oil lines and passages and interferes with engine lubrication.
Small Brushless – The existing line of small generators; 360, 440, and 580 frames; where customer line lead connection and regulator assembly is covered with a top-mounted, front-covered terminal box.
Small Power-Production Facility – As defined in the Public Utility Regulatory Policies Act (PURPA), a facility that produces energy solely by using as a primary energy source, biomass, waste, renewable resources, or any combination thereof, and has a power production capacity that, together with any other facilities located at the same site (as determined by the Commission), is not greater than 80 megawatts.

Snap Ring – A fastening device in the form of a split ring that is snapped into a groove in a shaft or in a groove in a bore.
Snubbers – Material used to absorb energy produced by a sudden change in motion.
Sodium Valve – A valve designed to allow the stem and head to be partially filled with metallic sodium.
Solar Cell –A photovoltaic cell that can convert light directly into electricity. A typical solar cell uses semiconductors made from silicon.
Solenoid – An electrically magnetic device used to do work.
Solid Injection–The system used in diesel engines where fuel as a fluid is injected into the cylinder rather than a mixture of fuel and air.
Solid Water System – A type of high temperature heat recovery system. Also known as ebullient system.
Solvent – A solution which dissolves some other material. For example, water is a solvent for sugar.
Sorbite – A late stage in the tempering of martensite when the carbide particles have grown so that the structure has a distinctly granular appearance. Further and higher tempering causes globular carbides to appear clearly.
S•O•S *Scheduled Oil Sampling*
Sound Attenuated (SA) – A term used to describe a generator set enclosure which has been specially designed to reduce the amount and severity of escaping noise.
Sound Power Level – The total sound power being radiated from a source, such as a generator set. The magnitude of the sound is independent of the distance from the source.
Space Heaters – Heating elements mounted in the unit to keep windings warm during shutdown periods which eliminate condensation on the electric components.
Spark Ignited Engine – For purposes of this specification, Spark Ignited Engine is synonymous with Gaseous Fueled Engine.
Spark Testing – An inspection method for quickly determining the approximate analysis of steel. It is intended primarily for the separation of mixed steel and, when properly conducted, is a fast, accurate, and economical method of separation. It consists in holding the sample against a high speed grinding wheel and noting the character and color of spark, which is compared with samples of known analysis.
Specific Fuel Consumption – The fuel rate divided by the power. Corrected specific fuel consumption is the value obtained when the corrected fuel rate is divided by corrected power.
Specific Gravity – The ratio of the weight of a given volume of any substance to that of the same volume of water.
Specific Heat – Ratio of quantity of heat required to raise the temperature of a body one degree to that required to raise the temperature of an equal mass of water one degree.
Specification Sheet – A technical overview of a particular engine or engine-related product. Sales features, engine specifications, performance data and curves, dimensions and weight, standard and accessory equipment, and rating definitions and conditions are among the standard contents.
Spline – A long keyway. The land between two grooves.

Split System –Refrigeration or air-conditioning installation which places condensing unit outside or remote from evaporator. Also applicable to heat pump installations.
Spool Valve – A hydraulic directional control valve in which the direction of the fluid is controlled by means of a grooved cylindrical shaft (spool).
Spot Weld – To attach in spots by localized fusion of the metal parts with the aid of an electric current.
Spur Gear – A toothed wheel having external radial teeth.
sq ft *square foot*
sq in *square inch*
Squish Area – The area confined by the cylinder head and flat surface of the piston when on compression stroke.
SR *Slave Relay*
STA *Series Turbocharged-Aftercooled*
Stability – The resistance of a fluid to permanent change such as that caused by chemical reaction, temperature changes, etc.
Stabilized – The steady or cyclic condition of an engine performance characteristic which remains unchanged with time while the engine is running under a given steady state condition.
Standard Atmosphere – Condition when air is at 14.7 psia pressure, at 68° F temperature.
