Marine Analyst Service Handbook

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Caterpillar Engine Division Service Training

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This book contains a list of formulas and terms for use by qualified Caterpillar Marine Analyst. Many of the formulas are “Rules of Thumb” but they do provide guidance in their respective areas. These formulas are generally accepted in the marine field. This book is intended as an aid to the Marine Analyst and ***NOT*** a replacement for professional ship design personnel.

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Formula for Calculating Horsepower

$$\text{Horsepower} = \frac{2\,\pi r \times \text{TORQUE} \times \text{RPM}}{33000}$$

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

Average horse walks at $2\frac{1}{2}$ 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 $\times$ $2\frac{1}{2}$ MPH = 13,200 FEET per HOUR

$$\frac{13200 \text{ FT/HR}}{60 \text{ Minutes}} = 220 \text{ FEET per MINUTE}$$

220 FT/MIN $\times$ 150 POUNDS = 33,000 FT. LBS per MINUTE

$2\pi r = 6.2831853$

$$\frac{33000}{6.2831853} = 5252$$

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

$$\text{Hp} = \frac{\text{Torque} \times \text{RPM}}{5252}$$ or expressed another way as

$$\text{Torque} = \frac{\text{Hp} \times 5252}{\text{RPM}}$$

Displacement Hull Calculation

If a vessel's displacement is not known, it can be determined from the dimensions of the vessel, using the following formula.

$$W = \frac{L \times B \times D \times Cb}{M}$$

Where:

W = The vessel's displacement expressed in long tons

L = The length of the vessel, in feet, measured at the actual or designed load waterline (LWL)

B = The extreme width or beam of the vessel, in feet, at the designed load waterline.

D = The vessel's molded draft, in feet, measured at its midship section, exclusive of appendages or projections such as the keel.

Cb = The block coefficient for the vessel.

Light Cargo, Fishing Vessels and Sailing yachts	.40 – .55
Heavy Cargo, Fishing and Tugs	.50 – .65
River Tow Boats	.55 – .70
Self-propelled Barges	.70 – .90
Barges	.85 – .90

M = The volume of water (cubic feet) per long ton

35 for sea water

36 for fresh water

Horsepower Requirements for Displacement Hulls

A displacement hull is define by having a taper at the bow, a taper at the stern, and a $\frac{1}{4}$ beam buttock angle of 8 degrees or greater.

The speed which corresponds to SL = 1.34 is referred to as the displacement hull limiting speed. Attempting to power a displacement hull above this speed will cause the stern of the vessel to “drop” into its own bow wave trough, exposing the oncoming water to the underside of the vessel and entraining air in the propeller. This will effectively cause the vessel to “climb uphill” and reduce the amount of power the propeller is capable of absorbing. This occurs at an SL = 1.34 for a pure displacement vessel, and any attempt to power a displacement vessel in excess of this speed would be considered a waste of fuel and money.

Now that the limiting speed of a displacement hull is defined, we can predict the power requirements to propel displacement hulls at different speeds.

The amount of power required to drive a displacement or a semi-displacement hull of a given weight at a given speed can be approximated by the relationship of the weight to the horsepower (Lbs/Hp). This is expressed as the formula:

$$SL = \frac{10.665}{\sqrt[3]{\frac{Lbs}{Hp}}}$$

SL = Speed – Length Ratio

Hp = Horsepower Delivered to the Propeller

Lbs = Vessel Displacement in Pounds

This formula can be rewritten as :

$$\left(\frac{10.665}{SL}\right)3 = \text{Lbs/Hp}$$

Due to the bow wave limitation discussed earlier, only the portion of the SL versus Lbs/Hp relationship below 1.34 applies to displacement hulls. This implies that it would not be appropriate to power a displacement hull with more than 1 horsepower delivered to the propeller for each 504 pounds of vessel displacement.

An example of how to apply this relationship will help clear this up. Consider a pure displacement hull with the following characteristics:

Waterline length = 200 feet

Vessel displacement = 440,000 pounds loaded

Desired speed = 18 knots

$\frac{1}{4}$ beam buttock angle = 9 degrees

With a $\frac{1}{4}$ beam buttock angle of 9 degrees (greater than 8°), it can be assumed that this vessel will be subject to the speed limit of 1.34.

The next step is to see if the designed SL is within the limits established for a displacement hull, using the formula

$$SL = \frac{\text{Speed}}{\sqrt{WL}} \qquad SL = \frac{18}{\sqrt{200}} \qquad SL = 1.27$$

Since the 1.27 calculated SL is below the limit of 1.34 the speed of 18 knots for this vessel is attainable.

The next step is to determine the Lbs/Hp relationship for this boat using the design SL of 1.27. This is done using the following formula:

$$\left(\frac{10.665}{SL}\right)3 = Lbs/Hp \qquad \left(\frac{10.665}{1.27}\right)3 = 592 \text{ Lbs/Hp}$$

The power required to drive this vessel at 18 knots would then be:

$$\text{Hp} = \frac{440000 \text{ Lbs}}{592 \text{ Lbs/Hp}}$$

$$\text{Hp} = 743$$

This horsepower requirement seems low, but it must be considered that this is the required horsepower delivered to the propeller, and it does not account for losses in the shafting, marine gear, and engine. It also does not allow for reserve horsepower to allow for added resistance due to wind and waves, towing, dragging nets, power takeoffs, or other load increases, which may occur. In actuality, the installed horsepower of this vessel may be higher than the 743 Hp requirement just calculated.

Horsepower Requirements for Semi-Displacement Hulls

Because of the way these hulls ride in the water, the calculations of required horsepower uses a different formula. A semi-displacement hull is defined as having a point at the bow and tapers to a full beam at the mid-section and then partially tapers to a narrow section at its stern. A semi-displacement hull can be described as a displacement hull with a portion of its after body cut off, or a planing hull with a portion of a tapered after body added on. Semi-displacement hulls can be expected to have a $\frac{1}{4}$ beam buttock angle of between 2° and 8°.

Semi-displacement vessels have displacement hull characteristics in that they are somewhat limited in attainable speed by the bow wave phenomenon. However, semi-displacement hulls also have some planing hull characteristics, which allow them to partially "climb" or plane out of the water at higher speeds. This partial planing characteristic causes the bow wave limitation to occur at higher speed length ratios. In general, speed-length ratios fall between roughly 1.4 and 2.9 for semi-displacement vessels. Effectively, semi-displacement hulls operate at higher speeds than displacement hulls because of their partial planing characteristics, yet are not as sensitive to weight addition as a planing hull, due to their partial displacement hull characteristics. These combined characteristics allow for relatively large cargo or passenger carrying capacity at speeds higher than displacement vessels of similar size.

To determine the power requirements for a semi-displacement hull, the SL versus Lbs/Hp relationship is utilized in the same manner as with displacement hulls. The problem in applying this relationship to semi-displacement hulls, however, lies in the fact that the limiting speed-length ratios can vary between 1.4 and 2.9 for different hulls. Before attempting a power requirement calculation for a semi-displacement hull at a given speed, it is first necessary to determine the SL ratio limit for the vessel to ensure that no attempt is made to power the vessel to speeds higher than this limit.

The limiting SL ratio for a semi-displacement hull is determined by evaluating a factor referred to as the Displacement Length Ratio (DL). The DL ratio can be defined by using the following formula:

$$DL = \frac{\text{disp T}}{(.01XWL)^3}$$

Where:

DL = Displacement-length ratio

disp T = displacement in long tons (1 long ton = 2240 pounds)

WL = Waterline length in feet

Once the DL ratio has been calculated for a semi-displacement hull, the SL to DL relationship can be applied to determine the limiting SL ratio. This SL ratio will then define the maximum attainable speed of the semi-displacement hull. No attempt should be made to power a vessel over this maximum attainable speed, as this is the point where the bow wave limitation occurs an a semi-displacement hull.

The limiting SL can be defined using the following formula:

$$SL\ ratio = \frac{8.26}{DL^{.311}}$$

Where:

SL ratio = Speed-length ratio

DL ratio = Displacement-length ratio

8.26 = constant used by Caterpillar for this calculation

The following example will help explain how to apply the formulas for calculating the horsepower required for a semi-displacement hull.

Let's use the following for boat characteristics:

WL	=	62 feet
$\frac{1}{4}$ beam buttock angle	=	3°
Displacement tons	=	44 Long tons (98,560 pounds)
Designed speed	=	11.5 knots
Beam width	=	18 feet at mid-section, tapering to 15 feet at the stern.

Based on this information (3° and slight taper) we can recognize a semi-displacement hull. Since this is a semi-displacement vessel and the DL ratio applies, the DL ratio must first be calculated in order to determine the limiting SL ratio for this vessel. The DL ratio is calculated in the following formula:

$$DL = \frac{44}{(.01 \times 62)^3}$$

$$DL = 184.6 \approx 185$$

$$SL = \frac{8.26}{(185)^{.311}}$$

$$SL = 1.628 \approx 1.63$$

Any speed used in predicting a power requirement for this vessel must correspond to an SL less than 1.63. 1.63 SL ratio corresponds to the maximum possible speed of this vessel due to bow wave limitation.

Since the maximum SL ratio is 1.63 has been calculated the next step is to determine the power required to drive the vessel 11.5 knots. As a check before proceeding, the SL ratio corresponding to the design speed of the boat should be calculated to ensure that it is less than the maximum attainable SL of 1.63.

$$SL = \frac{11.5}{\sqrt{62}}$$

$$SL = 1.46$$

Since 1.46 is less than 1.63, it is appropriate to try to power this vessel for 11.5 knots. If the SL had been greater than the 1.63 maximum attainable SL then the design speed of the vessel would have to be reduced before attempting a power prediction.

Know that we have the design SL (1.46) we can go to the formula used in the displacement hull problem. That formula was:

$$LB/Hp = \left(\frac{10.665}{SL}\right)^3$$

$$LB/Hp = \left(\frac{10.665}{1.46}\right)^3$$

$$LB/Hp = 389.8 \approx 390$$

$$HP = \frac{98560 \text{ Lbs for vessel}}{390 \text{ LB/Hp}}$$

$$Hp = 252.7 \approx 253 \text{ Hp}$$

So to power this vessel to the 11.5 knots design speed it would need 253 Hp to the propeller. This is only for the movement of the vessel through the water and does not take into account auxiliary driven equipment, rough seas, or strong currents. There for the actual Hp of the engine in the boat maybe larger than this calculation, due to the reserve Hp requirements.

Horsepower Requirements for Planing Hulls

A planing hull is a hull of a form which allows it to climb up on a full plane at high speeds. When up on a full plane, the reduced draft of the vessel causes the bow wave to become very small, and they do not limit the speed of the boat as with displacement and semi-displacement hulls. Because of the reduced draft and lack of a bow wave limitation while up on plane, planing hulls can achieve very high speeds. However, their performance is very sensitive to the addition of weight to the boat.

A planing hull begins with a point at its bow, and tapers to full beam at its midsection, then continues aft with no taper or at most a slight taper. The planing hull also has a $\frac{1}{4}$ beam buttock angle 2° or less.

Very few accurate methods exist for determining power requirements and speed predictions on full planing hulls. Often times, planing hulls are equipped with engines based on past experience and tested during sea trials to determine their level of performance. One simple method in existence for estimating planing hull speed potential is referred to as *Crouch's Planing Speed Formula*. The formula is:

$$\text{Speed} = \frac{C}{\sqrt{\text{Lbs/Hp}}}$$

Speed = Boat speed in knots

C = Coefficient Defining Hull Speed

Lbs = Vessel Weight in Pounds

Hp = Horsepower Delivered to the Propeller

This formula develops a power to speed relationship for planing hulls, and experimentation has determined which coefficients should be utilized to obtain acceptable results. The typical coefficients used at Caterpillar are:

150 = average runabouts, cruisers, passenger vessels

190 = high speed runabouts, light high-speed cruisers

210 = race boats

The following example will help explain how all of this works.

Let's use a boat with a displacement of 14,000 pounds. The boat has a narrow beam, deep vee planing hull powered by two (2) 435 Hp diesels. The boat is equipped with performance propellers and low drag stern drives, so we can consider the boat a race type. It will therefore have a "C" coefficient of 210.

First let's take the Hp of the engines 435 $\times$ 2 = 870. Then we must take into account the reduction gear efficiency, typically 3%. 870 Hp $\times$ .97 = 844 Hp available to the propellers. Then we determine the $\frac{\text{Lbs}}{\text{Hp}}$ by dividing the boat displacement by the horsepower available. In our case Lbs/Hp = $\frac{14000\ \text{Lbs}}{844\ \text{Hp}}$ or Lbs/Hp = 16.59. Now that we have our Lbs/Hp we can calculate the speed of the boat using Crouch's Planing Speed Formula.

$$\text{Speed} = \frac{210}{\sqrt{16.59}} \quad \text{Speed} = 51.56 \text{ Knots}$$

Let's say this customer wants 60 knots. We can calculate the needed Hp by using the information from the previous formula and working out the answer. The formula for this would be $\frac{C}{\text{Speed}}$ = X. Then Lbs/ Hp = X^2

Putting the data in from the previous formula we get the following:

$$\frac{210}{60} = 3.50^2$$

Lbs/Hp = 12.25

Since the weight of the boat is 14,000 pounds, we can divide the weight of the boat by the Lbs/Hp ratio of 12.25 to get the Hp needed to operate the vessel at the 60 knot speed.

$$\frac{14000 \text{ Pounds}}{12.25 \text{ Lbs/Hp}} = 1{,}143 \text{ Hp required.}$$

Demand Horsepower, for a hull of the propulsion system on a engine is in a cubic relationship with the speed of the boat.

Example: A vessel is cruising at 20 knots. The demand horsepower on the engine is 500 Hp. The captain now wants to go 25 knots. How much horsepower will it take?

$$\frac{25 \text{ kts}}{20 \text{ kts}} = 1.25 \qquad 1.25^3 = 1.953125$$

500 Hp $\times$ 1.953125 = **976.5625 Hp**

Boat Speed[(1)] = 20 Knts

Act. Hp = 500 Hp New Hp = 977 Hp

What is the new boat speed?

$$\text{Speed}^2 = \sqrt[3]{\left(\frac{\text{New Hp}}{\text{Act Hp}}\right)} \times \text{Boat Speed}^{(1)}$$

$$\text{Speed}^2 = \sqrt[3]{\left(\frac{977\ \text{Hp}}{500\ \text{Hp}}\right)} \times 20\ \text{Knts} = \sqrt[3]{1.954 \times 20}$$

$$1.250 \times 20 = 25\ \text{Knts}$$

Hull Speed vs Wave Pattern

Miles per Hour $\times$ 1.15 = Knots

Knots $\times$ 101.3 = Feet per Minute

Miles per Hour $\times$ 88 = Feet per Minute

$$\text{SPEED LENGTH RATIO (SLR)} = \frac{V}{\sqrt{LWL}}$$

Where:

V = Vessel Speed

LWL = Loaded waterline length

The generally accepted SLR limits are as follows:

Displacement type hulls	=	SLR 1.34
Semi-displacement type hulls	=	SLR 2.3 – 2.5
Planing hulls	=	No specific high limit, but not good below a SLR of 2.0

The maximum vessel speed can be calculated using the following formula:

$$V = SLR \times \sqrt{LWL}$$

The maximum vessel speed can also be estimated by watching the wave action along a displacement hull type of the vessel. When the crest to crest distance of the bow wave is equal to the LWL of the vessel, the hull is at its optimum speed. If the bow wave crest to crest distance is equal to $\frac{1}{2}$ the LWL then the vessel is at approximately $\frac{1}{2}$ the optimum hull speed.

Economical speed for displacement type vessels is in the SLR range of 1.0 to 1.2. The crest to crest distance for an SLR of 1.0 is (.56)(LWL). The crest to crest distance for an SLR of 1.2 is (.8)(LWL)

Basic Propulsion Theory

The essence of marine propulsion is the conversion of engine power into thrust through some type of propulsion device. Because of its simplicity and efficiency, the screw propeller – basically an axial flow pump – has become the most widely used propulsive device.

Propellers

The ability of a propeller to move a vessel forward, through the water, depends upon several factors:

1. The rotational speed of the propeller, which corresponds to the propeller shaft RPM;
2. The angle or pitch of the propeller blades;
3. The diameter and blade area.

These factors, in combination impose a thrust force on the propeller shaft. This thrust is transmitted through the shaft to the thrust bearing, the principle point where the forces generated by the rotating propeller act upon the hull, and cause forward motion.

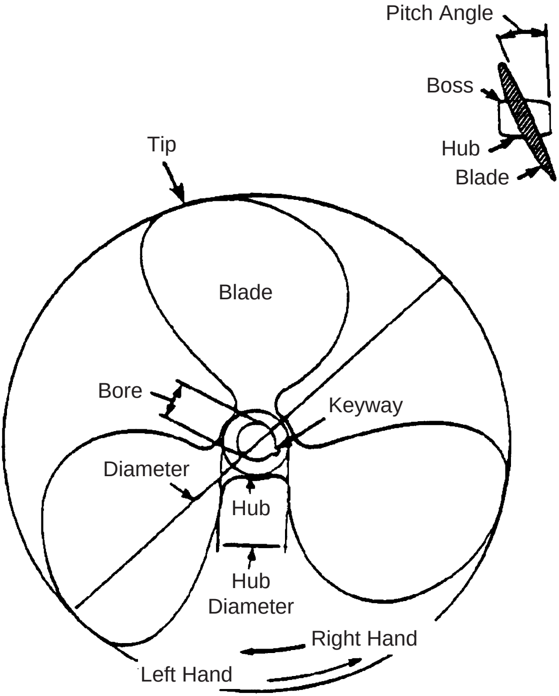


FIGURE 1

Figure 1 shows a typical 3-bladed propeller. To more intelligently understand the operation of a screw propeller, it is necessary to define the parts of a propeller:

- The *blade* does the work; it pulls water. Naturally, the wider the blade face, the more water it can pull. The more water that can be pulled, the stronger the thrust on the vessel and therefore, a greater amount of work can be done.
- *Propeller diameter* is the diameter of the circle described by the tips of the rotating propeller blades.

- *Blade Angle* is the angle the blade makes in relation to the center line of the hub. It is normally expressed as the distance, in inches. *Pitch* is the distance the blade would advance in one revolution, if it were a screw working in a solid substance.

An important concept in understanding propellers is the pitch ratio. The pitch ratio expresses the relation between the pitch and the diameter of the propeller; often it is referred to as the pitch/diameter ratio. It is obtained by dividing the pitch by the diameter. For example, if a propeller is 60 inches in diameter and has 42 inches of pitch (written as 60" × 42") then the pitch ratio is 42/60 = 0.70.

A general guide for the selection of approximate pitch ratio values is shown, by vessel application, in Figure 2.

PITCH RATIO BY VESSEL APPLICATION

Deep water tug boat	.50 – .55
River towboat	.55 – .60
Heavy round bottom work boat	.60 – .70
Medium wt. round bottom work boat	.80 – .90
Planing hull	.90 – 1.2

FIGURE 2

The propeller may be viewed as an axial pump that is delivering a stream of water aft of the vessel. It is this stream of water, equivalent in size to the diameter of the propeller, that is the power that provides thrust to move the vessel through the water. However, to produce thrust, the propeller must accelerate the mass of water it pulls against. In so doing, a portion of the pitch advance is lost to the work of accelerating the water mass. This is known as propeller slip; Figure 3 illustrates this concept.

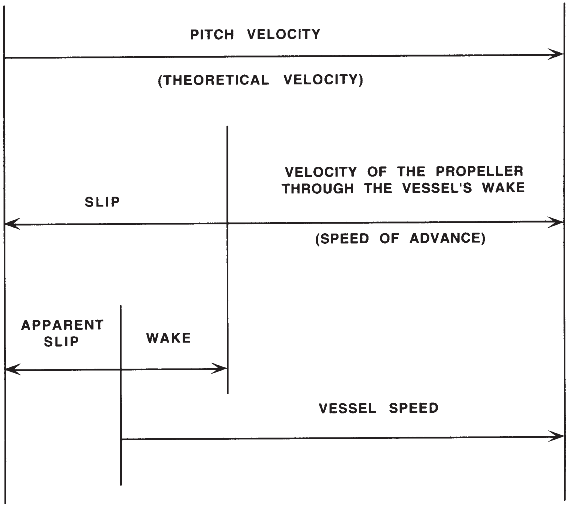


FIGURE 3

A propeller with a fixed pitch theoretically has a pitch velocity or linear speed it would travel in the absence of slip. However, because of the work needed to accelerate a mass of water, slip manifests itself as the difference between the pitch velocity and the velocity of the propeller through the vessel's wake or speed of advance.

As a vessel moves through the water, hull resistance, wave formation and converging water at the stern have a tendency to follow the hull. This results in a movement of water under the stern in a forward direction known as wake. The added factor of wake reduces slip to what is known as apparent slip. It also adds to the speed of advance to produce the actual vessel speed. It is obvious from this that propellers function in a very complex manner. There are many factors to be considered when selecting a propeller. The point to realize is that there is no formula that will automatically provide the ideal propeller size for a given vessel and application. This can only be approximated to various degrees of accuracy. The only true test is trial and error under actual operating conditions. Remember, all propellers are a compromise. The general practice is to use the largest diameter propeller turning at the best speed for the vessel's application within practical limits. These limitations are:

1. The size of the aperture in which the propeller is to be installed.
2. The application or type of work the vessel will be doing – towboat, crew boat, pleasure craft, and so forth.
3. Excessive shaft installation angles that may be required when using large diameter propellers.
4. The size of shafting that can be accommodated by the structural members of the hull where the shaft passes through.
5. Comparative weight of propellers, shafts and marine gears with respect to the size of the vessel.
6. The size of marine gears which the hull can accommodate without causing an inordinate degree of shaft angularity.
7. The vessel's inherent ability to absorb the high torque that results from the use of large slow turning propellers.
8. Comparing the cost of using large diameter propellers against any increases in efficiency or performance.

Number Of Propeller Blades

In theory, the propeller with the smallest number of blades (i.e. two) is the most efficient. However, in most cases, diameter and technical limitations necessitate the use of a greater number of blades.

Three-bladed propellers are more efficient over a wider range of applications than any other propeller. Four and sometimes five-bladed propellers are used in cases where objectionable vibrations develop when using a three-bladed propeller.

Four-bladed propellers are often used to increase blade area on tow boats operating with limited draft. They are also used on wooden vessels where deadwood ahead of the propeller restricts water flow. However, two blades passing deadwood at the same time can cause objectionable hull vibration.

All other conditions being equal, the efficiency of a four-blade propeller is approximately 96% that of a three-blade propeller having the same pitch ratio and blades of the same proportion and shape. A "rule of thumb" method for estimating four-blade propeller requirements is to select a proper three-blade propeller from propeller selection charts, then multiply pitch for the three-blade propeller by .914. Maximum diameter of a four-blade propeller should not exceed 94% of the recommended three-blade propeller's diameter. Therefore, we multiply diameter by .94 to obtain the diameter of a four-blade propeller.

For example, if a three-blade recommendation is:

$$48 \times 34$$

Multiply pitch (34") by .914 = 31"

Multiply diameter (48") by .94 = 45"

Four-blade recommendation 45" × 31"

As a word of caution, remember that this is a general rule...for estimating only. Due to the wide variation in blade area and contours from different propeller manufacturers, consult your particular manufacturer before final specifications are decided upon.

A “Rule of the Thumb” for all propeller selection is:

“Towboats – big wheel, small pitch”

“Speedboats – little wheel, big pitch”

All other applications can be shaded between these two statements of extremes.

Propeller Tip Speed

Tip speed, as the name implies, is the speed at which the tips of a rotating propeller travel in miles per hour (MPH). The greater the tip speed, the more power consumed in pure turning. As an example, a 30 inch propeller with a tip speed of 60 MPH absorbs approximately 12 horsepower in pure turning effort. This is a net horsepower loss because it contributes nothing to the forward thrust generated by the propeller.

The following formula can be used to calculate tip speed:

$$T = \frac{D \times \text{SHAFT RPM} \times 60 \times \pi}{12 \times 5280}$$

Where:

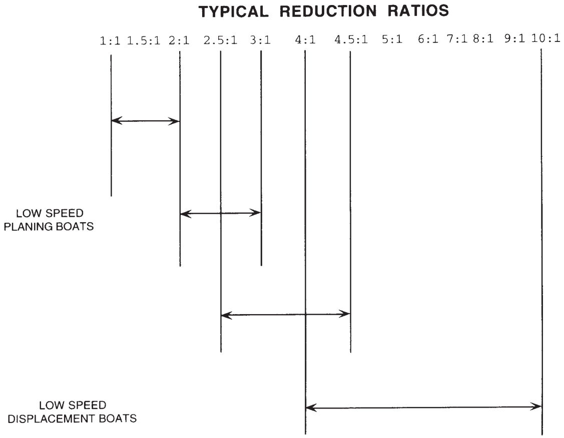
T = Tip speed in MPH

D = Propeller diameter in inches

Cavitation

When propeller RPM is increased to a point where suction ahead of the propeller reduces the water pressure below its vapor pressure, vapor pockets form, interrupting the solid flow of water to the propeller. This condition is known as cavitation.

One of the more common causes of cavitation is excessive tip speed, a propeller turning too fast for water to follow the blade contour. Cavitation can usually be expected to occur at propeller tip speeds exceeding 130 MPH. Cavitation results in a loss of thrust and damaging erosion of the propeller blades.



Reduction Gears

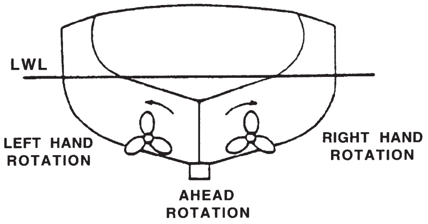
The reduction gear enables the propulsion engine and propeller to be matched so they both operate at their most efficient speeds.

The proper selection of the reduction gear ratio is an important decision in preparing a marine propulsion system. There is a range of commercially available reduction ratios that can help assure optimum vessel performance under a given set of operating conditions.

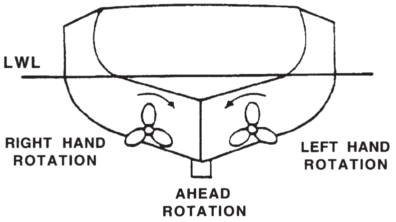
It is difficult to discuss the selection of reduction gear ratios without mentioning some of the other factors that can influence the selection. The major influencing factors are:

- Expected vessel speed
- Vessel duty cycle
- Propeller tip speed
- Type of vessel
- Pitch Ratio
- Engine horsepower

OUTBOARD TURNING PROPELLERS



INBOARD TURNING PROPELLERS



Propeller Overhang

The maximum distance from the stern bearing to the propeller should be limited to no more than one shaft diameter. Propeller shafts are apt to vibrate and produce a whip action if these limits are exceeded. This condition is greatly accelerated when a propeller is out of balance due to faulty machining or damage.

Propeller Rotation

Propeller rotation is determined from behind the vessel, facing forward. The starboard side is on the right and the port side on the left. Rotation of the propeller is determined by the direction of the wheel when the vessel is in forward motion. Thus, a clockwise rotation would describe a right-hand propeller and a counter-clockwise rotation would be a left-hand propeller.

Right-hand propellers are most frequently used in single screw installations. Twin screw vessels in the U.S. are normally equipped with outboard turning wheels. However, there are some installations where inboard turning wheels will be found. A rotating propeller tends to drift sideways in the direction of the rotation. In a single screw vessel this can be partially offset by the design of the sternpost and the rudder. In a twin screw vessel this can be completely eliminated by using counter-rotating propellers. Although the question of inboard and outboard rotating propellers has been debated many times, authorities on the subject agree that there are no adverse effects on maneuverability with either rotation. In fact, there are those who feel that a gain in maneuverability is obtained with outboard rotating propellers. One point in favor of inboard rotation is a decreased tendency for the propellers to pick-up debris off the bottom in shallow water.

Multiple Propellers

The most efficient method of propelling a vessel is by the use of a single screw. However, there are other factors which, when taken into consideration, make the use of a single propeller impossible. If a vessel has to operate in shallow water, the diameter of the propeller is limited. Therefore, it may be necessary to install two and sometimes three propellers to permit a proper pitch ratio for efficient propulsion.

Another condition requiring multiple propellers is encountered when higher speed yachts need more horsepower than a single engine can develop and still be accommodated in the engine space. As a general rule to follow for calculations in this text, the total SHP of all engines is used when making estimated speed calculations. For calculating propeller size, SHP of each individual engine is used.

Propeller Pitch Correction

An overpitched propeller will overload the engine. To permit the engine to reach its Full power and speed the load must be removed. The load must be reduced by amount proportional to the engine RPM ratio. This can be defined by the following formula:

$$LF = \frac{RPM1}{RPM2}$$

Where:

LF = % of Load

RPM1 = The engine RPM while overloaded " What you have."

RPM2 = The anticipated engine RPM "What you want to have."

EXAMPLE FORMULA

The M/V Cat has an engine that produces Full power at 1800 engine RPM. While being tested the engine would only turn to 1750 RPM. Applying the above formula we get the following equation:

$$LF = \frac{1750}{1800}$$

$$LF = .97 \times 100$$

$$LF = 97\%$$

This means to get the engine to turn the correct RPM we would have to reduce the load by 3%. If the overload is due to an overpitched propeller then the amount of pitch to be taken out of the current propeller can be determined using the following formula:

$$Pr = Pp \times \frac{RPM1}{RPM2}$$

Where:

Pr = Propeller pitch required

Pp = Present propeller pitch

RPM1 = The engine RPM while overloaded " What you have."

RPM2 = The anticipated engine RPM "What you want to have."

Ducted Propellers

Ducted propellers are best used on vessels such as trawlers, tugs, and towboats with towing speeds of 3-10 knots. Ducted propellers should not be used on vessels with relative high speeds.

To help assist in the selection of a ducted propeller, you can perform the following calculation. If the resultant Bp is <(less than) 30, the use of a ducted propeller should not be considered as it may result in a net loss of vessel performance.

$$Bp = SRPM \times \frac{\sqrt{SHP}}{(V_a)^{2.5}}$$

Where:

Bp = Basic Propeller Design Variable

SRPM = Propeller Shaft Speed, RPM

SHP = Shaft Horsepower

V_a = Velocity of Advance of the propeller (knots) generally equals 0.7 to 0.9 times boat speed.

