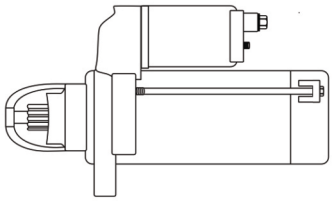
Electric Starter

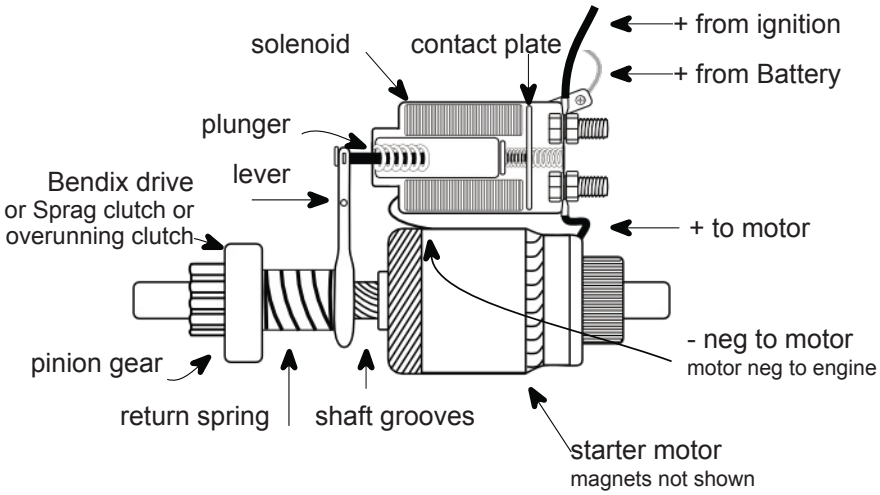
Function of an Electric Starter



The function of an electric starter (or any diesel engine starter) is to crank (rotate) the engine fast enough so that the air in the cylinders is compressed and heated enough to ignite fuel when injected into the cylinders.

Slow cranking too slowly (perhaps with a depleted battery) allows the heat generated by compression to be absorbed by the engine block so that fuel will not ignite.

Parts of a Pre-Engaged Starter



How an Electric Pre-Engaged Starter Works

An electric starter motor converts electrical energy into mechanical energy. When the ignition key is turned or button pushed, electrical energy in the battery energizes:

1. the solenoid:
   A) moves the drive pinion to engage with the engine's flywheel
   B) closes the contact allowing power from the battery to flow to the starter motor

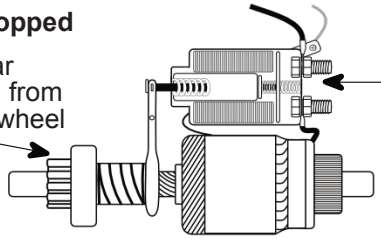
Because A) happens just before B) - this is called a *pre-engaged starter*

2. the starter motor:
   rotates the pinion gear to turn the flywheel cranking (rotating) the engine fast enough to allow the engine to start

(See *What a Diesel Needs to Start, p XX*)

A Engine Stopped

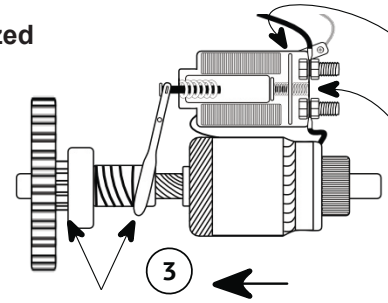
pinion gear withdrawn from engine flywheel



solenoid de-energized – contact plate disconnected from starter motor power terminals

B Solenoid Energized

1 ignition started with key or button



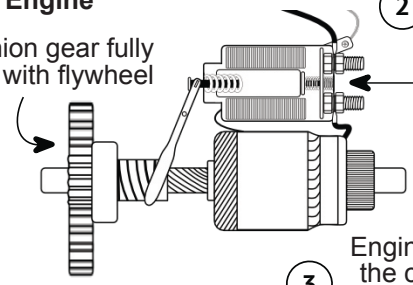
2 solenoid energized – plunger moves forward

