Marine Commissioning Procedure and Sea Trial Guide

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1. Document Purpose

The purpose of this document is to define the overall commissioning process of a Caterpillar Marine Engine Installation.
The intended audience for this specification is any individual who has an interest in the complete and thorough Commissioning of a vessel with Caterpillar Marine Engines installed. This includes, but not limited to, Caterpillar Marine Dealers, AMD's and OEM Commissioning Engineers.

1.1 Document Scope

The scope of this document is to cover the commissioning process of a vessel from installation review to sea trial and handover to customer. This document is not intended to cover the pre-installation sales process of the engines nor the pre-sales vessel design review. Caterpillar provides other publications supporting the sales and design review process, and references to these guides can be found in the "References" section of this document.

1.2 References

Media Number	Description
SEHS8716	Design and Construction Review Form
SEHS9031	Storage Procedure For Caterpillar Products
SENR5002	Troubleshooting for Marine Engine Electronic Displays
LEDM0131	Sea Trial Sensor Location 900 Numbers Used for CAMPAR Performance Analysis Report (PAR) Testing
LEBM0040	Sea Trial and Commissioning Tables
SEHS7654	Alignment - General Instructions
LEBW4978	Cooling Systems - Application and Installation Guide
LEGM0006	Caterpillar Bollard Pull Test Guide
LEBM5081	Sea Trial Guide (Legacy)
LEBW4971	Engine Room Ventilation
LEBM0047	Marine Aftertreatment Checklist
LEBM0088	Marine Aftertreatment - C280, 3500, C175, C32 - Initial Start-Up and Commissioning
LEEM0005	CAMPAR Tier 4 - Aftertreatment System Analysis Worksheet
LEBM0038	C7-C32 Marine Propulsion Startup & Commissioning Checklist
LEBM0053	C7 - C32 Marine Auxiliary and Generator Set Startup and Commissioning Checklist
LEBM0039	3500-C280 Marine Propulsion Startup & Commissioning Checklist
LEBM0057	3500 C280 Marine Auxiliary and Generator Set Startup and Commissioning Checklist

1.3 Links

Electronic Media Center (EMC)	https://emc.cat.com/
Ending Drawing Design Center (EDDC)	https://enginedrawings.cat.com/
Marine Service Interlink	https://serviceinterlink.cat.com/
Power Net	https://engines.cat.com/marine/
SIS Web	https://sisweb.cat.com/
TMI	http://tmiweb.cat.com/
Powernet CAMPAR Page	https://engines.cat.com/en/marine/application-installation/CAMPAR.html

2. Introduction

2.1 NOTE of Supersession

This document supersedes the following:

- Sea Trial Guide (LEBM5081)
- Caterpillar Marine Engine Performance Analysis Report (LEXM0581)

2.2 Forward

Commissioning is generally defined as "the process by which an equipment, facility or plant is tested to verify its functions according to its design objectives or specifications." One can have partial or complete commissioning depending on the state of completion of the vessel.

As all definitions generally leave room for interpretation, the details need to be adapted for every commissioning. It is incorrect to confuse the commissioning with some operational tests. It is important to understand that the sea trials have to be seen as a part of the commissioning process of the installation, hence using the terms commissioning and sea trials as the same thing is not correct. Caterpillar approved sea trials ensure that all the systems and circuits of the vessel are properly scrutinized and matched with the power system.

Engine-specific information and data is available from a variety of sources, however TMI is the preferred source. A list of sources is provided in the reference section of this guide. Systems and components described in this guide may not be available or applicable for every engine.

NOTE: *The owner of the commissioning process remains the selling dealer and its local organization.*

2.3 From Sales to Sea Trials: A Continuous Process

The success of a project depends on the synergy of all the composing activities. It is important that regardless of the business structure adopted by the dealer, sales people will collect information for every new project. Information should be organized and made available.

A powerful tool to retain all this data is the Marine Service Interlink web database. Information on this database can be found on Power Net.

Field experience confirms that a proper commissioning of the installation and thorough sea trials will pay back both in terms of customer satisfaction and in preventing future problems. Proper and uniform documentation of the process, communication, and updated records are necessary steps to achieve these results. Understanding the engine and the marine engine room components are pre-requisites for any engineer involved in a commissioning. Mastering the Caterpillar A&I guidelines, Caterpillar Project Guides, Cat ET, and CAMPAR are necessary for a proper understanding of the vessel behavior.

The engine installation should be designed to give safe, efficient and reliable operation. A poorly designed installation can hinder serviceability, and make routine maintenance and repairs difficult and costly. The neglect of specific design requirements for mounting, alignment and support systems can lead to poor performance and increased operational costs or even severe damages.

2.4 Marine Installations

Marine installations often have the practice of sailing from any location in the world to another. This obvious consideration should not be underestimated - the selling dealer and the servicing dealer are seldom the same. During its life, a vessel could be maintained by different dealerships and/or AMDs (Authorized Marine Dealers) in any part of the world. Remember also that vessel ownership will also likely change at some point in the life of the vessel.

Consider this document a guide for both commercial and pleasure craft customers.

3. Definitions

3.1 Abbreviations

ATAAC	Air-to-air aftercooled
CAMPAR	Computer Aided Marine Performance Analysis Report
Cat ET	Caterpillar Electronic Technician
CDL	Cat Data Link
ECM	Electronic Control Module from Caterpillar
EDDC	Engine Drawing Design Center
EMC	Engine Media Center
ERAT	Engine room air temp
JWAC	Jacket-water aftercooled
GPS	Global Positioning System
OATA	Outside air temp (actual)
OATD	Outside air temp (design)
OEM	Original Equipment Manufacturer
.ssd	Steady State Datalog File
SCAC	Separate-circuit aftercooled
SWAC	Sea water aftercooled
SWTA	Sea water temperature (actual)
SWTD	Sea water temperature (design)
TMI	Technical Marketing Information
.txt	General Info and Steady State Sea Trial Files for Import into CAMPAR

4. Commissioning

For our purposes, we assume that the commissioning process begins with the “installation review” of the dealer and ends with the “acceptance” of the vessel by the customer. Neither the “sales” nor the vessel “design review” are included in the process. Despite this, the importance of the “design review” remains and dealers should, as much as possible, take an active role in matching the installation and the propulsion system.

The purpose of this process is to ensure that the vessel design will meet Caterpillar guidelines prior to engine purchase and delivery. This is completed, as a general rule, for the first hull of a production run, during any significant change to a production run, for any custom boat, or for a re-power installation.

Caterpillar selling dealer defines Caterpillar engine installation requirements using the Application and Installation guides and, if needed, Marine Application Support Center.

Selling dealer and boat builder complete the cover sheet of the Start up and Commissioning Checklist for the applicable engine and determine if the current design will meet Caterpillar guidelines. Reference the Appendix for the list of Startup and Commissioning checklists which can be found on Power Net.

Selling dealer and boat builder work together to ensure design will meet Caterpillar guidelines.

Selling dealer submits the cover sheet of the Startup and Commissioning Checklist to the Marine Service Interlink web database.

4.1 Installation Review

It is important to repeat once again that the “installation review” is done before any plan to perform the sea trials. When the vessel is expected to sail for trials it is already too late for any engine room review!

If during commissioning, the vessel is located in a dry dock, use this opportunity to visually inspect the hull, propeller, sea chests and cooling water overboard outlets for marine growth or any other unintended restrictions or damages.

Caterpillar provides start up and commissioning checklists, which include a “pre-startup” checklist that dealers can utilize as a guide for an installation review.

4.2 Gathering Information

During this phase, the dealer should collect as much information as possible on the vessel. Referencing the Startup and Commissioning checklists (found on the CAMPAR Powernet Page) the dealer should collect installation drawings, vessel operational profile, etc. For installations with aftertreatment, there is an additional Aftertreatment Checklist LEBM0047.

This is also the time to complete the Design & Construction Review Form with general information about the owner, vessel and builder/installer, including the vessel’s physical features. A provision in this form is made for recording the propulsion and auxiliary systems descriptions, including serial numbers, and the manufacturer, where applicable. All the information is potentially important and its value for the future should be not underestimated. At this time, the selling dealer submits the Design & Construction Review Form to the Marine Service Interlink web database.

After the construction and installation are both in compliance with Caterpillar requirements, indicate this by placing a check in the box next to the system reviewed. If a system does not comply, there is a space to record the necessary corrective action. After the construction review and the construction review form are completed and any corrective action needed is agreed to, it is recommended that all parties concerned sign the construction review form at the designated location on the form.

Bear in mind that internet pages or shipyard websites could be removed or disappear, so don’t append links on these forms.

4.3 Stocking and Layup

All Caterpillar engines are tested at the source Caterpillar factory before shipment. After completion of the Factory Acceptance Test, the engines are prepared for shipment. Dealers can request special testing of the engine or genset package based on local requirements. Based on scheduled vessel build dates, dealers can request particular preservation procedures based on shipyard requests.

***NOTE:** Regarding any long term preservation requirements, refer to Special Instruction "Storage Procedure for Caterpillar Products" (SEHS9031, found on SIS Web).*

If for any reason the vessel was in lay-up and the engines were left non-operational for an extended period, ensure and document the proper start-up procedures, as per SEHS9031 (found on SIS Web), are performed.

4.4 Marine Application and Installation Guides

A complete set of Marine Application and Installation guides are available from Caterpillar. These are general guides that deal with the main topics related to marine installations for various installations. Additionally, Caterpillar also provides more specific Project Guides that pertain to certain engine models, which provide engine model specific installation information. In general, information in the Project Guide's should align with the universal A&I Guides. However, when information differs, the project guide should take precedent over the universal guideline. The complete set of universal A&I guidelines, as well as the Project Guides, can be found on Power Net.

5. Engine Startup

5.1 Pre-startup Review

Caterpillar provides pre-start up and commissioning checklists for its C7 through C280 Marine engine models. The pre-startup checklist is meant to assist the commissioning engineer during a safety and functional assessment of the engine room and its equipment. Small items such as leaks or loose wires, missing sensors, or incomplete documentation could lead to challenging sea trials – the intent of these checklists is to 1) help ensure the actual sea trial will be completed as seamlessly as possible and 2) provide sea trial documentation.

NOTE: *Upload all additional information in the Marine Service Interlink web database.*

Some checks and inspections are listed below. Refer to the Marine Commissioning Checklists on the CAMPAR Powernet Page for a complete list of suggested activities.

- Exhaust pipes should be shielded or guarded to prevent operator contact.
- All generator drive components and damper guards must be in place prior to operating the engine.
- All floor openings in the engine room must be covered with plating or grating.
- Chains and hooks on overhead lifting equipment must not endanger personnel.
- Floors must be cleaned of any debris or liquid spills.
- Engine heat shields must be in place prior to operating the engine.
- Remote emergency system stops must be guarded, but must operate during a safety simulation.
- Fire suppression systems should be tested prior to allowing normal operation. If this has already been completed, verify a certificate of system operation exists.
- Independently test all emergency stops for the engine while operating at no load.

5.2 Engine Break-in Procedure

5.2.1 New Engine from Factory

New Caterpillar engines shipped from a Caterpillar factory are considered “broken-in” after factory hot-test. Upon installation of a new engine, the engine is ready for a full sea-trial without any additional break-in procedure either at the dealership or in the vessel.

5.2.2 Rebuilt Propulsion Engine (excluding 3600 & C280)

For rebuilt engines (excluding 3600 and C280), refer to the following break-in procedure (REHS5705, found in SIS Web).

1. Check all fluid levels.
2. Start the engine.
3. Idle the engine with no load for 20 minutes
4. Check the engine for leaks.
5. Increase the engine rpm to half throttle once the coolant temperature begins to increase on the temperature gauge.
6. Run the engine for 10 minutes at half throttle with no load. Check and verify that there is water flow, oil pressure, fuel pressure, and no unusual sounds.
7. Once the pressures are verified, bring the engine back to idle and check the marine gear (if applicable) to ensure the gear engages properly.
8. Begin a sea trial running the engine at a low load condition until engine temperatures reach operating temperature.
9. Once the engine has reached operating temperature, begin increasing the engine rpm following the increments in the table below.
10. Slowly bring the engine speed back to low idle.
11. Engine is now ready for normal operation.

Engine Speed (RPM)	*Time (minutes)*
1000	Until engine reaches operating temperature
1200	10
1400	10
1600	10
1800	10
1900	10
2000	15
2100	15
2200	15
Wide Open Throttle (WOT)	10

NOTE: *Some modification to this chart may be required, depending on your particular rating or application requirements.*

6. Sea Trials

Sea trials, regardless the type, are the most effective way to evaluate the vessel performances in its real environment.

A sea trial provides data to effectively analyze the installation of the engine and its supporting systems. Caterpillar requires that a proper sea trial be performed on all new engine installations. CAMPAR is the recommended tool to be utilized in the sea trial process and the sea trial results should be loaded into Service Interlink. This sea trial aids in the identification of system problems that can lead to potential performance problems at commissioning and uploading the results into service interlink can aid in troubleshooting performance issues throughout the life of the engines. This will help both the customer and the dealer to develop maintenance and repair schedules that will provide the most economical and efficient cost of operation.

The selling dealer is responsible for ensuring the engines are installed correctly, which includes a sea trial to ensure the engines are operating properly and loaded correctly. The level of sea trial can vary, as a unique commercial build requires a more thorough PAR analysis than would the 10th vessel of a production build. Because of this, there are four types of sea trials, each of which will be discussed later in this section.

- Complete Sea Trial
- Pre-delivery OEM Sea Trial
- IMO III / EPA Tier 4 Aftertreatment Required Sea Trial
- Performance/Diagnostic Sea Trial

If a selling dealer does not plan to support a sea trial to ensure they are installed correctly, the dealer shall have an obligation to ensure provisions are made with the supporting dealer to ensure the engines are commissioned. Depending on the sales contract, commissioning/sea trials may have been included in the sales price of the engines. If this is the case, and the selling dealer cannot support complete sea trial, for various reasons, then the selling dealer should contract the supporting dealer to perform this work, as the customer has paid for full commissioning.

Prior to conducting a sea trial, electronic and control functional tests should be conducted. Each test will include an electronic functionality test to verify proper operation of all gauge panels, electronic components, data link, J1939 wiring requirements followed, compare vessel instrumentation to the service tool, throttle, mechanical throttle linkage check, switch operation if equipped (synchronization, slow vessel, trolling, trip clear and engine shut-off).

Photographs are a valuable documentation tool. Throughout the commissioning process, document both the good and the bad of engine installations. In addition to specific photos, such as air inlet and exhaust connections, water connections, and vibration isolators (mounting groups), also capture photographs of:

- Front View of Engine
- Rear View of Engine
- Right Side View of Engine
- Left Side View of Engine

6.1 Software Required

A computer with the following programs installed and hardware present is required during sea trials:

- Ensure the latest released version of Caterpillar Electronic Technician (ET) with Sea Trial Data Logger is installed. ET version 2016C or newer is required for use with CAMPAR. ET is used on electronic engines to communicate ECM monitored engine parameters.
- Sea Trial Data Reduction Web-Based Software: Computer-Aided Marine Performance Analysis Report (CAMPAR), which is available on Marine Service Interlink.
- Cat Communication Adapter: Used to communicate engine monitoring information between the engine ECM and Cat Electronic Technician (ET). 317-7482 Comm. Adapter 3 is preferred. 171-4400 or 275-5120 Comm. Adapters are also acceptable.
- Cat Data link “Y” Cable. Cable assembly 211-4988 that joins the data link between the port and starboard engines which provides the necessary connection to record both engines in sea trial data logger simultaneously.

NOTE: *This cable will not be required if the OEM has included the coupling of the engine’s data links in the vessel wiring or the Plug and Run wiring system was ordered from Caterpillar Inc.*

***NOTE:** The Cat Data Link cable only transfers data on the Caterpillar Data Link (CDL). Parameters being broadcast on J1939 network will not be broadcast via CDL cable.*

CAMPAR is the official software developed by Caterpillar to evaluate sea trials. The data that is taken during sea trials will be compared to and plotted against the performance data that can be found in TMI by test spec number. CAMPAR is used to aid certified marine analysts in:

- Formulating actual and factory-specified test results for marine propulsion engines and transmissions.
- Producing a graphic representation of the actual and factory-specified fuel rate, boost pressure and exhaust temperature results for propulsion systems utilizing fixed pitch propellers under normal operating conditions.
- Making consistent interpretations and recommendations from the test results, for marine propulsion engines and transmissions.

CAMPAR is accessed through the appropriately named tab on Marine Service Interlink. A CAMPAR User Guide can also be found on MSI. If the CAMPAR tab does not appear or the link is not valid, contact the MSI help desk for CAMPAR access. Additional CAMPAR resources can be found on the CAMPAR Powernet site.

CAMPAR follows the easy rule of "garbage in – garbage out". This means that incomplete or inconsistent data will not produce reliable results.

GPS Interface Module (recommended, but not required). The GPS interface module with the addition of a hand held Global Positioning System (GPS) will transmit the vessel's speed, latitude, longitude and heading to the Cat Data Link for recording these parameters via sea trial data logger. Refer to SENR5002 for GPS to GPSIM connections.

6.2 Data Measuring Points

WARNING

Pressurized system: Hot coolant can cause serious burn. To open cap, stop engine, wait until radiator is cool. Then loosen cap slowly to relieve the pressure.

WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

Before a test of the propulsion and/or auxiliary engines and transmissions, install the proper diagnostic tool, temperature probes and pressure sensors needed to obtain the performance data that is required. Caterpillar offers a Marine Sea Trial Kit which includes temperature probes, pressure transducers and an assortment of adapters to aid in the sea trial data collection.

Caterpillar provides a series of 900 numbers to identify the various test points on a given engine. To drive commonality the nomenclature for these test points are the same across all engine modules and designated by said 900 numbers. (Example: 906 – Intake Air Manifold Temperature)
The location of these test points are given in the general dimension drawings. The drawings also give the thread type and size at each location. The installation drawings showing specific test ports and corresponding sizes are available on the Engine Drawing Design Center (EDDC).

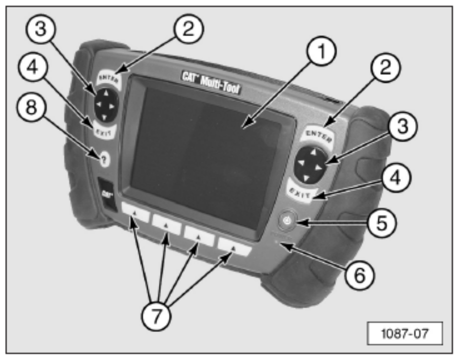
Refer to EDDC for available 900 ports and locations for your particular engine. A complete list of 900 Numbers is given in LEDM0131.

6.2.1 Required Diagnostic Tooling

Caterpillar Multi-Tool (368-9910)
Required for all sea trials.

A Caterpillar Service Tool like the 368-9910 Multi-Tool Group 3 is able to combine the following applications:
- Blow-by/Airflow Indicator
- Engine Timing Indicator

- Signal Generator
- Electronic Position Indicator
- Multi-Tach II
- Digital Thermometer
- Fuel Flow
- Pressure Meter
- Burn Rate Meter



(1) LCD Screen. (2) ENTER Keys. (3) Direction Keys.
(4) EXIT Keys. (5) POWER Button ON/OFF.
(6) Power ON Indicator Light. (7) Variable Function Keys.
(8) HELP Key.

Marine Sea Trial Adapter Group (464-1090)

Required for all Sea Trials

This adapter group is designed as an aid for commissioning technicians to improve accuracy and thoroughness of sea trials. Twenty digital channels are available for pressure and temperature readings during sea trial. This tool group is designed to work with the Multi-Tool Group (368-9910). Note that this kit does not have the capability to measure vacuum. For vacuum measurements, utilize the 5P-6582 vacuum/ pressure gauge or assemble your own vacuum gauge as described in Appendix A.

Features and Benefits:

- 20 Digital channels to take temperature and pressure readings during marine sea trial.
- Select 1-20 channels to display on Multi-Tool
- Uses 1/8-20 RTD temperature sensors
- Uses 500 psi sensors with quick couplers
- Extension cables keep technician away from engine
- Contains adapter fittings and O-rings
- Reduced setup time—everything required is in one place
- Adapters and fittings in labeled box making it easy to identify missing fittings and parts available in in the Cat® parts system
- Four Marine Sea Trial Groups can be connected to one Multi-Tool to display 80 channels

Fuel Gravity (API) Kit (398-9680)

Required for all sea trials

Includes hydrometer and measuring beaker to measure the API gravity and temperature of diesel fuel so corrected horsepower ratings can be calculated.

Crankshaft Deflection (155-8795) - ONLY 3500 & 3600/C280 engines
Required for all sea trials

Crankshaft Deflection. Starrett 696 Crankshaft Deflection Dial Indicator — is used to ensure the cylinder block has not been unduly stressed by incorrect engine mounting, resulting with crankshaft deflection.

Dial Indicator
Required for all sea trials

Dial indicator with magnetic base are used for basic alignment measures between the flywheel and coupling or coupling and gearbox.

Digital Multimeter
Required for all sea trials

Reliable and accurate Digital Multimeter for measuring electrical values and type K thermocouples. Caterpillar provides a range of multimeters with multiple options to meet various requirements. Reference the Caterpillar Dealer Service Tools Catalog for available options.

Infrared Thermometer (457-5269)
Required for all sea trials

Infrared Thermometer used for measuring surface temperatures.

***NOTE:** Infrared Thermometers should not be used in place of the Marine Sea Trial Adapter Group (464-1090). Surface temperatures are useful to help identify a potential issue but they are not a reliable and accurate tool to properly diagnose the health of a cooling system. If an IR Gun is used to record temperatures, then you must paint the part black and set the Emissivity = 1.0 to get an accurate reading.*

Fuel Flow Meter
Required for all sea trials

Caterpillar fuel flow meters are the most accurate and versatile measurement tool to aid the Caterpillar Marine Analyst in the evaluation of engine performance and fuel consumption during sea trials. Caterpillar fuel flow meters should be the preferred method to collect fuel consumption data over the fuel rate displayed via Cat ET or the engine display.

The Fuel Monitor System (FMS) is available in several different arrangements. Recommended part numbers are given below for engine families which have different expected fuel flow ranges.