Propeller Formulas and Related Tables

$$\text{Torque} = \frac{(5252 \times \text{Hp})}{\text{Rpm}}$$

Hp = Horsepower
Rpm = Revolutions per minute

Propeller Horsepower Curve Formula

$$\text{PHp} = C_{sm} \times \text{Rpm}^n$$

C_{sm} = sum matching constant

n = exponent from 2.2 to 3.0, with 2.7 being used for average boats

Rpm = Revolutions per minute

Displacement Speed Formula

$$\text{SL Ratio} = \frac{10.665}{\sqrt[3]{\dfrac{\text{LB}}{\text{SHP}}}}$$

Where:

SL Ratio = Speed-Length Ratio

and

$$\text{SL Ratio} = \frac{\text{Knts.}}{\sqrt{\text{WL}}}$$

Knts = Speed in knots = Boat speed or V

SHP = Shaft Horsepower at propeller

LB = Displacement in pounds

WL = Waterline length in feet

Displacement – Length Ratio Formula

$$\text{DL Ratio} = \frac{\text{disp T}}{(00.01\text{XWL})^3}$$

Where:

disp T = Displacement in long tons of 2,240 pounds, mt = 1.016 long tons

WL = Waterline length in feet

Maximum Speed-Length Ratio vs DL Ratio Formula

$$\text{SL Ratio} = \frac{8.26}{3.215\sqrt{\text{DL Ratio}}}$$

Where:

SL = Speed-length ratio

DL = Displacement-length ratio

Crouch's Planing Speed Formula

$$\text{Knts} = \frac{C}{\sqrt{\text{Lb/SHP}}}$$

Where:

Knts = Speed in knots = Boat Speed = V

C = Constant chosen for the type of vessel being considered

LB = Displacement in pounds

SHP = Horsepower at the propeller shaft

The speed predicted by this formula assumes a propeller has been selected that gives between 50% and 60% efficiency, with 55% a good average.

Analysis Pitch Formula

$$P_0 = \frac{101.33V_a}{N_0}$$

Where:

V_a = Speed in knots through wake at zero thrust

N_0 = Shaft Rpm at zero thrust

Pitch Ratio Formula

Pitch Ratio = P/D

Where:

P = Pitch

D = Diameter

Theoretical Thrust Formula

Thrust = Force = F

$$F = MA \text{ or } F = \frac{W}{g} \times (V_0 - V_1)$$

Where:

W = Weight in pounds the column of water accelerated astern by the propeller

g = the acceleration of gravity, 32.2 ft/sec.

V_0 = velocity of water before entering the propeller in feet per second

V_1 = velocity of water after leaving propeller in feet per second

M = Mass in slugs

A = Acceleration in feet per second squared

Developed Area to Projected Area Formula

$$\frac{Ap}{Ad} = 1.0125 - (0.1 \times PR) - (0.0625 \times PR^2)$$

Where:

$\frac{Ap}{Ad}$ = Approximate ratio of projected area to developed area

PR = Pitch ratio of propeller

Mean-Width Ratio Formula

Mean-Width Ratio = MWR

$$MWR = \frac{\text{Average Blade Width,}}{D} \text{ or}$$

$$MWR = \frac{\text{Expanded Area of One Blade}}{\text{Blade Height from Root to Tip}} \div D$$

Where:

D = Diameter

Disc-Area Ratio

$$\text{Disc Area} = \frac{\pi D^2}{4} \text{ or } 0.7854D^2$$

Disc-Area Ratio = DAR

$$DAR = \frac{\text{Expanded Area of all Blades}}{\text{Disc Area}}$$

Where:

D = Diameter

$\pi \approx 3.1412$

Disc-Area Ratio vs Mean-Width Ratio

$$DAR = \text{Number of Blades} \times 0.51 \times MWR$$

or

$$MWR = \frac{DAR}{\text{Number of Blades} \times 0.51}$$

Where:

DAR = Disc-area ratio

MWR = Mean-width Ratio

Note: These ratios assume a hub that is 20% of overall diameter, which is very close to average. Small propellers for pleasure craft may have slightly smaller hubs, while heavy, workboat propellers, particularly controllable-pitch propellers, may have slightly larger hubs.

Developed Area vs Disc-Area Ratio Formula

$$Ad = \pi \times \left(\frac{D}{2}\right)^2 \times DAR$$

Developed Area vs Mean-Width Ratio Formula

$$Ad = \pi \times \left(\frac{D}{2}\right)^2 \times MWR \times 0.51 \times \text{Number of Blades}$$

where for both the above formulas:

Ad = Developed Area

D = Diameter

DAR = Disc-area ratio

MWR = Mean-width ratio

$\pi \approx 3.1412$

Developed Area for Any Hub Diameter and MWR Formula

$$Ad = MWR \times D \times (1 - Hub\%) \times \frac{D}{2} \times \text{Number of Blades}$$

or

$$Ad = MWR \times \frac{D^2}{2} \times (1 - Hub\%) \times \text{Number of Blades}$$

Where:

Ad = Developed Area

MWR = Mean-width ratio

D = Diameter

Hub % = Maximum hub diameter divided by overall diameter, D

Blade-Thickness Fraction Formula

$$BTF = \frac{t_0}{D}$$

Where:

BTF = Blade-Thickness Fraction

D = Diameter

t_0 = Maximum Blade Thickness as Extended to Shaft Centerline

Rake Ratio Formula

$$\text{Rake Ratio} = \frac{\overline{BO}}{D}$$

Where:

$\overline{BO}$ = Distance between tip of blade projected down to the shaft centerline and face of blade extended down to shaft centerline

D = Diameter

Apparent Slip Formula

$$\text{Slip A} = \frac{\left(\frac{P}{12}\right) \times \text{RPM} - (\text{Knts} \times 101.3)}{\left(\frac{P}{12}\right) \times \text{RPM}}$$

Which can be restated as:

$$P = \frac{\text{Knts} \times 1215.6}{\text{RPM} \times (1 - \text{Slip A})}$$

Where:

Slip A = Apparent Slip

P = Propeller face pitch in inches

Knts = Boat speed through the water or V in Knots

RPM = Revolutions per minute of the propeller

Slip vs Boat Speed Formula

$$\text{Slip} = \frac{1.4}{\text{Knts}^{0.057}}$$

Where:

Knts = Boat speed in knots

DIA-HP-RPM Formula

$$D = \frac{632.7 \times \text{SHP}^{0.2}}{\text{RPM}^{0.6}}$$

Where:

D = Propeller diameter in inches

SHP = Shaft Horsepower at the propeller

RPM = Shaft RPM at the propeller

Optimum Pitch Ratio Formulas

$$\text{Average Pitch Ratio} = 0.46 \times \text{Knts}^{0.26}$$

$$\text{Maximum Pitch Ratio} = 0.52 \times \text{Knts}^{0.28}$$

$$\text{Minimum Pitch Ratio} = 0.39 \times \text{Knts}^{0.23}$$

These formulas have been found to check well with a wide variety of vessels.

Minimum Diameter Formula

$$D_{min} = 4.07 \times (BWL \times H_d)^{0.5}$$

D_{min} = Minimum acceptable propeller diameter in inches

BWL = Beam on the waterline in feet

H_d = Draft of hull from the waterline down (excluding keel,skeg or deadwood) in feet

(Hull draft is the depth of the hull body to the fair-body line, rabbet, or the hull's intersection with the top of the keel. It thus excludes keel and/or skeg.)

D_{min} for twin screws $= 0.8 \times D_{min}$

D_{min} for triple screws $= 0.65 \times D_{min}$

Allowable Blade Loading Formula

$$PSI = 1.9 \times V_a^{0.5} \times Ft^{0.08}$$

Where:

PSI = Pressure, in pounds per square inch, at which cavitation is likely to begin

V_a = The speed of the water at the propeller in knots

Ft = The depth of immersion of the propeller shaft centerline, during operation, in feet

Actual Blade Loading Formula

$$PSI = \frac{326 \times SHP \times e}{V_a \times Ad}$$

Where:

PSI = Blade loading in pounds per square inches

SHP = Shaft Horsepower at the propeller

e = Propeller efficiency in open water

V_a = Speed of water at the propeller, in knots

Ad = Developed area of propeller blades, in square inches

Thrust Formula

$$TA = \frac{326 \times SHP \times e}{V_a}$$

Where:

T = Thrust

SHP = Shaft Horsepower at the propeller

e = Propeller efficiency

V_a = Speed of water at the propeller, in knots

Approximate Bollard Pull Formula

$$T_s = 62.72 \times (SHP \times \frac{D}{12})^{0.67}$$

T_s = Static thrust or bollard pull, in pounds
SHP = Shaft Horsepower at the propeller
D = Propeller diameter in inches

This formula can also be expressed as:

$$T_s \text{ ton} = 0.028 \times (SHP \times D_{ft})^{0.67}$$

T_s ton = Thrust in long tons of 2240 pounds
SHP = Shaft Horsepower
D_{ft} = Propeller diameter, in feet

Taylor Wake Fraction Formula

$$Wt = \frac{V - V_a}{V}$$

or

$$V_a = V \times (1 - Wt)$$

Where:
Wt = Taylor wake fraction
V = Boat speed through the water
V_a = Speed of the water at the propeller

Wake Factor Formula

$$Wf = 1 - Wt$$

Speed of Advance Formula

$V_a = V \times Wf$

Where:

V = Boat Speed

Wf = Wake Factor

Wt = Taylor Wake Fraction

Wake Factor vs Block Coefficient Formulas for vessels with a SL Ratio of under 2.5

Single Screw $Wf = 1.11 - (0.6 \times Cb)$

Twin Screw $Wf = 10.6 - (0.4 \times Cb)$

Where:

Wf = Wake factor (percent of V “seen” by the propeller

Cb = Block coefficient of the hull.

Block Coefficient Formula

$$Cb = \frac{\text{Displacement}}{WL \times BWL \times H_d \times 64 \text{ Lb/cu.ft.}}$$

Where:

Displacement = Vessel displacement, in pounds

WL = Waterline length, in feet

BWL = Waterline beam, in feet

H_d = Hull draft, excluding keel, skeg or deadwood, in feet

Wake Factor vs Speed Formula

$$Wf = 0.83 \times Knts^{0.047}$$

Where:

Wf = Wake Factor

Knts = Speed in knots

Power Factor Formula

$$Bp = \frac{(SHP)^{0.5} \times N}{V_a^{2.5}}$$

Where:

Bp = Power Factor

SHP = Shaft Horsepower at the propeller

N = Number of shaft revolutions

V_a = Speed of advance of the propeller through the wake

Advance Coefficient Formula

$$\delta = \frac{N \times D_{ft}}{V_a}$$

or

$$\delta = \frac{N \times D}{12 \times V_a}$$

This may also be restated as:

$$D = \frac{\delta = V_a \times 12}{N},$$

Where:

δ = Advance coefficient

N = Shaft RPM

D_{ft} = Propeller diameter in feet

D = Propeller diameter in inches

V_a = Speed of advance of the propeller through the wake

Displacement Speed with Efficiency Formula

$$\text{SL Ratio} = \frac{10.665}{\sqrt[3]{\frac{LB}{SHP}}} \times \sqrt[3]{\frac{\eta}{0.55}}$$

Where:

SL Ratio = Speed-length ratio

LB = Displacement in pounds

SHP = Shaft horsepower at the propeller

η = Propeller efficiency

If the speed in knots is already known, we can multiply the speed directly by

$$\sqrt[3]{\frac{\eta}{0.55}}$$

Planing Speed With Efficiency Formula

$$\text{Knts} = \frac{C}{\sqrt{\frac{LB}{SHP}}} \times \sqrt{\frac{\eta}{0.55}}$$

Where:

Knts = Boat speed in knots

LB = Displacement in pounds

SHP = Shaft horsepower at the propeller

η = Propeller efficiency

If the speed in knots is already known, we can multiply the speed directly by

$$\sqrt[3]{\frac{\eta}{0.55}}$$

Shaft Diameter Formula Solid Tobin Bronze Propeller Shafts

$$Ds = \sqrt[3]{\frac{321000 \times SHP \times SF}{St \times RPM}}$$

Ds = Shaft Diameter, in inches

SHP = Shaft Horsepower

SF = Safety factor (3 for yachts and light commercial craft, 5 to 8 for heavy commercial craft and racing boats)

St = Yield strength in torsional shear, in PSI

RPM = Revolutions per minute of propeller shaft

Shaft Diameter Formula for Monel 400 Propeller Shafts

$$Ds = \sqrt[3]{\frac{321000 \times SHP \times SF}{St \times RPM}} \times .80$$

Ds = Shaft Diameter, in inches

SHP = Shaft Horsepower

SF = Safety factor (3 for yachts and light commercial craft, 5 to 8 for heavy commercial craft and racing boats)

St = Yield strength in torsional shear, in PSI

RPM = Revolutions per minute of propeller shaft

Shafts made of Monel 400 should be reduced by 20% the size shaft required for a solid Tobin Bronze shaft.

Shaft-Bearing Spacing Formula

$$Ft = \sqrt{\frac{3.21 \times Ds}{RPM}} \times \sqrt[4]{\frac{E}{Dens}}$$

Where:

Ft = Shaft-bearing spacing, in feet

Ds = Propeller shaft diameter, in inches

RPM = Propeller shaft speed, in revolutions per minute

E = Modulus of elasticity of shaft material, in PSI

Dens = Density of shaft material, in pounds per cubic inch

Propeller Weight Formulas (with 0.33 mean width ratio and a hub diameter of 20%)

Three-Bladed Propeller Weight

$$Wgt = 0.00241 \times D^{3.05}$$

Four-Bladed Propeller Weight

$$Wgt = 0.00323 \times D^{3.05}$$

Where:

Wgt = Weight of propeller in pounds

D = Diameter of propeller in inches

Brake Horsepower vs LOA Formula – Tugs

$$BHP = 100 + \left(\frac{LOA^{4.15}}{111000}\right)$$

Where:

BHP = Maximum brake horsepower of engine

LOA = Length overall of the tug at waterline, in feet

Towing Speed vs Brake Horsepower Formula

$$Knts = 1.43 \times BHP^{0.21}$$

Where:

Knts = Average speed in knots during average tow

BHP = Maximum brake horsepower of engine

D.W.T. of Barges Towed vs BHP Formulas

Low D.W.T. = $(1.32 \times \text{BHP}) - 255.25$

Avg D.W.T. = $(3.43 \times \text{BHP}) - 599.18$

High D.W.T. = $(5.57 \times \text{BHP}) - 943.10$

Where:

DWT = Deadweight tons of barges towed

BHP = Maximum brake horsepower of engine

Rules of Thumb for Propeller Selection

1. ***One inch in diameter absorbs the torque of two to three inches of pitch.*** This is a good rough guide. Both pitch and diameter absorb the torque generated by the engine. Diameter is, by far, the most important factor. Thus, the ratio of 2 to 3 inches of pitch equals 1 inch of diameter is a fair guide. It is no more than that, however. You could not select a suitable propeller based only on this rule.

2. ***The higher the pitch your engine can turn near top horsepower and RPM, the faster your boat can go.*** This is accurate as far as it goes. The greater the pitch, the greater the distance your boat will advance each revolution. Since top engine RPM is constant, increasing the pitch means more speed. Then, why aren't all propellers as small in diameter as possible, with gigantic pitches?

   The answer is simply that when the pitch gets too large, the angle of attack of the propeller blades to the onrushing water becomes too steep and they stall. This is exactly the same as an airplane wing's stalling in too steep a climb. If the pitches and pitch ratios selected are optimum, then within these limits it is worthwhile, on high-speed craft, to use the smallest diameter and greatest pitch possible.

3. ***Too little pitch can ruin an engine.*** This is quite true if the pitch and diameter combined are so low that it allows the engine to run at speeds far over its top rated RPM. Never should the engine be allowed to operate at more than 103% to 105% of rated RPM, while underway and in a "normal" operation. If your engine exceeds that figure, a propeller with increased pitch or diameter is indicated.

4. ***Every two-inch increase in pitch will decrease engine speed by 450 RPM, and vice versa.*** This is a good rough guide for moderate- to high-speed pleasure craft, passenger vessels, and crew boats. Like all rule of thumbs, though, it is no more than a rough guide.

5. ***A "square" wheel (a propeller with exactly the same diameter and pitch)* is the most efficient.** This is not true! There is nothing wrong with a square wheel; on the other hand, there is nothing special about it, either.

6. ***The same propeller can't deliver both high speed and maximum power.*** This is true! A propeller sized for high speed has a small diameter and maximum pitch. A propeller sized for power or thrust has a large diameter. For some boats you can compromise on an in-between propeller, but for either real speed or real thrust there is little common ground.

Related Propeller Tables

Suggested Shaft Speeds

Type of Vessel	SL Ratio	Range of Shaft RPM
Heavy Displacement hulls (Tugs, Push boats, Heavy Fishing Vessels)	Under 1.2	250 – 500
Medium-to-Light Displacement hulls (Fishing vessels, trawlers, workboats, trawler yachts)	Under 1.45	300 – 1,000
Semi-displacement Hulls (Crew boats, Patrol boats, motor yachts)	1.45 – 3.0	800 – 1,800
Planing hulls (Yachts, fast commuters and ferries, high-speed patrol boats)	over 3.0	1,200 – 3,000 +

Minimum Tip Clearance

RPM	SL Ratio	Minimum Tip Clearance
200 – 500	Under 1.2	8%
300 – 1,800	1.2 – 2.5	10%
1,000 and above	over 2.5	15%
High-speed Planing Craft	over 3.0	20%

Shaft Material Characteristics

Shaft Material	Yield Strength in Torsional Shear PSI	Modulus of Elasticity PSI	Density Lb/ Cu. In.
Aquamet 22	70,000	28,000,000	0.285
Aquamet 18	60,000	28,800,000	0.281
Aquamet 17	70,000	28,500,000	0.284
Monel 400	40,000	26,000,000	0.319
Monel K500	67,000	26,000,000	0.306
Tobin Bronze	20,000	16,000,000	0.304
Stainless Steel 304	20,000	28,000,000	0.286

Buttock Angle vs SL Ratio

Buttock Angle	Type Hull	SL Ratio
Less than 2°	Planing	2.5 or Higher
2° – 8°	Semi-displacement	1.4 – 2.9
Greater than 8°	Displacement	1.34 Maximum

Crouch's Formula Constants

C	Type of Boat
150	Average runabouts, cruisers, passenger vessels
190	High-speed runabouts, very light high-speed cruisers
210	Race boat types
220	Three-point hydroplanes, stepped hydroplanes
230	Racing power catamarans and sea sleds

Typical Slip Values

Type of Boat	Speed in Knots	Percent of Slip
Auxiliary sailboat, barges	Under 9	45%
Heavy powerboats, workboats	9 -15	26%
Lightweight powerboats, cruisers	15 -30	24%
High-speed planing boats	30 -45	20%
Planing race boats, vee-bottoms	45 -90	10%
Stepped hydroplanes, catamarans	over 90	7%

Typical Slip Values – Twin Screw

Type of Boat	Speed in Knots	Percent of Slip
Auxiliary sailboat, barges	Under 9	42%
Heavy powerboats, workboats	9 -15	24%
Lightweight powerboats, cruisers	15 -30	22%

Typical Properties of Various Engineering Materials

Material Property	Carbon and Low Alloy Steel	Aluminum Base Alloys	Copper Base Alloys	Magnesium Base Alloys
Utl Tens Str, PSI	60-200,000+	19-53,000	21-125,000	22-45,000
Tens Yield Str, PSI	30-170,000+	8-43,000	11-100,000	11-30,000
Comp Str, PSI	60-200,000	XXXX	XXXX	XXXX
Comp Yield Str, PSI	XXXX	**About** 8-43,000	8-60,000	**About** 11-30,000
Shear Str, PSI	XXXX	14-36,000	XXXX	14-21,000
Ductility **(% Elong in 2 in.)**	35-5	22-0	52-0	12-1
Red of Area, %	65-5	XXXX	40-4	XXXX
Brinell Hardness **(Load)**	130-750 **(3000 kg)**	40-140 **(500 kg)**	47-425 **(500 kg)**	45-84 **(500 kg)**
Stiffness **(Mod of Elasticity, PSI)**	30,000,000	10,300,000	9.1-20,000,000	9,000-13,000
Endurance Limit, PSI	0.4-0.5 × UTS	6,500-23,000	4,000-15,000	9,000-13,000
Impact Resistance **(Charpy, ft-lb)**	3 to 65	0 to 8	0.5 to 40 **(IZOD)**	0.5 to 10 **(IZOD)**
Density @ 68° F **(lb/cu in.)**	0.282-0.284	0.093-0.107	0.264-0.343	0.065-0.067
Coeff of Therm Exp **(10^{-6} in/in° F)**	6.1-7.1 **(32-212° F)**	11.6-15.0 **(68-572° F)**	9.0-12.0 **(68-1652° F)**	14.5 **(68-212° F)**
Melting Range, ° F	2600-2775	1000-1220	1675-1930	830-1190
Casting Range, ° F	2850-3150	1175-1475	1750-2350	1200-1550

Typical Properties of Various Engineering Materials (continued)

Material Property	Carbon and Low Alloy Steel	Aluminum Base Alloys	Copper Base Alloys	Magnesium Base Alloys
Machinability	< Other Ferrous Alloys	Good to Excellent	Fair to Good Depends on Hardness	Excellent
Damping Capacity	XXXX	XXXX	XXXX	XXXX
Wear Resistance **(Lub. Sliding Friction)**	Good, Improved by Heat Treatment	Poor to Excellent	Good to Excellent	Poor to Excellent
Suitability as a Bearing Material	Inferior to Cast Iron	Poor Except for Special Bearing Alloy	Good to Excellent	Poor
Abrasive Wear	Excellent	Poor	Poor to Good	Poor
Fluidity	Inferior to Cast Iron	Excellent	Fair to Good	Good to Excellent

Typical Properties of Various Engineering Materials (continued)

Material Property	Gray Cast Iron	Ferritic Malleable Iron	Pearlitic Malleable Iron	Ductile Iron
Utl Tens Str, PSI	20-60,000	48-60,000	60-120,000	60-160,000+
Tens Yield Str, PSI	Same as Ten Str	30-40,000	43-95,000	40-135,000
Comp Str, PSI	70-200,000	=UTS	=UTS	1-1.2 × UTS
Comp Yield Str, PSI	XXXX	XXXX	XXXX	XXXX
Shear Str, PSI	1.0-1.6 × UTS	0.9 × UTS	0.9 × UTS	0.9 × UTS
Ductility **(% Elong in 2 in.)**	<1	26-10	12-1	26-1
Red of Area, %	0	23-18	15-0	30-0
Brinell Hardness **(Load)**	135-350 + **(3000 kg)**	110-145 **(3000 kg)**	160-285 + **(3000 kg)**	140-330 + **(3000 kg)**
Stiffness **(Mod of Elasticity, PSI)**	12-18,000,000	25,000,000	28,000,000	23-26,000,000
Endurance Limit, PSI	0.4-0.6 × UTS	0.4-0.6 × UTS	0.4-0.6 × UTS	0.4-0.55 × UTS
Impact Resistance **(Charpy, ft-lb)**	Up to 5	16.5	5-12	16.5
Density @ 68° F **(lb/cu in.)**	0.25-0.266	0.258-0.274	0.258-0.274	0.25-0.28
Coeff of Therm Exp **(10^{-6} in/in° F)**	5.8 **(32-212° F)**	6.6 **(68-750° F)**	Somewhat Higher than Ferritic Malleable	6.4 **(68-212° F)** 7.5 **(68-1112° F)**
Melting Range, ° F	2000-2400	2000-2550	2000-2550	2000-2400

Typical Properties of Various Engineering Materials (continued)

Material Property	Gray Cast Iron	Ferritic Malleable Iron	Pearlitic Malleable Iron	Ductile Iron
Casting Range, ° F	2200-2850	2550-2850	2550-2850	2200-2700
Machinability	Good	Good	Good	Good
Damping Capacity	About 10 $\times$ Steel	--------------------Between Gray Iron and Mild Steel--------------------		
Wear Resistance **(Lub. Sliding Friction)**	Excellent	Good	Excellent	Good to Excellent
Suitability as a Bearing Material	Poor to Excellent	Good	Poor to Excellent	Poor to Excellent
Abrasive Wear	Poor	Good	Good	Good
Fluidity	Excellent	Good	Good	Excellent

Typical Properties of Various Engineering Materials (continued)

Material Property	Nickel Base Alloys	Titanium Base Alloys	Zinc Base Alloys
Utl Tens Str, PSI	50-145,000		25-52,100
Tens Yield Str, PSI	25-115,000		XXXX
Comp Str, PSI	XXXX		XXXX
Comp Yield Str, PSI	18-80,000		55-93,000
Shear Str, PSI	XXXX		31-46,000
Ductility **(% Elong in 2 in.)**	45-1		10-0.5
Red of Area, %	35-1		XXXX
Brinell Hardness **(Load)**	100-375		75-100 **(500 kg)**
Stiffness **(Mod of Elasticity, PSI)**	21.5-24,000,000	14-16,000,000	
Endurance Limit, PSI	XXXX		6,875-8,500
Impact Resistance **(Charpy, ft-lb)**	4-70 **(Keyhole)**		1-48 **(Unnotched)**
Density @ 68° F **(lb/cu in.)**	0.301-0.312		0.238-0.242
Coeff of Therm Exp **(10^{-6} in/in° F)**	6.8-7.4 **(68-212° F)**		15.1-15.4
Melting Range, ° F	2400-2600		727-932
Casting Range, ° F	2700-2900		740-800

Typical Properties of Various Engineering Materials (continued)

Material Property	Nickel Base Alloys	Titanium Base Alloys	Zinc Base Alloys
Machinability	Comparable to Steel		Excellent
Damping Capacity	XXXX		XXXX
Wear Resistance **(Lub. Sliding Friction)**	Probably Comparable to Steel		Poor
Suitability as a Bearing Material	Not Normally Used as a Bearing		Poor
Abrasive Wear	Poor to Good		Poor
Fluidity	Comparable to Steel		Excellent

Onset of Shallow Water Effect

As all Marine Analyst know, the desired depth of water to perform a P.A.R. test is $2\frac{1}{2}$ times the draft of the boat. This depth is a "Rule of Thumb" that should keep you out of the shallow water effect. If, as is the case on many river boats, the boat operates in water that is shallower than the desired ($2\frac{1}{2}$), then the test is performed under actual working water depths. The following information will give you some insight into how to determine if you are seeing the effects of shallow water on the load of the engine.

The behavior of a boat in shallow water is amazing. There are two kinds of increases in resistance due to running in shallow water.

1. There is a slight, but measurable, increase beginning when the boat advances into water whose depth is one half to one quarter the length of the boat. At high speeds, it begins when the boat advances into water whose depth is equal to the length of the boat.

2. There is a phenomenal and sudden increase in resistance beginning when the speed of the boat equals 2.3 times the square root of the depth of water in feet, or $V = (2.3)\sqrt{H}$. In which, V = speed in knots and H = depth of water in feet. When $V = (2\frac{1}{2})\sqrt{H}$, we have almost reached the limit at which the boat can be driven in shallow water. When $V = (3.36)\sqrt{H}$, we are at the utmost limit of speed for the boat unless the boat starts to plane, in which case the boat begins to out run the waves that normally would be produced in deep water. As the boat travels faster than its wave train, few waves can be produced; residual resistance decreases, and we have the phenomenon of full planing such as the case of a sport fishing and pleasure craft.

$V = 2.3 \times \sqrt{H}$

Where:

V = Vessel speed in knots

H = Water depth in feet

"Critical" Speed at which shallow water effect drops off

$V = 3.36 \times \sqrt{H}$

Where:

V = Vessel speed in knots

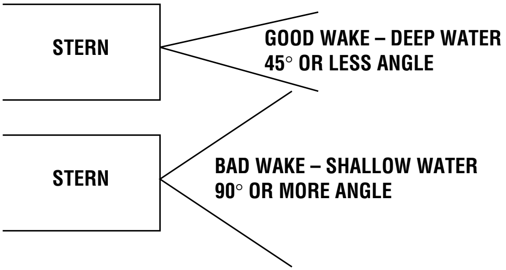
H = Water depth in feet

Let's take an example of a 200 foot boat traveling at 15 knots in deep water. As it is moving, it enters water about 20 feet deep. Since we know the boats speed and the water depth we must solve for the unknown = X. We would use the following formula: $V = (X)\sqrt{H}$ or $15 = (X)\sqrt{20}$ or $\times = 3.35$. This means that the boat would slow down appreciably as the speed of the boat equals 3.35 times the square root of the depth of water. For our example then this would be as follows: $V = (3.35)\sqrt{20}$ or V = 14.98 knots. In other words, this boat is at the "critical" speed it can operate in the 20 foot water depth. At this point, unless the water depth increases or the boat planes, it will suffer greatly from the effects of shallow water.

The wake that is trailing the boat would be at approximately a 45° angle to the center of the stern, in deep water, will now take a position of 90° to the centerline of the boat as it moves into the shallow water. The engines may begin to lug under the additional load and excessive vibration will become apparent throughout the boat.

Boat owners can watch the angle of their wake from the stern to see when they are getting loading from shallow water effect. The same is true for the Marine Analyst, when conducting a P.A.R. test. If you notice the wake is at a 90° angle from the stern of the boat, while conducting a "Normal Operation" test, then you should operate the boat test in deeper water.

Effects of shallow water on the wake of a boat



Ventilation System Formulas

As a rule of thumb, the installer should provide ventilation air flow of about 8 cfm (.22656 m^3/min) per installed horsepower (both propulsion and auxiliary engines). If combustion air is to be drawn from the engine room increase that figure to $9\frac{1}{4}$ cfm (.26196 m^3/min).