Standard Conditions – Used as a basis for air-conditioning calculations. Temperature of 68° F, pressure of 29.92 in Hg and relative humidity of 30 percent.
Standby Capacity – The capacity that is designed to be used when part or all of the prime source of power is interrupted.
Standby Power – Output available with varying load for the duration of the interruption of the normal source power. Fuel
stop power in accordance with ISO3046/1, AS2789, DIN6271, and BS5541.
Standby Rate – The utility charge for standby electricity.
Starboard The right side of a ship, when facing the front of the ship.
Starting Air – Compressed air used for starting an engine.
Starting-Air Valve – A valve which admits compressed starting air to the cylinder.
Static Electricity – Electricity at rest; pertaining to stationary charges.
Static Fuel System Setting – A setting of a fuel system, either mechanical or electronic, made in an attempt to obtain the desired fuel rate at a particular engine operating point. Settings are normally made to provide either full load fuel rate or the fuel rate at torque check rpm. They are identified respectively as Full Load Static Fuel Setting (FLSFS) or Full Torque Static Fuel Setting (FTSFS).
Static Head – The maximum height the coolant water is raised.
Static Pressure – The pressure exerted against the inside of a duct in all directions. Roughly defined as *bursting pressure.*
Stator – The fixed or stationary portion of a generator.
Staybolt – A stress bolt running diagonally upward from the bedplate to the opposite side of the frame.
STD *Standard*
Steady Flow – A flow in which the velocity components at any point in the fluid do not vary with time.
Stem – The point of the hull at the bow, where port and starboard sides meet, extending from keel to forecas-tle deck.

Stern – The back part of a ship, where the two sides meet. To move in that directions is to go aft.
Stern Strut – A device used to help support the propeller and propeller shaft.
Stern Tube – The part of the ship where the prop shaft goes through the hull of the ship.
Stethoscope –A device for conveying the sound of a body (engine noise) to the technician.
Straightening – Cold finished bars may require straightening following cold drawing, turning, or furnace treatment in order to meet the standard established for the particular type or grade being produced. These bars may be straightened by several different types of equipment designed to deflect the bar so that equalizing stresses are set up in the bar which keep it straight. See *Irregular Straightener*s, and *Medart, Punch Press.*
Streamline Flow – A nonturbulent flow, essentially fixed in pattern.
Stress – The force or strain to which a material is subjected.
Stress Relief – A method of relieving the internal stress set up in metal by forming or cooling operations. It consists in heating to a temperature of approximately 1050° F for a sufficient length of time to through heat the part, and cooling in air.
Stroboscope (timing light) – An instrument used to observe the periodic motion of injection visible only at certain points of its path.
Stroke – A single movement (usually repeated continuously) of a piston within a cylinder from one end of its range to the other; constitutes a half revolution of an engine.
Stroke-to-Bore Ratio – The length of the stroke divided by the diameter of the bore.
Structural Shapes – The general term applied to the rolled, flanged sections having at least one dimension of their cross section 3 inches or greater.
Stud –A rod with threads cut on both ends, such as a cylinder stud which screws into the cylinder block on one end and has a nut placed on the other end to hold the cylinder head in place.
Stud Puller – A device used to remove or to install stud bolts.
Stuffing Box – A chamber having a manual adjustment device for sealing.
Subcooling – Cooling of liquid refrigerant below its condensing temperature.
Suction – Suction exists in a vessel when the pressure is lower than the atmospheric pressure, also see *Vacuum.*
Suction Line – Tube or pipe used to carry refrigerant gas from evaporator to compressor.
Suction Valve – Often used interchangeably with *intake valve.*
Sulfur – An undesirable element found in petroleum in amounts varying from a slight trace to 4 or 5 percent.
Sulfur Dioxide (SO_2) – An engine emission made up of the oxidized portion of sulfur in fuel.
Sump – A receptacle into which liquid drains.
Sump Pump – A pump which removes liquid from the sump tank.