4 contact plate has not reached the power terminals - motor not turning

3 lever pushes pinion gear to engage with flywheel

C Motor Cranks Engine

1 pinion gear fully engaged with flywheel



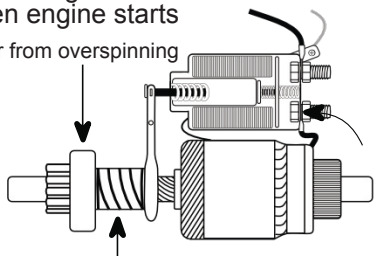
2 plunger fully closed - contact plate closes terminals – starter motor starts to rotate, rotating the flywheel and the engine

3 Engine starts when the air in the cylinders is hot enough (due to compression) to ignite the diesel fuel

D Starter Returns to Stand-By

Bendix gear (or Sprag or overunning clutch) releases pinion gear from flywheel when engine starts

1 protects motor from overspinning



2 ignition released - solenoid de-energized

3 spring returns plunger - contact plate moves back - opens terminals and the motor stops

4 spring returns lever when solenoid de-energized

3 Ways to Ensure Pinion Always Meshes with Flywheel

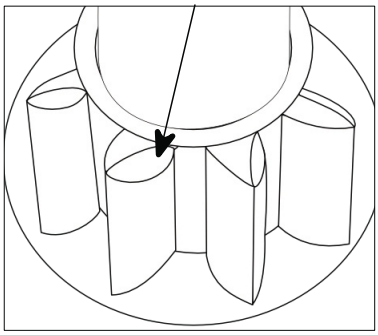
When the pinion gear moves to engage the flywheel, its teeth must mesh with the flywheel teeth, even if the flywheel has stopped slightly out of alignment to the pinion teeth. If the pinion does not immediately fully engaging with the flywheel (before the starter motor starts rotating), the teeth of the pinion gear may be damaged and will fail to rotate the engine.

Re-engaged starters use three safeguards to make sure the pinion teeth mesh with the flywheel teeth every time:

- bevels on the teeth of the pinion gear
- grooves rotate the pinion gear as it moves towards the flywheel
- spring in solenoid plunger allows motor to start to rotate pinion gear

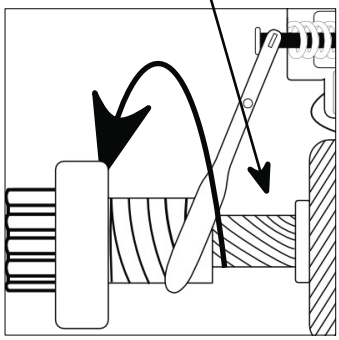
Bevels

bevels on the forward edge of each tooth help the pinion to mesh with the flywheel teeth



Grooves

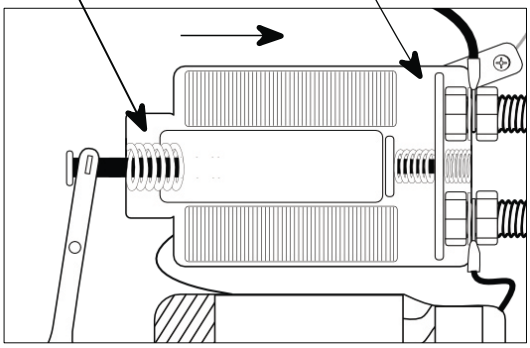
grooves in the shaft cause the pinion gear to rotate as it moves forward



Spring

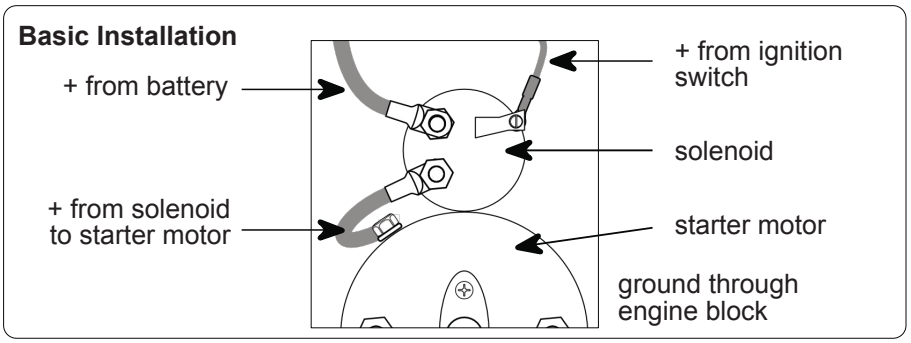
spring allows plunger to move when lever & pinion are stuck

