CATERPILLAR®

3600 Marine Engine Application and Installation Guide

- **Commissioning**

LEKM8473 8-98

CATERPILLAR®

Commissioning Guide

Design Review

General

A well planned main propulsion installation aids reliability, performance, and serviceability. The designer must be aware of the application and installation requirements for 3600 engines. The designer should first be aware of pertinent reference publications, such as the *3600 Marine Application and Installation Guide*, as well as other information available from Caterpillar.

A poor installation can hinder serviceability and make routine maintenance and repairs difficult. The neglect of mounting, alignment, and support system requirements can lead to poor performance and increased operational cost.

After the ship designer has completed a review of the Caterpillar application and installation requirements, have a discussion with Caterpillar and/or Caterpillar dealer personnel to cover remaining concerns on specific areas of the installation. This will establish ground rules for further working relationships in the design phase. After the initial machinery arrangement, piping and structural drawings have been completed, follow-up discussions should take place with the designer to insure preliminary designs meet the *3600 Marine Application and Installation Guide* requirements. Utilize the *3600 Main Propulsion Design Review Report* as a review aid.

Explanation of Design Review Report

The report provides a checklist for the dealer and is available from Caterpillar. It will help determine if sufficient information has been provided to the installation designer for completion of initial layouts in compliance with requirements in the *3600 Marine Application and Installation Guide.*

Complete the form with general information about the owner, vessel, and builder/installer. Using the design criteria of the ship, record specific data concerning physical characteristics as well as the engine supporting systems.

There are provisions to record Caterpillar reference materials provided to the designer, as well as a checklist for results of the design and serviceability review. Note compliance with Caterpillar requirements by placing an "X" in the space next to the system reviewed, indicating satisfactory or unsatisfactory compliance. If the design of a system does not comply, space is provided to record required follow-up action.

After completing the design review form, and after reaching agreement on the required corrective action, all concerned parties should sign the form in the designated location.

Unsatisfactory System Design Review or Installation Audit

Engine systems which are declared unsatisfactory during the design review or installation audit require corrective action prior to vessel commissioning. The cost and effort to make design changes during the early stages of the design will be much less than the rework of the system once the vessel is placed in service. Appropriate measurements of all engine operating parameters will be taken during dock or sea trials to ensure that engine system temperatures and pressures are within prescribed limits. Engines not meeting the prescribed limits will be derated (if derating the engine to lower power or speed results in operating conditions below the limit) or the shipyard, installer, or customer must accept responsibility for shorter engine life or engine failures resulting from a design or installation deficiency. Notify all concerned parties (including the vessel owner or operator) of any system design deficiencies. Caterpillar warranty for defective material or workmanship remains in effect; however, failures resulting from non-compliance with published application requirements and operating limits are not warrantable.

CATERPILLAR 3600
Main Propulsion Design Review Report

Directions: Fill in the blanks below, or circle the appropriate choice listed.

GENERAL

Selling dealer:		District or Subsidiary:	
Servicing dealer:		Customer:	
Equipment suppliers:		Address:	
		City, State, Zip:	

CONSIST

Engine model #:		Engine arrangement #:	
OT specification #:		Serial #:	
Rating:	bkW (bhp)	Speed:	
Engine cooling circuit:	Separate /Combined	Coolant used:	Antifreeze/Corrosion inhibitor
Governor model and type:		Oil used in engine:	
High idle specified:		"OT" specification:	
Low idle specified:		% Droop specified:	
Fuel used:	Distillate/Blended/Residual	Fuel gravity:	kg/1(lb/gal)
Fuel treatment:	Filter/Centrifuge	Viscosity control:	Yes/No

SHIP DATA

Type of hull:		Expected ship usage:	service hours/year
Water line length:	meters/feet	Expected vessel speed:	knots
Displacement:	long tons	Fuel capacity:	liters/gallons
Midship coefficient:		Water capacity:	liters/gallons
Prismatic coefficient:		Beam:	meters/feet
Hull material:		Draft:	meters/feet

CATERPILLAR 3600
Main Propulsion Design Review Report

Directions: Fill in the blanks below, or circle the appropriate choice listed.

REDUCTION GEAR DATA

Reduction gear manufacturer:	Reduction gear type:
Reduction gear model #:	Ratio, forward:
Clutch type: Hydraulic/Pneumatic	Ratio, reverse:

PROPELLER DATA

Manufacturer:	Model #:
Propeller type: Fixed/Controllable	Kort nozzle: Yes/No
Number of blades:	Diameter:
Pitch:	Radius of aperture:
Developed blade area:	Radius of aperture:

Contact for propeller design information:

Name:
Address:
Telephone:

SHAFTING DATA

Intermediate shaft, diameter:	Tail shaft, diameter:
Intermediate shaft, material:	Tail shaft, material:
Intermediate shaft, length:	Tail shaft, length:
Maximum angle of operation: from horizontal	Add'l engine driven loads:
Shaft brake manufacturer:	Shaft brake model #:

Contact for drive line/shafting design information:
Name:
Address:
Telephone:

CATERPILLAR 3600
Main Propulsion Design Review Report

Directions: Fill in the blanks below, or circle the appropriate choice listed.

MISCELLANEOUS SYSTEMS

Type of cooler for engine jacket water:	Fuel day tank capacity:
Manufacturer of J.W. cooler:	Day tank temperature rise evaluated? Yes/No
Model # of J.W. cooler:	Fuel cooler type:
Manufacturer of propulsion control system:	Manufacturer of F.O. cooler:
Type of propulsion control system:	Model # of F.O. cooler:
Model # of propulsion control system:	

APPLICATION SUMMARY

Provide any comments/remarks regarding this installation:

CATERPILLAR 3600
Design Review Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

SYSTEM	DESIGN COMPLIANCE WITH 3600 ENGINE REQUIREMENTS
Air Intake Satisfactory _____ Unsatisfactory_____	
Cooling Satisfactory_____ Unsatisfactory_____	
Starting Satisfactory_____ Unsatisfactory_____	
Exhaust Satisfactory_____ Unsatisfactory_____	

CATERPILLAR 3600
Design Review Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

SYSTEM	DESIGN COMPLIANCE WITH 3600 ENGINE REQUIREMENTS
Fuel Satisfactory _____ Unsatisfactory_____	
Lubrication Satisfactory_____ Unsatisfactory_____	
Engine Mounting Satisfactory_____ Unsatisfactory_____	
Driven Equipment Satisfactory_____ Unsatisfactory_____	

CATERPILLAR 3600
Design Review Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

SYSTEM	DESIGN COMPLIANCE WITH 3600 ENGINE REQUIREMENTS
Safety and Alarms Satisfactory _____ Unsatisfactory_____	
Engine Monitoring Satisfactory_____ Unsatisfactory_____	
Ventilation Satisfactory_____ Unsatisfactory_____	
Serviceability Satisfactory_____ Unsatisfactory_____	

CATERPILLAR 3600
Design Review Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

SYSTEM	DESIGN COMPLIANCE WITH 3600 ENGINE REQUIREMENTS
Equipment Safety Satisfactory _____ Unsatisfactory_____	
Propulsion Controls Satisfactory_____ Unsatisfactory_____	
Operation and Maintenance Satisfactory_____ Unsatisfactory_____	
Crankcase Ventilation Satisfactory_____ Unsatisfactory_____	

CATERPILLAR 3600
Design Review Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

SYSTEM	DESIGN COMPLIANCE WITH 3600 ENGINE REQUIREMENTS
Satisfactory _____ Unsatisfactory_____	
Satisfactory_____ Unsatisfactory_____	
Satisfactory_____ Unsatisfactory_____	
Satisfactory_____ Unsatisfactory_____	

CATERPILLAR 3600
Design Review Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

The following parties have discussed and agreed to the results and required action during the design review process:

Field Engineer Signature:____ Date__________

Builder/Installer Signature:______________________________________ Date__________

Owner Signature:____ Date__________

Installation Audit

Introduction

Vessel construction follows the satisfactory completion of the design review. During this phase, visit the shipyard *at least* two times to perform an ongoing review of the installation progress.

The first visit should follow the engine installation. Additional visits may be necessary depending on the difficulty of the installation and the stage of completion. Make the final visit before the initial startup process begins.

Visit objectives are to determine if the previously agreed on design criteria are being followed. These visits not only continue to produce a better understanding of Caterpillar requirements, but also provide the basis for a more reliable installation. To avoid costly delays, experienced shipbuilders will make necessary changes as soon as possible.

Explanation of the Installation Audit Report

The *Caterpillar 3600 Main Propulsion Installation Audit Report* is intended to provide a checklist for dealer use only, and is available from Caterpillar. The report is a simple checklist used to determine if the previously agreed on design criteria have been successfully implemented during the construction process.

Fill out the report with general information about the owner, ship particulars and builder/installer information, including the engine room physical features. Provisions are made for recording the propulsion system component descriptions, including serial numbers and manufacturer where applicable.

When the construction and installation are in compliance with Caterpillar requirements, indicate by placing an “X” in the space next to the system reviewed for satisfactory and unsatisfactory compliance to requirements. If a system does not comply, there is space to record the necessary corrective action. The following system-by-system review provides general guidance for the audit.

Air Intake System Evaluation

The total system must be evaluated from the source of the air for the engine to the turbocharger. This may include engine room air, or the air cleaner may be mounted outside the engine room. Consider the following items:

A. Combustion Air

Air inlet temperature to the engine must not exceed 45°C (113°F) for distillate and heavy fuel engines.

The quantity of available air must be sufficient for combustion. The 3600 engine requires approximately 0.1 m^3/min/bkW (2.5 ft^3 of air/min/bhp) for engines using distillate fuel. Heavy fuel engines require more air for proper component temperatures.

