Commissioning Guide

G3600

LEBW4987-02

Foreword

This section of the Application and Installation Guide generally describes wide-ranging requirements and options for Switchgear with a focus on Generator Paralleling Switchgear. Additional engine and generator systems, components, and dynamics are covered in other sections of this Guide.

Systems and components described in this guide may not be available or applicable for all Switchgear. While much of the content of this guide is applicable to all switchgear the primary focus of this guide is on the North American generator paralleling switchgear market.

1.0 Cat G3600 Engine Audit Report

☐ **Design Audit** ☐**Construction Audit** ☐**No Load Test** ☐**Commissioning**

General: Selling Dealer ____________ District or Subsidiary ______________

Servicing Dealer ____

Equipment Suppliers and Contractors: ____

____

____

Customer: ____

Address:____

Application:

Industrial: Driven Equipment _________ rpm @ ___________% load

Genset: Prime Power: ___________Continuous: ____________ @ _________ % load

Peak Shaving: ___________Standby: __________

Consist: Engine Model: ____________ Engine Arrangement No. ________________

OT Specification No. ___________________ Serial No. _________________________

Rating: _________RPM bhp: __________ bkW________ Emission Rating: ______

Governor: ☐Cat ☐Suction Pressure Controller ☐Discharge Pressure Controller

Other (specify) ____

☐ Load Share ☐ SPM-A ☐ LC ☐APTL ☐Import Export Controller

☐ Other (specify) ____

High Idle: Specified _____________________OT Specification _________________

Low Idle: Specified ____________________% Droop Specified ___________________

Fuel: ☐Pipeline Natural Gas ☐Field Gas ☐Landfill Gas ☐ Digester Gas

☐ Other (Specify) _____________ Lower Heat Value ______ mJ/m³ ________ Btu/scf

Caterpillar Methane Number ________Specific Gravity ______ Wobbe Index _________

Minimum Fuel Pressure _______ kPa ________ psi

☐ Cat Fuel Filter ☐ Other (specify) _______________________________

Cooling System: ☐ Inlet Controlled ☐ Outlet Controlled

Engine Stat Temperature ________ °C/°F Separate Circuit Stat Temperature ______°C/°F

Engine Coolant: ☐Cat Gas Engine Coolant ☐De-Ionized Water

☐ Distilled Water Antifreeze ______ % Corrosion Inhibitor %_________________

Separate Circuit Coolant: ☐ Cat Gas Engine Coolant ☐De-Ionized Water

☐ Distilled Water Antifreeze ______% Corrosion Inhibitor %__________________

Cat G3600 Engine Audit Report continued

Engine Oil Brand ____________________________ Viscosity ___________________

Engine site conditions: Elevation ___________ Meters _______________ Feet_______

Typical Ambient Temperature range for the year: _________________to______________

Atmospheric conditions: Typical relative humidity level: __________________________

Air Quality: Salty ___________ Dusty____________ Clean ___________

Site Emissions Permits

NOx ________ CO ________ VOC _________

Application Summary:

____
____
____
____
____
____
____
____
____
____

The areas selected below require action to comply with Caterpillar Application and Installation Guidelines.

	Air Intake		Cooling		Expansion Tank		Starting
	Exhaust		Fuel		Lubrication		Mounting and Alignment
	Driven Equipment		Safety and Alarms		Engine Monitoring		Ventilation
	Serviceability		Equipment Safety		Generator Controls		Switchgear
	Operation and Maintenance		Crankcase Ventilation				

The following parties have discussed and agreed to the results and required action during the design review process. *See details in Cat G3600 Engine Audit Results form.*

Signatures:
Commissioning Engineer: _________________________________ Date: ____________

Packager: ____ Date: ____________

Customer: ____ Date: ____________

2.0 Cat G3600 Engine Audit Results

☐ Design Audit ☐ Construction Audit ☐ No Load Test ☐ Commissioning

System	Design Compliance with G3600 Engine Requirements
Air Intake Satisfactory ☐ Unsatisfactory ☐	
Cooling Satisfactory ☐ Unsatisfactory ☐	
Expansion Tank Sizing Satisfactory ☐ Unsatisfactory ☐	
Starting Satisfactory ☐ Unsatisfactory ☐	
Exhaust Satisfactory ☐ Unsatisfactory ☐	
Exhaust Emissions Satisfactory ☐ Unsatisfactory ☐	
Fuel Satisfactory ☐ Unsatisfactory ☐	

Cat G3600 Engine Audit Results continued

☐ Design Audit ☐ Construction Audit ☐ No Load Test ☐ Commissioning

System	Design Compliance with G3600 Engine Requirements
Lubrication Satisfactory ☐ Unsatisfactory ☐	
Engine Mounting & Alignment Satisfactory ☐ Unsatisfactory ☐	
Driven Equipment Satisfactory ☐ Unsatisfactory ☐	
Safety and Alarms Satisfactory ☐ Unsatisfactory ☐	
Engine Monitoring Satisfactory ☐ Unsatisfactory ☐	
Ventilation Satisfactory ☐ Unsatisfactory ☐	

Cat G3600 Engine Audit Results continued

☐ Design Audit ☐ Construction Audit ☐ No Load Test ☐ Commissioning

System	Design Compliance with G3600 Engine Requirements
Serviceability Satisfactory ☐ Unsatisfactory ☐	
Equipment Safety Satisfactory ☐ Unsatisfactory ☐	
Generator Controls Satisfactory ☐ Unsatisfactory ☐	
Switchgear Satisfactory ☐ Unsatisfactory ☐	
Operation and Maintenance Satisfactory ☐ Unsatisfactory ☐	

Cat G3600 Engine Audit Results continued

☐ Design Audit ☐ Construction Audit ☐ No Load Test ☐ Commissioning

System	Design Compliance with 3600 Engine Requirements
Crankcase Ventilation Satisfactory ☐ Unsatisfactory ☐	
______ Satisfactory ☐ Unsatisfactory ☐	
______ Satisfactory ☐ Unsatisfactory ☐	
______ Satisfactory ☐ Unsatisfactory ☐	
______ Satisfactory ☐ Unsatisfactory ☐	
______ Satisfactory ☐ Unsatisfactory ☐	
______ Satisfactory ☐ Unsatisfactory ☐	

3.0 Design Review Introduction

A well-planned installation will aid reliability, performance, and serviceability. To be successful, the installation designer must be aware of the application and installation requirements for Cat G3600 engines. As a first step, the designer should be aware of all pertinent Caterpillar reference publications, such as the Gas Engines Application and Installation Guide, Form No. LEBW4950 & LEKQ2368, GERP (Gas Engine Rating Pro) Media No. LERW4485, as well as other information from Cat G3600 Engine family.

Design the installation to give efficient and reliable operation. A poorly designed installation can hinder serviceability, and make routine maintenance and repairs difficult. The neglect of specific design requirements for mounting, alignment, and support systems, can lead to poor performance and increased cost of operation.

When the installation designer has completed a review of the Caterpillar application and installation requirements, a discussion should take place with Cat® dealer personnel to cover concerns he may have about specific areas of the design. This will establish ground rules for further working relationships in the design phase. After the initial installation drawings have been completed, follow-up discussions with the designer should occur to make sure the drawings meet application and installation requirements. As an aid in the review of the design, use the Cat G3600 Engine Audit Report on pages 10-11, and Cat G3600 Audit Results on pages 12-15 of this publication.

3.1 Explanation of Installation Design Review Report

Use the Cat G3600 Audit Report in this guide as a checklist to review the design.

It is a checklist to determine if sufficient information has been provided to the installation designer for completion of initial layouts in compliance with requirements in the Gas Engines Application and Installation Guide or GERP (Gas Engine Rating Pro).

Complete the form with general information about the owner, power station, and builder/installer. Using the design criteria of the power station, record specific data concerning physical features of the site as well as the engine and generator or driven equipment support systems.

There is a provision to record Caterpillar reference materials provided to the designer as well as a checklist for results of the design and serviceability review. Compliance with Caterpillar requirements is noted by placing an “X” in the appropriate box next to the system reviewed, indicating satisfactory or unsatisfactory compliance. If the design of a system does not comply, space is provided to record action required to follow-up and correct the problem areas.

Work with packager prior to sharing the discrepancies with the customer. After completion of the audit forms, and after reaching agreement on required corrective action, all concerned parties sign the designated location.

4.0 Construction Review Shop Audit

4.1 Introduction

After the design review is satisfactorily completed, the next step is the construction of the installation site. During this phase, visit the construction site at least twice to perform a review of system installation progress.

The first visit should follow installation of the Cat G3600 unit(s). Additional visits may be necessary, depending on the difficulty of the installation, and the stage of completion. Make the final visit before the commissioning process begins.

The objective of these visits is to determine if the previously approved design is being followed. These visits not only continue to produce a better understanding of Caterpillar requirements, but also provide a more reliable installation for the customer. Experienced construction builders will make necessary changes as soon as possible, to avoid costly delays and eventual customer downtime.

4.2 Explanation of Construction Review Report

Use the Cat G3600 Audit Report as a checklist for the site audit. The report is a simple checklist used to determine if the previously agreed on design is being successfully implemented during the construction process.

Fill out the report with general information about the owner, installation site, and builder/installer, including the power station physical features. Provisions are made for recording the engine and generator systems descriptions, including serial numbers, and manufacturer, where applicable.

When the construction and installation are in compliance with Caterpillar requirements, indicate this by placing an "X" in the box next to the system reviewed for satisfactory or unsatisfactory compliance to requirements. If a system does not comply, there is space to record the necessary corrective action.

After the construction review and the construction review forms are completed, and before discussing with the customer, confer with the packager about any discrepancies found. After the packager has been notified and corrective action is agreed to, it is recommended that all concerned parties sign the construction review form at the designated locations on the report.

4.3 G3600 Engine Shop Audit (Non-Running Checks)

Note: Refer to A & I Guide – G3600 Packaging Tips (Form No.) for additional information

If a live engine test is to be performed at the construction/packaging audit, additional work needs to be completed (see second part of this section). The following is a reference to follow to ensure the package is designed and performing correctly. This will reduce the commissioning effort when the engine arrives at the site.

4.4 Serviceability

An important aspect of the shop audit is to consider all aspects of the package with regard to how well the Application and Installation Guide has been followed when designing and constructing the components.

A very important part of this activity is to consider how easily the technician can perform routine maintenance procedures considering how the package components are laid out and assembled. Here are just a few of the more important elements to consider as you inspect the package.

- How easily can a technician get to the air cleaners to inspect the elements? How easily can the technician carry replacement elements to the air cleaner?

- How cluttered is the skid on either side of the engine? Will it be difficult for the technician to access those components on either side of the engine for service work? Can the technician easily maneuver to get the side covers off to perform lower end service repairs? The time to check for easy access is now, not when the package is on site.
- Is the turning tool area easily accessible for rotating the engine during routine maintenance procedures?
- Is the cover on the front of the oil pan blocked so that the oil pump suction screen cannot be removed for cleaning and inspection? The required clearance is 22 inches.
- Are the expansion tanks easily accessible for checking the radiator cap and vent lines?
- Are the temperatures located down low and near the engine to facilitate routine servicing? Are they located high up on the side of the cooler? Or on a fabricated support that supports the expansion tanks?
- Is the exhaust and air inlet piping configured to allow reasonable access using an overhead hoist for top-end repairs (cylinder heads, turbochargers, etc.)?

These are the kinds of these to be on the lookout for during the audit inspection. The time to correct these kinds of errors is while the package is in the shop, not after it arrives at the operating site. Good hunting.

4.5 Air Inlet System

Note: Review the air inlet system for adherence to the A & I guidelines.

The air cleaner and piping system must be inspected to ensure it has not been contaminated with dirt and debris. The air cleaner elements should be removed from their housing. Carefully inspect the clean side of the air cleaner elements. While the elements are removed, inspect the air cleaner housing. It must be clean and free from debris, loose paint, rust, and corrosion. Inspect the welds and joints of the air cleaner housing on the clean side and look for gaps and openings that could let dust into the clean intake air. If any such possible dirt entry point is found, return the housing to the manufacturer or repair the part by welding or other suitable method.

The clean side air piping must be inspected for cleanliness. Inspect in place if possible. If it is not possible, remove the piping and inspect in a clean area. Any welding slag (stick or mig wire), dirt, dust, and debris must be removed. If the pipe is metallic material, it should be stainless steel or galvanized. If the pipe is welded inspect for pin holes and gaps in the weld. Rust is very abrasive and can wear an engine prematurely; however, painting is not recommended to control rust. PVC (schedule 40) is recommended for the air inlet piping. Fiberglass tubing may be used with caution and frequent inspections. The tubing may separate and cause major turbocharger damage.

If PVC is not used, the air inlet piping should be of seamless or welded seam piping to minimize the flow restriction. Use either T-bolt type or SAE type F hose clamps that provide a 360° seal. High quality clamps must be used. The clamps furnished by Caterpillar are recommended. Double clamps are recommended on connections downstream of the air cleaner.

The use of PVC piping has a number of benefits. It is lightweight, provides a good seal without the chance of weld slag coming loose and will not rust. If using PVC pipe, use at least schedule 40 pipe strength.

If ferrous material is necessary, it must be properly cleaned after fabrication and treated to prevent rust and scale from accumulating. Welded seams must be ground smooth to ensure sealing of the connecting rubber boot. Make sure the weld has sufficient penetration and material for grinding. Stainless steel ducting should be treated in the same manner. Flanged connections with gaskets are preferred over threaded connections.

Fasteners such as rivets should not be used and are not acceptable.

System pressures can be evaluated at the audit, but often maximum load cannot be obtained until the engine is at the customer's site. However, this is usually the best time and facility to install ports for pressure measurements if they are not already installed. Locate and install bosses (typically 1/2 inch female pipe) at the following locations:

Exhaust Outlet	Air Cleaner Housing Outlet
❑ 3 to 5 pipe diameters from elbow	❑ Housing Port

Table 4.1

4.5.1 Air Inlet Piping Design

Care must be exercised when combining inlet air piping. The transitions used to combine multiple ducts must follow typical design standards described in the A & I guide to achieve smooth transition flows.

When ductwork feeding two turbochargers is combined to form a single duct, a steadying zone must be provided after the dividing joint; as shown in the Figure 4.1. The steadying zone B must be a minimum of 5 times the pipe diameter: $B > 5 \times Dh_1$.

Note: Refer to the A & I Guide LEBW4969 and LEKQ7250 Air Intake Systems for more detail to guide the design process. See figure for examples of incorrect air inlet piping design.

Figure 4.1 – Example of Incorrect Air Inlet Piping Design That Creates Excess Turbulence

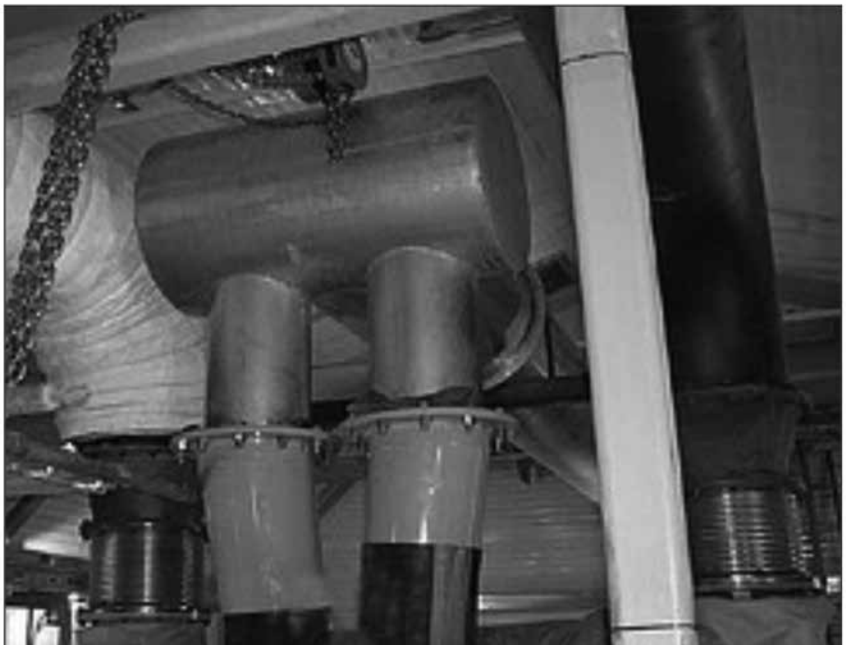

Figure 4.2 – Example of Incorrect Air Inlet Piping Design That Creates Excess Turbulence

4.5.2 Piping Support

Air inlet piping design must give consideration to appropriate routing, piping support, and system restriction, especially on G3600 engines, where overhead cranes are used to service the engines. Proper support for the piping adjacent to the engine is critical, so that the piping weight is not borne by the turbocharger or other engine-mounted components. No segment of the air inlet or exhaust piping should be supported from the engine.

4.5.3 Piping Connections

Verify that the inlet piping connections have sealing integrity. Offer encouragement to use flanged, gasketed connections for improved sealing. Verify/discuss that rubber boot connections will have two clamps per boot end for sealing integrity.

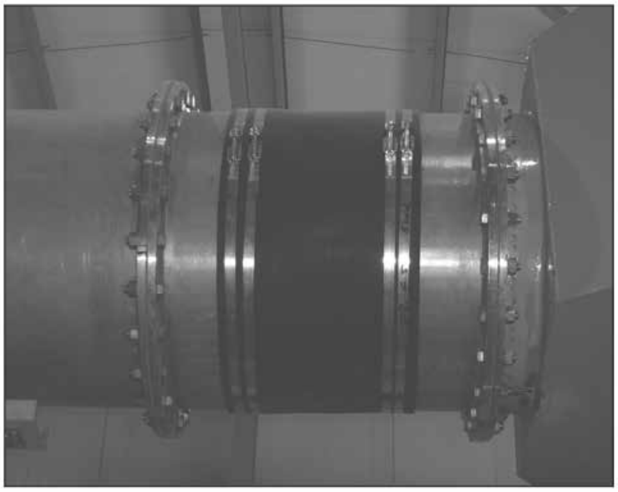

Figure 4.3 – A Good Example of Clamp Usage on Connecting Boots

4.5.4 Air Inlet Silencers

Verify that the air inlet silencer is of the correct design. Silencers which do not fully contain the silencing material within the confines of the baffling are not allowed. Inspect the silencers for cleanliness. Encourage the proper sealing protection of the silencer for shipment and storage on site during construction. Also make sure that the silencer is installed in the proper flow direction according to the manufacturer instructions.

4.5.5 Air Cleaner Mounting

Air cleaner elements must be accessible for easy servicing during periodic maintenance. Air cleaners that are mounted above grade should have a stair for accessibility instead of a ladder. A technician cannot easily and safely climb a ladder with a replacement air cleaner element in hand. Verify the air cleaner mounting configuration for performance and service accessibility.

Inquire to see if the air cleaner location will be inside or outside the building at the operating site. The engine should be able to get clean, cool air for best combustion performance. Locating the air cleaners inside a fully enclosed building will probably cause the inlet air temperature to exceed the temperature limits for G3600 engines. Also, verify whether an outside air cleaner will be located adjacent to a radiated heat source. It should also not be located in an area that would expose it to the high heat radiated from the exhaust silencer or cooler air discharge. Discuss the negative influence of the air cleaner being located in these high ambient temperature locations.

If the Cat air cleaner housing is used, the factory pressure port is adequate for measuring inlet air restriction. Otherwise, install a pressure port for this purpose.

4.5.6 Air Cleaner Provided by Others

Air cleaners not provided by Caterpillar for the engine must meet airflow and contamination containment requirements to protect the engine from shortened component life. This requires prior factory approval. Refer to A & I Guides LEBW4969 and LEKQ7250 for more information. Request and obtain a copy of the factory approval.

4.6 Exhaust System Piping

Exhaust system piping must be made of a material to withstand the effects of exhaust gas temperature, velocity, and thermal expansion. Ensure that any insulation added to exhaust piping does not deteriorate the piping since the pipe temperature will be higher than if not insulated.

Backpressure of the total piping system must be minimal to allow for muffler restriction, outlet piping from the muffler, and piping degradation during the life of the engine. Fuel consumption, exhaust emissions, detonation and exhaust explosion characteristics, and component life of the engine will be affected if the backpressure exceeds the recommended value of 12 inches of water pressure.

Exhaust backpressure on each bank of the twin turbocharged G3612 and G3616 (vee) engines must be balanced, even when the dual pipes exiting the turbochargers are transitioned into one larger pipe going to the muffler. Do not allow gas flow to turn at a right angle during a transition. Do not allow the exhaust system piping for a vee engine to be routed vertically from each turbocharger and then be blended horizontally. This will cause excessive backpressure on one bank. Blend the exhaust gases into a common pipe before the direction change is made or during a long radius bend in the directional change.

A point for measuring exhaust system backpressure should be in a straight length of the exhaust pipe at least 3 to 5 pipe diameters away from the last size transition change from the turbocharger outlet as close to the engine as possible. The minimum distance away from turbocharger bellows is 3 to 5 pipe diameters. System backpressure measurement is part of the engine performance testing during commissioning.

The exhaust emission piping access ports should be installed in a straight section of pipe 3 to 5 pipe diameters after a transition as close to the engine as possible (minimum 3 to 5 pipe diameters from the turbocharger flexible joint). Tube should extend into the exhaust air stream 6-12 inches for a better sample, especially when measuring backpressure. See Figure 4.4 for example of placement of ports.

Note: Caterpillar recommends explosion relief valves be installed the in the exhaust system before each major component. This will reduce the risk of damage in the event of an exhaust explosion. Caterpillar also recommends exhaust piping ventilation fans or draft inducers should be installed in the exhaust system.

There must be expansion joints and vertical supports in the appropriate positions to assure free movement of the exhaust piping during thermal expansion.

Figure 4.4 – Proper Location of Emission Sample Port in Exhaust Piping

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

The exhaust piping routing must not interfere with the service of the engine. Pay particular attention to the accessibility of an overhead bridge crane.

The air inlet and exhaust piping may not be installed during the shop audit. Make the effort to determine the configuration, support, and sample tap location.

4.7 Mounting and Alignment

During the design phase of the package, a torsional analysis must be completed for the engine, coupling, and driven equipment. This analysis should be performed by the packager. Caterpillar also provides this service.

Torsional Analysis:

❑ **Acceptable** ❑ **Unacceptable**

Correct mounting and coupling to driven equipment are essential to the success of any engine installation. Due to diversity of installation types, no single mounting system or method is universally acceptable. The recommended mounting system offered by Caterpillar on G3600 engines is a hard mounting system of engine feet and steel chocks.

The G3600 engine can be temporarily rested on the oil pan, but the oil pan is not intended to support the engine during shipment, or the final installation. The recommended practice is to support the oil pan under the entire width of the front and rear end plates with a wooden block.

The engine and driven equipment must be mounted on a structure suitable to support the equipment as well as provide torsional strength. This structure design and fabrication is typically provided by the engine packager. The base should be evaluated for structural strength for the application in question. The engine must be in alignment with the driven equipment. Typically the driven equipment is shimmed to obtain proper alignment. In some cases such as gas compressors, the engine is moved and shimmed to obtain proper alignment.

Note: Engine alignment must be done cold before first startup and again hot after the engine temperatures have stabilized at normal operating temperature. Recognize that any shop alignment procedures will be temporary; final permanent alignment will be performed at the site during package commissioning.

Note: Always prelube before rotating the crankshaft. Always use engine turning tool only for this procedure; do not use the engine starter. It is a good idea to operate the prelube during crankshaft rotation for easier rotation.

Engine Mounting Feet

G3600 engines are mounted from the cylinder block to engine bases with cast iron engine feet. A bolt-hole pattern is available at each cylinder block bulkhead for engine mounting feet with no provision for mounting from the front or the rear housing. The dimension from the crankshaft centerline to the bottom of the foot can be 450 mm (17.717 in) or 405 mm (15.945 in).

The inline engines normally use four feet at standard locations of front and rear. Each foot is attached to the block with four bolts. The vee engines normally use six feet. Each foot is attached to the block with six bolts. Again the standard locations are front and rear, with a middle location just to the rear of the center bulkhead. The G3600 engines can accommodate up to eight mounting feet.

Due to thermal expansion, [cast iron 11.7 x 10-6 mm/mm/°C, (6.5 x 10-6 in/in/°F)], a G3600 cylinder block may increase up to 3.08 mm (0.121 in) longitudinally and 0.88 mm (0.035 in) laterally as it heats up from ambient to operating temperature. This growth must not be restrained. The Cat mounting system used for the gen set locates the right rear engine mounting foot with a dowel and is designed to force engine thermal growth forward and to the left side. This design is not normally used in gas compression package construction.

The Cat mounting weld plates (chocks) are a prefabricated means of creating the attachment details for mounting an engine to a rigid base. They include not only the weld plates, but also leveling jack screws, dowels, shims, a guide block feature, and the engine foot-to-plate mounting bolts. In general the installation procedure is to mount the weld plates to the engine feet, establish engine location, weld the plates to the base (maintaining parallel mounting surfaces), loosen the plate from the foot, establish final alignment shimming between the foot and the plate to eliminate any gap or “soft foot”. It is vitally important that the mounting plate planes be parallel. This element is most important for long life mounting stability to prevent engine damage, such as main bearing failure. If these engine mounting planes on the skid are not parallel, “soft foot” will occur and the mounting integrity will not be acceptable. Partial shim use is not acceptable. The mounting plate will either have to be cut off and rewelded or machined to be parallel.

Another more common engine mounting is to mount the sole plate to the engine mounting feet. Position the engine in the correct position relative to the skid. Grout the sole plate to the skid mounting location which has been prepared to accept the grouted-in sole plate. Be sure to protect the threads of the jacking screw in the mounting so that the grout does not damage the threads.

Soft Foot

The first step before actual alignment should be a check for “soft-foot” on both the driven equipment and the engine. This is done to prevent engine block or driven equipment from being deformed. This affects main support bearings of both the engine and driven equipment. Corrections need to be made to bring soft foot readings to within .002 inches before proceeding. Gas compressors are usually grouted in place so a soft foot check is usually not necessary for the driven equipment, only the engine.

Note: Shim packs under engine should be 0.76 mm (0.030 in) minimum and 6 mm (0.236 in) maximum thickness. If more than 6 mm (0.236 in) is required, use plate material to minimize the number of shims used. (Refer to LEBW4974, LEBW4975, LEKQ7252, G3600 Mounting and Alignment modules from the Gas Engine Application and Installation Guide). Partial shims used to support the engine mounting foot are not allowed. This will not fully support the engine location and will lead to failures.

After and during alignment, each mounting surface must carry its portion of the load. Failure to establish this condition can result not only in misalignment, but also in springing of the substructure, high stress in welds or base metal, and high twisting forces in the engine or driven equipment. This “soft-foot” can be identified by the following procedure. Torque the foot-to-base mounting bolts at all feet. Set up a dial indicator from the base to the engine mounting foot. Loosen the bolts and observe the dial indicator for any movement one foot at a time. If the foot is solid, no movement will be observed. Record the soft foot data in Table 4.2.

Soft Foot Recorded Data		
Foot Location	**Deflection**	**Limit**
Right Front		≤0.05 mm (0.002 in)
Right Middle		≤0.08 mm (0.003 in)
Right Rear		≤0.05 mm (0.002 in)
Left Front		≤0.05 mm (0.002 in)
Left Middle		≤0.08 mm (0.003 in)
Left Rear		≤0.05 mm (0.002 in)
		≤0.05 mm (0.002 in) preferred
Soft Foot Test	❑ Acceptable	❑ Unacceptable

Table 4.2

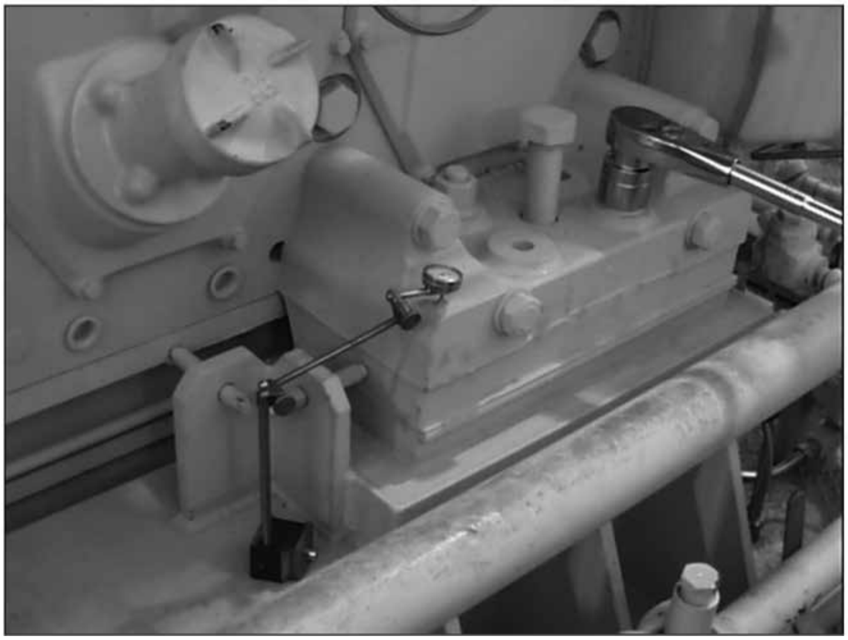

Figure 4.5 – Checking Soft Foot by Loosening Mounting Bolts and Measuring Foot Movement

Figure 4.6 – Checking and Adjusting Soft Foot by Adding/Removing Shims

If the engine is not doweled at all, as described for the Cat packaged gen set, the torque on mounting feet-to-base bolts must be checked every 1000 hours. The coupling alignment must be checked every 5000 hours. For engines using Cat mounting bolts, tighten the rear feet to a torque of 900 N•m (664 ft. lb.), the middle feet to 630 N•m (465 ft. lb.) and the front feet to 500 N•m (369 ft. lb.). The preferred torque that should be used is the value that the mounting bolt supplier specifies, if available, with the bolt torque greater at the rear, decreasing toward the front of the engine. The engine must be allowed to grow forward with an increase in operating temperature. If this growth is inhibited, the crankshaft deflection might be affected and cause major damage to the lower structure of the engine.

Adjustable chocks may also be used for mounting the G3600 engine, although this is not preferred. Checking for soft foot is performed using the same procedure.

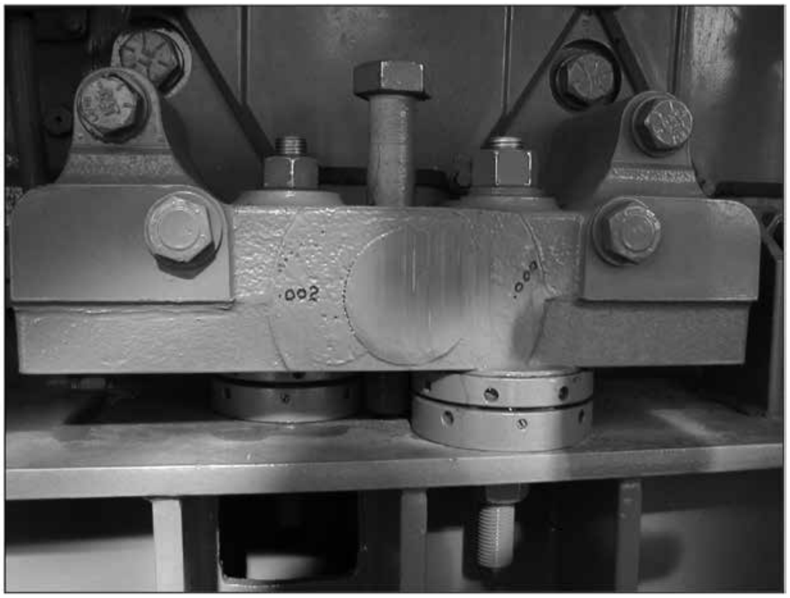

Figure 4.7 – Adjustable Chocks Used for Engine Mounting Require Soft Foot Check

Alignment/Deflection/Endplay – "Soft foot," alignment, crankshaft deflection, and crankshaft endplay must be checked "cold" before the initial package start-up and in the order listed here. These checks are used to verify position of engine in relation to the driven equipment. Shut off start air supply before conducting the alignment work.

Realize that any alignment adjustments in the shop are temporary and the unit must be aligned again after installation in the field.

Alignment

The alignment between the engine flywheel and driven equipment input flange must be measured in the axial and radial directions. This is done either with two dial indicators or a laser alignment tool. If dial indicators are used, it is important to have a very stiff indicator support. Any droop in the support for the dial indicators will corrupt the data. Magnetic mounts for the dial indicators are unacceptable. To obtain reliable axial alignment data, the engine and driven equipment must be thrusted against their respective thrust surfaces. This is done by jacking the engine crankshaft away from the driven equipment input flange. Refer to Special Instruction REHS0423 for more information.

The engine grows thermally between cold and hot operation. The engine grows vertically approx. 0.279 mm (0.011 in) and approximately. 0.127 mm (0.005 in) to the side as measured at the crankshaft. This growth must be considered in the cold alignment. Thermal growth of the engine must not be restricted. The engine and driven equipment must be prelubed prior to performing an alignment test.

❑ **Prelube completed**

Use Tables 4.3 and 4.4 to record the cold and hot alignment values.

Cold Alignment Data					
Cold	**12:00**	**3:00**	**6:00**	**9:00**	**12:00**
Face (Axial)	0.000 inch				
Bore (Radial)	0.000 inch				

Table 4.3

Hot Alignment Data					
Hot	**12:00**	**3:00**	**6:00**	**9:00**	**12:00**
Face (Axial)	0.000 inch				
Bore (Radial)	0.000 inch				

Table 4.4

If the start and finish 12:00 positions are greater than ± 0.025 mm (0.001 in), the alignment values must be rerun. To determine if the alignment is within specification, use Table 4.5.

Alignment Evaluation				
	12:00 - 6:00	**Tolerance**	**3:00 - 9:00**	**Tolerance**
Face (Axial)		±0.178 mm (0.007 in)		±0.178 mm (0.007 in)
	❑ Acceptable	❑ Unacceptable	❑ Acceptable	❑ Unacceptable
Bore (Radial)		±0.127 mm (0.005 in)		±0.127 mm (0.005 in)
	❑ Acceptable	❑ Unacceptable	❑ Acceptable	❑ Unacceptable

Table 4.5

Note: Always prelube before rotating the crankshaft. Always use engine turning tool only for this procedure; do not use the engine starter. It is a good idea to operate the prelube during crankshaft rotation for easier rotation.

See Gas Engine Application and Installation Guide, Technical Information section for more information.

If any of the above tests are unacceptable, shims can be used to correct the alignment problem. Typically, the driven equipment is shimmed. If this is impractical as in a gas compressor package, an engine shim pack is available under Cat part number, 7W8489, which provides 6 mm (0.236 in) worth of shims in two thicknesses, 0.05 mm (0.002 in) and 0.08 mm (0.0315 in). If equipped with adjustable chocks, use the supplier’s instructions for adjusting the chocks. Record the new alignment readings.

