Small Gas OEM Guide

Gas Compression G3300, G3400,
and CG137 Engines

LEBW0063

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Small Gas OEM Guide

Introduction

This OEM Guide provides packaging tips for Cat® G3300, G3400, and CG137 engines. At the time of publishing, this data is correct; updates will be included periodically and republished. Dealers and customers may use Gas Engine Rating Pro (GERP) for the most current data available.

This guide is intended to provide designers, manufacturers, and users of Cat G3300, G3400, and CG137 driven gas compression packages with field-tested best practices for the planning, design, and installation of the engines. The use of this guide is intended to complement the material available in the Application and Installation Guides (A&I Guides) by providing material specific to small gas engines. The A&I Guides remain the library for general technical information about Cat products and therefore, are the most suitable to address aspects of how engine systems work. This guide complements that material by providing material specific to how the installation of the engine in a gas compression package is performed. The OEM Guide and the A&I Guides, therefore, are intended to be the reference material for planning and design, up to the point of engine commissioning into operation. G3300, G3400, and CG137 maintenance is best addressed by the Operation and Maintenance Manual (OMM).

Adherence to these guidelines will help ensure the engines achieve their rated performance with high reliability, durability, and serviceability, while maintaining emissions compliance. The information contained in this guide is sourced from engineers and field personnel with significant experience in the commissioning and serving of small gas engines in gas compression applications. Following these recommendations will reduce the risks of package installation and start up issues, performance problems, and unplanned and/or extended maintenance downtime. Significant time and cost reduction during commissioning can be achieved by following the recommendations in this guide.

This guide is not intended to provide detailed package design information nor replace the expertise and engineering judgment of the system designer. It is also intended to complement, not replace, applicable A&I information and service manuals. Caterpillar acknowledges that specific project parameters may cause deviations from these guidelines. Exceptions to these guidelines are at the discretion of the manufacturer, operator, and owner of the compression package.

Small Gas Engines

Overview

Small gas engine offerings from Caterpillar include the G3300, the G3400, and the CG137 series engines. These engines are based on an internally combusted, open chamber, four-stroke cycle that is gaseous fueled, spark ignited, and either naturally aspirated or turbocharged-aftercooled. All small gas engines are rich burn, with the exception of the G3408C and G3412C lean burn ratings. The G3304, G3306, and G3406 engines are inline block configurations. The G3408, G3412, CG137-8, and CG137-12 are vee block configurations. The power ranges from 71 bkW (95 bhp) with the G3304B to 475 bkW (637 bhp) with the G3412C.

Certain G3300B and CG137 series engines use the ADEM™ A4 engine management system, which provides ignition, speed governing, air/fuel ratio control, and protection/diagnostics. The G3300 and G3400 rich burn engines use the Cat® Digital Ignition System (DIS), while the G3400C (lean burn) engines use the Cat Electronic Ignition System (EIS), both governed mechanically.

General

System Description Metric (English)	G3300			
	G3304	G3304B	G3306	G3306B
Cylinder Bore mm (in)	121 (4.75)			
Stroke mm (in)	152 (6)			
Displacement Per Cylinder L (in^3)	1.75 (106.3)			
Aspiration	NA		NA, TA, TAA	
Control and Protection	DIS, Governor, Shutoffs	ADEM A4	DIS, Governor, Shutoffs	ADEM A4
Combustion	Rich Burn			
Mean Piston Velocity m/s (ft/min)	3.8 (1800)			
Rotation (viewed from flywheel end)	Counter-clockwise			
Flywheel Teeth	156			

Table 1: G3300 Engine Specifications

System Description Metric (English)	**G3400**		
	G3406	**G3408 G3412**	**G3408C G3412C**
Cylinder Bore mm (in)	137 (5.4)		
Stroke mm (in)	165 (6.5)	152 (6)	
Displacement Per Cylinder L (in^3)	2.4 (149)	2.25 (137.3)	
Aspiration	NA or TA		TA
Control and Protection	DIS, Governor, Shutoffs		EIS, Governor, Shutoffs
Combustion	Rich Burn		Lean Burn
Mean Piston Velocity m/s (ft/min)	4.1 (1950)	3.8 (1800)	
Rotation (viewed from flywheel end)	Counter-clockwise		
Flywheel Teeth	113	136	

Table 2: G3400 Engine Specifications

System Description Metric (English)	**CG137**
Cylinder Bore mm (in)	137 (5.4)
Stroke mm (in)	152 (6)
Displacement Per Cylinder L (in^3)	2.25 (137.3)
Aspiration	TA
Control and Protection	ADEM A4

System Description Metric (English)	CG137
Combustion	Rich Burn
Mean Piston Velocity m/s (ft/min)	3.8 (1800)
Rotation (viewed from flywheel end)	Counter-clockwise
Flywheel Teeth	113 (CG137-8), 136 (CG137-12)

Table 3: CG137 Engine Specifications

G3304

Number of Cylinders 4
Arrangement.. I-4
Compression Ratio.................................. 10.5:1
Total Displacement.......................... 7 L (425 in^3)
Firing Order 1-3-4-2

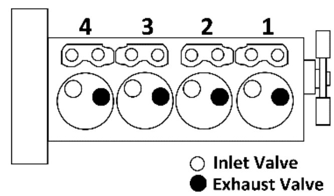


Figure 1: G3304 Valve Arrangement

G3306

Number of Cylinders 6
Arrangement.. I-6
Compression Ratio.........................8:1 or 10.5:1
Total Displacement..................... 10.5 L (638 in^3)
Firing Order 1-5-3-6-2-4

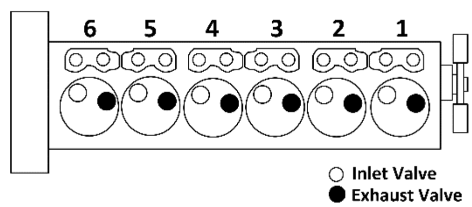


Figure 2: G3306 Valve Arrangement

G3406

Number of Cylinders 6
Arrangement.. I-6
Compression Ratio...................... 9.4:1 or 10.3:1
Total Displacement..................... 14.6 L (893 in^3)
Firing Order 1-5-3-6-2-4

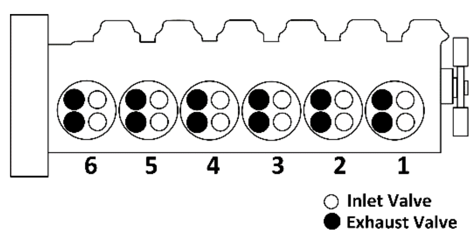


Figure 3: G3406 Valve Arrangement

G3408

Number of Cylinders 8
Arrangement..V-8
Compression Ratio..........................8.5:1 or 9.7:1
Total Displacement .... 18 L (1098 in^3)
Firing Order 1-8-4-3-6-5-7-2

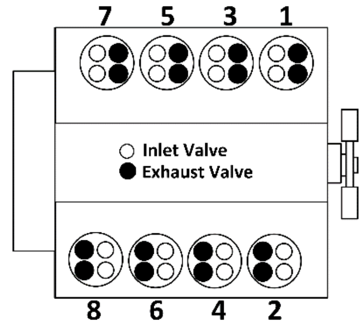


Figure 4: G3408 Valve Arrangement

G3412

Number of Cylinders 12
Arrangement..V-12
Compression Ratio.................................... 8.5:1
Total Displacement .... 27 L (1648 in^3)
Firing Order 1-4-9-8-5-2-11-10-3-6-7-12

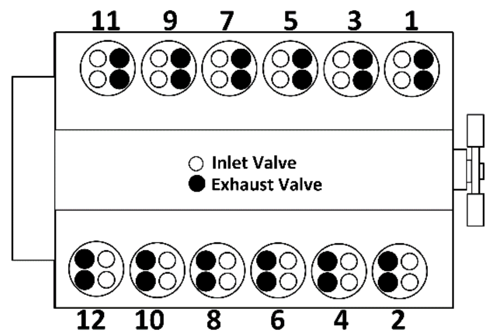


Figure 5: G3412 Valve Arrangement

CG137-8

Number of Cylinders 8
Arrangement..V-8
Compression Ratio.................................... 8.3:1
Total Displacement .... 18 L (1098 in^3)
Firing Order 1-8-4-3-6-5-7-2

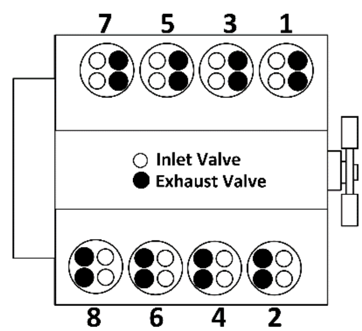


Figure 6: CG137-8 Valve Arrangement

CG137-12

Number of Cylinders 12
Arrangement.. V-12
Compression Ratio...................................... 8.3:1
Total Displacement .... 27 L (1648 in^3)
Firing Order 1-4-9-8-5-2-11-10-3-6-7-12

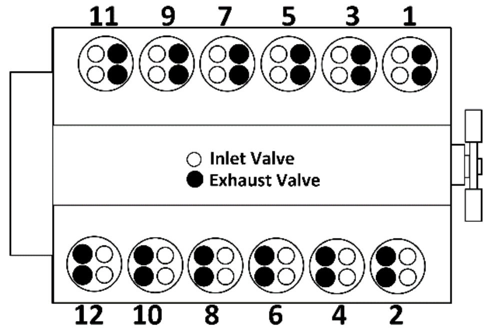


Figure 7: G137-12 Valve Arrangement

Engine Ratings

The standard ratings for the G3300, G3400, and CG137 engines are listed in Table 4, Table 5, Table 6, and Table 7. Depending on the particular engine and configuration, a wide range of fuel qualities are acceptable. Minimum methane content varies between engine series due to differences related to compression ratio and ignition control. Gas Engine Rating Pro (GERP) must be used to calculate a fuel samples compatibility with the engine. H_2S content is limited to either a maximum 10 ppm or 50 ppm.

Caterpillar may approve special ratings for fuel values not acceptable in GERP. A special rating request must be submitted to the appropriate dealer. Approved special ratings will depend on the individual characteristics of a fuel sample.

H_2S Restrictions

The following engines are limited to a maximum of 10 ppm H_2S with standard equipment and a maximum 50 ppm H_2S with special equipment:

- G3300 TA HPG
- G3400 TA LPG
- CG137-8
- CG137-12

G3304 Engines									
Engine Model	**Aspiration**	**Emissions Configuration**	**Rating Feature Code**	**Power/Rated Speed bkW (bhp)**	**Compression Ratio**	**Operating Speed** Range rpm**	**SCAC* Temp °C (°F)**	**NOx g/bhp-hr**	**O2 Setting**
G3304B	NA	Integrated Catalyst	HPW0095	71 (95) @ 1800 rpm	10.5	900 to 1800	N/A	0.5	-
G3304B	NA	Integrated Catalyst	HPW0095	71 (95) @ 1800 rpm	10.5	900 to 1800	N/A	1.0	-
G3304B	NA	Export Only	HPW0095	71 (95) @ 1800 rpm	10.5	900 to 1800	N/A	-	2.0%
G3304B	NA	Customer TWC and Cat AFRC	HPW0095	71 (95) @ 1800 rpm	10.5	900 to 1800	N/A	-	0.4%
G3304B	NA	Customer TWC and AFRC	HPW0095	71 (95) @ 1800 rpm	10.5	900 to 1800	N/A	-	0.4%

TWC – Three Way Catalyst
AFRC – Air/Fuel Ratio Control

* Separate Circuit Aftercooling
** Operating speed dependant on ambient conditions

Table 4: Currently Available Standard G3304 Ratings

G3306 Engines									
Engine Model	Aspiration	Emissions Configuration	Rating Feature Code	Power/Rated Speed bkW (bhp)	Compression Ratio	Operating Speed** Range rpm	SCAC* Temp °C (°F)	NOx g/bhp-hr	O2 Setting
G3306B	NA	Integrated Catalyst	HPW0145	108 (145) @ 1800 rpm	10.5	1000-to 1800	N/A	0.5	-
G3306B	NA	Integrated Catalyst	HPW0145	108 (145) @ 1800 rpm	10.5	1000-to 1800	N/A	1.0	-
G3306B	NA	Export Only	HPW0145	108 (145) @ 1800 rpm	10.5	1000-to 1800	N/A	-	2.0%
G3306B	NA	Customer TWC and Cat AFRC	HPW0145	108 (145) @ 1800 rpm	10.5	1000-to 1800	N/A	-	0.6%
G3306B	NA	Customer TWC and AFRC	HPW0145	108 (145) @ 1800 rpm	10.5	1000-to 1800	N/A	-	0.6%
G3306B	TA	Integrated Catalyst	HPR0203	151 (203) @ 1800 rpm	8	1200 to 1800	54 (130)	0.5	-
G3306B	TA	Integrated Catalyst	HPR0203	151 (203) @ 1800 rpm	8	1200 to 1800	54 (130)	1.0	
G3306B	TA	Export Only	HPR0203	151 (203) @ 1800 rpm	8	1200 to 1800	54 (130)	-	2.0%
G3306B	TA	Customer TWC and Cat AFRC	HPW0203	151 (203) @ 1800 rpm	8	1200 to 1800	54 (130)	-	0.3%
G3306B	TA	Customer TWC and AFRC	HPW0203	151 (203) @ 1800 rpm	8	1200 to 1800	54 (130)	-	0.3%
G3306B	TAA	Integrated Catalyst	HPR0211	157 (211) @ 1800 rpm	8	1200 to 1800	32 (90)	0.5	-
G3306B	TAA	Integrated Catalyst	HPR0211	157 (211) @ 1800 rpm	8	1200 to 1800	32 (90)	1.0	-
G3306B	TAA	Customer TWC and Cat AFRC	HPR0211	157 (211) @ 1800 rpm	8	1200 to 1800	32 (90)	-	0.3%

TWC – Three Way Catalyst
AFRC – Air/Fuel Ratio Control

* Separate Circuit Aftercooling
** Operating speed dependant on ambient conditions

Table 5: Currently Available Standard G3306 Ratings

G3400 Engines									
Engine Model	Aspiration	Emissions Configuration	Rating Feature Code	Power/Rated Speed bkW (bhp)	Compression Ratio	Operating Speed** Range rpm	SCAC* Temp °C (°F)	NOx g/bhp-hr	O2 Setting
G3406	NA	Customer TWC and AFRC	HPW0215	160 (215) @ 1800 rpm	10.3	1000 to 1800	-	-	0.4%
G3406	NA	Export Only	HPW0215	160 (215) @ 1800 rpm	10.3	1000 to 1800	-	-	2.0%
G3406	TA	Customer TWC and AFRC	HPW0276	206 (276) @ 1800 rpm	9.4	1400 to 1800	54 (130)	-	0.3%
G3406	TA	Export Only	HPW0325	242 (325) @ 1800 rpm	9.4	1400 to 1800	54 (130)	-	2.0%
G3408	NA	Export Only	HPW0255	190 (255) @ 1800 rpm	9.7	1000 to 1800	-	-	2.0%
G3408	TA	Export Only	HPW0400	298 (400) @ 1800 rpm	8.5	1400 to 1800	54 (130)	-	2.0%
G3408C	TA	Export Only***	HPW0425	317 (425) @ 1800 rpm	8.5	1400 to 1800	54 (130)	2.0	-
G3412	TA	Export Only	HPW0600	448 (600) @ 1800 rpm	8.5	1400 to 1800	54 (130)	-	2.0%
G3412C	TA	Export Only***	HPW0637	475 (637) @ 1800 rpm	8.5	1400 to 1800	54 (130)	2.0	-

TWC – Three Way Catalyst
AFRC – Air/Fuel Ratio Control

* Separate Circuit Aftercooling
** Operating speed dependant on ambient conditions
*** Customer oxidation catalyst required

Table 6: Currently Available Standard G3400 Ratings

CG137 Engines									
Engine Model	Aspiration	Emissions Configuration	Rating Feature Code	Power/Rated Speed bkW (bhp)	Compression Ratio	Operating Speed** Range rpm	SCAC* Temp °C (°F)	NOx g/bhp-hr	O2 Setting
CG137-8	TA	Customer TWC and Cat AFRC	HPW0400	298 (400) @ 1800 rpm	8.3	1350 to 1800	54 (130)	-	0.5%
CG137-12	TA	Integrated Catalyst	HPW0600	447 (600) @ 1800 rpm	8.3	1350 to 1800	54 (130)	0.5	-
CG137-12	TA	Integrated Catalyst	HPW0600	447 (600) @ 1800 rpm	8.3	1350 to 1800	54 (130)	1.0	-
CG137-12	TA	Customer TWC and AFRC	HPW0600	447 (600) @ 1800 rpm	8.3	1350 to 1800	54 (130)	-	4.0%

TWC – Three Way Catalyst
AFRC – Air/Fuel Ratio Control

* Separate Circuit Aftercooling
** Operating speed dependant on ambient conditions

Table 7: Currently Available Standard CG137 Ratings

Engine Configuration

The G3300, G3400, and CG137 engine configurations begin with a standard set of features to which mandatory and optional attachments are added. These options are available to increase the versatility demanded by different end-user applications. Listed below is an overview of options that can be implemented on small gas engines.

The standard and optional features in the pricelist are subject to change from what is listed in this section. Please consult your dealer for determining the latest available configurations.

Standard Equipment

Control System

The G3300B and CG137 series engines come equipped with the ADEM A4 control system. The ADEM A4 provides the engine with ignition, speed governing, and protection/diagnostics. Air/fuel ratio control is provided on select engine ratings. The ADEM A4 is CSA certified for Class 1, Div 2, Group D.

The G3400 series engine come equipped with the Woodward PSG governor, a hydraulically-actuated mechanical system. The speed control is through a manual positive locking mechanism.

The G3408C and G3412C engines are equipped with the Woodward ProAct II governor. The governor uses a digital control system, coupled with an electronic actuator to adjust the engine speed. The system is CSA certified for Class 1, Div 2, Group C&D, Zone 2.

Air Inlet System

The G3300B engines are supplied with an intermediate duty air cleaner, with a shipped loose rain cap as standard. The G3406 comes with a heavy duty air cleaner and rain cap. The G3408, G3412 and CG137 engines come standard with a single element air cleaner. All engines come standard with a service indicator for the air cleaner.

Cooling System

All small gas engines come equipped with an onboard jacket water thermostat and housing. The small gas engines also come standard with gear driven, centrifugal, non-self-priming water pumps for both the jacket water and aftercooler circuit (TA only). For TA engines, the onboard aftercooler contains a rust resistant stainless steel core, suitable for treated water and sea air atmospheres.

Exhaust System

All small gas engines come with water cooled exhaust manifolds and dry exhaust elbows. The G3300B and CG137-12 series engines have the option of either a Caterpillar supplied three-way catalyst or a customer supplied catalyst, based on selected rating.

Flywheels and Flywheel Housings

All small gas engines follow the standard SAE rotation (counter-clockwise while looking at flywheel end).

The G3406 engine has a single bolt pattern SAE No. 14 flywheel, surrounded by a SAE No. 1 flywheel housing.

The G3300B engine has dual bolt pattern SAE No. 11-1/2 and No. 14 flywheel, surrounded by a SAE No. 1 flywheel housing.

All other G3400 (except for G3406) and CG137 engines have a dual mount SAE No. 14 or No. 18 flywheel, surrounded by an SAE No. 0 flywheel housing.

Fuel System

All small gas engines come with a gas regulator and natural gas jetted carburetor. A fuel filter is required and does not come as standard but may be ordered as an optional attachment or provided by the customer.

The required gas pressure varies between engines and the specific requirements for the desired rating should be referenced. Generally, low pressure gas fuel systems are required to maintain an inlet pressure of between 10.3 kPa (1.5 psi) to 34.5 kPa (5 psi). High pressure gas fuel systems are required to maintain between 137.9 kPa (20 psi) to 172.4 kPa (25 psi).

Lubrication System

All small gas engines come standard with an oil cooler, an oil filtration system, and a top mounted crankcase breather system. The oil fill and oil dipstick are mounted on the right-hand side for the G3400 and CG137 engines and on the left for the G3300 engines.

The G3408C engine comes standard with a deep sump oil pan. The G3406 engine comes standard with either a shallow sump or deep sump oil pan. All other small gas engines come with a standard sized pan.

Mounting System

The G3300, G3400, and CG137-8 engines come standard with integrated engine supports. The G3412C and CG137-12 engines come standard with 254 mm (10 in) wide rail mounts.

Protection System

The G3300B and CG137 engine series utilize the ADEM A4 engine control system for protection. The ADEM A4 has alarm and shutdown features which monitors inlet manifold air temperature and pressure, oil temperature and pressure, coolant temperature, engine speed, battery voltage, as well as catalyst inlet/outlet temperatures. Service hours are also available via the ADEM A4 system.

The G3408C and G3412C engines come standard with detonation sensitive timing control through the Cat EIS. All other G3400 series engines require a selection of protection equipment under mandatory attachments.

General

All small gas engines come standard with Caterpillar yellow paint. The crankshaft vibration damper, front drive pulley and lifting eyes also come standard on all small gas engines. The CG137 series engines come standard with cylinder block inspection covers for quick access to the crankcase for service.

Mandatory Attachments (customer selection required)

Application

The market segment for which the engine will be used in must be selected. Options for the market include Industrial, Petroleum Land Drilling, Petroleum Gas Compression, Petroleum Land Production/Pumping, and Petroleum Offshore Production.

An export tag is required for engines that do not meet certain regulatory emission requirements. Certain engine ratings will require the export tag to be selected as an attachment.

Engine Sump Type

The G3406 engine requires a selection between a deep sump oil pan and shallow sump oil pan. The shallower pan will require a shorter oil change interval.

Compression Ratio

The G3406 engine requires the selection between two compression ratios, 9.4 or 10.3. The 9.4 compression ratio is for turbocharged engines and the 10.3 compression ratio is for naturally aspirated engines.

Fuel Pressure

The G3406 and G3408 engines require a selection of either high or low pressure gas supply. Site conditions and desired rating will dictate the required selection. Low pressure gas fuel systems are required to maintain an inlet pressure of between 10.3 kPa (1.5 psi) to 34.5 kPa (5 psi). High pressure gas fuel systems are required to maintain between 137.9 kPa (20 psi) to 172.4 kPa (25 psi).

Engine Rating and Speed

Ratings

Depending on the site conditions and required power needs, a selected rating and speed is required. If the site conditions and required power needs are not met, a special rating request can be submitted to the Applications and Installation team for further review.

Emissions Levels

The engines required emissions level must be selected as either standard emissions level, catalyst emissions level, or customer supplied catalyst emissions level depending on desired configuration.

Charging System

The CG137 engine series requires the selection of a 24V 65A alternator system or a customer supplied alternator system.

Cooling System

The CG137-8 requires the selection of either a factory installed SCAC thermostat or a customer supplied SCAC thermostat. The factory supplied thermostat is mounted on the left-hand side of the engine and regulates the inlet water at 54°C (129°F).

Instrumentation

The CG137 engines require the selection of having an enclosed operator interface panel or no operator interface panel.

European Certifications

European Union DOI certification is available for all small gas engines and a selection is required as to whether or not it is needed.

Ignition

G3408 and G3412 engines require the selection of the ignition system. The standard EIS system can be replaced with either a digital Canadian Standards Association (CSA) certified ignition system or a CSA ignition system with Air/Fuel Ratio Control (AFRC) control through a provided NOx sensor.

Lube System

The G3408, G3412, and CG137 engines have the option of having the engine filled at the factory with lubricating oil.

Protection System

G3400 engines have the option of varying shutoff types. Options available for shutoffs are either self-powered shutoff, auto start-stop shutoff, or customer supplied shutoff. All other small gas engines use the ADEM A4 for protection.

The G3406 has three different types of gas valves to choose from. A selection can be made from energized to start (ETS) (requires self-powered shutoff), gas shut off valve (GSOV), or a CSA certified GSOV.

The gas valve selection will be primarily based off the start-stop system selected.

Starting System

Several options are available for the starting system on a small gas engine. The selection will depend on available air or gas supply and/or whether or not CSA certification is required. All small gas engines have the option of a vane starter or a 24V electric starter. Turbine starters are available for the G3300 and CG137 engines. An option is also available for a customer supplied starter.

Power Take-Offs

CG137 engines have the option of selecting a flywheel stub shaft, a front stub shaft, and a crankshaft pulley listed under mandatory selections. The G3306B engine requires the selection of a damper guard or a customer supplied damper guard. All other power take-off options for the G3304B, G3400, and CG137 engines are listed under optional equipment.

Torsional Vibration Analysis

Caterpillar requires that all small gas engines have a torsional vibration analysis performed. An industrial torsional analysis is available for both the engine and reciprocating compressor applications. Additional compressor load cases for analysis can be added under optional equipment.

Optional Equipment

Air Inlet System

The G3400 and CG137 engines have the option of a precleaner, air cleaner adapter for a remote air intake, and rain caps for weather protection. The G3406's only option is for a precleaner as it already comes standard with a rain cap. The G3300 engines also come standard with rain caps shipped loose. Specifically, the G3408 and G3412 engines have the option of a dual element air cleaner, which enables servicing the air cleaner while the engine is running.

Charging System

A 24V 35A alternator is available as an option on all small gas engines. The G3300 engines have the option of selecting a CSA or non-CSA certified alternator. The G3400 series engines offer the option of an ammeter gauge and associated wiring. The CG137 engine lists the alternator option under mandatory attachments.

Control System

The G3406 engines come with the option of a 24 VDC motor for remote control of engine speed.

Cooling System

The G3300, G3406, and G3408 engines have the option of a jacket water radiator. G3300 and G3406 engines also have several fan drive options.

Exhaust System

All small gas engines offer a flexible fitting, elbow, and flange for the exhaust system. A catalyst extension harness is also available for the G3306B and CG137-12 engine. The G3406 engine has exhaust piping, a muffler, and rain cap available as an option.

Fuel System

A fuel filter is required for all small gas engines and is available from the factory as an option. The G3400 engine series offers stoichiometric and low pressure gas conversion kits.

Ignition System

The G3400 series engines offer CSA certified digital ignition system with available wiring harness and power supply. The G3408 and G3412 engines also offer a digital ignition alternator with or without CSA certification.

Instrumentation

The G3300 series engine offers the Messenger Operator Interface Panel shipped loose and either enclosed or not. The G3306 and CG137 engines offer the option of the Cat Connect® system, depending on the location of where the engine will be installed. An external or internal radio system is available, as is an external satellite antenna. Varying length interconnect harnesses are also available for the G3300 and CG137 engines.