Supercharger –A blower or pump which forces air into the cylinders at higher-than-atmospheric pressure. The increased pressure forces more air into the cylinder, thus enabling more fuel to be burned and more power produced.
Superficial Hardness – Measure of the degree of surface hardness with a more sensitive depth measuring system than is used with regular Rockwell

machines. It is recommended for use on thin strip or sheet material, nitrided or lightly carburized pieces.
Superstructure – The part of the ship above the main deck.
Supplemental Thermal – The heat required when recovered engine heat is insufficient to meet thermal demands.
Supplementary Firing – The injection of fuel into the recovered heat stream (such as turbine exhaust) to raise the energy content (heat of the stream).
Supplementary Power – Electric energy supplied by an electric utility in addition to that which the facility generates itself.
Supply Line – A line that conveys fluid from the reservoir to the pump.
Surge – A momentary rise and fall of pressure or speed in a system or engine.
Switchgear – The equipment between a generator and the lines of distribution that switches the electrical load to and from a generator, protects the generator from short circuits, monitors generator output, provides the means to parallel two or more units onto the system, and controls the operation of the engine.
Synchronization – The act of matching a generator set's frequency and phase with that of the system bus, before paralleling the set.
Synchronize – To make two or more events or operations occur at the proper time with respect to each other.
Synchronizer – An electronic device that monitors the phase relationship between two voltage sources and provides a correction signal to an engine governor, to force the generator set to synchronize with a system bus.
Synchronizing Check Relay – A device used in conjunction with both types of circuit breakers to assure that the incoming unit is within specified voltage and frequency limits before paralleling is accomplished.
Synchronizing Lights – Lamps connected across a circuit breaker of a generator set. The lights indicate when the voltage wave forms of the incoming and operating power sources coincide and paralleling can be completed. When the lights fade from light to dark, and they are at their darkest, the two sources are synchronized and paralleling can be accomplished.
Synchronous – Recurring operation at exactly the same time. The speed at which a rotating AC electrical machine would rotate if there were no slip. Example: Four-pole, 60 Hz generator has a synchronous speed of 1800 rpm.
Synchroscope – A meter that indicates the relative phase angle between an incoming set voltage and the bus voltage. The synchroscope pointer indicates whether the set is faster or slower than the bus and allows the operator to adjust the frequency (speed) accordingly before manually paralleling to the bus.
Synthetic Material – A complex chemical compound which is artificially formed by the combining of two or more compounds or elements.
System Shutdown – On the EMS II module, a flashing red light and a horn annunciate if the ECM initiates a system controlled emergency shutdown or if there is an active system fault. This may be an overspeed, low oil pressure, or high coolant temperature shutdown.
System Voltage – On the EMS II module, a flashing red light and a horn annunciate when the DC system falls below 20 volts.
T *Turbocharged*
TA *Turbocharged-Aftercooled*

Tachometer – An instrument indicating rotating speeds. Tachometers are sometimes used to indicate crankshaft rpm.
Tap – A cutting tool used to cut threads in a bore. (See *Chamfer*.)
Tap and Die Set – A set of cutting tools used to cut internal and external threads.
Tapered Roller Bearing – See *Roller Bearing.*
Tappet – The adjusting device for varying the clearance between the valve stem and the cam. May be built into the valve lifter in an engine or may be installed in the rocker arm on an overhead valve engine.
Tappet Noise – The noise caused by the excessive clearance between the valve stem and the rocker arm.
TC *Top Center*
TDR *Time Delay Relay (ESS)*
Temper – The condition of a metal with regard to harness achieved through heating and then suddenly cooling.
Temper Brittleness – The term applied to the brittleness or low impact resistance that may occur in medium carbon and many alloy steels that are slowly cooled from the tempering temperature. It may be corrected by water quenching after tempering. Molybdenum in amounts of 25% to 50% tend to retard the formation of temper brittleness.
