1200

Series

Perkins 1200F Series

Models MT, MU, MV and MW

DEF SYSTEM SUPPLEMENT

1204F-E44TA
1204F-E44TTA

Four cylinder diesel engines for agricultural, industrial, construction applications

Developed to meet EEC off-road mobile machinery Stage IV and U.S. EPA off-road Tier 4 Final legislation

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THE HEART OF EVERY GREAT MACHINE

This manual has been compiled to explain mandatory requirements, provide information for designers and provide information on the application and installation of the 1204F Perkins engines into Industrial equipment, to meet U.S. Environmental Protection Agency (“EPA”) Tier 4 Final regulatory requirements and European Union (“EU”) Stage IV non-road mobile machinery emissions legislation.

We endeavour to provide information in this manual that 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 therefore attention must be paid to ensure that the latest information is utilised and valid data is obtained from the engine specification manual.

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:

- Tier 4 Final Mechanical A and I manual – TPD1830
- Tier 4 Final Electrical and Electronic A and I Manual – TPD1836
- 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 (CAR)

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

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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.

Contents

1.0 INTRODUCTION 5

1.1 SAFETY REQUIREMENTS 5
1.2 TERMINOLOGY 6

2.0 MANDATORY INSTALLATION REQUIREMENTS 7

2.1 GENERAL REQUIREMENTS 7
2.2 CLEANLINESS 7
2.3 PROHIBITED MATERIALS 7
2.4 DEF SPECIFICATION 7
2.5 DEF TANK 8
2.5.1 General 8
2.5.2 Positioning 8
2.5.3 DEF Tank Mounting 9
2.5.4 DEF filler neck extensions/Remote Fill 9
2.6 TANK HEADER 9
2.7 PEU (WITH INTEGRATED DCU) 10
2.8 DEF COMPONENT RELATIVE POSITIONS 11
2.8.1 DEF tank to PEU 11
2.8.2 PEU to DEF injector 12
2.9 DEF COOLANT VALVE 13
2.10 DEF TANK COOLANT SUPPLY LINES 14
2.11 DEF LINES 15

3.0 SCR SYSTEM FUNDAMENTALS 16

3.1 PLATFORM TECHNOLOGIES 16
3.2 DIESEL EXHAUST FLUID (DEF) 16
3.2.1 General DEF Information 16
3.2.2 Standards 16
3.2.3 DEF Quality 16
3.2.3 DEF Storage 16
3.3 REGULATIONS 17

4.0 SCR SYSTEM 18

4.1 AT/ SCR SYSTEM SCHEMATIC 18
4.2 COMPONENTS 20
4.2.1 DEF Tank 20
4.2.2 DEF Filler Cap 21
4.2.3 DEF tank header 21
4.2.4 Coolant Lines and valve 22
4.2.5 DEF Pump 23
4.2.5 DEF Control Unit (DCU) 23
4.2.6 DEF Lines 24
4.2.7 DEF injector 25
4.3 OPERATIONAL PARAMETERS 26
4.3.1 DEF Component temperature Requirements 26
4.3.2 DEF Component Vibration Requirements 27

5.0 SCR SYSTEM DESIGN CONSIDERATIONS 28

5.1 DEF LINE AND COOLANT SCHEMATIC 28
5.2 CUSTOMER CONNECTIONS 28
5.2.1 Coolant Connections 29
5.2.2 DEF Connection Detail 31
5.3 MATERIALS 33
5.3.1 Rubber Components (Seals, etc.) 33
5.3.2 Metallic Components 33
5.4 DEF TANKS 34
5.4.1 DEF Tank Sizing 34
5.4.2 DEF Tank Mounting and Installation 35
5.4.3 DEF Tank Straps 35

5.4.4 Bulk Fuel and DEF Tanks *37*
5.5 DEF COMPONENT MOUNTING AND ISOLATION 38
5.5.1 PEU/DCU Mounting Requirements *38*
5.5.2 DEF Component Relative Positioning *39*
5.6 DEF TANK SERVICE CONSIDERATIONS 39
5.6.1 DEF Tank Filling *39*
5.6.2 Overfill Protection *39*
5.6.3 Remote Fill *40*
5.6.4 DEF Tank Draining *40*
5.7 PRODUCTION AND MANUFACTURING 40

6.0 RECORD OF AMENDMENT 41

6.1 CHANGES FROM ISSUE 1 TO ISSUE 2 41
6.2 CHANGES FROM ISSUE 2 TO ISSUE 3 41

1.0 Introduction

Tier 4 Final/Stage IV now includes the use of SCR technology to meet emissions legislation. DEF is required as part of this technology selection and this document has been written to explain the requirements of the 1204F DEF system. This document is supplementary to the Tier 4 Final/Stage IV1200F Application and Installation Manual, which details the other engine system mandatory requirements and recommendations.

The start of this document details the mandatory installation requirements relevant to the DEF system. These mandatory requirements include emission related requirements and warranty related requirements.

All mandatory requirements must be adhered to in order to ensure emission compliance and attain full engine warranty.

For engines operated within the US the following statement applies:

'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.'

For full details of the structure of the complete manual please refer to the table of contents.

For details of electronic and electrical systems please refer to the Tier 4 Final/Stage IV Electronic A and I Manual.

1.1 Safety Requirements

Diesel Exhaust Fluid (DEF) is an aqueous urea solution blended with *32.5%* high purity urea and *67.5%* deionized water. DEF solution is used in selective catalytic reduction (SCR) to lower NOx concentration in the exhaust emissions of diesel engines.

Diesel Exhaust Fluid Hazard Identification

Signal Word: CAUTION

Hazard Statement: May cause eye and skin irritation contains material that may cause target organ damage, based on animal data.

Precautionary measures: Do not breathe vapor or mist. Do not eat, drink or smoke when using this product. Avoid contact with eyes, skin and clothing. Wash thoroughly after handling.

Potential acute health effects

Inhalation: Exposure to decomposition products may cause a health hazard. Serious effects may be delayed following exposure.

Ingestion: No known significant effects or critical hazards.

Skin: Moderately irritating to the skin. Not expected to produce significant adverse health effects when the recommended instructions for use are followed.

1.2 Terminology

- SCR Selective Catalytic Reduction
- CDPF Catalysed Diesel Particulate Filter
- DEF Diesel Exhaust Fluid
- PETU Pump Electronic Tank Unit
- PEU Pump Electronic Unit
- DCU Dosing Control Unit
- ULSD Ultra Low Sulphur Diesel
- OEM Original Equipment Manufacturer
- CDV Coolant Diverter Valve

2.0 Mandatory Installation Requirements

'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.'

2.1 General Requirements

- The DEF tank capacity must be chosen or designed to facilitate at least a 1:1 filling ratio with the ULSD fuel tank.
  - This can be achieved considering a maximum DEF consumption rate of 4% of fuel
  - This should be calculated using the operational volume and taking into consideration the maximum tilt angle of the machine under continuous operating conditions - ref 5.4.1.
- The DEF component temperatures in table 4.2, section 4.3.1 must be adhered to.
- The DEF system components must be isolated from excessive vibration and fall within the component profile limits detailed in section 4.3.2.
  - Vibration levels must be measured on applications subject to high vibration during operation; including Rock Crushers, Tracked type Tractors and Pavers.

2.2 Cleanliness

- DEF Cleanliness must be adhered to as outlined in ISO 22241
- DEF system components are supplied with caps over hose connection points; these must not be removed before final assembly to ensure cleanliness is maintained.
- The following DEF system component cleanliness requirements must be maintained during the customer assembly process. In addition any components which have been supplied by the customer must also meet these specifications.
  - DEF lines – internal surfaces.
    No more than 5 particles > 1200x500x150um and 170mg/m^2.
  - DEF Tank, Header assembly and DEF pump – In contact with DEF fluid:
    50-100um = 600 particles;
    100-200um = 80
    200-500um = 8
    >500um = 0
- The cleanliness of the coolant and coolant system must be maintained and protected to ensure maintained operation of the coolant valve. Particles <1000 um.

2.3 Prohibited Materials

Any customer supplied metallic components expected to be in direct contact with DEF must not be made of the following materials:

- Aluminium
- Brass
- Copper
- Zinc
- Mild steel

2.4 DEF specification

- DEF must meet the requirements in section 3.2.2 , Standards
- The quality of the DEF must be maintained throughout the machine operation to maintain acceptable machine performance and prevent frequent fluid replacement.
- The level of DEF in the tank must cycle from the DEF low level warning to the DEF maximum fill level. This is required to provide an accurate indication of DEF quality, required for emissions compliance.

2.5 DEF Tank

2.5.1 General

- The DEF tank is an emissions related component and should be selected from Perkins product offering.
- The tank must be selected to suit the operational use of the machine- equivalent to a minimum of 4% of fuel consumption (1:1 DEF to Diesel fuel refill rate). Ref 5.4.1
- The DEF tank should be identified with the correct symbol on the fluid container or Fill point. The symbol markings should be in accordance to ISO 22241 and ISO 2575.
    - The colour is to be associated with the DEF fill point or cap should be blue as referenced in the standard.
- The DEF tank feed line must be submersed in all operating conditions.
- The DEF tank assembly must not be modified in any way from the supplied condition

2.5.2 Positioning

- The DEF tank must be mounted in a location to meet the temperature requirements of the DEF fluid and the DEF tank as tabulated in section 4.3.1
    - All temperatures must be tested in accordance with the defined test procedure
- The DEF tank must not be mounted in a location that is prone to dust or debris build up;
    - Which could cause physical damage to the tank or attached components.
    - Which could collect around the tank filler cap.
- The tank filler and drainage plug should be distanced or isolated from components which are not resistant to DEF in the event of spillage.
- The DEF tank must be positioned so that it is easily accessible for servicing, replenishing, draining and replacing the DEF.
- The DEF tank location must not risk contamination of the DEF with service fluids i.e. under oil or fuel filters
- The DEF tank must be protected from impact and projectiles
- The DEF tank must be protected from side loading
- The DEF tank drainage plug must be accessible

2.5.3 DEF Tank Mounting

The following information is for tanks sourced and designed by Perkins. Tank mounting is the OEM responsibility; the following must be adhered to for successful tank mounting.

- The bottom of the tank must be horizontal and fully supported by a structural platform
    - Full support is defined as a continuous material that is at least as large as the tanks base dimension.
    - Structural is defined as being able to support full tank mass with application dynamic loading without plastic deformation or failure.
- The tank mounting materials must be resistant to DEF
- The tank must be isolated from abrasive surfaces that may penetrate the tank material over time.
- The tank must be retained in all ambient and operating conditions without stressing the tank material while allowing for thermal expansion and contraction.
- The tank requires hold down straps to secure the tank to the structural platform in the vertical plane.
    - The pre-moulded tank grooves must be used for these hold down straps
    - The straps must always sit flat within the pre moulded grooves and must be sized considering the max and min strap and groove tolerances. Ref – table 5.6 in section 5.4.3
    - The straps must pass over the top of the tank- Ref - figure 5.7 in section 5.4.3
- There must be sufficient clearance between the tank walls and any other component to allow for thermo-cycling and tank mounting tolerances
    - A minimum gap of 9mm should be maintained on all side and top faces.
    - This 9mm space can be maintained by using spacers that are located in the tank strap grooves on the tank. This can also be achieved by increasing tank hold-down strap thicknesses to >9mm.
- Spacers must not be positioned elsewhere on the tank side walls.
- The tank side walls must not be mounted directly against any surfaces. Full coverage of any side wall is prohibited. If this is a requirement then Perkins approval is required and a full validation study conducted.

2.5.4 DEF filler neck extensions/Remote Fill

- A DEF tank filler extension must only be used with the compatible DEF tank option. Use of a filler extension with any other factory supplied tank is prohibited.
- The filler extension must be designed to meet the requirements in IGB 99-05.1

2.6 Tank header

- The DEF tank header is an emissions related component and must be selected from Perkins product offering.
- It is not permitted to re-orientate or modify the DEF tank header from its assembled position on the DEF tank as supplied by Perkins.
- The tank header must be electrically connected in accordance with the requirements in the Electronic Application and Installation manual.
- The tank header coolant inlet and outlet connections are identical in size and machine build processes must be put in place to prevent incorrect matching of hose to connector. Refer to section 4.2.3

2.7 PEU (with integrated DCU)

The PEU has an integrated DCU. It is supplied loose for customer fitment.

