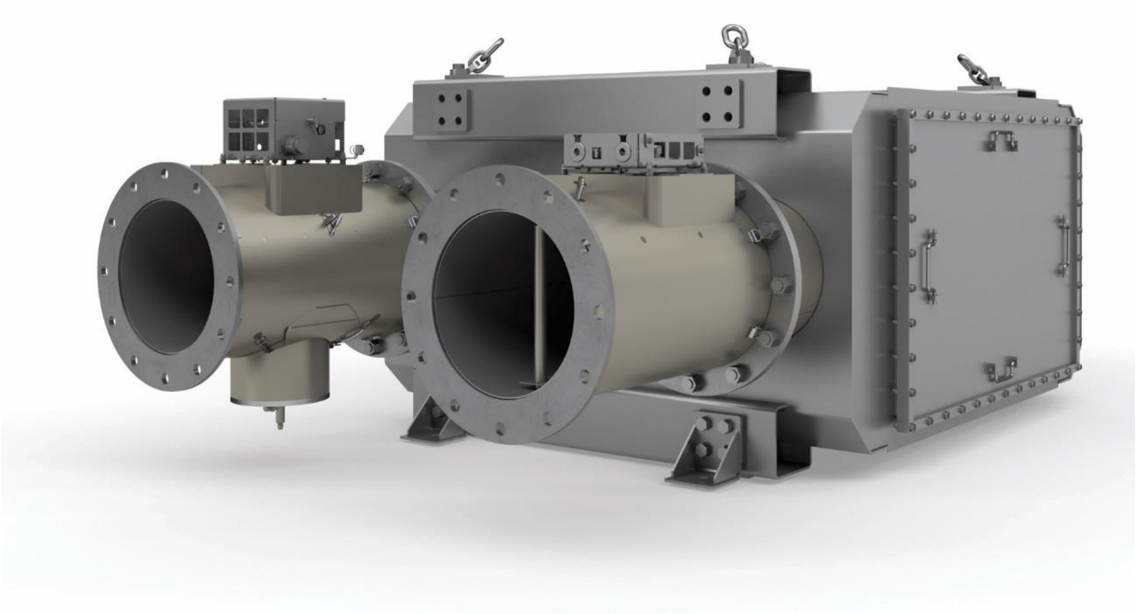
APPLICATION & INSTALLATION GUIDE

Cat® Clean Emissions Module



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I. INTRODUCTION

1 Purpose

This document is intended as a reference and guide for the correct installation of the Caterpillar Clean Emissions Module (Cat CEM) for Cat Engines. The primary purpose is to assist engineers and designers specializing in engine installations. The Engine Electrical and Electronic Applications and Installation Guide, Engine Application and Installation Guide, and Engine Data Sheets complement this booklet.

NOTE: The information in this document is subject to change as engine exhaust aftertreatments are revised, improved and required for emission reduction standards.

The Exhaust System and Cat CEM are an integral part of Caterpillar's EPA Tier 4 and IMO III engine solution. Caterpillar Engines are designed and built to provide superior value; however, achieving the end user's value expectations depends greatly on the performance of the complete installation to assure proper function over the design life of the installation. This proper detail will allow the engine to produce its published rated power, fuel consumption and conform to emissions regulations.

Caterpillar exercises all reasonable effort to assure engine and Cat CEM perform properly. However, it is the responsibility of the OEM / installer to properly install the engine and Cat CEM. Caterpillar assumes no responsibility for deficiencies in the installation. It is the responsibility of the OEM / installer to meet all of Caterpillar's requirements, as provided in this Application and Installation Guide. Caterpillar does not guarantee or approve the validity or correctness of any installation. Caterpillar's sole obligation with respect to any product is as set forth in the applicable Caterpillar warranty statement.

It is the installer's responsibility to consider and avoid possibly hazardous conditions, which could develop from the systems involved in the specific engine installation. The suggestions provided in this guide regarding avoidance of hazardous conditions apply to all applications and are necessarily of a general nature since only the installer is familiar with details of the installation. The suggestions provided in this guide should be considered general examples only and are in no way intended to cover every possible hazard in every installation.

Contact the appropriate application support group for the latest information on Cat CEM guidelines and requirements.

This document serves as Caterpillar's instructions required by U.S. EPA regulations (40 C.F.R. Part 1068) to facilitate the selection and application of the correct Cat CEM module by the OEM or "installer" based upon engine selection.

2 Requirements and Agreements

(1) Each OEM shall enter into a delegated final assembly agreement with Caterpillar, Inc. as required by 40 C.F.R. § 1068.261. This publication fulfills Caterpillar's obligation under 40 C.F.R. § 1068.261 (c) (2) to provide installation instructions to ensure the engine will be in certified configuration.

(2) OEM is required to follow Caterpillar's Applications and Installation requirements for proper Cat CEM integration with the Cat engine.

(3) A full sea trial, as described in the marine commission procedure (LEBM0025), utilizing camper is required to be performed on all engines equipped with an SCR system. The completed sea trial data must be uploaded by the authorized Caterpillar dealer in Service Interlink. The following forms must also be completed and uploaded into the Service Interlink: Design and Construction review Form, Start Up checklist for both the engine and SCR system.

Any deviation from these instructions resulting in improper installation or connection of Cat CEM may be considered an emissions-related defect requiring the OEM or installer to report to U.S. EPA pursuant to 40 C.F.R. § 1068.261 (h). OEM installations are subject to audit by Caterpillar pursuant to 40 C.F.R. § 1068.261 (d)(3), as further set forth in the delegated final assembly agreement.

Note: No aftertreatment component shall be placed between the engine out exhaust and the CEM inlet except for that which this document has specified.

Note: If the available Cat CEM option does not meet the application/installation requirements, the OEM Installer must contact his or her respective Caterpillar A&I Representative. Any deviation from these instructions resulting in the installation of Cat CEM not included as part of the applicable certified engine configuration will be considered a mis-build and must be reported immediately to Caterpillar.

II. CAT CEM IDENTIFICATION

Caterpillar will provide Auto-detection to ensure the proper Cat CEM is fitted to the proper engine. The engine will identify the CEM and allow proper operation of the engine and aftertreatment system. Failure to detect proper CEM will result in 100% derated engine performance on all EPA Tier 4 ratings.

The Caterpillar Clean Emissions Module will be stamped with a Caterpillar part number for identification and part service requirements. No OEM part numbers or supplier part numbers will be stamped on the device.

2 Document Layout

This document provides application information, specifications and installation procedures to install Cat CEM for selected Caterpillar engines that meet US Tier 4 and IMO III emissions regulations. To determine which module is available for your engine application please review the following Caterpillar Clean Emissions Strategy Table for the emissions technology provided for the selected engine Platform(s). After reading and understanding the Cat CEM technology overview proceed to that Cat CEM Components section for detailed design and installation information. The Appendix contains additional detailed design and installation information and is referenced throughout the document.

This document provides the required information for Cat CEM mounting including electrical, plumbing, and exhaust connections.

Note: There are critical specifications required for proper performance and compliance with U.S. EPA, IMO III regulations. Failure to meet these requirements will constitute a "mis-build" and prompt notification to Caterpillar is required. Installation Audits and Sea Trials are required for each new application build.

3 Tier 4 Emissions Strategy Table

Table I.3-1 – Caterpillar Clean Emissions Strategy Table

Caterpillar Clean Emissions Strategy		
Engine Platform	**Aftertreatment Technology**	**Applications**
C32 ACERT 3500E C175	AUS/DEF SCR	Marine/Petro Off shore
C280 M 20, M 25, M 32 M 34, M 43, M 46		

4 Safety

Most accidents that involve product operation, maintenance, and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. An OEM Installer must be alert to potential hazards. An OEM Installer should also have the necessary training, skills, and tools in order to perform these functions properly.

The information in this publication was based upon current information at the time of publication. Check for the most current information before you start any job. Caterpillar dealers will have the most current information.

> **Warning -** *Improper operation, maintenance, or repair of this product may be dangerous. Improper operation, maintenance, or repair of this product may result in injury or death. Do not operate or perform any maintenance or repair on this product until you have read and understood the operation, maintenance, and repair information. Burn's and fire hazards are possible. Failure to properly connect the After-treatment and properly route the exhaust gases away from the module may result in personal injury or death.*

Note: Failure to properly connect the after-treatment will result in poor engine performance, engine damage and after-treatment system damage.

Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are not all inclusive. If a tool, a procedure, a work method, or an operating technique that is not specifically recommended by Caterpillar is used, you must be certain that it is safe for you and for other people. You must also be certain that the product will not be damaged. You must also be certain that the product will not be made unsafe by the procedures that are used.

5 Pressure Air and Water

Pressurized air and/or water can cause debris and/or hot water to be blown out. This could result in personal injury. Always wear a protective face shield, protective clothing, and protective shoes when cleaning components. The maximum air pressure for cleaning purposes must be reduced to 205 kPa (30 psi) when the air nozzle is deadheaded and used with effective chip guarding (if applicable) and personal protective equipment. The maximum water pressure for cleaning purposes must be below 275 kPa (40 psi).

6 High Pressure Wash

Note: High-pressure wash systems, including high pressure spray washers and water cannons, are now in frequent use by maintenance people. Connector seals will fail when hit directly with high pressure spray. Many connection systems have adapters available that can be attached to the back of the connector to protect the wire seals from direct high pressure wash. ***Where direct exposure to high pressure wash systems cannot be avoided then protective shields will need to be designed and installed.*** *For the benefit of service, connectors should be placed in accessible locations.*

7 Welding

WARNING — *Welding on Cat CEM housing/ mixing tube is not recommended. If welding is required you must follow ECM protection guidelines for the ECM mounted in the dosing cabinet and the sensors mounted on the CEM. If welding is required then you must use welding rods that are compatible with 409 stainless steel. If attaching any brackets to the CEM or mixing tube whatever is attached must not affect the thermal expansion movement of the CEM. Need to make sure welds do not create holes in side walls of the CEM when welding. A failure as a result of improper welding techniques will not be covered by warranty.*

8 Painting

Painting of Caterpillar CEM is NOT recommended and strongly discouraged. Skin temperatures on the CEM can get to as high as 525 degrees Celsius during operation and will cause charring or burning of the paint.

9 Cleanliness

Air lines, Fuel lines, coolant lines and oil lines that connect to the CEM or engine should meet Caterpillar cleanliness specification contain in the A&I guide LEBW0019.

10 Replacement Parts

WARNING Notice — *When replacement parts are required for this product Caterpillar recommends using Caterpillar replacement parts or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.*
Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

11 Tier 4, IMO III - Emissions Requirements

This Installation Guide is intended for use for engines that must comply with Tier 4 and IMO III emission requirements. Proper fluids must be used to meet these requirements. Refer to the specific Operation and Maintenance Manual (OMM) for the Cat engine model being installed for the proper fuel, lubricants, and coolants that are to be used. The proper fuels, lubricants and coolants must be used to enable the engine to produce its published rated power, fuel consumption and conform to emissions regulations.

JP8 Diesel fuel is not compatible with Caterpillar Tier 4 and IMO III Cat CEM. U.S. EPA Tier 4 regulations require the use of commercial ULSD that conforms with the ASTM D975 specification of 15 ppm max sulfur fuel per US EPA Tier 4 requirements. IMO III requires that the fuel sulfur levels are below 1,000ppm. Consult Caterpillar or your Caterpillar dealer for further direction.

Table I.11-1: Tier 4 Engine Operating Fluids Limits

Engine Operating Fluids	
Fuel Tolerance – Sulfur (ppm)	Tier 4 15 or less IMO III 1,000
Oil Tolerance (ash content)	CJ4 or better
Fuel Tolerance – biofuels (ASTM 6751-075 B100)	B20 or less

NOTE: Oils that have more than 1% total sulfated ash should not be used in Aftertreatment device equipped engines.

In order to achieve expected ash service intervals, performance, and life, Aftertreatment device equipped diesel engines require the use of Cat DEO-ULS or oils meeting the Cat ECF-3 specification and the API CJ-4 oil category. Oils that meet the Cat ECF-2 specification and that have a maximum sulfated ash level of 1% are also acceptable for use in most aftertreatment equipped engines. Use of oils with more than 1% total sulfated ash in aftertreatment device equipped engines will cause the need for more frequent ash service intervals, and/or cause loss of performance. Refer to your engine specific Operation and Maintenance Manual, and refer to your aftertreatment device documentation for additional guidance.

> **Warning notice -** *Use of Oil Renewal System (ORS) is strictly forbidden. Any ORS that extends the oil life through the combustion process and topping off the oil reservoir with new oil will damage the aftertreatment device.*
> *Failures that result from non-approved oil are not Caterpillar factory defects. Therefore, the cost of repair would NOT be covered by the Caterpillar warranty for materials and/or the warranty for workmanship.*

Note: The U.S. Forest Service operates a national laboratory that provides spark arrester qualification testing pursuant to U.S. Forest Service Standard 5100-1c, "Spark Arresters for Internal Combustion Engines," which is currently being revised so as to extend its assessment beyond particle capture measurement. The CAT CEM with DPF is being validated per SAEJ350, "Spark Arrester Test Procedure for Medium Size Engines," which will not result in a formal qualification by U.S. Forest Service, but will document spark arresting particle capture capabilities.

All other CAT CEM's are pass through aftertreatment devices and cannot be validated to SAEJ350. If spark arresting is needed for these applications a dedicated device meeting SAEJ350 will need to be installed after the CEM.

12 Tier 4F EPA Recorder

EPA recognizes that it is unsafe and unacceptable to significantly derate or shut down a marine engine for an aftertreatment failure per EPA regulations 40 CFR 1042. EPA regulations require the engine manufacture to record certain failure codes if the customer does not keep its aftertreatment system operating correctly as designed by the engine manufacture. If any of the reportable fault codes are logged in the ECM the customer has 30 days to inform the EPA on what caused the fault code to occur. Refer to OMM for the list of reportable codes.

Caterpillar will provide an instruction on how to get the codes from the engine ECM in the Operation & Maintenance Manual (OMM). It is the customer or end users responsibility to report to the EPA if any of the required codes are recorded into non-volatile memory. A complete list of these codes are included in OMM manuals for each engine system. Refer to ECFR title 40 part 1068.

Caterpillar will alarm and record in standard engine ECM memory all other incidents relating to engine and aftertreatment operation and performance. All active codes will be displayed and recorded on the first and last incident. Each code will included the following information, the date, time and number of occurrences. This information will be stored in standard engine ECM memory.

13 Terminology

- The terminology used throughout this document will be as follows:
- API — American Petroleum Institute
- ASTM — American Society for Testing and Materials
- AT — Aftertreatment
- ATAAC — Air to Air After Cooler
- AUS — Aqueous Urea Solution per ISO Standard 22241
- AWG — American Wire Gauge
- BPV — Back Pressure Valve
- CAN — Controller Area Network
- Cat CEM — Cat Clean Emissions Module
- Cat ECF — Cat Engine Crankcase Fluid
- CCW — Counter Clockwise
- CDPF — Catalyzed Diesel Particulate Filter
- CEPRU — Caterpillar Electric Priming and Regeneration Unit
- CFD — Computational Fluid Dynamics
- CFR. — Code of Federal Regulations
- CG — Center of Gravity
- CISD — Compliance and Innovative Strategies Division
- CO — Carbon Monoxide
- CW — Clockwise
- AUS/DEF — Diesel Exhaust Fluid (also referred to as AUS32)
- Delta P — Differential Pressure
- DPI — Delta Pressure Indicator
- ECM — Electronic Control Module
- EH&S — Environment of Health & Safety
- EPA — Environmental Protection Agency
- FEA — Finite Elemental Analysis
- FMEA — Failure Modes & Effects Analysis
- GND — Ground
- HC — Hydro Carbon
- ID — Identification or Inside Diameter (Dimensional Reference)
- IEC — International Electro-technical Commission
- ISO — International Organization for Standardization
- JIC — Joint Industry Council
- MAF — Mass Air Flow
- MSDS — Material Safety Data Sheet
- NO_x — Nitrous Oxides – NO and NO2
- OEM — Original Equipment Manufacturer
- OMM — Operations & Maintenance Manual
- ORS — Oil Renewal System

- PM Particulate Matter
- P/N Part Number
- PSIg Pounds per Square Inch gauge
- PSPS Product Software Programming System
- SAE Society of Automotive Engineers
- SCAC Separate Circuit After Cooler
- SCR Selective Catalytic Reduction
- SOF Soluable Organic Fraction
- STOR Straight Thread O-Ring
- S/N Serial Number
- TBD To Be Determined
- ULSD Ultra Low Sulfur Diesel

III. CAT® CEM OVERVIEW

1 Caterpillar Clean Emissions Module (Cat CEM) Systems

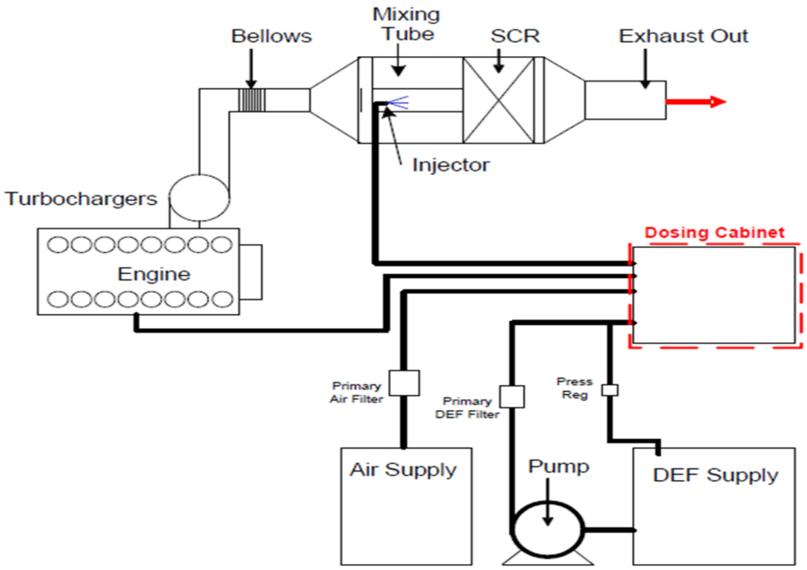
The Cat CEM consists of the key components necessary to support an engine arrangement for emissions compliance. Caterpillar Tier 4, IMO III engine systems use a variety of technologies for the reduction of particulate matter and NO_x emissions. Selection of the optimal module combination is based upon engine rating and application. Each of the emission reduction technology combinations is listed in the Cat CEM Strategy table in section above and described in this document.

2 Technology Component Descriptions

<u>SCR (Selective Catalytic Reduction) System</u>
SCR is one of a combination of several components. SCR units will require the use of urea or DEF (Diesel Exhaust Fluid also referred to as AUS32) along with flow-through honeycomb substrate catalysts.

AUS/DEF fluid is injected into the exhaust stream before entering the SCR. When injected into the exhaust stream, the AUS / DEF is atomized using compressed air then travels to the mixer. The mixer disrupts the exhaust flow and allows the AUS/DEF to be well distributed throughout the exhaust gas. The water evaporates due to the high temperature of the exhaust and releases the NH_3 that was chemically bound up in the AUS/DEF. The NH_3 is then free to react with the NO_x and the oxygen present in the exhaust stream. This reaction occurs on the SCR catalyst. The NH_3 and NO_x are converted into harmless gas particles of nitrogen and water.

Figure 2-1: SCR CEM System Diagram



Working Principle

$CO(NH_2)_2 + H_2O \rightarrow 2NH_3 + CO_2$

$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$

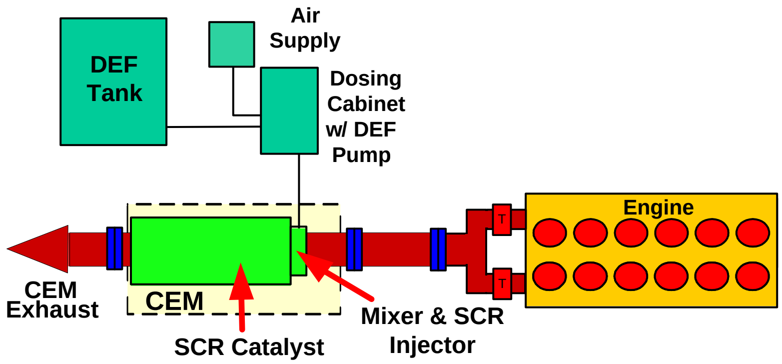
IV. SCR CLEAN EMISSIONS MODULES

1 Introduction and Purpose

Caterpillar's SCR emissions approach combines emission reduction technologies to comply with Tier 4 and IMO III emissions requirements. Selective Catalyst Reduction (SCR) catalyst technology is used to reduce NO_x emissions and particulate matter (PM), carbon monoxide (CO), hydrocarbons (HC) and soluble organic fraction (SOF).

Caterpillar's SCR is packaged in a module that contains the components necessary to support the specific engine configuration for emissions compliance. OEM installation will require connections between OEM module, engine, AUS/DEF tank and air source. These connections will include engine exhaust piping, electrical harness, air, and AUS/DEF lines.

Figure IV.1-1: System Hardware Overview



2 CEM Application Guide

The following table provides applicable CEM for a given application and engine platform. There will be several CEM for the marine and off shore applications.

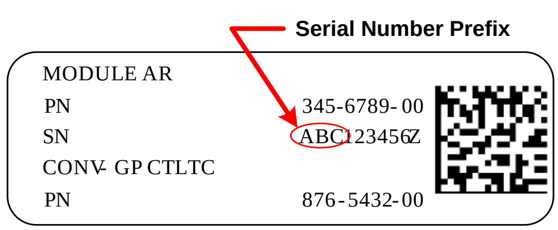
Table IV.2-1: CEM Application Guide

CEM Application Guide	
Engine Platform	CEM Design
C32	6 and 12 Brick U-flow and Z-flow CEM’s
3500E	12, 16, and 20 Brick U-flow and Z-flow CEM’s
C175	16 and 20 Brick U-flow and Z-flow CEM’s
C280-8/MaK	4x4 ft vertical CEM
C280-12/MaK	5x5 ft vertical CEM
C280-16/MaK	6x6 ft vertical CEM or (2) 4x4 vertical CEM’s

The CEM’s for the 3500 and C175 will be a 12, 16 or 20 brick version that will match the engine power setting and ratings.

Each CEM has a Serial Number that is compatible to a particular engine platform and is shipped as a set. This S/N must be verified at installation for compatibility to the engine. The serial number prefix will identify the CEM for correct application. The prefix on the CEM serial number label is indicated on the example below. The engine and aftertreatment software will help verify if the correct hardware is applied to each engine model.

Figure IV.2-1: Example



Refer to "Appendix B: Initial Startup Procedures" for location of serial number on CEM and dosing cabinet, documentation and first fit detection.

Table IV.2-1: Cat CEM Mandatory Interface Connections:

Connection Point	Description	Fitting Type
Dosing Cabinet to CEM	DEF Line from dosing cabinet to CEM	N0. 6 Female STOR (straight thread O-ring)
Dosing Cabinet to CEM	Air line from Dosing Cabinet to CEM	No. 8 Female STOR
Dosing Cabinet to CEM	Electronic harness from Dosing Cabinet to CEM	Quantity 1 24 Pin Connectors
Dosing Cabinet to Engine ECM	Electronic harness from Dosing Cabinet to Engine ECM	Quantity 1 24 Pin Connectors
Dosing Cabinet to Main DEF Tank	Electronic harness from Dosing Cabinet to Main DEF Tank	Quantity 1 24 Pin Connectors
Air Source to Dosing Cabinet	Air line into dosing cabinet from air source	3/8" Male JIC
Customer DEF tank to Dosing Cabinet	DEF line into dosing cabinet buffer tank from main tank	1/2" Male JIC
Dosing Cabinet Drain	DEF buffer tank manual drain	N0. 6 Female STOR (straight thread O-ring)
Dosing Cabinet Vent	DEF buffer tank vent & overflow	½" Hose Bead SAE AS5131
CEM to Dosing Cabinet	Air line from CEM to dosing cabinet	JIC Flare, SAE J514 ¾ X16
CEM to Dosing Cabinet	DEF line from CEM to dosing cabinet	JIC Flare, SAE J514 9/16X18
CEM to Dosing Cabinet	Electronic harness from CEM to Dosing Cabinet	24 Pin Connector
120V AC source to Dosing Cabinet	Electrical harness from Dosing cabinet to 120V AC source	Bus Bar (Inside Dosing Cabinet)
CEM to Turbo	Exhaust pipe into CEM from engine	1 - 18" Bolted Flange
CEM to Atmosphere	Exhaust pipe from CEM to atmosphere	1 - 18" Bolted Flange

3 Air System

Compressed Air is used:

- To assist in the atomizing of the liquid AUS / DEF as it is injected into the exhaust stream
- To shield the liquid AUS/DEF in the injector from the exhaust heat until injection, so that no crystallization occurs which could plug the injector nozzle
- To purge the AUS/DEF line during shutdown in order to prevent crystallization

Typically, compressed air will carry some oil from the compressor and some sediment from the piping. This debris can collect in the nozzle and clog the unit. Use a coalescing filter/separator that is 90 percent effective that is rated for 1069 kPag (155 psig) and 849.5 liter/min (30 CFM). Reference Air Filter Requirements in the sub section "Air Filter Recommendations" for details.

The air supply delivered to the dosing cabinet must meet the specifications in Table 4.2 when engine is running and any non-parasitic load.

Table IV.3-1: Air supply delivery requirements at Dosing Cabinet Inlet

Air Supply	
Air quality	ISO 8573.1 Class 5
Oil Content (mg/m^3) (Max.)	25 (mg/m^3)
Particle Size (Max) (micron)	40 micron
Particle Density (Max) (mg/m^3)	10 (mg/m^3)
Relative Air Humidity	<10%
Air delivery (compressor capability):	
Air Temperature	-40 to 50 C
Air Flow for 3500 and larger engines Air Flow for C32 engines	10 SCFM 4 SCFM
Air Consumption	Continuous during engine operation and purge
Air Pressure	482 to 1068 kPa
Air Pressure at Engine Startup	552 kPa at start up OR 482 kPa within 3 minutes maintaining <30% load or CEM outlet temp <250C
Purge Air Press/Vol at Shutdown	>482kPa /10 SCFM for 30 sec
Selected filter should meet the filter performance test per ISO 12500.3	

Note: An optional air compressor system will be available from Caterpillar that is designed specifically for use with the Caterpillar CEM (SCR).

3.1 Air Supply Line Requirements

The air supply line that is used for delivering air from the dosing cabinet to the injector is to be sized and routed such that the pressure loss across the line is no greater than 6.89 kPa at the maximum flow capacity.

Note: Routing of this air line must progress continuously without air locks or line bends that would allow condensation to form and freeze preventing air supply to Dosing Cabinet air valve.

3.2 Secondary Water / Oil Separator

The AUS / DEF dosing cabinet requires customer to provide compressed air to the dosing cabinet which meet ISO 8573.1 Class 5 requirements specified in Table IV.3-1 above.

A cabinet contains a secondary air screen filter at the dosing cabinet air inlet.

Air inlet port on the screen filter is Male 3/8" JIC. It is recommended to have a water / oil separator installed to catch any larger amounts of water in the air lines going to the dosing cabinet. See Air & AUS/DEF Filter Installation figure below for interface connection location on dosing cabinet.

See maintenance schedule for service interval of air filter. See service manual for service procedure.

3.3 Secondary DEF Filter Requirement

The AUS/DEF dosing cabinet requires a 40 micron filter/screen to be installed before the dosing cabinet, the filter/screen needs to meet ISO22241-1 quality requirements with a maximum particle size of 40 microns. The filter screen needs to be able to handle 5.67 liters/min within the pressure range of 34 to 69 kPa (5 to 10psi). The DEF filter/screen should be installed as close as possible to the inlet port of the dosing cabinet. An isolation valve may be considered for serviceability.

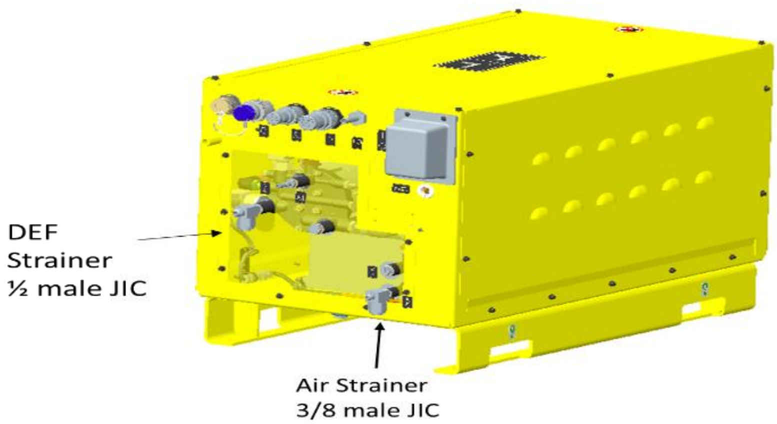
The dosing cabinet includes a DEF screen assembly at the connection point of the DEF line on the front face of the cabinet. The connection point and screen are all stainless steel fittings. This screen does not replace the need to include a 40 micron filter.

The DEF inlet port on the screen filter is a Male 1/2" JIC. If the system will be shutting down in freezing conditions or put into storage, the screen filter and supply line should be drained. Customer is responsible for protecting the supply line from freezing and damage from foreign objects (stainless steel supply line is recommended).

See maintenance schedule in the OMM for service interval of DEF screen filter. The filter is reusable and can be cleaned using an ultrasonic bath. Refer to figure below for interface and installation on dosing cabinet.

3.4 Air & DEF Strainer Locations

Figure IV.3.4-1: Dosing Cabinet Air & DEF Interface Connections



3.5 AUS/DEF System

3.5.1 AUS/DEF Specifications

For SCR applications the required AUS/DEF solution to be used is SCR Grade AUS32, or Aqueous Urea Solution of 32.5% or 40% concentration with quality properties per ISO 22241-1. A solution with 32.5% concentration provides the lowest possible freezing point, -11°C (12oF) while 40% concentration freezing point is at 0°C (32°F). The solution is homogeneous, allowing partial or total freezing and thawing without changing the concentration. The solution is basic, with a pH of about 9.0, and is slightly corrosive. Reference ISO 22241-3 standard for "Handling, Transportation, and Storage of AUS32 (DEF)".