Temperature of Compression – The temperature of the compressed air charge in a power cylinder at the end of the compression stroke before combustion begins.
Temporary Hardness – Dissolved substances which precipitate out when water is heated.
Tensile Strength – The maximum load in pounds per square inch that the sample will carry before breaking under a slowly applied gradually increasing load. In the stress/strain diagram, this is the highest point on the curve and is probably the most used steel specification.
Tension – Stress applied on material or body.
Terminal – The connecting point (post) of a conductor.
T-head Engine – An engine design wherein the inlet valves are placed on one side of the cylinder and the exhaust valves are placed on the other.
Theory – A scientific explanation tested by observations and experiments.
Thermal Capacity – The maximum amount of heat that a system can produce.
Thermal Efficiency – A gallon of fuel contains a certain amount of potential energy in the form of heat when burned in the combustion chamber. Some of this heat is lost and some is converted into power. The thermal efficiency is the ratio of work accomplished to the total quantity of heat in the fuel. (See also *Brake Thermal Efficiency* and *Indicated Thermal Efficiency.)*
Thermal Expansion – The increase of volume of a substance caused by temperature change.
Thermal Growth – The tendency for materials to expand when exposed to heat. Exhaust piping of a generator set undergoes this phenomenon.
Thermocouple – The part of a pyrometer which consists of two dissimilar metal wires welded together at the inner end and held in a protective housing.
Thermodynamics –

> **1st law of:** Energy can neither be created nor destroyed — it can only be changed from one form to another.
> **2nd law of:** To cause heat energy to travel, a temperature (heat intensity) difference must be created and maintained.

Thermometer – An instrument for measuring temperature.
Thermostat – A temperature-responsive mechanism used for controlling heating systems, cooling systems, etc. (such as between the cylinder block and the radiator) usually with the object of maintaining certain temperatures without further personal attention.
Thimbles – Separate the exhaust pipe from walls or ceiling to provide mechanical and thermal isolation.
Three Phase – An AC system having three voltages of the same frequency but displaced in phase by 120 degrees relative to another.
Throttling – Reducing the engine speed (flow of fuel).
Throw – The distance from the center of the crankshaft main bearing to the center of the connecting rod journal.
Thru-Bolt – Term usually applied to the stress rod passing through the engine frame to carry combustion stresses.
Thrust Bearing (Washer) –A bearing or washer of bronze or steel which restrains endwise motion of a turning shaft, or withstands axial loads instead of radial loads as in common bearings.
Thrust Load – A load which pushes or reacts through the bearing in a direction parallel to the shaft.
Thyristor Control – A method of powering a DC motor by an AC generator.
TIF *Technical Information File*
Time-Of-Use Rates – Electricity prices that vary depending on the time periods in which the energy is consumed. In a time-of-use structure, higher prices are charged during utility peak-load times.
Timing (Diesel) – The angular position of the crankshaft relative to top dead center at the start of injection.
Timing Gears – Gears attached to the crankshaft, camshaft, idler shaft, or injection pump to provide a means to drive the camshaft and injection pump and to regulate the speed and performance.
Timing Marks – The marks located on the vibration damper, flywheel, and throughout an engine to check injection and valve opening timing.
Timing (Spark Ignited) – The angular position of the crankshaft relative to top dead center at the time the spark plugs are energized.
TMI *Technical Marketing Information*
Tolerance – A permissible variation between the two extremes of a specification of dimensions. Used in the precision fitting of mechanical parts.
Ton – 12,000 Btu/Hour.
Ton of Refrigeration – Refrigerating effect equal to the melting of one ton of ice in 24 hours. This may be expressed as follows: 288,000 Btu/24 hr, 12,000 Btu/1 hr, 200 Btu/min, 3.52 kW
Top Center (TC) – The position of the crankshaft at the time the piston is at its highest position.
Top-Down – Must meet the most stringent law, but, based on environmental, energy, and economic considerations could step down to a less stringent law.