contact plate closes contacts starting the motor

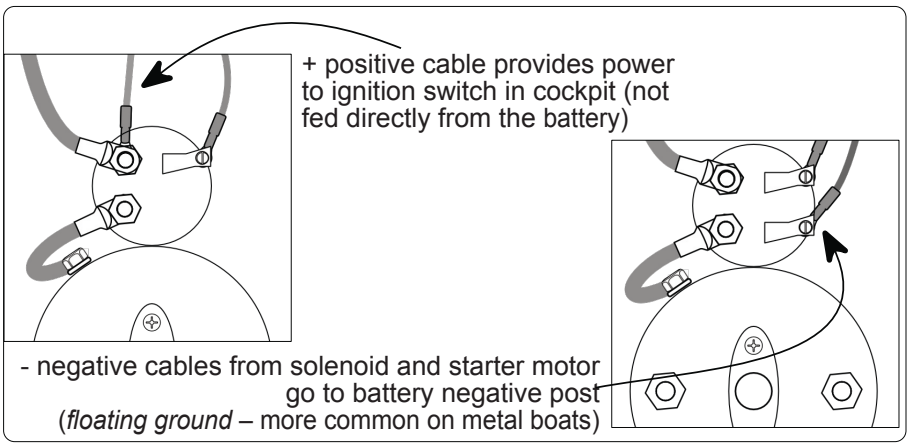


Wiring for Pre-Engaged Starter

Pre-engaged starters are wired in the same basic way, with some variations.



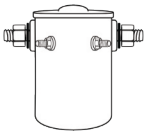
Two Variations in Installation



Pre-Engaged Starters with Permanent Magnets

Newer designs of electric pre-engaged starters uses permanent magnets instead of creating electromagnetic coils. These starters are typically much smaller and lighter than previous starters for the same size of engine. A smaller motor producing the same power to crank an engine is possible by using gears to convert the motor's high speed into lower speed and greater rotational energy (torque).

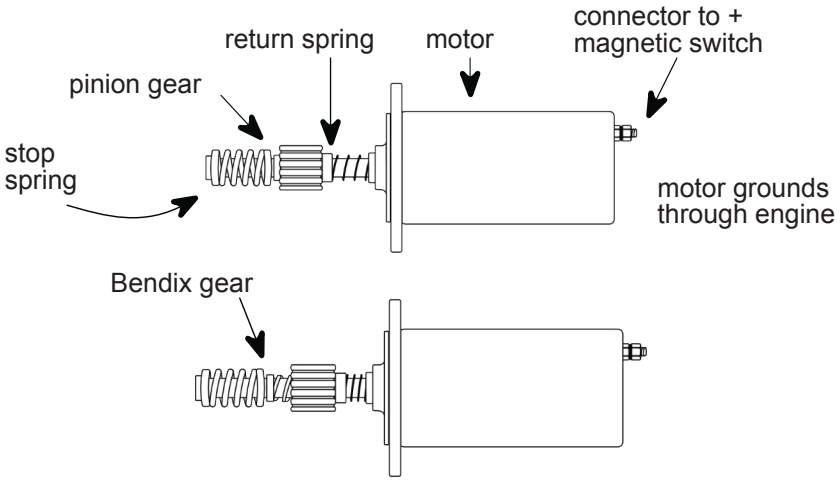
Inertia Starter, Bendix Drive,



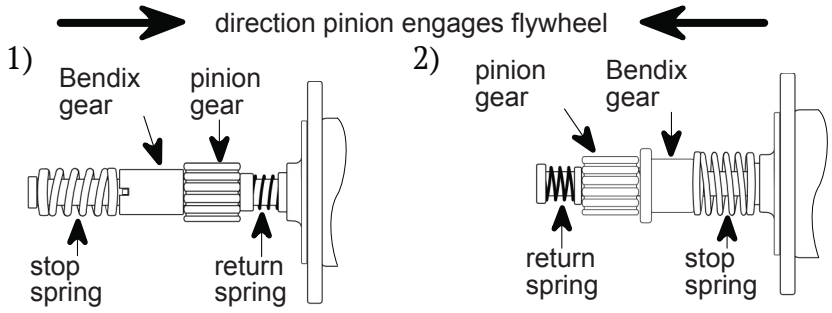
This earlier design of starter (which has largely been replaced by pre-engage starters) uses the spinning of the starter motor's shaft to both engage and disengage the pinion gear.