The G3400 engine series offers either a left or right mounted instrument panel with oil pressure and water temperature gauges. A tachometer is also available for mounting atop the instrument panel. The G3408 and G3412 engines also offer the PL1000T and PL1000E communications modules. The PL1000E is LAN capable and can communicate via MODBUS.

Lubrication System

The G3408 engine offers an auxiliary oil reservoir for shallow sump oil panned engines. The added oil capacity extends the oil change interval to 750 hours.

Power Take-Offs

The G3300 and G3400 engine series offer a flywheel and front stub shaft attachment as an option. The G3400 engine series offers an enclosed clutch and support. Auxiliary drive pulleys are available on the G3300 and G3406 engine. The G3306B specifically offers an auxiliary water pump option.

Protection System

As optional protection for the G3408 and G3412 engines, an ETS 24V CSA certified gas valve is offered. If the energize to start (ETS) system is selected, this gas valve can be selected as an option. See standard and mandatory attachments for other small gas engines.

Starting System

Several starting aids are available for the G3300 and G3400 series engines. The G3306B and G3406 engines offer 24V batteries with varying amperages of 1300, 1000, or 950 cold cranking amps. Accompanying battery cables and battery rack are also available. For air start based systems, an air pressure regulator and silencer is also available.

The G3406 also offers a jacket water heater to help aid in starting the engine in cold conditions.

General

A basic tool set is available for all small gas engines for performing basic maintenance tasks on the engine. The tool set group is listed as part number 9S-7977. The tool set contains standard US sized sockets, ratchet - ½ in, wrenches, 5 in and 10 in extension, screwdrivers, pliers, pry bar, grease gun, feeler gauge, and a tool box.

The G3400 engine series lists the accessory drive options for the digital ignition system as well as the diagnostic tool for timing the EIS (electronic ignition system).

Torsional Vibration Analysis

Additional torsional vibration compressor load cases are available as an option on all small gas engines.

Literature

Technical literature for each specific engine can be ordered in print or on a CD in languages other than English. Refer to the specific pricelist for the engine to see available languages.

Decals/ Paints

Special colored paint and decals in languages other than English are available as an option. Special colored paint not listed in the pricelist will require a DTO (design to order) quote.

Tests

A standard load test and a special fuel consumption multi-point test (full, three-quarter, and half load) are available. Both tests must be requested prior to the factory build. The tested rating is not guaranteed to be the same as the rating specified in the order.

Inspections

Inspection services are offered on all small gas engines by SGS or by a miscellaneous inspection service (agency name, address, contact information required).

Packing

Depending on shipping needs, varying levels of protection from basic shrink wrapping to export packaging is available.

Technical Data

Technical data for small gas engines is readily available through the GERP software, the Technical Marketing Information database (TMI), or publications such as this guide or the specification sheets available on PowerNet. GERP has the added capability of providing technical information based on site-specific conditions such as altitude, ambient temperature, and fuel quality. The use of GERP is highly encouraged to obtain the most accurate and up-to-date technical information of small gas engines.

Gas Engine Rating Pro (GERP)

GERP is a computer application designed to provide site ratings for Cat natural gas engines for the gas compression industry. For more information on how to access GERP please go to https://engines.cat.com/gerp

To obtain site-specific performance data, the user must select the engine rating of interest, enter the site altitude, ambient temperature, and select the type of fuel. One of the fuel types in GERP can be selected or the user can use the fuel analysis tool to determine the fuel properties based on their fuel composition. This option will require the user to have the results from a fuel analysis available. The fuel quality must fall within the ranges specified in GERP. If the fuel properties fall outside of those guidelines, a special rating from Caterpillar can be requested by submitting a Special Rating Request (SRR) to the appropriate dealer.

GERP will provide the following engine performance data at standard and site conditions:

- Engine power at standard and site conditions for 100%, 75%, and 50% load
- Altitude and ambient temperature capability without derate
- Engine-out emissions (NOx, CO, CO_2, THC, NMHC, VOC's, Formaldehyde, and exhaust oxygen)
- Heat rejection
- Engine power vs. inlet air temperature graph
- Engine power vs. engine speed graph
- Engine torque vs. engine speed graph
- Engine power vs. fuel consumption graph
- Inlet manifold pressure vs. engine power graph
- Engine exhaust temperature vs. engine power
- Engine gas flow vs. engine power
- Exhaust gas mass flow vs. engine power
- NOx, CO, THC, NMHC, NMNEHC, HCHO, CO_2, Exhaust oxygen vs. engine power
- Heat rejection to jacket water, atmosphere, lube oil, and aftercooler vs. engine power
- Engine power vs. engine speed
- Engine torque vs. engine speed
- Jacket water pump curves
- Auxiliary water pump curves
- Sound data

Note that GERP also contains installation drawings and spec sheets specific to the engine of interest.

Engine Installation

This section provides an overview of best practices for the installation of Cat small gas engines in their permanent place of operation. Proper engine installation is crucial to ensure performance, reliability, and durability of the engine. In addition, it will allow for timely and cost-effective commissioning of the unit. By following the recommendations in this section, the installer can ensure that the engine has been installed along the factory commissioning guidelines. This will reduce the risk of non-compliance during dealer or packager commissioning. The material in this section covers recommendations for the installation of the engine after it is received on-site, including mounting and alignment.

Storage and Protection from the Elements

It is crucial that the engine is properly protected against corrosion and deterioration caused by direct contact with the elements. While external corrosion can be evident to the end-user, internal corrosion is often unnoticed. Internal corrosion, especially in the cooling system, can occur quickly if proper provisions are not taken into consideration to prevent it.

If the package will be received on-site but not commissioned within three months, the storage provisions outlined in the following documents should be performed:

- SEHS9031 – Storage Procedure for Cat Products.
- PEHJ0241 – Cat Engine Storage and Preservation Datasheet.

Protection from the elements is also highly recommended to ensure the longevity of the engine and its components. Even a well designed, built, and maintained engine is susceptible to corrosion due to moisture, high humidity and UV rays. The ideal setting for a small gas engine is inside an engine room. However, outside installations are commonly seen in gas compression packages. In this case, a setup like the one shown in Figure 8 is recommended. This will help reduce the effect of rain, snow, and direct sunlight to the engine. The control panel should be protected from the elements as well if it is installed outside. Placing a small roof over the panel will enhance its life and improve the technician's work area.

Figure 8: Example of compression package protected from the elements.

Lifting

Proper handling of the engine when performing mounting procedures is important to ensure its structural integrity. Cat products are equipped with special lifting points that are designed solely for the purpose of handling the engine. The engine may only be lifted from these points for handling at the site and placement into its mounting base. The location of the lifting eyes can be found on the installation drawings, which can be found on the EDDC (Engine Drawing Design Center) website, https://enginedrawings.cat.com/ or GERP (Gas Engine Rating Pro).

Mounting

This section outlines best practices for mounting the engine on the customer provided base at the site. The configuration of the mounting arrangement at the site will vary based on the specific application and the driven equipment. Because of the high degree of variability between projects, there is no universal method for mounting the engine. This section, therefore, addresses multiple methods that have proven effective in the field. The actual mounting method must be determined by best judgment of the installer based on the site characteristics.

All small gas engines, except the twelve cylinder models, come with integrated engine supports. These can be mounted directly to the mounting base. Specifically, the G3412C and CG137-12 engines come standard with rail mounts.

Integrated supports and mounting rails are specifically designed to support the engine in its permanent setup. The base at the customer site must be designed to support the engine support or rails while maintaining clearance with the oil pan and all other engine components. Refer to the installation drawings for mounting rail locations and dimensions.

The most important function of a mounting base is rigidity and its ability to maintain alignment between the engine and the driven equipment under mechanical loads and thermal expansion. The main causes of misalignment are flexing of the base, poor installation methods, and incorrect alignment procedures. This section will address these three aspects of the mounting process.

General Design Considerations

A properly designed mounting base has solid, parallel planes for each engine mounting rail. The base must be rigid enough to adequately oppose the torque exerted by the engine on the driven equipment. At the same time, the mounting system must be compliant enough to allow for thermal expansion of the engine block.

In general, a properly designed mounting scheme will meet the following specifications:

- The mounting rail locations must be horizontal and parallel to one another. Partial shims shall never be used as a remedy to unparallel mounting rails.
- Grade 8 hardware or equivalent shall be used for mounting purposes.

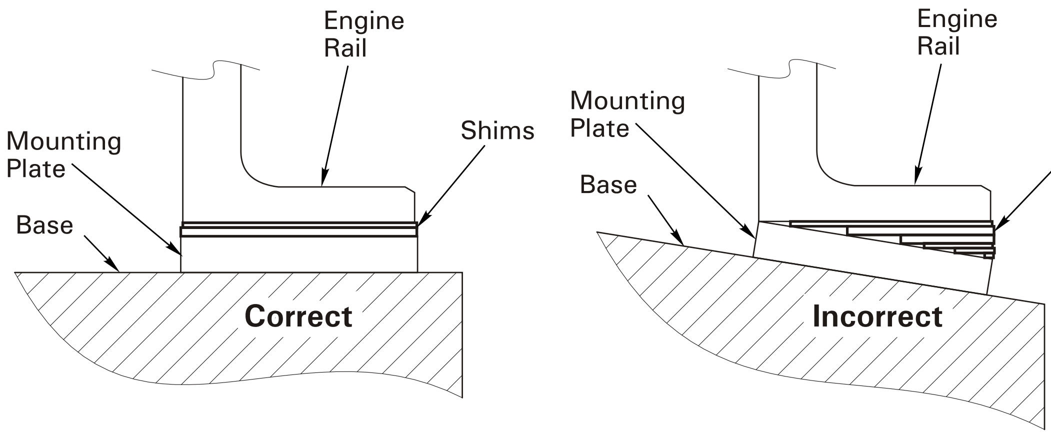


Figure 9: Correct and incorrect use of shims.

Shims

Shims are an acceptable method to get correct alignment between the engine and driven equipment. After the engine and driven equipment have been aligned, brass or some other type of non-rusting metal shims should be installed between the mounting rails of the engine or driven equipment and the base or other mounting surface. Under no circumstances should lead be used as a shim material. Lead is easily deformed under weight and vibration and has poor support characteristics. The minimum thickness of each shim pack under each mounting location should be at least 5 mm (0.200 in) to prevent later corrections requiring the removal of shims when there are too few or no shims remaining. After installation of the shims, each mounting location must carry its portion of the load.

Figure 10: Example of mounting using shims.

Mechanical Adjustable Chock Method

This method consists of securing the engine rails directly to the base by means of mechanical chocks. This mounting method is accepted but not recommended by Caterpillar. Mechanical chocks are threaded components whose height can be adjusted by turning one of the two ends. The entire weight of the load is supported by the thread of the chock and therefore, experience has shown that the threads may freeze up after long periods of operation. This results in the loss of the adjustable feature of the chock and leads to greater rework when the engine mounting needs to be adjusted. An advantage of this method is that the initial mounting of the engine is quicker and simpler. The height of the chock can be adjusted while under the load of the engine. Therefore, leveling the engine becomes a simpler task. An important note to remember when using adjustable chocks is that the concave and convex sections of the chocks must be properly lubricated before they are installed; refer to Figure 11.

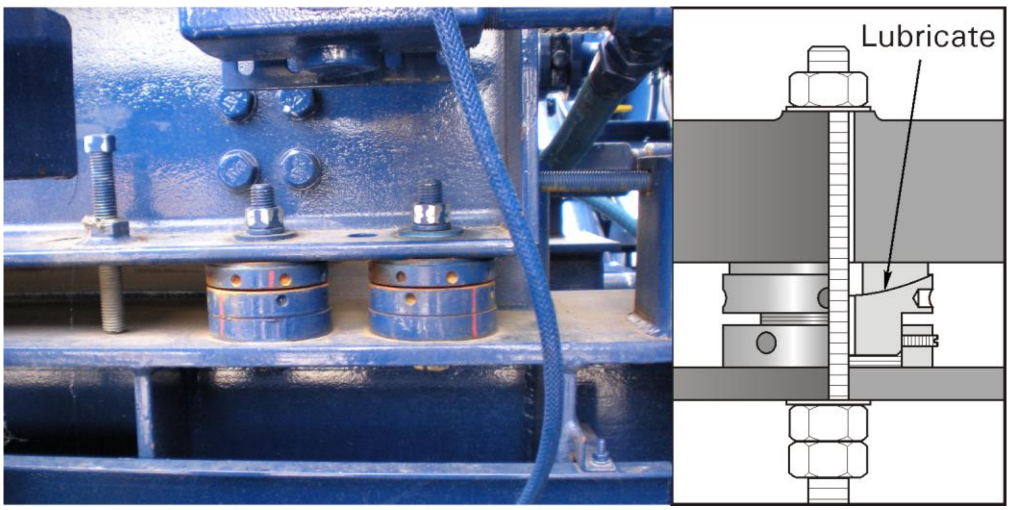


Figure 11: Example of a mechanical adjustable chock (left). Important lubrication location for proper functionality (right).

Fabricated Skids

While the previous methods are acceptable for mounting the small gas engines, the variability of projects may call for additional configurations of fabricated skids. This section provides general guidelines for mounting the engines on fabricated skids.

When the engine is mounted on a fabricated skid, the webs of the beams must be located directly under the engine mounting rails. Failure to do so will invite the use of cantilever systems between the skid and the engine's supports or rails. Arrangements like the one shown Figure 12 will have low stiffness and therefore, will twist under the torque action of the engine. The presence of unwanted vibrations is also a result of cantilever arrangements and therefore, cantilever configurations must be avoided.

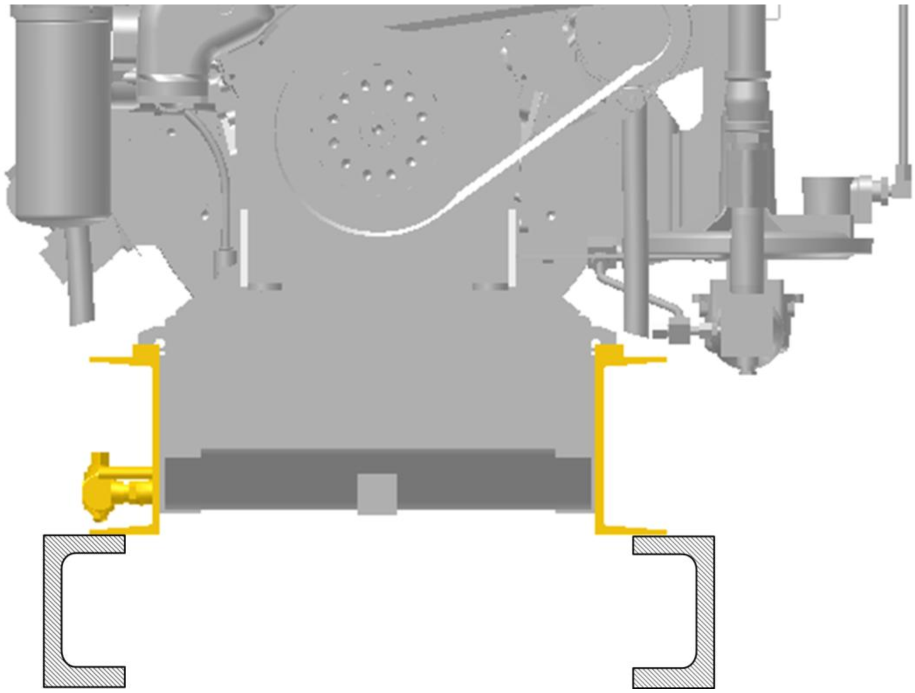


Figure 12: Example of incorrect mounting configuration due to low stiffness of a cantilever support.

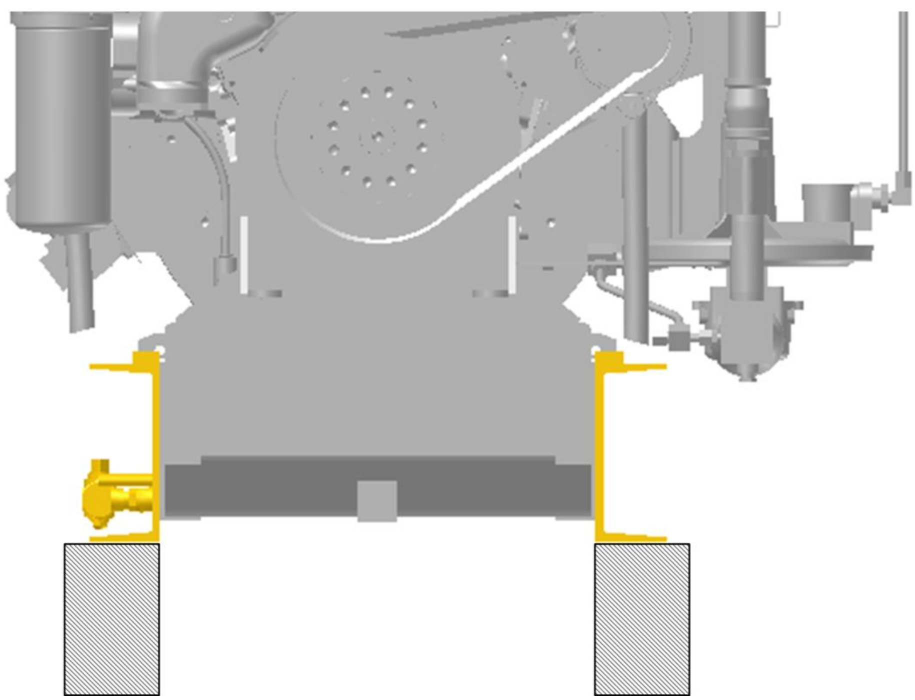


Figure 13: Example of correct mounting; No cantilever forces, engine is securely attached to the base.

Alignment

This section covers best practices for aligning the engine with the driven equipment. For a general description of alignment principles for Cat engines, please consult the Alignment A&I Guide, LEBW4975.

Proper alignment between the driving and driven equipment is crucial to ensure proper performance and the durability of the system. The procedures outlined in this section should be performed under cold and hot conditions. A cold crankshaft deflection test and alignment should be performed after the engine is secured to its foundation. The hot alignment consists of all three procedures (outlined below) performed at the operating temperature of the equipment. Once the hot results are satisfactory, the equipment has been successfully aligned.

Note: To determine when the "hot" condition has been reached, use an infrared thermometer to measure the temperature of the engine mounts. Once the temperature stops increasing, the hot operating condition has been achieved. Shut down the engine and perform the hot alignment procedures.

The following procedures should be performed when installing small gas engines in order to ensure proper alignment:

- Crankshaft end-play
- Crankshaft deflection
- Coupling alignment

Crankshaft Endplay

The crankshaft endplay alignment guarantees that the main shafts of both engine and driven equipment can move freely across their longitudinal range of motion. Failure to check endplay may result in excessive crankshaft thrust bearing loading and/or coupling failure. Cold and hot crankshaft endplay checks must be performed and the results must remain within the specification.

The inspection of the endplay on both the crankshaft and the driven equipment's main shaft must be performed. The endplay at operating temperature must not be less than endplay during cold alignment. This inspection will ensure that the thrust bearings for both devices are not damaged during operation.

Crankshaft Deflection

Improper crankshaft deflection is a consequence of poor mounting techniques. Thermal stresses, soft footing and lack of base rigidity can induce stresses into the engine block causing the crankshaft to deflect. This will substantially decrease the life of the internal components of the engine and lead to expensive repairs.

In order to check that the mounting techniques were properly performed, a cold crankshaft deflection test must be performed.

Consult the Alignment A&I Guide, LEBW4975, for a procedure to perform the crankshaft deflection test.

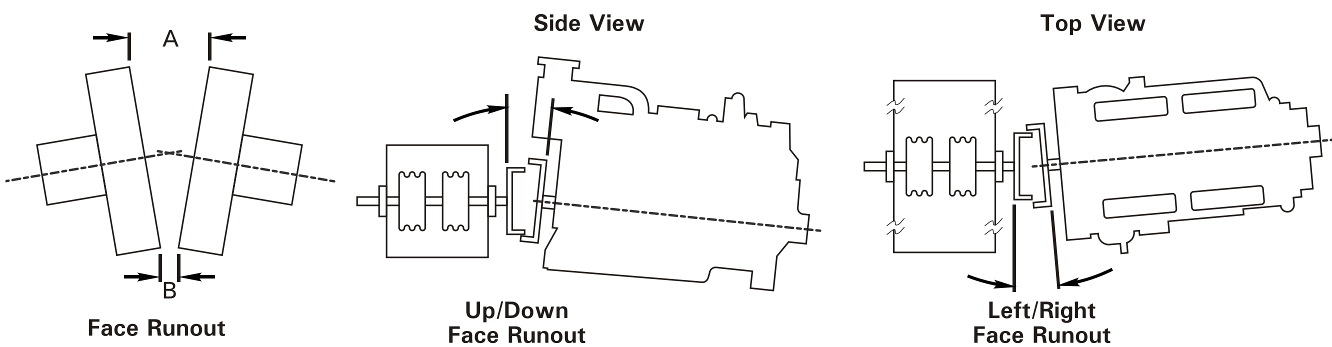
Coupling Alignment

This procedure is crucial to the proper operation of the engine in conjunction with its driven equipment. The coupler transmits power from the engine to the driven equipment and is designed to accommodate small misalignments between the two main shafts. However, those small misalignments must be within the manufacturer's specifications of the coupler. A proper alignment of the driver and driven main shafts will maximize the performance and durability of the system. Consult the Alignment A&I Guide, LEBW4975, for further explanation of potential misalignment types in small gas engines.

Alignment operations to adjust face runout and bore runout can be performed using a laser tool or dial indicators. Consult the "Laser Alignment" and "Dial Indicators" sections of REHS0423 for detailed instructions.

Face Runout

Consider two planes each perpendicular to the axis of each main shaft. If those planes are not parallel to each other, a face runout is present. Figure 14 shows a case where face runout is present in a coupler. Face runout can be an up/down or right/left misalignment. Face runout can be determined by subtracting distance B from distance A. Face runout should be measured at the 12:00 – 6:00 positions and the 3:00 – 9:00 o'clock positions. The result must be within the coupler's manufacturer's recommendation or, if not available, within the tolerance specified by Caterpillar. Caterpillar tolerances for face runout are outlined in the table in Figure 14.

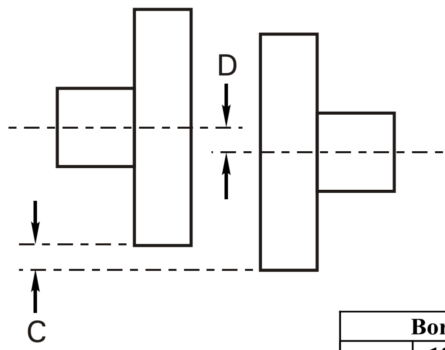


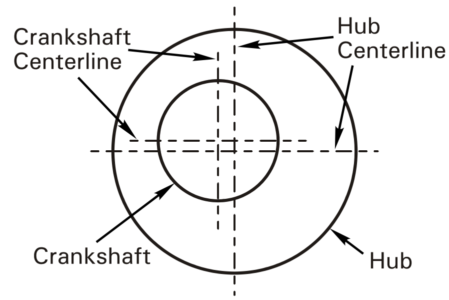
Face Runout Tolerances		
	12:00 – 6:00	3:00 – 9:00
A-B	±0.05 mm (±0.002 in)	±0.05 mm (±0.002 in)

Figure 14: Face runout and face runout tolerances.

Bore Runout

This alignment process ensures that the axis of the engine's shaft is concentric to the axis of the driven equipment. Figure 15 shows an example of bore runout. Bore runout (distance C) must be within the specifications of the coupler's manufacturer or, if not available, within the Caterpillar tolerance for face runout. The Caterpillar tolerance for face runout is outlined in Figure 15.





Bore Runout Tolerances		
	12:00 – 6:00	3:00 – 9:00
C, D	± 0.05 mm (±0.002 in)	± 0.05 mm (±0.002 in)

Figure 15: Bore runout and bore runout tolerances.

Torsional Vibration Analysis

This analysis is a valuable tool to ensure the compatibility between the engine and the driven equipment. A torsional vibration analysis studies the system as a whole rather than the driving and driven equipment separately. Because the results depend on the configuration of the system rather than on the individual components, it is crucial to perform this analysis every time a new configuration is implemented. Often, the vibrations from each piece of equipment interact and amplify causing unwanted vibrations in the system that can hurt performance or damage components.

Designing for Installation: Accommodating Vibration

The installation of the engine into a compressor package, and subsequently into the installation in which that package will operate, involves numerous connections between the engine’s systems and its surroundings. Those connections form a critical junction between a high vibration zone (the engine) and a relatively low vibration zone (the larger installation). The potential for relative movement between these two zones demands that all connections crossing the boundary between the zones be completed using flexible or compliant couplings. The image in Figure 16 is meant to emphasize the concept that all items connected to the engine should be understood to be in the high vibration zone and all items connected outside the box are part of a lower vibration zone. Any hard connections crossing the zone boundary will be subject to cyclic stresses due to the different levels of vibration present in the two zones, and for that reason are subject to fatigue.

The type of compliant connection used will depend on the requirements of the system being connected. Intake air can typically use flexible hose connections, while hot temperature exhaust commonly uses stainless steel bellows connectors. Smaller coolant connections can use hose sections, while larger diameters should use flexible joints of a design that meets the needs of the installation. Connections carrying combustible gas typically include stainless steel braided hose sections. Even electrical connections may benefit from a flexible section when crossing the vibration boundary.

When designing the connections, plan for the flexible portion of the connection to be as close to the engine as possible. All added mass that is fastened to the engine is subject to vibration; the goal is to prevent excitation of the connections by placing the mass outside the vibration boundary. Support for the connection piping is also a critical part of the design. Remember that all piping sections that extend from a point of external support can be excited by vibration. Provide support for the piping as close to the flexible connection as possible.

The engine mounts not only support the weight of the engine but also maintain its alignment with the driven equipment. For this reason these mounts must be rigid; vibration isolators are usually not allowed. Rigid mounting couples the engine and driven equipment to the larger installation. Dynamic modeling of the structures subjected to vibration can help reveal where resonant responses may occur, allowing for corrections where needed.