Topping-Cycle – A cogeneration facility in which the energy input to the facility is first used to produce useful power, with the heat recovered from power production then used for other purposes.
Torque – A measure of the tendency of a force to cause rotation, often used in engine specifications. Equal to the force multiplied by the perpendicular distance between the line of action of the force and the center of rotation.
Torque at TC rpm – The steady state torque developed by an engine at the torque check speed.

Torque Check Speed – The speed at which an engine is run to check the low speed performance characteristics.
Torque Curve or Lug Curve – A performance map created for a diesel engine, using high idle setting and rack setting values.
Torque Shaping – A way to optimize engine response through control of horsepower at a given engine speed.
Torque Wrench – A special wrench with a built-in indicator to measure the applied turning force.
Torsional Study – An analysis used to predict operating characteristics of the vibrating system of an engine, which includes pistons, rods, the crankshaft, the flywheel, coupling, the driven equipment, and associated shafting.
Torsional Vibration – The vibration caused by twisting and untwisting a shaft.
Total Energy Systems – The name previously used to refer to a form of cogeneration in which all electrical and thermal energy needs were met by on-site systems. A total energy system was usually completely isolated from or completely served by the electrical utility system for back-up. Generally a user was not served simultaneously by the electric utility grid and the cogenerator.
Transducer – A device for converting a variable physical parameter to a proportional electrical signal. The inputs can be temperature, pressure, position, voltage, current, or any other physical parameter. Outputs are typically 4-20 ma, 0-10 volts or some other signal easily accommodated by instruments and controlling devices.
Transfer Pump – A mechanical device for moving fuel from one tank to another or bringing fuel from the tank to the injection pump.
Transfer Switch – An electrical device for switching loads between alternate power sources. An automatic transfer switch monitors the condition at the sources and signals for starting of the emergency system if the preferred source fails. When the emergency source is available the load is switched. Upon return of the normal source the load is retransferred to normal power and the start signal is removed.
Transformer – A device used to convert from one voltage level to another with very little loss of power.
Transmission – The act or process of transporting electric energy in bulk from a source or sources of supply to other principal parts of the system or to other utility systems.
Trap – A receptacle often installed at the lowest point in generator set exhaust piping to drain moisture that could reach and damage the system's silencer.
TRG *Time Requirement Guide*
Trichlorotrifluoroethane – Complete name of refrigerant R-113. Group 1 refrigerant in rather common use. Chemical compounds which make up this refrigerant are chlorine, fluorine, and ethane.
Trim – The relationship between the fore and aft draft. A ship properly balanced fore and aft is in trim, other-wise she is down by the headop down by the stern.
Trip Unit – Adevice within a low voltage circuit breaker that provides overcurrent protection.

Troostite –A microconstituent of hardened and tempered steel which etches rapidly and therefore usually appears dark. It consists of a very fine aggregate of ferrite and cementite and is normally not resolved under the microscope.
Tropicalization – Thoroughly insulating rotor and stator with epoxy to provide high insulating and mechanical properties under severe moisture and temperature conditions.
Troubleshooting – A process of diagnosing or locating the source of the trouble or troubles from observation and testing. Also see *Diagnosis.*
TT *Twin Turbocharged*
TTA *Twin Turbocharged-Aftercooled*
Tube Cutter – A tube-cutting tool having a sharp disk which is rotated around the tube.
Tubing – That type of fluid line whose dimensions are designated by actual measured outside diameter.
Tune-Up – The act of checking, testing, measuring, repairing, and adjusting the engine components in order to bring the engine to peak efficiency.
Turbine – An engine or motor having a drive shaft driven either by steam, water, air, gas, etc., against curved vanes of a wheel or set of wheels, or by the reaction of fluid passing out through nozzles located around the wheel(s).
Turbine Generator – A device that uses steam, heated gases, water flow, or wind to cause spinning motion that activates electromagnetic forces and generates electricity.