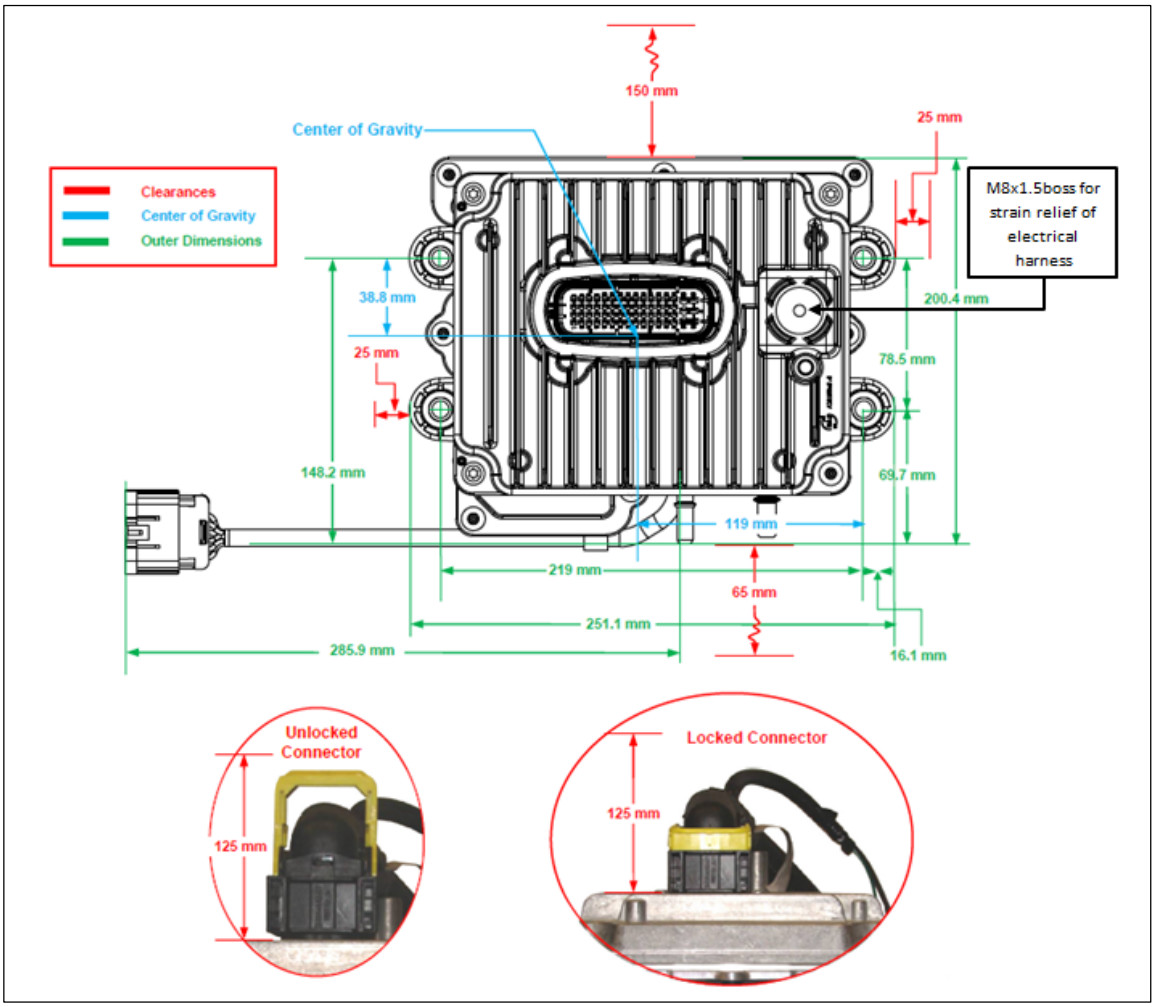


Fig 2.2 - PEU Dimensions and Clearance requirements.

- The PEU is an emissions related component and must be Perkins supplied.
- The PEU must be mounted vertically +/-5° with the two DEF connections at the bottom and the filter at the top to ensure injection and purge functionality
- The PEU must be mounted internally or externally via all four M8 mounting through holes ref section 5.5.1
  - The mounting face between the four points must be flat within a tolerance of +/- 0.5mm
- The maximum tilt during operation is 45°
- The PEU must be mounted so that the vibration falls within the specified limits in section 4.4.2
- The PEU must not be engine mounted. It is recommended that the pump is mounted on the machine chassis
- The PEU must be mounted in a location:
  - that is protected from splash, stone chips, dirt and debris
    - Care should be taken to ensure dust and debris does not build up on the box and does not block the vent on the rear of the unit.
    - Measures should be taken to prevent dust/debris falling into the filter chamber when removed for service
  - where the pump temperature limits are not exceeded- ref section 4.3.1
    - In order to achieve this, the pump should not be mounted near any heat source and there must be sufficient cool airflow round the pump.
- The following clearances are required for servicing:

- There must be a minimum of 150mm clearance above the filter cap to provide sufficient space to service the filter.
    - Access for a 22mm hex socket is required to replace the filter cap (to 14Nm +/- 2Nm)
- Minimum clearance of 125mm must be given for DCU connector removal
- Minimum clearance of 65mm must be given for DEF inlet and outlet connector fit/removal
- Minimum clearance of 25mm should be given to the left and right side of the PEU

- The pump must be specified to the correct voltage of the machine and wired in accordance with the Electronic A&I manual
    - There is an M8x1.5 tapping (21mm depth) on the RHS top face of the DCU which should be used for strain relief of the electrical harness. Torque limit is 15Nm=/-1.5Nm.
- The PEU must not be painted

2.8 DEF component relative positions

- All DEF system configurations require validation and approval to ensure the system requirements are met.

2.8.1 DEF tank to PEU

There are limitations on the relative position of the tank base level to the PEU inlet connection; these are detailed in fig 2.3 below.

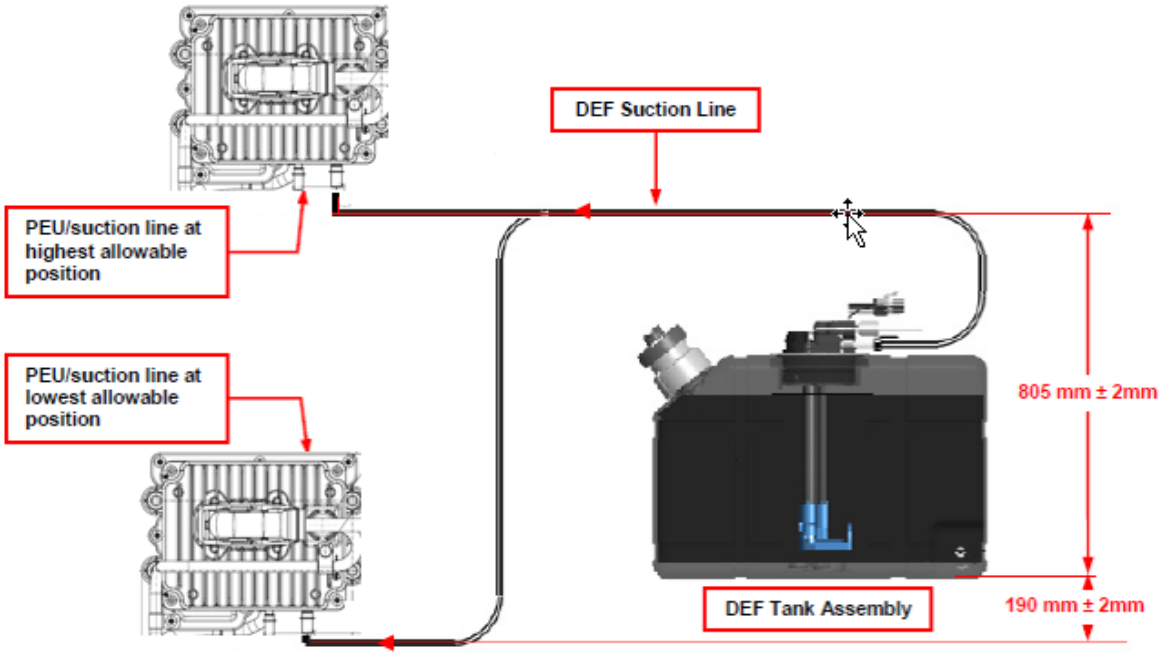


Fig 2.3 – DEF Tank Relative Position to PEU

- The longest DEF suction line allowed is 2000 mm
- The lowest point on the DEF suction line, which attaches to the PEU, should be no more than 190 mm ± 2 mm lower than the bottom of the standard tank.
- The highest point on the DEF suction line, which attaches to the PEU, should be no more than 805 mm ± 2 mm higher than the bottom of the standard tank.

2.8.2 PEU to DEF injector

There are limitations on the relative position of the PEU outlet and the DEF injector inlet connection; these are detailed in fig 2.4 below.

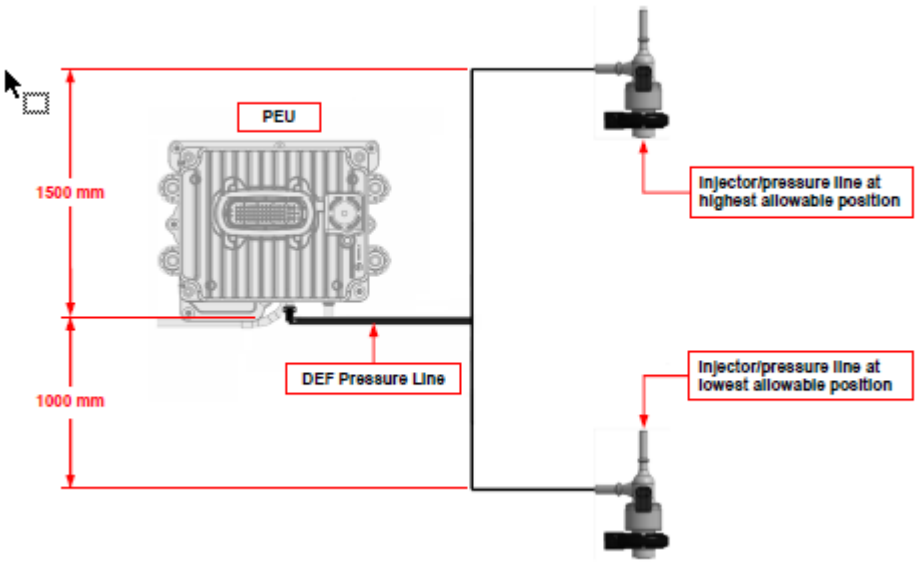


Fig 2.4 – PEU Relative Position to DEF Injector

- The longest DEF pressure line allowed is 4000 mm.
- The lowest point on the DEF pressure line, which attaches to the injector, should be no more than 1000 mm lower than the bottom of the PEU.
- The highest point on the DEF pressure line, which attaches to the injector, should be no more than 1500 mm higher than the bottom of the PEU
- A P-Trap should be used to prevent DEF pooling at the injector.
    - This requires the lines lowest point to be at least 100mm lower than the injector connection.

