950106-01198

Operation & Maintenance Manual

DIESEL ENGINE

D24NAP

Doosan Infracore

Preface

This Operation and Maintenance Manual provides information on engine management and maintenance techniques to customers and technicians of Doosan Infracore's D24NAP electronically controlled industrial diesel engine.

To provide the best engine to our customers, the D24NAP electronically controlled industrial diesel engine is designed to satisfy all requirements for low noise, economic fuel consumption, high speed and durability with the latest technology and quality.

Exact operation and proper maintenance are essential for operating engines for an extended time with optimum conditions and best performance. This Operation and Maintenance Manual provides detailed descriptions of specifications, specified values, defect diagnosis, component diagrams, and drawings for easier and more precise understanding of the product and for proper maintenance and troubleshooting.

With the help of the recommended operation methods and procedures, high-level maintenance techniques and safety of workers can be ensured. Please read and understand this manual before working with our engines.

To ensure best performance and quality as well as to enhance maintenance techniques, Doosan Infracore is doing it's best to continuously develop and invest. The design of our product may be changed without prior notice and Doosan shall not be held liable for the failure of this manual to contain all the design changes made to improve the product.

We, Doosan Infracore, do our best to provide more convenient and safe maintenance techniques and to meet the requirements of our customers.
If you have any questions or find any errors in this Operation and Maintenance Manual, please do not hesitate to contact us.

Thank you for purchasing our engine and we hope this Operation and Maintenance Manual be helpful for you.

2013.05
950106-01198
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General Information

This Operation and Maintenance Manual provides the most efficient methods for engine maintenance as well as quick, efficient methods to determine the cause of engine faults to ensure that any actions taken by professionally certified maintenance technicians are done in the most efficient and efficient way possible. If maintenance is performed by unskilled technicians, or maintenance without the specified tools and facilities, serious bodily injury or critical faults in engine performance may occur.

Regular inspection and maintenance are required to maintain long-term optimal engine conditions and best performance. In the event that a part must be replaced, only genuine parts as defined by the parts the list (PARTS BOOK) should be used. Doosan shall not be held liable for any critical damage or faults which may be caused by the use of unauthorized or remanufactured parts.

The maintenance methods stated in this Operation and Maintenance Manual are the most efficient and safest work procedures. Some work procedures require special tools.

For questions about genuine parts and special tools, please contact us.

This Operation and Maintenance Manual includes 'Danger,' 'Warning,' and 'Caution' in order to reduce possible injuries and engine faults which may occur while performing maintenance. If workers do not follow the instructions, critical faults in engine performance and operation or serious bodily injury may occurred. 'Danger,' 'Warning,' and 'Caution' instructions must be followed. However, we inform you that it is to describe all possible and unexpected dangers which may arise while performing engine maintenance.

1. General Introduction

Danger, Warning, Caution, and Note

General Information

This Operation & Maintenance manual divides maintenance operations such as performing engine checks, troubleshooting, or diagnosing faults into three categories, "Danger," "Warning," and "Caution." In addition, **Note)** is used to provide additional descriptions and information required for maintenance technicians to successfully operate our engines. The recommended repair methods and 'Danger,' 'Warning,' and 'Caution' can enhance the degree of completion of engine maintenance and prevent bodily injury which may occur to workers. However, this manual cannot predict all possible risks.

⚠ DANGER

Workers must observe instructions, otherwise fatal or serious injuries to workers and other persons may occur.

⚠ WARNING

Workers must follow this instruction as failing to do so may result in the death or serious bodily harm of workers or others.

⚠ CAUTION

Workers must observe this instruction since failing to do so may cause critical faults which can have impact on the engine performance and operation.

Note)Indicates additional description, information, and references for workers' easy understanding.

General Instructions

1. In order to maintain the best long term performance and safety, please read and understand this manual and execute routine inspections and regular inspections.
2. We have divided the content of this manual into causes of bodily injury and damage to assets and causes of pollution.