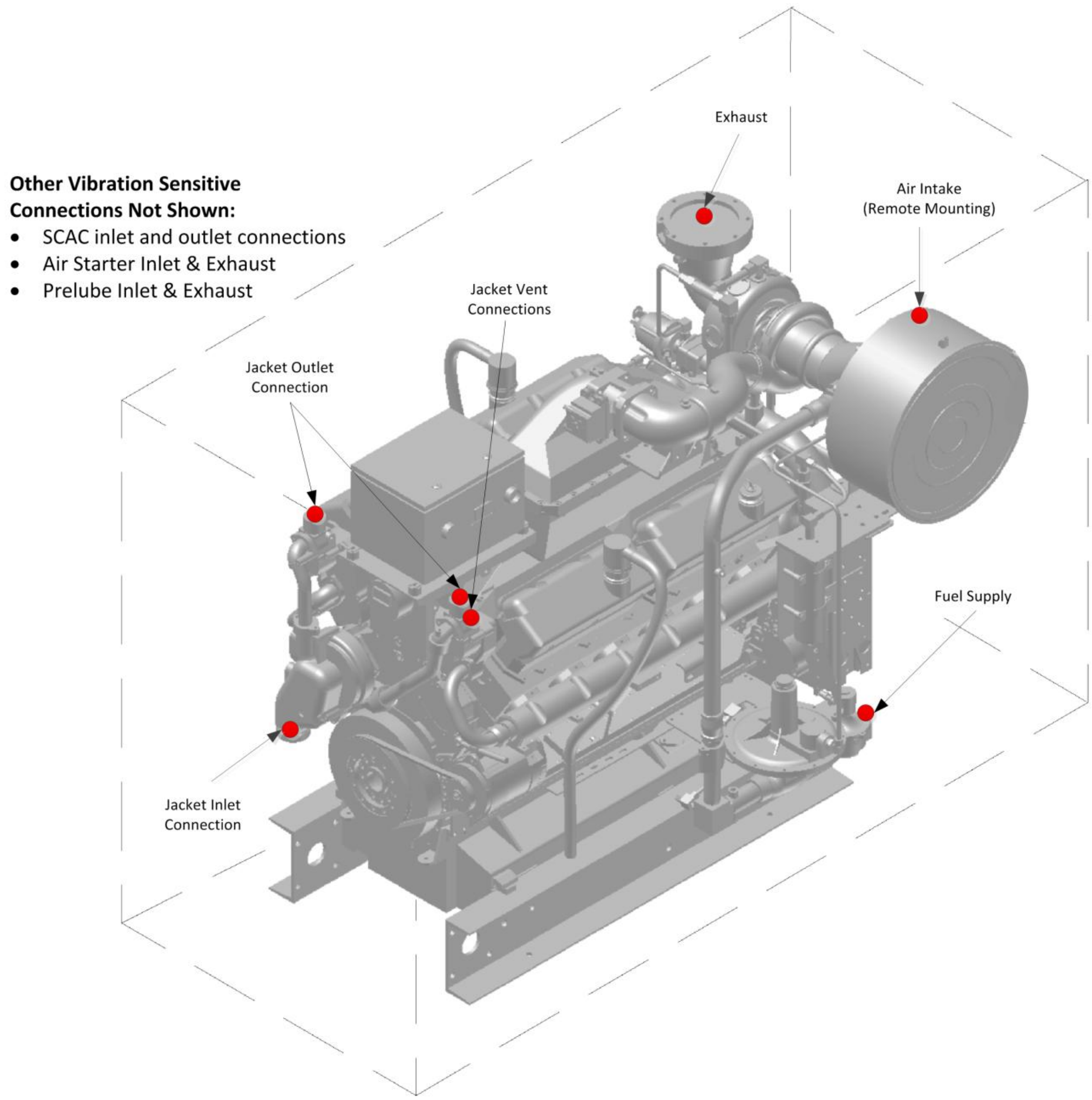


Figure 16: The engine as vibration source. All connections to the high vibration zone, shown in the boxed region, must be de-coupled from externally-supported connections (the low vibration zone) by means of flexible couplings.

Maintenance Clearances

This section provides a summary of clearance distances for maintenance purposes. A design that takes into consideration the recommended maintenance clearances in this section will benefit from improved maintenance, repair, and overhauling times in the future, thus reducing the cost associated with them.

Work Platforms

Work platforms enhance the technician's ability to do maintenance work efficiently and safely. Depending on the size of the engine and installation location, a work platform may or may not be necessary. On smaller sized engines, where a technician can easily access hard to reach maintenance components without a ladder, a work platform is not needed. The preferred work platform configuration for Cat engines complies with the following recommendations:

- Staircase Configuration - The staircase configuration shown in Figure 17 will provide the most effective means for technicians to access the platform and carry tools and parts.
- Removable Platform - Work platforms that are bolted to the ground but that can be removed are recommended. This will greatly reduce future maintenance costs of major components in the crankcase.
- Crankcase Cover - Adequate room should be provided around crankcase covers to allow comfortable access for technicians. Items accessed from the crankcase covers are connecting rods, main bearings, and piston cooling jets. Ensure that the work platform does not interfere with them.

Ensure that local regulations and codes are adhered to when constructing work platforms.

Figure 17: Work platform with staircase.

Engine Clearance

Small gas engines need adequate clearance at the front, top, and sides of the engine to perform routine and major maintenance. Common service items such as the oil filter, air filter, spark plugs, belts will need to all be serviced routinely. Clearance zones, specified in the following maintenance clearances section, are recommended to allow the technician easy access to these components for service or replacement.

General guidelines are also listed below to help facilitate the proper design and installation of the engine package. The servicing technician should always be kept in mind when making package design decisions. Adhering to these guidelines will help the technician safely, properly, and quickly service the engine.

General Guidelines for Maintenance Clearances

Lubrication System

Oil Dipstick

Oil dipstick should have a minimum clearance of 150 mm (5.9 in) around the base of the handle.

Oil Filler

Oil fill cap should have a clearance of 50.8 mm (2.0 in) around the base of the cap. Accommodations should also be made to allow a jug or bucket of oil to be easily poured into the filler neck.

Oil Drain

Oil drain should have a minimum access clearance of 150 mm (5.9 in) to allow an operators hand to reach the drain cap.

Oil Pan

Oil pan will need clearance to be removed in order to do further maintenance of the lubrication system, such as replacing the oil pump or an oil pan gasket. The G3400 and CG137 engines will have to have the engine supported from above or on a stand in order to remove the oil pan.

Air System

Air Cleaner

The air cleaner should have sufficient clearance to easily replace the air cleaner element. Refer to the typical maintenance clearances below or the specific engines installation drawing for the required clearance distance.

Air Cleaner Latches

The latches holding the air cleaner on need a clearance of 105 mm (4.1 in) in order to be able to be opened and closed correctly.

Other Common Maintenance Items

Belts

Any installed belts should have a clearance of 105 mm (4.1 in) between nearest components. This will help the technician in removal and installation of the belts.

Valve Cover

The valve cover should have an above clearance of 150 mm (6.0 in) from the highest point on the valve cover. This extra clearance helps during periodic valve lash adjustments.

Engine Barring

Engine barring ports and timing pins should have adequate access for finding the engines top dead center for the number one cylinder, a requirement for doing the valve lash adjustment.

Front Drive

The front drive system must be designed and configured in such a way that it does not require removal of front driven components while servicing the water pump, alternator, tensioner, or any other common service item located in the front of the engine.

Typical Maintenance Clearances for G3300 Engines

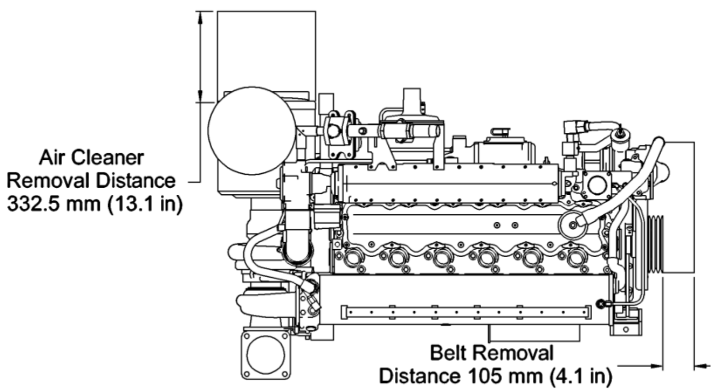


Figure 18

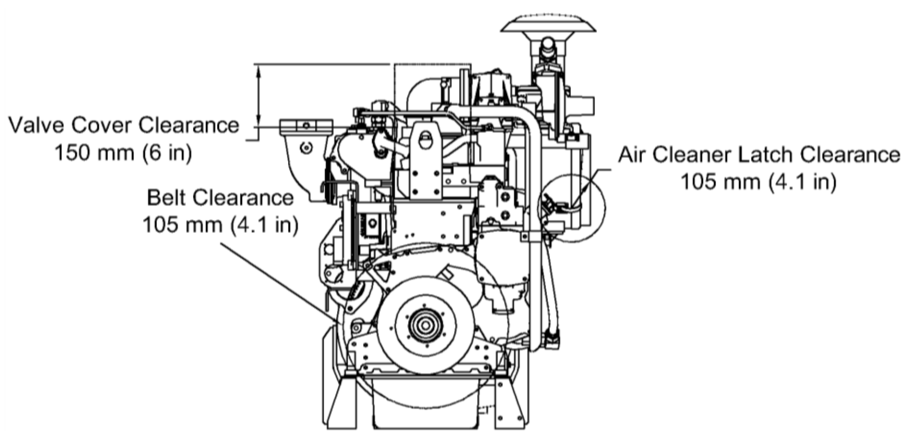


Figure 19

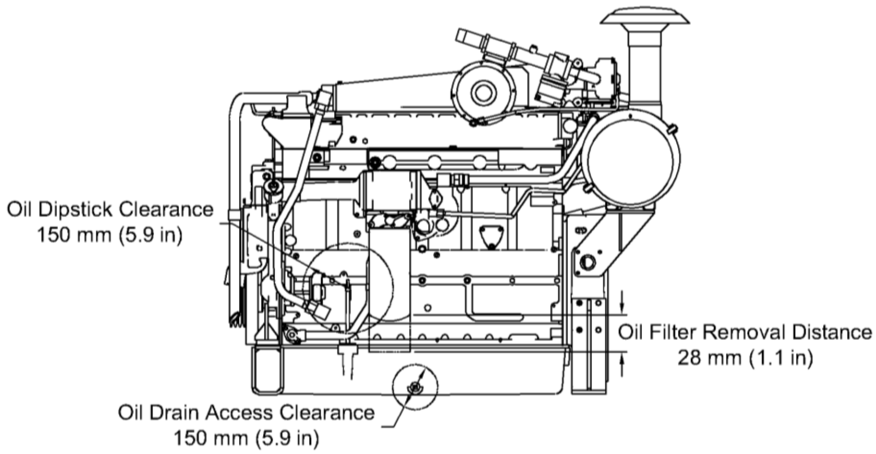


Figure 20

Typical Maintenance Clearances for G3400/CG137 Engines

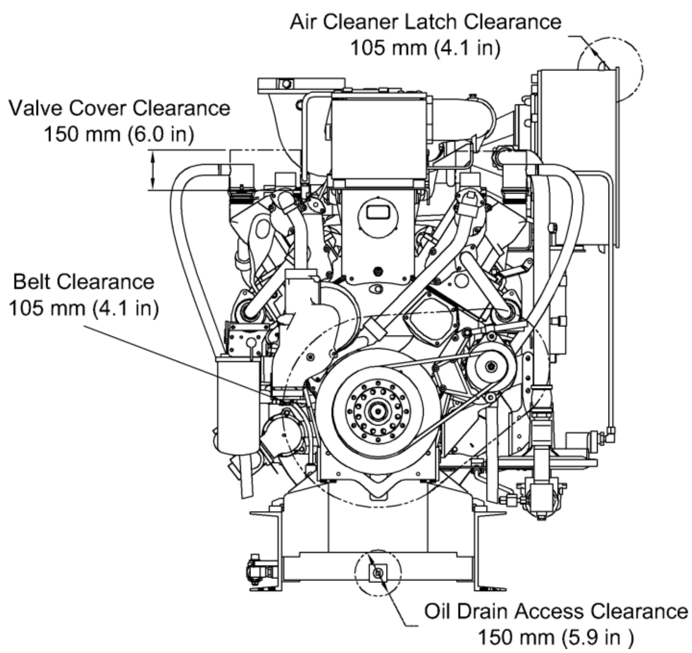


Figure 21

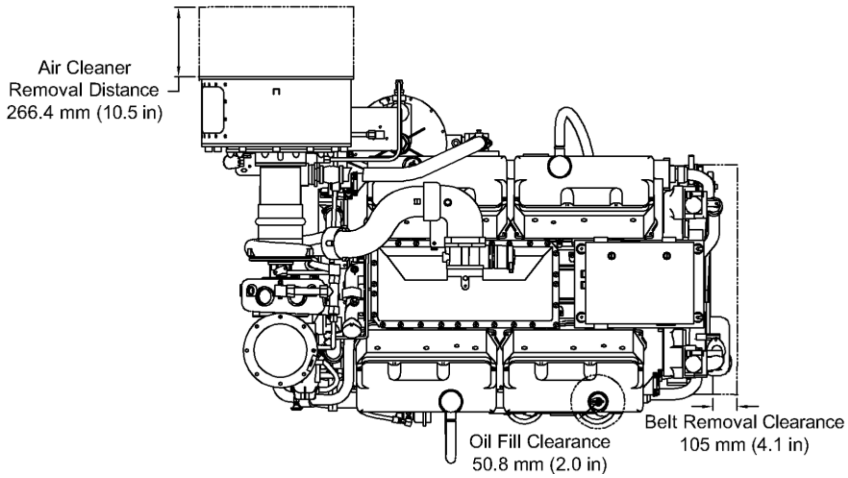


Figure 22

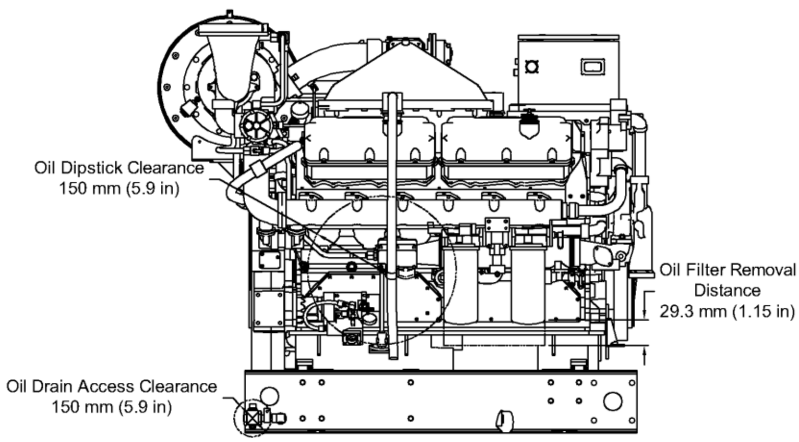
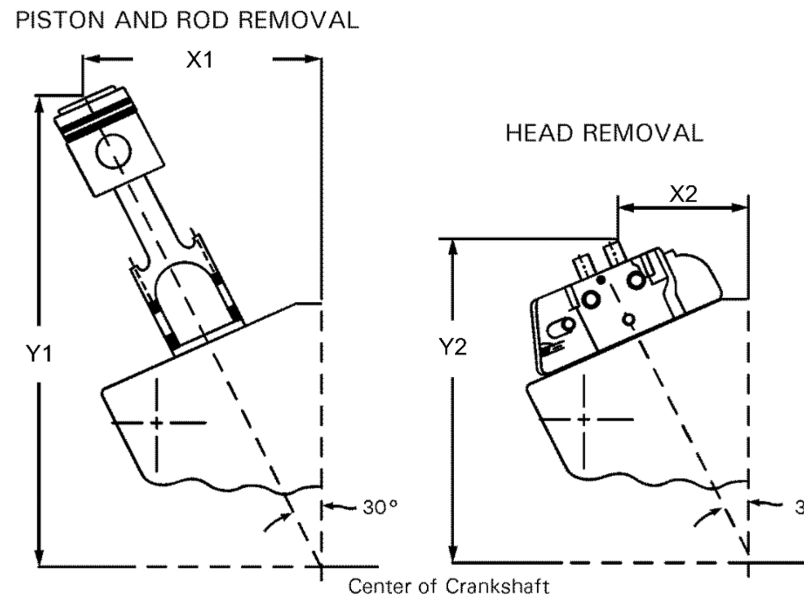


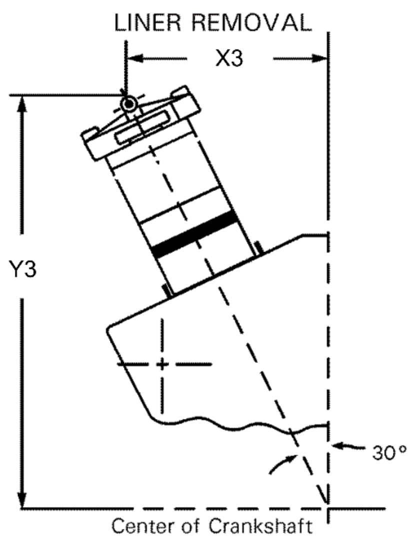
Figure 23

Piston, Head, and Liner Removal Distances for Small Gas Engines

A practical overhaul of the engine will be done with the engine removed from the field and in a shop. Maintenance and overhaul of the engine in the field will require adequate room for installation and removal of required components. A suitable lifting device will be required to remove heavier components and accommodations should be made for such devices. Refer to the specific engines Operation and Maintenance Manual for guidance on required maintenance.

Figure 24 shows approximate clearance distance needed for removing the piston, head, and liner. Ensure that the maintenance clearance distance above the engine accounts for the lifting equipment.





Distance	G3300 mm (in)	G3400/CG137 mm (in)
X1	-	454 (18)
X2	-	306 (12)
X3	-	373 (15)
Y1	746 (29)	712 (28)
Y2	520 (20)	547 (22)
Y3	638.5 (25)	585 (23)

Figure 24: Piston, head, and liner removal distances for small gas engines.

Air Intake and Exhaust Systems

This section provides an insight into best practices when designing, constructing, and mounting the air intake and exhaust systems. The recommendations in this section are intended to guide the installer in implementing an air intake and exhaust system that complies with commissioning requirements. By following the guidelines in this section, the end-user of the equipment can minimize commissioning costs and maximize engine performance, durability and reliability.

Air Intake System

A properly designed, constructed and mounted air intake system delivers a laminar flow of clean, cool air to the turbocharger while minimizing the pressure drop across the inlet. Additionally, the air intake system should be designed for serviceability and must remain isolated from the engine. This section will cover field-tested best practices to achieve these goals.

Air Cleaner Location

Air cleaners come installed on the engine; therefore, guidance related to the air intake system is for anyone electing to remote mount the air cleaners.

The air intake system should draw air from outside of the engine room. This will prevent the ingestion of hot air or fuel gas trapped within the engine room. The air inlet must be located away from exhaust outlets to prevent the air intake system from ingesting hot air or exhaust gases that can affect the engine performance. The air inlet should be elevated to avoid ingesting dirt or debris kicked up from the ground.

Heated engine room air may be required (for starting purposes only) in applications at very cold ambient temperatures, -25°C (-13°F). This assumes combustion air is being drawn from outside the engine building and the engine is preconditioned with pre-heaters for metal, water, and oil temperatures of 0°C (32°F).

General Design Considerations

The air inlet system should comply with the following design considerations:

- The air intake must be located away from exhaust outlets, large concentrations of dirt, chemicals, industrial waste, or any other source of hot or dirty air.
- The piping assembly must be sealed as to only allow air to enter through the filters and be delivered at the turbocharger inlet.
- The air inlet system must not contain abrupt changes in direction. Failure to follow this recommendation will cause turbulent flow inside the air intake piping system.
- The inner walls of the piping system must be smooth (no rivets, screws, protruding weld seams, or crimped sections).
- A straight steadying zone with length equal to five times the pipe’s diameter must be present before each turbocharger inlet.
- Pressure loss in the air intake piping system shall not exceed 3.7 kPa (0.54 psi).

- Piping system shall be designed such that maximum air velocity in the duct does not exceed 10 m/s (2000 fpm).
- Piping diameter shall be equal or greater than the air cleaner outlet and the turbocharger inlet.
- The air inlet piping shall be supported on an independent structure and shall not transfer loads to the turbocharger.
- A flexible bellow must be used to connect the air intake piping to the turbocharger inlet.
- The piping must be round and must withstand a minimum vacuum of 12.5 kPa (1.81 psi).
- The air inlet piping mounting structure shall allow access for engine service.

Piping Design

A properly designed piping system delivers a stream of the correct quantity and quality of air to the turbocharger. Use this section in conjunction with the Air Intake Systems A&I Guide, LEBW4969, to design a system that meets those characteristics.

The quantity of the airflow that the piping must supply is determined by the engine's air consumption requirement. This information can be found in GERP for standard and site-specific ratings. Always adjust the airflow requirements to the site conditions (consult LEBW4969, for a calculation method). The air intake system must be able to provide this amount of air while meeting guidelines 7, 8, and 9 in the list above. Consult LEBW4969 for a detailed explanation of pipe sizing calculations based on the restriction pressure drop.

In order to function efficiently, the air intake system must provide not only the right amount of air but must be designed to ensure the airflow has the right quality. Turbulent airflow (Figure 25) causes large pressure drops in the air intake system. A pressure loss greater than the allowed 3.7 kPa (0.54 psi) can occur in a relatively short pipe section if turbulent flow is present. High pressure drops in the air intake system lead to decreased engine performance and short filter life. Turbulence can also lead to failures in the turbocharger due to cyclical loading caused by irregular airflow through the compressor blades.

The cause of turbulent flow in the piping is mainly due to abrupt changes in direction and protrusions in the piping walls. Therefore, it is crucial to maintain gradual changes in direction and to ensure the inner walls of the piping system are smooth and clean. Junctions in the air intake piping system must always follow a "Y" type configuration as shown in Figure 25.

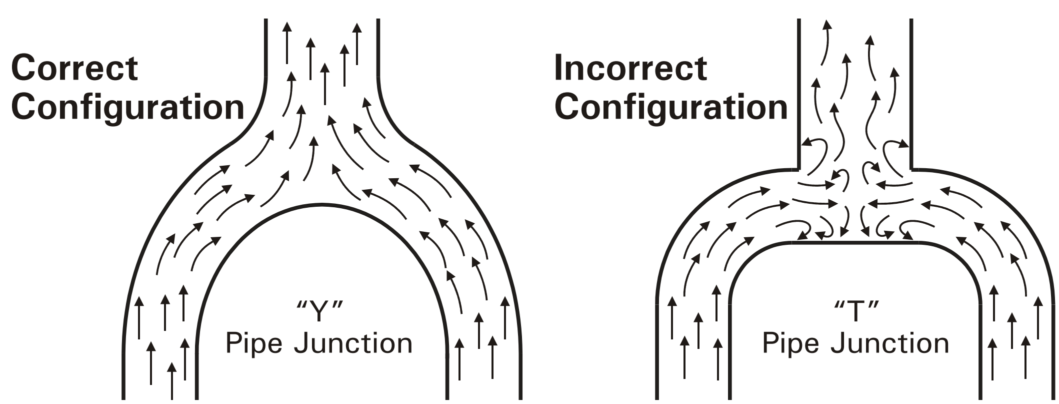


Figure 25: Correct and incorrect pipe junctions.

If any piping junction or change in direction is present before the turbocharger, a steadying zone at least five times the pipe diameter must be present to minimize any turbulence in the flow (Figure 26).

- Example A in Figure 26 shows a correct configuration. The pipe changes direction gradually to minimize turbulence and a steadying zone is provided after the bend to allow the intake air to return to a laminar flow.
- Examples B, C and D in Figure 26 show incorrect configurations.
- Example B shows a pipe that changes direction gradually but without a proper steadying zone. This can allow irregular airflow to enter the turbocharger.
- Example C shows protrusions into the piping. These protrusions will induce turbulence in the flow and increase pressure loss in the air intake piping system.
- Example D shows an abrupt change in direction. This will also allow irregular airflow to enter the turbocharger and greatly increase the air intake pressure loss.

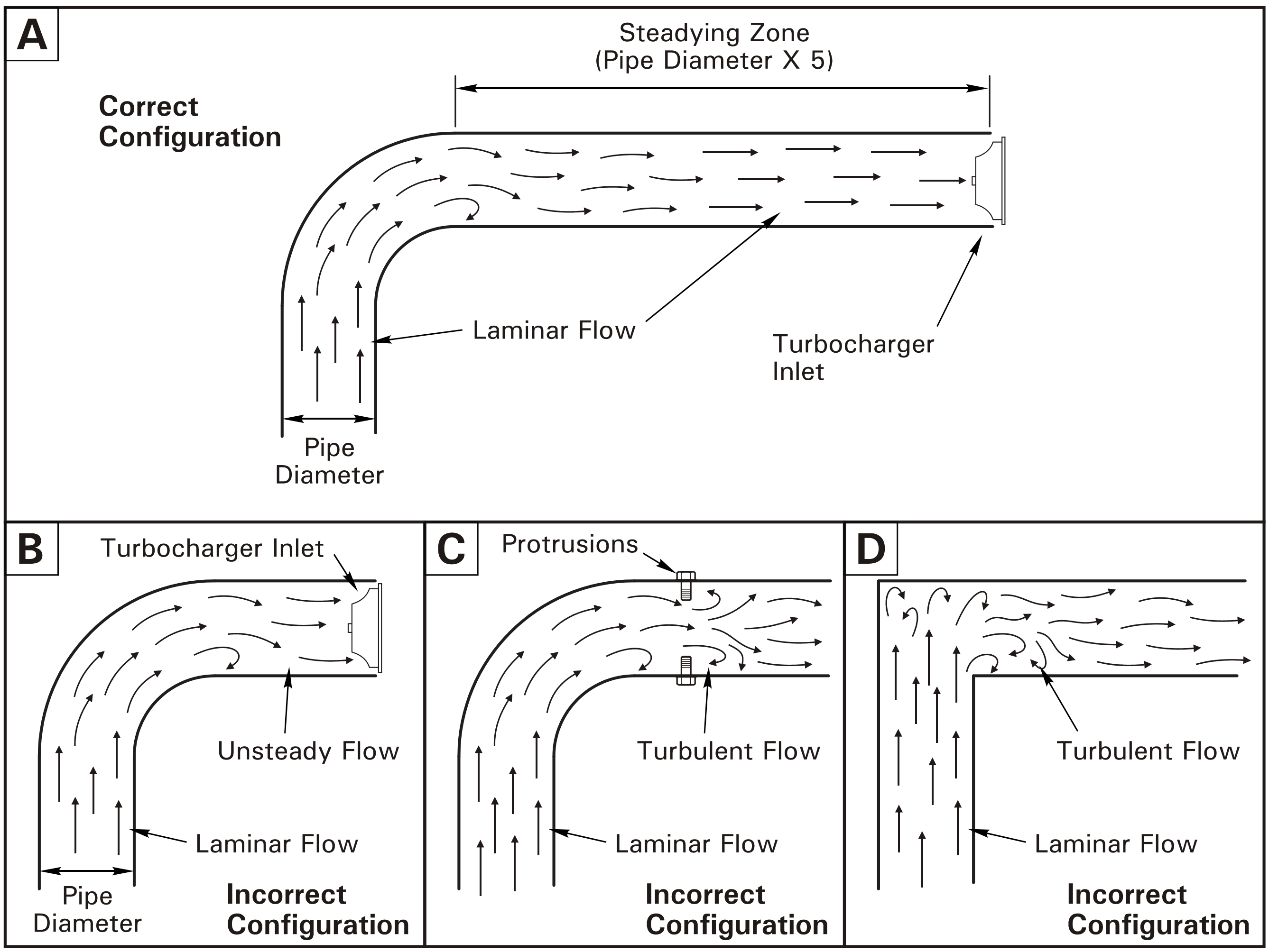


Figure 26: Examples of correct and incorrect intake air flow.