2.9 DEF coolant valve

- The DEF coolant valve is an emissions related component and must be selected from Perkins product offering.
- The DEF coolant valve must be connected with an electrical harness by the OEM in accordance with the Electronic A&I manual.
- The valve must be located on the inlet side of the of the tank header unit (between engine and Tank header)
- The coolant valve may be mounted at any angle provided the maximum operating angle of the valve, combined with the maximum machine operating tilt, is no greater than +/- 45deg from vertical in any direction. See fig 2.5 below.
    - It is recommended that the valve is mounted vertically (+/-5°).
    - If the coolant valve is mounted in the reverse direction, 2 mm spacers must be used between the mounting surface and the valve to prevent interference

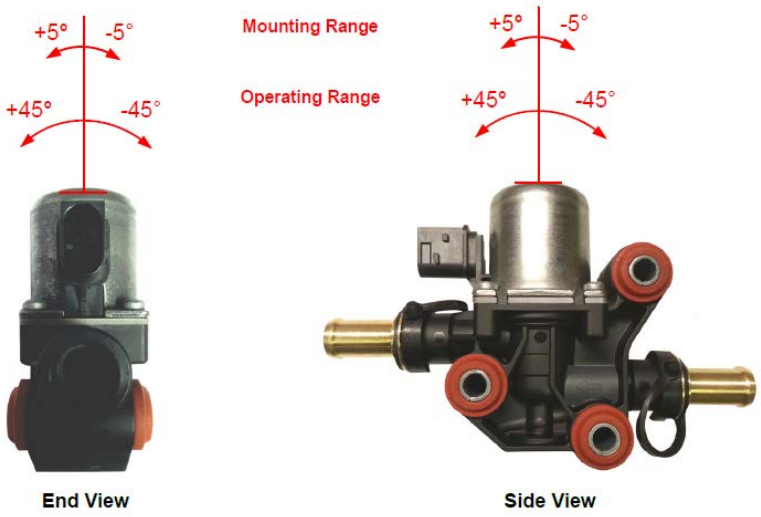


Fig 2.5 – DEF Coolant Valve

- The valve must be mounted with three M8 bolts. The bolt pattern is as shown in fig 2.6

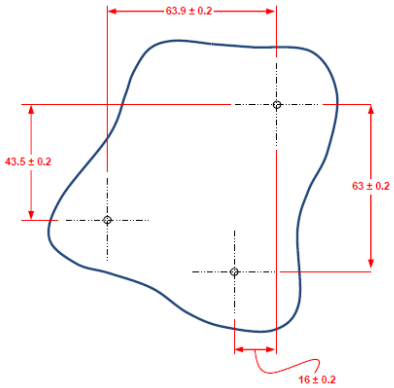


Fig 2.6 – Coolant Valve bolt pattern

- The temperature of the control valve must not exceed the limits detailed in Table 4.2 section 4.3.1.
    - This must be tested in accordance with the relevant test procedure
- The coolant valve must not be mounted on the engine.
- The coolant valve must be mounted so that the vibration falls within the specified limits in section 4.3.2
- The inlet and outlet are identical in size and machine build process must be in place to prevent misconnection of these (flow direction arrows are visible on valve body)
- The valve is supplied with quick connectors providing a push fit for hoses, however it is acceptable for the OEM to source 5/8” SAEJ2044 connectors if required.
- Side loading of the valve inlet/outlet should not exceed 10N in any direction and strain relief of coolant lines should be used.

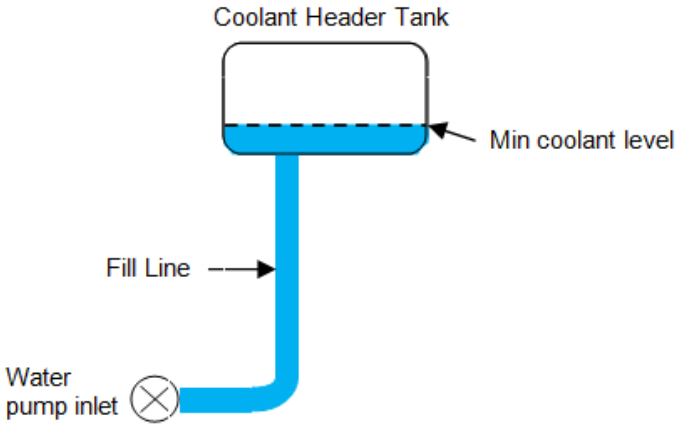
2.10 DEF tank coolant supply lines

- Only the designated coolant supply and return ports on the engine may be used as detailed in section 5.2.1
- The correct hose fittings must be used to connect to the engine; ref section 5.2.1
- The correct hose fittings must be used to match the DEF coolant valve; ref section 5.2.1
- Reinforced hose must be used to minimise expansion when system is pressurised
- To achieve adequate thaw of the DEF tank a minimum of 2l/min coolant flow and temp of 80°C temp must be maintained. To ensure sufficient flow the following requirements must be met:
  - The total length of the coolant hoses (supply and return from tank) must be less than 8m, including a maximum of two 90° hose fittings.
  - Use connectors and hoses with ID 16mm (5/8").
  - The maximum volume of coolant in the DEF tank coolant supply line must be such that:

  For a Portrait tank
  CV (litres) + 0.4 (litres) < RV (litres)

  For a Landscape tank
  CV (litres) + 0.6 (litres) < RV (litres)

  Where
  CV = Coolant Volume - the volume of coolant in DEF tank coolant supply line
  RV = Reserve Volume - this is equal to the volume of coolant below the minimum level in the coolant header tank added to the volume of coolant in the fill line as shown in the diagram below.



- The coolant lines must:
  - Be properly supported
  - Not impose stress on the mating connectors
  - Recommend support 150mm-250mm max from end connectors
  - Be secured such as to avoid abrasion with touching surfaces
  - Have minimal bends
- The coolant temperature drop (delta) between engine coolant temperature sensor and DEF tank temperature sensor must not exceed 10°C.

2.11 DEF lines

- DEF lines are emissions related components and should be selected from Perkins product offering.
- The total line length of the three DEF lines (pressure, suction and return) must not exceed:
  - 9.5m (12V)
  - 10 m (24V)
- The pressure drop across each of the DEF Lines must not exceed the limits shown in the table below. This includes the head height plus bends plus the pressure drop due to the line itself.
  - To achieve this a maximum of 4 x 90deg bends is permissible
  - The bend radius must not be less than 56mm

DEF Line	ΔP Limit (kPa)	Installed condition
Pressure Line	9.6	DEF Injector above PEU
	13.8	DEF Injector below PEU
Suction Line	9.6	

Table 2.1 – DEF line pressure requirements

- The DEF lines must;
  - Be routed as direct as possible with no dips or sags
  - Be secured such as to avoid abrasion with touching surfaces
  - Be properly supported and not impose any side load or stress on mating connectors
    - The supports for the DEF lines must provide strain relief to the DEF injector and DCU connections i.e. restrain on both sides of any bends in the DEF line.
  - Be supported 150mm maximum from end connectors
  - It is recommended that the lines are fully supported every 150-300mm along line length
- When DEF lines are mounted across surfaces with different relative movements, additional line length should be considered to prevent line tension.
- SAE J2044 connectors should;
  - be insulated where local air temperatures will exceed 120°C (reflective shield supplied pre-fitted at injector connection by Perkins)
  - be protected from airflow to prevent the connector from freezing
- The DEF lines must be electrically connected in accordance with the requirements detailed in the Electronic A &I Manual.

3.0 SCR System Fundamentals

3.1 Platform technologies

Overview of 1204F technology selection

3.2 Diesel Exhaust Fluid (DEF)

DEF fluid/Urea is made up of approximately 70% water which at temperatures below –11°C will expand by approximately 10% to 15%.

3.2.1 General DEF Information

For Perkins diesel engines that are equipped with SCR equipment, meeting the mandated exhaust emissions levels requires the use of diesel exhaust fluid (abbreviated DEF, also known as AdBlue or AUS32). DEF is the only fluid recommended by Perkins for use in SCR systems in Perkins diesel engines. DEF is available commercially, and its manufacture is regulated by the American Petroleum Institute (API) to assure all DEF meets stringent quality specifications, as defined in “ISO 22241-1 - NOx Reduction Agent AUS 32 – Part 1: Quality Requirements.”

3.2.2 Standards

- ISO 22241 – NOx reduction agent AUS 32
  The ISO 22241 series provides the specifications for quality characteristics (22241-1), for test method (22241-2), for handling, transportation and storage (22241-3), and for the refilling interface (22241-4) as well as the test methods, needed by the manufacturers of motor vehicles and their engines, by converter manufacturers, by producers and distributors of the DEF and by fleet operators.

- DIN 70070 – NOx-Reduction agent AUS 32
  This describes the quality requirements for the NOx deoxidizing agent AUS 32, required for the deployment of catalytic converters with SCR in diesel engine powered automobiles.

- 1200 Series engines and machines with DEF/SCR equipment used in the US, are required to use API (American Petroleum Institute) certified diesel exhaust fluid.

- Warning: Use of fluids that are not recommended by Perkins can result in numerous problems including damage to DEF/SCR equipment.

3.2.3 DEF Quality.

The quality of DEF is critical. Tight control on the individual constituents is necessary to:

- Maintain shelf life
- Prevent injector clogging
- Prevent formation of deposits
- Prevent poisoning of the catalyst

3.2.3 DEF Storage

- For DEF storage requirements refer to the OMM
- DEF has a finite storage life dependent on the fluids storage temperature and vessels type used.
- DEF is not classified as dangerous or hazardous waste but care must still be taken in disposal.
- DEF should not be disposed of in drains or waterways where DEF may enter the ground water. Refer to applicable local and national regulations regarding proper disposal for your location.

3.3 Regulations

The certification requirement on SCR systems can vary depending on the governing regulatory body specifically between the EU and EPA.

The regulatory requirement for the SCR system is that the control system monitors DEF level and detects control system malfunctions. The engine control system therefore, monitors the following key SCR system parameters and applies various warnings and inducement levels to meet these regulatory requirements.

- Low DEF level
- Degradation of DEF
- Interruption to DEF dosing (for reasons other than the tank is empty)
- Tampering or diagnostic system failure (to prevent unplugging of the level sensor for example)
- Frozen DEF (this will be detected as interruption to DEF dosing, as frozen fluid will stop injecting, however it is important to differentiate that the DEF is frozen as the timings and severity of inducements are different.)

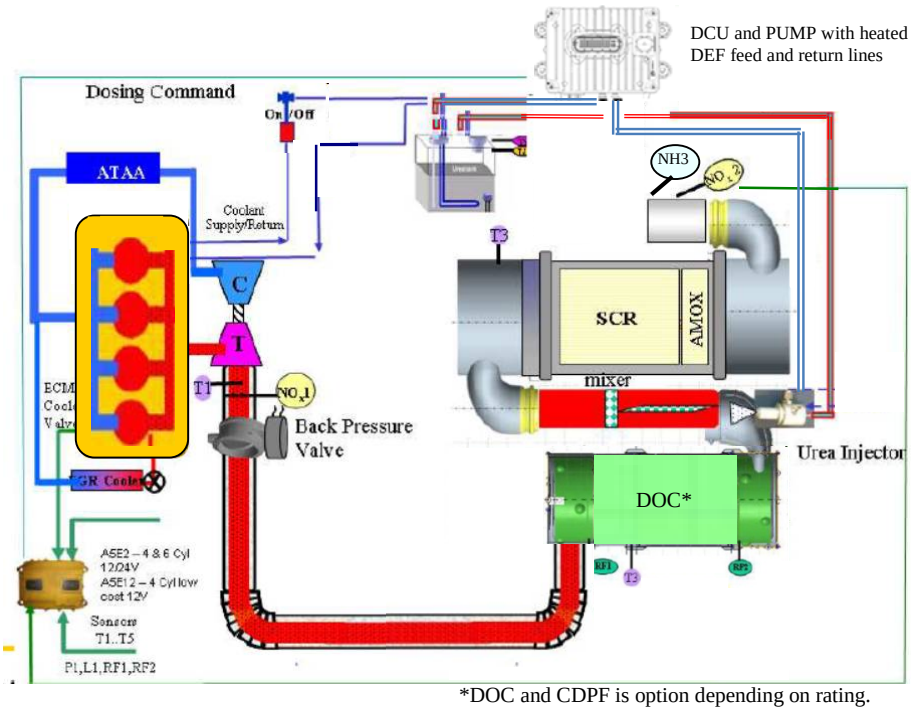
Inducement

Due to regulatory requirements, Tier 4 Final / Stage IV engines cannot be allowed to run when the DEF system is not functioning correctly. There can be several reasons why the DEF system might not be working properly.

Examples include poor quality DEF, lack of DEF in the tank, diagnostics, etc. In these cases, specific actions will be taken to notify the operator. These actions will include lamps and J1939 communication. However, it must be understood that once a defined series of communications has taken place, the engine will be required to shut down and in some cases, restart only briefly. This strategy will not be configurable in Perkins EST. The Tier 4 Final Electronic A&I manual provides specific information. This information is repeated here in the Mechanical Guide simply to emphasize the issue.

4.0 SCR System

4.1 AT/ SCR System Schematic



*DOC and CDPF is option depending on rating.

