3600 Marine Engine Application and Installation Guide

Ancillary Equipment
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Marine Gears
Couplings
  Torsional Limits
Propellers
  Fixed Pitch
  Controllable Pitch
Marine Gears

Reversing marine gears are used:

• To match relatively small, economical medium speed engines to the low propeller rpm necessary for high efficiency.

• To reverse the propeller rotation for the non-reversing 3600 Family of Engines.

Marine gears are selected to transmit rated engine horsepower (plus overload if required) at rated rpm. Design the gear to meet appropriate classification society rules. Inspection and Certification may be required. Advise the gear manufacturer of expected adverse conditions, such as operation in ice.

Main engine marine gears are normally single or double reduction, with the ratio of input and output speeds selected to meet the propeller design rpm. The gears are either uni-directional or reverse reduction depending on the type of propeller selected (either fixed or controllable pitch).

Pinion and bull gear bearings are either sleeve or antifriction. The thrust bearing is normally built into the gear casing and sized to take the reactive thrust of the propeller.

Clutches are normally pneumatic or hydraulically actuated, straight engagement, or slip type. Ahead and astern clutches are required if a reversing gear is used.

The gear box lubrication and cooling oil system is normally self-contained and fitted on the gearbox assembly. It is also used for hydraulic clutch actuation.

The marine gear is mounted to a rugged fabricated steel foundation securely welded to the ship's structure; refer to the Mounting and Alignment section of this guide. The gearbox is bolted to its foundation using either steel or epoxy resin chocks to ensure alignment between the shafting, gearbox, and main engines. Collision chocks are normally fitted at the corners of the gearbox mounting flange to maintain alignment in the event of an accident.

Care should be taken in selecting the capacity of the low speed output bearing. It must be capable of carrying loads imposed by the line shaft or tail shaft directly connected to the low speed coupling. Advise the gear manufacturer if a propeller blade actuating box is to be mounted on the gearbox, or if auxiliary equipment is to be driven from power takeoffs on the gear housing.

Carefully review the final arrangement of the gearbox in the engine room for the best overall installation. Space must be available for service and maintenance. The following are examples of typical arrangements used with the 3600 Family of Engines:

• Single input/single output, horizontal offset, reversing. See Figure 1.

• Single input/single output, vertical offset, reversing. See Figure 2.

• Single input/single output, concentric, reversing. See Figure 3.

• Twin input/single output, horizontal-vertical offset, non-reversing. See Figure 4.

• Twin input/single output, horizontal offset, non-reversing. See Figure 5.

The Torsional and System Stability Analysis section within General Information in this guide describes the required torsional analysis. The marine gear manufacturer must provide data.
Figure 1
Single Input/Single Output
Vertical Offset, Reversing

Figure 2
Figure 4

Twin Input/Single Output
Horizontal Vertical Offset
Non-Reversing
**Couplings**

A propulsion engine's power transmission is through a flexible coupling, or a combined flexible coupling and clutch mounted on the flywheel. A heavy coupling can be mounted on the flywheel or shaft flange without intermediate bearings. The type of flexible coupling to be used for each installation must be determined on the basis of torsional vibration calculations. Two fundamental coupling types are used. The first uses elastomer elements to provide both torsional flexibility and damping. Figure 6 illustrates a typical example of this coupling design. The number of required elements depends on the torsional vibration calculation. In addition, engines with a resilient mounting system require a balanced coupling.

**Note:** The application will determine the coupling size.

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**Figure 6**

DETAIL OF COUPLING

SCALE NONE

* HUB MACHINED TO CUSTOMER SPECIFICATION
A second type of coupling utilizes leaf or coil springs for torsional flexibility. Hydrodynamic damping is accomplished by oil displacement (dash pot). Figure 7 illustrates a typical example of this coupling type.
The selection of a coupling depends on the driveline configuration (gearbox, shafting, propeller, etc.). A complete set of driveline data is required to properly select a coupling. A Torsional Vibration Analysis (TVA) must be performed to confirm the coupling selection. The information required by Caterpillar to perform a TVA is shown in Figure 8. Also see Torsional Vibration Analysis under the General Information section of this guide.

**Torsional Limits**
The following guidelines should be used in the coupling selection process:

- **Crankshaft Amplitude Limits:**
  - Misfire calculated using #1 engine cylinder misfiring. Individual order analysis with or without misfire.
  - Amplitude limits at front of crank
    - Do not exceed $\pm 1.0^\circ$ for 0.5 order
    - Do not exceed $\pm 1.0^\circ$ for 1st order
    - Do not exceed $\pm 0.25^\circ$ for 1.5 order
    - Do not exceed $\pm 0.15^\circ$ for all orders above 1.5 at front of crank
    - Do not exceed $\pm 21$ MPa (3000 psi) crankshaft stress for each engine order
- **Vibratory Torque:** Limit of coupling with #1 cylinder misfire
- **Coupling Power Loss:** Limit of coupling with #1 cylinder misfire

**Coupling Selection**
- Develop a coupling selection matrix based on:
  - Engine model
  - Power
  - Inertia - driveline data
  - Ambient temperature
    - 45°C
    - 60°C
  - Application
    - Main Propulsion or Ship
    - Service Generator Set
- Select coupling that meets all the following criteria:
  - Coupling vibratory torque limits
  - Crankshaft vibration limits
- Analyze alternative couplings until all of the above conditions are met.

