400

Series

# Perkins 400J-E Series

Models: 403J-E17T, 404J-E22T, 404J-E22TA

# IOPU APPLICATION & INSTALLATION SUPPLEMENT

**Three and Four Cylinder Common Rail, engines for Industrial and construction applications, Meets EU Stage V/Bharat Stage V and EPA Tier 4 Final emissions regulation**

Developed to meet EPA Tier 4 Final and EU Stage V off highway emissions legislation.

Note: Information in this manual is preliminary and is subject to change or withdrawal.


TPD2404 V1.0

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THE HEART OF EVERY GREAT MACHINE

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**A&I Manual Introduction**

This manual has been compiled to explain mandatory requirements, provide information for designers, and provide information on the application and installation of the 400 Series engines into Industrial equipment, to meet U.S. Environmental Protection Agency (“EPA”) Tier 4 Final regulatory requirements and European Union (“EU”) Stage V non-road mobile machinery emissions legislation.

The information provided in this manual is correct at the time of issue. Continuing product developments and changing legal requirements will, however, continue to drive further changes in installation requirements and attention must be paid to ensure that the latest information is utilised, and valid data is obtained from the engine specification manual.

Serial number prefixes for the engines referenced in this manual are:
403J-E17T: IW
404J-E22T: IQ
404J-E22TA: IR

This manual is not an exhaustive source of instruction or data and should only be used in conjunction with advice from your local application engineers, sales manager and or technical support representative.
The following media publications for the relevant engine type should also be used for further technical information

400J-E Series Electrical and Electronic A and I Manual.
Operator and maintenance manual (OMM).
System Operation Test and Adjust (SOTA).
Specifications (Specs).
Disassembly and Assembly (D&A).
Engine Specification Manual (ESM).
Customer Assembly Requirements Document (CAR).

Correct practices, procedures and safety precautions should always be followed.

Please note:
The information provided may be subject to change.
Perkins Engine Company Limited (“Perkins”) has provided this information in good faith and are not liable for how this information is interpreted or applied.

Perkins is not responsible for failures resulting from attachments, systems, accessory items, and parts not sold nor approved by Perkins. Consult the applicable warranties for complete details of the Perkins warranty coverage.

The manufacturer and customer are reminded that it is their responsibility to ensure compliance with the requirements of the Health & Safety at Work Act 1974 and any other applicable legislation, both nationally and internationally, in relation to the engine installation applicable to the equipment concerned. In giving notice of approval in respect of the installation, Perkins do not assume such responsibilities on behalf of the manufacturer or customer and while engine installation approval and advice is an opinion given in good faith, the equipment manufacturer and customer remain responsible as detailed above and must act and insure accordingly.

# 1.0 Introduction

## 1.1 How to use this manual

This supplement has been written to outline the specific requirements for correct installation of 400 Series 1.7 and 2.2 Tier 4 Final/Stage V IOPU's. The manual is divided into 2 sections:

- Part 1. Mechanical Application and Installation Requirements
  This compliments the main Tier 4 Final/Stage V Application and Installation Manual TPD2115

- Part 2. Electrical and Electronic Application and Installation Requirements.
  This compliments the main Tier 4 Final/Stage V Electronic Application and Installation Manual TPD2193

It has been written as a supplementary document that complements but in no way replaces or changes the main mechanical application and installation manual or the electronic manual. These manuals should not be used in isolation and must be used together to ensure a correctly designed and compliant product.

This manual is applicable to all IOPU standard lists used in stationary, non-mobile. machinery. Bespoke lists or lists that have been modified from the standard lists, available from the engine factory, may require adherence to different mandatory requirements with additional validation, installation, and audit test requirements. Use of these lists in mobile machinery may also have an impact on the mandatory and sign off requirements as the engine assembly is exposed to different vibration inputs and environmental conditions to the fully validated product.

### 1.1.1 Mandatory Requirements

The Mandatory Requirements detailed in each section of this manual are specific requirements applicable only to the IOPU. These requirements are **additional** to those specified in main mechanical application and installation manual and the electronic application and installation manual. It assumes that the IOPU has not been modified in any way from the supplied condition. Mandatory requirements within all these publications must be adhered to unless stated otherwise. Any modifications made to the IOPU require approval and may result in additional or different requirements that need to be met. Consult your Applications Engineer.

All Emission Related Installation Instructions are highlighted by the **EM** symbol.

'Failing to follow these instructions when installing a certified engine in a piece of non-road equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'

### 1.1.2 Terminology

The terminology used throughout this book is as follows:

| | |
|---|---|
| AITP | Application and Installation Test Procedure |
| AT | Aftertreatment |
| ATAAC | Air to Air After-Cooled |
| BPV | Back Pressure Valve |
| CAR | Customer Assembly Requirements Document |
| CCB | Closed Crankcase Breather |
| CG | Centre of Gravity |
| $CO_2$ | Carbon Dioxide |
| CO | Carbon Monoxide |
| DCU | Dosing Control Unit |
| DEF | Diesel Exhaust Fluid |
| DOC | Diesel Oxidation Catalyst |
| DPF | Diesel Particulate Filter |
| EMAT | Engine Mounted Aftertreatment |
| ECM | Electronic Control Module |
| ESM | Engine Specification Manual |
| ELP | Electric Lift Pump |
| FIP | Fuel Injection Pump |
| HC | Hydrocarbon |
| $H_2O$ | Water |
| ID | Identification |
| IGB | Installation Guideline Bulletin |
| IOPU | Industrial Open Power Unit |
| MAF | Mass Air Flow |
| NOx | Nitrogen Oxides – NO and $NO_2$ |
| OMM | Operation and Maintenance Manual |
| OEM | Original Equipment Manufacturer (Machine) |
| PETU | Pump Electronic Tank Unit |
| PEU | Pump Electronic Unit |
| PM | Particulate Matter |
| PRV | Pressure Relief Valve |
| RF | Radio Frequency |
| ROA | Rise Over ambient |
| S/N | Serial Number |
| SOF | Soluble Organic Fraction |
| SCR | Selective Catalytic Reduction |
| ULSD | Ultra Low Sulphur Diesel |
| WIF | Water in Fuel |

## 1.2 Safety

The manufacturer and customer are reminded that it is their responsibility to ensure compliance with the requirements of the Health & Safety at Work Act 1974 and any other applicable legislation, both nationally and internationally, in relation to the engine installation applicable to the equipment concerned. In giving notice of approval in respect of the installation, The Engine manufacturer does not assume such responsibilities on behalf of the manufacturer or customer and while engine installation approval and advice is an opinion given in good faith, the equipment manufacturer and customer remain responsible as detailed above and must act and insure accordingly.

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. A person must be alert to potential hazards. This person 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. Distributors will have the most current information.

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.

The engine factory 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 Perkins is used, you must be sure that it is safe for you and for other people. You must also be sure that the product will not be damaged and / or made unsafe by the procedures that are used.

### 1.2.1 Safety Warnings

The following warnings are appropriate to the engines referenced in this manual.

⚠ **WARNING – Do not operate or work on this product unless you have read and understood the instructions and warnings in the relevant Operation and maintenance Manuals. Failure to follow the instructions or heed the warnings could result injury or death. Proper care is your responsibility.**

Correct practices and procedures including safety and lifting information should be followed as outlined in the following appropriate service manuals.

- Operation and Maintenance Manual (OMM)
- System Operation Test and Adjust (SOTA)
- Specifications (Specs)
- Disassembly and Assembly (A&A).

### 1.2.2 California Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

⚠ **WARNING - This product can expose you to chemicals including lead and lead compounds, which is known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to:**
www.P65Warnings.ca.gov

**Wash hands after handling components that may contain lead.**

⚠ **WARNING - This product can expose you to chemicals including ethylene glycol, which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to:**
www.P65Warnings.ca.gov

**Do not ingest this chemical. Wash hands after handling to avoid incidental ingestion.**

## 1.3 Engine Installer Responsibility

The following information forms part of the Engine Manufacturer safety compliance documentation, as a supplier of partly completed machinery. Consideration of the safety requirements detailed below forms part of the technical construction file for the product and should be taken into consideration and addressed during installation of the product into the final machine, before placing on the market.

This is a generic document that covers all engine families and therefore some of the safety considerations may not be relevant to the technology of the engine selected.

The Engine Manufacturer recommends that a risk assessment and FMEA is conducted on all installations to consider all aspects of machine/installation and operational safety.

The manufacturer and customer are reminded that it is their responsibility to ensure compliance with the requirements of the Health & Safety at Work Act 1974 and any other applicable legislation, both nationally and internationally, in relation to the engine installation applicable to the equipment concerned. In giving notice of approval in respect of the installation, The engine manufacturer does not assume such responsibilities on behalf of the manufacturer or customer and while engine installation approval and advice is an opinion given in good faith, the equipment manufacturer and customer remain responsible as detailed above and must act and insure accordingly.

### 1.3.1 2006/42/EC - Machinery Safety Directive, Annex 1 and for GB, The Supply of Machinery (Safety) Regulations 2008 and other applicable Enactments

**Fixed Guards:**
The Engine Manufacturer takes into account various applicable standards when designing guarding, however it cannot foresee all possible installation scenarios and any residual risks remain the responsibility of the engine installer. Although the Engine manufacturer offers guarding on some products to prevent some access to the hazards at the front of the engine, the expectation is that the engine will be fully installed in an enclosure that meets local guarding requirements. Particular attention should be made to hot surfaces and moving parts, residual risks associated with catastrophic failure of the engine or turbocharger, explosion in the aftertreatment due to ether abuse and high-pressure fluid leaks.

### 1.3.2 EN1679-1: 2011 - Reciprocating internal combustion engines – Safety Part 1: Compression ignition engines

**Safety requirements and / or measures**
**Starting Systems:**
The engine installer is responsible for understanding the requirements and properly installing other parts of the starting system.

**Normal Stopping:**
For engines installed in machines the OEM is responsible for installation of the stopping system, normally by ignition switch or key.

**Emergency Stopping - Manually controlled:**
For engines installed in machines the OEM is responsible for installation of the emergency stopping system.

**Emergency Stopping – Automatically controlled:**
The engine installer is responsible for understanding the requirements and properly installing the automated emergency stopping controls.

**Machine operation outside of defined gradient limits**
For engines fitted with closed circuit breathers, engine installers should be aware that in the event of machine operation outside of defined gradient limits (e.g., Machine roll over) there is the potential for lubricating oil to overwhelm the breather system and for oil to be carried over into the induction system of the engine resulting in engine runaway.

**Controls**
The engine installer is responsible for understanding the requirements positioning of engine controls. If a secondary control panel is fitted the installer should consider placing the panel in a safe operating position, not close to the side of the engine. The secondary control panel must be installed so that it cannot override the primary control panel.
Throttle controls on off road mobile machines should have sufficient resistance to ensure that when the machine is moving over bumpy ground minor fluctuations in pressure applied to the throttle do not result in undesired changes in engine/machine speed.
A robust signal is required from the machine ECM to the Engine ECM to ensure engine control is not compromised.
Hand controls for the engaging and disengaging of driven equipment such as hydraulic pumps should be positioned so as not to be close to the side of the engine.
Ensure that strategies to automatically increase engine idle for aftertreatment regeneration etc. have safeguards to prevent machine movement during operation.

**Monitoring devices:**
It is the engine installer's responsibility to understand the requirements and ensure warning indicators are present for functions such as delayed engine shutdown and Diesel Exhaust Fluid (DEF) system purge etc. - The engine installer should understand the requirements and consider installing a warning light to advise operators and technicians when the DEF system is purging.
Some engine health functions such as oil pressure monitoring can result in a derate where engine power can be reduced by up to 50%.

**Guarding against mechanical hazards:**
The Engine Manufacturer takes into account various applicable standards when designing guarding, however it cannot foresee all possible installation scenarios and any residual risks remain the responsibility of the engine installer. Although the Engine manufacturer offers guarding on some products to prevent some access to the hazards at the front of the engine, the expectation is that the engine will be fully installed in an enclosure that meets local guarding requirements. Particular attention should be made to hot surfaces and moving parts, residual risks associated with catastrophic failure of the engine or turbocharger, explosion in the aftertreatment due to ether abuse and high-pressure fluid leaks.

**Guarding against hot surfaces:**
Depending on the location of the hot surface & its temperature, the engine installer needs to decide if a hazard exists that should be guarded. For IOPUs, the engine installer should understand requirements and consider whether additional guarding is required to protect against hot surfaces including the aftertreatment. Consideration to fluid lines and components affected by heat should be given when mounting engine and aftertreatment. It is recommended that the engine installer gives consideration to the risk of burns from the exhaust system and mitigate the risk accordingly.

**Handling:**
When lifting or handling the engine or aftertreatment the engine installer should refer to the advice contained in the Operation and Maintenance Manual regarding safe practice.

**Fire protection:**
The engine Installer needs to understand the requirements for all fuel supply line routing.
Drain ports are supplied as standard and if the installation impedes access to all drain ports, the engine installer is responsible for rerouting the service point.

**Protection against explosion:**
The engine installer is responsible for compliance with local regulations, directives, and certification where appropriate if an engine is known to be going into an explosive atmosphere(s).
Due to the volatile nature of ether, the customer should ensure that ether supply lines are robust and securely clipped, and that they can operate at the intended system pressure to minimise the risk of leaks and the potential for explosion.

**Pressure vessels**
Engine components containing pressurised air or fluids are not considered pressure vessels. It is recommended that the engine installer understands requirements and considers the risk of escaping steam and hot or cold coolant from the radiator cap during its removal and take action to mitigate the risk.

**Hoses, Pipes, and electric harnesses:**
The risk of electrostatic discharge from fuel filter bowls and pipes should be considered as part of the Original Equipment Manufacturer or Cat Machine Group risk assessment conducted in support of machine manufacture.
As part of the machine risk assessment, the engine installer should understand requirements and consider whether guarding of the high-pressure fuel system is necessary, to protect the operator or bystanders from high pressure fluid penetration.
DEF pipes should not be positioned above other fluid pipes that could be damaged by leaking DEF, also consider of effects of DEF on other engine components due to potential corrosion.

**Access to service points**
It is recommended that the engine installer gives consideration to access of all service points on the engine during the installation process and takes action to mitigate the risk of injury to operators & maintenance technicians.

**Noise:**
The engine is not supplied with a silencer as it is considered partly completed machinery, the engine installer is responsible for ensuring that the completed machinery meets the noise regulations.

**Exhaust emissions:**
The engine is not supplied with an exhaust and is classed as "partly completed machinery" in the Machinery directive. The engine installer should understand requirements and is responsible for ensuring that the exhaust gases are directed away from the engine operator workstation. It is recommended that the engine installer gives consideration to the risk from inhaling exhaust fumes. If the engine is to be installed inside a building, take appropriate action to ensure the exhaust fumes are released outside and away from the operator workstation.

**Drainage:**
It is the responsibility of the installer to keep draining locations accessible, or to provide alternative means of draining if not possible.

**Special requirements:**
Some customer applications may require that the engine is designed to meet special requirements (e.g., health and safety regulations, hazardous environments, etc.) The party responsible for the installation of the engine must specify the special requirements to be met. Any new components or systems will be designed, validated, and documented individually.

### 1.3.3 EN60204-1:2006+A1:2009 – Safety of machinery – Electrical equipment of machines Part 1: General requirements

**Electrical Supply**
**Electrical supply – AC supplies:**
All power is DC, except for certain engine installer wired components, e.g., Engine Block Heater. Engine Installer is responsible for meeting the above standard as well as any local requirement for wiring electrical supply to various components.

**Electrical supply – Special supply systems:**
No Special supplies are available. The engine installer is responsible for any specialised electrical supply.
**Physical environment & operating conditions:**
**General:**
See normal operating conditions in respective clause.

Special requirements can be met if requested, for example cold weather packages, but this must be agreed in writing between the Engine Manufacturer and the purchaser.

**Electromagnetic compatibility:**
EMC testing is not applicable to engines, this is a requirement for the entire machine and must be completed by the end user before putting the machinery into use.

**Contaminants:**
The customer is responsible for external control.
**Ionizing and non-ionizing radiation:**
Engine installer responsibility

**Vibration, shock, and bump:**
The customer is responsible for external control.

**Supply conductor terminations and devices for disconnection and switch off:**
**Supply conductor terminations on generator sets:**
Engine installer responsibility.

**Terminal for connection to the external protective earthing system:**
It is the responsibility of the installer to connect engine to a grounding location on the machine, generating set or IOPU.

**Supply disconnecting device:**
Engine installer responsibility.

**Protection against electric shock:**
**Protection against indirect contact:**
**Protection by electrical separation:**
Engine installer responsibility.

**Protection by automatic disconnect of supply:**
Engine installer responsibility.

**Protection of equipment:**
**Abnormal temperature protection:**
Engine installer responsibility.

**Earth fault / residual current protection:**
Application specific, and the responsibility of the engine installer.

**Protection against over voltages due to lightning and to switching surges:**
Application specific, and the responsibility of the engine installer.

**Equipotential bonding:**
**General:**
Linking together of common earth connections. Engine installer controlled.

**Protective bonding circuit:**
Application specific, and engine installer responsibility.

**Functional bonding:**
Application specific, and engine installer responsibility.

**Measures to limit the effects of high leakage current:**
Application specific, and engine installer responsibility.

**Control circuits and control functions:**
**Control functions:**
Engine installer responsibility.

**Protective interlocks:**
Engine installer responsibility.

**Control functions in the event of a failure:**
Engine installer responsibility.

**Operator interface and machine mounted control devices:**
**General:**
Engine installer responsibility.

**Emergency stopping devices:**
**Types of emergency stop device:**
Engine only - Engine installer responsibility.

**Colour of actuators:**
Engine only - Engine installer responsibility.

**Local operation of the supply disconnecting device to effect emergency stop:**
Engine only - Engine installer responsibility.

**Control gear: location mounting and enclosures:**
Engine installer responsibility.

**Wiring outside enclosures:**
**Interconnection of devices on machine:**
Engine installer responsibility.

**Marking, warning signs, and referencing:**
**Functional identification:**
Engine installer responsibility.

**Marking of equipment:**
Engine installer responsibility.

**Reference designations:**
Engine installer responsibility.

**Verification:**
**Verification of automatic disconnect of supply:**
**General:**
Responsibility of the engine installer for the completed machine.

**Test methods in TN-systems:**
Responsibility of the engine installer for the completed machine, the engines are DC only.

**Application of the test methods for TN-systems:**
Responsibility of the engine installer for the completed machine, the engines are DC only.

**Retesting:**
Engine installer controlled.

# PART 1. MECHANICAL APPLICATION AND INSTALLATION MANUAL

# 2.0 Engine Selection and Application

### 2.1.1 Introduction

The purpose of the engine selection chapter is to provide guidance regarding the correct engine and aftertreatment system selection for the machine application.

## 2.2 Engine Selection and Application Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the **EM** symbol.

***Failing to follow these instructions when installing a certified engine in a piece of non-road equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

### 2.2.1 General

- The Installation design must allow for all service and maintenance procedures, including engine replacement, to be conducted safely in accordance with the guidelines published within the relevant service manual.
- The engine is supplied paired to the aftertreatment at the engine factory, so it is essential that the engine and aftertreatment are kept together.
    - Any deviance from this requires engine factory approval.
- To ensure thermal management can occur within the engines work cycle a 5 minute rolling average load >30% in its lightest know work cycle should be adhered to.
- Periods of low load/ low idle running should be minimised to avoid damage to the engine and aftertreatment.
- The engine must be subjected to at least 20 minutes of continuous operation at >30% load during every operating shift. (~8 hours)
- It is the responsibility of the OEM to ensure the installed engine can generate sufficient heat and maintain coolant temperatures in excess of 65°C whilst operating in low ambient and low load conditions.
- For engines operating at fixed speeds, OEM's should pay special attention to the installation's thermal management capability, where an increase in speed is not appropriate, customer load may be required to support thermal management. Where load is required to assist thermal management refer to **Section 13.0 in TPD2193**

### 2.2.2 Ratings

- **EM** The engine rating must be selected to have the necessary power and torque characteristics for the machine in which it is installed so that it can operate in all necessary environmental conditions.
- **EM** The engine must be selected to comply with all the necessary legislation for the area in which the machine is to be sold and operated. Legislative compliance should be checked on the power curve.
- **EM** An engine that has been certified for constant-speed operation must not be used in a variable speed application.
- The engine must be correctly selected and applied in accordance with the industrial rating tier to which the engine has been developed. Rating classifications can be found listed in the ESM.
- **EM** The engine must not be subjected to speeds in excess of 3700rpm (any customer supplied rotating equipment must be selected taking this into consideration).
- **EM** The engine low idle must not be reset to a value lower than the default setting unless approval from the engine factory has been obtained.
- **EM** In the installed condition, the engine must be able to achieve speeds greater than 1500rpm. The machine must not be allowed to constrain the engine speed in anyway such that speeds greater than 1500 rpm cannot be achieved.
- **EM** In the installed condition, the engine must not be constrained to exclusively operate within a power range that has more stringent emissions limits than the (sub-) category the engine belongs to e.g., >560kW engine must not be permanently constrained to operate exclusively below this power.
- **EM** The machine must be able to achieve the desired cold ambient capability with the configured elevated idle speed and machine parasitic load.

- This must be tested in accordance with the relevant engine exhaust temp test procedure.

EM It is the OEM's responsibility to ensure that the machine marking/labelling should be consistent with the unconstrained certified engine speed and power.

EM The installed engine must be operated within the parameters defined in the 'Application concept Appraisal' as detailed in the relevant engine audit form.

### 2.2.3 Labels

- EM The engine emission control information label must be in a location that is readily visible to the average person after all installation and assembly are complete.
- EM If a duplicate emission control information label is supplied with the engine, then the duplicate label must be permanently attached to the equipment, even if the label supplied fitted to the engine is not obscured.
- EM If a duplicate label is not supplied with the engine this must be requested from the Engine Factory.
- EM In all cases the duplicate label must be secured to a part needed for normal operation and not normally requiring replacement.
  - A procedure must be in place to ensure these labels are fitted and positioned correctly.
  - The use of a duplicate emission label must meet the regulatory requirements set out in 40CFR 1068.105(c).
- EM It is the responsibility of the equipment manufacturer to supply and permanently attach a separate label with the statement ‘Ultra low sulphur fuel only’ to the equipment near the fuel inlet in accordance with regulatory requirements 1039.135. This label is not supplied with the engine.
- If the Ether warning label is supplied loose with the engine it must be placed in a permanent location that is clearly visible where Ether would be applied into the engine induction system.
- EM If any of the engine labels are damaged or over sprayed after shipment of the engine it is the responsibility of the equipment manufacturer to replace these labels and fit them in accordance with the Engine Manufacturers’ instruction.
- EM For Installations where a factory provided oil filler cap is not used a visual aid, on or adjacent to the fill location is required to identify the correct oil specification for the engine and operating territory, information on the engines oil specification can be found in the operation and maintenance manual.

### 2.2.4 Service Life and Altitude

The information in this manual is only applicable to engines that operate up to a maximum altitude of 3000m.

For information about the effects of altitude on the service life of the engine, refer to the Operation and Maintenance manual.

## 2.3 Function of an Industrial Power Unit (IOPU)

An Industrial Power Unit is a variable speed engine package that contains the fundamental engine systems required for the engine to operate and be installed into an end application. This generally includes the starter motor and alternator, cooling system (coolant radiator, air to air charge air cooler, fan and shroud) Induction system, front and rear mounting feet and aftertreatment. The function of the IOPU is to provide a complete solution, simplifying engine integration and reducing the required installation design, test and approval work.

An IOPU can be selected from a large range of standard base lists, which provide a variety of options with different ratings, PTO capabilities and aftertreatment locations.

## 2.4 IOPU Usage and Applications

IOPU's are used in a vast array of different applications from stationary units to mobile applications, from completely open units to applications with canopies and completely enclosed engine compartments.

Typical applications include, pump sets for irrigation where they can be manned or operated without an operator for sustained periods of time, platform lifts, lighting towers, car crushers, chipper spreaders, crop sprayers and airport snow sweepers. They are also used in more arduous heavy-duty applications and harsh environments such as rock crushers, screening machines and rock drills in offshore applications. Heavy-duty filtration options for both fuel and air are available for selection for these specific installations and a harsh environment screen for the radiator is also available to help protect against radiator tube erosion in pusher fan applications.