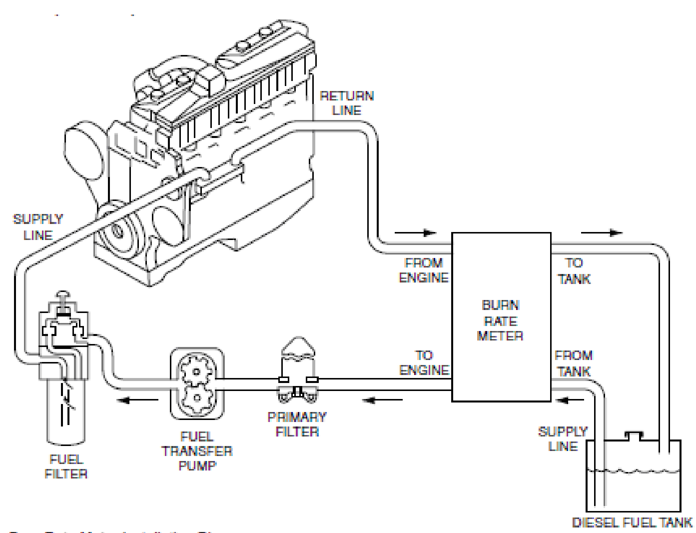
Part Number	*Engine Family*
368-9911	C18 and smaller
308-7271	C32 and larger

Always note the accuracy of the measuring tool when performing fuel flow measures. The accuracy of the meters can be calculated using the following formula:

±% Accuracy, Max. Error = (.5 x Supply Rate)(.5 x Return Rate) /Burn Rate

When it is installed and connected correctly, the Caterpillar Fuel Monitor System can provide accurate fuel flow measurements for Caterpillar marine diesel engines. Before installation and/or connection of the unit, locate the fuel supply and return lines for the engine, and determine the best location to make a connection. The fuel supply flow meter must be connected between the fuel supply tank and the fuel transfer pump. The return fuel flow meter must be connected into the fuel line that goes to the fuel tank. Use the hoses and connections from the hose adapter groups, as needed, to make these connections.

NOTE: *Make sure the area for fuel line disconnections and fuel monitor line connections is absolutely clean. No debris or paint chips must be permitted to enter the fuel system or the meters. When connecting a meter, always connect it so the flow of fuel is in the same direction as the fuel flow arrow on the side of the flow meter.*



Burn Rate Meter Installation Diagram

Water Manometer (8T-0452)
Optional for sea trials

The 8T-0452 water manometer provides an accurate measure of crankcase pressure and exhaust backpressure and can be made with a 2 ft (0.61 m) length of flexible clear plastic 3/8" (9.5 mm) I.D. tubing.

Vacuum/ Pressure Gauge (5P-6582)
Optional for sea trials

Provides the ability to measure small restriction values, particularly useful on the sea water pump inlet or air cleaner inlet restriction. Complete with 0.6 m (2 ft) of hose and 3 adapter fittings. The gauge has a multicolor dual scale dial with ranges from 0 to 68.9 kPa (0 to 10 PSI), 0 to 0.7 kg/cm2 (0 to 9.94 PSI) pressure and 0 to 70 cm (0 to 28 in) Hg vacuum.

Aftertreatment DEF Pressure Measurement Kit (528-1221)
Optional for Tier 4/IMOIII sea trials with DEF pressure measurements.

This kit is an add-on to the 464-1090 sea trial adapter kit and contains two quick coupler pressure sensors with 9/16-18 STOR stainless steel fittings which are compatible with DEF. These are intended to be used for taking measurements in the DEF system for Tier 4/IMOIII aftertreatment sea trials.

6.2.2 Optional Additional Tooling

It is recommended to use the digital sea trial tool kits listed above but in the event that manual measurements need to be taken, refer to Appendix A for a list of appropriate adapters and measurement tools.

6.3 User Interview

Before the sea trial test is performed, explain to the builder/installer and owner the purpose of the sea trial test. Discuss with them the systems that are to be evaluated, the expected results, and how the results are used to interpret performance conditions of the propulsion and auxiliary systems.

Before doing a sea trial performance evaluation, the vessel must have a load that is typical of the load that will be normally encountered. There should be at least a partial (safe manning requirement) crew on board to oversee operation of the vessel during the test period. The captain and crew should be notified of the test procedure and informed of what will be required of them during the test. During the test, it will be required to complete the captain's form from the bridge. This form can be found in LEBM0040 Sea Trial and Commission Tables.

6.4 Determine the Type of Sea Trial Test to be performed

There are 4 basic types of sea trials that can be performed. Refer to the following sections for details on when each sea trial is appropriate. A proper sea trial is required to verify correct installation as part of the marine commissioning procedure. The sea trial results must be uploaded to Service Interlink.

- Complete Sea Trial
- Pre-delivery OEM Sea Trial
- IMO III / EPA Tier 4 Aftertreatment Required Sea Trial
- Performance/Diagnostic Sea Trial

6.4.1 Complete Sea Trial

This is a comprehensive sea trial to analyze all the vessel touch points and some additional parameters. This sea trial is performed at the OEM or shipyard on new vessels for first hull of a production run, during any significant change to a production run, custom boat and/or re-powers on C32 and larger engines. This test uses Caterpillar Electronic Technician Sea Trial Data Logger to capture the data and CAMPAR to analyze the results and communicate a formal sea trial report to the customer.

The 900 number channels applicable to the sea trial are observed and recorded. Caterpillar fuel flow meters will be used during this sea trial to verify that the engine is operating to specifications and all systems are functioning properly. This sea trial is designed to be conducted on the first hull of a production run, a custom built vessel, a re-power or during any significant change to the hull or vessel loading. On a pleasure craft this sea trial includes a "transient" trial to measure the acceleration capability. This is usually not required on a commercial vessel.

NOTE: *Data from this sea trial must be uploaded to the Marine Service Interlink web database.*

Details on required measurements for the various subsystems are given in Section 8.3 Subsystem Analysis in CAMPAR Many data points can be obtained through Cat ET using on-engine sensors but some data must be taken manually. This varies depending on engine model and configuration.

6.4.2 Electronic Sea Trial

This is a sea trial that is normally preformed at the boat OEM using Caterpillar Electronic Technician Sea Trial Data Logger. This sea trial is conducted on new vessels to document basic performance and installation information for vessels. For C32 and larger engines, this type of sea trial is appropriate for subsequent hulls of a production vessel, after a complete sea trial has been completed on the first hull. For C18 and smaller engines, this type of sea trial is appropriate for all installations.

The procedure for this sea trial is not as thorough as a complete sea trial detailed in Section 6.4.1 and is used to provide the basic performance documentation. **This is the minimum level of sea trial which can be performed as part of a proper commissioning. Note that this is the minimum requirement, a Complete or Performance / Diagnostic Sea Trial may need to be performed depending on the circumstances.**

NOTE: *Data from this sea trial must be uploaded to the Marine Service Interlink web database.*

Before the sea trial, it is important to verify the latest software is installed in the ECM, check cooling system performance, engine performance, check for leaks, acceleration, and exhaust system performance. Along with measuring engine performance, engine vibration, stability and mounted component resonance should also be physically observed. Mounted components include items such as belt guard, remote mount key switch panels, any engine mounted gauges or other equipment.

If the engine(s) are not able to achieve rated engine speed (not including bollard tests), the engine speed and boost pressure data acquired should be evaluated against the fuel and boost curves provided in TMI using a CAMPAR analysis. The boost pressure generated by the engine(s) should be at specification +/- the spec tolerance as compared to the Max Power Curve. Exhaust temperatures may also be acquired during this sea trial for an added dimension of accuracy.

Please refer to Startup and Commissioning Checklists for Electronic Sea Trial checklists. Additionally, freeboard heights and draft must be taken and recorded. On a pleasure craft application, take aft measurements from the middle of the rubbing strip to the waterline. Take Forward (Bow) measurements from the middle of the rubbing to the waterline or on larger vessels from the top of the anchor plate to the waterline.

The Electronic sea trial includes all ECM measured parameters and no manual measurements. Based on the results of the sea trial, additional manual parameters may need to be measured to diagnose and correct installation issues.

6.4.3 Aftertreatment Emissions Compliance Sea Trial

This sea trial is **required** when commissioning an IMOIII or EPA Tier 4 engine equipped with aftertreatment. This sea trial is the **minimum required sea trial** for these engines, refer to section 6.4.1 for guidance on when a complete sea trial should be performed. A complete sea trial includes the requirements for this IMOIII / EPA Tier 4 required sea trial.

NOTE: *Data from this sea trial must be uploaded to the Marine Service Interlink web database.*

This sea trial includes all parameters described in Electronic Sea Trial along with the aftertreatment required parameters below. Some data is captured in CAT-ET but some must be captured manually. The relevant specifications for the system are available in TMI.

- **Caterpillar Emissions Module (CEM) Exhaust Inlet Temp (983):** This is measured at the inlet to the CEM. Temperatures must be high enough to enable proper dosing but remain below the maximum CEM module temperature limits.
- **Turbocharger to CEM Exhaust Temp Drop (912-983):** This is a change in temperature between the stack or engine outlet temp and the CEM exhaust inlet temp above. This temperature drop must remain below the maximum limit to ensure proper dosing.
- **Dosing Cabinet DEF Inlet Pressure (979):** This is measured at the inlet to the dosing cabinet. This is to ensure adequate DEF supply pressure to the system.
- **Dosing Cabinet to Nozzle DEF Pressure Drop (980-976):** This is a pressure drop measurement between the outlet of the dosing cabinet and the DEF pressure at the injection nozzle in the CEM. This is measured to verify the pressure drop in the vessel DEF piping is below the spec limit to ensure adequate DEF injection pressure.
- **Dosing Cabinet Air Outlet Pressure (978):** This is measured at the outlet of the dosing cabinet. This is to ensure adequate air pressure to the CEM for proper dosing.
- **Exhaust Pressure Drop Across CEM (984-985):** This is a pressure drop measurement between the CEM inlet and outlet pressure. This is to ensure the CEM is operating properly and is not imposing excessive restriction on the engine exhaust system.

Please refer to Section 8.3 of this document for more information on the CAMPAR calculations and details on what ports are ECM monitored.

6.4.4 Performance / Diagnostic Sea Trial

This is a test that should be conducted when troubleshooting performance related complaints or after performance related component changes. This test uses Caterpillar Electronic Technician Sea Trial Data Logger to capture the data and CAMPAR to analyze the results.

NOTE: *Data from this sea trial must be uploaded to the Marine Service Interlink web database.*

Remember that a Performance Sea Trial never gives a complete picture of the vessel propulsion system performance – only specific circuits. It can be used as a starting point to troubleshoot a performance issue, but deeper investigation may be required.

Prior to conducting a Performance Sea Trial, the dealer technician should determine which engine parameters are required to troubleshoot the performance complaint. Refer to LEDM0131 for a complete list of parameters.

6.4.5 Choosing the Correct Type of Sea Trial

It is the dealer’s responsibility to select the proper sea trial for the given engine installation

A Complete Sea Trial is required for the first hull of vessels with C32 and larger engines. For C18 and smaller engines, an Electronic Sea Trial only is required. Note that this is the minimum requirement, a Complete or Performance / Diagnostic Sea Trial may need to be performed depending on the circumstances. Additionally, an Aftertreatment Emissions Compliance Sea Trial is required on all engines equipped with IMO III or US EPA Tier 4 aftertreatment. Further detail on this is provided in the two tables below.

The table below provides a reference for the minimum required sea trial for engines ***without*** aftertreatment.

Engine Size	Custom Vessel, Repower or First Hull of Production Run	Subsequent Hulls of a Production Vessel
C18 and Smaller	Electronic Sea Trial	Electronic Sea Trial
C32 and Larger	Complete Sea Trial	Electronic Sea Trial

The table below provides a reference for the minimum required sea trial for engines ***with*** aftertreatment.

Engine Size	Custom Vessel, Repower or First Hull of Production Run	Subsequent Hulls of a Production Vessel
C18 and Smaller	Electronic Sea Trial and Aftertreatment Emissions Compliance Sea Trial	Electronic Sea Trial and Aftertreatment Emissions Compliance Sea Trial
C32 and Larger	Complete Sea Trial including Aftertreatment	Electronic Sea Trial and Aftertreatment Emissions Compliance Sea Trial

Some examples are provided below.

	Example	Correct Sea Trial
1	Twin 3516 propulsion engine installation in an offshore supply vessel. This vessel is the first vessel build of what will be 8 total vessels.	Complete sea trial
2	Twin 3516 propulsion engine installation in an offshore supply vessel. This vessel is the 6th vessel build of what will be 8 total vessels.	Electronic sea trial
3	C18 powered vessel is experiencing an overheating issue.	Performance/diagnostic sea trial
4	Tug with 3500 Tier 4 engines. First build of a new vessel design.	Complete sea trial including aftertreatment
5	Same as example 4 but a subsequent build of the same vessel design	Electronic sea trial ***AND*** Aftertreatment emissions compliance sea trial
6	Custom fishing boat with C9.3 engines, no aftertreatment	Electronic sea trial

6.5 Determine the Test Conditions

Before conducting the sea trial, consider the vessel application to determine if it is to be used in a towing or free-running operation. Application will determine if the propulsion segment of the sea trial is to be conducted under Bollard Pull (or Bollard Push) or normal (free-running) conditions. If vessel operation includes towing of kind, sea trial measurements should be taken while the vessel is towing its intended load. If testing under these conditions is not possible, a bollard pull test and a free running test are required to determine if the engine will attain rated RPM under full load conditions.

6.5.1 Free Running Test Guide

The main engines should be at operating temperature and capable of delivering full power and rpm before starting a free-running test. The vessel must remain in a “straight rudder” condition throughout the duration of the test

A major consideration before performing the sea trial test should be the selection of a test site that will ensure valid test results and minimal vessel downtime. The site should be convenient, and not obstructive to other marine traffic.

NOTE: *Pleasure-craft vessels should always be tested under free-running conditions.*

When performing a normal (free-running) test the vessel must have a load that is typical of the load normally encountered. This includes ensuring all fluid tank’s (Fuel, water, holding, ballast, etc.) onboard the vessel are full and all normal equipment and gear are onboard as well. If the vessel is not finished or the fluid tanks are not full, it’s advised to mimic the full vessel load with added ballast.

The test site must have adequate water depth and be long and wide enough to permit “straight rudder” throughout the duration of the test with minimum hull load from shallow water effect. The sea should be in a calm state to ensure good data.

Best practice for completing a free-running sea trial is to make two passes – one being with the current, the other against. This help to ensure the engine and propeller are sized and loaded correctly under different operating conditions.

Expected full load engine rpm should be within 1 to 3% over rated rpm, with nominal or rated rpm being the minimum allowable. Full throttle rpm of less than rated rpm is an indication of incorrect propulsion system sizing and/or excessive loads.

6.5.2 Bollard Pull Test Guide

Bollard pull is the zero speed pulling capability of a vessel (i.e., tug or AHTS). Ideally, a bollard pull test is completed once the vessel is built and is then certified by one of the marine classification societies. Bollard pull tests are also sometimes performed after major engine overhauls.

NOTE: *Experience has shown that conditions where bollard pull testes are usually conducted are not ideal for performance of the other engine system tests. Other sea trial measurements, therefore, should be made under free running conditions.*

Refer to publication Marine Commissioning Procedure: Bollard Pull Test Guide (LEGM0006) for information regarding Bollard Pull Testing. This document can be found on Caterpillar Electronic Media Center (EMC).

6.5.3 Auxiliary / Genset Test Guide

In addition to evaluating the propulsion system’s performance, the sea trial includes an evaluation of auxiliary systems. Most auxiliary performance evaluations can be conducted dockside, under the intended load at rated speed. The crew should be notified of the test procedure, and informed as to what will be required of them during the test. Use Cat ET to record all information, physical description, and performance data. For load step checklist and start-up checklists, please refer to the Appendix.

Generally, the load required with the vessel at mooring is only a fraction of the power demanded when in operation; reserve some time during sea trial to test the different generator sets with real loads and the load sharing apparatus. However, the best option to test the generator set packages is using a load bank, usually available from the shipyard.

7. Sea Trial Data Acquisition

This section outlines the data acquisition portion of the sea trial, including how to set up the Caterpillar ET General Information file, the Steady-State file, and guidance on the operating procedure for acquiring the sea trial data. One should be familiar with Caterpillar ET General Information files and Steady-State ".set" files prior to performing a sea trial.

7.1 Preparing for the Sea Trial

Before conducting the sea trial, it is important to understand what on-engine data points need to be captured and understand which points are measured by the ECM and which need to be measured manually. Since each engine is different in terms of what 900 numbers are required, ECM measured parameters and availability of ports, it is important to put together a plan before getting on the vessel for the sea trial. Below is a guide to a recommended method of preparing for the sea trial.

1. Refer to LEDM0131 for a complete list of 900 numbers. There is an embedded Excel file in this publication which can be used for creating a custom list of 900 numbers required for a sea trial.
2. Determine the type of sea trial being performed. If a Pre-Delivery OEM or Aftertreatment Emissions Compliance sea trial are being performed then refer to Sections **Error! Reference source not found.**~~6.4.2~~ or 6.4.3 respectively for details on which 900 numbers need captured. If a Complete Sea Trial is being performed, then the 900 numbers which need captured varies based primarily on engine cooling system configuration.
3. Utilize the embedded excel file in LEDM0131 to start a list of what 900 numbers need captured. For the Complete Sea Trial, work through each subsystem in Section 8.3 and mark in the sheet which 900 numbers need to be measured.
4. Look through the specific engine configuration or schematic to determine which locations are measured by an ECM sensor and which need to be measured manually.
5. Refer to the installation drawings in EDDC to determine the locations and thread sizes of ports for manual measurements.
6. All this can be marked in the LEDM0131 excel file and then filtered to create a complete list of 900 number measurement requirements for the sea trial.

An example of this is shown below for a complete sea trial on a C32 keel cooled engine. Note this is not a complete list, only 900 numbers through 920 are shown.

Following the steps above, column H has been populated per step 3 above using Section 8.3. In step 4, based on the ECM sensors on this engine column E has been populated. Note that as shown by 912B and 912D some sensors may be optional and not installed on every engine.

These 900 numbers are filtered on Column D to show only the 900 numbers which need measured. This can be filtered further to show only those for which a manual measurement is required.

	A	B	C	D	E	F	G	H
1	General System Designation	900	Description	Required for C32 Tier 4 Keel Cooled	ECM Value	Port Location	Port Size	Notes
3	JW Temp	901	Jacket water engine outlet temperature (before regulators)	Required	Yes	n/a	n/a	
4	JW Temp	902	Jacket water engine inlet temperature	Required	No	Pump Inlet	1/8-27 NPTF	Same as 921
5	AC Temp	903	Aftercooler water inlet temp to engine	Required	No	Pump Inlet	1/2-20 STOR	Same as 904
6	AC Temp	903A	Aftercooler water outlet temp from engine	Required	No	Outlet Casting near Shunt	1/2-20 STOR	
9	AC Temp	904	Aftercooler / Auxiliary low temp pump inlet pressure (treated water)	Required	No	Pump Inlet	1/2-20 STOR	Same as 903
11	Air Temp	906	Intake air manifold temperature	Required	Yes	n/a	n/a	
12	Air Press	907	Air cleaner inlet restriction (single or RH)	Required	Yes	n/a	n/a	
13	Air Press	907A	Air cleaner inlet restriction (LH)	Required	Yes	n/a	n/a	
14	Exhaust Press	908	Exhaust engine outlet stack pressure	Required	No	Stack		Installed on vessel stack piping
15	Speed	910	Engine speed	Required	Yes	n/a	n/a	
16	Air Press	911	Intake air manifold pressure	Required	Yes	n/a	n/a	
17	Exhaust Temp	912	Exhaust engine outlet stack temperature	Required	Yes	n/a	n/a	
19	Exhaust Temp	912B	Exhaust manifold right rear turbo temp	Optional	Maybe	n/a	n/a	ECM Sensor Installed on this engien
21	Exhaust Temp	912D	Exhaust manifold left rear turbo temp (or low pressure turbo)	Optional	Maybe	n/a	n/a	ECM Sensor Installed on this engien
22	Oil Temp	913	Engine oil to bearings temp	Required	Yes	n/a	n/a	
23	Oil Press	914	Engine oil to bearings pressure	Required	Yes	n/a	n/a	
26	Fuel Press	917	Engine fuel pressure (after filters)	Required	Yes	n/a	n/a	
29	JW Press	920	Jacket water pump inlet pressure	Required	No	Pump Inlet	1/8-27 NPTF	Same as 902

7.2 Configuring the General Information File

Use the General Information file within the Caterpillar Electronic Technician to record all physical aspects of the vessel being tested. At this point, begin the test by recording fuel gravity (API), sea water depth and temperature, and ambient and engine room air temperature. Check all fluid levels and add fluid where necessary. If applicable, intake and exhaust valve clearances and engine fuel timing must be measured, recorded, and corrected as necessary. When performing a Complete Sea Trial on 3500, C175, and 3600 engines measure crankshaft deflection (cold) at the crankshaft center throw (refer to Special Instruction SEHS7654 and LEKM7301 for 3600 engines).

Install the diagnostic tooling needed according to the tests that are to be performed. A list of tools required can be referenced in section 6.2 of this manual.

To conduct a thorough sea trial, there are two steps for most commercial vessels and three steps for pleasure craft vessels that must be completed:

- General Information
- Sea Trial Steady State
- Sea Trial Transient (usually pleasure craft only)

The General Information file contains vessel information such as:

- Vessel type, name, home port, customer, builder and dealer
- Hull type, lengths, displacement, and fluid capacities
- Required pre-test data including fuel API, sea water, engine room and ambient temperatures.
- Marine gear and propeller information if applicable
- Engine information

When entered in the general info file, this data will automatically be imported into CAMPAR for the sea trial analysis. If this data is not entered in the general info file, it can be added directly into CAMPAR during the analysis.

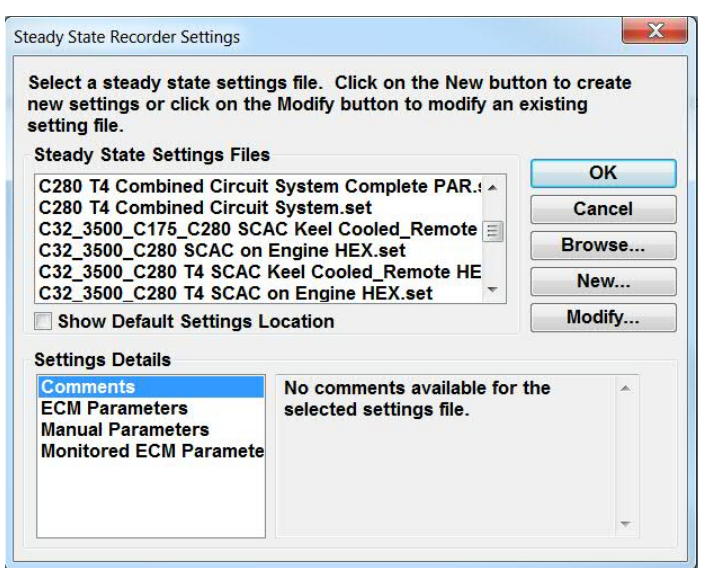
NOTE: *To complete the General Text file, the laptop and communications adapter must be connected to the ECM(s) with the ECM(s) powered.*

The General Information file can be uploaded to CAMPAR, via the Marine Service Interlink page, once completed or along with the steady state file once the sea trial is complete.

7.3 Configuring the Steady State File

The CAT-ET tool comes pre-loaded with steady state recorder files which are referred to as .set files. These are configured for various electronic engine configurations, an example list can be found below. The measurement points are grouped into “optional” and “required” parameters. The list of required parameters should be considered as the minimum list required for a full CAMPAR Analysis. Additional parameters from the optional list may be included as necessary for a specific analysis.