If you wish to compute more exact engine room air requirements it is necessary to determine the following factors:

H = Heat radiated to the engine room
This data is available from the TMI system for Caterpillar engines. Add in 4 Btu/min per generated 0.07032 kW for the normal maximum auxiliary generator load. Miscellaneous heat loads from other sources (pumps, motors, etc.) can be ignored if they are not exceptional.

Ta = Maximum ambient air temperature the vessel is expected to operate in during its whole life. [Usually assume 105° F (41° C).]

Sa = Density of the air at the maximum ambient air temperature.

Density of Air at Various Temperatures

° F/° C	lbs/cu. ft./kg/m³	° F/° C	lbs/cu. ft./kg/m³
0/–18	0.086/1.38	70/21	0.075/1.20
10/–12	0.084/1.35	80/27	0.074/1.18
20/–7	0.083/1.33	90/32	0.072/1.15
30/–1	0.081/1.30	100/38	0.071/1.14
40/4	0.079/1.27	**110/43**	**0.070/1.12**
50/10	0.078/1.25	120/49	0.068/1.09
60/16	0.076/1.22	130/54	0.067/1.07

dT = Maximum desired air temperature in the engine room. (Usually assume 15° F (9° C) rise above ambient)

When these factors have been determined, the ventilation air requirements in cubic feet per minute (cfm) can be calculated by the following formula:

$$Qa = \frac{H}{Sa \times 0.24 \times dT}$$

$$Qa = \frac{H}{Sa \times 0.017 \times dT} = \text{Metric}$$

Qa = Volume of inlet air required in cfm (m^3/min)

H = Radiated heat [btu/min (kW)]

Sa = Inlet air density [lbs/cu. ft. (kg/m^3)]

0.24 = Specific heat of air (btu/lbs/° F)

0.017 = Specific heat of air (kW•min/kg•° C)

dT = Temperature rise from ambient air to engine air [° F (°C)]

Ventilation Air Duct Sizing

Before the duct cross-sectional area can be calculated you must determine two elements.

Qcfm = Amount of Ventilation air and Combustion air (combine system) in cfm.

Va = Desired inlet air velocity [Not to exceed 2,000 feet per minute (609.6 m/min)]

Once these two elements have been determined then the following formula can be used to determine the minimum cross-sectional for both intake and exhaust ducts or openings.

$$Av = \frac{144 \times Q_a}{V_a} \qquad Av = \frac{Q_a}{V_a} = \text{Metric}$$

Av = Duct cross sectional area in square inches (m^2)

Q_a = Quantity of air flow in cubic feet per minute (m^3/min)

V_a = Velocity of air in the duct in feet per minute (m/min)

Combustion Air Formulas

If combustion air is to be drawn from the engine room, a slight modification is in order. Since the air used for combustion takes some engine room heat with it, it can be counted partially as ventilation air. This can be added into the calculation by adding about half of the combustion air required ($\frac{1}{2}$ Qc) resulting in the following equation:

$$Qa = \frac{H}{Sa \times 0.24 \times dT} + \frac{1}{2}\,Qc$$

$$Qa = \frac{H}{Sa \times 0.017 \times dT} + \frac{1}{2}\,Qc = \text{Metric}$$

Qa = Volume of inlet air required in cfm (m^3/min)

H = Radiated heat [btu/min (kW)]

Sa = Inlet air density [lbs/cu. ft. (kg/m^3)]

0.24 = Specific heat of air (btu/lbs/° F)

0.017 = Specific heat of air (kW•min/kg•° C)

dT = Temperature rise from ambient air to engine air [° F (°C)]

Qc = Combustion air required in cfm (m^3/min)

For combustion air requirement a good rule of thumb is to multiply the horsepower in the engine room by 2.5. Remember to include all engines in the engine room space for this calculation. If you need more exact combustion air figures then you can get that information from the TMI system. However, the 2.5 times rule is usually adequate for sizing purposes.

If the rule of thumb of 8 cfm/.22656 m^3/min of air per installed horsepower is applied, the minimum duct cross sectional area (Av) per installed horsepower would be:

$$Av = 0.6\ in^2/Hp\ (3.87\ cm^2/kW)\ @$$
$$Va = 2000\ fpm\ (609.6\ m/min)$$

$$Av = 0.9\ in^2/Hp\ (5.81\ cm^2/kW)\ @$$
$$Va = 1200\ fpm\ (365.8\ m/min)$$

If you included combustion air into the ventilation system [used 9.25 cfm (.262 m^3/min)]:

$$Av = 0.7\ in^2/Hp\ (4.52\ cm^2/kW)\ @$$
$$Va = 2000\ fpm\ (609.6\ m/min)$$

$$Av = 1.0\ in^2/Hp\ (6.45\ cm^2/kW)\ @$$
$$Va = 1200\ fpm\ (365.8\ m/min)$$

Remember air should enter the engine room freely. It is far better to have extra air than not enough. This installation parameter is second only to sufficient liquid cooling capacity in importance. If the rules of thumb are adhered to they will normally be sufficient, however, they are not overly conservative … Don't Cheat!

Sizing Combustion Air Ducts

Obtain the actual air requirement from the TMI system or use the rule of thumb (2.5 × Hp) to calculate the air required. The formula used to calculate the ventilation cross-sectional area can then be applied by using the appropriate combustion air volume and a velocity. (8000 fpm maximum)

This will most likely yield a cross-sectional area smaller than that of the factory connection to the air cleaner, however, be sure to keep the duct size equal to, or greater than, that of the factory connection.

If the straight length of duct is long, (over 25 × the diameter or diagonal of the factory connection) or includes more than two right angle bends, it would be wise to calculate the pressure drop at full air flow. This can be done using the following formula:

$$dP = \frac{Le \times S \times Q^2}{187 \times d^5} \qquad dP = 3{,}600{,}000 \times \frac{Le \times S \times Q^2}{d^5} = \text{Metric}$$

dP = Pressure loss [inches (kPa) of water]

Q = Air flow [cfm (m^3/min)]

d = Duct diameter [inches (mm)]

Le = Equivalent duct length [ft (m)]

S = Density of combustion air [lbs/cu.ft. (kg/m^3)]

Use the following method to determine Le:

Standard elbow = 2.75 × d

Long Sweep elbow = 1.7 × d

45° elbow = 1.25 × d

d = value must be in inches

Standard elbow = 0.033 × d = meter

Long Sweep elbow = 0.020 × d = meter

45° elbow = 0.015 × d = meter

d = value must be in mm

Exhaust System Formulas

Water Cooled Exhaust

There are two basic types of exhaust systems used in the marine area. The two systems are “wet” (water cooled) and dry exhaust systems. The main consideration is to design the system to remove the exhaust gases from the engine room and limit the backpressure to a minimum.

The limits for a given engines’ exhaust backpressure can be located in the TMI system. In general terms the backpressure limit is 27 inches of water for all Caterpillar turbocharged/turbocharged aftercooled engines. 34 inches of water is the limit for naturally aspirated engines. The 3600 series of engines have a limit of 10 inches of water. Some special rating, such as the 435 Hp 3208 E rating have a limit of 40 inches of water. You need to determine the limit of your engine, rating and then size the exhaust system to be below the limit. Remember that the closer you get to the limit the more affect the exhaust backpressure will have on the performance of the engine.

Many “wet” exhaust systems utilize an exhaust riser to help prevent sea water from entering the engine through the exhaust system when the engine is not operating or when the boat is “backed down” quickly. As a general rule of thumb the riser should be at least 22 inches above the level of the sea water to the lowest portion of the riser.

The minimum water flow requirements to a wet exhaust system can be calculated by using the following formula.

$$\text{Flow} = \frac{Vd \times Ne}{66000} \qquad \text{Flow} = \frac{Vd \times Ne}{285.785} = \text{Metric}$$

Flow = Gallons per minute (L/min)

Vd = Engine displacement [cubic inches (liters)]

Ne = Rated speed (rpm)

66,000 = constant for gallons

285.785 = constant for liters

A water lift muffler is also common in some of the smaller pleasure craft. If a water lift muffler is to be used the following are some points to pay close attention to.

1. Size the muffler outlet for a minimum exhaust velocity (gas only) of 5000 ft/min at rated engine power and speed. The following formula will give the maximum pipe diameter, "De" that can be used to insure the 5000 ft/min velocity.

   $$De = 0.19\sqrt{Qe} \qquad De = 28.67\sqrt{Qe} = \text{Metric}$$

   De = The maximum water lift exhaust outlet pipe diameter [inches (mm)]

   Qe = Exhaust flow rate from the muffler [cfm (m^3/min)]

2. The tank itself should be of sufficient size. A rule of thumb would be at least 8 cubic inches per rated horsepower.

3. The inlet pipe to the tank should be truncated near the top of the tank.

4. The outlet pipe should extend to near the bottom of the tank (about 1 inch from the bottom) and should be angle cut (mitered) to increase exit gas velocity at lower loads and flow rates.

5. A siphon break should be installed between the exhaust elbow and the high point of the outlet pipe from the muffler.

Dry Exhaust

The dry exhaust system has some typical points that need to be considered as well.

1. A flexible connection at the engine exhaust outlet. No more than 60 pounds of exhaust piping weight should be supported on the flexible connection.
2. Flexible connection(s) are installed on the horizontal portion and on the vertical stack of the exhaust system.
3. Horizontal portions of the exhaust system are sloped away from the engine
4. A spray shield/rain trap is used on the exhaust outlet.

The exhaust gas flow rate for a given engine and rating can be obtained from the TMI system. It can be closely estimated by using the following formula.

$$Qe = \frac{(Te + 460) \times Hp}{214} \qquad Qe = \frac{(Te + 273) \times kW}{3126.52} = \text{Metric}$$

Qe = Exhaust gas flow rate [cfm (m^3/min)]

Te = Exhaust gas temperature [° F (°C)]

Hp = Engine rated horsepower (kW)

After you have determined the exhaust gas flow rate the exhaust system backpressure can be calculated using the following formula.

$$dP = \frac{Lte \times Se \times Qe^2}{187 \times d^5} \qquad dP = 3{,}600{,}000 \times \frac{Lte \times S \times Qe^2}{d^5} = \text{Metric}$$

dP = Exhaust system backpressure [inches of water] or kPa

Lte = Total length of piping for diameter “d” [ft (m)]

d = Duct diameter [inches (mm)]

Lte is the sum of all the straight lengths of pipe for a given diameter “d”, plus, the sum of equivalent lengths, “Le”, of elbows and bends of diameter “d”. Straight flexible joints should be counted as their actual length if their inner diameter is not less than “d”.

Le = equivalent length of elbows in feet of straight pipe

Standard elbow – Le (ft) = 2.75 $\times$ d (inches)

Long elbow – Le (ft) = 1.67 $\times$ d (inches)

45 ° elbow – Le (ft) = 1.25 $\times$ d (inches)

Note: “Le” results are in feet but “d” must be in inches

Le = equivalent length of elbows in meters of straight pipe

Standard elbow – Le = 0.033 $\times$ d = (metric)

Long elbow – Le = 0.020 $\times$ d = (metric)

45 ° elbow – Le = 0.015 $\times$ d = (metric)

Note: “Le” results are in meters but “d” must be in mm

Qe = Exhaust gas flow [cfm (m^3/min)]

Se = Specific weight (density) of exhaust gas [lbs/cu. ft. (kg/m^3)]

The specific weight of the exhaust gas is calculated using the following formula.

$$Se = \frac{39.6}{(Te + 460)\ °F} \qquad Se = \frac{352}{(Te + 273)\ °C} = \text{Metric}$$

Se = Specific weight [lbs/cu. ft./kg/m^3)]

Te = Exhaust gas temperature [° F (° C)]

d = pipe diameter [inches (mm)]

The values of Lte, Se, Qe, and d must be entered in the units specified above if the formula is to yield valid results for backpressure.

To get the total exhaust pressure you must add to the answer from the above formula the pressure drop of the muffler. The pressure drop for Caterpillar mufflers is available in the TMI system.

Exhaust gas velocity should also be checked. If the velocity is too high, excessive noise or whistle may occur and inner pipe and wall surfaces may erode at an unacceptable rate. As a rule of thumb, the velocity is best kept to 18,000 ft/min or less. The velocity can be calculated using the following formula:

$$Ve = \frac{183 \times Qe}{d^2} \qquad Ve = \frac{1{,}270{,}691.83 \times Qe}{d^2} = \text{Metric}$$

Ve = Exhaust gas velocity [ft/min (m/min)]

Qe = Exhaust gas flow rate [cfm (m^3/min)]

d = Pipe diameter [inches (mm)]

API° Gravity Correction for Temperature

API = AMERICAN PETROLEUM INSTITUTE
SG = SPECIFIC GRAVITY

$$\text{IF API}° = \frac{141.5}{SG} - 131.5$$

THEN

$$SG = \frac{141.5}{(API + 131.5)}$$

THEN

$$141.5 = SG(API + 131.5)$$

The mean coefficients of expansion for different gravity materials up to about 400° F are in a range of 0.00035 – 0.00090. For fuels in the range of 15° API to 34.9° API the mean coefficient of expansion is 0.00040. Fuels in the range of 35° API to 50.9° API have a mean coefficient of expansion equal to 0.00050. Since most of the fuels we deal with at Caterpillar are in these two ranges, the average of the two will be used to perform the calculation. (0.00045 mean coefficient of expansion)*

Let's set up an example problem.

You measure the API gravity of a diesel fuel and find it to be 38° API @ 100° F. You would like to correct this to the standard and determine the weight of the fuel.

*** From the Physical Properties of Petroleum Oil**

To solve for this we will use the formula:

$$SG = \frac{141.5}{(API + 131.5)}$$

$$\text{Where } SG = \frac{141.5}{(38 + 131.5)}$$

$$SG = .8348$$

.8348 is the Specific Gravity of the fuel at 100° F. We want it at standard of 60° F. To correct the Specific Gravity we must do the following:

We know that for every 1° F we will have 0.00045 mean coefficient of expansion.

Since we are 40° F above the 60° F standard we will work it out as follows:

(40° F)(0.00045) = .018

1.00** – .018 = .982 Correction Factor

Specific Gravity can now be corrected by the following:

$$CSG = \frac{.8348 \text{ SG Measured}}{.982 \text{ Correction Factor}}$$

CSG = .8501

Now that we have the Corrected Specific Gravity (CSG) you can answer the original question by using the following formula:

$$API° = \frac{141.5}{SG} - 131.5$$

**** 1.00 IS THE SPECIFIC GRAVITY OF FRESH WATER**

As follows:

$$\text{Corrected API}^\circ \text{ @ } 60\,^\circ\text{F} = \frac{141.5}{.8501} - 131.5$$

Corrected API° @ 60 ° F = 34.95 ~ 35

We can also now calculate the weight per gallon of the diesel fuel. First we must realize that the weight of fresh water is 8.328 lbs per gallon. We have said that our Specific Gravity Corrected is .8501 that of water. Therefore the weight of our diesel fuel can be calculated by:

(.8501)(8.328) = 7.076 lbs/gallon.

Fuel System

Fuel Properties

Caterpillar Specifications for Distillate Fuel	
Specification (ASTM Test Procedure)	**Requirement**
Aromatics (D1319)	35 percent maximum
Ash (D482)	.02 percent maximum
Carbon residue on 10 percent bottoms (D524)	1.05 percent weight maximum
Cetane number (D613)	35 minimum (PC Engines 40 minimum (DI Engines)
Cloud Point	Maximum not above lowest expected ambient temperature
Copper strip corrosion (D130)	Number 3 maximum
Distillation (D86)	10 percent at 282° C (540° F) Maximum 90 percent at 360° C (680° F) Maximum
Flash point (D93)	Legal limit
API gravity (D287)	30 minimum, 45 maximum
Pour point (D97)	6° C (43° F) minimum below ambient temperature
Sulfur (D3605 or D1552)[1]	3 percent maximum[1]

[1] Caterpillar fuel systems and engine components can operate on high sulfur fuel. However, fuel sulfur levels effect exhaust particulate emissions. High sulfur fuels increase the potential for internal component corrosion. Fuel sulfur levels above 1.0 percent may SIGNIFICANTLY shorten the oil change interval. Refer to the TBN and fuel sulfur topic in the lubricants section for additional information.

Caterpillar Specifications for Distillate Fuel (Continued)

Specification (ASTM Test Procedure)	Requirement
Kinematic viscosity at 40° C (104° F) (D445)[2]	1.4 cSt minimum, 20.0 cSt maximum
Water and sediment (D1796)	.1 percent maximum
Water	.1 percent maximum
Sediment (D473)	.05 percent maximum
Gums and resins (D381)	10 mg per 100 ml maximum 5.8 grains per 1 US gal maximum
Lubricity by Scuffing Load West Test (SBOCLE) or High Frequency Reciprocating Rig (HFRR)[3]	3100 g minimum .45 mm (.018 in) maximum at 60° C (140° F) or .38 mm (.015 in) maximum at 25° C (77° F)

[2] The viscosity limits are for the fuel as delivered to the fuel injection pump. If low viscosity fuels such as JP-8, JP-5, Jet-A-1, or no. 1D diesel are used, fuel cooling may be required to maintain a 1.4 cSt at the fuel injection pump. When using high viscosity fuels or when operating in low temperature conditions, fuel heaters may be required to reduce viscosity to 20 cSt. Refer to SEBD0717, “Diesel Fuel And Your Engine”, for additional information.

[3] Lubricity of a fuel is a concern with low sulfur fuel. If the lubricity of a fuel does not meet the minimum requirements, consult your fuel supplier. Do NOT treat the fuel without consulting the fuel supplier. Some additives are not compatible and can cause problems in the fuel system.

Note: There are many after market additives available to treat fuel. Not all additives perform well in all fuel or in all fuel systems. Some lubricity additives may form deposits in the fuel injection system. If lubricity is an issue, consult your fuel supplier for proper recommendations regarding fuel lubricity additives.

Note: Caterpillar has adopted the EMA FQP1 lubricity limit as part of the Caterpillar preferred distillate fuels recommendation. See the above chart.

Blended (Heavy) fuels are usually described by their viscosity, expressed either in “centistokes” (cSt) or “Seconds Redwood”. The Redwood scale at 100° F is being phased out and replaced by the centistokes scale at 50° C. The centistoke viscosity may be preceded by the letters IF for “intermediate fuel” or IBF for “intermediate bunker fuel”. For example, IF 180 fuel has a viscosity of 180 cSt at 50° C. The following table gives the **approximate** relationship between the two scales.

cSt at 50° C	Seconds Redwood at 100° F
30	200
40	278
60	439
80	610
100	780
120	950
150	1250
180	1500
240	2400
280	2500
380	3500

Fuel Properties

Crude Oil Chart

Fuel Properties and Characteristics		Permissible Fuels As Delivered To The Fuel System
Cetane Number or Cetane Index (ASTM D613 or calculated index) (PC Engines)	Min.	35
(DI Engines)	Min.	40
Water and Sediment % volume (ASTM D1796)	Max.	0.5%
Pour Point (ASTM D97)	Min.	6° C (10° F) Below Ambient Temperature
Cloud Point (ASTM D97)	Min.	Not Higher than Ambient Temperature
Sulfur (ASTM D2788 or D3605 or D1552)	Max.	0.5% — See Page 95 to adjust oil TBN for Higher Sulfur Content
Viscosity at 38° C (100° F) (ASTM D445)	Min. Max.	1.4 cSt 20 cSt
API Gravity (ASTM D287)	Min. Max.	45 30
Specific Gravity (ASTM D287)	Min. Max.	0.8017 .875
Gasoline and Naphtha Fraction (Fractions Boiled off below 200° C)	Max.	35%
Kerosene and Distillate Fraction (Fractions boiled off between 200° C and cracking point)	Min.	30%

Fuel Properties

Crude Oil Chart (cont.)

Fuel Properties and Characteristics	Permissible Fuels As Delivered To The Fuel System	
Carbon Residue (Ramsbottom) (ASTM D524)	Max.	3.5%
Distillation — 10%	Max.	282° C (540° F)
— 90%	Max.	380° C (716° F)
— Cracking %	Min.	60%
— Residue (ASTM D86, D158 or D285)	Max.	10%
Reid Vapor Pressure (ASTM D323)	Max.	20 psi (kPa)
Salt (ASTM D3230)	Max.	100 lb per 1000 Barrels
Gums and Resins (ASTM D381)	Max.	10 mg per 100 ml
Copper Strip Corrosion 3 Hrs 100° C (ASTM D130)	Max.	No. 3
Flashpoint ° C/° F (ASTM D93)		Must be legal limit
Ash % Wt. (ASTM D482)	Max.	0.1%
Aromatics % (ASTM D1319)	Max.	35%
Vanadium PPM (ASTM D2788 or D3605)	Max.	4 PPM
Sodium PPM (ASTM D2788 or D3605)	Max.	10 PPM
Nickel PPM (ASTM D2788 or D3605)	Max.	1 PPM
Aluminum PPM (ASTM D2788 or D3605)	Max.	1 PPM
Silicon (ASTM D2788 or D3605)	Max.	1 PPM

Density and Specific Gravity

Specific Gravities and Densities of Fuel		
Gravity		Density
Degrees API at 15° C (60° F)	Specific Gravity at 15° C (60° F)	Pounds per gallon
25	.9042	7.529
26	.8984	7.481
27	.8927	7.434
28	.8871	7.387
29	.8816	7.341
30	.8762	7.296
31	.8708	7.251
32	.8654	7.206
33	.8602	7.163
34	.8550	7.119
35	.8498	7.076
36	.8448	7.034
37	.8398	6.993
38	.8348	6.951
39	.8299	6.910
40	.8251	6.870
41	.8203	6.830
42	.8155	6.790
43	.8109	6.752
44	.8063	6.713
45	.8017	6.675
46	.7972	6.637
47	.7927	6.600
48	.7883	6.563
49	.7839	6.526

Fuel API Correction Chart

API Gravity Corrected to 60° F

(Measured Fuel Temperature ° F)

Measured ° API Gravity	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°
	° API Gravity At 60° F															
29°	33	32.5	32	31	30	30	29	28	28	27	26.5	26	25	24.5	24	23.5
30°	34	33.5	33	32	31.5	31	30	29	29	28	27.5	27	26	25.5	25	24.5
31°	35	34.5	34	33	32.5	32	31	30	30	29	28.5	28	27	26.5	26	25
32°	36	35.5	35	34	33.5	33	32	31	30.5	30	29	29	28	27.5	27	26
33°	37	36.5	36	35	34.5	34	33	32	31.5	31	30	29.5	29	28.5	28	27
34°	38.5	38	37	36	35.5	35	34	33	32.5	32	31	30.5	30	29	29	28
35°	39.5	39	38	37	36.5	36	35	34	33.5	33	32	31.5	31	30	29.5	29
36°	41	40	39	38	37.5	37	36	35	34.5	34	33	32.5	32	31	30.5	30
37°	42	41	40	39	38.5	38	37	36	35.5	35	34	33.5	33	32	31.5	31
38°	43	42	41	40.5	39.5	39	38	37	36.5	36	35	34.5	34	33	32	32
39°	44	43	42	41.5	40.5	40	39	38	37.5	37	36	35	34.5	34	33	32.5
40°	45	44	43	42.5	41.5	41	40	39	38.5	38	37	36	35.5	35	34	33.5
41°	46	45	44.5	43.5	42.5	42	41	40	39.5	39	38	37	36.5	36	35	34.5
42°	47	46	45.5	44.5	44	43	42	41	40.5	39.5	39	38	37.5	37	36	35
43°	48.5	47.5	46.5	45.5	45	44	43	42	41.5	40.5	40	39	38	37.5	37	36
44°	49.5	48.5	47.5	46.5	46	45	44	43	42	41.5	41	40	39	38.5	38	37

Fuel API Correction Chart (cont.)

Measured ° API Gravity	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°
	° API Gravity At 60° F															
45	50.5	49.5	49	48	47	46	45	44	43	42.5	42	41	40	39.5	38.5	38
46	52	51	50	49	48	47	46	45	44	43.5	42.5	42	41	40	39.5	39
47	53	52	51	50	49	48	47	46	45	44.5	43.5	43	42	41	40.5	40
48	54	53	52	51	50	49	48	47	46	45	44.5	44	43	42	41	40.5
49	55	54	53	52	51	50	49	48	47	46	45.5	45	44	43	42	41.5
50	56	55	54	53	52	51	50	49	48	47	46.5	45.5	45	44	43	42
51	57.5	56	55	54	53	52	51	50	49	48	47	46.5	45.5	45	44	43
52	58.5	57.5	56	55	54	53	52	51	50	49	48	47	46.5	45.5	45	44
53	60	58.5	57	56	55	54	553	52	51	50	49	48	47.5	46.5	46	45

Tooling: Fuel Thermo-hydrometer 1P7408 Test Breaker 1P7438

Distillate Fuel Temperature

Maximum Fuel Supply Temperature:

— Without Power Reduction: 85° F (29° C)

Power is reduced 1% for each 10° F (5.6° C) above 100° F (38° C) if engine is running against fuel stop.

— Without Injector Damage: 150° F (65° C)

Correction Factors:

Fuel Temperature Correction Factors	
Fuel Temp ° F	**Correction Factor**
–10	.905
–5	.910
0	.915
5	.920
10	.925
15	.930
20	.935
25	.940
30	.945
35	.950
40	.955
45	.960
50	.965
55	.970
60	.975
65	.980
70	.985
75	.990
80	.995
85 [1]	1.000
90	1.005
95	1.010
100	1.015
105	1.020
110	1.025
115	1.030
120	1.035
125	1.040
130	1.045
135	1.050
140	1.055
145	1.060
150	1.065
155	1.070
160	1.075

[1] Standard value.

Fuel Density (API) Correction Factors	
Fuel API at 60° F	**Correction Factor**
31.5	.985
32.0	.987
32.5	.989
33.0	.991
33.5	.994
34.0	.996
34.5	.998
35.0*	**1.000**
35.5	1.002
36.0	1.004
36.5	1.006
37.0	1.009
37.5	1.011
38.0	1.013
38.5	1.015
39.0	1.017
39.5	1.020
40.0	1.022
40.5	1.024
41.0	1.026
41.5	1.028
42.0	1.031
42.5	1.033
43.0	1.035
43.5	1.037
44.0	1.040
44.5	1.042
45.0	1.044
45.5	1.046
46.0	1.049
46.5	1.051
47.0	1.053
47.5	1.055
48.0	1.058

*Standard Value. The measured fuel API and corresponding fuel temperature must be corrected to 60° F before selecting an API correction factor.

Inlet Air Temperature Correction Factors for Turbocharged and JWAC Engines	
Air Temperature °F	**Correction Factor**
–10	.969
–5	.971
0	.972
5	.974
10	.976
15	.978
20	.980
25	.982
30	.984
35	.985
40	.987
45	.989
50	.991
55	.992
60	.994
65	.996
70	.998
75	.999
77*	**1.000**
80	1.001
85	1.003
90	1.004
95	1.006
100	1.008
105	1.009
110	1.011
115	1.012
120	1.014

*Standard Value. Measure between air cleaner and turbo inlet.

Inlet Air Pressure Correction Factors for Turbocharged, JWAC and ATAAC Engines	
Air Pressure In. Hg	**Correction Factor**
31.5	.994
31.0	.997
30.5*	**1.000**
30.0	1.003
29.5	1.006
29.0	1.010
28.5	1.013
28.0	1.016
27.5	1.020
27.0	1.023
26.5	1.027
26.0	1.030
25.5	1.034
25.0	1.038
24.5	1.042
24.0	1.046
23.5	1.050
23.0	1.055
22.5	1.059
22.0	1.064
21.5	1.068
21.0	1.073
20.5	1.079
20.0	1.083

*30.5 In. Hg is used as the Standard Value to account for air cleaner restriction, vapor pressure (humidity) and exhaust back pressure.

Power Calculation:

$$HP = \frac{\text{Fuel Rate (GPH)} \times \text{Fuel Density}\left(\frac{LB}{GAL}\right)}{BSFC\left(\frac{LB}{HP \bullet HR}\right)}$$

$$kW = \frac{\text{Fuel Rate (L/HR)} \times \text{Fuel Density}\left(\frac{GRAM}{LITER}\right)}{BSFC\left(\frac{GRAM}{kW \bullet HR}\right)}$$

BSFC

$$\frac{\text{CSFC (GRAMS/kW HR)}}{454} = \text{LBS/kW HR}$$

$$\frac{\text{LBS/kW HR}}{1.34} = \text{BSFC (LBS/HP HR)}$$

Tolerances

Performance curves represent typical values obtained under normal operating conditions. Ambient air conditions and fuel used will affect these values. Each of the values may vary in accordance with the following tolerances:

Exhaust Stack Temperature	±42 DEG C
	±75 DEG F
Intake Manifold Pressure-Gage	±10 kPa
	±3 in Hg
Power	±3 Percent
Fuel Consumption	±6 g/kW-hr
	±.010 lb/hp-hr
Fuel Rate	±5 Percent

Conditions

Ratings are based on SAE J1349 standard conditions of 100 kPa (29.61 in Hg) and 25° C (77° F). These ratings also apply at ISO 3046/1, DIN 6271 and BS 5514 standard conditions of 100 kPa (29.61 in Hg), 27° C (81° F) and 60% relative humidity.

Fuel Rates are based on fuel oil of 35° API [16° C (60° F)] gravity having an LHV of 42 780 kJ/kg (18,390 Btu/lb) when used at 29° C (85° F) and weighing 838.9 g/liter (7.001 lbs/U.S. gal).