The duty cycle of these applications differs considerably and for pump sets, specific ratings have been developed and approved for this specific application.
As with all applications it is the responsibility of the equipment manufacturer to ensure that all the legislation applicable to the type of machine, the specific territory and the environment that the equipment operates in is met including, for example, exhaust emissions, noise, health and safety requirements.

# 3.0 Mounting Systems

## 3.1 Introduction

The mounting system chapter contains all information specific to the mounting of the IOPU in a stationary application. If mounted in a mobile machine, additional mounting requirements may need to be adhered which will require Application Engineering Approval.

For engines fitted with after treatment the mounting system is critical, not only to the engine, but to maintain compliance with emissions regulations.

When mounting an IOPU care must be taken to ensure that the integrity and durability of emission critical components must be maintained under all machine-operating conditions for the life of the engine.

- To meet emissions requirements the integrity and durability of emission critical components must be maintained under all machine-operating conditions for the life of the engine.
- For some engines additional consideration will need to be taken for the mounting of the electrical components associated with the after treatment.
- In all cases it is recommended that you contact your mount suppliers in the early stages of the installation design process.

## 3.2 Mounting System Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the **EM** symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of nonroad equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

### 3.2.1 IOPU Mounting General

- The engine mounting system must take into consideration the mounting of the engine mounted aftertreatment
- The IOPU must be mounted horizontal.
  - Any static installation angle requires engineering approval.
- The engine must not be mounted in a location where the engine can be submerged in water during operation and as a minimum the wading line must be at least 100mm below the crankcase open breather outlet pipe.
- The static engine installation angle, from horizontal, must not exceed:
  - +/-10° side to side and/or
  - - 7° down at rear. Nose down installation not acceptable.
  - Any Installed angle must be taken into consideration when considering grade ability. Refer to 9.0 Lubrication Systems for more information.
- **EM** The engine must be mounted so that equipment frame deflections do not stress the engine castings and engine to aftertreatment connection beyond allowable limits and must protect the engine and engine to aftertreatment connection from excessive machine vibrations and shock loads.
- The engine mounts must limit the engine movement from shock, inertia, or other forces so that the engine cannot make contact with chassis mounted components.
- The mounting system must adequately dampen 1st and 2nd order vibrations and not induce resonance throughout the normal operating speed range.
- The mounting system must adequately dampen power train or machine induced dynamic loading e.g., track pass frequency, rock hammer and compactor frequency.
- Engine mounts must not be subjected to fluid contamination resulting from oil / coolant servicing that will cause deterioration of the material and may have a consequential effect on the control of engine movement. The material tolerance to fluids is to be defined by the mount supplier.
- There must be sufficient airflow around the Anti-Vibration (AV) mounts to ensure that their maximum temperature limit is not exceeded
  - The maximum temperature of the radiator AV mounts is 100°C under continuous running.
- For IOPU Installations an assessment of the assembled powertrain (engine and transmission) should be conducted to decide on the best location of engine mounts in relation to the assembled centre of gravity. The supplied rear mounting foot on the IOPUs may not be appropriate for all applications and custom mounting feet off the flywheel housing mounting pad may be used.
- The engine must be supported at the front using the two front mounting locations provided under the radiator support bracket. The side pads at the front of the cylinder block must not be used
- The IOPU **MUST** be mounted using AV mounts directly under the mounting locations provided.
- The IOPU **MUST NOT** be hard mounted to a frame or the machine chassis.
- The dynamic bending moment and shear forces at the RFOB and the reaction forces at the front mount and rear mounts, where applicable, must be calculated using the correct Engine Bending Moment Calculator Tool for the engine type selected. The calculated values must be within the maximum and average loading limits in the vertical and lateral planes as detailed in the technical data.

## 3.3 IOPU Mounting System

The 400 Series IOPU has been verified for mobile use including the mounts used within the cooling system package as well as the aftertreatment system.
The shock loading capabilities of the IOPU Unit are as follows:

- 6G vertically @ 1e4 cycles,
- 4G vertically @1e6 cycles
- 4G side-side and fore-aft@ 1e4 cycles
- 3G side-side and fore-aft @ 1e6 cycles

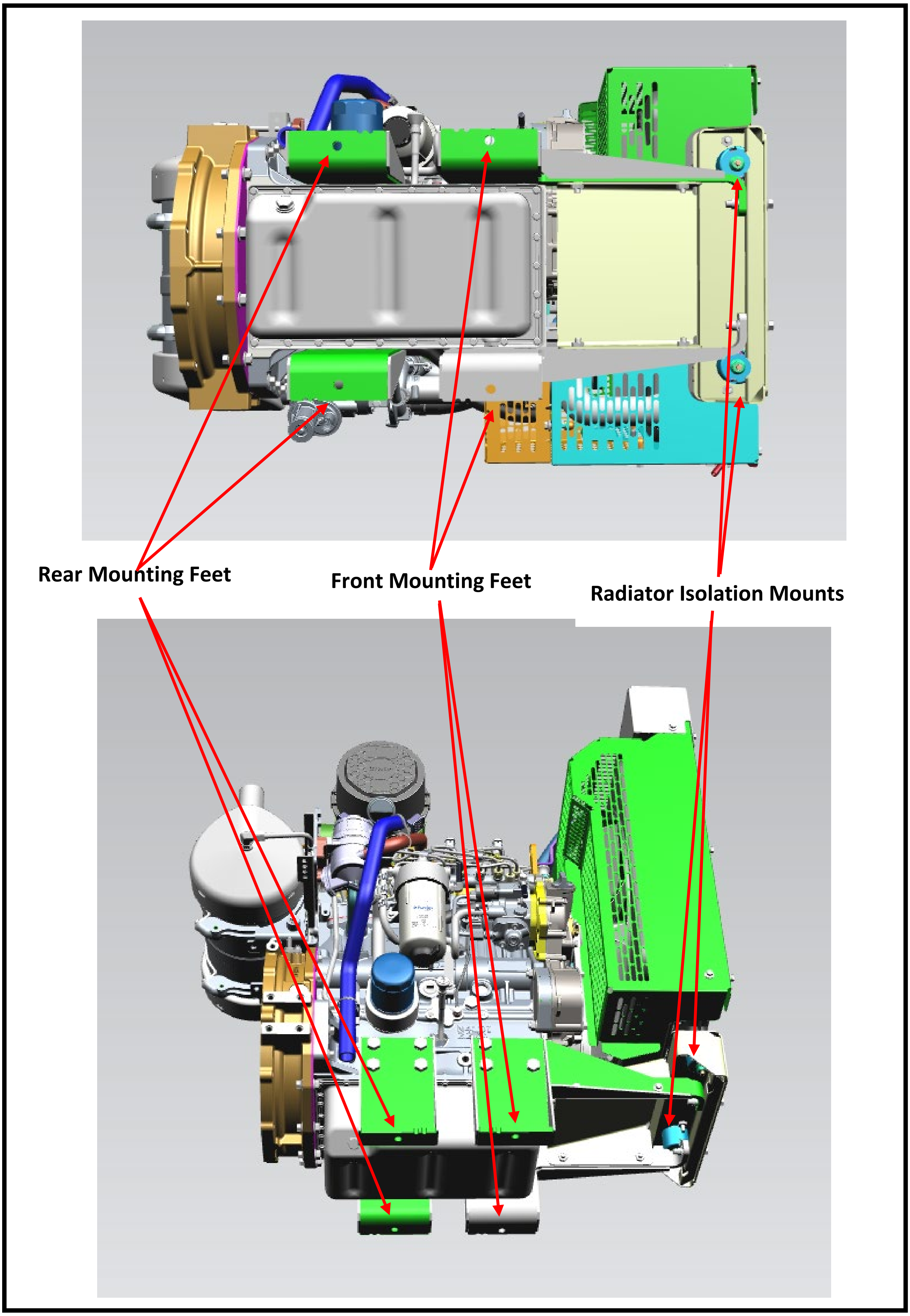
All components in the IOPU package including the engine and non- engine mounted components meet vibration criteria severity grade 71 based on ISO 10816-6.
Details of the mountings used on the IOPU unit are detailed in the following sections.

### 3.3.1 400 Series IOPU Mounting

The rear mounting feet are fitted to the rear of the cylinder block whilst the front mounting feet are incorporated into the radiator mounting bracket, which mounts off the front of the engine.
The radiator and charge cooler cores are mounted to the radiator bracket with isolation mounts as shown in **Figure 3-1**.

The aftertreatment is mounted on a bracket above the flywheel housing and the air filter is mounted on a bracket above the valve cover.

The IOPU **MUST** be mounted utilising the mounting feet provided.




**IOPU Mounting Position Figure 3-1**

# 4.0 Induction System

## 4.1 Introduction

The induction system is one of the most important aspects of an engine installation as it can have a direct effect on engine output, fuel consumption, exhaust emissions and engine life.

It is, therefore, essential to ensure that the Induction system and any associated components are correctly specified and installed to provide a robust and durable system that ensures emissions compliance throughout the life of the product.

With this in mind, the installed induction system must be designed to supply clean, dry, and cool air to the engine, with a minimum of restriction. The system must be designed to withstand the shock loadings and working conditions that will be met in service and must provide reliable sealing and durability with a minimum of maintenance.

Air-to-Air Charge Cooling requirements are covered separately in the cooling system, Chapter 6.0.

## 4.2 Induction System Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the **EM** symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of nonroad equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

### 4.2.1 Factory Fitted Air Cleaner

When customers take a factory supplied and fitted air cleaner, inclusive of all intake pipework, the following Mandatory requirements must be adhered to:

- The air cleaner assembly and air cleaner to turbocharger induction pipework must not be modified in any way from the supplied condition.
- Any modifications require applications approval and will require validation testing.
- The air inlet temperature sensor must not be removed or relocated from the air cleaner to turbocharger induction pipework and must be connected in accordance with the requirements detailed in section 2 of this manual.
- The air cleaner must have adequate dust-holding capacity to achieve acceptable air cleaner life in representative field applications Figure 4-1 below details the standard supplied filter capability.

| **Duty classification** | **Dust Holding Capacity** (Tested to SAE J726b or ISO 5011) | **Suitable Environments** | **Example Applications** |
|---|---|---|---|
| Medium Duty | 10g/cfm (353 g/m$^3$m) | No significant dust concentrations | General Agricultural and construction equipment. Gensets in buildings. FLT in normal factory conditions, airport equipment. |

**Figure 4-1 Air Cleaner Medium Duty Classification.** Correct table required

- The air filter element must be serviceable without major component removal.
  Distance for removal required
- The integrity of the pipework must not be disturbed for routine maintenance procedures.
- **EM** The restriction indicator must remain visible.
  - The restriction indicator is provided fitted to the side of the air filter and has been sized appropriately for the engine.
- The air cleaner itself must not be subject to excessive heat that may result in its deterioration.
  - The maximum peak skin temperature must not exceed 130degrees.
  - The normal operating temperature should not exceed 83°C sustained.
- The maximum clamping torque on the inlet and outlet connection must not exceed 2.5Nm
- **EM** The air inlet must be protected against the ingestion of water, foreign particles from dust or dirt and re-circulated hot air and exhaust gas.
- **EM** The air inlet must be protected against the ingestion of water, foreign particles from dust or dirt and re-circulated hot air and exhaust gas.
- The intake air temperatures must comply with all of the following conditions:
  - **EM** The air inlet temperature sensor must be no more than 5°C above the local machine ambient temperature.
  - The turbo compressor inlet temperature must be no more than 5°C above the air inlet temperature sensor reading
  - The turbo compressor inlet temperature should be no more than 10°C above the weather station ambient.
  - These must be measured in accordance with the relevant test procedure.
  - Refer to section the main industrial mechanical A&I manual for temperature definitions and further information

- The engine uses temperature offsets to establish a representative ambient temperature to use in fuelling calibrations and derate strategies. Therefore, it is imperative that the stated limits are complied with to avoid performance issues and unnecessary derates becoming active.
- Where pusher and puller fans are used the IOPU may require air to be ducted to the air filter from a colder region of the engine bay.
- For best performance it is recommended that the air is drawn from in front of the radiator, Compressor inlet depression limits will still apply in this case.

### 4.2.2 Air inlet

EM The induction depression for clean and dirty filters must not exceed the maximum limits detailed in the relevant ESM.

  - These must be tested in accordance with the Air Inlet Restriction test procedure

EM The air inlet must be protected against the ingestion of water, foreign particles from dust or dirt and re-circulated hot air and exhaust gas.

- The intake air temperatures must comply with all the following conditions:
  - EM The air inlet temperature sensor must be no more than 5°C above the local machine ambient temperature.
  - The turbo compressor inlet temperature must be no more than 5°C above the air inlet temperature sensor reading.
  - The turbo compressor inlet temperature should be no more than 10°C above the weather station ambient.
  - These must be measured in accordance with the relevant test procedure.
  - Refer to section 4.2.4.1 for temperature definitions and further information.
- The engine uses temperature offsets to establish a representative ambient temperature to use in fuelling calibrations and derate strategies. Therefore, it is imperative that the stated limits are complied with to avoid performance issues and unnecessary derates becoming active.
  - For IOPU applications using puller fans this may require air to be ducted to the air filter from a colder region of the engine bay.
  - For best performance it is recommended that the air is drawn from in front of the radiator. Compressor inlet depression limits will still apply in this case.

### 4.2.3 Air inlet Temperature Sensor

The air inlet temperature sensor and 'O' ring is supplied fitted.
It is a passive sensor used to measure the air temperature entering the turbo, after the air cleaner.

EM The factory supplied sensor must remain installed in the induction pipework upstream of the turbocharger.

EM The air inlet temperature sensor must not be exposed to temperatures in excess of 125°C.

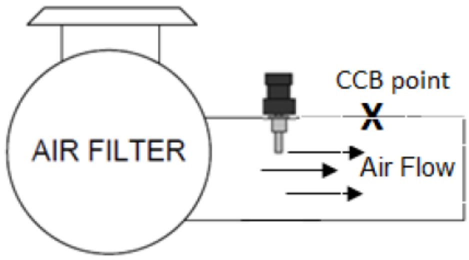



Figure 4-2 Air inlet temperature sensor location

### 4.2.4 Air Inlet Temperature

#### 4.2.4.1 Induction Temperature Definitions

- **Weather station temperature:**
  The temperature that would be measured by a static weather station in a given region.

- **Local Ambient temperature:**
  Air temperature into air inlet ducting.
  For installations that are permitted to draw air from an under-hood location then the ambient temperature shall be the air temperature immediately outside the hood.

- **Intake air temperature:**
  The temperature measured at the intake air temperature sensor.

#### 4.2.4.2 Induction Temperature Recommendations

- It is always advisable to keep the air temperature entering the engine as close as possible to the local ambient temperature. High intake air temperature means less dense air entering the engine, which may result in increased smoke, less power, increased fuel consumption, overheating and charge cooler performance issues.
- To encourage good machine design, help machine performance and avoid hot air recirculation there is also a requirement to keep the engine air inlet temperature less than 10 degrees rise over the weather station ambient. It is recognised, however, that for certain machines like a Backhoe Loader and Hydraulic Excavator, this is not always possible. In certain modes of operation these machines create and operate within their own temperature bubble causing an increased local machine ambient temperature.
- In all cases care should be taken to ensure that the correct temperature is used in machine design to maintain the required machine performance and capability under all operating conditions.

#### 4.2.4.3 Induction Temperature Measurements

Figure 4-3 below shows the allowed temperature rises above ambient within the induction system. Temperature measurements must be taken to ensure compliance with the mandatory requirements in section 4.2.2 in accordance with the defined test procedure.

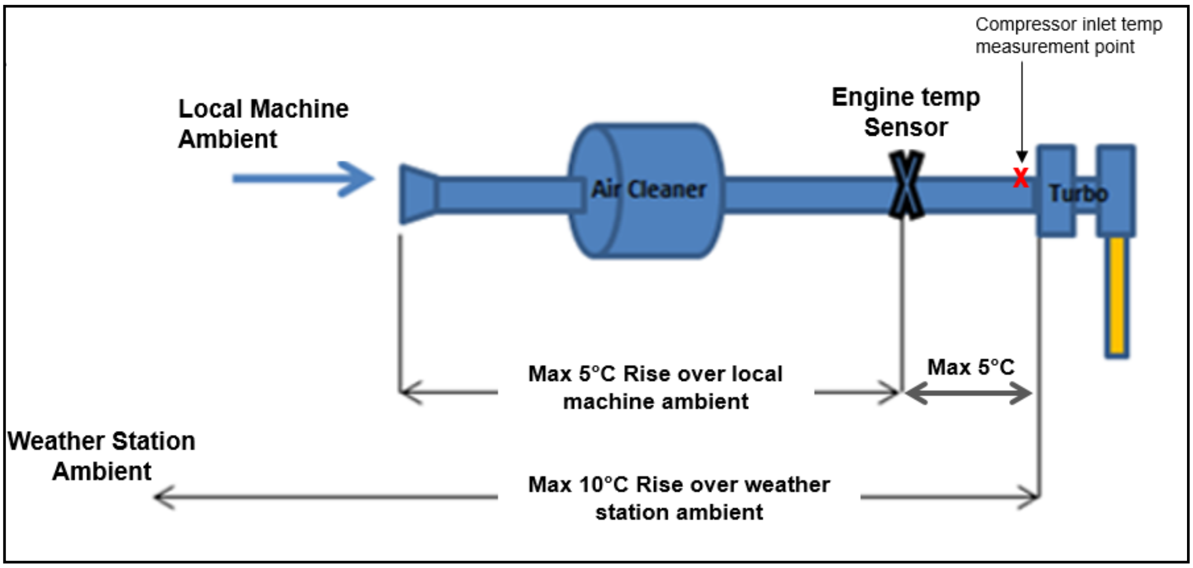



**Figure 4-3- Induction System Temperatures**

## 4.3 Induction System Overview

### 4.3.1 Air System Circuit

- The air system circuit for a 404J-E22TA Engine is shown in Figure 4-2 below.

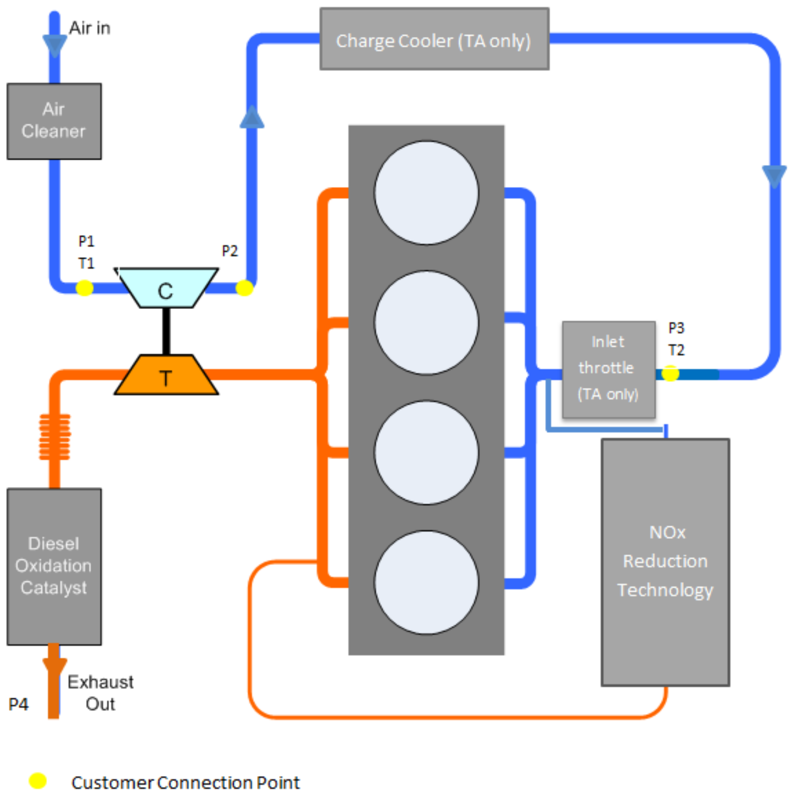



**Figure 4-2 - Air System Circuit 404J-E22TA**

| Channel | Channel Description |
|---|---|
| T1 | Compressor Inlet Temperature |
| T2 | NRS Inlet Temperature |
| P4 | Exhaust Backpressure |
| P1 | Inlet Restriction |
| P2 | Turbo Compressor Out / CAC Inlet |
| P3 | NRS Inlet Pressure |
| P4 | Exhaust Backpressure |

## 4.4 Induction System Components

### 4.4.1 Turbo -air inlet connection

Both 3- and 4-cylinder engines must have an air inlet connection (SV option) selected from the option offering. This provides a horizontal or vertical connection supplied fitted to the turbocharger inlet as shown in Figure 4-3.

- The Engine Factory supplied components within the crankcase breather system must not be modified, tampered, or disturbed in any way from the supplied condition. If this is a requirement contact your Application Engineer.
- Changing the factory supplied breather system on the engine i.e., from closed to open or from open to closed requires that the engine certification is checked to ensure the engine legislative status is maintained and that the engine software is modified accordingly.
- Operation of the breather system below -25°C requires additional precautions to be taken to ensure the breather gas does not freeze. This requires Engine Factory Approval and additional validation work.
- In certain circumstances for example where the cold air flow across the breather assembly is in excess of 1.5m/s, where there is low residual load or extended idle etc., the use of insulation or a heated breather maybe required at a higher ambient temperature than -$25^{0}$C. This is application dependant, and a risk assessment must be carried out as well as testing.

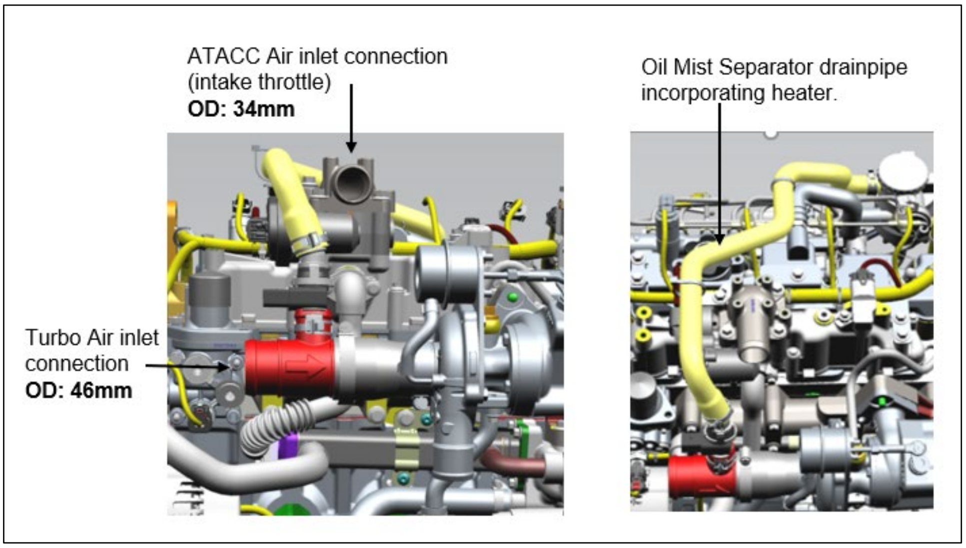



**Figure 4-3 – Turbo air inlet and ATACC inlet connection CCV**

### 4.4.2 Inlet Throttle

All engines use an inlet throttle on the engine intake manifold as shown in Figure 4-3 above. This throttle is a thermal management device used to ensure effective operation of the DOC at all engine operating conditions. The throttle assembly also incorporates the customer connection for cooled air into the intake manifold from the charge air cooler.

### 4.4.3 Induction Restriction

The induction system restriction, measured at the turbocharger inlet, is the total restriction due to:

- Air filter restriction
- Resistance to air flow due to pipe friction
- Air velocity effects.

If the restriction is excessive then the engine will not receive sufficient air for complete combustion to occur. This may result in a loss of power, increased DPF soot loading rate (DPF engines), risk of visible smoke (non DPF engines), poor fuel consumption and other issues that may impact emissions.

The maximum induction depression must be measured during installation audit testing and is a requirement for installation sign-off. This must be tested in accordance with the relevant engine test procedure.