Custom .set files can be created from a blank template or by creating a copy of an existing file and making modifications for specific sea trial analysis. **<u>When running a CAMPAR analysis, pre-loaded .set files must be used. Do not use custom .set files when running a CAMPAR analysis.</u>** The CAMPAR tool looks for specific 900 numbers which must be included in the uploaded file in order to generate an analysis. Using custom .set files may prevent them from properly importing into CAMPAR and a manual sea trial will need to be created.



7.4 Vessel Operating Procedure for Acquiring Sea Trial Data (Propulsion Applications)

The frequency of data points acquired is dependent upon the rated engine speed. Refer to the following description for the engine speeds at which data points are to be taken:

- Engines rated up to 1400 rpm — Low idle, then 600 rpm and every 100 rpm up to full throttle.
- Engines rated between 1401 to 1800 rpm — Low idle, then 1000 rpm and every 100 rpm up to full throttle.
- Engines rated 1801 and above — Low idle, then 1000 rpm and every 200 rpm up to 300 rpm below rated. Then every 100 rpm to full throttle.

Once the sea trial has begun, move the throttle lever to a position to achieve the desired engine speed and allow the engine speed to stabilize. This is necessary to obtain accurate steady state values.

For the best results, acquire the entire data run traveling in one direction. Currents and wind have a definite factor in boat performance and engine loading.

NOTE: *With derate enabled in the Programmable Monitoring System (PMS), Tier 3 C18 and C32 marine engines will experience derate in certain Ambient Air Temperature or SCAC Water Temperature situations. Ambient capability charts for applicable engine serial numbers can be found in TMI. Complete PMS tables can be found in SIS Web.*

NOTE: *After completion of a Complete PAR on all 3500, C175, and 3600 engines again record crankshaft deflection at the crankshaft center throw while the engine is at operating temperature. Refer to Special Instruction SEHS7654. For additional 3600 instruction, refer to the 3600 A&I Guide LEKM7301.*

7.5 Vessel Operating Procedure for Acquiring Sea Trial Data (Fixed-speed Applications)

The engine should be operated until it and related systems are at normal operating temperatures. Prior to beginning the sea trial, the engine room hatch must be closed, After the engine is at operating temperature and the correct operation of all supply systems is verified, the test can begin.

The best way to sea trial a fixed speed application is to utilize a load bank and load the engine in steps of 0, 25, 50, 75 and 100% load. A 110% load step for the duration of one hour might be required by some classification societies, but this 110% test is normally completed on the test bench at the dealership. It is understood that a load bank may not be feasible for all applications. In this case, it is recommended to simulate intended operational load utilizing the powered equipment on board to load the engine. Note that the Sea Trial data provided in TMI and utilized in the CAMPAR analysis is taken at maximum load conditions, typically 110% standby load.

In addition to the engine parameters recorded through CAT-ET, the additional parameters below should be recorded on the generator, if equipped, and entered in CAMPAR in the fixed speed load test tab.

- Actual Electric Power (ekW)
- Voltage
- Amperes
- Frequency
- Power Factor
- Generator Bearing Temperatures
- Generator Stator Temperature

NOTE: *With derate enabled in the Programmable Monitoring System (PMS), Tier 3 C18 and C32 marine engines will experience derate in certain Ambient Air Temperature or SCAC Water Temperature situations. Ambient capability charts for applicable engine serial numbers can be found in TMI. Complete PMS tables can be found in SIS Web.*

NOTE: *After completion of a Complete PAR on all 3500, C175, and 3600 engines again record crankshaft deflection at the crankshaft center throw while the engine is at operating temperature. Refer to Special Instruction SEHS7654. For additional 3600 instruction, refer to the 3600 A&I Guide LEKM7301.*

7.6 Sea Trial Data Capture

Sea trial data should be captured at the various speed or load points detailed in Section 7.4~~7.3~~ or 7.5~~7.4~~ depending on the engine application. Once the test point is reached, the engine should be allowed to reach a steady state operation condition. This can take in excess of 5 minutes depending on the engine and the application. Once the engine parameters have reached a steady state operating condition, the data run can be captured.

Note that many of the parameters are recorded directly from the on-engine sensors and reported through the ECM. However on CAT-ET 2017C and earlier, these recorded parameters do not directly link to the 900 numbers and their values must be entered manually in the list of 900 numbers in the file. On CAT-ET 2018A and later versions of CAT-ET, this has been updated to automatically populate these parameters down to their appropriate 900 numbers.

NOTE: *The CAMPAR tool utilizes the values associated with 900 numbers, not the ECM captured data.*

Monitored Parameters	Unit	
Engine Speed	rpm	1925
Active Diagnostic Codes Present		No
Engine Coolant Temperature	Deg F	230
Fuel Consumption Rate	gal/h	1.3

> ***For 2017C and earlier CAT-ET: The top section contains ECM monitored data. This data must be copied down to its appropriate 900 number.***
>
> For example, "Engine Coolant Temperature" equates to 901. This value should be copied down.

Captured Parameters		
Active Codes Present During Capture		
C32 ACERT Starboard		
Engine Speed within +/- 20 RPM		
C32 ACERT Starboard		
Fuel Pressure		
C32 ACERT Starboard		
Boost Pressure		
C32 ACERT Starboard		65
Engine Oil Pressure	psi	
C32 ACERT Starboard		30
Engine Coolant Temperature	Deg F	
C32 ACERT Starboard		230
Fuel Temperature	Deg F	
C32 ACERT Starboard		84
Engine Load Factor	%	
C32 ACERT Starboard		0
Right Exhaust Temperature	Deg F	
C32 ACERT Starboard		Disabled or Not Installed
Left Exhaust Temperature	Deg F	
C32 ACERT Starboard		Disabled or Not Installed
Fuel Consumption Rate	gal/h	
C32 ACERT Starboard		1.3
Engine Oil Temperature	Deg F	
C32 ACERT Starboard		Disabled or Not Installed
Transmission Oil Temperature	Deg F	
C32 ACERT Starboard		185
Transmission Oil Pressure	psi	
C32 ACERT Starboard		0
Inlet Air Temperature	Deg F	
C32 ACERT Starboard		87
901 JW Outlet Temperature (Before Reg)	Deg F	
C32 ACERT Starboard		

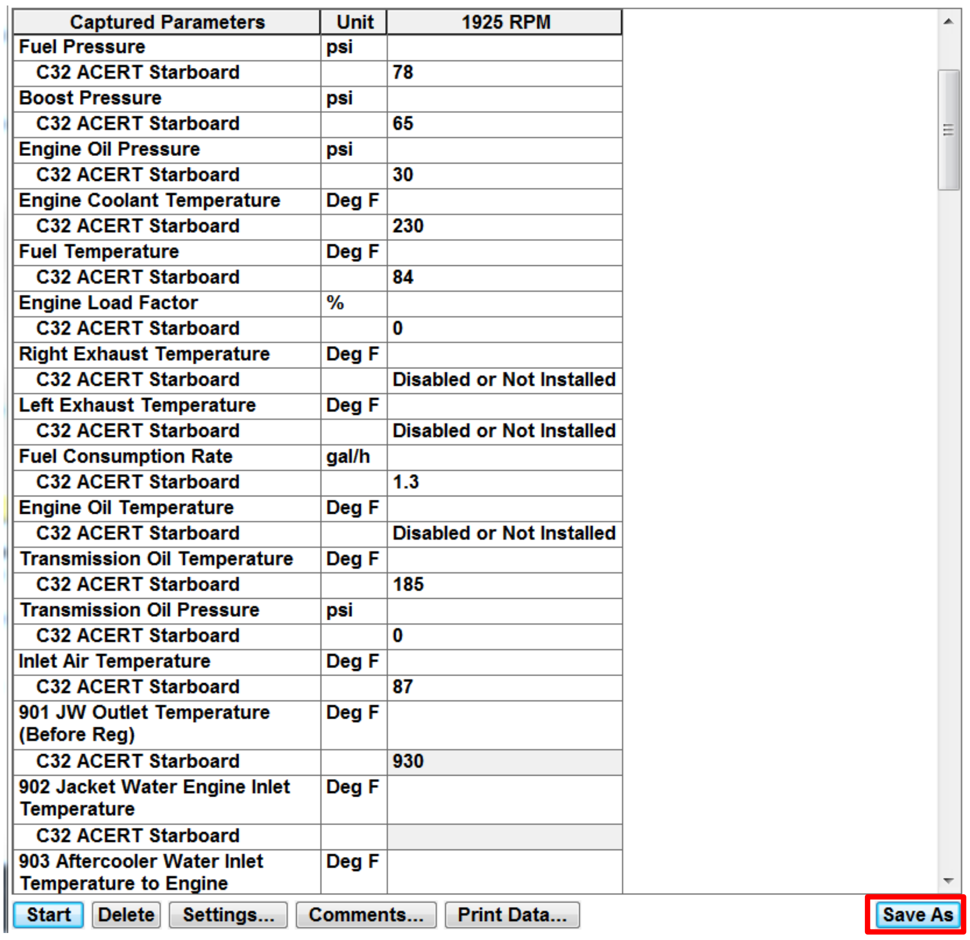
Monitored Parameters	Unit	
Engine Speed	rpm	1925
Active Diagnostic Codes Present		No
Engine Coolant Temperature	Deg F	230
Fuel Consumption Rate	gal/h	1.3

Captured Parameters		
Engine Speed		
Starboard (RNC00001)		
Active Codes Present During Capture		
Starboard (RNC00001)		No
Engine Speed within +/- 20 RPM		
Starboard (RNC00001)		Yes
Fuel Pressure	psi	
Starboard (RNC00001)		78
Boost Pressure	psi	
Starboard (RNC00001)		65
Engine Oil Pressure	psi	
Starboard (RNC00001)		30
Engine Coolant Temperature	Deg F	
Starboard (RNC00001)		230
Fuel Temperature	Deg F	
Starboard (RNC00001)		84
Engine Load Factor	%	
Starboard (RNC00001)		0
Right Exhaust Temperature	Deg F	
Starboard (RNC00001)		Disabled or Not Installed
Left Exhaust Temperature	Deg F	
Starboard (RNC00001)		Disabled or Not Installed
Fuel Consumption Rate	gal/h	
Starboard (RNC00001)		1.3
Engine Oil Temperature	Deg F	
Starboard (RNC00001)		Disabled or Not Installed
Transmission Oil Temperature	Deg F	
Starboard (RNC00001)		185
Transmission Oil Pressure	psi	
Starboard (RNC00001)		0
Inlet Air Temperature	Deg F	
Starboard (RNC00001)		87
901 JW Outlet Temperature (Before Reg)	Deg F	
Starboard (RNC00001)		230

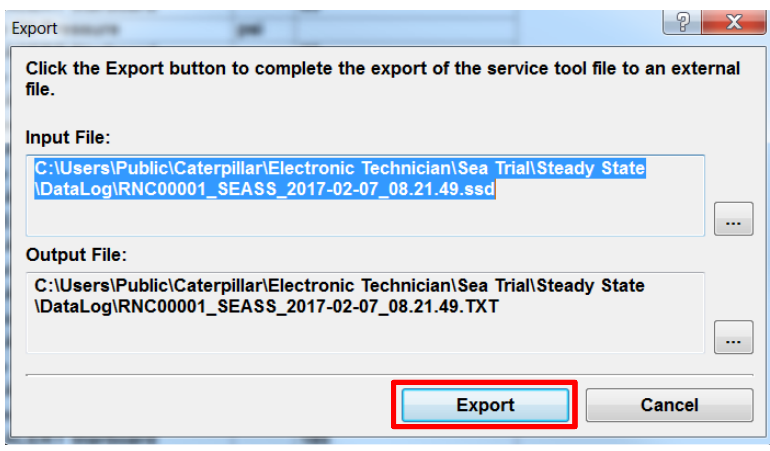
For 2018A and later CAT-ET: These ECM values are automatically copied down to their respective 900 numbers. Example below showing Engine Coolant Temperature to 901.

Once this data has been fully entered, the engine can be taken to the next speed or load step to repeat the process. Once data capture has been completed, the file should be exported using the “Save As” button in bottom right hand corner to create the steady state text file. After the .ssd file is created, a dialogue box will pop up allowing the user to export the .ssd file to a .txt file. Select “Export” to create this file.

NOTE: *The CAMPAR tool utilizes the .txt file for import into the tool.*



Captured Parameters	Unit	1925 RPM
Fuel Pressure	psi	
C32 ACERT Starboard		78
Boost Pressure	psi	
C32 ACERT Starboard		65
Engine Oil Pressure	psi	
C32 ACERT Starboard		30
Engine Coolant Temperature	Deg F	
C32 ACERT Starboard		230
Fuel Temperature	Deg F	
C32 ACERT Starboard		84
Engine Load Factor	%	
C32 ACERT Starboard		0
Right Exhaust Temperature	Deg F	
C32 ACERT Starboard		Disabled or Not Installed
Left Exhaust Temperature	Deg F	
C32 ACERT Starboard		Disabled or Not Installed
Fuel Consumption Rate	gal/h	
C32 ACERT Starboard		1.3
Engine Oil Temperature	Deg F	
C32 ACERT Starboard		Disabled or Not Installed
Transmission Oil Temperature	Deg F	
C32 ACERT Starboard		185
Transmission Oil Pressure	psi	
C32 ACERT Starboard		0
Inlet Air Temperature	Deg F	
C32 ACERT Starboard		87
901 JW Outlet Temperature (Before Reg)	Deg F	
C32 ACERT Starboard		930
902 Jacket Water Engine Inlet Temperature	Deg F	
C32 ACERT Starboard		
903 Aftercooler Water Inlet Temperature to Engine	Deg F	



After the Sea Trial has been completed, the General Info file along with the Steady State file should be uploaded into Service Interlink to begin the CAMPAR analysis procedure described in Section 8. Additionally, the Start-Up and Commissioning Checklist should be uploaded into Service Interlink, if not already, and attached to the vessel record.

8. CAMPAR for Data Analysis

8.1 Introduction

The CAMPAR tool should be used to analyze the results of the sea trial. The tool, along with documentation, support and training is available at the CAMPAR Powernet site.

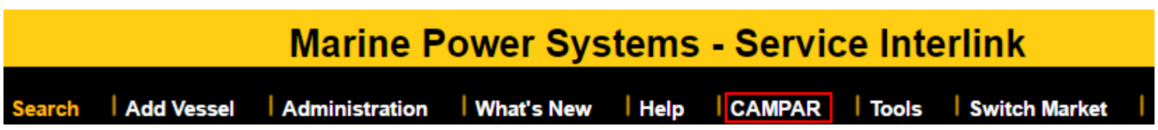
The following sections will give a brief overview of the tool which can be used as a reference.

The CAMPAR tool functions by comparing the data captured during the sea trial against the published specifications which can be viewed in the Sea Trial Data tab in TMI for a specific serial number. Note that the data provided in the Sea Trial Data tab in TMI is representative of a full speed, full load engine running condition. For variable speed engines, this is a 100% load condition, for fixed speed auxiliary and generator set engines, this is the 110% standby power point. This data in TMI should be referenced when evaluating the results of the CAMPAR analysis.

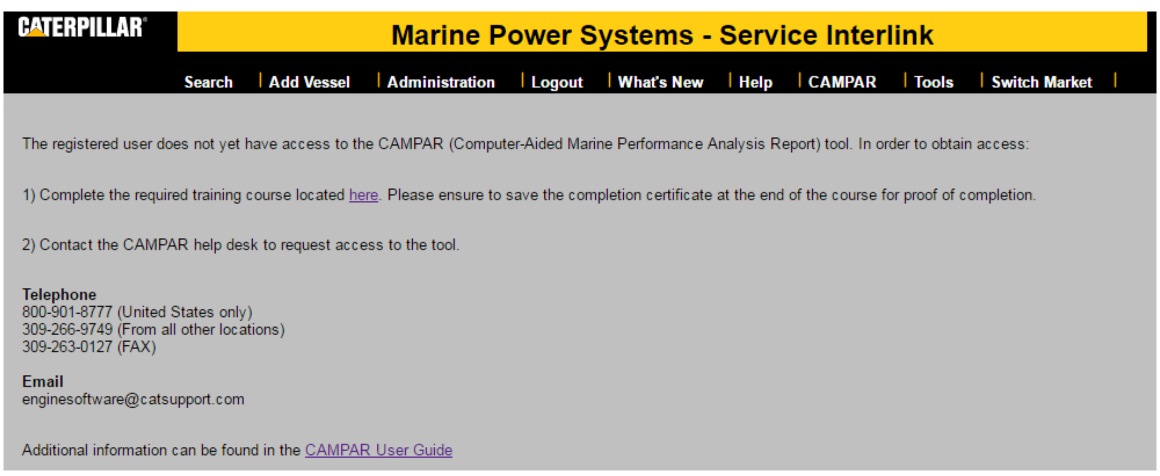
8.2 CAMPAR Navigation

8.2.1 Accessing CAMPAR

CAMPAR can be accessed through Marine Service Interlink via the tab on the top labeled “CAMPAR”.



If the current user does not have access to CAMPAR, this page will display a message detailing what must be don’t obtain access:



A link to a training video is provided. Once this training has been completed, contact the help desk via phone or email to obtain access to the tool.

Once the user has access, the CAMPAR tab in Service Interlink will display the CAMPAR home page. At the top of this page, links are provided to the CAMPAR User Guide as well as CAMPAR Powernet site where additional resources are located.

8.2.2 Creating a CAMPAR Analysis

This CAMPAR homepage provides three options for creating a sea trial:

- **Add a new sea trial in CAMPAR from local CAT ET files –** This is the most common choice to create a CAMPAR analysis after a sea trial has been run using CAT-ET as described in Section 7 Sea Trial Data Acquisition. To create this analysis, CAMPAR requires the user to upload a General Info .txt file and a Steady State .txt file.
- **View existing analysis or import CAT ET files from Service Interlink –** This choice is appropriate if the CAT ET files have previously been uploaded or if an analysis has been started but not finalized. Once this is selected, the user can search based on serial number to find uploaded CAT ET files. Additionally, CAMPAR will display the 5 most recent vessels the current user has created and the 5 most recent analysis the user has modified for quick access.

- **Add a new manual sea trial in CAMPAR –** This choice is appropriate if one or both of the CAT ET files were not generated during the sea trial. CAMPAR will prompt the user to enter serial numbers before continuing and all sea trial data will need to be entered manually.

Once an analysis is started, the user will need to link the analysis to a vessel record or, if a vessel record doesn't exist, a new one can be created. Everything in Service Interlink, including CAMPAR reports are linked to vessel records.

CAMPAR can analyze up to two engines in a single report. If creating a CAMPAR analysis from CAT ET files, both engines must be included in the same General Info and Steady State .txt files. If the engines are in separate files, separate analysis' can be created or a manual analysis can be created to combine the two sets of data.

8.2.3 Overview of CAMPAR Navigation and Screens

Once the CAMPAR analysis is started and linked to a vessel record the CAMPAR analysis screen will be shown. Refer to the CAMPAR User Guide for further details on navigating the tool.

8.3 Subsystem Analysis in CAMPAR

8.3.1 Cooling Systems

There are a wide variety of cooling systems across Caterpillar engines, each of which requires unique analysis to properly evaluate the cooling system and diagnose potential issues. The CAMPAR analysis is intended to diagnose both issues internal to the engine as well as vessel-side issues which may negatively impact the performance of the engine cooling system. In each configuration, temperature and pressure measurements are used to diagnose potential issues. The CAMPAR analysis is intended to bring attention to potential installation concerns, but not necessary provide a full troubleshooting instruction. In many cases, additional investigation in addition to what is provided through CAMPAR may be required to identify root cause and implement corrective action.

When completing a CAMPAR analysis, there are prompts on the Pre-Test tab to determine the cooling system. Depending on what is selected, the input data required and calculations performed will change. The guide below along with the cooling systems A&I guide LEBW4978 should be used when understanding the output of the CAMPAR tool.

Because the calculations and comparisons required vary depending on the type of cooling system equipped on the engine being tested, CAMPAR requires the user to make a selection for the type of aftercooler and heat exchanger or keel cooler system on the CAMPAR Pre Test tab. Selecting the correct configuration is critical to ensure the CAMPAR outputs are correct and the guide below is intended to provide guidance on these selections.

Aftercooler System:

- **Naturally Aspirated, Non-Aftercooled (NA):** This refers to legacy engine models which are not turbocharged or not aftercooled. Selection of this option disables calculations related to the aftercooler system.
- **Jacket Water Aftercooled (JWAC):** This refers to legacy engine models which use the jacket water circuit to provide cooling water for the aftercooler. Selection of this option disables calculations related to the aftercooler system.
- **Seawater Aftercooled (SWAC):** This refers to engines where seawater or raw water provides cooling directly to the aftercooler. This is the case on pleasure craft engines such as the C8.7, C18 and C32 as well as heat exchanger cooled EPA Tier 2 commercial C18 and C32 models and all C9.3 engines.
- **Separate Circuit Aftercooled (SCAC):** This refers to engines where treated water provides cooling water to the aftercooler. This applies to on-engine heat exchanger cooled engines with a dedicated, treated water aftercooler circuit and all keel cooled engines.
- **Air to Air Aftercooled (ATAAC):** This applies only to some radiator cooled engines in which the charge air is cooled directly in the radiator without a coolant loop in between. Selection of this option disables calculations related to the aftercooler system.

If there is uncertainty about the aftercooler system configuration of an engine, contact the Application Support Center (ASC). The NA and JWAC systems are legacy and not addressed extensively in the CAMPAR tool or this guide. For additional information and troubleshooting directions, refer to the legacy Sea Trial Guide (LEBM5081) and the Cooling Systems A&I Guide (LEBW4978).

Heat Exchanger or Keel Cooler System:

- **On Engine Heat Exchanger:** This is commonly referred to as a heat exchanger cooled engine. This engine configuration has a jacket water and possibly an aftercooler heat exchanger installed on the engine.
- **Keel or Remote Heat Exchanger, Separate Circuit:** This is commonly referred to as a keel-cooled engine. This engine configuration requires two vessel heat exchangers or keel coolers to provide cooling water to the jacket water system and aftercooler in separate circuits.
- **Keel or Remote Heat Exchanger, Combined Circuit:** This is also commonly referred to as a heat exchanger. The engine configuration requires a single vessel heat exchanger or keel cooler to provide cooling water to both the jacket water and aftercooler system in a single, combined circuit.
- **Radiator:** This system utilizes an air-cooled radiator to cool the jacket water and aftercooler circuits.

If there is uncertainty about the heat exchanger or keel cooler configuration of an engine, contact the Application Support Center (ASC).

8.3.2 Jacket Water System

There are two major types of jacket water cooling systems which are differentiated by the location of the regulator: inlet controlled and outlet controlled. This information is provided in the Sea Trial Data tab in TMI under Additional Data and automatically imported into CAMPAR.

With an outlet controlled system, the regulator or thermostat is typically located at the outlet of the cylinder head and the split of flow between the cooling system and bypass is dictated by the temperature of coolant out of the engine. On an inlet controlled system, the regulator is positioned prior to the inlet of the pump and the split of flow is dictated by the temperature into the coolant into the engine.

The measurements required for sea trial differ between (1) keel or remote heat exchanger and (2) on-engine heat exchanger configurations.