Fertilizer or technical grade urea may contain elements that will clog the injector nozzle. It should not be used to supply the dosing cabinet.

The AUS/DEF supply to the dosing cabinet inlet should be filtered. The filtration requirement is 40 microns to protect valves inside the dosing cabinet.

ISO 22241-3 has comprehensive list of AUS / DEF compatible materials including 300 and 400 series stainless steel, Ethylene Propylene Diene Monomer (EPDM), Polyethylene, Polypropylene, and etc.

Any O-rings must be EPDM. Reference "Material Selection for Tank and Piping" found later in this section for details regarding tank material, size, piping, fittings, etc.

CAUTION - *Base material and their alloys of copper, zinc, aluminum and magnesium are not compatible. Also soldering material containing silver and nickel coatings are considered not compatible with AUS/DEF. Carbon steels, zinc coated carbon steels, and mild iron are not to be used with AUS/DEF Do not store AUS/DEF in a tank or use supply lines or fittings that are made of the above materials.*

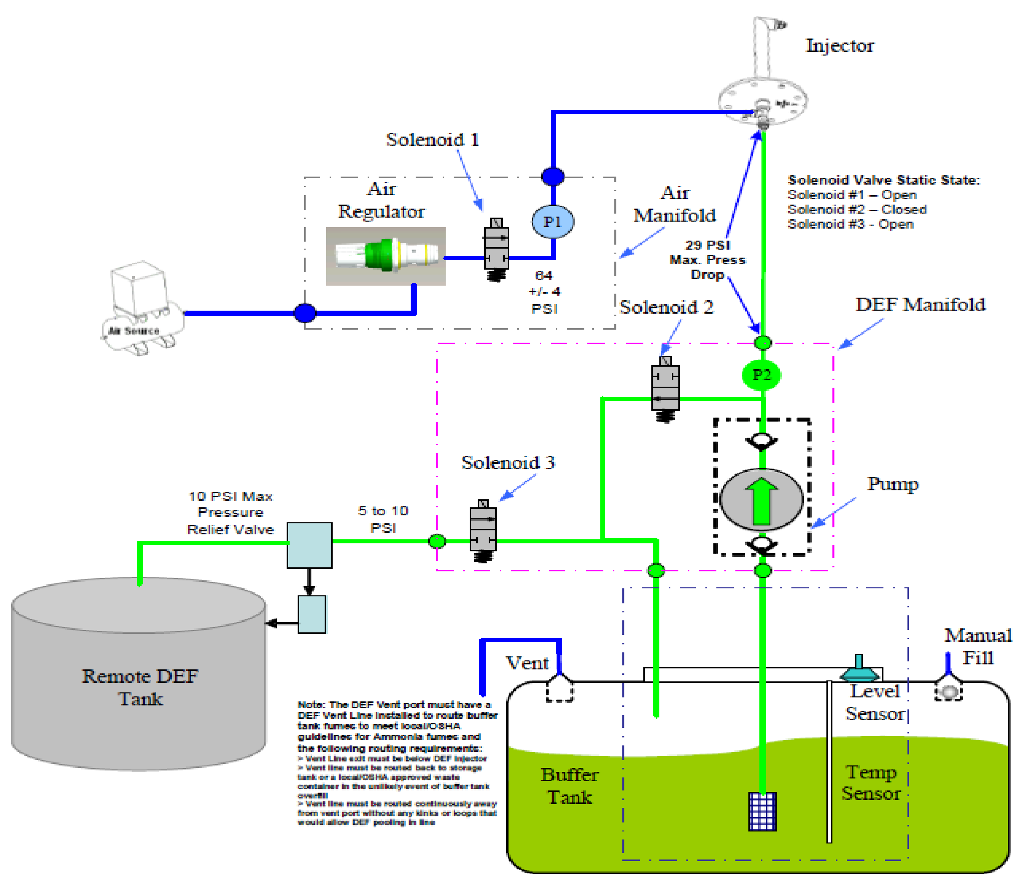
The 40% urea solution will have the advantage of smaller storage tanks, while maintaining the freezing point of water. Caterpillar recommends AUS 32.5% solution per ISO 22241-1. DEF must be kept below 50 °C (122 °F) to keep it from decomposing too quickly and above – 11 ºC (12 °F) to prevent it from freezing during cold operation. Storage near 25°C provides a shelf life of approximately 18 months while storage around 35°C reduces storage life to approximately six months.

The best operating temperature for the urea solution is – 5 ºC to + 50 ºC (23 ºF to 122 ºF). If ambient temperature goes below -11 ºC, AUS/DEF inside the tank and the lines outside of the dosing cabinet need time to thaw before the system will be able to starting dosing. The thawing time requirement is defined in the EPA SCR guideline (CISD-09-04).

3.6 Dosing Strategies

The dosing cabinet requires a AUS/DEF supply of 34-69 kPa (5-10 psi) with a max of 69 kPa at the dosing cabinet AUS/DEF supply inlet. There is no AUS/DEF return line back to the remote tank from the tank located inside the dosing cabinet. The vent in the dosing cabinet releases purged air & AUS/DEF vapor during purge event. The vent line may be routed back to the top of the main AUS/DEF tank.

Figure IV.3.6.-1: Dosing System Schematic



3.7 Dosing System Operations

As shown in Fig. IV.3.6.-1 air pressure must be present at the input to the dosing cabinet before dosing can begin. This air pressure going to the nozzle is regulated to 442kPa +/- 27 kPa from the Solenoid Valve #1. When dosing conditions are met the Aftertreatment ECM energizes Solenoid Valve #1 which looks for the required psig using P1 sensor. If air pressure is present Solenoid Valve #2 is energized to close and allows AUS/DEF to be supplied to the DEF Injector via the DEF Dosing Pump. The AUS/DEF Dosing Pump pulses AUS/DEF from the Dosing tank to AUS/DEF injector controlled by the Aftertreatment ECM. The DEF pressure signal is fed to the Aftertreatment ECM which then inhibits dosing without the required psig pressure from the DEF sensor signal. Purging is accomplished by energizing Solenoid Valve #1 and de-energizing Solenoid Valve #2 providing compressed air back through AUS/DEF Injector via Solenoid Valve #2 to Dosing Tank when dosing is not required.

The AUS/DEF fill is controlled by the Aftertreatment ECM to the buffer tank for the cabinet shown in Fig. IV.3.6.-1. When the buffer tank's AUS/DEF level is lowered and the AUS/DEF Level Sensor detects a low level condition the Aftertreatment ECM energizes Solenoid Valve #3 which fills the Dosing Tank to maintain adequate supply of AUS / DEF to the injector. The maximum AUS/DEF pressure allowed at the input to Solenoid Valve #3 is 69 kPa. The allowable range of AUS/DEF pressure and flow rate is 34 to 69 kPa and 4.73 to 9.5 liters per minute respectively. AUS/DEF pressure from the AUS/DEF main supply tank is typically 34 to 55 kPa. A 69 kPa maximum pressure relief valve is recommended in series with AUS/DEF Supply Tank.

3.8 Dosing Cabinet

Normal functions/operations of a dosing cabinet include:

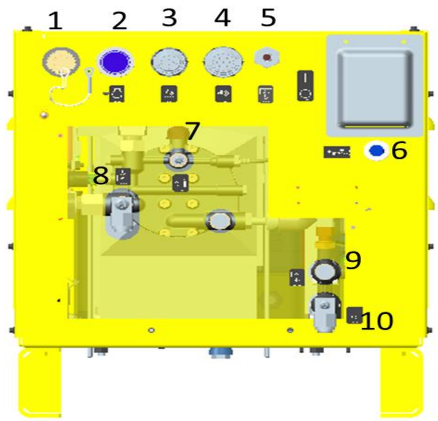
- Monitor and dose DEF
- Monitor and regulate compressed air
- House Electronic Control Module (ECM)
- Provide customer connections

The Aftertreatment ECM in the dosing cabinet will communicate with the engine over J1939 data link via the electronic connector on the cabinet interface illustrated below. Dosing cabinet is shipped fully calibrated to work within specified operating conditions. If the operating conditions change beyond the specification, additional care needs to be taken to address these issues. Whenever a critical component is replaced, recalibration might be required. Refer to trouble shooting guide if recalibration is going to be required. The dosing pump comes with a tamper evident sticker. If this sticker is damaged due to normal wear and tear, please contact the local dealer for replacement. An EPA violation will be implied if this sticker is tampered with.

3.9 Dosing cabinet connection points

Dosing cabinet communicates with external components via its connection points. These connections are electrical, air and DEF. For descriptions about the connections and their meaning see Table IV.2-1.

Figure IV.3.9.-1: Connection to Dosing Cabinet



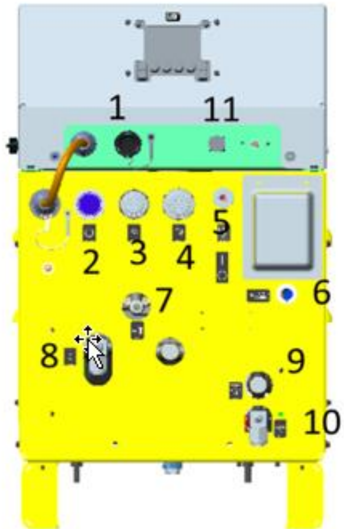


Table IV.3.9-1 – Dosing Cabinet Connection Points

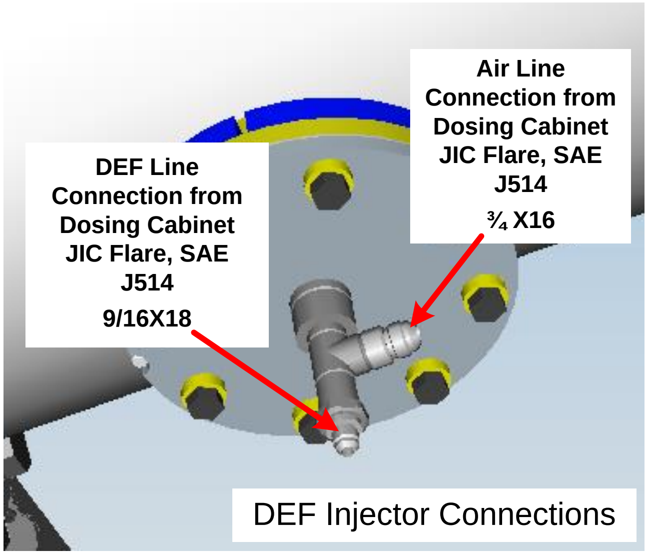
Connection Point *	Description	Fitting Type
1	Service tool connector	14 pin
2	Electrical harness from Dosing Cabinet to Engine ECM	24 Pin Connector
3	Electrical harness from Dosing cabinet to main Def tank (level sensor/transfer pump)	24 Pin Connector
4	Electrical harness from CEM to Dosing cabinet.	24 Pin Connector
5	DEF Vent Port (see Note below)	½” Hose Bead SAE AS5131
6	Electrical harness from Dosing cabinet to 120V AC source	Grommet for wiring & 3 Terminal Blocks
7	Def line from Dosing Cabinet to CEM	No. 6 STOR (Straight Thread O-Ring)
8	DEF inlet line to strainer on Dosing Cabinet.	1/2” JIC
9	Air line from Dosing Cabinet to CEM	No. 6 STOR (Straight Thread O-Ring)
10	Air line into Dosing cabinet	3/8” JIC
11	DC power for Display	3 pin connector

Note: The AUS/DEF Vent port of item 5 above must have an AUS/DEF Vent Line installed to route buffer tank fumes to meet local/OSHA guidelines for Ammonia fumes and the following routing requirements:

1. *Vent line must be routed back to top of main storage tank or a local/OSHA approved waste container must be provide in the unlikely event of buffer tank overfill. The vent line going into tank must be below the injector in the CEM.*
2. *Vent line must be routed continuously away from vent port without any kinks or loops that would allow AUS / DEF pooling in line.*

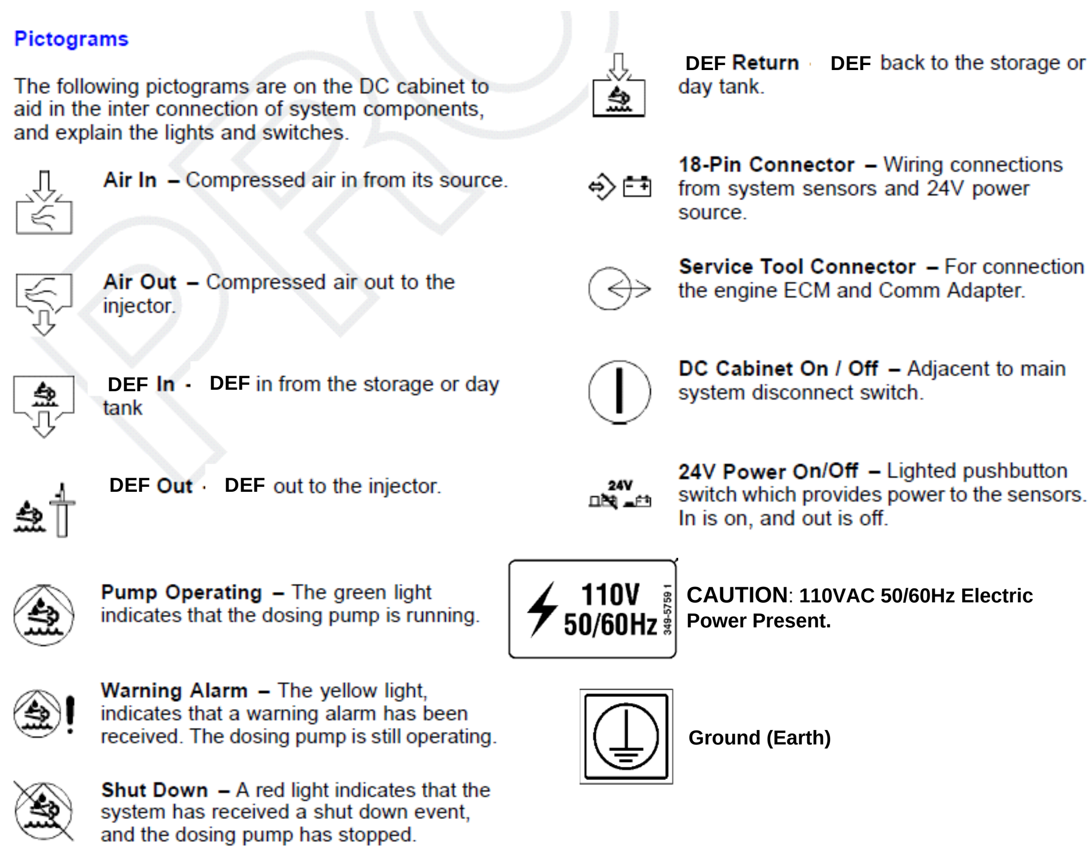
3.10 Dosing Cabinet to DEF Injector

Figure IV.3.10-1: DEF Injector Connections



3.11 Dosing cabinet symbols

Figure IV.3.11.-1: Pictograms



Pictograms

The following pictograms are on the DC cabinet to aid in the inter connection of system components, and explain the lights and switches.

Air In – Compressed air in from its source.

Air Out – Compressed air out to the injector.

DEF In - **DEF** in from the storage or day tank

DEF Out - **DEF** out to the injector.

Pump Operating – The green light indicates that the dosing pump is running.

Warning Alarm – The yellow light, indicates that a warning alarm has been received. The dosing pump is still operating.

Shut Down – A red light indicates that the system has received a shut down event, and the dosing pump has stopped.

DEF Return - **DEF** back to the storage or day tank.

18-Pin Connector – Wiring connections from system sensors and 24V power source.

Service Tool Connector – For connection the engine ECM and Comm Adapter.

DC Cabinet On / Off – Adjacent to main system disconnect switch.

24V Power On/Off – Lighted pushbutton switch which provides power to the sensors. In is on, and out is off.

110V 50/60Hz 349-5759 1

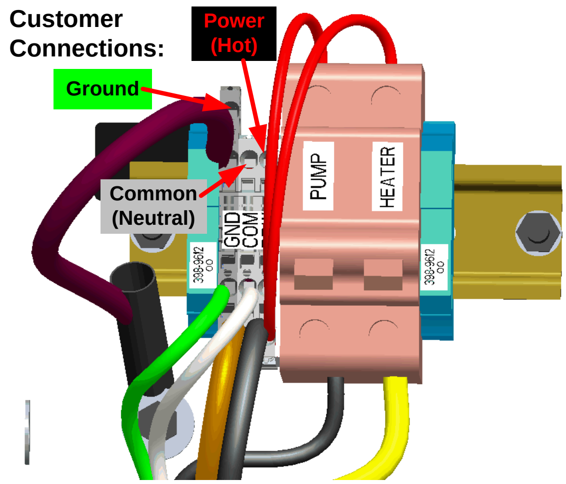
CAUTION: **110VAC 50/60Hz Electric Power Present.**

Ground (Earth)

3.12 AC Power Connection

During the installation of the dosing cabinet, external power supply (AC power only) has to be routed inside the cabinet via appropriate opening. The termination of these power lines are inside the cabinet at the junction block as shown below.

Figure IV.3.12-1: Example AC Power connection to Dosing Cabinet



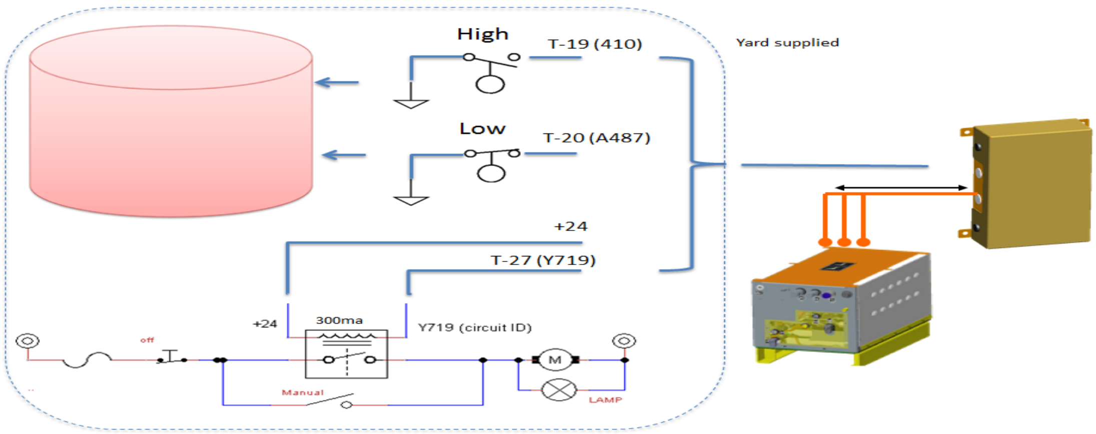
3.13 AUS/DEF Supply to the Dosing Cabinet

Desired fill rate is about 5.8 liters per min at 34-69 kPa AUS/DEF supply pressure at the dosing cabinet fill port. For example a 10 feet height difference generates 32 kPa AUS/DEF pressure. Fill rate and overall flow restriction in valves, lines, and filters upstream to the dosing cabinet needs to be accounted for when designing the AUS/DEF supply.

If a transfer pump is used to supply AUS/Def to the dosing cabinet. The transfer pump must be sized to provide 34-69 kPa with max of 69 kPa AUS/DEF pressure at the dosing cabinet AUS/DEF fill port based on the flow rate and total flow restriction in the line from the remote tank to the cabinet.

Dosing cabinet provides a 24VDC (max amp: 300 mA) signal via aftertreatment ECM connector to control a relay used to control the power supply to the transfer pump as shown in Fig. 6.10. Aftertreatment software will energize the relay at fill and turn it off when the fill is done. This relay is not provided with the dosing cabinet. To use this feature, the customer needs to wire the relay. In addition, the customer also needs to connect a wire from the pin J1-31 of the aftertreatment ECM connector inside the dosing cabinet to the pin 14 of the connector for Cabinet to Engine, i.e. item 1 shown in Fig. 4.6. The wiring diagram for the optional installer provided transfer pump example is shown below.

Figure IV.3.13-1: Transfer Pump Wiring Diagram with ECM and Relay



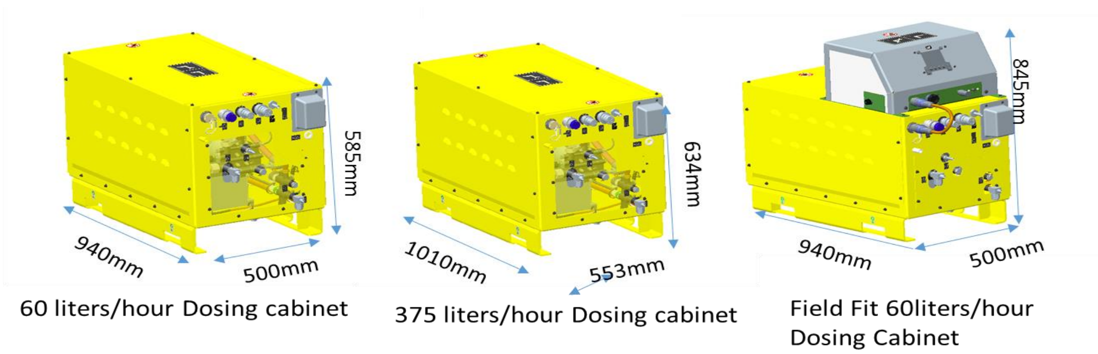
3.14 Weight and Dimensions

Both the 60 & 375 Dosing Cabinets have identical interface connections. However the 375 application has a larger footprint and space claim. The table below gives reference dimension refer to TMI or installation drawing for official dimensions.

Table IV.3.14-1: Weight and Dimensions

	60 liter/hr Dosing Cabinet	375 liter/hr Dosing Cabinet	Field Fit/IMO III Dosing Cabinet
Length (mm)	940	1010	940
Width (mm)	500	553	500
Height (mm)	585	634	845
Weight without AUS/DEF (kg)	95	140	120

Figure IV.3.14-1: 60 & 375 liters/hour Dosing Cabinets Space Claim

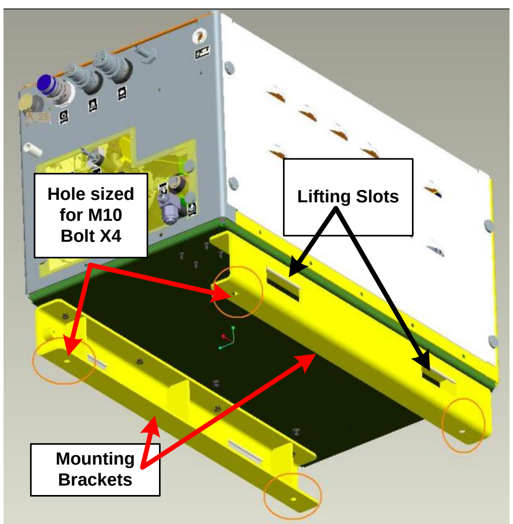


3.15 Lifting and Mounting:

The preferred method of lifting the dosing cabinet is to use two straps wrapped around and through the openings in the base frame as shown in Fig. 4.12.

The cabinet can be mounted by the use of bolts holes in the frame rails. The cabinet frame rails have four M4 bolt holes on inside of the rails. The cabinet can be hard mounted or soft-mounted to the vessel. The cabinet should not be mounted to the engine or engine frame rails. The cabinets should not be stacked on top of each other.

Figure IV.3.15-1: Mounting Dosing Cabinet

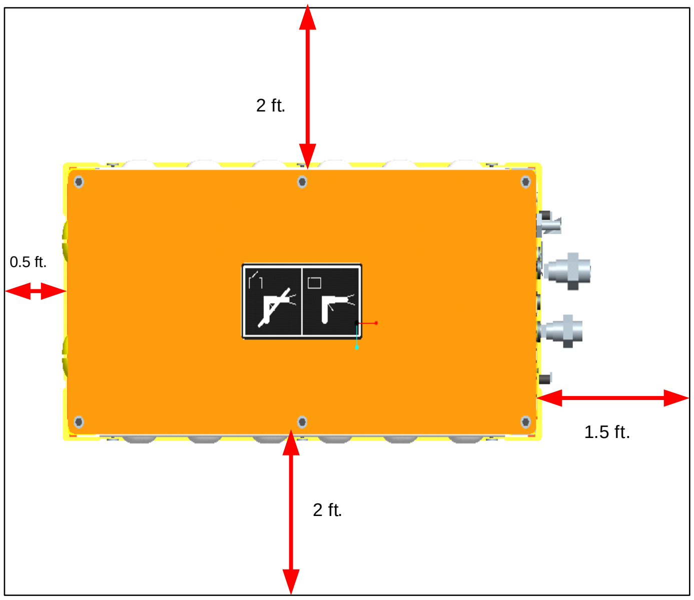


Refer to Section V. – Mounting Considerations for additional mounting guidelines.

3.16 Clearance:

Dosing cabinet is required to have 2 foot access clearances on at least one side of the cabinet. Clearance is also required on the front face of the cabinet to allow room to connect the air, AUS/DEF lines along with the electrical harness. The model below shows the required access distant. If you have side access you only need it on one side of the dosing cabinet.

Figure IV.3.16-1: Dosing Cabinet Mounting Clearance Requirements



<u>Orientation:</u>

The dosing cabinet has to be mounted per Fig. 4.12 in the vertical position. The cabinet needs to be mounted with the top of the cabinet parallel with the horizon.

<u>Location:</u>

Mounting location of the Dosing cabinet must be below the CEM injector and total line length must not exceed the pressure drop limit. The maximum pressure drop in the AUS/DEF line between the dosing cabinet and CEM injector nozzle is 200 kPa (29psi). Refer to TMI for installation parameters including pressure drop and DEF flow.

<u>Environment</u>:

The dosing cabinet needs to be located so that it will not be subjected to ambient temperatures higher than 55 C or lower than -11 C. The components within the dosing cabinet are designed to operate in temperatures per the above specifications.

3.17 AUS/DEF Delivery System

Caterpillar's Selective Catalyst Reduction (SCR) system is contained in a module and utilizes DEF to reduce engine-out NO_x. Urea is a solid at room temperature, but is typically placed into a de-ionized water solution to facilitate high resolution metering which is necessary for the DEF/SCR system to operate at high efficiencies without inducing ammonia slip. Also note that DEF ($CO(NH_2)_2$) itself is simply a safe "transporter" of ammonia (NH_3) which is what ultimately drives this SCR process. This is described in the global equations below.

$CO(NH_2)2 + H_2O \rightarrow 2NH_3 + CO_2$

$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$

Onsite or in the case of a Marine vessel, on board AUS/DEF storage must be provided by the installer and the piping to delivering the AUS/DEF water solution to the pump on the module which will inject the AUS/DEF into the engine exhaust stream where the AUS/DEF then decomposes into NH3 and reacts with NO_x primarily in the presence of the SCR catalyst.

3.18 DEF Handling

Refer to Appendix C: “AUS / DEF Handling” for appropriate handling methods.

3.19 Material Selection for Tank and Piping

Material compatibilities must be considered in the AUS / DEF storage and delivery system due to the caustic corrosive nature of the liquid.

- Highly alloyed austenitic Cr-Ni and Cr-Ni-Mo Steels or Stainless Steel (304, 304L, 316L, 409, 439) materials are recommended for use with AUS32 (urea water solution).
- Titanium is recommended for use with DEF water solution
- Metals & Plastics coated with nickel are not recommended. Nickel coating inner diameters of components makes the durability and resistance to flaking inconsistent.
- Polyethylene, Polypropylene, Polyisobutylene, Perfluoroalkoxyl alkane (PFA), Polyfluroethylene (PFE), Polyvinylidenefluoride (PVDF), Polytetrafluroethylene (PTFE) are all recommended materials
- Seal/Hose Materials – EPDM (1E0712B) and NBR (1E0741) are suggested materials for use with AUS32
- Aluminum and its alloys are not recommended for use as tank material for AUS/DEF tanks. Only certain grades of anodized aluminum are acceptable but due to variability of anodizing quality, it is not recommended as tank material either.
- Non-ferrous metals and alloys (copper, copper alloys, zinc, lead) are strongly not recommended.

3.20 DEF Lines

3.20.1 Connections

Typical fittings have mild steel as the base material, which are not be compatible with AUS/DEF. All connection points and fittings for the AUS/DEF lines are required to be stainless steel or AUS/DEF compatible material.

3.20.2 Line Specifications

<u>Dosing Cabinet to CEM AUS/DEF line</u>

Inside Diameter – Greater than 5.5mm

Maximum pressure drop from cabinet to nozzle 200 kPa

Oil resistant

<u>AUS/DEF Lines from storage tank to dozing cabinet inlet</u>

The dosing cabinet requires a positive pressure of AUS/DEF supplied to the inlet port of the cabinet at all times when the engine is running. The pressure at the inlet port of the dosing cabinet must be between 34 and 69 kPa (5-10psi) at all times during normal operation of the engine. This pressure range will allow the buffer tank to fill correctly. The pressure at the inlet port should not exceed 69 kPa at any time. The method of how the AUS/DEF is supplied to the dosing cabinet is up to the vessel designer and builders. As well as it is the responsibility of the vessel designer/ operator to make sure that the AUS/DEF is available to the inlet port of the dosing cabinet regardless of the ambient conditions and cabinet locations in the vessel.

<u>AUS/DEF Lines Installation & Routing</u>

AUS/DEF lines are to be installed following instructions based on DIN 20066 part 4. General routing and clipping rules should include keeping these lines from coming in contact with sharp edges that would fatigue and fail the line from vibration or system operating movements. Other considerations should include continuous routing without kinks, extreme bends and loops that would restrict AUS/DEF flow throughout the operating temperature extremes.