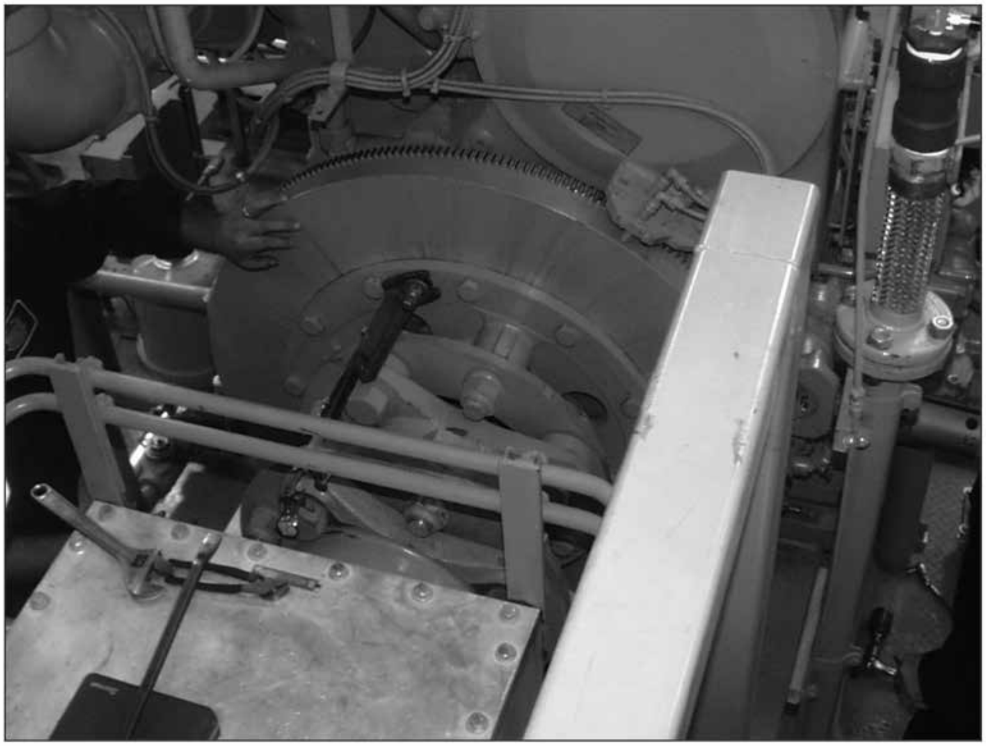

Figure 4.8 – Measuring Coupling Alignment Using the Dial Indicator Method

Note: A laser alignment tool will provide accurate readings and suggest corrective actions. This will improve and shorten the alignment process.

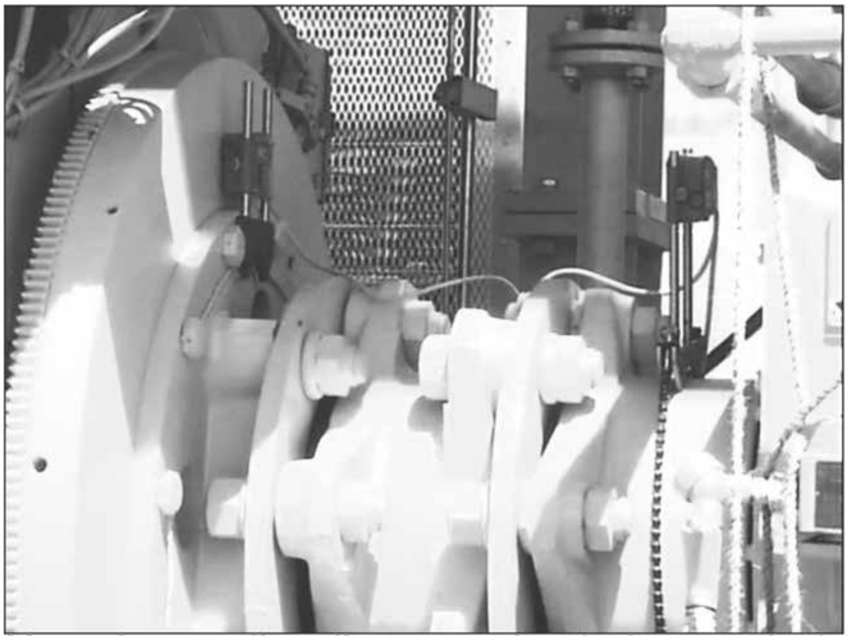

Figure 4.9 – Measuring Coupling Alignment Using the Laser Method

Endplay (Thrust)

The engine crankshaft endplay and deflection must be evaluated. Use Table 4.6 to determine if the endplay and deflection are acceptable.

Engine Endplay Evaluation (Cold)	
Endplay Measured	**Tolerance**
	203 to 0.610 mm (0.008 to 0.024 in)
❑ Acceptable ❑ Unacceptable	

Table 4.6

The driven equipment input shaft endplay must be evaluated if the driven equipment has oil lubricated journal bearings (not antifriction bearings). Determine the range of acceptable endplay from the driven equipment manufacturer and enter in the table below. Use Table 4.7 to determine if the endplay is acceptable. This is the responsibility of the packager.

Driven Equipment Endplay Evaluation (Cold)	
Endplay Measured	**Tolerance**
	203 to 0.610 mm (0.008 to 0.024 in)
❑ Acceptable ❑ Unacceptable	

Table 4.7

Crankshaft Deflection

The engine crankshaft deflection must be evaluated if the engine is to be run as part of the shop audit. This test is performed at the rod throw just to the front or rear of the center main journal on G3600 vee engines. On G3600 inline engines, perform this check at the rod throw just to the rear of the center main journal. This is the throw that has a threaded location for the bolt required to support the deflection measuring indicator.

See the Commissioning Section of this guide for this complete procedure.

4.8 Cooling System

The jacket water and auxiliary cooling system temperature regulators play an important role in the operation of the G3600 gas engine. Because the regulators are remote mounted (off engine), they have a more defined effect on coolant temperature control than when the temperature regulators are located on the engine.

The regulators must be placed correctly in the system for a two reasons:

1. For the best temperature and flow control of the coolant.
2. For the easiest access for serviceability.

The regulator groups must be located for easy servicing of the temperature elements. The regulator groups should be located near the engine for quick warm-up period. The regulator groups should not be mounted on the side of the cooler or high up from the grade above the engine elevation. The regulator group should not be mounted directly to the engine connection; use appropriate piping to locate the regulator group in a convenient location for service and performance.

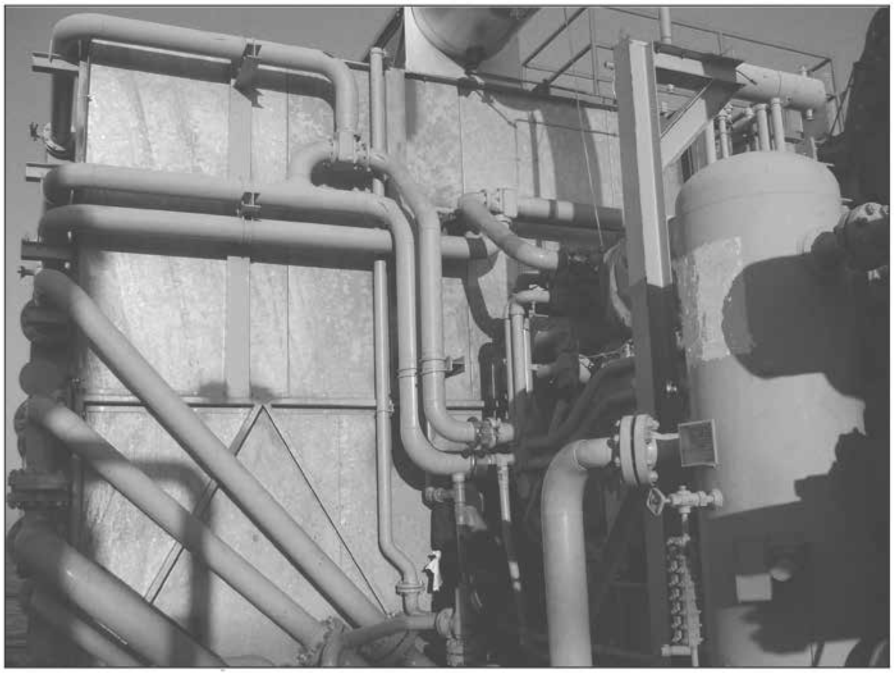

**Figure 4.10 – Poor Location for Mounting Temperature Regulators.
This Location is Not Convenient for Servicing.**

Cooling System Thermostat Housings (Direction) and Stats (Temp/Blocked Open) – Cooling systems equipped with Caterpillar supplied thermostat housings can be configured for either “inlet controlled” or “outlet controlled.” The normal configuration for gas compression engines is “outlet controlled” or “diverting” as the non Caterpillar term that is used. Consult the Gas Engine Application and Installation Guide for the proper control system for the site and then verify direction of thermostat housings. Ensure that the correct temperature regulators are installed in the auxiliary and jacket water cooling system. Both the auxiliary and jacket water system temperature regulator groups appear exactly the same once they are removed from the parts package. If they have not been identified, at least one of the groups will have to be disassembled to identify the correct temperature system placement.

Note: The part number and location of the engine jacket water orifice plate or plates and temperature regulators should be verified. The orifice plate should be on the pump bypass port of the thermostat housing. Record the part number.

Cat cooling system orifice plate part numbers:

- G3606 1-7C8798
- G3608 1-7C8798
- G3612 2-7C8635
- G3616 2-7C8635

Refer to the cooling system figures for the correct port matching of “A,” “B,” and “C” ports.

Cooling System Vent and Shunt Lines Inspected – The vent lines may not have been installed at this shop audit time. Discuss jacket water and auxiliary cooling system vent line and shunt line recommendation with the packager representative. Cooling system vent and shunt lines should be inspected for size, location, and proper installation. Refer to drawings in this publication, and the Gas Engine Application and Installation Guide for more information.

Vent lines must have a continuous upward slope, enter the expansion tank below normal water level, and contain no air traps. For the G3600, experience shows that a minimum vent line size should be 9.5 mm (0.375 in) inside diameter tubing. Use of a smaller size will clog and may not provide adequate venting ability. A vent line too large (larger than 12.7 mm [1/2 in]) may introduce a circuit that could contribute either to subcooling or overheating. A vent line size too large may also cause the system thermostats to lose their ability to control the system to the desired temperature. The recommended vent line size is at least 3/8 inch also because the vent line is susceptible to damage from dropped objects or personnel stepping on them. A vent line of 3 foot 8 inch allows some safety margin for crushing to prevent blockage. The vent lines should have a flexible connection at the point the vent lines leave the engine support going toward the expansion tanks. Failure to do this will result in a high likelihood of vent line breakage during operation.

Vent lines should also be connected to the far end (away from the engine) radiator headers to offset the normal sag that long horizontal coolers experience tubing have. The far end headers should be vented back to the expansion tank(s).

Cooling System Test Port Fittings Installed – Cooling system pressures must be checked during the commissioning of the engine. Evaluate system configuration during the shop audit. The shop audit is a good time to evaluate the cooling system piping, piping support, temperature regulator placement, and pressure taps for measuring cooling system performance. Check to confirm test port fittings have been installed so that cooling system pressures can be checked while the engine is running. Test ports should be added for pump inlet, pump outlet, circuit outlet, cooler inlet, and cooler outlet for both circuits; refer to the cooling schematic for all the test port locations. The best time to install ports for pressure and temperature measurements is during the fabrication phase of the package. While the coolant system is drained, locate and install bosses (typically 1/4” NPT female pipe) at the following locations shown in Table 4.8. It may be in the customer’s instructions to install ball valves at each test port location.

Jacket Water System	Separate Circuit
❑ Pump Inlet	❑ Pump Inlet
❑ Circuit Outlet	❑ Circuit Outlet
❑ Cooler Inlet	❑ Cooler Inlet
❑ Cooler Outlet	❑ Cooler Outlet

Table 4.8

To allow the system to be probed without coolant leakage, Cat sample port adapters should be installed at this time if they are not already installed. The part numbers are 5P2725 (1/4 inch male NPT pipe thread), 5P2720 (1/8 inch male NPT pipe thread), and 5P3591 (9/16 inch male straight thread). The locations shown in Table 4.8 and Figure 4.13 require a port adapter.

Cat sample port adapters – 5P2725 (1/4 inch male pipe thread), 5P2720 (1/8 inch male pipe thread), and 5P3591 (9/16 inch male straight thread), 164-2192 “Football needle” probe.

Figure 4.11

Strainers Installed In Cooling System – To ensure that the cooling system is free of debris, cooling system strainers should be installed in the coolant piping immediately before both water pumps.

At this point in the audit, carefully check the cooling piping. If an elbow is immediately connected to either water pump inlet, the packager should be alerted that the cooling system piping design should be changed for best cooling system performance. A sharp elbow immediately connected to the water pump increases the minimum inlet pressure requirement 10% to prevent cavitation. If an elbow must be connected to the pump inlet(s) due to length dimension constraints, the cooling system expansion tank(s) may have to be raised to provide for the increased pump inlet pressure requirement.

Figure 4.12 – An Elbow Immediately in Front of the Water Pump is Not Recommended

Use the diagram below for location of test port locations. Use Figure 4.13 (outlet controlled schematic) for locating taps in the cooling system to measure the cooling system pressures.

The best time to prepare the cooling system for commissioning is prior to system fill and engine starting. System pressures, and temperatures, can be checked at a no load test, but may not reflect the actual pressures and temperatures as installed on site.

Note: See Cooling System drawings in this publication.

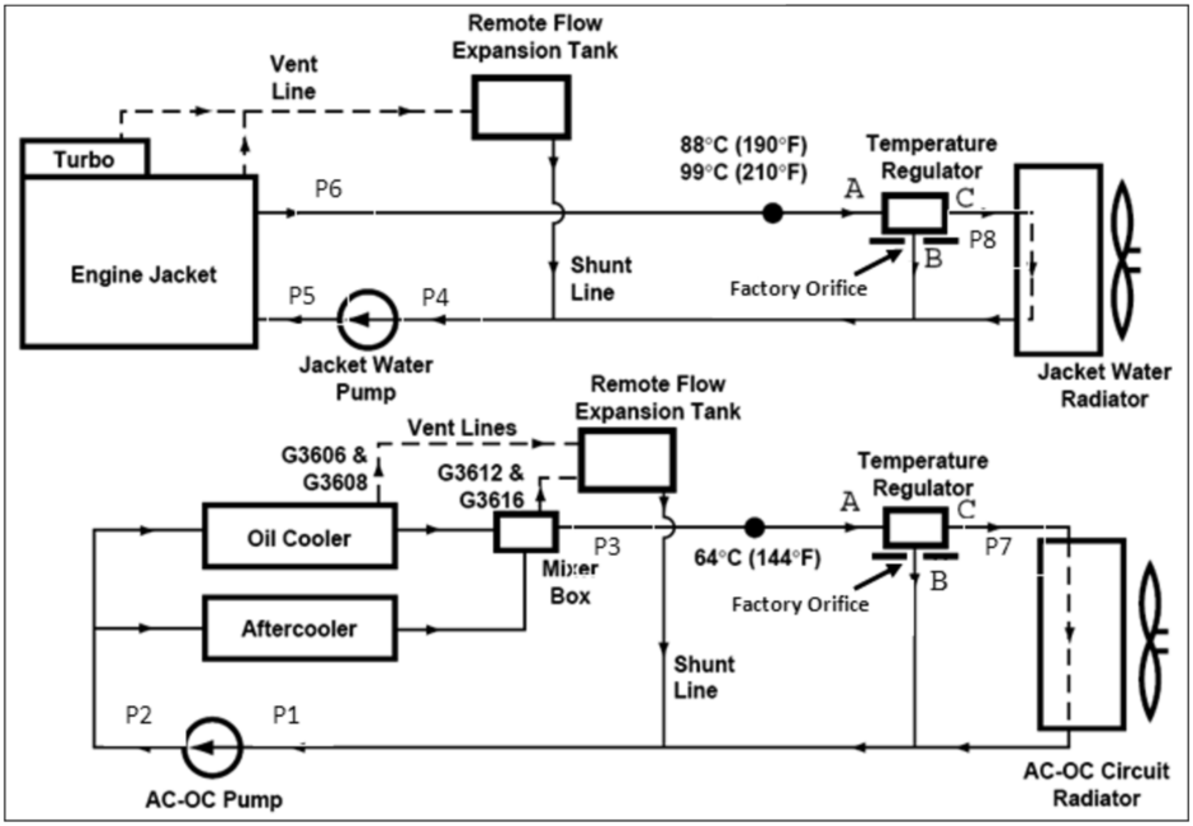

Figure 4.13 – G3600 Cooling System Schematic for Gas Compression

Description of pressure tap locations:

P1 Auxiliary cooling pump inlet

P2 Auxiliary cooling pump outlet (this tap is located in the Cat pump outlet)

P3 Auxiliary cooling system engine outlet

P4 Jacket water cooling pump inlet

P5 Jacket water cooling pump outlet (this tap is located in the Cat pump outlet

P6 Jacket water cooling engine outlet (this tap is located in the Cat outlet piping)

P7 Auxiliary cooling temperature regulator outlet to cooler

P8 Jacket water cooling temperature regulator outlet to cooler

Jacket Water System		Separate Circuit	
❑ Pump Inlet	P4	❑ Pump Inlet	P1
❑ Circuit Outlet	P5	❑ Circuit Outlet	P2
❑ JW Circuit Outlet	P6	❑ SW Circuit Outlet	P3
❑ Cooler Inlet		❑ Cooler Inlet	
❑ Cooler Outlet		❑ Cooler Outlet	

Table 4.9

Blocked open thermostats (Table 4.10) should be installed in the thermostat housings and screens should be installed in the pump inlets, while the engine is in the packager's shop. If the Cat thermostat housings are used, eight thermostats will need to be blocked open for an inline engine and 16 for a vee engine. Refer to EDS 50.5, LEKQ7235 on information on how to block open a thermostat.

Jacket Water System	Separate Circuit
❑ 4 blocked thermostats inline	❑ 4 blocked thermostats inline
❑ 8 blocked thermostats vee	❑ 8 blocked thermostats vee

Table 4.10

Temperature regulator housings are configured the same for installation. The ports are labeled A, B, and C.

Port A is always the engine connection. It is connected to the engine out location if the configuration is outlet controlled (diverting). Port A is connected to the pump inlet if the configuration is inlet controlled (mixing).

- Port B is always the bypass connection.
- Port C is always the cooler connection.
- Check the Gas Engine Application and Installation Guide for more information.

Jacket Water Heater

Verify that the jacket water heater is properly connected to the engine block. The coolant should be circulated from the lower engine block connection through the heater and discharged to the upper engine connection for best performance. Refer to Figure 4.14 for proper routing of the connections.

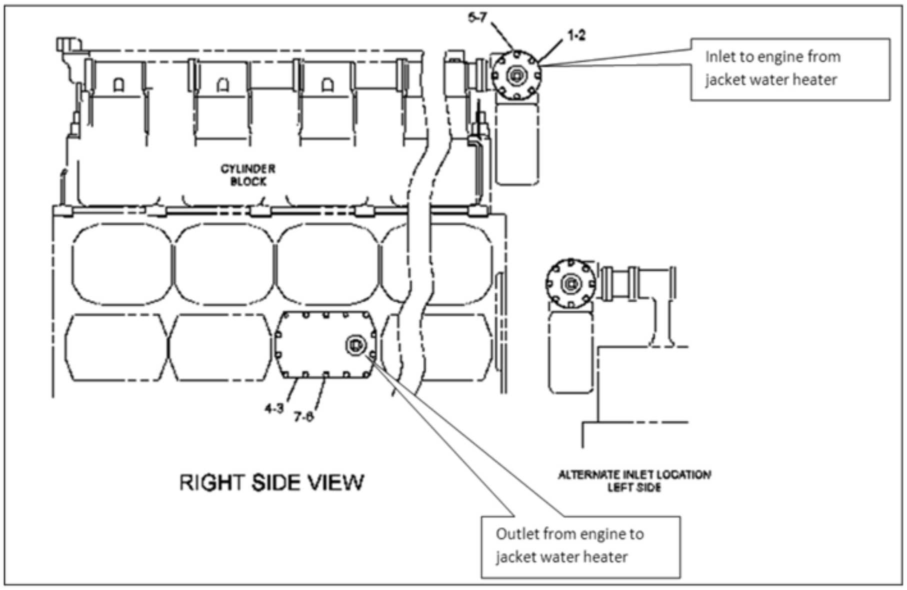

Figure 4.14 – Proper Jacket Water Heater Connections for Proper Coolant Flow

The jacket water heater should be set to maintain a coolant temperature of 38-43°C (100-110°F) for best starting results. A jacket water heater is recommended for all applications to offset high humidity and low temperatures for easier starting capability.

Fan Drive

The fan drive must be correctly designed in order to prevent operational issues and possible damage. The fan drive must limit the side load on the front stub shaft. The stub shaft inline load limit is 150 horsepower. The maximum static side load on the stub shaft with the use of pulleys is 890 N (200 lb) per 3/4 inch belt. The total maximum static side load on the stub shaft is 17,793 N (4,000 lb). Exceeding the 17,793 N (4,000 lb) static side load limit could cause the shaft or crankshaft damper adapter to fail.

The better design is to drive a fully supported fan pulley group inline with the engine stub shaft and a flexible coupling. The lay shaft must be correctly aligned to be inline with the stub shaft per standard tolerances for coupling alignment. The flexible coupling must perform with parameters that accept the engine growth during engine temperature changes. A design of this type will absorb the loads of the belt tension and drive the fan without imposing unacceptable side loads on the stub shaft.

4.9 Fuel System

4.9.1 Fuel Filters

Clean, dry gas is a requirement for Cat gas engines. The fuel filter(s) should be designed to remove liquids and particulates. Common liquids are water and heavier hydrocarbons. Small amounts of water are usually not detrimental to the engine, but large amounts can be damaging. Water, when combined with some gases such as carbon dioxide, cause acids which can attack the fuel system and engine. Water in the fuel line can generate rust which, if not filtered, can damage the engine. Heavier hydrocarbons like butane, pentane, hexane, etc. can exist in the fuel, particularly field gas. These hydrocarbons have very low detonation resistance and can cause detonation engine failures or nuisance detonation shutdowns in low emissions engines. These liquids can be removed by proper filters and de-misters; or they can be vaporized by using a fuel heat exchanger.

Particulates in the fuel need to be removed. Filter specifications for fuel are one micron maximum particle size. Failure to remove particulates can cause premature engine wear and damage. Landfill gas has a particularly difficult filtering requirement. Landfill gas has large quantity of sub-micron silicon particulates which must be removed for proper engine operation. Landfill gas may require fuel filter to be smaller than one micron size particles. Refer to the “Fuel Systems” section of the Gas Engine Application and Installation Guide for specifics.

Note: Fuel pressure regulator should be installed on the downstream side of the fuel filter to prevent debris from getting into the regulator.

4.10 Lubrication System

4.10.1 Oil Level Controller-Operation

The automatic oil level controller is an important item for an engine in gas compression that operates 24/7 unattended. This device must be installed correctly for reliable operation. A controller that does not operate correctly can cause the oil level to be too low which might cause crankshaft bearing or other damage; or it can cause the oil level to be too high which can cause excessive crankcase pressure and foamy oil.

Most oil level switches and oil level makeup devices are vented. If vented to the atmosphere, they will regulate to some erroneous level due to the crankcase pressure. The vent line from these devices should go to the crankcase (well above the oil line) to a “quiet zone” in the front or rear timing gear compartment. There must be no low spots in the vent line that could allow oil to collect and cause a blockage of the vent line.

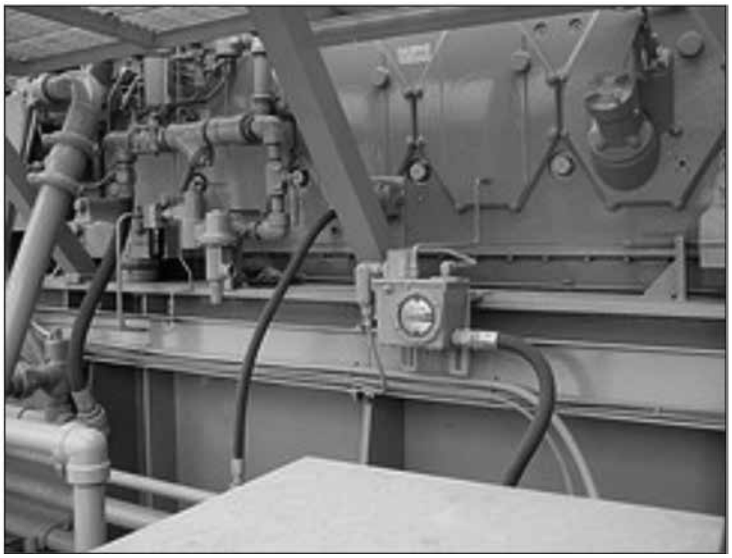

Figure 4.15 – Correct Location for Oil Level Controller; Incorrect Vent Line Connection

On a G3600 engine, the center of the oil level controller should be located 175 mm (6.88 in) below the engine oil pan gasket joint. This information is listed in the Lubrication Systems A & I Guide (LEBW4957). Figure 4.15 also shows an incorrect level controller vent location on a properly located controller.

4.10.2 Oil Pump Screen Access

The engine oil pump draws oil from the oil pan through a suction screen located behind the plate shown in Figure 4.16.

Figure 4.16 – Do Not Block This Oil Suction Screen Access Cover

This plate should not be blocked by any packaging item that prevents removal of the screen for cleaning maintenance at the oil change interval (5000 hours). The screen removal distance required is 55.88 cm (22 in). If an item must be placed in this location, it must be designed for easy removal for servicing the suction screen.

Lube Oil Heater

Verify that the lube oil heater is properly connected to the engine oil pan. The purpose of the oil heater is to heat the engine oil while circulating the fluid from one end of the oil pan and discharging into the other end of the oil pan. The lube oil heater pump should not be used for the prelube or postlube function. The lube oil heater should be set to maintain an oil temperature of 32-38°C (90-100°F).

4.10.3 Air Supply Piping (Skid)

A review of the piping on the skid should be performed during the shop audit. Verify that piping size is appropriate to provide a minimal pressure drop of supply air/gas from the receiver tank to the engine starter(s). Piping should include a flexible connection at the interface with the skid and at the connection of the skid piping to the starter and prelube pump. For gas compression applications, the starting supply piping should be a minimum diameter of 76.2 mm (3 in) to the starter connection to ensure sufficient flow to achieve target cranking speed. Piping should not interfere with access to the engine side covers for removal during engine service.

4.10.4 Engine Component Removal

Overhead and side clearance must be provided around the engine for major component removal and use of necessary tools. Unfortunately, at the time of commissioning, it may be too late to change the configuration so now is the time to consideration engine access.

Overhead lifting equipment must be provided. Most all major engine components are heavier than one man can safely lift. Review the overhead features for multi-direction motion. Most engine component removal involves at least two direction motions for removal.

Arrange multiple engine installations to use the same overhead lifting equipment without major disassembly of piping or ducting.

Equipment should be available for engine component movement to and from the engine room.

5.0 G3600 Engine Shop Audit (Start Up Run Process if performed)

Use the live engine data tables shown in the Commissioning Review section of this guide for recording data during a shop run.

5.1 G3600 Gas Engine Start Up Checklist

	Preliminary Review
	Safety Check – Guards in place, control panel in safe location, exit paths clear, etc.
	Before Coolant Is Added
	Cooling System Test Port Fittings Installed
	Strainers Installed In Cooling System
	Cooling System Thermostat Housings (Direction) And Stats (Temp/Blocked Open)
	Cooling System Vent And Shunt Lines Inspected
	Type of Coolant Deionized/Distilled Water With Conditioner or 50/50 Mix
	Cooling System Filled (check for leaks)
	Prior To Engine Start
	Lubrication System- (Engine, Type, Driven Equipment, Starters and Pre-Lube Pump)
	Fill Lubrication System
	Starting System- Blow Down/Pressure Regulator Set/Screens
	Soft foot/Alignment/Deflection/Endplay
	Fuel System- Lines Blown Down/Fuel Filter Installed/Pressure Regulator Set
	Inlet Air System-Inspect Air Cleaners/Piping/Turbochargers
	Check System Voltage
	Power Supply Ready (Batteries/Charger)
	Wiring Checks-Make Sure All Appropriate Jumpers Are In Place (Be Thorough)
	Actuator Inspection- No Binding
	Check Software Part Number Loaded In ADEM, Advisor and ICSM's For Most Current Version
	Check Settings in ADEM And ICSM's (Configuration and Monitoring)
	Fuel Analysis- Checked With Caterpillar Methane Number Program
	Enter Configuration Parameters For The Site (Btu, Specific Gravity, etc.)
	Crankcase Ventilation Caps Removed
	Guards In Place
	Install Gauge To Check Hydrax Pressure (Gauge Must Be Able To Read Minimum Of 300 PSI)
	Check Hydrax Fluid Level
	Air Pressure Module Calibration (Engine mode switch must be in STOP position)
	Record Needle Valve Setting And Compare To Factory Settings … **Do Not Change at this time**.
	Crank RPM Test (Fuel Off) 80 rpm minimum
	After Engine Start
	Stabilize RPM (Governor, Choke, Wastegate, Max Choke, Desired Exhaust Temp)
	Check Shutdowns (E-Stop, Oil Pressure, Temperature, Water Temperature, Crankcase Pressure, And Detonation Sensor)
	Check For- Noises/Leaks/Vibration/Temperatures/Etc.
	Hydrax Pressure 1517 ±34.5 kPa (220 ± 5 psi)

Table 5.1

Note: These are the minimum pre-start checks that should be made during the packager's No Load shop test. Depending on your shop installation additional checks may be required.

5.2 Explanation of Start Up Checklist

5.2.1 Preliminary Review

Walk around inspection for safe operation. Check guards for safety. Check exit paths for safety. Check that control panel is in a safe location. Check for e-stops and fuel shut-offs.

5.2.2 Before Coolant Is Added

Cooling System

Fill the engine cooling systems with coolant. Tap water, extended life coolant, and heat transfer fluids are unacceptable for a G3600 engine. Distilled water or deionized water must be used. Even for a short audit test, coolant conditioner must be used with distilled or deionized water because the engine will probably set for an extended period of time before being placed into service. Cat coolant conditioner, 8C3680, 18.9 l. (5 gallons) or 5P2907, 208 l. (55 gallons) or equivalent commercial SCA (Supplemental Coolant Additive), must be added to equal 5% to 6% of total volume to the cooling system. Discuss with the packager representative the need for proper preservation and sealing after construction while waiting to be shipped.

Note: Do not add more conditioner (SCA) than 6% by volume. High conditioner concentrations may damage the cooling system and create blockage.

A mixture of glycol and water is recommended for a shop run so that any residual coolant remaining in the engine passages will not freeze if engine is stored at temperatures below freezing temperature.

System volume can be estimated. Use Table 5.2 to estimate the volume of coolant in the piping. Cat gas engine coolant is complete with SCA installed. You can also use the spreadsheet found on the Caterpillar commissioning website.

❑ **Filled with coolant**

Pipe Factor			
Pipe Diameter		Volume of Coolant per Foot	Volume of Coolant per Meter
Inch	Cm	Gallons	Liters
0.75	1.91	0.02295*	0.869
1.0	2.54	0.048*	0.182
4	10.0	0.65	7.9
5	12.5	1.0	12.3
6	15.0	1.5	17.7
8	20.0	2.6	31.4

*These two rows are added to aid in cooler volume calculation.

Table 5.2

Go to Commissioning website https://engines.cat.com/cda/layout?m=349976&x=7 for Excel worksheet that can be used for calculating cooling system volumes. (231 cu. inches = 1 gallon)

To find the estimated total cooling system volume:

1. Find the total length of piping. Record this value in column 3 Tables 5.4 and 5.5.
2. Record the pipe factor found in Table 5.2 in column 2 or 12 in Tables 5.4 and 5.5.
3. Record the volume of the heat exchanger in column 5 or 15 in Tables 5.4 and 5.5. This can be found on the specification sheet for the device.
4. Record the engine coolant volume in column 6 or 16 in Table 5.4. Tables 5.4 and 5.5 will provide an engine capacity estimate.

Cooling System Capacities				
Engine	Jacket Water		Separate Circuit	
	Gallons	Liters	Gallons	Liters
G3606	90	340	16	60
G3608	124	470	16	60
G3612	177	670	17	64
G3616	238	900	19	72

Table 5.3

Jacket Water System					
1	2	3	4	5	6
Pipe Size	Pipe Factor	Length of Pipe	Column 2 x Column 3	Volume of Heat Exchanger	Volume of Engine
Total of columns: Column 4 + Column 5 + Column 6 = Total System Volume					

Table 5.4

Separate Circuit System					
11	12	13	14	15	16
Pipe Size	Pipe Factor	Length of Pipe	Column 12 x Column 13	Volume of Heat Exchanger	Volume of Engine
Total of columns: Column 4 + Column 5 + Column 6 = Total System Volume					

Table 5.5

Strainers Installed In Cooling System – To ensure that the cooling system is free of debris, cooling system strainers should be installed in the coolant piping immediately before both water pumps. Ensure that the pump inlet piping spool is straight and that it is of sufficient length to accommodate the strainer and allow easy removal during the commissioning. The cooling system will usually have debris in the piping. Strainers must be installed to protect the engine from the debris. Strainers are available in the following sizes with Cat part numbers:

- 4C9045 – 4 inch diameter pipe
- 4C9046 – 5 inch diameter pipe
- 4C9047 – 6 inch diameter pipe

These screens have 1.6 mm (0.063 in [1/16 in]) perforations for straining out debris in the coolant flow during commissioning. These dimensions translate to approximately 98 holes per square inch. These screens are approximately 190.5 mm (7.5 in) long. These perforation dimensions can be used if fabricated screens are used. The area open should be 150% of pipe size so that excessive restriction does not occur; don't make the screen too short.