Using round pipe for constructing the air intake system is ideal for meeting the recommendations outlined above. Round pipe allows for structural integrity in the system, gradual changes in direction, and eased construction. See “Piping Construction” for further details on piping construction recommendations.

Note: Insulation of the air intake piping system is recommended to prevent pre-heating of the intake air and reduce turbocharger noise emitted into the engine room.

Figure 27: Example of piping with gradual changes in flow direction and self-supporting air intake pipe.

Piping Construction

This section covers recommendations for piping construction techniques for the air intake system.

A properly constructed air intake system has the following characteristics:

- Sealed pipe with air entering through the air cleaner group only and exiting at the turbocharger inlet only.
- Smooth inner walls with no protrusions such as weld seams or rivets; weld seams must be ground smooth if a metallic pipe is being used.

The recommended material for fabricating the air intake piping is PVC. This material is preferred because of its light weight, resistance to corrosion, ease of assembly, and it is easy to seal.

Ferrous materials are also accepted in constructing the air intake system. Special care must be taken to ensure that all welded joints are ground smooth on the inside. Additionally, the material must be corrosion resistant or be treated for that purpose. Ferrous materials can be treated with 2-part epoxy paint or a “rust converter” that creates a uniform, stable, black oxidation layer. The downside of this technique is that complex piping can be challenging to treat.

Stainless steel and galvanized steel are suitable materials for the air intake piping. It is not recommended that HVAC type piping be used on air intake piping systems due to its lack of structural integrity.

Piping Connections

The interface between the air intake piping and the turbocharger inlet, when properly done, will ensure the following:

- Flexible connector between the pipe and the turbocharger inlet that transfers no load or vibrations.
- No outside air leaks through the connection.
- Double clamp scheme on each side of the connector.
- 25 to 50 mm (1 to 2 in) gap between rigid members for isolation.

In order to ensure the characteristics above, a flanged pipe section with a double clamped flexible bellow is the recommended approach. A gap between the end of the air intake piping and the turbocharger inlet must exist and measure between 25 to 50 mm (1 to 2 in). (Figure 28)

Note: Proper alignment is critical to the functionality of this assembly. Any lack of alignment must be corrected by repositioning the air intake pipe and should not be compensated by the flexible bellow.

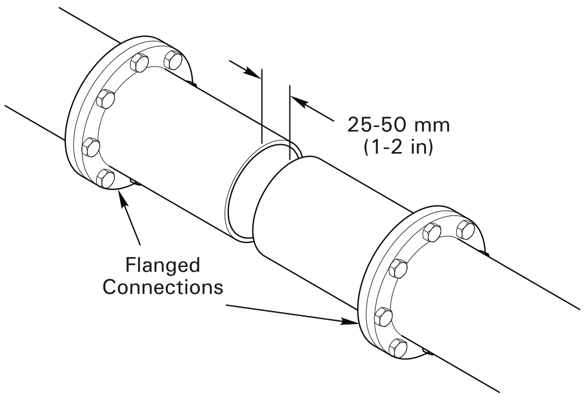


Figure 28: Example of preferred piping configuration between the intake air pipe and turbocharger inlet. It features flanged and axially aligned connections and a proper gap between the members.

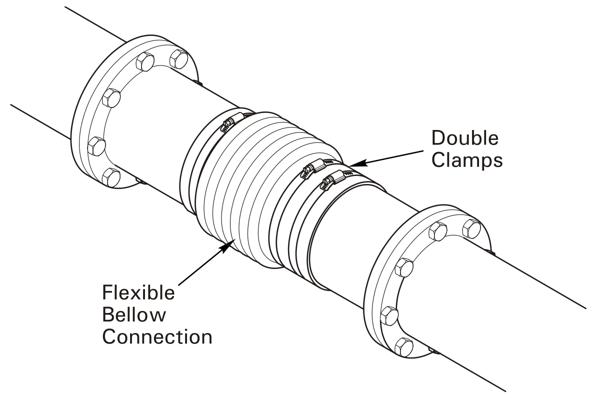


Figure 29: Example of an ideal flexible connection with double clamps on each connector.

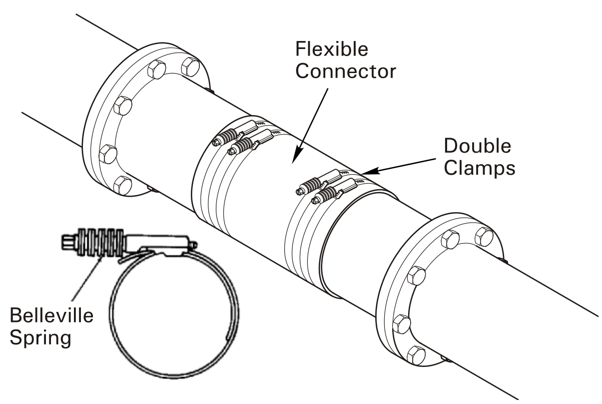


Figure 30: Example of an ideal flexible connection with double clamps on each connector.

Exhaust System

A properly designed exhaust system is a sealed, insulated piping structure that applies no load on the turbocharger due to the structure's weight or misalignment from improper installation or thermal growth. The exhaust system's outlet must be positioned such that no exhaust gases are ingested into the air intake system. Also, it should be designed to minimize the amount of heat transferred to the engine room. This section provides field-based best practices for designing, constructing, and mounting a suitable exhaust system.

General Design Considerations

The following design considerations are guidelines to implement an effective exhaust system:

- The exhaust pipe must be insulated to minimize noise and heat transfer to the engine room.
- The exhaust piping should be routed as far away from the engine as practical, as to not transfer heat to the engine.
- Paint or other materials should not be applied on or near exhaust system components unless they are suitable for high temperature applications.
- The exhaust pipe must be sealed such that gases only escape at the outlet end of the exhaust system.
- The exhaust outlet must be located such that no exhaust gases are ingested into the air intake system. Locate the exhaust outlet high and the air intake low, whenever possible.
- The exhaust piping must never be supported on the engine.
- Emissions sampling ports must be located at least three pipe diameters downstream of a pipe transition or two pipe diameters upstream of a pipe transition; locate the emissions sampling port on the horizontal pipe section whenever possible.
- The exhaust system backpressure must not exceed 3 kPa (12 in H_2O) for naturally aspirated engines or 6.7 kPa (27 in H_2O) for turbocharged engines.
- The target backpressure in the system should be half of the maximum.
- Use exhaust thimbles for any wall or ceiling penetrations per the instructions in the Exhaust Systems A&I Guide, LEBW4970.
- The exhaust piping must be slightly sloped away from the engine to prevent water from entering the engine and drainage provisions must be made in the piping system. (Refer to LEBW4970).

Aftertreatment

Small gas engines can utilize aftertreatment systems to lower emission levels. For maximum performance and efficiency, the aftertreatment system must be properly installed. A supplied three-way catalyst and air fuel ratio control is offered on the G3300B and CG137-12 engines. Installation of the catalyst and associated sensors requires adherence to the guidelines outlined in the General Requirements for CG137-12 and G3300B Engines, Special Instructions, REHS7128. Figure 31 shows an example of a typical horizontal aftertreatment installation.

General requirements are as follows for optimal performance and life of the catalyst:

- Spacing between exhaust outlet and catalyst inlet must be minimized to obtain the correct catalyst temperature.
- The inlet temperature must stay above 400°C (752°F) in all operating conditions.
- No supports on the actual catalyst are allowed, except on the flanged inlet and outlet.
- The piping also allows thermal expansion and growth, without allowing excessive vibrations to be transmitted from the engine.
- Sensors and wiring must be routed such that they are protected them from excessive heat and vibration.
- A minimum distance of 76.2 mm (3 in) from the catalyst is required for all wiring.

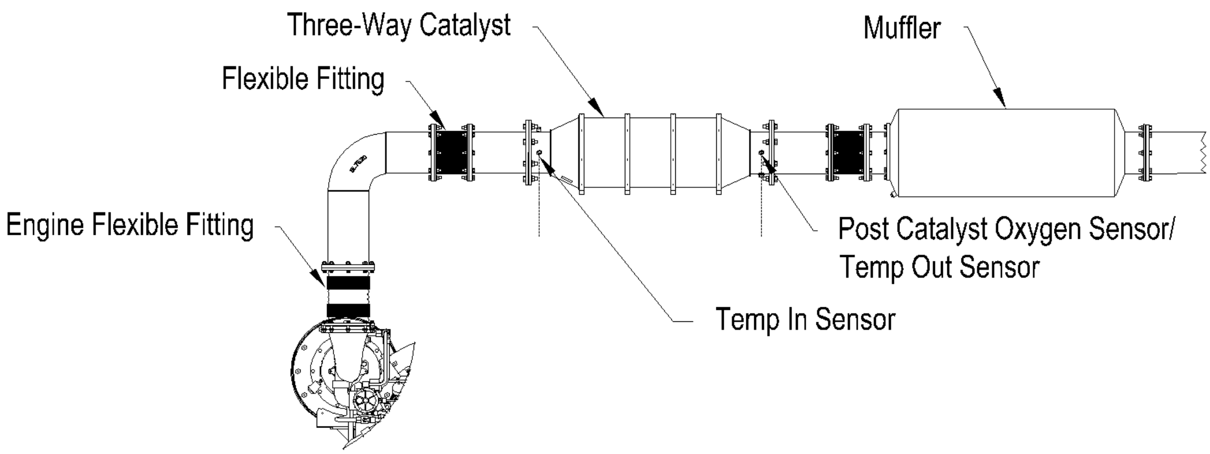


Figure 31: Example aftercooler and muffler system installed in the horizontal orientation. Proper piping, supports, and sensor wiring must be followed to ensure optimal engine performance. Reference the engine specific installation drawing in EDDC for a more detailed example.

Piping Construction

Similar to the air intake system piping, the exhaust system piping design should be designed with gradual changes in direction in order to maintain a laminar flow in the system. At the same time, sharp protrusions inside the pipe must be avoided. Failure to do so will result in the creation of turbulence in the exhaust system. The result can be compromised exhaust backpressure in the system, loss of engine performance, vibration, noise, and fatigue of the exhaust piping structure.

A ferrous metal is the best material choice for constructing the exhaust system. Stainless steel and galvanized steel with welded joints are the best materials due to their structural integrity and resistance to corrosion. Riveted joints are not acceptable due to their tendency to leak. For all welded seams, ensure that the inner walls of the pipe are ground smooth and the welds are treated to resist corrosion.

Flex Connectors

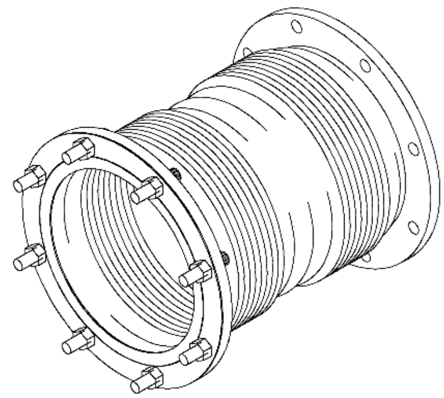


Figure 32: Cat exhaust flex connector. Available as an option.

All joints in the exhaust system should furnish a metallic flexible connector with flanged connections such as the one shown in Figure 32. This type of connector will withstand high temperatures, account for thermal deformations of the piping system, absorb vibrations, and provide a tight seal on both ends.

Ensure that the piping system is designed such that the flex connectors are installed at their designed length. Do not compress, extend, bend or twist the flex connectors to correct misalignments or gaps. Instead, reposition the pipe such that the flex connector can be assembled in its design position.

Note: The exhaust connector is usually shipped at its assembled length. The flex will have either wooden spacers secured in place or small iron straps welded in place between the flex flanges. This is the manufacturer's installed length for the flex to perform correctly as the exhaust system heats up during operation.

Heat wrap must be used to cover the flex connectors. Adding heat wrap helps the exhaust system by retaining heat to help the catalyst function properly and by shielding the wastegate from the hot exhaust temperatures.

Emissions Sampling Ports

Caterpillar supplied three-way catalysts come supplied with emission sampling ports already installed. These ports are designed for oxygen, temperature, and pressure sensors. The oxygen sensors provide feedback to the air fuel ratio control system. If additional sampling ports are required, Figure 33 shows the proper installation guidelines.

The following are guidelines that the installer should follow for proper location and installation of the emissions sampling ports:

1. Locate the engine-out emissions sampling port in the horizontal section of the exhaust pipe, at least three diameters downstream of the turbocharger outlet elbow and at least two diameters upstream of the catalyst/silencer. (Figure 33).

   Note: If an emissions sampling port is needed for installations that do not include a catalyst or silencer, install the engine-out emissions sampling port three diameters downstream of the turbocharger outlet elbow.

2. Locate the catalyst-out emissions sampling port at the outlet of the catalyst.
3. Provide a sample tubing arrangement from the sample port to ground level. (Figure 33).

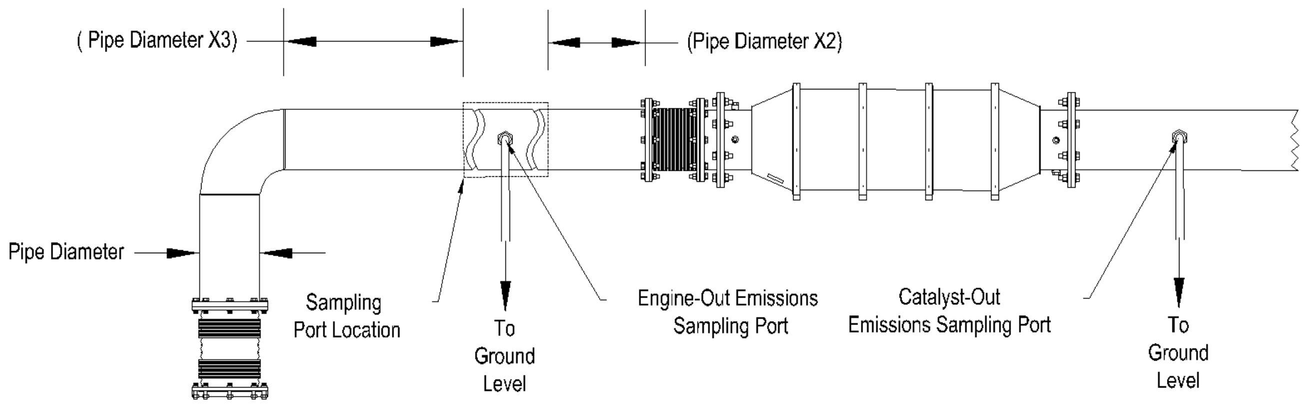


Figure 33: Example of proper emissions sampling port locations and configuration.

Piping Structural Support

The configuration of the inlet and exhaust piping is highly dependent on the design of the site where the equipment will be operating. As a result, the air intake and exhaust piping solution should be tailored to the particular application. The intent of this section is to provide general design guidelines to aid the designer of the site-specific inlet and exhaust piping system.

Regardless of the configuration used for the intake and exhaust systems, the design guidelines in this section should be followed closely. The support structure of the air intake and exhaust systems must be designed to withstand the full weight of the piping assemblies and prevent the engine from carrying any of such loads. The structure that supports the pipes must transfer the weight of the piping system to the engine foundation or the building structure. Any configuration where a point on the engine is used to support mounting structures for the pipes shall be avoided.

Note: The turbocharger shall never support the weight of the air intake or exhaust piping system. The only loads that the turbocharger should withstand are due to the weight of the components used to connect the pipes. Ensure that the moment applied to the turbocharger does not exceed 120 Nm (89 ft lb). Refer to "Turbocharger Loading" section in LEBW4969 for a method to calculate the moment applied to turbochargers due to installed components.

The structure used to support the air intake and exhaust piping can be attached to structural members in the engine room's ceiling or walls, or can be attached to the ground. Such configuration will depend on the on-site infrastructure. A ground-supported structure must also allow proper space for servicing the engine. Any structural member that is too close to the engine may obstruct maintenance procedures of other engine systems, resulting in increased downtime. Consult the "Maintenance Clearance" section for more details on maintenance clearances around the engine.

Use vibration isolating pipe supports for mounting the intake and exhaust pipes to their frame. This will help attenuate any vibrations transmitted from the engine to the piping systems and will ensure the durability of the intake and exhaust systems. When securing long stretches of pipe, place supports at unequal distances to prevent resonant vibrations from amplifying. For more information, consult the Exhaust Systems A&I Guide, LEBW4970.

Thermal Growth

The exhaust piping system will heat up during operation of the engine and will naturally expand. Thermal growth in the exhaust piping system should not be constrained and should be directed away from the turbocharger connection. A structural member must constrain the exhaust pipe immediately after the turbocharger elbow, on the horizontal section of the exhaust pipe. At the other end, the pipe must be allowed to expand along its axis. This will accommodate all thermal growth in the direction of the exhaust outlet, thus preventing the exhaust flexible connector from bending.

Regardless of the configuration of the exhaust system, flexible connectors must be used and provisions for thermal growth away from the engine must be made at all times.

If the exhaust piping system is routed through a wooden wall in an engine room, ensure that a metal thimble guard is installed. Thimble guards must be 305 mm (12 in) greater in diameter than the exhaust pipe.

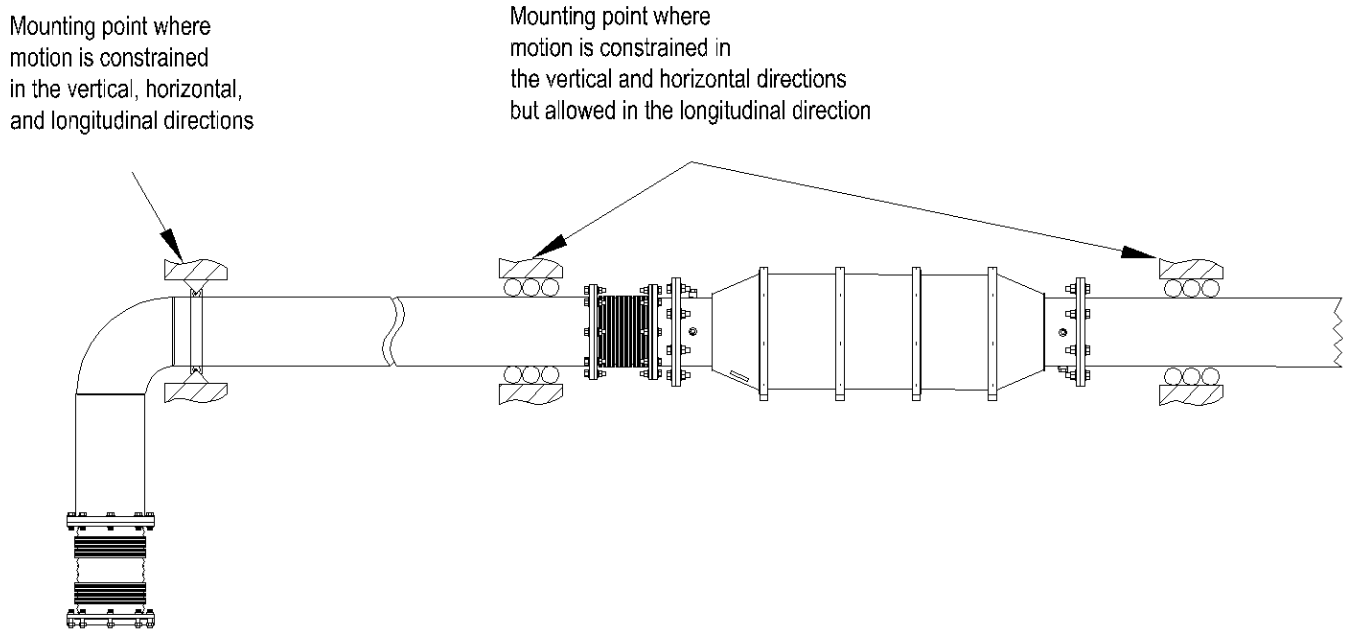


Figure 34: Example of exhaust pipe configuration to direct expansion toward the exhaust pipe outlet.

Exhaust Insulation

The site piping extending from the engine connection flange to the exhaust stack carries hot exhaust gases, raising issues of both piping surface temperatures and gas temperatures being delivered to an exhaust catalyst. Both issues favor the installation of insulating material around the exhaust piping.

With insulating material installed, personnel are better protected from the hot piping surfaces, making them less challenging to work around. Insulation also decreases heating of the engine enclosure by the exhaust, making it a more comfortable place in which to work. Insulation also helps maintain the temperature of the exhaust stream to ensure it does not fall below the minimum temperature required for optimum performance of an exhaust catalyst.

The exhaust gas temperature delivered to the catalyst should always be evaluated during the design phase and confirmed during on-site operation to ensure the catalyst delivers the required conversion efficiency.

Cooling System

This section provides an insight into best practices when designing, constructing, and mounting the external cooling system on the G3300, G3400, and CG137 engines and is intended to complement the material presented in the Cooling Systems A&I Guide (LEBW4978). Consult the A&I Guide for a detailed technical explanation of the engine's cooling system.

Schematics and descriptions of the cooling system circuits for small gas engines are found on the following pages.

- G3300 NA, (Figure 35 on Page 50).
- G3300 TA, (Figure 36 on Page 51).
- G3406 NA, (Figure 37 on Page 52).
- G3400 NA V-block, (Figure 38 on Page 53).
- G3400/CG137 TA V-block, (Figure 39 on Page 54).

Note: To simplify the cooling system circuits, the exhaust manifold, exhaust elbow and exhaust bypass valve are not shown.

G3300 NA

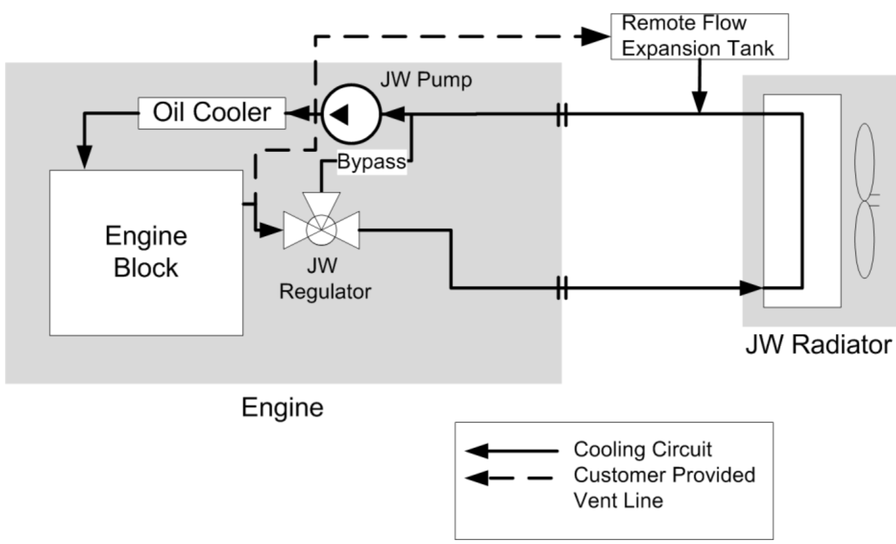


Figure 35: G3300 NA cooling system schematic.

JW Circuit

The G3300 NA cooling system requires only one circuit. Coolant is driven by the jacket water (JW) pump into the oil cooler and then the flow is split between the block and water cooled exhaust manifolds. Cooling flow to the oil cooler comes directly from the pump to provide the best cooling capability for the engine oil to prolong oil life. Coolant exiting the engine block flows upward through the cylinder heads, providing cooling for the valves and combustion deck. Flow from the head is then gathered with the water from the exhaust manifolds and sent to the temperature regulator. The temperature regulator controls the outlet temperature of the jacket water cooling circuit by managing a split in flow along two outlet paths:

- The bypass diverts coolant directly back to the jacket water pump inlet. This path is active primarily when the engine is below operating temperature.
- The system outlet directs flow to the radiator. This path is active when the coolant temperature is near the regulator's set point temperature.

Flow from these two paths are mixed immediately upstream of the jacket water pump inlet. The blended flow at the pump inlet determines the inlet temperature for the circuit.

Proper function of the engine's cooling system depends on correct sizing of the radiator. More information on these topics may be found in the Cooling Systems A&I Guide.