A shut off valve should be installed in the AUS/DEF supply line going to each dosing cabinet. This will allow the cabinet to be serviced while other cabinets in the vessel are still operating.

3.21 AUS/DEF Storage Tank

The OEM or installer must provide an AUS/DEF main storage tank and delivery system.

The OEM or Installer must provide a means to sample AUS/DEF in the tank to determine AUS/DEF Quality.

AUS/DEF storage tanks must be designed to the industry best practices for fluid storage tanks, but also with consideration for AUS/DEF you need to watch for ambient conditions for both high and low temperatures. If AUS/DEF would have a chance of freezing the tank or tanks would need a heat exchanger designed large enough to thaw the tank or tanks. Unlike other common operating fluids, such as diesel fuel and coolant: AUS/DEF freezes at a temperature within the operating limits of the engine.

AUS/DEF in the tank freezes from the outside to the center. The density of frozen AUS/DEF is lower than the density of the liquid AUS/DEF. This means that the frozen AUS/DEF floats on the liquid AUS/DEF. To ensure that the complete tank of AUS/DEF is thawed, at least part of the heating source has to be located at the bottom of the tank. The AUS/DEF pick-up location has to be very close to the heating source and draw from the bottom of the tank as well. As the AUS/DEF is consumed, the AUS/DEF level in the tank reduces and the cold AUS/DEF approaches the heater.

To facilitate the thawing process, the tank should have a simple rectangular or trapezoidal shape wherein the base of the tank is slightly larger than the top of the tank; a “pyramid” design (no plateaus) is recommended for best thawing performance. Shapes that do not assure the gradual reduction in the level of AUS/DEF have to be avoided. Tank shapes vary from application to application based on design and space limitations. Irregularity in these shapes is acceptable as long as the air pockets and/or stuck chunks of frozen AUS/DEF inside the ridges or any other contours of the tank can be avoided. It is also preferable to have the width of the tank equal or smaller than the height of the tank. Short and long tanks are not favorable for AUS/DEF freeze protection.

3.21.1 Tank Volume

Tank volume should be sized based on required refill frequency, AUS/DEF freeze expansion, and the volume of internal tank components. The AUS/DEF tank size is dependent upon AUS/DEF quality over duration of use and delivery infrastructure. The AUS/DEF must be sized never to run out. Tank sizes will depend on vessel designed operating profile and its normal fueling stops. AUS/DEF tanks must be sized such that sufficient AUS/DEF is always available to adequately operate the SCR system. The amount of AUS/DEF usage can be reasonably estimated as a direct fraction of the engine fuel burn, using a conservative average the amount of AUS/DEF consumed by the engine will be around 10% for C32 and 3500 engines and upwards of 15% for C280 engines and larger. The values here are for examples only consult TMI or work with local Cat dealer and Caterpillar A&I team for actual numbers for each engine rating. Example for 3500 engine is 1 gallon of DEF for every 10 gallons of fuel usage. Such a calculation must be based on the amount of fuel that may be burned by the engine/engines between AUS/DEF fill up opportunities. This value should be based on an operational knowledge of the vessels expected services and the engine projected fuel usage. The AUS/DEF tank should then be sized to accommodate the requisite fraction of AUS/DEF as outline in the table below. As an example, if an analysis of the operating profile of a 3500 sized engine shows that it could burn 1,000 gallons of fuel between AUS/DEF fill opportunities, the AUS/DEF tanks would need to be sized to hold at least 100 gallons of 32.5% AUS/DEF over and above any space taken up by and tank inserts, such as level switches. When figuring out the fuel usage and AUS/DEF usage the operation profile must be used to determine, fuel tank size and AUS/DEF tanks size.

Table IV.3.21.1-1: Ratio of DEF to Fuel for DEF Tank Sizing

	Ratio of DEF to Fuel for DEF Tank Sizing (Gallons Consumed)		
Fuel	32.5% DEF	Or	40% DEF
100	10		8.1
100	15		12.2

The urea (AUS/DEF) tank placement into a Marine Vessel must be design in a place that the urea will not be allowed to freeze. Caterpillar normally recommends a 2% of the total tank volume for freeze protection. Caterpillar recommends a capacity safety margin of 5% of the total tank volume. The EPA and IMO rules state that a vessel tanks must be designed and sized based on the operating load profile of the vessels with a safety factor of “never to run out”. Fuel and urea tank volume will be based on an operating profile and normal vessel fueling stops. If vessel operating in EPA areas and runs out of AUS/DEF the operator has to report each instances to the EPA within 30 days. Each instance where insufficient amounts of AUS/DEF will be recorded in nonvolatile memory by the engine.

3.21.2 Tank Connections

The AUS/DEF suction or pick-up connection should be placed towards the bottom of the tank, and as close to the heat exchanger as possible if installed. This location has the greatest potential for the first available liquid AUS/DEF during thawing. Adequate protection of the pickup tip is recommended to keep unthawed AUS/DEF, sludge and sediment from blocking the port. On the return side, melted AUS/DEF returning from the pump has the potential to help thaw the remaining frozen AUS/DEF. To take advantage of this potential, the return port on the tank should be at the top of the tank.

3.21.3 Tank Mounting

Proximity to heat sources should also be considered in tank placement, as prolonged exposure to elevated temperatures causes thermal degradation of AUS/DEF in the tank. The tank should be located in the vessel where the tank temperatures will not freeze and not exceed the high temperature requirements for proper storage. The proper storage temperature range for AUS/DEF is between -9°C and 25°C (15°F and 77°F). AUS/DEF that is stored above the 35°C (95°F) for longer than one month must be tested to make sure the quality is not degrading and AUS/DEF still meets its required spec’s. Tanks must be located on the Vessel to meet the temperature requirements to avoid degradation of AUS/DEF. If the location of the AUS/DEF tanks within a vessel can’t meet the temperature requirement for AUS/DEF then a way to cool or heat the fluid must be installed in the main AUS/DEF tanks. Use of thermal insulation is another way of keeping the tanks temperature with the proper temperature requirements for storage. Although high-density polyethylene is a poor conductor of heat, additional insulation will help to protect AUS/DEF from thermal degradation.

3.21.4 Tank Materials

Non-cross linked polyethylene (PE) is the material of choice for AUS/DEF tanks. It provides a wide temperature range of operation, has good strength properties, allows for flexibility in “shaping”, low in weight, and has been used other AUS/DEF applications.

3.21.5 In-Tank Filtration

In-tank filtration is required to protect the AUS/DEF delivery system.

An inlet strainer is required to prevent large debris from entering the tank. The strainer should be made of stainless steel with 30-mesh/500 micron filtration.

An “Iceberg Catcher” must be located at the end of the AUS/DEF pickup line in the tank to keep frozen chunks of AUS/DEF out of the delivery system. This will act as secondary filtration into the AUS/DEF delivery system, but will not provide enough filtration to meet the requirements for the AUS/DEF delivery systems. Functional specification for the iceberg catcher is consistent with Euro 4 (ES-2084). Technical requirements of the filter are for AUS/DEF flow capacity for the delivery system (area of the mesh) and the filtration requirements (size of the mesh - 100 um).

3.21.6 Tank Sensors

- <u>AUS/DEF Temperature Sensor</u>
  A optional customer storage tank temperature sensor may be installed connected to the Caterpillar system.
  Temperature sensor requirements based on the reference sensor include: operating temperature range –40C and 150C (probe end), –40C and 120C (connector end), vibration limits: 30Grms X 3 sigma for 0.03% of operational lifetime, electrostatic painting process and must be salt & DEF water corrosion resistant.

- <u>AUS/DEF Level Sensor</u>
  A low level urea tank sensor is required to be installed in main AUS/DEF tank per EPA regulations guidelines. Caterpillar provides a connection point on the dosing cabinet for a main AUS/DEF tank sensor. The sensor needs to be salt and AUS32 corrosion resistant, with an operating temperature range of –40°C to 85°C. The sensor will send a signal to the dosing cabinet ECM when the AUS/DEF level in the tank drops to 13.5% left in the tank. The dosing cabinet will then warn the vessel operator when the AUS/DEF main tank in starting to run low. No faults are recorded for low tank volume unless the tank runs empty of AUS/DEF. The sensor inside the dosing cabinet will record when the system is completely out of DEF. The low level sensor in the main DEF tank will only supply a warning to the operator that his DEF tank is running low. The low level sensor input into the dosing cabinet ECM is a switch input to GND. These two points are required to comply with EPA 1042 rules.

  It is recommended that along with the level sensor a warning light is provided to indicate when AUS/DEF level is low in the main vessel tank. The warning light should be set at a level that will provide adequate time to get quality AUS/DEF and refill the main tank.

3.21.7 Tank Heating

Heating of the AUS/DEF tank for thawing can be carried out in various ways. As it is the vessel design and owners response ability to make sure that urea/DEF is available at all temperatures. If the tanks are placed where the fluid could freeze then tank heating might be required. Heat can come from an electric heater, or a heat exchanger using one of the various working fluids on a Marine Vessel, including coolant, engine oil, hydraulic oil, and exhaust. Out of these sources, a heat exchanger using coolant is the optimal solution. Electricity is also acceptable for performance, but the amperage requirement is very high. Although other fluids may have equal or higher temperatures, coolant’s high specific heat enables it to outperform the others. Mass flow rate also plays a major role in determining the heating potential of a fluid.

While a heat exchanger using coolant has many advantages, it also has one major performance disadvantage compared to an electric heater. While an electric heater can begin thawing AUS/DEF almost immediately after startup, engine coolant warms up more slowly.

3.21.8 Heat Exchanger Design

Based on the highest rate of consumption, the heat exchanger (a stainless steel coolant line) can be sized to provide thawing. The sizing is accomplished by utilizing the following equation:

$mC_{p,\ solid\ DEF}dT_{solid\ DEF} + mH + mC_{p,liquid}dT_{liquid\ DEF} = UA\ (T_{coolant}-T_{DEF})$

where:

m = 2 x DEF consumption, kg/s

$C_{p,\ solid\ DEF}$ = specific heat of frozen DEF solution, kJ/kg-K

$C_{p,\ liquid\ DEF}$ = specific heat of liquid DEF solution, kJ/kg-K

$dT_{solid\ DEF}$ = -11C - Initial temperature of DEF, C

H = Latent heat of fusion of DEF solution, kJ/kg

$dT_{liquid\ DEF}$ = Final, required temperature of DEF - -11C, C

U = Overall heat transfer coefficient, kW/m^2-K

A = Heat transfer area, m^2

$T_{coolant}$ = AECD Coolant temperature, C

T_{DEF} = Required temperature of DEF, C

The overall heat transfer coefficient, U can be obtained from the following equation:

$$\frac{1}{UA} = \frac{1}{h_{coolant}A_{coolant}} + \frac{l_{ss}}{K_{ss}A_{ss}} + \frac{1}{h_{ice}A_{ice}}$$

<u>Where:</u>

$h_{coolant}$ = Convective heat transfer coefficient of the coolant inside the coolant line, which can be obtained from the equation

Nu = hD/K

$A_{coolant}$ = Surface area of the coolant, m^2

l_{ss} = thickness of the stainless steel tube, m

K_{ss} =Thermal conductivity of stainless steel, kW/m-K

A_{ss} = Mean surface area of the stainless steel tube, m^2

h_{ice} = Convective heat transfer coefficient of the frozen DEF solution surrounding the tube, kW/m^2-K

A_{ice} = Surface area of the OD of the tube, m^2

The heat transfer area, A, can be calculated from the above equation. This area can be translated into an equivalent length and diameter of the coolant line.

3.21.9 Insulation Requirements

Although non-metallic AUS/DEF tanks are a very poor conductor of heat, depending on the proximity of the AUS/DEF tank to a heat source, additional thermal insulation may be required. For metallic tanks, thermal insulation is required to help improve the AUS/DEF thawing process in addition to heat protection. AUS 32 freezes at –11°C and starts to degrade at elevated temperatures above 50 °C.

The main storage tank location in a vessel needs to be taken into consideration for both high and low temperature requirements of urea. If the tank is located in a high temperature area of the vessel then insulate the tank or design in some type of cooling design to keep the urea below the maximum temperature limits. If vessel will be spending time in cold operating areas then the urea tanks needs to be kept from freezing. This can be accomplished by insulating the tank or by adding heater to the tank to keep the temperatures from freezing.

3.22 Energy Source

3.22.1 Energy Requirements

For AUS/DEF thawing, the recommended melt rate for frozen AUS/DEF is twice the maximum consumption rate. This gives a brake-specific melting rate of 34 g/kW-hr and 21 g/kW-hr for ratings 175-750 hp and greater than 750 hp, respectively. These numbers should be used when sizing a heat exchanger or electric heater.

- Heat Exchanger Design
- Pickup/Return Location
- Flow rate/Thaw rate min.

3.23 Electrical

Block Diagram

Figure 3.23-1:
Dosing Cabinet Block Diagram – C32, 3516 and C175

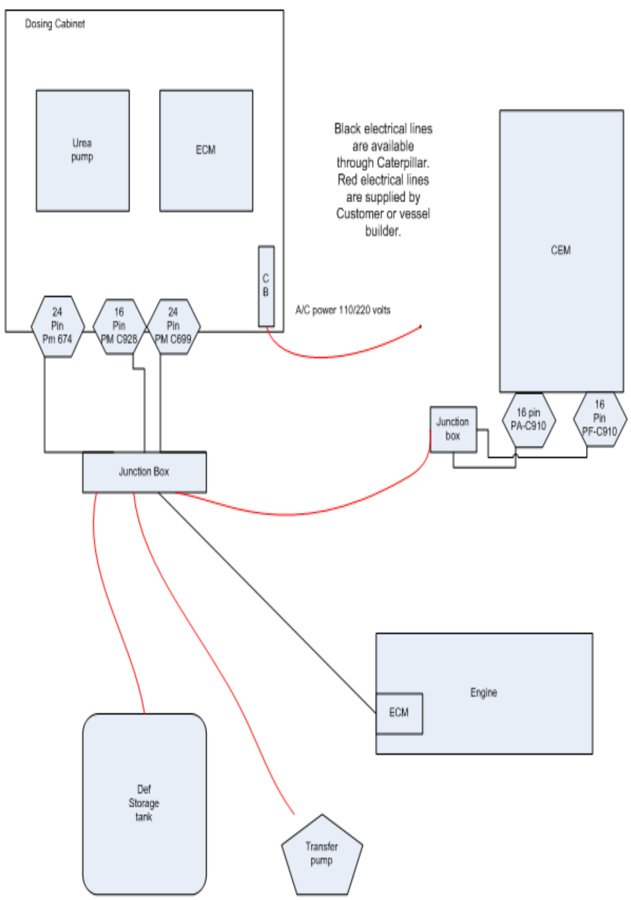
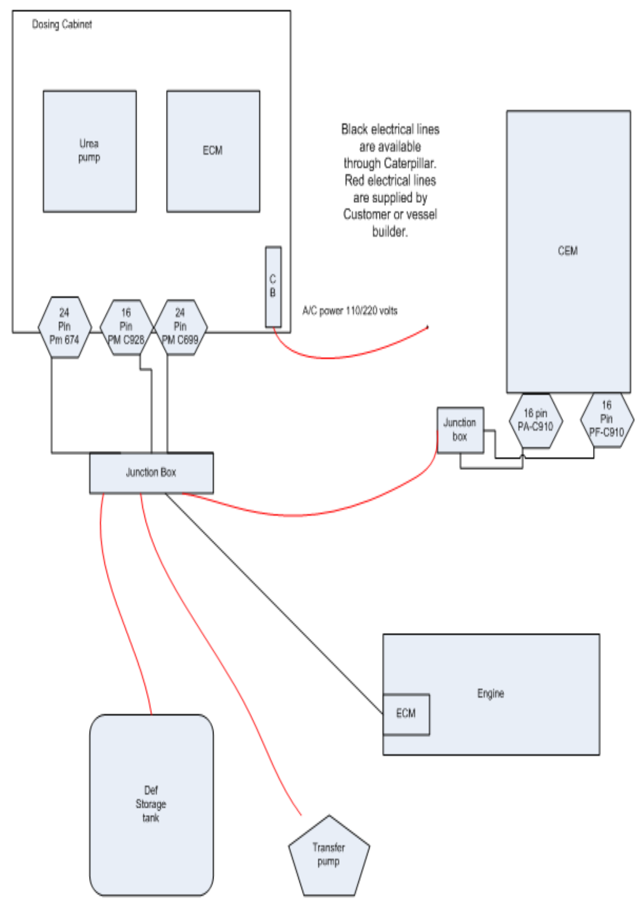


Figure 3.23-2:
Dosing Cabinet Block Diagram – C280 and MaK

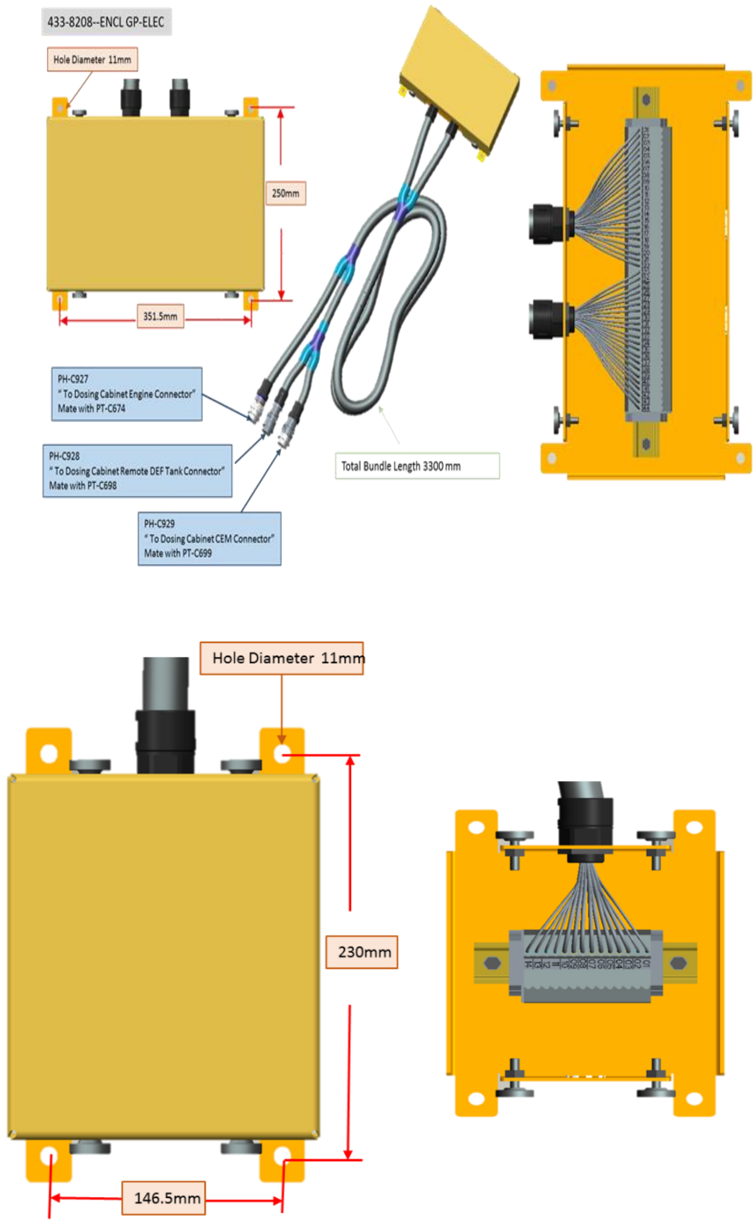


3.24 Electrical Connections

Interconnect Harness Connectors

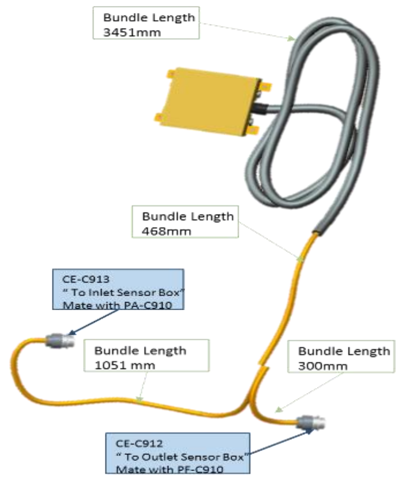
Dosing Cabinet Side - All Applications

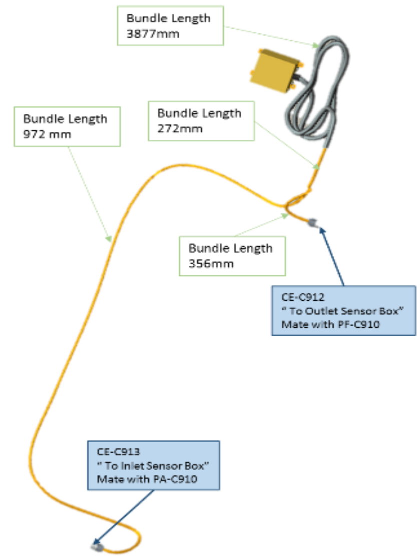
Figure IV.3.24-1: CEM Side U and Z Flow (438-0992 and 438-0996)



CABINET TERMINALS		
TERM NO.	WIRE ID	SIGNAL NAME
1	101	BATTERY(+)
2	101	BATTERY(+)
3	103	DEF MANF HEATER RELAY
4	103	DEF MANF HEATER RELAY HIGH
5	105	KEYSWITCH
6	229	DEF MANF HEATER RELAY
7	229	DEF MANF HEATER RELAY LOW
8	944	CAT DATA LINK(+)
9	945	CAT DATA LINK(-)
10	A250	BATTERY(-)
11	A250	BATTERY(-)
12	K900	GLOBAL CAN A (+)
13	K990	GLOBAL CAN A (-)
14	L638	UREA MANF HEATER RELAY LOW
15	P830	UREA MANF HEATER RELAY HIGH
16	R970	LOCAL CAN B (+)
17	R976	LOCAL CAN B (-)
18	Y719	DEF TRANSFER PUMP SW
19	410	TANK HIGH SW
20	A487	TANK LOW SW
21	H857	DEF LEVEL SENSOR
22	H811	DEF TANK TEMP
23	H839	DEF TANK HEATER RELAY
24	H938	DEF LINE HEATER LOW
25	P830	DEF LINE HEATER HIGH
26	T791	DEF TANK HEATER RELAY
27	Y719	DEF TRANSFER PUMP SW
28	Y947	ANALOG SENSOR RETURN
29	997	5V ANALOG SENSOR SUPPLY
30	997	5V ANALOG SENSOR SUPPLY
31	J807	DOUT RETURN
32	J807	DOUT RETURN
33	J890	SCR INLET GAS TEMP
34	J891	SCR OUTLET GAS TEMP
35	K895	AFTM #1 ID MODULE
36	L638	DEF LINE HEATER LOW
37	L920	INTAKE NOX SENSOR POWER
38	L921	OUTLET NOX SENSOR POWER
39	P930	DEF LINE HEATER HIGH
40	P938	SCR ABS PRESS
41	R970	LOCAL CAN B (+)
42	R976	LOCAL CAN B (-)
43	T993	ANALOG SENSOR RETURN
44	T993	ANALOG SENSOR RETURN

Figure IV.3.24-2: C280 and MaK: Vertical CEM design harness (needs 451-0087 and 451-0086). The 451-0086 goes on the mixing tube and then 451-0087 goes on CEM

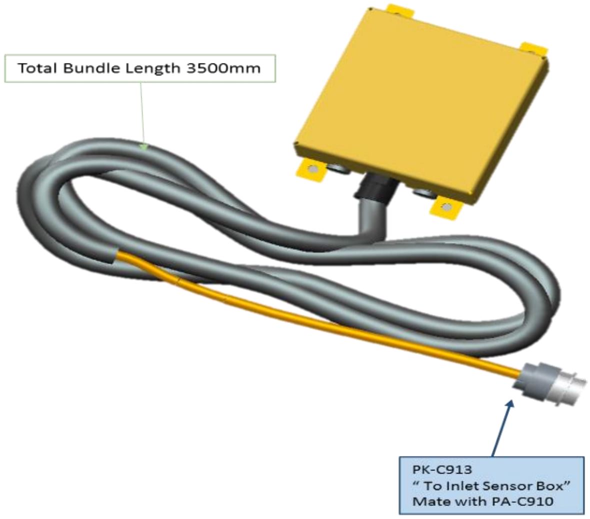


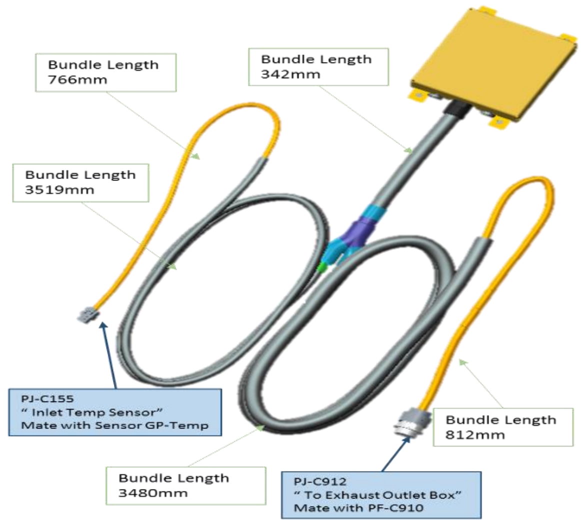


CEM TERMINALS		
TERM. NO.	WIRE ID	SIGNAL NAME
1	997	5V ANALOG SENSOR SUPPLY
2	997	5V ANALOG SENSOR SUPPLY
3	J807	DOUT RETURN
4	J807	DOUT RETURN
5	J890	SCR INLET GAS TEMP
6	J891	SCR OUTLET GAS TEMP
7	K895	AFTM #1 ID MODULE
8	L920	INTAKE NOX SENSOR POWER
9	L921	OUTLET NOX SENSOR POWER
10	P938	SCR ABS PRESS
11	R970	LOCAL CAN B (+)
12	R976	LOCAL CAN B (-)
13	T993	ANALOG SENSOR RETURN
14	T993	ANALOG SENSOR RETURN 438-9665

CEM INLET TERMINALS		
TERM. NO.	WIRE ID	SIGNAL NAME
1	997	5V ANALOG SENSOR SUPPLY
2	J807	DOUT RETURN
3	L920	INTAKE NOX SENSOR POWER
4	P938	SCR ABS PRESS
5	R970	LOCAL CAN B (+)
6	R970	LOCAL CAN B (+)
7	R976	LOCAL CAN B (-)
8	R976	LOCAL CAN B (-)
9	T993	ANALOG SENSOR RETURN 458-9656

CEM OUTLET TERMINALS		
TERM. NO.	WIRE ID	SIGNAL NAME
1	997	5V ANALOG SENSOR SUPPLY
2	J807	DOUT RETURN
3	J890	SCR INLET GAS TEMP
4	J891	SCR OUTLET GAS TEMP
5	K895	AFTM#1 ID MODULE
6	L921	OUTLET NOX SENSOR POWER
7	R970	LOCAL CAN B (+)
8	R976	LOCAL CAN B (-)
9	T993	ANALOG SENSOR RETURN 458-9653





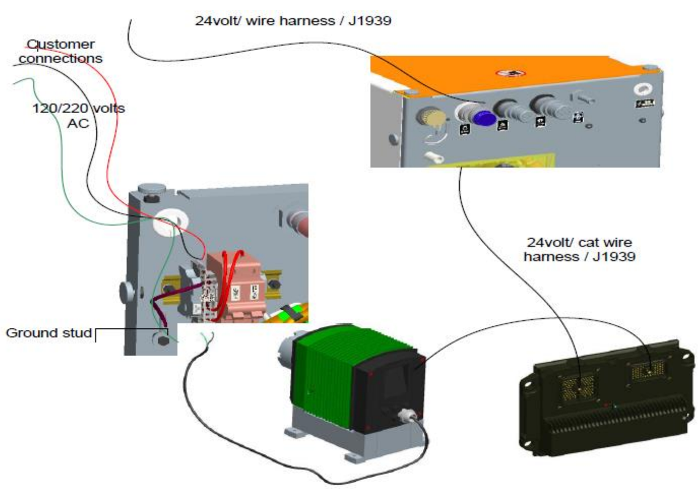
For all wire lengths and mounting information refer to installation drawings. The model views are only to show what hardware is available.

<u>120V Power Connection</u>

The dosing pump requires 120V AC power to operate. The connection for the power is made inside the dosing cabinet on a bus bar with the cable routing through a wiring grommet on the dosing cabinet. The hot and neutral wire coming into the cabinet will hook into the 120 volt terminal strip connectors. Then the ground wire needs to be hooked up to the grounding stud. This will allow the dosing cabinet to meet the grounding requirements. Refer to wiring example in Fig. 4.15.

Note: If using a GFI outlet make sure it meets all of the requirements and it is not tied with any other circuits as the load from dosing pump could cause the GFI outlet to trip.

Figure IV.3.24.3: 120V AC Connection Diagram



3.25 Electrical Loads

Table IV.3.25: Electrical Loads

SCR Component Electrical Load (Assume Cold Ambient Temps)							
Component	Power	AC		DC			
		AC max amp	AC max amp	DC max amp	DC Ave amp	DC max amp	DC Ave amp
		Engine Running	Engine Stopped	Engine Running	Engine Running	Engine Stopped	Engine Stopped
Dosing pump	AC	0.7	0.0				
Buffer Tank Heater	AC	2.9	2.9				
12V power conditioner	DC			1.0	0.2	1.0	0.2
ECM & connected items Total:	DC			11.4	3.7	4.2	2.0
• ECM	DC	0		0.3	0.3	0.3	0.3
• NO_x Sensors	DC	0		7.0	1.0	0.0	0.0
• Air supply enable solenoid	DC	0		2.0	0.5	2.0	0.0
• Reagent return solenoid	DC	0		0.2	0.1	0.0	0.0
• Pump fill solenoid	DC	0		0.2	0.1	0.2	0.0
• DEF Transfer Pump Relay (Optional – Customer Supplied)	DC	-	-	0.3	0.1	0.3	0.1
Total Component Current (Amps)		3.6	2.9	13.0	4.0	6.0	3.0
NOTE: Power consumption w/SCR Aftertreatment system. This does not include air compressor and air dryer.							