Figure 5.1 – Cooling System Cleaning Screens

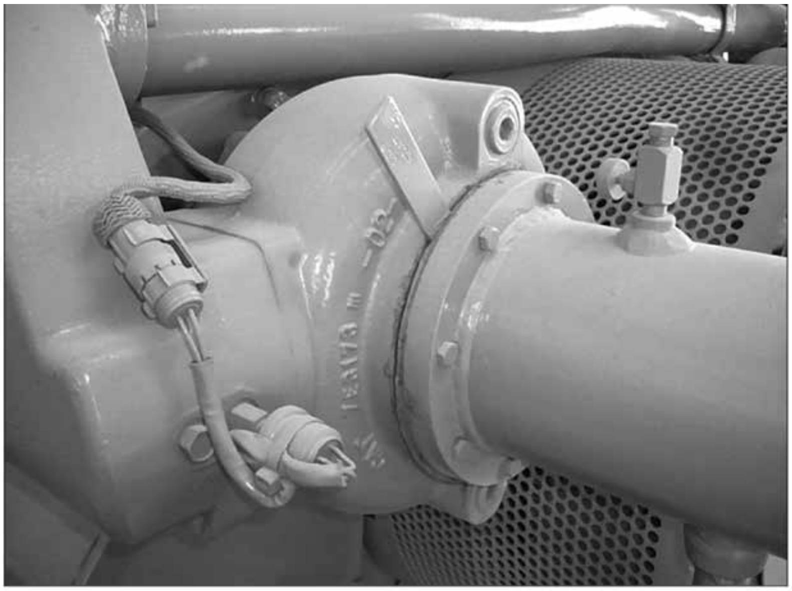

Figure 5.2 – Cooling Screen Installed in Jacket Water Pump Inlet

Jacket Water System	Separate Circuit System
❑ Pump inlet	❑ Pump inlet

Table 5.6

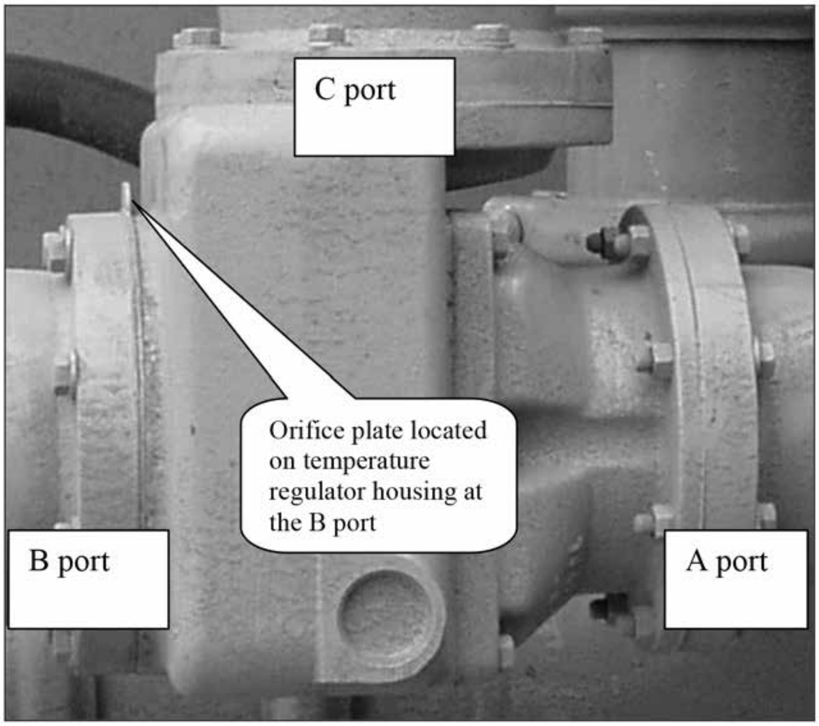

Figure 5.3 – Temperature Regulator Housing With Orifice Installed

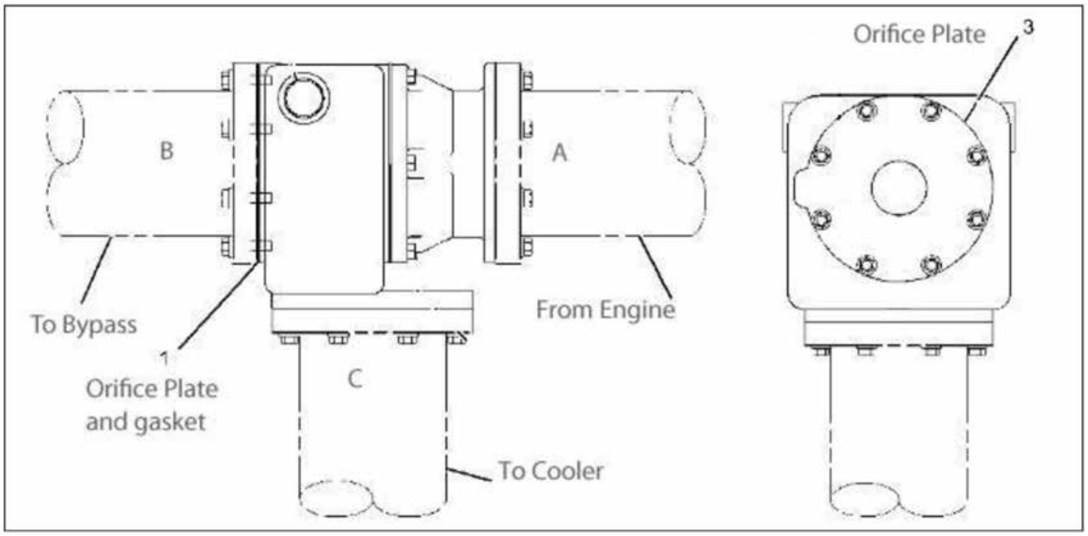

Figure 5.4 – Temperature Regulator Group

Cat cooling system orifice plate part numbers:
- G3606 1-7C8798
- G3608 1-7C8798
- G3612 2-7C8635
- G3616 2-7C8635

To flush the cooling systems, blocked open thermostats should be used to ensure that there is coolant flow through the entire cooling system (care must be taken to avoid engine damage as the result of low coolant temperature and high oil temperature). If blocked open thermostats are used, ensure that the proper thermostat part numbers are reinstalled in the correct thermostat housing and correct cooling system, and that the correct orifice plate is installed in the correct location. Refer to figures in this publication.

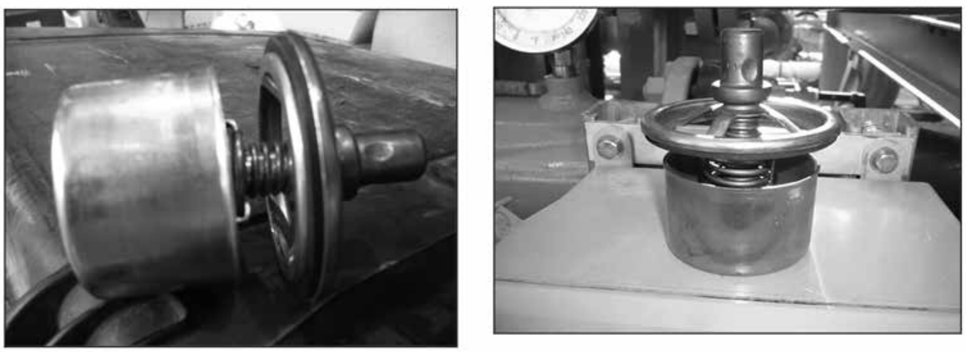

Figure 5.5 – Blocked Open Temperature Regulators

Cooling System Vent And Shunt Lines Inspected – Cooling system vent and shunt lines should be inspected for size, location, and proper installation. Refer to drawings in this publication, and the Gas Engine Application and Installation Guide for more information. Typical expansion tank radiator is rated at 48.3 kPa (7 psi). If the altitude is higher than 4,000 ft., use a pressure cap rated 82.7 kPa (12 psi). Review the pressure cap rating and record the data in Table 5.7.

Jacket Water System	Separate Circuit System
❑ Pressure Cap Rating ____________ psi	❑ Pressure Cap Rating ____________ psi

Table 5.7

5.2.3 Expansion Tank

The expansion tank volume should also be evaluated. The jacket water circuit expansion tank should be a minimum of 15% of the total volume of coolant. The separate circuit expansion tank should be a minimum of 8% of the total volume of coolant. The expansion tank will require reserve coolant in the tank site gauge when cold. This volume will have to be added to the system total when calculating the final expansion tank volume. This will provide for the expansion volume plus reserve capacity. Use Tables 5.8 and 5.9 together with Tables 5.3 through 5.5 to determine the appropriate expansion tank size.

Jacket Water System				
7	**8**	**9**	**10**	**Required Tank Volume**
Total from Column 4, 5 & 6 in the table above.	Cold volume of coolant in tank when visible in site gauge.	Total coolant in system. Column 7 plus column 8.	Column 9 X 15%	Minimum Tank Size Column 8 plus column 10.

Table 5.8

Separate Circuit System				
17	**18**	**19**	**20**	**Required Tank Volume**
Total from Column 14, 15 & 16 in the table above.	Cold volume of coolant in tank when visible in site gauge.	Total coolant in system. Column 17 plus column 18.	Column 19 X 8%	Minimum Tank Size Column 18 plus column 20.

Table 5.9

5.3 Prior To Engine Start

5.3.1 Fill Fluids (if shop run is performed)

5.3.2 Preliminary Review

Walk around inspection for safe operation. Check guards for safety. Check exit paths for safety. Check that control panel is in a safe location. Check for e-stops and fuel shut-offs.

Lubrication System – (engine, type, driven equipment, starters, and pre-lube pump) – Fill and check lubrication levels in all equipment and lubricators. Make sure all lubricants used are within Caterpillar specifications. Refer to SEBU6400 for more details.

Air Starter/Prelube Pump Starting System – purge/pressure regulator set/screens – Purge start lines whether it is air or gas. The starting medium in the packager's shop will probably be air but observe safety precautions when purging the piping. Ensure "Y" strainer screens are installed in the Caterpillar supplied start manifold. Ensure that a flexible member is used to connect the engine starter and prelube piping supply and exhaust to the "off engine" piping. Set the start regulator to the proper pressure. See the starter tag for correct operating pressure. See Gas Engine Application and Installation Guide, Technical Information section for more information.

Make sure the lubricators for the vane type air starter(s) and the pneumatic prelube pump are filled with the proper lubricant. This is typically a lightweight (SAE 10) mineral oil or diesel fuel. Both devices have flow control devices, which must be set for proper metering of oil into the air motor. Running either a vane type prelube pump or air starter without lubricant will cause premature failure and lockup.

Note: Turbine air motors do not require lubrication.

Alignment/Deflection/Endplay – Soft foot, alignment, crankshaft deflection and crankshaft endplay must be checked "cold" before the initial package start-up. These checks are used to verify position of engine in relation to the driven equipment. Shut off start air supply before conducting the alignment work.

Note: Always prelube before rotating the crankshaft. Always use engine turning tool only for this procedure; do not use the engine starter.

Accurate hot alignment and deflection checks cannot be made during a shop test as the temperatures reached do not reflect full expansion of the engine.

See Gas Engine Application and Installation Guide, Technical Information section for more information.

Inlet Air System – Inspect Air Cleaners/Piping/Turbochargers – Inspect clean side of filter housing, air inlet piping and turbochargers for cleanliness and leaks. Turbochargers must be free from dirt and rust and must turn freely. Install air filters; they must seal completely and piping must not allow air to bypass filters. See Gas Engine Application and Installation Guide, Technical Information section for more information.

If the air cleaner is not installed and connected during the shop audit test run, a panel type air cleaner element can be used over the inlet opening of each turbocharger for filtering. Be sure to properly secure the panel element to the turbocharger housing.

Fuel Analysis

If the engine is to be run at the construction/packager facility, the fuel that the engine will run on must be analyzed. The fuel analysis needs to be entered into the "Fuel Analysis" tab in LERW4485 Gas Engine Rating Pro (GERP). The output of the analysis will have important information on how to set up the engine control. Fill in the following information in Table 5.10 from the fuel analysis.

Parameter	Methane Number Program Value
Lower Heat Value	
Specific Gravity	
Wobbe Index	
Methane Number	

Table 5.10

Include the Customer Fuel Analysis in Audit Report.

Fuel System – Lines Purged/Pressure Regulator Set/Fuel Filter Installed – Fuel system must have a correct size filter installed in the fuel line. Fuel lines must be purged to remove construction debris and liquids from the fuel piping. Set engine fuel pressure regulator to 310 kPa (45 psi).

It may be that the packager's shop does not have high pressure fuel. If that is the situation, some modification to the engine fuel connection may be required in order to run the engine. The fuel components must be returned to the normal configuration after the test run.

See Gas Engine Application and Installation Guide, Technical Information section for more information.

Check System Voltage – Check DC system voltage and AC ripple at the advisor panel or engine mounted junction box, depending on configuration. The preferred operating range is 24-27 volts DC. The maximum acceptable electrical noise (ripple) is max 150 mV AC.

See Gas Engine Application and Installation Guide, Technical Information section for more information.

Wiring Checks – Make Sure All Appropriate Jumpers Are In Place (Be Thorough) – Check to ensure that all jumpers or system wires from the control panel are installed in the Advisor and engine mounted terminal box. Make sure that all wires are tight in the terminals. Use the 4.54 kg (10 lb.) pull test criteria to be sure all wires are secure. See Gas Engine Application and Installation Guide, Technical Information section for more information. Check E stops at all points. This can be done with engine not running. Also, see REHS1336 Installation and Start Up Guide Special Instruction.

Power Supply Ready (Batteries/Charger) – Ensure proper voltage and minimum voltage drop to the control panel. See Gas Engine Application and Installation Guide, Technical Information section for more information.

Actuator Inspection – No Binding – Ensure that all actuators move freely with no binding and actuators have proper travel. Refer to publication RENR5908 Systems Operation Testing and Adjusting for more information.

Check Software Part Number Loaded in ADEM, Advisor, and ISMs for Most Current Version – Part numbers loaded in the ADEM and the ISMs must be verified that they are the most current versions available. Verify emission rating.

Enter Configuration Parameters for the Site (BTU, Specific Gravity) – Enter LHV, specific gravity and check all values entered into the configuration screen using Cat Electronic Technician (ET). Fuel sample must meet Caterpillar fuel requirements.

See Gas Engine Application and Installation Guide, Technical Information section for more information.

Crankcase Ventilation Caps Removed – Crankcase ventilation caps must be removed so the crankcase pressure does not increase and shut the engine down. Consult the Gas Engine Application and Installation Guide for more information on ventilation piping.

Guards In Place – All guards must be in place before the engine is started. Guard design should be evaluated for ease of maintenance and service.

Install Gauge to Check Hydrax Pressure (Gauge Must Be Able to Read Minimum of 300 PSI) – Install pressure gauge in the Hydrax pressure block after the Hydrax filter to check the Hydrax system pressure. See the Gas Engine Application and Installation Guide for more details.

Air/Fuel Pressure Module Calibration – The pressure module calibration should be checked before the engine is started. The pressure module can be calibrated using Caterpillar Electronic Technician with the engine stopped. See RENR5908 Systems Operation Testing and Adjusting for procedure.

Record Needle Valve Settings and Compare to Factory Settings – Needle valve settings should be checked before starting engine.

Note: Leave needle valves at factory settings for the packager's shop run.

Crank RPM Test (Fuel Off) – With fuel valve off, perform a start sequence to check engine cranking speed. Preferred cranking speed is 100 rpm or higher. The minimum cranking speed is 80 rpm. See Gas Engine Application and Installation Guide, Technical Information section for more information.

Lubrication System – (Engine, Type, Driven Equipment, Starters, and Pre-Lube Pump) – Fill and check lubrication levels in all equipment and lubricators. Make sure all lubricants used are within Caterpillar specifications. Refer to publication Cat Gas Engine Lubricant, Fuel, and Coolant Recommendations (SEBU6400) for more details.

5.3.3 Engine Lubricating Oil

Fill the engine with the lubricating oil. Make sure to select oil that is approved for use in the G3600 series engine. When in doubt, use Cat Natural Gas Engine Oil available from your Cat dealer. Refer to Special Instruction SEBU6400 for lubricant recommendations. Table 5.11 will give an estimate on the oil capacities for the various engines. This does not include oil heaters, oil makeup systems, driven equipment, etc.

Engine Oil System Capacity		
Engine	Oil Capacity	
	Gallons	Liters
G3606	190	719
G3608	240	908
G3612	280	1,060
G3616	360	1,363

Table 5.11

Brand and Type of Oil: ______________________ **Viscosity of oil:** ______________________

❑ **Engine Filled** **Date:**______________________

5.3.4 Hydrax Fluid

Fill the Hydrax tank with SAE 10 hydraulic fluid. Make sure the fluid is visible in the upper area of the sight gauge.

Brand and Type of Oil: ______________________ **Viscosity of oil:** ______________________

❑ **Hydrax tank full** **Date:**______________________

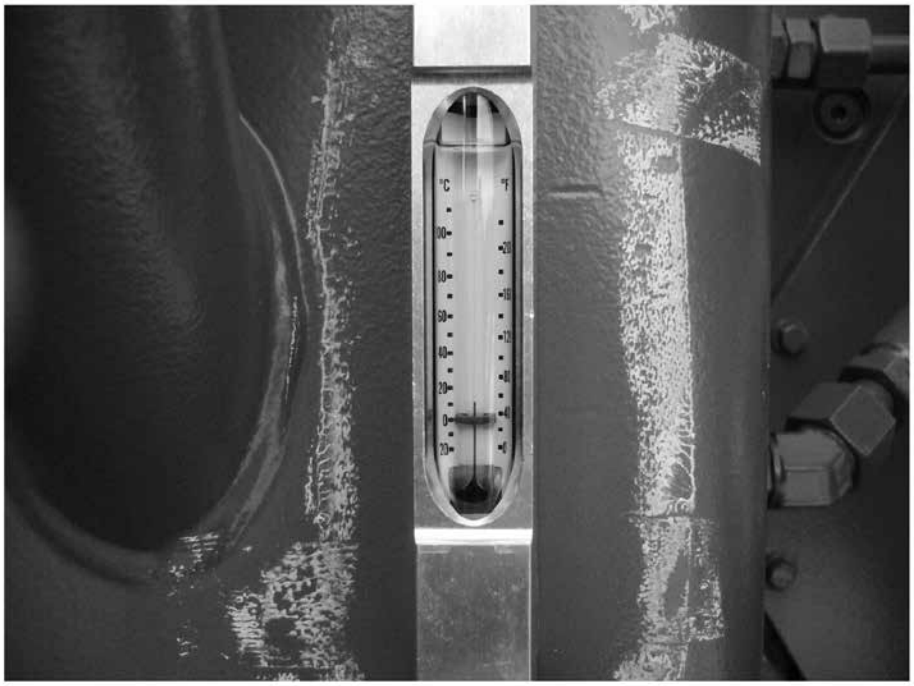

Figure 5.6 – Clean Oil Visible in the Hydrax Oil Level Sight Glass

5.3.5 Driven Equipment Lubrication

Fill the driven equipment to the manufacturer's specifications. Some compressors will use the same oil as the engine. Make sure to factor that amount into the lubrication requirements. Generators typically have separate oil reservoirs for the bearings. Make sure these reservoirs are filled to their capacity with the proper lubricant. Some generators are lubricated with grease. Make sure these antifriction bearings are properly lubricated with the manufacturer's recommended grade of grease. Make sure that if auxiliary oil coolers or heaters are used, the oil capacity is also accounted for. Make sure that these auxiliary devices are correctly to the engine to prevent oil entry into the cooling system or coolant into the engine lubrication area. If contamination occurs, special cleaning procedures must be used to remove the contamination before operating the engine to prevent damage. Some mechanical drives like gearboxes, dry clutches, oil clutches, etc. may have special lubrication requirements. Make sure to address these before attempting to power the equipment.

Brand and Type of Oil: ______________________________ **Viscosity of oil:** ______________________________

❑**Driven Equipment Filled** **Date:**______________________________

For a short in-shop run (no load), air cleaner panel type elements can be temporary mounted directly to the turbocharger inlet. They must be securely mounted at the turbo inlet and must be sealed (duct tape is usually adequate).

Inlet Air System – Inspect Air Cleaners/Piping/Turbochargers – Inspect clean side of filter housing, air inlet piping, and turbochargers for cleanliness and leaks. Turbochargers must be free from dirt and rust and must turn freely. Install air filters, they must seal completely and piping must not allow air to bypass filters. See Gas Engine Application and Installation Guide, Technical Information section for more information.

5.3.6 Inlet and Exhaust Preparation

System pressures can be evaluated at the audit, but often maximum load cannot be obtained until the engine is at the customer's site. However, this is usually the best time and facility to install ports for pressure measurements if they are not already installed. Locate and install bosses (typically 1/2 inch female pipe) at the following locations.

Exhaust Outlet	Air Cleaner Housing Outlet
❑ 3 to 5 pipe diameters from elbow	❑ Housing Port

Table 5.12

These ports should be installed in a straight section of pipe 3 to 5 pipe diameters after a transition as close to the engine as possible (minimum 3 to 5 pipe diameters from the turbocharger flexible joint). If the Cat air cleaner housing is used the factory pressure port is adequate. See Figure 5.7 for example of placement of ports.

The sample tube should extend into the exhaust air stream 6-12 inches for a better sample. This is especially true when measuring backpressure.

Figure 5.7 – Example of Proper Location of Emission Sample Port in Exhaust Piping

Fuel System – Lines Purged/Pressure Regulator Set/Fuel Filter Installed – Fuel system must have a correct size filter installed in the fuel line. Fuel lines must be purged to remove construction debris and liquids from the fuel piping. Set engine fuel pressure regulator to 310 kPa (45 psi).

Note: Fuel pressure regulator should be installed on the downstream side of the fuel filter to prevent trash from getting into the regulator.

See Gas Engine Application and Installation Guide, Technical Information section for more information.

5.3.7 DC Electrical

Power Connection and Quality

An interconnect harness is used between the engine ADEM III junction box and the Advisor panel or customer supplied panel. This harness must be installed to perform a live engine test.

Note: The following instructions are for a Caterpillar supplied advisor panel only. Refer to customer drawings if a customer-supplied panel is used.

To do this first remove the two Caterpillar supplied fuses from the engine-mounted ECM box (6 amp and 15 amp). Ensure the engine control switch is in the OFF/RESET position. Connect battery and charger or power supply to the Advisor panel. Verify 24 VDC between Advisor 1 and Advisor 2 terminals. The Advisor display should appear “dead” (while in OFF/RESET). Voltage must measure between 21 and 32 VDC and less than 150 mVAC pk-pk (approximately) 71.4 mVAC rms). If voltage is not within specification, troubleshoot power supply problem before turning Advisor to the STOP position. If voltage is within specification, insert fuses previously removed and turn engine control switch to the STOP position. The Advisor panel and engine ECM should power up.

The power supply should be evaluated for AC ripple (maximum ripple allowed is 150 mVAC). To do this, use a voltmeter on the AC scale to measure the voltage across the power supply. Record both the voltage using the DC scale and the AC scale. Record in Table 5.13.

Power Supply Voltage	
DC Voltage	**AC Voltage**

Table 5.13

If the Advisor panel is not used, check the power supply for correct voltage between the negative terminal T3 and the power connection T1 to the power fuses in the engine junction box.

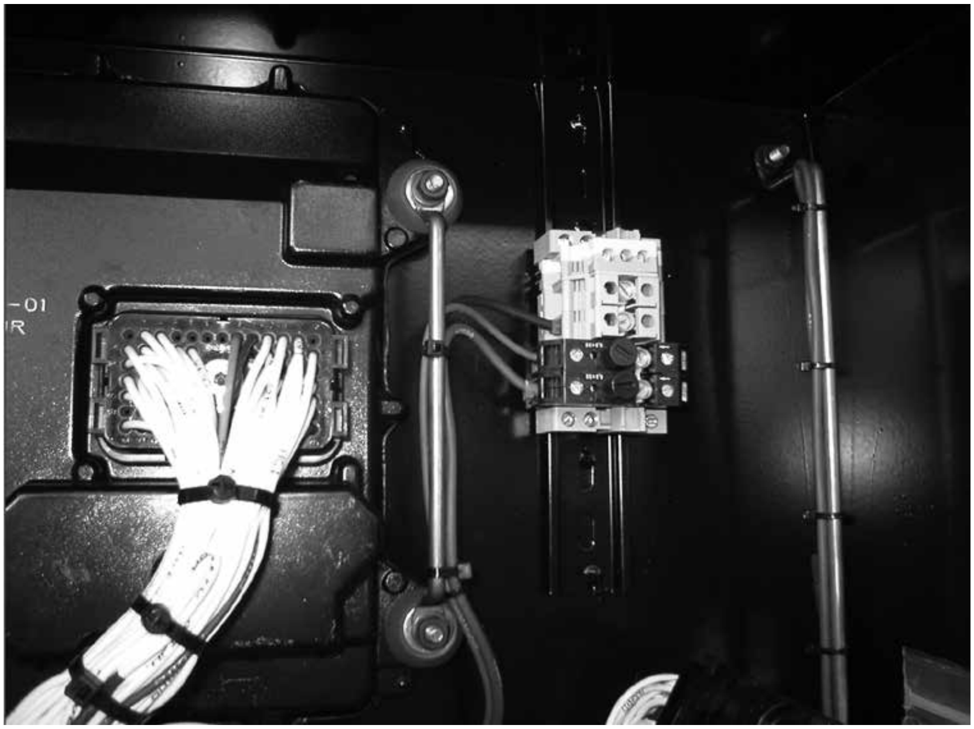

Figure 5.8 – Interior view of G3600 Engine-mounted Junction Box

Note: Engine will run at 550 rpm unless the idle/rated switch is closed (terminal 22 to terminal 8 in the Advisor Panel or terminal 40 and 41 in the engine mounted ECM box Customer Connector J-3).

Check System Voltage – Check DC system voltage and AC ripple at the Advisor panel or engine mounted junction box depending on configuration. See Gas Engine Application and Installation Guide, Technical Information section for more information.

Wiring Checks – Make Sure All Appropriate Jumpers Are In Place (Be Thorough) – Check to ensure that all jumpers or system wires from the control panel are installed in the Advisor or engine mounted terminal box. Make sure that all wires are tight in the terminals. See Gas Engine Application and Installation Guide, Technical Information section for more information. Check E stops at all points. This can be done with engine not running. Also, see REHS1336 Installation and Start Up Guide.

Power Supply Ready (Batteries/Charger) – Ensure proper voltage and minimum voltage drop to the control panel. See Gas Engine Application and Installation Guide, Technical Information section for more information.

Actuator Inspection – No Binding – Ensure that all actuators move freely with no binding and actuators have proper travel. Refer to RENR5908 Systems Operation Testing and Adjusting.

Check Software Part Number Loaded In ADEM ECM, Advisor, and ISMs for Most Current Version – Part numbers loaded in the ADEM and the ISMs must be verified that they are the most current versions available. Verify emission rating.

Fuel Analysis – Check With Caterpillar Methane Number Program – Fuel analysis must be available so the values can be entered into the Caterpillar Methane Number Program. Fuel sample must meet Caterpillar fuel requirements. See SEBU6400 and Caterpillar Gas Methane Number program. See Engine Application and Installation Guide, Technical Information section for more information.

Enter Configuration Parameters for the Site (BTU, Specific Gravity) – Enter LHV, Specific Gravity, and check all values entered into the configuration screen using Cat Electronic Technician. Fuel sample must meet Caterpillar fuel requirements. See Gas Engine Application and Installation Guide, Technical Information section for more information.

Crankcase Ventilation Caps Removed – For a shop run, the crankcase ventilation caps must be removed so the crankcase pressure does not increase and shut the engine down. Be sure to reinstall the caps after the engine run. Consult the Gas Engine Application and Installation Guide for more information on ventilation piping.

Guards In Place – All guards must be in place before the engine is started. Guard design should be evaluated for ease of maintenance and service.

Air/Fuel Pressure Module Calibration – The air pressure calibration should be checked before the engine is started. The air pressure module can be calibrated using Cat Electronic Technician with the engine stopped. See RENR5908 Systems Operation Testing and Adjusting for procedure.

Record Needle Valve Setting and Compare to Factory Settings – With packages that are run at the packager site under no load conditions, there is an urge to adjust the needle valve adjustments to get cylinders to fire at low fuel pressures. This will not cure the misfire. Needle valve settings should be checked before starting engine.

Note: Leave needle valves at factory settings for the packager’s shop run.

Crank RPM Test (Fuel Off) – See Gas Engine Application and Installation Guide, Technical Information section for more information. Crank the engine with the fuel shutoff (make sure to prelube first). A fault will likely be present during this cycle. With fuel valve off, perform a start sequence to check engine-cranking speed. Preferred cranking speed is 110 rpm or higher. The minimum cranking speed is 80 rpm. To obtain sufficient ignition voltage from the control system for starting, the engine must crank a minimum of 80 rpm. After 5 to 10 seconds of cranking, record the cranking speed and starting air/gas pressure in Table 5.14.

Cranking Test		
Cranking Speed	**Cranking Speed**	**Cranking Air Pressure**
rpm	≥ 80 rpm ❑ Acceptable	< 80 rpm ❑ Unacceptable

Table 5.14

Even though the fuel system and the ignition system are activated at engine speeds above 50 rpm, a minimum speed of 80 rpm is desirable for easier starting. It is desirable to have a target cranking speed of 100 rpm. This will allow the engine to start quicker, start at lower ambient temperature, and accelerate to rated speed quicker. Therefore, the higher the available starting air/gas pressure the better. **Do not exceed the pressure limit of the starter.**

If the site ambient temperature will be lower than 10°C (50°F), an engine oil heater must be used for best cranking results. Cold engine oil has severe negative impact on achieving the desired cranking speed.

Start the Engine

The engine should now be ready to start. Put the engine mode control switch in the START or AUTO (with initiate contact closed) position. The control should begin to prelube and the green “Manual Prelube” light should come on. After prelube is complete, the green light should go out followed by cranking of the engine if the driven equipment input is closed to battery negative. The green “Manual Prelube” light is lit only when prelube should be running. If the “Manual Prelube” light goes out but the engine does not crank, verify the Driven Equipment status is “Ready” on the relay screen of the Advisor panel or Cat ET. Also verify the barring device is disengaged.

Once the engine starts, it may be limited to 550 rpm by the idle/rated contact. To ramp to the speed set by the engine speed dial, terminal 22 in the Advisor panel must be closed to terminal 8 or terminal 2 (see wiring schematic) or at the customer connector in the engine mounted terminal box. Once at the desired speed, increase the speed by increasing the setting on the engine speed dial. If the engine is unstable, reference the System Operation Testing and Adjusting Manual RENR5908 for tuning instructions. (See initial settings in governor settings text in Commissioning Section.)

The feedback to the choke is exhaust temperature in the exhaust temperature feedback mode. The goal is to get the actual and desired exhaust temperatures to match and obtain stable idle. Sometimes the actual and desired may not match at the most stable idle. There is no feedback to the choke in the no feedback starting/warm-up mode. The ECM is controlling the air/fuel ratio using the maps in the software. The start choke position value should be determined by the setting that results in the best engine starting. The start choke position is effective in improving the engine ramp speed at start. The maximum choke position is more for preventing engine instability and excessive exhaust temperatures after desired speed is reached during warm-up. The maximum choke setting assists the air/fuel mapping to control these two parameters.

The fuel start burst value should be set to zero and the wastegate start position should be set to 90 unless the site conditions require adjustment of these two parameters. The desired exhaust temperature value should be set to achieve the exhaust temperature that you want (target should be between 510-538°C (950-1000°F). Site conditions may require the desired be higher than the exhaust temperatures observed. This is due to variations in the mapping and the site conditions. The exhaust temperature feedback delay time interval should be set to the value that results in the best engine loading performance. Refer to RENR5908 Systems Operation Testing and Adjusting for more information on engine operation.

5.4 After Engine Start

Check for Noises/Leaks/Vibration/Temperature/Etc. – After engine is started, check for any problems that would warrant the engine to be shutdown.

Stabilize RPM (Governor, Choke, Wastegate, Max Choke, Desired Exhaust Temp) – After engine is started, stabilize engine rpm using gain settings in the configuration screen of Cat Electronic Technician. The maximum choke position may also need to be reduced to achieve even engine speed while being run in the shop. See RENR5908 Systems Operation Testing and Adjusting for procedure. The engine will experience cylinder misfire during the shop run due to the very light load.

Check Shutdowns (E-stop, Oil Pressure, Temperature, Water Temperature, Crankcase Pressure, and Detonation Sensor) – After engine is started, test shutdowns to check the operation of the protection system.

Hydrax Pressure – Check Hydrax pressure after engine is started and adjust if necessary. Hydrax fluid should be at 150°F operating temperature before adjusting Hydrax pressure.

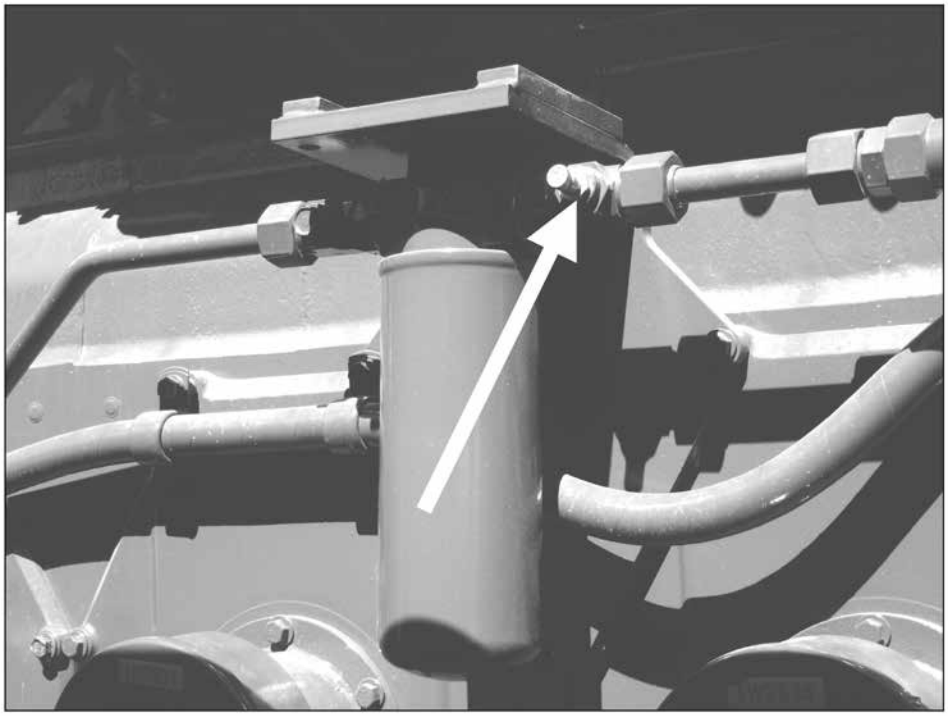

Figure 5.9 – Location to Check Hydrax Pressure

5.4.1 Cooling System Evaluation

Run the engine for 20 to 30 minutes. After the shop run, the strainer(s) should be inspected and cleaned and then reinstalled for the commissioning at the final site.

❑ **Inspect, Clean, and Reinstall Strainers**

Typically at an audit, the engine cannot be loaded, so a cooling test cannot be run. If a complete shop audit will be performed, using the cooler that will be used in the field, use the performance criteria located in the Commissioning Section of this guide.

Protection System

After the engine has been started, the protection system should be exercised to ensure that it will successfully protect the engine. After the engine has run for approximately 30 minutes and is steady, evaluate some of the shutdown protections. As a minimum, verify that each module can cause a shutdown. The recommended way to do this is to disconnect the connector at the filtered oil pressure sensor. This will verify that the ADEM III works properly for an oil pressure failure. Next, disconnect one of the detonation sensors. This will test communication between the ICSM /ISM and the ADEM III. All E-stop pushbuttons should also be tested.

Engine Performance

Use the following tables to record engine data during the construction/packaging audit. Remember, it is important to NOT adjust the needle valves during an unloaded shop run. This will not accomplish the desired results and will cause problems for the setup procedure during site commissioning. Table 5.15 is to be used for an inline engine and Table 5.16 is to be used for a vee engine.

Note: If engine cannot be loaded during the construction/packaging audit operation, engine data will not be as useful.

G3600 A3 Data Sheet – Inline

CATERPILLAR®

G3600 A3 Data Sheet - Inline

Project Name		Engine Serial #		Date	
Site Name		Ambient Temp		Time	
Customer Unit #		Barometric Press		Altitude	
		SCAC Coolant Temp			

Engine Status			A/F Status			Speed Status	
RPM			A/F Ratio			RPM	
Desired RPM			Desired A/F Ratio			Load	
Load			Fuel Quality			Speed Control	
Oil Pressure			Desired Air Press			Droop Setting	
Air Pressure			Specific Gravity			Governor Type	
Oil Temperature			Air Flow			Wastegate Command	
JW Temperature			Fuel Flow			Choke Command	
Fuel Correction Factor			Feedback Status			Fuel Command	

Pressure Status			Temperature Status			Miscellaneous	
Fuel Pressure			Air Temperature			Detonation Level	
Air Pressure			EJW Temperature			Service Hours	
Oil Pressure			Oil Temperature			Battery Voltage	
Differential Oil Pressure			Fuel Temperature			Multi Strike Mode	
Crankcase Pressure			Odd Bank Exh Avg			Multi Strike Switch	
EJW Pressure			Even Bank Exh Avg			Multi Strike Status	

Cylinder Number	B/T	Exh Temp	Needle Valve Position	Timing	Secondary Voltage
1					
2					
3					
4					
5					
6					
7					
8					
Average Burn Time			Desired Timing		
Desired Burn Time					
Turbo Temperature	In				
Turbo Temperature	Out				

	Gain	Stability	Compensation	Desired Exhaust Temp		Fuel Burst	
Governor				Start Choke Position		Exh Feedback Delay	
Aux Governor				Max Choke Position		Crank Termination	
Wastegate				Start Wastegate Position		Accel Rate	
Choke				Fuel Press to Regulator		Fuel LHV	
				Fuel Press to Engine		Specific Gravity	
			Methane Number			Flash File No.	