⚠ WARNING

When a safety accident, such as skin contact with corrosive acids or fuel, burns with hot oil, exposure of eyes to fuel or antifreeze, occurs while starting, inspecting, or repairing an engine, see a doctor immediately.

Cautions for Starting the Engine

1. Before starting the engine, please read this manual carefully and fully understand 'Danger,' 'Warning,' and 'Caution'. If you cannot fully understand it or have any question, please contact us.
2. For safety reasons, attach "Warning" signs around engines in operation to keep people other than workers from accessing the engines. Let engine operators know that they are responsible for the safety of the engine room.
3. Only authorized people may start and operate engines. Unauthorized people should not be allowed to handle engines.
4. Do not access running or rotating parts while the engine is in operation.
5. Be careful not to touch or contact the engine during operation since it becomes hot during operation.
6. Exhaust gas is poisonous. Fully ventilate before starting engine. If the space is airtight, ensure that it is well ventilated.

Cautions for Inspection and Repair

1. Inspection and repair of engine should be performed only when the engine is stopped. Otherwise, burns or safety accidents may occur, so do not perform inspection or repair while the engine is running.
2. If it is absolutely necessary to perform inspection or repair on the operating engine, do not get close to the rotating parts.

⚠ DANGER

When accessories such as necklaces, rings, watches, or gloves become stuck in rotating parts while the engine is running, serious bodily injury may occur.

⚠ WARNING

Do not exchange or disassemble a pipe or horse (from the engine fuel circuit, engine oil circuit, coolant circuit, or compressed air circuit) while the engine is running. The leaked liquid may cause bodily injuries.

3. Use an engine oil drain container that is large enough to prevent the overflow of engine oil while draining engine oil.
4. Open the engine coolant cap after fully cooling the engine to exchange or replenish coolant.

⚠ WARNING

If the coolant cap is opened while the engine is still hot, hot water will spurt out and may cause burns. Open the engine coolant cap after fully cooling the engine.

5. Fuel is highly flammable. Smoking or use of fire around an engine may cause fire.

⚠ WARNING

Only refuel when the engine is stopped.

6. Mark and separately manage the containers for storing coolant from beverage containers for avoiding confusion. See a doctor immediately in case of drinking coolant.
7. Follow the instructions provided by the battery manufacturer when checking or handling batteries.

⚠ WARNING

Battery fluid is corrosive and dangerous because of its explosiveness and toxicity. Therefore, it should only be handled by a skilled technician who specializes in battery fluid.

8. Only certified professional technicians should repair and maintain engines.
9. Only appropriate tools should be used. If the jaws of a wrench are worn out, the wrench might slip during use, causing safety accidents.
10. Do not allow other persons to stay or pass under an engine when lifting the engine with a crane. Before lifting the engine, ensure that there is no one around the engine and reserve enough safety space.
11. Before inspecting or replacing the electrical apparatus, disconnect the battery ground wire first. Connect the battery ground wire after completing all required work for checking or replacing the electrical apparatus in order to prevent a short circuit.
12. Before performing electric welding works, turn off engine, block the power supply to the engine, and remove the wire harness connector connected to the engine control unit (ECU).
13. Do not give any electric or mechanical shocks or perform welding works on the electrical apparatus or the ECU.

General Repair

1. Wait until the engine is properly cooled down before starting work, since you may get burned by the heated engine.
   Before performing fuel line work, check the common rail pressure and engine temperature by using the failure diagnosis device.
2. Disconnect the battery ground wire from to prevent damage of wires and sensors caused by a short circuit.
3. Engine oil and coolant may damage paint and should be stored in a separate container and marked for safe management.
4. Store the disassembled parts in a specified space to avoid damage or pollution.
5. Use specified and special tools for efficient and safe repair.
6. If parts need to be replaced, use only genuine parts for replacement. Using unauthorized or remanufactured parts may cause critical damage and faults in engine performance.
7. Replace parts such as cotter pins, gaskets, 0-rings, seal rings, oil seals, and washers with new

ones during repairs. Reuse of parts may be the cause of engine faults and engine may not operate properly.