### 4.4.4 Air inlet Location

The position of the air filter inlet, or of the inlet to the air filter extension if fitted, should be such that air is drawn from an area:

- Of the lowest possible dust concentration.
- Shielded from water ingress including spray and cleaning processes. Water will cause filter damage or plugging and possible engine and intake system corrosion.
- At a temperature, as close as possible to the prevailing ambient temperature. Additionally, care should be taken to minimise the possibility of exhaust fumes being drawn into the induction system, since this will result in a reduction in element life and increased air inlet temperatures.

**IOPU Installations**

When IOPU's are installed in open or enclosed applications air should be drawn from a cool source to ensure that the engines intake temperature does not exceed the rise over ambient temperature limits outlined in **FTP 14/03 Air Inlet Temperature (ROA)**

If ducting is required to obtain cooler air the filter should remain on the engine to prevent harmful dirt from leaking into the engine through ducting joints, ducting should be located away from the vicinity of the exhaust pipe or aftertreatment to ensure the air provided to the engine is as cool as possible.

When designing air intake ducting, consideration must be given to appropriate routing, duct support and system restriction, especially on engines where overhead cranes are used for servicing the engine or machine, proper support for ducting adjacent to the engine is critical to ensure the turbo and other engine components are not loaded with additional weight.

### 4.4.5 Air Intake Shutdown Valve

The use of an air intake shutdown valve is acceptable for use in an emergency and not a part of normal operating duty cycle.

The recommended installation of an air intake value also incorporates the use of pressure release (dump) valve and is summarised below:

- The air intake valve is installed after the charge air cooler and cuts off the air immediately A pressure release (dump) valve is also used and installed after the turbocharger. This prevents excessive pressure building up which may lead to surge issues and problems caused by excessive loading on the turbocharger compressor blades.

The air intake shutdown valve can be installed in the induction pipework before the turbocharger however, the loss of pressure on the intake side of the compressor may result in an internal oil leakage at the turbo bearing and although this is not likely to cause damage to the turbocharger itself there is a risk that the leakage of oil may be drawn into the charge air circuit contaminating the cooler and reducing its overall efficiency. The amount of oil leaked will depend on pressure delta, angular tilt, oil temp, oil pressure, turbocharger speed and time spent at that condition. For infrequent, emergency use only, the risk maybe considered as acceptable.

Installing the air shutoff valve after the turbocharger before the air charge cooler, however, is not acceptable as the build- up of pressure in the turbo compressor will cause surge events and high compressor blade loading, which if activated under high load conditions is likely to result in compressor blade failure.

#### 4.4.6 Pre–cleaners

- Pre-cleaners or dust evacuator valves must be matched to airflow of the engine.
- Evacuator valves must be installed vertically.

#### 4.4.7 Exhaust Assisted Evacuation

EM The use of exhaust assisted pre-filter evacuation systems is acceptable.
EM The exhaust /scavenge pipe must be connected into the exhaust pipe work after any aftertreatment canisters to prevent fouling.
EM A check valve must be incorporated into the scavenge line to prevent reverse flow during all conditions.
EM Provision will need to be made to exclude the scavenge line from the system during in use (Portable emissions measuring system PEMS) testing.

#### 4.4.8 Air intake Shutdown Valve

- The use of an air intake shutdown valve is acceptable for an emergency stop use only.
- The intake throttle must not be used as an emergency shutdown device.
- The valve should be installed in accordance with the requirements detailed in section 4.4.5 and details provided in the electronic A&I Manual.
- Refer to section 1.3.2 Emergency stopping in the Engine installer’s responsibility section.

# 5.0 Aftertreatment & Exhaust Systems

## 5.1 Introduction

To attain the relevant emissions standards, it is necessary for aftertreatment to be incorporated within the exhaust system of some engines. This aftertreatment is required to enable the engine to produce its published rated power, fuel consumption and conform to the new emissions standards.

This chapter outlines the mandatory requirements and design considerations for exhaust systems and components, including aftertreatment modules where relevant.

### 5.1.1 Safety

Warning: Improper operation, maintenance, or repair of this product may result in injury. 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 and fire hazards are possible.  Failure to properly connect the Aftertreatment, manage the regeneration gas temperature, adequately route exhaust gases, and remove debris around hot components significantly increases risk and may result in personal injury. High component skin temperatures also increase the risk on personal safety and care should be made to protect or advise the operator where necessary.

## 5.2 Aftertreatment and Exhaust Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the **EM** symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of nonroad equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

### 5.2.1 General Exhaust System Mandatory Requirements

- It is not permitted to use exhaust brakes on any engine model.
- **EM** The customer tailpipe:
    - Must be designed to prevent water and dirt ingress into the aftertreatment and engine.
    - Must be matched to suit the engine or aftertreatment outlet connection. This is detailed in 5-6 section 5.5.1
    - Must not exceed the bending moment limit at the aftertreatment outlet connection in 5-5 section 5.4.2.1.
        - Refer to section 5.4.2.2 for calculation process.
- **EM** The exhaust system backpressure must be within the limits published within the relevant ESM. Refer to section 5.4.1 for more information.
    - All testing must be conducted in accordance with the defined test procedure
- The Exhaust system component temperature limits must be adhered to:
    - Refer to Appendix D 'UHT and DEF test Acceptance Criteria and UHT Gauge map' in the relevant engine test procedure document for component temperature limits.
    - Component temperatures must be tested in accordance with the relevant engine test procedure.

### 5.2.2 General Aftertreatment Mandatory Requirements

- **EM** The engine must be installed and operated with the aftertreatment that has been matched to the engine to ensure emissions compliance.
- **EM** All joints used between the engine and aftertreatment must be industry standard, leak tight and must be durable for:
    - 8000 hours for engines >37kW.
    - 5000 hours for engines <37kW.
- **EM** Under no circumstances is it acceptable to modify, tamper or customise the aftertreatment assembly, aftertreatment components or engine to after treatment interconnecting pipework as supplied from the Engine Factory.
    - The aftertreatment and aftertreatment mounting brackets must not be re-orientated from the supplied position.
    - It is not permitted for the aftertreatment canister restraining clamps (to the mounting frame) to be loosened to re-orient the canister.
- **EM** The use of thermal insulation (for example thermal lagging or wrapping):
    - Must not be used on any engine or engine system component, including the aftertreatment, without factory approval.
- **EM** Welding components onto the aftertreatment canisters is prohibited.

- EM Mounting components, including the tailpipe support structures, to the aftertreatment or aftertreatment brackets is prohibited.
- EM The aftertreatment is not qualified as a spark arrestor. If this is an application requirement then it is recommended to work directly with the applicable bodies (i.e., U.S. Department of Agriculture, Forest Service) to ensure all the necessary requirements are met.
- Painting of any aftertreatment component is prohibited.
- EM If a Muffler, Dust Ejector or Spark Arrestor is required, it must be connected after the outlet from the aftertreatment can.

### 5.2.3 Cleanliness Requirements

EM The internal surfaces of all engine exhaust system pipework from the engine to the aftertreatment outlet must adhere to the cleanliness requirements detailed in Table 5-1 below:

- This is needed to prevent poisoning of the aftertreatment and requires the pipework to be clean and free of the additives used within the production process.
- The cleanliness must be maintained through the customer assembly process.

| Internal Specification reference | Type of surface the cleanliness requirement applies to | Largest Particle size allowed in any direction (μm) | Max mass of contaminants allowed per square meter of tube's fluid-wetted area. (mg/m2) |
|---|---|---|---|
| 1E0318E | Internal | 1200 | 230 |

**Table 5-1 Engine to aftertreatment pipe work Cleanliness**

#### 5.2.4 Aftertreatment Sensors

- The installation requirements for aftertreatment sensors can be found detailed in Chapter 11 section 11.3.

#### 5.2.5 Maintenance and In Use Testing Mandatory Requirements

EM Where the addition of a sample pipe to the exit of the exhaust stack does not provide a suitable non-diluted sample for in use testing (e.g., due to excessive backpressure, or use of air entrainment into the exhaust for cooling) adequate provision must be made in the design to enable emission-sampling equipment to be used successfully.

EM The aftertreatment is not serviceable. Only the aftertreatment temperature sensors can be replaced.

## 5.3 Aftertreatment System Overview

### 5.3.1 Engine Platform Technologies

Figure 5- below shows the aftertreatment technology for each engine platform and power band. These technologies have been selected as the optimal combination to meet emissions standards. The following section provides details of the aftertreatment arrangements.

| | | 403J-E17T | 404J-E22T | 404J-E22TA |
|---|---|---|---|---|
| EU Stage V | Displacement | 1.7L | 2.2L | 2.2L |
| | Cylinders | 3 | 4 | 4 |
| | Maximum power | 36 kW | 45 kW | 55 kW |
| | Maximum torque | 166 Nm | 222 Nm | 270 Nm |
| | Rated speed | 2800 rpm | 2800 rpm | 2800 rpm |
| | Aspiration | Turbo | Turbo | Turbo After-cooled |
| | Fuel system | High Pressure Common Rail | | |
| | Emissions Technology | EGR, DOC,DPF | | |
| | Thermal Management | Intake Throttle, Injection timing | | |

**Figure 5-2 - Platform Technologies**

#### 5.3.2 Aftertreatment Arrangements

DOC and DPF aftertreatment is required on all 400J-E engines with EPA Tier 4 Final and EU Stage V emissions certification. This is offered in both engine mounted aftertreatment and remote mounted variants

#### 5.3.2.1 System layouts/ Aftertreatment arrangements

Figure 5-3 below shows a generic layout of the exhaust system.

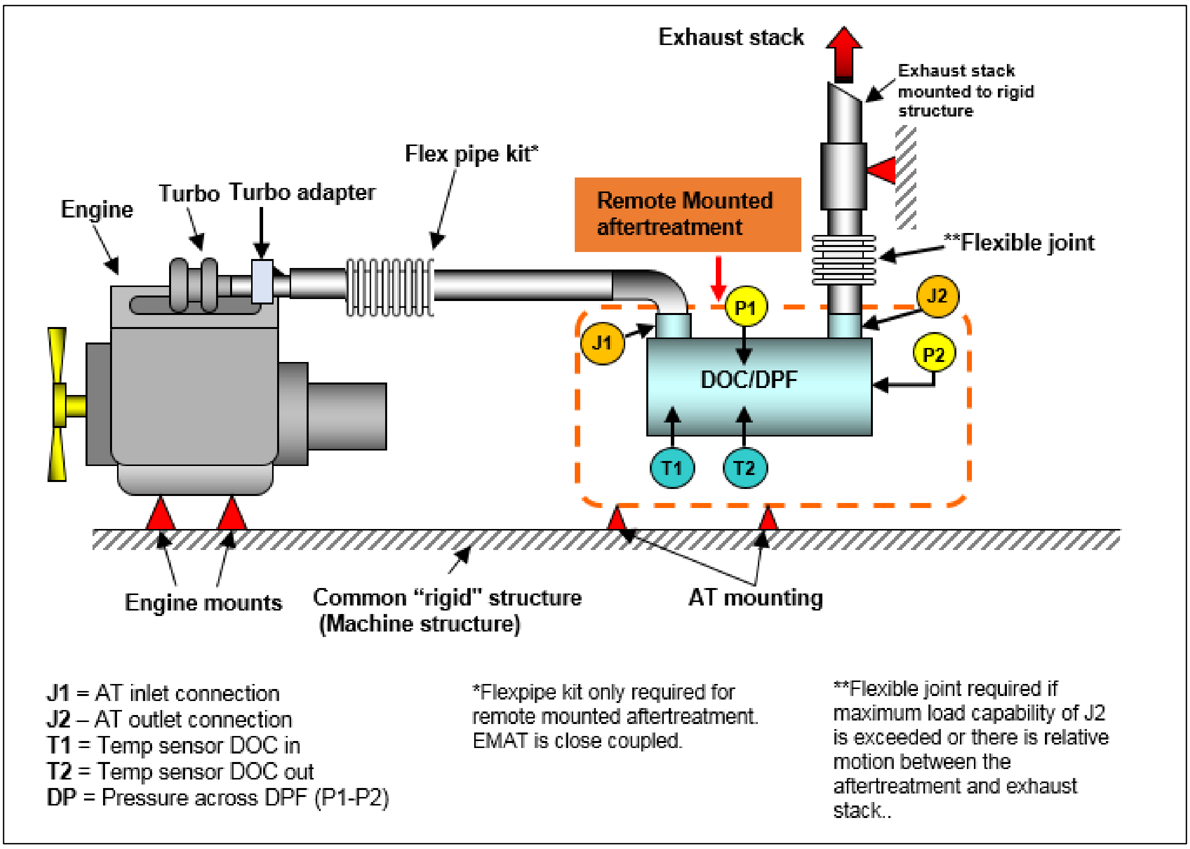



**Figure 5-3 - Aftertreatment Schematic**

#### 5.3.2.2 System Hardware Overview

The aftertreatment used on these engines is a single DOC/DPF cannister. It can be supplied engine mounted, transversely on the flywheel housing and close coupled to the engine as shown in Figure 5- or loose for remote mounting to the machine chassis using a flexible connection.

The aftertreatment, DOC/DPF cannister, is fit for life with a dual temperature sensor at the DOC inlet and outlet. These sensors are supplied fitted, the DPF delta pressure lines and the controller are supplied mounted to the DOC/DPF cannister, this is on the near side under the aftertreatment mounting.

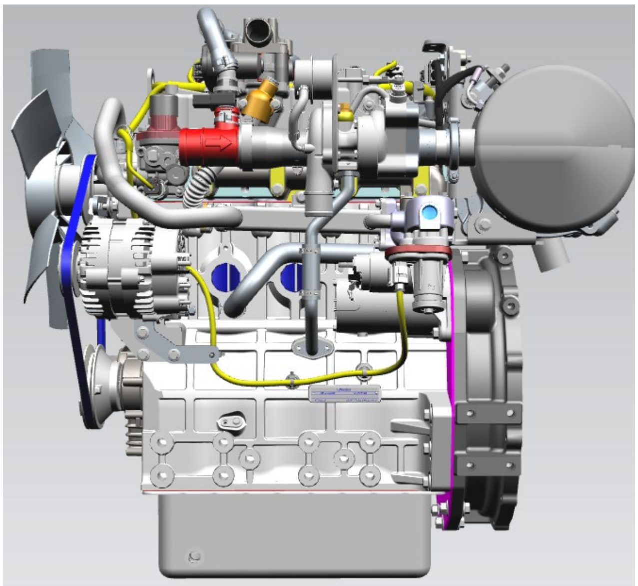


**Figure 5-4 - Engine Mounted aftertreatment (EMAT)**

## 5.4 Aftertreatment and Exhaust Operational Parameters

### 5.4.1 Backpressure Requirements

Refer to Mandatory Installation Requirements section 5.2.1 and section 5.2.2

The exhaust backpressure must be measured for both 3 and 4-cylinder engines.

As all engines include a DPF in the aftertreatment, the maximum pressure (back pressure) of the exhaust system is achieved when the aftertreatment is fully loaded with ash, this is known as the 'end of life' (EOL) condition.
A 'New' exhaust system must be designed and tested to be within the maximum and minimum 'start of life' (SOL) limits, which takes in to account the additional restriction as the DPF becomes loaded with soot. The minimum SOL condition is normally easily met by the exhaust system components supplied with the engine, however in some cases it is not, and it is necessary to meet a minimum back pressure as well as maximum.

The location of the exhaust backpressure measurement is dependent on whether the engine has engine mounted aftertreatment or if it is supplied loose for customer fitment on the machine chassis. For EMAT the backpressure should be measured at the DPF outlet to ensure an accurate measurement and prevent the need to disturb the close coupled engine to aftertreatment connection. For remote mounted aftertreatment, however, the exhaust back pressure must be measured at the turbo outlet.

The back-pressure limits depend on engine type and or rating and care should be taken to ensure the correct values are used. This information is detailed in the relevant engine ESM.
Note the value published on the power curve should not be used for this purpose.

All testing must be conducted in accordance with the defined test procedure.

### 5.4.2 Joint Loading

#### 5.4.2.1 Joint Loading Limits

Refer to mandatory installation requirements section 5.2.2.

Table 5-5 below shows details of the maximum allowable static and dynamic load on the Turbocharger and aftertreatment inlet and outlet connections. This must not be exceeded under any operating condition.

| Engine | Exhaust Component | Aftertreatment | | Static BM Limit (Nm) | Dymanic BM Limit (Nm) |
|---|---|---|---|---|---|
| | | EMAT | Remote | | |
| 403J-E17T, 404J-E22T, 404J-E22TA | Turbo outlet | | x | 0.24 | 24 |
| | DOC/DPF inlet | | x | | |
| | DOC/DPF outlet | x | x | | |

**Table 5-5 - Exhaust Component Load Limits**

#### 5.4.2.2 Aftertreatment Joint Loading

All pipe work connected to outlet should be carefully designed, assembled, and adequately supported to minimise the joint load, prevent induced stress, and avoid vibration and resonance. To establish whether the joint loading is acceptable for a particular installation, the step-by-step method, detailed below should be followed.

**Step 1.**
Calculate static load acting on the joint using the following formula:

Static Bending Moment = m x g x L

'm' = Total mass of the unsupported pipe including any sensors, sensor bosses etc

'g' = Acceleration due to gravity (9.8m/Sec2)

'L' = Total length of the unsupported pipe from the Aftertreatment outlet (including the engagement length with the ball/slip joint) to the centre of gravity of the pipe. Refer to worked examples below to calculate total length.

- If Static Bending Moment ≤ Value specified in Table 5-5. The design is acceptable and is approved.
- If Static Bending Moment > Value specified in Table 5-5. The Dynamic Bending Moment must be calculated -proceed to step 2.

**Step 2.**
Operate the machine on a regular work cycle and take acceleration measurements at the centre of gravity of pipe.
Calculate dynamic load using the following formula:

M = m x a x L

M= Dynamic load in Newton-Meter, Nm

'm' = Total mass of unsupported pipe (including any sensors, sensor bosses etc. that are supported by the joint) in Kilogram, Kg.

'a' = Peak Acceleration (not RMS) at the centre of gravity of the unsupported supported pipe in $m/s^2$. *Ensure Frequency limits from up to 200Hz are covered.*

L = Total length of the unsupported pipe from the aftertreatment outlet (including the engagement length with the ball/slip joint) to the centre of gravity of the pipe. Please see examples in section 2 to calculate Total length.

- If Dynamic Load is ≤ 24Nm – The design is acceptable and is approved.
- If Dynamic Load is > 24Nm – The design is not acceptable and must be re-designed - proceed to step 3.

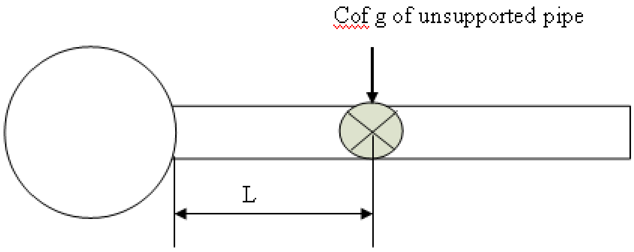
**STEP 3: Redesign Exhaust Stack Connection.**
If a redesign of the exhaust stack is necessary, then the following points should be considered:

- The use of shorter or lighter pipes.
- Supporting pipes using brackets. Use sufficiently stiff brackets to avoid system resonances. Brackets should be durable enough to meet machine durability life requirements. Ensure Brackets are supported by the machine chassis or other significant machine mounting structure and not the Engine or aftertreatment.
- A flexible bellows section and supporting brackets can be used to decouple tail pipe resonances from the aftertreatment. Support brackets are recommended on the machine side of the flex pipe. The mass of the bellows section should be taken into account to calculate any static or dynamic loading as above.

Any re-design must be re-evaluated to ensure the design is robust and the limits are met.

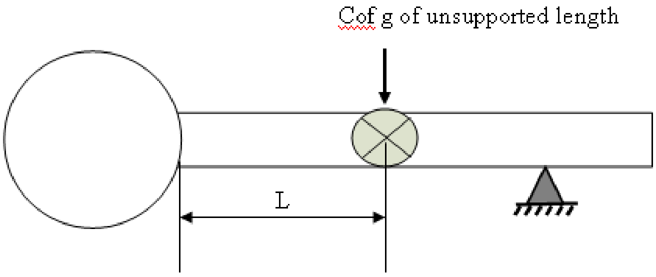
**Worked examples:**

**Case 1: Straight pipe, unsupported.**

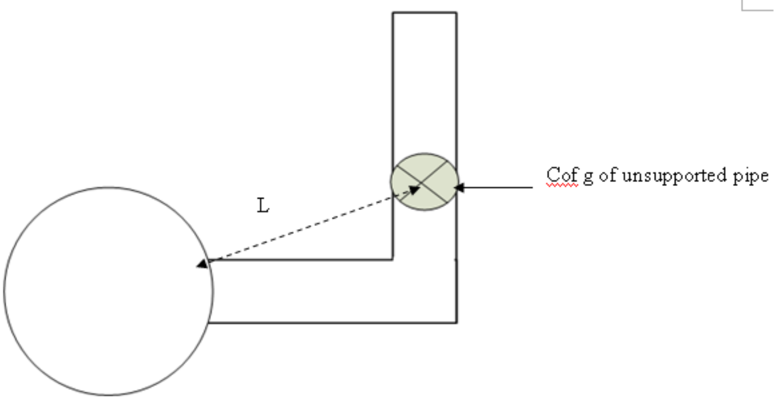



'L' = Total length from CEM outlet to the c of g of unsupported pipe.

**Case 2: Straight pipe supported**

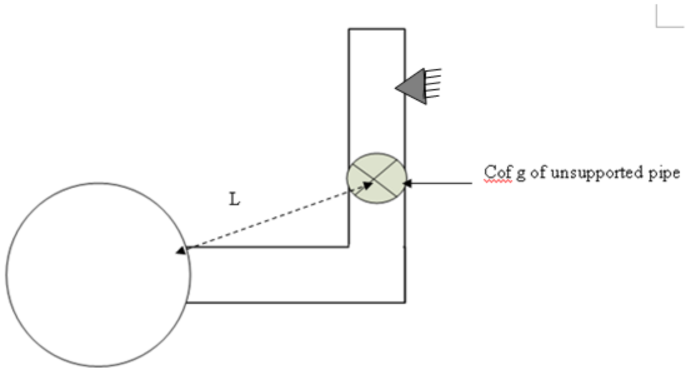



**Case 3: Bent Pipe unsupported**




$$L = \sqrt{(x)^2 + (y)^2 + (z)^2}$$

Where X, Y & Z are the distance of the c of g of the unsupported pipe from the aftertreatment outlet in each of the three planes.




$$L = \sqrt{(x)^2 + (y)^2 + (z)^2}$$

Where X, Y & Z are the distance of the c of g of the unsupported pipe from the aftertreatment outlet in each of the three planes.

**5.4.3 Temperature Requirements**
Refer to Mandatory Installation Requirement section 5.2.2.

Retention of exhaust temperature and reducing the heat lost from the turbo outlet to the aftertreatment inlet connection is vital to ensure effective and timely aftertreatment regeneration. Insufficient temperature can lead to reduced passive regen, increasing the need and frequency of active regeneration, which if required too often can initiate engine protection strategies.

The use of insulation is discussed in section 5.2.2.

**5.4.3.1 Engine Mounted Aftertreatment (EMAT)**
For EMAT the aftertreatment design has been fully validated taking into consideration a maximum air temperature and flow across it. It is, therefore, not mandated to measure the temperature drop at the aftertreatment inlet. If the installation design however provides a significant continual path of cool air flow across the aftertreatment or allows cool air to be blasted onto the aftertreatment then a temperature test will be required to ensure the minimum temperatures are maintained.

**5.4.4 Vibration Requirements**
All vibration limits are now contained within the relevant test procedure document.
The requirement to measure vibration is dependent on the engine type, aftertreatment configuration, EMAT or remote, the type of machine, installation itself and machine operation. Further advise and recommendations can also be found in the test procedure document.

## 5.5 Aftertreatment and Exhaust System Design Considerations

With the inclusion of aftertreatment into the engine system, emissions will no longer be regulated at the engine exhaust outlet but will be regulated at the aftertreatment outlet. This means that the aftertreatment unit itself and the connecting parts from the engine to the aftertreatment are now considered to be “emission critical components” under the legislative (EPA /EU) regulations, and must consequently, be very carefully designed and controlled to ensure the emissions regulations are adhered to throughout the life of the product.