Inertia starters have their magnetic switch (similar to a solenoid but usually installed vertically) positioned off the starter motor.

Parts of an Inertia Starter



Two Variants of the Bendix Gear



How an Inertia Starter Works

a) The pinion gear of an inertia starter engages the ring gear of the flywheel only after its electric motor has started spinning.

b) When the motor shaft spins, the pinion gear moves along threads, instead of rotating, because of the gear's initial inertia (resistance to rotate).

c) Depending on the design, the gear moves either backwards (inbound) or forwards (outbound same as pre-engage starter) to engage with the ring gear of the flywheel.

This is possible because the pinion gear is not fixed rigidly on the starter motor's shaft. The pinion gear only starts to spin after engaging the flywheel.

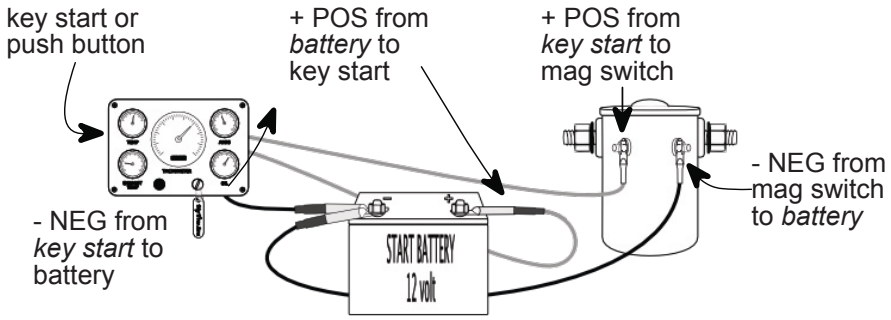
d) Once the engine starts, the rotating flywheel spins the pinion faster than the starter motor; inertia causes the pinion to be thrown off the flywheel, aided by a spring.

The mechanism that makes the pinion gear rotate and move along the threads to engage with the flywheel is called a *Bendix gear*. Though there are several designs, they all use an unbalanced weight and threads to both amplify the inertia and to rotate the pinion.

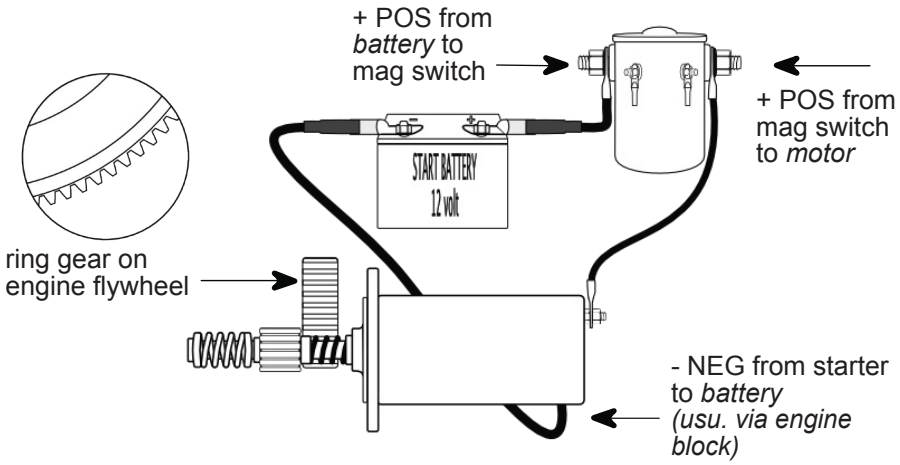
Inertia starters have two electrical circuits (similar to pre-engaged starters) except that the magnetic switch (solenoid) is located off the starter motor):

- **control circuit** - when the start key is turned, or start button pressed, power flows from the battery, energizing and closing the magnetic switch (solenoid)
- **power circuit** - power flows from the battery to the starter motor only while the magnetic switch is energized.