8. Group and store disassembled parts in disassembling order. The strength, shape, and screw torque of bolts and nuts are different according to their assembly position. Please divide and store them accordingly to these characteristics.
9. Clean disassembled parts to remove foreign substances before inspecting or reassembling parts. Use compressed air to clean the oil holes or holes.
10. Thinly spread oil or grease on rotating parts or parts requiring lubrication, before assembling them.
11. If required, use a specified adhesive to assemble gaskets to prevent water or oil from leaking.
12. Assemble bolts and nuts with the specified tightening torque.
13. After completing repairs, conduct a final inspection and perform a test operation to check if all works have been successfully completed.

Other Safety Instructions and Environmental Pollution

Observe the following instructions to protect workers from danger and to prevent the environmental pollution while performing engine repairs.

1. Good ventilation and low humidity should be maintained in the work space.
2. The workspace should be clean, in good order, and no flammables are allowed in the workshop.
3. Smoking is strictly forbidden in the workshop.
4. Workers should wear working clothes, protective goggles, and safety shoes.
5. Workers are not allowed to wear accessories such as necklaces, rings, watches, and earrings.
6. Start the engine in a well-ventilated space and fully ventilate the space before starting engine to prevent carbon monoxide poisoning.
7. Wait until the engine is properly cooled down before starting work, since you may get burned by the heated engine.
8. Do NOT work on rotating or running parts once the engine has been started.
9. Discard oil according to the regulations set forth by the relevant authorities.
10. If engine oil or fuel leaks on the floor or is improperly discharged, serious environmental pollution of sea, river or underground water may occur.
11. Discard the undiluted anticorrosive agent, antifreeze, filter elements, and cartridges as special wastes.
12. Discard coolant and special waste according to the regulations of the appropriate authorities.

⚠ WARNING

Failure to observe the regulations of the relevant authorities violates environmental pollution regulations and may be subject to legal penalties.

Use of Genuine Parts

An engine consists of many parts which are mechanically harmonized. To prevent engine faults in advance and use engines with best performance for a long period, maintenance and replacement of expendable parts should be conducted regularly.
Use of genuine parts is recommended. Using unauthorized or remanufactured parts may cause critical damage and faults to engine for which Doosan shall not be held liable.

Engine Management

Prevention of damage and abrasion

Using an engine for any purposes other than the designed purpose may cause critical faults in engine performance for which Doosan shall not be held liable. For details concerning the usage and purpose of the engine, please direct questions to our Sales Team. Do not adjust, convert, or change the ECU without our authorization.
If a problem is found in an engine, figure out and solve the cause to prevent the critical faults in advance.
Use of genuine parts is recommended. Using unauthorized or remanufactured parts may cause critical damage and faults to engine for which Doosan shall not be held liable.
Consider the following while managing engines.

1. Use clean, specified, and qualified fuel only. Use fuel recommended in this Operation and Maintenance Manual.

⚠ CAUTION

Using inappropriate or unspecified fuel may cause critical damage and faults in engine performance.

2. Do not operate an engine without lubrication oil or coolant. Use only the products (engine oil, cooling water, anticorrosive agent, and etc) recommended by Doosan.
3. Always keep surroundings of the engine clean.
4. Use fuel recommended in this Operation & Maintenance manual.
5. Conduct inspections and exchanges regularly according to the regular inspection table.
6. If the engine is overheated, do not stop it immediately, but operate it at idle status for five minutes or more to lower the engine temperature to the proper level.

⚠ WARNING

If the radiator cap is opened while the engine is still hot, hot water will spurt out and may cause burns.

7. Check the engine oil level on a flat surface. Do not exceed the maximum on the oil level gauge.

⚠ CAUTION

Immediately replenish engine oil when the engine oil level is below the lower limit of the engine oil gauge.

8. If there are gauges for battery, oil pressure and coolant and temperature, check if they indicate a normal status.
9. Do not operate engine without coolant.

⚠ CAUTION

Always use coolant mixed with antifreeze. If coolant without antifreeze is used, the coolant may freeze causing the coolant passage in the cylinder block to freeze and damaging the engine.