Fig 4.1 - Aftertreatment and SCR Schematic

Fig 4.1 above shows the components and system arrangement required to meet Tier 4 Final / Stage IV Emissions Legislation.

From Fig 4.1, it can be seen that DEF is drawn from the DEF tank through a 'suction' line to the DEF pump where it is pumped through a heated 'pressure' line to the DEF injector. The DEF injector, installed within the SCR mixer, then injects DEF into the exhaust gas to activate the reaction in the SCR canister and reduce the exhaust NOx. Any excess DEF is returned from the DEF injector back to the tank to create a continuous closed loop system.

Control of the DEF injection is managed by the DCU. The signal from the NOx sensor on the engine exhaust outlet prior to the after treatment and in the exhaust tailpipe is used along with other sensor inputs to meter the quantity and timing of DEF injection

To comply with the legislative freeze and thaw cycle requirements the temperature of the DEF is monitored, with a sensor in tank, by the DCU. The DCU can then control the flow of coolant from the engine through a diverter valve to heat the tank and the pump as required. The DEF lines are also electrically trace heated to ensure these are thawed and free from blockages; this is also controlled by the DCU.

As shown in Fig 4.1 the components required to meet the Tier 4 Final / Stage IV Emissions Legislation consists of:

Aftertreatment

- DOC and CDPF Canister or DOC only (rating dependant)
- Flexpipe
- Nox sensor
- Mixer
- SCR canister

All the components within this system must be supplied by Perkins.

DEF system

- DEF tank
- DEF tank header
- DEF pump
- DEF Control Unit (DCU)
- DEF Lines
    - Heated suction line
    - Heated return line
    - Heated pressure line
- DEF injector (supplied fitted in AT mixer tube)
- Coolant valve
- Coolant lines to DEF tank

The DEF pump and control unit assembly, DEF injector, DEF tank header and coolant valve must be supplied by Perkins as these are emissions critical components. The coolant lines are customer supplied.

A more detailed description of the DEF system components and their operation are all discussed individually in section 4.2 below.

4.2 Components

4.2.1 DEF Tank

The DEF tank is an emissions related component and should be selected from Perkins product offering. These tanks have been fully validated as part of an integrated solution to ensure durability, performance and adherence to legislative requirements.

The DEF tank is available in two sizes - a 19 litre tank available in portrait or landscape or a 38 litre tank in landscape orientation only. Note this capacity is the total volume of the tank and not the useable DEF volume which is required for tank sizing. Please also note that if remote fill is required then a compatible tank must be selected.

The DEF tank requires heating and this is done by engine coolant which is controlled by the coolant control valve (CCV.)

For maintenance of the DEF tank please refer to the engine OMM. Note for cleaning of the tank, it can be reverse flushed with distilled or de-ionized water through the drain, then flushed with new DEF just before use.

A typical DEF tank is shown in Fig 4.2. This shows the following features, which are incorporated into the tank design:

- **DEF tank header – ref section 4.2.3**
- **Drain plug**
- **Fill neck**
  Compatible with an ISO22241 compliant adapter and contains a serviceable 180 μ strainer. All adapters supplied by Perkins include a magnetic toggle which when filled from a nozzle with a magnetic safety switch will prevent DEF from being dispensed into a non-DEF tank. The size of the neck is such that it prevents a standard diesel or gasoline fill nozzle from being inserted into the tank resulting in a miss fill. There are, however, no devices in the adapter preventing a determined party from inserting a non-standard fill hose and filling the tank with fluids other than DEF. A remote fill adapter is also available as an option.
- **Fill cap with filtered vent –ref section 4.2.2**
  The DEF cap is designed such that it cannot be installed on other type of tanks (fuel, coolant, etc.) and conversely, other caps cannot be used on the DEF tank.
- **Overfill protection device** (incorporated into fill adapter)
  This maintains the volume of expansion space and is done by simply extending a tube to the required level then allowing the flow to back up in the nozzle activating its automatic shutoff.

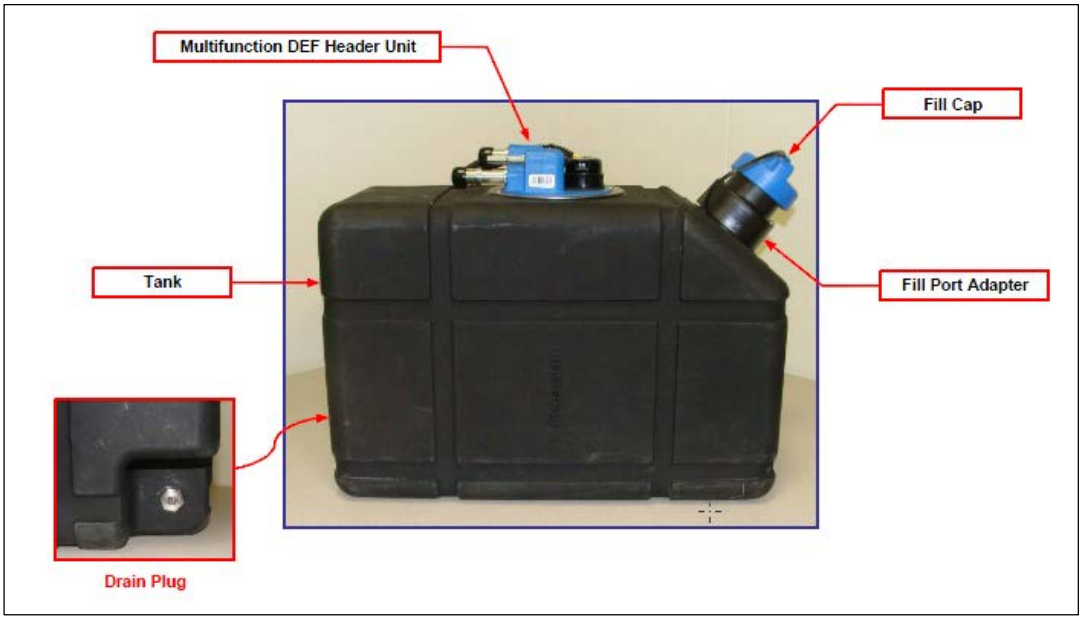


Fig 4.2 – Typical DEF Tank

4.2.2 DEF Filler Cap

The DEF cap is designed such that it cannot be installed on other type of tanks (fuel, coolant, etc) and conversely, other caps cannot be used on the DEF tank. The cap shall be UV resistant and resistant to splashing from diesel, coolant, DEF, hydraulic fluid, motor oil and water.

- The cap shall be coloured blue and the symbol and marking is done according to ISO 22241-1 and ISO 2575.
- The cap shall meet cleanliness requirements of ISO 22241-3.

The DEF cap features are:

- Cap lanyard
- Design clearances require 90° turn to remove cap
- Open venting to eliminate the build-up of pressure in the tank as gases/fluids expand as temperature increases per DEF Pump specifications.
- Cap Filter with Filtration Value - 100µ with a 4µ hydrophobic membrane.

4.2.3 DEF tank header

The tank header can be supplied installed in the DEF tank as part or supplied loose for fitment to an OEM designed tank (both in same engine option).

Fig 4.3 below shows the different elements that go to make up the Perkins DEF tank header

The correct fitment of the coolant lines to the DEF tank header is critical to ensure the venting of air and thawing efficiency. Arrows are cast into the header to identify inlet/outlet and customer lines should be marked or labelled to ensure the correct match is made.

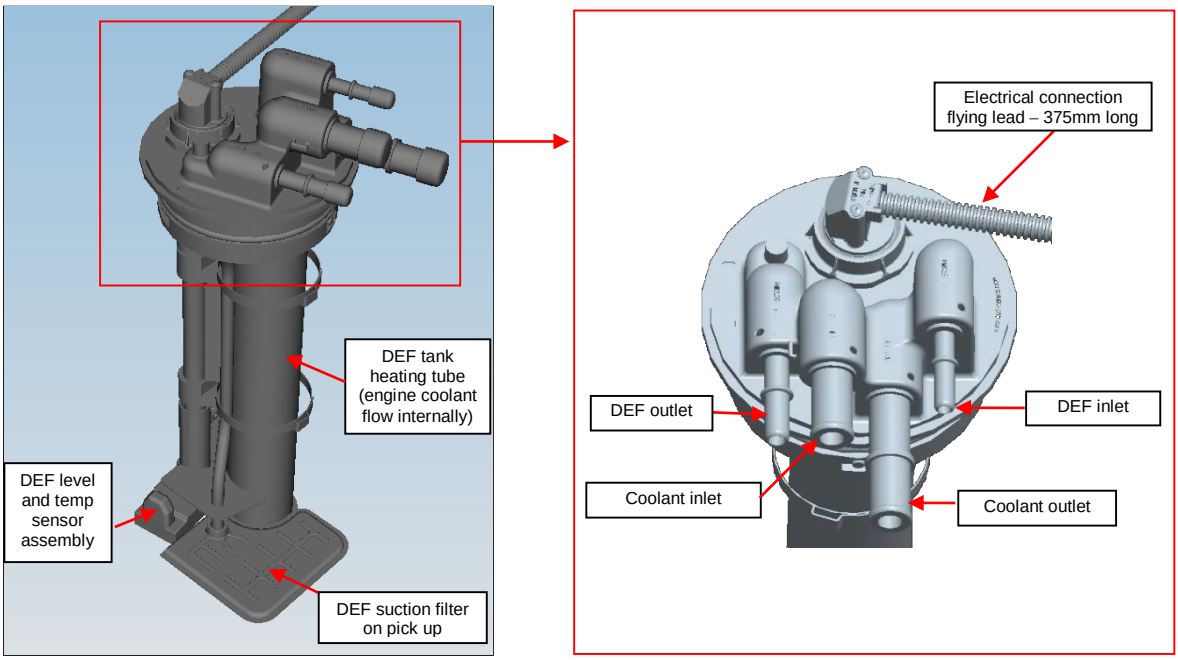


Fig 4.3 – DEF Tank header

	Inlet	Outlet
DEF Connector	5/16” SAE J2044 quick connect (return from injector)	3/8” SAE J2044 quick connect (supply to delivery system)
Coolant Connectors	5/8” un-barbed outer diameter (from engine)	5/8” un-barbed outer diameter (return to engine)

Table 4.1- DEF tank header customer connections

The Perkins tank header incorporates the following features:

4.2.3.1 Tank pick up

The DEF pick-up has a 40µm filter incorporated in the header. The filter is fit for life but can be serviced if required. The style of pickup was selected as the most compact and beneficial design with regard to tilt capability.

4.2.3.2 Level Sensor

This level sensor has been carefully designed and validated to work with Perkins supplied DEF tanks. It measures the DEF level to ensure proper inducement occurs and that all applicable regulations are met.

4.2.3.3 Temperature sensor

A temperature sensor is incorporated into the base of the header where it will read the DEF temperature near the DEF pick-up. The readings are used to control the flow of coolant to provide the proper rate of thawing. The sensor is sealed and not independently serviceable.

4.2.3.4 Heating tube

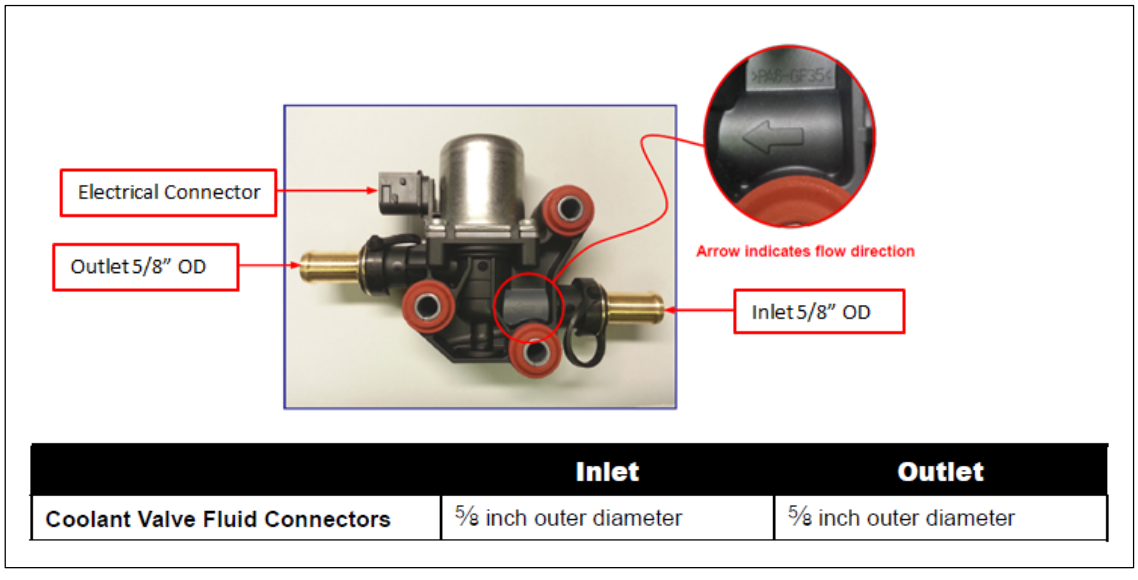
The tank is heated by engine coolant controlled by the operation of the coolant diverter valve from the DCU. The coolant flows within a heater tube which runs down and up the centre of the tank header unit.