The engine room or enclosure should not experience negative pressure if combustion air and ventilation air are from the same source.

In extremely cold climates, an alternate warm filtered air source must be available for starting the engine.

B. Remote Mounted Air Cleaners

Air cleaner elements must be accessible for periodic maintenance.

Mount the air cleaner elements in the housing to assure the engine does not ingest foreign material due to incorrect positioning.

The air cleaner housing air outlet must have a flexible transition attaching the air inlet ducting. Double band clamping at each end of the flex is required to assure nonfiltered air does not enter the ducting.

The epoxy paint provided on all Caterpillar supplied air cleaner housings must be maintained for good surface protection in harsh environments, such as salty atmosphere.

Air inlet restriction is recommended not to exceed 381 mm (15 in.) of water. New, clean systems should be near 127 mm (5 in.) of water restriction to allow appropriate service intervals for the filter elements.

The air cleaner housing must be mounted in a position that will not allow recirculating exhaust gases, crankcase fumes, rain, or sea spray to mix with the combustion air.

A typical method of conveying combustion air to the engine is with the air cleaner drawing outside air through the elements, and to use air ducting to the turbo inlet. The air cleaners may also be located within the engine room if the ambient conditions meet allowable air inlet temperatures.

In cold climates, the air cleaner can be subjected to filter icing when mounted outside the engine room. Consider the service of the ship and the potential variations in climate. The engine must receive filtered inlet air regardless of the geographic location of the ship.

C. Air Inlet Ducting

The intake air ducting must be clean and free of weld slag, debris, rust, or corrosion prior to operating the engine. Ducting must be inspected prior to initial startup.
The interior surface of the intake ducting must be protected from future rust and corrosion due to intake air quality.

If a single straight length from the air cleaner housing is not possible, the intake air piping must have long gentle radius bends (2 x Dia = bend radius) and generous straight lengths.

The diameter of the intake ducting must be the same or larger than the air cleaner housing outlet and the air inlet adapter for the turbocharger. Any abrupt transitions must be avoided. For further information and guidance, see the Engine Systems - Air Intake section of the *3600 Marine Application and Installation Guide* on air inlet ducting.

The air inlet restriction created by the ducting must be minimal to allow normal service intervals for the air cleaner elements.

Air inlet ducting must not be rigidly mounted to either the air cleaner housing or to the turbocharger inlet. Flexible nonmetallic connections must be used between the ducting of both the air cleaner housing and the turbocharger. The turbocharger must not support the weight of the ducting. Double band clamping must be used to insure nonfiltered air does not enter the engine.

Note the proximity of the exhaust piping and the air intake ducting. If heat transfer between the two sets of piping is evident, insist that either or both are insulated to protect both air inlet temperature and the non-metallic connections.

Air inlet ducting must be inspected for leaks during engine operation.

D. Filtered Engine Room Air

An ABB air intake silencer can be used at the turbocharger inlet if combustion air supplied to the engine room is properly filtered. The combustion air must also be free of insulation pericles, exhaust leakage, or other sources of contamination from the engine room

If an ABB intake silencer is remote-mounted, the same requirements apply for ducting to the turbocharger inlet as in the case of a remote-mounted air cleaner housing.

E. Air Cleaner Provided by Others

Engine air cleaners not provided by Caterpillar must meet air flow and contamination containment requirements to protect the engine from shortened component life. This requires prior factory approval.

Cooling System Evaluation

A cooling system evaluation must include engine operating parameters, external system piping, water quality and external cooling components. A properly controlled cooling system is essential for satisfactory engine life and performance. Defective cooling system and careless maintenance are a direct cause of many engine failures. Consider the following:

A. Engine Cooling Circuits

Water flow from the left side pump (viewed from the rear) is split between the aftercooler and oil cooler. Flow balance orifices are used on the outlet of both components. Insure the orifices are in place.

The right-hand pump (viewed from the rear) supplies water to the jacket water system. Insure the orifice is in place.

The two pump design can be used as either a combined or separate circuit cooling system. The temperature of the water is always inlet controlled.

During performance testing of the engine, be sure the appropriate inlet water temperature is being supplied to both circuits and the temperature rise of the water is within specified limits.

B. System Coolers

3600 propulsion engines have the coolant water cooled by various methods, including shell and tube heat exchangers, plate and frame heat exchangers, keel coolers, and box coolers.

It is the user/installer's responsibility to provide proper venting and isolation of the cooler for required maintenance or repair.

C. Cooling System Pressure Drop

The external system resistance must be site adjusted to specifications based on the rated speed of the engine and full flow to the external system. Circuits with thermostats must be replaced with blocked open stats (for adjustment only) to allow full flow.

The inlet and outlet pressure of the coolant must be measured as close to the engine as possible to obtain a correct external system resistance. Customer piping must have monitoring ports for this measurement.

Insure that the flow control orifice is positioned in the outlet lines from the engine to the cooler. A lockable plug valve is preferred but a plate-type orifice or other type adjustable valves are permitted. The external system resistance *must* be maintained at the specified value. See the Engine Systems - Cooling section of the *3600 Marine Application and Installation Guide.*

The method used to set external resistance depends on cooling system geometry.

Method 1: Used with Caterpillar expansion tank and regulators mounted on the front module. External pressure drop is measured from the engine outlet to the cold flow entrance at the regulator housing (see Figure 1).

rpm (Δ) P (P_1 - P_2) kPa (psi)	
1000	90 (13)
900	73 (11)
750	51 (7.5)
720	47 (7)
Tolerance:	± 10%

Method 2: Used when the circuit includes a remote-mounted expansion tank and remote regulators. External pressure drop is measured from the engine outlet to the pump inlet (see Figure 2).

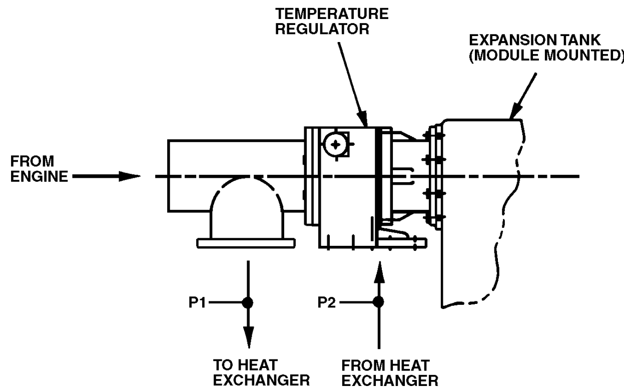
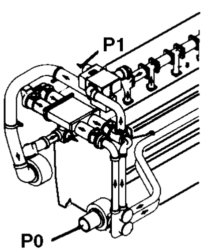


Figure 1

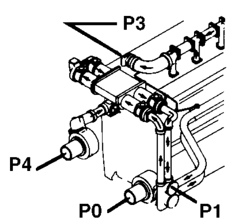
3606 and 3608 Combined Circuit

External Circuit Resistance, kPa (psi)



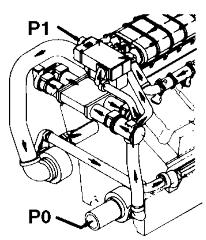
Engine Speed rpm	Low Temperature Circuit (Δ) P (P1-P2)	High Temperature Circuit (Δ) P (P3-P4)
1000	91 (13)	—
900	71 (10)	—
750	45 (6.5)	—
720	40 (5.8)	—
Tolerance:	± 10%	—

3606 and 3608 Separate Circuit



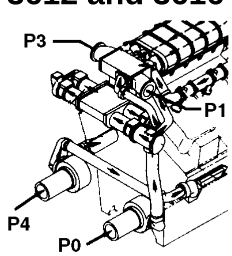
1000	104 (15)	99 (14)
900	84(12)	77 (11)
750	58 (8)	50 (7)
720	52 (7.5)	44 (6)
Tolerance:	± 10%	± 10%

3612 and 3616 Combined Circuit



1000	85 (12)	—
900	66 (9.6)	—
750	42 (6)	—
720	38 (5.5)	—
Tolerance:	± 10%	—

3612 and 3616 Separate Circuit



1000	85 (12)	103 (15)
900	66 (9.6)	81 (12)
750	42 (6)	52 (7.5)
720	38 (5.5)	47 (7)
Tolerance:	± 10%	± 10%

Figure 2

D. Expansion Tanks

The water level in the expansion tank should be at the highest point in the cooling system to allow proper venting during initial filling of the system. This will also provide a single fill point for the cooling system.

If the expansion tank is not the highest point in the system, it is the user/installer's responsibility to provide an auxiliary expansion tank at the highest point in the system. The auxiliary tank must be interconnected with the expansion tank to provide complete venting of the system.

Run vent lines from other cooling system components to the auxiliary tank, or vent them independently.

Initial filling of the system must be done at a rate to allow complete venting of the system. Always be ready to add supplemental volume of water to system at initial start-up in case air has been trapped in the system. The Caterpillar expansion tank is provided with a 48 kPa (7 psi) pressure cap. Remove the pressure cap during the testing and adjusting the external system resistance. Reinstall the pressure cap prior to the engine performance testing under load.

If an expansion tank pressure cap is not used, adjust the water temperature alarm and shutdown contactors according to atmospheric conditions to insure adequate engine protection.

If a non-Caterpillar expansion tank or a shunt style cooling system is used, a complete test must be done complying with requirements listed in Caterpillar EDS 50.5, *Cooling System Field Test,* Form No. LEKQ7235.