8.3.2.1 Keel or Remote Heat Exchanger

For this configuration, the CAMPAR tool analyzes the vessel touch points to the jacket water cooling system as well as temperature of the system. Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. **The points in the table below are required for a complete sea trial, additional points may be required for running a diagnostic sea trial. Refer to the system diagrams and complete 900 number list.**

A typical outlet controlled system diagram with 900 numbers labeled is shown in Figure 1 and a typical inlet controlled system diagram with 900 numbers labeled is shown in Figure 2. Refer to engine specific installation drawings for the 900 number port location on that particular engine.

The jacket water system analysis for keel or remote heat exchanger cooled utilizes the data parameters shown below.

900 Number/ Abbreviation	Name	Notes
SWTA	Seawater temp (actual)	Measured sea water temperature during sea trial testing.
SWTD	Seawater temp (design)	Designed maximum sea water temperature
901	Jacket water engine outlet temperature (before regulators)	This is the engine coolant temperature leaving the engine.
902	Jacket water engine inlet temperature	On outlet controlled engines, this may be measured at the same location as 922
920	Jacket water pump inlet pressure	
921	Jacket water pressure from cooling system	
922	Jacket water temp from HEX outlet	On outlet controlled engines, this may be measured at the same location as 902
948	Jacket water pressure to cooling system from engine (HEX inlet)	

The calculations performed by the CAMPAR jacket water system analysis are below:

- Coolant outlet temperature
- Estimated coolant outlet temperature at design conditions
- Coolant temperature rise across engine
- Jacket water external restriction
- Jacket water pump inlet restriction

NOTE: *Estimated coolant outlet temperature at design conditions utilizes sea water temperature measurements as part of the performance calculations. This calculation assumes a fully open thermostat at the test conditions.*

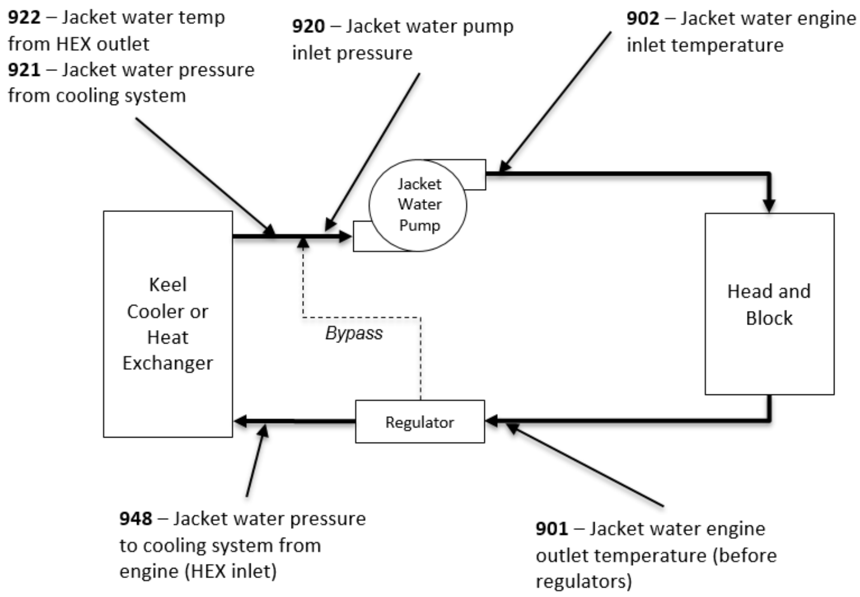


Figure 1: Outlet controlled, keel or remote heat exchanger.

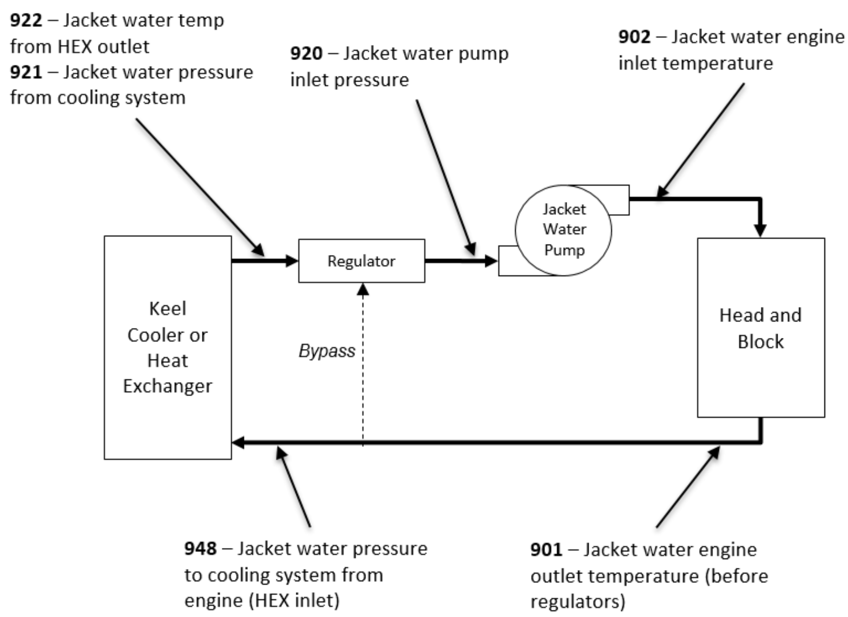


Figure 2: Inlet controlled, keel or remote heat exchanger.

8.3.2.2 On-Engine Heat Exchanger

For this configuration with a heat exchanger installed from the factory, there are no vessel touch points to analyze. Therefore points only need taken to evaluate temperature of the system. Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. **The points in the table below are required for a complete sea trial, additional points may be required for running a diagnostic sea trial. Refer to the system diagrams and complete 900 number list.**

A typical outlet controlled system diagram with 900 numbers labeled is given in Figure 3. A typical inlet controlled system diagram with 900 numbers labeled is given in Figure 4. Refer to engine specific installation drawings for the 900 number port location on that particular engine.

The jacket water system analysis for keel or remote heat exchanger cooled utilizes the data parameters shown below.

900 Number/ Abbreviation	Name	Notes
SWTA	Seawater temp (actual)	Measured sea water temperature during sea trial testing.
SWTD	Seawater temp (design)	Designed maximum sea water temperature
901	Jacket water engine outlet temperature (before regulators)	This is the engine coolant temperature leaving the engine.
902	Jacket water engine inlet temperature	On outlet controlled engines, this may be measured at the same location as 922

The calculations performed by the CAMPAR jacket water system analysis are below:
- Coolant outlet temperature
- Estimated coolant outlet temperature at design conditions

NOTE: *Estimated coolant outlet temperature at design conditions utilizes sea water temperature measurements as part of the performance calculations. This calculation assumes a fully open thermostat at the test conditions.*

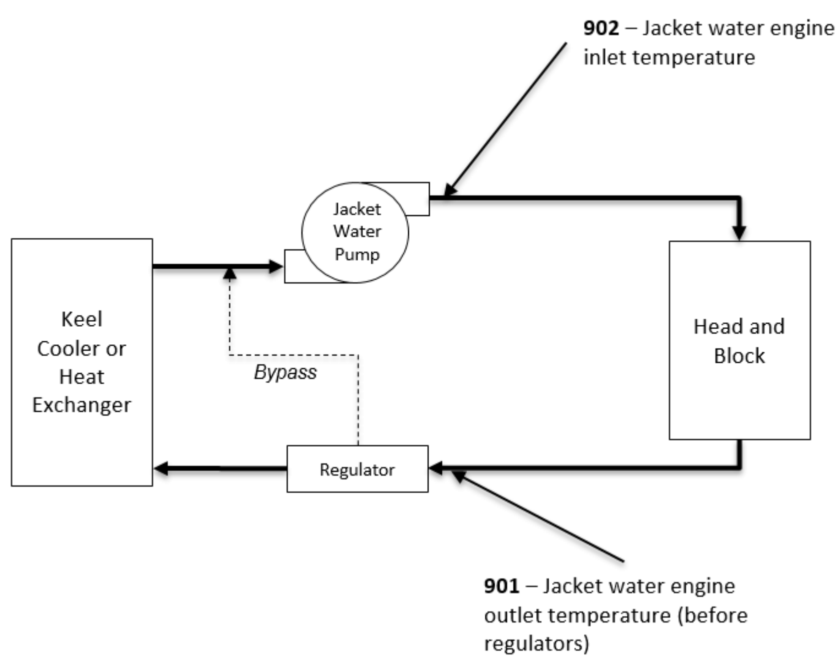


Figure 3: Outlet controlled, on-engine heat exchanger.

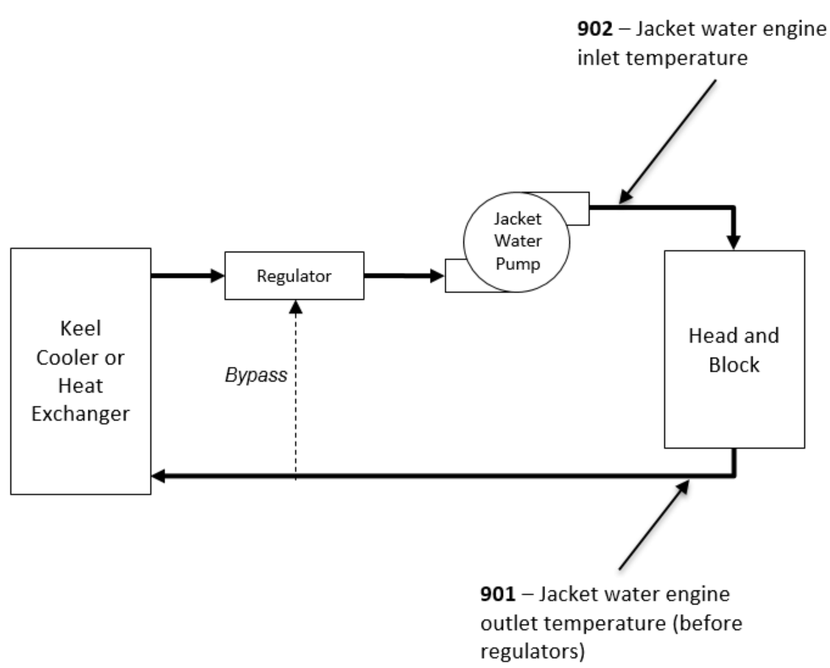


Figure 4: Inlet controlled, on-engine heat exchanger.

8.3.3 Aftercooler System

There are two primary types of aftercooler systems on current marine engines: Seawater Aftercooled (SWAC) and Separate Circuit Aftercooled (SCAC). Details of these two cooling systems are given in the sections below and CAMPAR will perform different calculations for each of these.

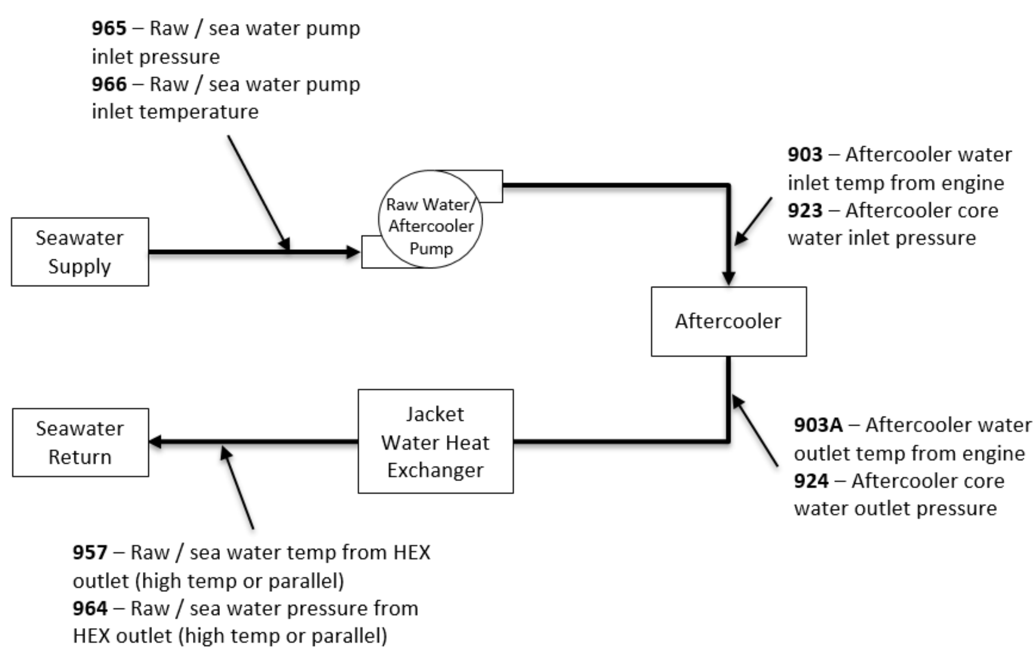
Legacy marine engines may be equipped with either a naturally-aspirated (NA) system or a jacket water aftercooled system (JWAC). CAMPAR will not perform calculations specific to these two systems and a manual sea trial process should be used to analyze them. Refer to the legacy Sea Trial Guide (LEBM5081) and the Cooling Systems A&I guide (LEBW4978) for additional details on these systems.

Some marine radiator packages may utilize an air-to-air aftercooled system (ATAAC). CAMPAR will only analyze the intake manifold air temp (IMAT) in this case which is part of the air system.

8.3.3.1 Sea Water Aftercooled (SWAC)

The SWAC system routes sea water or raw water directly through the aftercooler, and then to the jacket water heat exchanger. This type of cooling system typically provides lower temperatures to the aftercooler than a SCAC system. This is common on smaller engines and high performance engines. In this system, the raw water and aftercooler cooling system are one and analyzed as a single system.

A typical SWAC system diagram with 900 numbers labeled is given below. Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. **The points in the table below are required for a complete sea trial, additional points may be required for running a diagnostic sea trial. Refer to the system diagrams and complete 900 number list.**



The SWAC system analysis utilizes the data parameters shown below.

900 Number/ Abbreviation	Name	Notes
SWTA	Seawater temp (actual)	Measured sea water temperature during sea trial testing
SWTD	Seawater temp (design)	Designed maximum sea water temperature
903	Aftercooler water inlet temp from engine	Temperature of water into the aftercooler. On some engines, this may be the same as 966.
903A	Aftercooler water outlet temp from engine	Temperature of water out of the aftercooler, into the jacket water heat exchanger
923	Aftercooler core water inlet pressure	Raw water pressure into the aftercooler. On some engines, this may be the same as 963.
924	Aftercooler core water outlet pressure	Raw water pressure out of the aftercooler, into the jacket water heat exchanger

957	Raw / sea water temp from HEX outlet (high temp or parallel)	Temperature of water out of the engine
964	Raw / sea water pressure from the HEX outlet (high temp or parallel)	Water pressure out of the engine, also referred to as outlet restriction
965	Raw / sea water pump inlet pressure	Water pressure into the pump, also referred to as inlet restriction
966	Raw / sea water pump inlet temperature	Temperature of water into the pump. On some engines, this may be the same as 903.

The calculations performed by the CAMPAR SWAC system analysis are below:
- Raw water inlet temperature
- Raw water temperature rise across aftercooler
- Estimated raw water inlet temperature at design conditions
- Raw water outlet temperature
- Raw water outlet temperature at design conditions
- Raw water pump inlet restriction
- Pressure drop across aftercooler
- Heat exchanger outlet pressure (external restriction)

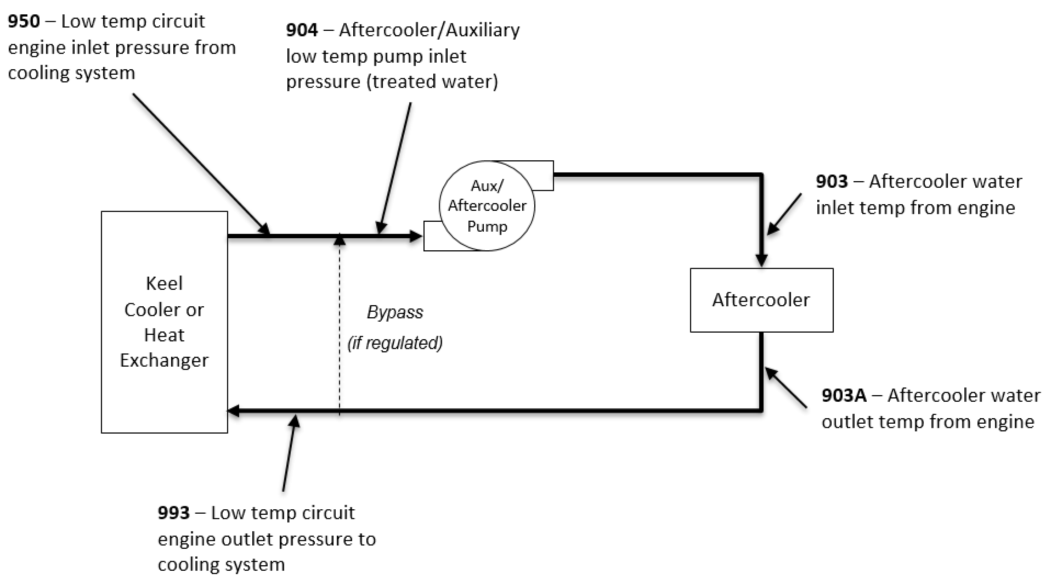
8.3.3.2 Separate Circuit Aftercooled (SCAC)

The SCAC system has a dedicated, treated water circuit for the aftercooler. As with the jacket water system, the measurements required for sea trial differ between (1) keel or remote heat exchanger and (2) on-engine heat exchanger configurations. The latter configuration has an on-engine raw water system which is detailed in 8.3.4 Raw Water System.

8.3.3.2.1 Keel or Remote Heat Exchanger

For this configuration, the CAMPAR tool analyzes the vessel touch points to the jacket water cooling system as well as temperature of the system. Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. **The points in the table below are required for a complete sea trial, additional points may be required for running a diagnostic sea trial. Refer to the system diagrams and complete 900 number list.**

A typical SCAC system diagram with 900 numbers labeled is given below. Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. Refer to engine specific installation drawings for the 900 number port locations on that particular engine.



The SCAC system analysis utilizes the data parameters shown below.

<u>**900 Number/ Abbreviation**</u>	<u>**Name**</u>	<u>**Notes**</u>

SWTA	Seawater temp (actual)	Measured sea water temperature during sea trial testing.
SWTD	Seawater temp (design)	Designed maximum sea water temperature.
903	Aftercooler water inlet temp from engine	Temperature of water into the aftercooler. On some engines, this may be the same as 903.
903A	Aftercooler water outlet temp from engine	Temperature of water out of the aftercooler, into the separate circuit heat exchanger
904	Aftercooler / Auxiliary low temp pump inlet pressure (treated water)	On some engines, this may be the same as 950
950	Low temp circuit engine inlet pressure from cooling system	On some engines, this may be the same as 904.
993	Low temp circuit engine outlet pressure to cooling system	On some engines, this may be the same as 903A.

The calculations performed by the CAMPAR SCAC system analysis are below:

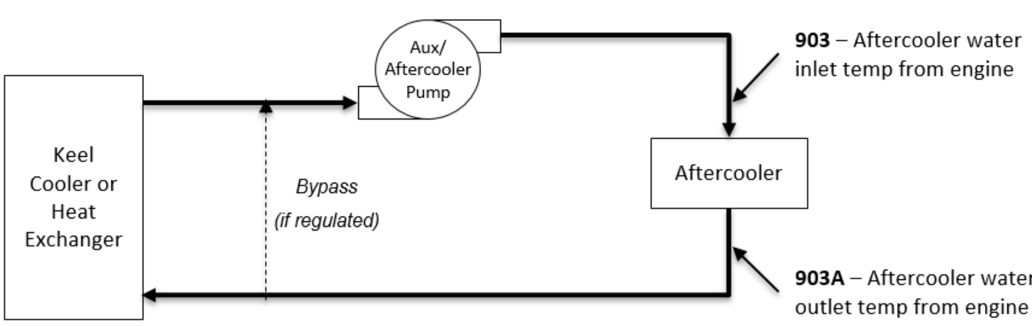
- Aftercooler water inlet temperature
- Estimated aftercooler water inlet temperature at design conditions (only for C32 and smaller engines)
- Coolant temperature rise across aftercooler
- Aftercooler water pump inlet restriction
- External restriction of aftercooler circuit

NOTE: *On 3500, C175 and C280 engines, the aftercooler water inlet temp specification is scaled based on sea water temperature measurements following the low temperature cooling sizing chart in TMI.*

8.3.3.2.2 On Engine Heat Exchanger

For this configuration with a heat exchanger installed from the factory, there are no vessel touch points to analyze. Therefore points only need taken to evaluate temperature of the system. Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. **The points in the table below are required for a complete sea trial, additional points may be required for running a diagnostic sea trial. Refer to the system diagrams and complete 900 number list.**

A typical SCAC system diagram with 900 numbers labeled is given below. Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. Refer to engine specific installation drawings for the 900 number port locations on that particular engine.



The SCAC system analysis utilizes the data parameters shown below.

900 Number/ Abbreviation	**Name**	**Notes**
SWTA	Seawater temp (actual)	Measured sea water temperature during sea trial testing.