Additional Formulas Used to Develop Marine Par Curves

For Torque Check GPH proceed as follows:

Torque Check GPH = TQ COR. Fuel Rate (G/MIN) ÷ 454 × 60 = LBS/HR

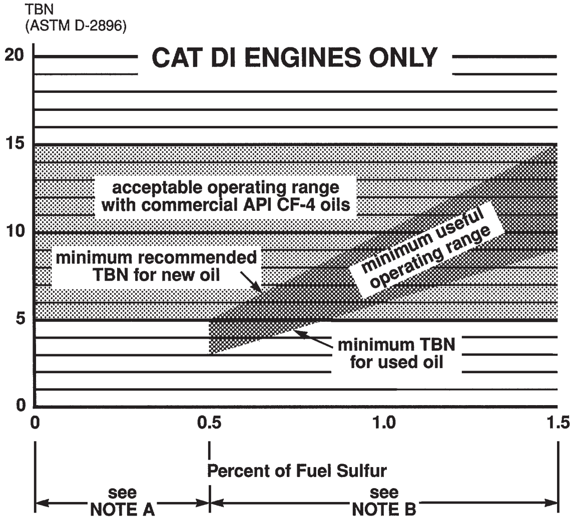
LBS/HR ÷ 7.076 = GPH

For BSFC proceed as follows:

BSFC = Adjusted CSFC (G/kW HR) ÷ 454 = LBS/kW HR

LBS/kW HR ÷ 1.34 = BSFC (LBS/HP HR)

Oil TBN vs. Fuel Sulfur Content



Graph for determination of necessary TBN. Find the fuel sulfur percentage on bottom of the graph. Find point where the new oil TBN line intersects the sulfur content line, and read the required TBN at the left side of the chart.

Rule of Thumb: New oil TBN should be 10 times fuel sulfur content. Change oil when TBN drops to $\frac{1}{2}$ its original value when using API CF-4 or better oil and you are using a DI engine.

Additives

There are chemical substances added to a petroleum product to impart or improve certain properties.

Additives strengthen or modify certain characteristics of the base oil. Ultimately, they enable the oil to meet requirements quite beyond the abilities of the base oil.

The most common additives are: detergents, oxidation inhibitors, dispersants, alkalinity agents, anti-wear agents, pour-point depressants and viscosity improvers.

Here is a brief description of what each additive does and how.

Detergents help keep the engine clean by chemically reacting with oxidation products to stop the formation and deposit of insoluble compounds.

Oxidation inhibitors help prevent increases in viscosity, the development of organic acids and the formation of carbonaceous matter.

Dispersants help prevent sludge formation by dispersing contaminants and keeping them in suspension.

Alkalinity agents help neutralize acids.

Anti-wear agents reduce friction by forming a film on metal surfaces.

A pour-point depressant keeps the oil fluid at <u>low</u> temperatures by preventing the growth and agglomeration (the gathering together into a mass) of wax crystals.

Viscosity improvers help prevent the oil from becoming too thin at <u>high</u> temperatures.

Anti-Wear Additive

This is an additive in a lubricant that reduces friction and excessive wear.

API (American Petroleum Institute)

This is a trade association of petroleum producers, refiners, marketers, and transporters, organized for the advancement of the petroleum industry by conducting research, gathering and disseminating information, and maintaining cooperation between government and the industry on all matters of mutual interest. One API technical activity has been the establishment of API Engine Service Categories for lubricating oils.

API Engine Service Categories

Gasoline and diesel engine oil performance levels are established jointly by API, SAE, and ASTM called API Engine Service Classifications. API Service Categories are as follows:

Diesel Engine Oils

API Letter Designation		API Engine Service Description
		Key: X Obsolete Test Techniques O Active Test Techniques
CA	X	Diesel Engine Service (Obsolete)
CB	X	Diesel Engine Service (Obsolete)
CC	X	Diesel Engine Service

CD	O	Diesel Engine Service The category CD denotes service typical of certain naturally aspirated, turbocharged, or supercharged diesel engines where highly effective control of wear and deposits is vital or when using fuels of a wide quality range, including high sulfur fuels. Oils designed for this service were introduced in 1955 and provide protection from bearing corrosion and from high-temperature deposits in these diesel engines.
CD-II	O	Severe Duty Two-Stroke Cycle Diesel Engine Service typical of two-stroke cycle diesel engines requiring highly effective control over wear and deposits. Oils designed for this service also meet all performance requirements of API Service Category CD.
CE	X	1983 Diesel Engine Service Service typical of certain turbocharged or supercharged heavy-duty diesel engines manufactured since 1983 and operated under both low-speed, high-load and high-speed, high-load conditions. Oils designed for this service may also be used when API Engine Service Category CD is recommended for diesel engines.
CF-4	O	1990 Diesel Engine Service Service typical of certain turbocharged or supercharged heavy-duty diesel engines manufactured and operated under both low-speed, high-load and high-speed, high-load conditions. Oils designed for this service may also be used when API Engine Service Category CD and CE are recommended for diesel engines.
CG-4		1995 Diesel Engine Service Service for engine wear and deposits issues linked to fuel specifications and engine designs that are required to accommodate 1994 EPA emission regulations for low sulfur fuel (0.05%).

Gasoline Engine Oils

API Letter Designation		API Engine Service Description
SA	(No test required)	Formerly for Utility Gasoline and Diesel Engine Service (Obsolete)
SB	X	Minimum Duty Gasoline Engine Service (Obsolete)
SC	X	1964 Gasoline Engine Warranty Maintenance Service (Obsolete)
SD	X	1968 Gasoline Engine Warranty Maintenance Service (Obsolete)
SE	X	1972 Gasoline Engine Warranty Maintenance Service (Obsolete Starting in 1989)
SF	X	1980 Gasoline Engine Warranty Maintenance Service
SG	O	1989 Gasoline Engine Warranty Maintenance Service The category SG denotes service typical of present gasoline engines in passenger cars, vans, and light-duty trucks operating under manufacturers' recommended maintenance procedures. Category SG quality oils include the performance properties of API Service Category CC. (Certain manufacturers of gasoline engines require oils also meeting the higher diesel engine Category CD). Oils developed for this service provide improved control of engine deposits, oil oxidation, and engine wear relative to oils developed for previous categories. These oils also provide protection against rust and corrosion. Oils meeting API Service Category SG may be used when API Service Categories SF, SE, SF/CC, or SE/CC are recommended.
SH	O	API category for use in service typical of gasoline engines in present and earlier vehicles. These oils have been tested according to the CMA product approval code of practice and may be used where API category SG and earlier categories have been recommended. They must meet all API SG requirements and use Multiple Test Acceptance Criteria (MTAC).

Ash Content

This is the noncombustible residue of a lubricating oil or fuel. Lubricating oil detergent additives contain metallic derivatives, such as barium, calcium, and magnesium sulfonates, that are common sources of ash. Ash deposits can impair engine efficiency and power. See detergent.

ASTM (American Society for Testing and Materials)

This organization is devoted to “the promotion of knowledge of the materials of engineering and the standardization of specifications and methods of testing.” A preponderance of the data used to describe, identify, or specify petroleum products is determined in accordance with ASTM test methods.

Base Stock

Base stock is a primary refined petroleum fraction, usually a lube oil, into which additives and other oils are blended to produce finished products.

Bid Oil

This is oil produced by an oil company which just meets the minimum of the diesel engine oil performance specifications. These oils are usually the least expensive because they have only the minimum amount of additives to just get by. These oils might be acceptable for lightly loaded applications but could cause problems in more severe machine application.

Blow-By

This comes from an internal combustion engine where seepage of fuel and gases past the piston rings and cylinder wall into the crankcase, results in crankcase oil dilution and sludge formation.

BMEP

Brake mean effective pressure is the theoretical average pressure that would have to be imposed on the pistons of a frictionless engine (of the same dimensions and speed) to produce the same power output as the engine under consideration; a measure of how effectively an engine utilizes its piston displacement to do work.

Borderline Pumping Temperature °C (ASTDM D3829)

This is the temperature at which the oil becomes too viscous (thick) and cannot be moved when force is applied. The oil, however, is not yet a solid (pour point).

Bulk Delivery

This is a large quantity of unpackaged petroleum product delivered directly from a tank truck, tank car, or barge into a consumer's storage tank.

Colloid

A colloid is a suspension of finely divided particles 5 to 5000 angstroms in size in a gas or liquid, that do not settle and are not easily filtered. an Angstrom is a unit of wave length of light equal to one ten billionth of a meter which carries a positive or negative charge.

Colloids are usually ionically stabilized by some form of surface charge on the particles to reduce the tendency to agglomerate (gather into a ball or mass). A lubricating grease is a colloidal system, in which metallic soaps or other thickening agents are dispersed in, and give structure to, the liquid lubricant.

Color Scale

These scales serve primarily as indicators of product uniformity and freedom from contamination. The scale is a standardized range of colors against which the colors of petroleum products may be compared. There are a number of widely used systems of color scales, including: ASTM scale (test method ASTM D 1500), the most common scale, used extensively for industrial and process oils.

Crude Oil

Crude oil is a complex, naturally occurring fluid mixture of petroleum hydrocarbons, yellow to black in color, and also containing small amounts of oxygen, nitrogen, and sulfur derivatives and other impurities. Crude oil was formed by the action of bacteria, heat, and pressure on ancient plant and animal remains, and is usually found in layers of porous rock such as limestone or sandstone, capped by an impervious layer of shale or clay that traps the oil. Crude oil varies in appearance and hydrocarbon composition depending on the locality where it occurs. Crude is refined to yield petroleum products.

Demerit Rating

This is an arbitrary graduated numerical rating sometimes used in evaluating engine deposit levels following testing of an engine oil's detergent-dispersant characteristics. On a scale of 0-10, the higher the number, the heavier the deposits. A more commonly used method of evaluating engine cleanliness is merit rating. See Engine Deposits.

Detergent

This is an important component of engine oils that helps control varnish, ring zone deposits, and rust by keeping insoluble particles in suspension and in some cases, by neutralizing acids. A detergent is usually a metallic compound. Because of its metallic composition, a detergent leaves a slight ash when the oil is burned. A detergent is normally used in conjunction with a dispersant.

Dispersant

A dispersant is an engine oil additive that helps prevent sludge, varnish, and other engine deposits by keeping soot particles suspended in a colloidal state (prevents these particles from gathering into a ball or mass).

Engine Deposits

These are hard or persistent accumulations of sludge, varnish, and carbonaceous residues due to blow-by of unburned and partially burned (partially oxidized) fuel, or from partial breakdown of the crankcase lubricant. Water from condensation of combustion products, carbon, residues from fuel or lubricating oil additives, dust, and metal particles also contribute. Engine deposits can impair engine performance and damage engine components by causing valve and ring sticking, clogging of the oil screen and oil passages, and excessive wear of pistons and cylinders. Hot, glowing deposits in the combustion chamber can also cause pre-ignition of the air-fuel mix. Engine deposits are increased by short trips in cold weather, high temperature operation, heavy loads (such as pulling a trailer), and over-extended oil drain intervals.

EPA (Environmental Protection Agency)

The EPA is an agency of the federal executive branch, established in 1970 to abate and control pollution through monitoring, regulation, and enforcement, and to coordinate and support environmental research.

Fighting Grade Oil

See Bid Oil.

Flashpoint

This is the lowest temperature at which the vapor of a combustible liquid can be made to ignite momentarily in air. Flash point is an important indicator of the fire and explosion hazards associated with a petroleum product.

Lubrication

Lubrication is the control of friction and wear by the introduction of a friction-reducing film between moving surfaces in contact. The lubricant used may be a fluid, solid, or plastic substance.

Merit Rating

This is an arbitrary graduated numerical rating commonly used in evaluating engine deposit levels when testing the detergent-dispersant characteristics of an engine oil. On a scale of 10-0, the lower the number, the heavier the deposits. A less common method of evaluating engine cleanliness is demerit rating. See Engine Deposits.

Mineral Oil

This is any petroleum oil, as contrasted to animal or vegetable oils. Also, a highly refined petroleum distillate, or white oil, used medicinally as a laxative.

OSHA (Occupational Safety and Health Administration)

Oxidation

Oxidation is the chemical combination of a substance with oxygen. All petroleum products are subject to oxidation. This degrades their composition and lowers their performance. The oxidation process is accelerated by heat, light, metal catalysts (agents which bring about a chemical reaction) and the presence of water, acids or solid contaminants.

These substances react with each other to form sludges, vanishes and gums that can impair equipment operation.

To minimize oxidation and its effects, carefully select a good base stock oil, insure an oxidation inhibitor is added to the base stock and maintain equipment and change oil to prevent contamination and excessive heat.

Oxidation Inhibitor

This is any substance added in small quantities to a petroleum product to increase its oxidation resistance, thereby lengthening its service or storage life; also called anti-oxidant. An oxidation inhibitor may work in one of three ways (1) by combining with and modifying peroxides (compounds high in oxygen) to render them harmless, (2) by decomposing the perioxides, or (3) by rendering an oxidation catalyst (metal or metal-ions) inert; that is, lacking in a chemical reaction. See Oxidation.

Oxidation Stability

This is the resistance of a petroleum product to oxidation; hence, a measure of its potential service or storage life. There are a number of ASTM tests to determine the oxidation stability of a lubricant or fuel, all of which are intended to simulate service conditions on an accelerated basis. In general, the test sample is exposed to oxygen or air at an elevated temperature, and sometimes to water or catalysts (usually iron or copper). Depending on the test, results are expressed in terms of the time required to produce a specified effect (such as pressure drop), the amount of sludge or gum produced, or the amount of oxygen consumed during a specified period.

Pass-Oil

See Bid Oil.

Pour Point

Pour point is the lowest temperature at which an oil or distillate fuel is observed to flow, when cooled under conditions prescribed by test method ASTM D97. The pour point is 3° C (5° F) above the temperature at which the oil in a test vessel shows no movement when the container is held horizontally for five seconds. Pour point is lower than wax appearance point or cloud point. It is an indicator of the ability of an oil or distillate fuel to flow at cold operating temperatures.

Ring Land

This is the area on the surface of the piston that is between either the top of the piston and first ring groove or between two adjacent ring grooves.

Ring Sticking

Ring sticking is freezing of a piston ring in its groove, in a piston engine or reciprocating compressor, due to heavy deposits in the piston ring zone. This prevents proper action of the ring and tends to increase blow-by into the crankcase and to increase oil consumption by permitting oil to flow past the ring zone into the combustion chamber. See Engine Deposits.

SAE (Society of Automotive Engineers)

The Society of Automotive Engineers reviews the total automotive engine and lubricant situation and defines the requirement for new oil specifications.

SAE Oil Viscosity Classification

Because of the important effects of oil viscosity the Society of Automotive Engineers (SAE) has developed a system for classifying lubricating oils in terms of viscosity only; no other physical or performance characteristics are considered.

The viscosity numbers without the letter W are based upon 210° F viscosities. Viscosity at that temperature correlates with oil consumption and other oil performance characteristics influenced by viscosity at normal engine operating temperatures. The viscosity numbers with the letter W are based on 0° F viscosities.

The 0° F viscosities for W-numbered oils were selected because they correlate with the cranking characteristics of motor oils in the average automobile engine under low-temperature starting conditions.

Viscosity Grades for Engine Oils

SAE Viscosity grade	Viscosity (cP)[a] at temp. (° C) max	Boderline[b] pumping temp. (° C) max	Viscosity[c] at 100° C (cSt) min	max
0W	3250 at –30	–35	3.8	—
5W	3500 at –25	–30	3.8	—
10W	3500 at –20	–25	4.1	—
15W	3500 at –15	–20	5.6	—
20W	4500 at –10	–15	5.6	—
25W	6000 at –5	–10	9.3	—
20	—	—	5.6	< 9.3
30	—	—	9.3	<12.5
40	—	—	12.5	<16.3
50	—	—	16.3	<21.9
60	—	—	21.9	<26.1

Note: 1cP = 1mPa s, 1cSt = 1 mm^2/s

[a] ASTM D 2602 (cold cranking simulator)

[b] ASTM D 4684 (MRV TP-1)

[c] ASTM D 445 (capillary viscometer)

Single-Grade Oil

This is the engine oil that meets the requirements of a single SAE viscosity grade classification. i.e., SAE 10W, 30 and 40.

Scote

Scote stands for single cylinder oil test engine. Cat developed, tested and supports the single cylinder oil test engine for the CF-4 engine oil service category. This test is known as the Cat 1K Scote.

Shear Stability

Shear stability is the ability of a multiviscosity oil to resist shear forces (sudden and abrupt changes in movement) on the oil that would cause it to revert to the base oil and become too thin to provide adequate lubrication.

Sludge

In diesel engines, sludge is a soft, black, mayonnaise-like emulsion of water, other combustion by-products, and oil formed during low-temperature engine operation. Sludge plugs oil lines and screens, and accelerates wear of engine parts. Sludge deposits can be controlled with a dispersant additive that keeps the sludge constituents finely suspended in the oil. See Engine Deposits.

Soot

This is unburned fuel. Black smoke and a dirty air filter indicate its presence. It causes oil to turn black.

Synthetic Lubricant

A synthetic lubricant is a lubricating fluid made by chemically reacting materials of a specific chemical composition to produce a compound with planned and predictable properties. The resulting base stock may be supplemented with additives to improve specific properties. Many synthetic lubricants — also called synlubes — are derived wholly or primarily from petrochemicals; other synlube raw materials are derived from coal and oil shale, or are lipochemicals (from animal and vegetable oils). Synthetic lubricants may be superior to petroleum oils in specific performance areas. Many exhibit higher viscosity index (V.I.) better thermal stability (heat resistance) and oxidation stability, and low volatility (which reduces oil consumption). Because synthetic lubricants are higher in cost than petroleum oils, they are used selectively where performance or safety requirements may exceed the capabilities of a conventional oil.

Total Base Number (TBN)

Understanding TBN requires some knowledge of fuel sulfur content. Most diesel fuel contains some degree of sulfur. How much depends on the amount of sulfur in the crude oil from which it was produced and/or the refiner's ability to remove it. One of the functions of lubricating oil is to neutralize sulfur by-products, namely sulfurous and sulfuric acids and thus retard corrosive damage to the engine. Additives in the oil contain alkaline compounds which are formulated to neutralize these acids. The measure of this reserve alkalinity in an oil is known as its TBN. Generally, the higher the TBN value, the more reserve alkalinity or acid-neutralizing capacity the oil contains. Caterpillar uses ASTM test D2896 to determine TBN.

Toxicology

This is a science that deals with poisons and their affect and with the problems involved (as clinical, industrial or legal).

Viscosity

Viscosity is one of the more critical properties of oil. It refers to an oil's thickness or its resistance to flow. Viscosity is directly related to how well an oil will lubricate and protect surfaces that contact one another. Regardless of the ambient temperature or engine temperature, an oil must flow sufficiently to ensure an adequate supply to all moving parts.

The more viscous (or thicker) an oil is, the thicker the oil film it will provide. The thicker the oil film, the more resistant it will be to being wiped or rubbed from lubricated surfaces. Conversely, oil that is too thick will have excessive resistance to flow at low temperatures and so may not flow quickly enough to those parts requiring lubrication. It is therefore vital that the oil has the correct viscosity at both the highest and the lowest temperatures at which the engine is expected to operate.

Viscosity Index (VI)

Oil thins out as temperature increases. The measurement of the rate at which it thins out is called the oil's viscosity "index" (or VI). New refining techniques and the development of special additives which improve the oil's viscosity index help retard the thinning process.

The Society of Automotive Engineers (SAE) standard oil classification system categorizes oils according to their quality (via an alphabetical designation, like CD) and viscosity (via a number).

Zinc

This is widely used as an anti-wear agent in motor oils to protect heavily loaded parts, particularly the valvetrain mechanisms (such as the camshaft and cam followers) from excessive wear. It is also used as an anti-wear agent in hydraulic fluids and certain other products.

Δ T-Flow Relationship

$$\Delta T\ (^\circ F) = \frac{\text{Heat Rejection (BTU/MIN.)}}{\text{Flow (GPM)} \times \text{Density (LB/GAL.)} \times \text{Spec. Heat (BTU/LB}\bullet^\circ\text{ F)}}$$

	Pure Water	Sea Water	50/50 Water — Glycol	Diesel Fuel
Density (LB/GAL.)	8.1	8.5	8.6	7.1
Specific Heat (BTU/LB•° F)	1.0	0.94	0.85	0.45

$$\Delta T\ (^\circ C) = \frac{\text{Heat Rejection (kW)}}{\text{Flow (L/MIN.)} \times \text{Density (KG/L)} \times \text{Spec. Heat} \left(\frac{\text{kW}\bullet\text{MIN.}}{\text{KG}\bullet^\circ\text{ C}}\right)}$$

	Pure Water	Sea Water	50/50 Water — Glycol	Diesel Fuel
Density (KG/L)	0.98	1.02	1.03	0.85
Specific Heat $\left(\frac{\text{kW}\bullet\text{MIN.}}{\text{KG}\bullet^\circ\text{ C}}\right)$	0.071	0.066	0.06	0.032

Piping Design — Flow Relationships

Recommended Coolant Velocities
- Jacket Water: 2-8 FT./SEC. (0.6-2.5 M/SEC.)
- Sea Water: 2-6 FT./SEC. (0.6-1.9 M/SEC.)

Maximum Fresh Water Velocities for 3600 Engines
- Pressurized Lines: 14.8 FT./SEC. (4.5 M/SEC.) Max.
- Suction Lines: 4.9 FT./SEC. (1.5 M/SEC.) Max.

Pipe Dimensions

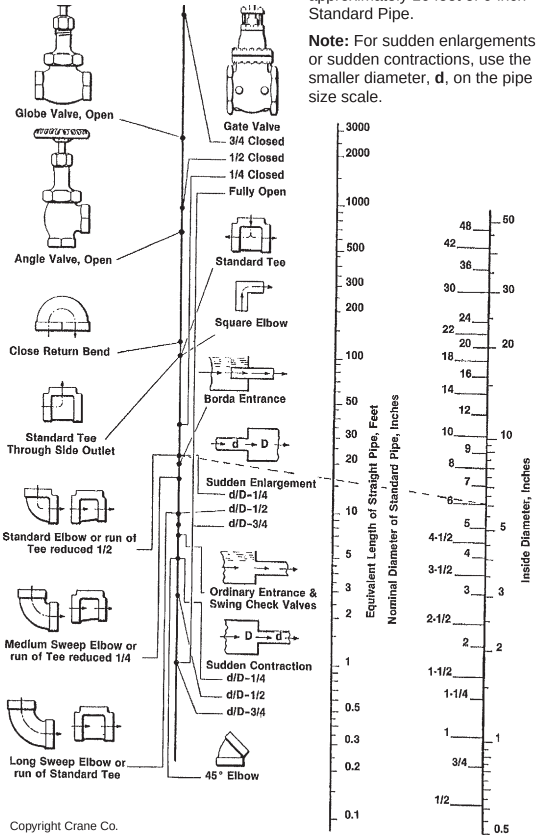
Standard Iron Pipe

Nominal Size		Actual I.D.		Actual O.D.		ft. per gal.	m per Liter	ft. per cu. ft.	m per m^3
in.	(mm)	in.	(mm)	in.	(mm)				
1/8	3.18	0.270	6.86	0.405	10.29	336	27.0	2513	27,049
1/4	6.35	0.364	9.25	0.540	13.72	185	16.1	1383	14,886
3/8	9.53	0.494	12.55	0.675	17.15	100.4	8.3	751	8,083
1/2	12.7	0.623	15.82	0.840	21.34	63.1	5	472	5,080
3/4	19.05	0.824	20.93	1.050	26.68	36.1	2.9	271	2,917
1	25.4	1.048	26.62	1.315	33.4	22.3	1.9	166.8	1,795
1 1/4	31.75	1.380	35.05	1.660	42.16	12.85	1.03	96.1	1,034
1 1/2	38.1	1.610	40.89	1.900	48.26	9.44	.76	70.6	760
2	50.8	2.067	52.25	2.375	60.33	5.73	.46	42.9	462
2 1/2	63.5	2.468	62.69	2.875	73.02	4.02	.32	30.1	324
3	76.2	3.067	77.9	3.500	88.9	2.60	.21	19.5	210
3 1/2	88.9	3.548	90.12	4.000	101.6	1.94	.16	14.51	156
4	101.6	4.026	102.26	4.500	114.3	1.51	.12	11.30	122
4 1/2	114.3	4.508	114.5	5.000	127	1.205	.097	9.01	97
5	127	5.045	128.14	5.563	141.3	0.961	.077	7.19	77
6	152.4	6.065	154	6.625	168.28	0.666	.054	4.98	54
7	177.8	7.023	178.38	7.625	193.66	0.496	.04	3.71	40
8	203.2	7.982	202.74	8.625	219.08	0.384	.031	2.87	31
9	228.6	8.937	227	9.625	244.48	0.307	.025	2.30	25
10	254	10.019	254.5	10.750	273.05	0.244	.02	1.825	19.6
12	304.8	12.000	304.8	12.750	323.85	0.204	.016	1.526	16.4

Resistance of Valves and Fittings to Flow of Fluids

Example: The dotted line shows that the resistance of a 6-inch Standard Elbow is equivalent to approximately 16 feet of 6-inch Standard Pipe.

Note: For sudden enlargements or sudden contractions, use the smaller diameter, **d**, on the pipe size scale.



This chart is for illustrative purposes only. Do not attempt to use this for measurement. Refer to Application Installation Guides for full scale measurements.

Flow Restriction of Fittings Expressed as Equivalent Feet of Straight Pipe

Size of Fitting	2"	2½"	3"	4"	5"	6"	8"	10"	12"	14"	16"
90 Ell	5.5	6.5	8	11	14	16	21	26	32	37	42
45 Ell	2.5	3	3.8	5	6.3	7.5	10	13	15	17	19
Long Sweep Ell	3.5	4.2	5.2	7	9	11	14	17	20	24	27
Close Return Bend	13	15	18	24	31	37	51	61	74	85	100
Tee — Straight Run	3.5	4.2	5.2	7	9	11	14	17	20	24	27
Tee — Side Inlet or Outlet	12	14	17	22	27	33	43	53	68	78	88
Globe Valve Open	55	67	82	110	140						
Angle Valve Open	27	33	41	53	70						
Gate Valve Fully Open	1.2	1.4	1.7	2.3	2.9	3.5	4.5	5.8	6.8	8	9
Gate Valve Half Open	27	33	41	53	70	100	130	160	200	230	260
Check Valve	19	23	32	43	53						

Strainers:

As a general rule of thumb, strainers should be of adequate capacity to create no more than 1.5-2.0 psi (10-14 kPa) of pressure drop under clean strainer conditions at maximum flow.

Typical Friction Losses of Water in Pipe

(Old Pipe)

(Nominal Pipe Diameter)

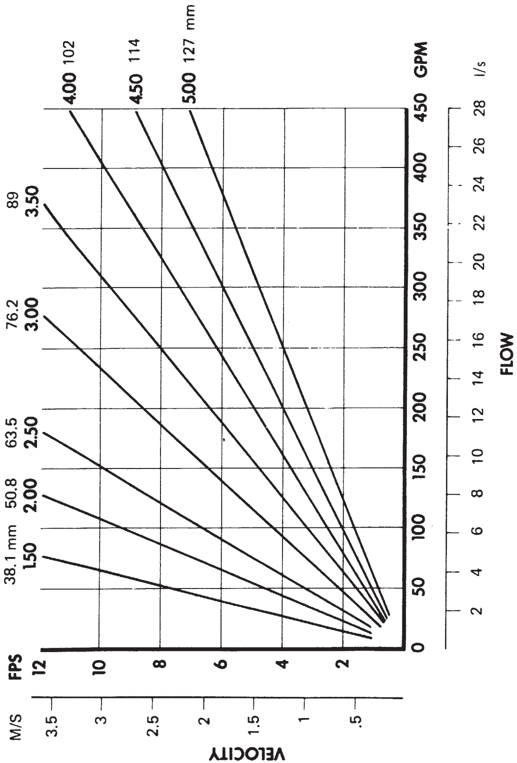
Gallons per Minute		Head Loss in Feet of Water per 100 ft. of Pipe (m per 100 m)							Gallons per Minute	
gpm	**(l/s)**	**¾" (19.05 mm)**	**1" (25.4 mm)**	**1¼" (31.75 mm)**	**1½" (38.1 mm)**	**2" (50.8 mm)**	**2½" (63.5 mm)**		**gpm**	**(l/s)**
5	.34	10.5	3.25	0.84	0.40	0.16	0.05	**3" (76.2 mm)**	5	.34
10	.63	38.0	11.7	3.05	1.43	0.50	0.17	0.07	10	.63
15	.95	80.0	25.0	6.50	3.05	1.07	0.37	0.15	15	.95
20	1.26	136.0	42.0	11.1	5.20	1.82	0.61	0.25	20	1.26
25	1.58	**4" (101.6 mm)**	64.0	16.6	7.85	2.73	0.92	0.38	25	1.58
30	1.9	0.13	89.0	23.0	11.0	3.84	1.29	0.54	30	1.9
35	2.21	0.17	119.0	31.2	14.7	5.10	1.72	0.71	35	2.21
40	2.52	0.22	152.0	40.0	18.8	6.60	2.20	0.91	40	2.52
45	2.84	0.28	**5" (127 mm)**	50.0	23.2	8.20	2.76	1.16	45	2.84
50	3.15	0.34	0.11	60.0	28.4	9.90	3.32	1.38	50	3.15
60	3.79	0.47	0.16	85.0	39.6	13.9	4.65	1.92	60	3.79
70	4.42	0.63	0.21	113.0	53.0	18.4	6.20	2.57	70	4.42
75	4.73	0.72	0.24	129.0	60.0	20.9	7.05	2.93	75	4.73
80	5.05	0.81	0.27	145.0	68.0	23.7	7.90	3.28	80	5.05
90	5.68	1.00	0.34	**6" (152.4 mm)**	84.0	29.4	9.80	4.08	90	5.68
100	6.31	1.22	0.41	0.17	102.0	35.8	12.0	4.96	100	6.31
125	7.89	1.85	0.63	0.26	**7" (177.8 mm)**	54.0	17.6	7.55	125	7.89
150	9.46	2.60	0.87	0.36	0.17	76.0	25.7	10.5	150	9.46

Typical Friction Losses of Water in Pipe (cont.)

gpm	(l/s)	4" (101.6 mm)	5" (127 mm)	6" (152.4 mm)	7" (177.8 mm)	8" (203.2 mm)	2½" (63.5 mm)	3" (76.2 mm)	gpm	(l/s)
175	11.05	3.44	1.16	0.48	0.22		34.0	14.1	175	11.05
200	12.62	4.40	1.48	0.61	0.28	0.15	43.1	17.8	200	12.62
225	14.20	5.45	1.85	0.77	0.35	0.19	54.3	22.3	225	14.20
250	15.77	6.70	2.25	0.94	0.43	0.24	65.5	27.1	250	15.77
275	17.35	7.95	2.70	1.10	0.51	0.27	**9" (228.6 mm)**	32.3	275	17.35
300	18.93	9.30	3.14	1.30	0.60	0.32	0.18	38.0	300	18.93
325	20.5	10.8	3.65	1.51	0.68	0.37	0.21	44.1	325	20.5
350	22.08	12.4	4.19	1.70	0.77	0.43	0.24	50.5	350	22.08
375	23.66	14.2	4.80	1.95	0.89	0.48	0.28	**10" (254 mm)**	375	23.66
400	25.24	16.0	5.40	2.20	1.01	0.55	0.31	0.19	400	25.24
425	26.81	17.9	6.10	2.47	1.14	0.61	0.35	0.21	425	26.81
450	28.39	19.8	6.70	2.74	1.26	0.68	0.38	0.23	450	28.39
475	29.97		7.40	2.82	1.46	0.75	0.42	0.26	475	29.97
500	31.55		8.10	2.90	1.54	0.82	0.46	0.28	500	31.55
750	47.32			7.09	3.23	1.76	0.98	0.59	750	47.32
1000	63.09			12.0	5.59	2.97	1.67	1.23	1000	63.09
1250	78.86				8.39	4.48	2.55	1.51	1250	78.86
1500	94.64				11.7	6.24	3.52	2.13	1500	94.64
1750	110.41					7.45	4.70	2.80	1750	110.41
2000	126.18					10.71	6.02	3.59	2000	126.18

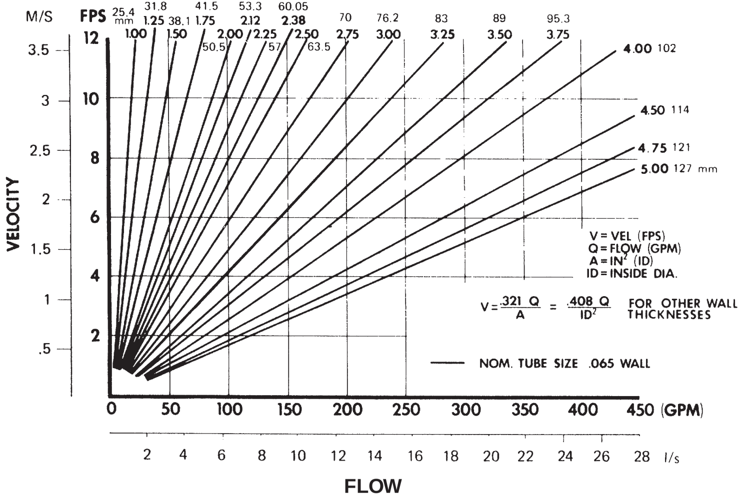
VELOCITY vs FLOW

STD. PIPE SIZES 1½" TO 5" (38.1 to 127 mm)



VELOCITY vs FLOW

TUBE SIZES FROM 1" TO 5" O.D. (25.4 mm to 127 mm)
(COMMON USAGE WALL THICKNESS)



Helpful Formula's for the Marine Analyst

The outside surface area of a pipe can be determined using the following formula:

Outside surface area in Square Feet per Foot = 0.2618 × Pipe Diameter

The velocity of water in a pipe can be calculated using the following formula:

$$V = \frac{GPM \times 0.408}{D^2}$$

V = Velocity in Feet per Minute
GPM = Gallons per minute of water flow
D = Pipe diameter nominal – Inches

The velocity of water in a tube can be calculated using the following formula:

$$V = \frac{GPM \times 0.427}{D^2}$$

V = Velocity in Feet per Minute
GPM = Gallons per minute of water flow
D = Pipe diameter nominal – Inches

The multiplier for determining the length in feet of **channel** to get a certain amount of surface area, can be determined by using the following formula:

$$L = \frac{12}{\text{web height} + 2 \times \text{flange width}}$$

Length of Channel to achieve surface area require = L × Square foot area requirement.