Emissions				Notes:
O_2		NOx		
CO				
CO_2		Left	Right	Codes:
Exh Back Pressure				
Inlet Air Restriction				

Table 5.15

G3600 A3 Data Sheet – Vee

CATERPILLAR

G3600 A3 Data Sheet - Vee

Project Name		Engine Serial #		Date	
Site Name		Ambient Temp		Time	
Customer Unit #		Barometric Press		Altitude	
		SCAC Coolant Temp			

Engine Status			A/F Status			Speed Status	
RPM			A/F Ratio			RPM	
Desired RPM			Desired A/F Ratio			Load	
Load			Fuel Quality			Speed Control	
Oil Pressure			Desired Air Press			Droop Setting	
Air Pressure			Specific Gravity			Governor Type	
Oil Temperature			Air Flow			Wastegate Command	
JW Temperature			Fuel Flow			Choke Command	
Fuel Correction Factor			Feedback Status			Fuel Command	

Pressure Status			Temperature Status			Miscellaneous	
Fuel Pressure			Inlet Air Temperature			Detonation Level	
Air Pressure			EJW Temperature			Service Hours	
Oil Pressure			Oil Temperature			Battery Voltage	
Diff. Oil Pressure			Fuel Temperature			Multi Strike Mode	
Crankcase Pressure			Odd Bank Exh Avg			Multi Strike Switch	
EJW Pressure			Even Bank Exh Avg			Multi Strike Status	

Cyl #	B/T	Exh	NV	Timing	Sec V	Cyl #	B/T	Exh	NV	Timing	Sec V
2						1					
4						3					
6						5					
8						7					
10						9					
12						11					
14						13					
16						15					
Average Burn Time						Average Burn Time					
Desired Burn Time						Desired Burn Time					
Engine Avg BT											
L Turbo Temp	In					R Turbo Temp	In		Desired Timing		
L Turbo Temp	Out					R Turbo Temp	Out				

	Gain	Stability	Compensation	Desired Exh Temp		Fuel Burst Setting	
Governor				Start Choke Setting		Exh FB Delay	
Aux Governor				Max Choke Setting		Crank Termination	
Wastegate				Start Wastegate Setting		Accel Rate	
Choke				Fuel Press to Regulator		Fuel LHV	
				Fuel Press to Engine		Specific Gravity	
			Methane Number		Flash File Number		

Emissions				
O_2		NOx		Notes:
CO				
CO_2		Left	Right	Codes:
Exh Back Pressure				
Inlet Air Restriction				

Table 5.16

6.0 Commissioning Review

Note: This complete section should be read before starting this procedure.

6.1 Introduction

This document gives guidance to personnel commissioning the Cat G3600 family of engines. Use the included information to prepare the final commissioning report and documentation of performance of each engine as it goes into full service. Any deletion of information can cause confusion during future maintenance or warranty activity. Document each item included in each discussion in the final report establishing the initial condition of engine operation.

Note: Go to the Caterpillar Commissioning Website at Global Petroleum for forms and other resources: https://engines.cat.com/cda/layout?m=349976&x=7

Commissioning an engine has many activities associated with its definition. The field engineer responsible for commissioning must be prepared to give guidance to all areas of the project as well as being the final evaluator of operating systems and engine performance. This module is intended to assist in this activity and to complement the existing "Gas Engines Application and Installation Guide."

It is important to understand the standards established for each system and the specifications accompanying those standards to give the Cat G3600 family of engines the highest reliability and customer satisfaction possible. Any deviation from the standards or specifications can be detrimental to the life of the product. Normal operation of systems can cause deterioration in their performance over their expected life. Starting with deviated standards and specifications will only shorten the expected life.

Items included in the system guides are intended to assist in the documentation of facts to be included in the final commissioning report. Pictures and other schematics or visual aids must be included as attachments to the commissioning report. These items are valuable to help others understand the descriptions given in the report.

Caterpillar and Cat dealer personnel are available to commission G3600 generator sets and industrial engines for a nominal fee. If this is not done, the responsibility of system evaluations and full commissioning is that of the described party designated by the project manager for any project. The selling dealer for G3600 gas engines into the gas compression market is responsible for seeing that a certified commissioning technician performs this important service. G3600 engines sold into a biogas application requires the assistance of Caterpillar commissioning personnel.

There are some items that are important for the field engineer to address as soon as he arrives on the commissioning site. It is important that these items be reviewed as soon as possible after arriving on site. If any of these areas need attention or modification, making a punch list of the items early will give time for the construction crew to remedy the deficiencies without possible delay of the engine commissioning.

Review the installation for these items first to determine early action required:
Are the pressure taps in place in the air inlet piping, the exhaust piping, the auxiliary cooling system piping, and the jacket water system piping? These must be in place to measure the pressures and temperatures required to evaluate the performance of the engine and support systems.

Is the starting and fuel gas piping in place and clean? Is the piping for the compressor in place and clean? You cannot operate the engine if the compressor is not operable.

Are there any items supported from the engine? If so, these configurations must be changed before the engine is placed into service.

Is the air inlet piping system clean? If it is not clean, it must be cleaned before starting the engine. The configuration may require that the air inlet piping be disassembled for thorough cleaning.

Is the cooling fan drive arrangement satisfactory? It should not impose excessive side load on the front stub shaft.

Are the cooling screens in place in the auxiliary and jacket water system pump inlets? The engine should not be run without the screens in place. Experience has shown that there can be all kinds of foreign material in the non-engine components due to carelessness during construction.

Is the coolant and lubricant for the engine and compressor on site?

The punch list of these items should be conveyed to the packager representative for correction before the engine can be run.

6.2 G3600 ADEM III Site Readiness Criteria

Item Checked	Customer Rep Initials	Date	Caterpillar Rep Initials	Date
Inlet Air System				
Inlet air piping to turbos clean (dirt, weld slag, etc.) (observe)				
Inside of air inlet piping should be made of non-rusting material or coated with non-flaking epoxy				
Flexible joints installed at air cleaner and turbocharger end				
Double band clamps used at all flexible joints				
2 to 4-inch gap at air filter housing and turbocharger adapter so metal parts do not contact and cause metal flaking. This gap will be sealed by the flexible joints.				
Piping complete				
Piping supported to keep weight off of turbochargers				
Piping not supported by the engine				
Cooling System				
Temporary cooling system strainer installed in both cooling systems				
Must have test ports installed in the cooling system piping (inlet to both coolant pumps, outlet of both coolant pumps, and circuit outlet of both systems) to test internal and external restriction of the cooling system (strainers must be removed for these tests)				
Blocked open thermostats installed or available for testing cooling system external restriction and flushing the cooling system (expansion tank cap off). Do not use blocked open thermostats at ambient temperatures lower than 21ºC (70ºF)				
Vents installed to eliminate trapped air in the cooling system (engine, piping, radiators, etc. see A&I Guide)				
Flexible connection installed in vent lines				
Check configuration of thermostat housing for proper direction (inlet or outlet control; A, B, and C ports)				
Flexible connections installed at pump inlet and circuit outlet				
Make sure water quality guidelines are followed (Cat Gas Engine Lubricant, Fuel, and Coolant Recommendations SEBU6400)				
Piping complete and supported				
Expansion tank must be highest point of cooling system				
Engine jacket water heaters should be used to aid starting in high humidity and low temperatures				
Extended Life coolant should not be used in Cat gas engines				
Start System				
Start air or start gas available				
Lubricators filled with proper oil (vane motors only)				
Flexible connection installed at engine manifold				
Piping complete and supported				
Drains available to remove condensation from tanks and lines				
Lines blown down to remove liquids and debris (observe)				
Performance				
SRR (Special Rating Request) approved and available (if applicable)				
Exhaust System				
Must have flexible connection at the turbocharger outlets				

G3600 ADEM III Site Readiness Criteria continued

Piping must be supported and must not apply load to the turbochargers				
Piping complete and supported; not supported from the engine				
Must have test ports 3 to 5 pipe diameters from the last transition as close to the turbocharger as possible for testing backpressure and emission samples				
Must not have common exhaust system between multiple engines				
Piping insulated				
Drains installed in muffler so rain water and condensation can be removed before entering the engine				
Exhaust piping expansion from heat must be directed toward horizontal bellows keeping the vertical bellows in line with the turbocharger exhaust				
Fuel System				
Recent site fuel analysis available				
Balance (sensing) line installed on fuel regulator				
Fuel available for starting and loading engine				
Flexible connection installed at engine				
Fuel piping blown down to remove debris (observe)				
Piping complete and supported				
Fuel to engine must be clean and dry				
Fuel filter is 1 micron filtration				
Lubrication System				
Engine crankcase filled with proper oil (Cat Gas Engine Lubricant, Fuel, and Coolant Recommendations SEBU6400)				
Make-up system operational and height properly adjusted				
Waste oil and fill system operational				
Oil heaters recommended if ambient temperature drops below 10ºC (50ºF)				
Pre-lube for engine and driven equipment operational				
Lubricator for starter/pre-lube pump filled with proper oil (vane motor only)				
Crankcase Ventilation				
Crankcase piping must be able to be removed easily for maintenance and repair				
Crankcase ventilation piping should slope downward away from engine				
Separate ventilation piping installed for each engine				
Oil collection in the ventilation piping must be able to be drained				
If piping rises from the engine a trap must be installed to prevent oil and water from re-entering breathers				
Engine Mounting				
Isolator must not have metal to metal contact (gen set)				
Alignment complete and ready to be checked by commissioning engineer				
All engine and driven equipment hold down bolts torqued to the proper values (higher torque value at rear mounting)				
Soft foot within Caterpillar specification				
Engine Monitoring and Control System				
All interconnect wiring installed and terminated				
Interconnect harness and ancillary equipment wiring complete and point to point checks complete				
External Systems				
Wiring for all external systems complete				
All systems ready to allow loading of engine to 100%				

G3600 ADEM III Site Readiness Criteria continued

Serviceability				
Air Cleaner easily accessed for cleaning and element change				
Engine side covers accessible for lower end service work				
Engine turning tool accessible for engine maintenance				
Front cover on oil pan clear for oil pump strainer service				
Cooling system expansion tanks easily accessed for service				
Temperature regulators located low for easy servicing				
Exhaust piping system allows access to top of engine for service				
Miscellaneous				
Product support plan approved and in place				
Servicing dealer will provide spare parts and special tooling required to support commissioning				
Engine manuals on-site and available				
Ancillary Equipment				
All engine related ancillary equipment and engine driven equipment complete and ready for start and loading				
Gas available for loading the compressor				

All persons who initial above must print name and position.

Name:____**Position:**_________________________________

Name:____**Position:**_________________________________

Name:____**Position:**_________________________________

Note: Apply as needed depending on your installation.

Note: This should be used as a general reference, when the Factory Commissioning Engineer is on site he will make these checks plus additional pre-start checks.

Note: This list, while not all-inclusive, must be performed prior to the Commissioning Engineer's arrival.

Table 6.1

6.2.1 Combustion Air System

The air cleaner and piping system must be inspected to ensure it is not contaminated with dirt and debris. The air cleaner elements should be removed from their housing. Carefully inspect the clean side of the air cleaner elements. While the elements are removed, inspect the air cleaner housing. It must be clean and free from debris and rust. Inspect the welds and joints of the air cleaner housing on the clean side and look for gaps and openings that could let dust into the clean intake air. If any such possible dirt entry point is found, return the housing to the manufacturer or repair the part by welding or other suitable method.

The clean side air piping must be inspected for cleanliness. Inspect in place if possible. If it is not possible, remove the piping and inspect in a clean area. Any dirt, dust, and debris must be removed. If the pipe is metallic material, it should be stainless steel or galvanized. Rust is very abrasive and can wear an engine prematurely; however, painting is not recommended to control rust. PVC or fiberglass piping is recommended.

6.3 Air Intake System Evaluation

To evaluate the engine air intake system, the total system must be evaluated from the air source for the engine to the inlet to the turbocharger. This may include engine room air or the air cleaner may be mounted outside the engine room. Whichever the case, consider the following items when evaluating the air intake system.

6.3.1 Combustion Air

Is the quantity of air available for combustion sufficient? This requires an air flow volume of approximately 0.10 m^3/min/bkW (2.5 ft^3/min/bhp) for low emission engines.

The engine room or enclosure should not experience negative pressure if combustion air and ventilation air are from the same source. For extremely cold climates, an alternate warm filtered air source should be available for operating the engine. Air inlet temperature to engine should not exceed 45°C (113°F) or be less than -25°C (-13°F).

6.3.2 Air Cleaner Provided by Others

Air cleaners not provided by Caterpillar for the engine must meet airflow and contamination containment requirements to protect the engine from shortened component life. This requires prior factory approval. Refer to Air Intake Systems A & I Guide LEBW4969 for information about customer-supplied air cleaners. Request and obtain a copy of the factory approval from the packager representative or customer and include with the commissioning report.

6.3.3 Remote-mounted Air Cleaners

Air cleaner elements must be accessible for periodic maintenance. Air cleaners that are mounted above grade should have a stair for accessibility instead of a ladder. A technician cannot safely climb a ladder with a replacement air cleaner element in hand.

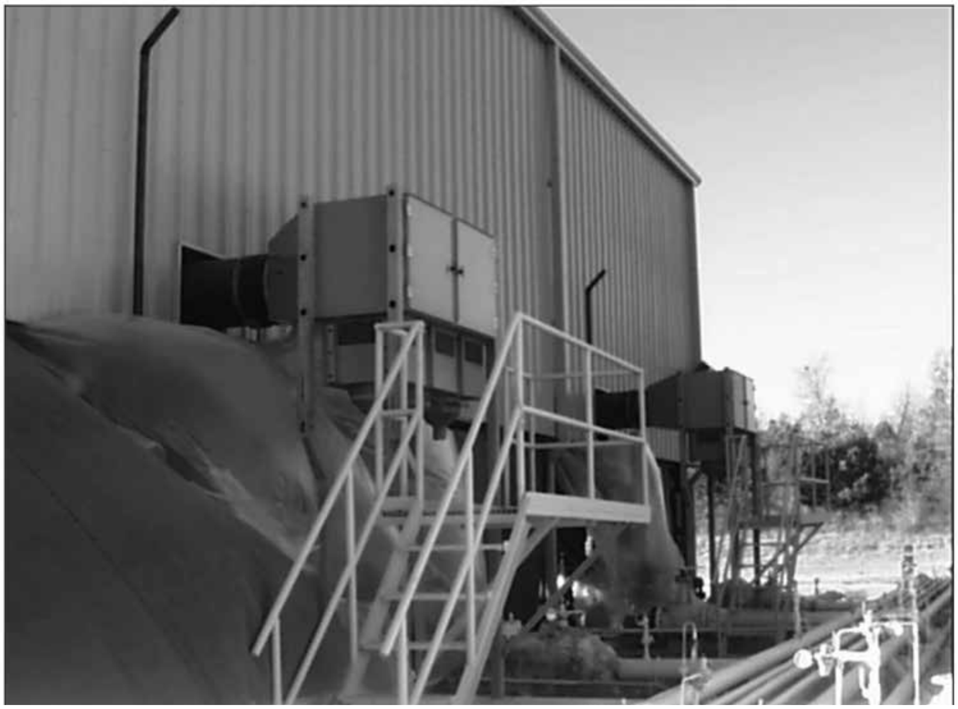

Figure 6.1 – Good Access to Air Cleaner Housings

The air cleaner element(s) must be mounted in the housing to ensure the engine does not ingest foreign material due to incorrect positioning.

The air cleaner housing must have surface protection when subjected to a harsh environment such as salty atmosphere.

Air inlet restriction must not exceed 38 cm (15 in) of water. New, clean systems should be near 13 cm (5 in) of water restriction to allow appropriate service intervals for the filter elements. Inlet air restriction must be measured during commissioning. If a Caterpillar supplied air filter housing is used, the factory pressure port is adequate. If a non Cat air filter housing is used, provisions must be made for a pressure tap to check inlet air restriction.

The air cleaner housing must be mounted in a position that will not allow recirculating exhaust gases, hot air radiated from grade mounted silencers, crankcase fumes, rain, or sea spray to mix with the combustion air. If mounted outside, the air cleaner housing should have rain deflectors to prevent rain water being drawn into the air cleaner. This is especially important for the heavy duty air cleaner groups that have the precleaner groups installed. The air cleaners should draw outside air through the elements and use air ducting to the turbo inlet.

In cold climates, the air cleaner can be subjected to filter icing when mounted outside the engine room. Consider the year-round conditions at the site, and ensure provisions are available for the engine to receive filtered inlet air during all periods of engine operation.

6.3.4 Air Inlet Ducting

The intake air ducting must be clean and free of any weld slag (stick and mig wire), debris, rust, or corrosion prior to operating the engine. This must be inspected by the commissioning engineer prior to initial start-up. Do not rely on others for cleanliness inspection of piping. Removal of air inlet ducting may be required to inspect for cleanliness. While inspecting ducting, engine turbochargers should be inspected for cleanliness and that they rotate freely. Silencers must be installed correctly with regard to air flow direction.

The interior surface of the intake ducting must be protected from future rust and corrosion which might be caused by poor intake air quality.

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

The cross sectional area of the intake ducting must be the same or larger than the air cleaner housing outlet and the air inlet adapter for the turbocharger. Do not use rectangular design piping; this will be susceptible to the “oil can” effect and will not be successful. Any abrupt changes must be avoided, see “Air Intake System” of Gas Engine Application and Installation Guide for more information on air inlet ducting.

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

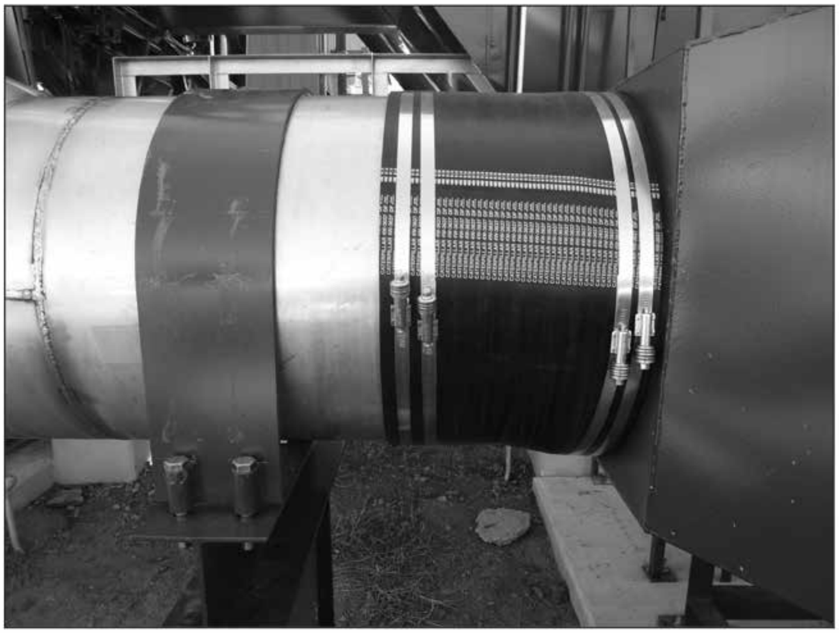

Figure 6.2 – Good Example of Double Band Clamping at the Air Cleaner

Air inlet ducting must not be rigidly mounted to the air cleaner housing or to the turbocharger inlet. The air cleaner housing outlet must have a flexible transition attaching the air inlet ducting. The turbocharger must not support the weight of the ducting. The ducting must be supported by substantial fabrication from the skid, grade, or building but not the engine. Flexible non-metallic connections must be used between the ducting of both the air cleaner housing and the turbocharger. Also, there must be double band clamping on each end of the flexible connectors to insure non-filtered air does not enter the engine. Offset the clamping hardware if possible.

Observe the proximity of the exhaust piping and the air intake ducting. Ensure there is no heat transfer from the exhaust piping to the inlet air piping. If evident, insist either or both are insulated to protect both air inlet temperature and the non-metallic connections.

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

❑ **Combustion air line(s), air cleaner housing(s), and air cleaner element(s) inspected and clean.**

6.3.5 Inlet Air Preparation

System pressures can be evaluated at maximum load. Install ports for pressure measurements if they are not already installed. Locate and install bosses (typically 1/2 inch female pipe) at the following locations:

❑ **Air cleaner housing outlet**

6.4 Exhaust System Evaluation

The exhaust system for G3600 engines must be evaluated from the turbocharger to the atmospheric conditions existing at the muffler outlet. Fuel consumption, exhaust emissions, detonation and exhaust explosion characteristics, and component life of the engine are affected by the exhaust system design and proper installation.

Consider the following items when evaluating the exhaust system.

6.4.1 Exhaust System Warnings

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

The engine installer must provide appropriate drains and rain caps to protect the engine from rainwater entering the engine through the exhaust piping. The last few feet of the exhaust outlet should be installed to prohibit rainwater entry without inducing excessive exhaust backpressure.

Note: A common exhaust system between multiple engines is not acceptable.

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

6.4.2 Exhaust System Piping

Exhaust system piping must be made of a material to withstand the effects of exhaust gas temperature, velocity, and thermal expansion. Ensure that any insulation added to exhaust piping does not deteriorate the piping since the pipe temperature will be higher than if not insulated.

Backpressure of the total piping system must be minimal to allow for muffler restriction, outlet piping from the muffler, and piping degradation during the life of the engine. Fuel consumption, exhaust emissions, detonation and exhaust explosion characteristics, and component life of the engine will be affected if the backpressure exceeds the recommended value of 12 inches of water pressure.

Note: Caterpillar recommends pressure relief valves be installed in the exhaust system before each major component. This will reduce the risk of damage in the event of an exhaust explosion. Caterpillar also recommends exhaust piping ventilation fans be installed in the exhaust system.

Exhaust backpressure on each bank of the twin turbocharged G3612 and G3616 (vee) engines must be balanced, even when the dual pipes exiting the turbochargers are transitioned into one larger pipe going to the muffler. Do not allow gas flow to turn at a right angle during a transition. Do not allow the exhaust system piping for a vee engine to be routed vertically from each turbocharger and then be blended horizontally. This will cause excessive backpressure on one bank. Blend the exhaust gases into a common pipe before the direction change is made or during a long radius bend in the directional change.

There must be expansion joints and vertical supports in the appropriate positions to assure free movement of the exhaust piping during thermal expansion.

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

The exhaust piping routing must not interfere with the service of the engine. Pay particular attention to the use of an overhead bridge crane.

6.4.3 Exhaust Preparation

System pressures can be evaluated at maximum load. Install ports for pressure measurements if they are not already installed. Locate and install bosses (typically 1/2 inch female pipe) at the following locations:

❑ **Exhaust Outlet**

A point for measuring exhaust system backpressure should be in a straight length of the exhaust pipe at least 3 to 5 pipe diameters away from the last size transition change from the turbocharger outlet as close to the engine as possible. The minimum distance away from turbocharger bellows is 3 to 5 pipe diameters. System backpressure measurement is part of the engine performance testing.

Figure 6.3 – Locate Emission Taps in the Straight Section or Exhaust Piping

This tap location should be brought down to grade level for easy access for measuring both the exhaust emission level and the exhaust system backpressure.

Figure 6.4 – Example of Correctly Located Exhaust Emission Sample Ports

6.4.4 Exhaust Emissions

The exhaust emissions from G3600 engines often are regulated by country, state, county, or local legislation. G3600 engines can operate over a wide range of NOx emission level and can be adjusted to meet most regulations. The various versions of G3600 engines can operate from 0.5 g/bhp-hr NOx to 0.7 g/bhp-hr NOx. This is one reason why the G3600 is chosen over its diesel counterpart. Proper selection of engine arrangements is required to obtain the proper emissions, power, fuel consumption, and performance.

The air/fuel ratio is controlled by the ADEM III control module with commands to the actuators. These actuators control the air and fuel management to the engine. An actuator is located at the choke butterfly valve to control idle and low load air flow. A second actuator is located at the wastegate butterfly valve to control the turbocharger air delivery at mid to rated loads. A third actuator controls the fuel valve which controls engine speed relative to load.

Consider the following when evaluating exhaust emissions.

Legislation

It is the customer's responsibility to understand the legislation at all levels in the area where the engine is to be operated. In the United States, the U.S. Federal EPA has the responsibility to regulate emissions throughout the U.S.A. Many states have even stricter regulations than the U.S. Federal EPA. States that are known to have stricter regulations than the U.S. Federal EPA are Arizona, California, Colorado, Connecticut, Illinois, Kansas, Louisiana, Maine, Massachusetts, Nebraska, New Hampshire, New Jersey, New Mexico, New York, Oklahoma, Pennsylvania, Rhode Island, Texas, Utah, Vermont, and West Virginia, Wyoming, and many other states. Certain local regions have even stricter regulations. These are currently located in the southwest and northeast. Many countries in Europe and Asia have strict regulations as well.

Review with federal, state, and local government agencies the regulations in the area where the engine will be operated.

Emission Permitting

It is the customer's responsibility to obtain required operating permits for the area the engine will be operated. All emission regulatory agencies need to be considered. The permitting process may be a time consuming exercise and may delay power production if not initiated early. Ensure that the customer is informed of the emission rating of the engine.

Emissions Compliance

The engine emissions should be evaluated in the field. Due to site conditions, gaseous fuel used, etc. the engine may require resetting to obtain the desired emissions level. An accurate exhaust emissions analyzer must be used to verify that the engine complies with the desired NO, NOx, and CO emissions level in the exhaust, compared to the engine performance data sheet. Additional exhaust treatment may be required by the customer to meet the site emission requirement.

For additional guidance see the Emissions section of the Gas Engines Application and Installation Guide.

6.5 Cooling System Evaluation

A cooling system evaluation for the Cat G3600 family of engines must include engine operating parameters, external system piping, water quality, and external cooling components. A properly controlled cooling system is essential for satisfactory engine life and performance. Deficient cooling systems and careless maintenance are a direct cause of many engine failures.

Consider the following when evaluating the engine cooling system.

6.5.1 Engine Cooling Circuits

Coolant flow from the left side pump (viewed from the rear) is split between the aftercooler and oil cooler. The right hand pump (viewed from the rear) supplies water to the jacket water system. The two pump design provides jacket water and separate circuit cooling systems. The separate circuit is used to cool both the aftercooler and the oil cooler. The separate circuit and the jacket water circuit can be either inlet or outlet controlled. During performance testing of the engine, ensure the appropriate inlet coolant temperature is being supplied to both circuits and the temperature rise of the coolant is within specified limits.

Inlet controlled (mixing) designed cooling systems are usually used with a shell and tube or plate and frame heat exchanger. Outlet controlled (diverting) designed cooling systems are usually used with a fan cooled cooler (radiator) such as a gas compression application.

6.5.2 System Coolers

Radiators are the most common way to cool coolant for the G3600 family. Other methods include heat exchangers and cooling towers. It is the user/installer's responsibility to provide proper venting and isolation of the cooler for required maintenance or repair.

If an open cooling tower system is used, ensure the water from the cooling tower does not enter the engine. Debris collected by the water from the atmosphere can be detrimental to water pumps and be deposited in the engine. Consider using the cooling tower water as raw water for cooling the engine circuits' closed-loop that uses heat exchangers.

When impractical to route vent lines long distances to a common venting point, a 5N3727 float valve or APCO air release valve, Model 200AB.3, or equivalent is recommended. It has a cast iron body and stainless steel trim. The cover includes a 1/2 inch NPT plug that should be removed for installation of a nipple and ball valve allowing rapid venting during initial fill of the system. The valve's internal diaphragm collects entrained air and automatically releases it to atmosphere during operation. Remember that any released air/liquid may be flammable.

6.5.3 Cooling System Pressure Drop

Regardless of the type of cooler used, the external system resistance in the piping and through the cooler must be measured. The pressure is based on the rated speed of the engine and full flow to the external system. Circuits with thermostats must be replaced with blocked open stats to allow full flow and prevent bypass circuit flow during the measurement.

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

The internal resistance of the engine should be measured as well. This is done with the blocked open stats installed also. The pressure drop should be measured from the pump outlet to the engine outlet on both the jacket water and separate circuit systems. The pressure drop depends upon the speed of the engine, and therefore the pressure should be measured at rated speed. From the pressure drop a coolant flow rate can be obtained from pump curves published in GERP (Gas Engine Rating Pro).

Make sure to identify and enter in the correct engine configuration and circuit from information found in GERP. This value should be compared with the corresponding flow rate determined by the external resistance chart also in GERP. These two values must be in the usable flow range and should agree within ± 20%. If the flow is too high, then additional external resistance should be added.

If the flow is too low, determine the cause – usually excessive external resistance – and make correction to this deficiency.

6.5.4 Expansion Tanks

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

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

Any other cooling system component should have vent lines run to the auxiliary tank or must be vented independently. Vent lines should be added if not provided. The vent lines should run from the highest point on the engine for each circuit, to the highest point in the expansion tank or auxiliary tank if provided. Vent lines should be 9.53 mm (3/8 in) diameter minimum tubing, stainless steel or copper. Refer to "Cooling Systems" section of the Gas Engine Application and Installation Guide.

Initial filling of the system must be done at a rate so that complete venting of the cooling system can occur. Always remove the radiator cap during cooling system fill. Loosen the vent line connection at the engine to ensure air has been purged from the systems during filling. Always be ready to add a supplemental volume of water to system at initial start-up in case air has been trapped in the system. The Cat expansion tank is provided with a 48.3 kPa (7 psi) pressure cap. During testing and adjusting the external system resistance, the pressure cap must be removed. Re-install the pressure cap prior to the engine performance testing under load.

When altitude becomes a consideration for the boiling point of water, ensure the standard pressure cap is adequate to prevent coolant boiling below the alarm and/or shutdown protection settings. For example, a jacket water temperature shutdown would require a 51.7 kPa (7.5 psi) cap at sea level to maintain 98°C (208°F). At 3048 m (10,000 ft), the pressure cap would only provide the equivalent of 27.6 kPa (4 psi) and the boiling point of water is reduced to approximately 93°C (200°F). The shutdown setting would not protect the engine; a radiator cap rated at 96.5 kPa (14 psi) would be required.

Note: If an expansion tank pressure cap is not used, adjust water temperature alarm and shutdown contactors according to atmospheric conditions to insure adequate engine protection. The expansion tank may have to be raised to furnish the minimum pump inlet pressure to the system.

If a non Cat expansion tank or a shunt style cooling system is provided for the engine, a complete test must be done complying with requirements listed in EDS 50.5, Cooling System Field Test, Form No. LEKQ7235.

6.5.5 Cooling System Protection

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

- High jacket water temperature alarm and shutdown (engine mounted)
- High oil temperature alarm and shutdown (engine mounted)
- Jacket water pressure low pressure alarm and shutdown (engine mounted)
- High air inlet manifold temperature alarm and shutdown (engine mounted)
- Low coolant level alarm (customer supplied)

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

6.5.6 Central Cooling Systems

Cooling multiple engines from a common system is not recommended. A dedicated cooler for each engine is preferred.

If a central cooling system is used for the installation, ensure that the system performance is evaluated with the maximum heat rejection possible from all engines being cooled from the system. Since every central cooling system, application, and installation will be unique each system must be approved by Caterpillar before construction and operation. If a central cooling system is used, Caterpillar is not responsible for the cooling system performance.

6.5.7 External System Piping

Review "Cooling System Test Preparation" to ensure all test ports, temporary strainers, and blocked open thermostats have been installed correctly.

The external system piping must be clean and free of weld slag and other debris that can be damaging to engine components.

Inspect cooling system piping prior to the initial filling of the system. If debris is found, ensure the piping is cleaned before filling the system.

Install temporary strainers at the engine in the coolant inlet line(s) and blocked open thermostats in the thermostat housings prior to initial engine operation. Operate the engine at no-load and rated speed for at least 15 minutes. Remove the strainers and check for debris. If debris is found, reinstall the strainers and repeat the operation. Continue this procedure until no debris is found in the screen. Once no debris is found in the screens, remove temporary strainers, re-fill cooling system, and run the engine. Pressure drop readings can be taken with blocked open thermostats still installed. Fill out all tables in the “Cooling System Evaluation” section of the “Live Engine Test” section of this commissioning guide. Once all “Cooling System Evaluation” tables are completed and flows have been verified to be within Caterpillar specification, blocked open thermostats can be removed and production thermostats can be installed. Do not adjust external system resistance with the temporary strainers installed. The temporary strainers are available from Caterpillar for 101.6 mm (4 in) – 4C9045; for 127.0 mm (5 in) pipe – 4C9046; and for 152.4 mm (6 in) pipe – 4P9047.

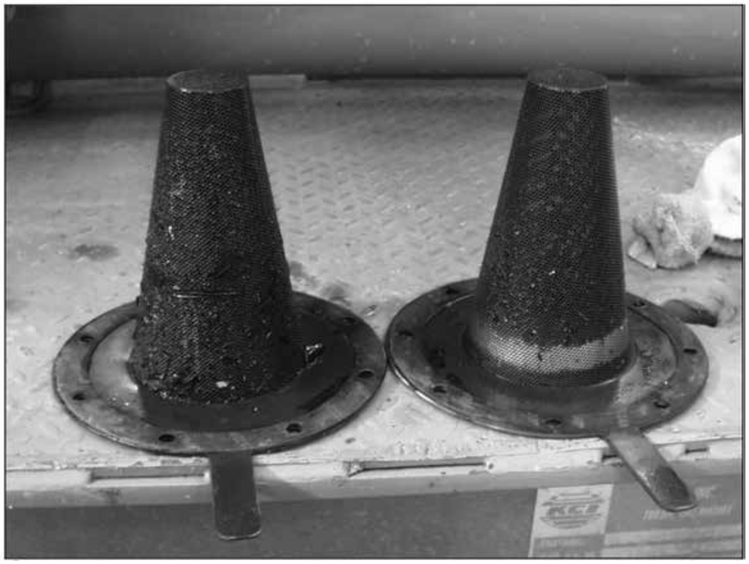

Figure 6.5 – Cat Cooling System Strainers

Temporary strainers must not be left in place without pump pressure differential monitoring installed when the commissioning engineer leaves the site at commissioning completion.

If a permanent strainer in the coolant inlet lines is provided by the user/installer, ensure pressure drop across the strainer can be monitored. Excessive pressure drop can cause improper coolant flow to engine. Follow the same procedure for permanent strainers as described for temporary strainers during initial engine operation. At maximum flow condition, any clean strainer should have maximum capacity to create no more than 10-14 kPa (1.5-2.0 psi) pressure drop.

External piping must be isolated from the engine and driven equipment. The recommended flexible couplings are; 4P5906 for 6 mm (4 in) pipe, 4P5905 for 127.0 mm (5 in) pipe, and 4P5907 for 152.4 mm (6 in) pipe. Install the couplings between the point of piping support on the engine and the closest external piping support to the engine.

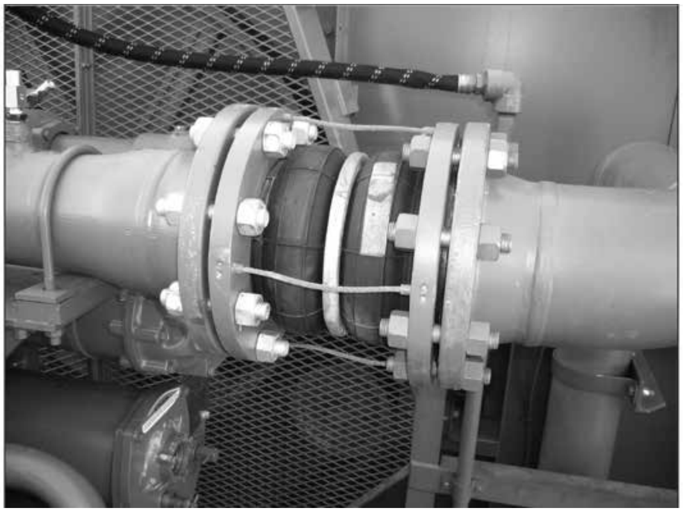

Figure 6.6 – Example of Flexible Coolant Piping Coupling With Ground Straps

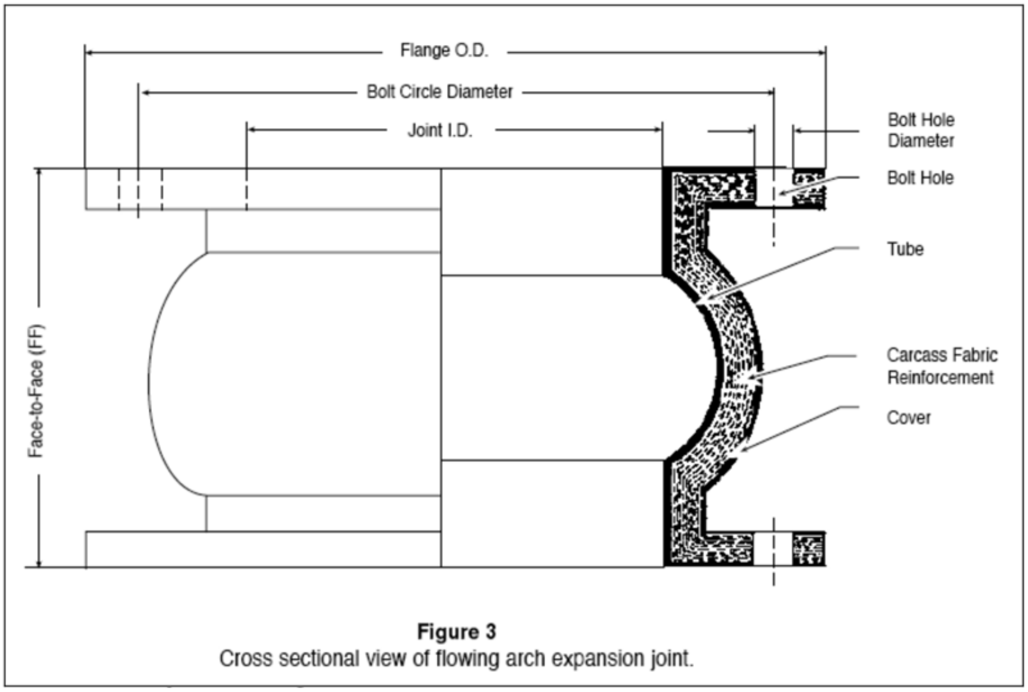

Figure 6.7 – Drawing of Typical Cal Coupling

6.5.8 Corrosion Protection

Caterpillar guidelines established for water quality must be followed precisely. These guidelines are published by Caterpillar and available in the standard publication system. Engine Installation and Service Handbook, Form No. LEBV0915, and Coolant and Your Engine, Form No. SEBD0970, are two sources for information.