Again this design has been optimised and validated specifically for Perkins supplied DEF tanks, which ensures that the DEF fluid is available at the required rate and condition under all the specified parameters to ensure emissions compliance.

4.2.4 Coolant Lines and valve

Coolant supply lines are required to supply coolant from engine to the header and into the heating tube; via the coolant control valve (CCV) to heat the DEF in the tank. These lines must be supplied by the customer as they are not supplied as part of the engine offering and must adhere to the mandatory requirements detailed in section 2.10. Guidance on the material and fitting requirements can be found in section 5.2.1 design considerations

Fig 4.4 below shows the coolant control valve. When closed, a new coolant valve will have a leak rate of 2 L/h. This leak rate increases to 3 L/h after the valve completes its useful life. These values are calculated based on an ambient temperature of 20 °C, coolant temperature of 105 °C, and coolant pressure between 0.5 bar and 1.0 bar.

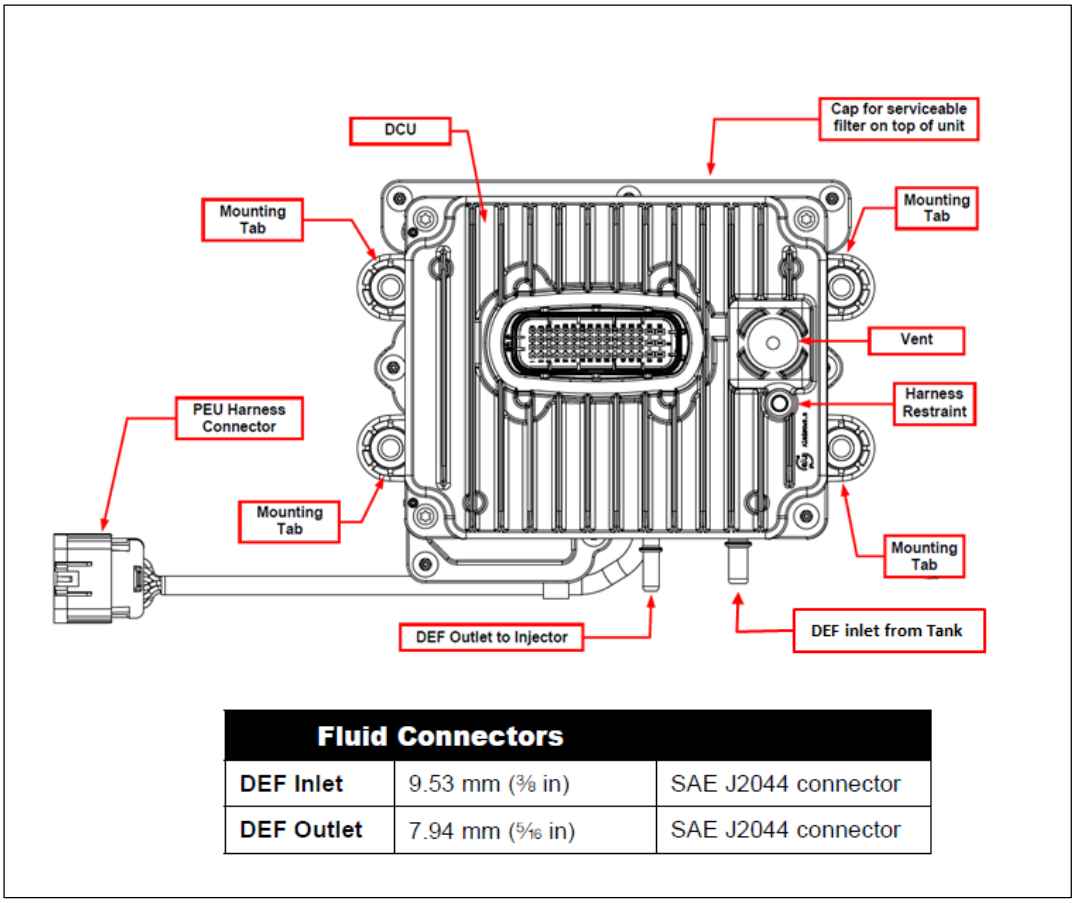


	Inlet	Outlet
Coolant Valve Fluid Connectors	5/8 inch outer diameter	5/8 inch outer diameter

Fig 4.4 –Coolant Control valve

4.2.5 DEF Pump

The DCU is supplied as part of the DEF pump assembly and transfers DEF from tank to DEF injector and back to tank.
Figure 4.5 below shows the different constituent parts within the PEU.



Fluid Connectors		
DEF Inlet	9.53 mm (⅜ in)	SAE J2044 connector
DEF Outlet	7.94 mm (5⁄16 in)	SAE J2044 connector

Fig 4.5 – PEU components

4.2.5 DEF Control Unit (DCU)

The DCU is supplied as part of the DEF pump assembly. The DEF control unit takes inputs from various sensors within the system to:

- Accurately control the delivery of DEF to the DEF injector.
- Control the coolant diverter valve to maintain the DEF tank temperature and control the freeze thaw cycle
- Provide an input into the engine inducement strategy

4.2.6 DEF Lines

The following 3 DEF lines are required:

- Suction line – Tank to pump
- Pressure Line - supply from pump to DEF injector
- Return line – return from injector back to tank

The DEF lines are electrically heated lines available in either 12 or 24V. They are supplied with the appropriate quick fit connectors and available in various lengths.

The lines are heated by embedded heater wires to prevent solids from forming in the DEF solution in colder temperatures below –11°C; the point at which DEF freezes. They have been designed, optimised and validated to be used with system provided taking into consideration both the flow requirement and current draw.

Correct operation of these lines is required to ensure adherence to emissions requirements. These parts should, therefore, be selected from the Perkins product offering.



Figure 4.6 – Heated DEF Lines

4.2.7 DEF injector

The DEF injector is a critical emission critical component. It is supplied pre-fitted into the mixer as an integral part of the aftertreatment system.

The injector is supplied with DEF, controlled by the DCU, through the heated DEF lines, which are fitted by the OEM. The mandatory requirements for these lines can be found in section 2.11 and further guidance on their fitment is contained in section 5.2 design considerations. The connection points for the heated lines are shown in Fig 4.7 below along with the installed location of the DEF injector.



Figure 4.7 – DEF Injector

4.3 Operational Parameters

4.3.1 DEF Component temperature Requirements

COMPONENT	MAX TEMP °C
DCU/PEU – Ambient temperature around all sides (worst case)*	-40 to 70°C Continuous Operational -40 to 75°C max 120 minutes intermittent -40 to 85°C Storage
DEF Injector – Ambient temperature *	-40 to 125°C Continuous Operational
DEF Tank Surface – Ambient temperature *	65°C continuous 68°C – 10 minutes max intermittent
Coolant Valve – Ambient temperature *	-40 to 105°C continuous 150°C –15 minutes max intermittent
DEF lines - Ambient temperature *	-40 to 120°C continuous 140°C –15minutes max intermittent; with DEF flowing

*Temperatures to be measured in accordance with the appropriate test procedure.

Table 4.2 – DEF Component Temperature Limits

4.3.2 DEF Component Vibration Requirements

Vibration needs to be taken into consideration for all DEF system components.

DEF components must be mounted on a structure that will provide sufficient rigidity to support the mass of the components and avoid system resonances during the machine operating cycle including the worst case cycle and shock loading.

It is recommended that testing is conducted to ensure that the vibration profile falls below the curve shown in Fig 4.8

This information, coupled with knowledge of the machine type, duty cycle and location of the mounting should also help determine the mounting requirements and establish if isolation mounting is needed.

Further advice on vibration testing requirements and the necessary test procedures will follow in a later release of this supplement in the meantime please contact your Application Engineer for further information.

Tank header assembly, coolant valve and PEU

Operational Loads Baseline Combined High and Low Frequency		
Frequency	**Power**	
Hz	**(RMS) (m/s^2)"2/Hz**	**(RMS) g^2/Hz**
10	3.19	0.033111
20	2.29	0.023840
30	2.29	0.023840
45	1.02	0.010595
180	0.06	0.000662
2000	0.06	0.000662

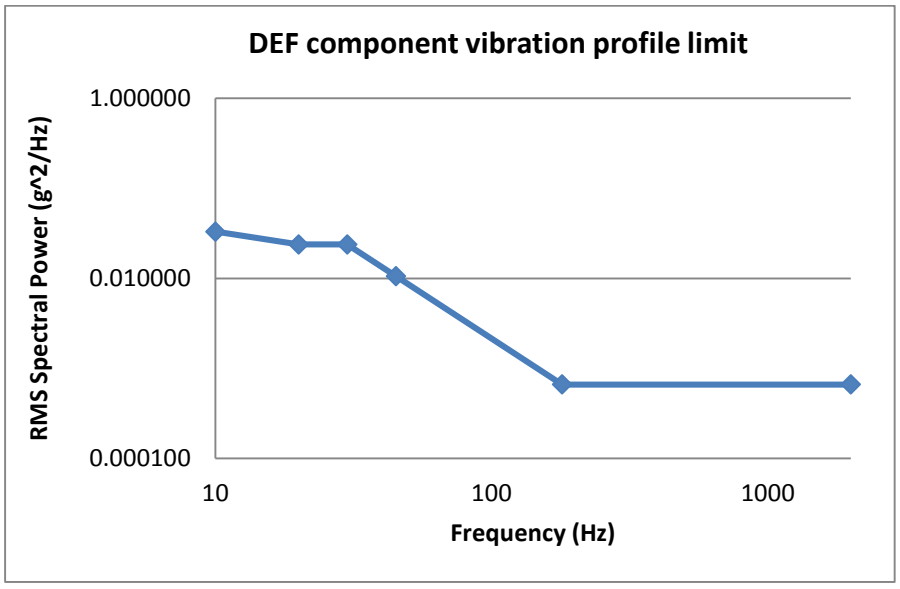


Fig 4.8 - Tank header assembly, coolant valve and PEU Vibration Profile

5.0 SCR system Design Considerations

5.1 DEF Line and Coolant schematic

Fig 5.1 below shows the system cooling and DEF line schematic; detailing each individual line and its relevant option code designation thus enabling a cross reference to be made to the ESM in order to select the most appropriate line length option. Details of the line requirements and connections specifications that must be made by the customer are detailed in the following sections.