Compliance with regulations governing emissions related components is imperative. In order to comply with these requirements, there are a number of key elements that must be considered when designing the exhaust system. These are detailed in the sections below:

### 5.5.1 Engine Mounted Aftertreatment

An on engine mounted aftertreatment is available as part of the option offering. This is a fully validated approved solution and should be used for all machines where the installation allows.

The EMAT should not be modified in any way from the supplied condition, this includes the mounting or welding any components to the aftertreatment or aftertreatment brackets, which is prohibited.

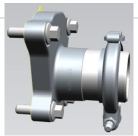
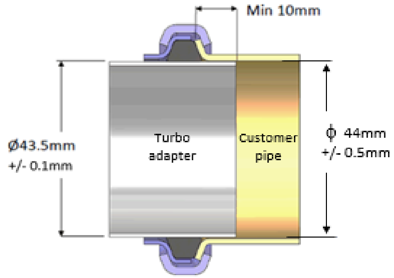
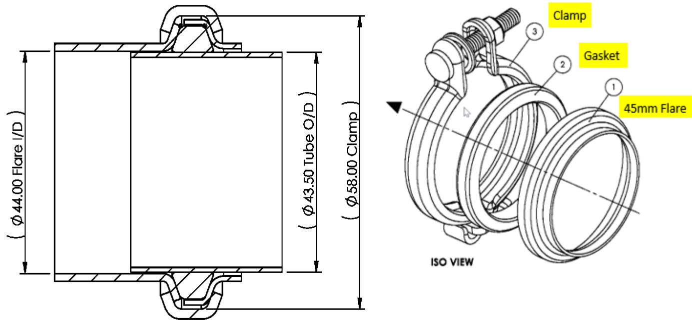
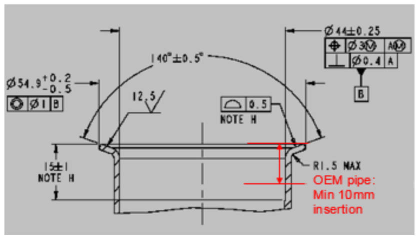
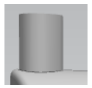
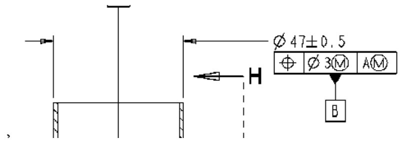
| Engine | Exhaust Component | Engine side Connection | Required customer connection Type and size | |
|---|---|---|---|---|
| | Turbo outlet adapter (SD034)<br> | 43.5 +/- 0.1mm OD straight connection | Suitable for direct connection of Flexpipe (bellows). Or swaged up tube with flared end **44+/-0.25mm ID** Min 1.5mm wall thickness and 10mm insertion. |  |
| | Flexpipe - SU012 Bellows<br> | 44+/-0.25mm ID Teconnex flared connection | Plain pipe 43.5+/-0.1mm OD |  |
| 403J-E17T, 404J-E22T, 404J-E22TA | Clamp<br> | 58mm Teconnex Clamp | On Assembly all components in slip joint must be assembled in correct sequence shown. This clamp has a graphite gasket and provides a leak free seal. It is ft for life bit must be replaced once disturbed after the engine has run. | |
| | DOC/DPF inlet<br> | 44 +/- 0.25mm ID | Plain pipe or swaged down 43.5mm +/- 0.1mm OD. Min 10mm insertion SS304 |  |
| | DOC/DPF Outlet<br> | Slip Join 47 +/-0.5mm OD | Plain pipe 48+/-0.5mm ID 35-45mm insertion (connection for venturi also acceptable) |  |

**Table 5-6-Exhaust Component Connection Sizes**

### 5.5.2 Exhaust pipe outlets

- The exhaust pipe outlet must be adequately supported to minimise the joint load, prevent induced stress, and avoid vibration and resonance.
- The design **MUST**:
  - Not exceed the maximum dynamic joint load of the DPF outlet connection. Refer to section 5.4.2.1.
  - Must have a nominal internal diameter to match the aftertreatment outlet connection. Refer to Table 5-6.
- Exhaust outlets must be provided with an appropriate means of preventing water ingress. This can be accomplished by several methods, but these can impose restrictions that can significantly increase the backpressure so careful consideration must be taken during selection.
  - The use of a rain cap, exhaust flaps, slots within the exhaust pipe or angled outlets are commonly used methods.
- It is most important to select the direction of the tail pipe exit so that the exhaust gas:
  - Is not drawn into any dry element air cleaner, subsequently rapidly clogging the element, and reducing service life.
  - Is not drawn back through the radiator by a puller fan installation. This is likely, where exhaust exit, and radiator entry are both on top of the machine.
  - Is directed away from the sight lines of the machine operator.
- Consideration should also be given to the noise regulations or requirements that must be met (i.e., bystander, operator, etc.) as some advantage may be gained by directing the outlet away from microphones or observers.
- The exhaust pipe can accumulate a considerable amount of condensed moisture, especially when the pipe is long. To avoid internal corrosion, a condensate trap with an open drain can be provided at the lowest point in the system.
- The exhaust pipe should avoid touching or passing close to the air cleaner, fuel and lubricating oil filters, fuel tank or piping, injection or lift pumps, radiator, or sump and also, alternator, starter motor wiring or any electronic components. If this is unavoidable then suitable heat shields should be employed.

#### 5.5.2.1 For 4-cylinder engine mounted aftertreatment:

When designing the exhaust pipe for on engine mounted aftertreatment care must be taken to ensure that the exhaust pipework avoids 4th order resonant speeds. In addition, it:

- Must not induce any resonant conditions in the exhaust system
- Must not exceed the maximum dynamic joint load in section 5.4.2.1.
  - In order to achieve this limit, the pipework must be kept as short as possible and should not exceed 700mm (including engagement length) TBD.
  - If this length is exceeded, then the dynamic load must be calculated using the calculation method described in section 5.4.2.2 or a verification test must be conducted to validate the system.

### 5.5.3 Spark Arrestors

The aftertreatment is not qualified as a spark arrestor. If this is an application requirement then it is recommended to work directly with the applicable bodies (i.e., U.S. Department of Agriculture, Forest Service) to ensure all the necessary requirements are met.

The DPF cannot, as a component, be USFS (US Forestry Service) certified as a spark arrester because USFS certification using their current draft standard has requirements in addition to spark arresting.

### 5.5.4 Thermal Management

Please refer to the Chapter 7 Thermal Management for detail of the component temperature limits and suggested methods to reduce and control temperatures within the engine bay.

The addition of aftertreatment on EU Stage V and EPA Tier IV Final engines and muffler, if fitted, will increase under hood temperatures due to radiated heat. Ways to dissipate this heat and improve airflow across the engine and aftertreatment will be necessary particularly over sensitive electronic components.

### 5.5.5 Design Considerations for Electrical Components

Please refer to Chapter 11.0 Mounting of Electronic Components for more information and the Electrical and Electronic Application and Installation Manual for details of the control systems, harnessing and connection of the aftertreatment.

All aftertreatment contains electronics and subsequent wiring harness connections.

### 5.5.6 Service and Maintenance

Refer to mandatory requirements 5.2.5.
Please refer to OMM for detailed service requirements

# 6.0 Cooling Systems

## 6.1 Introduction

All internal combustion engines produce heat as a by-product of combustion and friction.

Within the engine the exhaust gas recirculation, cylinder block and cylinder head are all water-cooled, and the lubricating oil temperature is maintained within acceptable limits through the use of a water cooled, engine mounted cooler.

The use of after-treatment, auxiliary emissions control strategies and turbo charging to increase boost temperatures and pressures all add additional heat load into the system.

It is essential to manage both the heat to coolant and the induction air temperature to maintain engine life, performance, durability, and emissions compliance for the life of the engine. The integration between engine and machine is critical.

In all cases a system must be designed to maintain engine temperatures within the specified limits under the most extreme conditions of ambient and operation that the machine will encounter.

This chapter outlines the mandatory requirements and design considerations for engine cooling and charge air cooling systems.

## 6.2 Cooling System Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the **EM** symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of non-road equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

### 6.2.1 Cooling System Mandatory Requirements

- The engine must be run on a 50:50 water/ethylene glycol (antifreeze) mix.
- The coolant system has been designed to meet the maximum coolant top tank temperature specified on the relevant IOPU technical data sheet
- If any changes are made to the cooling system, then full cooling system performance validation and applications approval will be required.
  - Testing must be conducted in accordance with the relevant test procedure
  - **EM** Changes that affect the charge air cooler must be tested to ensure emissions compliance.
    - The intake manifold inlet temperature, after the charge air cooler, must fall within the range detailed on the relevant IOPU technical data sheet.
- If any of the cooling components are modified or moved from their standard location, then applications approval is required as this may have an effect of the vibration characteristics of the system and may affect cooling performance.
- The radiator frontal area must not be obstructed by any other cooling core or auxiliary component without full cooling system performance validation and applications approval.
- The mounting holes on the front face of the radiator should not be used for anything other than a stone guard due to load limitations and potential implications on vibration. The maximum load must not exceed the limit specified on the IOPU technical data sheet.
- Coolant should only be taken from the engine using the approved connections in the authorised locations (cab heater, compressor and aftertreatment module)
  - Hoses must be specified to the correct material and be within the maximum diameter and length limits. Requirements can be found in the main mechanical application and installation manual and Stage V DEF system supplement.
- The EGR cooler will drain through the engine.
- If the IOPU is installed in a machine which does not have a floor panel below the cooling fan area a guard should be fitted to the machine.
- **EM** Requirements for coolant lines to the DEF system components must be adhered to and are detailed within the Stage V DEF system supplement:

### 6.2.2 Ambient Clearances & Altitude Requirements

- Full details of the IOPU cooling system can be found on the relevant IOPU technical data sheet. This includes details of the cores used, the pressure cap setting, and the ambient clearance capability achieved at different engine speeds with different air flow and duct allowances. It also provides detail of the maximum top tank temperature and maximum Intake manifold temperature limits after the charge air cooler.

# 7.0 Under Hood Thermal Management

## 7.1 Introduction

The addition of aftertreatment components to engine exhaust systems can both add radiated heat and restrict airflow within the engine compartment. This drives the need for increased focus on thermal management systems and strategies which have become a necessity to control the additional temperatures and protect sensitive electronic components.

For separate air systems (engine compartment separate from the cooling package), higher temperatures will melt the components and/or reduce the effective life of the components. For integrated systems, (where the engine and aftertreatment are in the same compartment), besides the component failure issues, higher under hood temperature may also increase the temperature of the air entering the cooling cores, affecting the air-to-core (ATC) rise.

Table 7-1 indicates the temperature capabilities for the engine and supplied components. You should aim not to exceed these general limits. Some local temperature limits will however be lower or higher and are defined in Appendix D 'UHT and DEF test Acceptance Criteria and UHT Gauge map' in the relevant engine test procedure document.

| Under-bonnet Temperatures | | | |
|---|---|---|---|
| **Ambient Temp in Engine bay (°C)** | **Engine state** | **Percentage of engine life** | **Max time at Max Ambient temp** |
| 120 | Stopped, but must be startable (heat soak) | 2 | 20mins |
| 105 | Running | 13 | 3 hours |
| 85 | Running | 85 | Indefinite |

**Table 7-1 under bonnet temperatures**

## 7.2 Thermal Management Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the **EM** symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of non-road equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

### 7.2.1 General

**EM** Adequate cooling for all engine components must be provided within the enclosure design to ensure they do not exceed their maximum temperature limit for all conditions or exceed the maximum intermittent temperature limit in worst case operating conditions (hot shut down).

- The component temperature limits are detailed in Appendix D 'UHT and DEF test Acceptance Criteria and UHT Gauge map' in the relevant engine test procedure document.

**EM** Where extremely high local temperatures are measured additional cooling, methods must be used to control the component temperatures.

**EM** The use of thermal insulation (for example thermal lagging or wrapping):

- Is not permitted on any engine component including: the exhaust manifold, turbocharger and EGR pipework.
- Is not permitted on the flexible section (bellows) of the engine to aftertreatment connection.

# 8.0 Fuel Systems

The fuel system is a critical engine system and plays a vital role in delivering not only engine performance, but also compliance with emission regulations.

For a diesel engine to function correctly it must be supplied with an adequate supply of fuel. The fuel must meet the recommended specification and be free from air, water, and solid matter. The fuel system must be installed correctly and must adhere to installation instructions, cleanliness standards and be subject to regular maintenance following correct practices and procedures.

## 8.1 Introduction

### 8.1.1 Fuel System Safety Requirements

- Correct practices and procedures should be followed as outlined in the following appropriate service manuals:
    - Operator and maintenance manual (OMM)
    - System Operation Test and Adjust (SOTA)
    - Specifications (Specs)
    - Disassembly and Assembly (D&A).

- Due to the high pressures generated by the Common Rail Fuel system the following safety requirements MUST be adhered to when working on the engine.
    - After the engine has stopped the fuel pressure must be dissipated from the high-pressure (HP) fuel lines before any service or repair is performed on the fuel system. To do this please follow the service guidelines detailed in the OMM.
    - Contact with high-pressure fuel may cause fluid penetration and burn hazards. High Pressure fuel spray will cause a fire hazard.
    - Inspection of the fuel lines, hoses, filters, and system components should be undertaken to check for wear and deterioration and to ensure there are no foul conditions. Correct fitment of clamps and heat shield should also be ensured.

- Care must also be taken to ensure the fuel return to tank line does not become blocked or restricted in anyway and the tube assemblies for the low-pressure fuel system are correctly installed. Failing to follow this warning could lead to premature failure, product damage, personal injury, or death.

- Failure to follow the correct inspection, maintenance and service instructions may cause personal injury or death.

## 8.2 Fuel System Mandatory Installation Requirements

All Emission Related Installation Instructions are highlighted by the EM symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of non-road equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

### 8.2.1 General Requirements

- No electrically powered engine cranking is allowable without both the ECM powered up and the HP fuel pump electrically connected. However manually turning the engine over by hand, where the engine speed can never exceed 15 rev/min, is acceptable. Refer to the Electrical and Electronic A&I manual for further information.
- The engine must be equipped and operated with the filters supplied with the engine.
- Under no circumstances is it acceptable to modify the fuel system components or replace/customise sections of the fuel system that were supplied with the engine (as delivered).
- It is not acceptable to disturb or alter the fuel system lines, mounts, clips, or common rail assembly.
- The use of fast fill requires engine factory approval.
- It is not permitted to prime the fuel system by utilising compressed air.

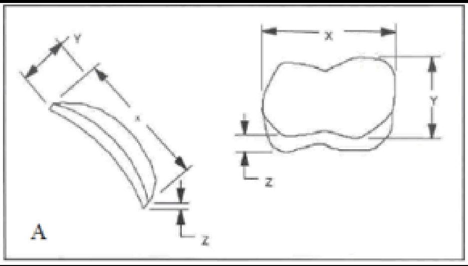
### 8.2.2 Cleanliness

- The fuel entering the tank and the supply prior to the water separator must meet cleanliness requirements detailed in the Standard ISO 4406: 1999 level 18/16/13. Engine specific requirements are in the OMM or the Perkins Diesel Engines Fluids Guide M0113102.
- Fuel lines and components from the fuel tank to the primary filter /water separator must meet internal cleanliness requirements 1E2500C, detailed in Figure 8-1.
- Fuel lines and components installed between the primary filter /water separator and main engine (secondary) filter must meet the cleanliness specification 1E2500A detailed in Figure 8-1.
- When the Main (secondary) engine fuel filter is supplied connected to the FIP by the engine factory it is not permitted to disturb any components after the main engine fuel filter.
- When the Main (secondary) engine fuel filter is NOT supplied connected to the FIP by the engine factory then the following requirements must be adhered to:
    - Components after the main (secondary) fuel filter must meet cleanliness standard 1E2500G detailed in Figure 8-2.
    - Controls and procedures must be in place to ensure this.
- Fuel lines and components used for the return to tank must meet internal cleanliness requirements 1E2500C, detailed in Figure 8-1.
- All metal components must be deburred to internal standard 1E0009 section 7 onwards or an equivalent external standard.
- Where applicable, the fuel filter caps, fuel line caps and fuel pump caps must only be removed just prior to fitment of the fuel line.

**Fuel System Component Cleanliness Standard**

This specification defines cleanliness levels applicable to finished engine components and assemblies.
All cleanliness standards are based on flushing the specified area with solvent filtering the flushed solvent onto a membrane filter patch, measuring particle dimensions with a microscope and measuring total particle mass with an analytical balance.
The specified cleanliness must be met at the time of assembly
Particle to be measured for size are metallic, rust (either free or loosely attached), slag, sand, and other abrasives. If particles are fragile and break up with gentile probing (gentle probing will not tear a membrane filter patch), only the remaining solid pieces are to be measured for specification performance.

| Largest Particle Allowed, in microns (A) | | | | | Maximum No. Particles allowed per given particle length, In Microns (a) | | Maximum mass allowed (B) | | Abrasive (Oxide) restricted (B) |
|---|---|---|---|---|---|---|---|---|---|
| | | X | Y | Z | # | X | mg/m2 | mg | > 40µm |
| 1E2500A | Pre Secondary Filter | 1200 | 500 | 150 | 4 | 500-1200 | 170 | 10 | Allowed (C) |
| 1E2500C | Tank to Primary Filter | 2000 | 2000 | 200 | 4 | 1000-2000 | 535 | - | Allowed |




(C) For fuel system components only, No more than 10 abrasives greater than 40 microns in size per cleanliness patch
# = Number of particles

**Figure 8-1 - Fuel Component cleanliness before Main Engine filter**

**LP Fuel line assembly Cleanliness Requirements per 1E2500G**

| Assembled Line Length (up to 13mm dia) | Max Allowable absolute mass (mg) | Max Allowable particle number against particle size – Particle Size (µm): 100-200 | 201-300 | 301-400 | >401 | Abrasives (Oxides) >100µm |
|---|---|---|---|---|---|---|
| <1m | 0.5 | 50 | 10 | 2 | 0 | Not Allowed |
| 1 – 2m | 1 | | | | | |
| >2m | 2 | | | | | |

Maximum allowable residual magnetic flux density: 1 gauss
Audit filter patch: 5µm Micropore
Fibre particles counted in mass only

**Cleanliness Requirements per 1E2500G**

| Max Allowable contamination per fluid-wetted area (mg/m²) | Max Allowable absolute mass (mg) | Max Allowable particle number against particle size – Particle Size (µm): 100-200 | 201-300 | 301-400 | >401 | Abrasives (Oxides) >100µm |
|---|---|---|---|---|---|---|
| 55 | 2 | 50 | 10 | 2 | 0 | Not Allowed |

Maximum allowable residual magnetic flux density: 1 gauss
Audit filter patch: 5µm Micropore
Fibre particles counted in mass only

**Figure 8-2 - Fuel Component Cleanliness after Main Engine filter**

### 8.2.3 Fuel Specification

- Engine specific fuel requirements are in the OMM or the Perkins Diesel Engines Fluids Guide M0113102.

### 8.2.4 Pressure and Temperature limits

- Please refer to Table 8-2 for the process limits of the fuel system.

### 8.2.5 Fuel Tank requirements

- The fuel tank must meet cleanliness standard 1E2500C detailed in Figure 8-1.
- The fuel tank must be vented, and the vent filtered to a maximum filtration level between 4 and 10 microns depending on efficiency i.e.
    - 10 microns - 99% efficient.
    - 4 microns – 84% efficient.
- The vent must be serviceable, and an appropriate maintenance instruction included in the machine manual.
- A serviceable large particle filter must be used within the tank filler neck to ensure the fuel in the tank meets the required cleanliness specification specified in the OMM.
    - The use of non-serviceable fuel tank inlet filter (filler neck) is not permitted.
    - The use of any type of filter on the fuel supply/pick up line is not permitted including any mesh, gauze, strainer, or any device that may become blocked.
    - Refer to Figure 8-3 below.
- The fuel tank must be designed so the fuel pick-up and return meet the requirements detailed in section 8.2.6.
- The tank material must be able capable of withstanding the maximum temperature requirements, withstand the fuel types required for use and must not contain any materials listed within Table 8-1 - Prohibited materials.

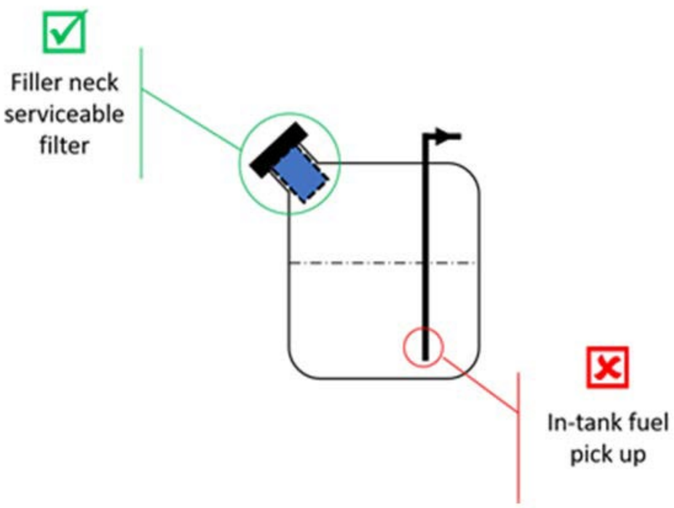



**Figure 8-3 - Fuel Tank Filtration**

### 8.2.6 Fuel Line Requirements

- Customer supplied fuel lines must adhere to SAE J30 R9/DIN 73379 (inclusive of a Fluro elastomer liner) or better or must meet internal standard 1E4340B. This should be discussed with the fuel line supplier to ensure that the hose material:
    - Can meet the fuel and under hood temperatures
    - Is durable within its operating environment
    - Is robust to electrostatics
    - Is compatible with all fuel specifications to prevent injector deposits.
- Fuel lines must be adequately supported as short and direct as possible with no dips, sags, or kinks. They should be kept away from heat sources and be clear of all fouls with other components.
- Shut off valves must not be used in either the supply or return line. If employed an electrical interlock must be employed to prevent the engine cranking with the valves closed. Cranking/running with the supply/return valves(s) closed will cause damage to the electric fuel pump or common rail pump.

#### 8.2.6.1 Fuel supply line

- The fuel supply line must be a minimum of 150mm away from the fuel return line or lines, at their point of termination inside the fuel tank.
  - This is to prevent the hot return fuel being sucked straight back into the engine though the supply line.
- The fuel supply line must not become uncovered under any operating conditions (machine pitching/slewing, gradeability etc.)
- The use of any type of filter on the fuel supply/pick up line is not permitted including any mesh, gauze, strainer, or any device that may become blocked.
- All fuel supply lines prior to the ELP must have a minimum id of 8mm.

#### 8.2.6.2 Fuel Return line

- This engine requires two fuel return lines. The main engine fuel return line returning fuel from the injector, fuel pump and common rail and an additional return line from the transfer pump regulator/PRV.
- The return lines must terminate below the minimum fuel level within the fuel tank and must not be directed towards the supply line.
  - This is to prevent jetting (aeration of the fuel)
  - This is also to prevent drain down of the fuel system when the engine is not running.
- It is recommended that the main and regulator fuel return lines are not joined. If this is a requirement then:
  - The backpressure in the regulator return line must not exceed the limit in Table 8-2 - Fuel System Limits Table 8-2.
  - The join must be after the fuel cooler.
- If the fuel supply tank is above the fuel filters, then a non-return or isolation valve with an electrical interlock should be fitted in main return line after the fuel cooler to prevent fuel system drain back.
- A non-return valve may be fitted in the RTT line provided the limits in Table 8-2 are not exceeded.
- The fuel-return line from engine to fuel cooler must be capable of withstanding a maximum temperature of 145°C.
- It is recommended that the fuel return lines have a minimum diameter of 8mm.

### 8.2.7 Fuel Filter Requirements

- Only Engine Factory supplied filters may be used within the fuel supply system.