G3300 TA

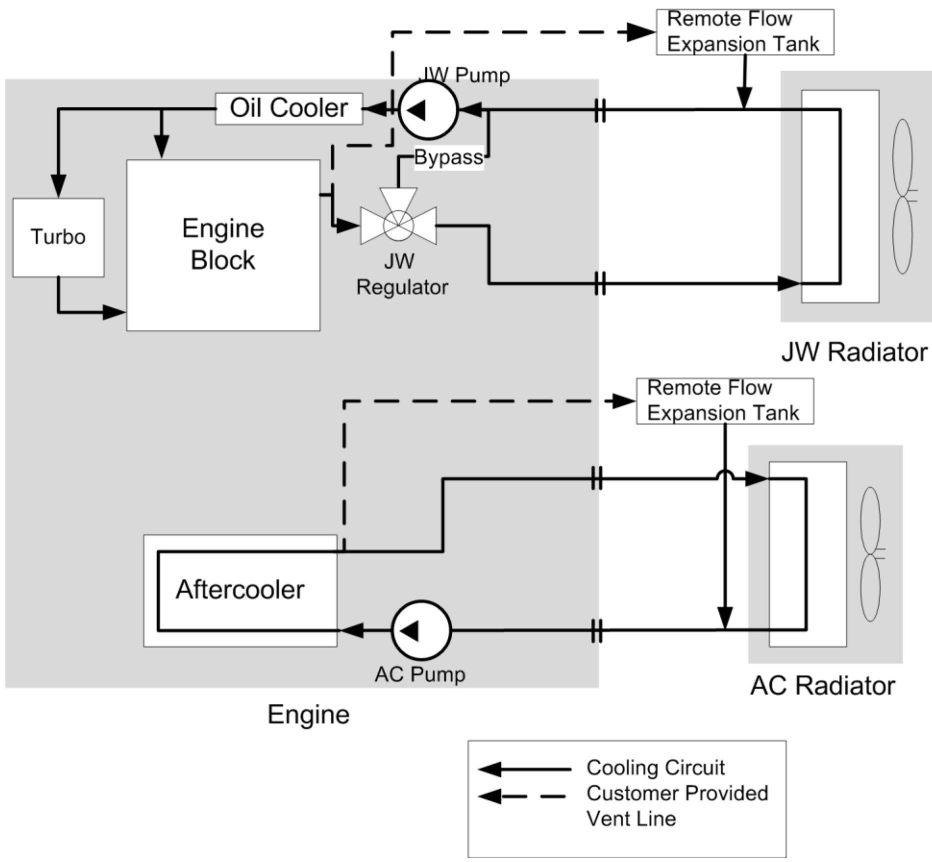


Figure 36: G3300 TA cooling system schematic.

JW Circuit

The G3300 TA uses the same jacket water cooling arrangement as described for the G3300/G3406 NA inline configuration.

AC Circuit

In addition, a second circuit dedicated to managing the combustion air temperature being delivered to the cylinders is added. This circuit is often referred to as either separate circuit aftercooling (SCAC) or the “auxiliary” circuit. The auxiliary circuit provides its own dedicated coolant pump. Flow from the auxiliary circuit cooling pump is directed to the aftercooler, an air-to-liquid heat exchanger that removes the heat of compression generated in the turbocharger. As with the jacket water circuit, this circuit requires a separate, dedicated radiator section, sized properly to reject the heat collected by the coolant in the aftercooler.

G3406 NA

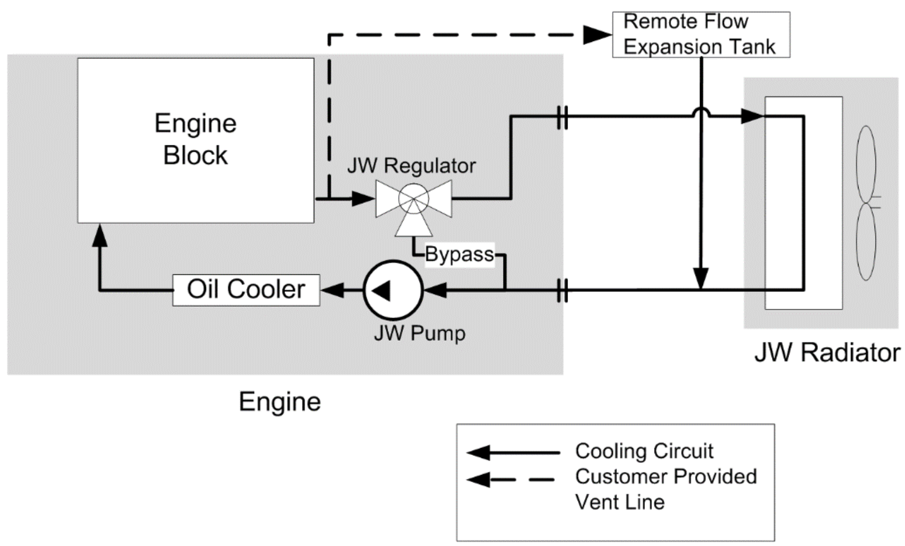


Figure 37: G3406 NA cooling system schematic.

JW Circuit

The G3406 NA cooling system, like the G3300 NA, requires only one circuit. The key differences of the two systems are in the location of the pump, oil cooler, and regulator. Coolant is driven by the jacket water (JW) pump into the oil cooler and then the flow is split between the block and water cooled exhaust manifolds. Cooling flow to the oil cooler comes directly from the pump to provide the best cooling capability for the engine oil to prolong oil life. Coolant exiting the engine block flows upward through the cylinder heads, providing cooling for the valves and combustion deck. Flow from the head is then gathered with the water from the exhaust manifolds and sent to the temperature regulator. The temperature regulator controls the outlet temperature of the jacket water cooling circuit by managing a split in flow along two outlet paths:

- The bypass diverts coolant directly back to the jacket water pump inlet. This path is active primarily when the engine is below operating temperature.
- The system outlet directs flow to the radiator. This path is active when the coolant temperature is near the regulator’s set point temperature.

Flow from these two paths are mixed immediately upstream of the jacket water pump inlet. The blended flow at the pump inlet determines the inlet temperature for the circuit.

Proper function of the engine's cooling system depends on correct sizing of the radiator. More information on these topics may be found in the Cooling Systems A&I Guide.

G3400 NA V-block

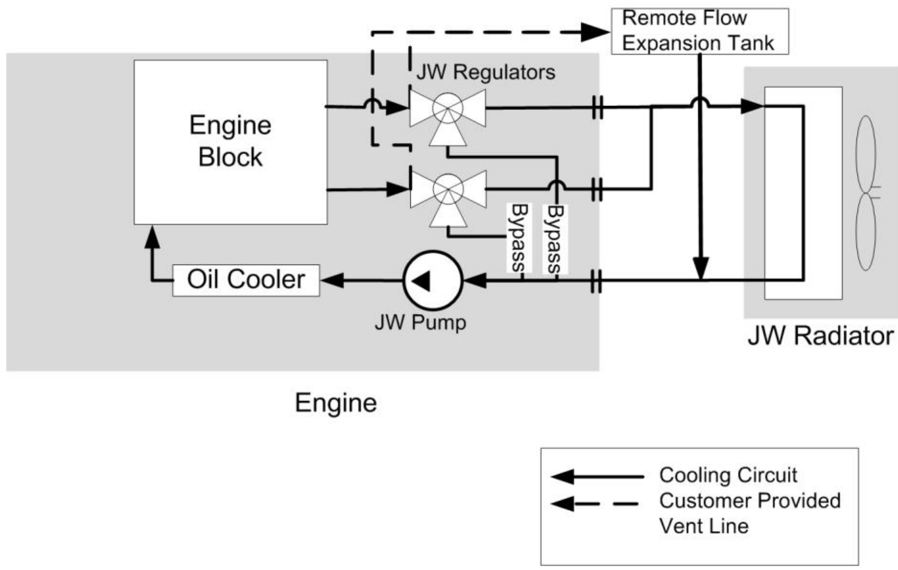


Figure 38: G3400 NA V-block cooling system schematic.

JW Circuit

Like the G3300/ G3406 NA, the G3400 NA V-block cooling system requires only one circuit. Coolant is driven by the jacket water (JW) pump into the oil cooler and then to the block. Cooling flow to the oil cooler comes directly from the pump to provide the best cooling capability for the engine oil to prolong oil life. Coolant exiting the engine block flows upward and splits through the cylinder heads and into the exhaust manifolds, providing cooling for the valves, combustion deck, and exhaust. Flow from the head is then gathered again with the coolant from the exhaust manifolds and sent to the temperature regulators. The V-block engine configurations use two temperature regulators and outlets, unlike the inline configurations which only use one outlet. The temperature regulator controls the outlet temperature of the jacket water cooling circuit by managing a split in flow along two outlet paths:

- The bypass diverts coolant directly back to the jacket water pump inlet. This path is active primarily when the engine is below operating temperature.
- The system outlet directs flow to the radiator. This path is active when the coolant temperature is near the regulator's set point temperature.

Flow from these two paths are mixed immediately upstream of the jacket water pump inlet. The blended flow at the pump inlet determines the inlet temperature for the circuit.

Proper function of the engine's cooling system depends on correct sizing of the radiator. More information on these topics may be found in the Cooling Systems A&I Guide.

G3400/CG137 TA V-block

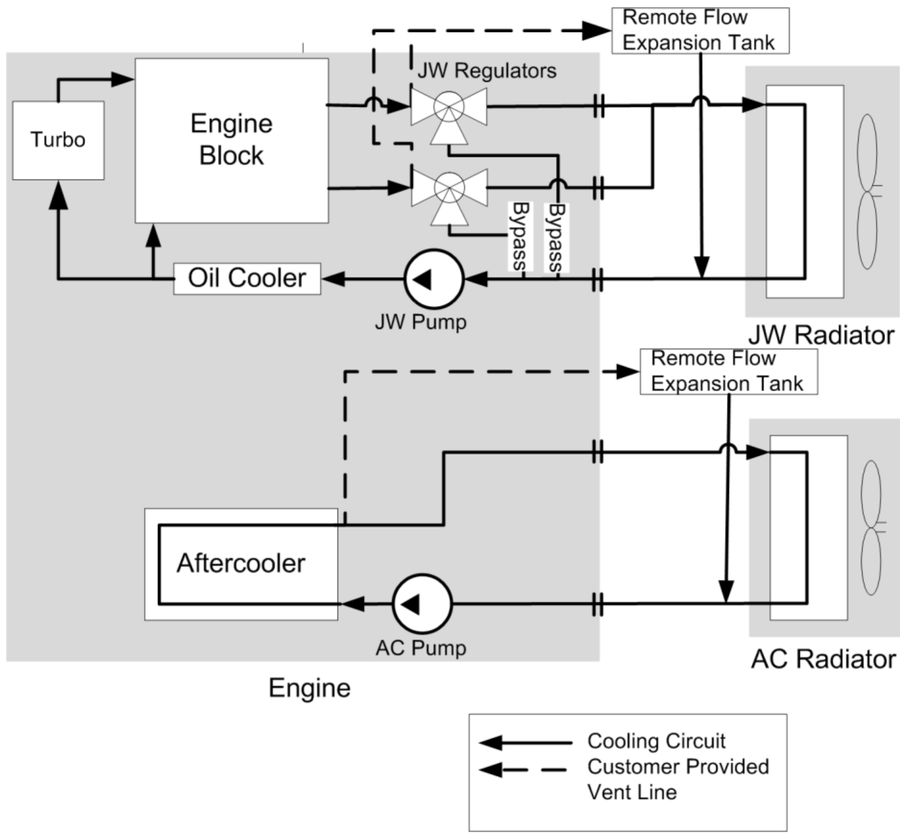


Figure 39: G3400/CG137 TA V-block cooling system schematic.

JW Circuit

The G3400/CG137, like the G3300 TA, uses two circuits to achieve proper cooling of the engine. The first circuit, the jacket water system, uses a gear driven pump to circulate coolant. Cooling flow to the oil cooler comes directly from the pump to provide the best cooling capability for the engine oil to prolong oil life. After the oil cooler, the coolant flow is diverted into both the engine block and to the turbo charger. Coolant exiting the engine block flows upward and splits through the cylinder heads and into the exhaust manifolds, providing cooling for the valves, combustion deck, and exhaust. The coolant coming from the turbo is also merged with the exhaust manifolds inlet. Flow from the head is then gathered again with the coolant from the exhaust manifolds and sent to the temperature regulators. The V-block engine configurations use two temperature regulators and outlets, unlike the inline configurations which only use one outlet. The temperature regulator controls the outlet temperature of the jacket water cooling circuit by managing a split in flow along two outlet paths:

- The bypass diverts coolant directly back to the jacket water pump inlet. This path is active primarily when the engine is below operating temperature.

- The system outlet directs flow to the radiator. This path is active when the coolant temperature is near the regulator's set point temperature.

Flow from these two paths are mixed immediately upstream of the jacket water pump inlet. The blended flow at the pump inlet determines the inlet temperature for the circuit.

AC Circuit

A second circuit dedicated to managing the combustion air temperature being delivered to the cylinders is added. This circuit is often referred to as either separate circuit aftercooling (SCAC) or the "auxiliary" circuit. The auxiliary circuit provides its own dedicated coolant pump. Flow from the auxiliary circuit cooling pump is directed to the aftercooler, an air-to-liquid heat exchanger that removes the heat of compression generated in the turbocharger. As with the jacket water circuit, this circuit requires a separate, dedicated radiator section, sized properly to reject the heat collected by the coolant in the aftercooler.

Temperature Regulators

Small gas engines have engine mounted, outlet controlled temperature regulators. Outlet controlled systems have temperature regulators located in the engine JW outlets. They control the flow of coolant between the bypass circuit and the cooling circuit. Temperature regulators have three valve positions that direct the coolant flow depending on the temperature of the coolant. When the engine has just started and is cold, the temperature regulators divert all flow through the bypass circuit, allowing the engine to warm-up quickly. After a minimum temperature in the bypass circuit has been reached, the temperature regulators allow flow into the external cooler circuit to bring the entire cooling system to temperature. When that is achieved, most flow will be diverted to the cooling circuit, and variations will occur in the temperature regulators to maintain a constant jacket water temperature. However, the cooling capacity is determined by the performance of the external cooling device, such as a radiator or other type of heat exchanger.

Cooling System External Connections

The engine's cooling systems must connect to the external coolant piping and in doing so it will cross the vibration boundary between the engine and its surroundings. Flexible joints must be used in these connection locations to provide:

- Tolerance for misalignment of the two piping systems
- Compliance for relative movement and thermal growth
- Isolation to limit transmission of vibration through the connection

Different styles of flexible joints contribute different properties when used, and the characteristics of each must be considered when selecting a particular style for your installation.

The rubber spherical joint provides the greatest flexibility within the joint. It is considered the best choice for achieving isolation across the joint, but it will not provide much support for long cantilevered pipe runs where structural supports cannot be placed near the joint. This style of joint is recommended because it excels at all three of the properties above. Two-chamber joints, such as the one shown in the photograph in Figure 40, provide superior isolation.

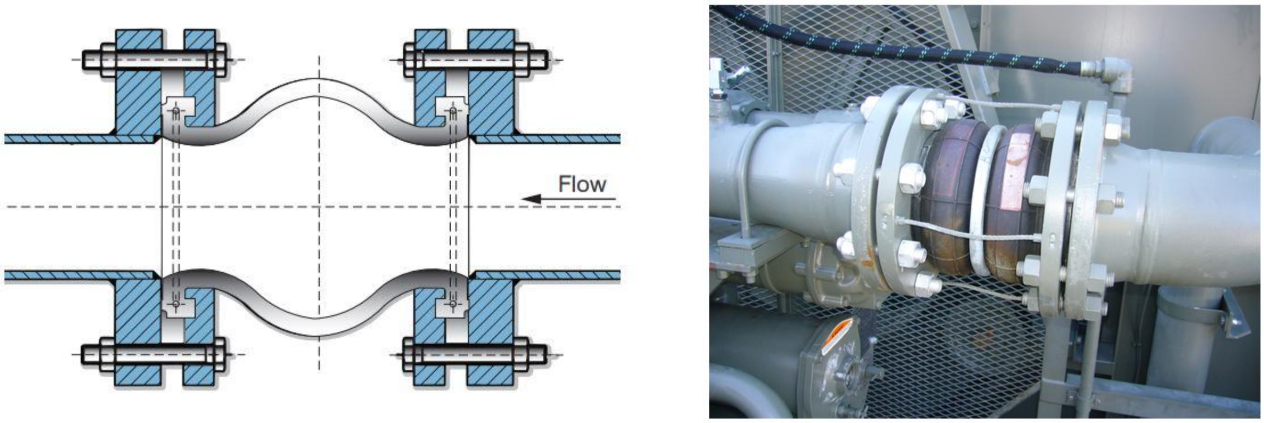


Figure 40: Rubber spherical pipe joint.

The Flexmaster coupling is very commonly seen in engine cooling system applications. It provides some degree of compliance for all three of the properties above, but is not as compliant as the rubber spherical design. The nature of the slip joints on each end limits the amount of misalignment it can support, and it does transmit more vibration through the joint due to the rigid sleeve joining the two sides. This increased rigidity does mean this style of joint can provide more support to the free end of a pipe run than is contributed by the rubber spherical design. While not recommended as a primary support for the pipe, this increased rigidity across the joint can help to limit the vibration response of the pipe to vibrations it may experience from its surroundings.

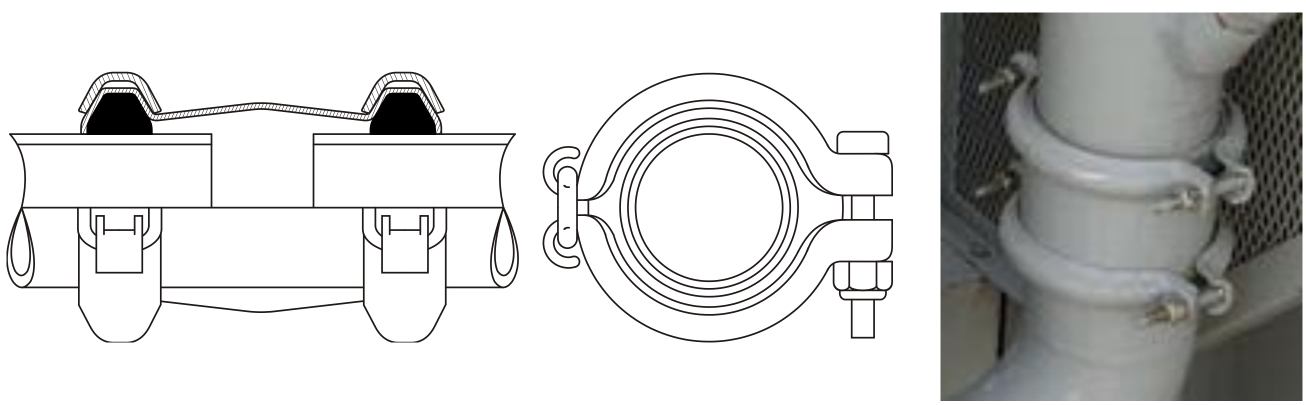


Figure 41: Flexmaster Coupling

Another coupling commonly seen in use is the Dresser style. It is a simple design in which the two pipe ends are joined by a rigid sleeve sealed at the ends by wedge-shaped rubber rings clamped in place by bolted flanges. While this design is economical it provides little isolation for vibration through the joint and seals only across a limited range of pipe misalignment offset distances. It is not recommended for large engine installations.

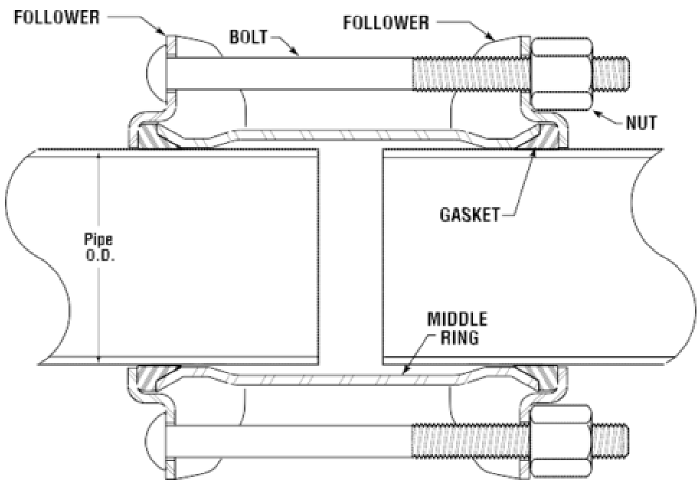


Figure 42: Dresser Coupling

A consistent requirement regardless of the style of coupling used is the need for proper alignment and support of both sides of the connection. Improper alignment subjects the joint to static stresses that are made worse by the cyclic forces of vibration. Inadequate support causes the piping connected to the joint to become a suspended mass supported by the joint. As with misalignment, vibration acts on the suspended mass, exerting cyclic forces on the joint that can lead to premature fatigue. Make certain your installation design properly addresses these two critical considerations.

Water Pump Inlet and Cleaning Screens

The water pumps are designed for laminar flow at the inlet. Unsteady or turbulent flow will have a tendency to cavitate, causing premature wear to the pump and increasing the possibility of a failure in the cooling system. Guides indicate that a straight steadying zone of 1.5 m (59 in) should be present before the water pump inlet. This will allow any turbulent water flow caused by the elbow to disappear before entering the pump.

Compact designs with a steadying zone shorter than 1.5 m (59 in) are not recommended by Caterpillar. If a compact configuration must be implemented, the minimum suction pressure provided to the pump must be increased by 10% to minimize the possibility of pump cavitation. Note that compact designs must allow the minimum length for installation and removal of the cleaning screen used during commissioning.

All small gas engines utilize temporary cooling screens at the water pump inlet during commissioning. The pump inlet spool that fastens to the water pump inlet must be longer than the temporary screen to allow the installation and removal of the screen during commissioning.

Expansion Tanks

Typically, small gas engines used for gas compression applications use remote expansion tanks. The function of the expansion tank is to contain the expansion of the coolant as it heats up, provide a positive head to the water pump, and provide a refill/venting mechanism to the cooling system.

Cat small gas cooling systems are designed as pressurized circuits. This elevates the boiling temperature of the water in the system, allowing for better performance. In this case, the expansion tank must be equipped with an automotive-type adapter and pressure cap (as shown in Figure 43) with the following pressure specifications:

Figure 43: Expansion tank with automotive-type adapter and pressure cap.

- 48 kPa (7 psi) for installations below 1,200 m (3,940 ft) above mean sea level.
- 96 kPa (14 psi) for installations above 1,200 m (3,940 ft) above mean sea level.

In general, a well-designed expansion tank system follows these characteristics:

- Separate expansion tanks: each cooling circuit (JW and SCAC) operates at different temperatures and flow rates. Therefore, common expansion tank configurations cannot be used.
- The expansion tanks must be located at the highest point in the system. This will provide a venting path for air in the system and provide a positive head at the water pump inlets.
- Expansion tanks must be equipped with automotive-type pressure caps in order to maintain system pressure and proper cooling performance.
- Vent lines must be installed from the highest points in the cooling system to the expansion tanks below the water level, preferably at the bottom (see “System Venting” section for more details).
- A sight glass or other mechanism should be installed for monitoring the coolant level.
- The tank should be easily accessible for system refill.

System Venting

For various reasons air bubbles will always get trapped in the coolant. Without a path to escape they will accumulate at the high points and inversions in the coolant flow path, and if left unchecked they can produce localized hot spots or even a "vapor lock" that inhibits proper flow of the coolant. For these reasons, a properly designed and constructed vent system must be an integral part of the cooling system design.

Vent lines should connect to the on-engine system at the locations identified on the installation drawings. These connections have been positioned to permit air bubbles to exit the moving coolant stream and migrate upward through the vent lines through the natural forces of buoyancy. The following sections describe some points to consider when designing the venting system for an installation.

Vent Lines Materials Selection

Vent lines must have an inner diameter of at least 9.5 mm (0.375 in) but no larger than 12.7 mm (0.5 in) for best results. Smaller tube sizes tend to inhibit air bubble movement, while larger sizes may promote coolant circulation through the vent system, which can diminish performance of the whole cooling system.

Reciprocating engines and compressors form a high vibration environment for the venting system. Any vibrations transmitted to the vent lines will induce shaking forces in proportion to the mass of the lines. For this reason, tubing is preferred over heavy gauge pipe. Light weight tubing will be subject to much lower shaking forces, reducing stresses on bending points in the system.

Vent Lines System Layout

As noted above, the buoyancy of the air bubbles is what moves them up and out of the cooling system. To promote this movement, the vent lines must be installed to provide a continuous upward slope from the venting points on the engine to the outlet location, typically in the cooling system expansion tank. Care must be taken to ensure there are no inversions – portions of the routing that bend downward for even a short distance – as these can form traps that inhibit the function of the vent lines. Watch for inversions in fittings and flex lines, which can occur simply due to how the pieces are installed on site.

Due to the nature of the venting process, vent lines are located in open space high on the engine. In this location they are exposed to possible contact with large components or tools, or to use as a step by servicing personnel. The vent system design should be protected from damage from these and other sources. Structural channel, when used as a support structure for tubing runs, can also provide such protection for the vent lines system. Ensure that all areas of contact between the vent lines and the channel are protected from abrasion with compliant materials suited to use in this high temperature environment.

Venting System Mounting and Support

Because the engine is a source of vibration, supports tying the vent lines to the engine are considered undesirable. Wherever possible the vent lines should be supported from an external structure. All mounting systems must provide clear measures to limit the effects of vibration on the vent system. As with the structural channel mentioned above, the points of contact between the supports and the vent lines should be protected from abrasion through the use of compliant materials suited to the high temperature environment.

Supports should be located to limit the size of cantilevered lengths in the vent lines system. Place mounts near the ends of the lines to eliminate free lengths that can shake in open space. Place additional supports along the vent lines at a spacing that limits the bending of the lines due to shaking forces.

Venting System Vibration Management

Regardless of the support design, vibration will induce some relative movement between the venting system and its surroundings. Compliant materials in the mounts help to eliminate chafing of the lines that can occur when hard surfaces rub together over time. Fasteners used to secure the mounting points should be selected to prevent their loosening when exposed to vibrations over long periods.

Bending forces due to shaking are often greatest at the points of connection between the vent lines and the engine. All connections between the engine's vent locations and the vent lines should be completed with flexible elements. These flexible components will better tolerate the stresses of the cyclic bending at those junctions. All such flexible connections must be suited to the high temperature environment. Take care to design and install the flexible connections so they do not create inversions, as mentioned earlier. Avoid the use of close nipples in the connections as they serve as stress risers that are more susceptible to fatigue from the cyclic bending of the shaking forces.

Venting System Outlet Design

In most cases the vent lines should terminate at the cooling system expansion tank for the circuit on which they provide venting. Do not combine vent systems; if two outlets are provided on a separate circuit cooled engine, route each through a separate vent lines system to its respective expansion tank. For any single engine circuit that has multiple vent connection points, those points may be combined into a single vent lines system. Vent lines must enter the expansion tank below the fluid level to ensure best function. Typically they will be joined at or near the bottom of the tank to ensure this requirement is met for all fluid levels in the tank.

Headers on the cooler must also provide for venting. On site utilizing a horizontal cooler, the header at the end furthest from the expansion tanks provides another location prone to collecting and trapping air. Be certain to provide proper venting from those headers to the expansion tanks (as shown in Figure 46), following many of the same guidelines listed above for the engine.

Some installation designs can make it difficult or even impossible to design the vent lines system to meet all of the above requirements. Remote coolers and overhead structures can serve as obstacles that interfere with the best system design. In such cases automatic vent valves (sometimes referred to as "burp valves") may be viewed as an alternative to allow completion of a functioning vent system. Due to a lack of documented field evidence on their proper use, automatic vent valves are considered undesirable and should be avoided if at all possible.

