Facts worth knowing about

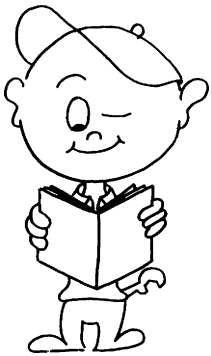
Oil pumps

Danfoss

Burner Components



Facts worth knowing about oil pumps
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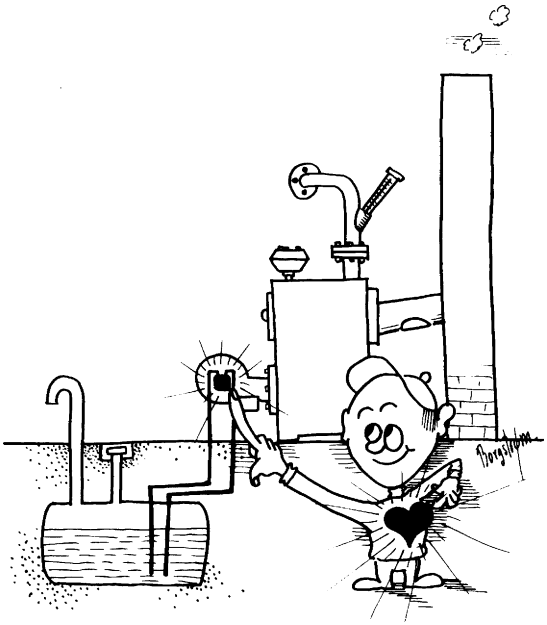
Introduction

Just as no human being can function without a heart, so the oil pump is vital to the operation of an oil-fired heating plant. For people who have anything to do with oil burner a knowledge of the nature and characteristics of oil pumps – can be very useful.

The »blood« of an oil burning plant, the fuel oil, must be transported from the tank to the burner with safety and reliability. In an oil burning plant the oil must be filtered and be subjected to a suitably high and stable pressure. Here, the parallel with the human body ceases, for oil flow in a burner plant must start and stop accurately in step with the requirements made on it.

The oil pump is designed to carry out these functions, but it will only do so if it is properly looked after.

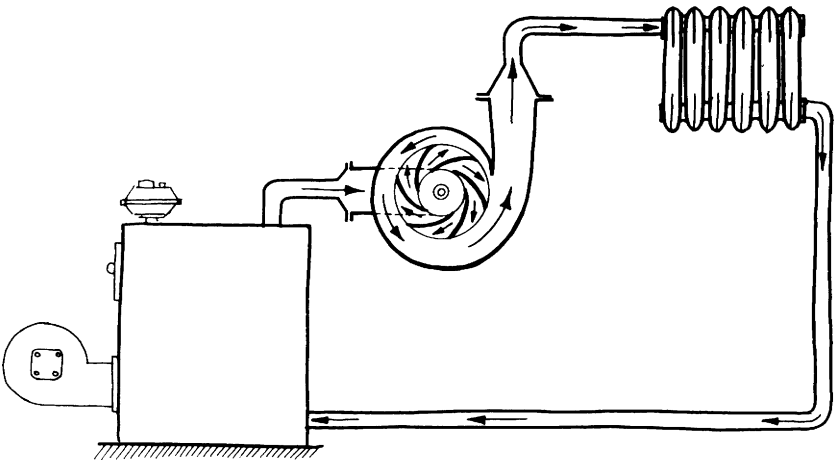
How? That is what this booklet is all about.



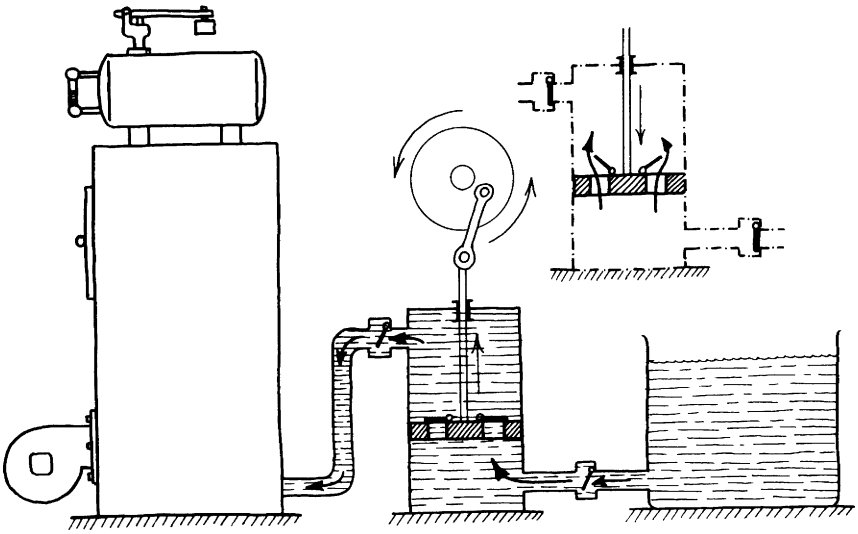
How does a pump work?

On a heating plant many different types of pumps are used, their common task being to move liquid. The design and method of operation of a pump will depend partly on how much liquid it must deal with and partly on how much pressure the pump must yield.

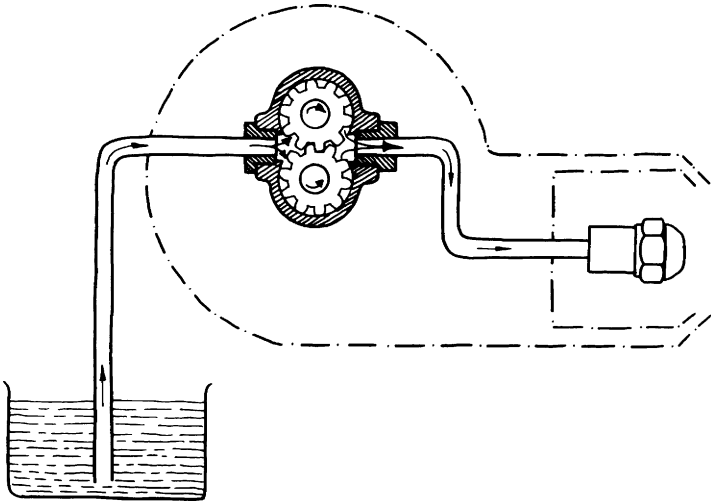
Centrifugal pumps are mainly used to circulate liquid; hot water in a central heating system for example. This type of pump is not self-priming.
Liquid enters at the centre of the pump and is flung by the rotation of the impeller out to the walls of the pump housing. In this way pressure is built up at the outlet of the pump.