For a cogeneration system, the jacket water temperature is greater than 111°C (230°F). Boiler class water complying with information found in the publication, EDS 56.0 Water Treatment Recommendations for Ebullient and Solid Water Cooled Engine, Form No LEKQ8567, should be used.

Ensure the proper quality of fresh water is installed in the system. Also ensure that the water is properly treated with corrosion inhibitor. Refer to Spec Instructions – Recommendations for Cat Gas Engine Cooling Systems, Form No. REHS1657, for additional cooling system information.

If ambient conditions require anti-freeze to be used, ensure only low silicate anti-freeze is installed. Test concentration with a Coolant Tester (5P0957 for °F or 5P3514 for °C).

Ensure that the Cooling System Test Kit (8T5296) or Coolant Test Strips (4C9297) are used to evaluate the concentration of corrosion inhibitor in the system. Excessive concentrations are as damaging to the engine as are insufficient concentrations.

6.5.9 Heat Recovery

Recovering heat from the engine coolant can improve the efficiency of the operation, but can also be detrimental to the engine if not designed and installed properly.

Ensure that any external temperature regulators for the cooling system do not inhibit coolant flow to the engine and that temperature control is maintained.

Ensure external heat recovery components do not contribute excessive resistance to coolant flow.

Ensure the water temperature returning to the engine has been cooled sufficiently to achieve the required coolant temperature at the engine pump inlet(s).

6.5.10 Fill Fluids

Cooling System

Fill the engine cooling systems with coolant. Tap water is unacceptable for a G3600 engine cooling system. Use distilled water or deionized water. If the coolant will be exposed to temperatures lower than 0°C (32°F), antifreeze must be added to the water. Two types of antifreeze are commonly used; ethylene glycol and propylene glycol. Caterpillar recommends using Natural Gas Engine Coolant (NGEC). This coolant is available in various container sizes. The coolant/antifreeze must be low in silicates.

Use coolant conditioner whether or not antifreeze is used. Cat coolant conditioner 8C3680 19 L (5 gal) or 5P2907 208 L (55 gal), should be added at approximately 5 to 6% by volume to the coolant. System volume can be estimated. Use Table 6.2 to estimate the volume of coolant in the piping.

Go to Commissioning website https://engines.cat.com/cda/layout?m=349976&x=7 for an Excel worksheet that can be used for calculating cooling system volumes. (231 cu. inches = 1 gallon)

Coolant

The coolant must have protection against freezing and conditioners to prevent corrosion. Record the antifreeze protection level, type of antifreeze, type of water, and conditioner concentration level.

- ❑ Filled with Coolant

Type of Water:

- ❑ Distilled
- ❑ Deionized
- ❑ Other
- ❑ Coolant Contains Antifreeze

Antifreeze Level ____________% (EC/EF)

Type of Antifreeze:

- ❑ Ethylene Glycol
- ❑ Propylene Glycol
- ❑ Other
- ❑ Coolant Conditioner

Conditioner Level ______ % _______(PPM)

Pipe Factor			
Pipe Diameter		Volume of Coolant per Foot	Volume of Coolant per Meter
Inch	cm	Gallons	Liters
0.75	1.91	0.02295*	0.869
1.0	2.54	0.048*	0.182
4	10.0	0.65	7.9
5	12.5	1.0	12.3
6	15.0	1.5	17.7
8	20.0	2.6	31.4

*These two rows are added to aid in cooler volume calculation.

Table 6.2

Find the total length for the respective system and multiply it by the factor shown in Table 6.2. Add to that the volume in the coolant exchanger, whether it is a heat exchanger or radiator. This can be found on the spec sheet for the device. Finally, add the volume of coolant that is in the engine. Table 6.3 will provide an engine capacity estimate:

Cooling System Capacities				
Engine	Jacket Water		Separate Circuit	
	Gallons	Liters	Gallons	Liters
G3606	90	340	16	60
G3608	124	470	16	60
G3612	177	670	17	64
G3616	238	900	19	72

Table 6.3

The total of the three amounts should approximate the volume of the individual cooling system circuits. Record them in Table 6.4 and Table 6.5:

Jacket Water System					
1	2	3	4	5	6
Pipe Size	Pipe Factor	Length of Pipe	Column 2 x Column 3	Volume of Heat Exchanger	Volume of Engine
Total of columns: Column 4 + Column 5 + Column 6 = Total System Volume					

Table 6.4

Separate Circuit System					
11	12	13	14	15	16
Pipe Size	Pipe Factor	Length of Pipe	Column 12 x Column 13	Volume of Heat Exchanger	Volume of Engine
Total of columns: Column 4 + Column 5 + Column 6 = Total System Volume					

Table 6.5

6.5.11 Expansion Tank

The expansion tank volume of each cooling system should also be evaluated. Rule of thumb volumes are 8% of the total system volume should be used for the separate circuit and 15% for the jacket water systems. This will provide for the expansion volume plus the reserve capacity. Check the A & I Guide, Cooling section for exact capacities if the expansion tank volumes in columns 10 and 20 in Table 6.6 and 6.7 are negative.

Jacket Water System			
7	8	9	10
Total from Column 4, 5, & 6 in the table above.	Actual expansion tank volume	Column 7 x 15%	Column 8 – Column 9
❑ Yes ❑ No Is Column 10 positive:	❑ Acceptable	❑ Yes ❑ No Is Column 10 negative?	❑ Unacceptable

Table 6.6

Separate Circuit System			
17	18	19	20
Total from Column 14, 15, & 16 in the table above.	Actual expansion tank volume	Column 17 x 8%	Column 18 – Column 19
❑ Yes ❑ No Is Column 20 positive:	❑ Acceptable	❑ Yes ❑ No Is Column 20 negative?	❑ Unacceptable

Table 6.7

6.6 Starting System Evaluation

The Cat G3600 family of engines has electronically actuated pneumatic starters. The working fluid is compressed air, field gas, or natural gas.

Consider the following when evaluating the engine starting system.

6.6.1 Air Compressor

The air compressor must be sized to match the air receiver tank(s) make-up rate due to starting. Also consider site for altitude and air density influence.

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

6.6.2 Air Receiver Tanks

Ensure the air receiver tanks are sized to provide the required consecutive engine starts without depletion of air pressure below the minimum starting pressure.

Receiver tanks must have manual or automatic drains to allow oil and water condensate to be drained daily to prevent damage to the starters. Inform operators of this requirement.

Receiver tanks must meet specific characteristics, such as the specifications of the American Society of Mechanical Engineers (ASME). Ensure each receiver tank has been tested at 1-1/2 times the normal working pressure unless local codes require some greater value. Set the tank relief valve pressure at a level below the test pressure.

Receiver tanks must be equipped with a maximum pressure relief valve and a pressure gauge. These should be monitored periodically to assure proper operation. The air supply should not be turned off from the engine during operation. If the air supply is turned off, the post lube function will be disabled and damage to the turbocharger can result during shutdowns.

6.6.3 Air Supply Piping

Size piping to provide a minimal pressure drop of supply air from the receiver tank to the engine starters. Piping should not be smaller than the connection at the engine and should include a flexible connection at the interface with the skid. For gas compression applications, Caterpillar recommends that the starting supply piping should be a minimum diameter of 76.2 mm (3 in).

Piping should be routed so that water vapor and oil deposits collect at a trap in the lowest point in the piping without blocking flow. Drain the trap daily. Operators must be informed of this requirement.

Prior to initial start-up of the engine, disconnect the air piping from the engine and allow controlled air to purge any water vapor, oil deposits, or debris out of the pipe to prevent ingestion into starters. The commissioning engineer should observe this purge procedure. Follow the site safety procedures during this procedure, especially if gas is used for the starting medium.

6.6.4 Engine Starters and Accessories

Adjust the starter lubricator (for vane starters and vane prelube motors) during the initial starting of the engine to limit slobber of starter lubricant at the starter air outlet.

Take care when starting the engine that the starter silencer discharge does not endanger personnel safety. If the discharge is directed toward any potential occupied area, provide shielding between the starter and the area in question. If gas is the starting fluid, the exhaust must be routed away from the engine and/or outside the building.

Ensure that there is a 34.5 kPa (5 psi) backpressure valve in installed to protect the starter/engine flywheel ring gear if the starting motor discharge is connected to a common vent. Excessive backpressure can cause the pinion to be pushed out and engage the flywheel ring gear and cause serious damage, if the engine is running.

6.6.5 Alternate Forms of Starting

The Cat G3600 family of engines can use a 24 VDC electric start system. The size of storage batteries as well as the number of starters should be selected depending on the ambient temperature starting capability required. The price list can be used to help select the proper componentry.

6.6.6 DC Electrical

Power Connection and Quality Interconnect Harness

An interconnect harness is used between the engine ADEM III junction box and the Advisor panel or customer supplied panel. This harness must be temporarily installed to perform a live engine test during the shop audit. Refer to Special Instruction REHS1336 for more information about the interconnect connection.

Note: The following instructions are for a Caterpillar supplied Advisor panel only. Refer to customer drawings if a customer-supplied panel is used.

To do this first remove the two Caterpillar supplied fuses from the engine junction box panel at terminals 1 and 3 (6 amp and 15 amp). Ensure the engine control switch is in the OFF/RESET position. Connect battery and charger or power supply to the Advisor panel terminals 1 and 2 and turn on. Verify 24 VDC between Advisor T1 and Advisor T2 terminals. The Advisor should appear “dead” (while in OFF/RESET). Voltage must measure between 21 and 32 VDC and <150m VAC pk-pk (approx. 71.4 mV AC rms) – Table 6.8. If voltage is not within specification, troubleshoot power supply problem before turning Advisor to the STOP position. If voltage is within specification, insert fuses previously removed and turn engine control switch to the STOP position. The Advisor panel should power up.

Power Supply Quality

The power supply should be evaluated for AC ripple (electrical noise). Ensure proper voltage and minimum voltage drop to the control panel. To do this, use a voltmeter to measure the voltage across the power supply. Record both the voltage using the DC scale and the AC scale. The power supply maximum ripple should be evaluated (maximum ripple allowed is 150 m VAC). The preferred operating range is 24-27 volts DC. Record the measured data in Table 6.8.

If the Advisor panel is not used, check the power supply for correct voltage between the negative terminal T3 and the power connection T1 to the power fuses in the engine junction box.

See Gas Engine Application and Installation Guide, Technical Information section for more information.

Power Supply Voltage	
DC Voltage	**AC Voltage**
Spec: 21 VDC to 32 VDC	Spec: ≤ 150 mVAC pk-pk
❑ Acceptable ❑ Unacceptable	❑ Acceptable ❑ Unacceptable

Table 6.8

Wire Length and Gauge

Also, the length of wire and gauge of wire from the power supply to the Advisor panel needs to be recorded. Use Table 6.9 to record the power wire information.

Wire Gauge Test	
Length	**Gauge**

Table 6.9

To verify the wire gauge is adequate for the length of wire used, measure the voltage to the power fuse with the fuse switch open, and record the voltage. Measure the voltage again with the fuse closed, the mode switch in the STOP position, and prelube pushbutton depressed. This will cause all the control devices, sensors, and actuators to be powered; record the voltage. Use Table 6.10 to evaluate if the wire size is adequate.

Wire Gauge Test			
DC Voltage Fuse Open	**DC Voltage ECM Powered**	**Difference**	**Maximum Difference**
≤ 1.0 VDC ❑ Acceptable		≤ 1.0 VDC ❑ Acceptable	

Table 6.10

Wiring Checks– Make Sure All Appropriate Jumpers Are In Place (Be Thorough) – check to ensure that all jumpers or system wires from the control panel are installed in the Advisor or engine mounted terminal box. Make sure that all wires are tight in the terminals. See Gas Engine Application and Installation Guide, Technical Information section for more information. Check E-Stops at all points. This can be done with engine not running. Also, see Special Instruction, REHS1336, Initial Installation and Start Up Guide.

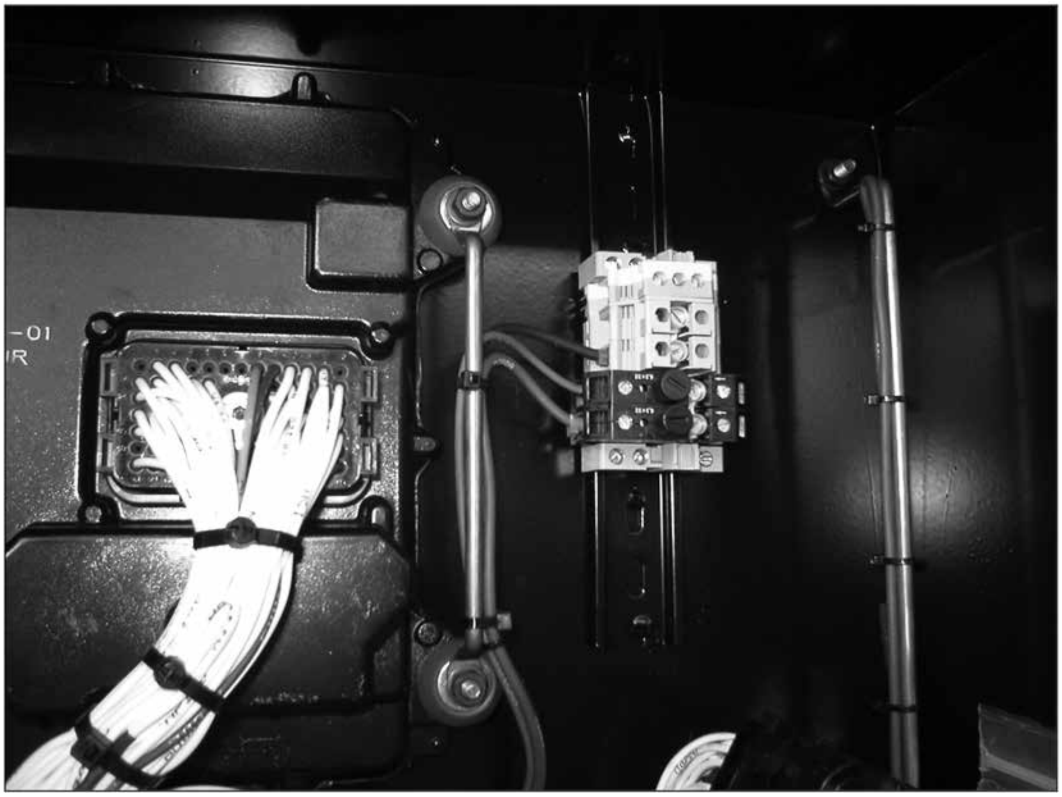

Figure 6.8 – Engine Junction Box Interior

Note: Engine will run at 550 rpm unless the idle/rated switch is closed (terminal 22 to terminal 8 in the Advisor panel or terminal 40 and 41 in the engine mounted ECM box customer connector J-3).

6.6.7 Batteries

Caterpillar offers various size batteries for starting, depending on the desired ambient starting capability required. These batteries are low maintenance lead acid batteries and should be mounted near the engine to keep electrical cabling short. Because a small amount of explosive gases that can be generated by lead acid batteries during charging, they should be well ventilated. This is another reason to mount the batteries near the engine to take advantage of the engine room ventilation. Other battery types can be used, such as NiCad batteries. These batteries are maintenance free and reportedly have longer service life.

Ensure that the battery terminal connections are clean and secure. The 24 VDC power supply should be clean and free from electrical noise. The recommended maximum voltage ripple is 150 mVAC. The engine electrical system ground must be common with the compressor control panel ground.

6.6.8 Battery Charger

In addition to the starting requirements, the Cat G3600 family of engines has an ADEM III control system, which operates using 24 VDC power. The ADEM III provides engine control, engine protection, status indication, and electric governor. The switchgear is typically 24 VDC powered as well. The charging system, whether AC to DC battery charger or engine powered alternator, should be sized to handle the peak electrical demand of starting plus the continuous current draw of the ADEM III control system and auxiliary electrical equipment. A battery charger must be evaluated for electrical noise, which can cause abnormal operation of the control system.

6.6.9 Wire and Cabling

Interconnect wires and cables must be sized adequately for the control circuits. A minimum of 16 gauge wire is recommended regardless of the current requirement. For additional guidance see the “Starting” section of the Gas Engines and Application and Installation Guide.

6.6.10 Cold Ambient Starting

For cool ambient temperatures, jacket water heaters are recommended. These AC electric heaters circulate warm coolant through the engine making a cold start much easier. Also available are AC electric oil heaters, which also improve engine starting. Jacket water heaters are recommended for all but the hottest ambient temperatures for easiest starting. Humidity is as great a deterrent to easy starting as is low ambient temperature. An oil heater is recommended if the ambient temperature will be 10°C (50°F) or lower. An engine oil pressure switch should be used to turn the heaters off when the engine is running.

Figure 6.9 – A Combination Jacket Water and Engine Oil Heater Group

For extremely cold ambient temperatures, an alternate, warm filtered combustion air source should be available for starting the engine. The temperature for starting should not be less than 0°C (32°F).

Note: Ensure that the lube and coolant heater connections are properly connected before filling the oil pan or the cooling systems to prevent installing the wrong fluid into the compartment.

6.7 Fuel System Evaluation

Cat G3600 engines can operate on a wide range of gaseous fuels. This ranges from field gas with a lower heating value (LHV) of approximately 1050 Btu/SCF to landfill gas with a LHV of 400 Btu/SCF. Fuel supply pressure required is 310 kPa (45 psig). Because the engine is designed and built for a specific fuel heat value, this information should be provided at the time the engine order is placed.

Note: Low BTU fueled engines require different engine components and a different flash file in the ADEM ECM.

The combustion of fuel is required to obtain the desired primary output, the production of power (and heat). The saying, “You are what you eat.” applies equally well for Cat gas engines.

Consider the following when evaluating the fuel system.

6.7.1 Gaseous Fuels

Gaseous fuels consumed by the engine are rarely pure. Rather, they are a blend of various combustible gases, inert gases, contaminant gases, liquids, and particulates. For proper engine operation, the composition of the fuel gas must be known. A gas analysis is very important for proper long term engine operation.

6.7.2 Heat Value

To produce power, whether gas or liquid fueled, all engines combust fuel to produce heat. The amount of heat produced determines the amount of power produced. The unit for heat is Joules (J) or British thermal unit (Btu). For hydrocarbon fuels, the lower heat value (LHV) portion of the fuel is what produces power. Liquid fuel is regulated by the petroleum industry and is very consistent. Gas fuels can vary dramatically. For proper engine set-up and operation, the LHV and specific gravity of the fuel must be known. The composition of the gas is what determines its heat value. The lower heat value of a gas is described in mJ/m^3 or Btu/SCF of gas. Each constituent in the gas has a different heat value. The sum of the mole percentage of each constituent multiplied by the respective heat value determines the heat value of the fuel in question. Caterpillar and Cat dealers have a software program, the Methane Number calculation found in GERP (Gas Engine Rating Pro), to help determine the lower heating value of a fuel from a gas analysis. Caterpillar uses 905 LHV Btu/SCF as the standard fuel and corrects all engine data to this standard.

6.7.3 Detonation Characteristics

Fuel composition also affects the rate of fuel combustion. The rate of combustion determines the detonation characteristics of the fuel when burned in an engine. The Methane Number is the unit of measure for resistance to detonation. This is similar to the more familiar Octane Number for liquid fuels. Similar to lower heat value, each constituent has a different Methane Number. The Methane Number of a fuel gas can be determined from the percentages of each constituent that makes up the gas.

6.7.4 Contaminant Gases

Some gases found in fuel gas can cause premature engine wear and failure. These gases produce chemical attack of the engine if not treated properly. The gases of concern are those that contain sulfur, chlorine, and fluorine atoms. The most common contaminants are hydrogen sulfide (H_2S) and chlorofluorocarbons (CFC). $_2S$ is found in field gas, digester gas, and landfill gas. CFCs are found in common solvents and refrigerants. CFCs are commonly found in landfill gas. When these compounds are burned in the engine, they produce very strong acids which can attack engine components and cause premature engine wear and failure. Allowable limits, precautions, treatment, and maintenance procedures are covered in the “Low Btu Engines” section of the Gas Engine Application and Installation Guide.

6.7.5 Fuel Pressure

The G3600 family is available in a high pressure fuel configuration only. The fuel pressure requirement for this low emission engine is 310 ± 13.8 kPa (45 ± 2 psig) for complete operating range. Fuel pressure to the engine must be within specified limits to obtain proper engine operation. Use a fuel pressure gauge with a scale for accurate reading. Do not use a gauge higher than a 100 psi maximum scale. Refer to the Fuel System section of the Gas Engine Application and Installation Guide for specifics.

Figure 6.10 – Good Scale Gauge Showing the Correct G3600 Fuel Pressure

6.7.6 Fuel Lines

The fuel supply line to the engine must be adequate in size to provide the required fuel rate without causing a pressure loss to the engine fuel system. Fuel density must be considered when sizing fuel lines. Fuels such as landfill gas and digester gas are low in heat value, are very dense, and require special attention to fuel line sizing.

Prior to initial start-up of the engine, disconnect fuel piping from the engine and allow controlled fuel to blow out the pipe to remove water, oil, and debris preventing ingestion by the engine. The commissioning engineer should observe this purge procedure. Be sure to follow the customer’s safety rules when performing this potentially explosive procedure.

6.7.7 Fuel Filters

Clean, dry gas is a requirement for Cat gas engines. A fuel filter(s) can be used to remove liquids and particulates. Common liquids are water and heavier hydrocarbons. Small amounts of water are usually not detrimental to the engine, but large amounts are. Water, when combined with some gases such as carbon dioxide, cause acids which can attack the fuel system and engine. Water in the fuel line can generate rust which, if not filtered, can damage the engine. Heavier hydrocarbons like butane, pentane, hexane, etc. can exist in the fuel, particularly field gas. These hydrocarbons have very low detonation resistance and can cause detonation engine failures or nuisance detonation shutdowns in low emissions engines. These liquids can be removed by proper filters and de-misters; or they can be vaporized by using a fuel heat exchanger.

Particulates in the fuel need to be removed. Filter specifications for fuel are similar to those used for inlet air. The element should have a one micron rating for solid particles. Failure to remove particulates can cause premature engine wear and damage. Landfill gas has a particularly difficult filtering requirement. Landfill gas has large quantity of sub-micron silicon particulates which must be removed for proper engine operation. This may requirement a special micron rating for the element. Refer to the “Fuel Systems” section of the Gas Engine Application and Installation Guide for specifics.

6.7.8 Governors

The G3600 engine governor function is accomplished by the Advanced Digital Engine Management (ADEM III). This governor is electronic and works in conjunction the fuel actuator on the engine. The fuel actuator is located at the fuel control valve to control fuel delivery to the engine to control speed relative to load. The governor in the ADEM III will function well with either industrial driven equipment such as compressors, pumps, etc. or electrical power generation. The flash file will be different for the different applications. The engine speed is set by a speed control potentiometer on the front panel of the Advisor panel or customer supplied panel. The speed pot can be remote-mounted if required. For gas compressor applications, a suction pressure/discharge pressure speed control is available. This controls the optional 4-20 mA speed reference to vary the engine speed to maintain the target values of the compressor. The governor can be adjusted for isochronous operation or up to 10% droop for gen set operation. The governor can be used for stand-alone generators and can provide isochronous operation. Stability and response of the governor are very good. If the engine needs to be paralleled with other generator sets, a special Woodward load sensor will be required to parallel the governor with other equipment. The industrial and gas compressor applications setting should be isochronous and 0% droop. The governor has the provision to be field adjusted to optimize stability and/or response. This adjustment is accomplished via Cat Electronic Technician (Cat ET). The Cat governor can be used in conjunction with other Woodward equipment like SPM-A synchronizer, Automatic Generator Load Control (AGLC), and Automatic Power Transfer and Load Control (APTL). Refer to the Governors section of the Gas Engine Application and Installation Guide for additional information.

Note: For generator applications, the auxiliary gains configuration function must be wired into the Advisor panel or to the engine mounted terminal box with a customer contact connection to give breaker closure status to the ADEM III. This will allow one set of governor PID gains for paralleling and a different set of governor PID gains for loading.

6.8 Lubrication System Evaluation

The lubrication system supplies a constant oil flow to engine components. Oil is filtered, cooled, and pressure regulated throughout the engine operating range. Bearing failure, piston ring sticking, and excessive oil consumption are classic symptoms of oil related engine failures. Maintaining the lubrication system, scheduled oil sampling, and quality oil can mean the difference between repeated oil-related failures and satisfactory engine life. Consider the following when evaluating the Cat G3600 lubrication system.

6.8.1 Engine Oil

Engine oil must meet Caterpillar requirements prior to filling the oil sump. Record the oil brand and type.

Type of Oil: ____

Weight of Oil: ______________________________________

- ❑ **Engine Filled**
- ❑ **Date:**

Note: Refer to the "Lubrication" section of the Gas Engine Application and Installation Guide and "Cat Spark Ignited EPG/Industrial Engine Lubrication Recommendations," Form No. SEBU6400 for additional information.

Schedule oil samples every 250 engine hours with appropriate transportation to provide adequate turn around time for results. Submit a sample of new oil for testing prior to the first interval sample. If transportation is a serious problem, ensure the minimum oil change period is communicated. Only after several sampling periods during this mode of operation should the engine be allowed to go beyond the recommended minimum change period. Ensure the appropriate oil information is provided to the operating personnel and other appropriate personnel to enforce this. Instruct the personnel on trending the results of the oil analysis. Refer to the appropriate Operation and Maintenance Manual for Form No. SEBU6278 and G3600 Inline Industrial and EPG Gas Engines, G3600 Vee Industrial and EPG Gas Engines, Form No. SEBU6496.

Engines operating on landfill gas or other potentially corrosive gas may require lubricating oil with a higher total base number (TBN) to counteract the acids generated. Refer to the “Lubrication” section of the Gas Engine Application and Installation Guide for additional information.

6.8.2 Engine Lubricating Oil

Fill the engine with the lubricating oil. Make sure to select oil that has demonstrated acceptable performance in the G3600 series engine. Where no performance verification exists for the lubricant in question, use Cat Natural Gas Engine Oil available from your Cat dealer. Table 6.11 will give an estimate on the oil capacities for the various engines. This does not include oil heaters, oil makeup systems, driven equipment, etc.

Engine Oil System Capacity		
Engine	Oil Capacity	
	Gallons	Liters
G3606	190	719
G3608	240	908
G3612	280	1,060
G3616	360	1,363

Table 6.11

6.8.3 Engine Sump

The oil sump must be filled through the oil filler tube. Do not remove the engine crankcase cover to fill the sump. If the oil is filled though a remote pump, as in a gas compressor package, the oil supply and piping must be clean and free of debris to prevent debris from entering the engine oil pan.

The user must connect oil sump drain valves to external piping for draining oil during an oil change. Provide a flexible connector between the external piping and the drain valve. A system must be in place to properly handle waste oil from the engine oil changes.

Use a dedicated pump if oil is to be pumped into and out of the oil sump. This helps eliminate the chance of foreign material or debris entering the oil sump.

Ensure cold engine oil level is correct and check the oil level several times during initial engine operation. Allow engine oil temperature to reach normal operating temperature 82-85°C (180-185°F). An oil heater is recommended if the ambient temperature will be 10°C (50°F) or lower. This is an important consideration to improve engine cranking speed for easier starting in cold weather. An engine oil pressure switch should be used to turn the oil heater off when the engine is running.

Hydrax Fluid
Fill the Hydrax tank with SAE 10 hydraulic fluid. Make sure the fluid is visible in the upper range of the site gauge.

Brand and Type of fluid: ________________________________

Viscosity of fluid: ________________

Hydrax tank full: **Date:**______________________________

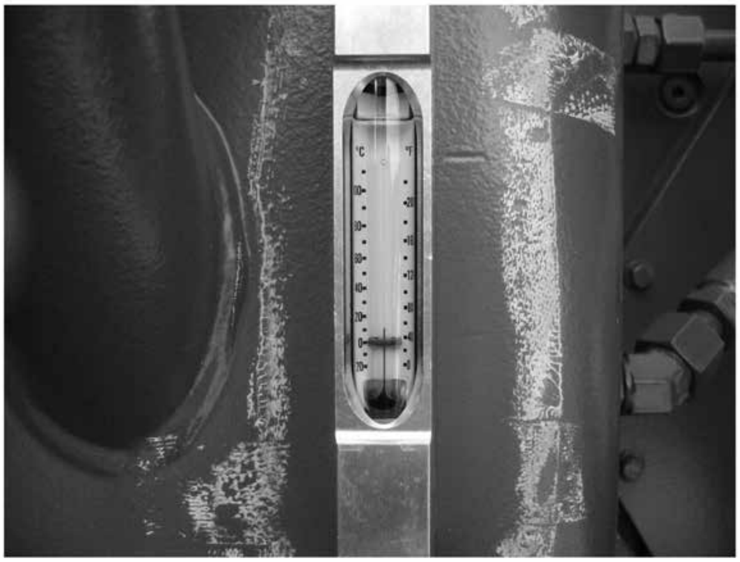

Figure 6.11 – Hydrax Sight Glass for Fluid Level

Driven Equipment Lubrication
Fill the driven equipment to the manufacturer's specifications. Some compressors will use the same oil as the engine. Make sure to factor that amount into the lubrication requirements. Generators typically have their own oil reservoir for the bearings. Make sure these reservoirs are filled to their capacity with the proper lubricant. Some generators are lubricated with grease. Make sure these antifriction bearings are properly lubricated with the manufacturer's recommended grade of grease. Make sure that if auxiliary oil coolers or heaters are used, that the oil capacity is accounted for as well. Some mechanical drives like gearboxes, dry clutches, oil clutches, etc. may have special lubrication requirements. Make sure to address these needs before attempting to power the equipment.

Type of Oil: ____

Weight of Oil: ____

❑ **Driven Equipment Filled – Date:**________________________

Air Starter and Prelube Pump
Make sure the lubricators for the vane type air starter(s) and the pneumatic prelube pump are filled with the proper lubricant. This is typically a light weight (SAE 10) mineral oil or diesel fuel. Both devices have flow control devices which must be set for proper metering of oil into the device. Running either a vane prelube pump or vane air starter without lubricant will cause premature failure damage.

6.8.4 Engine Prelube

Prelube is standard on the G3600 family of engines. Two types of prelube systems are available.

The first is a pneumatic motor powered oil pump that operates on an intermittent basis prior to engine starting. An interlock prevents engine cranking until the engine has reached prelube pressure. The pump motor is factory wired and plumbed. The customer must complete the interconnect wiring from the Advisor panel or customer-supplied panel to the engine mounted ADEM III junction box and connect an air/gas supply which is the same as the pneumatic starter. Check the air receiver tank sizing for this additional air requirement. This type of prelube system requires approximately one minute to complete the prelube operation and allow engine cranking.

A second prelube system is used in certain unusual, extreme applications (primarily gen set usage), where a prelube delay cannot be tolerated before starting the engine. A continuous prelube system is available for engines that must start and be available quickly. This uses an AC motor powered oil pump that operates continuously. A spill valve is used to prevent unwanted accumulation of oil in cylinder and turbocharger housings. Once the engine is started, a pressure switch turns the continuous prelube motor off. The customer must wire the AC power to the motor which must be considered in the plant design. The prelube pump motor is three-phase AC. The direction of rotation must be determined by bumping the motor. If the pump is operated for even a short period of time in the wrong direction, the oil pump shaft seal is blown out causing a severe oil leak.

Note: This prelube option is a 3600 diesel price book option. Its usage requires a special order for a G3600 and must be approved by Caterpillar.

6.8.5 Postlube

The prelube pump is operated for the “Engine Post-Lube Duration” time that is entered into the configuration system in Cat ET after the engine is shutdown for any reason except E-stop and Overspeed. The “Engine Post-Lube Duration” is adjustable within Cat ET but it is recommended that the value be left at the default of 180 seconds. The post lube time can be extended as desired but cannot be shortened. This accomplishes a post lube function which is designed to deter turbocharger bearing wear and decreased service life because of engine shutdowns.

6.8.6 Oil Pressure and Oil Temperature Shutdown

Oil pressure and oil temperature shutdown is provided on the G3600 engines. A two level pressure protection is used. A low pressure setting is used a lower speeds and a high pressure setting at higher speeds. An oil temperature shutdown is also included. These shutdowns are integrated into the ADEM III control system.

There is also a protection from a condition of hot engine oil and cool engine coolant. These temperature differential settings should be 1°C (2°F) – Alarm and 3°C (5°F) – Shutdown. These important settings must be checked during commissioning (refer to EN Sept. 29, 2008 SEBD9559).

6.9 Mounting and Alignment Evaluation

Cat G3600 family of engines, using the Cat rigid base, comprises self-supporting structures. The gen set/industrial package will maintain alignment if the mounting support is true (flat). The Cat spring vibration isolators can be adjusted to minimize forces transmitted to the floor. In industrial or generator applications where a Caterpillar supplied base is not used, it is the responsibility of the base designer to ensure adequate support is given to the engine, driven equipment and additional items that may be mounted on the base.

Torsional Analysis

During the design phase of the package, a torsional analysis must be completed for the engine, coupling, and driven equipment. This should be done by the packager for every different configuration. Caterpillar also provides this service. Verification results of this procedure should be requested from the packager and included in the commissioning report.

Torsional Analysis:

❑ Acceptable **❑ Unacceptable**

Consider the following when evaluating the proper mounting of the package and checking alignment of the engine and generator or engine and drive equipment on-site.

6.9.1 Engine Base

After the package is moved to the end-user's site or if the driven equipment and/or engine have been removed during shipment, ensure that the engine, coupling, and generator or driven equipment mounting bolts are properly tightened prior to alignment checks. In general, the engine mounting bolt torque should be greater for the rear bolts to allow engine growth toward the front away from the driven equipment. If the engine is not doweled at all, the recommended torque on the mounting feet-to-base bolts must be checked every 1000 hours and the alignment must be checked every 5000 hours. Tighten the rear feet to a torque value of 900 N•m (664 ft.lb.), the middle feet to 630 N•m (465 ft. lb.), and the front feet to 500 N•m (369 ft. lb.). These are the torque values that should be used if the packager mounting bolts do not have a torque specification.