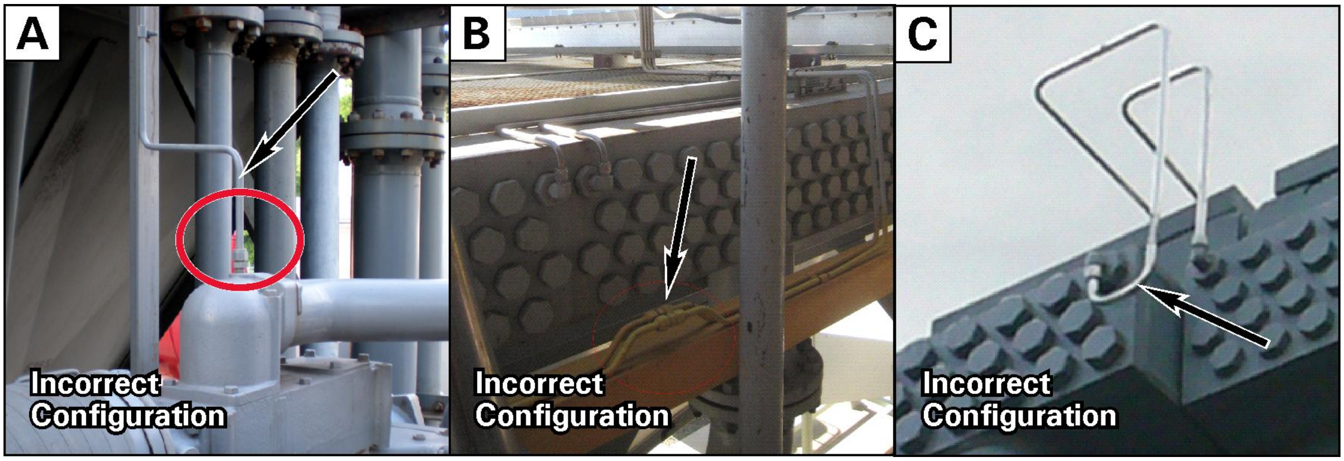


Figure 44: Incorrect routing of coolant vent lines.
A: Vent line should have a flexible hose at the engine connection (red circle) and line should have a continuous upward slope, and not the 90° bends.
B: Incorrect vent line setup that will cause air to become trapped at the high point.
C: Incorrect vent line setup due to "U" shaped connection that creates an air trap; air trapped in the cooling system can lead to catastrophic engine failures.

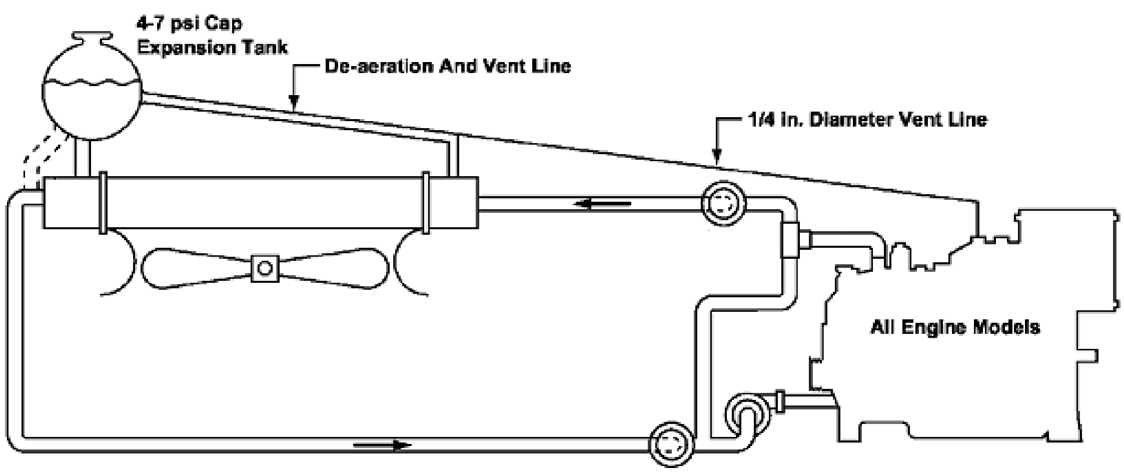


Figure 45: General layout for engine with cooler (horizontal core cooler shown). This image shows how the vent lines must maintain a continuous upward slope throughout their run from the vent connection point to their termination at the expansion tank.

Figure 46: Primary vent line routing. This image shows the cooling system vent line running over the engine. Note the continuous upward slope along the run, and the structural channel used in the installation to protect the tubing from damage.

System Fill

The maximum recommended fill rate through the filler cap is 19 L/min (5 gal/min). The system can also be filled by pumping coolant through the bottom of the engine, for which case the fill rate must be not exceed 112 L/min (30 gal/min). Air trapped at the highest points in the cooling system must be vented. The vent lines are not always reliable for venting air during the cooling system's initial fill. Therefore, it is advisable to loosen the vent line connection at the front of the engine to ensure all entrained air has been purged from the cylinder block.

Note: Always remove the pressure cap when performing a system fill by pumping coolant through the bottom of the engine.

Pressure Checks

It is important to perform pressure checks in the cooling system and record the results. There are two types of pressure checks: static and dynamic. Static pressure checks are performed with the engine stopped and dynamic pressure checks are performed while the engine is in normal operating conditions.

Pressure checks can be highly simplified by the installation of pressure gauges or pressure fittings at the locations specified in Figure 48 to Figure 51. Caterpillar offers pressure probe adapters (Figure 47) 5P2720, 5P2725 and 5P3591 and pressure probe 164-2192, which facilitate both static and dynamic pressure checks.

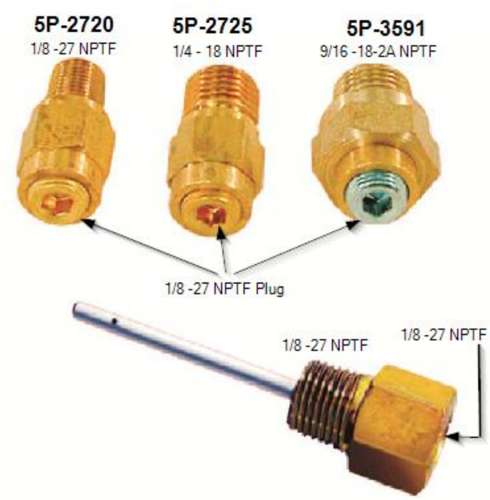


Figure 47: Cat pressure probe groups.

Pressure Probe Adapter	External Thread Size
5P-2720	1/8 – 27 NPTF THD
5P-2725	1/4 – 18 NPTF THD
5P-3591	9/16 – 18 NPTF THD
Pressure Probe	**External Thread Size**
164-2192	1/8 – 27 NPTF THD

Table 8: Pressure Probe Sizes

Recommended Pressure Check Points

Note: Items A through H are an approximation of specific port locations. Installation drawings should be referenced for exact locations. Bolded items are typically customer supplied ports.

- **A. Jacket water pump inlet**
- B. Jacket water pump outlet
- C. SCAC pump inlet
- D. SCAC pump outlet
- E. Jacket water temperature regulator inlet
- F. Jacket water temperature regulator outlet
- **G. SCAC temperature regulator inlet**
- **H. SCAC temperature regulator outlet.**

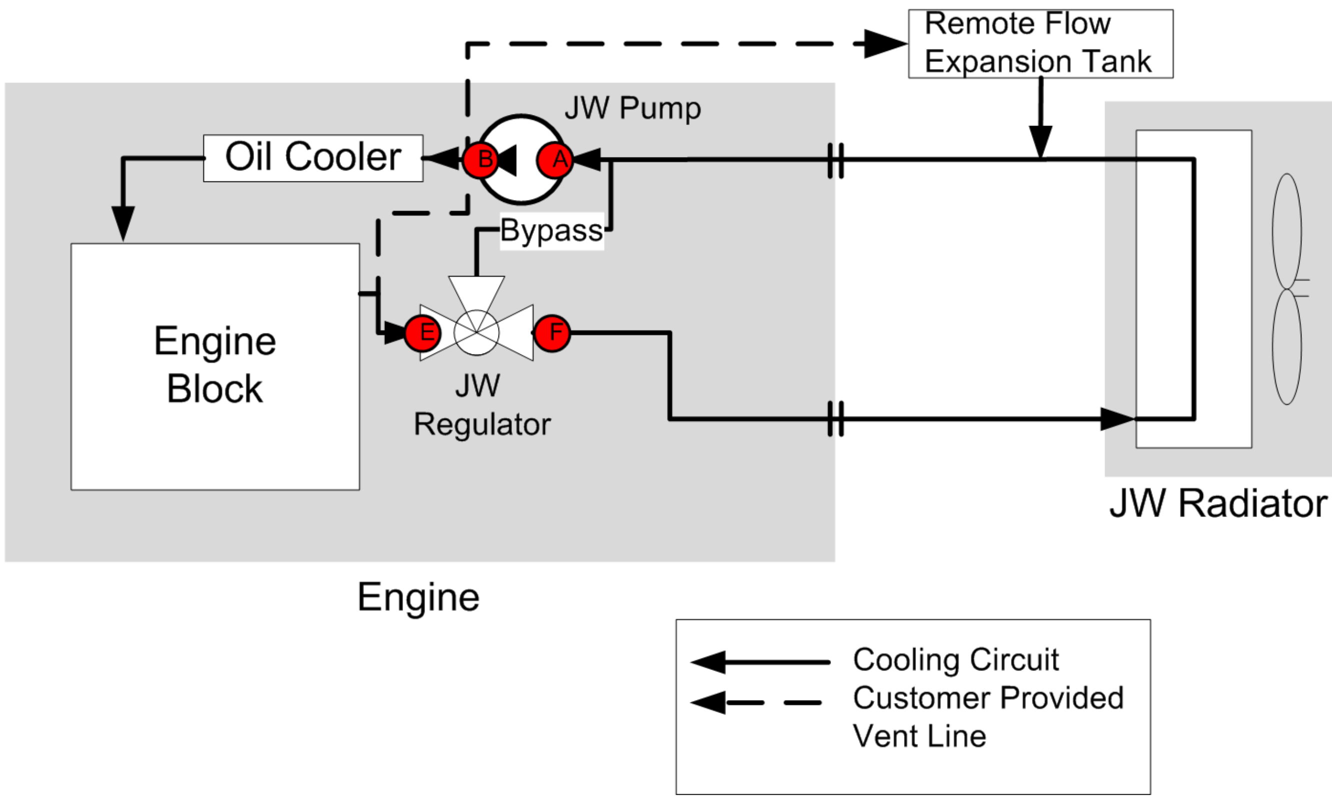


Figure 48: G3300 NA cooling system pressure check locations.

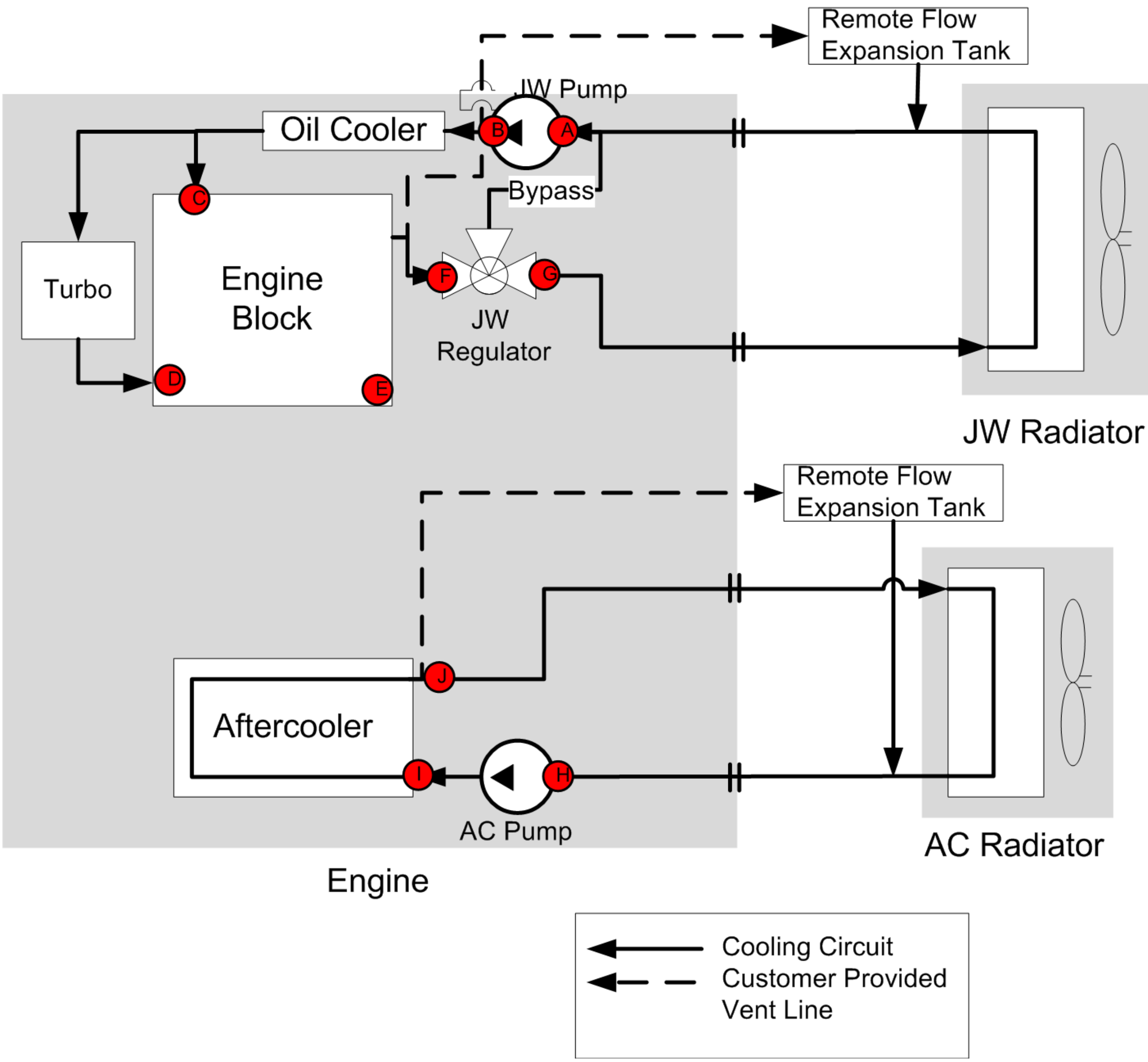


Figure 49: G3300 TA cooling system pressure check locations.

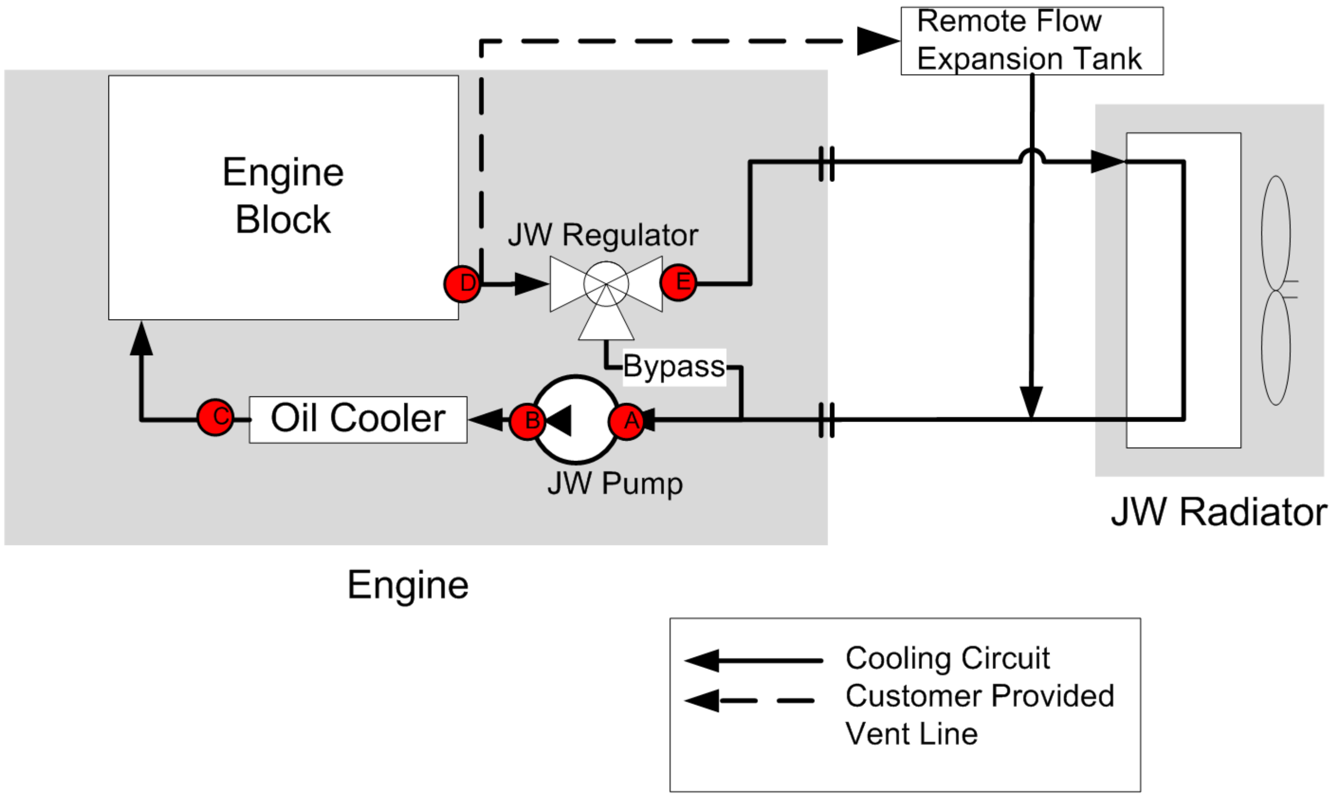


Figure 50: G3406 NA cooling system pressure check locations.

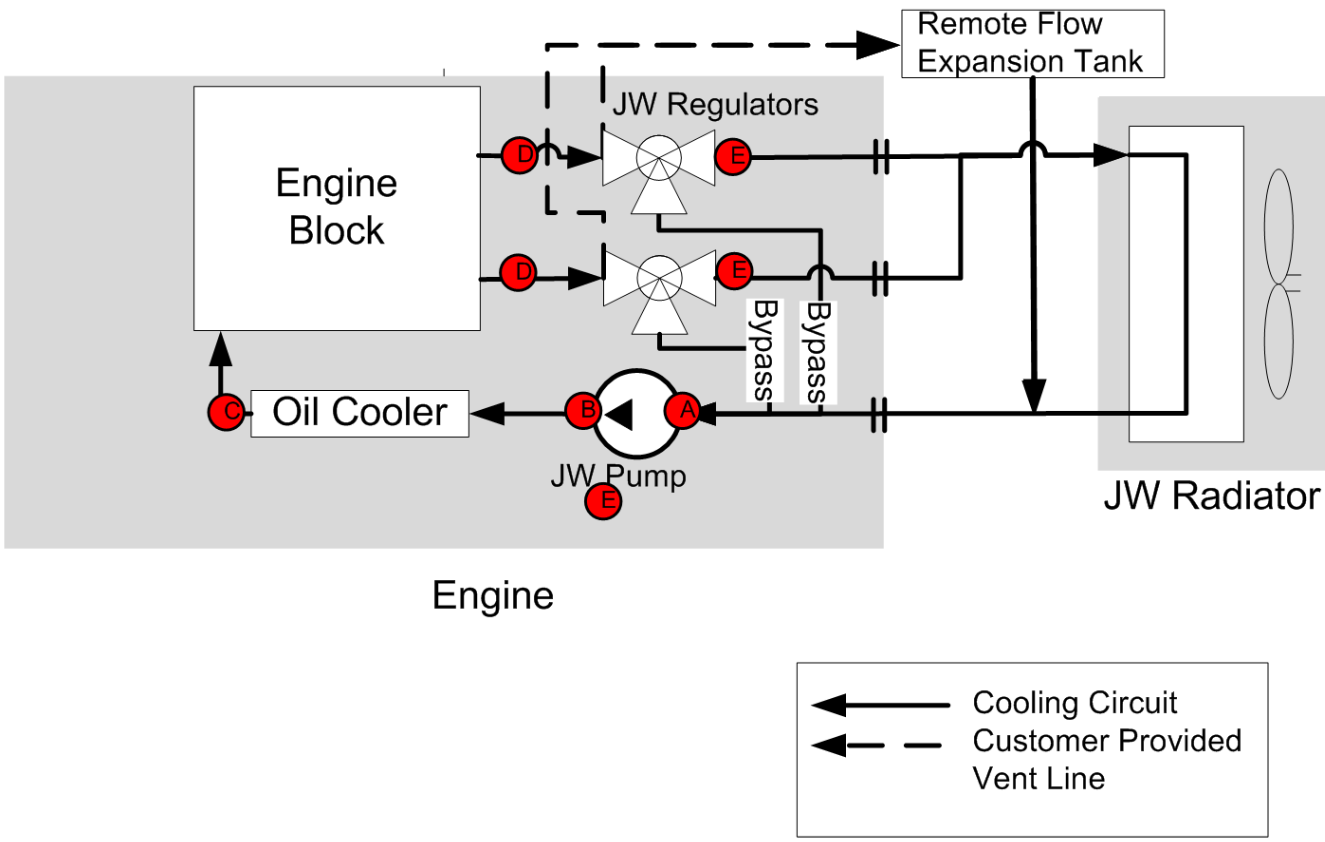


Figure 51: G3400 NA V-block cooling system pressure check locations.

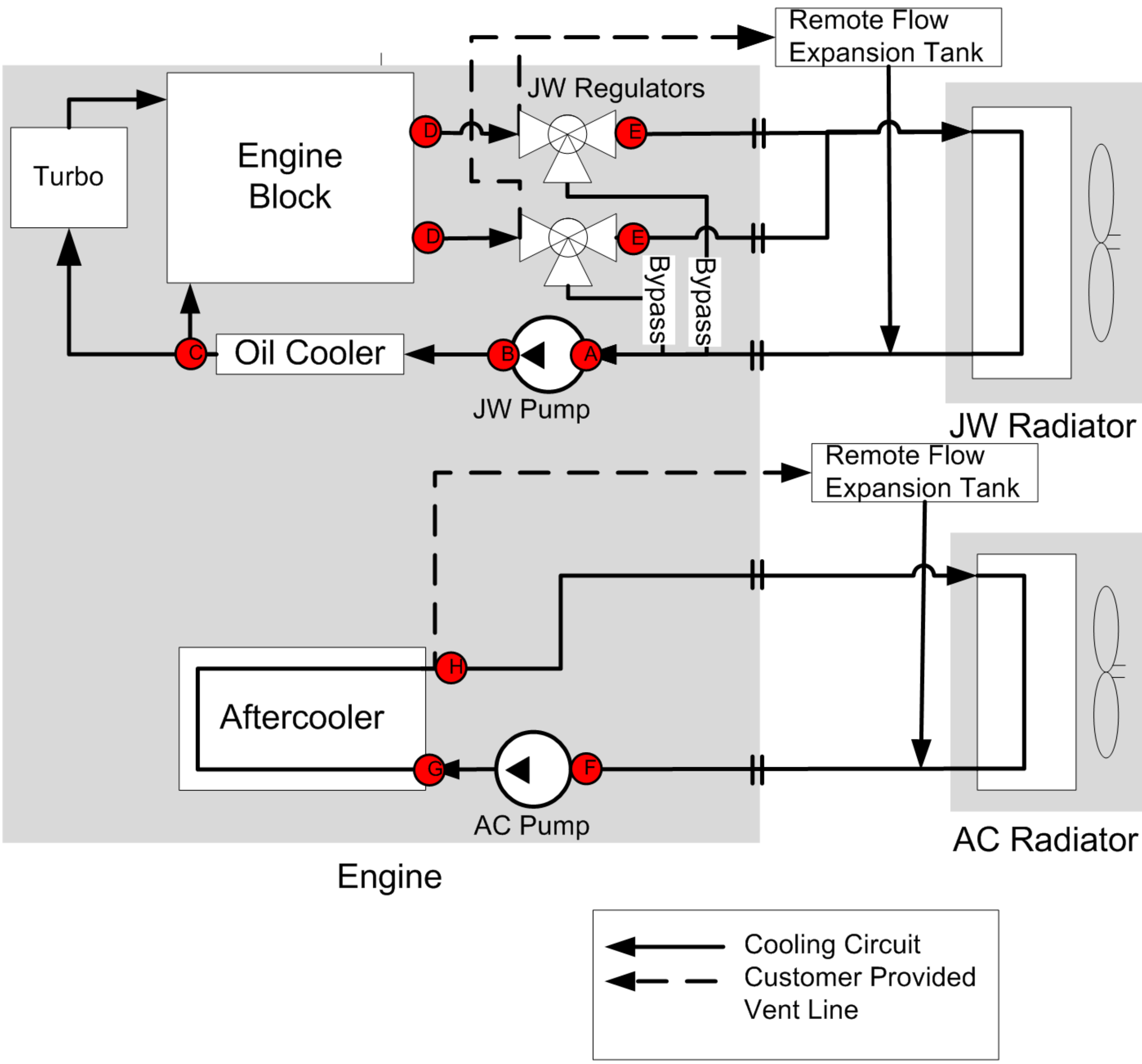


Figure 52: G3400/CG137 TA V-block cooling system pressure check locations.

Jacket Water Heaters

Engine start can be difficult during cold ambient conditions. Jacket water heaters are required when starting an engine in 16°C (60°F) or lower ambient temperatures. These devices heat up the jacket water and circulate it through the engine block, allowing for faster and easier starting, as well as quicker warm-up cycles. With smaller sized blocks, the jacket water also helps warm up the engine oil, eliminating the need for an oil heater in smaller engines. In environments with low temperature, high moisture conditions, moisture condensation around the spark plug can prevent the engine from starting. Jacket water heaters are highly recommended under these conditions to prevent the engine head from cooling down during shutdown periods. Follow the mounting and sizing guidelines in the Cooling System A&I Guide, LEBW4978.

Convection Heater - Caterpillar Supplied

On select small gas engines, there is a pricelist option for convection style jacket water heaters that are UL recognized and engine mounted from the factory. The jacket water heater is not CSA certified. These heaters use thermosiphon action, the natural expansion and rising action of a heated fluid, to circulate heated coolant throughout an engine's water jacket.