Piston pumps are used to transport liquid where a particular high pressure is required at the pump outlet. An example is where feed water must be supplied to a steam boiler.
As can be seen from the illustration, when the piston travels upwards the water above it is forced into the boiler. At the same time, the suction created below the piston sucks water from the condensed water tank into the pump. When the piston travels downwards the (black) flap valve lifts and water flows into the space above the piston so that the pumping process can be repeated at the next stroke of the pump.



Gear pumps are used where good suction and good pressure characteristics are required – in an oil burning plant for example. The simplest type of gear pump contains two indentical meshing gearwheels.
As the gearwheels rotate, the disengagement of the teeth at the lefthand side of the pump (the suction port) creates underpressure (vacuum) and oil is sucked into the pump housing and around the clearance between gearwheels and pump housing. When the gear teeth engage at the righthand side of the pump the oil is forced out through the oil nozzle.
The trochoidal gearwheel set used in Danfoss oil pumps is a development of the gears in a simple gear pump and will be referred to later in this booklet.



High pressure oil pump principle

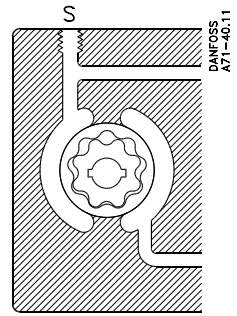
In principle, a high pressure oil pump consist of:

- a pump component that sucks oil and pressurizes it.
- a valve component that regulates the oil pressure.

Pump component

Great demands are made on an oil pump, among them are:

- large suction capacity
- large pressure capacity
- quiet operation
- low starting torque
- low energy comsumption.



It is just these characteristics that Danfoss have achieved in fitting their oil pumps with the special TROCHOIDAL GEARWHEEL SET.

What is a trochoidal gearwheel set?

A trochoidal gearwheel set is made up of an external »tooth rim« supported in a gearwheel plate, and a gear pinion seated on the pump shaft (fig. A).

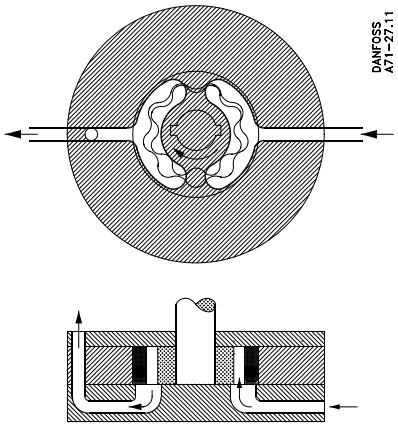
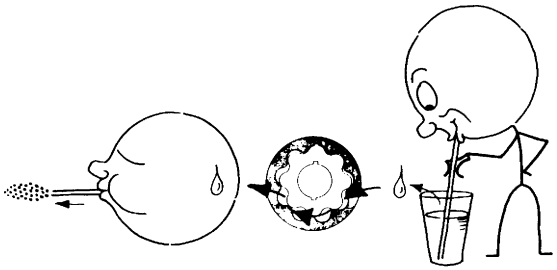


Fig. A

When the pump shaft rotates it turns the gear pinion and the specially formed »teeth« on the pinion engage and also turn the gear rim. One side of the gearwheel set is faced by a »cover plate« which contains suction and pressure channels. The other side of the gearwheel set is faced by the pump housing. When the gearwheel set rotates, oil is sucked in and forced out by virtue of the clearance between the gear teeth. Thus gearwheel suction and discharge sides are created. From the latter, oil is led to the pump pressure regulating valve.



Pressure regulating valve

The requirement of the valve is to regulate and maintain a stable oil pressure, and to direct the amount of oil not used by the oil nozzle back to the suction side of the pump or return it to the tank. A regulating valve in its simplest form comprises a piston, a compression spring and an adjusting screw (fig. A).

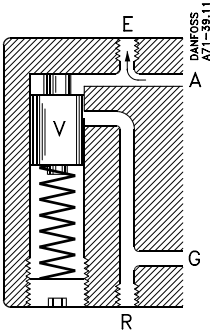


Fig. A

If the regulating valve is set to deliver a low pressure through the nozzle the spring will be under less compression so that the spring force on the piston is low. When oil enters at »A« it leaves the valve at »E«. If the pump delivers more oil to the regulating valve than the nozzle can pass via »E« the piston will be pressed further back until it opens sufficiently for return flow through »R«. This means that oil pressure in the valve piston is able to balance the set spring force so that oil can flow to the nozzle at the set pressure (fig. B).

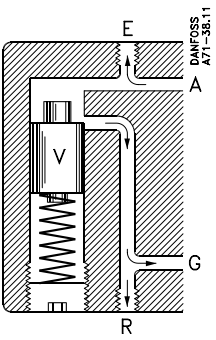


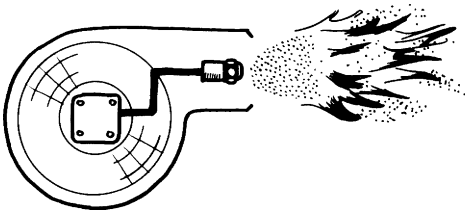
Fig. B

On a two-pipe installation excess oil is led back to the tank, while on a onepipe system it will flow through the return channel »G« to the suction side of the pump. If a higher oil pressure is required at the nozzle discharge the spring must be tightened. With more compression in the spring a higher oil pressure is necessary to make the piston open for return flow through »R« which, in turn, means a higher pressure at the nozzle.
Every Danfoss pump consists of a pump component and a valve component. The many versions of Danfoss pumps are made up of different size and valve components having various functions.

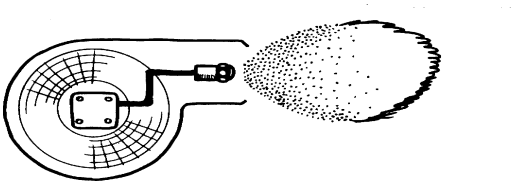
Why a cut off is required?