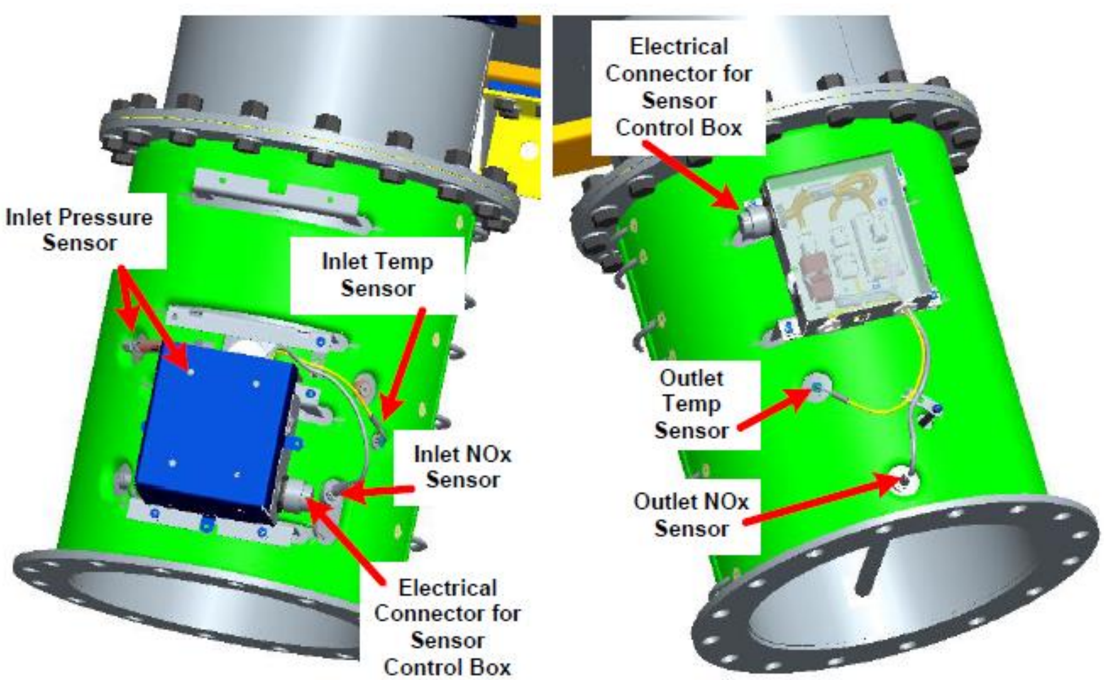
3.26 Electrical Component temperature limits

There are components on the CEM that are required to stay under specified temperature limits. The sensor box on the CEM contains the critical electrical components such as the NO_x sensors and temperature sensors. The pressure sensors may or may not be located in the sensor box. It is necessary that the components in Table IV.3.26-1 do not exceed the listed specifications during operation of the engine system. Due to the high temperature of the engine exhaust, it is recommended that the CEM either be wrapped of have good air flow around the CEM to make sure the ambient air temperature stays below the recommended temperature list below in the chart.

Table IV.3.26-1: Electrical Component Temperature Limits

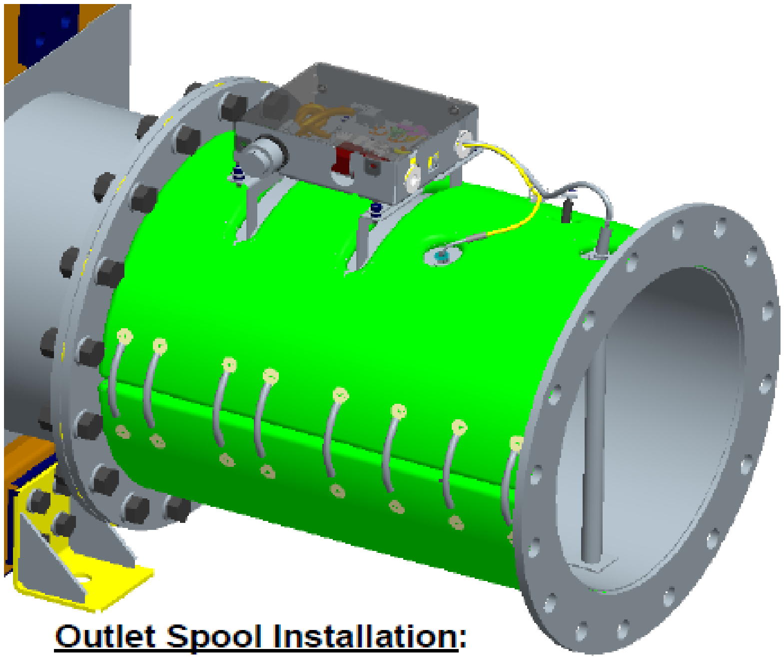
Component Temperature Limits	
Component	**Temp Limit (C)**
Temperature Sensor	120
NO_x Sensor Control Box	100
Delta Pressure Sensor	125
NO_x Senor wire from probe end to control box	200

Figure IV.3.26-1: 3516 Inlet/Outlet Spool Electrical Component Locations



The above figure shows the electrical components for the inlet and outlet exhaust spools that attach to the CEM both U and Z flow configurations.

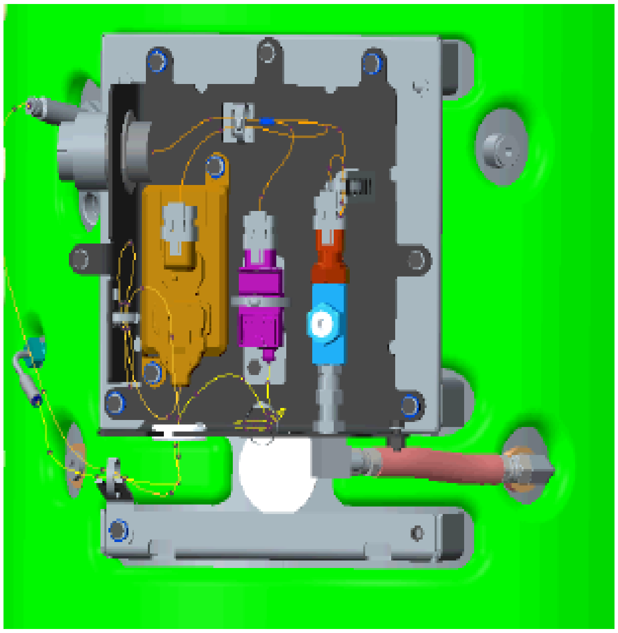
Figure IV.3.26-2: Spool Orientation



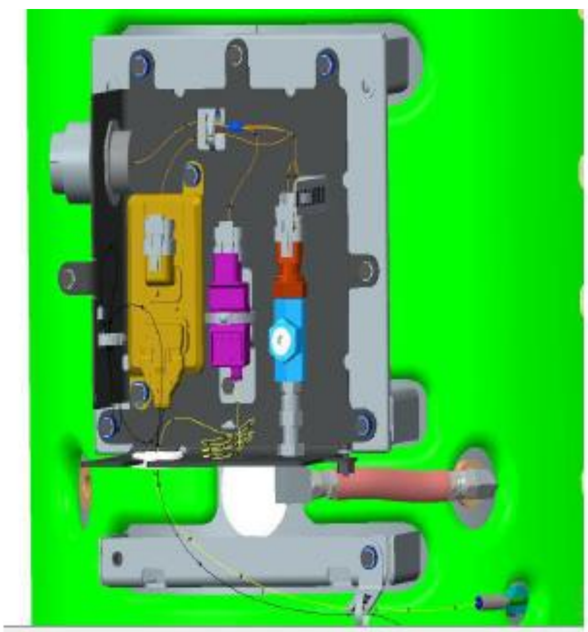
On all U and Z flow CEM installations, the sensor box inlet and outlet spools are to be mounted on the top side of the spools with adequate clearance to allow service of the NO_x Sensors and pressure sensors on the spools. The sensor box on the C280 mixing tube must also be mounted on top side of the mixing tube. The photo below shows how the pressure sensor needs to be mounted inside the sensor box. The pressure sensor is used to monitor the health of the catalyst so it’s important that the sensor is mounted in the correct position. Mounting the inlet spool which contains the pressure sensor is very important. If CEM is mounted vertically (on its end) the spools must be oriented to allow easy access to the NO_x sensors for service.

If you have a Z flow CEM that is mounted in the vertical position the sensor box on the inlet spool needs to be moved to the other mounting brackets and the pressure sensor needs to be moved to the other pressure sensor port which has the bosses installed in the spool. On all of the other positions of the Z flow make sure the sensor box in mounted on the top side of the spools.

Figure IV.3.26-2: Sensor Position



Standard position of sensors



Position of sensors in vertical Z flow installation

Once the spools are mounted in their final and correct positions, the spools must be supported. The spools are not designed to hold any of the exhaust pipe weight. Some type of support is required to support the spools and the exhaust pipe. The supports should be located within 6 inches of the flange or fasten to the mounting flange on the spool.

3.27 Exhaust System

3.27.1 Exhaust Connections for U and Z flow CEMs

Both the inlet and outlet exhaust connections to the CEM utilize a ANSI bolt hole pattern in the flanges. A gasket and standard bolt torques are required to maintain a leak tight seal. Any connections for the exhaust that are between the turbo out and CEM inlet are required to be leak tight and utilize industry standard exhaust connection components.

For further Exhaust System Requirements reference “Section VIII – Exhaust System.”

Figure IV.3.27.1-1: Top front view of “Z” style SCR CEM

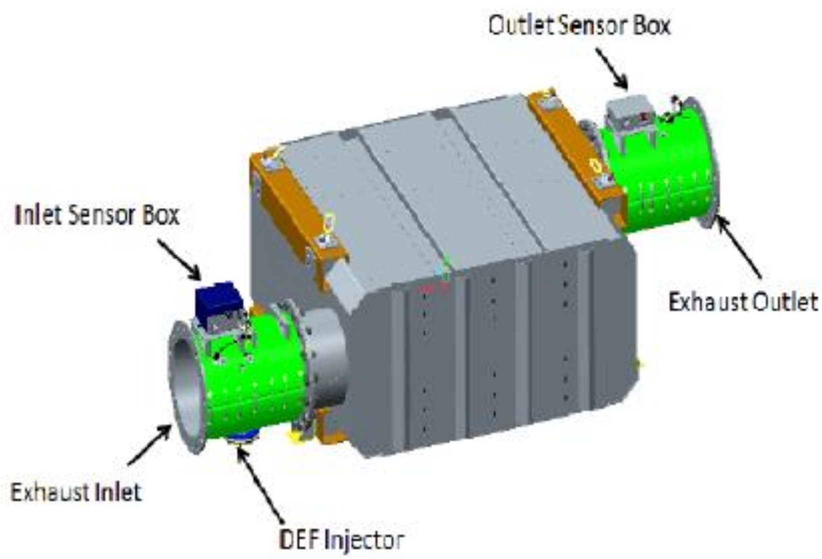
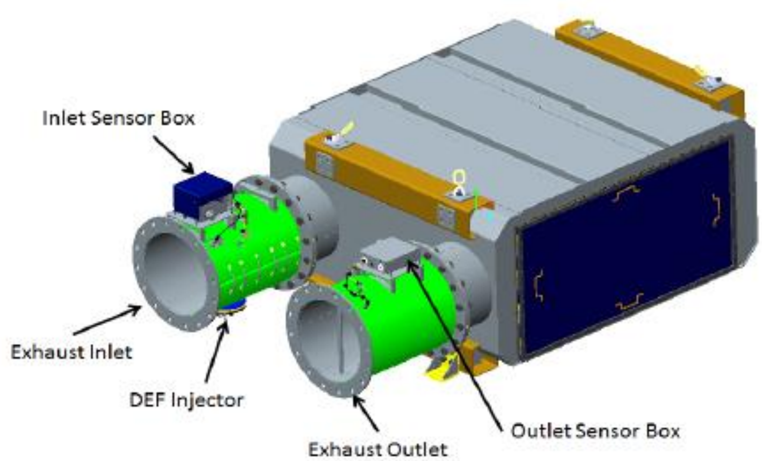


Figure IV.3.27.1-3: Top front view of “U” style SCR CEM



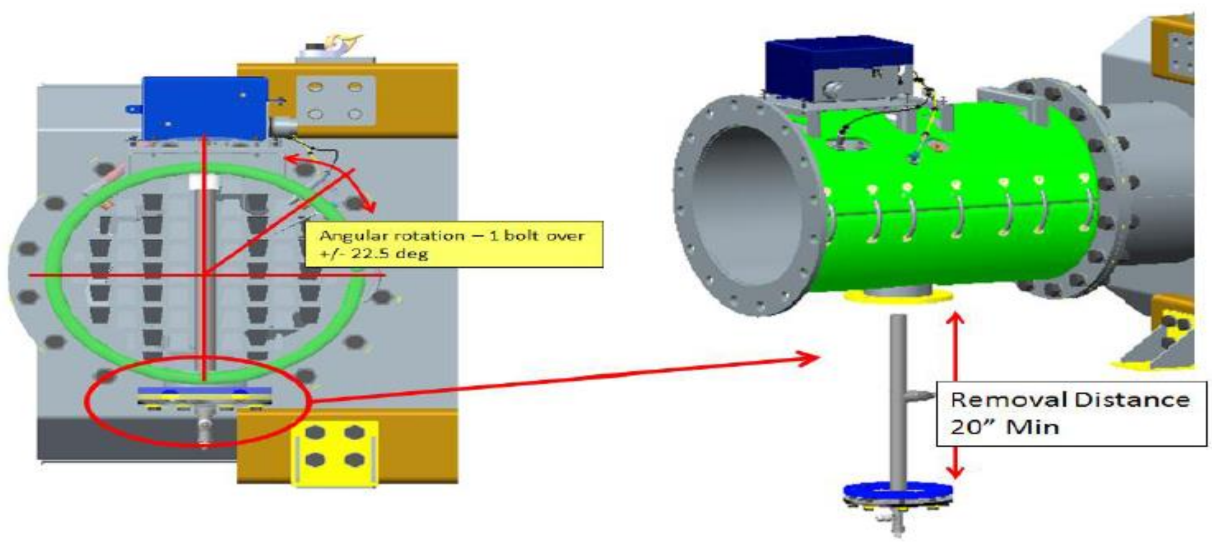
3.27.2 Sound Attenuation

For sound attenuation data of the engine and aftertreatment system contact your Caterpillar Dealer.

3.27.3 Installation

CEM installation considerations should be based on application, location, environment and serviceability. Serviceability, is not just limited to, repair and maintenance of the CEM and system components. This may include dosing cabinet, sensors, catalyst and dosing injectors. The inlet spool on the CEM that houses the AUS/DEF injector is flexible through orientation for better serviceability.

Figure IV.3.27.2



Note: Clearance for servicing the AUS/DEF injector must be maintained by providing 20inches (508mm) clearance for injector access and removal. Spool orientation option may assist you when designing for CEM installation.

3.27.4 Temperature Limits

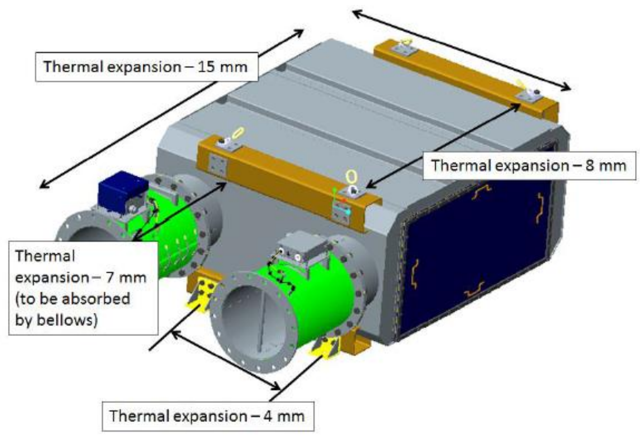
Ventilating air should enter near the engine and then flow upward around the engine and/or Cat CEM module before exiting above the engine.

Room ventilation should be designed to bring the air flow around the Cat CEM module. If the engines and modules are placed in the same room then ventilating air should flow out the top of the room. The source of the air should come in low in the room and rise across the engine and Cat CEM and other equipment.

For personnel comfort, maintaining air velocity at 1.5 m/sec (5 ft/sec) in areas of heat sources or areas that exceed 38°C (100°F). Potential dead air spaces should be checked for temperature rise during engine operation. Check all electrical and mechanical equipment in the dead air space for any detrimental effects caused by excessive temperatures. Require corrections if necessary. Engine room pressure should not become excessively negative. This woKathuld indicate a shortage of ventilating air or excessive ventilating fans if equipped.

3.27.5 Marine Aftertreatment Estimated Thermal Expansion

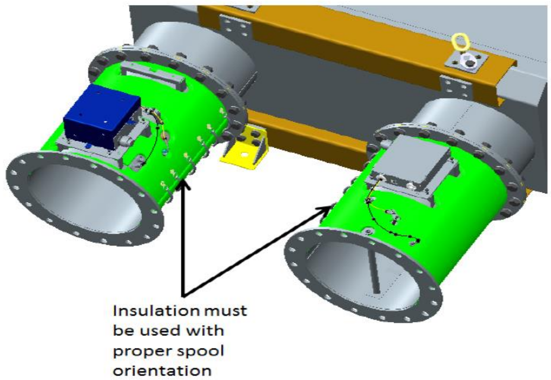
Figure IV.3.27.5-1



3.27.6 Thermal Insulation

Insulation is required around the CEM to help make sure the Catalyst can maintain temperature. It is recommended that the exhaust piping between the engine outlet and the CEM inlet be insulated to allow the system to maintain proper exhaust temperature in the CEM. The temperature drop requirements between the engine and CEM are called out in table VIII.4.2.4-1. Insulation on the spool and under the sensor boxes will help in keeping the sensor boxes components under there required temperature limits.

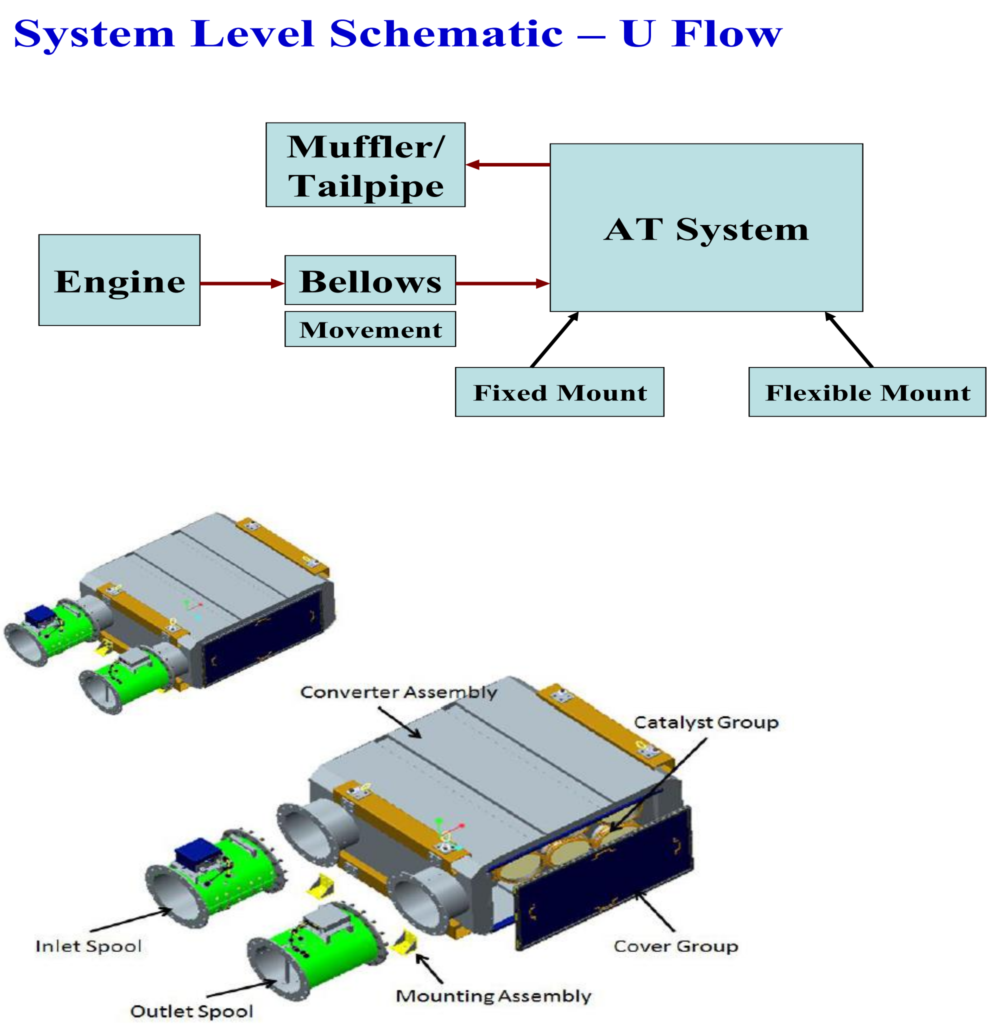
Figure IV.3.27.6



3.27.7 U Flow System Level Schematic

As shown in the schematic below, for U-flow, the exhaust gas inlet and outlet are on the same side of the CEM. The CEM is supported with fixed mount on the inlet & outlet side to keep this side of the CEM rigid limiting the stresses on the bellows on upstream side of CEM. However, the other side of the CEM needs to be supported on flexible mounts to take care of dynamic conditions and allow thermal expansion of the CEM.

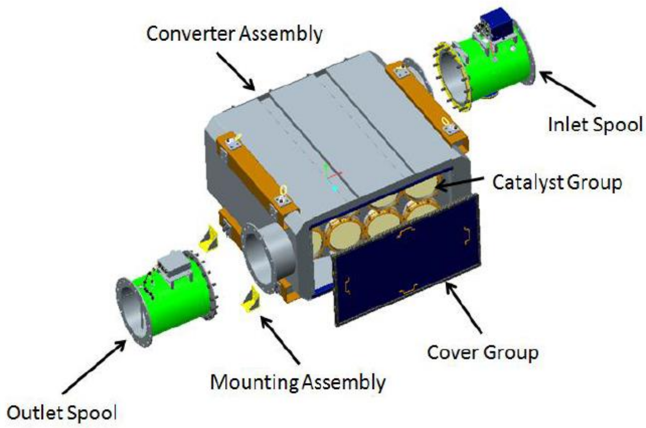
Figure IV.3.27.7-1



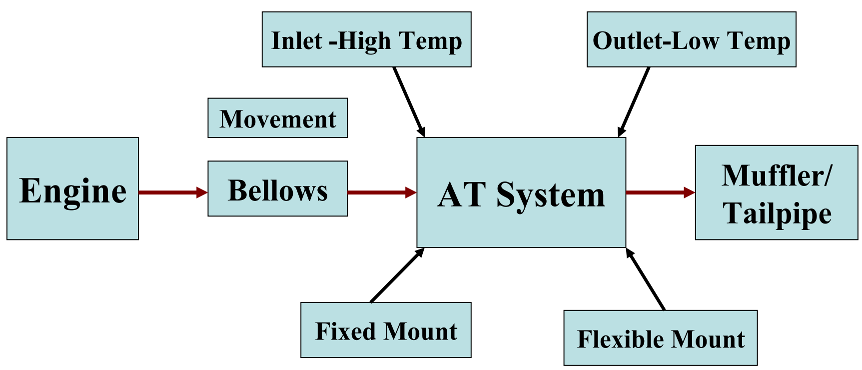
3.27.8 Z Flow System Level Schematic

As shown in the schematic, for Z-flow, the exhaust gas inlet and outlet are on the opposite side of the CEM. The CEM is supported with fixed mount on the inlet side to limit stresses on bellows and flexible mount on the outlet side of the CEM to allow flexibility and thermal expansion of CEM.

Figure IV.3.27.7-2



System Level Schematic – Z Flow



V. MOUNTING CONSIDERATIONS

1 Introduction

This section is comprised of two parts, Mounting Requirements and Mounting Guidelines. The first part describes metrics that a mounting system must meet for the CEM installation to be successful. The second part gives some tips about how to approach the design and validation of a mounting system that should make it easier (though not guaranteed) to meet the requirements in the first part. Every installation is unique, so individual customers may have to adapt the methods described here to better fit an individual application.

The CEM has been designed and validated to provide accepted durability in a wide variety of applications with load less that 60hz without the use of isolation mounts. However, certain applications may still require the use of isolation mounts for one of the following reasons.

- The CEM hard mounted to a particular structure would be exposed to vibrations greater than 60hz.

- The mounts supporting the CEM move independently of each other and would cause damage to the CEM or mounting supports.
- The noise generated by a hard mounted CEM would be objectionable
- Some flexibility in the attachments may make assembly easier and/or reduce assembly stress.
- The volume is low enough where it may be preferable to add component cost in order to reduce validation cost.

Notice: Mounting the aftertreatment to the engine frame rails is not recommended.

2 Mounting

2.1 Mounting Requirements

The CEM may be attached with or without the use of rubber isolation mounts. Regardless of the style of design or the method used to validate it, any successful CEM attachments must meet the following criteria:

- CEM vibration (during operation, shipping, etc) must not exceed required limits for CEM component durability for load input frequencies of less than 60 Hz. A majority of applications will operate with frequencies less than 60 Hz.
- If load frequency input is greater than 60 Hz, the CEM must use tuned isolation mounts to reduce loads at greater input frequency than 60 Hz or work with a Caterpillar A&I engineer to design/select a CEM suited for the particular application.
- Any brackets, bolted joints, mounts, welds or other structural elements supporting the CEM must be able to withstand all mechanical loads seen during operation (including thermal growth) or shipping. Each of these elements may have different load limits, and the limits may depend on the direction of loading or number of load cycles expected during the products lifetime. For Marine applications the CEM G-loading limits have been evaluated up to +/- 1G.
- Any structural elements must provide acceptable strength and durability over the entire temperature range expected to be experienced in the application.
- Motion of the CEM during operation must not exceed what can be accommodated by the flexible connections attached to the CEM and the clearances between the CEM and surrounding objects.

Caterpillar strongly recommends keeping the mounting contact points within the perimeter of the mounting feet. If the mounting structure extends beyond the mounting feet perimeter, care must be taken to ensure that the structure does not interfere with other components of the CEM that may extend below the mounting feet plane.

2.2 Mounting Guidelines

There are a number of (sometimes conflicting) goals and criteria to keep in mind when designing a CEM mounting system. It’s important to check several criteria for any given mounting system. The specific criteria to check depend on whether or not soft mounts are used in the design.

2.3 Hard mounted

A hard mounted design should be evaluated with a stress-quality FEA model. The model should have at a minimum all structural components meshed between the CEM cradle and whatever is acting as "ground." An experienced analyst should be involved to ensure that all the important sources of stiffness, mass, and loads are being accounted for in each application. At least the following analyses should be run:

- Modal analysis: Check natural frequencies and compare with the firing frequencies of the engine over the operating engine speeds and other sources of strong vibration (for example, if the primary load on the engine is a pump, compare to the pumping frequency). If one of the system natural frequencies is close to a frequency of excitation, a harmful resonance condition could occur.
- Static g-loading: The model should be run with a number of load cases to simulate both low-cycle and high-cycle (fatigue) shock events. The specific loads to apply will depend on the application. Predicted stresses should be compared to material limits (endurance limit for high cycle, yield strength for low cycle). Loads through bolted joints should be compared to joint capacity. For marine applications the CEM G-Loading limits have been evaluated up +/- 1G.

Some applications may need additional analyses run or additional criteria checked. Consult with your Caterpillar A&I Engineer if you require assistance.

2.4 Soft mounted

Soft mounted systems must meet the same requirements as hard mounted systems, so the same techniques described above can be helpful. In practice, some additional screening tools can be useful to evaluate soft mounted systems more efficiently using a lower level of detail than a full FEA model. One such tool is a rigid body analysis. This type of analysis assumes that everything is rigid except the mounts, and just uses six degrees of freedom to describe the motion of the CEM. Also, the mounts are assumed to be the only connection between the CEM and ground (i.e. the pipes, hoses, and wire harnesses are assumed to contribute negligible stiffness). This tool is often used at the early stages of mounting system design in order to quickly evaluate several possible mounting configurations before moving on to more thorough analysis such as FEA. Caterpillar's Resilient Mounts Group can assist with this analysis, or it can be run by individual customers on their own commercial or in-house software.

The analyses run with a rigid body code are identical to those described above for FEA. The only differences are that the rigid body analysis can be built, run, interpreted, altered, and rerun much faster than FEA, and that some additional model outputs need to be checked. In particular, the static g-loading results should be checked in the following ways:

- Peak loads through mounts should be compared with limits associated with the bolted joints.
- High cycle mount deflections should be compared to the deflection (strain) limits for the mounts being used.
- Motion across the exhaust bellows should be compared to their limits.
- Motion of other critical parts of the CEM (extremities near tight clearances, for example) should also be checked.

Once a design has been found which meets all the criteria that a rigid body model check can, the next step is to move on to a FEA model to check the same things (plus stresses of metallic structures) with more precision.

Using analysis results to guide design changes

If a particular design did not pass all the criteria after running rigid body or FEA analysis. The results of the failed design can help determine what changes are necessary to improve the design. Some examples of corrective actions are listed below.

- If component stresses are too high: Try using a material with higher stress limits, strengthening the section, or changing the relative stiffness of different members in order to adjust how the loads are distributed.
- If mount strain is too high: Consider using a stiffer mount, using a larger mount, or changing relative stiffness or mount pattern in order to change the distribution of loads.
- If motion is too high at bellows: Consider using a stiffer mount, spreading out the mount pattern, putting the plane through the mounts closer to the CEM center of gravity, or putting the bellows closer to the CEM center of gravity.