Use torsional limit stops (coupling locks if operated beyond limits) on couplings providing the sole source of transmitting propulsive power. A single screw vessel is an example. The vessels should have a take-home feature if the coupling fails.

**Note:** Germanischer Lloyd and Bureau Veritas may not permit a torsional limit stop because of potentially severe torsional problems when the propulsion system is operated with a failed coupling.

**Propellers**

**Fixed Pitch**
The dimensions of fixed pitch (FP) propellers must be carefully reviewed for each application. They control the level of engine power that can be used in a ship installation.

Factors influencing the design are:
- Propulsion resistance of the ship increases with time.
- Wake factor for the ship increases with time.
- Propeller blade frictional resistance in water increases with time.
- Bollard pull requires higher torque than free running.
- Propellers rotating in ice require higher torque.

Fixed pitch propellers are normally designed to absorb 85% of the Maximum Continuous Rating (MCR), or 90% of the Continuous Service Rating (CSR) at normal speed when the ship is on trial at specified speed and draft (see Figure 9).

Consider the accessory equipment power requirements for shaft generators or hydraulic pumps when sizing FP propellers.
3600 Torsional Vibration Analysis Request

The information on this form is to be used for a specific request for a torsional vibration analysis on the above 3600 Diesel Engine application. Please provide a timely verbal response followed by a written report to the responsible project engineer. The following information describes the major components and performance data for this application:

**Engine Model and Rating:**
E29 ________ (36 ________); ________ kW (_______ bhp)
Low Idle rpm ________  Rated Speed rpm ________
Engine Regulation: Isochronous (Y/N) ________, or Percent Droop ________ %

**Application Specifics:**
________________________________________________________________________
________________________________________________________________________
(quantity engines -- custom base -- front driven equipment, etc.)

**Engine Room Maximum Ambient Temperature**

**Generator** (______); and/or **Marine Gear** (______); plus **Other Driven Equipment** (______)

**Supplier Name and Model Number**

**Rotating Inertia/Drawing(s)**

**Rotating Stiffness/Shaft Drawing(s)**

**Gearbox Drawing** __________  **Propeller Inertia** __________

**Description (e.g. two bearing or single bearing)**

(attached are supplier data sheets)

**Part Numbers of Components:**

**Flywheel Group** __________  **Coupling Group** __________
**Drive Group** __________  **Damper Group** __________
**Ring Gear Group** __________  **Other Groups** __________
**3161 Governor Group** __________  **Heinzmann Governor** __________
**EGB29P** __________  **Electronic Control Group** __________
**Actuator Assembly** __________

**Engine Ship Date (RTS)**

**Torsional Completion Date Required**

Caterpillar Project Engineer

(Revised 4-25-97)
Fishing or towing ships should use a propeller designed for 85% MCR of the engine, the normal speed for fishing or bollard pull or at towing speed. The absorbed power at free running and normal speed is usually lower (about 65% to 85%) than the output at fishing or bollard pull.

Consult Caterpillar for special applications with additional torque requirements, such as dredges or ships operating in thick ice.

Figure 8 shows the permissible operating range for a FP propeller installation and the design point at 85% MCR at nominal speed. The minimum speed is decided separately for each application. The speed control system should give a boost signal to the speed actuator to prevent engine speed from decreasing when clutching in. Select the clutch to provide a slip time of 5-7 sec. Install a propeller shaft brake to facilitate fast maneuvering (ahead, astern, stop). See the Engine Performance section of this guide for a full explanation of the rating curve. Also see the section for Controls.
Controllable Pitch

Controllable pitch (CP) propellers are normally designed at 90 to 100% of the Continuous Service Rating (CSR) at rated rpm. See the Engine Performance section of this guide. This power level is used when the ship is on trial with a clean hull at specified speed and draft. Consider the shaft generators or generators connected to the free end of the engine when dimensioning CP propellers if continuous generator output is used at sea. Overload protection or load control is recommended in all installations.

Figure 10 shows the operating range for a typical CP propeller installation, see the Engine Performance section for a full explanation of the rating curve. The recommended combinator curve is valid for single engine installations. In installations where several engines are connected to the same propeller, overload protection or load control is necessary. Loads close to the combinator curve are also recommended when all engines are not operating. The idle (clutch-in) speed will be determined separately in each case.
Materials and specifications are subject to change without notice.