Automatic air release valves are recommended when it is not practical to route vent lines to a common venting point. The heavy duty (cast iron body) style is recommended. The valves usually have a *fast-vent* port which can be replaced by a ball valve to allow venting during the system initial fill. An internal diaphragm collects entrained air and automatically releases it to atmosphere.

E. Cooling System Protection

Protecting the engine from cooling system problems is imperative. Insure the engine is equipped with the following, and the protection system functions according to specification.

- High jacket water temperature alarm and shutdown
- High oil temperature alarm and shutdown
- Low water detector alarm and shutdown
- High air inlet manifold temperature alarm

The protection system functions listed above may require modification due to the involvement of marine classification societies and other regulatory bodies.

It is the user/installer's responsibility to provide additional pressure and temperature gauges and alarms in the external system for the operators to monitor daily. Detection of a developing cooling system problem can prevent an unscheduled shutdown of the engine or an operation alarm condition.

F. Central Cooling Systems

Cooling multiple engines from one system is becoming common on large ocean going vessels.

If a central cooling system is used, the system performance must be evaluated with the maximum heat rejection possible from all engines being cooled. Since every system, application and installation will be unique, they must be approved by Caterpillar.

G. External System Piping

The external system piping must be clean and free of weld slag and other debris. Insure the piping is thoroughly cleaned before filling the system.

Install temporary strainers at the engine in the coolant inlet lines prior to initial engine operation. Operate the engine at no-load and rated speed for at least 15 minutes. Remove the strainers and check for debris. If debris is found, reinstall the strainers and repeat the operation. Continue this procedure until no debris is found in the screen. *Do not* adjust external system resistance with the strainers installed. The temporary strainers are available from Caterpillar for 101 mm (4 in.) [4C9045], 127mm (5 in.) [4C9046], and 152 mm (6 in.) [4C9047] pipe.

If a permanent strainer in the coolant inlet lines is provided by the user/installer, the pressure drop across the strainer must be monitored as well as alarmed. Excessive pressure drop can cause improper coolant flow to the engine. The same procedure should be followed for permanent strainers as was described above for temporary strainers during initial engine operation. At maximum flow condition clean strainers should have no more than a 10-14 kPa (1.5-2 psi) pressure drop.

H. Corrosion Protection

Ensure that Caterpillar guidelines established for water quality are followed precisely. They are published by Caterpillar and available in the standard publication system. *Engine Installation and Service Handbook*, Form No. LEBV0915, and *Coolant and Your Engine*, Form No. SEBD0970, are two publications containing information.

Ensure the system is filled with the proper quality fresh water. It should also be treated with corrosion inhibitor. Caterpillar Coolant additive is 8C3680 and 5P2907 in 18.95 L (5 gal) and 208 L (55 gal) containers. Caterpillar does not approve other additives.

If ambient conditions require antifreeze, only low silicate antifreeze is allowed. Caterpillar Antifreeze is available in 3.8 L (1 gal) and 208 L (55 gal) containers, part No's. 8C3684 and 8C3686 respectively. Use the Cooling System Test Kit (8T5296) to evaluate the concentration of corrosion inhibitor in the system. Excessive concentrations are as detrimental to the engine as insufficient concentrations.

I. Heat Recovery

Recovering heat from the engine coolant can improve the efficiency of the operation but can also be detrimental to the engine if not designed and installed properly. A common example of heat recovery is using engine jacket water heat to operate fresh water distilling plants.

External temperature regulators must not, in any way, inhibit the operation and temperature control of the engine temperature regulators.

The external heat recovery components must not cause excessive coolant flow resistance.

Inlet temperature control at the engine is often misunderstood during the design of the system. The water temperature returning to the engine must be cooled sufficiently to achieve the required coolant mix temperature at the engine pump inlets.

J. Cooling System Performance

The complexity of the external cooling system, which may include heat recovery and/or some other cooler, is best understood by reviewing the installed system and producing a schematic of that system. The schematic should indicate all of the system flow paths, test and monitoring points, and external system components. It should be included as an attachment to the Installation Audit Report.

Assign 900 series description numbers to each of the test and monitoring points and record their readings on the Installation Audit Report test sheet.

Starting System Evaluation

Air starting is typical for 3600 engines. The system components can have a significant effect on the life of the starters.

A. Air Compressor

Must be sized to match the air receiver tank(s) make-up rate due to starting.

An air dryer is suggested on the compressor outlet to prevent water vapor in the air from freezing if expanded below 0°C (32°F).

B. Air Receiver Tanks

Tanks should be sized to provide the required consecutive engine starts without depleting the air pressure below minimum required starting pressure.

Manual or automatic drains should allow oil and water deposits to be drained daily. Operators must be informed of this requirement.

Receiver tanks must meet specific characteristics, such as the specifications of the American Society of Mechanical Engineers (ASME). If the ship is classed, the Classification Societies may have specific requirements for air receivers (unfired pressure vessels). Each receiver tank should have been pretested at 1 1/2 times the normal working pressure unless the cognizant Classification Society requires some greater value. Make sure the tank pressure relief valve is set at a level below test pressure.

Receiver tanks must be equipped with a maximum pressure relief valve and a pressure gauge. Provide monitoring to assure proper operation.

C. Air Supply Piping

Size piping to provide a minimal pressure drop of supply air from the receiver tank to the engine starters. Piping must not be smaller than the connection at the engine.

Route piping to trap water vapor and oil deposits at the lowest point in the piping. Drain the trap daily if a manual trap is used, or install an automatic trap for this purpose. Operators must be informed of this requirement. If possible, the supply piping can be routed upward from the reservoir to the engine allowing condensation to drain to the reservoir.

Piping systems should withstand 1 1/2 times the normal working pressure unless the cognizant Classification Society requires some greater value. See note in Air Receiver Tanks above.

Prior to the initial startup of the engine, disconnect the air piping from the engine and allow controlled air to blow water vapor, oil deposits or debris out of the pipe. Starter damage can result otherwise.

D. Engine Starters and Accessories

Note: *Maximum air pressure to the starter inlet ports is 1550 kPag (225 psig). An air regulator must be used if supply pressure exceeds this level.*

Adjust the starter lubricator to limit excessive leakage of starter lubricant at the starter air outlet. This should be done during initial engine startup. The starter silencer discharge must not endanger personal safety. Provide shielding if the discharge is directed toward potentially occupied areas.

E. Start-up and Shutdown Procedure

The following procedure is a guide for:

- 3600 engine start-up procedures
- Design consideration of the engine control systems.

Before Starting the Engine

- Check the coolant level in the expansion tank site glass.
- Check the crankcase oil level using the engine dip stick. Be sure to use the side marked “Engine Stopped Cold Oil”. Mark the dipstick for operating and non-operating conditions.
- Be sure all protective guards are in place and the barring device is disengaged.
- Open and close the drain valve on the bottom of the starting air tank and fuel day tank to drain condensation and sediment.
- Open the starting air shutoff valve at the side of the engine.
- Check the starting air pressure. There must be a maximum of 1551 kPa (225 psi) or a minimum of 861 kPa (125 psi) air pressure available for starting.
- Check the air starter lubricator oil level. Check the prelube motor lubricator oil level (if air prelube equipped).
- Be sure the engine control system allows engine shutdown from the engine starting panel.
- Remember that other engine support systems or control systems must be prepared before engine startup. This includes reduction gear prelube and external piping system valve position.
- Open the combustion chamber snifter valves (Keine valves) and with the fuel control switch in the *OFF* position, rotate the engine with the air starters while watching for fluids expelled from Keine valves. After this step is completed, close the Keine valves hand tight. If the valves are over tightened, the seat may be damaged when the engine reaches operating temperatures.

Starting the Engine

- Put the engine fuel on/off switch to the *ON* position.
- Put the engine start/prelube switch in the prelube position. The green indicator will light when prelube oil pressure reaches 7 kPa (1 psi). The engine can now be started. Verify oil gauge pressure if time is not a critical factor.
- Move engine start/prelube switch to the *START* position while viewing the engine tachometer. At 130 to 150 rpm, the start/prelube switch can be released from the start position. If not the starters will automatically disengage when the engine reaches 170 rpm.
- The engine should stabilize at low idle speed, typically 350 rpm. Check the gauge panel oil and fuel pressure readings to see they reach normal levels.

- Inspect the engine for leaks and listen for abnormal noises.
- After proper engine operation is assured, adjust the engine and other control systems to increase engine speed/load to normal operation.

After starting the engine

- Close the starting air shutoff valve.
- Monitor engine operating parameters every hour and record the readings on an appropriate log sheet.
- Compare the operating parameters recorded to the factory specifications on a daily basis. Monitor operating trends and take action when discrepancies are found.

Stopping the engine

- Reduce load on engine to zero.
- Allow the engine to operate for the period of time necessary to reduce jacket water temperature to 85°C (185°F) and the average cylinder exhaust temperature (of all cylinders when exhaust pyrometer equipped) is reduced to below 150°C (302°F). Fifteen minutes of operating time will normally achieve the cooler temperatures.
- Request the wheelhouse to release propulsion system control to the engine room.
- Turn the engine fuel on/off switch to the *OFF* position. The engine will coast to a stop by energizing the fuel shutoff solenoid.
- Check (and put into shutdown mode) all other non-engine driven system components that have been operating to support engine operation.

Exhaust System Evaluation

The exhaust system for 3600 engines must be evaluated from the exit of exhaust gases from the turbocharger to the atmospheric conditions at the muffler outlet. Fuel consumption and component life of the engine are affected by a faulty exhaust system.
Consider the following items:

A. Exhaust System Warnings

The engine installer must protect engine room equipment and personnel from the heat of exhaust system piping.