The multiplier for determining the length in feet of **pipe** to get a certain amount of surface area, can be determined by using the following formula:

$$\mathbf{L = \frac{12}{Pi \times outside\ diameter}}$$

Length of pipe to achieve surface area require = L × Square foot area requirement.

$$\frac{\text{GPM}}{60} = \text{Gals. second}$$

Gals. second × 0.1337 = cubic feet/second

$$\frac{\text{Cubic feet/second}}{\text{square foot cross sectional area}} = \text{Velocity in feet/second}$$

Coolant Chemical and Physical Properties

Minimum Acceptable Water Characteristics for Use in Engine Cooling Systems

Properties	Limits	ASTM[1] Test Methods
Chloride (Cl), gr/gal (ppm)	2.4 (40) max.	D512b, D512d, D4327
Sulfate (SO4), gr/gal (ppm)	5.9 (100) max.	D516b, D516d, D4327
Total Hardness, gr/gal (ppm)	10 (170) max.	D1126b
Total Solids, gr/gal (ppm)	20 (340) max.	D1886a
pH	5.5 – 9.0	D1293

[1]American Society for Testing and Materials

Boiling Point of Coolant at Varying Antifreeze Concentrations

% Concentration	Temperature at Which Coolant with Ethylene Glycol Will Boil[1]
20	103° C (217° F)
30	104° C (219° F)
40	106° C (222° F)
50	108° C (226° F)
60	111° C (231° F)
70	114° C (238° F)

[1]At sea level.

Protection Temperatures for Antifreeze Concentrations[1]

Protection to:	Concentration
–15° C (5° F)	30% antifreeze, 70% water
–24° C (–12° F)	40% antifreeze, 60% water
–37° C (–34° F)	50% antifreeze, 50% water
–52° C (–62° F)	60% antifreeze, 40% water

[1]Ethylene glycol-based antifreeze.

Barometric Pressures and Boiling Points of Water at Various Altitudes

Barometric Pressure

Altitude	Inches Mercury	Lb. per Square Inch	Feet Water	Point Water Boiling
Sea Level	29.92 In.	14.69 P.S.I.	33.95 Ft.	212.0° F
1000 Ft.	28.86 In.	14.16 P.S.I.	32.60 Ft.	210.1° F
2000 Ft.	27.82 In.	13.66 P.S.I.	31.42 Ft.	208.3° F
3000 Ft.	26.81 In.	13.16 P.S.I.	30.28 Ft.	206.5° F
4000 Ft.	25.84 In.	12.68 P.S.I.	29.20 Ft.	204.6° F
5000 Ft.	24.89 In.	12.22 P.S.I.	28.10 Ft.	202.8° F
6000 Ft.	23.98 In.	11.77 P.S.I.	27.08 Ft.	201.0° F
7000 Ft.	23.09 In.	11.33 P.S.I.	26.08 Ft.	199.3° F
8000 Ft.	22.22 In.	10.91 P.S.I.	25.10 Ft.	197.4° F
9000 Ft.	21.38 In.	10.50 P.S.I.	24.15 Ft.	195.7° F
10000 Ft.	20.58 In.	10.10 P.S.I.	23.25 Ft.	194.0° F
11000 Ft.	19.75 In.	9.71 P.S.I.	22.30 Ft.	192.0° F
12000 Ft.	19.03 In.	9.34 P.S.I.	21.48 Ft.	190.5° F
13000 Ft.	18.29 In.	8.97 P.S.I.	20.65 Ft.	188.8° F
14000 Ft.	17.57 In.	8.62 P.S.I.	19.84 Ft.	187.1° F
15000 Ft.	16.88 In.	8.28 P.S.I.	18.07 Ft.	185.4° F

Caterpillar Diesel Engine[1]
Antifreeze Protection Chart
(Fahrenheit)

Gallons or Quarts Antifreeze Concentrate

Cooling System Capacity (gallons or quarts)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
6	5	-34																
7		-18	-54															
8		-7	-34															
9		0	-20	-47														
10		5	-12	-34	-62													
11			-5	-22	-44													
12			0	-16	-34	-56												
13			3	-8	-24	-44												
14				-5	-18	-34	-53											
15				0	-13	-26	-42	-62										
16				3	-7	-20	-34	-50										
17					-3	-14	-26	-42	-59									
18					0	-10	-20	-34	-47									
19					3	-7	-16	-26	-39	-56								
20					5	-3	-12	-22	-34	-47	-62							
21						0	-8	-18	-26	-39	-53							
22						2	-5	-14	-22	-34	-44	-59						
23						5	-3	-10	-18	-28	-39	-50						
24							0	-17	-16	-24	-34	-44	-56					
25							2	-5	-12	-20	-28	-39	-50	-62				
26							3	-1	-8	-16	-24	-34	-44	-56				
27								0	-7	-14	-20	-28	-39	-47	-59			
28								2	-5	-10	-18	-24	-34	-42	-53			
29								3	-1	-8	-14	-22	-28	-39	-47	-59		
30								5	0	-7	-12	-18	-26	-34	-42	-53	-62	
31									2	-3	-10	-16	-22	-28	-39	-47	-56	
32									3	-1	-7	-14	-20	-26	-34	-42	-50	-59

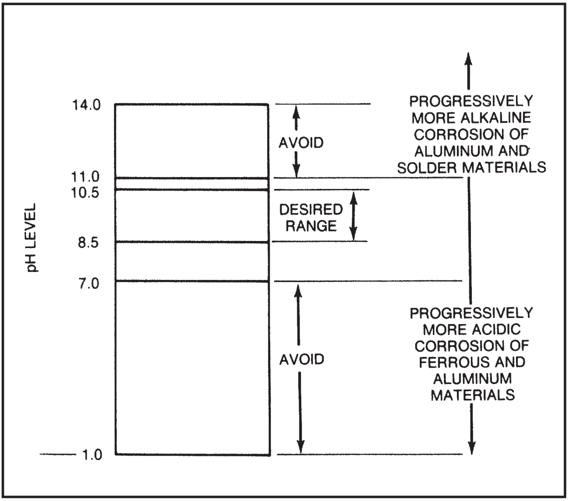
Caterpillar Diesel Engine[1]
Antifreeze Protection Chart
(Celsius)

Gallons or Quarts Antifreeze Concentrate

Cooling System Capacity (gallons or quarts)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
6	-15	-37																
7		-28	-48															
8		-22	-37															
9		-18	-29	-44														
10		-15	-24	-37	-52													
11			-21	-30	-42													
12			-18	-27	-37	-49												
13			-16	-22	-31	-42												
14				-21	-28	-37	-47											
15				-18	-25	-32	-41	-52										
16				-16	-22	-29	-37	-46										
17					-19	-26	-32	-41	-51									
18					-18	-23	-29	-37	-44									
19					-16	-22	-27	-32	-39	-49								
20					-15	-19	-24	-30	-37	-44	-52							
21						-18	-22	-28	-32	-39	-47							
22						-17	-21	-26	-30	-37	-42	-51						
23						-15	-19	-23	-28	-33	-39	-46						
24							-18	-22	-27	-31	-37	-42	-49					
25							-17	-21	-24	-29	-33	-39	-46	-52				
26							-16	-18	-22	-27	-31	-37	-42	-49				
27								-18	-22	-26	-29	-33	-39	-44	-51			
28								-17	-21	-23	-28	-31	-37	-41	-47			
29								-16	-18	-22	-26	-30	-33	-39	-44	-51		
30								-15	-18	-22	-24	-28	-32	-37	-41	-47	-52	
31									-17	-19	-23	-27	-30	-33	-39	-44	-49	
32									-16	-18	-22	-26	-29	-32	-37	-41	-46	-51

[1]Also for use in natural gas engines

pH Scale for Coolant Mixture



Temperature Regulators

CAT Part No.	Opening Temperature*	Fully Open Temperature
4W0018	27° C (81° F)	37° C (99° F)
7C0311	45° C (113° F)	55° C (131° F)
7E1237	68° C (154° F)	81° C (178° F)
4P0301	68° C (154° F)	81° C (178° F)
4W4011	77° C (170° F)	89° C (192° F)
7E6210	77° C (171° F)	89° C (192° F)
7N0208	79° C (175° F)	91° C (196° F)
9N2894	79° C (175° F)	92° C (197° F)
7E7933	83° C (181° F)	92° C (198° F)
4W4794	84° C (183° F)	92° C (198° F)
7N8469	88° C (190° F)	96° C (205° F)
7C3095	88° C (190° F)	98° C (208° F)
4W4842	88° C (190° F)	98° C (208° F)
7W0371	95° C (203° F)	104° C (219° F)
9Y7022	100° C (212° F)	110° C (230° F)
9Y8966	110° C (230° F)	129° C (265° F)

*Normally stamped on regulator

New Temperature Regulators

1330, 1355

3606 (8RB), 3608 (6MC), 3612 (9RC), 3616 (1PD) Industrial Engines

The 3600 Family of Engines has three sets of temperature regulators. The regulators are the jacket water (JW) inlet control, the oil cooler and aftercooler (O/C and A/C) inlet control, and the oil cooler oil temperature control. The chart identifies the new and former regulators. The recommended service hours of temperature regulators is every **6000 service meter hours** or annually, whichever occurs first.

Temperature Regulators

Application	New Regulator Part No.	Former Regulator Part No.	Nominal Temperature ° C (° F)	Temperature Range ° C (° F)
JW Inlet Control Distillate Fuel	6I4957[2]	4W4794	90 (194)[1]	85-95 (185-203)
JW Inlet Control Distillate Fuel	6I4950[3]	4W4794	87.5 (189.5)[1]	82-92 (179.8-197.6)
JW Inlet Control Residual Fuel	6I4956	7C3095	93 (199.4)[1]	88-98 (190.4-208.4)
O/C-A/C Inlet Control Distillate Fuel	6I4952	7C0311	46 (118)	48-50 (114,8-122)
O/C-A/C Inlet Control Residual Fuel (Two Step)	6I4963[2] 614951	4W0018 7E1237	32 (89.6) 75 (167)	27-37 (80.8-98.6) 68-81 (154.4-177.8)
Oil Cooler	6I4954[2]	7E6210	83 (181.4)	76-89 (168.8-192.2)
Oil Cooler	6I4955	4P0301	75 (167)	68-81 (154.4-177.8)

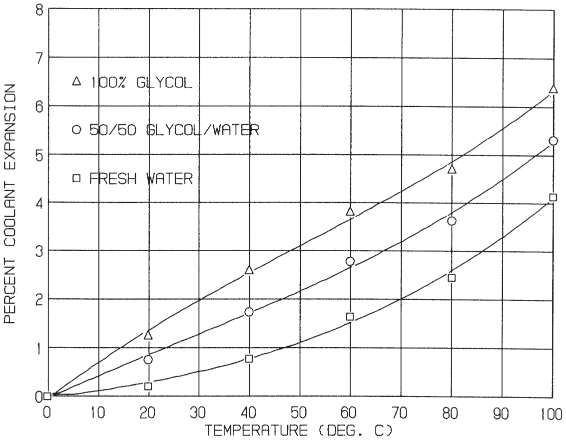
NOTES:
1. Jacket water thermostats control jacket water inlet temperature, while water temperature gauge reads **outlet** temperature.
   If the external cooling system has the proper restriction and the engine is operating at full load, the **outlet** temperature will be approx. 9° F above inlet temperature.
2. These part numbers are recommended for inland tow boat applications.
3. Alternate thermostats used if application has an outlet temperature of 210° F.

Diagnostic Tooling

Self-Sealing Probe Adapters:

Size	CAT Part No.
⅛" NPT	5P2720
¼" NPT	5P2725
½" O-ring	4C4547
9⁄16" O-ring	5P3591
¾" O-ring	4C4545
Pressure Probe	164-2192

Coolant Expansion Rates



As a rule of thumb, expansion tanks should have a capacity of 16% of the total system coolant volume for expansion plus reserve.

Densities of Liquids [at 60° F (16° C)]

Liquid	lb/U.S. gal	lb/cu ft	kg/cu meter	Specific Gravity
Water, Fresh	8.3	62.1	994.6	1.00
Water, Sea	8.5	63.6	1018.3	1.02
Water/Glycol	8.55	64.0	1024.4	1.03
Diesel Fuel	7.1	53.1	850.7	0.855
Lube Oil	7.6	56.8	909.7	0.916
Kerosene	6.7	50.1	802.7	0.807

Supplemental Coolant Additive (Conditioner or Inhibitor)

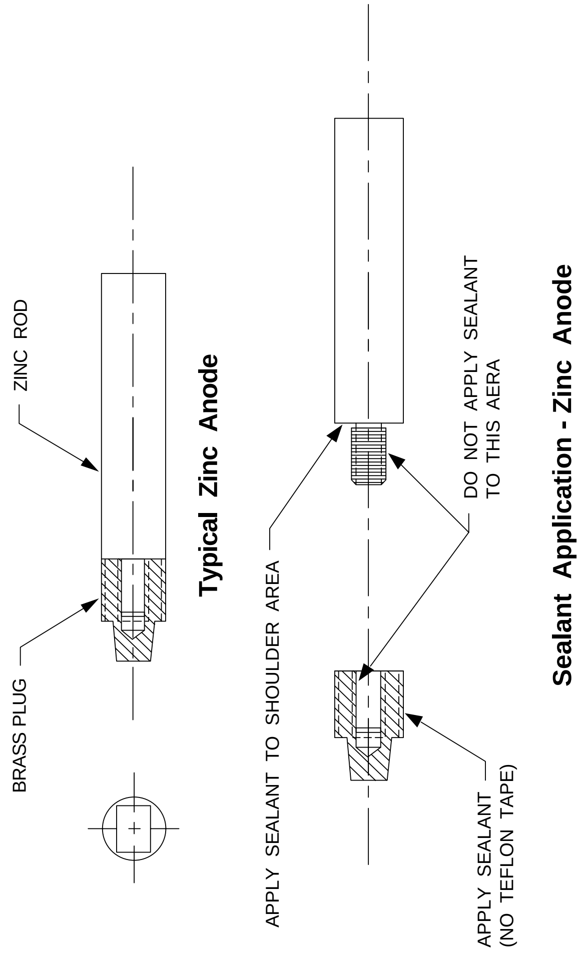
	SCA %
30% – 60% Antifreeze solution	3% to 6%
Water-only coolant	6% to 8%

Caterpillar recommends using antifreeze in the coolant mixture to get maximum life from cooling system components. 30% is minimum recommendation.

Zinc Anode Summary

	Straight Thread	Rod Length From Shoulder		Zinc Rod Diameter	
Zinc Rod	Size	(mm)	(in)	(mm)	(in)
6L3104	1/4 - 20	38.1	1.50	9.5	0.38
6L2283	1/4 - 20	57.0	2.25	10.0	0.39
6L2287	3/8 - 16	22.4	0.88	12.7	0.50
6L2281	3/8 - 16	30.2	1.19	12.7	0.50
6L2280	3/8 - 16	41.0	1.62	13.0	0.51
5B9651	3/8 - 16	50.8	2.00	16.0	0.63
6L2288	3/8 - 16	63.5	2.50	16.0	0.63
6L2289	3/8 - 16	76.0	3.00	16.0	0.63
7F9314	3/8 - 16	114.3	4.50	16.0	0.63
6L2016	5/8 - 18	20.5	0.81	22.0	0.87
6L2284	3/4 - 10	53.8	2.12	31.8	1.25
6L2285	3/4 - 10	63.5	2.50	31.8	1.25

Apply sealant only to the shoulder of the zinc rod before assembling to the brass plug. Sealant is *not* to be applied to the straight threaded joint between the rod and plug. Apply thread sealant to the external pipe thread of the plug following normal procedures and specifications as illustrated below.



Brass plugs currently available through the Caterpillar Parts System for use with Caterpillar zinc rods are shown below. Check status and availability prior to final selection. Sacrificial anodes are not provided with the factory supplied heat exchangers. They can be ordered through the Caterpillar parts distribution system.

Brass Plug Summary

Rod Thrd.	Brass Plug	External Plug Thread	Drill Dia. (mm)	Boss Min.Dia. (mm)	Boss Min.Thk. (mm)
1/4 - 20	6L2282	1/4 - 18	11.2	28	6
3/8 - 16	6L2279	3/8 - 18	14.5	30	7
3/8 - 16	5B9169	1/2 - 14	18.0	35	8
5/8 - 18	6L2020	3/4 - 14	23.2	40	9
3/4 - 10	6L2286	1-1/4 -11-1/2	38.0	55	11

Similar to galvanic corrosion, electrolytic corrosion occurs with an external source of current flow through the coolant. Despite sea water or engine coolant mixture quality, presence of an electrical potential can cause electrolytic corrosion damage to the cooling system materials. Aluminum materials are attacked very rapidly by this type of corrosion. Most materials common to cooling systems, such as copper, brass, bronze, copper-nickel, steel, and cast iron, are susceptible to electrolytic corrosion.

Electrical systems must be designed to eliminate continuous electrical potential on any cooling system component. Electrolytic corrosion is extremely difficult to troubleshoot, since the source of electrical current must be located. A common cause is improper grounding or corroded ground connections. Care must be taken during design, installation, and maintenance phases to assure all grounds are tight and corrosion free.

Marine Growth

Over a period of time, marine growth will adversely impact the efficient operation of heat exchangers. It is necessary to periodically *disassemble* heat exchangers to clean heads and tubes. The use of local thermometers, high temperature alarms, and other instrumentation can warn of gradual loss of sea water flow, and are highly recommended. Periodic chemical treatment will also combat marine growth in sea water systems. The chemical type and concentration must be controlled to prevent deterioration of components in the sea water circulating system, and to minimize environmental impact. Contact a knowledgeable supplier if a chemical treatment system is to be installed. Continuous low concentration chemical treatment via either bulk or self-generating electrical processes are available from various manufacturers.

Corrosion

Galvanic Corrosion in Sea Water

When two dissimilar metals are electrically connected and both submerged in salt water, they form a battery and an electrochemical reaction takes place. In this process, one metal is eaten away. The rate of deterioration is proportional to a number of factors:

- The differential potential between the two metals on the electrochemical series.
- The relative areas of the two metals: If there is a small area of the more noble metal relative to the less noble metal, the deterioration will be slow and relatively minor. If there is a large area of the more noble metal such as copper sheathing on a wooden hull, and a much smaller area of the less noble metal, such as iron nails holding the copper sheathing to the wood, the wasting away of the iron nails will be violent and rapid.

Dissimilar Metal Combinations to Avoid

- Bronze Propeller on Steel Shaft
- Mill Scale on Hull Plate (Internal or External)
- Aluminum Fairwaters Fastened to a Steel Hull
- Steel Bolts in Bronze Plates
- Bronze Unions and Elbows Used With Galvanized Pipe
- Bronze Sea Cocks on Iron Drain Pipes
- Brass Bilge Pumps on Boats With Steel Frames
- Brass, Bronze, or Copper Fasteners in Steel Frames
- Stainless Steel Pennants on Steel Mooring Chains
- Bronze or Brass Rudder Posts With Steel Rudders
- Bronze Rudders With Steel Stopper-Chains

- Steel Skegs (Rudder Shoes) Fastened With Bronze or Brass Leg Screws
- Steel and Brass Parts in the Same Pump

Rule of Thumb: Do not put iron or steel close to or connected with alloys of copper under salt water.

The Protective Role of Zinc

In electronics, the more active metal is called the ***ANODE*** and the less active is called the ***CATHODE***. We use **zinc** at Caterpillar as a sacrificial **anode**.

If alloys of copper (bronze, brass), iron (steel), and zinc are all connected together and submerged in salt water, the zinc will be eaten away, protecting the iron (steel). It is necessary to have a metallic electrical connection to the metals to be protected. This is usually easy to accomplish on a steel hull. It is more difficult on a fiberglass hull, since special electrical connection may be required unless the zincs are connected directly to one of the metals, preferably the copper alloy.

The Zinc Must Never Be Painted! When electrical contact is made through the fastening studs, it's desirable to put galvanized or brass bushings in the holes in the zincs so that contact will be maintained as the zincs corrode.

Zincs should be periodically inspected. As they work, a white, crust-like deposit of zinc oxides and salts form on the surface. This is normal. If it does not form and the zincs remain clean and like new, they are not protecting the structure.

If the zincs are not working, look for the following conditions:

- The anode is not electrically bonded to the structure.
- The paint on the structure is still in near perfect condition.

Electro-chemical Series

Corroded End — Least Noble
Magnesium
Zinc
Cadmium
Mild Steel or Iron
Low Alloy Steel
Aluminum Bronze
Naval Brass
Yellow Brass
18-8 Stainless Steel (Active)
18-8-3 Stainless Steel (Active)
Lead
Tin
Brasses
Copper
Bronzes
Copper-Nickel Alloys
Monel
Silicon Bronze
Tin Bronze
Silver
Titanium
Gold
Platinum
Protected End-Most Noble

The further metals are apart on the list, the greater the activity. For example, zinc connected to graphite would deteriorate faster than zinc connected to say mild steel.

Metals freely erode at approximately the following voltages depending on their composition:

	Erode
Bronze	300 millivolts
Steel	500 millivolts
Aluminum	650 millivolts

	Protect
Bronze	600 ± 100 millivolts
Steel	850 ± 100 millivolts
Aluminum	800 to 1050 millivolts

The voltages of metals can be estimated by measuring the voltages between sea water and the metal. The following scale is what you can expect to see in sea water @ 75° F

Metal or Alloy	Millivolts
Magnesium	1580
Zinc	1050
Cadmium	860
Mild Steel or Iron	790
Low Alloy Steel	740
Aluminum Bronze	625
Naval Brass	450
Yellow Brass	450
18-8 Stainless Steel (Active)	*
18-8-3 Stainless Steel (Active)	*
Lead	420
Tin	500
Brass(60/40)	330
Copper	340
Copper-Nickel Alloys	200
Monel	110
Silicon Bronze	260
Tin Bronze	260
Silver	80
Titanium	100
Gold	< 0
Platinum	< 0

* - Stainless Steel could read from 0 to 575 depending on composition and oxygen content of the sea water.

Rule of thumb: Select metals to be connected, or close in wet wood, that are within 200 millivolts of each other to reduce galvanic corrosion.

Corrosion Rates of Various Metals in Sea Water

Representative Corrosion Rates in Sea Water (Mils per year)

Aluminum	1 to 3
Zinc	1
Lead	.5
Iron (Steel)	5
Copper	1 to 2
Stainless Steel**	0
Copper-Nickel Alloys	0
Nickel Alloys	0
Titanium	0
Silicon Bronze	1 to 2
Austenitic Cast Iron	2

*Rates are ranges for general loss in sea water at ambient temperatures and velocities no greater than 1 m (3 ft) per second. Pitting penetration is not considered.
**Many stainless steels exhibit high rates of pitting in stagnant sea water.

Multiply mils by 25 for um/year

Electrolysis

The results of electrolysis appear to be the same as galvanic action. However, electrolysis is caused by an external current rather than a current developed by the different metals in contact with an electrolyte.

When electrical current passes through impure water the water will decompose; impurities present in the water will help the decomposition. Also, when the current passes from a positive source to a negative source through the water, the positive source disintegrates. The decomposition of the positive source is commonly termed electrolysis.

The greatest cause of electrolysis is improper grounding of electrical equipment.

RULE OF THUMB: All electrical grounds should be grounded back to the negative on the battery. ***Never use the hull as a ground.***

The following list are common sources for stray currents:

A.C. polarity reversals
Improperly installed polarity alarms **(low resistance polarity indicator circuits should include a normally off, momentary test switch)**
A.C. shorts from hot to case
Frayed, cut or waterlogged insulation
Wire in bilge water
Salt bridges on terminal strips or junction blocks
Staples, nails or screws through wires
Improperly grounded equipment
D.C. equipment using bonding system of the hull for return wire negative
Loose connections.

Procedure to troubleshoot an electrolysis problem:

1) **Start by turning on and off all A.C. & D.C. circuit breakers and master switches** including the boat shore power transfer switch. Unplug shore power to the boat.

2) Measure the hull potential (Hull to sea water)

3) Plug in the shore power cable

Measure the hull potential. If there is a sustained voltage reading, as opposed to a "spike" or no reading, it is indicating a stray current down the ground wire or between the power inlet and the master switch or breaker. **Find and fix the problem!**

If there is no difference in hull potential proceed to step 4.

4) Turn on first circuit breaker, usually ship-shore or shore power breaker.

If hull potential changes find and correct the problem.

If no change was noted in the hull potential then move on to the next switch or breaker in line. Correcting any problem encountered.

Each problem circuit must be checked by tracing the wire from the output side of the breaker, to the electrical equipment on that circuit, and back to the neutral bus.

Every time there is a branch in the circuit, you must check each branch out separately to determine which branch contains the problem.

It is important that as each circuit is turned on the equipment actually controlled by that circuit should actually be turned on.

Keel Cooler Performance Correction Factors

Correction Factors for Cooling System Water:

Water meets Caterpillar specifications	(baseline)1.00
Extremely hard water (>15 grains/gal)	0.90

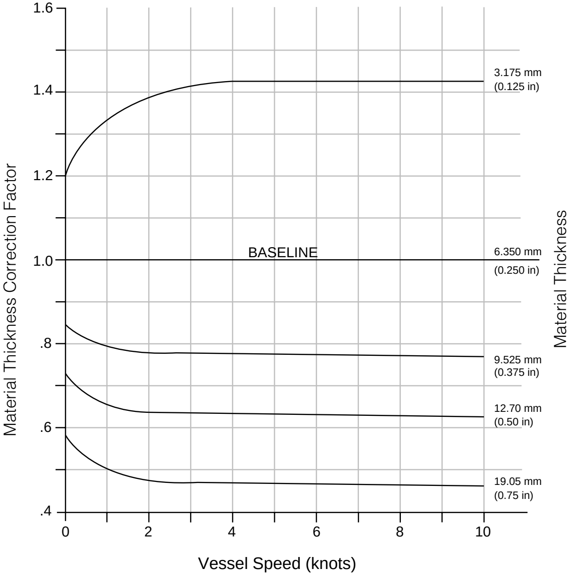
Correction Factors for Antifreeze:

0% glycol	(baseline)1.00
10% glycol	0.97
20% glycol	0.94
30% glycol	0.91
40% glycol	0.88
50% glycol	0.85

Correction Factors for Raw-Water Type

Raw-Water Description	*Fouling Factor	Correction Factors @ Vessel Speed <2 knots	Correction Factors @ Vessel Speed >2 knots
River water (baseline)	0.0030	1.00	1.00
Open sea (ocean water)	0.0007	1.11	1.16
Great Lakes	0.0010	1.10	1.13
Chicago Canal	0.0060	0.88	0.85

* Fouling factor is shown here for reference only and is used to calculate the vessel speed correction factor.