#### 8.2.7.1 Primary (Pre-filter)

Two primary filter options are available from the option offering, one with a WIF switch and serviceable filter element and the other without a WIF switch which does not have a serviceable element. The installation requirements of these filters are detailed below:

- The factory supplied primary fuel filter with serviceable water separator must be installed prior to the ELP.
- The filter must be installed and assembled the correct way around to ensure correct flow through the filter head, as shown by the arrow on top of the filter head.
- The primary filter must:
  - Not be mounted on engine.
  - Be mounted and assembled the correct way around to ensure correct flow through the filter.
  - Be mounted in a location that is isolated from excessive vibration to prevent the emulsification of water in fuel.
  - Not be subject to G loading in excess of 10g vertical low cycle acceleration
  - Be fitted in a position that is clearly visible and allows sufficient access for servicing safely without damage to other components.
  - Be mounted vertically within a tolerance of +/-5° to prevent air entrapment.
  - Not have the filter head as the highest point in the fuel system. If this is a necessary, then priming and aeration checks must be conducted.
  - Not be mounted directly above hot surfaces or electrical components.

- The primary filter without WIF must be mounted using:
  - A single M8 bolt - Refer to Figure 8-5 section 8.4.1.

- The primary filter with WIF must be mounted using:
  - The 2 slotted holes - Refer to Figure 8-6 section 8.4.2.
  - M8 x 1.25 flange head bolts
  - grade 8.8.
  - length 110mm
  - Torque 22+/-2Nm.
- The primary filter with WIF switch requires:
  - A minimum of 50mm clearance for element removal.
  - The WIF switch to be connected in accordance with the requirements in the Electronic Application and Installation manual.

**8.2.7.2 Secondary (main engine) Filter**

For the 4-cylinder engine - The main engine fuel filter is supplied engine mounted as standard, but a remote mounted filter is available as an option. For the 3-cylinder engine - There is no in engine mounted option and the main fuel filter is remote mounted. Mounting of remote mounted fuel filters is the responsibility of the customer and the following requirements must be adhered to:

- Remote mounted filters are supplied fitted to a temporary transit bracket. This bracket
  - Must be discarded before engine installation.
  - Must not be used to mount the fuel filter in the installed condition.
- The integrity of the filter assembly must be maintained. It is not permitted to disturb or replace any of the supplied hoses or hose connections.
- The secondary filter supply fuel line must meet material standard specified in section Fuel Line Requirements 8.2.6.
- The secondary filter fuel supply line must have an internal bore no less than 8mm
- The secondary filter must:
  - Be mounted using the 2 slotted holes on the filter head -and 2xM10 bolts – Refer to Figure 8-8 section 8.4.4.
  - Not be mounted on engine, except when supplied as an installed option from the engine factory.
  - Be mounted in a location that is isolated from excessive vibration.
  - Not be subject to G loading in excess of 10g vertical low cycle acceleration
  - Be located in a position that is clearly visible and allows sufficient access for servicing safely without damage to other components.
  - Be in a location that is clearly visible and allows sufficient access for servicing safely without damage to other components.
  - Be mounted vertically within a tolerance of +/-5° to prevent air entrapment.
  - Not have the filter head as the highest point in the fuel system. If this is a necessary, then priming and aeration checks must be conducted.
  - Not be mounted directly above hot surfaces or electrical components
- The pressure at the FIP inlet must be measured on all remote secondary Filter Installations and must be within the limits specified in Table 8-2.

### 8.2.8 Electric Lift Pump (ELP)

- The factory supplied ELP must be installed in the fuel line between the primary filter and the main engine (secondary) fuel filter.
- The pump can be mounted in any orientation, but the pump outlet should face upwards and be no lower than the inlet
  - It is recommended that it is mounted at 45 degrees to the vertical.
- The ELP must not be mounted on the engine.
- The ELP must be mounted:
  - Using the 2 mounting holes provided on the pump Refer to Figure 8-7.
  - So that it is isolated from excessive vibration. Vibration exposure must not exceed 5 to 800Hz: 10g peak in any direction.
  - So that it is clearly visible and allow sufficient access for servicing safely without damage to other components.
  - So that the pump body is earthed.
- To aid priming performance the ELP should be mounted as close to the fuel tank as possible and below the minimum level of fuel.
- The ambient temperature surrounding the ELP must not exceed 93°C
- The ELP inlet restriction must not exceed the limit in Table 8-2.
  - This must be measured at the ELP inlet in accordance with the relevant test procedure.
  - To help meet this restriction limit the height between the ELP and the minimum fuel level should not exceed 0.8m.
- The ELP must not:
  - Be used without the supplied primary filter.
  - Be operated without a fuel supply.
  - Operate submerged in water or any other fluid. Direct jet washing is prohibited
- Installation Torque 13.5-20Nm (10-15ft-lbs).
  - When installing fittings, hold the inlet and outlet Hex with a second wrench isolate the torque.

### 8.2.9 Prohibited Materials

- Table 8-1 contains a list of prohibited materials that must not be used within the fuel system.
- These should be taken into consideration when selecting and designing any fuel system components such as the fuel tank or fuel cooler. Particular care should be taken with the application of any plating and /or coatings that are used.
- Use of these materials may contaminate the fuel leading to coking of the injector nozzle

| Prohibited Material | Symbol |
|---|---|
| Lead | Pb |
| Sodium | Na |
| Calcium | Ca |
| Zinc or Zinc Plating | Zn |
| Copper | Cu |

**Table 8-1 - Prohibited materials**

- The use of the following Zinc plates is acceptable for FUEL CONNECTORS ONLY.
  - Zinc Phosphate: ASTM 117,
  - D609 Zinc Chromate/ Trivalent plates: ASTM 4042.

These materials along with chemical compounds may also be present in fuel and certain fuel additives, e.g., corrosion inhibitors, the presence of which can cause Internal Diesel Injector Deposits (IDID). These deposits may affect the proper functioning of the fuel injectors.

In order to prevent this, fuel additives that have measurable levels of any of the following listed substances should not be used:

- Acids e.g., Dimmer and Fatty (Oleic, Stearic and Linoleic); including DDS (Diamino Diphenyl Sulfone)
- Alkali metals e.g., Sodium, Calcium, Potassium, etc; including compounds, e.g., sodium chloride, sodium hydroxide, sodium nitrate, etc
- Carboxylates
- Organic amides

If in doubt, please consult your Application Engineer for further guidance

## 8.3 Fuel system Overview

### 8.3.1 Fuel System Schematic

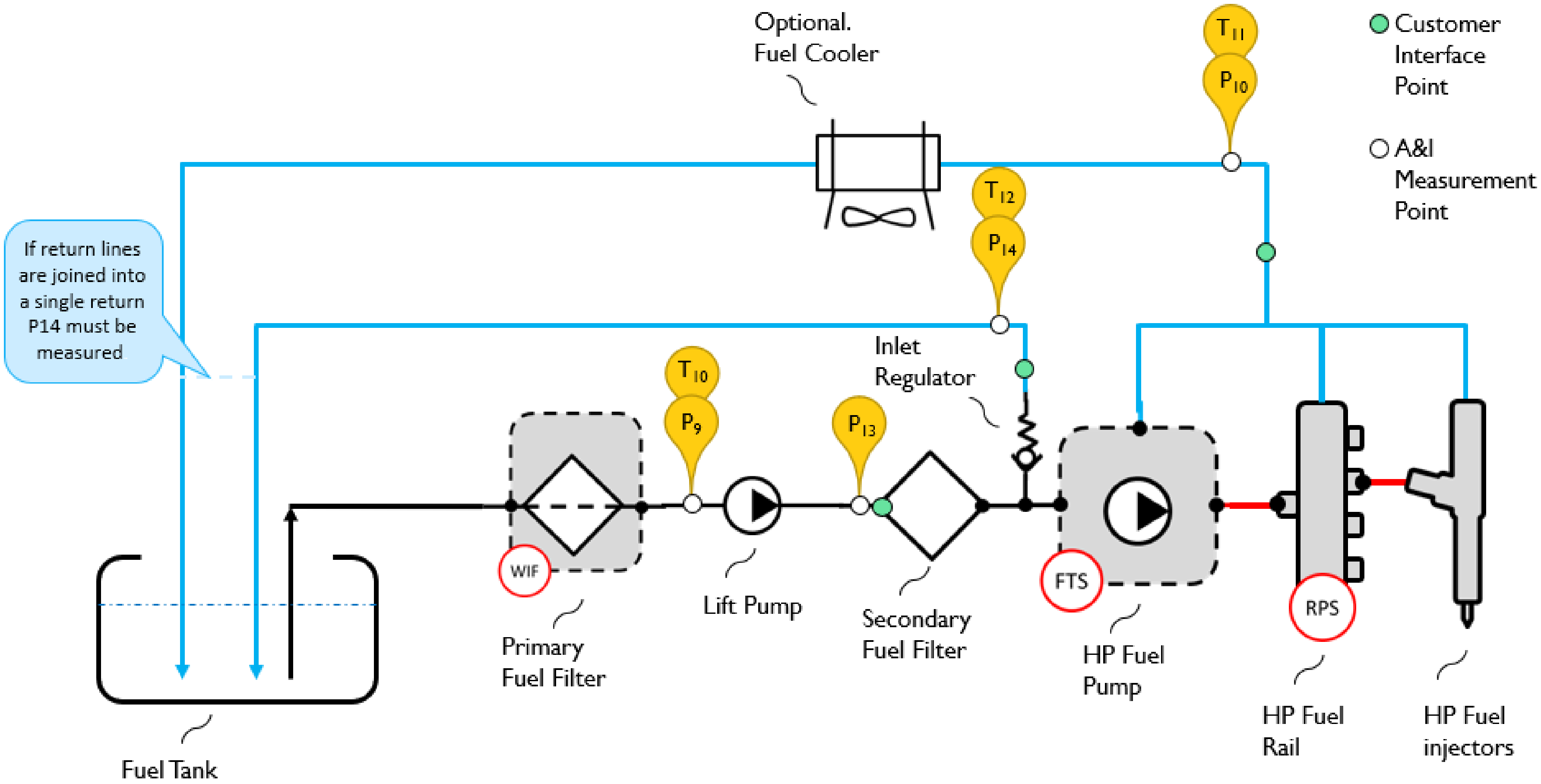



Figure 8-4- Fuel System Schematic

The required pressure and temperature measurement points are shown on the fuel system schematic above. The limitations and requirements for these are detailed in below:

### 8.3.2 Fuel System Limits

| Component | Channel | Min | Max | Measurement Condition/Position | Comments |
|---|---|---|---|---|---|
| Transfer Pump Inlet | **P9** | -11kPa | +10kPa | Engine off, ELP on, Min Fuel* | **Pass/Fail** |
| | **T10** | | 70°C | | **Guideline**<br>**R**equired to meet T12 |
| FIP inlet | **T12** | | 75°C | FLRS, min fuel*<br>Measured at LP Regulator (secondary) Return | **Pass/Fail** |
| Secondary Filter inlet | **P13**** | 30kPa | 70kPa | low idle, min fuel* | **Pass/Fail** |
| Main Return to Tank | **T11** | | 145°C | Measured at LP Regulator (secondary) Return | **Pass/Fail** |
| | **P10** | 0kPa | 20kPa | FLRS, Min Fuel* | **Pass/Fail** |
| LP Regulator (Secondary) return connection | **P14** | +ve kPa | +10kPa | Engine off, ELP on, Min Fuel* | **Pass/Fail** |

**Table 8-2 - Fuel System Limits**

* *If the fuel tank is above the fuel inlet connection, then the pressure at the Max fuel level must be measured.

**P13 needs to be measured to ensure the pressure into the HP pump is within specification. The limit depends on the pressure in the TP regulator return line (P3) as this pressure effects the operation of the TP inlet regulator, which controls the HP inlet pressure.

In order to meet the maximum fuel inlet temperature at HP pump T12 it may be necessary to install a fuel cooler in the return leak-offline from injectors and pump.

For fuel cooler sizing:

- The maximum fuel temperature leak off return - 145 ºC.
- The fuel return flow is expected to be between 0.8 and 1.2 l/min

### 8.3.3 Fuel Specifications

Please refer to mandatory Installation requirements for details of fuel specifications, quality, and cleanliness requirements.

### 8.3.4 Ultra-low sulphur diesel (ULSD)

ULSD is required in all diesel applications using a diesel particulate filter (DPF and DOC). The fuel must adhere to the specification detailed in the OMM. High sulphur levels will rapidly damage the DPF and DOC, likely resulting in the need to replace the aftertreatment unit. Damage to the DPF and/or DOC may impact emissions.

For cleaning and replacement of the DPF please contact your service dealer.

### 8.3.5 Biodiesel

Bio-diesel fuel may be used as long as it adheres to the specification and requirements detailed in the OMM.
Bio-diesel use is limited by percentage bio-fuel dilution by volume and the use of an appropriate approved additive is normally required. Higher concentrations that those approved will affect performance, durability, and warranty conditions.

As biofuel is chemically more reactive than the mineral oil used in diesel fuel, it is imperative to consider the effects of this fuel on all components that it may come into contact with.

Advice should be sought from the Applications department if the use of biodiesel is required.

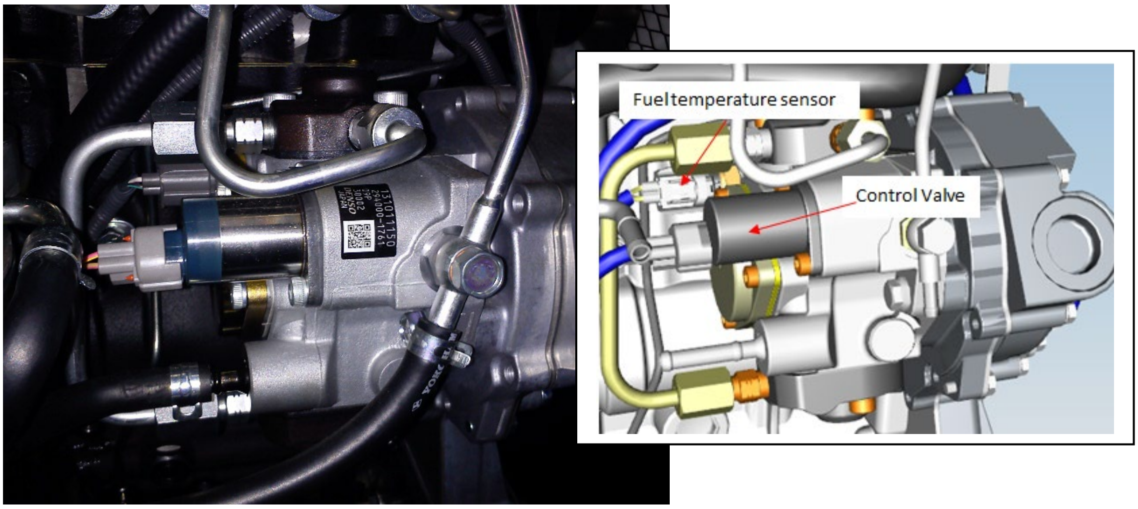
### 8.3.6 Temperature & Viscosity

The 400J-E series engine measures the fuel temperature in the fuel pump and provided the temperature does not exceed the maximum fuel temperature limit, makes the necessary compensations to maintain performance.

High fuel inlet temperatures can be avoided by careful routing of the fuel lines, ensuring that they do not run, in close proximity to any heat source, and ensuring there is good air flow across the lines within the engine and machine enclosure. If the fuel temperature is high, then it may be necessary to use a fuel cooler.

### 8.3.7 High Pressure Fuel System

The HP fuel system consists of a gear driven fuel pump, run at half engine speed and a high-pressure common rail. A control valve within the fuel pump controls the fuel pressure in the rail depending on the speed and load of the engine. The ECM then controls the beginning of injection and duration for each cylinder.
A fuel temperature sensor measures the temperature of the fuel in the pump to allow the necessary compensations to be made to maintain performance.




### 8.3.8 Low Pressure Fuel System

The LP pressure fuel system consists of a pre-filter/water separator, electric lift pump (ELP) then a single main engine fuel filter.

Priming of the low-pressure fuel system is achieved via energizing the ELP during service. This can be achieved via ignition key operation (refer to OMM). Please note that the ELP should not be energized for longer than 2 minutes without a fuel supply otherwise ELP damage may result. Nor should it be energized when the fuel supply is shut off; there is a mandatory requirement for an electrical interlock on any shut off valves in the supply or return lines.

The system is self-venting, and therefore you must not loosen the LP or HP pump, rail or injector pipes during priming of the system.

## 8.4 Fuel System Components

### 8.4.1 Pre-filter/ Water Separator (NO WIF sensor)

Reference should be made to the Mandatory Installation Requirements in section 8.2.7.1.

The pre-filter /water separator without WIF sensor is provided loose for customer fitment off engine. It separates water from the fuel and also provides filtration to 100µm. It must be fitted prior to the Engine Factory supplied ELP.

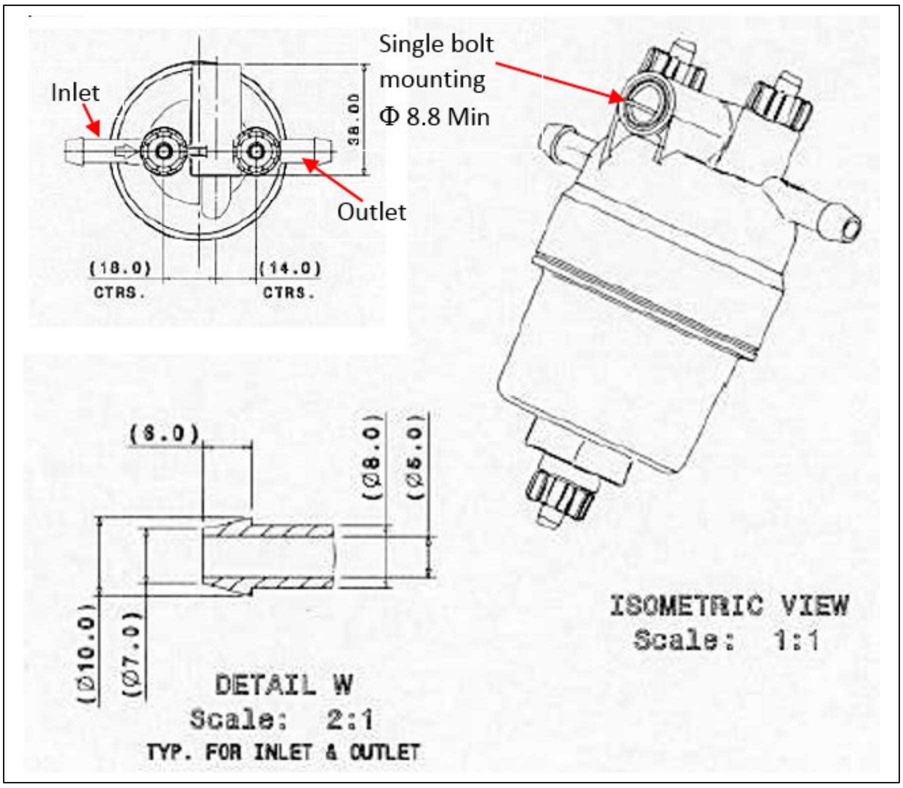



**Figure 8-5 - Pre-filter/water Separator -No WIF sensor**

### 8.4.2 Pre-filter/ Water Separator (including WIF sensor)

Reference should be made to the Mandatory Installation Requirements in section 8.2.7.1

The pre-filter /water separator with WIF sensor is provided loose for customer fitment. It must be fitted prior to the Engine Factory supplied ELP and must be wired in accordance with the Electronic A&I manual.

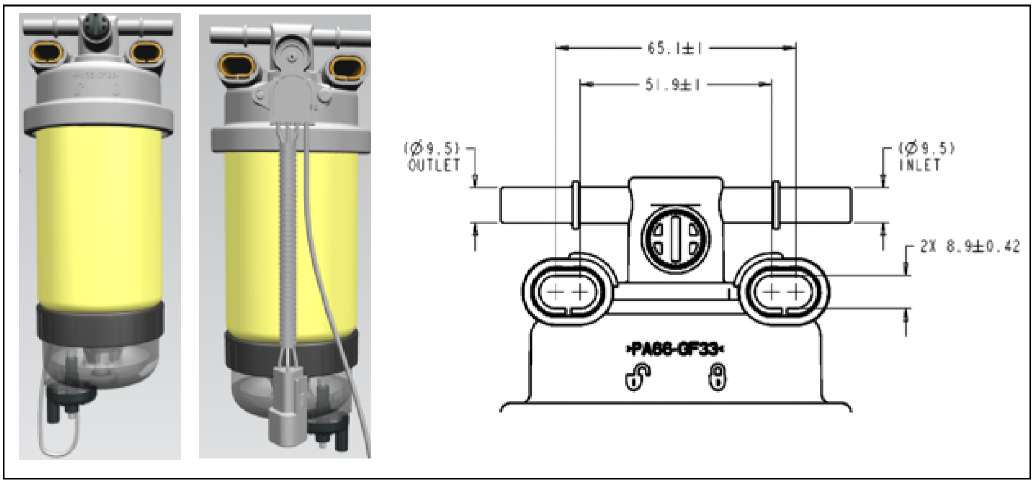



**Figure 8-6 Pre-filter/water separator with WIF sensor**

### 8.4.3 Electric lift pump (ELP)

Reference should be made to the Mandatory Installation Requirements in section 8.2 .

The electric lift pump is a solid-state pump with a reciprocating plunger and is self-priming.
It supplied as a loose component for customer fitment, off engine.
The pump should be mounted using the 2 slotted mounting holes detailed in Figure 8-7 below:
It can be mounted in any orientation, but the pump outlet should face upwards and be no lower than the inlet. It is recommended that it is mounted at 45 degrees to the vertical.
For details of the required electrical connections and requirements please refer to the Electrical and Electronic A&I manual.

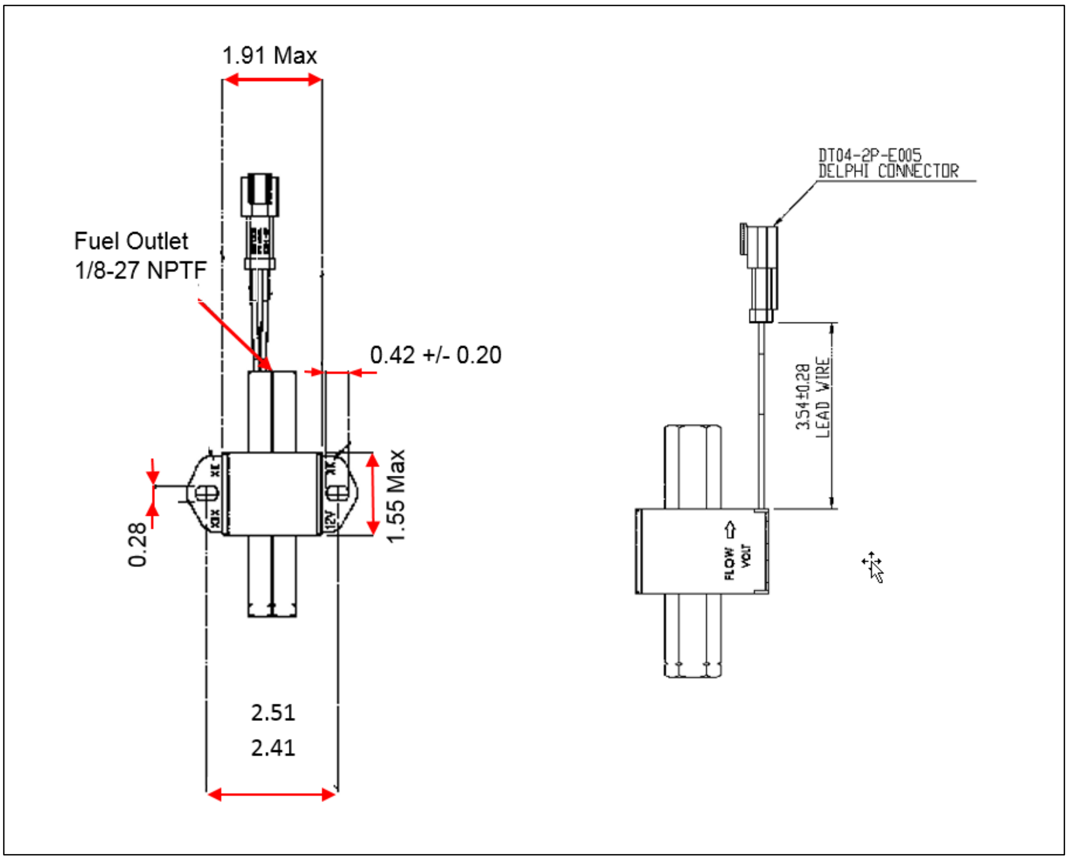



**Figure 8-7 - Electric Lift Pump**

### 8.4.4 Main Engine Fuel Filter

Reference should be made to the Mandatory Installation Requirements in section 8.2.7.2.