There is more to an oil pump than just a simple combination of gearset and valve components before it is suitable for operation in a modern burner plant. Taking the start and stop sequence of an oil pump:

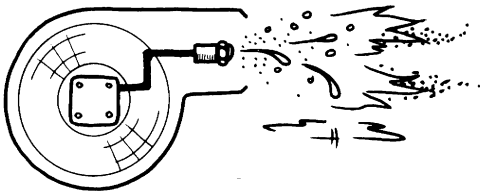
1. When the oil burner starts there will be a moment before the motor, driving the oil pump and fan, reaches full speed. This can mean that the air pressure is not at full strength when oil is released to the nozzle so that there is a risk of the atomized oil receiving an inadequate air supply.
   The result of this inadequacy may be pulsating, sooty combustion.



2. With the motor at full speed, air pressure and air volume will be in order so that combustion becomes stable, clean and economic.



3. When the oil burner stops, motor speed falls. Oil and air pressure will fall evenly until the motor comes to a standstill. During this period combustion could again be pulsating and sooty and nozzle dribble from the oil nozzle may occur.



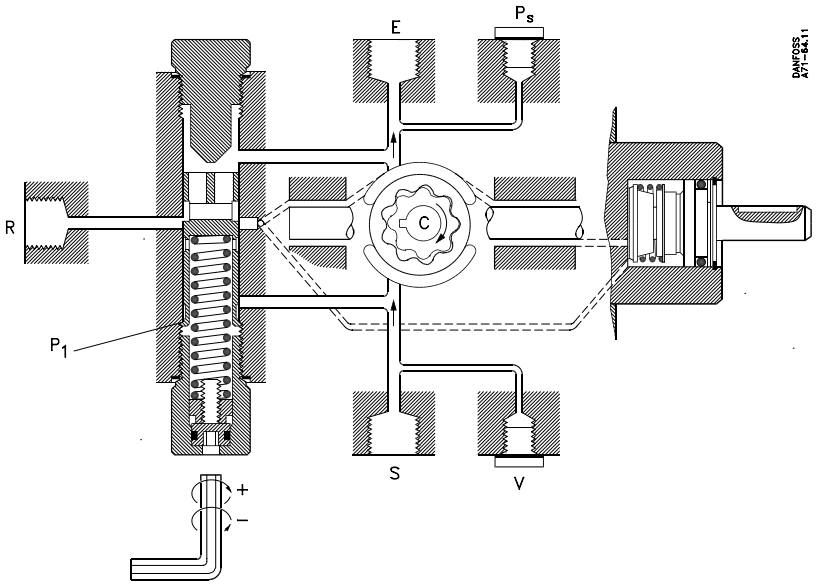
Today, to avoid these unfortunate consequences of poor combustion, pumps with a electrically operated cut-off valves, are being brought into use more and more. The solenoid valve controlled cut-off valve, and the commonly known solenoid valve installed in the nozzle line are all technical solutions which have been developed from the simple regulating valve to ensure problem-free stop-start function.

Why are there different types of oil pumps?

Different sizes and types of oil pumps are needed so that different requirements for oil volume and correct start-stop operadon can be met.
Oil volume is determined by the size and speed of the gearwheel set, while the different start-stop operations depend on the valve design chosen for the pump. The valve can be designed to operate as follows:

Regulation valve

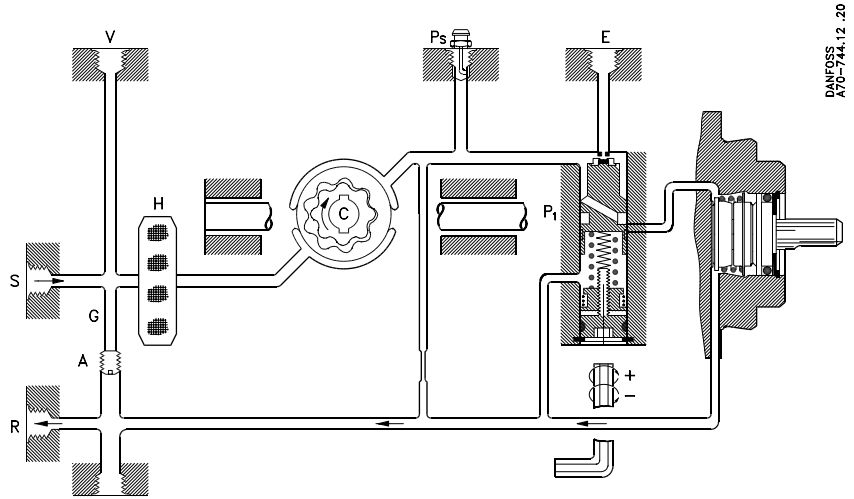
The sole purpose of this valve is to regulate oil pressure to the nozzle. This type of valve is used in the Danfoss type KSA oil pump and is illustrated below.



S = Suction line
R = Return line
C = Gearwheel set
P_s = Pressure gauge + bleed port
P_1 = Pressure regulation
E = Nozzle port
V = Vacuum gauge port

Regulating and cut-off valve

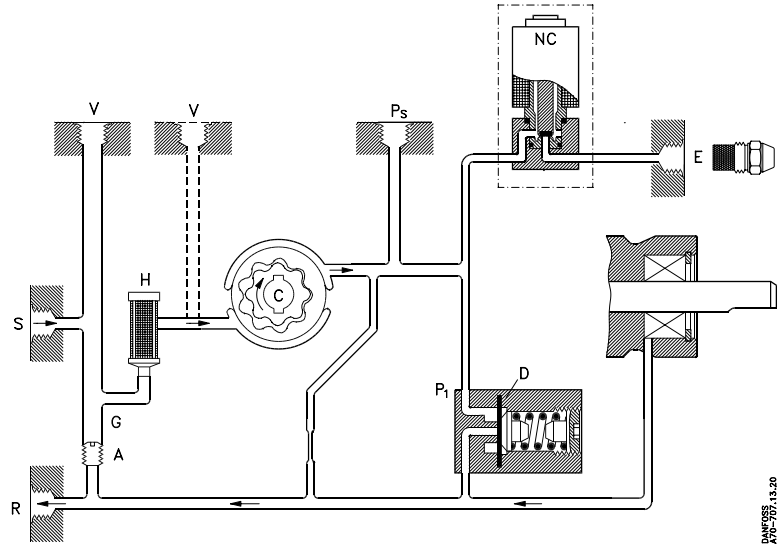
The valve regulates oil pressure to the nozzle and cuts off oil flow when the pump stops rotating. Examples of oil pumps with regulating and cut-off valves are Danfoss types RSA.
This type of valve is used in Danfoss types RSA and RSH oil pumps.