SWTD	Seawater temp (design)	Designed maximum sea water temperature.
903	Aftercooler water inlet temp from engine	Temperature of water into the aftercooler.
903A	Aftercooler water outlet temp from engine	Temperature of water out of the aftercooler, into the separate circuit heat exchanger

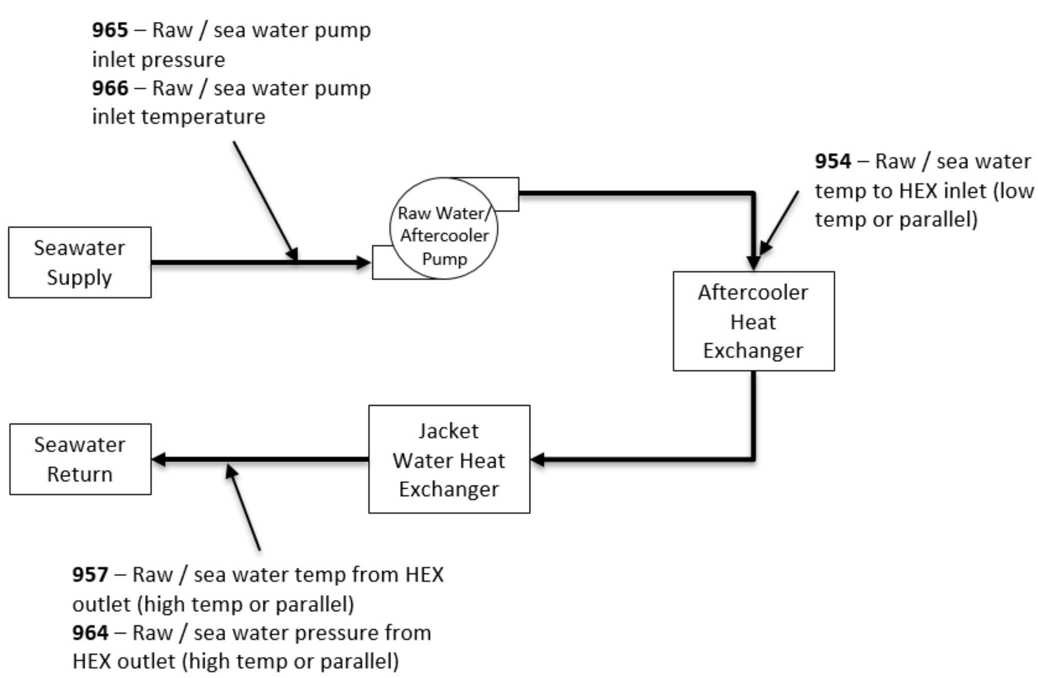
The calculations performed by the CAMPAR SCAC system analysis are below:
- Aftercooler water inlet temperature
- Estimated aftercooler water inlet temperature at design conditions (only for C32 and smaller engines)
- Coolant temperature rise across aftercooler

NOTE: *On 3500, C175 and C280 engines, the aftercooler water inlet temp specification is scaled based on sea water temperature measurements following the low temperature cooling sizing chart in TMI.*

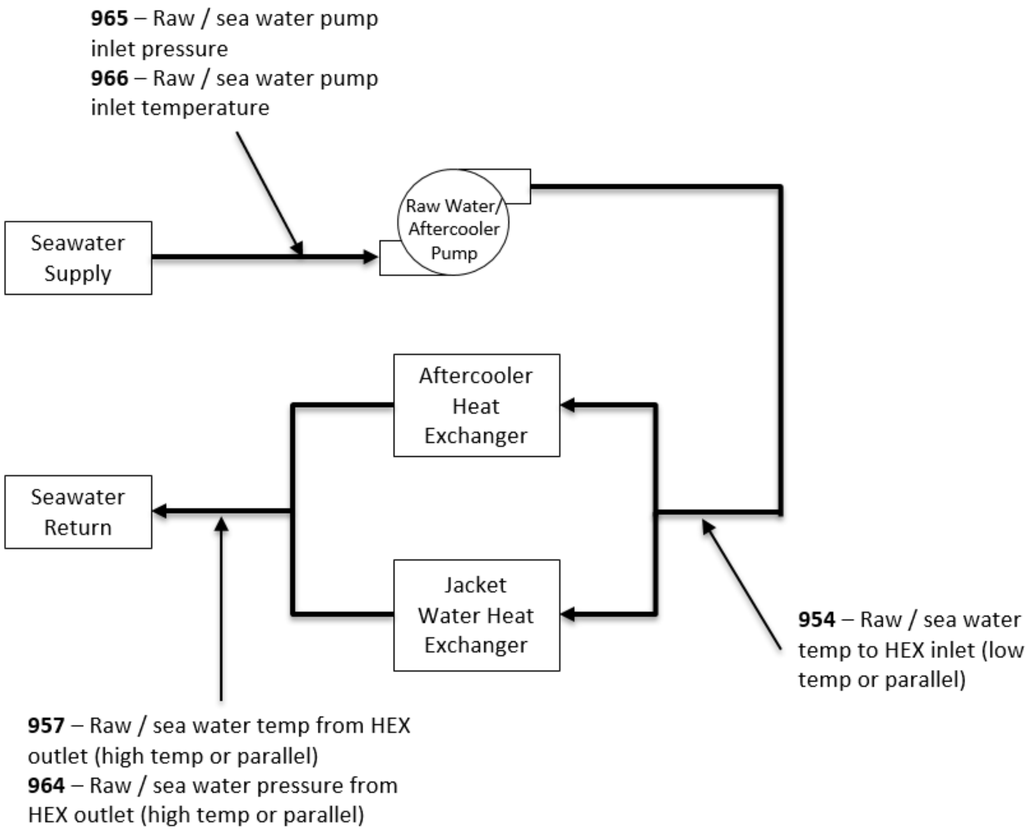
8.3.4 Raw Water System

In SCAC cooling system configurations with on-engine heat exchangers, there is an independent raw water cooling system. This system typically includes an on-engine pump with separate aftercooler and jacket water heat exchangers.

A typical raw water system diagram with 900 numbers labeled is given below. Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. **The points in the table below are required for a complete sea trial, additional points may be required for running a diagnostic sea trial. Refer to the system diagrams and complete 900 number list.** Refer to engine specific installation drawings for the 900 number port locations on that particular engine.



Some raw water systems may have the aftercooler and jacket water heat exchangers arranged in parallel instead of series. An example of this diagram is shown below. Note that the 900 numbers used to analyze the system are unchanged.



There may be raw water cooling systems on remote heat exchanger engines. These raw water systems are independent of the engine and not analyzed by the CAMPAR tool. As far as the engine is concerned, these systems are no different than a keel cooled setup and should be analyzed in the same way.

The raw water system analysis utilizes the data parameters shown.

900 Number/ Abbreviation	**Name**	**Notes**
SWTA	Seawater temp (actual)	Measured sea water temperature during sea trial testing.
SWTD	Seawater temp (design)	Designed maximum sea water temperature.
954	Raw / sea water temp to HEX inlet (low temp or parallel)	On some engines, this may be the same as 966
957	Raw / sea water temp from HEX outlet (high temp or parallel)	Raw water temperature out of the engine
964	Raw / sea water pressure from HEX outlet (high temp or parallel)	Water pressure out of the engine, also referred to as outlet restriction.
965	Raw / sea water pump inlet pressure	Water pressure into the pump, also referred to as inlet restriction.
966	Raw / sea water pump inlet temperature	Temperature of water into the pump. On some engines, this may be the same as 954.

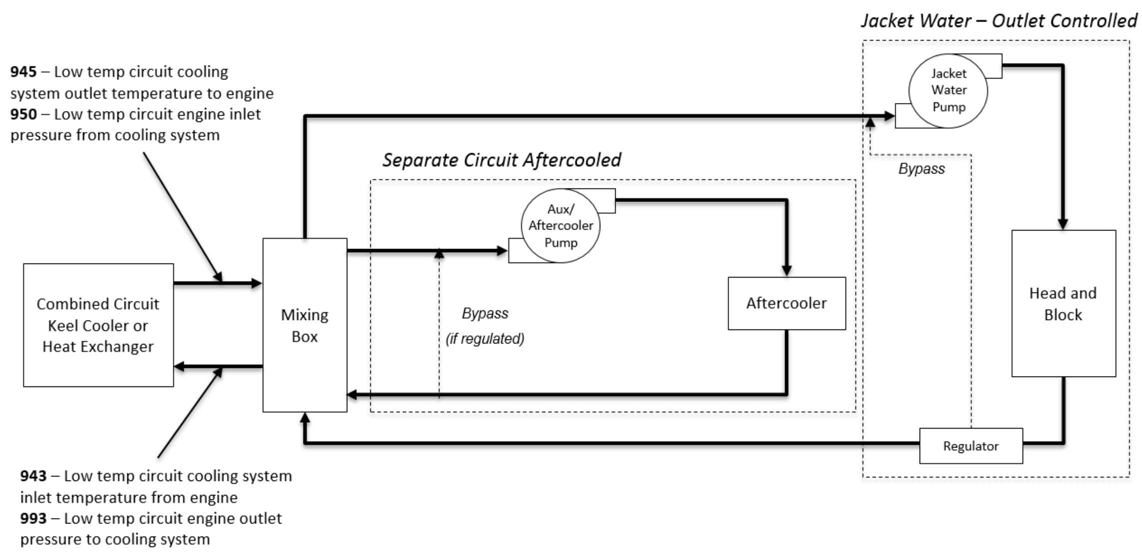
The calculations performed by the CAMPAR raw water system analysis are below:
- Raw water pump inlet temperature
- Raw water engine outlet temperature
- Raw water temperature rise across engine
- Estimated sea water outlet temperature at design conditions
- Raw water pump inlet restriction
- Heat exchanger outlet pressure (external restriction)
- Pressure drop across raw water system

8.3.5 Combined Circuit Cooling Systems

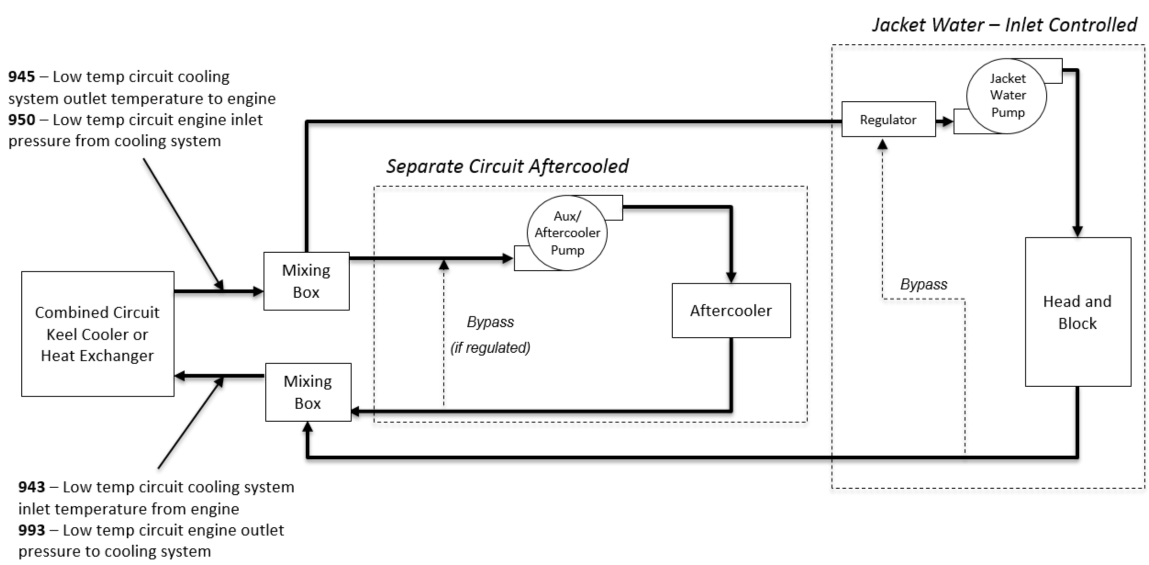
In some cases, the fresh water aftercooler and jacket water systems can be combined into a single, off-engine circuit requiring a single keel cooler or remote heat exchanger instead of two separate ones. CAMPAR utilizes specific equations to analyze combined circuit cooling systems.

There are several different types of combined circuit systems. Example combined circuit system diagrams with 900 numbers labeled are given below. **The points in the table below are required for a complete sea trial, additional points may be required for running a diagnostic sea trial. Refer to the system diagrams and complete 900 number list.** Refer to engine specific installation drawings for the 900 number port location on that particular engine.

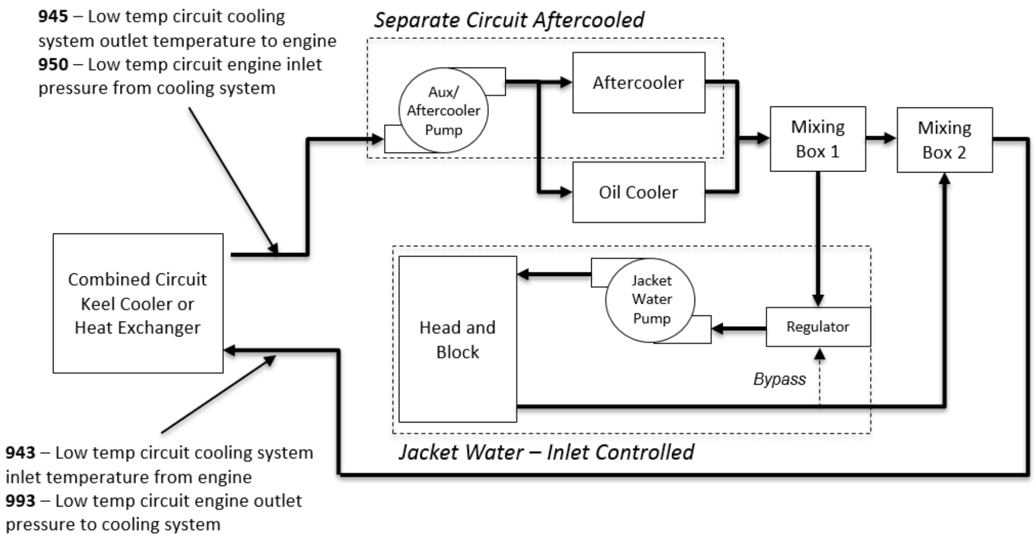
A combined circuit cooling system common on C9, C9.3 and C12 engines is shown below. In these systems a mixing box is used for the vessel connections and the aftercooler and jacket water systems are analyzed just like in Section 8.3.2 Jacket Water System and 8.3.3.2 Separate Circuit Aftercooled (SCAC).



A combined circuit cooling system common on 3500 engines is shown below. This system is similar to the one above except there are two separate mixing boxes and the aftercooler and jacket water systems are analyzed just like in Section 8.3.2 Jacket Water System and 8.3.3.2 Separate Circuit Aftercooled (SCAC).



A combined circuit cooling system common on C280 engines is shown below. This system is different and the mixing boxes are integrated into the cooling system. Still, the aftercooler and jacket water systems are analyzed just like in Section 8.3.2 Jacket Water System and 8.3.3.2 Separate Circuit Aftercooled (SCAC).



Regardless of the type of combined circuit setup, the jacket water and aftercooler systems are analyzed the same way. The difference on the combined circuit is that the temperature rise across the engine and external restrictions are taken from the combined circuit connection points.

The combined circuit system analysis utilizes the data parameters shown below.

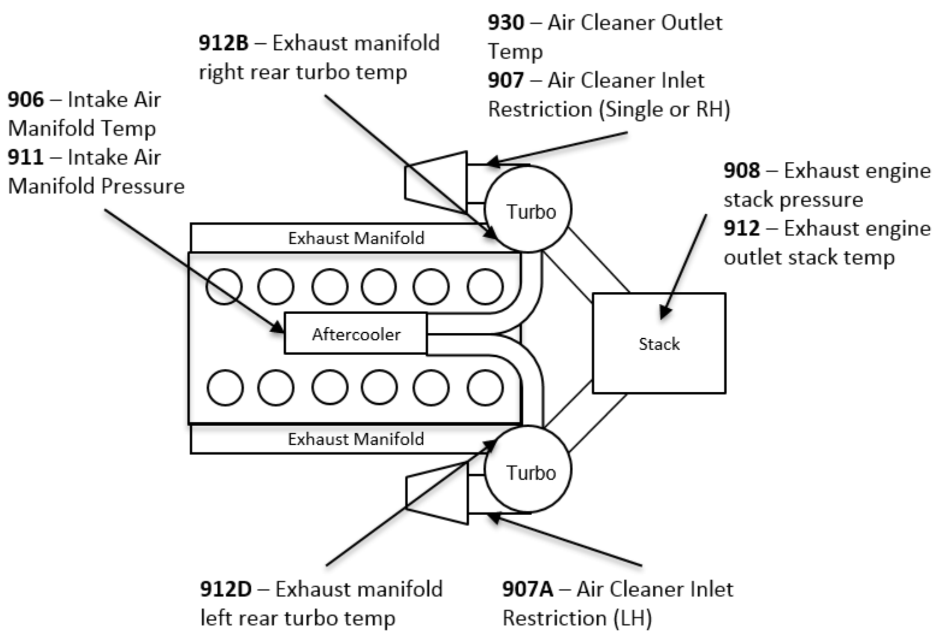
900 Number/ Abbreviation	**Name**	**Notes**
943	Low temp circuit cooling system inlet temperature to engine	Combined circuit engine inlet temperature
945	Low temp circuit cooling system outlet temperature to engine	Combined circuit engine outlet temperature
950	Low temp circuit engine inlet pressure from cooling system	Combined circuit engine inlet pressure
993	Low temp circuit engine outlet pressure to cooling system	Combined circuit engine outlet pressure

The calculations performed by the CAMPAR raw water system analysis are below:
- Temperature rise across combined engine circuit
- External restriction of combined circuit

8.3.6 Air System

CAMPAR performs a full analysis on the engine intake and exhaust air system to ensure the engine installation is within the limits specified in TMI.

An example of the system layout with 900 number locations for CAMPAR analysis is given below. Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. Refer to engine specific installation drawings in EDDC for locations on your particular engine.



8.3.6.1 Intake

The air intake system analysis utilizes the data parameters shown below with optional parameters shown in *italics* and shaded.

900 Number/ Abbreviation	Name	Notes
OATA	Outside air temp (actual)	Measured outside air temperature during sea trial testing
OATD	Outside air temp (design)	Designed maximum outside air temperature
ERAT	Engine room air temp	Measured engine room air temperature during sea trial testing
906	Intake manifold air temp	Inlet air temperature to cylinders, post aftercooler (IMAT).
930	Air cleaner outlet temp	Compressor inlet temperature
907	Air cleaner inlet restriction (single or RH)	Measured at the inlet to the compressor
907A	*Air cleaner inlet restriction (LH)*	*For dual air cleaner installations*
911	Intake air manifold pressure	Inlet air pressure to cylinders (Boost Pressure)

Engine room air temperature (ERAT) should be measured in the vicinity of the air cleaner for each engine. On some vessels the engine room air temperature may vary significantly, and it may even vary between air filters on an engine, due to ventilation design practices. It is advisable to check the engine room temperatures at various points to understand this impact. If there is a measurable difference, document this with a diagram highlighting the difference in temperatures throughout the engine room. For additional supporting information regarding engine room ventilation reference the A&I Guide: Engine Room Ventilation (LEBW4971).

The calculations performed by the CAMPAR intake air analysis are below:
- Engine room temperature
- Engine room temperature rise over ambient
- Temperature rise across air cleaner
- Air cleaner outlet temperature
- Estimated air cleaner outlet temperature at design conditions
- Inlet manifold temperature (IMAT)
- Estimated IMAT at design conditions
- Air inlet restriction
- Inlet manifold pressure (IMAP)

NOTE: *Estimated IMAT at design conditions utilizes sea water temperature measurements as part of the performance calculations.*

NOTE: *The estimated air cleaner outlet temperature and estimated IMAT at design condition calculations use the current air and seawater temperatures compared to the design conditions. The output of these equations should be compared to the programmable monitoring system setpoints and* *ambient capability charts to understand what derates may be at the design conditions. These should be treated as estimates only and verified with qualification testing if necessary.*

8.3.6.2 Exhaust

The exhaust system analysis utilizes the data parameters shown below with optional parameters shown in *italics* and shaded.

900 Number/ Abbreviation	**Name**	**Notes**
912	Exhaust engine outlet stack temperature	Exhaust outlet temperature after flower pot, before muffler/ silencer
912A	*Exhaust manifold right front turbo temp*	*Exhaust temp from manifold to turbo inlet*
912B	*Exhaust manifold right rear turbo temp*	*Exhaust temp from manifold to turbo inlet*
912C	*Exhaust manifold left front turbo temp (or high pressure turbo)*	*Exhaust temp from manifold to turbo inlet*
912D	*Exhaust manifold left rear turbo temp (or low pressure turbo)*	*Exhaust temp from manifold to turbo inlet*
908	Exhaust engine stack pressure	Exhaust pressure leaving the engine, also referred to as exhaust backpressure.

The calculations performed by the CAMPAR exhaust analysis are below:
- Exhaust stack temperature
- Exhaust pre-turbo temperature(s) (optional)
- Exhaust stack backpressure

8.3.7 Lube System

The lube oil system analysis utilizes the data parameters shown below with optional parameters shown in *italics* and shaded. Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. Refer to engine specific installation drawings in EDDC for locations on your particular engine.

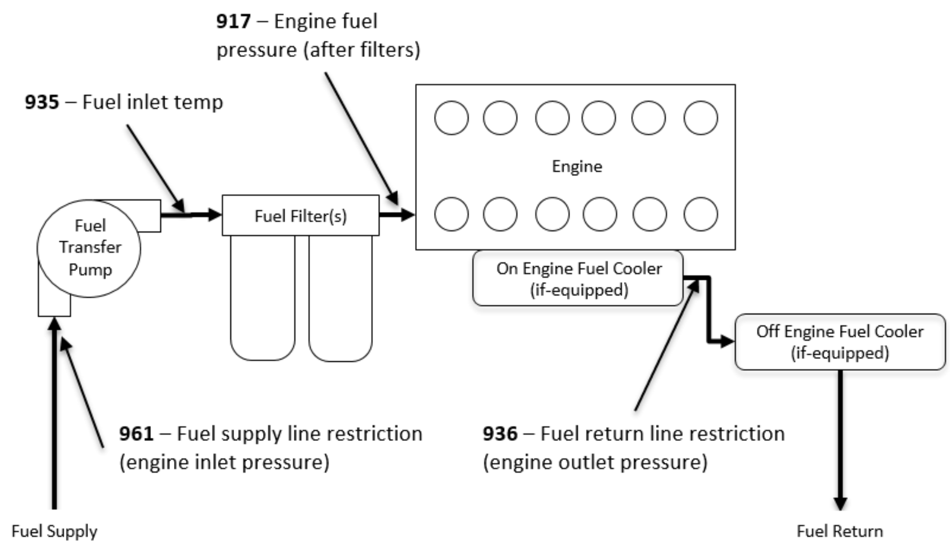
900 Number/ Abbreviation	**Name**	**Notes**
913	Engine oil to bearings temp	
914	Engine oil to bearings pressure	
927	*Oil filter inlet pressure*	
928	*Oil filter outlet pressure*	*On some engines this may be measured at the same location as 914*
932	Crankcase pressure	

The calculations performed by the CAMPAR lube system analysis are below:
- Oil to bearing Temperature
- Oil to Bearing Pressure
- Differential Pressure Across Oil Filter – Optional
- Crankcase Pressure

8.3.8 Fuel System

CAMPAR performs a full analysis on the engine fuel system to ensure the engine installation is within the limits specified in TMI.

Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. Refer to engine specific installation drawings in EDDC for locations on your particular engine.



The fuel system analysis utilizes the data parameters shown below.

900 Number/ Abbreviation	Name	Notes
917	Engine fuel pressure (after filters)	
935	Fuel inlet temp	
936	Fuel return line restriction (engine outlet pressure)	
961	Fuel supply line restriction (engine inlet pressure)	

NOTE: *936 is measured after any installed, on engine fuel cooler but before any vessel-side, off engine fuel cooler which may be in the system.*

8.3.9 Aftertreatment System

CAMPAR performs a full analysis of IMOIII/EPA Tier 4 SCR, air-assisted aftertreatment systems when selected in the Pre Test configuration utilizing the data parameters shown below. These calculations are only intended to be performed on engines which utilize an aftertreatment system and can be enabled by selecting "Tier 4/IMOIII SCR Based Aftertreatment" on the CAMPAR Pre Test Tab.