The main engine fuel filter provides 4µm filtration with 99% efficiency and provides additional water separation capacity.

All 4-cylinder engines have the main engine fuel filter supplied mounted to the engine, as standard but a remote mounted filter is available for selection from the option offering.

On the 3-cylinder engine, however, there is no on-engine mounted option and the main engine fuel filter must always be mounted remote from the engine.

**The remote filter:**

- Is shipped mounted to the engine on a temporary transit bracket, which must be removed and discarded before fitment to the machine chassis. The bracket is not suitable to be used to mount the filter permanently in the installation.
- Is supplied with the clean side of the filter already connected to the FIP with a standard length of fuel hose which is coiled up and attached loosely to the temporary transit bracket. The hose should be uncoiled but remain connected during installation of the filter onto the machine chassis. This means that the integrity of all connections clean side of the filter is maintained, which is critical as this filter is the last serviceable filter before the fuel enters the high-pressure pump, fuel rail and injectors.

Details of the customer connection points; the inlet and secondary fuel return connection are shown in Figure 8-8 below.

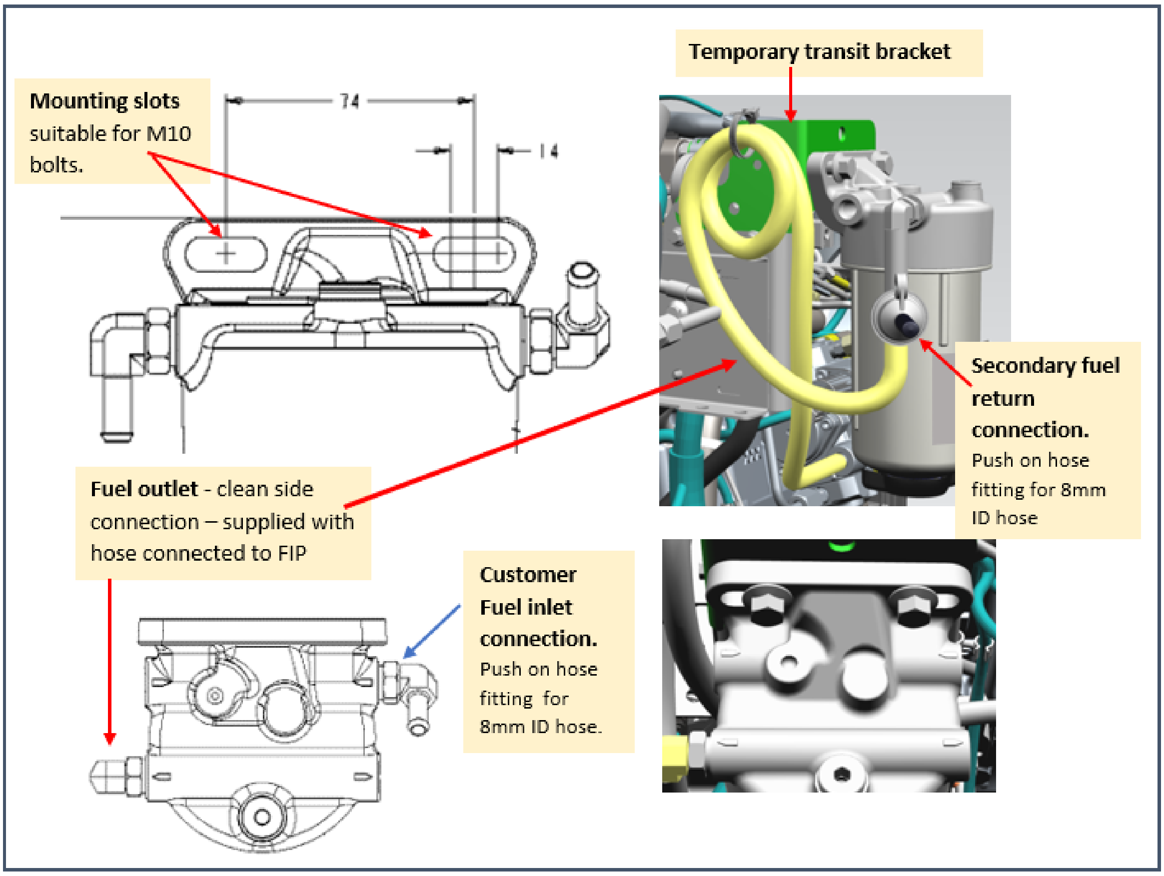



**Figure 8-8-Main Engine Fuel Filter**

### 8.4.5 Main return to Tank

The main fuel return to tank connection is situated on the side of the FIP and is suitable for an 8mm ID push on hose as shown in Figure 8-9 below.

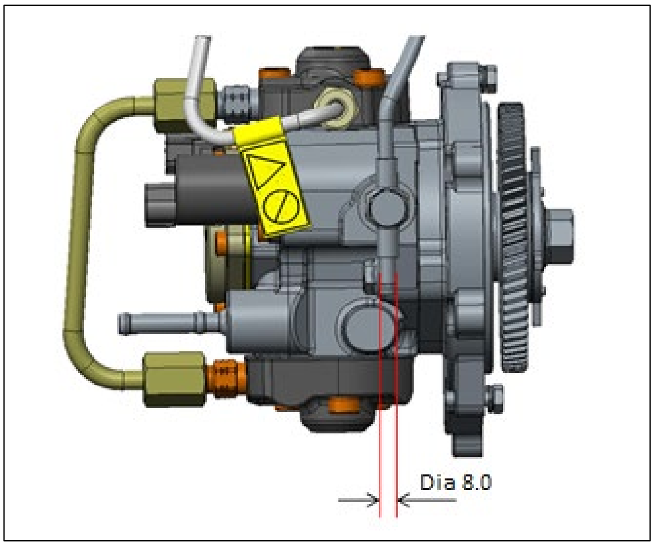



**Figure 8-9- Main Engine return to tank connection**

### 8.4.6 Secondary Return to tank line

A secondary fuel return line is required from the pressure relief value outlet in the fuel line between the secondary filter and the FIP. This connection is found on the side of the Main fuel filter as shown in Figure 8-8 in Section 8.4.4.

For the pressure relief valve to function correctly the pressure in the secondary return line must be kept to a minimum and must under no circumstance exceed the limit in Table 8-2, Section 8.3.2. This means it may be necessary to have the secondary return line discharge directly into the fuel tank and not be joined to the main engine return to tank line.

## 8.5 Fuel System Design Considerations

### 8.5.1 Fuel System Lines and Connectors

The customer is responsible for fitment of the following fuel lines:

- Tank to Water Separator
- Water separator to ELP
- ELP to Main engine filter
- Main return to tank (including fuel cooler, if required)
- Secondary (PRV) return to tank.

Most customer fuel system connections supplied on the 400 series engine are suitable for push on hoses secured by hose/jubilee clips.

Table 8-3 below provides detail of the customer fuel connections and sizes.

| Customer connection | Size | Ref Section 8.4 |
|---|---|---|
| Pre filter /Water Separator inlet/outlet (No WIF) | For 8mm ID Hose | Figure 8-5 |
| Pre filter Water Separator inlet/outlet with WIF) | 9.49 OD dia. male quick fit - requires female. | Figure 8-6 |
| ELP inlet/outlet | 1/8 -27NPTF | Figure 8-7 |
| Main engine fuel filter inlet | For 8mm ID Hose | Figure 8-8 |
| Main Return to tank | For 8mm ID hose | Figure 8-9 |
| Secondary fuel return to tank | For 8mm ID Hose | Figure 8-8 |

Table 8-3 - Customer Fuel connections

### 8.5.2 Fuel system pipework

- All fuel lines should be designed to be as short and direct as possible with no dips, sags, or kinks. They should be kept away from heat sources and be clear of all fouls with other components.
- Pipework must be to the material specifications outlined in this document. It is recommended that all fuel supply lines have a minimum internal diameter of 8mm.
- Fuel lines should be clipped and adequately supported within 100mm of the screen and ELP interfaces.
- The use of shut off valves must not be used in either the supply or return line unless an electrical interlock is employed. This is to prevent the engine cranking with the valves closed. It should be noted that cranking/running with the supply/return valve(s) closed can cause electric fuel pump or engine damage.
- The fuel return lines must terminate below the minimum fuel level within the fuel tank. This is to prevent jetting (aeration of the fuel) and prevent drain down of the fuel system when the engine is not running.

### 8.5.3 ELP and water separator

- A fuel pre-filter is supplied as part of the water separator. The water separator must be fitted prior to the ELP to maintain the performance of the pump, without which, the performance may degrade, and premature failure may occur.
- All connections to and from the water separator and ELP must be clean, tight and leak free.
- The water separator must be mounted to a rigid flat surface that is not subject to vibration
- The ELP must be adequately supported to prevent any vibration or transmission through the fuel lines, which may cause consequential damage.

- The ELP and water separator should be in a location that is easily accessible for service. Areas that are exposed to collision, operator or service damage should be avoided as well as positions that are close to any source of heat. They should be placed in a location with good airflow to ensure that the temperature under all conditions remains below the maximum component temperature and fuel temperature limit reference 8.2.8 and Table 8-2.
- To prevent damage to the ELP then there must also be a continuous, uninterrupted fuel supply to the pump to prevent premature failure of the pump or motor.

### 8.5.4 Fuel Tank Design and Installation

The fuel tank must be located to ensure that the maximum fuel pressure head, fuel supply and fuel return restrictions are not exceeded.
The tank must be designed to include the following features:

- Expansion space
- Sediment space (required to prevent suction screen plugging)
- Drainage
- *Tank vent and filter – see mandatory requirements
- Serviceable large particle filter, within tank filler neck.

Tank Baffling should be considered, particularly where machines can experience extreme or frequent changes in gradient. It is essential to ensure that under all achievable gradient conditions that there is sufficient fuel level to cover the fuel supply line; this is to prevent unnecessary machine stoppages or reduced ELP pressure/flow and hence engine performance. Min tank volume of 5% or more.
Care should be taken not to exceed the maximum high-pressure pump inlet pressure specified in the ESM when applying fast fill procedures during machine assembly; adequate venting during filling should control this.

*The tank vent must be serviceable and sized to achieve a 500-hour service interval, taking into consideration the environment where the machine is operating, particularly if high levels of air borne debris are likely.

**Material Specifications**

The fuel tank material should be matched to the calculated return to tank fuel temperatures as stated in the mandatory requirements. This should include the fuel temperatures seen in all operating conditions and under all tank fuel levels.
The tank should not contain any of those materials on the prohibited materials list see Table 8-1.

If the use of biofuels is likely then care should be taken that the material selected is resistant to the solvent effects and their associated degradation, which may adversely affect some tank paints and surface coatings. The tank should not be translucent, as light can cause photo-degradation of biofuels.

### 8.5.5 Fuel Cooling

In order to meet the maximum fuel inlet temperature then it may be necessary to employ a fuel cooler in the main engine return line.

- The expected fuel temperature in the fuel return line is 92°C with a maximum of 145°C.
- The flow is approximately 0.8 l/min.

### 8.5.6 Serviceability

All filters and screens must be in locations, which are easily accessible for service with sufficient space allowed for filter removal and access to the water drain. Consideration should be made for the addition of a hose on the water drain which may be required to help capture the water when draining.
Care must be taken to ensure that filters are not placed directly above any rotating electrics or hot surfaces which would be at risk from any fuel leaks and spillages during normal operating practices.
In addition to the fuel filters the fuel tank vent location must also be accessible for service and the filter media easily removed and replaced as part of a routine maintenance schedule for the machine.

# 9.0 Lubrication Systems

## 9.1 Introduction

It is important to ensure that the lubrication system is compatible with the particular application and operating conditions to which the engine will be subjected.

Factors that should be taken into consideration include:

- Lubricating oil specifications
- Lubricating oil temperatures
- Oil sump capacity and gradeability (tilt)
- Pressure losses in any external systems
- Protection from dirt contamination
- Reference should also be made to Chapter 6 Cooling Systems, in relation to lubricating oil cooling.

## 9.2 Lubrication System Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the EM symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of non-road equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act. '***

### 9.2.1 General Requirements

- The correct oil must be used as specified in the OMM.
- The engine must be operated with a factory supplied oil filter and oil cooler.
- The maximum operating temperature of the oil must not exceed 125°C continuous and 135°C intermittent:
    - This must be measured in accordance with the appropriate engine test procedure.
    - Intermittent is defined as when the maximum sustained temperature is limited to 10% of the total machine operation or no more than 1 hour in every continuous operating period.
- The maximum gradeability (tilt) of the machine must be within the capability of the selected oil pan.
    - This must include the installed engine angle plus the maximum machine tilt in operation.
- Care must be taken to ensure that the machine design minimises build-up of debris around the sump to help improve heat rejection.
- The maximum oil change interval and oil specification is specified in the OMM.
  In certain circumstances the engine oil change period may be reduced i.e., for machines that operate with a high average load factor or that operate in severe conditions e.g., heavy dust or elevated operating temperatures. This requires engineering approval.
- A minimum of 15mm clearance is required for removal and servicing of the oil filter canister.
- Sufficient clearance must be provided for access and removal of the sump oil drain plug or valve.
- For Installations where a factory provided oil filler cap is not used a visual aid, on or adjacent to the fill location is required to identify the correct oil specification for the engine and operating territory, information on the engines oil specification can be found in the operation and maintenance manual.

### 9.2.2 Customer Components requiring oil feed

- It is not permitted for the engine oil to be used to lubricate ancillary components.
- Customer supplied ancillary components requiring engine oil feed require Engine Factory Approval.

## 9.3 Lubrication System Overview

The lubrication system includes a gear driven oil pump, pressure relief valve, engine oil filter, oil cooler, oil pan, suction tube and strainer, oil level gauge and oil switch.

The oil pan and oil level gauge are customer selectable options. All the other components are standard non selectable components.

Oil from the oil pan travels through the strainer and suction pipe to the oil pump where it is pumped to the filter and cooler before reaching the main oil gallery and cylinder head. From here it is directed through oil passages to feed all the required engine components.

### 9.3.1 Oil temperature

The maximum operating temperature of the oil must not to exceed 125°C continuous and 135°C. Intermittent *(measured at filter head).

Intermittent is defined as when the maximum sustained temperature is limited to 10% of the total machine operation or no more than 1 hour in every continuous operating period.

### 9.3.2 Approved Oils

It is important to use only lubricating oil that conforms to an approved specification to suit a particular engine type. The engine ESM gives approved oil specifications. Information is also given on viscosity ranges recommended for operation within various ambient temperature ranges.

## 9.4 Lubrication System Components

### 9.4.1 Lubricating Oil Filters

- The engines are supplied with full flow lubricating oil filters as standard.
- These filters are designed specifically for use on diesel engines to adequately handle the flow, temperature and pressure involved, and provide the required filtration capacity.
- It is not recommended that any filter type other than that supplied with the engine should be used.

### 9.4.2 Lubricating Oil Cooler

- All engines are fitted with an engine mounted oil filter and coolant cooled oil cooler between the oil filter and block as shown in Figure 9-1 below.

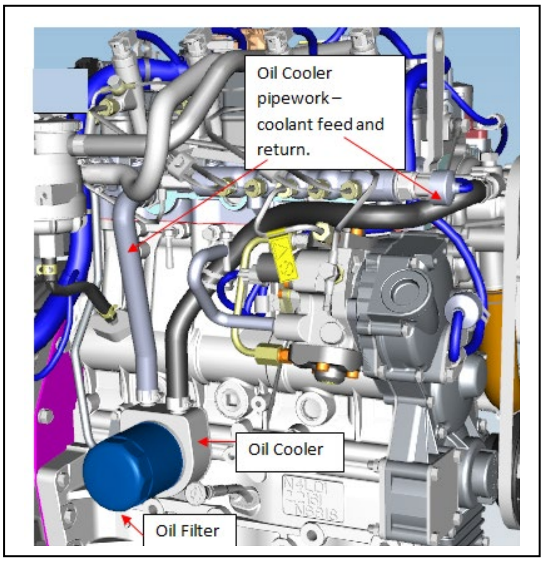



**Figure 9-1 Oil Filter and Cooler**

- A remote mounted filter can be selected as an option from the engine offering.

### 9.4.3 Sump Eco drain valve

An Eco drain valve can be selected as part of the engine offering and is supplied fitted to the sump in the horizontal drain position.

## 9.5 Lubrication System Design Consideration

### 9.5.1 Oil Temperature

Working within the maximum oil temperature limits specified in the mandatory requirements helps to:

- Protect bearings, oil seals and all wearing surfaces of the engine, as well as avoiding excessively high oil consumption.
- Control Viscosity.
- Ensure that oil condition is managed satisfactorily up to the specified oil change periods.

The engine oil temperature is directly related to coolant temperature by using a water-cooled engine mounted oil cooler. To help keep the oil temperature, within the mandatory limits, the Installation should be designed to provide good airflow across the engine; particularly around the sump (Oil Pan) area where hot air can stagnate.

To maintain the oil temperature within the maximum limits an oil cooler is fitted on all engines. Refer to section 9.3.1 Operational Parameters

### 9.5.2 Serviceability

- To achieve satisfactory engine service life, it is essential to adhere to the oil and filter cartridge change periods recommended in the OMM.
- To facilitate oil changes and filter cartridge removal, it is essential for these and the dipstick to be positioned in a readily accessible position and to be protected from possible damage.
- Whenever possible it should not be necessary to remove the engine in order to remove the oil sump (Oil Pan).
- It should be recognised that the oil cooler can hold significant quantities of oil, which may not be fully drained and changed in the course of routine engine oil changes.

# 10.0 Crankcase Ventilation Systems

## 10.1 Introduction

From Tier IV regulations onwards, all crankcase emissions are required to be included in the total system emission values. It is, therefore, essential; to ensure that the crankcase ventilation system and any of its associated components are correctly installed to provide a robust and durable system that ensures compliance throughout the life of the product.

The correct Installation of the crankcase ventilation system is mandatory to enable installation approval.

## 10.2 Crankcase Ventilation System Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the **EM** symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of nonroad equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

### 10.2.1 General Requirements

- **EM** Recirculation of the breather gas is mandatory for engines supplied as CCV.
- **EM** Under no circumstance may any of the Engine factory supplied components within the engines breather system be modified, tampered, or disturbed in any way:
  - Changes to the factory supplied breather system components may affect the emissions compliance of the engine, any changes to the as shipped configuration must be agreed be risk assessed and approved by the engine factory.
- **EM** The use of the factory supplied turbo compressor air inlet pipe is Mandatory as this forms part of the certified breather system.
  - Removing or replacing this supplied connection is prohibited.
- **EM** The standard factory fitted crankcase ventilation system is expected to operate down to -25°C.
- **EM** An engine factory approved cold climate protection kit must be used to operate in temperatures from -25°C to -32°C.
- **EM** In certain circumstances i.e., high air flow across the breather hose, low residual load, extended idle etc., this cold climate kit maybe required at higher temperatures. This is application dependant and can be assessed by measurement of the gas temperature.
- **EM** Temperature of all ventilated gases, between engine and intake connection should be kept above 10°C (under all operating ambient temperatures).
- **EM** The closed crankcase breather system must be protected from exposure to any direct blasts of cold air.
  - This is a particular concern where remote cooling fans are utilised.
- **EM** The crankcase ventilation systems component operating temperature limits must not be exceeded.
  - Refer to Appendix D 'UHT and DEF test Acceptance Criteria and UHT Gauge map' in the relevant engine test procedure document for component temperature limits.
  - Component temperatures must be tested in accordance with the relevant engine test procedure.
- **EM** The crankcase breather hose must be clear of any interference or constriction to ensure the free flow of gas.

## 10.3 Crankcase ventilation System Overview

Crankcase emissions result from combustion by-products and/or exhaust fumes escaping around the piston rings, turbo chargers, valve stem seals and auxiliary driven equipment into the crankcase. These escaping fumes are commonly called blow-by. The overall volume of blow-by varies due to cylinder pressure, piston ring pressure and component wear.

Elements found in blow-by can include wear particles, oil, fuel, gas, and air. The specific composition of the elements varies due to fuel type, engine type, engine speed, load, and maintenance history. Typically, blow-by is made up of hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO2) and nitrogen oxides (NOX).

Regulatory requirements drive the need to manage these emissions.

Both 4- and 3-cylinder Stage V, EPA Tier 4 Final engines can be supplied supplied with a low pressure integrated closed circuit or open circuit breather system

For engines supplied with CCV the crankcase gas is routed through an external pipe from the engine top cover to the oil mist separator (OMS). This uses a serviceable filter element to separate the oil vapor from the blow-by gases. The condensed vapour is returned back to the block via the breather filter drain valve. The gas exiting the filter is directed into the low-pressure side of the turbo charger through an external pipe from the top cover to the turbocharger air inlet hose as shown in Fig 10.1 below. A breather heater is also incorporated into this hose to prevent any freezing in low ambient conditions – refer to Chapter 14.0 for more detail.

This gas is then ingested the turbocharger, passing through the charge air cooler then entering the engine again through the intake manifold.

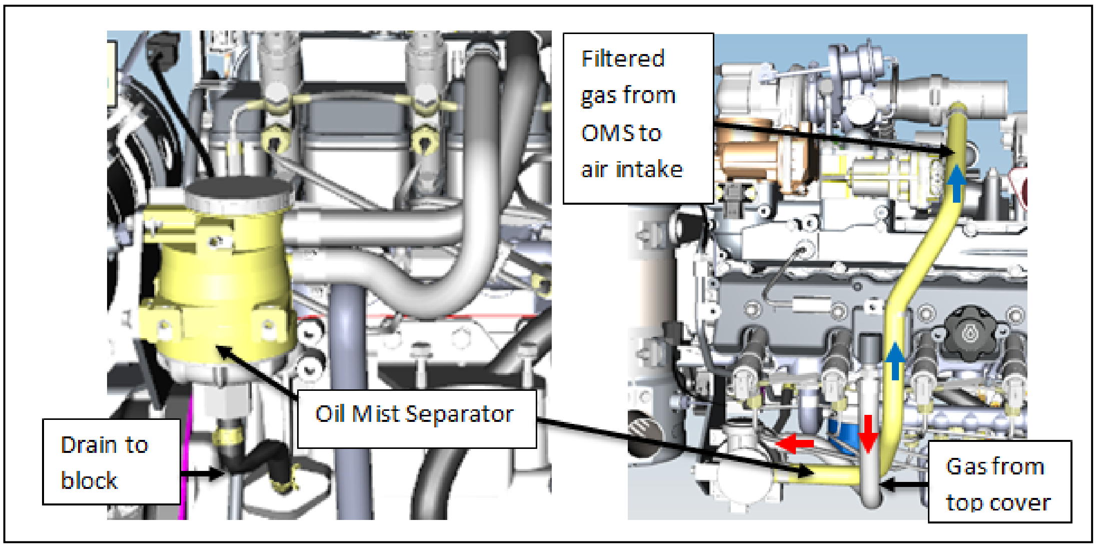



**Figure 10-1 - Closed Crankcase Breather System**

## 10.4 Crankcase ventilation System Components

### 10.4.1 Oil Mist Separator (OMS)

The oil mist separator uses a serviceable filter element to separate the oil vapor from the blow-by gases. The oil mist separator includes a pressure relief valve to prevent excessive crankcase pressure build-up, which can lead to the damage of oil seals resulting in engine oil leaks.

The OMS is mounted high on the rear upper RHS of the engine on a bracket located directly off the aftertreatment mounting bracket. If a remote aftertreatment is selected, then the OMS is still in the same location but mounted from a different mounting bracket so the position may vary slightly. Figure 10-1 shows the location of this filter.

The OMS filter must be serviced at predefined service intervals in accordance with the requirements detailed in the OMM.

## 10.5 Crankcase Ventilation Design Considerations

### 10.5.1 Operation in cold ambient conditions

Refer to Mandatory Requirements section 10.2.