SCR dosing system option summary

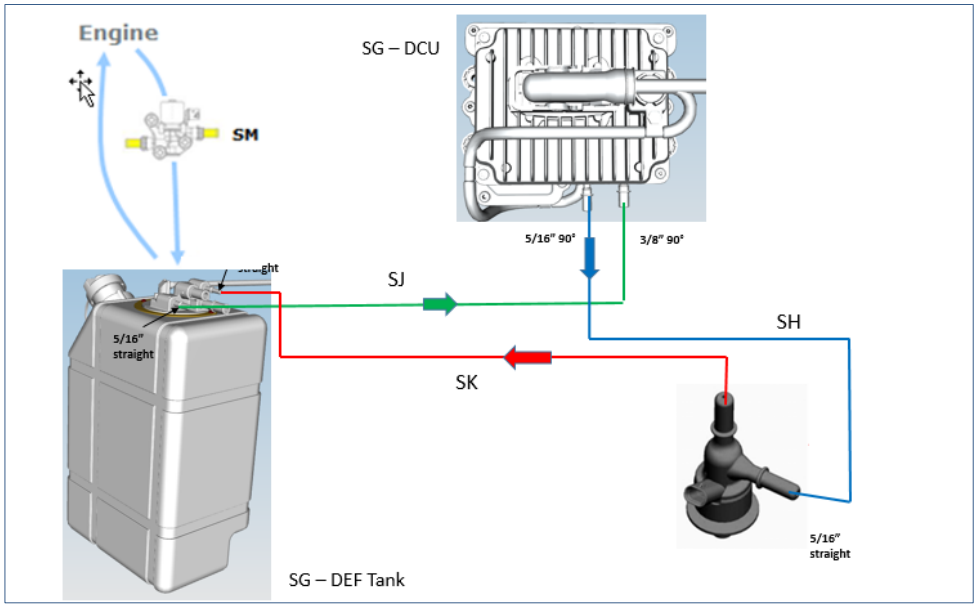


Fig 5.1 – DEF lines

Option	Description
SG	DEF Tank, Header and Pump
SH	DEF Line – Pump to injector
SJ	DEF Line – Tank to Pump
SK	DEF Line – Injector to pump
SM	DEF Coolant Valve

Table 5.1 – DEF Line Options

5.2 Customer Connections

Table 5.2 and table 5.3 which follow summarise the connections that the customer is responsible for providing, depending on the factory supplied options selected.

Each of the individual connection ports referenced in the tables (A to H and I to N) are clearly identified in the following section 5.2.1 and 5.2.2 component breakdowns, with a more detailed explanation and the corresponding installation requirements.

For the coolant supply and return connections, a number of suitable connection ports on the engine maybe available for use. These are referenced in Fig 5.2

DEF line supply and return connection locations are detailed in Fig 5.3, Fig 5.4 and Fig 5.5.

5.2.1 Coolant Connections

Coolant must be supplied from the engine to the DEF tank header in order to heat the DEF in cold conditions. The coolant is supplied via the coolant valve which is controlled via the DCU.

Coolant is taken from the coolant outlet on the engine to the coolant valve, then to the tank header, returning directly back to the engine at the water pump inlet.

The table below outlines locations specifically for this purpose. If you wish to feed and return coolant using ports normally reserved for cab heater connections please contact your applications engineer.

Line	Line Start			Line End			Recommended Diameter
	#	Size	Connection point	#	Size	Connection point	
Engine Coolant feed to Coolant Valve	A	M18x1.5 STOR (ISO 6149)	Top centre cylinder head	C	5/8" OD for push fit hose	Coolant Valve Inlet	5/8" (15.8mm) ID
	B	M18x1.5 STOR (ISO 6149)	Left front side of cylinder head				
Coolant Valve to Tank Header	D	5/8" OD for push fit hose	Coolant Valve outlet	E	5/8" OD for push fit hose	Tank Header coolant inlet	5/8" (15.8mm) ID
Tank Header Return to Engine	F	5/8" OD for push fit hose	Tank Header coolant outlet	G	½" – 14 NPSI	Top of water pump housing	5/8" (15.8mm) ID
				H	5/16" -12 STOR	'T' into shunt line connection	5/8" (15.8mm) ID
Total hose length must not exceed 8000mm, this may include 90° fittings at each end. Additional fittings within this line length will reduce acceptable line length.							

Table 5.2 – Coolant connection Details

See below Fig 5.2 for identification of acceptable location to use on the engine for feed and return.

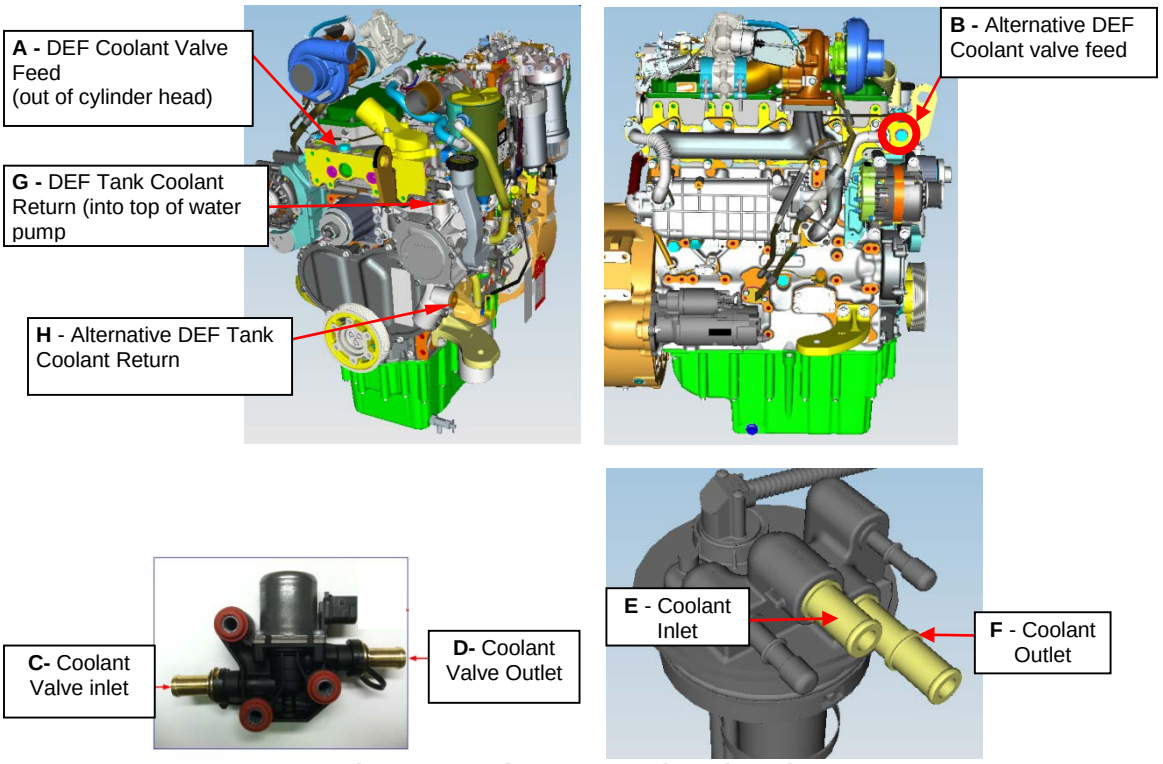


Fig 5.2 – Coolant connections locations

5.2.1.1 General Coolant Line recommendations

- The coolant hoses should be standard coolant hose material.
- The hoses must be as short and direct as possible with minimal bends to reduce restriction.
- The hoses must not contain any dips or sags which may encourage air entrapment.
- The hoses should be adequately supported to prevent vibration and must not pre-load the connector with side loads or moments. The recommended distance between the support device and the connector point is a maximum of 200mm.
- The coolant hoses must be free from fouling, abrasion and should be routed clear or shielded from excessive heat sources.
- The use of hose retaining/positioning clamps should be designed and controlled to prevent coolant flow restriction.

5.2.1.2 Coolant supply Line De-aeration

A risk to the DEF coolant circuit is the trapped air in the long lines used in applications where the DEF tank is installed far away from the engine coolant outlets.
When the engine is first filled, it is possible to trap air in coolant lines to the DEF tank and this trapped air should be vented over time through Engine operation. It is best, however, to reduce the amount of trapped air in the lines in the first place so it doesn't affect the effective running of the emission critical components.

Ideally, the DEF tank should be installed no higher than the engine for effective filling. However, where this is not possible, it is recommended that it is placed no higher than 1m above the coolant feed point.

In the applications where these recommendations are exceeded, it may be required to employ additional measures to vent the cooling lines. The following methods may be used.

- Bleeding the lines manually by unplugging them from the DEF components to let the air out Bleeding the lines manually by installing a bleed valve to the lines, the valve location should be as close to the DEF component as possible. The valve must not restrict the flow when it is not used and care should be taken to ensure they are not left open.
- It may also be necessary to run a venting procedure – testing should be conducted to establish the acceptable method.

5.2.2 DEF Connection Detail

The following DEF lines are required to be installed by the customer
These DEF lines should be selected from the option offering.

- A DEF suction line from the tank header to the pump - Fig 5.3
- A DEF pressure line from the pump back to the injector - Fig 5.4
- A DEF return line from the injector to the tank header - Fig 5.5

The individual connection points for each connection are detailed below. Failure to meet minimum line length values can lead to pump instability as well as thermal stress to the heater filament

Line	Line Start			Line End			Recommended point for line heater connection	Line lengths	
	#	SAE J2044 Size	Connection point	#	SAE J2044 Size	Connection point		Min (mm)	Max (mm)
DEF Suction Line	I	9.53mm (3/8”)	DEF tank header outlet	J	9.53mm (3/8”)	PEU Inlet	PEU Inlet	1000	2000
DEF Pressure Line	K	7.94mm (5/16”)	PEU Outlet	L	7.94mm (5/16”)	Injector Inlet	PEU Outlet	1500	4000
DEF Return Line	M	9.53mm (3/8”)	Injector Outlet	N	7.94mm (5/16”)	DEF tank header inlet	DEF tank Inlet	1500	4500
NOTE: PERKINS LINES ARE SUPPLIED PRE-FITTED WITH APPROPRIATE SAEJ2044 CONNECTORS, SEE FIG 5.2 Refer to section 2.11 for maximum total line length of the system									

Table 5.3- DEF Line Connections

DEF supply - DEF suction line from the tank header to the PEU

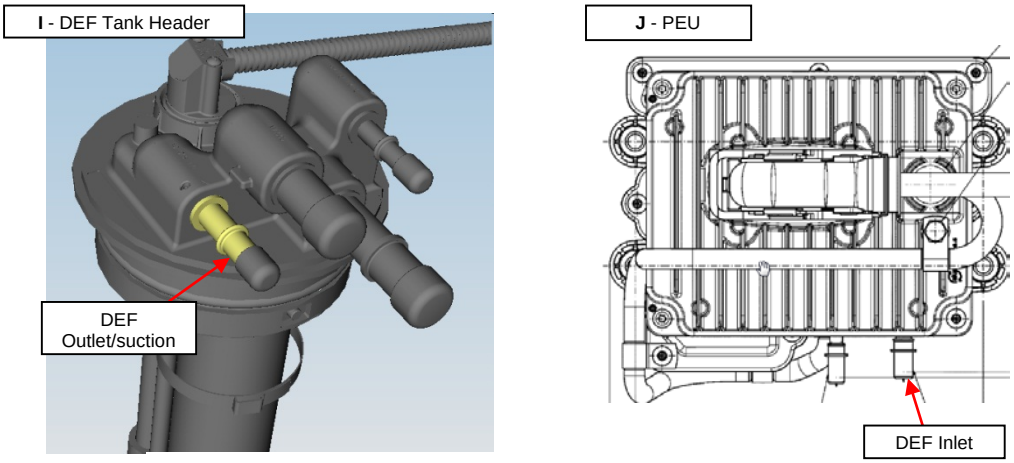


Fig 5.3

DEF supply - PEU to injector

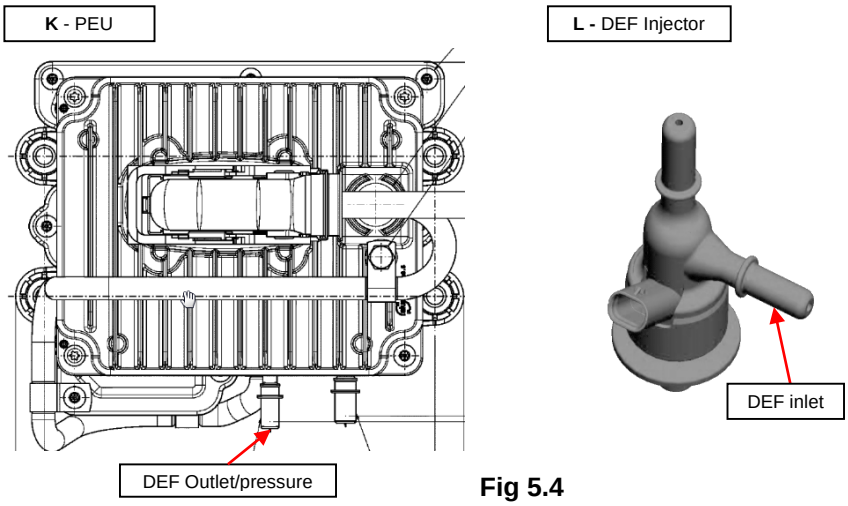


Fig 5.4

DEF return - DEF Injector to Tank Header

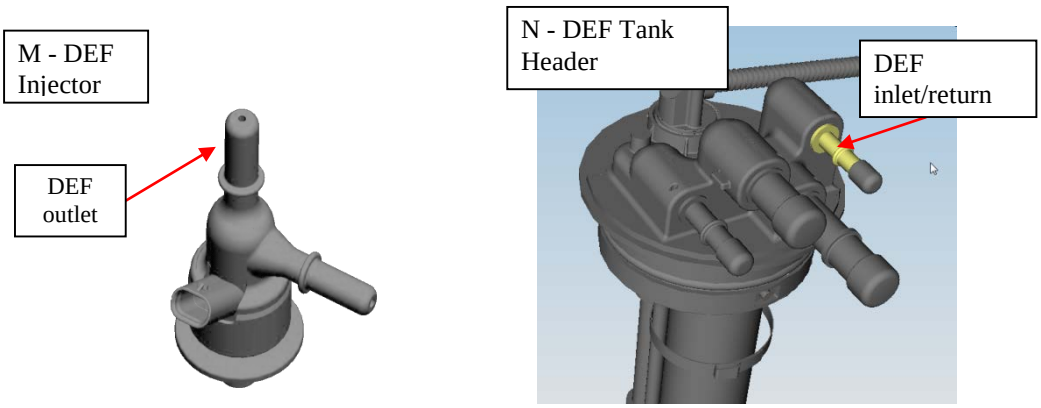


Fig 5.5

5.2.2.1 DEF Hose recommendations

These recommendations are in addition to the mandatory requirements detailed in section 2.11, which must be adhered to.