Keel Cooler Performance & Sizing
Capacity Corrections for Material Thickness
(Structural Steel)

KEEL COOLER SIZING WORKSHEET

GENERAL INFORMATION:

Project ______________________________ Engine __________

Application ______________________________

Fuel Type ______________________________

Rated Power ____________________ bkW   Rated Speed __________ rpm

Cooling System Type (Combined or Separate) ______________________________

DESIGN-POINT CONDITIONS:

Engine Power	__________	bkW
Engine Speed	__________	rpm
Heat Rejection Data (from TMI):		
Jacket Water	__________	kW
Oil Cooler	__________	kW
Aftercooler	__________	kW
Vessel Speed	__________	knots
Maximum Expected Raw Water Temperature	__________	°C
Raw Water Type / Description	____________________	

CIRCUIT ANALYSIS INFORMATION:

Circuit Being Analyzed	____________________	
Total Circuit Heat Rejection	__________	kW
Max Allowable Coolant-to-Engine Temp	__________	°C
Regulator (Thermostat) Part Number	____________________	
Start-to-Open Temperature	__________	°C
Full-Open Temperature	__________	°C
Total Circuit Flow	__________	L/min
Coolant Velocity thru Keel Cooler	__________	m/sec
Max Allowable Circuit Resistance	__________	kPa
Coolant Water Type	____________________	
Antifreeze Content (glycol)	__________	%
Steel Thickness of Heat Transfer Surface	__________	mm

CIRCUIT ANALYSIS INFORMATION:

Baseline Unit Heat Rejection Capacity (Figure 17) = __________ $\frac{\text{(kW/sq m)}}{°\text{C}}$

Total Correction Factor (see Figures 18 and 19):

Water Factor (______) x Glycol Factor (______) x Raw-Water Factor (______) x Thickness Factor (______) = __________

Corrected Unit Heat Rejection Capacity:

Baseline Capacity (________) x Total Correction Factor (________) = __________ $\frac{\text{(kW/sq m)}}{°\text{C}}$

Temperature Difference Calculation:

Coolant-to-Engine Temperature (________) °C - Raw Water Temperature (________) °C = __________ °C

Unit Heat Rejection Capacity @ Design Temperatures:

Corrected Unit Capacity (________) x Temperature Difference (________) = __________ kW/sq m

Total Surface Area Required:

Total Circuit Heat Rejection (________) / Unit Capacity @ Design Temps (________) = __________ sq m

Piping Symbol

Symbol	Description	Symbol	Description	Symbol	Description
	Gate Valve		Un-Insulated Pipe		Tank Heating Coil
R	Gate Valve with Remote Operating Gear Attached		Insulated Pipe		Gauge Glass (Automatic Closure)
LO	Locked "Open" Valve		Air Vent with Flame Screen		Plate Heat Exchange
LC	Locked "Closed" Valve		Air Vent w/Flame Screen & Closure		Shell and Tube Heat Exchanger
	Globe Valve		Air Vent w/Flame Screen, Check Valve & Closure		Centrifugal Pump
T	Screw Down Non-Return Valve		Drip Pan		Positive Displacement Pump
LS	Lock Shut Valve	T	Thermometer		Manhole in Tank
	Swing Check Valve		Thermometer	FM	Flow Meter
	Three -way Cock	HTA	High Temperature Alarm		Pipe Return to Tank
	Air Operated Three-Way Cock (or Valve)	LTA	Low Temperature Alarm		Pump Suction Bell
	Relief Valve	HLA	High Level Alarm	F	Filter
	Angle Valve	LLA	Low Level Alarm	P	Differential Pressure Indicator
	Pressure Control Valve	PSH	Pump Start	PS	Pressure Switch
	Self-Contained Temperature Control Valve w/ Manual Override	PSL	Pump Stop	A	Alarm
	Butterfly Valve		Pressure Switch	M	Motor
	Ball Valve		Steam Blow-Out		
	In-Line Relief Valve		Sounding Valve with Lever		
	Diverting Valve with Manual Lever	S	Simplex Strainer		
	Temperature Control Valve	S S	Duplex Strainer		
	Air Operated Butterfly Valve		Orifice Plate		
	Flexible Connector	P	Pressure Gauge		
	Flexible Connector	L	Level Indicator		

Schedule of Piping

##	SYSTEM: SERVICE	PIPING: SIZE	PIPING: TYPE	TAKE DOWN JOINTS: SIZE	TAKE DOWN JOINTS: TYPE	BOLTS	NUTS	GASKETS	VALVES: SIZE	VALVES: PRESS	VALVES: MATERIAL	VALVES: TRIM	FITTINGS: SIZE	FITTINGS: TYPE	GENERAL NOTES
1	Cooling Fresh Water	Above 10 mm (.5 in.)	Seamless, ASTM A106, Sch. 40 Grade A or B	Above 10 mm (.5 in.)	Steel Slip-on Welded Flanges, Butt Welded or Sleeve	ASTM A307 Grade B	ASTM A307 Grade B	Inserted Rubber Sheet	50 mm (2 in.) and above	125#	Cast Iron or Forged Steel Flanged	Brass	50 mm (2 in.) and Above	Forged Steel Std. Wt., Butt Welded ends, ASTM A-234	
		10 mm (.5 in.) and Below	Seamless Copper, ASTM B88, Type K or L	Below 10 mm (.5 in.)	Brass Unions, Bite Joint or Sleeve				40 mm (1-.5 in.) and below	200#	Bronze	Brass	40 mm (1.5 in.) and Below	Ductile Iron, Forged Steel, or Brz., Screwed	
2	Cooling Sea Water	Above 10 mm (.5 in.)	90 / 10 CuNi Pipe	Above 10 mm (.5 in.)	Bronze Flanges, Brazed.	ASTM A307 Galv.	ASTM A307 Galv.	Inserted Rubber Sheet	50 mm (2 in.) and above	125# 150#	Cast Iron, Flanged Cast Steel, Flanged	Brass or Monel	Above 10 mm (.5 in.)	Bronze, Brazed; or Built-up Cu, Flanged	Or use ## 3 which is acceptable substitute
		10 mm (.5 in.) and Below	Seamless Copper, ASTM B88, Type K or L	Below 10 mm (.5 in.)	Brass Unions, Bite Joint or Sleeve				40 mm (1-1/2 in.) and below	200#	Bronze, Flanged or Screwed	Brass or Monel	10 mm (.5 in.) and Below	Brass Joints	
3	Sea Chest, Overboard, Air Vent, and Blow-Out Conn.	All	Seamless, ASTM A106, Sch. 80 Grade A or B, Galvanized	Above 10 mm (.5 ft.)	Steel Slip-on Welded Flanges, Butt Welded or Sleeve	ASTM A307 Galv.	ASTM A307 Galv.	Inserted Rubber Sheet	50 mm (2 in.) and above	150#	Cast Steel, Flanged	Brass or Monel	50 mm (2 in.) and Above	Butt Welded Galvanized	
				Below 10 mm (.5 ft.)	Brass Unions, Bite Joint or Sleeve				40 mm (1-.5 in.) and below	200#	Bronze, Flanged	Brass or Monel	40 mm (1.5 in.) and Below	Ductile Iron or Forged Steel, Galv. Screwed	
4	Oil & Fuel-Filling, Transfer, and Service	Above 10 mm (.5 in.)	Seamless, ASTM A106, Sch. 40 Grade A or B	Above 10 mm (.5 in.)	Steel Slip-on Welded Flanges, Butt Welded or Sleeve	ASTM A307 Galv.	ASTM A307 Galv.	Nitrile	50 mm (2 in.) and above	125# 150# *	Cast Iron or Forged Steel, Flanged Cast Steel, Flanged	Brass	50 mm (2 in.) and Above	Forged Steel Std. Wt., Butt Welded ends, ASTM A-234	*Valves on Oil & Fuel tanks will be Cast Steel Flanged
		10 mm (.5 in.) and Below	Seamless Copper, ASTM B88, Type K or L	Below 10 mm (.5 in.)	Brass Unions, Bite Joint or Sleeve				40 mm (1.5 in.) and below	200#	Bronze, Flanged or Screwed	Brass	40 mm (1.5 in.) and Below	Ductile Iron or Forged Steel Screwed or Socket Weld	
5	Exhaust Gas	All	Steel Resistance Welded, ASTM A53*	All	Steel Plate Flanges	ASTM A307 Galv.	ASTM A307 Galv.	Hi-Temp., Asbestos Free					All	Forged Steel, Butt Welded Flngd. (Flex conns. to be Stainless Steel)	*Pipe to be at least 7 mm (.25 in.) thick
6	Exhaust Gas - Open Drains	All	Steel Resistance Welded, ASTM A53 Sch.40						50 mm (2 in.) and above	200#	Bronze, Flanged or Screwed	Brass	All	Forged Steel, Butt Welded	
									40 mm (1.5 in.) and below	200#	Bronze, Flanged or Screwed	Brass	All	Forged Steel, Butt Welded	
7	Starting Air and Control Air	Above 10 mm (.5 in.)	Seamless, ASTM A106, Sch. 40 Grade A or B	Above 10 mm (.5 in.)	Steel Slip-on Welded Flanges, Butt Welded or Sleeve	ASTM A307 Galv.	ASTM A307 Galv.	Nitrile	50 mm (2 in.) and above	150#	Cast Iron or Forged Steel, Flanged	Brass	50 mm (2 in.) and Above	Forged Steel, Flanged or Butt Welded	
		10 mm (.5 in.) and Below	Seamless Copper, ASTM B88, Type K or L	Below 10 mm (.5 in.)	Brass Unions, Bite Joint or Sleeve				40 mm (1.5 in.) and below	200#	Bronze, Flanged or Screwed	Brass	40 mm (1.5 in.) and Below	Forged Steel, Screwed or socket weld	

Mounting and Alignment

Available Installation and Alignment Instructions

Engine Data Sheet 102.2	Installation/Alignment Instructions for Caterpillar Engines with Reintjes Free Standing Marine Gears and Vulcan Rato Flexible Couplings
Special Instruction SEHS9070	Installation and Alignment of 3606 and 3608 Marine Engines on Resilient Mounts
LEKM2005	3600 Marine Application & Installation Guide
LEKX1002	3600 Electric Power Generation Application & Installation Guide
Special Instruction SEHS7654	Alignment — General Instructions
Special Instruction SEHS7456-01	Alignment of Caterpillar Marine Transmissions and Marine Engines
Special Instruction SEHS7956	Alignment of Caterpillar Diesel Engines to Caterpillar Marine Transmission (7271-36W)
Special Instruction SEHS7073	Alignment of Two Bearing Generators

Marine Engine Final Alignment Conditions

Do not attempt final alignment of propulsion engines unless the following conditions are met:

1. The vessel is in the water.
2. All permanent ballast is in place.
3. Fuel, water, and temporary ballast tanks are filled to normal average operating levels, generally $\frac{1}{2}$ to $\frac{3}{4}$ filled.
4. All major machinery — weighing over 1,000 lbs (450 kg) — is either installed or simulated by equivalent weights appropriately located.

Make final alignment immediately prior to sea trials.

Marine Gear Output Flange Runout

Model	Face Runout		Bore Runout	
	inches	**(mm)**	**inches**	**(mm)**
MG502	0.004	(0.100)	0.004	(0.100)
MG506	0.004	(0.100)	0.004	(0.100)
MG507	0.004	(0.100)	0.004	(0.100)
MG509	0.004	(0.100)	0.004	(0.100)
MG514	0.004	(0.100)	0.004	(0.100)
Reintjes	0.004	(0.100)	0.004	(0.100)

Allowance for Expansion due to Thermal Growth

Cast iron has a thermal expansion coefficient of 0.0000066 in. per in. per Degree F (0.000012 mm per mm per Degree C). Steel has an average thermal expansion coefficient of 0.0000063 in. per in. per Degree F (0.000011 mm per mm per Degree C).

The engine mounting system must allow for this expansion through the proper use and placement of clearance bolts, fitted bolts, and dowels. Failure to allow for thermal expansion will result in driven equipment misalignment and engine block distortion.

Compensation offsets must be incorporated into alignment procedures to accommodate this growth when alignment is performed cold.

Thermal expansion = Expansion Coefficient × Linear Distance* × Δ T

* Linear distance is the length or width of engine for horizontal growth and the distance between the mounting surface and the crankshaft centerline for vertical growth.

Examples: 3606 — Cast Iron Block, Length of block between rear fitted bolt and front clearance bolt is 87.6 in. (2226 mm). Δ T = 130° F (72° C). Expansion allowance required is:

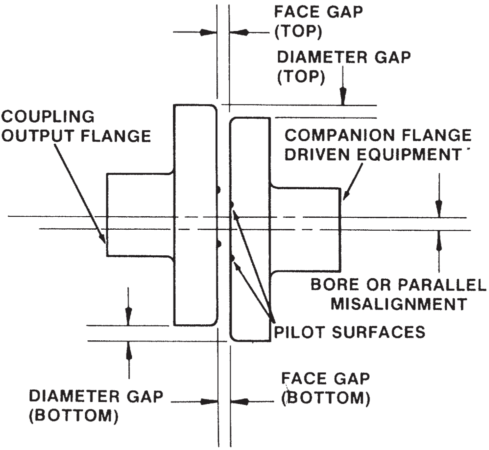
0.0000066 (0.000012) × 87.6 in. (2226 mm) × 130° F (72° C) 0.075 in. (1.9 mm)

Collision Blocks for Marine Engines

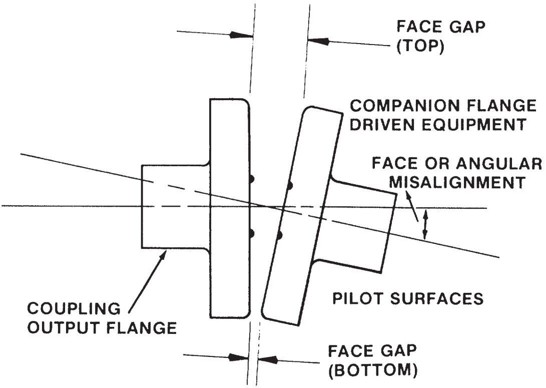
When marine classification societies or local marine practice requires the use of collision blocks, they should be located with sufficient clearance to allow for thermal growth of the engine. Prefabricate the collision blocks and install them while the engine is at operating temperature with approximately 0.005 in (0.12 mm) *hot* clearance. Collision blocks are recommended to resist the shock loads encountered in hard docking collisions and groundings.

Types of Misalignment

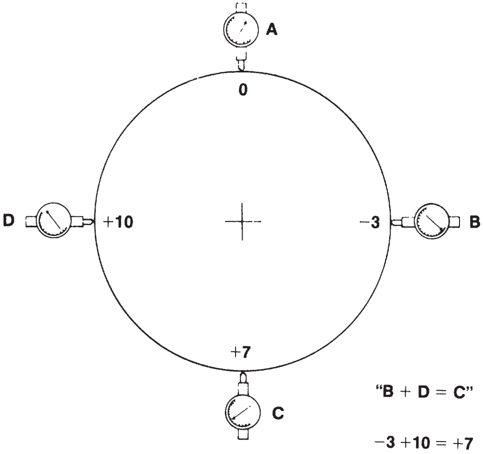
Parallel or bore misalignment occurs when centerlines of driven equipment and engine are parallel but not in the same plane.



Angular or face misalignment occurs when centerlines of driven equipment and engines are not parallel.



Dial Indicator Quick Check



When both shafts are rotated together, the algebraic sum of the readings at D and B should equal the reading at C. This check is useful for identifying improper indicator setup or procedure. The example shown is out of alignment.

Required Foundation Depth for Stationary Installations

Calculate foundation depth to equal generator set weight by:

$$FD = \frac{W}{D \times B \times L}$$

FD = foundation depth in feet (meter)

W = total wet weight of generator set in pounds (kg) Use 125% of actual weight if vibration isolators are not used.

D = density of concrete in pounds per cubic foot (kg/m^3)
NOTE:Use 150 for English unit and 2402.8 for metric unit.

B = foundation width in feet (meter)

L = foundation length in feet (meter)

Pressure on Supporting Material

$$P\ (\text{psi}) = \frac{W\ (\text{Pounds})}{A\ (\text{inches})^2} \qquad kPa = \frac{kg}{m^2}$$

$$P = \frac{W}{A}$$

Where: P = Pressure in psi (kpa)

W = Weight in pounds (kg)

A = Area in square inches (m^2)

Pressure imposed by the generator set weight must be less than the load-carrying capacity of supporting material.

General Torque Specifications

The following charts give general torque values for fasteners of SAE Grade 5 or better and Metric ISO Grade 8.8.

Torques for Bolts and Nuts With Standard Threads

Thread Size	Standard Torque	
Inch	**N•m***	**lb ft**
1/4	12±4	9±3
5/16	25±7	18±5
3/8	45±7	32±5
7/16	70±15	50±10
1/2	100±15	75±10
9/16	150±20	110±15
5/8	200±25	150±20
3/4	360±50	265±35
7/8	570±80	420±60
1	875±100	640±80
1 1/8	1100±150	800±100
1 1/4	1350±175	1000±120
1 3/8	1600±200	1200±150
1 1/2	2000±275	1480±200

*1 Newton meter (N•m) is approximately the same as 0.1 mkg.

(Continued)

Torques for Taperlock Studs

Thread Size	Standard Torque	
Inch	N•m*	lb ft
¼	8±3	6±2
5⁄16	17±5	13±4
⅜	35±5	26±4
7⁄16	45±10	33±7
½	65±10	48±7
9⁄16	90±15	65±11
⅝	110±15	80±11
¾	170±20	125±15
⅞	260±30	190±22
1	400±40	300±30
1⅛	500±40	370±30
1¼	650±50	480±37
1⅜	750±50	550±37
1½	870±50	640±37

*1 Newton meter (N•m) is approximately the same as 0.1 mkg.

Metric ISO Thread

Thread Size	Standard Torque	
	N•m*	lb ft
M6	12±4	9±3
M8	25±7	18±5
M10	55±10	40±7
M12	95±15	70±10
M14	150±20	110±15
M16	220±30	160±20
M18	325±50	240±35
M20	450±70	330±50
M22	600±90	440±65
M24	775±100	570±75
M27	1150±150	840±110
M30	1600±200	1175±150
M33	2000±275	1480±200
M36	2700±400	2000±300

Vibration

Vibration Summary

Vibrations can have many causes such as those listed in A through F:

A. Unbalance of rotating or reciprocating parts.

B. Combustion forces.

C. Misalignment of engine and driven equipment.

D. Inadequate anchoring of equipment.

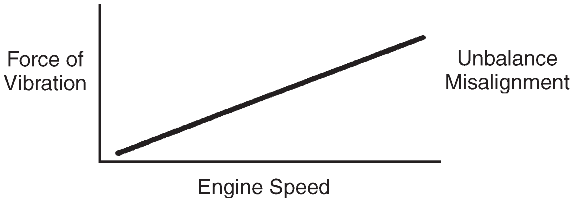
E. Torque reaction.

F. Resonance with the mounting structure.

Causes of vibrations can usually be identified by determining if:

1. Vibration forces increase with speed. These are caused by centrifugal forces bending components of the drive train.

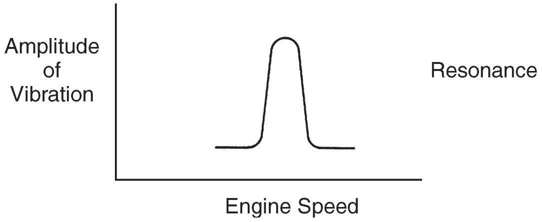
These are normally caused by A, B, or C.



2. Vibrations occur within a narrow speed range. This normally occurs on equipment attached to the engine-pipes, air cleaners, etc. When vibrations "peak out" in a narrow speed range, the vibrating component is in resonance.

   These vibrations can be modified by changing the natural frequency of the part by stiffening or softening its mounting. A defective viscous vibration dampener can also cause this.

   These are normally caused by A, C, or F.



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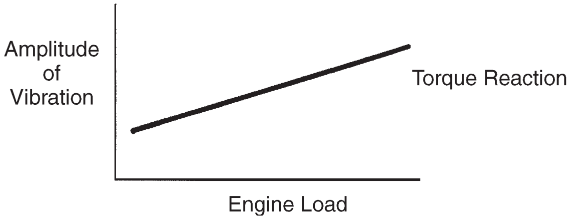
3. Vibrations increase as load is applied. This is torque reaction and can be caused by insecure mounting of engine or driven equipment, or by a base or foundation which is not sufficiently rigid to withstand the driving torque of the engine or defective worn couplings.

   These are normally caused by D or E.



Order of Vibration

$$\text{Order} = \frac{\text{Vibration Frequency (Hz)}}{\text{Engine RPM/60}}$$

Order of Firing Frequency

$$\begin{array}{l}\text{Firing Frequency} \\ \text{(4 Cycle Engines)}\end{array} = \frac{\text{Number of Cylinders}}{2}$$

Data Interpretation

Order of Vibration:	**Possible Cause:**
0.5 Order	Misfire of one or more cylinders
1.0 Order	Out of balance component rotating at crankshaft speed
2.0 Order	Out of time balancer gears rotating at twice engine speed. Misaligned U-Joint. Piston or upper end of connecting rod is too light or too heavy.
Order-Firing Frequency	Normal, may also occur at 0.5 orders adjacent to firing frequency

First Order Vibration Frequencies for Standard Rated Speeds

$$\text{Frequency (Hz)} = \frac{\text{RPM}}{60}$$

Engine RPM	First Order Frequency (Hz)
700	11.7
720	12
800	13.3
900	15
1000	16.7
1200	20
1225	20.4
1300	21.7
1350	22.5
1500	25
1600	26.7
1800	30
2000	33.3
2100	35
2200	36.7
2400	40
2600	43.3
2800	46.7
2900	48.3

Relationships of Sinusoidal Velocity, Acceleration, Displacement

English		Metric	
$V = \pi f D$		$V = \pi f D$	
$V = 61.44\ g/f$	D = inches pk-to-pk	$V = 1.56\ g/f$	D = meters pk-to-pk
$g = 0.0511\ f^2 D$	V = inches/second	$g = 2.013\ f^2 D$	V = meters/second
$g = 0.0162\ Vf$	f = Hz (cps) or RPM/60	$g = 0.641\ Vf$	f = Hz (cps) or RPM/60
$D = 0.3183\ V/f$	g = 386.1 in/sec^2	$D = 0.3183\ V/f$	g = 9.806 65 m/sec^2
$D = 19.57\ g/f^2$		$D = 0.4968\ g/f^2$	

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

Location Points

900 Series Designation	Location Description
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*	Aftercooler water temperature between front and rear housing
938	Oil cooler water outlet temperature
939	Oil cooler water outlet pressure
940*	Aftercooler/Oil cooler water outlet mixing box temperature
941*	Aftercooler/Oil cooler water outlet mixing box pressure
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

Location Points

900 Series Designation	Location Description
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

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.

Caterpillar Sea Trial Rules of Thumb

Marine Engine Performance Specifications*

Engine Jacket Water System:

JW Temp (From Cooler):

All except 3208 (355/375 HP)	99° C-Delta T ° C/ 210° F-Delta T ° F Max.
3208 (355 and 375 HP)	102° C-Delta T ° C/ 215° F-Delta T ° F Max.

JW Outlet Temp (Before Reg):

All except 3208 (355/375 HP)	99° C/210° F Max.
3208 (355 and 375 HP)	102° C/215° F Max.

JW Temp (After Water Pump):

All except 3208 (355/375 HP)	99° C-Delta T ° C/ 210° F-Delta T ° F Max.
3208 (355 and 375 HP)	102° C-Delta T ° C/ 215° F-Delta T ° F Max.

Engine Lubrication System:

Oil Temperature to Bearings:

3200	116° C/240° F Max.
3300, 3400, 3500, 3114/3116	110° C/230° F Max.
300	104° C/220° F Max.

Oil Manifold Pressure:

3114/3116	250 kPa/36 psi Min.
3200	345 kPa/50 psi Min.
3300	207 kPa/30 psi Min.
300, 3400, 3500	276 kPa/40 psi Min.

Engine Fuel System:

Fuel Transfer Pump Pressure:

All except 3500	172 kPa/25 psi Min.
3500	379 kPa/55 psi Min.

Engine Exhaust Back Pressure:

Exhaust Back Pressure:

Naturally Aspirated	8.5 kPa/34 in-H_2O Max.
Turbocharged	6.7 kPa/27 in-H_2O Max.
3208 @ 435 HP	10.0 kPa/40 in-H_2O
3116 @ 300 HP	10.0 kPa/40 in-H_2O

*Excluding 3600.

Marine Engine Performance Specifications* (cont.)

Engine Crankcase Pressure:	
Crankcase Pressure:	
All except 3208	0.5 kPa/2 in-H_2O Max.
3208	1.0 kPa/4 in-H_2O Max.
Engine Air System:	
Inlet Air Temp @ Air Cleaner	49° C/120° F Max.
Engine Room Temperature	8° C/10° F above ambient (5.5° C)
Inlet Air Restriction	4 kPa/15 in-H_2O
Inlet Air Manifold Temp:	
Naturally Aspirated	49° C/120° F Max.
Turbocharged	163° C/325° F Max.
Turbocharged JWAC	118° C/245° F Max.
Turbocharged SCAC 85° F	52° C/125° F Max.
Turbocharged SCAC 100° F	66° C/150° F Max.
3208 High Performance (435 and 375 HP)	60° C/140° F Max.
Engine Aftercooler System:	
Aftercooler Inlet H_2O Temp:	
Turbocharged JWAC	99° C-Delta T ° C/ 210° F-Delta T ° F Max.
Turbocharged SCAC 85° F	29° C/85° F Max.
Turbocharged SCAC 110° F	43° C/110° F Max.
Aftercooler Outlet H_2O Temp.	
Turbocharged JWAC	99° C/210° F Max.
Turbocharged SCAC 85° F	52° C/125° F Max.
Turbocharged SCAC 110° F	66° C/150° F Max.
3208 (355 and 375 HP)	60° C/140° F Max.

*Excluding 3600.

Refer to T.M.I. for exact engine specifications.

TMI — GKN401 — 07 — Sea Trial Data

Caterpillar Sea Trial Rules of Thumb

Marine Gear Performance Specifications

Transmission Lubrication System:

Transmission Oil Temp: Twin Disc

502, 506, 507, 509, 514C, 521	93° C/200° F Max.
514, 514M	82° C/180° F Max.

Transmission Minimum Oil Pressure: Twin Disc

502, 506, 507	2067 kPa/300 psi Min.
506 w/3208 DIT 300 bhp @ 2800 RPM Engine	2412 kPa/350 psi Min.
514, 514C, 514M	1275 kPa/185 psi Min.
521	1447 kPa/210 psi Min.
509	1206 kPa/175 psi Min.

Transmission Maximum Oil Pressure: Twin Disc

502	2412 kPa/350 psi Max.
506, 507	2205 kPa/320 psi Max.
506 w/3208 DIT 300 bhp @ 2800 RPM Engine	2549 kPa/370 psi Max.
509	1378 kPa/200 psi Max.
514, 514C, 514M	1530 kPa/222 psi Max.
521	1998 kPa/290 psi Max.

Transmission Oil Temp: 7200 Series

7211, 7221, 7231, 7271	93° C/200° F Max.
7241, 7251, 7261	79° C/175° F Max.

Transmission Minimum Oil Pressure: 7200 Series

7211, 7221, 7231, 7241	1757 kPa/255 psi Min.
7251	1688 kPa/245 psi Min.
7261	1826 kPa/265 psi Min.
7271	1998 kPa/290 psi Min.

Transmission Maximum Oil Pressure: 7200 Series

7211, 7221, 7231, 7241, 7261	1964 kPa/285 psi Max.
7251	1895 kPa/275 psi Max.
7271	2136 kPa/310 psi Max.

Marine Gear Performance Specifications (cont.)

Transmission Oil Temp: Reintjes	
LAF, VAL, WAF, WAV, WVS	87° C/185° F Max.
Transmission Minimum Oil Pressure: Reintjes	
LAF, VAL, WAF, WAV, WVS	1600 kPa/232 psi Min.
Transmission Maximum Oil Pressure: Reintjes	
LAF, VAL, WAF, WAV, WVS	2000 kPa/290 psi Max.
Transmission Cooling System:	
Transmission Cooler Inlet Water Temp: Twin Disc	
All	91° C/195° F Max.
Transmission Cooler Inlet Water Temp: 7200 Series	
7211, 7221, 7231	91° C/195° F Max.
7241, 7251, 7261, 7271	49° C/120° F Max.
Transmission Cooler Inlet Water Temp: Reintjes	
LAF, VAL, WAF, WAV, WVS	49° C/120° F Max.

3600 Performance Analysis Rules of Thumb

Air Intake System:	
Air Temp at Air Cleaner	49° C (120° F) Max.
Inlet Air Restriction	15 in-H_2O/5 in New Max.
Intake Manifold Air Temperature	65° C (150° F) Nominal 92° C (197° F) Alarm
Intake Manifold Air Pressure	Nominal Values in Perf Book Measure at part and full load
Crankcase Pressure/ Vacuum	–1 to +2 in-H_2O (–0.25 to +0.5 kPa) 2.5 in-H_2O (1 kPa) Alarm

3600 Performance Analysis Rules of Thumb (cont.)

Exhaust System:	
Exhaust Stack Temperature	Nominal Temp in Perf Book 550° C (1022° F) Alarm
Individual Cyl Exhaust Port Temperature	50° C (122° F) Maximum Variation between Cyl
Exhaust Back Pressure	10 in-H_2O (2.5 kPa) Max. 0.8% Loss in fuel economy (increase in BSFC) for each 10 in-H_2O above 10 in-H_2O
Lubrication System:	
Engine Oil to Bearing Temperature	85° C (185° F) Nominal 92° C (197° F) Alarm
Engine Oil to Bearing Pressure	450 kPa (65 psi) Nominal 320 kPa (46 psi) Alarm
Oil Filter Pressure Differential	100 kPa (15 psi) Max.
Fuel System:	
Fuel Pressure	425-550 kPa (62-80 psi)
Fuel Supply Temperature	*Distillate Fuel 29° C (85° F) Max. Desired 1% Power reduction for each 6° C (10° F) increase above 29° C (85° F) 65° C (150° F) Max. to prevent injector damage
Fuel Filter Pressure Differential	70 kPa (10 psi) Max.
Fuel Pump Inlet Restriction	–39 kPa (–6 psi) Max.
Fuel Return Line Restriction	350 kPa (51 psi) Max.