Crankcase ventilation gases contain a large quantity of water vapour. This water can freeze in cold ambient conditions and block or damage parts of the crankcase ventilation system. The extent of vulnerability is highly dependent on the application.
To prevent this from happening a heated breather is supplied fitted to the engine and must be used in applications that operate in ambient conditions of -25°C or below. In certain circumstances i.e., high air flow across the breather hose, low residual load, extended idle etc., this heater maybe required at slightly higher temperatures. Applications with a pusher (blower) fan are particularly vulnerable. This must be assessed by testing and advise sought from engineering.

Figure 10-2 shows the heated breather which is incorporated into the external breather pipe and includes an electrical connector which must be wired in accordance with the requirements in the Electrical and Electronic A&I Manual.

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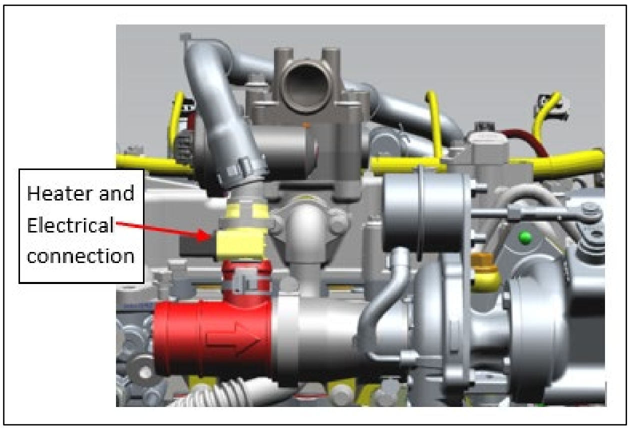



**Figure 10-2 - Heated Breather**

# 11.0 Mounting of Electronic Components

## 11.1 Introduction

This chapter includes the Mandatory requirements for installation of the electronic components that are supplied loose with the engine. This includes the ECM and electronic sensors related to the aftertreatment system. Electronic connection of all these parts is covered in detail in the relevant engine Electronic Application and Installation Manual.

## 11.2 ECM Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the **EM** symbol.

'***Failing to follow these instructions when installing a certified engine in a piece of nonroad equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

These engines use an **A6:E10** ECM which is supplied loose with the engine. Mounting of the ECM is the customer's responsibility and must follow the installation requirements detailed below.

### 11.2.1 ECM General

- The ECM must not be painted.
- The ECM must not be submersed. The pressure compensation valve and integral barometric sensor will not operate correctly if submersed in fluids.

### 11.2.2 ECM Mounting

- The ECM must NOT be mounted to the engine or any engine mounted component.
- The ECM must be mounted in a location:
    - That is protected from exposure to fluids and debris.
        - to prevent foreign object damage and clogging of the air-cooling fins and connector mechanisms.
        - If necessary, measures must be taken to prevent fluids channeling towards the ECM through conduit or wiring.
    - That is protected from exposure to chemicals.
    - In an area where there is a free flow of cooling air and not stagnant hot air.
    - That provides sufficient clearance to allow connection and removal of the connectors.
- The ECM must be mounted so that:
    - It does not touch other machine or engine components under any operating conditions.
    - It does not exceed the component vibration profile. Refer to Appendix G 'Vibration acceptance Criteria and Gauge Map' in the relevant engine test procedure document:
        - To achieve this, the ECM may be hard mounted to the machine chassis, however the design should allow for the provision of ISO mounts; should vibration testing indicate this is a requirement.
        - Vibration testing must be conducted on all ECM's and must be in accordance with the appropriate test procedure.
    - It does not exceed the specified component temperature limits in Table 11-1 below.

| ECM Type | Measurement Location | Temp Limits (°C) | |
|---|---|---|---|
| | | Hard (Chasis Mount) | ISO Mount |
| A6-E10 | ECM surface (case) | | -40 to 100 |
| | ECM ambient (50mm from surface) | -40 to 105 | -40 to 75 |
| | ECM Mounting surface | -40 to 70 | |

**Table 11-1- ECM Temperature Limits**

- This limit is specified as an ECM surface temperature, an ambient air temperature limit and a mounting surface temperature limit, as the ECM's mounting feet are used as a heat sink to help dissipate heat. These limits dependent on how the ECM is mounted.
- Temperature testing must be conducted on all ECM's and must be in accordance with the appropriate test procedure.

- The ECM must be mounted using all 4 fixing points.
  - Using M6 flat shouldered stainless-steel bolts (not countersunk).
  - Tightened to a torque between 9 - 12Nm.
- To ensure the ECM case is not twisted, which will damage the internal circuit board:
  - All 4 mounting holes must be in the same plane and flat within a maximum 1mm tolerance.
  - Each mounting point must be flat within a maximum 0.5mm tolerance.
  - Each mounting point must sit on a boss with a minimum diameter of 20mm.
  - Mounting the ECM to a flat surface is acceptable provided the flatness tolerance is met.
  - Refer to Figure 11-1 below:

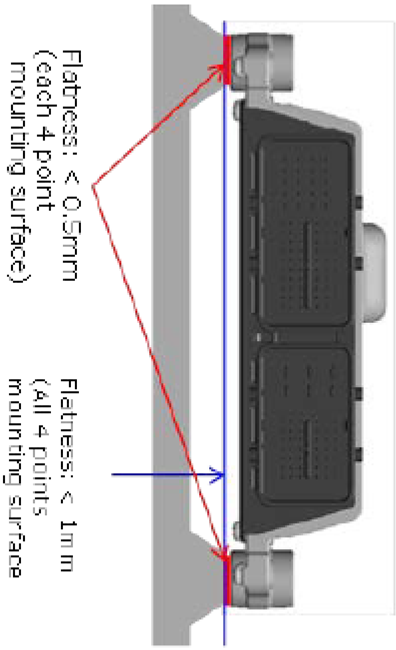



**Figure 11-1 - ECM Mounting**

### 11.2.3 ECM Orientation

- The mounting orientation of the ECM must not allow water ingress or water collection on the ECM surface, harness, or sensor.
    - To ensure this, the ECM must be meet the orientation requirements detailed in Figure 11-2 for the X-Y plane.

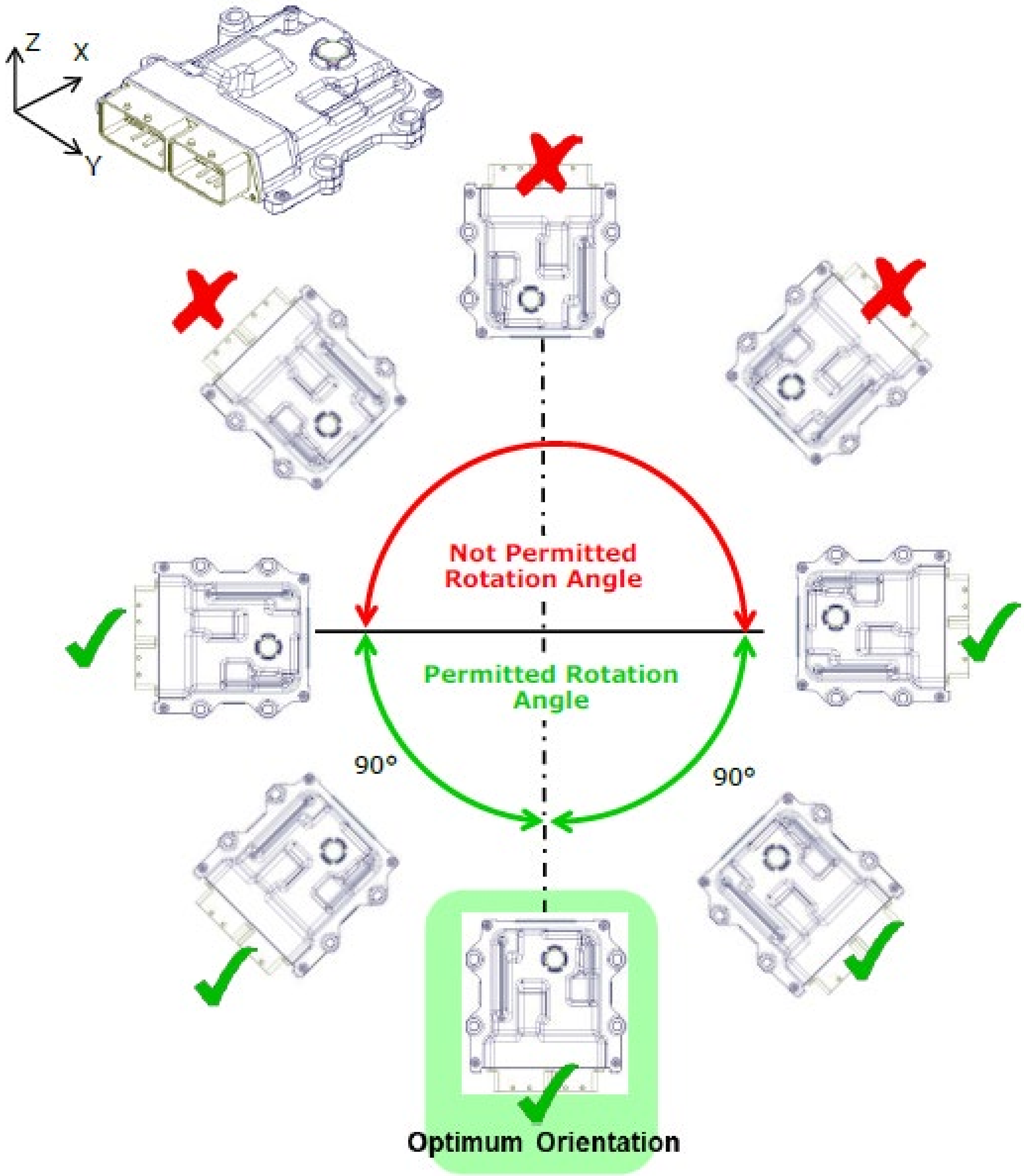



Figure 11-2 - ECM Orientation XY Plane

- To ensure this, the ECM must be meet the orientation requirements detailed in Figure 11-3 for the X-Z plane.

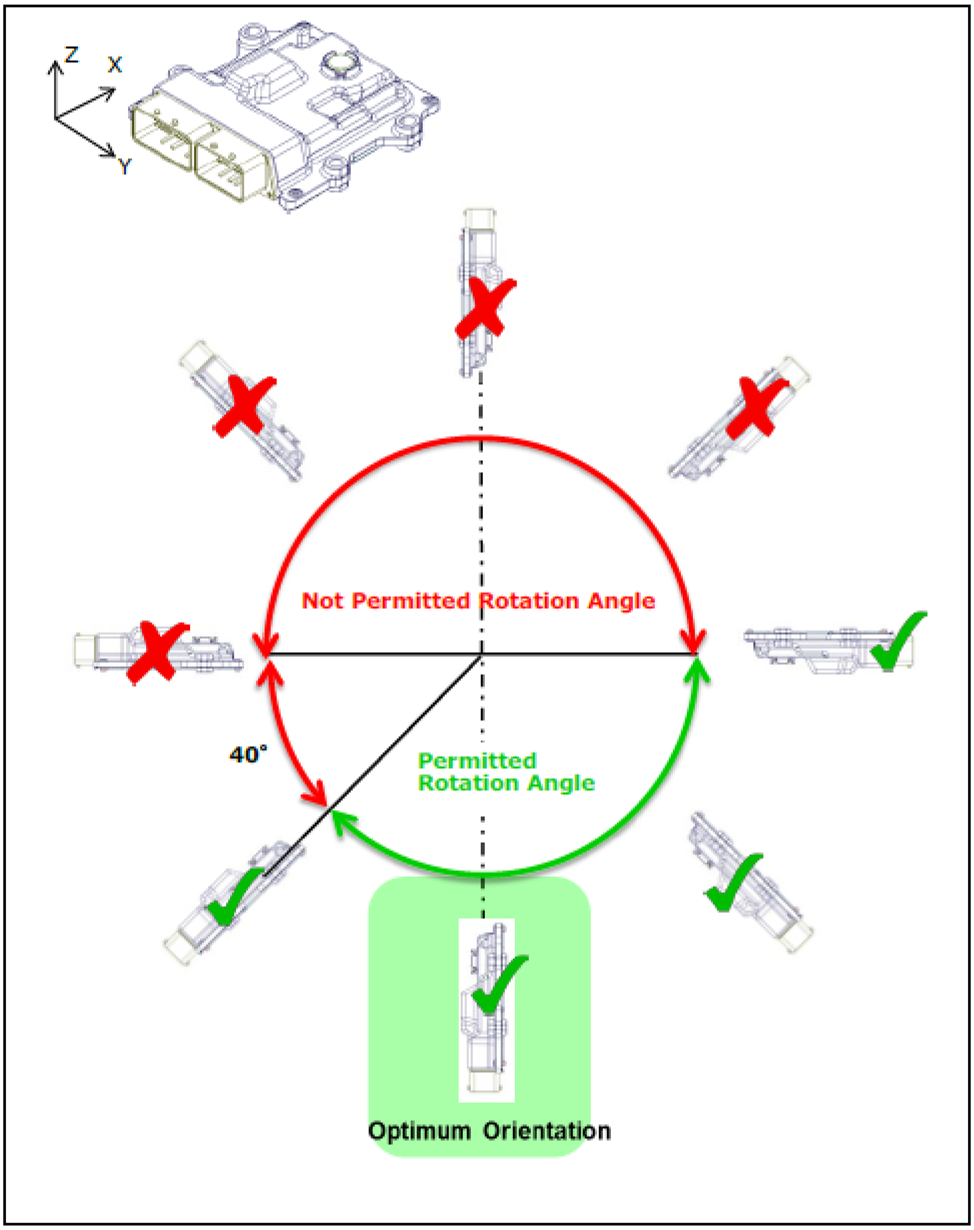



**Figure 11-3 - ECM Orientation in the XZ Plane**

### 11.2.4 ECM Wiring

- The ECM wiring harness must always point down to prevent water from collecting at the ECM connector.
- Acceptable and unacceptable wiring harness locations are shown in Figure 11-4 below:

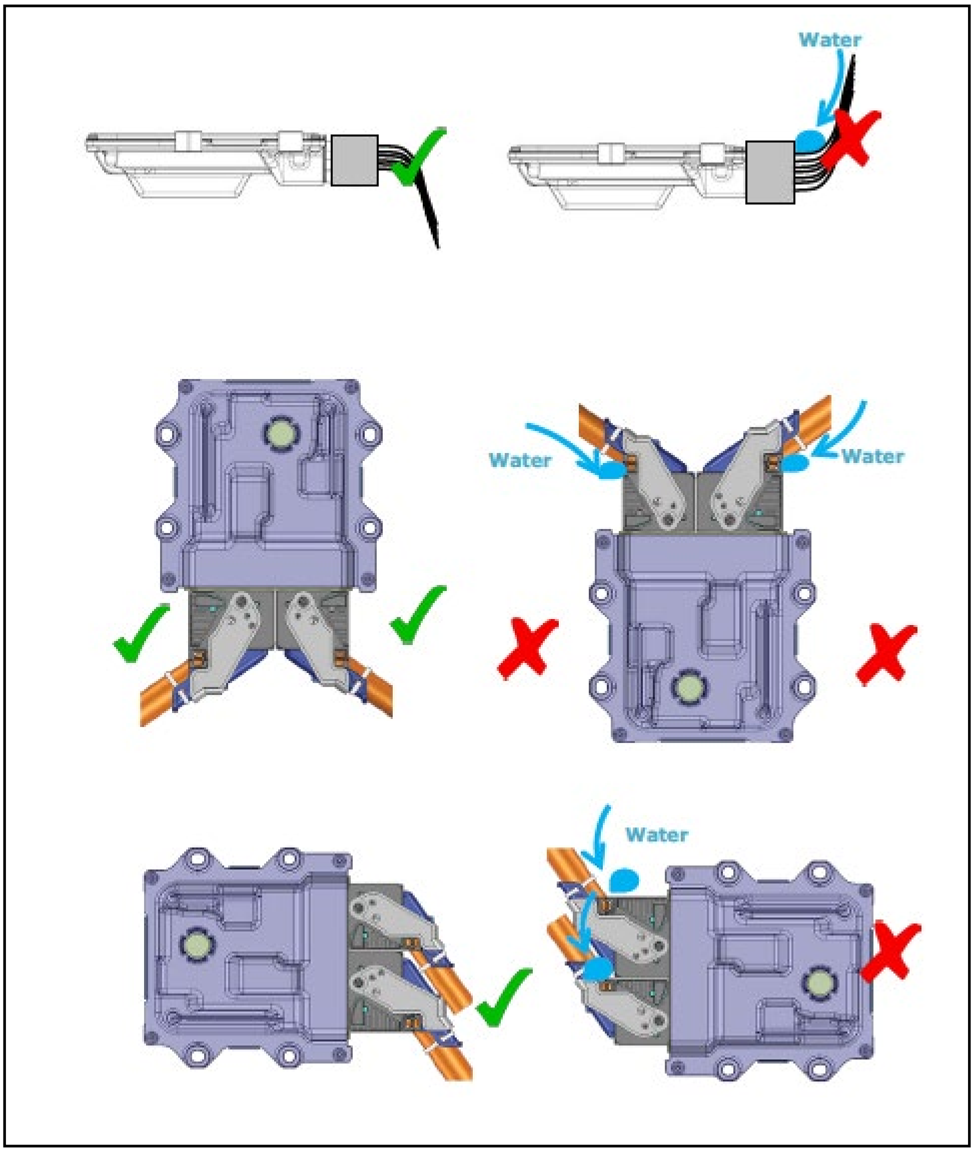



**Figure 11-4 - ECM Wiring Harness Direction**

- Strain relief must be applied to the ECM harness to ensure durability of the connectors:
  - The first strain relief point must be a maximum of 200mm away from the edge of the ECM connector and must be fixed to the same structure as the ECM, to ensure the ECM and connector are subject to the same vibration inputs.
  - The next strain relief point must be 300-400mm away from the first.
  - Refer to Figure 11-5 - Harness Strain Relief.

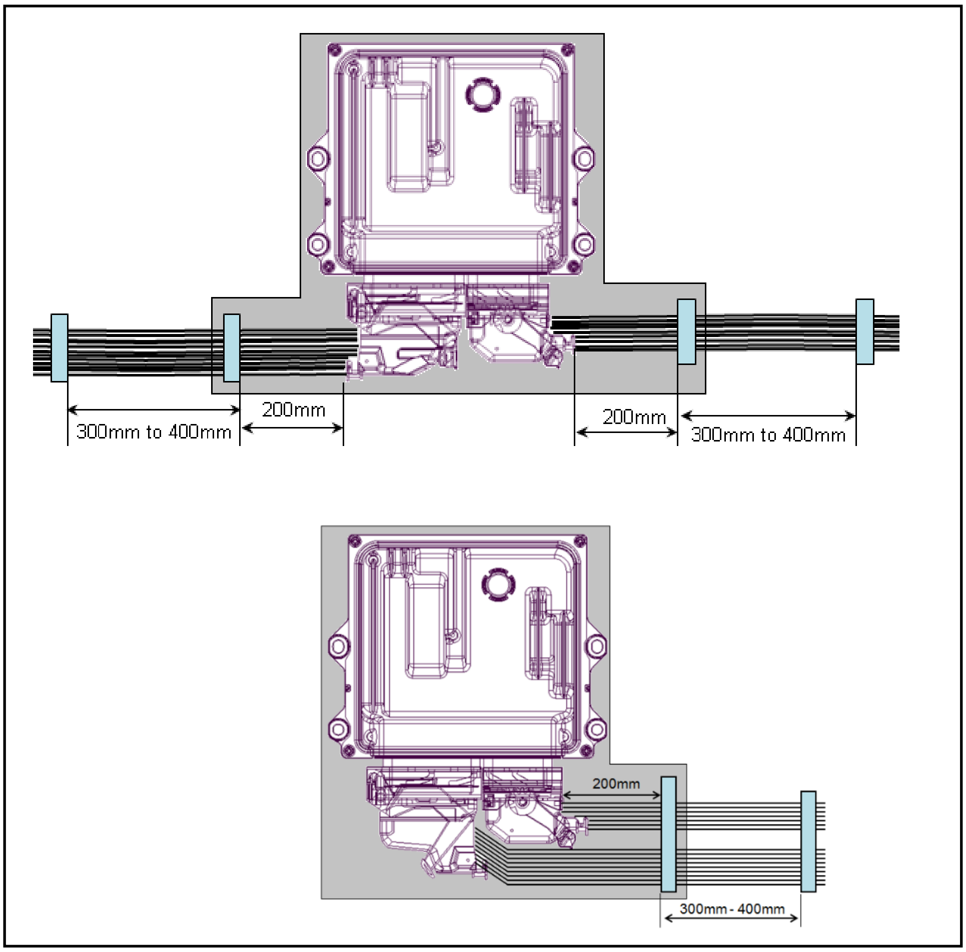



**Figure 11-5 - Harness Strain Relief**

## 11.3 Aftertreatment Sensors Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the **EM** symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of nonroad equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

### 11.3.1 Aftertreatment Temperature Sensors

The aftertreatment temperature sensors are supplied fitted for engine mounted aftertreatment and supplied loose for customer fitment, with remote aftertreatment.

#### 11.3.1.1 General temperature sensor requirements

- For EMAT the temperature sensors and control module are supplied fitted and must not be moved from their supplied position.
- The sensors must be wired in accordance with the wiring requirements detailed in the Electronic Application and Installation manual.
- Painting of the sensor and sensor control module is prohibited.

### 11.3.2 Delta P sensors

The Delta P sensors are supplied mounted on the Aftertreatment cannister.

- The Delta P sensor assembly must not be moved or modified in any way from the supplied position.
- The ambient temperature of the Delta Pressure sensor must be within -40° to 140°C, avoiding locations that are susceptible to freezing during engine operation.
- The sensor connector must not exceed 125°C.
- The sensor must not be exposed to vibrations in excess of the component vibration profile. Refer to Appendix G Vibration Acceptance Criteria and Gauge Map' in the relevant engine test procedure.
- The sensor must be wired in accordance with the wiring requirements detailed in the Electronic Application and Installation manual.

## 11.4 Electronic Component Design Considerations

If isolation of the ECM is found to be necessary in order to meet the vibration limits (Refer to Appendix G 'Vibration acceptance Criteria and Gauge Map' in the relevant engine test procedure) then the guidelines in the following sections should be considered in order to achieve a successful design.

### 11.4.1 ECM Isolator Mounting Plate

- In order to design an acceptable mounting solution, the ECM must be hard mounted to a metallic mounting plate which is then iso-mounted to the machine body/chassis. The purpose of this plate is to provide a stiff flat mounting surface that provides sufficient surface area to adequately dissipate the heat generated from the ECM. The mounting feet are used to transfer heat from the ECM to the chassis and therefore must not be isolated from the mounting material.
- The design of the ECM mounting plate must:
    - Be metal - zinc electroplated or similar
    - Meet the flatness required detailed in Figure 11-1.
    - Allow adequate dissipation of heat in order to achieve a maximum ambient temperature around the mounts detailed in Table 11-1.
    - Have a thermal conductivity > 52.0 W/mK (i.e., mild steel).
    - Have a 2D surface area > 286 $cm^2$ around the ECM mounting points.
    - Have a thickness > 5mm.
    - Have a surface finish that is not painted and is zinc electroplated or similar.
    - Incorporate strain relief / support of electrical connection cables.
- The ECM fasteners must not be used for secondary retention of pipe or wire clips.
- The mounting plate must be iso-mounted to a stiff rigid structure that is not subject to high vibration levels. It should be mounted in a firm location on the machine body or chassis avoiding flimsy panels which might vibrate.
- The plate should be iso-mounted to the machine body/chassis using a 3-point mount arrangement. The mounts should be equally spaced round the centre of mass of the system.
    - For details of isolation mount design refer to section 11.4.2 and 11.4.3 below:
- An earth strap will not be required to the ECM mounting plate as the main earth connections to through the ECU main connector are used for all ECU grounding. It is, however, recommended that the ECM case is connected to chassis ground by the fixing points.