S = Suction line
R = Return line
G = By-pass (one-pipe)
A = Two-pipe screw
C = Gearwheel set
P_s = Pressure gauge + bleed port
P_1 = Pressure regulation
E = Nozzle port
H = Filter

Diaphragm regulation

Diaphragm regulation is a combination of pressure regulation and a cut-off function. The built-in solenoid valve is a separate function unit which gives effective start and cut-off.
The drawing below shows diaphragm regulation as used in BFP and MS oil pumps.

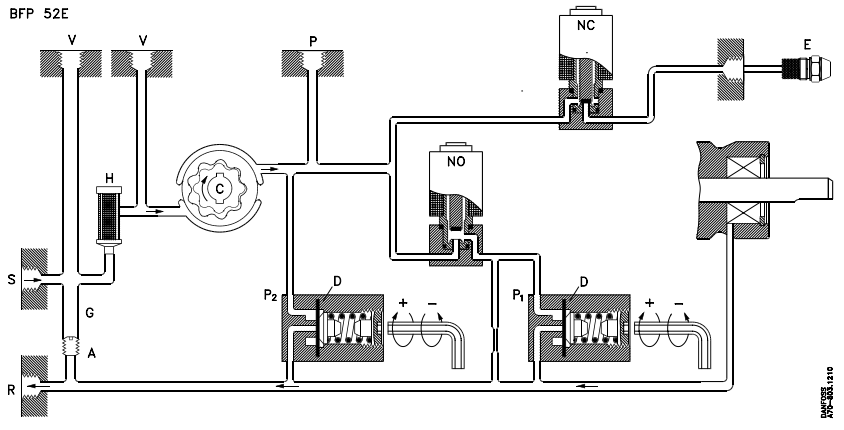


S = Suction line
R = Return line
G = By-pass (one-pipe)
A = Two-pipe screw
C = Gearwheel set
P_s = Pressure gauge + bleed port
P_1 = Pressure regulation
E = Nozzle port
D = Diaphragm
V = Vacuum gauge port
H = Filter

What is a two stage oil pump?

In the foregoing section we described the function of the oil pump as being the heartbeat of the oil burner. The pump maintains stable pressure to the nozzle. If a human being has to exert more energy, e.g. begin to run, the heart beats more rapidly and more blood is circulated around the body. This is parallel to the oil pump being speeded up. Since the oil pump consists of a pumping section (its heart) and a form of pressure regulation, the oil is pumped at a certain pressure to the nozzle.

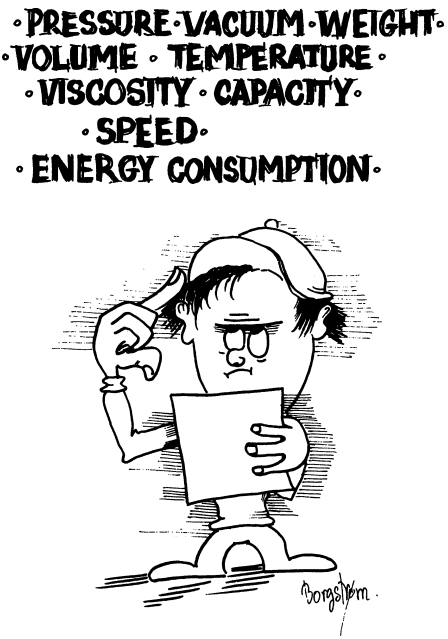
But, as it is the oil pressure that determines how much the nozzle yields, increasing the pump speed serves little purpose, because the oil pressure is governed by the regulating valve spring. To make the pump yield more, i.e. increase its pressure setting, we must change the regulating valve spring force. The ideal way of doing this is to have two separate regulating systems where one is used for pressure stage 1 (e.g. 8 bar) and the other for pressure stage 2 (e.g. 20 bar). Changeover between the two valve systems occurs via a solenoid valve, as shown in the drawing below.



S = Suction line
R = Return line
G = By-pass
A = Two-pipe screw
C = Gearwheel set
P = Pressure gauge + bleed port
P_1 = Pressure regulation
P_2 = Pressure regulation
E = Nozzle port
D = Diaphragm
V = Vacuum gauge port
H = Filter

Which units of measurement are used in connection with oil pumps?

To be able to compare oil pumps, and to be able to select the correct pump for a plant, it is necessary to understand and be familiar with the appropriate technical terms when talking oil burners. Through the centuries, people have used many measuring systems. To compare them is difficult because the conversion from one system to another often involves complicated calculations together with a series of conversion factors hard to keep track of.
Today, agreement has been reached on an international measuring system, the »SI-system«, a development of the metric system. Since this publication uses SI units to present technical data, there follows a brief account of the relevant ones and a comparison with units previously used.



Pressure

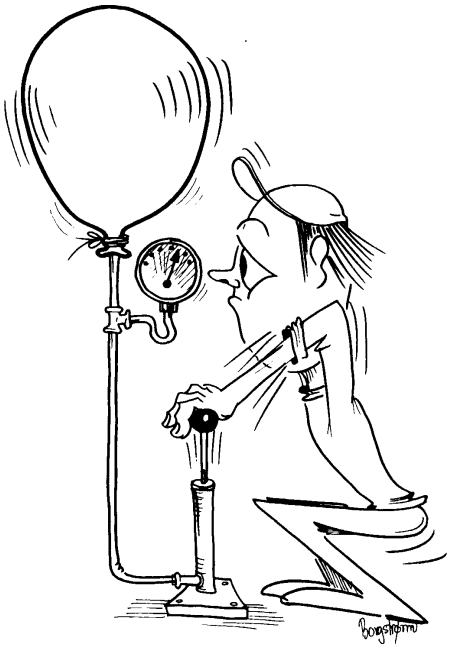
When an oil pump operates, oil is pumped out under a pressure lying within the pressure range of the pump.
The SI unit of pressure is the N/m^2 (newtons per square metre), also called the pascal (Pa).
Since this unit represents a very small pressure (1 kp/cm^2 = 100.000 Pa), the bar is used extensively.
l bar = l00.000 Pa = 100 kPa (kilopascal) = 0.1 MPa (megapascal).

Conversion of bars to other units

1 bar = 1.02 kp/cm^2 = 0.98 at; in practice the conversion becomes 1 bar = 1 kp/cm^2 = 1 at = 10 metre water column = 76 cm Hg. (14.5 psi).
The pressure referred to up to now is overpressure above atmospheric pressure. To avoid misunderstandings in connection with pressure, some technical literature contains an added pressure designation.

p_e = effective pressure,
i.e. that which is normally taken as being the pressure,
(atmospheric pressure = 1 bar p_e

p_a = absolute pressure.
This designation is used when calculating atmospheric pressure.
It is seldom used in ordinary technical literature.