- DEF lines should be routed on the cool side of the engine and kept clear of any heat sources or hot surfaces.
- For applications that are required to operate in cold environments it may also be necessary to protect the DEF lines from exposure to the elements and wind chill.
- Avoid routing lines through locations exposed to accidental damage by the operator
- The use of P clips to retain the DEF lines is acceptable
- Appropriate sized silicone coated and rubber coated p-clips are recommended for routing points in close proximity to and away from the aftertreatment respectively.

5.3 Materials

Any component coming into direct contact with DEF should be constructed of stainless steel. Aluminium is not suitable for use without special coatings and is not recommended.

Refer to ‘Appendix A – Chemical Compatibility table’ to see Perkins supplied components compatibility/resistance to common chemicals/fluids. An X indicates resistance.

5.3.1 Rubber Components (Seals, etc.)

Seals and other rubber components material require compatibility with water based solutions. It may also be considered to choose a material with high swell resistance to diesel fuel in the case of incorrect DEF tank fill. Due to its good water sealing capability and resistance to swelling, it is recommended to use NBR seals and O-rings when possible.

5.3.2 Metallic Components

Any components expected to be in direct contact with DEF (drain plug or valve) shall be constructed of stainless steel. Aluminum is not suitable for use without special coatings and is not recommended.

5.4 DEF Tanks

5.4.1 DEF Tank Sizing

To meet regulatory requirements and adhere to good service practices the DEF tank capacity must facilitate at least a 1:1 filling ratio with the ULSD tank. This can be achieved considering a maximum DEF consumption rate of 4% of fuel – a higher percentage may be used in the calculation if a ratio greater than 1:1 is required. In all cases it must be calculated considering the maximum tilt angle of the machine under all operating conditions.

The ratio can be simply calculated for any given tank using the following information:

Operational volume of **DEF** at maximum machine gradeability	:	***Operational** volume **of Diesel Fuel** at maximum machine gradeability.

A ratio of greater or equal to 1 is acceptable.
Any ratio less than 1 will require specific Applications approval and will be application dependant.

*The total operational volume of diesel fuel must include the volume of any remote bulk fuel supply that the application uses during machine operation refer to section 5.4.4.

Detail on the volume apportionments of the DEF tank are shown in the Fig 5.6 below. Further detail on the actual tank volumes of Perkins DEF tanks is shown in Table 5.4 below.

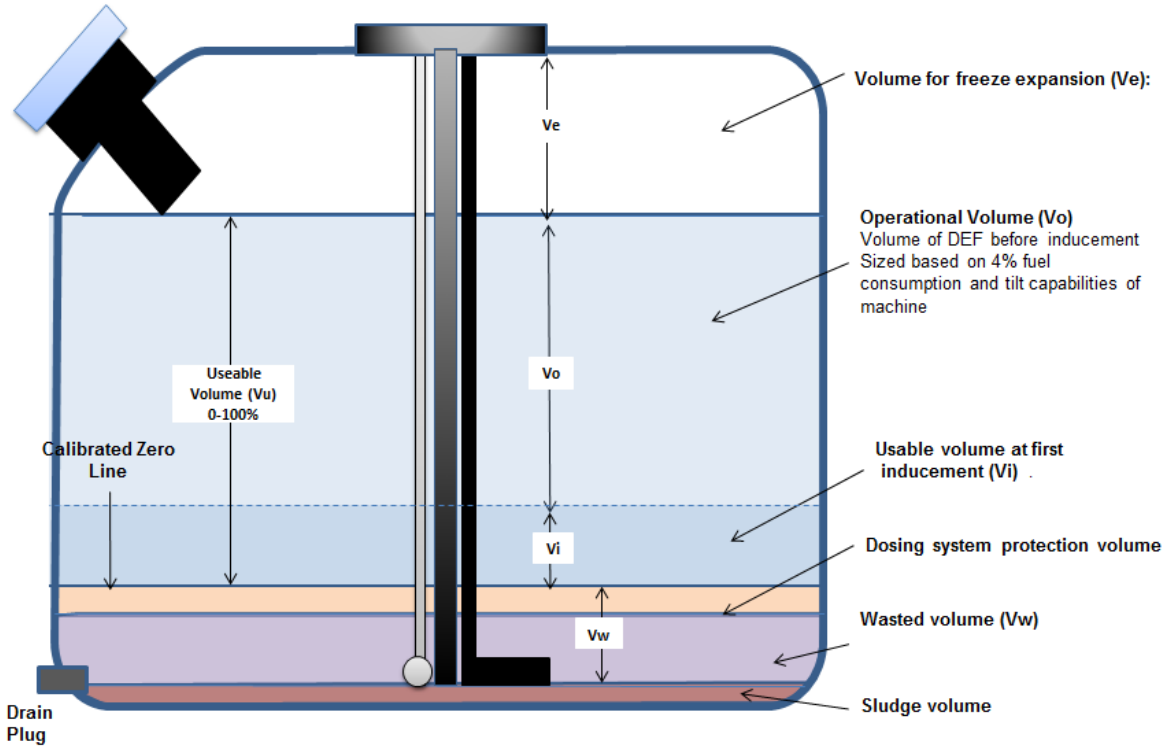


Fig 5.6 DEF tank Appoprtionment

DEF Tank		Total Tank Volume (Vt)	Useable Volume (Vu)	Operational Tank Volume (Vo)	Recommended Minimum Factory Fill
Option	Description	Litres	Litres	Litres	Litres
SG002	19L Landscape	18.5L	13	11.3	10
SG004	19L Portrait	19	15	12.5	10
SG007	19L Portrait tank with remote fill	19	15	12.5	10
SG006	38L Landscape	38	30	25.7	15

Table 5.4 - DEF tank Volumes

5.4.2 DEF Tank Mounting and Installation

- The DEF tank should be located to avoid heat sources or stagnant hot air build up which will lead to overheating of the DEF.
- Proper distance and elevation from DEF injector –ref 5.4
- Ease of tank drain
- Ease of filling with care taken regarding spillage
- Tank fill vent away from HVAC air intake (unpleasant odor in cab may result)
- Out of direct sunlight preferred
- The tank must be +/-5° from horizontal when filling with DEF
- An anti-friction mat is recommended under the tank base.

- Table 5.5 below details the weight of the Standard DEF tank options when filled with DEF to 100% full.

Volume	Configuration	Dimensions L, W, H (mm)	Weight (g) – 100% DEF fill level
19L	Landscape	457.2 x 203.2 x 304.8	26270
19L	Portrait	304.8 x 203.2 x 457.2	26513
38L	Landscape	571.5 x 203.2 x 457.2	49444

Table 5.5 – DEF Tank Mounting Details

5.4.3 DEF Tank Straps

- The Perkins supplied DEF tanks feature grooves to help locate the tank straps. The groove tolerances are shown in table 5.6 below. The Mandatory requirements are detailed in section 2 and must be adhered to.

- The strap design must consider both the static assembled conditions plus the loads from machine operation that are typically used as design points for a given machine. It is recommended that FEA is conducted on the tank and mounting design.

Tank	Units	Groove		
		High	Nominal	Low
19 L	in	0.855	0.78	0.705
	mm	21.717	19.812	17.907
38 L	in	1.2	1.125	1.05
	mm	30.48	28.575	26.67

Table 5.6 – DEF Tank Groove Tolerances.

- All DEF tanks held down by straps must have their base fully supported by a structural platform. Full support is defined as a continuous material that is at least as large as the tank's base dimensions. Structural is defined as being able to support full tank mass with application load without plastic deformation or failure

- The use of an Anti-Friction rubber mat under the tank base is recommended. Inadequate clamp loads and / or insufficient coefficient of static friction, between the tank and mounting surface, can allow the tank to slip under extreme conditions. It is recommended that either 60 or 70 durometer 2mm thick rubber may be used. This is a chloroprene rubber, appropriate for DEF, with temperature range between -40°C and 100°C.

- Any metallic surfaces contacting the tank should be free of burrs, weld splatter, sharp edges.

- The tank straps require a preload when installed. Thermal expansion and contraction of the tank may loosen the straps if a preload is not applied. The magnitude of the preload is a balance between enough preload to form the strap, to resist slip, preventing excessive plastic deformation of the tank and having adequate life for the components. It is recommended that a study be conducted to understand preload impacts and that care must be taken during assembly to ensure that excessive preload is not applied. At assembly, a new, unformed flat strap undergoes permanent yielding or deformation when bending around the tank corners

- The DEF tank strap should lie flat in the strap groove incorporated into the tank to help keep the strap in place.

- Having a locked joint is a requirement. This can be accomplished by using either a jam or lock nut.

- The strap should be long enough to support the bolt dimensions. If there is not enough free bolt length assembly may be difficult.

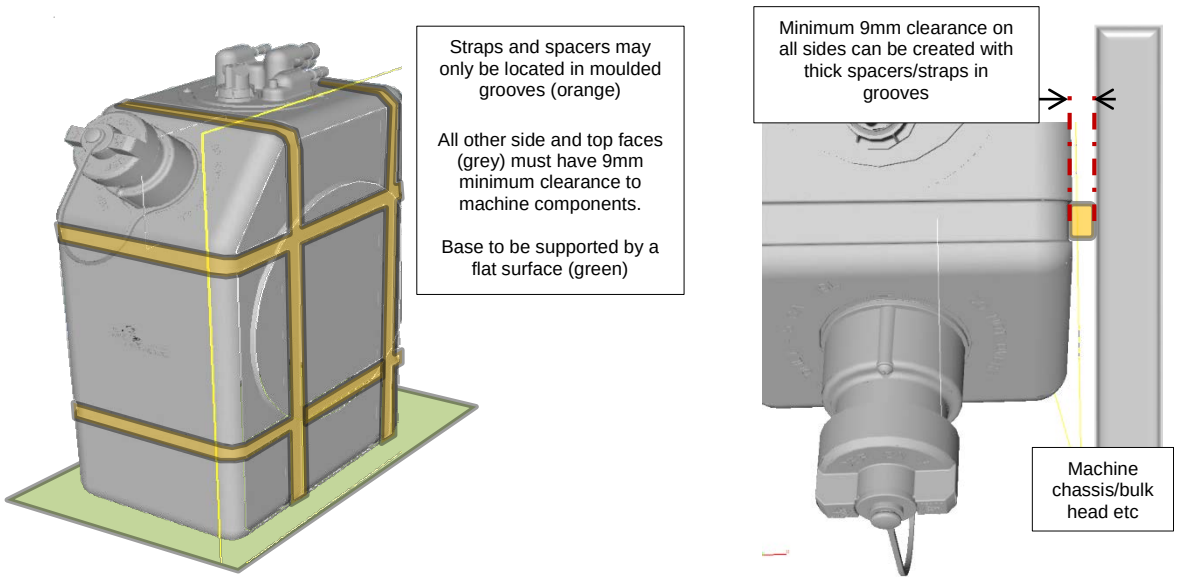


Fig 5.7 – DEF Tank straps

5.4.4 Bulk Fuel and DEF Tanks

Where a bulk fuel tank supply is used a remote DEF tank will be required in addition to the on board machine DEF tank ref 5.4.1

In order to maintain DEF quality and emissions compliance, the DEF level in the tank MUST cycle from the low DEF warning level to the maximum DEF fill level. Consequently using a trickle feed to maintain the max fill level is NOT permitted.