Engine mounting soft-foot must be measured to ensure that the engine cylinder block is not distorted. This procedure should be performed first in the alignment process.

Ensure that flexible connectors are used between the generator set or driven equipment and external system components rigidly mounted off the package.

6.9.2 Engine to Driven Equipment Alignment

Ensure that the engine and driven equipment are properly aligned by taking bore and face dial indicator readings. Make necessary adjustments to the alignment prior to starting the engine.

Note: Always prelube before rotating the crankshaft. Always use engine turning tool only for this procedure; do not use the engine starter. It is a good idea to operate the prelube during crankshaft rotation for easier rotation.

Soft Foot/Alignment/Deflection/Endplay – Soft foot, alignment, crankshaft deflection and crankshaft endplay must be checked "cold" before the initial package start-up. These checks are used to verify position of the engine in relation to the driven equipment. Shut off start air supply before conducting the alignment work. Final cold and hot readings taken for alignment, engine crankshaft deflection and engine crankshaft endplay must be included in the commissioning report.

Realize that any alignment adjustments that were made in the shop are temporary and the unit must be aligned after installation in the field.

See Gas Engine Application and Installation Guide, Technical Information section for more information.

Soft-foot Evaluation (Cold)

The packager should perform a soft-foot test. A soft-foot test consists of determining the amount of deflection that takes place between an engine mounting foot and the engine mounting base. This is typically measured by placing a dial indicator stylus to the horizontal surface of the foot, with the indicator mounted to the base. With the indicator zeroed, the foot-to-base mounting bolts are loosened and the amount of deflection recorded. Record the soft-foot in Table 6.12:

Foot Location	Deflection	Limit
Right Front		≤0.05 mm (0.002 in)
Right Middle		≤0.08 mm (0.003 in)
Right Rear		≤0.05 mm (0.002 in)
Left Front		≤0.05 mm (0.002 in)
Left Middle		≤0.08 mm (0.003 in)
Left Rear		≤0.05 mm (0.002 in)
		≤0.05 mm (0.002 in) PREFERRED
Soft – Foot Test	❑ Acceptable	❑ Unacceptable

Table 6.12

Figure 6.12 – Measuring Engine Soft-foot

If any of the above tests are unacceptable, shims can be used to correct the alignment problem. Typically, the driven equipment is shimmed. If this is impractical, an engine shim pack is available under Cat part number, 7W8489, which provides 6 mm (0.236 in) worth of shims in two thicknesses, 0.05 mm (0.002 in), and 0.08 mm (0.003 in). Record the new alignment readings.

Alignment (Cold)

The engine and driven equipment must be mounted on a structure suitable to support the equipment as well as provide torsional strength. This is typically provided by the packager. The base should be evaluated for structural strength for the application in question. The engine must be in alignment with the driven equipment. Typically the driven equipment is shimmed to obtain proper alignment. In some cases such as gas compressors, the engine is moved and shimmed to obtain alignment.

Note: Shim packs under engine should be 0.76 mm (0.030 in) minimum and 6 mm (0.236 in) maximum thickness (see LEKQ7252, the G3600 Mounting and Alignment module from the Gas Engines Application and Installation Guide).

The alignment between the engine flywheel and driven equipment input flange must be inspected in the axial and radial directions. This is done either with two dial indicators or a laser alignment tool. If dial indicators are used, it is important to have a very stiff indicator support. Any droop in the support will corrupt the data. Magnetic mounts for the dial indicator are unacceptable. After coupling alignment, the end play of the engine and the compressor must be checked. To obtain these measurements, the engine and driven equipment must be thrusted each way against their respective thrust surfaces. This is done by jacking the engine crankshaft forward and rearward and measuring the movement. Perform this same movement with the compressor crankshaft. The engine grows thermally between cold and hot operation. The engine grows vertically approx. 0.011 inch and approx. 0.005 inch to the side as measured at the crankshaft. This growth must be considered in the cold alignment. Thermal growth of the engine must not be restricted. The engine must be prelubed prior to performing an alignment test.

❑ **Prelube completed**

Use Table 6.13 to record the cold alignment values:

Cold Alignment					
	12:00	**3:00**	**6:00**	**9:00**	**12:00**
Face (Axial)	0.000 inch				
Bore (Radial)	0.000 inch				

Table 6.13

If the start and finish 12:00 positions are greater than ± 0.025 mm (0.001 in), the alignment values must be rerun. To determine if the alignment is within specification, use Table 6.14.

Cold Alignment				
	12:00- 6:00	**Tolerance**	**3:00 - 9:00**	**Tolerance**
Face (Axial)		± 0.178 mm (0.007 in)		± 0.178 mm (0.007 in)
	❑ Acceptable	❑ Unacceptable	❑ Acceptable	❑ Unacceptable
Bore (Radial)		± 0.127 mm (0.005 in)		± 0.127 mm (0.005 in)
	❑ Acceptable	❑ Unacceptable	❑ Acceptable	❑ Unacceptable

Table 6.14

Endplay (Thrust) (Cold)

The engine crankshaft endplay must be evaluated. Use Table 6.15 to determine if the endplay is acceptable.

Cold Engine Endplay Evaluation	
Endplay Measured	**Tolerance**
	0.203 mm (0.008 in) to 0.610 mm (0.024 in)
❑ Acceptable ❑ Unacceptable	

Table 6.15

The driven equipment input shaft endplay must be evaluated if the driven equipment has oil lubricated journal bearings (not antifriction bearings). Determine the range of acceptable endplay from the driven equipment manufacturer and enter in the table below. Use Table 6.16 to determine if the endplay is acceptable.

Driven Equipment Evaluation	
Endplay Measured	**Tolerance (from manufacturer)**
	____ mm to _____ mm (______ inch to______inch)
❑ Acceptable ❑ Unacceptable	

Table 6.16

Crankshaft Deflection (Cold)

The engine crankshaft deflection must be evaluated. This test is performed at the rod throw just to the front or rear of the center main journal on G3600 vee engines. On G3600 inline engines, perform this check at the rod throw just to the rear of the center main journal. This is the throw that has a threaded location for the bolt required to support the deflection measuring indicator.

Note: If the connecting rod(s) hit the indicator, it will likely fall into the oil filled pan. To allow easy retrieval of the tool, tie a string tether to it with the other end secured outside the block.

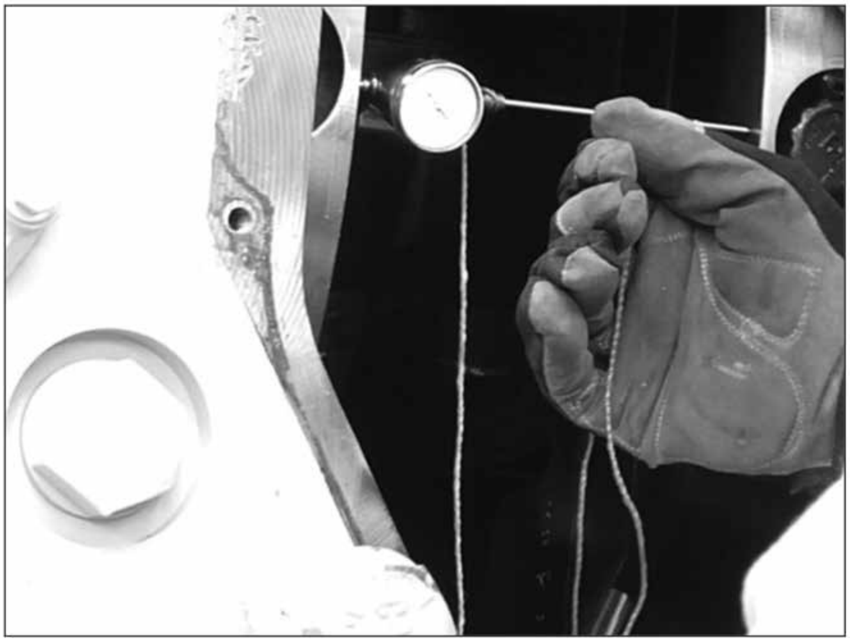

Figure 6.13 – Checking Crankshaft Deflection; Tether Tied to Indicator for Safe Retrieval

Figure 6.14 – Checking In-line Engine Crankshaft Deflection

To perform the test, remove the side access door(s) at that throw. Install a crankshaft deflection dial indicator such as a Cat 155-8795 Starrett #696 or equivalent between the counterweights for that throw. Locate the dial gauge within 10 mm (0.39 in) of the end of the counterweight. Tap a light center punch mark at this measured dimension for the dial indicator to use. On inline engines there is only one counterweight and a 1-8 THD X 6 inch bolt and locking nut must be installed into the crankshaft to support the free end of the dial indicator.

Note: With bolt and locking nut installed, crankshaft will not be able to be rotated 360°, attempting to rotate the crankshaft 360° will cause the 1-8 THD X 6 inch bolt to hit the cylinder liner causing damage. Remove bolt and locking nut before rotating engine crankshaft 360°.

The engine (and driven equipment) must be prelubed before crankshaft rotation.

Zero the indicator at the top of the stroke. Rotate the engine taking readings at the positions listed in Table 6.17. Since the rod(s) impede full rotation of the crankshaft when the tool is installed, the direction of rotation must be reversed to return to the initial starting position.

Now turn the crankshaft in the opposite direction to the starting position. The dial indicator must now read zero. If the dial indicator does not read zero, do the procedure again. Record the same measured points again on the return direction. Use Table 6.17 to record data.

Deflection Values (Cold)					
	1:00	**3:00**	**6:00**	**9:00**	**11:00**
Center	0.000 inch				
Drive End					

Table 6.17

If the difference between start and finish, 11:00 and 1:00, positions are greater than ± 0.0127 (0.0005 in), the deflection values must be rerun.

Maximum Acceptable Dial Indicator Readings	
Front and Rear Cylinders	**Middle Cylinders**
0.18 mm (0.007 inch)	0.04 mm (0.0016 inch)

Table 6.18

If center crankshaft deflection is out of spec, check soft foot on package. Loosen the bolts that hold the engine mounting feet to the foundation mounting rails. If shimming is adjusted, coupling alignment and end play must also be rechecked. Also check to see if the engine mounting bolts have enough clearance to let the engine expand as it gets hot.

Back off every adjustment jack screw after all the mounting hardware has received a final torque procedure. Mounting bolt torque should be decreasing from rear to front to allow engine growth toward the front as the operating temperature increases.

6.9.3 Hot Mounting and Alignment

Vibration
At full load, evaluate the vibration level of the engine and driven equipment. Record the values using proper instrument and include in the commissioning report.

Coupling Temperature Rise
The coupling will heat up if the alignment is not correct or the coupling is undersized for the application. Use an infrared thermometer to measure the temperature of the flexing element in the drive coupling. Also measure the temperature of a non-flexing drive element such as the engine flywheel or driven equipment input flange. Record the temperature measurements in Table 6.19.

Coupling Temperature Rise	
Temperature of Flex Element	
Temperature of Non-flex Element	
Coupling Temperature Rise	

Table 6.19

Alignment (Hot)
A hot alignment should be performed on the engine to driven equipment and recorded in Table 6.20.

Hot Alignment Values					
	12:00	**3:00**	**6:00**	**9:00**	**12:00**
Face (Axial)	0.000 inch				
Bore (Radial)	0.000 inch				

Table 6.20

If the start and finish 12:00 positions are greater than ± 0.025 mm (0.001 in), the alignment values must be rerun. To determine if the hot alignment is within specification, use Table 6.21.

Hot Alignment Evaluation				
	12:00 - 6:00	Tolerance	3:00 - 9:00	Tolerance
Face (Axial)		± 0.007 inch		± 0.007 inch
	❑ Acceptable	❑ Unacceptable	❑ Acceptable	❑ Unacceptable
Bore (Radial)		± 0.005 inch		± 0.005 inch
	❑ Acceptable	❑ Unacceptable	❑ Acceptable	❑ Unacceptable

Table 6.21

Endplay (Thrust) (Hot)

The engine crankshaft endplay must be evaluated. Use Table 6.22 to determine if the endplay is acceptable.

Hot Endplay Evaluation	
Endplay Measured	Tolerance
	0.203 mm (0.008 in) to 0.610 mm (0.024 in)
❑ Acceptable	❑ Unacceptable

Table 6.22

The hot driven equipment input shaft endplay must be evaluated if the driven equipment has oil lubricated journal bearings (not antifriction bearings). Determine the range of acceptable endplay from the driven equipment manufacturer and enter in the table below. Use Table 6.23 to determine if the endplay is acceptable.

Hot Driven Equipment Endplay Evaluation	
Endplay Measured	Tolerance (from Manufacturer)
	(________ inch to ________ inch)
❑ Acceptable	❑ Unacceptable

Table 6.23

Deflection (Hot)

The hot crankshaft deflection must be evaluated. This test is performed at the rod throw just to the rear of the center main journal. To perform the test, remove the side access door(s) at that throw. Install a crankshaft deflection dial indicator such as a Cat 155-8795 Starrett #696 or equivalent across the counterweights for that throw. On inline engines there is only one counterweight and a 1-8 thd X 6 inch bolt must be installed into the crankshaft to support the free end of the dial indicator

Note: Preheat the dial indicator assembly by laying the gauge on a mounting foot while the engine is running prior to performing the crankshaft deflection measurement. If the deflection gauge is not at engine temperature, measuring accuracy and repeatability difficulty will be experienced.

Note: With bolt and locking nut installed, crankshaft will not be able to be rotated 360°, attempting to rotate the crankshaft 360° will cause the 1-8 thd X 6 inch bolt to hit the cylinder liner causing damage. Remove bolt and locking nut before rotating engine crankshaft 360°.

Because the engine and deflection tool are at different temperatures, the tool will not hold a steady reading until it matches the temperature of the engine. This may take several minutes to accomplish. But rushing the temperature stabilization step will result in erroneous values that will have to be rerun. Warming time of the indicator can be reduced by laying the indicator on a foot next to the engine block. The engine (and driven equipment) must be prelubed. Zero the indicator at the top of the stroke. Rotate the engine taking readings at the positions listed in Table 6.25. Since the rod(s) prevent full rotation of the crankshaft when the tool is installed, the direction of rotation must be reversed to return to the initial starting position. (Tip: If the rod(s) hits the indicator, it will likely fall into the oil filled pan. To allow easy retrieval of the tool, tie a string tether to it with the other end secured outside the block.) Record the same measured points again on the return direction. Use Table 6.25 to record data:

Engine Mounting Foot Temperature Evaluation	
Cold Temperature Measured	**Hot Temperature Measured**
❑ Acceptable ❑ Unacceptable	

Table 6.24

Deflection Values (Hot)					
	1:00	**3:00**	**6:00**	**9:00**	**11:00**
Center	0.000 inch				
Drive End					

Table 6.25

If the difference between start and finish, 11:00 and 1:00, positions are greater than ± 0.0127 (0.0005 in), the deflection values must be rerun.

Maximum Acceptable Dial Indicator Readings	
Front and Rear Cylinders	**Middle Cylinders**
0.18 mm (0.007 inch)	0.04 mm (0.0016 inch)

Table 6.26

6.9.4 Vibration Isolators

It is the user/installer's responsibility to provide adequate support and isolation between the engine and driven equipment base and the floor. The foundation must be designed and constructed to support the engine. Vibration isolators are normally used on gen sets (not industrial applications) to isolate the engine from the foundation to reduce vibration and noise. The correct isolator adjustment is important for best performance.

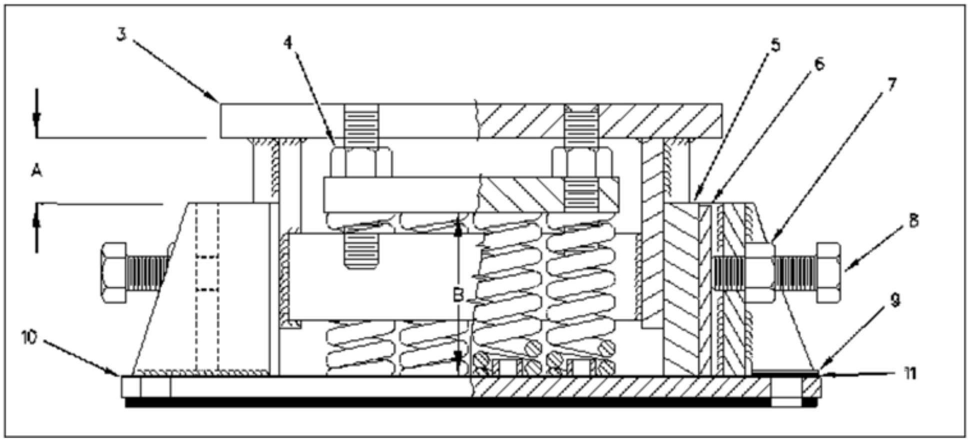

Figure 6.15 – Typical Cat G3600 Gen Set Spring Isolator

- Use shims or grout in the foundation in order to provide a flat surface for the spring isolators. The maximum difference in elevation that can be tolerated is 6.35 mm (0.250 in). Isolator base plates must rest on a flat surface.
- Check the engine level. If the engine is not level, turn both leveling nuts (4) of all isolators that are on the low end of the engine. Turn each of the leveling nuts clockwise in even increments until the engine is level.

Note: Tightening snubber bolt (8) greater than finger tight reduces the efficiency of the isolator. Efficiency will be obtained if the snubber compression plates are barely contacting snubber blocks (5). Only use the snubber blocks to help prevent excessive movement of the engine due to excessive dynamic loads. Excessive use of the snubber blocks will result in an increase in vibration.

Also refer to Special Instruction SEHS9162 Spring Isolator Group Installation and Adjustment Procedure for the complete adjustment procedure. Refer to the Vibration section of the Gas Engine Application and Installation Guide for more information.

6.10 Driven Equipment Evaluation

Driven equipment for the G3600 family of engines has been selected based on the particular load profile of the site. When more than one unit is involved, each piece of equipment must be described in a separate commissioning findings report.

Consider the following items while evaluating the driven equipment.

6.10.1 Driven Equipment

Record the manufacturer, model number, and serial number of the driven equipment and other appropriate data relating to rated pressure, rated flow, rotating speed, rated torque, temperature rise, etc.

6.10.2 Generator

Record the manufacturer, model number, and serial number of the generator and other appropriate data relating to rated voltage, rated current, frequency, temperature rise, etc.

Ensure the generator space heaters have been operational several days prior to anticipated startup date. To be effective in many situations, covering the air inlet and outlet screens on the generator may be necessary. Ensure the generator space heaters are controlled to be off during generator set operation and powered on during shutdown periods.

6.10.3 Coupling

If a two bearing generator or other driven equipment is to be used, ensure that an appropriate coupling has been selected. Features such as engine speed, torque capacity, rotating inertia, etc. need to be considered in selecting the coupling. Check coupling temperature for performance evaluation.

6.10.4 Torsional Analysis

A torsional analysis to ensure torsional vibration amplitudes will be within acceptable limits must include the data for the selected coupling and damper.

6.11 Engine Protection System Evaluation

The engine protection system gives operators an early alert to pending problems or it shuts down the engine. This protects the engine and/or driven equipment from imminent failure and limits the contingent damage due to failure. Proper maintenance and periodic testing is imperative for a reliable protection system.

Consider the following when evaluating the engine protection system.

6.11.1 Engine Protection

Ensure the following shutdowns are provided and are functional on G3600 family of engines:

- Engine oil temperature
- Engine oil pressure
- Jacket water temperature
- Detonation
- Emergency stop switch

Standard G3600 engines have the above shutdowns provided. The actual set points will vary depending on the configuration of engine ordered. These shutoff points are programmable and the set points need to be verified at commissioning. Refer to the engine service manual for proper verification and programming procedure.

Troubleshooting codes are displayed on the Advisor panel or by using Cat ET. Troubleshooting codes can also be displayed on a customer provided PLC by using an optional Caterpillar interface module between the Advisor panel or ADEM III and the PLC.

While an emergency stop switch is provided on the engine mounted terminal box and the optional Advisor panel, it is important for the user to provide remote emergency stop switches. Locate these switches in areas where an operator can shut the engine down without risking personal injury. Typical locations would be at the switchgear panel and the monitoring panel. Emergency stop switch(es) should be guarded from accidental personnel contact, but still be operational by personnel in the case of an emergency. Keep in mind that postlube is disabled with an engine emergency stop so the turbocharger does not have lubrication during spin down. Make sure the customer is aware of this feature. Nuisance ESD shutdowns that have the engine E-stop in the circuit can contribute to decreased turbocharger life.

6.12 Monitoring System

Monitoring of the engine requires periodic reading of gauges, sensors, readout, and displays to assure all systems are performing satisfactorily.

Consider the following when evaluating monitoring system operation.

6.12.1 Engine Operating Parameters

Gauges and instrumentation must give accurate readings of operational parameters for the engine basic support systems. These include oil pressure, coolant temperature, manifold pressure, and exhaust port temperatures. These parameters are provided for by the ADEM III.

Periodic maintenance of oil, fuel, and air filters is based on differential pressure as well as hours. Assure the gauges or restriction indicators are provided to monitor filter condition. The service hour value is required to log all engine parameters.

6.12.2 Driven Equipment Parameters

The user must assure the driven equipment can be monitored to assure proper operation and to schedule maintenance. It is often desirable to have instrumentation monitoring the work being performed, whether it is compression of gas, water flow, torque, or electrical production. In generator application, it is the end user's responsibility to monitor winding and bearing conditions.

6.12.3 External Engine Support Systems

The user is responsible for providing gauges and or instrumentation to monitor operation of the external engine support systems. These should include but are not exclusive to the following:

- Oil storage tank site glass.
- Coolant temperature to and from external cooler. This may include radiators, heat exchangers, or cooling towers.
- When strainers are permanently installed before the pump inlets, monitor pump inlet pressure for condition of strainers.

6.12.4 Daily Log Sheet

The user is responsible to provide a log sheet to record all gauge and instrumentation readings periodically by operators and/or automatic monitoring system.

The user must maintain trained personnel capable of recognizing operational changes in a monitored parameter, and be aware of the effect the change may have on engine operation.

6.13 Ventilation System Evaluation

The radiated heat from generator sets, switchgear or engines, and driven equipment can cause site temperature rise and adversely affect operating and maintenance personnel as well as equipment performance. Ideally, clean, cool air should be supplied to switchgear rooms and engine rooms and flow across and around the equipment to carry the radiated heat to the outside.

Consider the following when evaluating the ventilation system.

6.13.1 Engine Room Ventilation

Ventilating air should flow near the floor of the engine room and then upward around the engine before exiting above the engine.

Design building ventilation to bring the coolest air to the generators or driven equipment.

If the building has a pitched roof, ventilating air should flow out at the peak or near the top of the gable ends. The source of the air must be low in the room and rise across the engine or generator set and other equipment.

For personnel comfort, maintain air velocity at 1.5 m/sec (5 ft/sec) in areas of heat sources or areas exceeding 38°C (100°F). Engine room temperatures above this level can also affect engine horsepower performance. Radiated engine heat can increase the building temperatures if the proper ventilation is not present. Consider drawing combustion air from outside the building if room temperatures are higher than this level.

Check potential dead air spaces for temperature rise during engine operation. Check all electrical and mechanical equipment in the dead air space for any detrimental effect from the temperature rise. Require corrections if necessary.

Engine room pressure should not become excessively negative ($\geq$ .5 in. H_20). This would indicate a shortage of ventilating air. For additional information refer to the Engine Room Ventilation section of the Engine Application and Installation Guide.

6.14 Crankcase Ventilation System Evaluation

Normal combustion pressures of an internal combustion engine cause a certain amount of blow-by past the piston rings into the crankcase. These crankcase fumes must be piped away from the engine to atmosphere. In some areas, local air quality regulations require that the engine crankcase fumes be captured as fugitive emissions. If an apparatus is installed to perform this function, ensure that it is properly installed and functional. Ensure that the customer is aware of additional maintenance necessary for this apparatus.

Consider the following when evaluating crankcase ventilation systems.

6.14.1 Crankcase Breathers

Crankcase breathers can be arranged in several positions to match the best piping routing away from the engine. Ensure that breather connections can be easily disconnected for scheduled maintenance.

6.14.2 Crankcase Ventilation Piping

Generally, piping of the same size as the breather outlet is suitable unless the length and or bends cause excessive restriction and a false crankcase pressure measurement and potential caution or nuisance shutdowns.

Note: See the “Crankcase Ventilation” section of the Engine Application and Installation Guide for additional information on pipe sizing requirements. Consideration must be given to the blow-by requirements of a worn engine when initially sizing the pipe.

A separate ventilation piping system must be installed for each engine.

Piping should slope away down from the engine at a minimum of 13 mm per 300 mm, (1/2 in. per ft). If piping rises from the engine, a trap must be installed to collect any condensation or oil droplets before they re-enter the breathers.

Configure the outlet to collect oil droplets prior to fumes exiting the piping.

Crankcase fumes must never be discharged in the engine room. Crankscase fumes may contain combustible gas that could cause an explosion if these fumes accumulate in the engine room.

6.15 Serviceability Evaluation

Well designed engine rooms include features contributing to the serviceability of the engine(s) and support equipment. These features can include overhead lifting, push carts, component storage and cleaning, and building equipment arrangement along with the required tools. Evaluate the installation for access to the engine side covers for routine service procedures. Structures and piping on the skid that hinder this access should be modified for easy access.

Consider the following for the evaluation of serviceability.

6.15.1 Engine Component Removal

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

Overhead lifting equipment must be provided. Most all major engine components are heavier than one man can safely lift. Review the overhead features for multi-direction motion. Most engine component removal involves at least two direction motions for removal.

Arrange multiple engine installations to use the same overhead lifting equipment without major disassembly of piping or ducting.

Equipment should be available for engine component movement to and from the engine room.

6.15.2 Engine Maintenance

The engine, generator, and driven equipment installer is responsible for providing an engine service platform to perform all periodic maintenance functions. This should consider all daily inspections and activities including an engine overhaul.

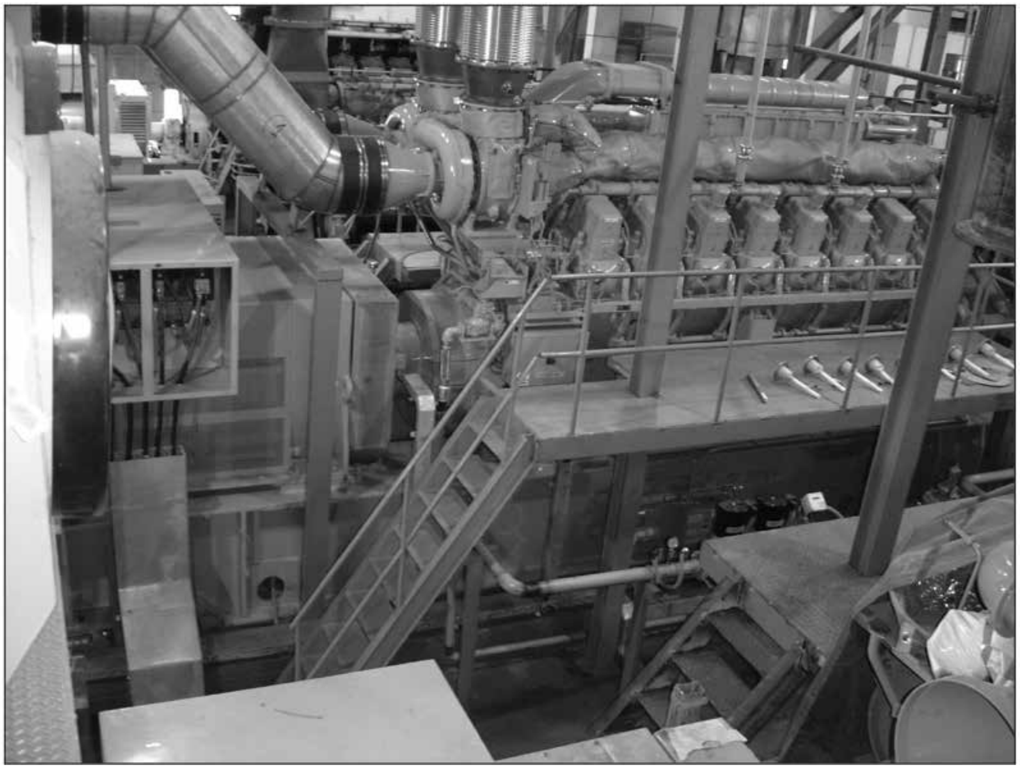

Figure 6.16 – Typical Good Design Work Platform

Overhead and/or side clearance and a platform must be provided for servicing all periodic maintenance components; for example, changing air, fuel or oil filters, setting valve lash, etc. Remember, that a ladder with just a 10° incline from vertical is much easier for a technician to climb. A set of stairs as shown in the photo is much easier and safer.

6.15.3 Reserved Work Area

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

6.15.4 Spare Parts Storage

Reserve an area for storage of spare parts and tools for all equipment in the engine room. Provide an inventory parts and tools to ensure ready access during a repair. Ensure the area can be locked to prevent missing parts or tools that would impair scheduled maintenance or repair. For latest spare parts list go to website at this link: https://largepower.cat.com/cda/layout?m=6220&x=7

6.16 Equipment Safety Evaluation

The commissioning engineer must be able to recognize a safe operating environment. The entire system operation must be reviewed to provide operator and technician safety during any normal or abnormal situation.

Consider the following when evaluating the safety of operating systems.

6.16.1 Engine Room

Shield or guard hot engine water pipes to prevent operator contact. Heat shields on the engine must be in place prior to operating the engine. Identify piping circuits for easier identification in case of emergency situations.

All generator drive components and damper guards must be in place prior to operating the engine. Follow user's safety rules during engine operation.

- All floor openings in the engine room must be covered with plating or grating.
- Chains and hooks on overhead lifting equipment must not endanger operating personnel.
- Floors must be cleaned of any debris or liquid spills.
- Remote emergency system stops must be guarded, but must operate during a safety simulation.
- Test fire suppression systems 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.
- Check engine room noise levels in normal operating areas and compare to general rules or local specifications. Include this data in the commissioning report.

6.16.2 Control Room

- Ensure that the control system meets local fire protection codes.
- Ensure that control room emergency stops are guarded to prevent accidental contact.
- Ensure that all high voltage equipment and cabinets are inaccessible via locks and/or cages with locks. Ensure Kirk-Key interlocks are available for the appropriate switchgear cabinets.
- Check control room noise levels and compare to general rules or local specifications. Include this data in the commissioning report. Refer to A & I Guide-Noise (LEBW4973) for additional information.

6.17 Generator Control Evaluation

Control of generator output is imperative to maintain the residential and/or commercial customers during prime power operations. Generator sets located in severe climates are extremely important to provide life support power. Standby generator sets can also be applied in both of the above situations. It is not typically the responsibility of the commissioning engineer to make these systems operate according to required specifications, but to ensure the systems are compatible with the design requirements. Consider each of the following items during the evaluation and the specific application requirements during the evaluation.

6.17.1 Generator Voltage Control

The voltage regulator must have the voltage droop adjusted to be compatible with the system and/or with other generator sets being paralleled to provide electrical power onto a distribution bus.

For paralleled generator sets, cross-current compensation is necessary.

Ensure automatic voltage control systems have manual control that can be operated if problems develop with the automatic control.

Even though not required, monitoring exciter DC voltage is a common gauge to detect any diode or surge suppressor problem in the exciter. Ensure gauge is operating properly, if provided.

Several different voltage regulators are supplied for specific applications. Volts-per-hertz, constant voltage, and the combination of both functions are available. Ensure that the regulator output to the generator provides the correct system voltage and voltage response to load changes.

If a constant voltage regulator is used, ensure that the excitation circuit can be turned off before the engine is started and ramped up to speed, or is stopped and ramped down in speed. Operating at other than synchronous speed can be very detrimental to the constant voltage regulator.

6.17.2 Generator Monitoring

Generators are supplied with either 10 Ohm or 100 Ohm RTDs (Resistance Temperature Detectors) mounted in the windings and the bearing housing(s).

Ensure the temperatures can be monitored daily. Several types of alarms and or shutdowns are optional. If included, ensure they function properly.

Ensure generator voltage, amperage, power factor, and kW load are gauges in the control panel and are monitored on a daily basis. Compare initial readings to engine operating parameter to ensure proper wiring.

6.18 Switchgear Evaluation

The switchgear is a necessary part of distributing electrical power produced, as well as providing input to monitoring and control systems. This equipment is not typically provided by Caterpillar, but its interaction and possible detrimental effect on engine and generator operation makes it necessary to ensure that the system functions according to specifications.

Consider the following when evaluating switchgear systems.

6.18.1 Switchgear Cabinets

- Ensure switchgear cabinets are properly vented and ventilation air is available.
- Mount switches and controls not involved in daily operations inside the cabinets.
- Ensure that any high voltage cabinet has Kirk-Key interlocks (or equivalent) to lock the cabinet and prevent accidental personnel contact.

6.18.2 Current and Potential Transformers

Inspect mounting and wiring of all current and potential transformers to ensure they are installed properly before energizing the voltage control circuit. This is imperative for proper engine operation monitoring.

6.18.3 Circuit Breakers

- Ensure the circuit breaker has been manually tested before installing in the test position.
- Ensure the circuit breaker is in the test position during any testing of the generator controls and/or engine safety system.
- Initial energizing of the electrical system with the circuit breaker should be coordinated with all on-site personnel. Safety is paramount during the commissioning process.

Note: Important appropriate arrangements must not be overlooked by all site disciplines.

6.18.4 Electrical Cables

- Electrical cables between the generator and the switchgear cabinets must be high-pot tested prior to terminating. Review data from tests and include in the commissioning report.
- Ensure terminations have shielding removed from ends prior to connecting.

6.18.5 Generator Protective Relays

Ensure the generator protective relay setting for both the instantaneous and time delay functions agree with the results of the Relay Coordination Study of the system.

6.18.6 Control Voltage

- A mixture of control voltages may require multiple banks of batteries. Ensure the appropriate charging method for the batteries is maintained.
- Ensure the batteries are placed between the charger and the controls to prevent the controls from receiving voltage spikes or stray currents from the battery charger.

6.18.7 Paralleling Operations

Protect manual paralleling operation against out-of-phase engagement of the circuit breaker. A synch check relay or SPM Synchronizer are typical components to provide this protection.

Auto paralleling is typically controlled by an SPM Synchronizer; both engine speed and generator voltage, or just engine speed, can be controlled. If voltage control is not included, the system voltage must not vary more than the voltage regulator compensation capability with a closed circuit breaker. It is imperative to ensure the generator rotation and phasing match the distribution bus before attempting to parallel to the bus or other generator.

Generators operating in parallel must have the same pitch to prevent harmonics from creating current flow on the neutral side of the system. Use a neutral ground resistor if neutral currents exist.

6.19 Operation and Maintenance Evaluation

Operation and maintenance training for operators designated to be involved in the operation and/or maintenance of Cat G3600 family of engines, and the associated support equipment, is an important factor in achieving dependable generator set operation. The commissioning engineer should be prepared to give this basic training on the engine and generator or driven equipment.

Consider the following when evaluating how well operation and maintenance will be completed.

6.19.1 Engine Operation and Maintenance

Ensure each operator is introduced to the maintenance guide for the engine and each of the topics is explained. This may require the presentation to be given several times to match the shift work of the operators. Coordinate the effort with the appropriate operating supervisor.

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

6.19.2 Engine Support Equipment

Review the list of equipment suppliers that will be on-site during commissioning. If the representative is going to be on-site, ensure they are prepared to train operators.

6.19.3 Mechanical Training

Train operators and maintenance personnel to make minor repairs if needed; or provide assistance to the dealer technician while making a repair. Emphasize the importance of establishing the valve recession base line dimension at first valve lash adjustment interval.

6.19.4 Maintenance Contracts

Review any maintenance contract to ensure all maintenance and repair responsibilities are defined for each activity. Also, understand and record the duration of the contract. Ensure responsible personnel are properly trained to perform their respective functions. If a training deficiency is found, recommend corrective action.