Vacuum

»Vacuum« or »negative pressure«, means pressure lying below atmospheric pressure. When an oil pump sucks oil from a tank so much vacuum occurs in the suction line, that the atmospheric pressure (which freely enters the tank through the vent port) presses the oil to the pump.
The SI unit of negative pressure is the same as for overpressure, the N/m^2 (newton per square metre). Again, where oil pumps are concerned, a derived unit (bar) is most often used.

A negative is given a negative sign E.g. $p_e = –0.5$ bar.
Conversion factors:
In the »old« system, vacuum was given in mm Hg (millimetre mercury column) or in Wg (inches water gauge).
The highest possible vacuum is 760 mm Hg and corresponds to – 1 bar in the SI system. 1 mm Hg corresponds to –0.0013 bar.



Viscosity

The viscosity of an oil is its thickness or its ability to flow. The higher its viscosity number the thicker the oil is.
The SI unit of viscosity is:
mm^2/s, which is also called the centistoke (cSt).
Kerosene has a viscosity of 1.3 to 1.8 mm^2/s (cSt) at 20 °C, gasoil has a viscosity between 3 - 6 mm^2/s (cSt) at 20 °C.
Heavy fuel oil can have a viscosity up to 270-370 mm^2/s (cSt) at 50 °C.
In the old system, viscosity was given as, for example:
Degrees Engler (°E), seconds
Redwood (sec R) seconds
Saybolt (SSU).



Speed

An oil pump normally runs at the same speed as the burner motor.
The SI unit of speed is min^{-1}.
Example: 2800 min^{-1}
This designation is international, unlike previous designations which were often abbreviations of a phrase in a particular language:
RPM for »revolutions per minute«.

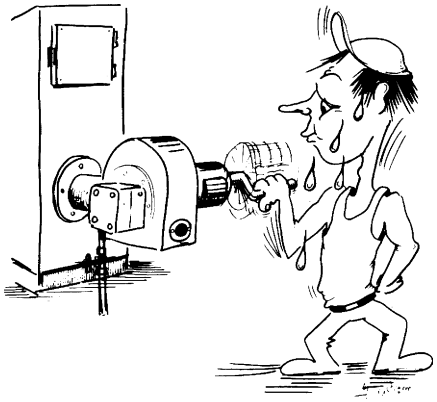


Energy consumption

The power that must be used to rotate an oil pump can be given in different ways. If the energy consumption has to be expressed as a power (e.g. BFP 11 L3: 40 watts) the figure given applies only at particular pressure, a particular oil viscosity, and a particular speed. The SI unit for power is watts (W).
To facilitate oil pump power calculations for other values of pressure and speed, Danfoss express oil pump energy consumption as torque on the shaft. This is normally given both as starting torque and operating torque.

- The starting torque of an oil pump is the torque that must be applied to the shaft to start the pump.
- The operating torque of a pump is the torque that must be applied to the shaft to keep it running at a given speed, atomizing pressure, and oil viscosity.

The SI unit of torque is the Nm (newton metre).
The power consumption of an oil pump can be calculated using the formula:
$P = 0.103 \times n \times M(W)$ when pump torque (M) and speed (n) are known.



Example
Oil pump type BFP type 3 data:
Torque: 0.14 Nm at an atomizing pressure of 10 bar and a viscosity of 4.3 mm^2/s.
Oil pump power consumption at 2800^{-1} is thus:
$P = 0.103 \times 2.800 \times 0.14$
$P = 40.376$ W

Capacity

The amount of oil a pump yields to a nozzle can be expressed in two ways:

Weight per unit of time

This means that a pump delivers, for example, 25 kilograms of oil during the course of 1 hour (25 kg/h).



Volume per unit of time

Here, a pump will deliver for example 45 litres of oil in the course of 1 hour (45 l/h) or, approx. 11.5 - 12 USgal/h.



Converting to different units of capacity
If a capacity has to be converted to a different set of units, the first thing to establish is whether the conversion is volume to volume, or volume to weight, etc.

To illustrate this:

- An oil pump delivers 45 l/h.
  How much is this in USgal/h?

Both litres and US gallons are units of volume. Therefore the calculation is direct, given how many litres there are in a US gallon.
1 US gallon = 3.785 litres
45 litres = 45 ÷ 3.785 = 11.889 or 11.9 USgal/h.

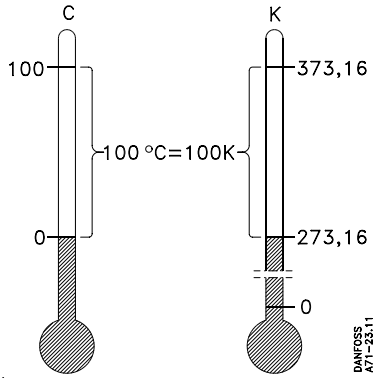
- An oil pump delivers 12 kg/h.
  How much is this in USgal/h?

As the kilogram is an expression of weight and USgal an expression of volume, direct calculation with a conversion factor (as in the first excample) is not possible.

First, it is necessary to find the volume of 12 kg of oil (the number of litres). Then the »density« of the oil must be found, i.e. how much 1 litre of oil weighs. If the specific gravity of the oil is 0.83 (at 15 °C), 1 litre weighs 0.83 kg (at 15 °C) . Thus, 12 kg oil has a volume of 12 ÷ 0.83 = 14.46 litres.
Converting now from 14.46 litres oil to USgal:
14.46 ÷ 3.785 = 3.82 USgal.
Therefore, 12 kg/h is the same as 3.82 USgal/h, but only with an oil having a specific gravity of 0.83 (at 15 °C).

Temperature

The SI unit of temperature is usually °C (degrees Celsius). In the case of absolute temperature the SI unit is degrees Kelvin (K).



In some countries the SI unit K (Kelvin) is used to express temperature difference. 1 °C and 1 °K have the same value.



SI units

Each SI unit consists of a basic unit to which a fixed value designation can be added to give multiples of that basic unit.

Taking an everyday example:

The basic unit of length is the metre (m). For long lengths (distances) it is usual

to use kilometre (km). In other words, the basic unit »metre« has been prefixed with »kilo«, which means the total unit now designates 1000 metre.
To give small lengths the millimetre (mm) can be used. Here, the basic unit »metre« has been prefixed with »milli«, which is a way of expressing $^{1}/_{1000}$ of a metre.