3600 Performance Analysis Rules of Thumb (cont.)

Cooling System:

Heat Exchanger System External Resistance
(Combined & Separate Circuit)

— Measure at engine outlet and compare to heat exchanger outlet (before regulators)

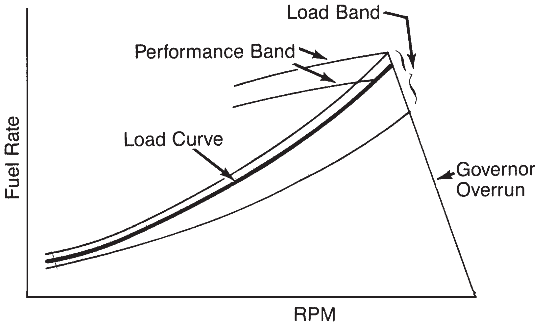
— Temperature Regulators 100% OPEN (blocked)
SPECS:

1000 RPM	90 kPa (13 psi)
900 RPM	73 kPa (11 psi)
720 RPM	47 kPa (7 psi)

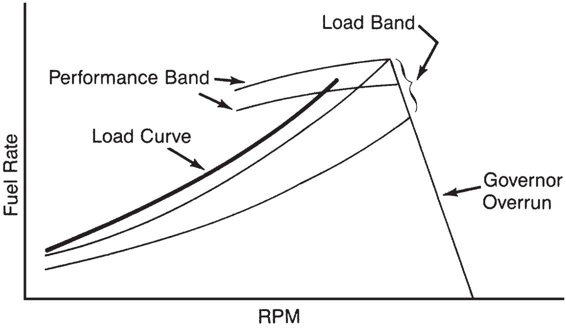
Aftercooler Water Inlet Temperature	50° C (122° F) Nominal *65° C (150° F) Max. under certain special conditions
Aftercooler Water Outlet Temperature	50° C (122° F) + Delta T
Oil Cooler Water Inlet Temperature	50° C (122° F) Nominal *65° C (150° F) Max. under certain special conditions
Oil Cooler Water Outlet Temperature	50° C (122° F) + Delta T
Jacket Water Pump Inlet Temperature	85° C (185° F) Nominal
Jacket Water Block Outlet Temperature	85° C (185° F) + Delta T
A/C & O/C Water Pump Inlet Pressure	–5 kPa (–20 in-H_2O) Min.
Jacket Water Pump Inlet Pressure	30 kPa (5 psi) Min.

Analysis of P.A.R. Fuel Rate Curves

Normal Test
Shaft Load and Fuel Rate Correct

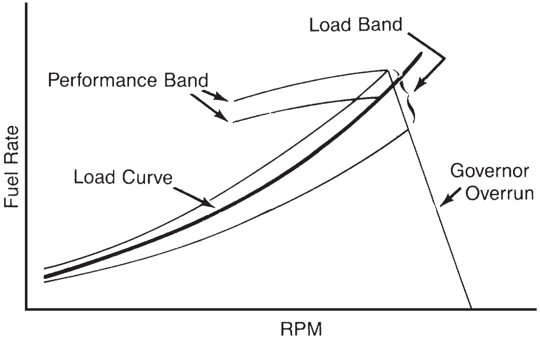


Normal Test
Shaft Load High, Fuel Rate Correct

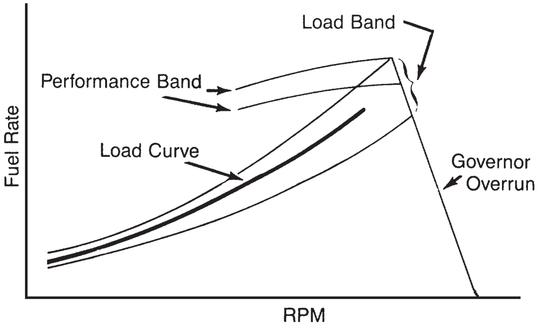


Charts are for illustrative purposes only.

Normal Test
Shaft Load Correct, Fuel Rate High

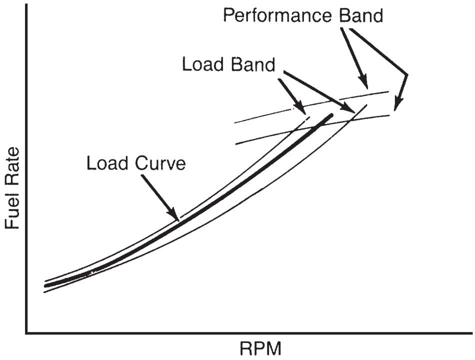


Normal Test
Shaft Load Correct, Fuel Rate Low

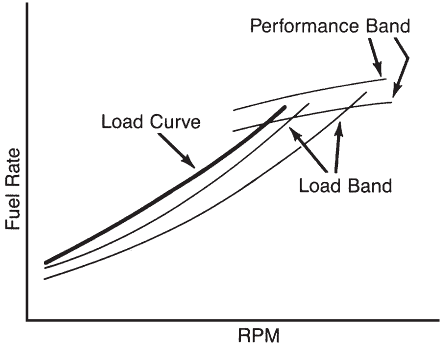


Charts are for illustrative purposes only.

Bollard Test
Shaft Load and Fuel Rate Correct

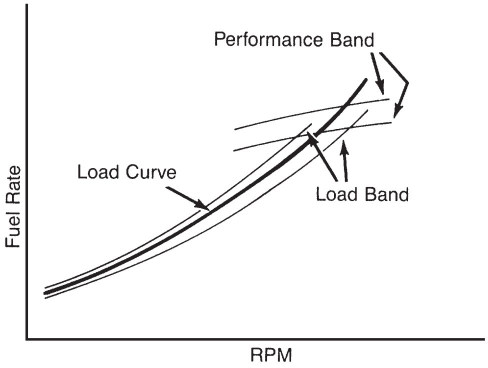


Bollard Test
Shaft Load High, Fuel Rate Correct

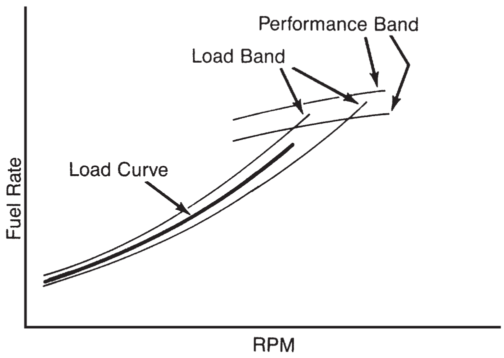


Charts are for illustrative purposes only.

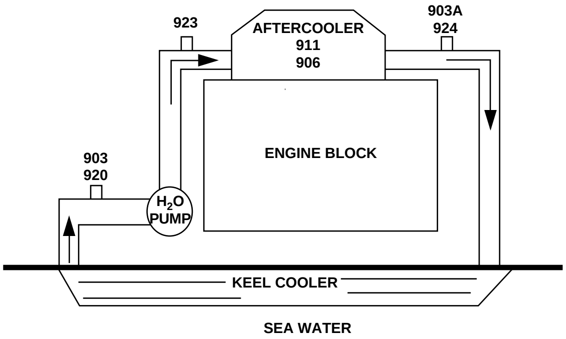
Bollard Test
Shaft Load Correct, Fuel Rate High



Bollard Test
Shaft Load Correct, Fuel Rate Low



Charts are for illustrative purposes only.



Sea Trial Formulas

Aftercooler Water Inlet-to-Inlet Manifold Temperature Δ T

906 (Actual Inlet Manifold Air Temperature)
– 903 (Actual Aftercooler Water Inlet Temperature)

Actual Δ T

85° A/C

Spec 906 = 125° F
– Spec 903 = 85° F

Spec Δ T = 40° F

110 A/C

Spec 906 = 150° F
– Spec 903 = 110° F

Spec Δ T = 40° F

3082 E – Rating

Spec 906 = 140° F
– Spec 903 = 85° F

Spec Δ T = 55° F

Jacket Water A/C

Spec 906 = 245° F
– Spec 903 = 210° F – Engine Δ T

Spec Δ T = Varies with each Engine Rating

Aftercooler Water Inlet-to-Aftercooler Water Outlet Temperature Δ Ts

$$\begin{array}{rl} & \text{903A Actual Aftercooler Water Outlet Temperature} \\ - & \text{903 Actual Aftercooler Water Inlet Temperature} \\ \hline & \textbf{Actual } \Delta \textbf{ T} \end{array}$$

85° A/C

$$\begin{array}{rl} & \text{Spec 903A} = 95^\circ \text{ F to } 100^\circ \text{ F} \\ - & \text{Spec 903} = 85^\circ \text{ F} \\ \hline & \text{Spec } \Delta \text{ T} = 10^\circ \text{ F to } 15^\circ \text{ F} \end{array}$$

110 A/C

$$\begin{array}{rl} & \text{Spec 903A} = 120^\circ \text{ F to } 125^\circ \text{ F} \\ - & \text{Spec 903} = 110^\circ \text{ F} \\ \hline & \text{Spec } \Delta \text{ T} = 10^\circ \text{ F to } 15^\circ \text{ F} \end{array}$$

Jacket Water A/C System

$$\begin{array}{rl} & \text{Spec 903A} = 210^\circ \text{ F} \\ - & \text{Spec 903} = 210^\circ \text{ F} - \Delta \text{ T} \\ \hline & \text{Spec } \Delta \text{ T} = \text{Varies with Engine Ratings} \end{array}$$

Aftercooler Water Inlet Temperature-to-Sea Water Temperature Δ Ts

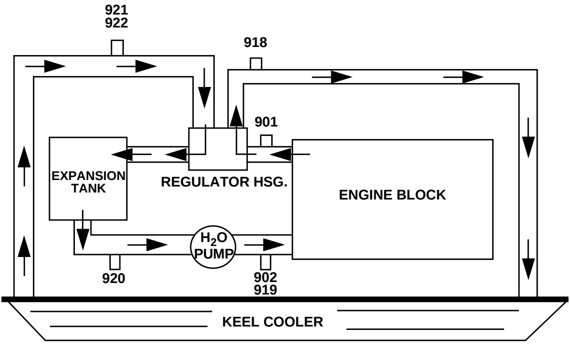
$$\begin{array}{rl} & \text{903 Actual Aftercooler Water Inlet Temperature} \\ - & \text{Actual Sea Water Temperature} \\ \hline & \textbf{Actual } \Delta \textbf{ T} \end{array}$$

85° A/C

$$\begin{array}{rl} & \text{Spec. 903} = 85^\circ \text{ F} \\ - & \text{Spec. Sea Water Maximum} = 75^\circ \text{ F} \\ \hline & \text{Maximum } \Delta \text{ T} = 10^\circ \text{ F} \end{array}$$

100 A/C

$$\begin{array}{rl} & \text{Spec. 903} = 110^\circ \text{ F} \\ - & \text{Spec. Sea Water Maximum} = 100^\circ \text{ F} \\ \hline & \text{Maximum } \Delta \text{ T} = 10^\circ \text{ F} \end{array}$$



Jacket Water Circuit Analysis

Jacket Water Pump Outlet Temperature-to-Jacket Water Outlet Temperature (Before the Regulator) Δ T

901 Actual Jacket Water Outlet Temperature
– 902 Actual Jacket Water Inlet Temperature

Actual Δ T = Varies with Engine Ratings

All Engines except 3208 T/A E-rating

901 Spec. = 210° F
– 902 Spec. = 210° F – Δ T
(Varies with Each Engine Rating)

Spec Δ T = Varies with Each Engine Rating

3208 T/A E-rating

901 Spec. = 215° F
– 902 Spec. = 215° F – Δ T
(Varies with Each Engine Rating)

Spec Δ T = Varies with Each Engine Rating

$$\Delta T = \frac{\text{Heat Rejection to Coolant (Btu/Min)}}{\text{Jacket Water Pump Flow (GPM)} \times 8.1}$$

Sea Water-to-Heat Exchanger/Keel Cooler Δ T

922 Actual Water from the Cooling System
– Actual Sea Water Temperature

Actual Δ T = Varies with Each Engine Rating

922 Spec. = 210° F – Δ T
(Varies with Each Engine Rating)
– Spec Sea Water = Maximum expected in area of operation

Spec Δ T = 110° F

If Actual Δ T is greater than 110° F then it means that the cooling system is too small for Hp being produced or has a capacity problem.

If the Actual Δ T is less than 110° F then it means that the cooling system can operate in sea water that is hotter than the water the actual test was conducted in.

Determine the Maximum Sea Water Temperature Vessel can Operate

Δ T HIGH = Greater than 110° F

901 Actual – 901 Spec = Δ T

Δ T 2

Actual Sea Water Temperature
+ Δ T = Maximum Sea Water

Maximum Sea Water System
can Operate as Tested

Δ T LOW = Less than 110° F

$$\frac{\begin{array}{l}\text{922 Actual Water from the Cooling System} \\ +\ \text{902 Actual Jacket Water after the Water Pump}\end{array}}{\text{Equals } \textbf{“K”}}$$

$$\frac{K}{2} = \text{Actual Average Water Inlet Temperature}$$

$$\frac{\begin{array}{l}\text{922 Spec.} = 210^\circ\text{ F} - \Delta\text{ T} \\ \textbf{(Varies with Each Engine Rating)} \\ +\ \text{902 Spec.} = 210^\circ\text{ F} - \Delta\text{ T} \\ \textbf{(Varies with Each Engine Rating)}\end{array}}{\text{Equals } \textbf{“J”}}$$

$$\frac{J}{2} = \text{Spec Average Water Inlet Temperature}$$

$$\frac{\begin{array}{l}\text{Spec Average Water Inlet Temperature} \\ -\ \text{Actual Average Water Inlet Temperature}\end{array}}{\text{Equals } \boldsymbol{\Delta}\textbf{ T 1}}$$

$$\frac{\begin{array}{l}\text{Actual Sea Water Temperature} \\ +\ \Delta\text{ T 1}\end{array}}{\text{Maximum Sea Water Capability}}$$

Ventilation System

$$\frac{\begin{array}{l}\text{930 Actual Air after the Air Cleaner} \\ -\ \text{Actual Ambient Air Temperature}\end{array}}{\text{Minimum } \Delta\text{ T} = 10^\circ\text{ F}}$$

Maximum Ambient Air Temperature that the Vessel can Operate as Tested

930 Spec. Air Temperature After the Air Cleaner
– 930 Actual Air after the Air Cleaner
(Varies with the Installation)

Equals Δ **T2**

Actual Ambient = Varies with test climate
+ Δ T2

Maximum Ambient Air Capability

Engine Lubrication System

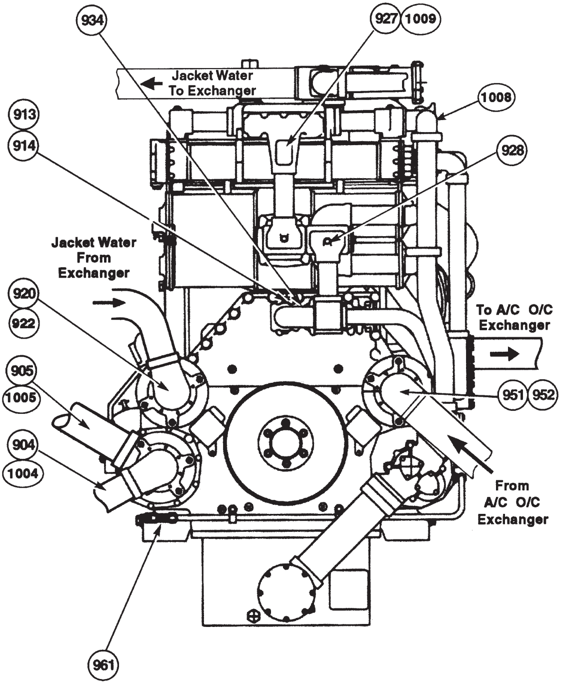
913 Actual Oil to Bearings Temperature
– 901 Actual Jacket Water out of the Engine

Δ T3 Varies with Engine Family

Maximum Δ T Spec. for Engine Families

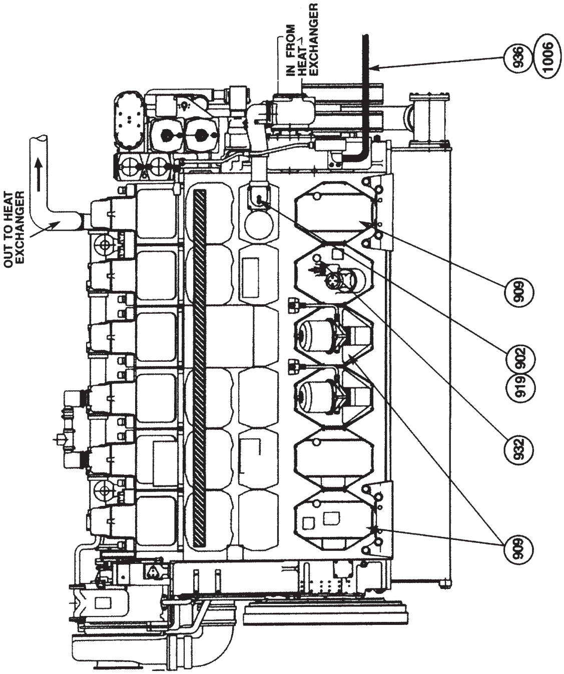
3208 = 30° F
3300, 3400, 3500 = 20° F
D300 Series = 10° F

900 Number Test Locations for 3600 Inline Separate Circuit



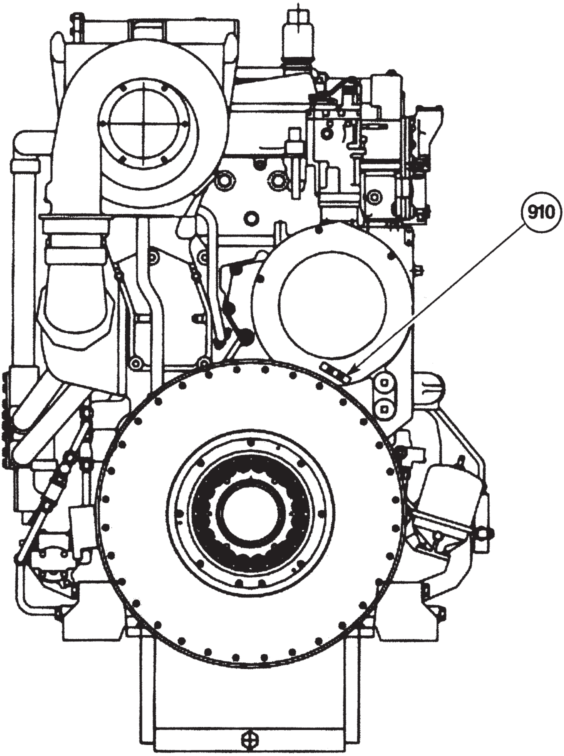
Front View

900 Number Test Locations for 3600 Inline Separate Circuit



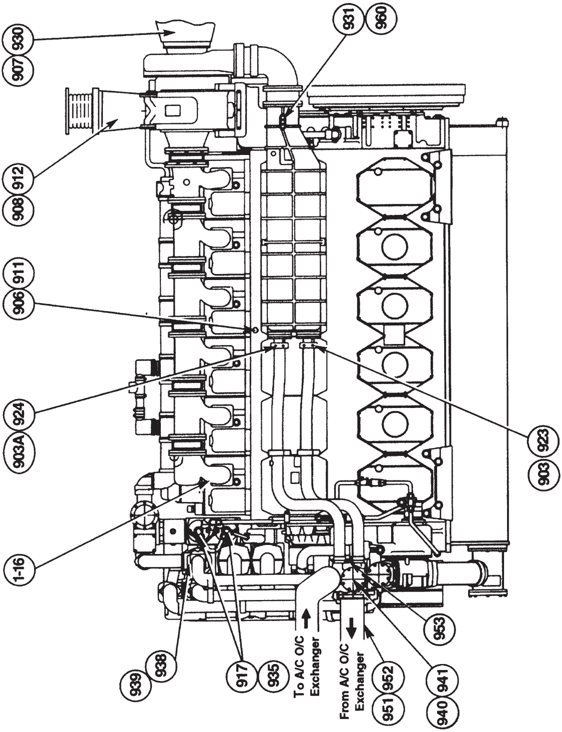
Right Side View

900 Number Test Locations for 3600 Inline Separate Circuit



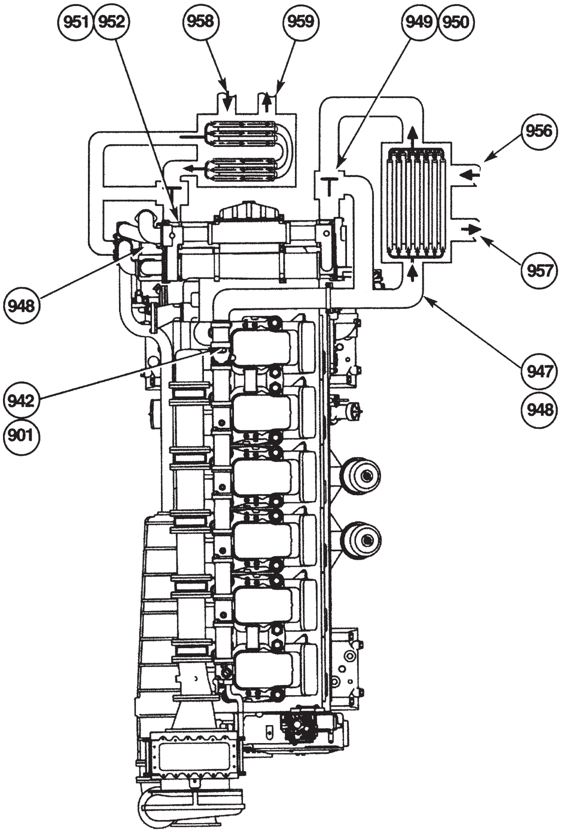
Rear View

900 Number Test Locations for 3600 Inline Separate Circuit



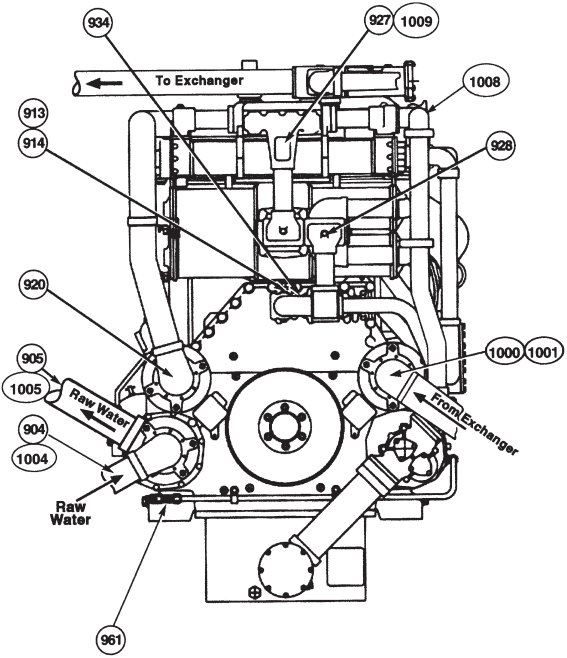
Left Side View

900 Number Test Locations for 3600 Inline Separate Circuit



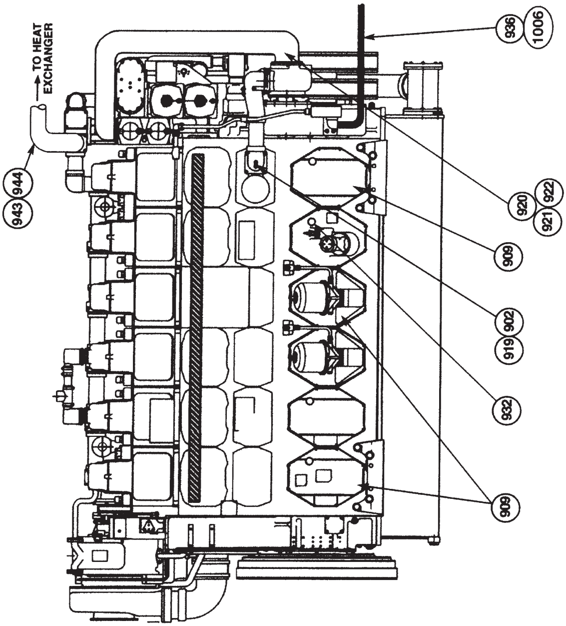
Top View

900 Number Test Locations for 3600 Inline Combined Circuit



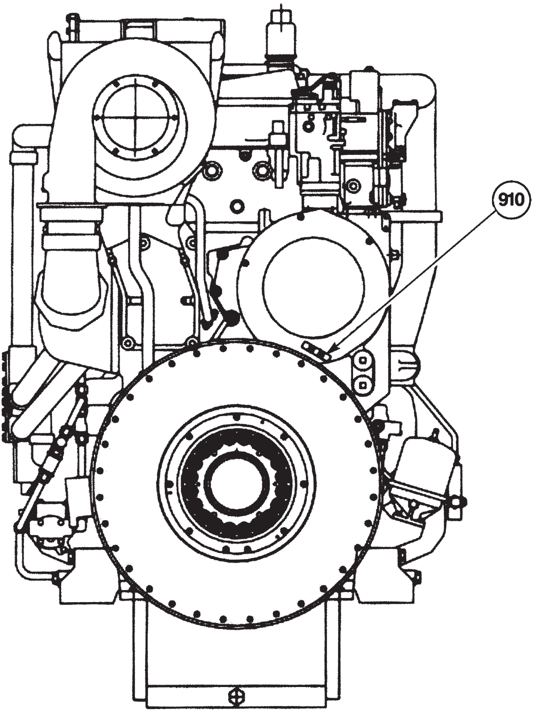
Front View

900 Number Test Locations for 3600 Inline Combined Circuit



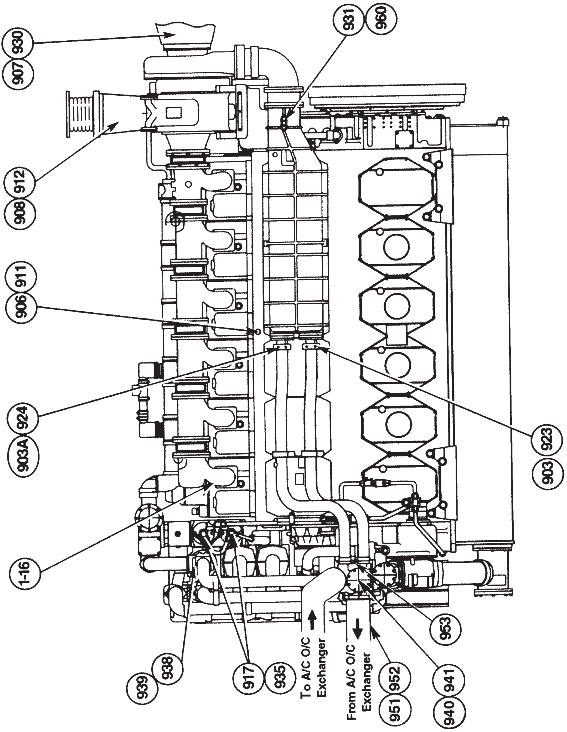
Right Side View

900 Number Test Locations for 3600 Inline Combined Circuit



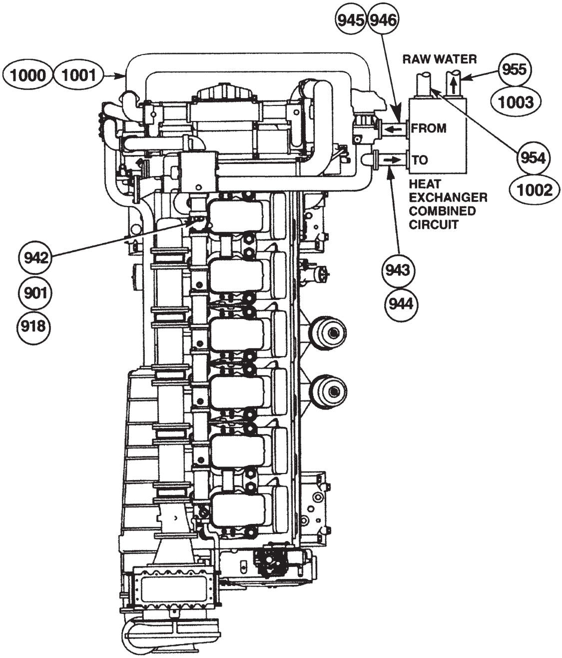
Rear View

900 Number Test Locations for 3600 Inline Combined Circuit



Left Side View

900 Number Test Locations for 3600 Inline Combined Circuit



Top View

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 percentage 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	1.562×10^{-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 $\times$ 1 in	Cubic inches
British Thermal Units	0.2520	Kilogram – calories
British Thermal Units	777.6	Foot – lbs
British Thermal Units	3.927×10^{-4}	Horsepower – hrs
British Thermal Units	107.5	Kilogram – meters
British Thermal Units	2.928×10^{-4}	Kilowatt – hrs
BTU/min	12.96	Foot – lbs/sec
BTU/min	0.02356	Horsepower
BTU/min	0.01757	Kilowatts
BTU/min	17.57	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