Turbocharger – A type of charger driven by a turbine powered by exhaust gases.
Turbocharging – Increasing the intake air charge to a reciprocating engine by using a turbine driven by the energy of the engine's exhaust.
Turbulence – A disturbed, irregular motion of fluids or gases.
Turbulence Chamber – A combustion chamber connected to the cylinder through a throat. Fuel is injected across the chamber and turbulence is produced in the chamber by the air entering during compression.
Turning and Polishing – Whereas cold drawing reduces the cross sectional area by subjecting the bar to compressive and elongating forces, turning and polishing accomplishes the same by turning 1/16 to 3/16 inches from the diameter, depending on the bar size, usually following by polishing and straightening in a combination straightening and polishing machine.
Twist Drill – See *Drill.*
Two-Cycle Engine – An engine design permitting a power stroke once for each revolution of the crankshaft.
Two-Stage Combustion – Combustion occurring in two distinct steps such as in a precombustion chamber engine.
Two-Stroke Cycle – The cycle of events which is complete in two strokes of the piston or one crankshaft revolution.
"U" Factor – The amount of heat energy in Btu/h that will be absorbed by one square foot of surface for each degree of mean temperature difference through the surface material.
Undervoltage Relay – Operates when the monitored voltage is below the relay setpoint. It can be used to detect a failure in a power system or to indicate that a generator set is ready to be connected to a load on initial start-up.
Uniflow Scavenging – Scavenging method in which air enters one end of the cylinder and exhaust leaves the opposite end.

Uninterrupted Power Supply (UPS) – A power supply which maintains regulated power during a shortage to under- or overvoltage or no voltage.
Unit Injector – A combined fuel injection pump and fuel nozzle.
Updraft – A carburetor type in which the mixture flows upward to the engine.
***UPS** Uninterrupted Power System*
U.S. gallon [gal (U.S.)] – United States gallon (231 in 3).
Utility – A commercial power source that supplies electrical power to specific facilities from a large power grid.
Utility Grade Relay – Refers to a draw-out relay.
Utilization Factor – The ratio of the maximum demand of a system (or part of a system) to its rated capacity.
Vacuum – A perfect vacuum has not been created as this would involve an absolute lack of pressure. The term is ordinarily used to describe a partial vacuum; that is, a pressure less than atmospheric pressure — in other words a suction.
Vacuum Fluorescent (VF) – A type of visual display, often used on system control/ monitoring panels, which provides excellent visibility in a variety of lighting conditions.
Vacuum Gauge – A gauge used to measure the amount of vacuum existing in a chamber or line.
Vacuum Pump – Special high efficiency compressor used for creating high vacuums for testing or drying purposes.
Valve – Any device or arrangement used to open or close an opening to permit or restrict the flow of a liquid, gas, or vapor.
Valve Clearance – The air gap allowed between the end of the valve stem and the valve lifter or rocker arm to compensate for expansion due to heat.
Valve Duration – The time (measured in degrees of engine crankshaft rotation) that a valve remains open.
Valve Expansion – Type of refrigerant control which maintains pressure difference between high side and low side pressure in a refrigerating mechanism. Valve is caused to operate by pressure in low or suction side. Often referred to as an Automatic Expansion Valve or AEV.
Valve Face – That part of a valve which mates with and rests upon a seating surface.
Valve Float – A condition where the valves are forced open because of valve-spring vibration or vibration speed.
Valve Grinding – Also called valve lapping. A process of lapping or mating the valve seat and valve face usually performed with the aid of an abrasive.
Valve Guide – A hollow-sized shaft pressed into the cylinder head to keep the valve in proper alignment.
Valve Head – The portion of the valve upon which the valve face is machined.
Valve Keeper (valve retainer) – A device designed to lock the valve spring retainer to the valve stem.
Valve Lash – Clearance set into the valve mechanism to assure that when hot, the valve will not be held open.