The heaters are customer wired. The heater thermostats must be used in a control circuit with a contractor for switching the main power to the heating elements. The customer will need to provide a contactor and box for a 240/480V, 6kW, single phase heater that disables the jacket water heating system when the engine is running. Field wiring and the contactor box are not part of the Caterpillar CSA certification scope.

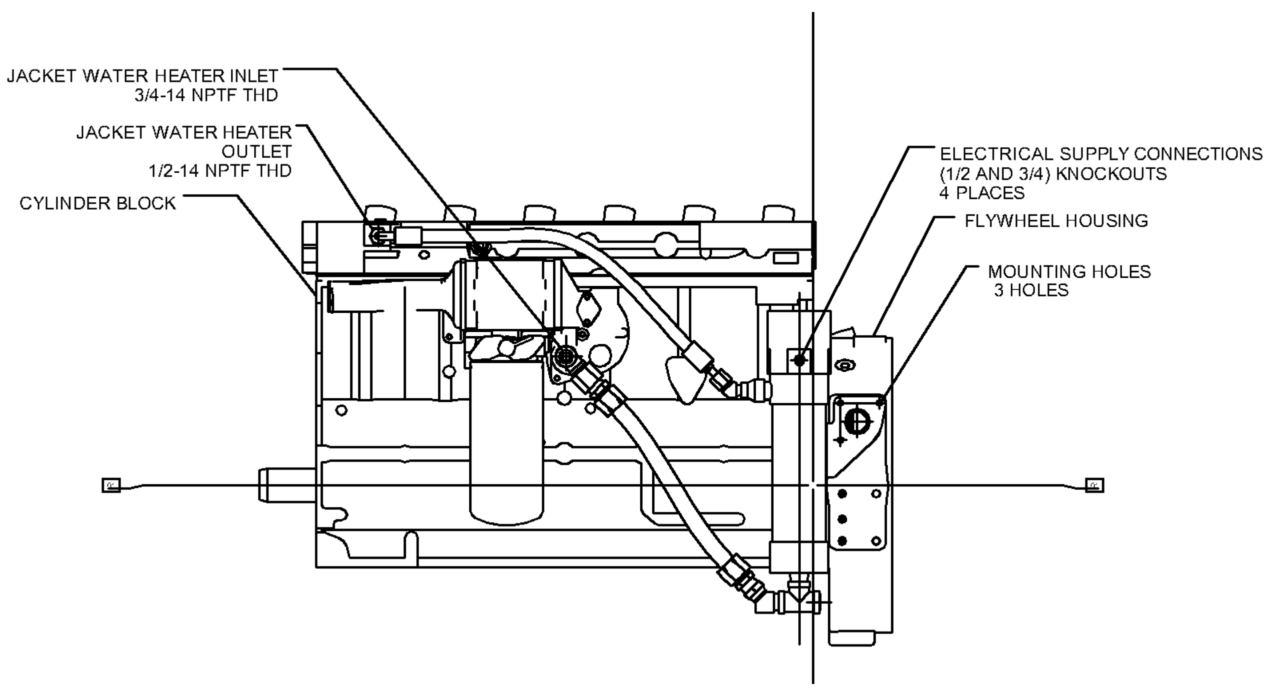


Figure 53: Convection heater installed on a G3306 engine.

Aftermarket - Pump Style Heater

For engines that do not offer an onboard convection style jacket water heater, an aftermarket off-board pump style heater can be used. Figure 54 shows an example of an aftermarket pump style, combined jacket water and oil heater. Only heating the jacket water is necessary on small gas engines, due to the smaller block and subsequent heating of the oil from the jacket water.

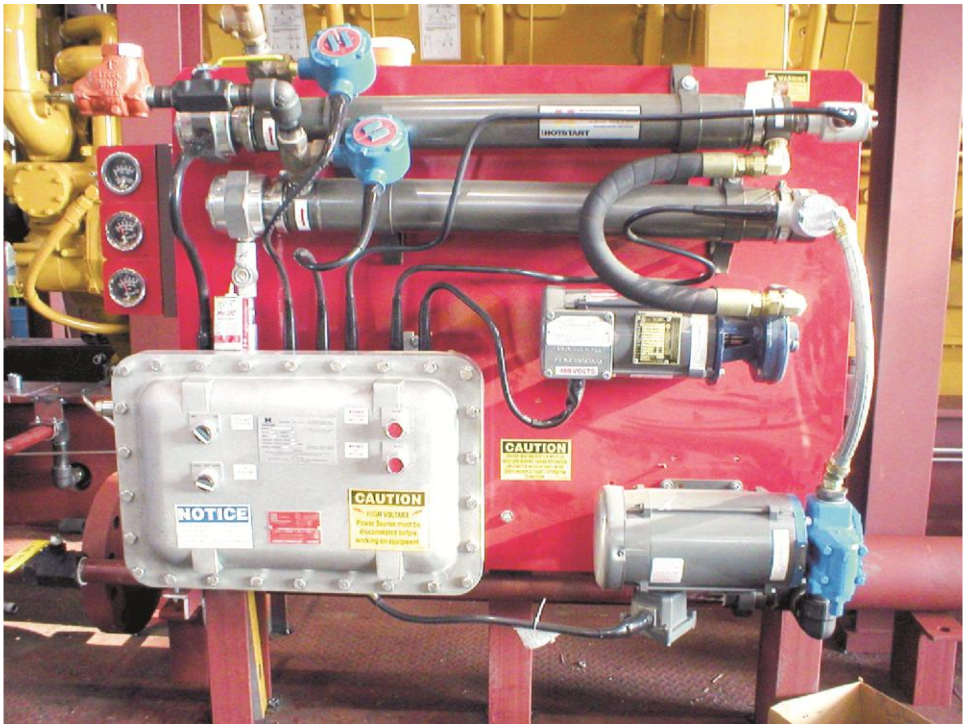


Figure 54: Aftermarket style jacket water heater.

General Installation Guidelines for Pump Style Heaters

- Mount the heater as low as possible.
- The cold water inlet (suction) to the heater should be from the jacket water inlet piping immediately ahead of the pump piping connection within 305 mm (12 in). This connection should be near the pump inlet/bypass connection.
- Avoid loops or any situation where an air lock could be created to prevent flow of the coolant.
- Join the hot water side (discharge) of the heater near the lower rear section the engine jacket water cooling system. Include a check valve in this line to prevent pressure from backfeeding to the heater during engine operation. This will prolong the JW heater pump seal life. Use the jacket water heater connections group to locate this inlet to the cylinder block coolant section.
- Use the same pipe size (or larger) as the heater connections.
- Caution: Do not create hot water loops. Hot water line should enter the engine in either a horizontal or slightly upward inclined plane, eliminating the possibility of forming a steam pocket.
- This should be used for a jacket heater which uses a pump for flow.

Fan Drive

Due to the smaller size of the necessary radiator, typically small gas engines will have a radiator mounted closely to the front of the engine or offset from the front of the engine, as shown in Figure 55.

If a larger radiator is necessary and a remote fan drive is used, the engine crankshaft and pulley system must able to handle the side load. Excessive side loads may cause failure of the stub shaft and/or bearings or excessive crankshaft deflection.

Figure 56, shows a situation in which an off-board fan drive is being used. In this case, the measured side load must not exceed the maximum allowable torque on the crankshaft mounting face. Figure 57 and Figure 58 show the allowable side loads on the crankshaft based on the distance of the farthest belt. Table 9 shows the optional stub shafts available and their total length. For the graphs, the load is assumed to be 90° vertically upward with respect to horizontal.

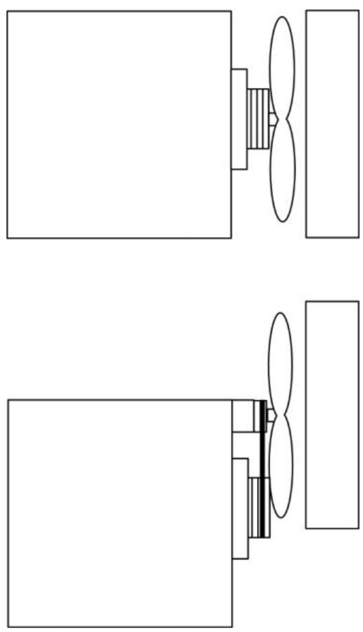


Figure 55: Comparison of a center mounted fan drive vs. an offset mounted fan drive. Both of these drive layouts are considered an on-board fan drive.

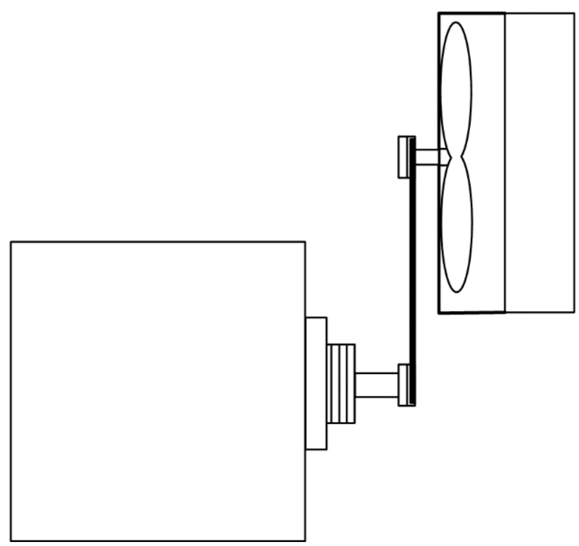


Figure 56: Example of a remote, off-board fan drive, with an enclosure. The side loading on the crankshaft must be calculated to ensure that excessive loading of the bearings do not occur.

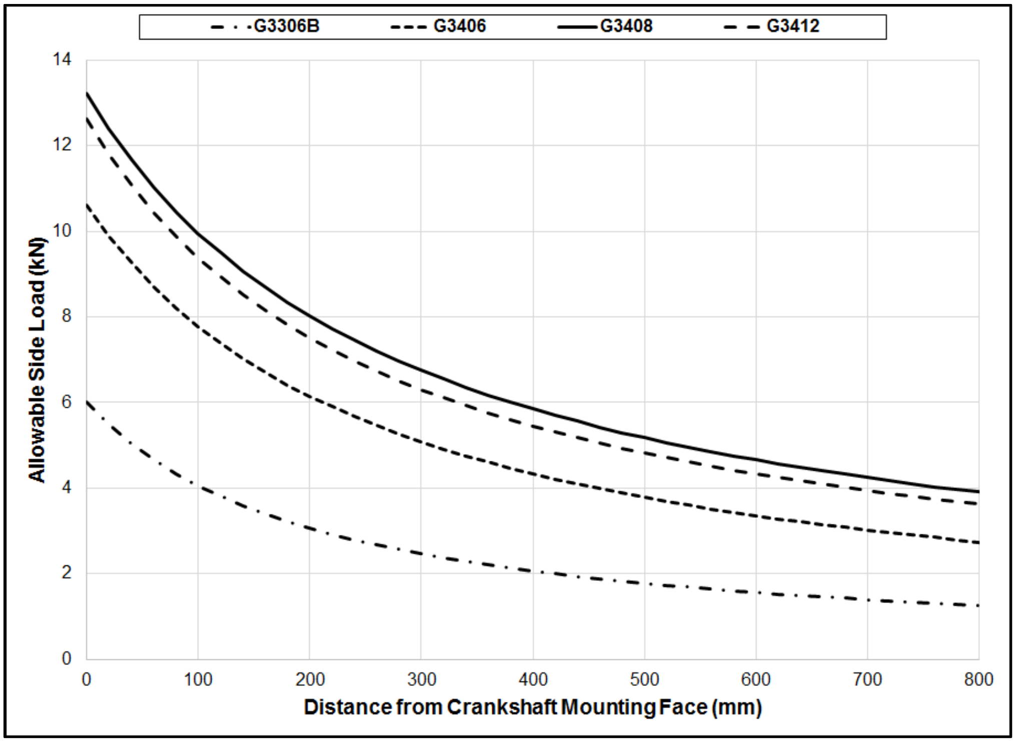


Figure 57: Fan drive side load limits vs. distance from crankshaft mounting face. (Metric units)

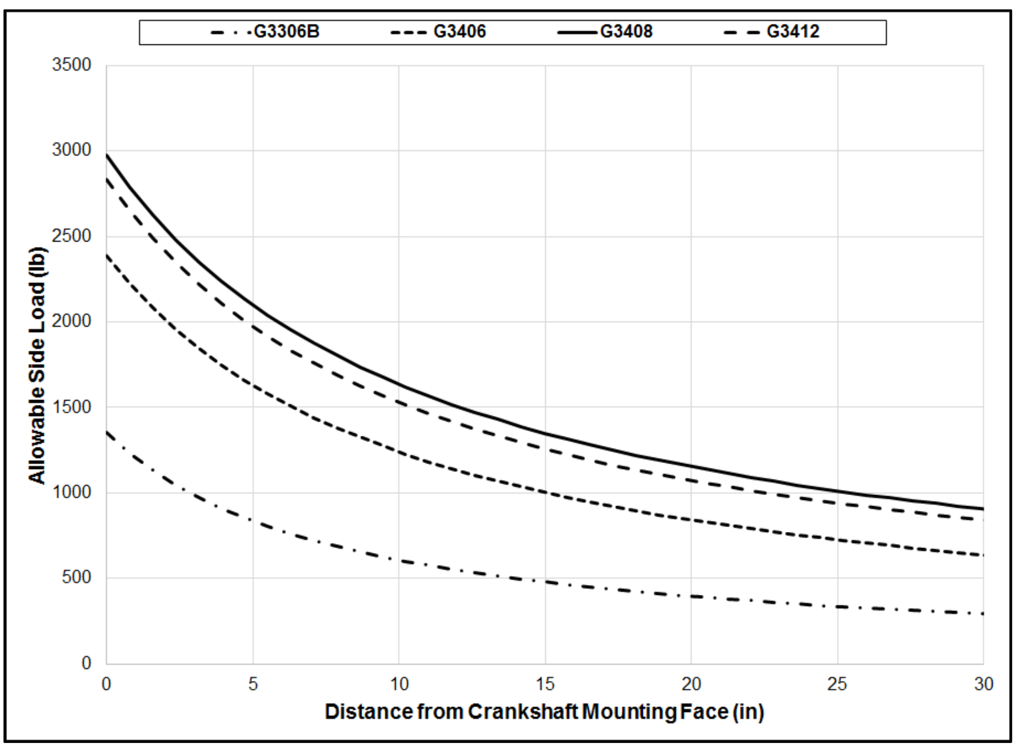


Figure 58: Fan drive side load limits vs. distance from crankshaft mounting face. (English units)

Engine	FC	Stub Shaft Part Number	Damper	Distance from CMF to ENDSS mm (in)	Notes
G3304B/ G3306B	STSFR01	6L2681	1678123	260.8 (10.27)	Front Stub Shaft
	STS0004	6L2704	-	190.2 (7.49)	Flywheel Stub Shaft
G3406	STSFR05	4931222	1678126	183.4 (7.22)	Front Stub Shaft
	STSFL01	3N6537	-	260.4 (10.25)	Flywheel Stub Shaft
G3408/ G3408C	STSFR01	3N6059	1678130	263.4 (10.37)	Front Stub Shaft
	STSFL01	3N6537	-	260.4 (10.25)	Flywheel Stub Shaft
G3412/ G3412C	STSFR01	3N6059	1678130	263.4 (10.37)	Front Stub Shaft
	STSFL01	3N6537	-	260.4 (10.25)	Flywheel Stub Shaft
CG137-8	STSFR04	3N6059	1678130	263.4 (10.37)	Front Stub Shaft
	STSFL02	3N6537	-	260.4 (10.25)	Flywheel Stub Shaft
CG137-12	STSFR03	3N6059	1678130	263.4 (10.37)	Front Stub Shaft
	STSFL01	3N6537	-	260.4 (10.25)	Flywheel Stub Shaft
Note: CMF (Crankshaft Mounting Face), ENDSS (End of Stub Shaft)					

Table 9: Stub shaft part numbers and length from crankshaft mounting face to end of stub shaft.

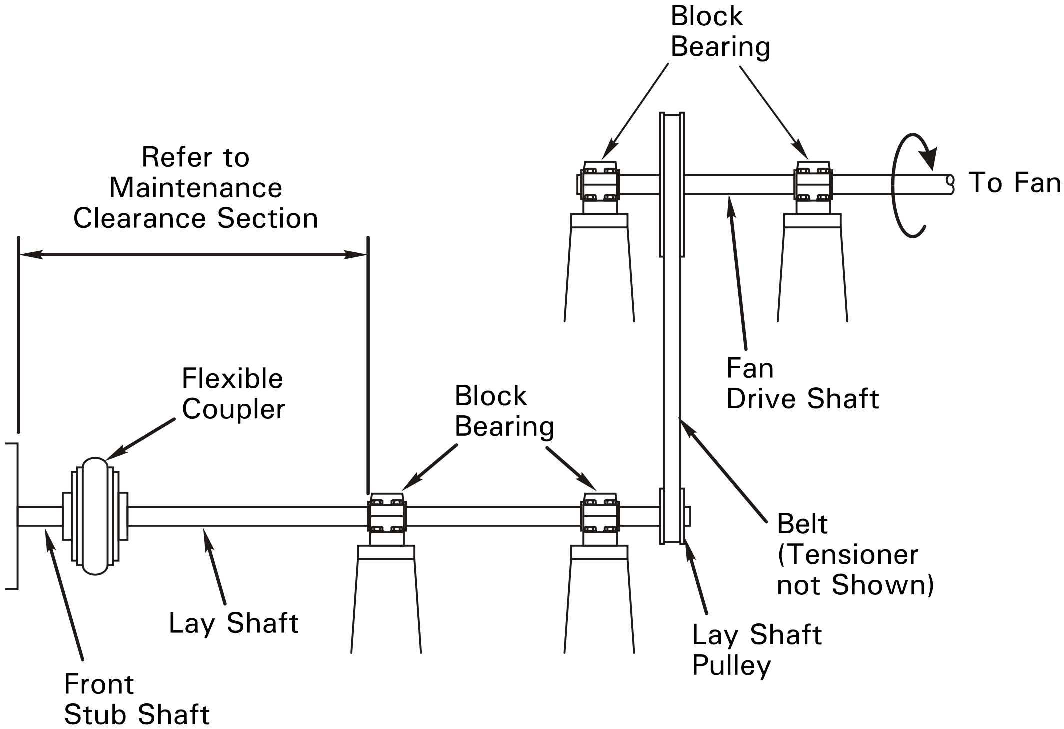


Figure 59: Sample fan drive.

The use of a flexible coupler to transfer power from the stub shaft to the fan drive is highly recommended. This device will accommodate slight misalignments and thermal growth. The installer must always ensure that they are within the tolerance of the coupler's manufacturer.

Always ensure thermal growth is accounted for in fan drive design. Thermal growth will occur not only along the axis of the shaft, but vertical growth of the engine will occur as well.

The example in Figure 59 is an effective configuration because of the following features:

- A flexible coupler absorbs the engine's vertical growth, and allows small misalignments between the front stub shaft and the lay shaft
- The lay shaft is supported by two block bearings, which support the entire side load applied by the belt on the lay shaft
- The maintenance clearance length is maintained and consistent with the recommendation in the "Maintenance Clearances" section of this guide
- The fan drive shaft is located at the desired fan height and supported by two block bearings, thus ensuring reliable alignment.

Fan drive configurations vary extensively depending on the application. However, these general recommendations should be followed in all designs in order to ensure the reliability and durability of the fan drive system while ensuring the serviceability of the front of the engine.

Electrical System

The customer's DC circuit must be 24 volts and capable of providing a minimum of 20 amperes. The return must be capable of absorbing a minimum of 20 amperes. The voltage drop must be no more than 1 volt at the maximum current draw with a maximum of 150 mV AC ripple voltage. If a power supply is used instead of batteries, the output must also meet this noise level specification.

Earth Ground

The engine block must be connected to an earth ground using #6 or #8 wire size cable or straps. Cable connection points must be clean, rust-free, and protected from possible oxidation. Silver soldered and bolted joints are electrically and mechanically sound, and therefore recommended for grounding purposes.

The earth ground connection must be made directly between the engine block and the skid's ground connection. A ground connection to the engine's mounting bolts shall be avoided.

Fuel System

This section is a compilation of tips and best practices related to the installation and commissioning of fuel systems for small gas engines. The recommendations provided in this section are based on experiences gathered from the field. For detailed information about gaseous fuel systems, please consult the Gaseous Fuel Systems A&I Guide, LEBW5336.

All Caterpillar small gas engines use a carburetor for air/fuel mixing. Except for the G3400C low emission engines, a rich burn combustion strategy is employed. Depending on the engine and rating, air/ fuel ratio control is either supplied by Caterpillar or to be provided by the customer. For more information, consult the specific engines pricelist.

General Design Considerations

The purpose of a properly designed external fuel system is to ensure that the engine is provided with a constant supply of clean gas at a constant pressure and desired temperature. The performance of the engine is dependent on the quality of the fuel supply. Therefore, a proper setup of gas pressure regulators, filters and heaters/coolers (if necessary) is required to ensure correct operation of the engine. The actual setup will be highly dependent on the local conditions and fuel. For example, a fuel supply of very high pressure will require additional knockdown pressure regulators before the fuel can be fed into the system. Similarly, a cold weather operation may require a fuel heater to bring the temperature of the gas within the requirements of the fuel system.

It is the end user's responsibility to ensure that clean fuel at the proper temperature and pressure is used for combustion. Failure to do so may result in one or more of the following:

- Unstable engine operation due to fuel pressure variations
- Severe engine damage due to particles, water, or ice in the fuel
- Detonation or engine derate due to fuel temperature outside of limits
- Engine damage due to other contaminants in the fuel, including hydrogen sulfide
- Fuel system failure due to formation of liquid hydrocarbons in the fuel system caused by low fuel temperatures in the system.

In order to prevent such situations, it is recommended that the external fuel system be designed around the following considerations:

1. Fuel pressure into the engine must stay constant and in the following range:
    - G3300 NA ....10.3 to 68.9 kPag (1.5 to 10 psig)
    - G3300 TA ....82.7 to 172.4 kPag (12 to 25 psig)
    - G3400 NA ....10.3 to 34.5 kPag (1.5 to 5 psig)
    - G3406 TA ....Low Pressure 10.3 to 34.5 kPag (1.5 to 5 psig)
    - G3400 TA ....High Pressure 137.9 to 172.4 kPag (20 to 25 psig)
    - G3400C.................................10.3 to 34.5 kPag (1.5 to 5 psig)
    - CG137...................................Low Pressure 10.3 to 34.5 kPag (1.5 to 5 psig)
    - CG137-8 (ST8 Prefix) ....High Pressure 137.9 to 275.8 kPag (20 to 40 psig)
2. Fluctuations in fuel pressure at the engine inlet must not exceed 1.7 kPa (0.25 psi).
3. The fuel temperature at the engine connection must be 10°C to 60°C (50°F to 140°F).
4. Large pressure drops in fuel shall be avoided. If a large pressure drop between the fuel supply and the engine must be implemented, consider multiple knockdown pressure regulators to bring the pressure down in steps.
5. A fuel filter must be included and have the following capabilities:
    - 1 micron solids filter
    - Coalescer
    - Automatic liquid dump valve
    - Sight glass
    - Manual drain
6. Fuel heater/cooler devices are recommended for extreme ambient weather installations to maintain the fuel temperature within the specifications in 3.
7. Ensure that the GSOV, Gas Pressure Regulator, and related equipment do not exceed their maximum pressure ratings.

An example of an external fuel system is shown in Figure 60. Note that the system's fuel pressures are only examples to represent the functionality of the elements. Fuel pressures and temperatures will be dependent on the site.

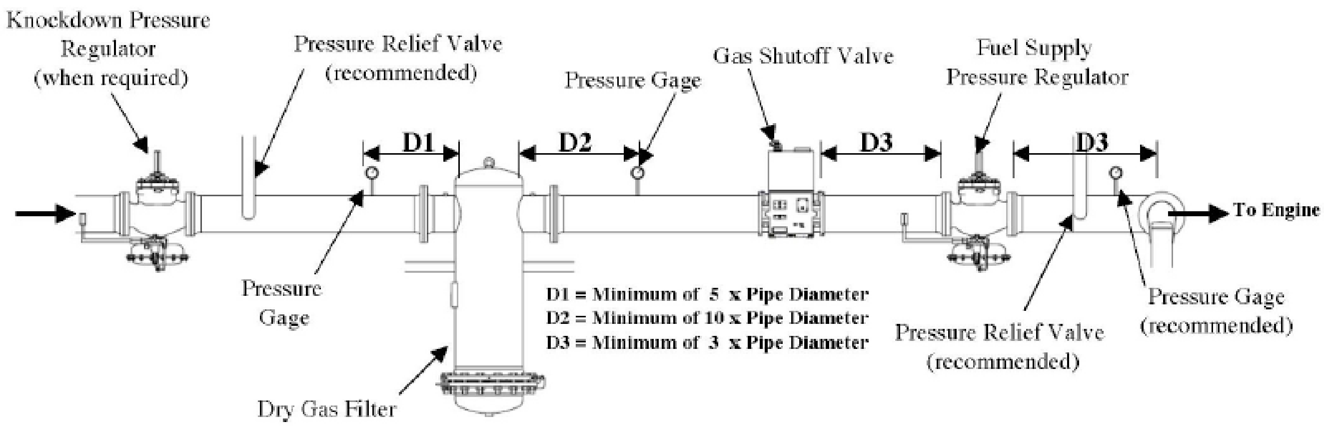


Figure 60: Example of an external fuel system configuration.

Note: Fuel filters supplied by Caterpillar are designed to remove particles only, not liquids. If this filter is used, additional provisions must be made to ensure the removal of liquids from the fuel.

Connections

It is critical that the connection between the external fuel system and engine fuel inlet is made by means of a flexible hose or a hazardous area connection component. Under no circumstances should a regular rigid tube connection be used.

Thermal expansion of the engine, torque reaction movements, or any other relative motion between the engine and the external fuel system may cause a rigid tube to undergo cyclical loads and fail due to fatigue. Breaking this connection will cause a dangerous leak of flammable gas fuel.

Note: Follow the same considerations when using gas to power the engine starter.

If the pressure regulator has a vent port, there must be piping to direct any gas from the vent safely away from the engine.