7.0 Cat G3600 Generator Set Commissioning Report

General:

Selling Dealer ________________________ District or Subsidiary _________________

Equipment Suppliers and Contractors: ____
____
____

Customer: ____

Address:____

Application: Prime Power: _______ Continuous ______________ @ _________ % load

Peak Shaving: ______ Standby: ________________

Consist:

Engine Model: ________________________ Engine Arrangement No. _______________

OT Specification No. ___________________ Serial No. ___________________________

Rating: bhp: ____________ bkW _______ Emission Rating_______________

Engine Cooling System: Separate Circuit _______________ Combined Circuit ________

Governor: Cat ____________ EPG Load Share __________ SPM-A _________________
APTL _____________Import Export Controller ___________ Other (specify)__________

High Idle: Specified ______________________OT Specification __________________

Low Idle: Specified ______________________% Droop Specified __________________

Fuel Used: Pipeline Natural Gas __________ Field Gas __________ Landfill Gas________

Digester Gas ___________ Propane (HD-5) ___________ Other (Specify) ____________

Fuel Lower Heat Value ______________ mJ/m^3 (Btu/scf) Methane number ____________

Specific Gravity _________________________ Wobbe Index _______________________

Minimum Fuel Pressure ___________________ kPa (psi) Fuel Filtration _______________

Filter Efficiency ____

Engine Coolant: Antifreeze ________ % Corrosion Inhibitor _____Heat Recovery______

Separate Circuit Coolant: Antifreeze ______________% Corrosion Inhibitor ___________

Oil to be used in engine ____

Engine site conditions: Elevation ____

Typical Ambient Temperature range for the year: ______________to_________________

Atmospheric conditions: Typical relative humidity level: _______________________%

Air Quality: Salty ___________ Dusty____________ Clean ___________

Cat G3600 Generator Set Commissioning Report continued

Application Summary:

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

Field Engineer Signature: ________________________________ Date: ____________

Builder/Installer Signature: ________________________________ Date: ____________

Owner Signature: ____ Date: ____________

8.0 Cat G3600 Industrial Engine Commissioning Report

Note: The online commissioning report found at this link should be used for the final report:
https://engines.cat.com/cda/layout?m=349976&x=7

General:

Selling Dealer ________________________ District or Subsidiary _________________

Servicing Dealer ____

Equipment Suppliers and Contractors: ____
____
____

Customer: ____

Address:____

Application: Prime Power: ______ Continuous _____________ @ _________ % load

Gas Compression: _________ Other Service: _________________

Consist:

Engine Model: ________________________ Engine Arrangement No. _______________

OT Specification No. ___________________ Serial No. ___________________________

Rating: bhp: ____________ bkW __________ Emission Rating__________________

Engine Cooling System: Separate Circuit _______________ Combined Circuit ________

Governor: Cat ____________ Suction Pressure Controller _________________

Discharge Pressure Controller _____ Other (specify)_________________

High Idle: Specified ______________________OT Specification __________________

Low Idle: Specified ______________________% Droop Specified __________________

Fuel Used: Pipeline Natural Gas ___________ Field Gas ________ Landfill Gas_______

Digester Gas ___________ Propane (HD-5) ___________ Other (Specify) ___________

Fuel Lower Heat Value _________________ mJ/m^3 (Btu/scf) Methane number _________

Specific Gravity _________________________ Wobbe Index ______________________

Minimum Fuel Pressure ___________________ kPa (psi) Fuel Filtration ______________

Filter Efficiency ____

Engine Coolant: Antifreeze ________ % Corrosion Inhibitor _____Heat Recovery______

Separate Circuit Coolant: Antifreeze ______________% Corrosion Inhibitor ___________

Oil to be used in engine ____

Engine site conditions: Elevation ____

Typical Ambient Temperature range for the year: ______________ to ______________%

Atmospheric conditions: Typical relative humidity level: _________________________

Air Quality: Salty ___________ Dusty____________ Clean ___________

Cat G3600 Industrial Engine Commissioning Report continued

Application Summary:

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

Field Engineer Signature ______________________________ Date: ____________

Builder/Installer Signature: ______________________________ Date: ____________

Owner Signature: ______________________________ Date: ____________

9.0 G3600 ADEM III Gas Engines Commissioning Checklist

	Preliminary Review
	Mounting: Soft foot/Alignment/Deflection/Endplay
	Report Data (Descriptions, Serial Numbers, etc.)
	Evaluate access to sides of engine for routine maintenance and service procedures
	Before Coolant Is Added
	Cooling System Test Port Fittings Installed
	Cooling System Thermostat Housings (Direction) And Stats (Temp/Blocked Open)
	Cooling System Vent And Shunt Lines Inspected
	Strainers Installed In Cooling System
	Type of Coolant Deionized/Distilled Water With Conditioner or 50/50 Mix
	Cooling System-Measure Cooling System Piping and Coolers For Capacity
	Expansion Tank (Size, Location, Cap Pressures etc.)
	Prior To Engine Start
	Lubrication System- Engine, Type, Driven Equipment, Starters and Pre-Lube Pump
	Inlet Air System-Inspect Air Cleaners/Piping/Turbochargers/Inlet Silencers
	Fuel System- Lines Purged/Fuel Filter Installed/Pressure Regulator Set
	Starting System- Lines Purged/Pressure Regulator Set/Screens
	Check System Voltage
	Wiring Checks-Make Sure All Appropriate Jumpers Are In Place (Be Thorough)
	Power Supply Ready (Batteries/Charger)
	Actuator Inspection- No Binding
	Check Software Part Number Loaded In ADEM, ADVISOR and ISM For Most Current Version
	Check Settings in ADEM And ISM (Configuration and Monitoring)
	Fuel Analysis- Checked With Caterpillar Methane Number Program
	Enter Configuration Parameters For The Site (Btu, Specific Gravity)
	Crankcase Ventilation Caps Removed , correct piping configuration
	Safety- Guards In Place
	Inspection Port Installed To Check Emissions/Backpressure/Inlet Air Restriction
	Install Gauge To Check Hydrax Pressure (Gauge Must Be Able To Read Minimum Of 300 PSI)
	Calibrate Air Pressure Module (Engine Must Be Stopped)
	Record Needle Valve Setting And Compare To Factory Settings
	Crank RPM Test (Fuel Off)
	After Engine Start
	Stabilize RPM (Governor, Choke, Wastegate, Max Choke, Desired Exhaust Temp)
	Check Shutdowns (E-Stop, Oil Pressure, Air Inlet Temperature, Water Temperature, Crankcase Pressure, And Detonation Sensor)
	Check For- Noises/Leaks/Vibration/Temperatures/Etc.
	Hydrax Pressure Measured/Adjusted
	After Engine Is Loaded and At Operating Temperature
	Adjust Emissions Using A NOx Emissions Analyzer And **Tune Engine according to procedure**
	Check Cooling System Pressures And Temperatures (Using Test Ports, ADVISOR And Infrared)
	Record running final Performance Data for commissioning report
	After Package Is Heat Soaked
	Hot Checks: Alignment, Deflection And Endplay
	Photos taken for commissioning report

Note: Use this checklist for commissioning the engine on the customer's site.

10.0 Explanations of G3600 Commissioning Checklist

10.1 Preliminary Review

Soft Foot/Alignment/Deflection/Endplay – Soft foot, coupling alignment, crankshaft deflection, and crankshaft endplay should be checked "cold" before the initial package start-up. These checks are used to verify position of engine in relation to the driven equipment. Consult the Gas Engine Application and Installation Guide for tolerances and further information.

Report Data (Descriptions, Serial Numbers, etc.) – Record descriptions of each engine system to be included in the commissioning report (i.e. pipe lengths, diameters, capacities, etc.). Record serial numbers, model number, and manufacturer name of major equipment (engine, driven equipment, regulators, filters, etc.) also to be included in commissioning report.

10.1.1 Before Coolant Is Added

Cooling System Test Port Fittings Installed – Cooling system pressures must be checked during the commissioning of the engines. Before the coolant is added, test port fittings should be installed so that cooling system pressures can be checked while the engine is running. Check the Gas Engine Application and Installation Guide for test port fitting locations.

Cooling System Thermostat Housings (Direction) and Stats (Temp/Blocked Open) – Cooling systems equipped with Caterpillar supplied thermostat housings can be configured for either "inlet controlled" or "outlet controlled." Consult the Gas Engine Application and Installation Guide for the proper control system for the site and then verify direction of thermostat housings. To flush the cooling systems in cold weather blocked open thermostats should be used to ensure that there is coolant flow through the entire cooling system (care must be taken to avoid engine damage as the result of low coolant temperature and high oil temperature. Blocked open temperature regulators should not be used at ambient temperatures below 21ºC (70ºF). Engine should not be fully loaded with blocked open regulators installed). If blocked open thermostats are used, ensure that the proper thermostat part numbers are installed in the correct thermostat housing at reassembly. Check the Gas Engine Application and Installation Guide for more information.

Cooling System Vent and Shunt Lines Inspected – Cooling system vent and shunt lines should be inspected for size, location, and proper installation. Refer to the Gas Engine Application and Installation Guide for more information.

Strainers Installed in Cooling System – To ensure that the cooling system is free of debris, cooling system strainers should be installed in the coolant piping right before both water pumps. Using the engine-mounted or remote-mounted water pumps to circulate coolant through the strainers. Coolant must be allowed to circulate through the entire system (radiators, heat exchangers, etc.). After the coolant is circulated through the entire system for a minimum of 30-minutes, stop water pumps, drain coolant and inspect strainers. If strainers have debris in them, they must be re-installed and coolant circulated again. Once strainers are removed and they are free of debris, they are not re-installed in the cooling system. Check the Gas Engine Application and Installation Guide for more information.

Type of Coolant Deionized/Distilled Water with Conditioner or 50/50 Mix – Coolant must meet Caterpillar specification. See Gas Engine Application and Installation Guide for coolant requirements.

Cooling System – Measure Cooling System Piping and Coolers For Capacity – Measure cooling system piping for both systems and add to engine and cooler capacity to figure total system capacity to be included in the commissioning report. See the Gas Engine Application and Installation Guide for further information.

Expansion Tank (Size, Location, Cap Pressures, etc.) – If supplied by manufacturers other than Caterpillar, expansion tank volumes, location, and pressure cap rating must be checked and recorded. Check the Gas Engine Application and Installation Guide for more information.

10.2 Prior To Engine Start

Lubrication System – (Engine, Type, Driven Equipment, Starters, and Pre-Lube Pump) – Check lubrication levels in all equipment and lubricators. Make sure all lubricators used are within Caterpillar specifications. A lubricator is not required with a turbine starter or motor. Refer to the Gas Engine Application and Installation Guide for more details.

Inlet Air System – Inspect Air Cleaners/Piping/Turbochargers – Inspect clean side of filter housing, air inlet piping, and turbochargers for cleanliness. Turbochargers must be free from dirt and rust and must turn freely. Filters must seal completely and piping must not allow air to bypass filters. Check the Gas Engine Application and Installation Guide for more information.

Fuel System – Lines Purge/Pressure Regulator Set/Fuel Filter Installed – Fuel system must have a correct size filter installed in the fuel line. Fuel lines should be purged to remove construction debris and liquids from the fuel piping. Set fuel pressure regulator to the proper setting. Consult the Gas Engine Application and Installation Guide.

Starting System – Purge/Pressure Regulator Set/Screens – Purge start lines whether using air or gas. Ensure "Wye" strainer screens are installed in the Caterpillar supplied start manifold. Set the start regulator to the proper pressure. See the Gas Engine Application and Installation Guide for more information.

Check System Voltage – Check DC system voltage and AC ripple at the Advisor panel or engine mounted junction box depending on configuration. Refer to the Gas Engine Application and Installation Guide for further information.

Wiring Checks – Make Sure All Appropriate Jumpers Are In Place (Be Thorough) – Check to ensure that all jumpers or system wires from the control panel are installed or connected in the Advisor or engine-mounted terminal box. Make sure that all wires are tight in the terminals and connectors. Check the Gas Engine Application and Installation Guide for more information.

Power Supply Ready (Batteries/Charger) – DC backup system should be fully functional in the case of a power outage. Consult the Gas Engine Application and Installation Guide for more information.

Actuator Inspection, No Binding – Ensure that all actuators move freely with no binding and actuators have proper travel.

Check Software Part Number Loaded In ADEM, Advisor and ISM For Most Current Version – Part numbers loaded in the ADEM, ECM, and the ISM must be verified that they are the most current versions available.

10.3 Fuel Analysis

The fuel that is to be used must be analyzed. The fuel analysis must be entered into the "Fuel Analysis" tab of GERP (Gas Engine Rating Pro). The output of the analysis will have important information on how to set up the engine control. Fuel sample must meet Caterpillar fuel requirements. Consult the Gas Engine Application and Installation Guide for more information. Fill in the following information in Table 10.1 from the fuel analysis.

Parameter	Methane Number Program Value	Limits
Lower Heat Value		850-1050 Btu/SCF using standard flash file
Specific Gravity		
Wobbe Index		
Methane Number		≥ 60 for 9.2:1 CR down to 45 MN depending on SCAC rating and flash file

Table 10.1

Include a copy of the fuel analysis and Caterpillar Methane Number calculation in the commissioning report.

Landfill, Sour Gas, or Digester Gas

Corrosive elements are present in these gasses. If they exceed Caterpillar recommended limits, significant reduction in engine service life will result. A fuel analysis for halogens (chlorines and florines) is required to be performed on landfill gas. A fuel analysis for hydrogen sulfide (H_2S) is required to be performed on sour gas and digester gas. These values are normalized by dividing the mass total of the contaminants by the lower heating value (LHV) of the fuel. Enter the contamination values in Table 10.2.

Parameter	Value	Limits
Total Halogens (Cl & F)	µg/Btu	40 µg/Btu
Hydrogen Sulfide	µg/Btu	47 µg/Btu

Table 10.2

Enter Configuration Parameters for the Site (BTU, Specific Gravity) – Enter LHV and specific gravity into the configuration screen using Cat Electronic Technician. Fuel sample must meet Caterpillar fuel requirements. Consult the Gas Engine Application and Installation Guide for more information.

Fuel and Start Lines Inspection and Setting

Both fuel and starting air lines should be inspected for debris and purged to ensure they are clean. Caution should be used when purging the gas because of the potential for fire and explosions. Follow the customer safety procedures during purging of the fuel and start gas piping. Set the fuel pressure regulator to 310 ± 7 kPa (45 ± 2 psi). Set starting air pressure. Do not exceed the maximum start air pressure as stated on the starter ID tag. Set engine speed dial to 750 rpm as displayed on Cat ET or the Advisor display.

- ❑ **Fuel line inspected**
- ❑ **Start air line inspected**
- ❑ **Fuel pressure regulator set ____________ kPa (psi)**
- ❑ **Start air pressure regulator set ____________ kPa (psi)**
- ❑ **Fuel energy set __________________ Btu**
- ❑ **Fuel specific gravity set __________________ Btu**
- ❑ **Engine speed set ____________ rpm**

10.4 Initial Settings

Air/Fuel Pressure Module Calibration

Prior to starting the engine, the air/fuel pressure module must be calibrated. The engine must be stopped with the mode control switch in the STOP position to perform this calibration. Disconnect the air and fuel pressure lines from the pressure module and follow the ET procedure. Connect Cat ET to engine and go to "Service" menu and then to "Calibrations." Select "Air Press Module Calibration" from the available choices and enter in the uncorrected barometric pressure.

Note: The fuel pressure sensor is also calibrated during this procedure to read "zero."

The local barometric reading is usually an altitude corrected value. The UNCORRECTED value is the one that is required. If an accurate barometer reading is not available and the elevation is known, the following formula can be used to obtain an approximate value. See example. It can also be used to verify that the independent value obtained is correct. Pressure is in kPaa and elevation is in feet.

Atmospheric Pressure (Gauge) = Atmospheric Pressure at Sea Level - [(√Altitude) x 0.0778] – (Altitude x 0.00236)

Turn mode switch to OFF/RESET to power down the control panel. Again turn the mode switch to STOP. Verify the inlet air manifold pressure is within ± 1 kPa (0.145 psi) of the desired setting. If not, repeat procedure.

Note: This graph is based on normal atmospheric conditions (103 kPaa atmospheric pressure). The curve will shift with a change in atmospheric pressure.

Figure 10.1 – Atmospheric/Altitude Chart

Example:

Atmospheric Pressure at Sea Level = 103 kPa

Altitude = 3000 ft.

Atmospheric Pressure = 103 – [(√3000) x 0.0778] – (3000 x 0.00236) = 91.7 kPa

❑ Pressure Module Calibration Set ____________________ kPa (psi)

Go to the Caterpillar commissioning website for an atmosphere pressure calculation formula if the local barometric pressure is not available. You must know the site altitude to use this formula. Cat website: https://engines.cat.com/cda/layout?m=349976&x=7

Governor Choke and Wastegate Dynamics

Prior to starting the engine, the governor, choke and wastegate dynamics should be set to 100. Connect Cat ET and open the "Configuration" screen. Reset the parameters to 100 (default setting). In the case of a gas compressor application, the governor dynamics should be set to 60 as a starting point.

❑ **Governor Dynamics Set**

Proportional Gain (Gain)______________________

Integral Gain (Stability)_______________________

Derivative Gain (Compensation)______________

❑ **Aux Governor (on grid dynamics for gen set)**

Proportional Gain (Gain)______________________

Integral Gain (Stability)_______________________

Derivative Gain (Compensation)______________

❑ **Wastegate Dynamics Set**

Proportional Gain (Gain)______________________

Integral Gain (Stability)_______________________

Derivative Gain (Compensation)______________

❑ **Choke Dynamics Set**

Proportional Gain (Gain)______________________

Integral Gain (Stability)_______________________

Derivative Gain (Compensation)______________

❑ **Start Choke Position**_________________________

❑ **Max Choke Position** _________________________

❑ **Start Wastegate Position** ___________________

❑ **Desired Exhaust Temp** _______________________

❑ **Start Fuel Burst Command** __________________

Note: For inline engines, the recommended setting is 0; for vee engines the recommended setting is 5-30, whichever setting allows easiest starting.

❑ **Exhaust Temp Feedback Time Delay** __________________

Customer Adjustable Parameters

The low idle and high idle should be set prior to starting the engine. Connect Cat ET and open “Configuration” screen and reset “Minimum Engine Low Idle Speed” and “Maximum Engine High Idle Speed” to the desired site requirements.

❑ **Low Idle Speed _________________ rpm**.

❑ **Minimum Engine High Idle Speed _________________ rpm.**

❑ **Maximum Engine High Idle Speed _________________ rpm.**

❑ **Desired Speed Input Configuration _________________**.

10.5 Droop/Isochronous

The Droop/Isochronous should be set prior to starting the engine. Connect Cat ET and open “Configuration Tool” and reset “Governor Setting” to the desired site requirements. The initial settings should be Isochronous and Zero % droop.

❑ **Governor Droop Selected**

❑ **Isochronous Selecte**d

Engine Speed Droop

The Governor Droop should be set prior to starting the engine. Connect Cat ET and open “Configuration” screen and reset “Engine Speed Droop” to the desired site requirements.

❑ **Engine Speed Droop ___________________** %

Generator

On generators, the voltage regulator should be turned off. This may require disconnecting wires, fuses, etc. Also, the generator breaker should be racked out or otherwise disarmed and locked out.

❑ **Turn off Voltage Regulator**

❑ **Lockout Generator Breaker**

Industrial

For industrial applications, make sure the driven equipment and ancillary equipment is ready for an engine start.

Crank Test

Crank the engine with the fuel shutoff (make sure to prelube engine and driven equipment first). A fault will likely be present during this cycle. To obtain sufficient ignition voltage from the control system for starting, the engine must crank a minimum of 80 rpm. After 5 to 10 seconds of cranking, record the cranking speed and starting air/gas pressure in Table 10.3.

Cranking Test	
Cranking Speed	**Cranking Air Pressure**
≥ 80 rpm ❑ Acceptable	< 80 rpm ❑ Unacceptable

Table 10.3

Even though the fuel system and the ignition system are activated at engine speeds above 50 rpm, the minimum cranking speed is 80 rpm for starting. It is desirable to have a target cranking speed of 100 rpm. This will allow the engine to start quicker, start at lower ambient temperature, and accelerate to rated speed quicker. Therefore, the higher the available starting air/gas pressure the better, (up to the pressure limit of the starter). With the correct air pressure, the air starting motor can turn the heavily loaded engine at the same speed and for the same duration as the air starting motor can turn a lightly loaded engine.

If the site ambient temperature will be lower than 10°C (50°F), an engine oil heater must be used for best cranking results. Cold engine oil has severe negative impact on achieving the desired cranking speed.

Crankcase Ventilation Caps Removed – Crankcase ventilation caps must be removed so the crankcase pressure does not increase and shut the engine down. Consult the Gas Engine Application and Installation Guide for more information.

Guards In Place – All guards should be in place before the engine is started.

Inspection Ports Installed to Check Emissions/Backpressure – Ports must be installed in the exhaust piping to allow for emissions testing and for checking exhaust backpressure. Check the Gas Engine Application and Installation Guide for more information.

Install Gauge to Check Hydrax Pressure (Gauge Must Be Able to Read Minimum of 300 PSI) -–Install pressure gauge in the Hydrax pressure block after the Hydrax filter to check the Hydrax system pressure. See the Gas Engine Application and Installation Guide for more details.

Air/Fuel Pressure Module and Calibration – The air pressure calibration should be checked before the engine is started. The air pressure module can be calibrated using Cat ET with the engine stopped.

Record Needle Valve Setting and Compare to Factory Settings – With packages that have been run at the packager site under no load conditions, the needle valve adjustments may have been altered to get cylinders to fire at low fuel pressures and no load. Needle valve settings should be checked before starting engine.

Crank RPM Test (Fuel Off) – With fuel valve off, go through a start sequence to check engine-cranking speed. See the Gas Engine Application and Installation Guide for more details.

Start the Engine

The engine should now be ready to start. Put the engine mode control switch in the START or AUTO (with initiate contact closed) position. The control should begin to prelube and the green “Manual Prelube” light should come on. Once the prelube is complete, the green light should go out followed by cranking of the engine. The green “Manual Prelube” light is on only when prelube should be running. If the “Manual Prelube” light goes out but the engine does not crank, check to see if the Driven Equipment status is “Ready” on the relay screen of the Advisor panel or Cat ET.

After the engine starts, it may be limited to 550 rpm by the idle/rated contact. To ramp to the speed set by the engine speed dial or 4-20mA input, Advisor 22 terminal or terminal 21 at the customer connector in the engine mounted terminal box must be grounded. Once the engine is at the rated speed, increase the speed by increasing the setting on the engine speed dial or the 4-20mA input. Examine the exhaust port pyrometers to make sure all cylinders are firing. If the engine is unstable, the choke may need adjustment.

The “Maximum Choke Position” should be set while the engine is running at high idle. Normal setting for “Maximum Choke Position” is 75 to 85 percent closed. This adjustment can be made by connecting Cat ET and opening the “Configuration Tool” and reset “Maximum Choke Position” to the desired site requirements. The goal is to get the actual and desired air/fuel ratio to match and obtain stable idle. Sometimes the actual and desired may not match at the most stable idle.

❑ **Maximum Choke Position __________**

Protection System

After the engine has been started, the protection system needs to be exercised to ensure that it will successfully protect the engine. After the engine has run for approximately 30 minutes, evaluate some of the shutdown protections. As a minimum, verify that each module can cause a shutdown.

The recommended way to do this is to disconnect the connector at the filtered oil pressure sensor. This will verify that the ADEM III works properly for an oil pressure failure. Next, disconnect one of the detonation sensors. This will test communication between the ICSM /ISM and the ADEM III. All E-stop pushbuttons should also be tested.

ADEM III Shutdown: ❑ **Acceptable** ❑ **Unacceptable**

ICSM: ❑ **Acceptable** ❑ **Unacceptable**

E-Stop: ❑ **Acceptable** ❑ **Unacceptable**

The photos that follow illustrate the locations for testing these functions.

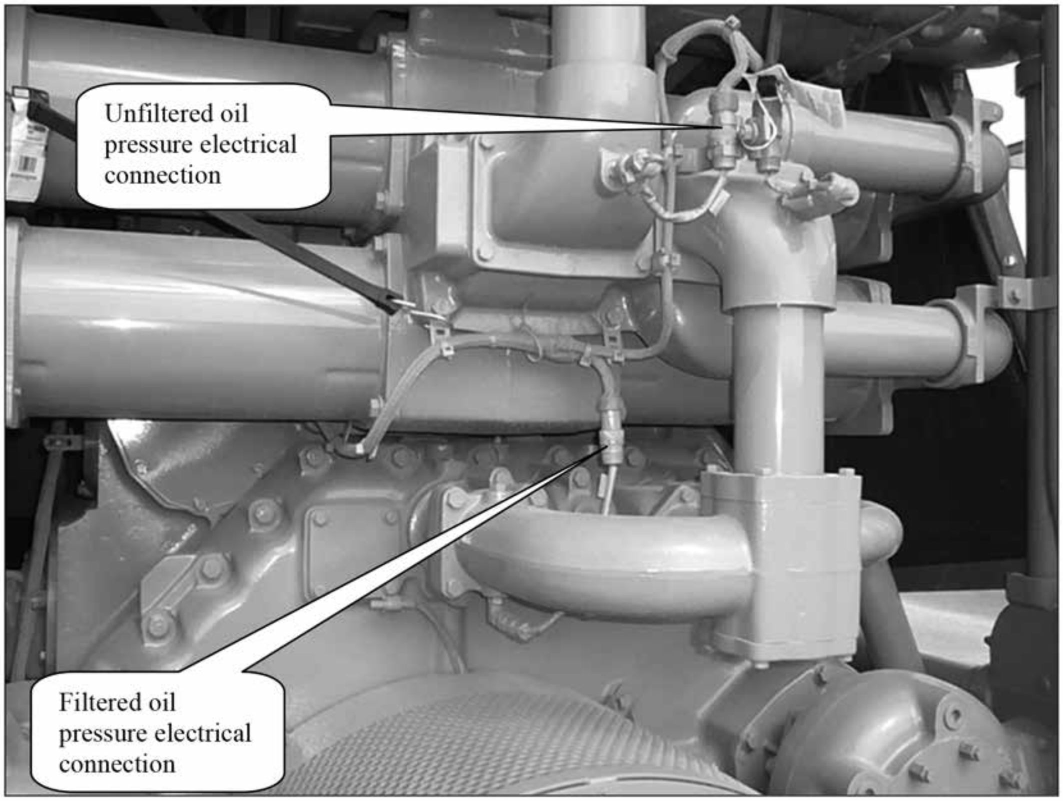

Figure 10.2

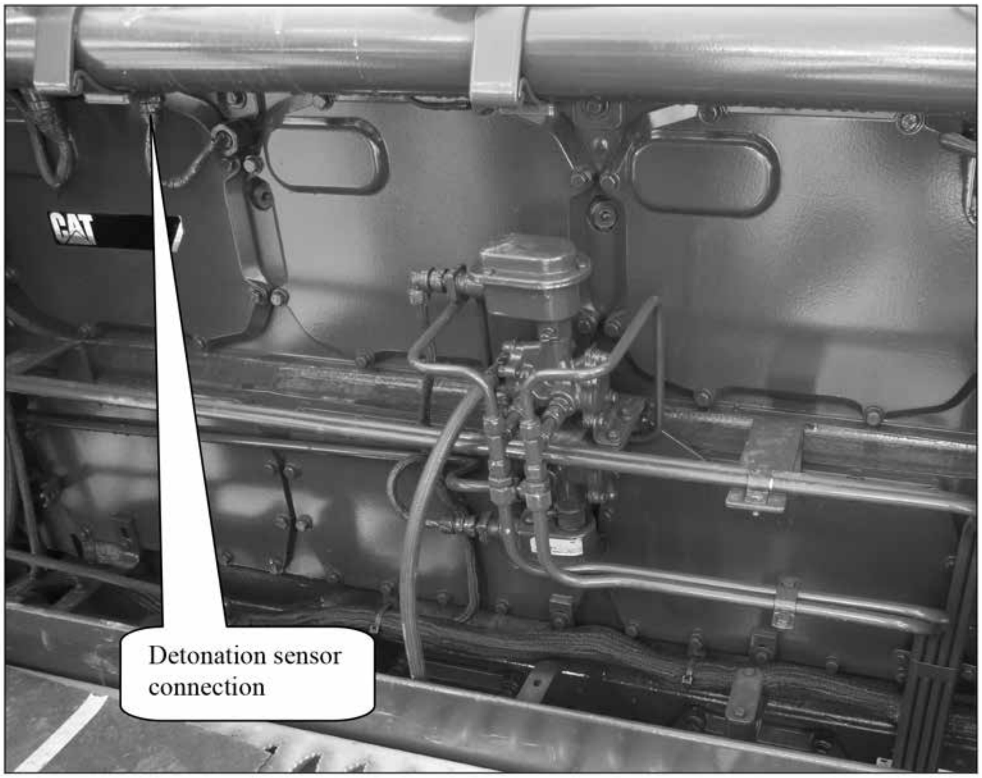

Figure 10.3

Figure 10.4 – Remote Panel with Advisor Display

10.6 After Engine Start

Note: Be sure that all personnel are aware of a pending engine start for safety. As soon as the engine speed is stable, check and vent the jacket water immediately; first to be sure that the air has been purged from the jacket water system before proceeding further.

Stabilize RPM (Governor, Choke, Wastegate, Max Choke, Desired Exhaust Temp) – After engine is started, stabilize engine rpm using settings in the configuration screen of Cat ET.

Check Shutdowns (E-stop, Oil Pressure, Temperature, Water Temperature, Crankcase Pressure, and Detonation Sensor) – After engine is started, test shutdowns to verify the operation of the protection system.

Check for – Noises/Leaks/Vibration/Temperature/Etc. – After engine is started, check for any problems that would warrant the engine to be shutdown.

Hydrax Pressure – Check Hydrax pressure after engine is started and adjust if necessary. Hydrax oil should be at operating temperature before adjusting Hydrax pressure.

Generator

Verify the phase rotation on a three-phase system. This can be done on a low voltage machine (< 1000 VAC) with a rotation meter. If the system is a higher voltage, the phase and rotation needs to be measured at the generator breaker cabinet. With the breaker racked up, use two hot stick voltmeters to verify the phases are in synch. To do this, place hot stick #1 at Phase A between the utility and generator bus and hot stick #2 at Phase B. The voltage should rise and fall on both in synch. Repeat for the other phase combinations and record the results in Table 10.4. If at any time the phases rise and fall out of synch, determine the cause and correct.

Hot Stick #1	Hot Stick #2	Synch
ø A	ø B	
ø A	ø C	
ø B	ø C	

Table 10.4

Cooling System Evaluation

Run the engine for 20 to 30 minutes. Shutdown and inspect the strainers. Remove strainers if clean and free from debris. If not, clean the strainers and reinstall. Restart the engine. Repeat this process until the strainers are clean.

❑ **Inspect and Remove Strainers**

Load the Engine

To complete the cooling test, the ambient capability procedure can be done if the customer requests this evaluation (see later section). This is done at the maximum load available. However, the engine must be correctly tuned to successfully operate at that load. A pre-chamber (PC) calibration (Cal) must be performed on the engine.

Generator Set

Do not depend on synch lights, synch check relays, etc. to confirm the phase and rotation!

Rack in the generator breaker and charge if necessary. Synchronize the engine speed and match the generator voltage to the utility. Synchronize the phases and close the breaker. Load the engine. If a load bank is used to load the engine, be sure to isolate the load side of the bus from the load banks.

Industrial

Ensure that the driven equipment and all ancillary equipment are ready to be loaded.

10.7 After Engine Is Loaded and At Operating Temperature

Adjust Emissions Using Analyzer and Tune Engine – Once engine is loaded to proper load and at operating temperature, check emissions and adjust as needed. In PC CAL, first confirm emissions are within Caterpillar specifications. If not, first adjust Btu to obtain desired emissions. The second step is to tune engine to desired burn time by adjusting the needle valves using Cat Electronic Technician. Make these adjustments only when the system is in PC CAL and under the correct load. Consult the System Operation Testing and Adjusting Manual-RENR5908-11, "BTU and Precombustion Chamber Adjustments" for more information.

Check Cooling System Pressures and Temperature (Using Test Ports, Advisor, and Infrared) – Once engine is started, check cooling system pressures and temperatures using test ports, Advisor panel and infrared temperature gun. These readings should be used to check internal and external restrictions and evaluate the cooling system. See the Gas Engine Application and Installation Guide for more details.

10.8 PC Calibration

Increase the load to 75% of rated or the maximum available if less than 75%. The engine may not be stable at maximum load. Adjust the governor and wastegate to obtain stable operation.

Governor

The governor should be programmed for the proper dynamics for stable yet responsive to load and speed changes. The governor dynamics should be adjusted electrically (refer to System Testing and Adjusting, RENR 5908). This can be accomplished using Cat ET. Use Cat ET and view the "configuration" screen. Changes can be made to the governor and governor gain, stability, and compensation to obtain the most stable actual rpm reading. Record settings in Table 10.5.

Governor		
Gain	Stability	Compensation
Auxiliary Governor Gains (if applicable)		

Table 10.5

After the governor adjustments are complete, proceed to wastegate dynamic adjustments.

Wastegate

The wastegate should be programmed for the proper dynamics for stable yet responsiveness to load and speed changes. The wastegate dynamics should be adjusted electrically (refer to System Testing and Adjusting, RENR 5908). This can be accomplished using Cat ET. Use Cat ET and view the "configuration" screen. Changes can be made to the wastegate gain, stability, and compensation to obtain the most stable actual rpm reading. Record the settings in Table 10.6.

Wastegate		
Gain	Stability	Compensation

Table 10.6

To continue with PC Calibration, the engine must be warmed up with the temperature stabilized and at load. Let the engine operate for at least 30 minutes before attempting to calibrate the emissions and prechamber needle valves.

To perform the PC Cal procedure, the engine control must be in the PC Cal mode. This can be accomplished through Cat ET. Use Cat ET and click "Service" tab, "Calibrations" tab and "Prechamber Calibration" tab. Displayed on Cat ET-PC CAL screen will be desired burn time, filtered burn times for all of the cylinders on an inline engine, or all of the odd or even cylinders on a vee engine and unfiltered burn times for all cylinder on an inline engine or all of the odd or even cylinders on a vee engine. Make sure the BTU and Specific Gravity are set in the configuration screen using Cat ET at the proper setting for the fuel being use.

1. Measure the NOx in the engine exhaust with an accurate emission analyzer. If the NOx value is not correct, adjust the Btu value to obtain the correct NOx value.
2. Adjust the respective cylinder prechamber needle fuel flow control valve to obtain actual burn time readings within ± 0.20 msSec of desired. Make an effort to get the burn times closer than ± 0.20 mSec of desired. The result will be a better tuning result. Make only small adjustments and allow sufficient time (several minutes) for the reading to stabilize. It is beneficial to record the combustion times prior to adjustment. It is also helpful to record the amount the respective needle valve is moved, as well as the stabilize burn time for that adjustment. The benefit is that not all cylinders' needle valves and check valve flow are identical and the trending will make this time consuming process much quicker.
3. Verify that the NOx value is correct. After the tuning is complete, record the needle valve positions; also monitor exhaust port temperatures. If a port temperature is excessively high or low, ensure that the combustion probe burn time is within acceptable limits. If not, troubleshoot the cause. After all cylinders have been adjusted, review them again to ensure they have stabilized. Readjust as required.
4. After the PC Cal is complete, record the inlet manifold air pressure in Table 10.7. To return the control to the combustion feedback mode, exit "Prechamber Calibration" mode in Cat ET. This will return the control to feedback mode. Wait at least two minutes and record the inlet manifold air pressure again in Table 10.8. It should not vary more than ± 2 kPa (.4 psi) from the value in PC Cal at the same load and speed. If it does, PC Cal may need to be redone. Also verify that the inlet air manifold pressure is within ± 5 kPa of that listed in the engine performance specification for the engine at the designate speed and load.