The engine installer must provide appropriate drains and/or rain caps to protect the engine from rain water and sea spray entering the engine through the exhaust piping. The configuration of the last few feet of exhaust outlet should prohibit rain water or sea spray entry without excessive exhaust backpressure.

Common exhaust systems between engines are to be strictly avoided.

The turbocharger must be protected from debris entering the exhaust outlet during construction of the exhaust piping. A properly tagged blanking plate is recommended. It must be removed prior to initial engine operation. The debris collected on the plate must not enter the turbocharger.

B. Exhaust System Piping

The exhaust system piping material must withstand the effects of exhaust gas temperature, velocity, and thermal expansion. Insulation added to the exhaust piping must not deteriorate the piping. Insulated pipe temperatures are higher than non-insulated.

Exhaust backpressure of the total piping system must be minimal to allow for muffler restriction, outlet piping from the muffler, and piping degradation during the life of the engine. Fuel consumption and component life will be affected if the backpressure is beyond the recommended value of 254 mm (10 in. H_2O). *Heavy fuel engines are limited to 254 mm (10 in. H_2O). Consult Caterpillar if higher backpressures are anticipated.*

Exhaust backpressure on each bank of the twin turbocharged 3612 and 3616 (vee) engines must be balanced, even when the dual pipes exiting the turbos are transitioned into one larger pipe going to the muffler. Do not allow gas flow to turn at a right angle during a transition. If possible, do not allow the exhaust system piping for a vee engine to be routed vertically from each turbocharger and then be blended horizontally. This will cause excessive backpressure on one bank. Blend the exhaust gasses into a common pipe before making the directional change. If this is not possible, the blending area must be designed to maintain equal bank-to-bank restriction.

Measure backpressure in a straight length of the exhaust pipe at least 3 to 5 pipe diameters away from the last size transition change from the turbocharger outlet. System backpressure measurement is part of the engine performance testing and must be recorded. A 1/4 in. NPT or 1/8 in. NPT fitting is required in the exhaust piping for backpressure measurements. Extensions may be required to protect instrumentation from heat damage and reach through exhaust lagging into the gas stream. Backpressure gauges are available to continuously monitor pressure levels.

Do not support exhaust piping from the engine package and do not allow it to interfere with the service of the engine.

Expansion joints and vertical supports in appropriate positions must allow for free movement of the exhaust piping during thermal expansion.

The exhaust piping must be rigidly supported (with off- engine supports) near the engine to minimize compression and offset of the engine exhaust bellows. Exhaust pipe expansion must be directed away from the engine. Rollers are strongly recommended when vertical supports are required between expansion joints and rigid supports.

Fuel System Evaluation

Clean fuel meeting Caterpillar's fuel recommendations provides the maximum engine service life and performance; anything less is a compromise and the risk is the user's responsibility. The fuel system must be evaluated from the storage tank to the engine, including the engine fuel controls. A fuel sample must be analyzed to verify engine performance. The data is used in the Caterpillar CAMPAR evaluation. The governor control system should be described along with information concerning the governor's interaction with the engine.

A. Fuel Tanks

Fuel tanks vented to atmosphere must have some form of flame arrester in the vent opening to prevent flames entering or exiting the tank. As a minimum precaution, install a fine mesh screen at the outlet opening in the tank vents to act as a flame arrester. Other forms of flame arresters can be used and the vent opening must never be left totally open to atmosphere.

The fuel supply piping should draw fuel from approximately 100 mm (4 in.) above the bottom of the day tank. The fuel return to the day tank must enter at the top (above the fuel level) and opposite the supply end.

A tank valve must be provided to drain water and sediment. Typically classification societies or other regulatory bodies require the valve to be a fast acting spring closure type.

B. Fuel Lines

Galvanized fittings or piping must not be used in any portion of the lines. Zinc can leak from piping or fittings and react with sulphur in the fuel during the combustion process to form zinc sulphate with a detrimental effect on exhaust valves. Fuel line size and length must conform to the fuel transfer pump inlet and return restriction limits. The inlet restriction must not exceed 39 kPa (5.7 psi) and the fuel return line restriction must not exceed 350 kPa (51 psi). Measure and record the values.

Note: The limits are independent of each other and should not be combined in the evaluation.

Fuel lines must be treated (pickled) and coated on the inside with lube oil prior to final assembly.

Fuel lines must never be smaller than the engine connections of 32 mm (1.25 in.) pipe for the supply and 25 mm (1 in.) pipe on the return.

C. Fuel Filters

Monitor initial fuel filter differential pressure to eliminate premature plugging of engine filters.

The user and/or installer is responsible for providing primary filtering of the fuel supplied to the engine. Water separation is of prime concern. Install water separators or coalescing filters. If the fuel does not meet the required recommendations, use a fuel centrifuge/purifier. Recirculate the fuel in the day tank through the centrifuge for 24 hours prior to operating the engine. A stock of engine fuel filters should be on-board prior to initially starting the engine.

D. Fuel Coolers

A fuel cooler may be required if the day tank is not large enough to handle heat transfer from the injection pumps. Size the fuel cooler to cool fuel returning to the day tank to below 40°C (100°F) with distillate fuel. Return heavy fuel oil (HFO) to the booster module without cooling to allow viscosity control back to the engine. Parallel HFO and distillate systems must have control valves to send fuel to the cooler when switching to distillate. HFO systems are operated at higher temperatures to ˚ maintain proper viscosity.

Note: *See the section on Engine Systems - Fuel in this guide for additional information.*

A *water-to-fuel* cooler is typical but a cooler failure can result in water entering the fuel supply leading to subsequent fuel injector failures. If sea water is used for a cooling medium, the operator must inspect the sacrificial anodes at least once a week until a consumption rate has been established.

Governors/Actuators

The governor type and its operating characteristics must be described in the Installation Audit Report.

If a hydra-mechanical governor is used, the smoke limiter and droop must be properly adjusted to assure optimum response to load changes.

If a Heinzmann or Woodward electronic governor is used, evaluate proper governor operation prior to initial startup. Consult the governor operator's manual for procedures.

Lubrication System Evaluation

The lubrication system supplies a constant flow of oil to engine components. The oil is filtered, cooled, and pressure regulated throughout the engine operating range. Bearing failure, piston ring sticking, and excessive oil consumption are classic symptoms of oil related engine problems. Maintaining the lubrication system, using scheduled oil sampling and quality oil can make the difference between repeated oil related failures and satisfactory engine life.

A. Engine Oil

The oil must be evaluated for 3600 oil requirements prior to filling the sump, including scheduled oil sampling (S•O•S). Record oil brand and type. Note: Refer to the *Engine Systems - Lubricating Oil* section of this guide for additional information. An S•O•S sample must also be evaluated after sea trails completion.

A system must be in place to properly handle waste oil from engine oil changes.

B. Engine Sump

The oil sump may be filled through the oil filler tube or via the sump valves through the lube oil transfer system. All lube oil transfer piping must be pickled and flushed prior to being placed in service. Inspect the proposed oil storage tank prior to filling.

The user may connect one of the oil sump drain valves to external piping for draining oil during an oil change. Use a flexible connector between external piping and the drain valve.

Insure that the cold engine oil level is correct and check the oil level several times during initial engine operation. Allow the engine oil temperature to reach normal operating temperature, which is 82°-85°C (180°-185°F). The dipstick must be marked for the proper operating level at rated speed and installed engine tilt angle.

C. Engine Prelube

If equipped, insure that the air prelube motor is properly lubricated prior to operation.

Check the air receiver tank sizing for the required starting requirements. Consider air prelubing requirements.

Prelube time must be within the required engine starting time. If not, a larger pump or continuous prelube may be required.

Electric prelube systems must have motor starters sized for the proper current draw to maintain pump operation until prelubing is complete.

Continuous prelube systems must have the Caterpillar spill tube system installed to prevent oil collecting in the cylinders, resulting in hydraulic lock and damage to cylinder components on startup.

D. Oil Pressure and Temperature

Provide safety shutdowns and alarms for these engine operating parameters.

Mounting and Alignment Evaluation

See guide section on *Mounting and Alignment* for detailed instructions and guidelines. The commissioning engineer should record final alignment measurements and include them as an attachment to the Installation Audit Report. It is also necessary to check crankshaft end play and crankshaft deflection. Record the readings in the Installation Audit Report. Consult Caterpillar publication *3600 Generator Set Commissioning Guide*, Form No. LEKX6560, when a generator set is involved.

Driven Equipment Evaluation

Driven equipment can be in many configurations, but each must be evaluated according to the external distribution system requirements. When more than one engine is involved, each must be described in the commissioning report. Ensure engine mounting, alignment, and connections are correct per the *Mounting and Alignment* section of this guide. Consider the following items:

A. Torsional Coupling

Record all manufacturer's data (serial number, model number, etc.) and other information relating to features such as torsional stops or emergency take home devices. Route cooling air into the vicinity of the coupling.

B. Marine Reduction Gear

- Record all manufacturer's data (serial number, model number, reduction ratio, etc.) and the manufacturer and type of clutches utilized.
- Record marine gear oil pressure and temperature during initial operation.

C. Fixed Pitch Propeller Installation

Record all propeller data (number of blades, type of material, diameter, pitch, etc.). If the propeller uses a Kort nozzle, record nozzle data and note if fixed or steerable. Develop a sketch of the shafting. Indicate the placement and type of line shaft bearings, shafting material and dimensions. Describe the type, manufacturer, and external equipment associated with the stern tube and the stern tube bearings.

Use the Caterpillar CAMPAR program to evaluate the propeller match.