The system used to control this refill should be activated using the low level warning broadcast but must not use the max DEF level broadcast to determine when the system is full as the output does not update fast enough to prevent overfill, critical to maintain sufficient expansion space. Use of a pre-determined volume to set the max fill level is recommended.

5.5 DEF Component Mounting and isolation

5.5.1 PEU/DCU Mounting Requirements

The Mandatory requirements in section 2.7 must be adhered to.

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Fig 5.8 below shows the mounting holes that must be used.

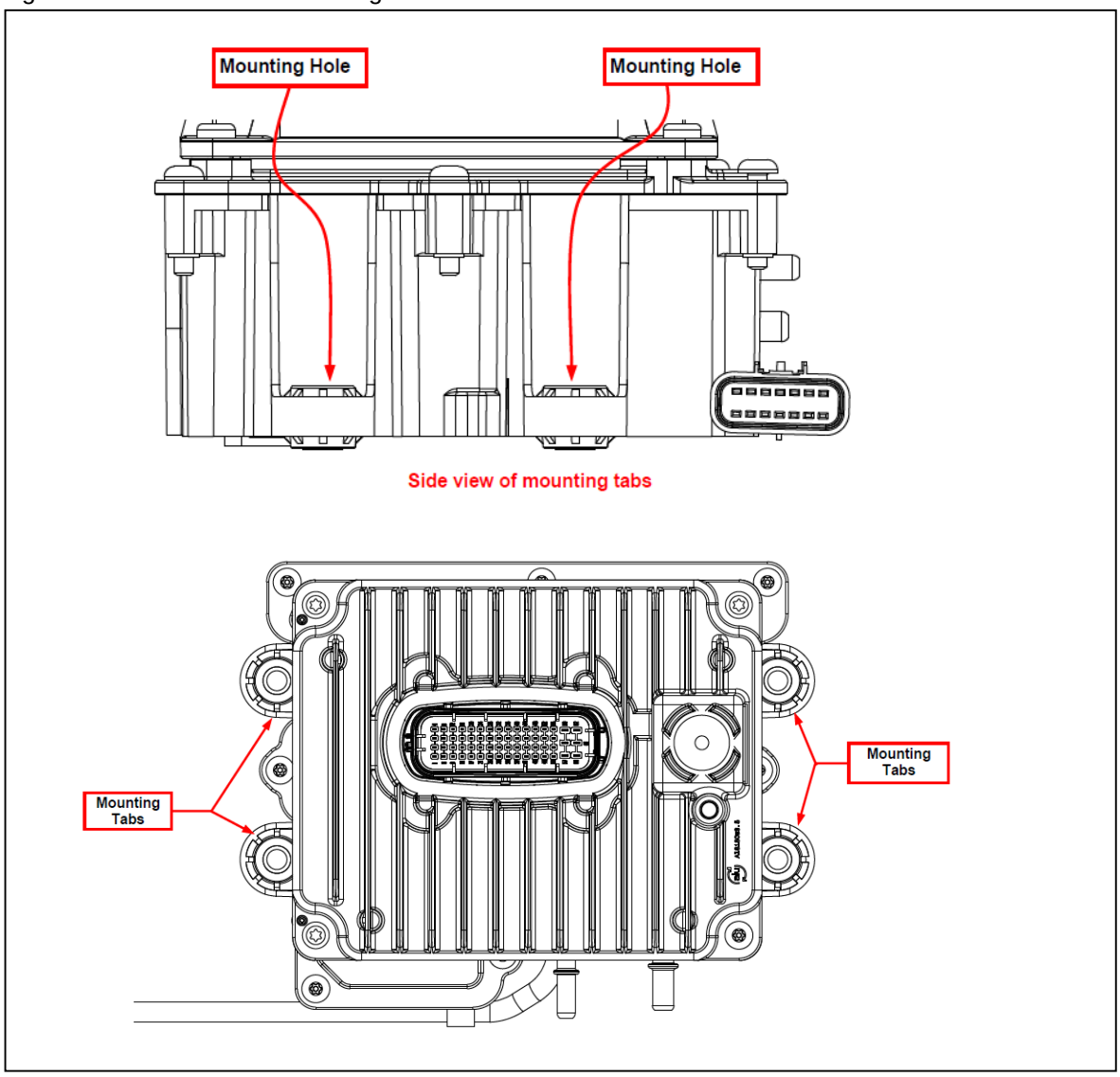


Fig 5.8 – PEU mounting

5.5.2 DEF Component Relative Positioning

See mandatory requirements section 2.8

5.6 DEF Tank Service Considerations

5.6.1 DEF Tank Filling

The ISO 22241-4 standard is primarily aimed at defining the standard for the refilling interface. It is recommended that all refilling be performed utilizing an ISO 22241-4 compliant nozzle.

The fill neck interface is poke-yoke from a diesel fill nozzle by it is smaller in diameter. The DEF nozzle has an OD of 19mm ± 0.25mm. The fill neck ID is 19.75mm ± 0.25mm.

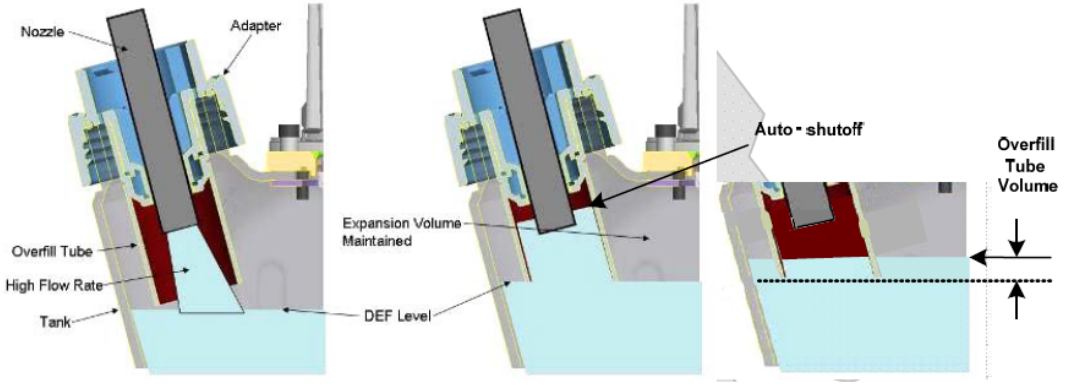
The fill neck is designed to:

- **Comply with ISO 22241-4**
  This standard is primarily aimed at defining the standard for the refilling interface. It is recommended that all refilling be performed utilizing an ISO 22241-4 compliant nozzle.
- **Fill at a rate, which is faster than the fuel tank.**
  It is recommended that the target design flow rate for DEF splash fill systems is between 20 to 40 LPM with 0 splash back.5.5
- **Help discourage or prevent mis-fill**
- **Prevent overfill**

All adapters supplied by Perkins include a magnetic toggle. The customer's fill nozzle may or may not have the magnetic safety switch.
The nozzle switch only prevents DEF from being dispensed into a non-DEF tank. The neck size prevents a standard diesel or gasoline fill nozzle from being inserted into the tank and a resulting miss fill. There are, however, no devices in the adapter preventing a determined party from inserting a non-standard fill hose and filling the tank with fluids other than DEF.

5.6.2 Overfill Protection

The DEF tank requires an expansion volume be maintained for when DEF freezes. An expansion volume of approximately 10% must be maintained. Overfilling of the tank will result in tank rupture upon freezing.
Overfill protection can be provided by simply extending a tube to the required level, and allowing the flow to back-up into the nozzle activating its auto shut-off. After the nozzle is shut off, a weep hole in the adapter will allow the DEF to slowly settle out of the adapter down into the tank. If the operator then tops off the tank it will be subject to freeze expansion risk. Any operator instruction manuals should clearly state that the operator should NEVER top of the DEF tank. See Figure 5.9 below.



When DEF level reaches overfill tube, the DEF level quickly backs up into the nozzle triggering Auto-shutoff. After Auto-shutoff occurs, the DEF will slowly settle into the tank. Operators must be advised to NEVER top of the DEF Tank.

Fig 5.9- DEF Tank Overfill Protection

5.6.3 Remote Fill

Remote fill is defined as a system where the ISO 22241-4 adapter is not fastened directly to the tank. If a remote fill is required then the requirements detailed in IGB 99.05.1 must be adhered to.

5.6.4 DEF Tank Draining

A drain port is included in the DEF tank design and must be located in an accessible location that is easily available to service. The drain is necessary to:

- **Maintain the quality of the DEF**
  Allowing any dirt, debris, deposits or poor quality DEF that may enter the DEF tank to be flushed out. Poor quality DEF may occur by tank mis-fill or poor storage control.
- **Drain the Tank before long-term storage**.
  DEF tanks should be drained before long term storage –reference should be made to the service manual.

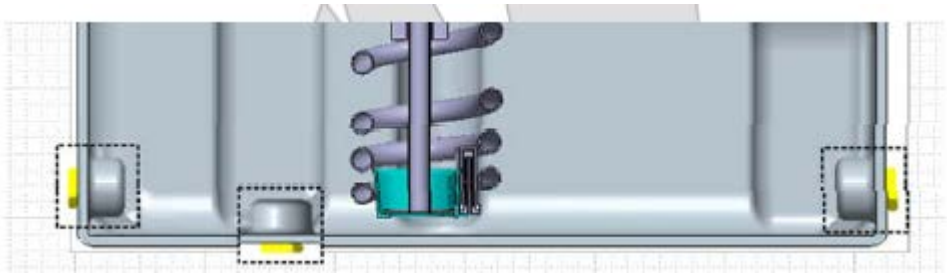


Fig 5.10 - DEF Tank Drain Port

5.7 Production and Manufacturing

All components supplied with protective caps must remain fitted until installation of the component.

- **Recommendation for Initial Factory Fill**
  Clean DEF meeting the ISO 22241 specification should be added to the DEF tank to the recommended minimum initial factory fill level detailed in Table 5.4 section 5.4.1.
  - By filling the DEF tank to this minimum fill level, the low DEF indicator should not trigger through the storage and transportation time for the machine.

- **Recommendation for Machine Storage**
  Machines in storage for periods longer than 18 months should have the DEF checked with a refractometer to ensure that the concentration remains between 29 and 35 weight percent. If the concentration is lower than 29 weight percent, the concentration may be raised by adding fresh DEF to the tank.
  - If adding DEF is required, add approximately 10% of the DEF tank volume and recheck with a refractometer. If it remains low, repeat this process until the concentration is between 29 and 35 weight percent.

6.0 Record of Amendment

6.1 Changes from Issue 1 to Issue 2

2.4 New Mandatory added on cycling of DEF in Tank
5.4.1 Amended to refer to section 5.4.4 for bulk tanks
Table 5.4 updated
5.4.4 New section added on Bulk Fuel and DEF Tanks
5.6 New section added on DEF Tank Service considerations
5.7 Added Recommended Factory Fill and Storage requirements

6.2 Changes from Issue 2 to Issue 3

2.8.1 Fig 2.3 included arrows on DEF lines and changed DEF lines to router to inlet of DEF pump
2.8.2 Fig 2.4 changed DEF line to route from the DEF pump outlet
2.9 Side loading of valve changed from 10Nm to 10N.
5.1 Fig 5.1 revised line routing to represent correct inlet and outlet connections on tank header
5.2.2 Fig 5.5 corrected DEF header and pump inlet and outlet connection labels.

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