Control Circuit (Inertia Starter)



Power Circuit (Inertia Starter)



Aids to Starting

Diesel engines depend on the temperature of the air compressed inside the cylinders to ignite the diesel fuel - and will not start if, for any reason, this falls below diesel's auto-ignition temperature of 210°C (410°F). Usually this is because the engine block or intake air are cold, or because slow cranking (weak battery) is allowing the engine block to absorb too much heat from the air. Even in the tropics, an engine that has been sitting for weeks may need help it get started.

For this reason most diesel engines come with at least one aid to starting:

- electric glow plugs
- electric intake air heater
- diesel fuel burner intake air heater
- decompression lever
- starting fluids - NOT recommended

Glow Plugs

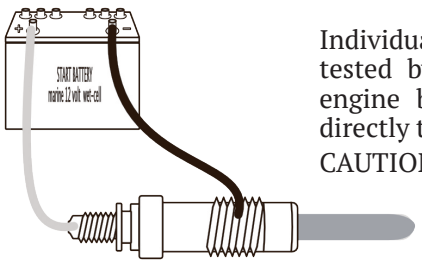
Glow plugs thread into the side of the engine block, with a tip reaching into the pre-combustion chamber of each cylinder. Their purpose is to heat the air and metal around the chamber to ensure fuel ignites as soon as it is injected. (An engine with direct combustion (no pre-combustion chambers) usually has a heating element in the air intake.)

Glow plugs are powered by the vessel's engine electrical system (12v or 24v); the specific voltage may vary from 5v to 24v, depending on the specific design for the engine, and is controlled by a resistor.

Glowplugs are turned on by either turning a key ignition or by pushing a button on the engine dashboard for up to 30 seconds before the engine is cranked. Glow plugs may be wired in parallel, so that if one glow plug fails the others will still work, or in series.

Engines use specific designs and specifications of glow plugs; they are rarely interchangeable between engines. So it's prudent to keep a full set of spares.

In addition to being aids to starting, glow plugs are also used to reduce start-up exhaust emissions in diesel engines with electronic control modules (electronically controlled diesels).

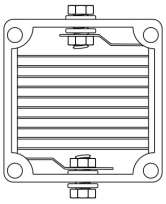


Individual glow plugs can be tested by removing from the engine block and connecting directly to a battery.

CAUTION: tip becomes red hot

Electric Intake Air Heater, Manifold Heater, Grid or Plug Heater

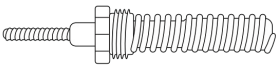
These heaters warm cold air coming into the engine through the air intake (charge air) - warmer air for combustion makes the engine easier to start. They are typically installed on direct injection interference engines as an alternative to glowplugs, where there is no space in the cylinder for the tip of a glowplug. (Indirect injection engines have pre-combustion or swirl chambers which can accommodate glowplugs (See Engines, page XX).



Some electronically controlled engines may have both glowplugs and intake air heaters.

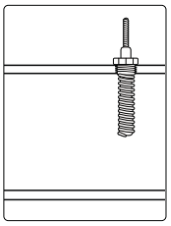
Power is provided from the engine's battery and controlled by turning the ignition key, or pushing a button on the control board, or automatically if the engine is electronically controlled. These heaters can draw up to 100A so a relay (solenoid) is usually used to minimize the size of control cables and avoid voltage drop in the power cables.

Electric air intake heaters are typically of two designs - grid or plug, depending on the engine manufacturer. Both have the same functions and are wired in similar ways.



Two disadvantages of electric intake air heaters are:

1. body of the heater restricts the flow of air through the intake manifold - by up to 20%. For this reason, the heater is sometimes removed from an engine operating in warmer climates where cold starting is not needed.
2. less efficient than glowplugs because some of the heat will be lost to the body of the air manifold, therefore using more electrical power



Functions of an Intake Air Heater

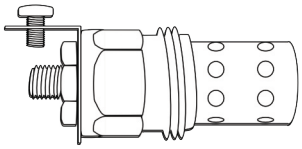
These heaters may have two functions, depending on whether or not the engine is electronically controlled:

- pre-heat incoming cold air to help the engine to start more easily
- control exhaust emissions by reducing white and grey smoke in the period when the engine is still warming up. This is activated and controlled by the engine's ECM

Variants

Some grid heaters may have two heating elements wired to separate relays but both controlled by the engine's ECM (electronic control module).