Valve Lift – The distance a valve moves from the fully closed to the fully open position.
Valve Lifter – A push rod or plunger placed between the cam and the valve on an engine. It is often adjustable to vary the length of the unit. (Also see *Cam Follower.)*

Valve Margin – The distance between the edge of the valve and the edge of the face.
Valve Oil Seal – A sealing device to prevent excess oil from entering the area between the stem and the valve guide.
Valve Overlap – The period of crankshaft rotation during which both the intake and exhaust valves are open. It is measured in degrees.
Valve Rotator – A mechanical device locked to the end of the valve stem which forces the valve to rotate about 5° with each rocker-arm action.
Valve Seat – The surface on which the valve face rests when closed.
Valve Seat Insert – A hardened steel ring inserted in the cylinder head to increase the wear resistance of the valve seat.
Valve Spring – A spring attached to a valve to return it to the seat after it has been released from the lifting or opening means.
Valve Stem – That portion of a valve which rests within a guide.
Valve Stem Guide – A bushing or hole in which the valve stem is placed which allows lateral motion only.
Valve, Suction – Valve in refrigeration compressor which allows vaporized refrigerant to enter cylinder from suction line and prevents its return.
Valve Timing – The positioning of the camshaft (gear) to the crankshaft (gear) to ensure proper valve opening and closing.
Valve-in-head Engine – Same as Overhead Valve Engine.
Valve-seat Insert – A hardened steel ring inserted in the cylinder head to increase the wear resistance of the valve seat.
Vanes – Any plate, blade, or the like attached to an axis and moved by or in air or a liquid.
Vapor – Word usually used to denote vaporized refrigerant rather than the word gas.
Vapor Lock – A condition wherein the fuel boils in the fuel system, forming bubbles which retard or stop the flow of fuel to the carburetor.
Vaporization – The process of converting a liquid into vapor.
Vaporizer – A device for transforming or helping to transform a liquid into a vapor; often includes the application of heat.
***VDC** DC to DC Voltage Converter (75 to 24 Vdc)*
Vee – A type of cylinder arrangement in an engine where the cylinders form the shape of the letter "V."
Venturi – A specially shaped tube with a small or constricted area used to increase velocity and reduce pressure.
***VI** Viscosity Index*
Vibration Damper – A device to reduce the torsional or twisting vibration which occurs along the length of the crankshaft used in multi-cylinder engines; also known as a *harmonic balancer.*
Viscosity – The property of an oil by virtue of which it offers resistance to flow.
Viscosity Index (VI) – Oil decreases in viscosity as temperature changes. The measure of this rate of change of viscosity with temperature is called the *viscosity index* of the oil.
Volatile – Evaporating readily at average temperature on exposure with air.
Volatility–The tendency for a fluid to evaporate rapidly or pass off in the form of vapor. For example, gasoline is more volatile than kerosene as it evaporates at a lower temperature.
Volt (V) – A unit of electromotive force that will move a current of one ampere through a resistance of 1 ft.

Voltage – Electric potential or potential difference expressed in volts.
Voltage Adjust Potentiometer – Controls generator voltage output through the generator voltage regulator.
Voltage Dip – The momentary drop of generator output voltage that occurs whenever a load is added to the system. There is a momentary increase in output voltage whenever a load is removed from the system. This is called "Voltage Rise." "Voltage Rise" is seldom of concern with an adequate voltage regulator.
Voltage Droop – Gradual fall of voltage with increase in electrical load.
Voltage Drop – Voltage loss due to added resistance caused by undersized wire, poor connection, etc.
Voltage Flicker – Term commonly used to describe a significant fluctuation of voltage.
Voltage Regulator – A circuit which senses the generator output voltage and automatically adjusts the field coil current to maintain the desired output.
Voltmeter –A test instrument for measuring the voltage or voltage drop in an electric circuit.