Prevention of Pollution

Consider the following to manage engine without causing environmental pollution.

1. Discharge oil and coolant using collection containers.
2. Discard oil and coolant according to the regulations of the relevant authorities.
3. Be careful not to let discharged oil and cooling water flow into the ground or the sewer. Otherwise, serious pollution of the drinking water source may occur.
4. Classify the oil, filters, and filter cartridges as environmental pollution wastes and discards them according to regulations.
5. Classify the antifreeze, cooling water, and anticorrosive agent as hazardous wastes and discards them according to the regulations.

Handling of Engine Oil

Prolonged and repeated contact of skin with engine oil may cause skin to dry out and contract, causing dermatitis. Engine oil includes substances toxic to the human body. Handle engine oil by observing the following safety rules:

1. Do not expose skin to new engine oil for a long time.
2. Always wear working clothes and gloves.
3. If skin comes in contact with engine oil, immediately wipe it off with water, soap or hand cleaners.
4. Do not clean skin with gasoline, fuel, thinner, or solvent.
5. Apply a skin protective cream after cleaning from oil.
6. Do not put oil-stained gloves or cloth in ones pocket.

⚠ WARNING

Discard oil according to the regulations set forth by the relevant authorities. Disposing of discharged oil into the ground, sewers, drains, rivers, or the sea will cause serious environmental pollution. Violation of regulations regarding discard of engine oil without observing the handling regulations, will be punished.

2. Operation and Management

Operation and Management

Starting and Stopping of the Engine

Preparing for Start

Check the following before starting the engine for the first time after purchase.

1. Before starting an engine, check the levels of fuel, coolant, and oil and replenish those fluids if required.
2. Check if engine oil level is between the upper and lower limit of the oil level gauge. The upper and lower limit of the oil level gauge indicate the maximum and minimum of the engine oil level.

⚠ CAUTION

When replenishing engine oil, do not exceed the maximum on the oil level gauge. Too much oil may cause damage to the engine.

3. Be careful not to mix foreign substances in fuel, engine oil, or coolant while adding the fluid, and keep the fluid clean while it is not in use. Use fuel, oil, and coolant recommended by Doosan. Otherwise, critical damage to the engine may occur.

Starting the Engine

Observe the following when starting the engine.

1. For a cold start, start the engine after preheating it sufficiently through the glow plug.
2. Starting the engine too quickly leads to engine rotation without lubricating the supercharger and other engine parts, causing abnormal wear to or burning of bearings. Therefore, start the engine with the starter motor to check raising of oil pressure (until the gradation of the oil pressure gauge mounted on the apparatus moves or the pressure indicator lamp is turned on).
3. If the engine was not used or kept cold for a long period of time, oil circulation will be poor. If you replace oil, oil filter cartridge, or lubrication system parts or use an engine in cold areas, or the engine has been stopped for a long period, loosen the oil pipe joint at inlet of the supercharger and run the starter motor until oil flows out. After completing the work, tighten the oil pipe joint again and start the engine.

After Starting the Engine

1. Do not rapidly raise the rpm while the engine and turbocharger do not rotate smoothly after starting the engine. Otherwise, it may increase the load upon the engine and burning may occur at the positions that have not been sufficiently lubricated yet. To prevent this, rotate the engine at idle after starting it to lubricate the turbocharger with oil.
2. Oil, air, or gas leaks may lower the oil pressure. Additionally, oil leaks may cause burning of bearings. As such, if oil, air, or gas leaks occur, check the leaking parts and solve the problem.

During Operation

1. Insufficient oil pressure may cause abnormal wear and burning of bearings and excessive oil pressure may cause leaks.
2. Continuing to operate the engine after noises or vibrations coming from the engine may lead to serious engine damage. As such, if noises or vibrations come from the engine, slowly decrease the rpm to a stop the engine and examine the cause.

Stopping the Engine

Do not suddenly stop the engine after it was operated under high loads for a long period. If oil burns because of heat sent from the high-temperature turbine blade to the bearing part, the bearing metal and rotating shaft may burn. As such, if the engine was operated under high loads for a long period, sufficiently rotate the engine at idle before stopping it.