3 CEM Vibration Acceptability Overview

CEM vibration capability is difficult to assess. When vibration isolation mounts are used and properly specified, it is understood that CEM vibration will likely be acceptable. In some cases, extensive vibration measurements may be required. Each of the scenarios discussed in this section will designate the need for vibration measurements.

3.1 Exhaust Flex pipe and CEM Vibration Design Considerations:

Each Installation may have an established choice for engine mounting. This design process may be iterative in order to satisfy both exhaust flex pipe and CEM vibration considerations. Both engine and CEM vibrations mounts must be concerned and check to make sure correct mounting is used.

3.2 Handling and Shipping

The Cat CEM unit will be packed in order to protect the assembly during shipping and delivery. Shipping plugs will be installed on all flange connections. The shipping covers MUST be removed before the unit is placed into service.

3.3 Lifting

For requirements Reference 3 – Mounting Considerations.

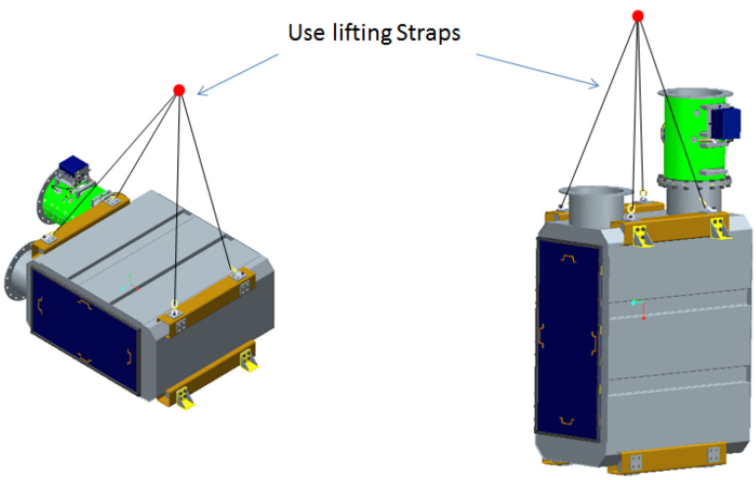
In addition to the above requirements, please note the g-load requirements for the following CEM families:

1. U and Z flow design CEM
    a. Fore/Aft – up to 1 G's
    b. Vertical – up to 1 G's
    c. Side to Side – up to 1 G's
2. Vertical CEM design:
    a. Fore/Aft – up to 1 G's
    b. Vertical – up to 1 G's
    c. Side to Side – up to 1 G's

> **Warning:** *Standing on top of the CEM and using the top of the CEM as work platform is strictly prohibited.*

When lifting the CEM four lifting links need to be used and bolted to the CEM assembly and lifted as illustrated below. Spreader bar is not be required if lifting straps are used, and if the straps are keep away from all sensors, wiring harness on the inlet/outlet spools and the CEM. When lifting the CEM into position care must be taken not to allow the CEM to set on the inlet or outlet spools. The outlet spool must be removed from the CEM when lifting and moving CEM. If a lift truck is being used to move or lift the CEM, the CEM must be on a pallet. As the forks of a lift truck could go through the skin of the CEM creating a hole that may not be repairable.

Figure V.3.3-1



Lifting Links are available to facilitate handling of Cat CEM units. Refer to appropriate Service Manual and OMM for lifting details.

Important: Lifting links are rated to support the weight of the Clean Emissions Module unit ONLY! Remove all lifting links after the CEM installation is completed!

> **Warning**: *Care must be used when lifting the CEM. Lifting at adverse angles to the lifting bracket may cause damage to the CEM and potential injury to the handler. Always lift in line with the bracket. Spreader bars are mandatory for lifting the CEM when inline lifting cannot be achieved with chains/strap.*

3.4 Vertical CEM

3.4.1 Guidelines for Lifting and Installation:

- Use all lifting lugs when lifting the CEM (Clean Emission Module) into place.
- Use all mounting feet when securing the CEM into its operating position.
- Make sure all ports; openings and connections are clear from obstruction.

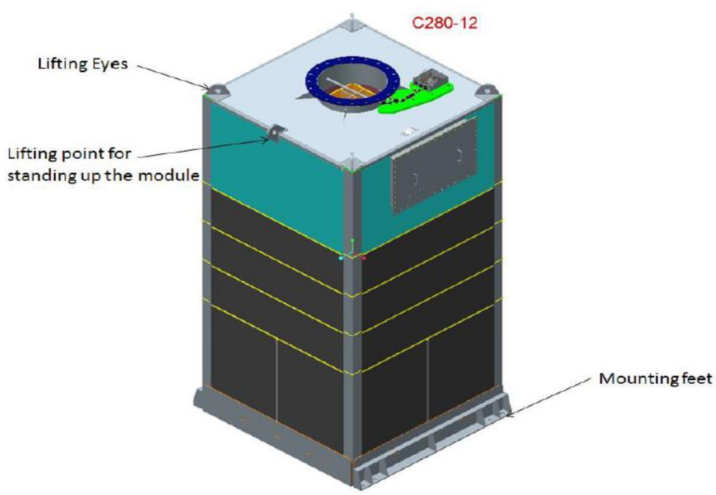
3.4.2 Lifting Instructions:

(1) The CEM will be delivered lying on its side in the horizontal position; the lifting eyes must be used to remove the CEM from the shipping pallet or the delivery truck.
(2) Use single center lifting eye as the main lifting point to raise the CEM from its side position to upright position. This will keep the bottom free to rotate. Use at least 2 or the lifting eyes with safety chains to help raise the CEM housing to an upright position.
(3) Rotate CEM into the upright position first.
(4) When lifting the CEM to the upright position make sure the bottom of the CEM is not pivoting on the inlet flange and inlet spool. The inlet spool will extend at least 165mm below the mounting feet.
(5) Set the CEM on the mounting feet when in upright position and not on inlet flange.
(6) Use all of the top Corner lifting eyes when lifting the CEM in the upright position.

Warning: *Failure to follow these instructions could result in accidents, potential injury and equipment damage.*

Note: Unit is shipped without the support brackets that hold block catalysts installed; these cassettes will need to be installed after the unit is installed in its permanent location.

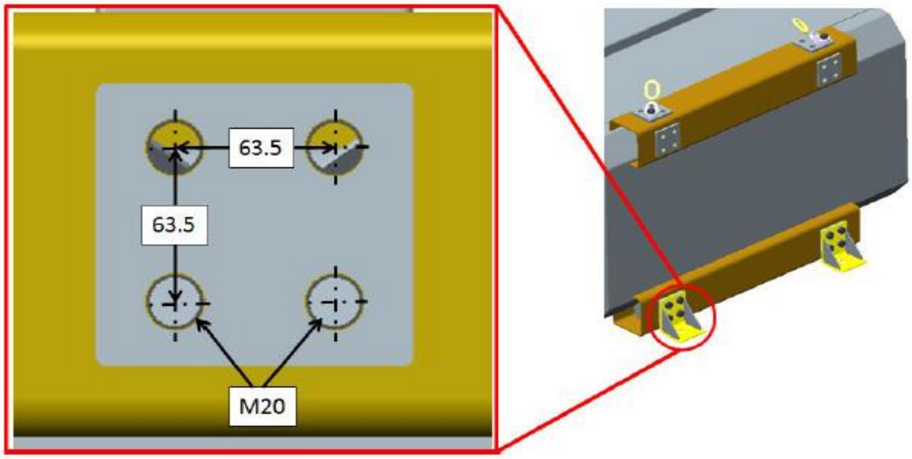
Figure V.3.4.2-1:



3.4.3 U and Z Flow CEM Mounting

The U and Z flow CEM provide 4 bolt pattern on each mounting pad. There are number of pad locations depending on which way the CEM is mounted in the vessel. Mounting requires the use of at least four mounting pads. The CEM's require four M 20 x 10.9 grade bolts per pad.

Figure V.3.4.3-1:



There are two types of CEM's which are based on the exhaust flow direction. One type is U-flow and another one is Z-flow. In U-flow configuration, both the inlet and outlet of exhaust gas are on same side of the CEM.

Whereas, in case of Z-flow configuration, the inlet and outlet of exhaust gas are on opposite sides of the CEM.

The mounting components should be able to meet the following requirements:

(1) Mount should be able to support the weight of the CEM
(2) It should be able to withstand the high temperature of exhaust gases, which could reach 550°C.
(3) It should be able to limit the stresses on bellows from displacement and thermal growth, which necessitates the fixed mount on the inlet side.
(4) There should be a flexible mount on the outlet side to take care of dynamic conditions and thermal expansion of the CEM.

3.4.4 Mounting Support

Caterpillar recommends using isolation mounts to mount the CEM to the support beams. Isolation mounts need to be able to sustain the thermal expansion, operating temperatures and dynamic loads from the CEM.

12, 16 and 20 Brick U Flow Mounting Configuration

3.4.5 Horizontal Mounting (Mounted on Floor)

The basic U-flow CEM mounting configuration is the horizontal mounting as shown below. The two mounting feet on inlet and outlet sides are fixed and that on the opposite side are allowed to move using flexible mounting.

Figure V.3.4.5-1: U-Flow Aftertreatment Mounted – Upside Down

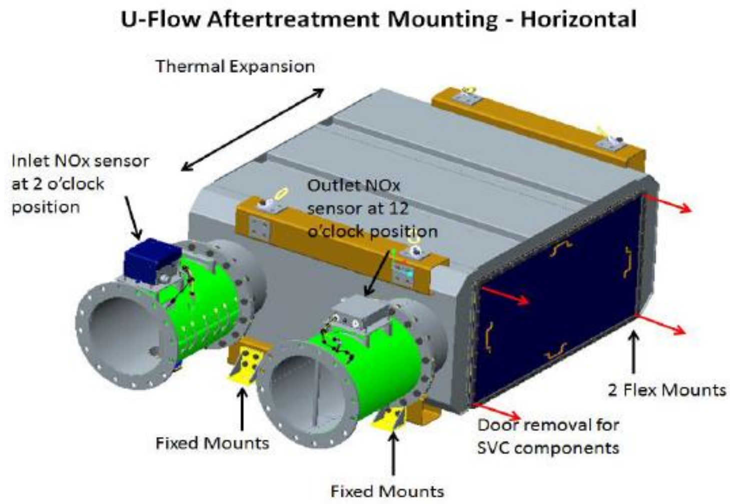
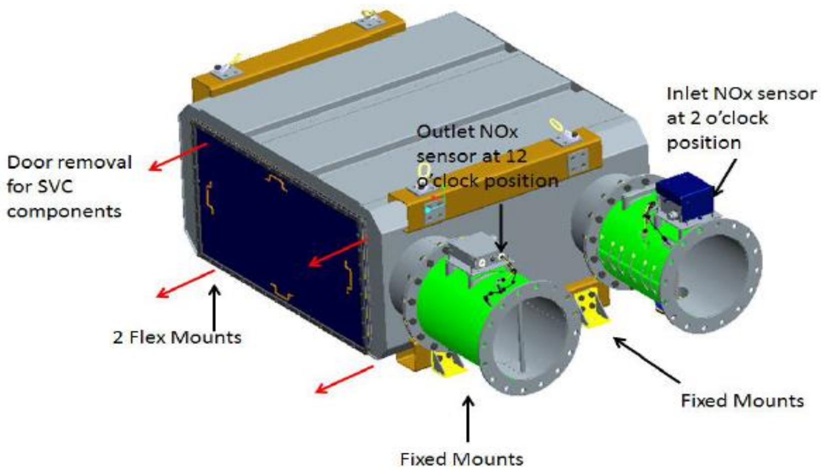


Figure V.3.4.5-2:

From factory change inlet and outlet spools rotation and move mounting feet to top brackets.

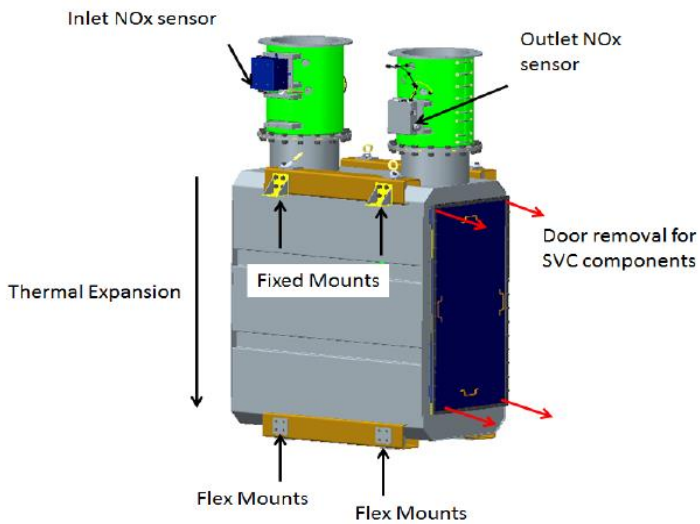


SVC=Service

3.4.6 Vertical Mounting (Vertical Flow)

The U-flow aftertreatment can be mounted on rear end with fixed mounting on the inlet and exhaust end and flex mounts on the rear end. This is a vertical exhaust flow system design. The mounting feet will have to be move to the inlet and outlet end and supported by a stand.

Figure V.3.4.6-1:



3.4.7 Side Vertical Mounting (Mounting on Floor)

The U-flow aftertreatment can be mounting on the side vertical with the fixed mounting brackets, on bottom front and rear as shown below. At least one set of flexible mounts shown be used on the top side of the CEM as shown below.

Figure V.3.4.7-1:

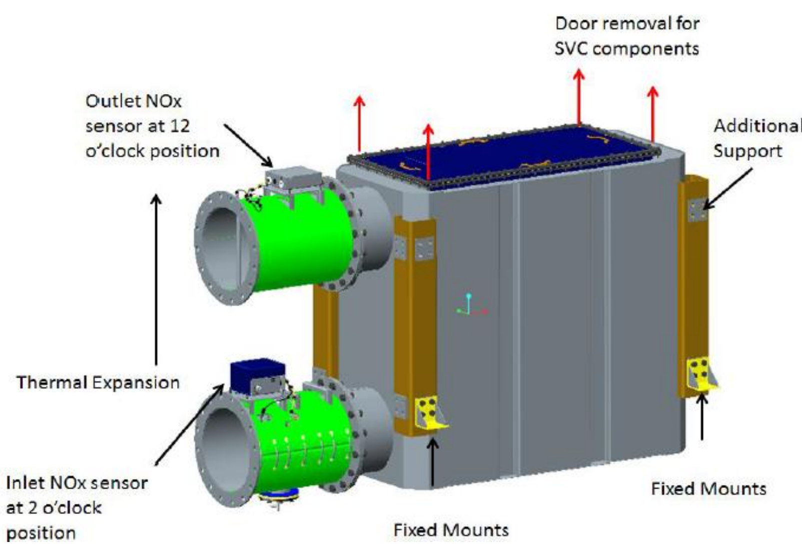
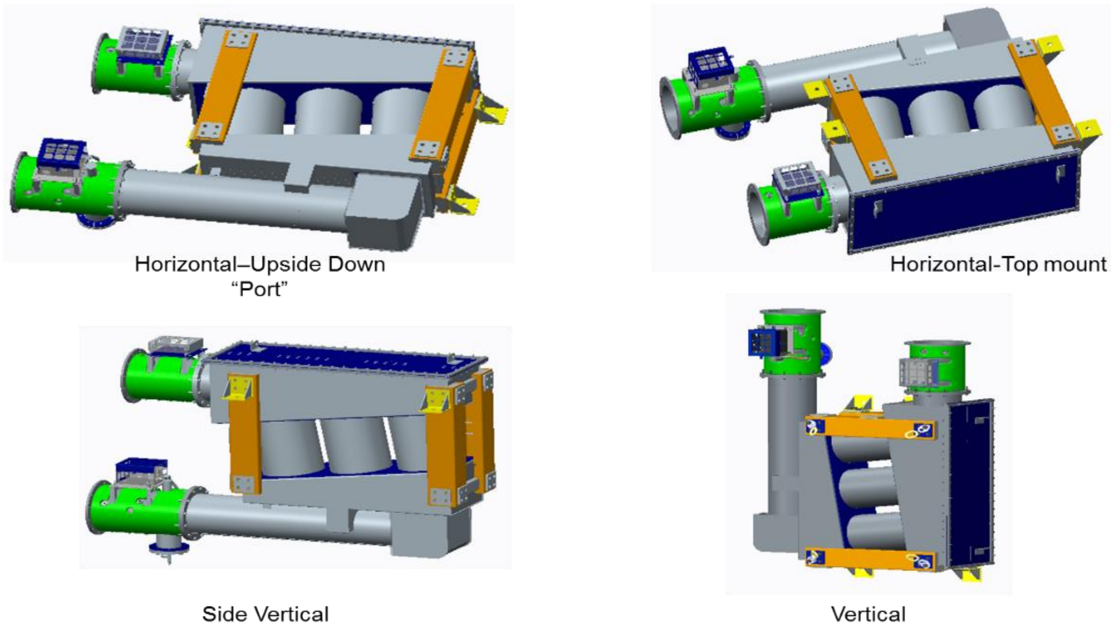


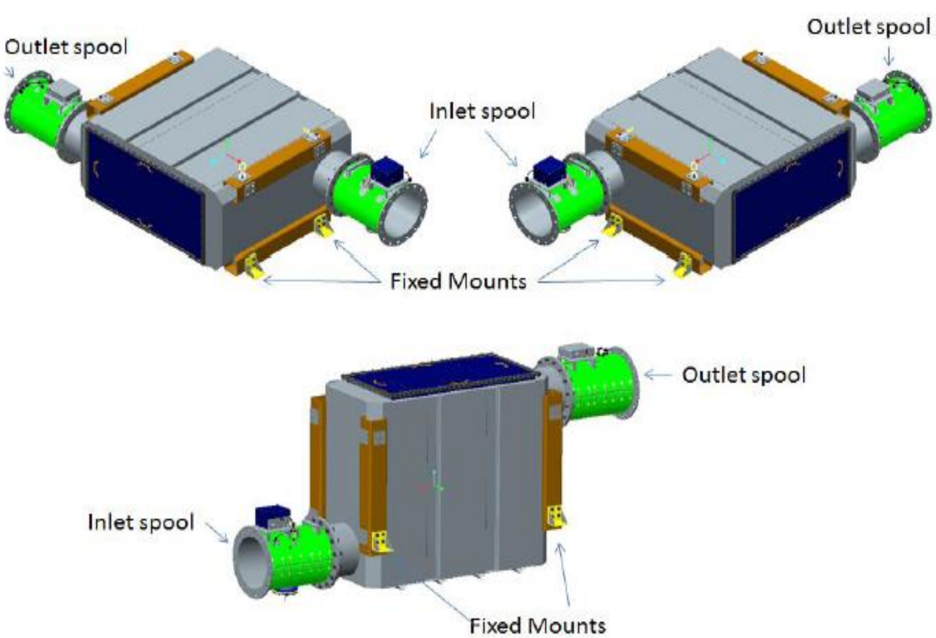
Figure V.3.4.7-2: Six brick U flow mounting positions:



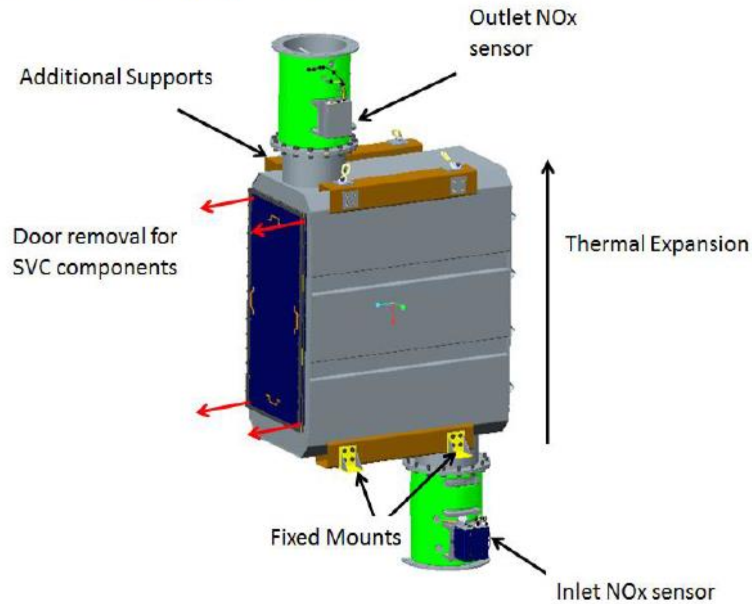
3.4.8. 12, 16 and 20 Brick Z Flow Mounting Configuration

Z Flow mounting has similar mounting requirements as U-Flow mounting, but the exhaust flow is from end to end instead of in and out at the same end. This difference should drive more consideration for exhaust interface and use of bellows to align engine exhaust to CEM. Refer to U-Flow fixed and flexed mounting. The vertical mounting will require additional capabilities for bellows movement.

Figure V.3.4.8-1



Z-Flow Aftertreatment Mounting Vertical

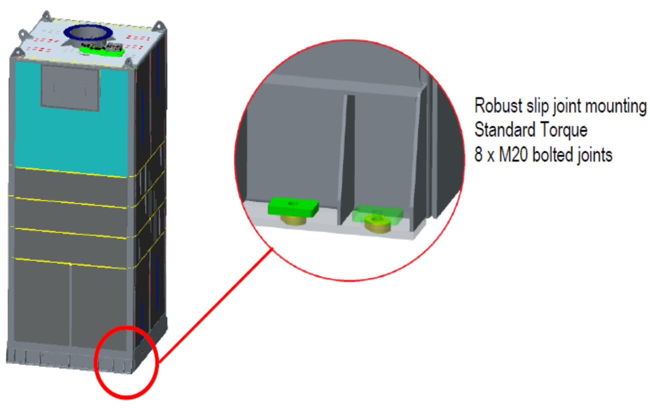


3.5 Vertical CEM Mounting

3.5.1. Mounting the SCR Reactor

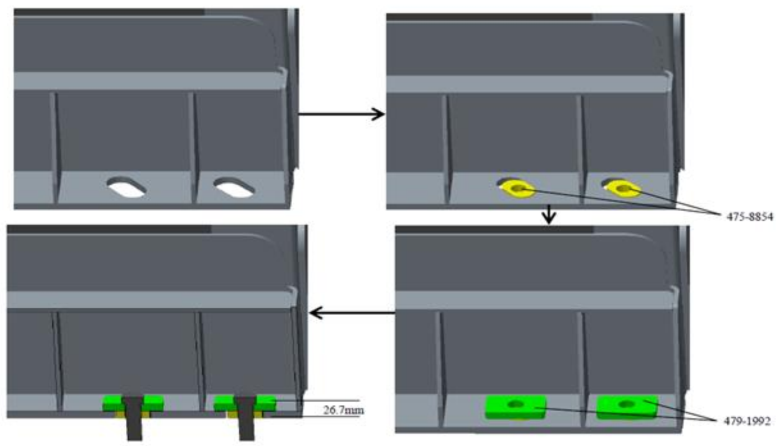
Bolt the SCR reactor to the support frame using the mounting plates on the base of the reactor unit. The elongated mounting holes are 22 x 44 mm and the holes run parallel to the short axis of the mounting bracket. The customer provided mounting platform that the unit rests on should have pre-fabricated 22 x 44 mm slotted holes running parallel to the long axis of the mounting bracket as shown below.

Figure V.3.5.1-1:



Mounting the CEM – Bolting Instructions

Mounting feet and brackets

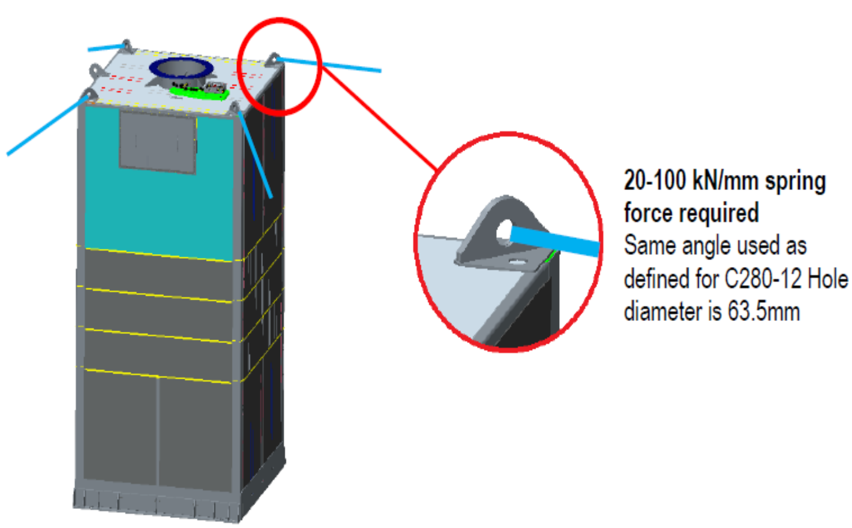


When the mounting feet are set on the mounting frame the slots will form a cross. This allows the unit to thermally expand sideways and long ways. Retainer plates should be used on the top of the mounting feet and a flat washer on the bottom side of the support frame when installing the CEM housing. The torque collar needs to rest on the supporting frame and inside the slots on the mounting feet of the housing. The threaded fastener holds the torque collar in place and will allow the unit expands by shifting around the torque collar. The torque collar dimensions are 15 mm thick, ID -17 mm, and OD- 30 mm. SAE grade eight (8) M 20 bolts are recommended and torque to 250 +/- 40N-m. Both top and bottom must be secured. Secure the top once the bottom has been bolted in place.

Note: It is mandatory that all mounting feet are contacting the mounting surface to distribute the load over the entire surface.

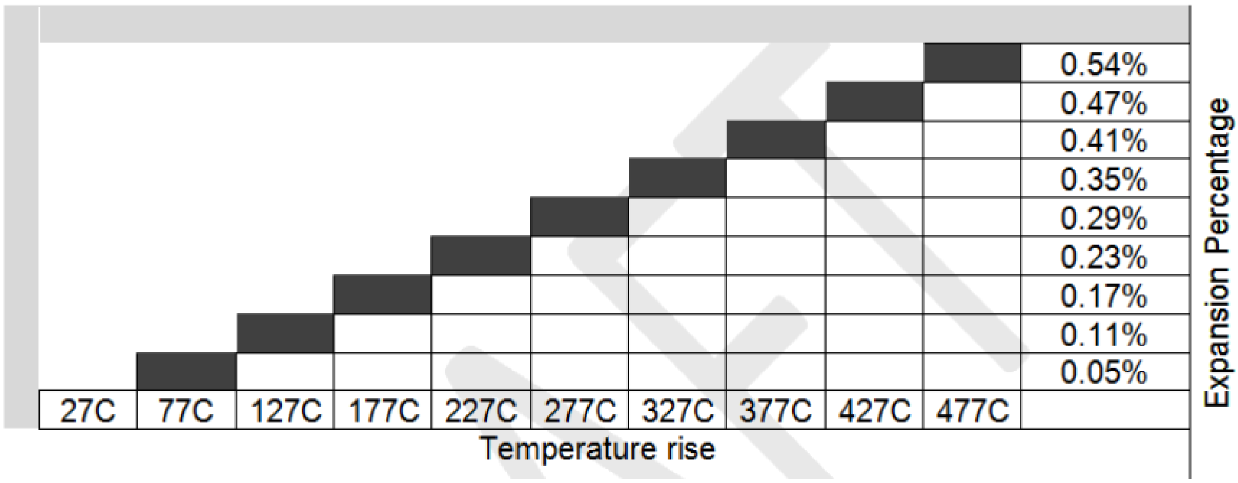
3.5.2 Top of Mounting of CEM

Figure V.3.5.2-1:



Use the lifting eyes on the top of the CEM to secure the top of the CEM. The mounting brackets should be oriented at 135 degrees to each side and align with the center of the CEM. A 20-100kn/MM spring tension of compression is required when the CEM is mounted in resting position and cold state. The top mounts must be able to resist a side load once one is applied. Make sure mounts can handle the thermal expansion as shown in the chart.

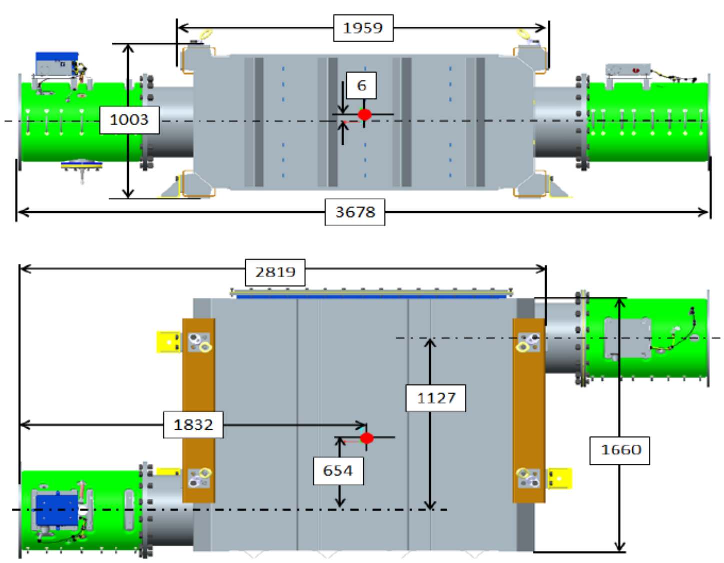
Table V.3.5.3-1



3.6 Installation Dimensions and General Views:

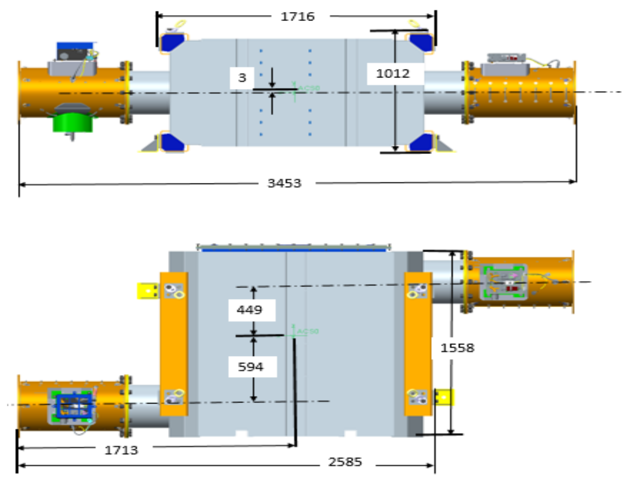
Refer to TMI data for weights of CEM. Please make sure you refer to the installation drawings for all mounting connection points. Numbers in this guide are only to be used as reference only.