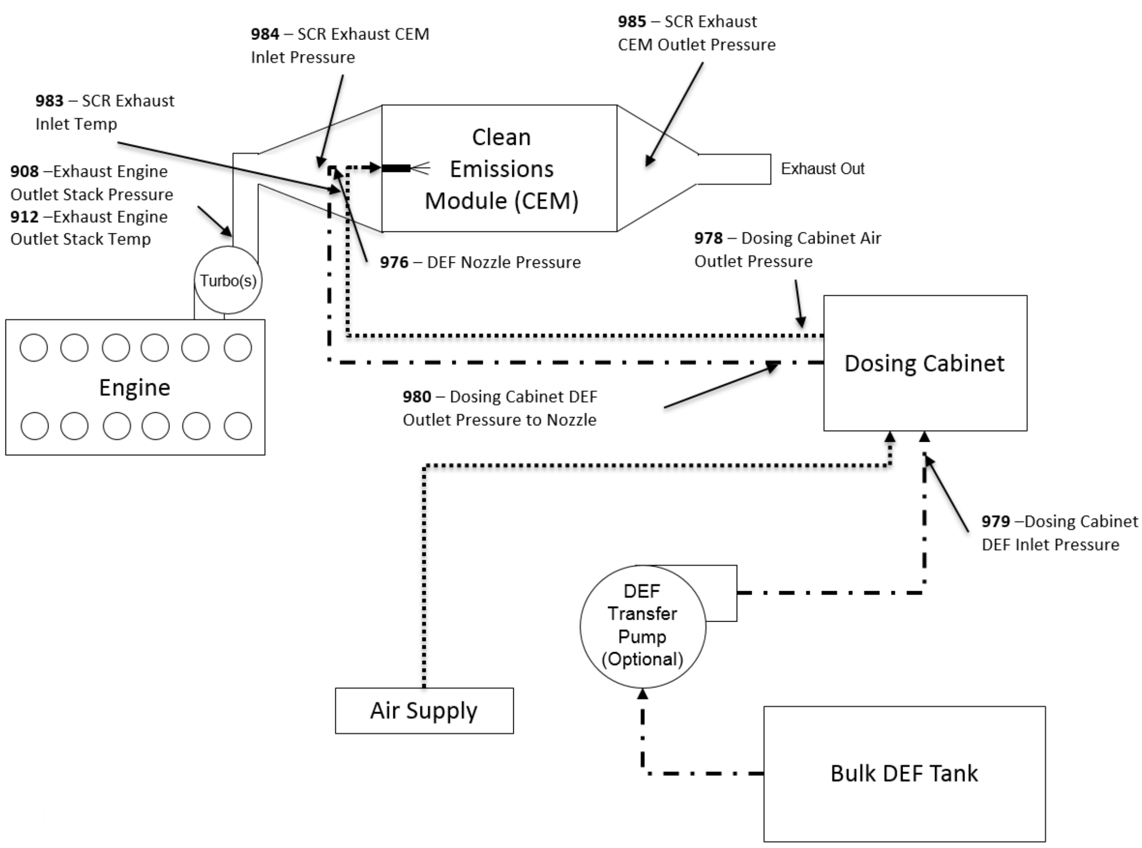
NOTE: *Any engine equipped with an IMOIII or Tier 4 SCR system is **required** to have a sea trial conducted including measurement of the parameters below and have a CAMPAR analysis uploaded into service interlink.*

For additional troubleshooting information on the aftertreatment system, refer to the Cat Clean Emissions Module A&I Guide, LEBM0023 and the Marine Aftertreatment Initial Startup and Commissioning Guide, LEBM0088.

900 Number/ Abbreviation	Name	Notes
912	Engine outlet stack temperature	Measurement location must be added in vessel exhaust piping
976	DEF nozzle pressure	Measurement location must be added in vessel DEF piping
978	Dosing cabinet air outlet pressure	

979	Dosing cabinet DEF inlet pressure	Measurement location must be added in vessel DEF piping
980	Dosing cabinet DEF outlet pressure to nozzle	
983	SCR exhaust inlet temperature	
984	SCR exhaust inlet pressure	
985	SCR exhaust outlet pressure	Measurement location must be added in vessel exhaust piping

These data locations are shown in the system diagram below. Depending on the engine configuration, these locations may be monitored through the engine ECM or may need to be manually measured. This analysis utilizes the data parameters shown below. Refer to engine specific installation drawings in EDDC for locations on your particular engine.



The calculations performed by the CAMPAR aftertreatment analysis are below:

- SCR Exhaust Inlet Temperature
- Turbo to Caterpillar Emissions Module (CEM) Temperature Drop
- DEF Dosing Cabinet Inlet Pressure
- DEF Pressure Drop from Dosing Cabinet to Nozzle
- Dosing Cabinet Air Outlet Pressure
- CEM Exhaust Pressure Drop

Refer to Section 10.1 Aftertreatment in Appendix B: CAMPAR Calculations for details on the aftertreatment calculations necessary to evaluate the aftertreatment installation.

***NOTE:** For some initial pre-production orders, the aftertreatment data may not populate properly on the engine sea-trial tab in TMI. This will prevent this data from pulling properly into CAMPAR. In these cases, recommend to use LEEM0005 CAMPAR Tier 4 – Aftertreatment Systems Analysis Worksheet to perform the aftertreatment calculations outside of CAMPAR. This should be uploaded into Service Interlink along with the CAMPAR report.*

8.4 Fuel Rate and Performance Analysis

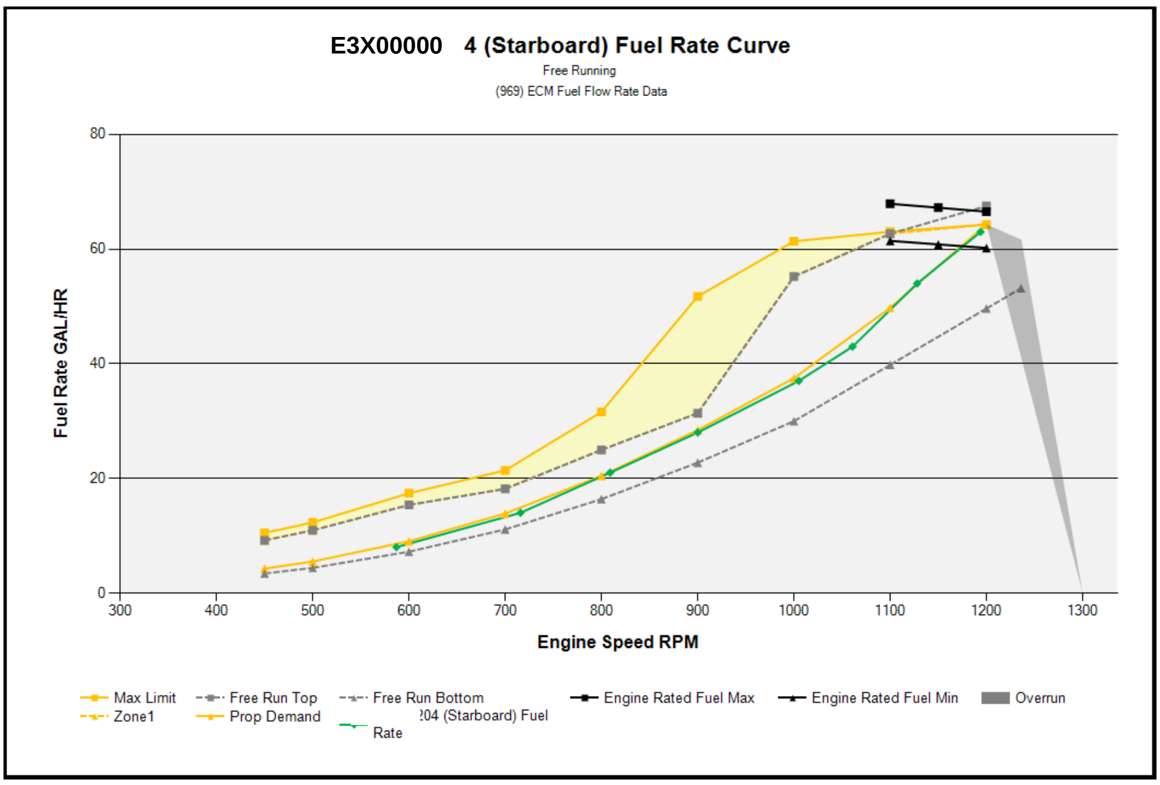
CAMPAR compares the fuel rate of a Caterpillar marine propulsion engine to the factory performance data for that specific engine in TMI. This comparison is made for the entire operating range of the engine. If the fuel rate and boost pressure data from the sea trial are within the acceptable range for load and performance specifications, it is an indication that the engine is operating correctly and the propulsion system was sized correctly.

However, if the actual fuel rate and boost pressure curves fall outside the acceptable range for load and performance specifications, adjustments and/or repairs for the fuel system and/or engine loading conditions may be necessary. Further investigation may be needed to determine the root cause of the performance issue and take necessary corrective actions.

There are two different types of fuel curve analysis that can be run in the CAMPAR tool: free running and bollard. The selection of this curve type should correspond to the type of sea trial that has been performed referring to Section 06.5. Depending on the analysis and engine rating, different curves will display in the fuel rate curve graph.

8.4.1 Free Running Example Plot

This free running condition applies to a vessel which is operating in a lightly or normally loaded state. This does not apply to vessels which may be pushing or pulling a load or doing a bollard pull test. During a free running test, the engines are expected to be running 1% to 3% above rated speed. For example, on an engine rated at 1200 rpm, the engine speed at full throttle would be expected to be between 1212 and 1236 rpm.

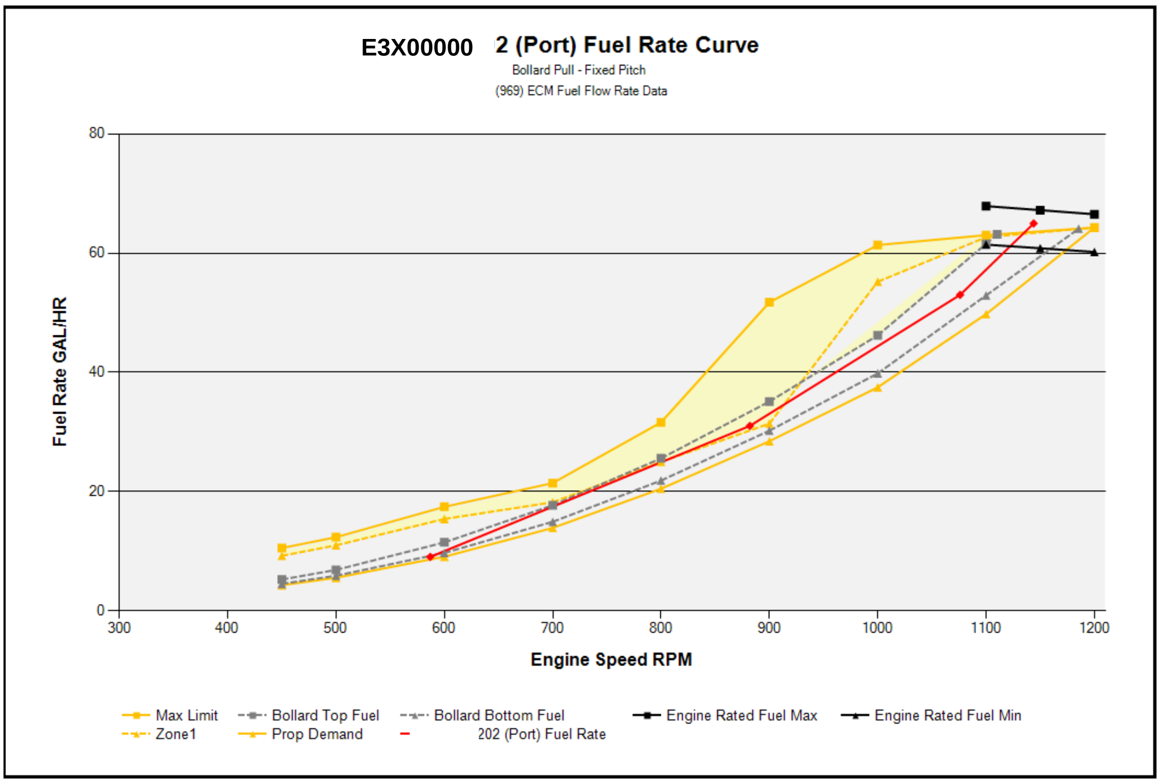


Explanations of the various curves on a free running plot are given below:

Max Limit: This curve represents the maximum possible engine fuel rate at a given engine speed. The actual engine fuel rate should never exceed this line.
Prop Demand: This curve represents the theoretical propulsion demand curve line with a 3.0 exponent, fixed pitch, displacement hull. While not all applications will load the engine exactly according to this line, it is used as a reference.
Zone 1: This curve represents the maximum allowable fuel rate for continuous operation. Operation above this line is acceptable for limited periods of time and under transient conditions based on rating guidelines. This curve is not present on all engines. If the Zone 1 curve is not present, operation up to the max limit line is acceptable while adhering to application guidelines.
Yellow Zone: The yellow zone refers to the area between the Zone 1 curve (if present) and the max limit curve. Operation within this zone is acceptable for limited periods of time and transient conditions based on rating guidelines. This zone will not be present if a Zone 1 curve is not present.
Free Run Top: On engines with a Zone 1 curve, the free run top curve follows the Zone 1 curve until it intersects the prop demand curve at which point it transitions to the prop demand curve + 5%. On engines without a Zone 1 curve, the free run top curve follows the max limit curve. This curve represents the allowable continuous load while still complying with rating guidelines.
Free Run Bottom: The free run bottom curve is based on the prop demand curve and represents 80% of the prop demand fuel rate. It is expected that loading below this level represents an under-utilized or under-loaded engine. This curve runs to 103% of rated speed.
Engine Rated Fuel Max and Min: These performance bands represent the fuel rate tolerance of the specific engine within +/-5%. It is expected that at full throttle, the engine fuel rate should have within this performance band.

8.4.2 Bollard Example Plot

A bollard condition refers to a vessel which is performing a bollard pull test. This type of plot can also be used for a vessel which is heavily loaded during the test to simulate a real world push or pull condition. In this loading condition, it is expected that the engines will lug back from rated speed and should fall within 93% to 97% of rated speed. For example, on an engine rated at 1200 rpm, the engine speed at full throttle would be expected to be between 1116 and 1164 rpm. The maximum allowable lug performance condition is 90% of rated engine speed. A bollard pull test engine rpm that is less than 90% of rated engine speed indicates an incorrect propulsion system sizing and excessive shaft loads.



Explanations of the various curves under a Bollard plot are given below:

Max Limit: This curve represents the maximum possible engine fuel rate at a given engine speed. The actual engine fuel rate should never exceed this line.
Prop Demand: This curve represents the theoretical propulsion demand curve line with a 3.0 exponent, fixed pitch, displacement hull. While not all applications will load the engine exactly according to this line, it is used as a reference.
Zone 1: This curve represents the maximum allowable fuel rate for continuous operation. Operation above this line is acceptable for limited periods of time and under transient conditions based on rating guidelines. This curve is not present on all engines. If the Zone 1 curve is not present, operation up to the max limit line is acceptable while adhering to application guidelines.
Yellow Zone: The yellow zone refers to the area between the Zone 1 curve (if present) and the max limit curve. Operation within this zone is acceptable for limited periods of time and transient conditions based on rating guidelines. This zone will not be present if a Zone 1 curve is not present.
Bollard Top and Bottom: These curves are based on the prop demand curve and represent expected engine loading on a fixed pitch, displacement hull vessel when operating in a bollard condition. These curves are generated based on the Caterpillar recommendation that in a full throttle bollard condition, the engines should be between 93% and 97% of rated speed.
Engine Rated Fuel Max and Min: These performance bands represent the fuel rate tolerance of the specific engine within +/-5%. It is expected that at full throttle, the engine fuel rate should have within this performance band.

8.4.3 Properly Loaded Examples

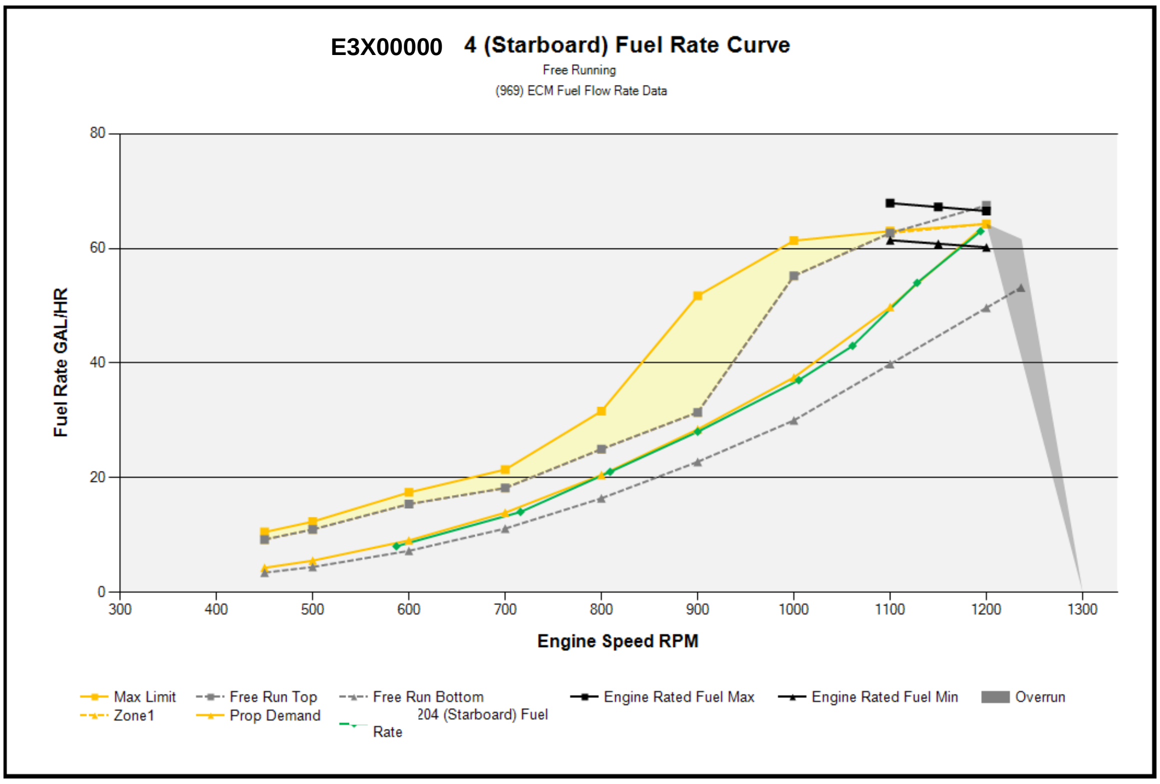
An engine is considered properly loaded when the engine is consuming the maximum amount of fuel and reaching maximum boost pressure at rated engine speed.

To account for hull fouling and other factors that may degrade performance as the engines and vessel age, Caterpillar recommends a free running application should be 1% to 3% above rated speed.

For a bollard pull application with a fixed pitch propeller, Caterpillar recommends engines to be operating 93% to 97% of rated speed.

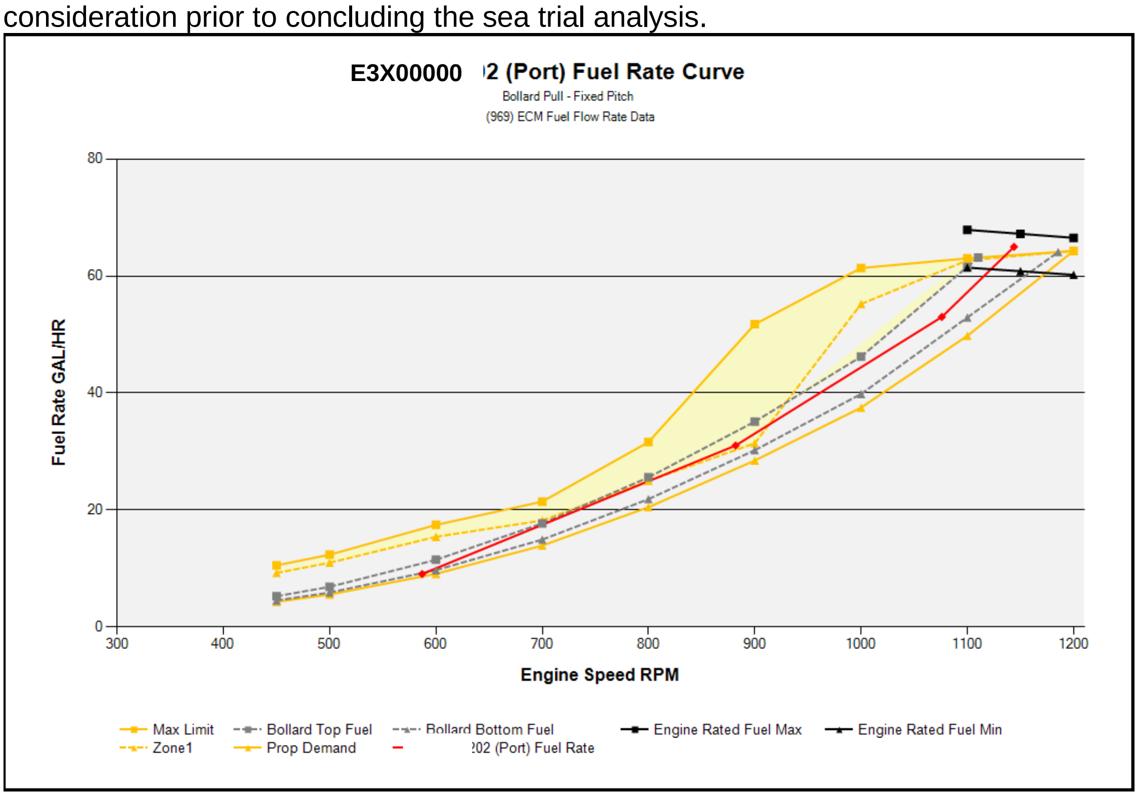
8.4.3.1 Properly Loaded – Free Running

Engine speed reaches rated speed under free running conditions and fuel rate at maximum engine speed falls within the fuel rate performance bands. This is an indication that the engines are properly loaded to achieve rated speed or higher and consuming the amount of fuel that equals the rated fuel consumption specified in TMI. Engine performance conclusions should not be made on only one parameter. The boost pressure graph should also be taken into consideration prior to concluding the sea trial analysis.



8.4.3.2 Properly Loaded – Bollard

Engine speed reaches 1140 RPM which is 95% of rated engine speed and between the 93-97% expected in a bollard condition. The fuel rate at full throttle condition falls with the fuel rate performance bands. This is an indication that the engines are properly loaded to achieve rated speed or higher under normal running conditions. Engine performance conclusions should not be made on only one parameter. Note that in the curve shown below, the engine performance curve crosses into the yellow shaded area above the zone 1 curve around 900 rpm. This is acceptable if this is a transient condition, however if this is a continuous run point, this may violate the rating guidelines and should be reviewed. The boost pressure graph should also be taken into consideration prior to concluding the sea trial analysis.