D. Controllable Pitch Propeller Installation

Record all propeller data (number of blades, type of material, diameter, pitch, etc.). Indicate the manufacturer and system model number. Describe the CPP control system and identify the engine governor and CPP system interfaces. If a Kort nozzle is used, record nozzle data and note if fixed or steerable. Develop a sketch of the shafting. Indicate the placement and type of line shaft bearings, shafting material, and dimensions. Describe the type, manufacturer, and external equipment associated with the stern tube and stern tube bearing.

Use the Caterpillar CAMPAR program to evaluate the propeller operation and match.

E. Auxiliary Equipment Vibration

Measure vibration of engine mounted auxiliary equipment. Mounting resonances should not be present.

F. Auxiliary Power Takeoffs (PTOs)

Record the serial number of the auxiliary PTOs and other appropriate data relating to horsepower, rotational speed, etc. (typical nameplate data).

Safety System Evaluation

The safety systems on the engine must give early notice to the operator of pending problems and shut the engine down to protect it from imminent danger, or to limit contingent damage due to failure. Proper maintenance of the system is imperative for constant protection. Consider the following when evaluating the engine safety system:

A. Engine Contactors

Ensure the minimum Caterpillar required shutdowns and alarms are on the engine. The *minimum* requirements for propulsion engines are generally determined by the classification society and/or regulatory body involved in the project. The commissioning engineer must be prepared to demonstrate how shutdown and alarm contactors activate and de-activate according to Caterpillar specifications. Record demonstrated values. If the vessel is classed, notify a society surveyor at the time of demonstration.

The user must provide both audible and visual annunciation of faults in both the engine room and the control room. This should include horns, rotating beacons, or other forms of audible or visual alert.

B. External Engine Support Systems

The user must provide alarms and/or shutdowns on external system components that can adversely affect engine operation in a fault condition. These components may include fuel day tanks, primary fuel filters and/or centrifuges, sea water cooling pumps, etc.

C. Emergency Stops

The user must provide both local (at the engine) and remote emergency stop buttons, allowing an operator to safely shutdown the system without endangering personnel. The stop buttons must be guarded from accidental personnel contact, but still be operational by trained personnel in case of an emergency. Locate them in the engine room, the control room, and the bridge control console.

Monitoring System Evaluation

Monitoring the propulsion system requires periodic readings of gauges and readouts during a 24 hour period to insure all systems are not changing more than normal.

A. Engine Operating Parameters

Gauges and instrumentation on the engine gauge panel or mounted by user/shipbuilder on the external systems should give accurate readings of operational parameters for the oil, water, fuel, air and exhaust systems for the engine.

Periodic maintenance of oil, fuel and air filters is based on differential pressure as well as hours. Ensure gauges are provided to monitor filter conditions. An hour meter is required to properly monitor operating time.

B. External Engine Support Systems

The user is responsible for providing instrumentation to monitor operation of the external engine support systems. These should include, but not be limited to, the following:

- Fuel day tank site glass
- Oil storage tank site glass
- Water temperature to and from external cooler. This will include both treated cooling water and raw water to and from the heat exchangers.
- When strainers are permanently installed before the pump inlets, monitor pump inlet pressure to check strainer condition.

C. Daily Log Sheet

The user is responsible to provide a log sheet to record gauge and instrumentation readings taken periodically by the operators and/or the automatic monitoring system. Regulatory bodies usually require an engine room log book.

Ventilation Evaluation

Radiated heat from the engine and driven equipment can cause engine room temperature rise to adversely affect personnel and the propulsion system performance. Supply clean, cool air to the control rooms and engine rooms. It flows across and around equipment to carry radiated heat to the outside.

A. Engine Room Ventilation

Direct ventilating air toward the floor of the engine room and then upward around the engine before exiting above the engine. Design the machinery space ventilation to bring the coolest air to the turbocharger intake ducting/air cleaner. For personnel comfort, maintain the air velocity at 1.5 m/sec (5 ft/sec) in areas of heat sources or areas exceeding 38°C (100°F).

Check the temperature rise in potentially dead air spaces during engine operation. Check all electrical and mechanical equipment in the dead air space. If necessary, require corrections to be made.

Engine room pressure should not become negative. This indicates a shortage of ventilating air or excessive exhaust fan flow.

Serviceability Evaluation

Well designed engine rooms include serviceability features for the engines and support equipment. They include overhead lifting, space for component storage and cleaning, and required service tools. Consider the following when evaluating serviceability:

A. Engine Component Removal

Overhead and side clearance must be provided around the engine for major component removal and serviceability. Unfortunately, at the time of commissioning it may be too late to change the configuration.

Overhead lifting equipment must be provided. Most engine components are heavier than one man can safely lift. Review the overhead features for multidirection motion. Most engine component removal involves at least two direction motion for removal. Arrange for multiple engine installations to use the same overhead lifting equipment without major disassembly of piping or ducting. Equipment should be available for engine component movement to and from the engine room.

B. Engine Maintenance

The shipbuilder is responsible for locating the deck plating adjacent to the engine. It should not hinder periodic maintenance functions, daily inspections, or engine overhauls.

C. Reserved Work Area

Provide a work area in the engine room for disassembly and cleaning engine components and support equipment. Overhead lifting capacity must be sized for the largest component expected to be placed in this area.

D. Spare Parts Storage

Reserve an area for storage of spare parts and tools for all equipment in the engine room. They should be inventoried to ensure ready access during a repair. Lock the area. Missing parts or tools can impair scheduled maintenance or repair.

Equipment Safety Evaluation

The commissioning engineer must be able to recognize a safe operating environment. The entire system operation must be reviewed to provide operator safety in all situations. Consider the following when evaluating the safety of the operating systems:

A. Engine Room

- Shield or guard hot engine water pipes to prevent operator contact.
- Generator drive components and damper guards must be in place prior to operating the engine.
- Floor openings in the engine room must be covered with plating or grating.
- Chains and hooks on overhead lifting equipment must not endanger operating personnel.
- Floors must be cleaned of debris or liquid spills.
- Engine heat shields must be in place prior to operating the engine.

- Remote emergency system stops must be guarded but operable during a safety simulation.
- Test fire suppression systems prior to allowing normal operation.
- Independently test all engine emergency stops while operating at no load.
- Check engine room noise levels in normal operating areas. Include the data in the Installation Audit Report.

B. Control Room

- Ensure control room emergency stops are guarded to prevent accidental contact.
- Check control room noise levels and include this data in the Installation Audit Report.

Propulsion System Control Evaluation

Propulsion control system consists of the equipment for safe and precise operation of the main engine and the other components in the propulsion system.

There are two fundamental types of control systems — electric and pneumatic. A number of variations can be developed from these two basic schemes.

A. Pneumatic Controls

Thoroughly blow-down the air supply to purge debris and moisture prior to placing the control system in service. It is important to perform a point-to-point tubing connection inspection to assure individual control lines have been properly installed. Typically, the control system calibration is a joint effort between the Caterpillar commissioning engineers and the pneumatic control manufacturer. Exercise extreme caution while operating the main engine alongside a dock to prevent accidental clutch engagements. When the air supply is contamination free, the engine governor pneumatic speed adjustments can be evaluated. Ensure throttle boost is part of the system to facilitate crash reversals.

B. Electronic Controls

Delays must be part of the system to allow the engine speed to increase slightly as the clutch is engaging.

Prior to energizing the control system evaluate the power supply to determine if AC ripple and DC voltage levels are within control supplier tolerances. This may be accomplished by using a portable battery powered oscilloscope. Another method using standard test instrumentation is:

Before turning on the power of the governor control unit, disconnect the power supply input leads and connect a multimeter in the DC volts mode across the conductors. Turn on power to the governor control unit. The voltage must be 20 to 35 VDC (preferably 24 VDC). With the multimeter still connected, put the multimeter in AC volts mode. If it reads more than approximately 1 VAC, the voltage supply must be inspected to find the source of the excessive AC voltage. *Do not connect* the power supply leads to the controller if any excessive AC voltage is present. The governor system will not function properly and can be damaged.

After the power supply has been satisfactorily inspected, the electrical interconnections must be reviewed. This will prevent damage to sensitive components when the control system is placed in service. Locate the control components in a vibration free air conditioned space.

Operation and Maintenance Evaluation

Operating and maintenance training for the ship's crew involved in the operation and/or maintenance of 3600 engines and support equipment is an important factor in achieving dependable engine operation. The Commissioning Engineer should be prepared to give this training at the time of commissioning.

A. Engine Operation and Maintenance

Introduce each engineer to the engine maintenance guide and explain each topic. This may require a presentation be given several times to match the rotation of the watch-standing engineers. Coordinate the effort with the ship's chief engineer.

Ensure instruction is given for starting and stopping the engine. Include a demonstration at the engine and allow each operator to observe and follow the directions given. Follow the procedure outlined in the *Starting System Evaluation* section.

B. Engine Support Equipment

Review the list of equipment suppliers that will be on-site during commissioning. If representatives are on-site, ensure they are prepared to train the engineers.

C. Mechanical Training

Train shipboard engineers and shore-side maintenance personnel to make major repairs as well as be familiar with routine maintenance.

Crankcase Ventilation System Evaluation

Crankcase fumes must be piped away from the engine to atmosphere.

A. Crankcase Breathers

Crankcase breathers can be arranged in several positions to match the best piping routing away from the engine. Breather connections must be easily disconnected for scheduled maintenance. Piping of the same size as the breather outlet is suitable unless the length and/or bends cause excessive restriction. This can cause a false crankcase pressure measurement. See the *Engine Systems* section of this guide for additional information on pipe sizing requirements. Consideration must be given to the blow-by requirements of a worn engine when initially sizing the pipe.