### 11.4.2 ECM Isolation Mounts

- In order to protect the electronic components within the ECM it is recommended that the isolated ECM mounting system (ECM, ECM mounting plate, harness, and fixings) should start to isolate vibration at frequencies of 100 Hz and above.
    - This assumes that there is no significant vibration present on the machine mounting structure below 100Hz.
    - Targeting 100Hz offers a significant reduction to the vibration input to the ECM using a relatively stiff mount that should also offer suitable durability performance, assuming an adequate rubber profile is selected for the environment. 1.7.1 below shows an example of this in practice. It does however use an isolation frequency around 80Hz but does show the theory being applied.
    - Figure 11-6 shows the effect of using a similar mount which targets an isolation frequency around 80Hz.
- The selected mounts must be resistant to oil, fuel, and coolant.

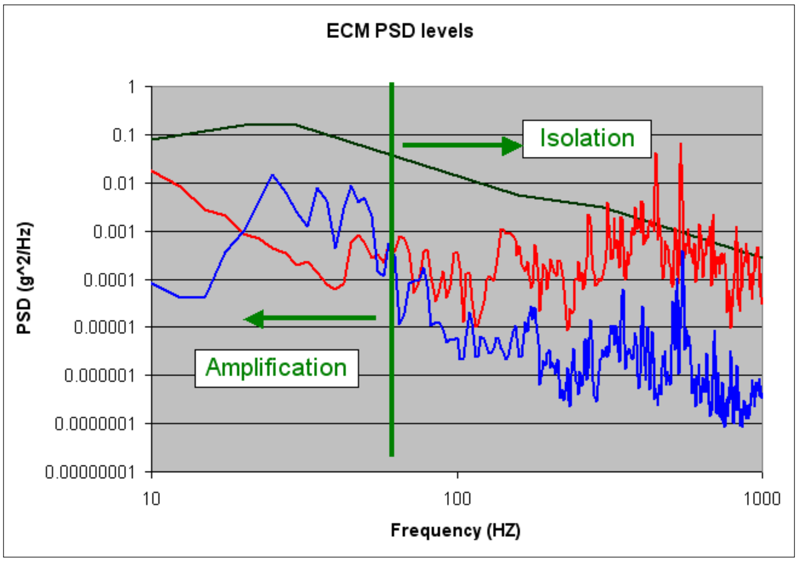



Figure 11-6 Example of resultant effect of isolation

### 11.4.3 Isolation Mount Type

- It is recommended that a simple 'sandwich' style mount is used as shown in Figure 11-7
    - The use of double ended mounts like this gives the flexibility to attach the mounts using nuts or a tapped hole.

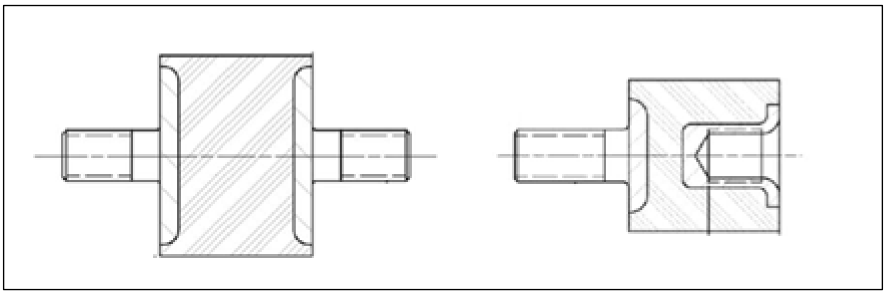
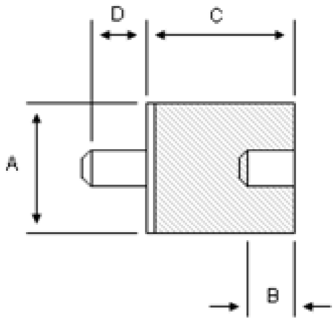


Figure 11-7 Recommended Isolation Mounts

- The precise specification of the isolators will be dependent upon the mass of the mounting plate, the type of mount used, the orientation of the mount, the number of mounts used and the input force direction. As a result, it is recommended that you contact your mount suppliers in the early stages of the installation design process.
- If the ECM and bracket is circa 2Kg, mounts of a similar specification detailed below have been found to be in the correct region on some applications. Softer and harder mounts either side should also be considered. The specifications below should only be used as a rough guideline only.
- Figure 11-8 below shows an example of an acceptable ECM mounting system. The features of this system meet the recommended requirements and are summarised below:

| Shear | | | | Compression | | | |
|---|---|---|---|---|---|---|---|
| Maximum Static Load | | Spring Rate Ks | | Maximum Static Load | | Spring Rate Ks | |
| lbs | N | lbs/in | N/mm | lbs | N | lbs/in | N/mm |
| ≈4 | ≈18 | ≈90 | ≈16 | ≈17 | ≈76 | ≈510 | ≈89 |




| Part Dimensions | | | | | | | |
|---|---|---|---|---|---|---|---|
| A | | B | | C | | D | |
| in | mm | In | mm | in | mm | in | mm |
| ≈0.6 | ≈15 | ≈0.25 | ≈6 | ≈0.6 | ≈15 | ≈0.5 | ≈13 |

**Figure 11-8 - Isolation mount dimensions**

# 12.0 Driven Equipment

## 12.1 Introduction

The standard front-end belt drive arrangement consists of a single-vee belt to drive the water pump/fan drive and alternator. The tension of the belt is manually controlled by the alternator tensioning arm. There is also a 5 rib multi-vee belt available from the option offering which is also tensioned by the alternator and requires the selection of the correct crank and fan drive options with compatible pulleys.

Additional belt driven accessories can be driven using a secondary pulley off the crank pulley which can be selected from the standard offering in the ESM.

An SAE A drive is available on the rear of the timing case as a selectable option.
Refer to the ESM for options and compatibilities.

## 12.2 Driven Equipment Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the EM symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of non-road equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

### 12.2.1 FEAD (Front End Accessory Drive)

#### 12.2.1.1 General

- The minimum distance of any component from the inside or outside face of the belt must not be less than +/-5% of the unsupported span length and no less than 6mm from the edge of the belt.
- Painting - Any over-spraying operation that is conducted must adhere to strict masking guidelines and procedures, which must be controlled and repeatable. Please contact your application engineer for further information.
- The front of the engine must be accessible to meet servicing requirements. Refer to OMM for servicing information

#### 12.2.1.2 Standard configured front-end arrangements

For standard configured front-end arrangements where the belts and all driven components are supplied fitted. For 400 series engines this includes the supply of the Fan and Fan extension.

- The supplied arrangement must not be modified and should be serviced regularly in accordance with the OMM.
- For customer supplied fans, fan hubs, alternators, belts, and air conditioning units the requirements detailed in section **Error! Reference source not found.** and **Error! Reference source not found.** below must be adhered to.

### 12.2.2 Mandatory Installation Requirements PTO (power take off)

#### 12.2.2.1 Gear driven (timing case) PTO

- The maximum static bending moment exerted on the timing case from auxiliary pumps and associated lines must not exceed 3Nm.
    - Where the unsupported mass exceeds the limit, it is recommended that an adequate support bracket is fitted.
    - Any bending moment in excess of this limit requires Engine Factory approval.
- The maximum torque taken off the PTO drive must not exceed the maximum limit for the duty cycle using the drive option as specified in the relevant ESM.
    - A maximum instantaneous 10% overshoot is allowed, at the point of the load being applied (not continuous).
    - For hydraulic pumps the maximum rate of pressure rise must be less than 4000bar/sec.
- Additional PTO installation, test and approval requirements must be adhered to, refer to your Application Engineer for more information.
- Any customer supplied PTO gear requires Engine Factory approval.

#### 12.2.2.2 Rear Crankshaft PTO

Attaching large/heavy unsupported transmission components to the engine's flywheel increases the loads on the engine's crankshaft and bearings. There is a limit to the amount of mass and bending moment the crankshaft can support:

- Any rear crankshaft overhung loading must have Engine Factory approval.
- Any gear or belt driven load taken off the rear of the crank must not exceed the limits specified on the polar moment diagram in the relevant ESM.
- Any unsupported mass bolted to the crank palm (inclusive of flywheel and transmission components) must not exceed the maximum limits specified in the ESM.
- The maximum permissible rear crankshaft thrust loads must not exceed those specified in the relevant ESM.
    - This accounts for movement in both the forward and reverse direction.
- Any driven equipment taken from the rear of the crank must be within the maximum inertia limit specified in the ESM.

#### 12.2.2.3 Front Crankshaft PTO

- Taking power from the front crankshaft pulley requires applications approval and must meet the requirements detailed in the main industrial mechanical Application and Installation manual.

# 13.0 Noise Control

## 13.1 Introduction

There are no legislative noise requirements directed at the engine itself. Despite this, we recognise that it is a significant contributor to overall machine noise and as such have developed the engine to the lowest practical noise level within economic and technological constraints.

Noise reduction features are incorporated into the design of every engine and are part of the standard offering. Features designed into the engine itself include good control over piston dynamics, an optimised fuel system and good control of clearances within the gear train.

## 13.2 Noise Control Mandatory Requirements

There are no legislative noise requirements directed at the engine itself.

## 13.3 Noise Control Design Considerations

Reference should be made to the General Installation Manual for a detailed Introduction to noise, including in depth design considerations. This manual includes information on:

- The Definition of Noise (Sound Pressure and Sound Power)
- Measurement of Noise
- Calculation Methods (addition and subtraction of decibels)
- Legislation and marketing impacts
- Composition of machine Noise
- Identification of Noise Sources
- Nature of Engine Noise
- Noise Reduction Techniques including absorption, damping, stiffness, Isolation and separation
- Detail on Exhaust, Induction, Cooling, Cab and Other Sources of Noise.

It also Provides a good Noise Reduction Check List.

# 14.0 Cold Weather Operation

## 14.1 Introduction

Diesel engines are more demanding than spark ignition engines when starting at low ambient temperatures because ignition of the fuel relies on the compression of the air.

Satisfactory starting is the ability of the engine to fire and pick up speed without damage or abuse to the engine, starting equipment or driven machinery. In order to achieve a satisfactory cold start and operate under cold weather conditions the engine and machine must be specified with the correct equipment suitable for the engine type and intended machine operation. This equipment must be correctly operated and maintained and the correct fuel and oil must be used.

Particular care must be taken in selecting and installing the relevant equipment, and the necessary information must be provided for the machine operator.

The following chapter details the mandatory requirements and aspects that need to be taken into consideration when operating a machine in low ambient conditions. It has been written to complement but not change the other installation requirements and recommendations within this manual. Further details can be found in chapter 11 of this manual, the Electrical and Electronic Application and Installation Manual, the Starting and Charging document, the relevant engine specification manual (ESM) and also in the OMM.

## 14.2 Cold Weather Operation Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the EM symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of nonroad equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

### 14.2.1 General

- In order to achieve satisfactory cold start performance:
    - The engine must be operated with the correct fuel and oil for the machine operating temperature (ref OMM)
    - The engine must be equipped and operated with the necessary cold start aids for the machine operating temperature.
- To achieve satisfactory starting with either Engine Factory or OEM supplied rotating electrics and glow plugs fitted as standard, the following conditions must be achieved at the lowest ambient temperature that the machine is expected to operate:
    - Minimum cranking speed over TDC > 60rpm.
    - The minimum mean cranking speed must be > 100 rpm.
- Cold start testing should be conducted on all machines.
- Where fitted, glow plugs must be connected to improve starting, run up and smoke characteristics.
- For temperatures of -25°C or below the breather gas must be protected from freezing refer to chapter 10.0 Crankcase Ventilation Systems.
- The use of Ether is not permitted.

## 14.3 Cold Start Components

### 14.3.1 Auxiliary cold start aids

Starting aids are required for the engine to start satisfactorily below a certain ambient temperature. Unaided starting limits are given in the E.S.M and it can be seen that the limiting minimum ambient temperature varies according to engine specification; electric starting equipment and the engine lubricating oil viscosity.

Both 3 and 4-cylinder engines are supplied with glow-plugs as a standard factory fit. Other starting aids can be used in addition to this for more extreme operating ambient conditions.

### 14.3.2 Glow Plugs

The glow plug is a device, which protrudes into the combustion chamber of each cylinder, and, when activated, has a high temperature that ignites the fuel/air mixture. Precise tip protrusion is required to enable the sprayed fuel to be properly ignited during cranking, without causing a significant drop of combustion efficiency during engine running. As glow plugs enable the engine to start instantaneously, no other starting aid is necessary down to minus-25°C and below.
Due to their high current draw a suitable relay must be used to actuate glow plugs.
Activation of the glow-plugs is controlled by the ECM, which monitors the coolant and air inlet temperature and decides whether the glow plugs are required. The exact control strategy for glow plug control can be found in the Electrical and Electronic Applications and Installation manual.

### 14.3.3 Heated Breather – CCV Only

Refer to Chapter 10.0 Crankcase Breathing.
A heated breather is connector is supplied with the closed crankcase breather hose as standard, for operation in cold ambient temperatures from -25° to -32°. If operation is required below -32° then a cold weather service kit will be required to provide additional protection such as insulation to the breather hose.

### 14.3.4 Block heaters

Block /Jacket Water Heaters are electrical heaters that maintain the jacket water at a temperature high enough to allow easy starting of the engine. Heaters pre-condition engines for quick starting and minimize the high wear of rough combustion, by maintaining the coolant temperature during shutdown periods. Heaters thermostatically control jacket water temperature near 30°C to 50°C to promote fast starts. Higher temperatures accelerate aging of gaskets and rubber material.

When using a block heater, it is essential that the unit selected is compatible with the engine. Due to tight internal clearances in the water jacket care must be taken to ensure that the element does not touch the internal walls of the casting, cause damage to the bore and result in sub sequential leaks.

For the 4-cylinder engine the block heater can be fitted in:

- The middle D plug ports on the LHS of the engine block.
  - The front D plug port is not suitable as the access is restricted by the EGR cooler hose.
  - Care must be taken that the heater does not foul on the internal walls
- The block drain on the RHS of engine.

For the 3-cylinder engine the block heater can be fitted in:

- The block drain on the RHS of engine ONLY
- The D plug ports on the LHS of the engine is not suitable due to accessibility with the EGR cooler hose.

Detail of the different block heater types and the ports are shown in Figure 14-1 and Figure 14-2.

There is no block heater in the engine offering and no specific supplier recommendations can be made. The following components, however, are believed to fit :

D plug - Philips and Temro p/n 310049 400W, 120V
Block Drain: - Philips and Temro p/n 3510606 400W, 115V, 522-0032
- Philips and Temro p/n 3510607 400W 240V, 522-0034.

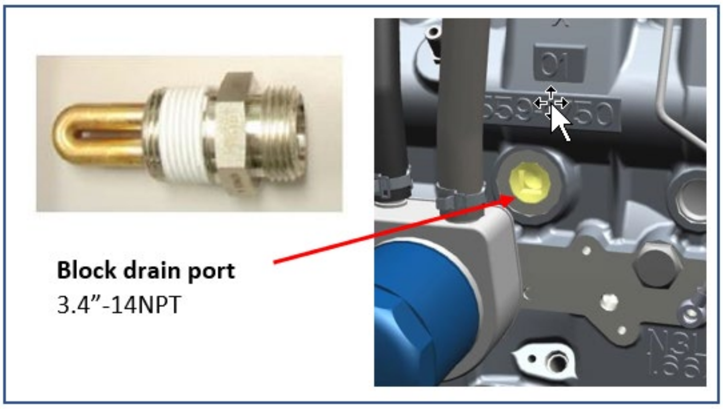



Figure 14-1 - Block Heater - Block Drain Port

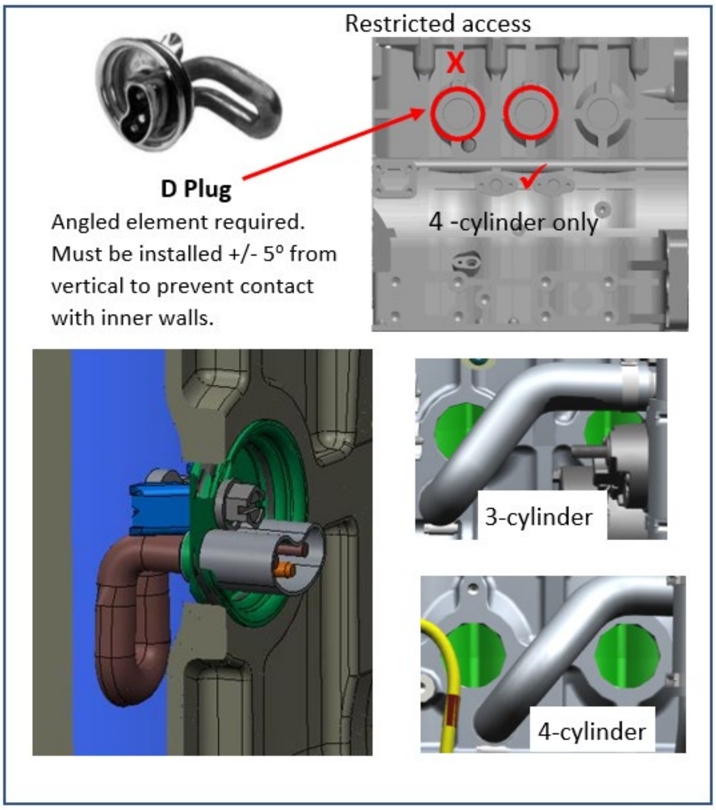



Figure 14-2 - Block Heater - D Plug Port

#### 14.3.5 Elevated Idle

For all applications wishing to operate at low idle for long periods of time at an ambient below - 25°C a thermal management process is required to elevate the exhaust temperature and allow correct operation of the aftertreatment system. This is done by elevating the low idle setting to a fixed speed at level 1 then increasing the idle again at level 2, if required.
The configured elevated idle speed must be tested and validated to ensure sufficient temperature can be generated with the machine parasitic load at the lowest desired machine cold ambient. This must be tested in accordance with the relevant engine exhaust temp test procedure.

For further information and details of the wiring, operation and control of this feature refer to the Electrical and Electronic Application and Installation Manual.

### 14.4 Cold Start Design Considerations

The General Installation Manual contains detailed information on the use of Machines in cold weather and the appropriate precautions and design considerations that need to be made as a consequence. This includes information on:

- Cold Starting Requirements
- Starting Equipment
- Starting Aids
- Installation Requirements
- Extremely Low Temperatures and
- Testing requirements.

Other appropriate information containing relevant information on this subject include:

- The ESM
- The Electronic Application and Installation Manual
- Starting and Charging Manual and
- The OMM for appropriate fluids.

# 15.0 Production and Manufacturing

## 15.1 Introduction

The purpose of the Production and Manufacturing chapter is to provide awareness, at the machine design stage, of some of the considerations that need to be made and adhered to when installing these engines in the production facility.

Additional Production and Manufacturing requirements can be found detailed in the CAR (Customer Assembly requirement) document. Please contact your Application or Product Support representative for more information.

## 15.2 Production and Manufacturing Mandatory Requirements

All Emission Related Installation Instructions are highlighted by the EM symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of non-road equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

- EM The Engine must be assembled in accordance with the requirements detailed in the Customer Assembly Requirements document (CAR).
- EM The correct fluids must be used in the engine refer to the relevant engine OMM for details.
- EM At no point within the production process should the engine, aftertreatment and electrical connectors exceed the maximum temperature limits of the individual components detailed in Appendix D 'UHT and DEF test Acceptance Criteria and UHT Gauge map' in the relevant engine test procedure document.
- EM For remote mounted aftertreatment the flexible exhaust Installation kit must be assembled following the correct procedure detailed in the Customer Assembly Requirements (CAR) document.
- EM It is not permitted to modify, tamper or affix anything to the supplied emissions critical components during the manufacturing or assembly process.
- The ELP should be not be electrically connected until the machine has been filled with fuel this is to prevent the ELP from being operated dry.
- EM If electrostatic paint spraying is used the engine must be specially prepared. Refer to the Electronic Application and Installation Manual.
- EM Painting of the aftertreatment, flexible installation kit and any associated electronic components is prohibited.
- EM If any over spraying of the engine is required, then the engine must be correctly masked please contact your Application Engineer for further information.
    - Masking requirements include the waste gate and the oil mist separator (to prevent blocking of vent holes)

# 16.0 Installation and Audit Testing

## 16.1 Introduction

The Application and Installation test and approval requirements for an IOPU are generally not as extensive as those required for a loose engine, as the cooling capability of the IOPU unit is known and validated.

The level of testing that is required is highly dependent on the application of the IOPU, whether the machine is mobile or not, the engine compartment and to what extent the IOPU has been modified.

| | AITP 14/01 | AITP 14/02 | AITP 14/03 | | AITP 14/04 | | AITP 14/05 | AITP 14/06 | AITP 14/07 | AITP 14/11 | | | AITP 14/13 | AITP 14/16 | AITP 14/17 | AITP 14/19 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Installed Engine Cooling Test | | | | | Low Pressure Fuel System Test (temp and restriction) | | | | | | | | |
| | Air Inlet Restriction Test | Charge Cooler Restriction Test | Air Charge Cooler Efficiency | Inlet Air Temp (ROA) | Ambient Clearance test | Cooling system restriction test | Cooling Fill Rate Test | De-aeration and Hot ShutDown Test | Exhaust Back Pressure Test | Fuel Temps inlet and return | Fuel inlet restriction | Fuel return line restriction | Underhood thermal Test | DEF Temperature Test | Vibration Test | Exhaust Temperature Drop Test | Bellows Calculator | Approval Required |
| Open IOPU | | | | x | | | | | | | x | x | | | | x | | |
| Enclosed IOPU | | | x | x | x | | | | | x | x | x | x | x | | x | | |
| | | | | | | | | | | | | | | | | | | |
| Add Cab Heater | | | | | | | x | x | | | | | | | | | | |
| Remote aftertreatment | | | | | | | | | x | | | | x | x | x | | x | x |
| Add JW to Oil Cooler | | | x | | x | | x | x | | | | | | | | | | x |
| Add Air to Oil/Fuel Cooler | | | x | | x | x | | | | x | | | | | | | | |
| Add Freon Condenser | | | x | | x | | | | | x | | | | | | | | |
| Relocate Cooling Pack | | x | x | | x | x | x | x | | x | | | x | | | | | x |
| Relocate or add air cleaner | x | | | x | | | | | | | | | | | | | | |
| Add silencer/Exhaust pipework | | | | | | | | | x | | | | | | | | | x |
| Change cooling Fan | | | x | x | x | | | | | x | | | x | | | | | x |

**Figure 16-1 IOPU Test Requirements**

Figure 16-1 IOPU Test Requirements provides guidance on the minimum testing requirements for various different applications. This table has been provided for reference only and the decision on the number and type of tests is the responsibility of the Application Engineer who will make an Engineering judgement based on the actual installation.

Application and Installation Test Procedures are available for all engine ranges. The test procedure document details the specific tests, has a recommended order of test, the test method, instrumentation required, gauge maps where necessary and sign off criteria. For IOPU's some of the sign off criteria will be specified on the relevant engine technical data sheet.

## 16.2 Installation and Audit Testing Mandatory Requirements

All Emission related Installation Instructions are highlighted by the **EM** symbol.

***'Failing to follow these instructions when installing a certified engine in a piece of non-road equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.'***

- Application audit testing must be conducted on all engine installations in line with the test requirements detailed in Figure 16-1 IOPU Test Requirements and in line with the Application Engineering Policy.
- Testing must be conducted in accordance with the latest test procedure document.

# PART 2. ELECTRICAL AND ELECTRONIC APPLICATION AND INSTALLATION MANUAL

## 17.0 IOPU Electrical A&I Requirements

Please refer to the A&I document TPD2193, for all required electrical A&I requirements of the 404J-E22 IOPU.

## 18.0 IOPU Electrical A&I Wiring

Please refer to the A&I document TPD2194 or TPD2195, for all required and optional wiring of the 404J-E22 IOPU.

## 19.0 IOPU Control Panel

The 404J-E22 engine has a Perkins branded panel that supports all the mandatory and optional lamps, diagnostics and J1939 engine messages and information. The control panel also supports a range of optional switch inputs. For more information of this control panel please refer to the control panel A&I supplement, document TPD2344.

# 18.0 Record Of Amendment

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Application and Installation Manual TPD2404 V1.0

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Series

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