Figure V.3.6-1: Center of Gravity Location: 16 brick Z flow CEM



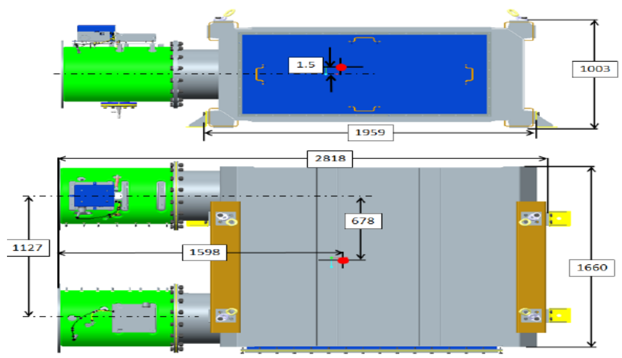
Mass of the Z flow is 1399 Kg. The catalysts are arranged in an 8 x2 stack design.

Figure V.3.6-2: Center of Gravity Location: Z flow 12 Brick design CEM



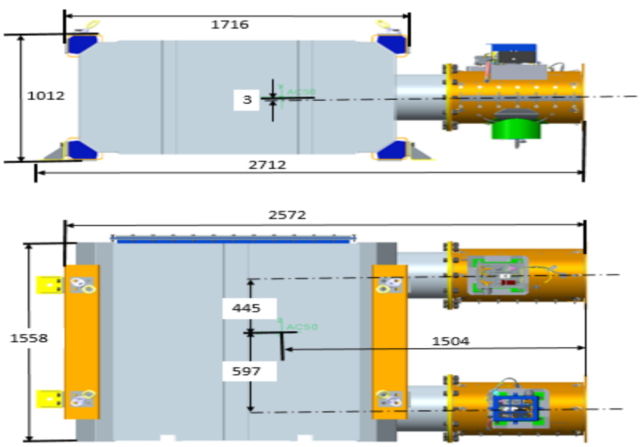
Mass of the Z flow is 1253.6 kg. The catalysts are arranged in a 6 x2 stack design

Figure V.3.6-3: Center of Gravity Location: U flow 16 brick design CEM



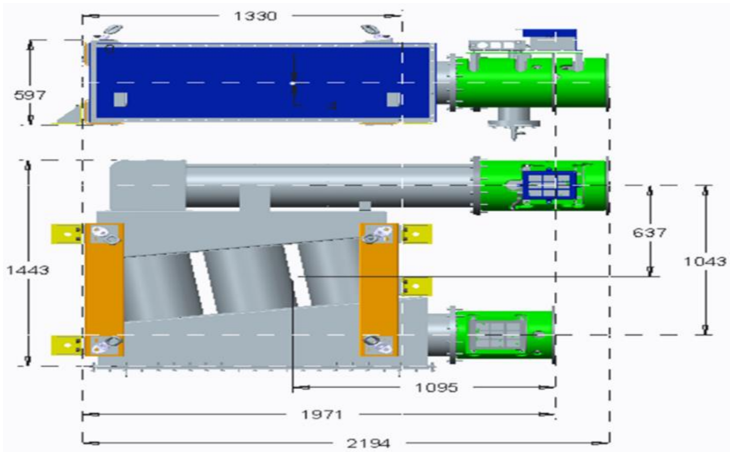
Mass of the U flow is 1390 kg. The catalysts are arranged in an 8 x2 stack design.

Figure V.3.6-4: Center of Gravity Location: U flow 12 brick design CEM



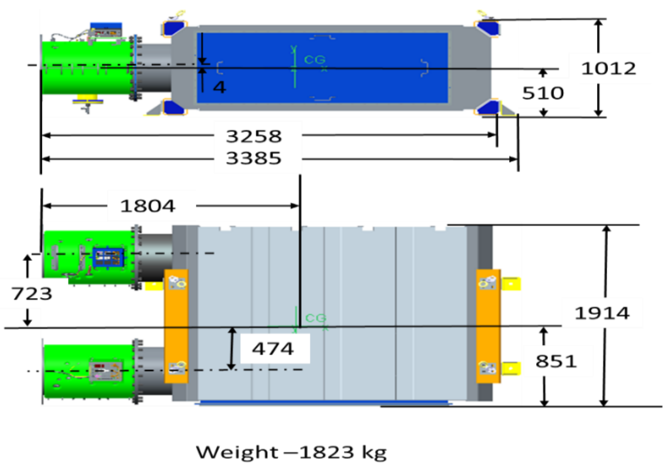
Mass of the U flow is 1261.5 kg. The catalysts are arranged in an 6 x2 stack design

Figure V.3.6-5: Center of Gravity Location: U flow 6 brick CEM



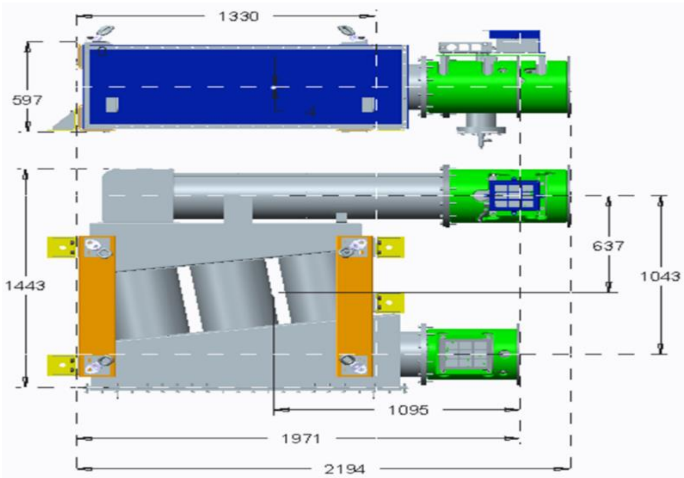
Mass of U flow is 498 kg the catalyst are arranged in a 3x2 stack design

Figure V.3.6-6: Center of Gravity Location: U flow 20 brick design CEM



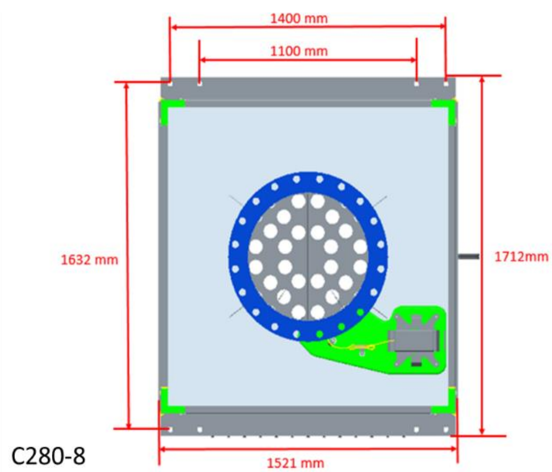
Mass of U flow is 1823 kg the catalyst are arranged in a 10x2 stack design

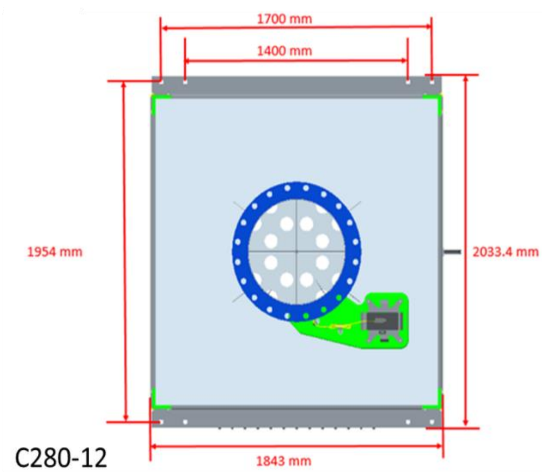
Figure V.3.6-6: Center of Gravity Location: U flow 6 brick design CEM

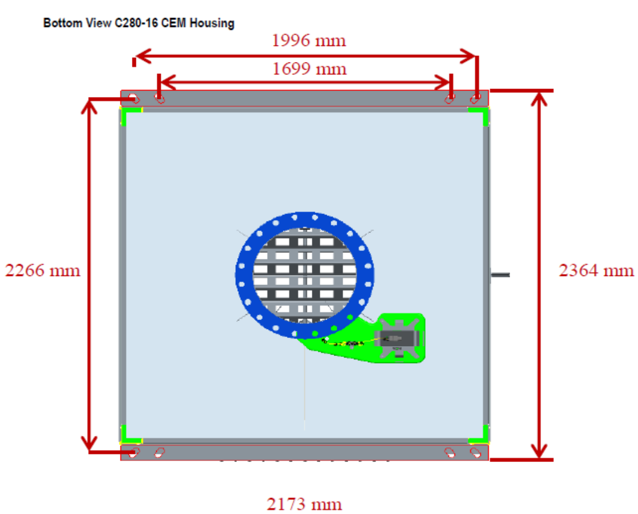


Mass of U flow is 498kg the catalyst are arranged in a 3x2 stack design

Figure V.3.6-7: Reference mounting feet dimensions for Vertical CEMs







VI. INITIAL STARTUP

See Appendix B: Initial Startup Procedures

VII. SERVICE AND MAINTENANCE

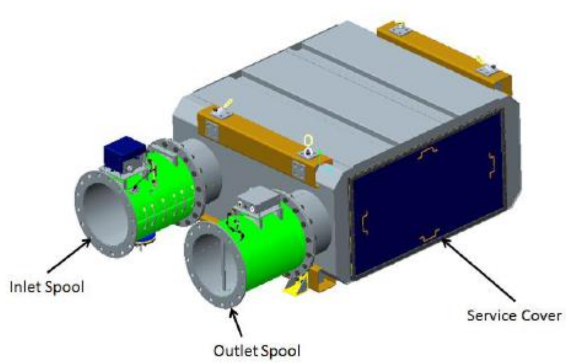
1 Catalyst Storage

The catalyst for the vertical C280 and MaK CEMs will be shipped on separate pallets from the factory. It is the responsibility of the builder to keep the correct pallets of the catalyst for each CEM housing separate and then install the catalyst as descripted in the installation procedures. Caterpillar requires the catalyst need to be stored indoors out of the weather until the catalyst are installed in the CEM. The shipping pallets that the catalyst are shipped in are not totally sealed so the pallets needs to be stored out of the weather. Rain water must not be allowed on the catalyst in any manner.

2 U and Z Flow SCR Access:

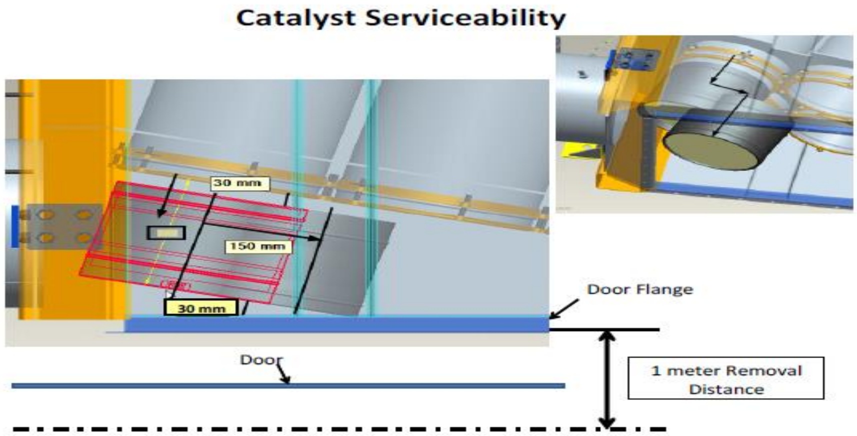
Access to the catalyst on the U and Z flow SCR units is through the service cover. The space claim needs to be considered when designing the CEM into a vessel. The ability to remove the service cover and the SCR catalyst is required. The minimum catalyst removal length is 450 mm which includes the handle and the catalyst. The handle is used for pulling the catalyst out of the CEM and the ability to carry the catalyst. The minimum length shown below is only needed on the service cover side of the CEM. The service cover is the only access point into the CEM besides the inlet and outlet ports. Refer to the Dis-Assemble and Assembly guide for complete instructions on how to remove the catalyst from the CEM.

Figure VII.2-1



Top figure above shows the inlet, outlet and the service cover for the catalyst. The figure below shows the required removal distance to pull the catalyst out of the CEM.

Figure VII.2-2



To service the catalyst the service cover needs to be removed. Then each catalyst can be removed with the service tool by removing the retention bolts and pulling the catalyst out. When replacing the catalyst all new retention hardware and gaskets will be required when installing the new catalyst.

Important Note: *Non-Caterpillar supplied SCR system components that are an integral part of the SCR system must meet the Tier 4 EPA requirements for maintenance and service intervals. The key criteria for meeting the regulation is that any regularly scheduled adjustment, replacement, cleaning or repair of components must be at a minimum of 4500 engine hours. Component life must meet 10,000 engine hours for 3500 and C175 engines and 20,000 hours for C280 engines.*

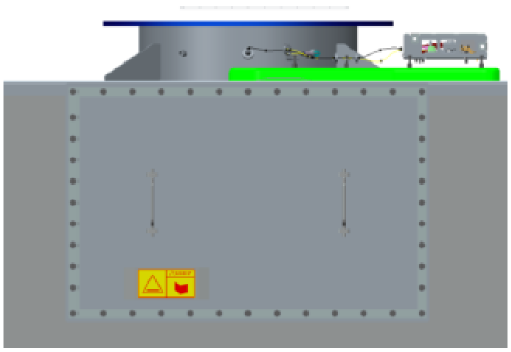
3 C280/MaK SCR Access:

Special Instructions
Access Service Cover Removal

To avoid injury when removing and installing, please use the mounting provision and use a hoist to lift the access door. The service door of the reactor housing weight is 24.1kg (53 lbs.).

It is recommended when using lifting hooks that the hooks be equipped with a spring latch to ensure the lifting hooks are positioned correctly. Ensure that the hoist, chains or slings and lifting hooks are in good working condition and can withstand the service cover weight.

Figure VII.3-1:



Reinstallation of the service cover:

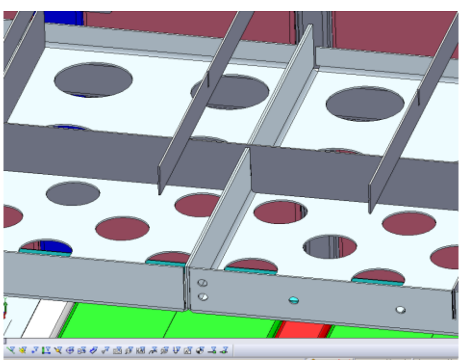
1. Align the cover, gasket and flange to the holes. These parts need to lay flat against one another with their holes lined up so the bolts can go straight in. Apply anti seize compound to all the threads to avoid thread galling.
2. The bolts must be hand-tightened to the point where the cover, gaskets and flange are held together. The bolts may need to be gently tapped through the holes before the parts are completely lined up.

4 C280 and MaK Vertical CEM designs

SCR Block Installation
Grid Installation

The grids that hold the cassette of the vertical design housing have to be installed after the housing in mounting in place in the vessel. The grids and cassette can be installed any time after the rest of the exhaust stack has been completed. Once the grids and the cassettes are install need to make sure no rain water and enter the top of the CEM housing. No extra sealing to going to be required around the grids and cassettes if installed correctly and all pins and T strips are installed as designed. No special tools are required to install the grids and cassettes in the CEM housing. After service cover is remove you will be able to see the diffuser pan.

Figure VII.4-1:



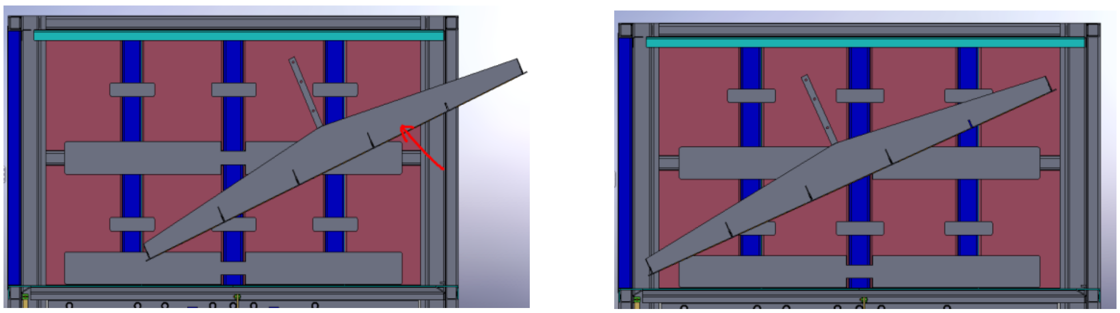
The bottom most part of the reactor has a diffuser pan, this pan which allows the exhaust to flow through while keeping the back pressure of the exhaust low.

This pan can be stood on to install the first grid layer.

5 Installing the grid

To install the grids easily, you will need at least 2/3 of the width of the CEM in front of the access cover to get the grids to slide into the CEM. The grids will be shipped on separate pallets. For the bottom most layer, bring 1 grid half in rotated as shown to fit in the door. The channel support on the ceiling can be used to hoist the grid into place. To make installation easier, the quarter inch “T” pinned anchors on the sides can be removed and re pinned after the grids are in place.

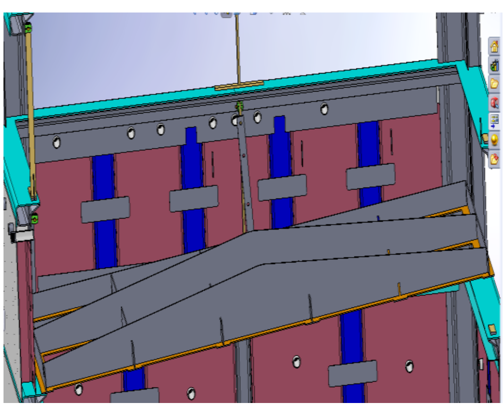
Figure VII.5-1:



Note: The vertical quarter inch beam with the 3 holes in it is located on the inner most triangular support on the grid. In the corresponding images it is shown located on the outside.

Lower the grid half into place by keeping it rotated as shown. Once the grid edge is resting on the bottom grid support ledge, push the grid edge into this corner and allow the grid to rotate until the other flat surface hits the other side of the ledge. Start from the back working your way out towards the cover opening.

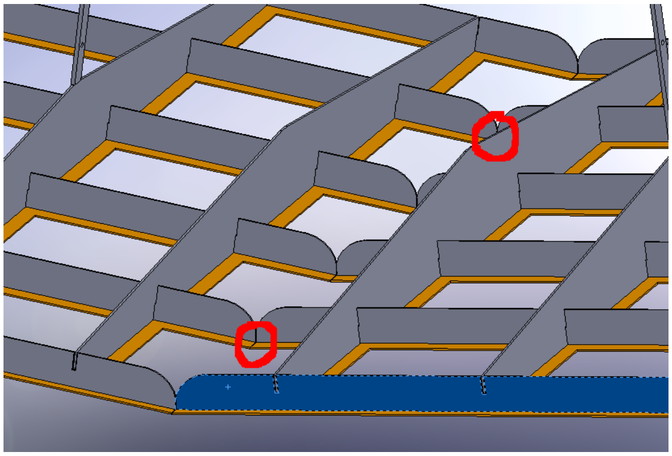
Figure VII.5-2:



With one grid in place, repeat the procedure to bring in a second grid half that has the corresponding number posted on its triangular beam section. Rotate the grid so that the slotted connections align. Use the clevis pins to join the two sections together. Remove any tape that remains on the grid halves.

A rubber mallet can be used to adjust the grids into place.

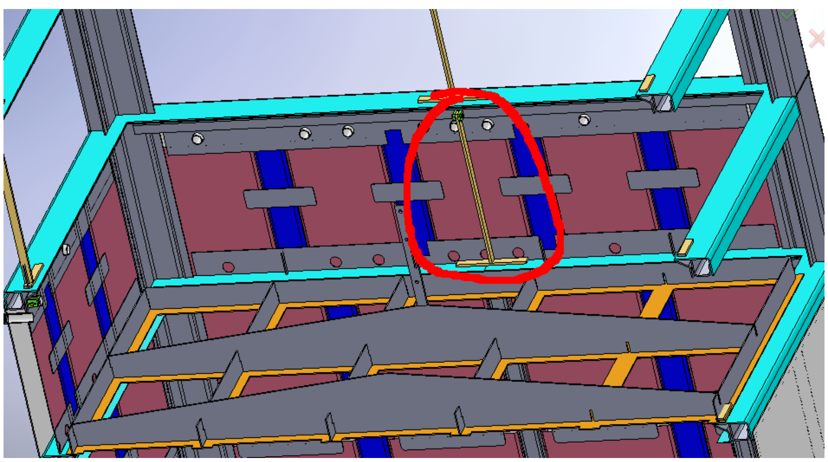
Figure VII.5-3:



Once the grids are in place, the T shaped anchors are pinned into place. Ensure that the lanyards remain looped through the T anchors.

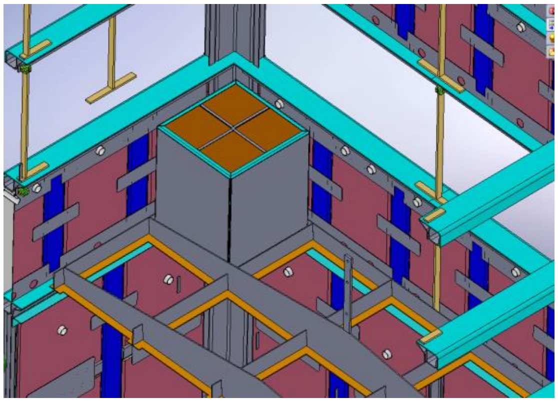
Pin all T anchors on all sides.

Figure VII.5-4:



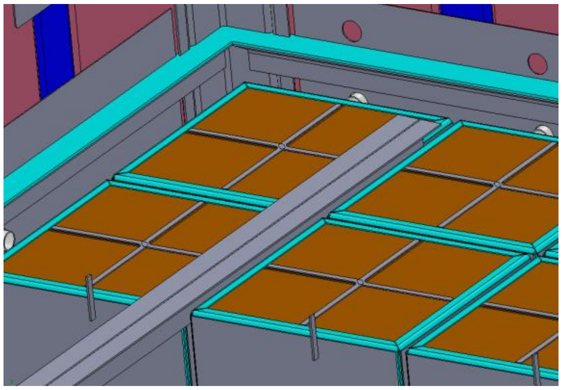
Once the grid is on the first ledge, with two pins secured beneath the grids and the T anchors installed, insert the first 4 bricks in each corner.

Figure VII.5-5:



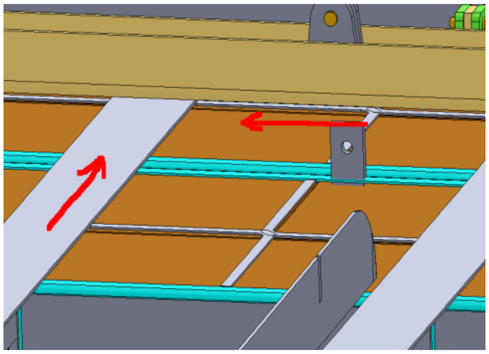
Install the 3 bricks on each side between the corners next. Once all bricks are installed around the perimeter, install the center bricks

Figure VII.5-6:



Install the T beams in one direction perpendicular to the vertical quarter inch holed connectors. The T beams are held in place by a U shaped channel that is pinned to these quarter inch holed bars.

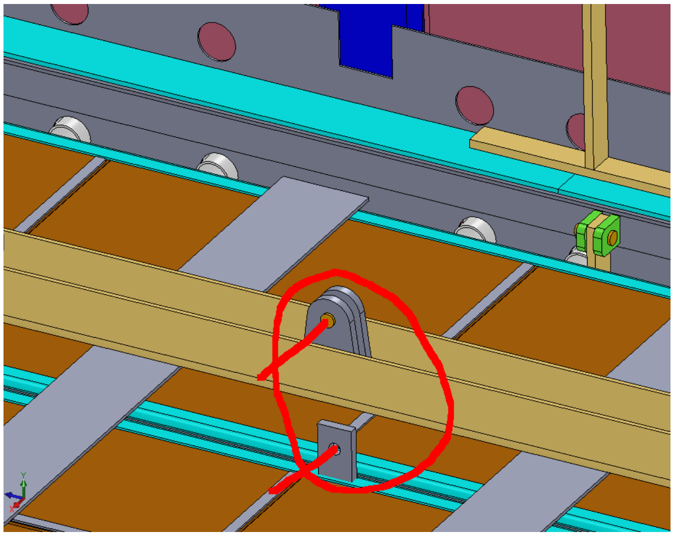
Figure VII.5-7:



Once all of the T beams are placed between the catalyst modules, install the U shaped bars across the top of the T beams on each side.

Insert the clevis pin into each slot on each side.

Figure VII.5-8:



Perform these steps for each of the 4 layers on the reactor.

VIII. EXHAUST SYSTEM

1 Introduction

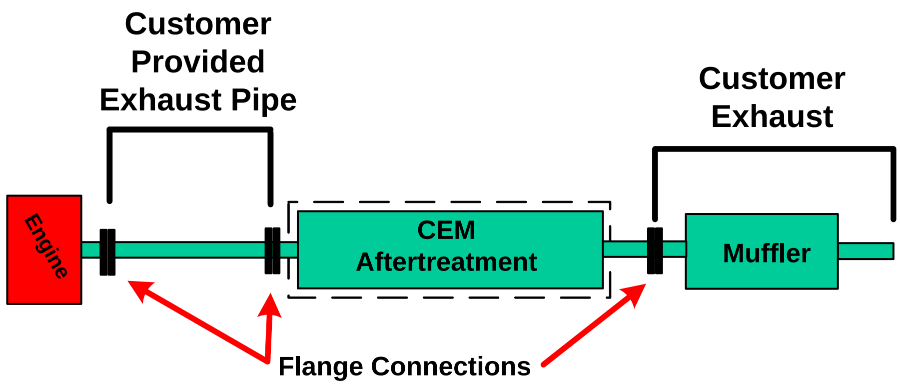
The engine Exhaust System discussed in this section consists of the interface of the turbo exhaust gases to the Cat CEM. This includes Cat Bellows Assembly or flexpipe assembly, Cat CEM or aftertreatment and muffler or exhaust pipe.

Cat CEM exhaust gas inlet receives the engine exhaust gas through flex coupling joints allowing for misalignment that may occur from the many installation arrangements of the Cat CEM. Caterpillar recommends the combination of bellows, ball and slip joints. Particular attention must be taken to ensure proper design and placement of the Cat CEM to maintain alignment with the engine exhaust and stay within the vibration and industry standard leak tight connection requirements.

The engine and aftertreatment should be considered as a system. The mounts for the engine limit pitch and roll and therefore reduce the requirement on the bellows assembly. Refer to Engine A&I guide for information on Engine Mounts.

2 Exhaust System Overview

Figure VIII 2-1: Exhaust System Example



3 Mandatory Requirements:

- Flexpipe Design
- OEM Supplied Exhaust Pipe Requirements
  - Pipe Size
  - Pipe Material
  - Backpressure Apportionment
  - Exhaust Gas Temperature Loss Through Exhaust Pipe
  - Water Ingress Prevention
  - Bellows

3.1 Flexpipe Design

Each application requires understanding of the installation requirements for proper location of the Cat CEM relative to the engine exhaust. The actual flexpipe (bellows) will account for movement during engine operation. The following application parameters should be considered before selection of flexible joint that accommodates the application needs:

- Tolerance Stack-Up (static)
- Worst Case Engine Operation/Duty Cycle
- Vibratory- High cycle low displacement
- Thermal Growth
- Shock Loading- Low cycle high displacement
- Temperature
- Pressure

3.1.1 Flange-pipe Design Requirements (Vee Engines – 3500, C175):

The Vee Engine design requirements are included in the following sections where appropriate when interfacing with a flange-pipe connection.

Note: Additional general guidelines for Exhaust Systems A&I is available in Media Number LEBW4970 "Exhaust Systems".

3.1.2 Engine Exhaust Flange Loading

Careful consideration must be given to the load be applied by any external piping, that may induce on the exhaust flange. To minimize the load carried by the flange, downstream exhaust piping must be self-supporting. The thermal growth of horizontal piping connections to the flange must also be accounted for in the design of the complete exhaust system.

Maximum allowable vertical load and bending moment limits are provided for each engine model. Consult the Technical Marketing Information (TMI) for the appropriate information or your local Caterpillar Dealer.

3.1.3 Flexible Joints

Flexible joints are needed to isolate engine movement, vibrations, and Marine Vessels frame deflection. Bellows take up dynamic axial and lateral movement. Ball joints compensate for radial misalignment. Slip joints compensate for axial misalignment. Additionally they are needed to offset assembly tolerances and thermal expansion and contraction of the main exhaust. Great care should be taken to ensure that these factors are accounted for in the design and development of the flexible sections of these systems.

From its cold state, 304L Stainless Steel will expand 0.3mm (.0119in) per 305mm (1ft) per 50° C (122°F) temperature rise. If not accounted for, the thermal growth can exert undue stress on the engine and Cat CEM connections, as well as the pipe supports. See the Allowable Joint Loading section for specific requirements

The Cat CEM exhaust outlet piping with additional components such as exhaust temperature cooling devices, exhaust stacks and long lengths of unsupported pipe should be designed and reviewed per Caterpillar, OEM and installer agreement. All installation requirements per this A&I guide must be complied with per agreement outlined in the introduction of this document.

It is important that the flexible sections continue to meet the pressure drop and leakage specs throughout the life of the installation in order to ensure compliance with emissions regulations. A robust flexible joint will accommodate all the various movements of these routings through the many thermal, vibration and loading cycles experienced by the application.