A separate ventilation piping system must be installed for each engine. Slope piping away from the engine at a minimum of 13 mm per 300 mm, (.5 in. per ft). Configure the outlet to collect oil droplets prior to fumes exiting the piping. If piping rises from the engine, a trap with an appropriate drain valve must be installed to collect condensation or oil droplets before they reenter the breathers. Crankcase fumes must never be discharged directly to the engine room.

After the installation audit and the installation audit forms are completed and corrective action agreed to, it is recommended that all parties concerned sign the installation audit form at the designated locations on the report.

CATERPILLAR 3600
Main Propulsion Installation Audit Report

Directions: Fill in the blanks below, or circle the appropriate choice listed.

GENERAL

Selling dealer:	District or Subsidiary:
Servicing dealer:	Customer:
Equipment suppliers:	Address:
	City, State, Zip:

CONSIST

Engine model #:		Engine arrangement #:	
OT specification #:		Serial #:	
Rating:	bkW (bhp)	Speed:	
Engine cooling circuit:	Separate /Combined	Coolant used:	Antifreeze/Corrosion inhibitor
Governor model and type:		Oil used in engine:	
High idle specified:		"OT" specification:	
Low idle specified:		% Droop specified:	
Fuel used:	Distillate/Blended/Residual	Fuel gravity:	kg/1(lb/gal)
Fuel treatment:	Filter/Centrifuge	Viscosity control:	Yes/No

SHIP DATA

Type of hull:		Expected ship usage:	service hours/year
Water line length:	meters/feet	Expected vessel speed:	knots
Displacement:	long tons	Fuel capacity:	liters/gallons
Midship coefficient:		Water capacity:	liters/gallons
Prismatic coefficient:		Beam:	meters/feet
Hull material:		Draft:	meters/feet

CATERPILLAR 3600
Main Propulsion Installation Audit Report

Directions: Fill in the blanks below, or circle the appropriate choice listed.

REDUCTION GEAR DATA

Reduction gear manufacturer:	Reduction gear type:
Reduction gear model #:	Ratio, forward:
Clutch type: Hydraulic/Pneumatic	Ratio, reverse:

PROPELLER DATA

Manufacturer:	Model #:
Propeller type: Fixed/Controllable	Kort nozzle: Yes/No
Number of blades:	Diameter:
Pitch:	Radius of aperture:
Developed blade area:	Radius of aperture:

Contact for propeller design information:

Name:

Address:

Telephone:

SHAFTING DATA

Intermediate shaft, diameter:	Tail shaft, diameter:
Intermediate shaft, material:	Tail shaft, material:
Intermediate shaft, length:	Tail shaft, length:
Maximum angle of operation: from horizontal	Add'l engine driven loads:
Shaft brake manufacturer:	Shaft brake model #:

Contact for drive line/shafting design information:

Name:

Address:

Telephone:

CATERPILLAR 3600
Main Propulsion Installation Audit Report

Directions: Fill in the blanks below, or circle the appropriate choice listed.

MISCELLANEOUS SYSTEMS

Type of cooler for engine jacket water:	Fuel day tank capacity:
Manufacturer of J.W. cooler:	Day tank temperature rise evaluated? Yes/No
Model # of J.W. cooler:	Fuel cooler type:
Manufacturer of propulsion control system:	Manufacturer of F.O. cooler:
Type of propulsion control system:	Model # of F.O. cooler:
Model # of propulsion control system:	

APPLICATION SUMMARY

Provide any comments/remarks regarding this installation:

CATERPILLAR 3600
Installation Audit Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

SYSTEM	DESIGN COMPLIANCE WITH 3600 ENGINE REQUIREMENTS
Air Intake Satisfactory _____ Unsatisfactory_____	
Cooling Satisfactory_____ Unsatisfactory_____	
Starting Satisfactory_____ Unsatisfactory_____	
Exhaust Satisfactory_____ Unsatisfactory_____	

CATERPILLAR 3600
Installation Audit Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

SYSTEM	DESIGN COMPLIANCE WITH 3600 ENGINE REQUIREMENTS
Fuel	
Satisfactory _____	
Unsatisfactory_____	
Lubrication	
Satisfactory_____	
Unsatisfactory_____	
Engine Mounting	
Satisfactory_____	
Unsatisfactory_____	
Driven Equipment	
Satisfactory_____	
Unsatisfactory_____	

CATERPILLAR 3600
Installation Audit Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

SYSTEM	DESIGN COMPLIANCE WITH 3600 ENGINE REQUIREMENTS
Safety and Alarms	
Satisfactory _____	
Unsatisfactory_____	
Engine Monitoring	
Satisfactory_____	
Unsatisfactory_____	
Ventilation	
Satisfactory_____	
Unsatisfactory_____	
Serviceability	
Satisfactory_____	
Unsatisfactory_____	

CATERPILLAR 3600
Installation Audit Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

SYSTEM	DESIGN COMPLIANCE WITH 3600 ENGINE REQUIREMENTS
Equipment Safety Satisfactory _____ Unsatisfactory_____	
Propulsion Controls Satisfactory_____ Unsatisfactory_____	
Operation and Maintenance Satisfactory_____ Unsatisfactory_____	
Crankcase Ventilation Satisfactory_____ Unsatisfactory_____	

CATERPILLAR 3600
Installation Audit Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

SYSTEM	DESIGN COMPLIANCE WITH 3600 ENGINE REQUIREMENTS
Satisfactory _____ Unsatisfactory_____	
Satisfactory_____ Unsatisfactory_____	
Satisfactory_____ Unsatisfactory_____	
Satisfactory_____ Unsatisfactory_____	

CATERPILLAR 3600
Installation Audit Report Results

Directions: Fill in the blanks below, or circle the appropriate choice listed.

The following parties have discussed and agreed to the results and required action during the design review process:

Field Engineer Signature:____ Date__________

Builder/Installer Signature:______________________________________ Date__________

Owner Signature:____ Date__________

Dock Trials

A thorough *Dock Trial* of the main propulsion system has extreme value to both the builder and the propulsion machinery commissioning engineers. It allows system design validation at the shipyard.

A typical dock trial consists of making a vessel fast to a suitable structure capable of withstanding the vessel's developed forward thrust (Bollard pull). The fundamental purpose of the dock trial is:

- To evaluate the main engine's ancillary systems with the systems operating under simulated at sea conditions.
- With vessels such as tug boats, trawlers or push boats, the propeller's developed thrust can be measured to validate the propeller design criteria.

The commissioning engineer's primary responsibility is to operate the propulsion machinery in a safe manner. The following are key items crucial to a successful trial:

- Work closely with the owner and builder in the development of a thorough trial agenda. The value of the dock trial is only as good as the data recorded and the tests performed.
- Determine the points to be monitored. Usually these will be the same as those for sea trials. This will allow sufficient time to install additional necessary instrumentation. See Figure 3 and Figure 4 for guidance on engine monitoring point locations. For guidance on sensor self sealing plug types available from Caterpillar, see Figure 5.
- Assemble all available performance data (OT, sea trial data, and test cell report) prior to the dock trial date.

Self Sealing Probe	
Plug Size	**Cat P/N**
1/8 in. NPT	5P2720
1/4 in. NPT	5P2725
1/2 in. O-Ring	4C4547
9/16 in. O-Ring	5P3591
3/4 in. O-Ring	4C4545
Pressure Probe Adapter	5P2718

Figure 5

3600 COMMISSIONING SENSOR POINTS

Function & Use Index	G - Gauge	H - HMSO	M - Manufacturing	T - Temperature	L - LEVEL
		A - Alarm	P - Pressure	POS - Position	S - SPEED

Cooling System:

Name	Point 1		Point 2		Point 3		Point 4		Point 5		Function				
	Type	Use	Type	Use	Type	Use	Type	Use	Type	Use	1	2	3	4	5
Elbow - H_2O Pump Out	#6 O-Ring	S	#6 O-Ring	S							T	P			
Elbow - Engine Out	#6 O-Ring	S	1/2" NPT	G	1/2" NPT	H	1/2" NPT	A	#6 O-Ring	S	T	T	T	T	P
Tube - AS Turbo Inlet	#6 O-Ring	S	#6 O-Ring	S							T	P			
Elbow Turbo H_2O Out	#6 O-Ring	S	#6 O-Ring	S							T	P			
Adapter - A/C In	#6 O-Ring	S	#6 O-Ring	S							T	P			
Water Terminal - A/C Out	1/2" NPT	G									T				
Elbow Seawater -Pump Out	#6 O-Ring	A									P				

Lube System:

Name	Point 1		Point 2		Point 3		Point 4		Point 5		Function				
	Type	Use	Type	Use	Type	Use	Type	Use	Type	Use	1	2	3	4	5
Priority Valve Body	#6 O-Ring	S	#6 O-Rin	G&P							P	P			
Elbow - Temp. Reg. Out	#6 O-Ring	S&M	1/2" NPT	G	1/2" NPT	H	1/2" NPT	A			T	T	T	T	
Elbow - Scav. Pump Out	#6 O-Ring	G									G				
Tee - Pump Discharge	#6 O-Ring	S									P				
Oil Manifold (External)	#6 O-Ring	S&M	#6 O-Ring	G	#6 O-Ring	H	#6 O-Rin	A			P	P	P	P	
Oil Pan (Level)	#6 O-Ring	S	4 bolt hole	A							T	I	L		

Fuel System:

Name	Point 1		Point 2		Point 3		Point 4		Point 5		Function				
	Type	Use	Type	Use	Type	Use	Type	Use	Type	Use	1	2	3	4	5
Fitting - Pump In	#6 O-Ring	S									P				
Housing End of Fuel Filter	#6 O-Ring (In)	S	#6 O-Ring (In)	G	#6 O-Ring (Out)	S&M					P	P	P		
backpressure Regulator Body	#6 O-Ring	S	#6 O-Ring	G							T	P			
Tee - Lines Out of filter	37° Fitting (Out)	G&A									P				
Tee - Lines Into Filter	#7 O-Ring (In)	S&M									T				

Speed System:

Name	Point 1		Point 2		Point 3		Point 4		Point 5		Function				
	Type	Use	Type	Use	Type	Use	Type	Use	Type	Use	1	2	3	4	5
Camshaft Cover	5/8"-18-2B	S	5/8"-18-2B	S	5/8"-18-2B	S					S	S	S		
Housing - HMSO	5/8"-18-2B	A	5/8"-18-2B	A	5/8"-18-2B	A									

Figure 3 (continued on page 43)

3600 COMMISSIONING SENSOR POINTS

Function & Use Index					
	G - Gauge	H - HMSO	M - Manufacturing	T - Temperature	L - LEVEL
		A - Alarm	P - Pressure	POS - Position	S - SPEED

Intake System:

Name	Point 1		Point 2		Point 3		Point 4		Point 5		Function				
	Type	Use	Type	Use	Type	Use	Type	Use	Type	Use	1	2	3	4	5
Silence GP	#6 O-Ring	S	#6 O-Ring	G							P	P			
Aftercooler Hsg	#6 O-Ring	S	#6 O-Ring	G	#6 O-Ring	S					P	P	T		
Block	#8 O-Ring	S&M	#8 O-Ring	S&M	#8 O-Ring	G					T	P	T		
Engine Room	Ambient Air Temperature										T				
Elbow Assy - Air Inlet	#6 O-Ring	S	#6 O-Ring	G	#6 O-Ring	S					T	P	P		

Exhaust System:

Name	Point 1		Point 2		Point 3		Point 4		Point 5		Function				
	Type	Use	Type	Use	Type	Use	Type	Use	Type	Use	1	2	3	4	5
Exhaust Stack	1/2" NPT	G	1/2" NPTF	A							T	T			
Exhaust Manifold Ports	1/4" NPSF	G									T				

Air Start System:

Name	Point 1		Point 2		Point 3		Point 4		Point 5		Function				
	Type	Use	Type	Use	Type	Use	Type	Use	Type	Use	1	2	3	4	5
Distributor - Air Rcvr.	#6 O-Ring	G&A									P				

Crankcase:

Name	Point 1		Point 2		Point 3		Point 4		Point 5		Function				
	Type	Use	Type	Use	Type	Use	Type	Use	Type	Use	1	2	3	4	5
Front Housing	#6 O-Ring	S	#6 O-Ring	A							P	P			

Figure 3

3600 COMMISSIONING INSTRUMENTS SENSING LOCATION BY FUNCTION

Cooling System

Function	Location	Plug Type
Jacket water temp. rise	Elbow - JW pump out	#6 O-ring
	Elbow - engine out	#6 O-ring
Jacket water temperature	Elbow - engine out	12mm(1/2") NPT (3)
Temperature rise across turbo	Tube ass'y - turbo inlet	#6 O-ring
	Elbow - turbo water out	#6 O-ring
Turbo water flow restriction	Tube ass'y - turbo water in	#6 O-ring
(pressure drop)	Elbow - turbo water out	#6 O-ring
Jacket water flow restriction	Elbow - JW pump out	#6 O-ring
(pressure drop)	Elbow - engine out	#6 O-rin
Temp. rise across aftercooler	Adapter - A/C in	#6 O-ring
	Adapter - A/C out	#6 O-ring
A/C water flow restriction	Adapter - A/C in	#6 O-ring
(diff. pressure)	Adapter - A/C out	#6 O-ring
A/C & O/C coolant temperature	Water terminal	12mm(1/2") NPT
Seawater pump pressure	Elbow - pump out	#6 O-ring
Jacket water temperature	Manifold water	12mm(1/2") NPT

Lube System

Function	Location	Plug Type
Main oil manifold pressure	Elbow	
Piston cooling jet manifold press.	Priority valve body	#6 O-ring
		#6 O-ring
Engine oil temperature	Elbow - temp. reg. out	#6 O-ring
		12mm(1/2") NPT(3)
Scavange pump pressure	Elbow - pump discharge	#6 O-ring
Pressure drop across oil filter	Elbow - oil filter in	#6 O-ring
	Elbow - oil filter out	#6 O-ring
Main oil pump pressure	Tee - pump discharge	#6 O-ring
Main manifold pressure	Manifold ext. to turbo	#6 O-ring (3)
Temp. drop from manifold to pan	Oil pan	#6 O-ring
Pan oil level	Oil pan	4 bolt hole
Priority valve position	Priority valve body	

Speed System

Function	Location	Plug Type
Engine speed "rpm"	from camshaft cover, or	5/8"-18-2B(3)
	Hydro/mechanical shut off housing	5/8"18-2B(3)

Figure 4 (continued on page 45)

3600 COMMISSIONING INSTRUMENTS SENSING LOCATION BY FUNCTION

Fuel System

Function	Location	Plug Type
Press. rise across transfer pump	Fitting - pump in	#6 O-ring
	Housing-end fuel filter in	#6 O-ring (2)
Pressure drop across filter	Housing-end fuel filter out	#6 O-ring
	Tee - filter out37° fitting (2)	
Temp. rise across injector	Fitting-fuel filter in	#6 O-ring
	Regulator body	#6 O-ring
Regulator setting	Regulator body	#6 O-ring
Fuel temp. into eng. (hi-low alarm)	Tee - transfer pump out	37° fitting

Intake System

Function	Location	Plug Type
Engine room temperature, or temperature rise across turbo	Elbow ass'y - air inlet	#6 O-ring
	Aftercooler housing	#6 O-ring
Pressure rise across turbo	Silencer GP	#6 O-ring (2)
	Elbow ass'y - air inlet	#6 O-ring (2)
	Aftercooler housing	#6 O-ring (2)
Air plenum temperature	Block - adapter	#6 O-ring
	Block - adapter	12mm(1/2") NPT
Air plenum pressure	Block - adapter	#6 O-ring

Exhaust System

Function	Location	Plug Type
Exhaust stack temperature	Exhaust stack	12mm(1/2") NPTF
Exhaust port temperature	Manifold	7mm(1/4") NPSF

Air Start System

Function	Location	Plug Type
Main manifold pressure	Distributor - air	#6 O-ring

Crankcase

Function	Location	Plug Type
Crankcase pressure	Front housing#6 O-ring (2)	

Figure 4

Sea Trials

Sea trials are the final test of the installed machinery. The duration and complexity of a sea trial is related to the vessel type, the propulsion system configuration, and the class of service.

The commissioning engineer *must* play an active role in planning the Sea Trial Agenda relating to the propulsion system. All points highlighted under the previous dock trial section are applicable to preparing for the sea trial. In addition to the standard gauge panel instrumentation, Figure 6 can be used to customize sensor points needed to validate performance of unique marine installations.

Ensure test data and fuel rate are entered in the CAMPAR program for evaluation. Figure 7 can be used to draw a performance curve based on actual fuel rate at operating conditions.

ENGINE PERFORMANCE DATA

Record the following data using field equipment while the engine is at rated conditions and speed:

SHIP NAME: ______________
DATE: ______________
TIME: ______________
ENGINE S/N #: ______________ **Speed:** ______________

900 SERIES POINTS	DESCRIPTION	FACTORY SPEC.	ACTUAL MEASUREMENT TAKEN
910	Engine speed - Low idle		
910	Engine speed - High idle		
910	Engine speed - Free running		
910	Engine speed - Bollard pull		
910	Engine speed - Towing/trawling		
910	Engine speed - Emergency reversal		
	Engine room air temperature		
930	Air temperature at air cleaner		
907	Air inlet restriction		
906	Intake manifold temperature		
911	Intake manifold pressure		
931	Turbocharger compressor outlet temperature		
960	Turbocharger compressor outlet pressure		
908	Exhaust backpressure		
912	Exhaust stack temperature		
932	Crankcase pressure		
913	Engine oil to bearings temperature		
914	Engine oil to bearings pressure		
934	Engine oil to cooling jet pressure		
927	Oil filter inlet pressure		
928	Oil filter outlet pressure		
909	Crankshaft deflection		
	Fuel temperature - Injector inlet		
917	Fuel pressure - Injector inlet		
	Fuel temperature - Injector outlet		
	Fuel pressure - Injector outlet		
936	Fuel return line restriction		
961	Fuel pump - Inlet restriction		
901	Jacket water cyl. block outlet temperature		
942	Jacket water cyl. block outlet pressure		
943	Water temp. to combined circuit heat exch.		
944	Water press. to combined circuit heat exch.		
945	Water temp. to reg. from comb. circ. H/E		
946	Water press. to reg. from comb. circ. H/E		
954	R. W. temp. to combined circuit heat exch.		
	Auxiliary pump inlet temperature		
904	Auxiliary pump inlet pressure		
	Auxiliary pump outlet temperature		

Comments:

Figure 6 (continued on page 48)

ENGINE PERFORMANCE DATA

Record the following data using field equipment while the engine is at rated conditions and speed:

SHIP NAME: ______________
DATE: ______________
TIME: ______________
ENGINE S/N #: ______________ **Speed:** ______________