Flame Start, Thermostart, Glow-Plug

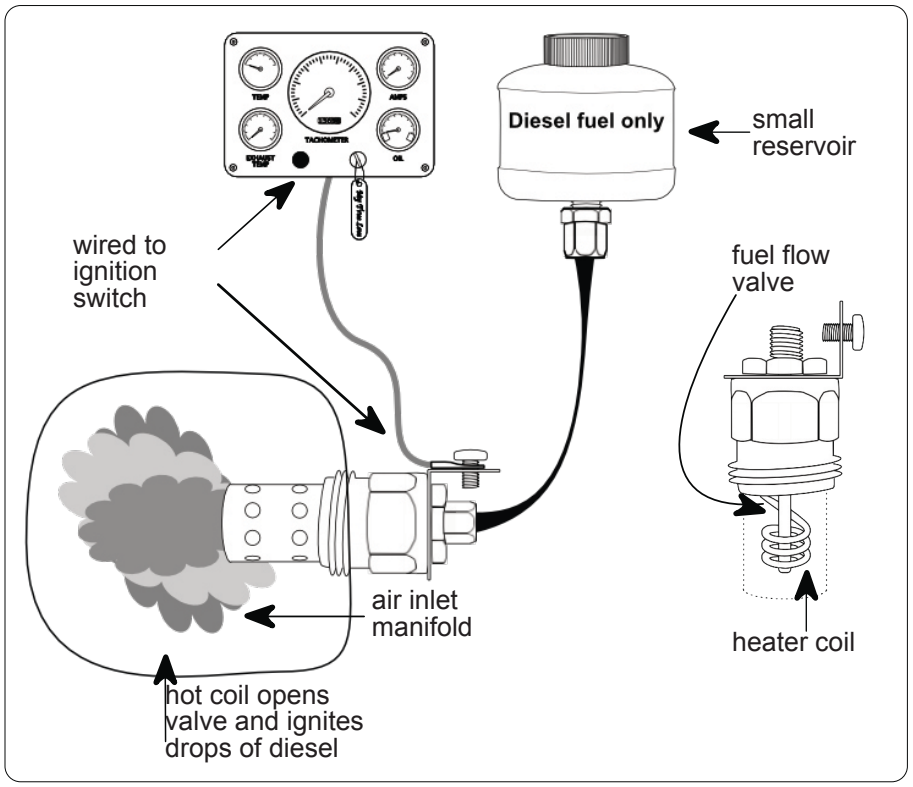


These devices help engine starting by burning a small amount of diesel fuel inside the air inlet manifold to heat the incoming combustion air which warms the pre-combustion chamber, making fuel easier to ignite when injected by the injectors. These devices are only fitted to naturally aspirated engines, not engines fitted with turbochargers.

How A Thermostart Works

The device is threaded into the side of the air manifold. and connected to a small diesel reservoir and 12v power from the ignition switch. When the key (or button) is turned to AUX or Glow Plug, a coil inside the device heats up until red hot. The heat 1) opens a valve allowing drops of fuel to flow from the reservoir, and 2) ignites the diesel to burn inside the air manifold. The heated air is sucked into the engine's pre-combustion chambers or cylinders as the engine is being cranked.

When coil in the Thermostart is turned off (by turning the ignition key back to ON or RUN) and cools, the fuel stops flowing and the flame goes out.



Alternatives to Electric Starters

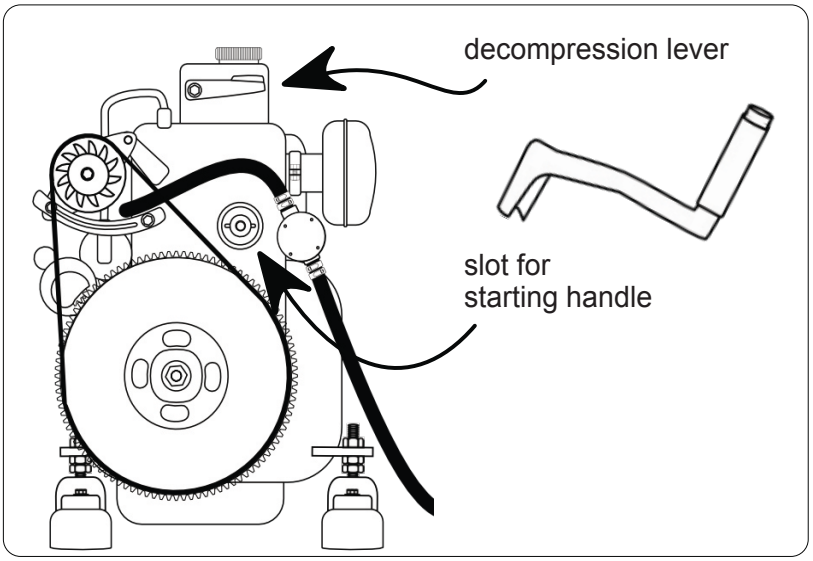
Several non-electric starters are commercially available for small and medium-sized diesel engines:

- hand-starting with decompression lever
- spring starter
- hydraulic starter
- air starting - used on large engines (including most ships.

Engine Decompression Lever

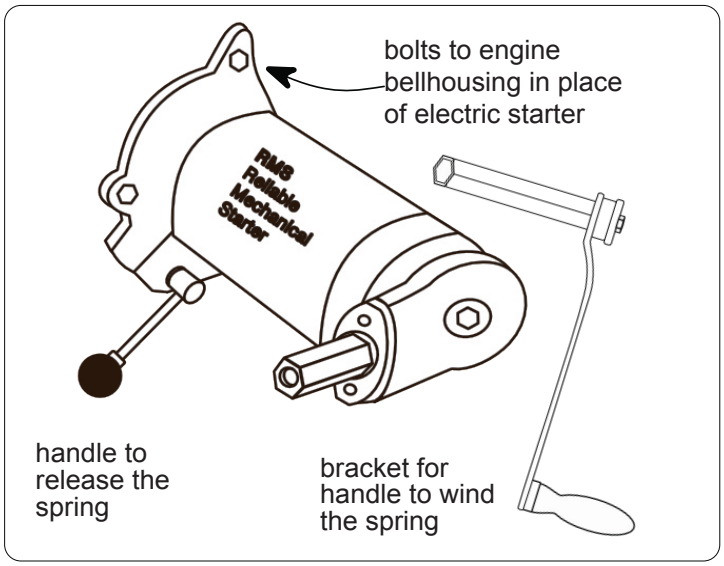
Some smaller engines (typically up to 3 cylinders) are fitted with a decompression lever to aid starting. The lever opens the exhaust valve(s) which prevents compression in the cylinder(s), making the engine much easier to rotate using a cranking handle.

1. is activated
2. starting handle is engaged
3. engine is rotated as fast as possible using the starting handle
4. spring-loaded decompression lever is released
5. exhaust valve(s) closes
6. pistons compress air in the cylinders
7. injected diesel ignites and engine starts

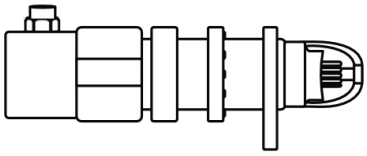


Spring-Driven Starter

A spring-driven starter can be used in place of an electric starter; often in vessels such as lifeboats that may not be used for long periods. The spring is wound with a handle and the spring released by a moving short lever.



Hydraulic-Driven Starter



An hydraulic starters can be practical on vessels already equipped with hydraulic systems, such as fishing boats. Oil pressure is stored in an accumulator and released to crank the engine's flywheel.

The starter can be recharged when the engine is running using a PTO-driven pump; some models include a manual pump to recharge the accumulator.

Air-Driven Starter

Diesel engines on ships are typically started using air pressure. Air starters – very similar to hydraulic starters – are also available for diesel engines found on workboats and recreational vessel. An air supply is needed to recharge the starter's accumulator.

Dangers of Starting Fluids

Spraying a volatile chemical into a diesel engine's air intake can help start an engine in cold weather but **risks doing severe damage**. These fluids work by igniting at a lower temperature than diesel fuel – so require less compression to ignite. Diethyl ether auto-ignites at 160^{O}C (320^{O}F). Diesel fuel auto-ignites at 260^{O}C (500^{O}F).

The danger is that the starting fluid will ignite early (detonation) – while the piston is still coming up the cylinder on the compression stroke. This can cause severe damage to pistons, connecting rods and the cylinder head gasket. Hot glow plugs or hot intake air heater, left on after the engine has started, can also cause early ignition and engine damage.