PC Cal Inlet MAP	Feedback Inlet MAP	Difference	Specification
			> ± 2 kPa
< ± 2 kPa (0.4 psi) ❑ Acceptable		> ± 2 kPa(0.4 psi) ❑ Unacceptable Re-tune PC CAL	

Table 10.7

Feedback Inlet MAP	Performance Specification	Difference	Specification	Altitude
			> ± 2 kPa	
> ± 5 kPa ❑ Acceptable		> ± 5 kPa ❑ Unacceptable Re-tune PC CAL		

Table 10.8

Check altitude for correction factor for correct comparison of data.

Record Running Performance Data – After engine is tuned and at operating temperature, record running data to include in the commissioning report.

10.9 After Package Is Heat Soaked

Hot Checks – Alignment, Deflection, and Endplay – After the engine has operated under load sufficiently to heat soak the package, shutdown engine and perform hot checks. Refer to the Gas Engine Application and Installation Guide for further information.

11.0 Live Engine Test (Commissioning Cooling System Performance)

Additional work needs to be performed to complete the site commissioning. The following is a reference to follow to ensure the package is designed and performing correctly.

11.1 Cooling System Test Preparation

Evaluate system pressures. If the pressure taps are not already installed, install all taps at the recommended locations. With the coolant system empty, locate and install bosses (typically 1/4 inch female pipe) at the following locations shown in Table 11.1 and Figure 11.2.

Jacket Water System	Separate Circuit
❑ Pump Inlet	❑ Pump Inlet
❑ Circuit Outlet	❑ Circuit Outlet
❑ Cooler Inlet	❑ Cooler Inlet
❑ Cooler Outlet	❑ Cooler Outlet

Table 11.1

To allow the system to be probed without coolant leakage, sample port adapters should be installed if they are not already installed. The part numbers are 5P2725 (1/4 inch male pipe thread), 5P2720 (1/8 inch male pipe thread), and 5P3591 (9/16 inch male straight thread), 164-2192 “Football needle” probe, 4M5317 (1/8”NPT X 1/4”NPT bushing), 6B5072 (1/4”NPT X 1/2”NPT bushing). These are shown in Figure 11.1. If the customer or packager has chosen to install a ball valve in these locations, that is acceptable. The following locations shown in Table 11.2 need a port adapter.

Figure 11.1 – Cat Port Adapters and Pressure Probe

Jacket Water System	Separate Circuit
❑ Pump Inlet	❑ Pump Inlet
❑ Pump Outlet	❑ Pump Outlet
❑ Engine Outlet	❑ Engine Outlet
❑ Cooler Inlet	❑ Cooler Inlet
❑ Cooler Outlet	❑ Cooler Outlet

Table 11.2

Blocked open thermostats need to be installed in the thermostat housings according to Table 11.3. If the Cat thermostats are used, eight thermostats will need to be blocked open for an inline engine and 16 thermostats for a vee. Refer to EDS 50.5, LEKQ7235 for information about how to block open a thermostat

Jacket Water System	Separate Circuit
❑ 4 Blocked Thermostats Inline	❑ 4 Blocked Thermostats Inline
❑ 8 Blocked Thermostats Vee	❑ 8 Blocked Thermostats Vee

Table 11.3

Also, the cooling system will likely have some debris in the piping. Strainers must be installed before the engine is operated. Strainers are available through Caterpillar and have the following part numbers.

4C9045 – 4 inch diameter pipe

4C9046 – 5 inch diameter pipe

4C9047 – 6 inch diameter pipe

Install the proper size strainer in the following locations shown in Table 11.4.

Strainers Installed for Run Test	
Jacket Water System	Separate Circuit
❑ Pump Inlet	❑ Pump Inlet

Table 11.4

11.2 Cooling System Performance

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

The items of interest are pump coolant pressure rise, coolant pressure drop across the engine, and external system resistance (**Note:** internal and external restriction pressure measurements must be taken with blocked open thermostats with no bypass flow). This information can be obtained by making some pressure measurements. Recording data in Table 11.2 will provide the needed information:

Note: Before performing the cooling system test the part number and location of the engine jacket water orifice plate or plates should be verified. The orifice plate should be on the pump inlet side of the thermostat housing. Record the part number in Table 11.5.

Jacket Water System
❑ Orifice Part Number

Table 11.5

Use the following diagram when performing cooling system testing during G3600 engine commissioning. Keep in mind that this diagram does not reflect the dimensional relationship of the component locations.

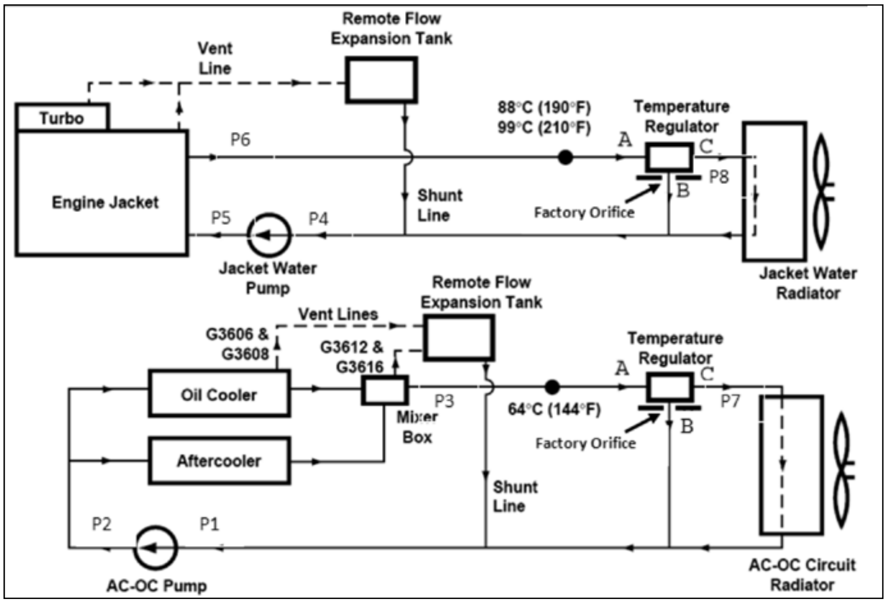

Figure 11.2 – Outlet Control (Diverting) Cooling Schematic Used in Gas Compression Applications

Pump Performance				
	Jacket Water System	**Pressure Designation**	**Separate Circuit System**	**Pressure Designation**
Pump Inlet Pressure (Static)		P4		P1
Pump Inlet Pressure (Static–Specification)		P4 *34.5 kPa (5 psi) minimum 145 kPa (21 psi) maximum		P1 *34.5 kPa (5 psi) minimum 145 kPa (21 psi) maximum
Pump Inlet Pressure (Dynamic)		*19.3 kPa (2.8 psi) minimum		*19.3 kPa (2.8 psi) minimum
Pump Outlet Pressure (Dynamic)		P5		P2
Pump Outlet Pressure (Maximum Dynamic)	67		67	
Engine Outlet Pressure		P6		P3
Engine Speed				
Pump Rise		P5 - P4		P2 - P1
Specification Minimum (Table 83)		Inline and Vee		Inline and Vee
❑ Acceptable ❑ Unacceptable				

*Numbers based on 5 feet of straight pipe ahead of pump inlet. Add 10% if inlet to water pump inlet is directly after a 90° bend. Minimum number is also based on coolant temperature.

Table 11.6

You can use the graph in Figure 11.3 to determine minimum pump inlet pressure.

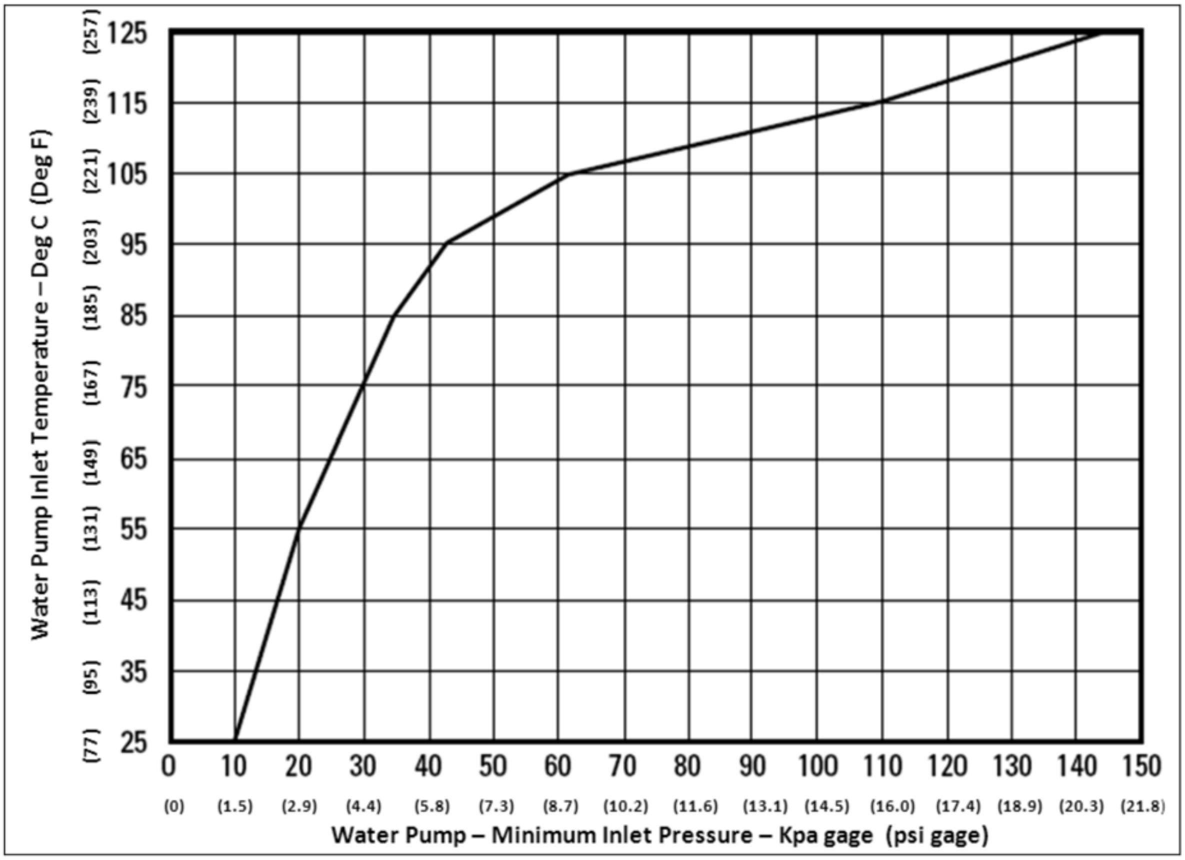

Figure 11.3

To evaluate the pump rise (performance), use Table 11.6, Table 11.7, and Table 11.8.

Pump Rise Specification				
RPM	Jacket Water System		Separate Circuit System	
	Minimum Pump Rise		Minimum Pump Rise	
	Inline & Vee		Inline & Vee	
1000	260 kPa	38 psi	295 kPa	43 psi
900	210 kPa	30 psi	240 kPa	35 psi
750	140 kPa	20 psi	170 kPa	25 psi

Table 11.7

Since the pump rise is flow (engine speed) dependent, the specification of acceptable pump rise must be determined from accessing information in GERP (Gas Engine Rating Pro).

Static Pump Inlet Pressure			
System	**Pressure**	**Specification**	**Acceptable**
Jacket Water (P4)		*34.5 kPa (5 psi) minimum 145 kPa (21 psi) maximum	❑ Yes ❑ No
Separate Circuit (P1)		*34.5 kPa (5 psi) minimum 145 kPa (21 psi) maximum	❑ Yes ❑ No

*Numbers based on 5 feet of straight pipe ahead of pump inlet. Add 10% if inlet to water pump inlet is directly after a 90° bend. Minimum number is also based on coolant temperature.

Table 11.8

The static suction pressure must be recorded. If the expansion tank is in its final configuration, measure static suction pressure in Table 11.8.

The internal system resistance must be within certain limits for optimum cooling system performance. To evaluate pressure drop across the engine (internal restriction), use Table 11.9. The internal resistance value is to be used also when sizing an external pump (non-engine driven) when designing high temperature cooling systems such as a biogas fuel site.

Internal Resistance				
	Jacket Water System	**Pressure Designation**	**Separate Circuit System**	**Pressure Designation**
Pump Outlet Pressure		P5		P2
Engine Outlet Pressure		P6		P3
Engine Resistance Pressure		P5 - P6		P2 - P3
Specification (GERP)		Inline and Vee		Inline and Vee
❑ Acceptable ❑ Unacceptable				

Table 11.9

Since the engine resistance is flow (engine speed) dependent, the specification of acceptable engine resistance must be determined from accessing GERP (Gas Engine Rating Pro). The external resistance will also affect the coolant flow and must be considered if the measured engine resistance is too low for the operating engine speed. The system resistance in this circumstance will likely be high. The goal is to obtain more than the minimum coolant flow rate through the engine.

The external system resistance must be within certain limits for optimum cooling system performance. Use Table 11.10 to evaluate the system (external restriction) resistance:

External Resistance				
	Jacket Water System	Pressure Designation	Separate Circuit System	Pressure Designation
Engine Outlet Pressure		P6		P3
Pump Inlet Pressure		P4		P1
External Resistance		P6 - P4		P3 - P1
TMI Specification		Inline		Inline
TMI Specification		Vee		Vee
❑ Acceptable ❑ Unacceptable				

Table 11.10

The coolant flow rate through the cooling system can be determined. The flow rate from the external resistance can be determined by accessing GERP (Gas Engine Rating Pro) and finding the appropriate chart. The flow is engine speed dependent and the proper speed curve must be used. Record the flow value in the following evaluation Table 11.11.

The flow rate from the internal resistance or engine resistance needs to be determined. Find the appropriate engine specific tech data sheet and, pump curve chart within GERP (Gas Engine Rating Pro). The flow is engine speed dependent. Record the flow value in Table 11.11. The flows must agree within ± 20%, and must be within the minimum and maximum flow range for that circuit. Use Table 11.11 to determine if the flow is acceptable.

Cooling Flow Measurement				
	Jacket Water System		Separate Circuit System	
	Pressure Drop	Flow Rate (from GERP pump curve)	Pressure Drop	Flow Rate (from GERP pump curve)
External Resistance				
Engine Internal Resistance				
Evaluation				
Engine JW Flow = External flow ± 20%	❑ Acceptable		❑ Unacceptable	
Engine Aux Flow = External flow ± 20%	❑ Acceptable		❑ Unacceptable	

Table 11.11

If the internal and external flow values do not meet the acceptable criteria, the external piping of the system must be rechecked and the cause for the excessive flow difference must be determined in order to have the desired cooling system performance.

11.3 Ambient Cooling Test

Note: This test can be performed at customer request. The weather cannot be rainy; the ambient temperature must be greater than 30°C (85°F) for the results to be accurate.

The cooling system can now be evaluated for its ambient capacity. To obtain good results with a radiator system, the ambient air temperature must be above 30°C (85°F) or if an evaporative cooler is used, the dew point temperature (wet bulb) must be above 4°C (40°F). Refer to Engine Data Sheet 50.5 LEKQ7235 for additional information on the ambient capability test. Run the engine at maximum load (minimum of 85%) and record engine inlet and outlet coolant temperatures as well as the ambient temperature and the dew point temperature for an evaporative cooler.

Maximum system air flow for a radiator or maximum raw water flow for a heat exchanger system must be used. Enter the stabilized temperatures into Table 11.12.

Temperature	Stabilized Temperature Reading
Ambient Air (Dry Bulb)	
Dew Point (Wet Bulb)	
Jacket Water Inlet	
Jacket Water Outlet	
Separate Circuit Inlet	
Separate Circuit Outlet	

Table 11.12

Evaluate the ambient performance in Table 11.12.

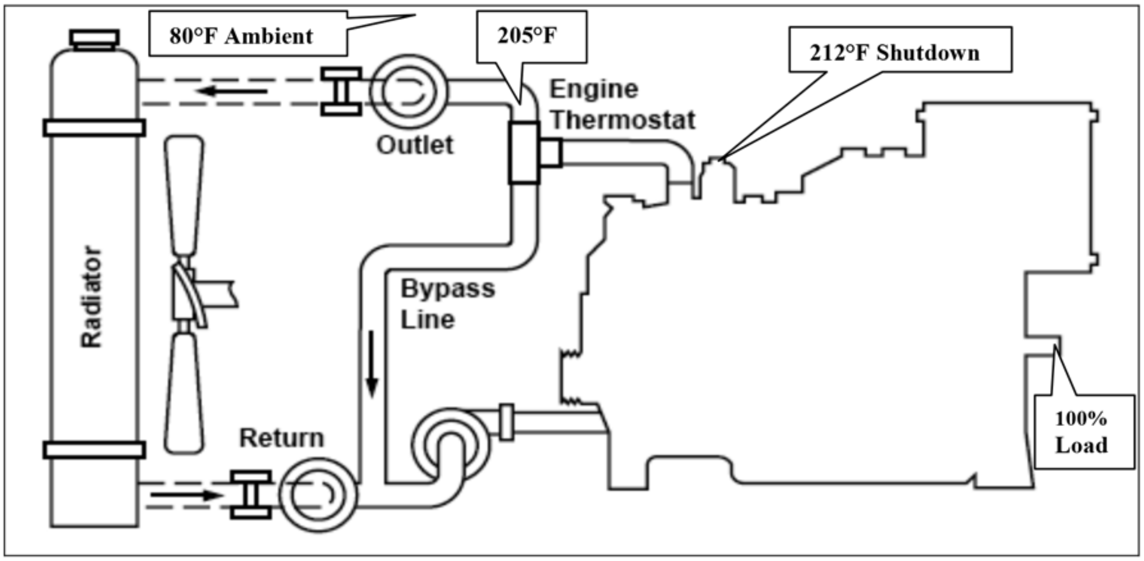

Figure 11.4 – G3600 Jacket Water Cooling System Functional Schematic

Maximum Ambient Capability = Shutdown Temperature for Jacket Water System $\left[\frac{\text{Outlet Temperature – Ambient Temperature}}{\text{\% Load}}\right]$

Example: (See Figure 11.4): Given the conditions below, find the Maximum Ambient Capacity for the Jacket Water System.

Shutdown Temperature = 100°C (212°F)

Outlet Temperature = 96°C (205°F)

Ambient Temperature = 27°C (80°F)

Max. Ambient Capability = 100°C (212°F) - $\left[\frac{\text{96°C (205°F) - 27°C (80°F)}}{\text{100\%}}\right]$ = 31°C (87°F)

Max. Ambient Capability = 31°C (87°F)

Jacket Water System (Radiator System)	
Shutdown Temperature	________________________ºC/ (ºF)
Outlet Temperature	________________________ºC/ (ºF)
Ambient Temperature	________________________ºC/ (ºF)
% Load	________________________%
Maximum Ambient Capability	$\frac{\text{\_\_\_\_\_\_ (Shutdown Temp) - \_\_\_\_\_\_ (Ambient Temp) = \_\_\_\_\_\_ °C (°F)}}{\text{\_\_\_\_\_\_ (\% Load)}}$

Table 11.13

Jacket Water System (Evaporative Cooler System)	
Shutdown Temperature	________________________ºC/ (ºF)
Outlet Temperature	________________________ºC/ (ºF)
Ambient Temperature	________________________ºC/ (ºF)
% Load	________________________%
Maximum Ambient Capability	$\frac{\text{\_\_\_\_\_\_ (Shutdown Temp) - \_\_\_\_\_\_ (Ambient Temp) = \_\_\_\_\_\_ °C (°F)}}{\text{\_\_\_\_\_\_ (\% Load)}}$

Table 11.14

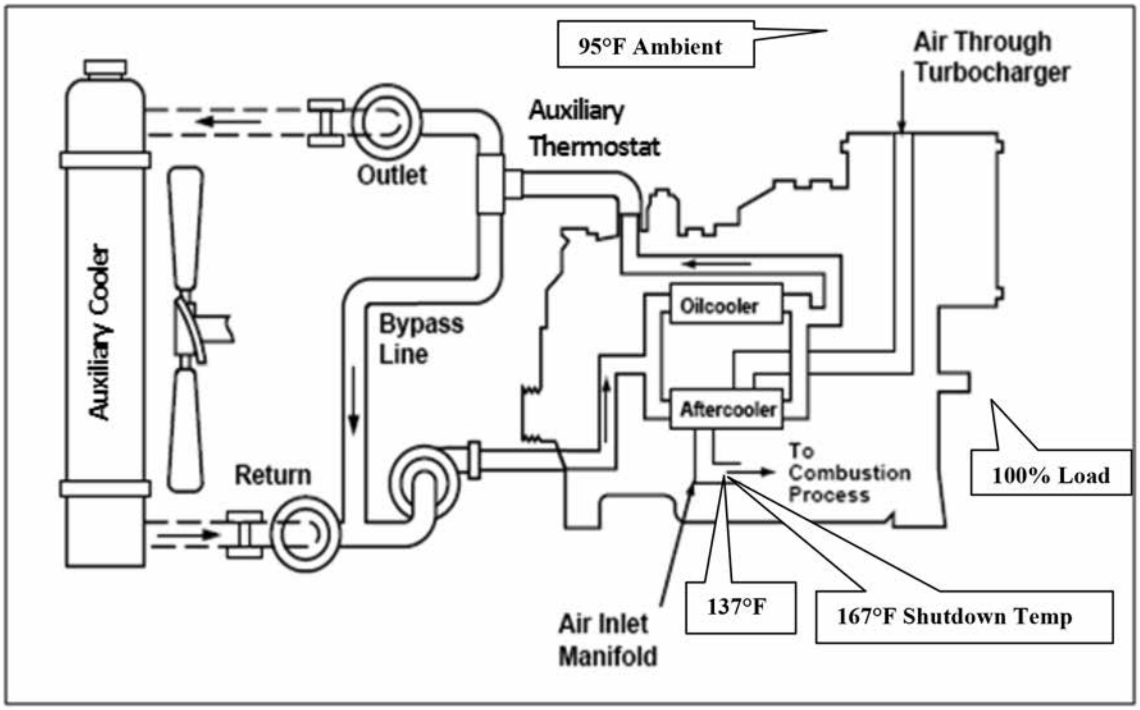

Figure 11.5 – G3600 Auxiliary Cooling System Functional Schematic

$$\text{Maximum Ambient Capability for Aftercooler/Oil Cooler System} = \text{Shutdown Temp} - \frac{\text{Inlet Manifold Air Temp} - \text{Ambient Temp}}{\text{\% Load}}$$

Example: (See Figure 11.5): Given the conditions below, find the Maximum Ambient Capacity for the Aftercooler/ Oil Cooler System.

Shutdown Temperature = 75°C (167°F)

Inlet Man Temperature = 58°C (137°F)

Ambient Temperature = 35°C (95°F)

Load = 100%

$$\text{Max. Ambient Capability} = 75°C\ (167°F) - \left[\frac{58°C\ (137°F) - 35°C\ (95°F)}{100\%}\right] = 52°C\ (125°F)$$

Auxiliary Cooling System (Radiator System)	
Shutdown Temperature	________________________ EF
Outlet Temperature	________________________ EF
Ambient Temperature	________________________ EF
% Load	________________________%
Maximum Ambient Capability	_____ (Shutdown Temp) - _____ (Ambient Temp) = _____ °C (°F) _____ (% Load)

Table 11.15

Auxiliary Cooling System (Evaporative Cooler System)	
Shutdown Temperature	______________________ EF
Outlet Temperature	______________________ EF
Ambient Temperature	______________________ EF
% Load	______________________%
Maximum Ambient Capability	_____ (Shutdown Temp) - _____ (Ambient Temp) = _____ °C (°F) _____ (% Load)

Table 11.16

Note: This test is only performed if the customer requests it or if cooling system experiences overheating problems.

Note: When using blocked open thermostats, care must be taken to prevent piston seizure due to low EJW temperature and higher oil temperature. If EJW temperature becomes lower than the oil temperature the test must be stopped.

Note: Available load must be above 85%.

Coolant Correction

If the ambient capability test was not run with the coolant to be used, that needs to be considered as well. If the test was performed with water and the engine will be filled with a water antifreeze blend, subtract 3°C or 6°F from the ambient capability.

Compare the ambient capability values with the performance sheet of the heat exchanger device.

Temperature Regulation Test

The temperature regulation of the thermostats needs to be evaluated in Table 11.17. To do this, drain the cooling system and remove the blocked open thermostats and replace with the normal control thermostats:

System	Thermostat	Part #	Temperature Rating
Jacket Water	❑ Inlet Controlled ❑ Outlet Controlled		
Separate Circuit	❑ Inlet Controlled ❑ Outlet Controlled		

Table 11.17

Refill the systems. Restart the engine and run at half load or less. Record the stabilized inlet and outlet of the engine temperature in Table 11.18.

Operating Temperatures			Ambient Temperature
System	Inlet	Outlet	
Jacket Water			
Separate Circuit			

Table 11.18

Data Sheet

A full data sheet should now be completed to record the actual engine performance using the appropriate pages below.

CATERPILLAR®

G3600 A3 Data Sheet - Inline

Project Name		Engine Serial #		Date	
Site Name		Ambient Temp		Time	
Customer Unit #		Barometric Press		Altitude	
		SCAC Coolant Temp			

Engine Status			A/F Status			Speed Status	
RPM			A/F Ratio			RPM	
Desired RPM			Desired A/F Ratio			Load	
Load			Fuel Quality			Speed Control	
Oil Pressure			Desired Air Press			Droop Setting	
Air Pressure			Specific Gravity			Governor Type	
Oil Temperature			Air Flow			Wastegate Command	
JW Temperature			Fuel Flow			Choke Command	
Fuel Correction Factor			Feedback Status			Fuel Command	

Pressure Status			Temperature Status			Miscellaneous	
Fuel Pressure			Air Temperature			Detonation Level	
Air Pressure			EJW Temperature			Service Hours	
Oil Pressure			Oil Temperature			Battery Voltage	
Differential Oil Pressure			Fuel Temperature			Multi Strike Mode	
Crankcase Pressure			Odd Bank Exh Avg			Multi Strike Switch	
EJW Pressure			Even Bank Exh Avg			Multi Strike Status	

Cylinder Number	B/T	Exh Temp	Needle Valve Position	Timing	Secondary Voltage
1					
2					
3					
4					
5					
6					
7					
8					
Average Burn Time			Desired Timing		
Desired Burn Time					
Turbo Temperature	In				
Turbo Temperature	Out				

	Gain	Stability	Compensation	Desired Exhaust Temp		Fuel Burst	
Governor				Start Choke Position		Exh Feedback Delay	
Aux Governor				Max Choke Position		Crank Termination	
Wastegate				Start Wastegate Position		Accel Rate	
Choke				Fuel Press to Regulator		Fuel LHV	
				Fuel Press to Engine		Specific Gravity	
			Methane Number		Flash File No.		

Emissions				Notes:
O_2		NOx		
CO				
CO_2		Left	Right	Codes:
Exh Back Pressure				
Inlet Air Restriction				

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G3600 A3 Data Sheet - Vee

Project Name		Engine Serial #		Date	
Site Name		Ambient Temp		Time	
Customer Unit #		Barometric Press		Altitude	
		SCAC Coolant Temp			

Engine Status			A/F Status			Speed Status	
RPM			A/F Ratio			RPM	
Desired RPM			Desired A/F Ratio			Load	
Load			Fuel Quality			Speed Control	
Oil Pressure			Desired Air Press			Droop Setting	
Air Pressure			Specific Gravity			Governor Type	
Oil Temperature			Air Flow			Wastegate Command	
JW Temperature			Fuel Flow			Choke Command	
Fuel Correction Factor			Feedback Status			Fuel Command	

Pressure Status			Temperature Status			Miscellaneous	
Fuel Pressure			Inlet Air Temperature			Detonation Level	
Air Pressure			EJW Temperature			Service Hours	
Oil Pressure			Oil Temperature			Battery Voltage	
Diff. Oil Pressure			Fuel Temperature			Multi Strike Mode	
Crankcase Pressure			Odd Bank Exh Avg			Multi Strike Switch	
EJW Pressure			Even Bank Exh Avg			Multi Strike Status	

Cyl #	B/T	Exh	NV	Timing	Sec V	Cyl #	B/T	Exh	NV	Timing	Sec V
2						1					
4						3					
6						5					
8						7					
10						9					
12						11					
14						13					
16						15					
Average Burn Time						Average Burn Time					
Desired Burn Time						Desired Burn Time					
Engine Avg BT											
L Turbo Temp	In					R Turbo Temp	In		Desired Timing		
L Turbo Temp	Out					R Turbo Temp	Out				

	Gain	Stability	Compensation	Desired Exh Temp		Fuel Burst Setting	
Governor				Start Choke Setting		Exh FB Delay	
Aux Governor				Max Choke Setting		Crank Termination	
Wastegate				Start Wastegate Setting		Accel Rate	
Choke				Fuel Press to Regulator		Fuel LHV	
				Fuel Press to Engine		Specific Gravity	
				Methane Number		Flash File Number	

Emissions				Notes:
O_2		NOx		
CO				
CO_2		Left	Right	Codes:
Exh Back Pressure				
Inlet Air Restriction				

11.4 Engine S/N ____________ Generator Set

Engine Instrument Panel and Generator Control Panel Instrument Readings

Description		0%	25%	50%	75%	100%	110%
Actual Load	EMW						
Voltage	kV						
Amperes	A						
Power Factor	LAG	0.	0.	0.	0.	0.	0.
Gen Bearing Temp	°C						
Gen Stator Temp	°C						
Engine Coolant	°C						
Air Inlet Man. Temp	°C						
Air Inlet Restr. LH	kPa						
Air Inlet Restr. RH	kPa						
Oil Pressure	kPa						
Oil Temperature	°C						
Oil Filter Press Diff	kPa						
Fuel Filter Press Diff							
Crankcase Pressure	kPa						
Air Inlet Man. Press	kPa						
Fuel Pressure							
Engine Hours							
Stack Exh Temp RH	°C						
Stack Exh Temp LH	°C						
Cyl Exh Temp 1	°C						
Cyl Exh Temp 2	°C						
Cyl Exh Temp 3	°C						
Cyl Exh Temp 4	°C						
Cyl Exh Temp 5	°C						
Cyl Exh Temp 6	°C						
Cyl Exh Temp 7	°C						
Cyl Exh Temp 8	°C						
Cyl Exh Temp 9	°C						
Cyl Exh Temp 10	°C						
Cyl Exh Temp 11	°C						
Cyl Exh Temp 12	°C						
Cyl Exh Temp 13	°C						
Cyl Exh Temp 14	°C						
Cyl Exh Temp 15	°C						
Cyl Exh Temp 16	°C						

12.0 Performance Approval

If all of the preceding tests are checked Acceptable, the engine is ready to put into service. If any are checked Unacceptable, that item should be placed on a punch list and discussed with all responsible parties. This includes the customer, packager, and the servicing dealer. It may also require discussion with the contractor and consulting engineers. These items should be attempted to be corrected at the time of commissioning. If that is not possible or practical, the servicing dealer can be used as the commissioning agent to report on corrective action. Once all items are corrected, a follow-up visit for inspection and testing is recommended. A copy of the commissioning report must be submitted to the G3600 Commissioning website within 30 days. A copy of the commissioning report must also be sent to the servicing Cat dealer. The copy sent to the dealer should be directed to the technical communicator for industrial engines.

If Cat product problems are experienced during the commissioning, they should be reported to Caterpillar through the area district office. This is best communicated by e-mail over the Caterpillar network.

13.0 G3600 Spare Parts List

Quantity	Description
1	Water Temperature Sensor
1	Needle Valve Fuel
8	Spark Plug
1	Engine Speed Sensor
16	Gasket – Combustion Probe
9	Gasket – Thermostat Hsg – JW/SCAC
6	Oil Filters
1	Filtered/Unfiltered Oil Press Sensor
1	Crankcase Pressure Sensor
12	Seal – Thermostat (ALL)
1	Filter – Fuel
2	Air Cleaners
1	Thermocouple – Cyl Head
1	Gasket Kit – Fuel Metering Valve
1	Seal Kit – Fuel Metering Valve
2	Seal – Oil Filter Cover
1	Seal – Valve Mech
8	Adapter – Head Ferrule
1	Cover Gp – Magneto (Board As)
1	Check Valve As – Prechamber
16	Gasket – Check Valve
2	Seal Kit – JW/SCAC Pump
3	Gasket – Thermostat Hsg JW/SCAC
1	Transformer Ignition
1	Engine Oil Temperature Sensor
1	Oil Pressure Sensor
1	Kit – Gas Shutoff Rebuild
1	Rod End – LH
1	Rod End – RH
1	Seal – Block Side Cover
1	Seal – Rocker Base Cover
1	Air/Fuel Temperature Sensor
1	Detonation Sensor
1	Air Start Solenoid
8	Combustion Probes
16	Gasket – Main Chamber Spark Plug
1	Gas Shutoff Valve
1	Gasket – JW Cover
2	Gasket – Thermostat Has Oil
2	Was As – Sensor (Combustion)

14.0 G3600 Engine Commissioning References

Title	Form Number
Gas Engines Application and Installation Guide	LEKQ2368
EDS 50.5 – Cooling System Field Test	LEKQ7235
Engine Installation and Service Handbook	LEBV0915
Coolant and Your Engine	SEBD0970
EDS 56.0 – Water Treatment Recommendations for Ebullient and Solid Water Cooled Engines	LEKQ8567
Service Manual 3606 & 3608 Spark Ignited Engines	SENR5500
Service Manual 3612 Spark Ignited Engines	SEBU6278
Operation and Maintenance Manual: G3600 Inline Industrial and EPG Gas Engines	SENR4259
Operation and Maintenance Manual: G3600 Vee Industrial and EPG Gas Engines	SENR5535
Spark Ignited Engine Programs (Methane No. and NOx) 3 1/2 inch diskettes	LEKQ6378
Gas Engine Lubrication Specification	SEBU6400
G3600 Sales Manual	LEKQ3478
Installation and Initial Start-up Procedure for G3600 Engines	REHS1336

15.0 G3600 Engine Commissioning Tools List

Quantity	Description	Part Number
As required	Adapter 1/4 in NPT male	5P2725
As required	Adapter 1/8 in NPT male	5P2720
As required	Adapter 9/16" STOR (3J1907 O-ring seal)	5P3591
2	Probe	5P2718
As required	1/8"NPT X 1/4" NPT bushing	4M5317
As required	1/4"NPT X 1/2" NPT bushing	6B5072
1	Screwdriver – Phoenix contact	9U6461
1	Pressure group	1U5470
1	Coolant tester °F	5P0957
1	Coolant tester °C	5P3514
1	Coolant conditioner test strips	4C9297
1	Coolant test kit	8T5296
1	Multimeter (Fluke 87)	9U7330
1	Scopemeter (Fluke 99) (optional)	131-4870
1	Probes-multimeter spoons	7X1710
1	Temperature adapter group	6V9130
8 Inline; 16 Vee	Regulator (thermostats must be block open)	4W4011, etc.
4 Inline; 8 Vee	Gasket-housing cover (thermostat)	7W3688
4 Inline; 8 Vee	Gasket-housing flange (thermostat)	1S5772
4	Gasket-pump inlet	4W7749
As needed	Gasket-spark plug	9Y6792
1	Socket-spark plug	4C4601
1	Exhaust analyzer	COSA6000
1	Yoke	6V2042
1	Bar	6V2043
2	Dial indicator test group	8T5096
1	Crankshaft deflection dial indicator	Starrett #696

G3600 Engine Commissioning Tools List continued

Quantity	Description	Part Number
1	Indicator – spark plug firing	9U6695
1	Bolt-1" 8 thd NC X 7 1/2" long (for inline engine)	2B7218
1	Nut-thin (or 2J3507 full Nu	1B4333
1	Tester- Magneto	9U6958
1	Ammeter-clamp on	8T0900
1	Cat Electronic Technician installed on laptop	NEXG5007
1	Communications II Adapter and Software	171-4400
1	Dielectric grease	4C9504

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