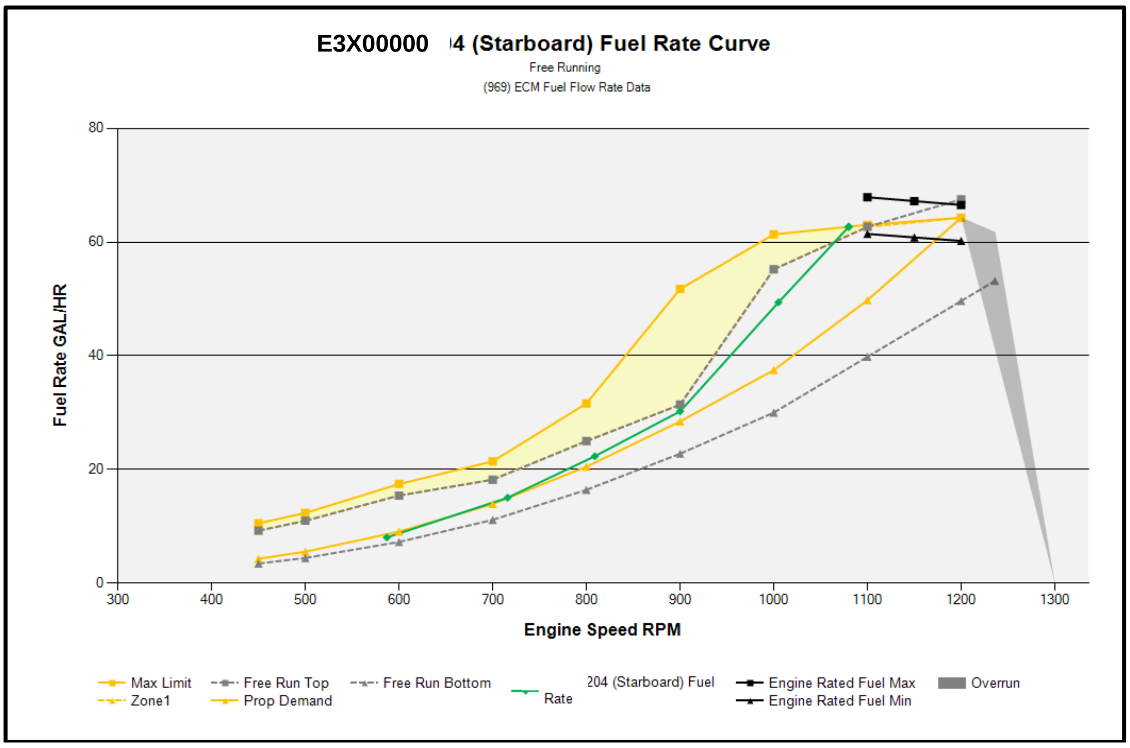


8.4.4 **Overloaded Examples**

An engine is considered overloaded when the engine is consuming the maximum amount of fuel and reaching maximum boost pressure for a given engine speed, but the engine cannot reach its rated speed. There are a number of causes that can contribute to an engine being overloaded including, but not limited to, propeller pitch size, vessel load, hull fouling and weak fuel energy content.

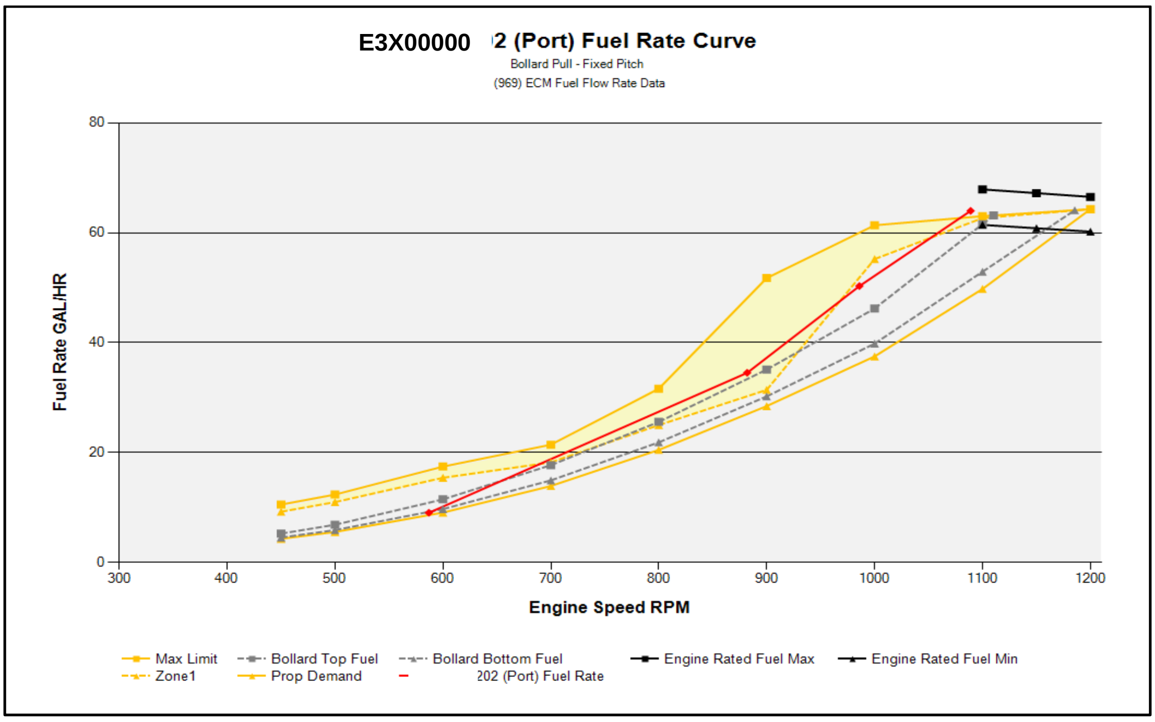
8.4.4.1 Overloaded – Free Running

Fuel Rate at Maximum Engine Speed Intersects the Maximum Limit Curve. This is an indication that the engine is consuming the maximum amount of fuel for a given engine speed, but has too much load to allow the engine to reach its rated speed. Engine performance conclusions should not be made on only one parameter. The boost pressure graph should also be taken into consideration prior to concluding the sea trial analysis.



8.4.4.2 Overloaded – Bollard

Fuel Rate at Maximum Engine Speed Intersects the Maximum Limit Curve and the engine speed reaches 90% of rated speed under full bollard. This is an indication that the engine is consuming the maximum amount of fuel for a given engine speed, but has too much load to allow the engine to reach the 93-97% of rated engine speed that Caterpillar suggests for a fixed pitch bollard. This is an indication that the propellers are slightly heavy, meaning they are over pitched for the application. This curve also shows that the engine is operating almost exclusively in the yellow shaded zone above the zone 1 curve from 700 rpm to full throttle. This indicates that the engine is likely operating continuously above the zone 1 curve which may violate the rating guidelines. Engine performance conclusions should not be made on only one parameter. The boost pressure graph should also be taken into consideration prior to concluding the sea trial analysis.

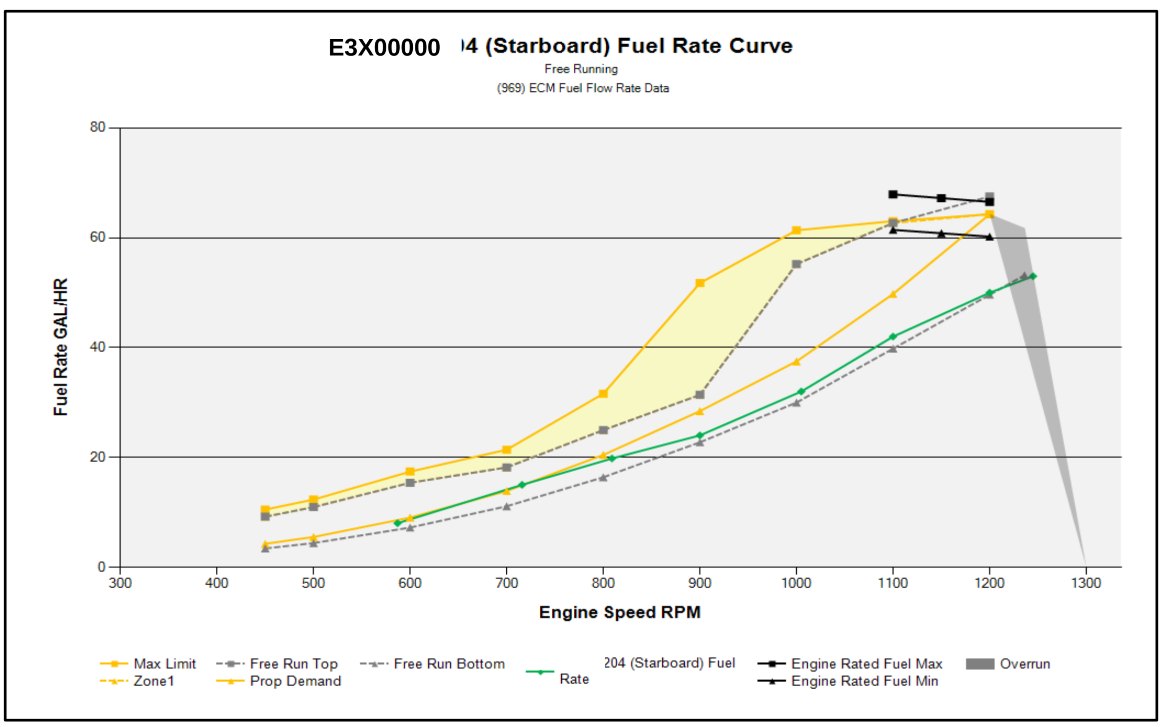


8.4.5 **Underloaded Examples**

An engine is considered underloaded when the engine speed is into the overrun curve and the fuel rate is below the performance bands. A low boost pressure coupled with this scenario would further support and underloaded condition. There are a number of causes that can contribute to an engine being underloaded including propeller pitch size and vessel load.

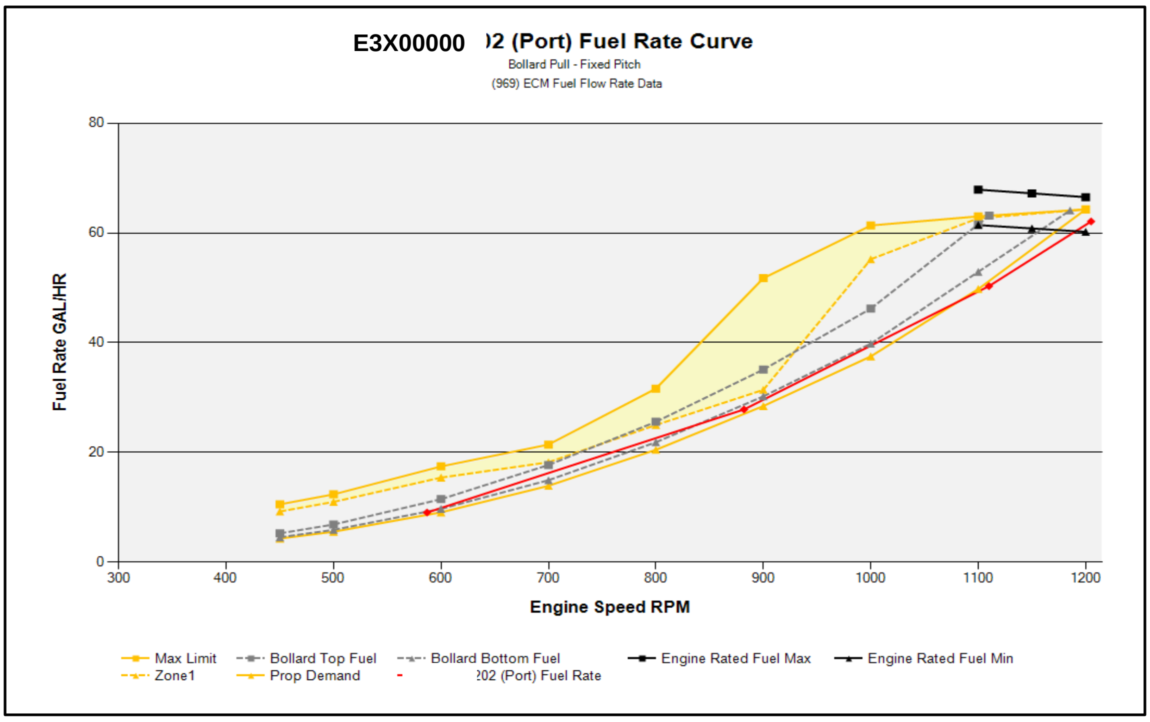
8.4.5.1 Underloaded – Free Running

Fuel rate at maximum engine speed is below the performance bands and the engine speed extends well into the overrun curve. This would be an indication that the load placed on the engines is not great enough to cause the engines to require a high enough rate of fuel, resulting in an under-loaded situation. Engine performance conclusions should not be made on only one parameter. The boost pressure graph should also be taken into consideration prior to concluding the sea trial analysis.



8.4.5.2 Underloaded – Bollard

Fuel rate at maximum engine speed is within the performance bands and the engine speed is greater than rated speed. Under normal free running operation this would be considered ideal, however, when in a bollard condition with a fixed pitch propeller, this would be an indication that the load placed on the engines is not great enough to cause the engines to lug back to 93-97% of rated speed. This indicates that the engines are running in an under-loaded situation. Engine performance conclusions should not be made on only one parameter. The boost pressure graph should also be taken into consideration prior to concluding the sea trial analysis.

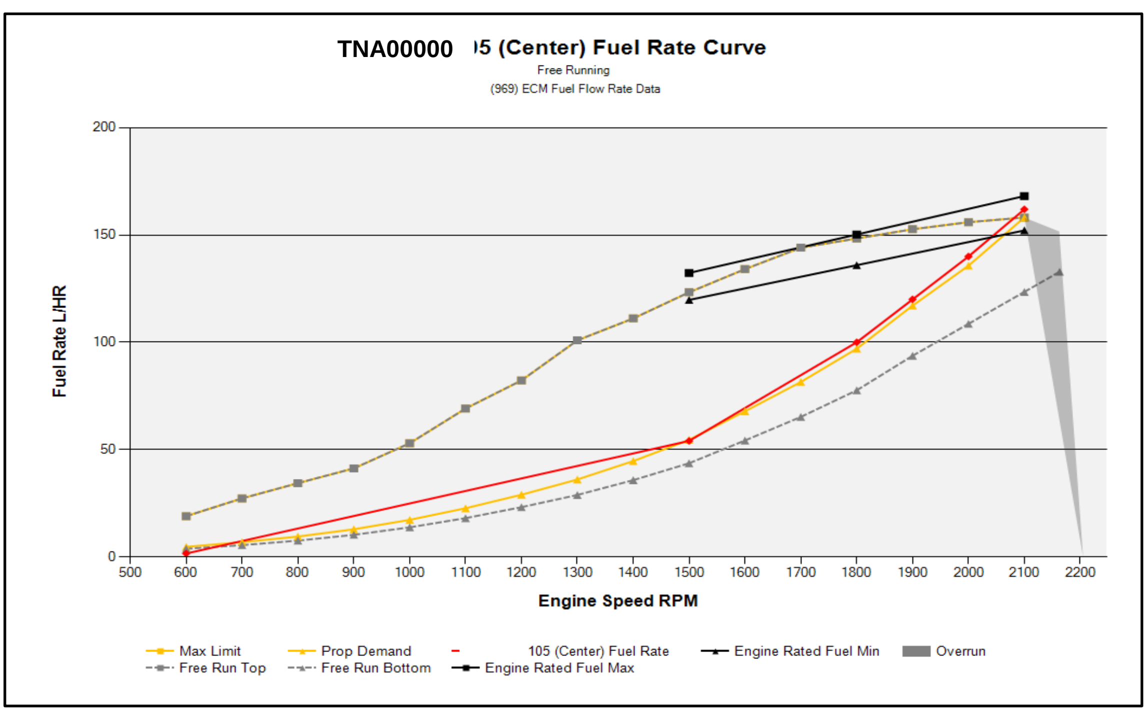


8.4.6 Examples without Zone 1 Curve

Some Caterpillar engine models and ratings are developed without any zone restrictions and therefore a Zone 1 curve may not be present. If the Zone 1 curve is not present, engine operation up to the max limit line is acceptable while adhering to application rating guidelines. If a Zone 1 curve is not present, then the yellow transition zone discussed previously will also not be present.

Below is an example fuel plot of a properly loaded engine that does not have the Zone 1 curve and transition zone.

NOTE: *The max limit fuel rated curve represents the capability of the engine. There may be other driveline components with limited torque capability and it is the responsibility of the commissioning engineer to ensure load is not exceeding driveline capability.*

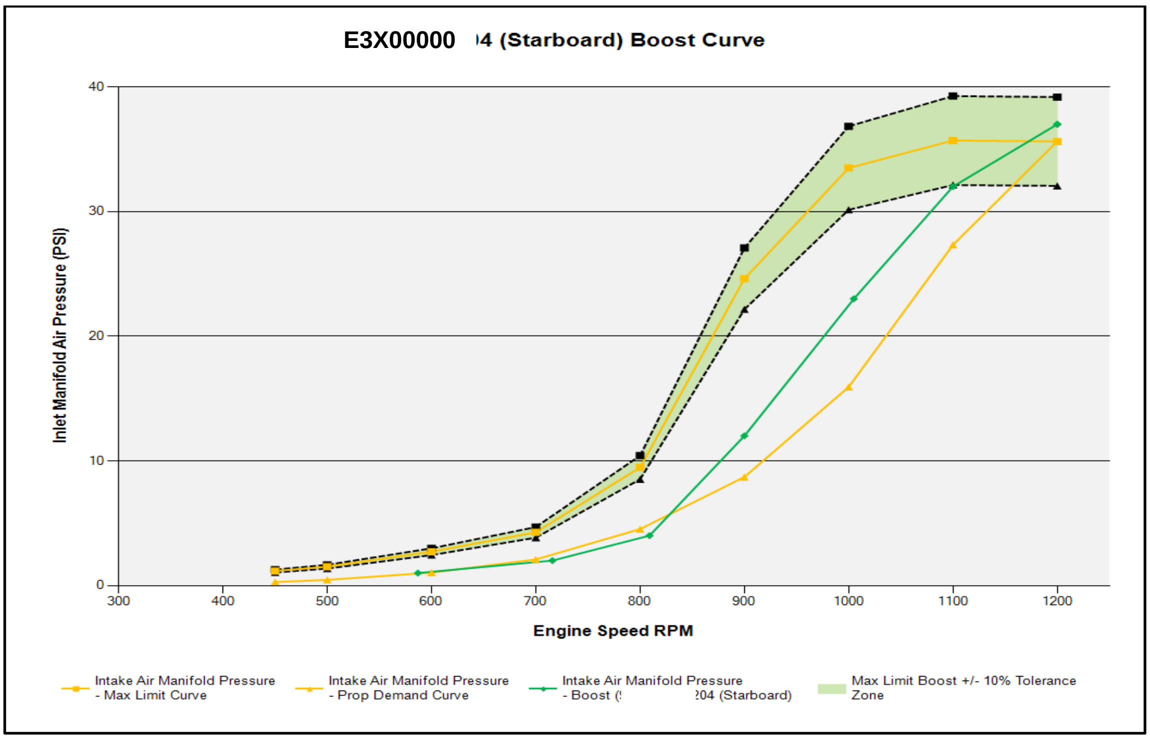


8.5 Boost Performance Analysis

CAMPAR compares the Inlet Manifold Air Pressure, or "Boost", of a Caterpillar marine propulsion engine to the factory performance data for that specific engine in TMI. This comparison is made for the entire operating range of the engine. If the boost pressure data from the sea trial are within the acceptable range for load and performance specifications, it is an indication that the engine is operating correctly and the propulsion system was sized correctly.

However, if the actual boost pressure curves fall outside the acceptable range for load and performance specifications, adjustments and/or repairs for the air system and/or engine loading conditions may be necessary. Further investigation may be needed to determine the root cause of the performance issue and take necessary corrective actions.

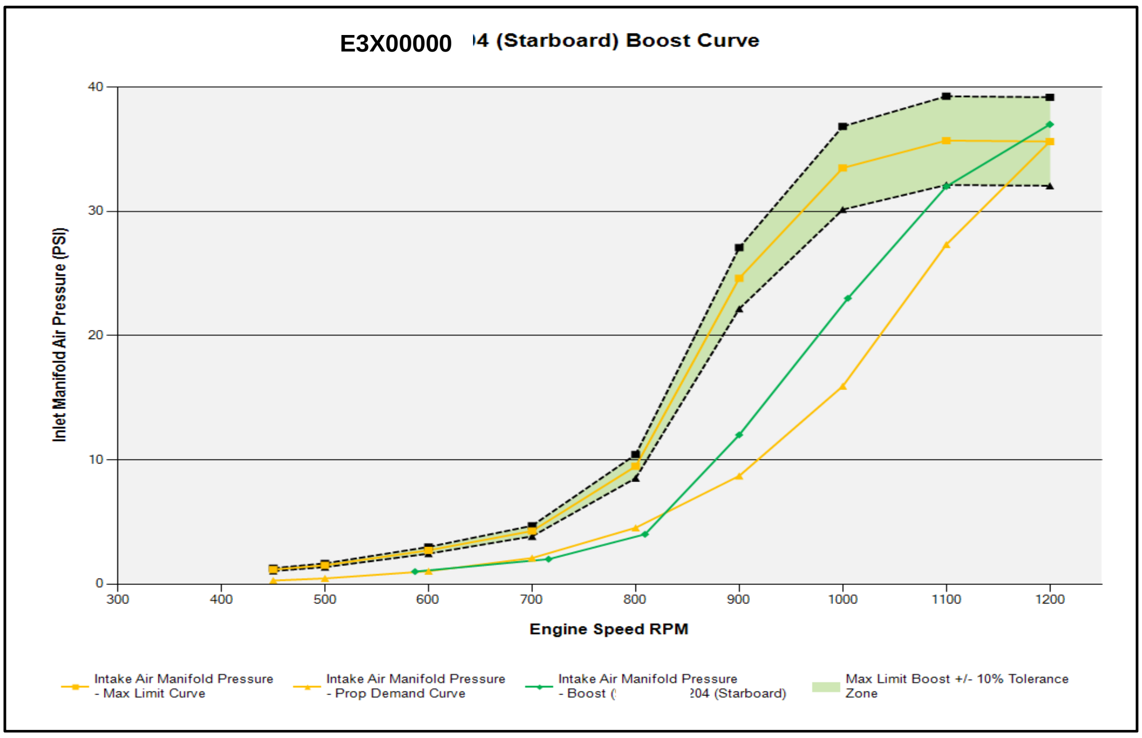
Below is an example boost plot from the CAMPAR analysis and explanations of the various curves displayed.



Max Limit: This curve represents the expected inlet manifold air pressure (boost) at a given engine speed while an engine is operating at the maximum limit.
Prop Demand: This curve represents the expected inlet manifold air pressure (boost) while operating along the theoretical propulsion demand curve line with a 3.0 exponent, fixed pitch, displacement hull. While not all applications will load the engine exactly according to this line, it is used as a reference.
Green Zone: The green zone refers to a +/-10% tolerance area on the max limit curve.