Multiply	By	To Obtain
Centimeters/sec	1.969	Feet/min
Centimeters/sec	0.03281	Feet/sec
Centimeters/sec	0.036	Kilometers/hr
Centimeters/sec	0.6	Meters/min
Centimeters/sec	0.02237	Miles/hr
Centimeters/sec	3.728×10^{-4}	Miles/min
Cms/sec/sec	0.03281	Feet/sec/sec
Cubic centimeters	3.531×10^{-5}	Cubic feet
Cubic centimeters	6.102×10^{-2}	Cubic inches
Cubic centimeters	10^{-6}	Cubic meters
Cubic centimeters	1.308×10^{-6}	Cubic yards
Cubic centimeters	2.642×10^{-4}	Gallons
Cubic centimeters	9.999×10^{-4}	Liters
Cubic centimeters	2.113×10^{-3}	Pints (liq)
Cubic centimeters	1.057×10^{-3}	Quarts (liq)
Cubic feet	2.832×10^{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	5.787×10^{-4}	Cubic feet
Cubic inches	1.639×10^{-5}	Cubic meters
Cubic inches	2.143×10^{-5}	Cubic yards
Cubic inches	4.329×10^{-3}	Gallons
Cubic inches	1.639×10^{-2}	Liters
Cubic inches	0.03463	Pints (liq)
Cubic inches	0.01732	Quarts (liq)

Multiply	By	To Obtain
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
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

Multiply	By	To Obtain
Feet	1/3	Yards
Feet of water	0.0295	Atmospheres
Feet of water	0.8826	Inches of mercury
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
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	1.286×10^{-3}	British Thermal Units
Foot – pounds	5.050×10^{-7}	Horsepower – hrs
Foot – pounds	3.240×10^{-4}	Kilogram – calories
Foot – pounds	0.1383	Kilogram – meters
Foot – pounds	3.766×10^{-7}	Kilowatt – hours
Foot – pounds/min	2.140×10^{-5}	BTU/sec
Foot – pounds/min	0.01667	Foot – pounds/sec
Foot – pounds/min	3.030×10^{-5}	Horsepower
Foot – pounds/min	5.393×10^{-3}	Gm – calories/sec
Foot – pounds/min	2.260×10^{-5}	Kilowatts
Foot – pounds/sec	7.704×10^{-2}	BTU/min
Foot – pounds/sec	1.818×10^{-3}	Horsepower
Foot – pounds/sec	1.941×10^{-2}	Kg – calories/min
Foot – pounds/sec	1.356×10^{-3}	Kilowatts
Gallons	3785	Cubic centimeters
Gallons	0.1337	Cubic feet
Gallons	231	Cubic inches
Gallons	3.785×10^{-3}	Cubic meters

Multiply	By	To Obtain
Gallons	4.951×10^{-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	2.228×10^{-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	Pennyweights (troy)
Grains (troy)	2.0833×10^{-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
Grams	.001	Kilograms
Grams	1000	Milligrams
Grams	0.03527	Ounces
Grams	0.03215	Ounces (troy)
Grams	2.205×10^{-3}	Pounds
Grams/cm	5.600×10^{-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	1.076×10^{5}	Square feet
Hectograms	100	Grams
Hectoliters	100	Liters
Hectometers	100	Meters
Hectowatts	100	Watts
Horsepower	42.44	BTU/min

Multiply	By	To Obtain
Horsepower	33,000	Foot – lbs/min
Horsepower	550	Foot – lbs/sec
Horsepower	1.014	Horsepower (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	1.98×10^6	Foot – lbs
Horsepower – hours	641.6	Kilogram – calories
Horsepower – hours	2.737×10^5	Kilogram – meters
Horsepower – hours	0.7457	Kilowatt – hours
Inches	2.540	Centimeters
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 water	0.002458	Atmospheres
Inches of water	0.07355	Inches of mercury
Inches of water	25.40	Kgs/sq meter
Inches of water	0.578	Ounces/sq inch
Inches of water	5.202	Lbs/sq foot
Inches of water	0.03613	Lbs/sq inch
Kilograms	980,665	Dynes
Kilograms	2.205	Lbs
Kilograms	1.102×10^{-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	3085.9	Foot – lbs/min
Kilogram – cal/min	0.09351	Horsepower
Kilogram – cal/min	69.733	Watts

Multiply	By	To Obtain
Kgs/meter	6.720	Lbs/foot
Kgs/sq meter	9.678×10^{-5}	Atmospheres
Kgs/sq meter	3.281×10^{-3}	Feet of water
Kgs/sq meter	2.896×10^{-3}	Inches of mercury
Kgs/sq meter	0.2048	Lbs/sq foot
Kgs/sq meter	1.422×10^{-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
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	56.907	BTU/min
Kilowatts	4.425×10^{4}	Foot – lbs/min
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	2.655×10^{6}	Foot – lbs
Kilowatt – hours	1.341	Horsepower – hrs
Kilowatt – hours	860.4	Kilogram – calories
Kilowatt – hours	3.671×10^{5}	Kilogram – meters
Liters	10^{3}	Cubic centimeters
Liters	0.03531	Cubic feet
Liters	61.02	Cubic inches
Liters	10^{-3}	Cubic meters
Liters	1.308×10^{-3}	Cubic yards

Multiply	By	To Obtain
Liters	0.2642	Gallons
Liters	2.113	Pints (liq)
Liters	1.057	Quarts (liq)
Liters/min	5.886×10^{-4}	Cubic ft/sec
Liters/min	4.403×10^{-3}	Gals/sec
Lumber Width (in) $\times$ $\frac{\text{Thickness (in)}}{12}$	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	1.609×10^{5}	Centimeters
Miles	5280	Feet
Miles	1.609	Kilometers
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

Multiply	By	To Obtain
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)	2.909×10^{-4}	Radians
Ounces	16	Drams
Ounces	437.5	Grains
Ounces	0.0625	Pounds
Ounces	28.3495	Grams
Ounces	0.9115	Ounces (troy)
Ounces	2.790×10^{-5}	Tons (long)
Ounces	2.835×10^{-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
Pennyweights (troy)	0.05	Ounces (troy)
Pennyweights (troy)	4.1667×10^{-3}	Pounds (troy)
Pounds	16	Ounces
Pounds	256	Drams
Pounds	7000	Grains
Pounds	0.0005	Tons (short)

Multiply	By	To Obtain
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)	3.6735×10^{-4}	Tons (long)
Pounds (troy)	4.1143×10^{-4}	Tons (short)
Pounds (troy)	3.7324×10^{-4}	Tons (metric)
Pounds of water	0.01602	Cubic feet
Pounds of water	27.68	Cubic inches
Pounds of water	0.1198	Gallons
Pounds of water/min	2.670×10^{-4}	Cubic ft/sec
Pounds/cubic foot	0.01602	Grams/cubic cm
Pounds/cubic foot	16.02	Kgs/cubic meters
Pounds/cubic foot	5.787×10^{-4}	Lbs/cubic inch
Pounds/cubic inch	27.68	Grams/cubic cm
Pounds/cubic inch	2.768×10^{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	6.944×10^{-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 mercury
Pounds/sq inch	703.1	Kgs/sq meter
Quadrants (angle)	90	Degrees
Quadrants (angle)	5400	Minutes
Quadrants (angle)	1.571	Radians
Quarts (dry)	67.20	Cubic inches
Quarts (liq)	57.75	Cubic inches
Quintal, Argentine	101.28	Pounds

Multiply	By	To Obtain
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	1.745×10^{-3}	Radians/sec/sec
Revolutions/min/min	2.778×10^{-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)	4.848×10^{-6}	Radians
Square centimeters	1.076×10^{-3}	Square feet
Square centimeters	0.1550	Square inches
Square centimeters	10^{-4}	Square meters
Square centimeters	100	Square millimeters
Square feet	2.296×10^{-5}	Acres
Square feet	929.0	Square centimeters
Square feet	144	Square inches
Square feet	0.09290	Square meters
Square feet	3.587×10^{-8}	Square miles

Multiply	By	To Obtain
$\frac{1}{\text{Sq ft/gal/min}}$	8.0208	Overflow rate (ft/hr)
Square feet	1/9	Square yards
Square inches	6.452	Square centimeters
Square inches	6.944×10^{-3}	Square feet
Square inches	645.2	Square millimeters
Square kilometers	247.1	Acres
Square kilometers	10.76×10^{6}	Square feet
Square kilometers	10^{6}	Square meters
Square kilometers	0.3861	Square miles
Square kilometers	1.196×10^{6}	Square yards
Square meters	2.471×10^{-4}	Acres
Square meters	10.76	Square feet
Square meters	3.861×10^{-7}	Square miles
Square meters	1.196	Square yards
Square miles	640	Acres
Square miles	27.88×10^{6}	Square feet
Square miles	2.590	Square kilometers
Square miles	3.098×10^{6}	Square yards
Square millimeters	0.01	Square centimeters
Square millimeters	1.550×10^{-3}	Square inches
Square yards	2.066×10^{-4}	Acres
Square yards	9	Square feet
Square yards	0.8361	Square meters
Square yards	3.228×10^{-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)

Multiply	By	To Obtain
Tons (short)	0.89287	Tons (long)
Tons (short)	29166.66	Ounces (troy)
Tons (short)	0.90718	Tons (metric)
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	1.341×10^{-3}	Horsepower
Watts	0.01434	Kg – calories/min
Watts	10^{-3}	Kilowatts
Watt – hours	3.414	BTU
Watt – hours	2655	Foot – lbs
Watt – hours	1.341×10^{-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

Volume Conversion

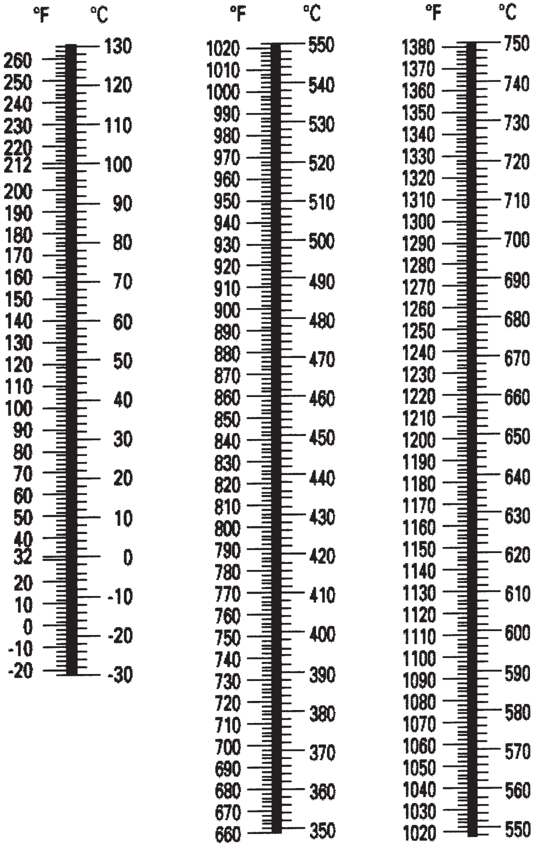
	cc	**cu in**	**quarts**	**liters**	**gallons**	**cu ft**
cc	1.0	.06102	.001056	.001	.000264	.0000353
cu in	16.387	1.0	.0173	.016387	.00433	.000578
quarts	946.3	57.75	1.0	.9464	.250	.0334
liters	.1000	61.02	1.056	1.0	.264	.0353
gallons	3785.4	231	4	3.785	1.0	.1337
cu ft	28314.8	1728	29.92	28.315	7.4805	1.0

	drops	**tsp**	**tbsp**	**cup**	**quart**	**gallons**	**ounces**
drops	1.0	.01666	.00555	.000347	.0000866	.000216	.00277
tsp	60	1.0	.333	.02083	.0052	.0013	.166
tbsp	180	3.0	1.0	.0625	.0156	.0039	.5
cup	.2880	48.0	16	1.0	.25	.0625	8
quart	.11520	192	64	4.0	1.0	.25	32
gallon	.46080	768	256	16.0	4.0	1.0	128
ounces	.360	.6	.2	.125	.03125	.00107	1

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

Conversions

Temperature Conversion



Celsius (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.

Physics Formulas

Velocity $= \dfrac{\text{Distance}}{\text{Time}}$ **Distance** = (Velocity)(Time)

Time $= \dfrac{\text{Distance}}{\text{Velocity}}$ **Acceleration** $= \dfrac{\text{Difference in Velocity}}{\text{Difference in Time}}$

Force = (Mass)(Acceleration) **Mass** $= \dfrac{\text{Force}}{\text{Acceleration}}$

Acceleration $= \dfrac{\text{Force}}{\text{Mass}}$ **Momentum** = (Mass)(Velocity)

Work = (Force)(Distance)

Work = (Mass)(Acceleration)(Distance)

Power $= \dfrac{\text{Work}}{\text{Time}}$

Heat = (Mass)(Specific Heat)(Temperature Change) or
Heat = (M)(C)(ΔT)

Where:

M = Mass

C = Specific Heat

ΔT = Temperature Change

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° Kelvin(K) or –273° Centigrade(C) or –459° Fahrenheit(F)

Physic Formulas

Boyle's Law: If temperature is kept constant, the volume of a given mass of gas is inversely proportional to the pressure which is exerted upon it.

$$\frac{\text{Initial Pressure}}{\text{Initial Volume}} = \frac{\text{Pressure Change}}{\text{Volume Change}}$$

Charles Law: If the pressure is constant, the volume of a given mass of gas is directly proportional to the absolute temperature.

$$\frac{\text{Initial Volume}}{\text{Initial Temperature } ^\circ\text{ K}} = \frac{\text{Volume Change}}{\text{Final Temperature } ^\circ\text{ K}}$$

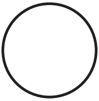
Theoretical Horsepower to Compress Air:

$$\text{Hp} = \text{CFM} \times \text{PSI} \times 0.0007575$$

Hp = Compressor Horsepower
CFM = Air flow in cubic feet per minute
PSI = Air pressure in pounds per square inch
(assumes Atmospheric Pressure = 14.7 psi, temperature 60° F)

Math Formulas

Circle



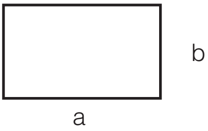
Circumference - 2 $\times$ diameter

Circumference = $2\pi r$

Area = πr^2

Area = $\pi \frac{d^2}{4}$

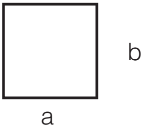
Math Formulas



Rectangle

Area = (a) (b)

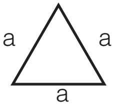
If a = b then it is a square



Perimeter = 2(a +b)

Diagonal = $\sqrt{a^2} + b^2$

Equilateral Triangle = all side equal



Perimeter = 3 a

$Area = a^2 \frac{\sqrt{3}}{4}$ $Area = 0.433 a^2$

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

Miami 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	Hong Kong 5,060	Honolulu 3,820	Los Angeles 5,658
Pago Pago 1,565	Panama 6,516	Papeete 2,216	San Francisco 5,680
Sitka 6,176	Sydney 1,280	Vancouver 6,191	Yokohama 4,789

Cape Horn to

Auckland 6,232	Hong Kong 10,404	Honolulu 6,644	Los Angeles 6,100
Pago Pago 5,381	Panama 4,162	Papeete 4,333	San Francisco 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	Los Angeles 6,380
Pago Pago 4,948	Panama 9,195	Papeete 6,132	San Francisco 6,044
Sitka 5,136	Sydney 4,086	Vancouver 6,361	Yokohama 1,585

Honolulu to

Auckland 3,820	Cape Horn 6,644	Hong Kong 4,857	Los Angeles 2,228
Pago Pago 2,276	Panama 4,685	Papeete 2,381	San Francisco 2,091
Sitka 2,386	Sydney 4,420	Vancouver 2,423	Yokohama 3,395

Los Angeles to

Auckland 5,658	Cape Horn 6,100	Hong Kong 6,380	Honolulu 2,228
Pago Pago 4,163	Panama 2,913	Papeete 3,571	San Francisco 349
Sitka 1,640	Sydney 6,511	Vancouver 1,091	Yokohama 4,836

Pago Pago to

Auckland 1,565	Cape Horn 5,381	Hong Kong 4,948	Honolulu 2,276
Los Angeles 4,163	Panama 5,656	Papeete 1,236	San Francisco 4,151
Sitka 4,635	Sydney 2,377	Vancouver 4,549	Yokohama 4,135

Panama to

Auckland 6,516	Cape Horn 4,162	Hong Kong 9,195	Honolulu 4,685
Los Angeles 2,913	Pago Pago 5,656	Papeete 4,493	San Francisco 3,245
Sitka 4,524	Sydney 7,674	Vancouver 4,032	Yokohama 7,682

Papeete to

Auckland 2,216	Cape Horn 4,333	Hong Kong 6,132	Honolulu 2,381
Los Angeles 3,571	Pago Pago 1,236	Panama 4,493	San Francisco 3,663
Sitka 4,537	Sydney 3,308	Vancouver 4,396	Yokohama 5,140

San Francisco to

Auckland 5,680	Cape Horn 6,458	Hong Kong 6,044	Honolulu 2,091
Los Angeles 349	Pago Pago 4,151	Panama 3,245	Papeete 3,663
Sitka 1,302	Sydney 6,448	Vancouver 812	Yokohama 4,536

Sitka to

Auckland 6,176	Cape Horn 7,705	Hong Kong 5,136	Honolulu 2,386
Los Angeles 1,640	Pago Pago 4,635	Panama 4,524	Papeete 4,537
San Francisco 1,302	Sydney 6,595	Vancouver 823	Yokohama 3,640

Sydney to

Auckland 1,280	Cape Horn 7,301	Hong Kong 4,086	Honolulu 4,420
Los Angeles 6,511	Pago Pago 2,377	Panama 7,674	Papeete 3,308
San Francisco 6,448	Sitka 6,595	Vancouver 6,814	Yokohama 4,330

Vancouver to

Auckland 6,191	Cape Horn 7,248	Hong Kong 6,361	Honolulu 2,423
Los Angeles 1,091	Pago Pago 4,549	Panama 4,032	Papeete 4,396
San Francisco 812	Sitka 823	Sydney 6,814	Yokohama 4,262

Yokohama to

Auckland 4,789	Cape Horn 9,642	Hong Kong 1,585	Honolulu 3,395
Los Angeles 4,839	Pago Pago 4,135	Panama 7,682	Papeete 5,140
San Francisco 4,536	Sitka 3,640	Sydney 4,330	Vancouver 4,262

Geographic Range Table

The following table gives the approximate 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 × square root of H + 1.17 × square root of h. Where d = visible distance, H = height of the object, and h the height of eye of the observer.

HEIGHT Feet	HEIGHT Meters	DISTANCE International Nautical Miles
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

(continued)

HEIGHT Feet	HEIGHT Meters	DISTANCE International Nautical Miles
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:

GLOSSARY OF TERMS

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 greater or lesser degree, human health or comfort.

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 × 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.

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 ½ 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 ordinary 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 as 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 horsepower without 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 or residual fuel and a lighter fuel. This fuel type tends to creates 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 calculated value or 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 of 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 therma 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 the 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 produced 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 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 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 refrigeration 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 electronic 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 or 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 crankcase 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 that 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 of 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 unit.

CYANIDING – Surface hardening by carbon and nitrogen absorption of an iron-base alloy article 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.

$$\text{Cyclic Irregularity} = \frac{\text{rpm (maximum)} - \text{rpm (minimum)}}{\text{rpm (average)}}$$

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 cylinders 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 gases is equal to sum or individual vapor pressures of gases 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 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 or 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 – $\frac{1}{360}$ 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.

DEHUMIDIFY 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 line-leads.

DIGITAL – A numeric valve representing the valve 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 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 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 a *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 fool 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 precharged 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 revolving object is in the 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 “spec-ing” 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 circuits 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 determined 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 exciter 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 contaminants 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 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 bold 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 regulator 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 are of sub-area.

FEELER GAUGE – A strip of steel ground to a precise thickness used to check clearance.

FERC *Federal Energy Regulator 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 th 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 contact.

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 wo 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 or 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 of 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 of 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 produced 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 ½ revolution of the crankshaft. These strokes are (1) intake stroke, (2) compression stroke, (3) power stroke, (4) exhaust stroke.

FOUR-STROKE ENGINE – 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 th 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 even 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 or 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 brand 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 type 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 or 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 765kV); 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 of 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 an anchor chain, for storage 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 or 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 gases, both specific heat and 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, convention, 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 or fuel.

HELICAL GEAR – A gear wheel or 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 or 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 temperature. 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 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 used 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.

$$\text{HC concentration (ppm)} = \frac{2067 \times \text{HC mass emissions (g/hr)}}{\text{Exhaust mass flow (kg/hr)}}$$

HYDROGEN – One of the elements constituting fuel and lubricating oil.

HYDROMECHANICAL GOVERNOR – A governing system which used 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 Actuator 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 determinate 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 inborad of ball bearing. This design is okay where shaft deflection between bearing center and engine drive flange mounting is not a problem.

INCLUSION – 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 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 reversal, 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 PUMP – A high-variable pressure pump delivering fuel into the combustion chamber.

INJECTOR 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 or 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 lose 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 inclinometer, 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 used 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 salt 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 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 $\frac{1}{2}$" to 2 $\frac{7}{8}$" 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 CH_3Cl. 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 gauge 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 $CHClF_2$. 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 non-interruptible 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.

NOx [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.

$$\text{NOx Concentration (ppm)} = \frac{629 \times \text{NOx mass emissions (g/hr)}}{\text{Exhaust mass flow (kg/hr)}}$$

NOx RACT – Reasonable Available Control Technology being applied to NOx 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 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:

$$\text{Piston speed} = (\text{stroke (ft)} \times \text{rpm} \times 2) \text{ or } \frac{(\text{stroke (in)} \times \text{rpm})}{6}$$

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):

$$\text{Power Factor} = \frac{\text{Actual Power (watts)}}{\text{Apparent Power (kV}\bullet\text{A)}}$$

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 outlet.

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 – A visual 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 propellers 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.

R504 – 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 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 of 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 forth (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 or 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.

REFRIGERANT-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 engines' ability to develop increasing torque at constant speed.

RESPONSE CHECK IDLE SPEED – The engine speed specified for the cooldown 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 beakers 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.

ROUGING 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 × 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 beakers 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 forecastle deck.

STERN – The back part of a ship, where the two sides meet. To move in that direction 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 Straighteners,* 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 beakers 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 of 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, otherwise she is down by the head or down by the stern.

TRIP UNIT – A device 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 temperate 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.

TUBE-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 $\frac{1}{16}$ to $\frac{3}{16}$ 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 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 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 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 surface 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.

Y2 *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.

Cat Marine / Industrial Engine Diagnostic Codes

Code	Description
1-11	Cylinder 1 Fault
2-11	Cylinder 2 Fault
3-11	Cylinder 3 Fault
4-11	Cylinder 4 Fault
5-11	Cylinder 5 Fault
6-11	Cylinder 6 Fault
17-5	Shut Off Solenoid Open Circuit
17-6	Shut Off Solenoid Short Circuit
22-13	Check Timing Sensor Calibration
23-2	Excessive Engine Power
23-5	Rack BTM Open Circuit
23-6	Rack BTM Short Circuit
24-2	Loss of Rack Sensor
24-3	Rack Sensor Open Circuit
24-4	Rack Sensor Short Circuit
24-7	Rack System Fault
24-8	Invalid Rack Sensor Signal
24-10	Rack Sensor Rate of Change
41-3	8 Volt Supply Above Normal
41-4	8 Volt Supply Below Normal
64-0	Backup Engine Overspeed Warning
64-2	Loss of Backup Engine RPM Signal
64-8	Backup Engine Speed Out of Range
68-3	Secondary Atm Pr Sensor Open Circuit
68-4	Secondary Atm Pr Sensor Short Circuit
68-10	Secondary Atm Pr Sensor Rate of Change
69-0	High ACOC Coolant Temperature Warning
91-8	Invalid Throttle Signal
91-10	Throttle Sensor Rate of Change
91-13	Throttle Sensor Calibration

Cat Marine / Industrial Engine Diagnostic Codes

Code	Description
94-1	Low Fuel Pressure Warning
94-3	Fuel Pressure Sensor Open Circuit
94-4	Fuel Pressure Sensor Short Circuit
95-0	High Fuel Filter Differential Pr Warning
98-1	Low Oil Level Warning
99-0	High Oil Filter Differential Pr Warning
100-1	Low Oil Pressure Warning
100-3	Oil Pressure Sensor Open Circuit
100-4	Oil Pressure Sensor Short Circuit
100-10	Oil Pressure Sensor Rate of Change
100-11	Very Low Oil Pressure
100-14	Low Oil Pressure Shutdown
101-0	High Crankcase Pressure Warning
101-14	High Crankcase Pressure Shutdown
102-0	Boost Pressure Reading Stuck High
102-1	Boost Pressure Reading Stuck Low
102-3	Boost Pressure Sensor Open Circuit
102-4	Boost Pressure Sensor Short Circuit
102-13	Boost Pressure Sensor Calibration
105-0	High Inlet Manifold Temp Warning
105-3	In Manifold Temp Sensor Open Circuit
105-4	In Manifold Temp Sensor Short Circuit
105-11	Very High In Manifold Temp
106-1	Low Atmospheric Pressure Reading
106-3	Atm Pressure Sensor Open Circuit
106-4	Atm Pressure Sensor Short Circuit
106-10	Atm Pressure Sensor Rate of Change
108-3	Atmospheric Pr Sensor Open Circuit
108-4	Atmospheric Pr Sensor Short Circuit
110-0	High Coolant Temperature Warning
110-1	Low Coolant Temperature
110-3	Coolant Temp Sensor Open Circuit

Cat Marine / Industrial Engine Diagnostic Codes

Code	Description
110-4	Coolant Temp Sensor Short Circuit
110-11	Very High Coolant Temperature
110-14	Low Coolant Temperature Shutdown
111-1	Low Coolant Level Warning
111-2	Coolant Level Sensor Fault
111-11	Very Low Coolant Level
127-0	High Trans Oil Pressure Warning
127-1	Low Trans Oil Pressure Warning
127-3	Trans Oil Pr Sensor Open Circuit
127-4	Trans Oil Pr Sensor Short Circuit
127-10	Trans Oil Pr Sensor Rate of Change
127-11	Very Low Trans Oil Pressure
168-01	Battery Voltage Below Normal
168-02	Intermittent Battery
172-0	High Inlet Air Temp Warning
172-3	Inlet Air Temp Sensor Open Circuit
172-4	Inlet Air Temp Sensor Short Circuit
174-0	High Fuel Temp Warning
174-3	Fuel Temp Sensor Open Circuit
174-4	Fuel Temp Sensor Short Circuit
175-0	High Engine Oil Temperature Warning
175-1	Low Engine Oil Temperature
175-3	Engine Oil Temp Open/Short to Battery +
175-4	Engine Oil Temp Short to Ground
175-14	High Engine Oil Temperature Shutdown
177-0	High Trans Oil Temperature Warning
177-3	Trans Oil Temp Sensor Open Circuit
177-4	Trans Oil Temp Sensor Short Circuit
177-11	Very High Trans Oil Temperature
190-0	Engine Overspeed Warning
190-2	Loss of Engine RPM Signal
190-8	Engine Speed Out of Range

Cat Marine / Industrial Engine Diagnostic Codes

Code	Description
190-10	Engine Speed Rate of Change
190-14	Engine Overspeed Shutdown
232-3	5 Volt Supply Above Normal
232-4	5 Volt Supply Below Normal
241-0	5 Volt Open Circuit
241-1	5 Volt Short Circuit
241-2	8 Volt Open Circuit
241-3	8 Volt Short Circuit
248-9	CAT Data Link Fault
252-11	Incorrect Engine Software
252-12	Personality Module Fault
253-2	Check Customer or System Parameters
254-12	ECM Fault

Cat Marine / Industrial Engine Diagnostic Codes

Flash Code	Description
12	Coolant Level Sensor Fault
13	Fuel Temp Sensor Fault
21	Sensor Supply Voltage Fault
22	Rack Position Sensor Fault
24	Oil Pressure Sensor Fault
25	Boost Pressure Sensor Fault
26	Atmospheric Pressure Sensor Fault
27	Coolant Temperature Sensor Fault
28	Check Throttle Sensor Adjustment
32	Throttle Position Sensor Fault
33	Engine RPM Signal Out of Range
34	Engine RPM Signal Fault
35	Engine Overspeed Warning
37	Fuel Pressure Sensor Fault
38	Inlet Manifold Temp Sensor Fault
42	Check Sensor Calibration
43	Rack Subsystem Fault
45	Shut Off Solenoid Fault
46	Low Oil Pressure Warning
48	Excessive Engine Power
51	Intermittent Battery
52	Personality Module Fault
53	ECM Fault
55	No Faults Detected
56	Check Customer or System Parameters
58	CAT Data Link Fault
59	Incorrect Engine Software
61	High Coolant Temperature Warning
62	Low Coolant Level Warning
63	Low Fuel Pressure Warning
64	High Inlet Manifold Temp Warning

Cat Marine / Industrial Engine Diagnostic Codes

Flash Code	Description
65	High Fuel Temperature Warning
67	Transmission Oil Temp Sensor Fault
72	Cylinder 1 or 2 Fault
73	Cylinder 3 or 4 Fault
74	Cylinder 5 or 6 Fault
81	High Transmission Oil Temp Warning
86	Transmission Oil Pressure Warning

Caterpillar Policy

One Worldwide Measurement System – SI
(SI – International System of Units – Modern Metric System)

Worldwide Interchangeability of Parts

Metric Drawing – Process and Inspect in Metric

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) (1 inch = 25.4 mm exactly)	× 0.03937	=	inch	× 25.4	=	mm
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) (1 mL = 1 cm^3)	× 0.034	=	oz.-liq	× 29.6	=	mL
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.

SI PREFIXES

AMOUNT	SYMBOL	NAME	
1 000 000 000	G	giga	jig' a (a as in about)
1 000 000	M	mega	as in megaphone
1 000	k	kilo	as in kilowatt
100	h	hecto	heck' toe
10	da	deka	deck' a (a as in about)
0.1	d	deci	as in decimal
0.01	c	centi	as in sentiment
0.001	m	milli	as in military
0.000 001	µ	micro	as in microphone
0.000 000 001	n	nano	nan' oh (an as in ant)

THINK METRIC!

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