Other common multiples of basic units can be seen in the table below.

Designation	Name	Multiple	Example	
G	giga	10^{9} (1.000.000.000)	1 gigacalorie	= 1 Gcal
M	mega	10^{6} (1.000.000)	1 megawatt	= 1 MW
k	kilo	10^{3} (1.000)	1 kilometre	= 1 km
h	hecto	10^{2} (100)	1 hektogram	= 1 hg
da	deca	10^{1} (10)	1 decanewton	= 1 daN
–	–	1	1 metre	= 1 M
d	deci	10^{-1} (1/10)	1 decilitre	= 1 dl
c	centi	10^{-2} (1/100)	1 centimetre	= 1 cm
m	milli	10^{-3} (1/1000)	1 millimetre	= 1 mm
µ	micro	10^{-6} (1/1.000.000)	1 microampere	= 1 µA

The oil pump in the installation

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Relationship between tank and burner – suction height/ suction length

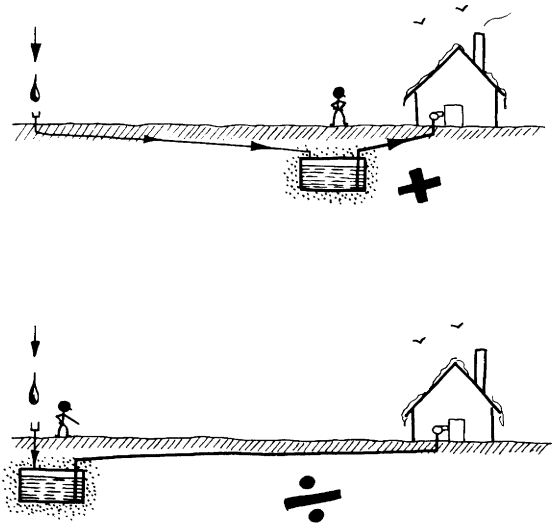
The suction capacity of the pump and the associated pipe dimensions must be accurately known *before* the oil tank is buried. The reliability of the system depends entirely on whether the pump can lift oil from the tank and deliver it to the burner.

Another factor to be considered is the situation of the tank; it must be easily accessible to the oil delivery crew.

Broadly speaking, new pumps have a suction capacity of –0.6 bar to –0.8 bar. This capacity must cover raising the oil from the bottom of the tank and overcoming various resistances in the suction line (bends, valves, etc.).



Operating with too strong a vacuum must however be advised against. Countless experiments have shown that at as little as –0.33 bar (corresponding to 4 m head) air begins to separate from the oil. This air separation can lead to »oil starvation« in the gearwheel set and result in increased wear and noise. The safest way is to follow the pump manufacturer's instructions as regards pipe diameter, suction length and suction height. It is also better to get the oil delivery crew to supply the oil through a *long* hose so that the suction line need only be *short* than vice versa.



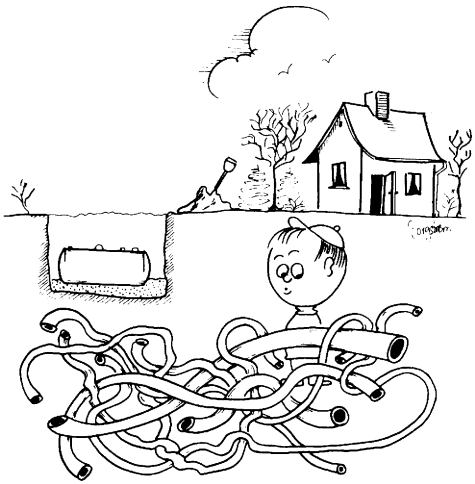
How to select the correct pipe diameter and pipe length

Since oil burner reliability is dependent on the capacity of the oil pump to suck oil from the tank and deliver it to the burner, the instructions supplied by the manufacturers of the oil pump regarding pipe layout, pipe diameter and pipe length should be followed – always.

To be able to determine the correct pipe diameter and length, the following must be known:

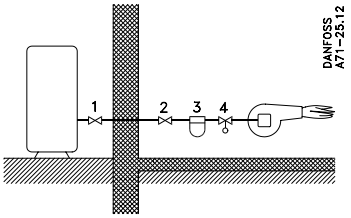
- Oil viscosity. This is usually given in Centistokes (cSt) or in degrees sec. Redwood at a given temperature.
- Height difference between the lowest oil level in the tank and the suction port of the pump, in metres.
- Total suction length, in metres.
- The various resistances involved arising from valves, filters, bends, etc. in the suction line. Suction line tables from pump manufacturers will in most cases take account of a certain number of valves and bends.
- Maximum oil volume per hour to be handled by the pipe layout.

With a one-pipe system the oil nozzle selected will determine the pipe dimension because the oil pump will only pull the amount of oil that is forced out of the nozzle.
In a two-pipe system it is the total capacity of the oil pump that determines the pipe dimension. Here, the pump lifts oil at full capacity. Oil not forced through the nozzle is returned to the tank. Pipes must be installed with as few joints as possible and without sharp elbows.
Free-lying copper pipes must be protected against being crushed.
If because of local conditions it is necessary to take oil-carrying copper pipes outdoors where low winter temperatures occur, the pipes ought to be insulated.

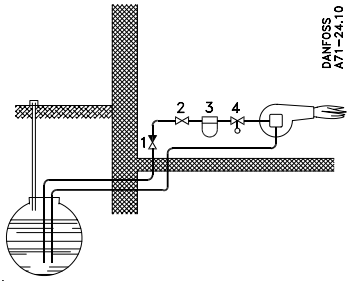


What devices ought to be used in the suction line

A suction line is not merely a pipe between oil tank and pump. Extra equipment is necessary in the line, to ensure reliability and to meet statutory requirements. Looking first at a one-pipe system, the diagram below illustrates how it should be built up to meet requirements on reliability, ease of servicing, and standards.



1) Manual shut-off valve
2) Manual shut-off valve inserted immediately in front of the filter to make it easy to clean or replace the filter.
3) Pre-filter to protect the plant from dirt and sediment in the oil tank. If this filter is fitted with a valve, item No. 2 can be omitted.
4) Melt-fuse valve fitted immediately in front of the burner.
   Local bylaws and regulations must also be complied with.
   The sketch below shows a two-pipe plant layout.