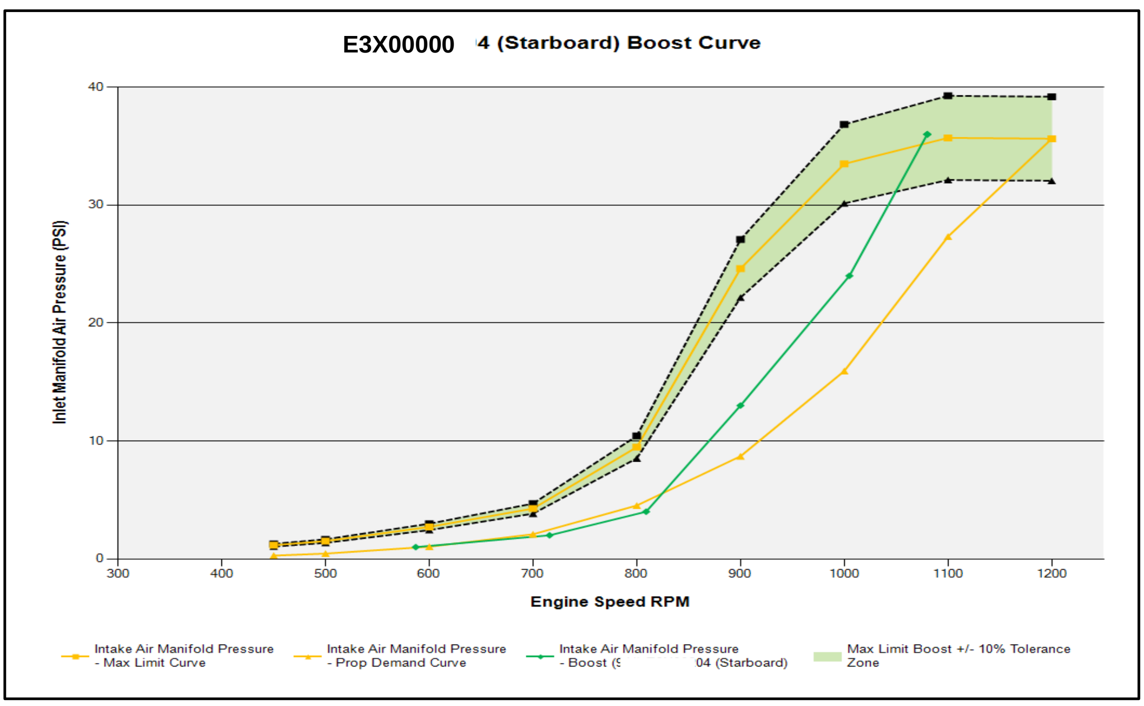
8.5.1 Properly Loaded Example

The inlet manifold pressure (boost) follows the theoretical prop demand curve along the engine speed range. Engine speed reaches rated speed and the inlet manifold pressure (boost) at maximum engine speed falls within the green tolerance zone. This is an indication that the engine is properly loaded as it has reached rated speed and boost pressure is with the tolerances specified in TMI. Engine performance conclusions should not be made on only one parameter. The fuel rate graph should also be taken into consideration prior to concluding the sea trial analysis.



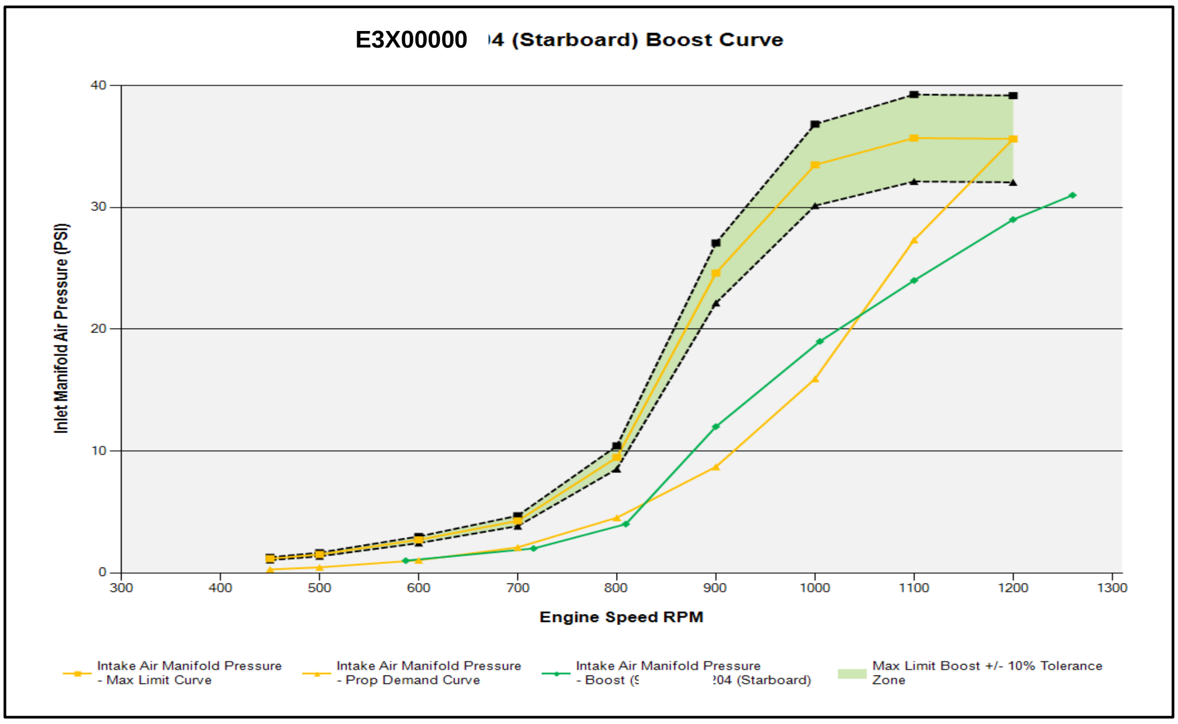
8.5.2 Overloaded Example

The inlet manifold pressure (boost) reaches the green zone, however, engine speed fails to reach rated speed. This is an indication that the engine is operating properly but it is in an overloaded situation. Engine performance conclusions should not be made on only one parameter. The fuel rate graph should also be taken into consideration prior to concluding the sea trial analysis. There are a number of causes that can contribute to an engine being overloaded including, but not limited to, propeller pitch size, vessel load, hull fouling and weak fuel energy content.



8.5.3 Underloaded Example

The inlet manifold pressure (boost) fails to reach the green tolerance zone and the engine speed is greater than rated speed. This is an indication that the engine is operating properly but it is in an underloaded situation. Engine performance conclusions should not be made on only one parameter. The fuel rate graph should also be taken into consideration prior to concluding the sea trial analysis. There are a number of causes that can contribute to an engine being underloaded including propeller pitch size and vessel load.

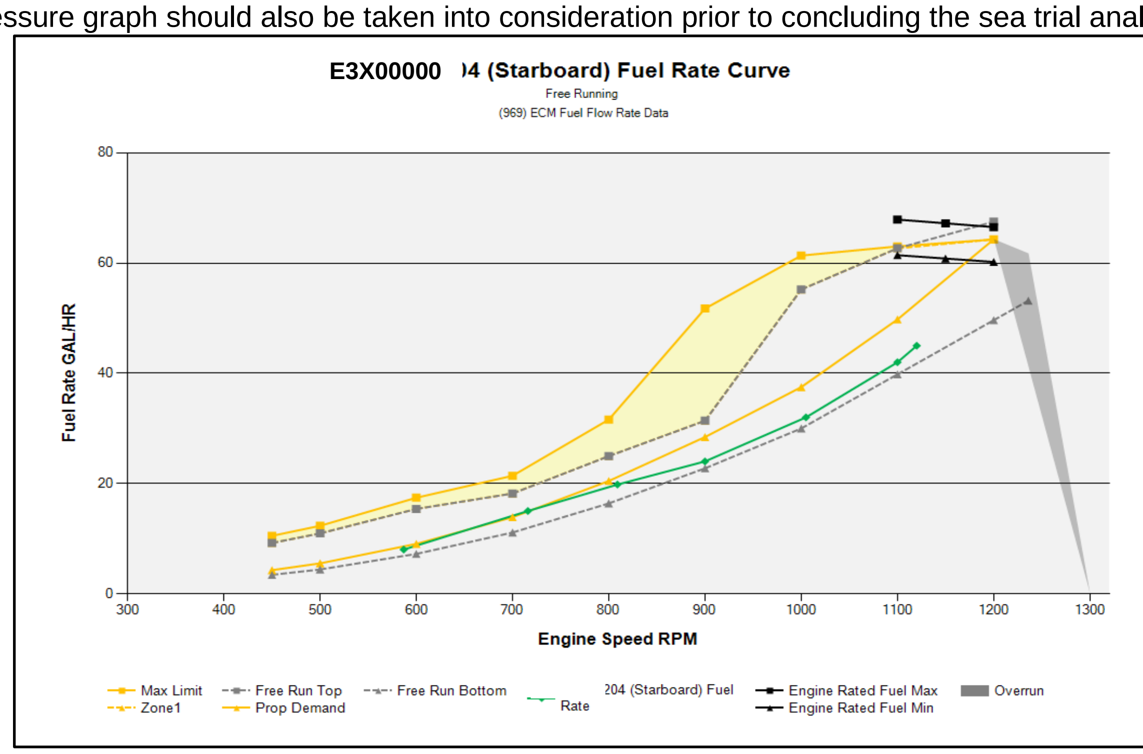


8.6 Engine Troubleshooting Examples

Fuel and boost curves can be used to troubleshoot engine performance issues. A few examples are given below of these instances. These do not represent all possible scenarios and marine analyst training is recommended for further instruction on interpreting fuel and boost curve plots.

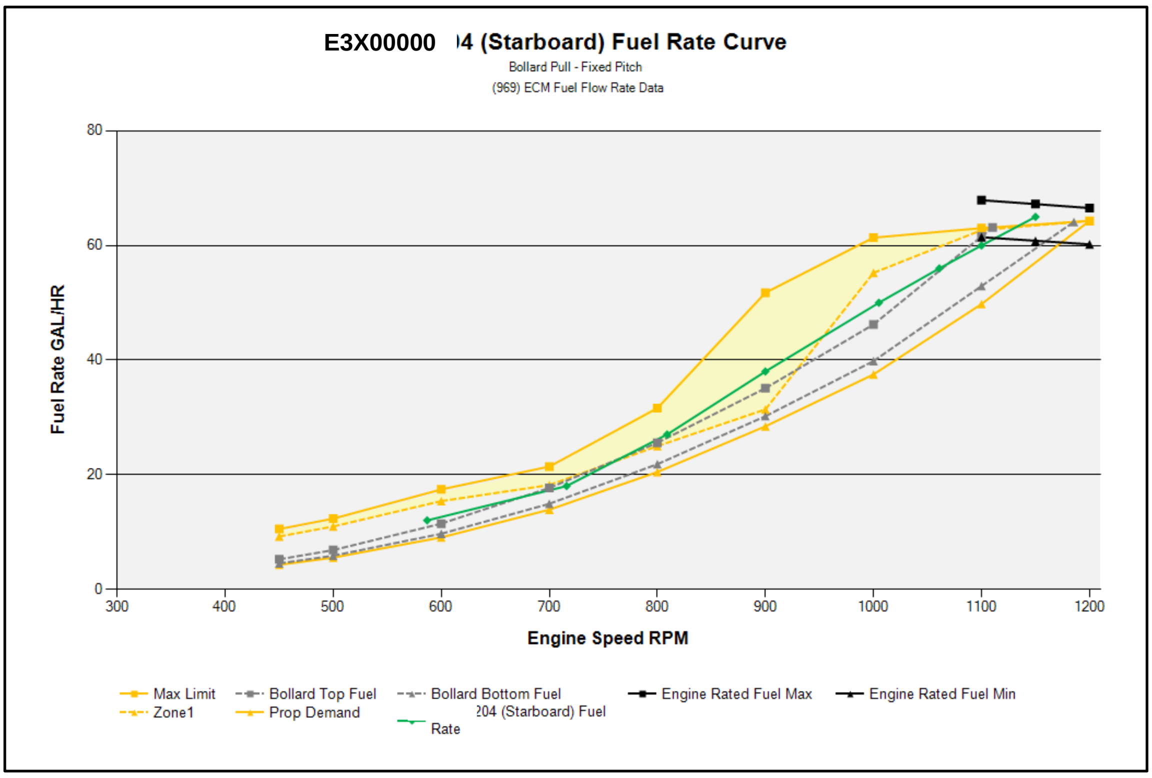
8.6.1 Electronics or Fuel Delivery

In this scenario, the engine fails to reach rated speed and the fuel rate at maximum engine speed falls well below the maximum limit curve. This could be an indication that the engine is not getting the correct amount of fuel to achieve rated speed. A number of factors may cause this including the desired speed set to low, the throttle not reaching full throttle, fuel rate set incorrectly, or an excessive fuel restriction that is severely limiting flow. Recommended troubleshooting should include reviewing the engine speed settings, throttle position, and fuel settings. Engine performance conclusions should not be made on only one parameter. The boost pressure graph should also be taken into consideration prior to concluding the sea trial analysis.



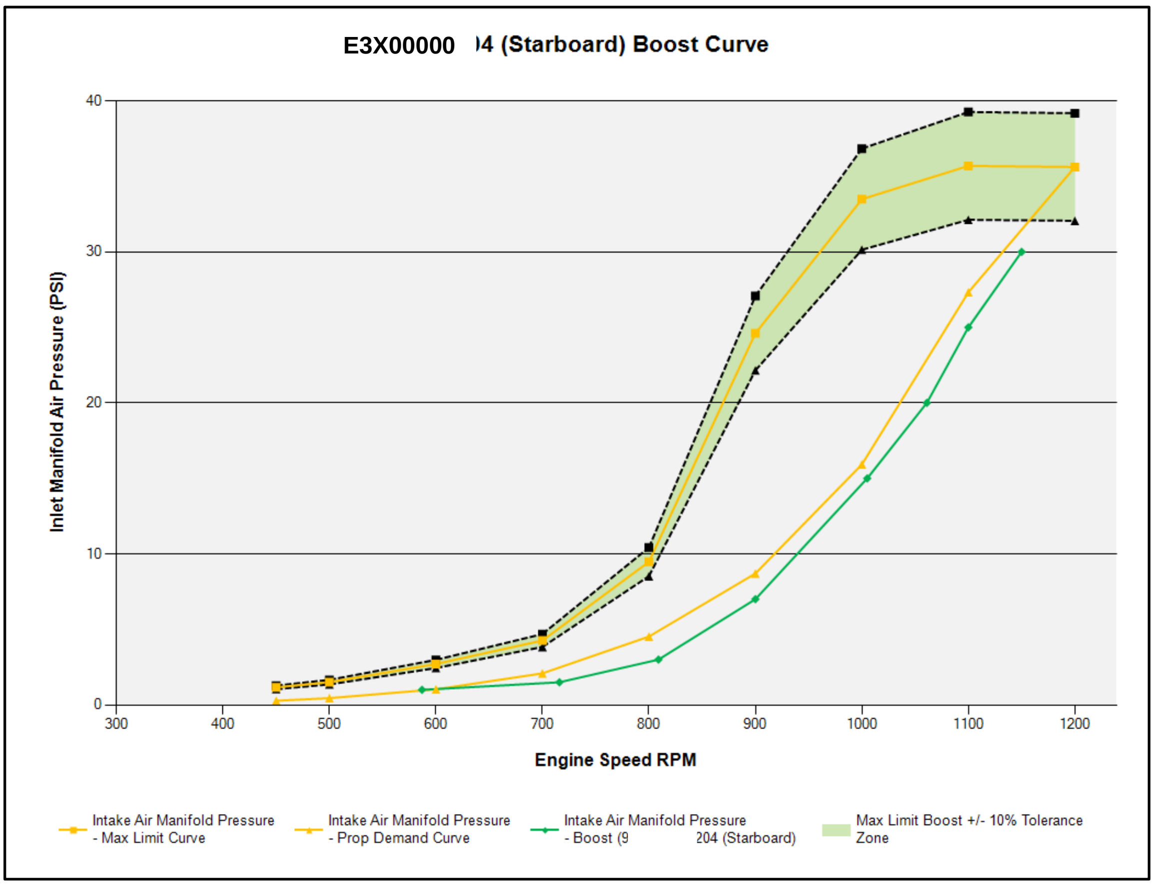
8.6.2 Vessel Design

In this bollard scenario, engine speed reaches 93-97% of rated speed and the engine fuel rate at maximum engine speed falls within the fuel rate performance bands, however, at the middle of the RPM range the engine is operating in the yellow transition zone. While the engine is properly loaded at rated load, there may be an issue with operation at lower engine speeds. If the vessel intends to operate frequently at a point within this transition zone, the engine may exceed the rating guideline definitions. Running outside of the rating guidelines can result in early wearout and, therefore, the need for shorter maintenance intervals and potentially a reduced overhaul life. Engine performance conclusions should not be made on only one parameter. If an engine is operating in the transition zone, it is advised to review the engine rating and the rating guidelines, as well as a discussion with the vessel operator to understand the intended operating speed for various work cycles.



8.6.3 Inadequate Air System

In this scenario, maximum boost pressure does not intersect the green zone and engine speed does not reach rated engine speed. This would be an indication that the engine may have a deficient air system, full throttle not being achieved or a fuel system problem. The fuel rate graph should also be taken into consideration prior to concluding the sea trial analysis. If the fuel rate graph is indicating the engine is receiving maximum fuel for the given engine speed, then an air system problem is suspected. A restriction either in the intake or exhaust or an intake system leak after the turbocharger could be present not allowing the engine to achieve the boost required to reach the green zone. Engine performance conclusions should not be made on only one parameter.


E3X00000)4 (Starboard) Boost Curve
Inlet Manifold Air Pressure (PSI)
40
30
20
10
0
300
400
500
600
700
800
900
1000
1100
1200
Engine Speed RPM
Intake Air Manifold Pressure - Max Limit Curve
Intake Air Manifold Pressure - Prop Demand Curve
Intake Air Manifold Pressure - Boost (9 204 (Starboard)
Max Limit Boost +/- 10% Tolerance Zone

9. Appendix A: Sea Trial Tooling

Below is a summary table of the sea trial tooling described in 6.2 Data Measuring Points. The below sea trial tools, or equivalent, are preferred for use on all sea trials.

Part Number	**Name**	**Function**
368-9910	Caterpillar Multi-Tool	Electronic viewing tool to monitor temperatures and pressures
464-1090	Marine Sea Trial Adapter Group	Provides pressure transducers, thermocouples and various common adapters for marine engines
398-9680	Fuel Gravity (API) Kit	Hydrometer and beaker for measuring fuel API and temperature
155-8795	Crankshaft Deflection Kit	Measure crankshaft deflection to ensure correct mounting
Multiple	Dial Indicator	Alignment measurements between flywheel and coupled equipment, and crankshaft end play. Various indicators available.
Multiple	Digital Multimeter	Measuring electrical parameters. Caterpillar provides many options, alternatively 3rd party tools are available and acceptable.
457-5269	Infrared Thermometer	Measuring surface temperatures
368-9911 308-7271	Fuel Flow Meter	Measure fuel consumption with increased accuracy
8T-0452	Water Manometer	Measure low pressures including exhaust backpressure and crankcase pressure

Probe seal adapter groups may be used with manual temperature and pressure measuring diagnostic tools. They allow probe insertion through the center, and they seal when the probe is removed. The adapters can be permanently installed and are equipped with a hex head plug to eliminate leakage and debris accumulation. The following list of probe seal adapters available through Caterpillar.

Part Number	**Size**	**Function**
5P-2720	1/8“-27 NPT	Probe Seal Adapter
5P-2725	1/4"-18 NPT	Probe Seal Adapter
5P-3591	9/16“-18 STOR	Probe Seal Adapter
4C-4545	3/4“-16 STOR to 1/4" NPT	Probe Seal Adapter
4C-4547	1/2"-20 STOR to 1/4" NPT	Probe Seal Adapter

A set of manual pressure gauges can be created from a list of available Caterpillar parts. The parts list below will create two manual pressure gauges:

- One from 0 to 58 PSI (0 to 400 kPa)
- One from -15 to 72 PSI (-100 to 500 kPa)

Part Number	**Quantity**	**Description**
8T-0853	1	0 to 58 PSI Gauge
8T-0862	1	-15 to 72 PSI Gauge
164-2192	2	Pressure Probe
4M-5317	2	1/4" NPT (male) to 1/8“ NPT (female)
3F-2779	4	1/4" NPT (female) to 1/4“ NPT (female)
5K-5068	2	1/8" NPT (male) to 1/8“ NPT (male)
Various	1	Hose

10. Appendix B: CAMPAR Calculations

The following section contains detailed information about the calculations performed by the CAMPAR tool.

10.1 Aftertreatment

The following calculations are performed by the CAMPAR aftertreatment module. The TMI specs are imported from the TMI sea trial tab. In some cases, the TMI sea trial tab may not auto populate this data. In those cases, a manual analysis can be done utilizing the information below.

Dosing Cabinet DEF Inlet Pressure

The 979 measurement must be manually taken and a measurement port should be installed in the DEF transfer pump inlet piping right before the cabinet. The TMI minimum and maximum specifications are drawn from the physical data of the MODULE AR-DEF. If a DEF transfer pump is utilized, it may cycle which would require this measurement to be taken when the DEF transfer pump is operating.

$$979_{TMI\ min} \leq 979_{measured} \leq 979_{TMI\ max}$$

DEF Pressure Drop from Dosing Cabinet to Nozzle

This measurement is the difference between 980 and 976. 980 is measured by an ECM sensor, however the 976 measurement must be manually taken and a measurement port should be installed in the DEF piping right before the nozzle. The TMI minimum and maximum specifications are drawn from the physical data of the MODULE AR-DEF.

$$0 \leq 980_{measured} - 976_{measured} \leq DEF\ Pressure\ Drop_{TMI\ max}$$

Dosing Cabinet Air Outlet Pressure

977 is measured by an ECM sensor. The TMI minimum and maximum specifications are drawn from the physical data of the MODULE AR-DEF.

$$978_{TMI\ min} \leq 978_{measured} \leq 978_{TMI\ max}$$

Exhaust Pressure Drop across CEM

This measurement is the difference between 984 and 985. 984 is measured by an ECM sensor, however the 985 measurement must be manually taken and a measurement port should be installed in the exhaust piping after the CEM. The TMI maximum specification is drawn from systems data in TMI as this specification varies based on engine rating.

$$984_{measured} - 985_{measured} \leq CEM\ Pressure\ Drop_{TMI\ max}$$

SCR Exhaust Inlet Temperature

This calculation evaluates 983 against the TMI specifications. 983 is measured by an ECM sensor in the CEM inlet spool. The TMI maximum specification is drawn from the physical data of the MODULE AR-EXH.

$$983_{measured} \leq 983_{TMI\ max}$$

Turbo to CEM Temperature Delta

This measurement is the difference between 912 and 983. 983 is measured by an ECM sensor in the CEM inlet spool but 912 must be manually measured at the turbo outlet on the vessel piping. The TMI maximum specification is drawn from the physical data of the MODULE AR-EXH. The temperature into the CEM should always be less than the temperature out of the turbo.

$$0 \leq 912_{measured} - 983_{measured} \leq Temperature\ Delta_{TMI\ max}$$

Caterpillar Marine

LEBM0025-03

To find your nearest dealer, please visit: www.cat.com/marine

Materials and specifications are subject to change without notice.
The International System of Units (SI) is used in this publication.