Proper assembly of the flange is necessary to form a strong seal that provides a leak tight joint.

4.2 OEM Supplied Exhaust Pipe Requirements

4.2.1 Pipe Material

Material
The material selection is an important part of ensuring that the system will continue to perform over the life of the Marine Vessel. Traditional steel and aluminized steel, have lower thermal stability and corrosion resistances than higher-grade stainless materials. 300 series stainless steel material is recommend to be used for OEM supplied exhaust pipe between the AUS/DEF injector and CEM inlet. CEM and turbo connections are ductile iron and have similar thermal expansion coefficients as the 304SST.

Recommend: OEM Pipe Material: 304 Low carbon Stainless Steel (SAE30304L)

4.2.2 Exhaust Backpressure

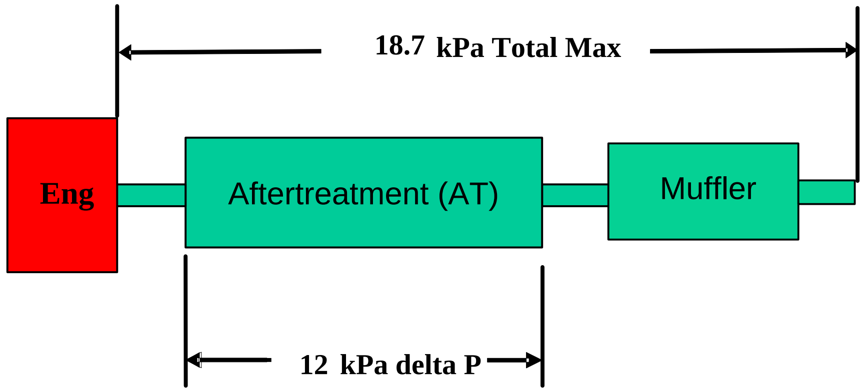
Exhaust System Apportionment

Commercial Engines
If apportioned exhaust backpressure is higher than specified in table below it could result in poor engine performance. Refer to Caterpillar Dealer who can look at TMI for maximum backpressure per engine rating.

Table VIII.4.2.2-1: Commercial System Backpressure

Engine	Apportioned Max Press Drop
	KPA
C32, C175/3500	6.7
C280	2.5

Figure VIII.4.2.2-1: Exhaust System Example for Cat Aftertreatment



Example of Apportioned Pressure Drop Calculation: (Reference figure and table above)

OEM/Installer (kPa) = Total Backpressure (kPa) – Cat CEM (kPa)

OEM/Installer (kPa) = 18.7 – 12 = 6.7

Where:

Total Backpressure = 18.7 kPa

Cat CEM = 12 kPa

4.2.3 Calculating Exhaust Restrictions

Estimation of the OEM piping backpressure can be done with this formula:

$$\frac{.22 L_{eq} Q^2}{(460 + T) D^5}$$

P = Pressure drop (backpressure) measured in inches of water.

L = Total equivalent length of pipe in feet.

Q = Exhaust gas flow in cubic feet per minute at rated conditions

D = Inside diameter of pipe in inches.

T = Exhaust temperature in °F.

Table VIII.4.2.3: Pipe Diameter D5 Calculations

Nom Pipe Dia. (in.)	Actual ID (in.)*	D^5 ($in.^5$)
5	4.87	2740
6	5.87	6970
8	7.87	30192
10	9.87	93671
14	13.87	513328
21	20.87	3959319

*Based on a tube width of 1.65mm. Calculation will vary if thickness is different, such as 1.8mm.

To determine values of straight pipe equivalent length for smooth elbows use:

Standard 90° elbow = 33 x pipe diameter

Long sweep 90° elbow = 20 x pipe diameter

Standard 45° elbow = 15 x pipe diameter

To determine values of straight pipe equivalent length for flexible tubing use:

L = Lf x 2

Important considerations:

- Sharp bends in the exhaust system will significantly increase exhaust backpressure. The piping size decision assumes a minimum number of short radius bends. If a number of sharp bends are required, it may be necessary to increase the exhaust pipe diameter. Since restriction varies inversely with the fifth power of the pipe diameter, a small increase in pipe size can cause an appreciable reduction in exhaust pressure.
- It is essential that the system does not impose more than the allowable maximum backpressure. The maximum backpressure must not exceed the limit while certifying each engine model for conformity to exhaust smoke and exhaust gas emissions under Federal, California, and other agency regulations. To avoid this problem, exhaust system backpressure should be calculated before finalizing the design. Testing should be done to validate design is compliant with A&I requirements.
- Exhaust piping is a critical component in the Cat CEM operation required to meet emission standards. Care should be exercised in configuring and designing the exhaust piping to meet packaging and exhaust component load and operational limits.
- OEM pipe diameter has a significant impact on the pressure drop through the system. The engine and Cat CEM connections have been configured for the

recommended pipe diameter in order to meet the pressure drop requirements.

4.2.4 Exhaust Temperature Loss

Exhaust Temperature

<u>Introduction</u>

The Cat CEM relies on a minimum average exhaust temperature during operation to provide the necessary emissions reduction. Controlling the temperature loss through the exhaust pipe, from the turbo outlet to the CEM inlet is required. Maintaining the temperature drop is the one way Caterpillar knows that the catalyst will see the correct exhaust temperature. Do to the different vessel installations and exhaust pipe routing, Caterpillar is not providing any insulation for the exhaust pipe and around the CEM. It is the responsibility of the vessel designer and builders to provide proper insulation to meet the temperature drop requirements listed below. Due to the high exhaust temperature inside the CEM consideration must be taken to make sure not one touches the CEM while the engines are running, or the CEM should be insulated to reduce the temperature surface temperature on the CEM. Insulation the CEM will only help make sure the catalyst are see the correct temperature. When wrapping the CEM care must be take not to cover the sensors with the exhaust wrapping. The Sensor and wiring have to be on the outside of all exhaust insulation. The sensors all have temperature limits and wrapping the exhaust piping and CEM helps in keeping the sensors below the temperature limits.

<u>Exhaust temperature loss requirement</u>

The acceptable exhaust temperature loss through the exhaust pipe is shown below in the table. This temperature drop is from engine outlet to CEM inlet.

Table VIII.4.2.4-1: Allowable temperature loss from turbo to CEM

Engine Platform	SCR	
	10% Rated Engine Load	
	Max Allowable Temp Drop (deg C)	Allowable Engine RPM during test
3500	10	Rated Speed
C175		
C280	30	

4.2.5 Joint Loading & Supports

Loading

Flange load limit, CEM connection flange load limit for either end of the exhaust pipe connection has a maximum allowable load limit. This load is a function of the material and geometry of the flange exhaust outlet and the CEM exhaust inlet.

The flexible joint should typically be positioned to minimize cantilever type loads to the turbo exhaust outlet connection.

The following table provides guidelines for Dynamic loading of the connection interface at the engine turbo exhaust and Cat CEM inlet and outlet. All reference to turbo outlet load must be verified with TMI load requirements for the engine of your application.

Table VIII 4.2.5-1: Exhaust Joint Loading Table Guidelines

Exhaust Component Connection	Maximum Allowable Dynamic load
CEM Inlet on U/Z	**800 N-m**
CEM Outlet U/Z	**350 N-m**

<u>Determining Allowable Joint Loading</u>

Joint loading is complicated by several factors that fall within OEM design control. Application installation design should be designed to protect the Cat CEM devices from dynamic loading in addition to the resonance concerns that would cause system overload.

- Exhaust pipe Supports
  - Support Locations
  - Type of exhaust support
- Pipe Considerations from closest support to Cat CEM connection points
  - Weight
  - Length
- Center of Gravity (CG)
- Location of Flex Joint

The allowable joint load should be evaluated using dynamic load. The dynamic load is the combination of factors including weight, length of pipe, center of gravity and maximum acceleration rate. Maximum acceleration rate is typically the maximum anticipated G-load. As a reference point, 5 G is often used in cases where the maximum dynamic load is not well known.

CEM or Turbo flange loading will be calculated one of two ways depending upon how the exhaust pipe is supported.

<u>Method #1: Simple Cantilever Loading:</u>

If the pipe is simply connected to the:

- Inlet or Outlet (CEM or Turbo connection)
- To the flex joint

Without any other support points, then this method can be used to determine the

Estimated loading:

$M = maL$

Where:

M = Dynamic load in Newton-Meter (pound-foot), N-m (lb-ft)

m = Mass of the pipe supported by the joint in kilogram (pound), kg (lb)

a = Acceleration, maximum amplitude of the CG location of the supported pipe in meters/second squared (feet/second squared), m/s2 (ft/s2)

L = Distance from the CG of the supported pipe to the Cat CEM joint in meter (feet), m (ft)

Method #2: Supported Exhaust Pipes:

If the pipe is connected to the:

- CEM Inlet or Turbo Outlet connection
- Flex joint
- And is supported in some way off of the engine or CEM or it's mounting structure

This alternative method must be used to evaluate the flange loading.

Some form of rigid support is recommended on both sides of the flexible joint to

prevent joint failure at the CEM or engine.

- If supporting between the bellows and engine the support structure should be mounted on the engine.
- If supporting between bellows and aftertreatment system the support structure should be mounted from the aftertreatment system.
- This will insure the bellows functionality and not induce undue stress in the flexpipe system components.

It is critical that exhaust pipe support be done in such a way that thermal growth of the exhaust pipe does not result in loading either the turbo exhaust outlet or the CEM inlet. This may mean that the pipe may need to be supported for typical static weight and G-loading. While also allowing movement, so the exhausting pipe thermal growth is taken up the flex joint, rather than exerting a force on the turbo exhaust outlet or the CEM inlet.

Allowable loads must not be exceeded when designing the flexpipe interface connections.

A tri-axial mounting support is recommended within 915 mm (3 ft) of the Cat connections. A tri-axial support provides support to the X-Axis, Y-Axis, and Z-Axis planes.

The flexible joints that isolate the CEM from the engine vibrations should be positioned to prevent cantilever arm type loads to the CEM connections. Cantilever arm type loads due to pipe weight can easily create vibration/resonance that can overload the connection on the CEM causing a joint failure.

Method #3

The force method is another way to determine if you are exceeding the limits on the turbo and CEM inlets and outlets.

Figure VIII.4.2.5-1:

The external pipe and flanges can be replaced by a combination of a force, **F**, and moment, **M**. The values of **F** and **M** can be obtained using the following expressions:

$$F = W_{pe}L + 2W_{fl}$$

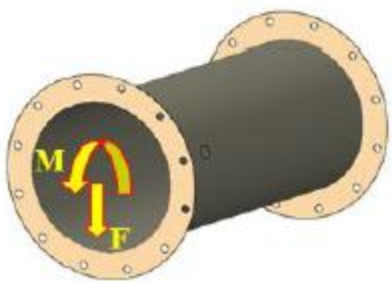
$$M = \frac{W_{pe}L^2}{2} + W_{fl}\left(\frac{t_{fl}}{2} + L\right)$$

where L = Pipe Length

W_{pe} = Weight per unit length of pipe

W_{fl} = Flange weight

t_{fl} = Flange thickness



Refer to the Exhaust Joint Loading Table above for the maximum allowable dynamic load for each specific joint connection.

4.2.6 Water Ingress Prevention

Moisture Limits

<u>Introduction</u>

The presence of water in the CEM can cause failures such as cracking of catalyst from freeze/thaw cycles, cracking of catalyst by water causing thermal gradients across the catalyst. Exhaust system outlets must be provided with an appropriate means of preventing snow, rainwater or sea spray from entering the CEM through the exhaust piping. This can be accomplished by several methods, but must be given careful consideration. The selected method can impose significant restrictions that must be taken into account when calculating system backpressure.

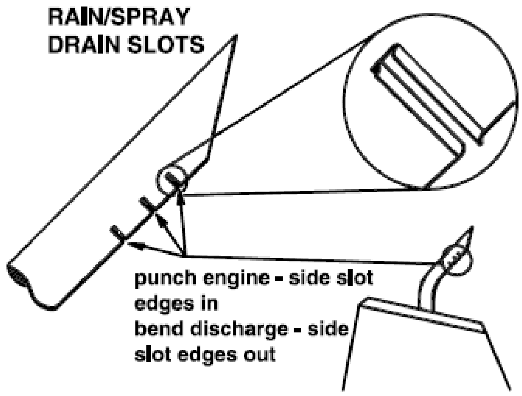
For engine applications with >750 HP/560 KW ratings the maximum water ingress is 1 Liter at maximum 5 degree angle.

One simple method, used primarily with horizontal exhaust pipes, is to angle cut the end of the exhaust pipe with the point at the top.

A common method used with vertical exhaust pipes is to angle the pipe at 45 or 90° from vertical using an appropriate elbow, then angle cutting the pipe end as previously described.

Another feature that may be used in conjunction with either of the above methods is Rain/Spray Slots as shown in figure below.

Figure VIII.4.2.6 – Rain/Spray Drain Slots



Slots are cut into the exhaust pipe to allow rain/spray to drain harmlessly. The edges of each slot are deformed as shown in the previous graphic. The engine side of the slot is bent inward and the downstream side of the slot is bent outward. No more than a 60° arc of the pipe circumference should be slotted in this way.

For applications where none of the above methods are possible, it may be necessary to fit some form of rain cap to the end of the vertical pipe section. This method can provide a positive means of water ingress prevention, but not without imposing a significant backpressure restriction.

4.2.7 Sampling Port

In accordance with MEPC 103.49 requirements (On-board NO_x Verification Procedure – Direct Measurement and Monitoring Method) the exhaust system must provide a sampling port located downstream of the last exhaust treatment system to measure gaseous emissions. Please refer to regulations on type and correct location for the sample port. A copy of the requirement is stated below.

The sampling probes for the gaseous emissions shall be fitted at least 0.5m or 3 times the diameter of the exhaust pipe – whichever is the larger - upstream of the exit of the exhaust gas system, as far as practicable, but sufficiently close to the engine so as to ensure an exhaust gas temperature of at least 343K 570°C at the probe.

In the case of a multi-cylinder engine with a branched exhaust manifold, the inlet of the probe shall be located sufficiently far downstream so as ensure that the sample is representative of the average exhaust emission from all cylinders. In multi-cylinder engines having distinct groups of manifolds, such as in a "Vee" engine configuration, it is permissible to acquire a sample form each group individually and calculate an average exhaust emission. Other methods which have been shown to correlate with the above methods may be used. For exhaust emission calculation, the total exhaust mass flow must be used.

If the composition of the exhaust gas influenced by any exhaust after-treatment system, the exhaust sample must be taken downstream of this device.

4.2.8 Exhaust System Verification

Verification Introduction

The exhaust system must be designed to be leak tight and comply with the minimum EPA useful life requirements. During the useful life, the piping cannot contribute to plugging, abrasion, exhaust gas leakage, or other damage to Cat CEM.

To ensure proper operation of the engine / Cat CEM package during the life of the engine, care must be taken to ensure these systems are constructed of proper materials with reliable joints, flexible sections, and mountings. Exhaust piping must provide for movement and thermal expansion to ensure undue stresses are not imposed on Cat CEM components or engine connections.

General Requirements Summary

Attention should be given to exhaust gas flow restriction with the following recommendations:

- The exhaust backpressure must not exceed the limits given for each engine family and Cat CEM installation. Reference TMI System Data or Engine Sales Manual for Commercial applications and Engine Technical Specifications.
- The exhaust piping must allow for movement and thermal expansion so that undue stresses are not imposed on the turbocharger structure or exhaust manifold.
- Never allow the turbocharger to support more than allowable loads. Reference TMI System Data or Engine Sales Manual for Commercial applications and Engine Technical Specifications.
- Allowable Distance from Turbocharger to Cat CEM is restricted by the maximum backpressure and maximum length for engine application.

To determine values of straight pipe equivalent length for smooth elbows use:

Standard 90° elbow = 33 x pipe diameter

Long sweep 90° elbow = 20 x pipe diameter

Standard 45° elbow = 15 x pipe diameter

4.2.9 Backpressure Verification

Excessive pressure drop (backpressure) in the exhaust will adversely affect the performance of the engine and the Cat CEM system. It is required that the systems meet these criteria for optimal performance. Excessive pressure drops can yield higher than expected exhaust temperatures, lower fuel economy, reduced altitude capability, and less than rated power. The maximum pressure drop for the systems is shown in the backpressure Table VIII.4.2.2-1 – Commercial System Backpressure Table.

Measuring Backpressure:

Exhaust backpressure is measured as the engine is operating under full rated load and speed conditions (High Idle for Naturally Aspirated engines). Either a water manometer or a gauge measuring inches of water may be used. Refer to Fig. VIII.4.2.9-1 or Fig. VIII.4.2.9-2.

Figure VIII.4.2.9-1: Manometer used to Measure Exhaust Backpressure

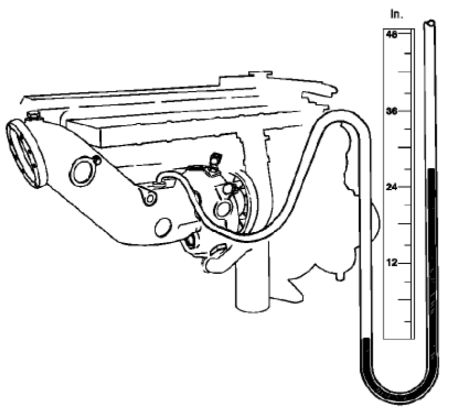
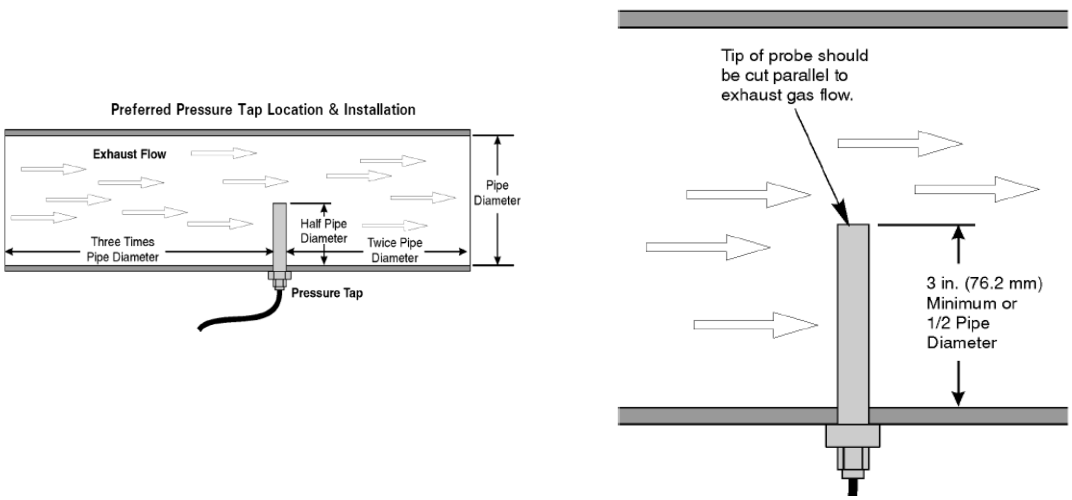


Figure VIII.4.2.9-2: Exhaust Backpressure Sensor Recommended Location



Pressure Drop Measurement (testing procedure)

Exhaust system pressure drop is measured while the engine is operating at rated speed and full load conditions (refer to the Engine Data Sheet for rated RPM and load conditions). Either a water manometer or a pressure gauge can be used. If not equipped, install two pressure taps on a straight length of exhaust pipe. The first tap should be located as close as possible to the beginning of the pipe section, but at least 12 in. downstream of a bend. The second tap should be located just before the end of the pipe section. If an uninterrupted straight length of at least 18 in. is not available (12 in. preceding and 6 in. following the tap), locate the probe as close as possible to the neutral axis of the exhaust gas flow.

For example, a measurement taken on the outside of a 90° bend at the pipe surface will be higher than a similar measurement taken on the inside of the pipe bend. A 1/8 NPT half coupling can be welded or brazed to the exhaust pipe to create a pressure tap. After the coupling is attached, drill a 3-mm (1/8 in) diameter hole through the exhaust pipe wall. If possible, remove burrs on the inside of the pipe so the gas flow is not disturbed. The gauge or gauge hose can then be attached to the half coupling.

This procedure can be repeated for each pipe section. (Reference SEBD6729 for additional information.)

Information that can be used for CFD analysis of the exhaust piping systems is contained in the engine data sheet for the engine rating that the exhaust is being designed. The data sheet will contain information required for CFD such as exhaust flow and exhaust stack temperatures.

Sound Pressure Level

Reference TM7080 for procedure in TMI – Definitions/Performance Def of how to obtain data.

A muffler may be added if sound attenuation is required in addition to the aftertreatment. The muffler or resonator must meet the backpressure requirements described in exhaust backpressure sub section above and must be installed after the Cat CEM.

For CEM noise attenuation data can be found in TMI. Contact Caterpillar Dealer for that information.

4.3 Thermal Management

Introduction

The main exhaust piping routes exhaust gas form the engine to the CEM. Normal operating temperatures can reach up to 525°C at peak load on the engines. Proper precaution should be taken to ensure that the Cat CEM is not mounted in close proximity to components that may be damaged by heat.

In addition, Marine Class Societies have a 220°C Skin temperature requirement, per SOLAS regulation Chapter II-2, Regulations 4, Paragraph 2.2.6.1.

4.3.1 Thermal Protection

The Aftertreatment skin temperatures and the gas temperature are difficult to measure and/or simulate and are depend upon many factors including the following: the nature of the engine/aftertreatment, the design and packing of aftertreatment in vessel, Engine speed/load conditions and the ambient temperature conditions around the aftertreatment. Therefore the potential temperature are provided as a guidelines for safe design of the installation even under conditions of unexpected engine and aftertreatment. Proper caution should be taken to insure that the aftertreatment device is properly shield and not mounted in close proximity to surrounding component that may be damaged by heat.

4.3.2 Thermal Wrapping

<u>Introduction</u>

The main exhaust piping routes exhaust gas from the engine to the Cat CEM. Normal operating temperatures can reach up to 525°C at peak torque. Therefore, thermal insulation on the surface of the main exhaust piping may be required. Proper precaution should be taken to ensure that the Cat CEM is not mounted in close proximity to components that may be damaged by heat.

Thermal Protection

The main exhaust piping routes exhaust gas from the engine to the Cat CEM. Normal operating temperatures can reach up to 525°C at peak torque. Therefore, thermal protection from the surface of the main exhaust piping may be required. Proper precaution should be taken to ensure that the aftertreatment device is not mounted in close proximity to components that may be damaged by heat.

Note: The aftertreatment skin temperature and the gas temperature are difficult to measure and/or simulate and are dependent upon many factors including the following: the nature of the engine/aftertreatment failure, the design and packaging of the aftertreatment, the engine speed/load conditions, the condition of the aftertreatment, and the ambient conditions. Therefore, the potential temperatures are provided as a guideline for safe design of the installation even under conditions of unexpected engine and/or aftertreatment failure; and proper precaution should be taken to insure that the aftertreatment device is properly shielded and not mounted in close proximity to surrounding components that may be damaged by heat.

In general surface temperature will increase with emissivity assuming all else being equal. Geometry also plays a role. The Rubber Hose has lower surface temperature than the Nylon Strip because of its size and shape and surface orientation to the heat source relative to the CEM.

Various types of insulation and shielding are readily available and can be applied according to the requirements of the specific application. Insure that the chosen thermal management device is adequate for the application under all conditions. Special consideration must be given to conduction, as well as radiation effects due to each option.

Thermal Wrapping

Caterpillar strongly recommends wrapping the engine exhaust aftertreatment. Applications must look into alternative means of reducing radiated heat effects from the aftertreatment device such as increased air flow around the aftertreatment and/or heat shields to protect heat sensitive devices.

There are components and areas on the Cat CEM that require protection from high temperatures. Follow the component temperature limit requirements found in this A&I document to ensure adequate thermal protection is adhered to.

When wrapping the CEM and exhaust piping make sure wrap does affect the follow areas:

The temperature limits of electronics sensor on and CEM.

Clearance must be maintained around the wrap to avoid points where wear abrasion can take place.

Wraps must allow sensor probes to pass through and still be able to meet the sensor temperature limits in all operating conditions.

IX. APPENDICES:

1 Appendix A: Cat CEM Harness Installation Guide

Wiring Harness Components

Deutsch DT Jumper Harness Connectors (C3,C4)

The DT connector is the low-cost preferred choice for inline applications. The connector is available in 2, 3, 4, 6, 8, and 12 terminal configurations. It is also intended for SAE J1939 application use. The wire size range the connector will accept is 0.8 mm^2 (18 AWG), 1.0 mm2 (16 AWG), and 2.0 mm^2 (14 AWG). The plug assembly with interface seal accepts socket terminals and the receptacle assembly accepts pin terminals. Sealing plugs are to be used in unused wire cavities.

The DT connector has a wedge that locks the pins and the sockets in place. The wedge can be removed and replaced without cutting the wires. The wedge removal tool (p/n 147-6456) can be used to aid in the removal of the wedges. When the receptacle is inserted into the plug, a click should be heard as the two halves lock together. The connector should not be able to be pulled apart.

The following table contains the Caterpillar part numbers for DT inline connector plug and receptacle kits for all available number of pin positions. The kit is comprised of the plug or receptacle and the respective locking wedge.

Standard DT Connectors		
Position	**Cat Part Number**	
	Plug Kit	**Receptacle Kit**
2	155-2270	102-8802
3	155-2260	102-8803
4	155-2271	197-7565
6	155-2274	102-8805
8	155-2265	102-8806
12	155-2255	102-8801

Contact the local Deutsch sales contact for more information on these connectors.

Deutsch AEC Jumper Harness Connectors (C1,C2)

The connector is available in 24, 40, and 70 terminal configurations. It can be used for inline or bulkhead mountings. The connector is frequently used in electronic box applications. The wire size range the connector will accept is 0.8 mm^2 (18 AWG), 1.0 mm^2 (16 AWG), and 2.0 mm^2 (14 AWG). The plug assembly with interface seal accepts socket terminals and the receptacle (header) assembly accepts pin terminals. Sealing plugs are to be used in unused wire cavities.

The Caterpillar OEM/Installer harness uses the AEC14-40PAE-E019 terminal configuration. OEM/Installer interface with this harness is the 40-position plug connector (Caterpillar part number 324-6267). This connector is labeled as PJ-C1 and PJ-C2 on Jumper Harness. The AEC connectors are keyed to align correctly when the two parts are mated together. An Allen head screw holds the two connectors in place. Ensure that the Allen head screw is tightened to a torque of 6 +/- 1.0 N•m (4.4 +/- 0.7 lb-ft.).

Connector Terminal Contacts

There are two types of terminal contacts available for production use: machined, and stamped and formed. Machined terminal contact, also referred to as a solid contact, is used for low volume harness production and for field repair. Stamped and formed contact is used for high volume harness production and is the lowest cost terminal contact option.

Terminal contacts are available with nickel or gold plating. Gold plating should be used for applications of 5 volts or less and/or less than 100 milliamps. Typically these low level circuits require low resistance at the pin/socket connection and gold plating is the best low-cost choice. Nickel-plated contacts can be used in power-type circuits or circuits where low resistance at the pin/socket connection is not a concern.

Gold-plated contacts can be used in all circuit applications regardless of the voltage and current requirements. Gold plating provides some marginal improvement in vibration versus nickel plating. Caterpillar requires that only gold-plated sockets are used in the ECU connector (J1).

Note: Deutsch nickel-plated stamped and formed terminals are not recommended for use because of excessive voltage drop experience in laboratory tests.

Wire Type and Gauge Size

Wire Selection

Wire must be of a type suitable for the application. Wire must be selected so that the rated maximum conductor temperature is not exceeded for any combination of electrical loading, ambient temperature, and heating effects of bundles, protective braid, conduit, and other enclosures. Typical factors to be considered in the selection are voltage, current, ambient temperature, mechanical strength, connector sealing range, abrasion, flexure, and extreme environments such as areas or locations susceptible to significant fluid concentrations.

Wire Size

The minimum conductor size used on Caterpillar products is 0.8 mm^2 (18 AWG). Smaller conductors are susceptible to breakage and fatigue failures. SAE J1614, wiring distribution systems for construction, agricultural, and off-road work machines require wire sizes no smaller than 0.8 mm^2 (18 AWG).

Jumper harness wire size requirements per connection are defined in the Cat CEM and Engine Jumper Harness Definition tables below.

Wire Insulation

NOTE: Thermoplastic Polyvinyl Chloride (PVC) insulation shall not be used in wire harness designs because of its low operating temperature range (-40 to 85° C), and melt and flammability characteristics.

Cross Linked Polyethylene (XLPE) is the primary wire insulation type used in chassis, cab, and engine compartment locations. It has a temperature rating of -50 to 120° C. The voltage rating for Caterpillar 1E0815 wire and SAE J1128, Type GXL is 50 volts. The circuit voltage shall be considered when making wire selections. This wire insulation is also available with 50, 150, 300, or 600-volt ratings.

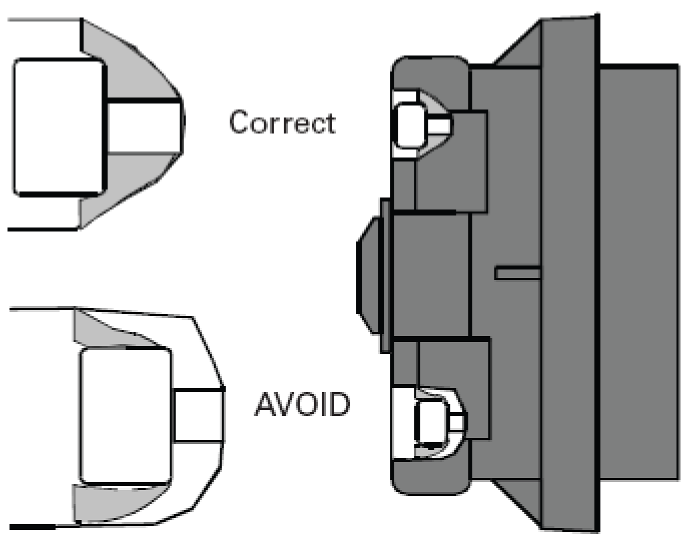
Outside diameter insulation range is 2.26 to 3.33 mm (0.089 to 0.131 in.). The table below provides insulation diameter range for each gauge and wire type.