1) Check valve in suction line to prevent oil »loss« during standstill. The check valve should be fitted as close to the tank as possible without making it too hard to get at when servicing. Placing the valve close to the tank ensures the largest possible oil volume on starting.
2) Manual shut-off valve. Such a valve in front of the filter makes it easy to clean and replace the filter.
3) Pre-filter to protect the plant from dirt and sediment in the oil tank.
4) Melt-fuse valve fitted immediately in front of the burner.

It must again be remembered that local bylaws and regulations must be complied with.

How various resistances in the suction line affect the pump

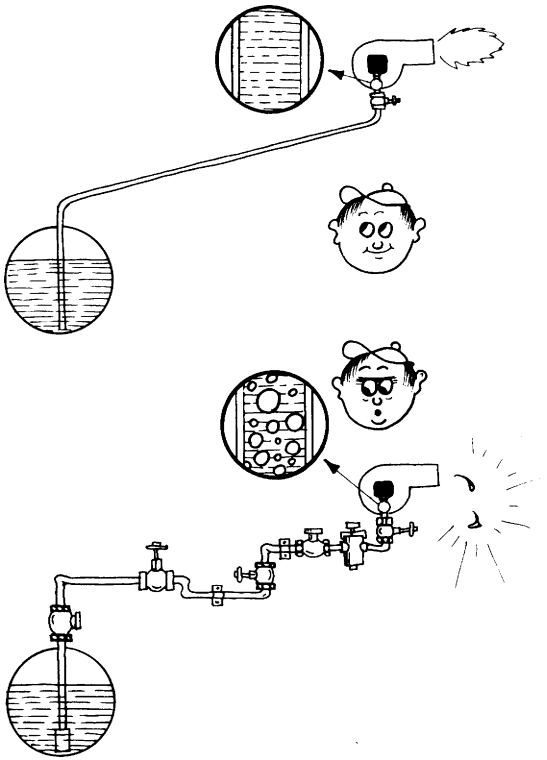
If fuel oil is subjected to too strong a vacuum, amounts of air and oil vapour will separate from the oil. The effect will be noticeable and detrimental to burner operation.

In suction lines oil is subjected to vacuum

The more valves, filters, pipe bends, etc. there are in a suction line the *bigger the resistance* to be overcome by the pump and the higher the vacuum in the line. The oil can thus be subjected to high vacuum *with the risk of air separation.*

If air separation does occur it can produce *oil pump whine* and the flame may become unstable and disappear. The phenomenon often manifests itself when vacuum in the suction line lies at approx. –0.5 to 0.7 bar.

Therefore, the suction line must contain as few joints, bends, valves, filters, etc. as possible – not least if the tank is a long way below the oil pump.



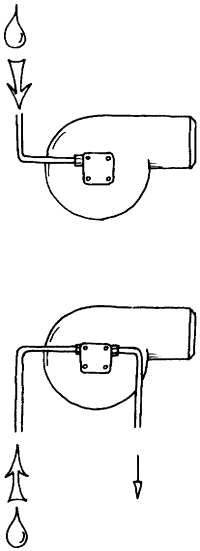
Why use one-pipe or two-pipe systems?

Of course it is cheaper and easier to connect an oil tank to an oil burner with a single pipe, but the most reliable system will be one that follows current European practice.

On an installation where the oil can flow from tank to pump by gravity, obviously the tank must be located higher than the pump. Thus, a one-pipe system can be used, i.e. a suction line and no return line.

On an installation where the tank is below the level of the pump the oil must be lifted. Most commonly used for this application is the two-pipe system, i.e. both a suction and a return line.

There are also some types of systems where the oil pump can be used as a »Monotube«, i.e. the pump is connected to a one-pipe system with underlying tank. This type of system has been quite popular in the UK when the tank is only l or 2 metres beneath the level of the burner.

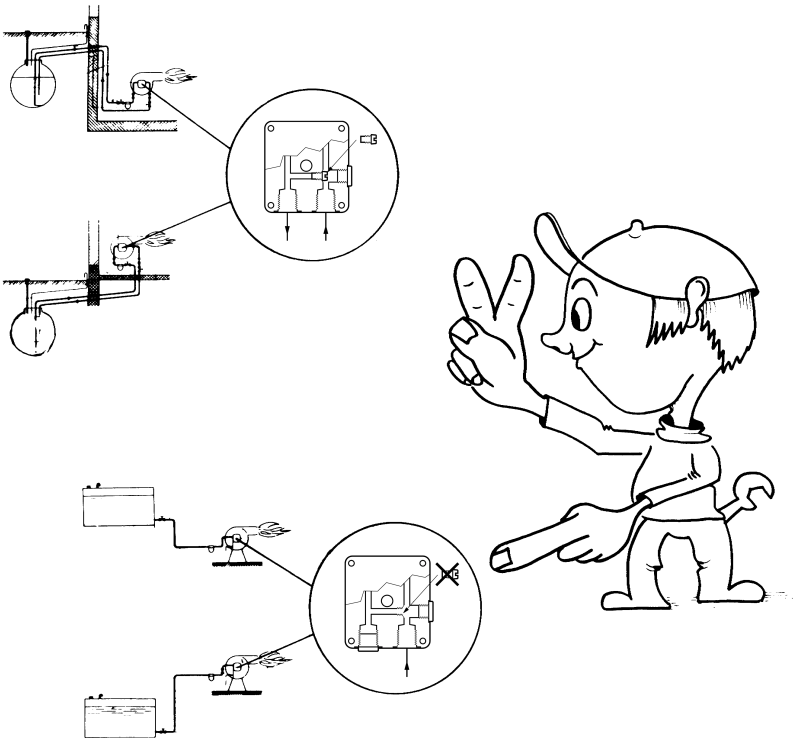


Whatever the application, it is always advisable to read the instructions issued by the pump manufacturer.

Note! Before starting up a new installation, check to see whether the pump is set for one-pipe or two-pipe operation.

How to change over a Danfoss oil pump from one-pipe to two-pipe operation

When a Danfoss oil pump is supplied as a one-pipe pump, a changeover screw for two-pipe operation is included in an accompanying plastic bag.



To change a pump from one-pipe to two-pipe operation it is necessary to fit the screw from the plastic bag into port G. To change a pump from two-pipe to one-pipe operation the screw has to be removed from port G and the return port R has to be blanked off.
Fitting instructions for the changeover screw accompany every Danfoss pump.

Please note! Some BFP 11 types have the 2-pipe screw under the cover.