Break-in Period of the Engine

General Information

Doosan engines are subjected to a final approval test to ensure the provision of high quality engines before being shipped to ensure the best quality possible. However, engines are not operated for a long period of time in this test. Therefore, new engines require a break-in period of during the initial 50 hours after delivery. By properly breaking-in an engine, the highest levels of engine performance can be maintained long-term.

Break-in Period of a New Engine

If the engine's bearings are not properly broken in, they may be easily damaged and the lifetime of the engine may be shortened by overloading or high-speeds. In order to prevent this, please follow the guidelines below for the initial 50 hours after delivery of new engine.

1. Fully warm up the engine until the engine temperature reaches normal operation condition, before starting operation of the engine.
2. Do not overload the engine or operate it at excessive RPM.
3. Do not operate the engine with high speed at idle.
4. Do not rapidly start up or stop the engine.
5. Operate the engine with less than $\overline{70}$ % of the engine load.
6. Inspection, check, and repair of engines should be managed by officially-certified technicians at certified service centers in compliance with corresponding rules.

Check Points

check the following during the break-in period of a new engine.

1. Periodically check if the engine oil level is between the minimum and maximum limit of the oil level gauge.

⚠ CAUTION

If you cannot accurately check the oil level through the oil level gauge, rotate the oil level gauge to 180 degree, put it in the guide tube, and then pull it out again to check.

2. If the oil indicator lamp on the apparatus is turned on or blinks, the oil pressure may be insufficient. In this case, check the oil level and replenish the oil if required. When replenishing engine oil, do not exceed the maximum on the oil level gauge. If the oil level is normal, check other related parts such as the oil pressure sensor, oil pump, or oil line.

⚠ CAUTION

The oil pressure may increase with high rpm and decrease with low rpm. In addition, the pressure of cold oil may be higher at a specific rpm than of warm oil. This phenomenon may occur when the engine is operating successfully.

3. Check the coolant gauge on the apparatus and if the coolant circulates properly. If the coolant level in the supplementary tank is too low, the coolant gauge may be inaccurate. (may be disturbed).
4. Exchange engine oil and oil filter after the break-in period.

⚠ CAUTION

If engine oil and oil filter need to be replaced, use only the genuine engine oil and parts recommended by Doosan.

Operation after Break-in

Slowly preheat the engine when starting up during cold weather or in areas with cold climate. Do not rapidly raise the rpm while the engine has not been properly preheated yet. The engine consumes additional oil until its piston ring is positioned properly and operates successfully. Please check the engine oil level frequently during the initial 50 hour break-in period.

Inspection after Starting the Engine

Check the pressure of the engine lubrication system by using the engine oil pressure gauge mounted on the apparatus while the engine is in operation. If the oil pressure is low on oil pressure gauge, immediately stop the engine. In addition, make sure that the recharge alarm indicator lamp of the alternator is turned off while the engine is operating.

1. Tightly connect the +/- terminals to prevent gaps between them. The sheath of battery connection cables should not be damaged or broken.
2. If the recharge alarm indicator lamp suddenly turns on or blinks during engine operation and the engine stops, fix the fault of the electric apparatus.
3. If color or odor of exhaust gas is unusual during operation, stop the engine, diagnose the cause and fix the fault.
4. Check the engine status through the alarm indicator lamp and gauges mounted on the apparatus during operation.

Engine Oil Pressure

If the engine oil pressure is not consistent at idle or does not reach the reference value while the engine is operating in high speed mode, immediately stop the engine and check the oil level and leakage.

Coolant Temperature

Operating an engine with insufficient coolant temperature increases fuel consumption, abrasion of the cylinder liner, shortening the engine's life span.

Revolutions per Minute (rpm)

In the electronic control engine, the engine control unit (ECU) prevents the engine from being operated at too high rpm over the specifications to protect the engine. The memory of ECU has various functions which cannot be changed by operators, such as fuel flow control, ignition time delay, and blocking of fuel and ignition.