PJ Connector Wire Insulation and Gauge Size		
Wire Type	**Wire Gauge**	**Insulation Diameter**
GXL	14	0.114 – 0.125
	16	0.098 – 0.112
	18	0.089 – 0.098

Metric Equivalents for AWG Wire Numbers							
AWG	20	19	18	16	14	12	4
Diameter (mm^2)	0.5	0.65	0.8	1	2	3	19

Connector Seal Plug

All unused cavities for sockets and pins must be filled with seal plugs in order to ensure that the connector is sealed. Two options are available for plugging unused connector cavities. Either the Deutsch 114017 (Caterpillar part number 8T-8737) or PEI Genesis 225-0093-000 (Caterpillar part number 9G-3695) sealing plugs can be used.



Plug Insertion in Unused Connector Cavity

The seal plugs are installed from the wire insertion side of the plug or receptacle. Correct installation of either of these cavity plugs is critical to maintain connector sealing integrity.

Figure above illustrates the correct insertion of the plug. The seal plug cap is designed to rest against the seal, not inserted in the hole in the seal.

Harness Routing

Wiring shall be routed to ensure reliability and to offer protection from the following:

(1) Chafing/rubbing/vibrating against other parts.
(2) Use as handholds or as support for personal equipment.
(3) Damage by personnel moving within the vehicle.
(4) Damage by impact, or thrown or falling debris.
(5) Damage by battery acid fumes, engine and hydraulic oil, fuel, and coolant.
(6) Abrasion or damage when exposed to rocks, ice, mud, etc.
(7) Vandalism damage (to the maximum extent practicable).
(8) Damage by moving parts.
(9) Harsh environment such as nitrite mines, high temperatures, or areas susceptible to significant fluid or fume concentration.

Wire harnesses shall not be located in close proximity to oil and fuel fluid fill areas or below fuel and oil filter locations. If these locations cannot be avoided, additional protective covers and shields must be provided to protect the harness.

Harnesses shall be located a minimum of 50 mm from high heat sources (e.g. exhaust manifolds, turbochargers, hydraulic components, etc.) to avoid insulation and/or connector deterioration.

Harness Maintenance Considerations

The maintainability of the wiring system shall be an important consideration in the selection, design, and installation of harnesses, cable assemblies, and other wiring system components. All wiring components shall be accessible, repairable, and replaceable (i.e. connector terminals).

High-pressure wash systems are now in frequent use by maintenance people. When locating electrical connectors, place them in accessible locations while using other physical elements for protection and prevention of direct exposure to wash systems (e.g. brackets, housings, sheet metal structure, etc.). Where direct exposure to high pressure wash systems cannot be avoided, protective shields will need to be designed and installed.

Harness Appearance

The primary purpose for the wiring system is to provide electrical and electronic component function. There is, however, another important and intangible value to consider when designing the wiring system. The appearance of the wire harness and its routing path should reflect an orderly, well-thought-out design plan. A poorly executed plan can have a negative impact on OEM/Installer perceptions of the entire product. Use the product’s horizontal and vertical lines for routing paths. Design preformed bends into large harnesses to facilitate product assembly and improve appearance. Use other product elements to shield or hide the harness from view. Benchmark new automotive product applications for ideas.

Harness Bends

Routing of the harness should insure connector seals are not stressed because the harness curvature is too close to the connector. This applies to routing of OEM/Installer lines on or near the engine harness as well as the ECU OEM/Installer connector (J1/P1).

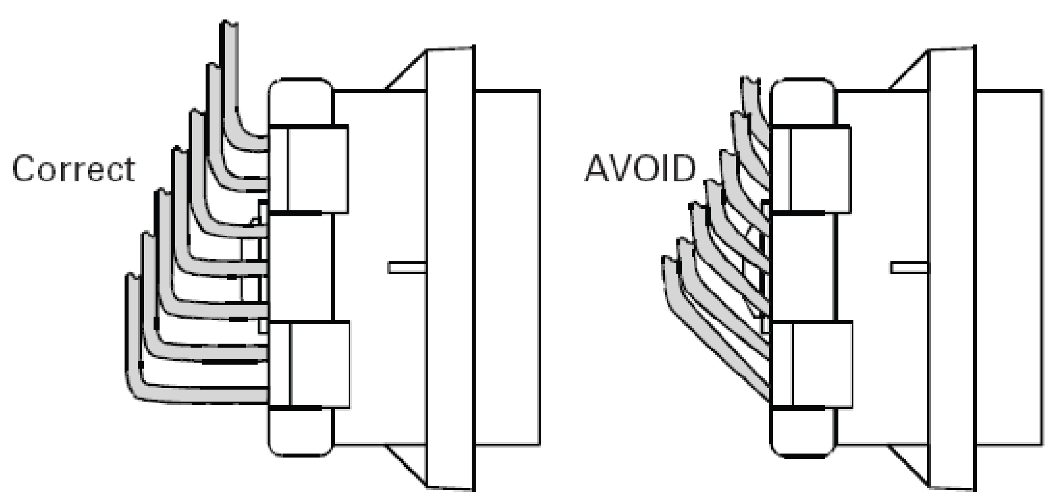
The minimum bend radius for a braided wire harness as measured from the inside of the bend shall be four times the outer diameter of the harness. Tighter bends are possible if the bend is performed during harness manufacture. The bend radius size and location must be specified on the wire harness drawing.

Bends in jacketed cables shall be based on manufacturer recommendations. A bend must not adversely affect the operating characteristics of the cable. For flexible coaxial cables, the bend radius must not be less than six times the outside diameter. For semi-rigid coaxial cable, the bend radius must not be less than ten times the outside diameter of the cable.

The minimum bend radius for flexible conduit must be six times the outer diameter of the conduit. Conduit bends shall not cause internal chafing of the wiring.

Harness Bends near Connectors

Avoid wire harness bends within 25 mm (1.0 in.) of the connector. When a harness bend is too close to the connector, the connector seal is stretched away from the wire, providing an opening for moisture entry. The wire should exit perpendicular to the connector before curving as necessary for routing. Refer to illustration in Figure below.



Example of Wire Harness Routing at the PJ-C1,C2 Connectors

Wire harness bends near a connector must be no less than twice the wire harness diameter. Special consideration shall be given to connectors with large wire counts. Stresses placed upon the retention system of the connector can cause contact retention failures and wire pull-out. In order to avoid this problem consider the following options:

(1) Pre-form the harness to the required bend. The harness assembly drawing shall detail the harness bend requirements (e.g. location and radius). The harness braid protection should be applied up to the tangent point of the bend furthest from the connector. Connector orientation to the bend may be necessary and should be specified on the harness print.
(2) If harness braiding is used, increase the unbraided harness length to 150 mm. This will allow the wires to fan out when the harness is bent, greatly reducing the forces placed on the connector contact retention system. The connector should also be oriented properly with respect to the harness so that upon installation to the product the harness will not need to be twisted to align the connector.

Drip Loop

When a harness is routed downward to a connector, terminal block, panel, or junction box, a trap or drip loop shall be provided in the harness. This feature will prevent fluids or condensate from running into the above devices.

Sealing Splices and Ring Terminals

Caterpillar requires all ring terminals and splices connected to the engine ECU be sealed using Raychem ES2000 adhesive lined heat shrink tubing or equivalent. Refer to Table below for heat shrink tubing sizing information.

Heat Shrink Tubing Reference Table

Cat Part Number	I.D. Before Shrink		I.D. After Shrink	
	(mm)	(inch)	(mm)	(inch)
125-7874	5.72	0.225	1.27	0.050
125-7875	7.44	0.293	1.65	0.065
119-3662	10.85	0.427	2.41	0.095
125-7876	17.78	0.700	4.45	0.175

Wire Connection Guidelines

The following requirements ensure the correct installation of solid contacts into connector terminals:

- Do not solder the contact (socket or pin) to the wire.
- Never crimp more than one wire into a contact. Connector contacts are designed to accept only one wire of a specified gauge or gauge range, do NOT insert multiple wires of a smaller gauge.
- All contacts should be crimped on the wires. Use the Crimp Tool (Caterpillar part number 1U-5804) for 12 to 18 AWG wire.
- Perform the pull test on each wire. The pull test is used to verify that the wire is properly crimped in the contact and the contact is properly inserted in the connector terminal. Each contact and connector terminal should easily withstand 45 N (10 lb) of pull such that the wire remains in the connector body.

SAE J1939/11 — Data Bus Wiring

J1939 Data Bus Harness Design

The data bus connector that Caterpillar uses is a modified DT connector, special wedge, cable, and extended socket. The harness assembly requirements are unique to typical Caterpillar wire harnesses. Caterpillar recommends two conductor shielded cable from Raychem Corp (Raychem part number 2019D0309-0/Cat part number 153-2707) for all J1939 data link wiring. This is twisted pair wiring. If the Caterpillar recommended cable is not used, the cable must meet J1939 specifications for conductors. For additional information regarding the electrical system design see the SAE publication J1939/11 Physical Layer.” The minimum bend radius for the data bus cable is 40 mm.

Table 2: J1939 Conductor Specifications

J1939 SPECIFICATIONS FOR CONDUCTORS			
	Minimum	**Nominal**	**Maximum**
Impedance (ohm)	108	120	132
Capacitance between conductors (pF/m)	0	40	75
Capacitance between the conductors and the shield (pF/m)	0	70	110

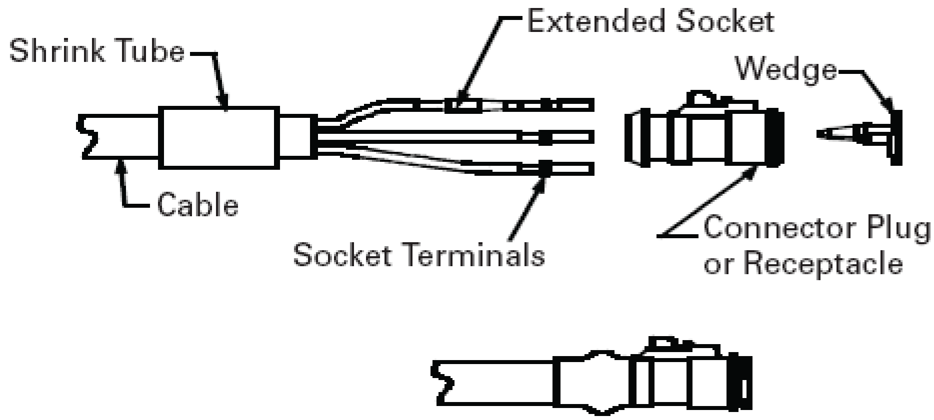
In order that the data bus will function as intended the following requirements must be identified on the customer wire harness print.

(1) Remove 75 mm of the outer jacket of data link shielded cable. (Reference Cat part number 153-2707)
(2) Remove the foil shield from the exposed wires to within 3 mm of the cable jacket end.
(3) Crimp gold-plated socket terminals to the wires and the extended socket terminal to the drain wire.
(4) Slide heat shrink tube over the cable end. (Reference Cat part number 125-7876)
(5) Install the terminals into the appropriate connector cavity positions.
(6) Install the wedge into the connector.

(7) Apply the heat shrink tube over the back of the connector body and the jacket of the cable.

The above components and assembly procedures must be used to ensure the cable to connector joint will be sealed. Failure to conform to these requirements will result in cable contamination and result in loss of shield performance. See Figure 6.

Figure 6: SAE J1939 Connector Assembly



NOTE: *Refer to SAE J1939-11 "Physical Layer" document for more information.*

Connecting Modules to the CAN Data Link

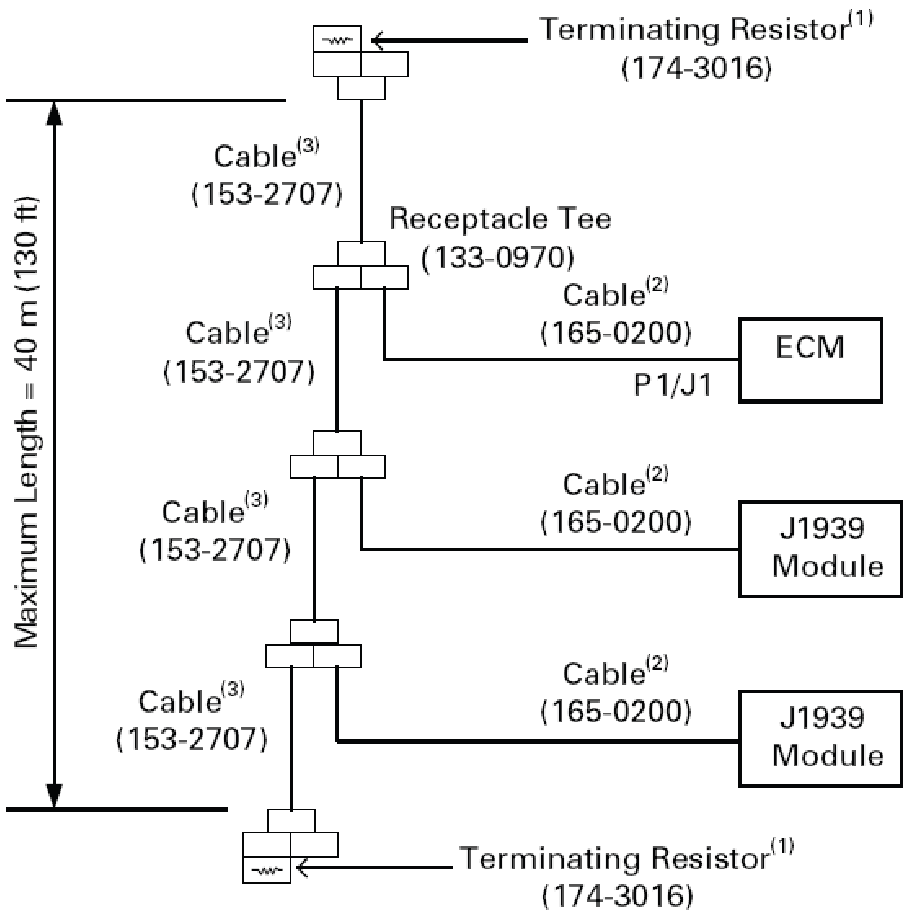
The SAE J1939 data link is used to communicate engine information to an SAE J1939 compatible display or other desired SAE J1939 compatible modules. Refer to SENR9764 "Installation Guide for Industrial Electronic Engine Displays" for more information on connecting J1939 displays to Caterpillar industrial engines.

The illustration in Figure 7 shows two J1939 modules properly connected to the J1939 data bus. The key components to note are as follows:

- The total length of the data link between terminal resistors must not exceed 40 m (130 ft).
- Length of each branch, or stub length, must not exceed 1 m (3.3 ft). Reference cable assembly (Cat part number 165-0200) that is .15 m long with Deutsch DT 3 pin plug on one end and J1939 signal and shield wires with appropriate crimped socket on the other end for insertion into J1939 module connector.
- All splices and end nodes can be implemented using a connector tee. (Reference Deutsch DT receptacle assembly — Cat part number 133-0970).
- Two terminal resistors must be installed. One resistor is required at each end of the data link in order to ensure proper operation. These two terminal resistors are critical for the proper operation of the network.

(Reference Deutsch DT plug with integrated termination resistor — Cat part number 174-3016).

Figure 7: J1939 Multiple Module Installation Example



(1) Two terminal resistors are required. Optional Customer
(2) Harness provides the resistor at the ECM if installed
(3) Maximum stub length = 1 m (3.3 ft)
(4) Fabricate 153-2707 cable to length

NOTE: If the requirements for J1939 data link connections are met, any number of display modules or service tool connectors may be connected to the J1939 data link.

NOTE: One terminal resistor for the J1939 data link is included in the optional customer harness. If the optional customer harness is not present, two terminal resistors must be installed. Any J1939 data link must have a terminal resistor at each end of the data link.

NOTE: A terminal resistor is required at the terminal ends of the data link cable. A terminal resistor is not required at each node on the data link.

2 Appendix B: Initial Startup Procedure

Engine and Aftertreatment Compatibility Check

After completing installation of the aftertreatment hardware, a hardware compatibility check is required. There are three criteria for meeting aftertreatment compatibility check.

(1) Automatic compatibility check at key on
(2) Verifying that the CEM and Dosing cabinet serial numbers match
(3) Documentation of CEM and Engine serial number

Automatic compatibility check at key on

All CEM's contain a chip that will check for proper compatibility with the engine. At first start up the engine ECM will read the CEM chip and write the serial # information to the engine ECM. The engine ECM will then determine if a compatible CEM and dosing cabinet has been installed with the engine.

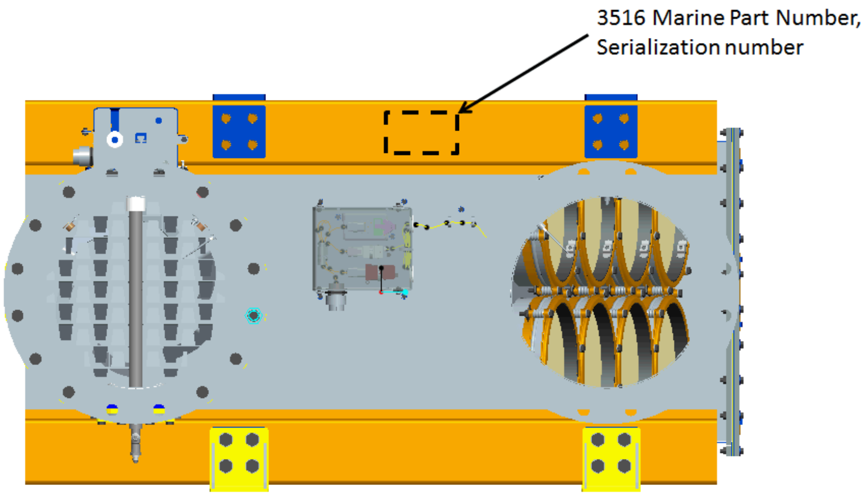
- If the CEM and/or dosing cabinet is not compatible with the engine, the engine will derate and trigger an active fault. A compatible CEM and/or dosing cabinet for the engine will need to be installed to resolve this issue.
- If the CEM and dosing cabinet is compatible the engine will not derate and there will be no fault code. No further action for the automatic compatibility check is required.

The engine will continue the compatibility check of the CEM for the first 25 hours of operation of the installation. If for any reason the engine ECM is replaced or aftertreatment is replaced within the first 25 hours of operation the engine ECM will rewrite the CEM serial# from the CEM chip. The 25 hour clock for compatibility check will also restart after initial compatibility check of the new hardware.

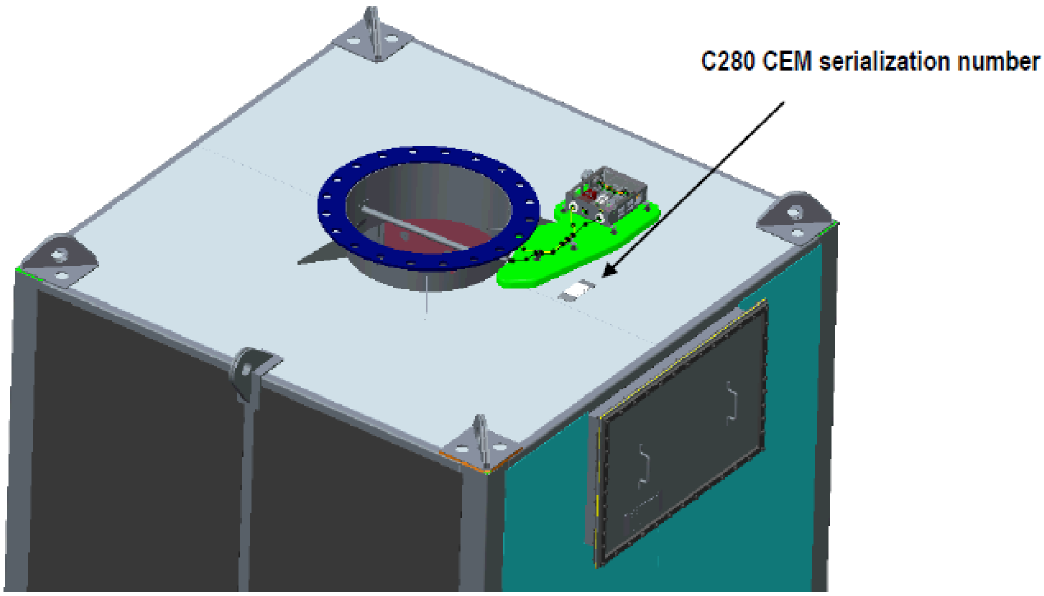
Verifying that the CEM and dosing cabinet serial numbers match

CEM and dosing cabinet are shipped as a matched set from Caterpillar. It is required that the installer use a CEM and dosing cabinet with matching serial numbers for any installation. Verify that the serial numbers are identical for both the CEM and dosing cabinet.

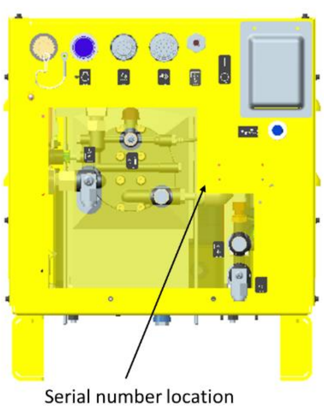
Location of CEM Serial Number:



Location C280 CEM serial Number:



Location of Dosing Cabinet serial number:



Documentation of CEM and Engine Serial Number

Documentation of engine serial number and CEM serial number is a requirement for all installations

The final installer of the engine and CEM will be required to document the engine and CEM serial number and provide that information to Caterpillar. The Dealer will follow the standard reporting requirements through the Web Portal Tier 4 Commercial Engine Application. This site requires an Installation Audit and Serial Number pairing entry on either an individual engine system basis or part of a mass upload performed by the Dealer.

Engine and Aftertreatment Assembly documentation

Documentation of the engine and CEM serial number is to be done to be reported back to Caterpillar to meet the EPA requirements. The engine and aftertreatment serial numbers are to be required within the DFA.

3 Appendix C: DEF Handling

Refer to Caterpillar Fluid document PELJ1160-01 for additional information on DEF fluids.

Hazards Identification

DEF (AUS32 - aqueous urea solution, 32 or 40%) is a colorless liquid with a slight ammonia (pungent) odor.

Note: Consult the Material Safety Data Sheet (MSDS) provided by your AUS32 supplier. MSDS example is:

- *MSDS Number 2046 (Revised October 4, 2006) for Urea Liquor supplied by Terra Industries Inc.*

Warning: *AUS/DEF is a stable material, but highly reactive with strong oxidizers. Avoid contact with all oxidizers. AUS/DEF reacts violently with sodium hypochlorite (such as CloroxTM) or calcium hypochlorite to form the nitrogen trichloride, which spontaneously explodes or rapidly decomposes creating toxic fumes, which may cause personal injury or death.*

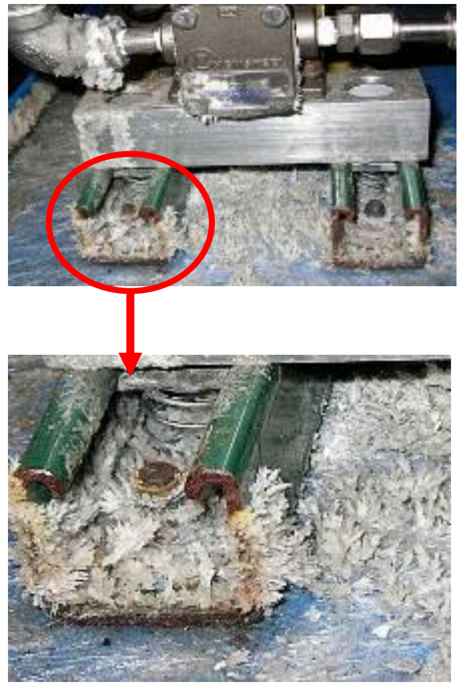
When heated, AUS/DEF releases ammonia. When heated to decomposition, such as in a fire, it emits toxic fumes of nitrogen oxides (NO_x), ammonia, and cyanuric acid. Use water to control fires involving DEF liquor if water is compatible with burning material. Note that both DEF liquor and solid DEF are non-flammable.

In storage, a very small amount of the DEF in the liquor will hydrolyze forming gaseous ammonia and carbon dioxide. The ammonia, which is soluble in the liquor, will cause the corrosiveness of DEF solution to increase as it ages due to its increasing concentration. That is, the higher ammonia concentration makes it more caustic. Note that high storage temperatures increase the rate of this decomposition.

Since DEF liquor is caustic, delivery and storage requires materials that are not susceptible to corrosion.

Recommended Materials:

- Stainless-steel
  - 300 series: OK
  - 400 series: Slow corrosion
  - Corrosion rate increases with temperatures > 60 °C
- Plastics



Materials to Avoid:

- Unalloyed steel
- Aluminum
- Brass
- Galvanized steel
- Copper

Eye contact may cause mild eye irritation, including stinging, watering, and redness. Wear safety glasses. Safety shield may be needed in some conditions.

Skin contact may cause mild skin irritation including redness and burning. No harmful effects from skin absorption have been reported. Use rubber gloves to prevent skin contact (All rubber types OK).

Vapor Inhalation may cause irritation leading to cough or difficulty in breathing.

Note: Contact hazards are from the caustic pH (7.5 – 10) factor of solution. DEF in solution slowly decomposes into ammonia causing the caustic reaction. “Aged” DEF solution is more caustic (high pH) than “fresh”.

Leaks and/or Spills

There is visible evidence should a leak occur:

- DEF stalactites & stalagmites
  - Formed from slow leaks and evaporation of water
  - Rate of water evaporation determines size of crystal formation
- Need to verify that joints are tight
  - Stop leaks when first noticed
    - Solid DEF will continue to accumulate
    - DEF solution is corrosive to steel and other metals
- Solid DEF is water soluble

- **But…** may be slow to get into solution

- Clean up spills and leaks before components can corrode
  - Minor spills: Use paper towels or absorbent mat
- Solid DEF is highly water soluble
  - Hot water will re-dissolve solid DEF faster
  - Small amount of soap or detergent in hot water may enhance clean up
  - Plenty of hot water is key to removing dry DEF
- DEF solution contains small amount of ammonia
  - Skin irritant
  - Wear gloves

4 Appendix D: Installation Checklist

	Marine Emission Installation Audit Questions		
	Installation Audit ID		
	Audit Description		
	Selling Dealer Name		
	Selling Dealer Code		
	Sales Model		
	Engine Serial Number		
	Aftertreatment Serial Number		
	Dosing Cabinet Serial Number		
	End Customer Name		
	Vessel Name		
	Test Engineer Name		
	Emissions Audit Questions:		
1	Is the original engine emissions label clearly visible?		Yes/No
2	If no, Describe location of duplicate.		Yes/No
3	Is there and oil renewal system present(any form of system that attempts to combust used engine oil)?		Yes/No
4	Is API CJ-4, ACEA-E(or DEO-ULS oil sticker visible at all lube fill points?		Yes/No
5	Is ULSD Sticker clearly visible on all fuel filling points? Please describe all locations.		Yes/No
6	Are the flexible bellows int eh exhaust system supplied by Cat?		Yes/No
7	If yes, Caterpillar flexible bellows part Numbers (S)		Yes/No
8	For third party flex bellows in the exhaust system is there a copy of the fatigue analysis (similar t EJMA calculation)		Yes/No
9	Is the exhaust piping stainless steel from the mixing tube/urea injection nozzle to CEM? the required 300/400 series Stainless.		Yes/No
10	Is the turbo to CEM inlet exhaust piping fully insulated?		Yes/No
11	Does the installation provide engine and SCR system warning fault communication to the operator. Specify either Lamp or type of communication and indication.		Yes/No
12	Any customer supplied aftertreatment components installed before of after the factory CEM		Yes/No
13	Is the inlet and outlet spool on the CEM oriented and supported correctly per A&I guide instructions		Yes/No
14	Does CEM installation account for thermo growth per A&I guidelines		Yes/No
15	Is the Dosing cabinet is located correctly to lance/nozzle per A&I instructions		Yes/No
16	Does AUS/DEF (urea) tank meet A&I guide lines		Yes/No
17	Is their a low level DEF Sensor installed in main urea tank and monitored by Cat ECM correctly		Yes/No
18	Is the factory insulation installed on CEM inlet and outlet spools correctly and no other insulation around and over the sensors.		Yes/No
19	Is the pressure sensor on the inlet spool mounted on vertical orientation per A&I guidelines.		Yes/No
20	Is the Nox sensor box oriented correctly on the inlet and outlet spool per A&I guidelines. (Nox sensors box located on top).		Yes/No
22	Checked for all Electrical codes to make sure all system is operating correctly.		Yes/No
23	Was a Complete PAR test performed and uploaded into the Cat system?		Yes/No
24	Air inlet restriction at full load rated speed with clean filter element measured at turbo compressor inlet (if Vee, Left)		KPA
25	Air inlet restriction at full load rated speed with clean filter element measured at turbo compressor inlet (if Vee, Right)		KPA
26	Enter full load exhaust backpressure at turbo outlet. (if Vee Left)		KPA
27	Enter full load exhaust backpressure at turbo outlet. (if Vee Right)		KPA
28	Enter the full load backpressure at CEM		KPA
29	CEM inlet temp at 100% rated load		KPA
30	AUS/DEF (urea) Delta P between lance and dosing cabinet		KPA
31	AUS/DEF (urea) pressure to dosing cabinet		KPA
32	Air supply pressure to dosing cabinet		KPA
33	AUS/DEF (urea) concentration % (32.5 or 40%)		%
34	Vessel fuel tank capacity		liters
35	AUS/DEF (urea) tank capacity		liters

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