900 SERIES POINTS	DESCRIPTION	FACTORY SPEC.	ACTUAL MEASUREMENT TAKEN
905	Auxiliary pump outlet pressure		
951	AC/OC water pump inlet temperature		
952	AC/OC water pump inlet pressure		
953	AC/OC water pump outlet pressure		
903	AC/OC water inlet temperature		
923	AC/OC water inlet pressure		
937	AC water temp. between front & rear housing		
903A	AC/OC outlet water temperature		
924	AC/OC outlet water pressure		
940	AC/OC outlet mixing box temperature		
941	AC/OC outlet mixing box pressure		
938	Oil cooler water outlet temperature		
939	Oil cooler water outlet pressure		
920	Jacket water pump inlet pressure		
902	Jacket water pump outlet temperature		
919	Jacket water pump outlet temperature		
922	Jacket water temp. from cooling system		
947	Water temperature at engine outlet to		
	separate circuit heat exchanger		
948	Water pressure at engine outlet to		
	separate circuit heat exchanger		
949	Water temperature to regulator from		
	separate circuit heat exchanger		
950	Water pressure to regulator from		
	separate circuit heat exchanger		
956	R. W. temperature to separate circuit		
	jacket water heat exchanger		
957	R. W. temperature from separate circuit		
	jacket water heat exchanger		
958	R. W. temperature to separate circuit		
	AC/OC water heat exchanger		
959	R. W. temperature from separate circuit		
	AC/OC water heat exchanger		
915	Reduction gear lube oil temperature		
916	Reduction gear lube oil pressure		
925	Reduction gear oil cooler inlet water temperature		
926	Reduction gear oil cooler outlet water temperature		

Comments:

Figure 6

Caterpillar Marine Engine Performance Analysis Report

Vessel Name ________ Engine Model ________ Test Number ________ Customer ________ Engine S/N ________ HOURS ________

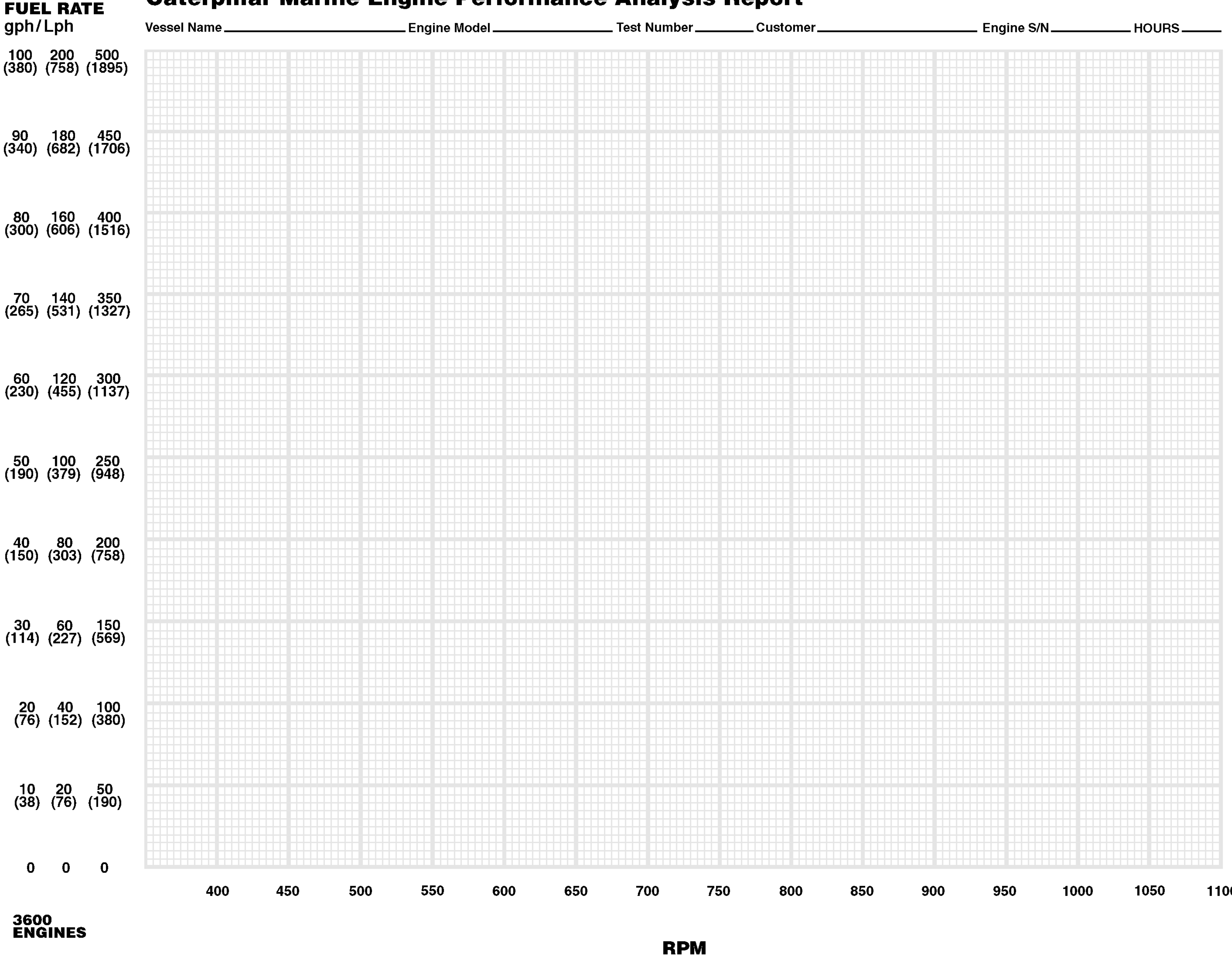


Figure 7

Sea Trial Conditions

Perform sea trial running tests under the following conditions:

- Load the vessel the same as during normal service: 50% to 75% load of fuel, fresh water, cargo, and ships' stores. Properly located ballast may be substituted.
- All gauges, panels, and test instruments must be in good operating condition before conducting tests.
- The engines and reduction gear must be operated under full throttle and load long enough to allow temperatures and pressures to stabilize.
- If the ship operation includes towing or trawling, take sea trial measurements while the vessel is towing its intended load. If testing under actual working conditions is impossible, Bollard pull engine speed and free-running engine speed are required to determine if the engine will attain rated rpm under full load conditions.

Experience has shown that conditions where Bollard pull tests are usually conducted are not ideal for performance of the other engine system tests. Other sea trial measurements should be made under free-running conditions after the Bollard pull engine speed has been measured.

Figure 8 is a sample of a main engine sea trial log sheet.

Record machinery and structure vibration levels at various engine speed and load conditions. The data becomes part of the permanent engine commissioning record.

Take lube oil samples after the completion of the sea trial and the analysis results have been made a permanent part of the engine commissioning record.

Check crankshaft deflections immediately after the engine has been secured following the sea trial. This will help validate engine mounting and insure unrestricted thermal expansion of the machinery.

ENGINE INSTRUMENTATION DATA

Record the following data using field equipment or by recording instrument readings while the engine is at rated conditions and speed:

SHIP NAME: ____________________

DATE: ____________________

TIME: ____________________

ENGINE S/N #: ____________________

MEASUREMENT POINTS	FACTORY SPEC.	ACTUAL READINGS			
Engine operating hours (Hrs.)					
Tachometer (rpm)					
Engine coolant temperature [°C (°F)]					
Air inlet manifold temperature [°C (°F)]					
Air inlet restriction-left [kPa (in. H_2O)]					
Air inlet restriction-right [kPa (in. H_2O)]					
Lube oil pressure [kPa (psi)]					
Lube oil temperature [°C (°F)]					
Lube oil filter diff. pressure [kPa (psi)]					
Fuel oil filter diff. pressure [kPa (psi)]					
Fuel oil pressure [kPa (psi)]					
Crankcase pressure [kPa (psi)]					
Air inlet manifold pressure [kPa (psi)]					
Stack exhaust temp.-left bank [°C (°F)]					
Stack exhaust temp.-right bank [°C (°F)]					
#1 Cylinder exhaust temperature [°C (°F)]					
#2 Cylinder exhaust temperature [°C (°F)]					
#3 Cylinder exhaust temperature [°C (°F)]					
#4 Cylinder exhaust temperature [°C (°F)]					
#5 Cylinder exhaust temperature [°C (°F)]					
#6 Cylinder exhaust temperature [°C (°F)]					
#7 Cylinder exhaust temperature [°C (°F)]					
#8 Cylinder exhaust temperature [°C (°F)]					
#9 Cylinder exhaust temperature [°C (°F)]					
#10 Cylinder exhaust temperature [°C (°F)]					
#11 Cylinder exhaust temperature [°C (°F)]					
#12 Cylinder exhaust temperature [°C (°F)]					
#13 Cylinder exhaust temperature [°C (°F)]					
#14 Cylinder exhaust temperature [°C (°F)]					
#15 Cylinder exhaust temperature [°C (°F)]					
#16 Cylinder exhaust temperature [°C (°F)]					
Fuel rack position (from governor)					

Comments:

Figure 8

The attached report reflects the analysis of authorized Caterpillar or Caterpillar dealer representative(s). It is based on information provided by the customer and other manufacturers. Caterpillar is not responsible for the accuracy of information provided by these third parties. Caterpillar warrants this report to be free from errors in calculations. Failure to comply with the recommendations in this report will have a direct effect on suggested engine operation. Caterpillar will not be responsible for any auxiliary supporting system or operation associated with the 3600 engines when the specific recommendations within this report are not followed and completed. Caterpillar will not be responsible for any changes in the engine, engine system, or system malfunctions occurring after the time of the initial evaluation other than those specified in the applicable Caterpillar warranty. This warranty is expressly in lieu of any other warranty, express or implied, including any warranty of merchantability or fitness for a particular purpose. Caterpillar disclaims and will not be responsible for any incidental or consequential damages.

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