Volts-per-Hertz Regulation – Providing fast recovery under block loading conditions, maintaining close voltage control over the normal load range, and producing rapid response of an engine/generator set by matching generator output to engine performance.
Volume – The amount of space within a given confined area.
Volumetric Efficiency – The difference between the volume of air drawn in on the intake stroke and the air mechanically entering the cylinder.
VOP *Valve Opening Pressure*
Vortex – A whirling movement of a mass of liquid or air.
VR3 – This new regulator replaces both VR1 and VR2 conversion of existing product line complete through 580 frame. VR3 meets all Cat premium custom specs.
VR4 – This new generator is used for alternate energy applications. Premium custom specs do not apply.
Water Brake – A device for engine testing in which the power is dissipated by churning water.
Water Jacket – The enclosure directing the flow of cooling water around the parts to be cooled.
Water Loop – The test cell water piping is plumbed to allow flow and temperature control to the evaporator, measured in tons.
Water-Cooled Condenser – Condensing unit which is cooled through use of water.
Waterline – The line where the hull meets the sur-face of the water.
Water-Steam Circuit – Piping to direct the flow of steam.
Water Vapor Pressure – The partial pressure of the water vapor in the combustion air being supplied to an engine.
Watt –The unit of measure for electrical power.
Watt-Hour Demand Meter – Similar to a watt-hour meter except that it also provides an indication of the highest kW load level achieved during operation.
Watt-Hour Meter – A recording device that totals the average power (kW) passing through it in a period of time. The reading is kilowatt hours — a measure of the total energy consumed by the load.
Wattmeter – Simultaneously measures voltage current and power factor, and automatically multiplies the results to measure true power.
Waveform – The graphic representation of a voltage plotted against time.

Wear Testing – Wear is due to several unrelated actions such as cutting, abrasion, corrosion, galling, and fatigue. In wear testing, first the type of wear developed in service is determined, then suitable laboratory equipment is developed for the test, duplicating service conditions.
Weather Protective (WP) – A type of enclosure often used for generator sets to prevent damage from natural elements.
Wet Bulb – Device used in the measurement of relative humidity. Evaporation of moisture lowers temperature of wet bulb compared to dry bulb temperature in the same area.
Wet Sleeve – A cylinder sleeve which is about 70 percent exposed to the coolant.
Wheel – Another name for the “screw” or “propeller”.
Wheel House – The area of the ship which has the controls for the rudders. This control can be a “ship’s wheel” or a “tiller”. This may or may not be the same area as the “Bridge”.
Wheeling – The use of the transmission facilities of one system to transmit power for another system.
White Smoke – The emission caused by vaporized but unburned fuel passing through an engine; usually occurs during startup of a cold engine.
Withstand Rating – The maximum current of an automatic transfer switch on a generator set a fault condition when the switch is closed and on normal service. The ATS is required to withstand the energy let through the normal service protective device while that device interrupts the fault.
Wrist Pin – The journal for the bearing in the small end of an engine connecting rod which also passes through piston walls. Also known as a *piston pin.*
Wye Connection – A means of connecting generator windings with the option of using the neutral connection.
Y2K *Year 2000*
Yield Point – The load per unit of original cross section at which, in soft steel, a marked increase in deformation occurs without increase in load. In other steels and in nonferrous metals, yield point is the stress corresponding to some definite and arbitrary total deformation, permanent deformation or slope of the stress deformation; this is more properly termed the yield strength. See *Yield Strength.*
Yield Strength – Stress corresponding to some fixed permanent deformation such as 1% or 2% offset from the modulus slope. Not to be confused with yield point which, for steel, may occur over a wide range of elongation. It is the result of an effort to obtain the equivalent of the yield point by a standard means that provide reliable, easily reproducible determination. In general, the determination may be made by the offset method or by the use of the extensometer or other appropriate measuring device.
Yoke – A link which connects two points.
Zener Diode – A diode that allows current to flow in reverse bias at the designed voltage.