Fuel System for Multiple Engines

Many installations that use several engines have a common fuel supply. This setup is acceptable as long as the following design considerations are followed:

1. Header sized for 110% of full load fuel consumption. Consult your specific technical data sheet for engine fuel consumption

2. Fuel pressure regulator on each engine

3. Fuel header pressure within the allowable pressure range of individual fuel pressure regulators

4. Header must be designed such that no condensation of hydrocarbons occurs. Failure to properly design the header may cause liquid hydrocarbon drop out and clogging of the fuel header

Item 4 will be highly dependent on the conditions at the site. The conditions under which hydrocarbon condensation will occur depend on the fuel composition, pressure and temperature at which it enters the header. Large drops in pressure in knockdown pressure regulators will induce hydrocarbon condensation under the right conditions.

Lubrication System

This section is a compilation of tips and best practices related to the lubrication system of small gas engines during their installation and commissioning. Proper lubrication of the engine is crucial to its performance, reliability, and durability. This section addresses recommendations for the end user that, if followed, will increase the productivity of the equipment and reduce its downtime. For detailed information about lubrication systems in Cat engines, please consult the Lubrication Systems A&I Guide, LEBW4957.

Type of Oil

Caterpillar only recommends the use of Cat NGEO (Natural Gas Engine Oil) in G3300, G3400, and CG137 engines. This oil is specifically designed to meet all the requirements related to the performance and operating condition of the engine. In addition, its additive package has been proven through Caterpillar field-testing.

If the end user desires to use oil from other suppliers, it is recommended to check with Caterpillar to verify that the field test is available. Gas engine oils that have completed 7,000 hours of documented field service in G3300, G3400, and CG137 engines are acceptable.

Engine oil used in small gas engines must comply with the following characteristics:

- Formulated specifically for heavy duty gas engines
- Ash values is between 0.4% and 0.6%
- SAE 40 viscosity

Refer to “Gas Engine Lubricants, Fuel, and Coolant Recommendations”, publication SEBU6400, for more information.

Starting System

Several starter options are available for small gas engines. The air or gas starter is available in either a vane or turbine type design, with either CSA or non CSA certification. The electric starting motor requires 24V. For a detailed description of starting systems in Cat engines, consult the Starting Systems A&I Guide, LEBW4980.

Installations with multiple engines commonly use gas powered starters whose exhaust is connected to a common piping system. It is particularly important to ensure that the backpressure in each starter exhaust does not exceed 103 kPa (15 psi). If the backpressure in the starter exceeds such pressure level, the pinion may be pushed into the flywheel's outer ring, causing severe damage. Additionally, ensure that one starter backpressure valve is installed in each starter.

Care must be taken to ensure that piping to the starter is the correct size. The engine must reach a minimum speed to start. Even if the correct pressure has been reached to start the engine, if the piping is too small, the engine may not start if the required volume of air is not reached. For the engine starter requirements, refer to the specific engine series Technical Information A&I Guide.

The air or gas used for starting must filtered and dry prior to entering the starting motor.

The installation of the starter using natural gas is similar to the air installation except all fittings, piping, valves and regulators must be compatible with natural gas.

Proper control of natural gas is a major consideration when used in the starter system. All starters using natural gas must pipe the exhaust according to industry codes and local regulations, and ensure it is routed safely away from the engine.

There is a natural gas vent port in the turbine housing that is plugged for compressed air use. This vent is used to remove any natural gas that could leak past the primary turbine shaft seal. Remove this 3/8" NPT plug (See Figure 61) and install a line to carry gas away from the starter area to a safe location.

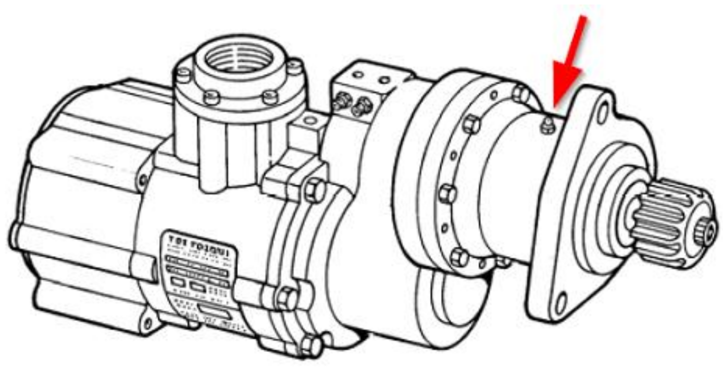


Figure 61: Natural Gas Vent Port

WARNING: Do not connect the turbine housing vent line to the turbine exhaust line. Exhaust gas can pressurize the turbine housing.

Starter Venting

If combustible gas is used to operate the starting motor, it must be routed safely away from the engine. The exhaust port on both the prelube and starter solenoid valve must be connected to piping to direct the gas away from the engine. Some solenoid valves have 3 ports, with the 3rd port being a vent. If the solenoid valve has a vent port, it must also have piping to direct the gas safely away from the engine. Each port should have its own pipe. Refer to the specific engines installation drawing for the vent size.

Caution must be taken when designing these exhaust and venting systems. These piping systems should not be connected to a piping system which may see higher pressures. The higher pressure systems can backflow these systems and cause damage to lower pressure rated devices. One-way check valves may be helpful in preventing such backflows, but care must be taken to ensure the valves are rated for the pressures and flows involved. Improperly sized check valves will restrict flow, creating back pressure. In many cases the safer approach is to keep high pressure systems completely separated from these low pressure systems.

The starter's solenoid valve is shipped with a check valve installed on the exhaust port. The existing check valve has a cap that must be removed if possible. If the cap cannot be removed, remove the entire check valve and install a new check valve in the exhaust line. The check valve must operate with pressures up to 1034 kPa (150 psi).

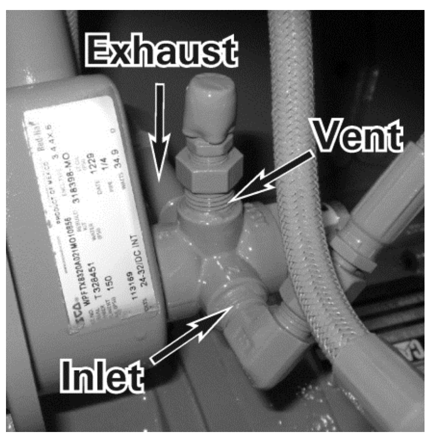


Figure 62: Starter Solenoid Ports

Package Considerations

The integration of a small gas engine into a gas compression package involves design decisions for the package that must work well with the engine's performance and capabilities. The piping and controllers used in the process lines to and from the compressor are one such area of concern.

Compressor Bypass

The engine's starting system is sized to accommodate the cranking torque requirements of the engine and an unloaded gas compressor with some additional capability in reserve. It is not realistic for the start-up scheme of the engine to be capable of supporting the full operating torque of the compressor. This is one reason it is common practice to design in a valve-controlled bypass that returns the gas from the compressor's discharge to its suction side. This bypass allows the compressor to be unloaded to a reduced torque condition without "blowing-down" the gas path to the atmosphere. When operated together with valves on the station suction and discharge connections, the bypass allows the compressor to be isolated from the station's external connections when needed.

With the valves set to place the compressor in this isolated "bypass" mode, the compressor discharge goes directly back to the suction-side piping where the pressure will settle out to a particular level depending on station design variables such as the isolated suction piping volume, compressor discharge pressure, and compressor gas flow volume. The torque demand of the compressor will depend on the resulting "settle-out" suction and discharge pressures and, if flow rates are high enough, the sizing of the bypass piping. Bypass pipes that are too small in diameter may add torque demand by restricting gas flow through the bypass.

The starter options available from the factory are generally capable of cranking the package at the desired RPM if the compressor's total turning torque does not exceed 25% of the engine's full rated torque value. This rule of thumb scales well across various engine sizes and thus serves as a general design guideline. This start-up condition can be evaluated by comparing the torque capability of the starter arrangement to the sum of the driven torques in the package, including:

- The engine's cranking torque, available in the Technical Information A&I Guide;
- The compressor's cranking torque, often available as an estimated value from the compressor manufacturer's sizing tool;
- Any other significant torque loads that are connected during cranking.

The torque capabilities of the factory starter arrangements are also available in the Technical Information A&I Guide. These are presented as graphs of torque versus starter RPM, relative to the starter input (starter supply pressure for air/gas starters or amp draw for electric starters). It is important to remember to convert starter torque and RPM to their equivalent at the engine's flywheel by using the gearing ratio between the starter pinion and engine's flywheel ring gear. This is simply the ratio of teeth on these two gears, and the tooth count values for each gear are included among the starter information presented in the Technical Information guides.

Suction Controllers

Installations where a single header supplies fuel gas to multiple gas compressor packages are common. In such cases a dedicated suction controller should be installed for each compressor. Dedicated suction controllers will help prevent the shutdown of a single compressor package from affecting other neighboring units. This control configuration can greatly enhance the uptime and reliability of the entire compression station.

Instrumentation and Controls

The G3300B and CG137 engine series utilizes ADEM A4 control system for speed governing, ignition control, air fuel ratio control, and built in protection/ diagnostic functionality. These engines are started and stopped through the ADEM A4 control logic. Cat ET (Electronic Technician) service tool is used by Cat dealer technicians to setup and adjust engine parameters. The optional OCP (operator control panel) is available on the G3300B and CG137 engines and provides a user-friendly interface for the operator of the engine. Further information on the OCP can be found in the OCP Interface CG137 Special Instruction Guide (M0065654) and in the OCP Systems Operation Troubleshooting Testing and Adjusting Guide (UENR3193).

The G3408C and G3412C engines use either the standard EIS (electronic ignition system) or the optional CSA digital ignition system. Several protection system options are available for these engines, as outlined in the engine configuration section. An optional instrumentation panel is available on the G3400 engine series.

For more specific information on instrumentation and controls see the Gas Control Systems & Ignition Guide (LEBW4982) which contains more information on the engine control, protection, and monitoring systems of the small gas engine series.

Cat® Connect

Cat Connect is Caterpillar's telematics solution that provides remote monitoring capability to the engine for specific users. A list of available countries where the Cat Connect radio can operate are listed in the engines pricelist. A choice of cellular radio or satellite based radio and antenna is available.

Operation

This section addresses field-based recommendations that have been acquired from successful operation practices of small gas engines. It is designed for its use in conjunction with the Operation and Maintenance Manuals.

Engine Start

Proper engine start procedures must be followed to ensure that the engine or the driven equipment will not suffer any damage due to improper starting techniques.

Caterpillar recommends as best practice to always use jacket water and oil heaters before starting engines when the ambient temperature falls below 10°C (50°F). Caterpillar requires a jacket water and oil heater before starting when the ambient temperature falls below 0°C (32°F). This will reduce the torque required for starting and will allow the engine to warm-up quicker.

Before performing either automatic or manual start procedures, ensure that the bypass valve is fully open as to relieve the engine from any load during start-up.

Warm-up

Warm-up should always be performed at low idle speed under no-load condition. Refer to the next paragraph for further detail.

Loading

Loading of the engine should be performed at the rated engine speed and after the minimum oil pressure has been reached. Follow these considerations when proceeding to load the engine:

- Increase the engine speed to rated rpm. Ensure that the gauges are in the normal ranges for the engine rpm.
- Engage the driven equipment with no load on the driven equipment.
- The engine can be loaded up to 50% of full load before the outlet temperature of the jacket water reaches 77°C (170°F).
- Ramp to full load after the outlet temperature of the jacket water reaches 77°C (170°F).

Low Load Operation

Cat gas engines are designed for optimal lubrication system performance at rated power conditions (full speed and full load). The pressures in the intake manifold and in the combustion chamber vary significantly with engine load, enough to have a significant impact on the rate of oil ingestion at the intake valve guides and piston rings. This increased intake of oil can lead to the formation of carbon deposits at either location. Deposits on the valves tend to coat the seating surface of the valve, potentially affecting air flow or in extreme cases allowing leaks across the seat that can result in a guttered valve. Deposits in the combustion chamber can create hot spots that contribute to detonation/preignition.

These conditions should be expected to have a detrimental effect on the service life of the engine, adding to down time and costs for more frequent servicing or, less commonly, for repairs to damaged parts. For these reasons Cat gas engines should not be operated at low loads for extended periods of time. Information about the recommended limits for time spent in operation at low loads may be found in the Operation and Maintenance manual for each engine model. For most engine models the threshold for what would be considered as "low" loads is 50% of full rated power.

Engine Stop

Before stopping the engine, ensure that the bypass valve is fully open. Reduce engine speed to low idle and allow the engine to cool down for one to two minutes. Stop the engine by turning the engine control switch to the “STOP” position. The automatic stop function will automatically perform a pre-programmed cool down cycle, followed by the engine shutoff and operation of the prelube pump for post lubrication of the internal engine components.

Pushing the E-stop button shuts down all components on the engine and disables the post-lube function. This does not allow oil to circulate which could cause damage to the turbocharger and/or internal engine components. Because of this, the E-stop button should only be used to shut down the engine under extreme situations.

References

The following information is provided as additional reference to subjects discussed in this guide.

SEHS9031 - Storage Procedure for Cat Products

PEHJ0241 - Cat Engine Storage and Preservation Datasheet

SEBU8553 - Operation and Maintenance Manual – CG137 engines

SEBU6356 - Operation and Maintenance Manual – G3304 and G3306 engines

SEBU8446 - Operation and Maintenance Manual – G3304B and G3306B engines

SEBU6359 - Operation and Maintenance Manual – G3406 engines

SEBU6682 - Operation and Maintenance Manual – G3408 and G3412 engines

SEBU6883 - Operation and Maintenance Manual – G3408C and G3412C engines

LEBW4969 - Application and Installation Guide – Air Intake Systems

LEBW4975 - Application and Installation Guide – Alignment

LEBW4970 - Application and Installation Guide – Exhaust Systems

LEBW4978 - Application and Installation Guide – Cooling Systems

LEBW4957 - Application and Installation Guide – Lubrication Systems

LEBW4980 - Application and Installation Guide – Starting Systems

LEBW4982 - Application and Installation Guide – Gas Control Systems & Ignition

SEBU6400 - Gas Engine Lubricants, Fuel, and Coolant Recommendations

SEHS7654 - Alignment – General Instructions

M0065654 - Special Instruction – OCP Interface for CG137

UENR3193 - Special Instruction – OCP Systems Operation and Troubleshooting

Small Gas Engine General Arrangement Drawings

Arrangement drawings can be found either in GERP or on the Engineering Drawing Design Center (EDDC) website https://enginedrawings.cat.com/

Auditing / Commissioning

Scheduled reviews of the package and installation are critical to ensuring the best practices shared in this document have been put to use. It is the responsibility of the project manager to ensure that reviews or audits are built into the project timeline to make certain they are completed at the appropriate stages. As described in our published materials on commissioning, it is best to conduct such audits at least once during three major phases of the project:

1. Design – during the development of the design and prior to any actual execution or completion of the build itself.
2. Construction – during the actual build process.
3. Commissioning – the final review of the completed installation prior to it being put into service.

Please review our publications regarding the final commissioning stage, as a very specific, detailed process is used to ensure all aspects of the installation have been checked out and the findings documented for future reference. The procedures used for this final stage serve as a guide for how audits may be conducted in the earlier stages of the project.

Auditing Checklist

Many of the details required for final commissioning are not available until that stage of completion of the project. Regardless, there are still many aspects of the design and execution that can be reviewed in advance to keep things in line with the application requirements and best practices shared here and elsewhere in the A&I Guides.

The following pages provide a generalized checklist for a pre-commissioning audit, using an orderly system-by-system approach. Please note that variations among projects make it impossible to build a checklist to cover all of the details that should be reviewed. Consider this checklist a tool that can help lend structure to an audit; however, there is no replacement for experience and understanding in completing the audit. Understanding the standard established for each system and the specifications accompanying each are critical to proper completion of the review. The auditor conducting the review must know where to deviate from (or add to) this outline of topics to ensure a thorough assessment of the package and installation.

Gas Compression Engine Installation Audit Checklist

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General Data

Project Name		Start Date	
Site Location		Time	
Site Address			
Customer			
Address		Contact Name and Phone #	
Audited By (Company and Address Info)		Auditor Name and Phone #	

Application: Describe the application, its purpose, and general details of the installation.

Cat Dealer Information

Selling Dealer		Servicing Dealer	
Address		Address	
Contact Name and Phone #		Contact Name and Phone #	

Auditor Information

Audited By (Company and Address Info)		Auditor Name and Phone #	

EQUIPMENT AND SITE INFORMATION

Engine Data		Compressor Data	
Engine Model		Compr. Model	
Serial Number		Serial Number	
Arrangement #		Arrangement #	
Rated Power and Speed		Frame Rating (Power/Speed)	
Performance #		Throws/Stages	

Compressor Configuration: Describe the compressor arrangement including suction and discharge pressures, target gas flow, cylinders selected, numbers of throws per stage, and any variable volume or unloading devices installed.

Site / Environment Information (indicate units)

Max. Ambient Temperature	**°F °C**	Engine Room Temperature	**°F °C**
Elevation	**feet meters**	Relative Humidity	**%**
Environment (describe)			

Fuel Information: Obtain current fuel composition from site and run through Caterpillar Methane Number (MN) Program. Describe the source of the fuel feed and any pertinent details or unusual aspects of it.

Lower Heating Value (LHV)	**Btu/scf MJ/Nm^3**	Wobbe Index	**Btu/scf MJ/Nm^3**
Caterpillar MN		Total Inerts	**%**

Notes:

AIR SYSTEM

Air Source: Locate the combustion air inlet. Inspect the surroundings for factors that could affect the quality of the inlet air flow.

Air Cleaners: Examine and evaluate the air cleaners for location, installation, cleanliness, and serviceability. Note whether the air cleaner housing is easily accessed for service by a technician carrying new filter elements. Indicate the integrity of the clean air path to seal out contaminants.

Describe any items needing remedy in the notes section. When corrected, check the "FIXED" box and date and initial to document the correction.

	INITIAL AUDIT			FOLLOW-UP REVIEW		
	YES	NO	NOTE or N/A	FIXED ?	DATE	INITIALS
Inlet opening is adequate (no obstructions, enough space for air flow, etc.)	☐	☐		☐		
Inlet opening is protected from water ingestion (either direct or splashed from nearby surface)	☐	☐		☐		
Inlet opening is not subject to heat sources or recirculation from engine/radiator exhaust flow	☐	☐		☐		
Precleaner is used for dusty environment	☐	☐		☐		
Air cleaner mounting is accessible/serviceable	☐	☐		☐		
Air cleaner housing is clean and intact (no dirt/debris, no corrosion/damage; no leaks)	☐	☐		☐		
Air filter elements fit and seal properly	☐	☐		☐		

Notes:

AIR SYSTEM

Air Piping: Examine and evaluate the air piping layout and installation.

Describe any items needing remedy in the notes section. When corrected, check the "FIXED" box and date and initial to document the correction.

	INITIAL AUDIT			FOLLOW-UP REVIEW		
	YES	NO	NOTE or N/A	FIXED ?	DATE	INITIALS
Air piping material is in accordance with Caterpillar A & I guidelines. If possible, indicate piping material and schedule below.	☐	☐		☐		
Piping is clean and free from debris	☐	☐		☐		
Pipe welds are ground smooth; slag removed	☐	☐		☐		
Flexible connections are present and located to isolate the piping from engine vibration	☐	☐		☐		
Flexible connectors are installed correctly, with proper alignment and gaps between pipe runs	☐	☐		☐		
Hose clamp joints are completed correctly, with double clamps present & 360° sealing on pipe	☐	☐		☐		
Piping runs are located to avoid interfering with service access to engine & driven equipment	☐	☐		☐		
Piping is adequately supported from a braced external structure (not from the engine)	☐	☐		☐		
Piping layout includes proper straight lengths for engine inlet and measurement taps	☐	☐		☐		
Joining/dividing pipes are in accordance with Caterpillar A & I guidelines (dual air inlets only)	☐	☐		☐		
Pressure test ports are present and properly located. List locations below.	☐	☐		☐		

Notes:

EXHAUST SYSTEM

Exhaust Piping: Examine and evaluate the exhaust piping layout and installation.

Describe any items needing remedy in the notes section. When corrected, check the "FIXED" box and date and initial to document the correction.

	INITIAL AUDIT			FOLLOW-UP REVIEW		
	YES	**NO**	**NOTE or N/A**	**FIXED ?**	**DATE**	**INITIALS**
Exhaust piping material is in accordance with Caterpillar A & I guidelines. If possible, indicate piping material and schedule below.	☐	☐		☐		
Piping is clean and free from debris	☐	☐		☐		
Pipe welds are ground smooth; slag removed	☐	☐		☐		
Flexible connections are present and located to accommodate thermal growth and to isolate the piping from engine vibration	☐	☐		☐		
Flexible connectors are installed correctly, with proper alignment and gaps between pipe runs	☐	☐		☐		
Piping runs are located to avoid interfering with service access to engine & driven equipment	☐	☐		☐		
Piping is adequately supported from a braced external structure (not from the engine)	☐	☐		☐		
Pipe supports accommodate thermal growth	☐	☐		☐		
Piping layout includes slope away from engine and condensate drain location	☐	☐		☐		
Piping layout includes proper straight lengths for engine inlet and measurement taps	☐	☐		☐		
Joining/dividing pipes are in accordance with Caterpillar A & I guidelines (dual exhaust outlets only)	☐	☐		☐		
Pipe diameters are adequate, do not create excessive restriction/backpressure	☐	☐		☐		
Pressure/emissions test ports are properly located. List locations below.	☐	☐		☐		

Notes:

FUEL & FUEL SYSTEM

Fuel Supply: Examine and evaluate the fuel supply system layout and installation. Ensure required elements are present.

Describe any items needing remedy in the notes section. When corrected, check the "FIXED" box and date and initial to document the correction.

	INITIAL AUDIT			FOLLOW-UP REVIEW		
	YES	NO	NOTE or N/A	FIXED ?	DATE	INITIALS
Gas supply piping material is in accordance with industry practices. If possible, indicate piping material and schedule below.	☐	☐		☐		
Flexible connections are present and located to isolate the piping from engine vibration	☐	☐		☐		
Piping is adequately supported from a braced external structure (not from the engine)	☐	☐		☐		
Pressure/gas sampling test ports are properly located. List locations below.	☐	☐		☐		
Gas filters are present. If possible, provide filter information below	☐	☐		☐		
Coalescers are present. If possible, provide coalescer information below.	☐	☐		☐		
Coalescer liquids can be drained	☐	☐		☐		

Notes:

STARTING/PRELUBE SYSTEM

Starting & Prelube Systems: Examine and evaluate the supply, exhaust, and vent piping layout, installation, cleanliness, and serviceability.

Describe any items needing remedy in the notes section. When corrected, check the "FIXED" box and date and initial to document the correction.

	INITIAL AUDIT			FOLLOW-UP REVIEW		
	YES	NO	NOTE or N/A	FIXED ?	DATE	INITIALS
Air or gas supply piping material is in accordance with industry practices. If possible, indicate piping material and schedule below.	☐	☐		☐		
Flexible connections are present and located to isolate the piping from engine vibration	☐	☐		☐		
Piping is adequately supported from a braced external structure (not from the engine)	☐	☐		☐		
Air or gas are provided from a clean dry source	☐	☐		☐		
The starter & prelube control valves are vented (if required). Combined vent systems do not create a backflow risk.	☐	☐		☐		
Gas-driven systems only -- The starter & prelube exhausts are piped to a safe location.	☐	☐		☐		

Notes:

LUBRICATION & HYDRAULIC OIL SYSTEMS

Lube Oil & Hydrax Systems: Examine and evaluate the provisions for filling and servicing. Examine and evaluate installations of oil level controllers and/or automatic make-up systems.

Describe any items needing remedy in the notes section. When corrected, check the “FIXED” box and date and initial to document the correction.

	INITIAL AUDIT			FOLLOW-UP REVIEW		
	YES	**NO**	**NOTE or N/A**	**FIXED ?**	**DATE**	**INITIALS**
Oil fill volume is correct (check dipstick)	☐	☐		☐		
Oil suction screen is present and can be accessed for servicing	☐	☐		☐		
Oil heater intake and return connections are located properly and use flex connections	☐	☐		☐		
Oil drain connections are properly located	☐	☐		☐		
Oil level controller is properly installed/vented	☐	☐		☐		
Oil make-up lines are properly routed and supported, with flex connections as needed	☐	☐		☐		
G3600 only - Hydrax oil fill volume is correct.	☐	☐		☐		

Notes:

COOLING SYSTEM

Coolant Piping: Examine and evaluate the coolant piping layout, installation, and serviceability. Include temperature regulators, vent lines, expansion tanks, and cooler fan drive system.

Describe any items needing remedy in the notes section. When corrected, check the "FIXED" box and date and initial to document the correction.

	INITIAL AUDIT			FOLLOW-UP REVIEW		
	YES	NO	NOTE #	FIXED ?	DATE	INITIALS
Coolant piping material is in accordance with industry practices. If possible, indicate piping material and schedule below.	☐	☐		☐		
Flexible connections are present and located to isolate the piping from engine vibration	☐	☐		☐		
Coolant suction screens are present and accessible for servicing	☐	☐		☐		
Coolant temperature regulator is installed properly with adequate access for servicing	☐	☐		☐		
Pressure/gas sampling test ports are properly located. List locations below.	☐	☐		☐		
Coolant heater intake and return connections are located properly and use flex connections	☐	☐		☐		
Expansion tanks are properly located, accessible, and use the correct pressure cap	☐	☐		☐		
Coolant vent connections are located properly and use flexible connections	☐	☐		☐		
Coolant vent lines are the proper diameter	☐	☐		☐		
Coolant vent lines have a continuous upward slope throughout their run (no inversions)	☐	☐		☐		
Coolant vent lines are adequately supported and protected from damage and chafing	☐	☐		☐		
The fan drive system is correctly connected	☐	☐		☐		

Notes:

MOUNTING, ELECTRICAL & OTHER ITEMS

Mounting: Examine and evaluate the foundation structure, engine mounts, and alignment of engine to driven equipment.

Describe any items needing remedy in the notes section. When corrected, check the "FIXED" box and date and initial to document the correction.

	INITIAL AUDIT			FOLLOW-UP REVIEW		
	YES	**NO**	**NOTE #**	**FIXED ?**	**DATE**	**INITIALS**
The mounting system is installed according to manufacturer's instructions and/or Caterpillar A&I guidelines. List mount type/details below.	☐	☐		☐		
The foundation mount locations do not include overhung or cantilevered supports	☐	☐		☐		
External electrical connections are completed to meet any prevailing code (e.g, hazardous locations, etc.; surveyor input may be req'd)	☐	☐		☐		

Notes:

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