When and how must the pump be bled

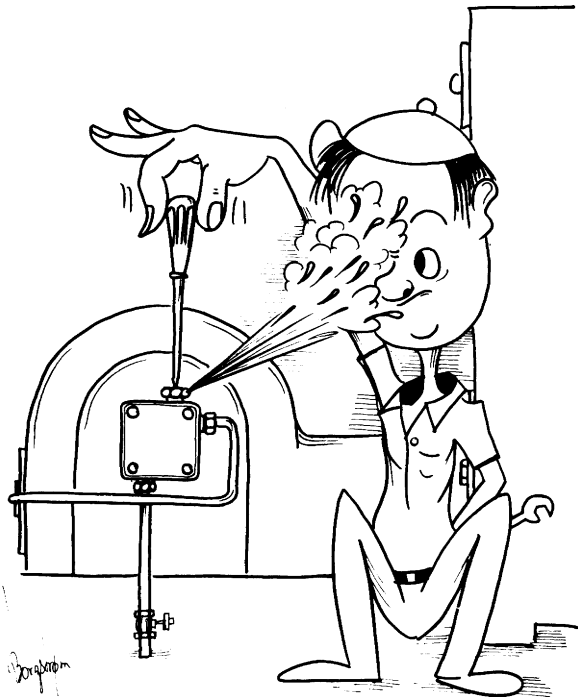
When starting up a new installation or one that has been stripped down there will always be air in the pipes and the oil pump. This air must be removed effectively when the burner is to be started, otherwise it may cause untimely burner stop.

On two-pipe installation a Danfoss oil pump will itself ensure that the system is bled. Each pump has a »passage« to allow air in the suction line to escape to the return line and back to the oil tank.

On one-pipe installation with gravity feed the oil pump must be bled.

Bleeding a Danfoss oil pump is very easy since all types have a bleed screw – a special bleed plug or a bleed port.

During bleeding, oil will flow from the screw and must be collected and prevented from squirting out into the boiler room; it gives off a very unpleasant smell.



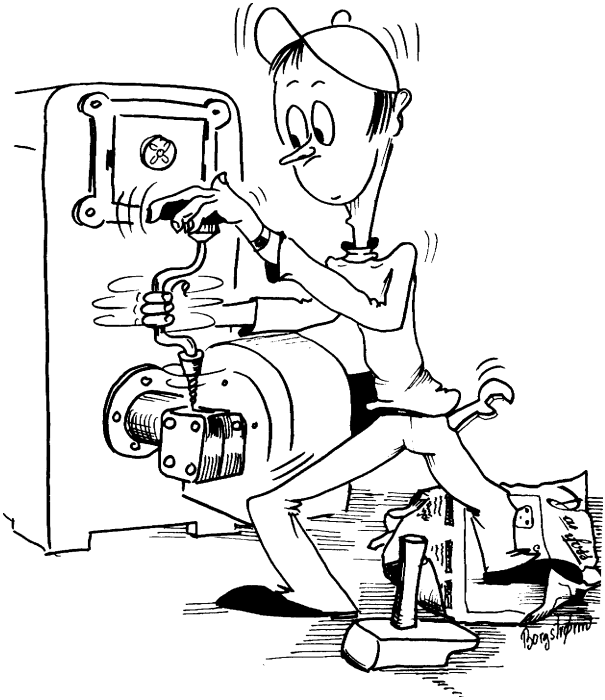
Questions that can arise when working with oil pumps

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What do the pump instructions contain?

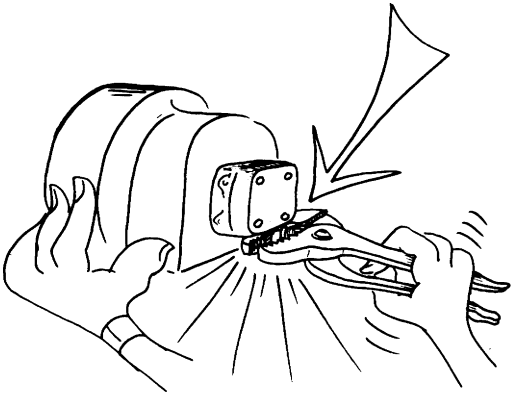
Every Danfoss oil pump is accompanied by instructions which gives information on technical data and installation in words and illustrations.
For new pump installation, the instructions give suction pipe dimensions and show how to change over for one-pipe system or two-pipe system.
Information is also given on bleeding the pump and adjusting pressure settings.
Likewise, if service work has to be done, there is relevant information in the instructions.
A great deal is to be learned about pumps by reading the instructions. The motto, »When all else fails, read the instructions« is highly humorous but hardly wise when working with oil burner installations.



What happens if the wrong tools are used?

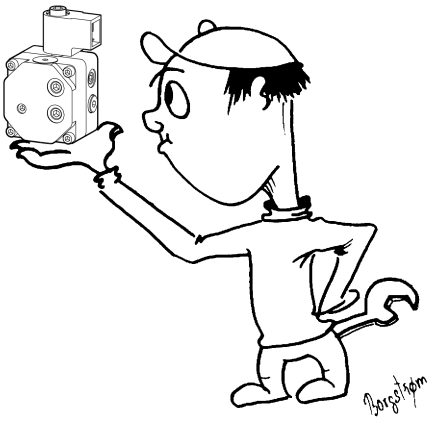
In line with good engineering practice, the best tool for hexagon nipples and unions is THE CORRECT SIZE OF SPANNER.
An adjustable spanner can be used in an emergency, but the tendency is often to use too large a spanner. This ruins both connector and hexagon fittings.

The worst tools to use are pipe wrenches, locking wrenches, Stillsons, etc. These not only damage the hexagon fittings, they can sometimes make it impossible to obtain a seat without the use of excessive force with the consequent risk of damage to the pump housing.



How can the condition of the pump be checked?

When adjustments are made to an oil burner that has been in operation for some years the opportunity can be used to check the oil pump whilst the vacuum and pressure gauges are still connected. The method is as follows:
First, make a note of the vacuum and oil pressure during normal operation.
Next, shut off the suction line by closing the valve fitted in the line (most often a melt-fuse valve) and check how much vacuum the pump will produce.
If when max. vacuum has been reached (–0.5 to 0.7 bar for example) the pump begins to whine, open the valve again. A pump can be damaged if run for too long a period with air which has been separated from the oil under high vacuum.
When starting up a system with an empty suction line, and only normal vacuum is involved, the pump can be allowed to run for 5 min with the amount of oil left in it from factory assembly.
Check the pressure producing capacity of the pump by giving the pressure regulating screw a couple of turns to see if the resulting pressure change occurs smoothly.
If the pressure capacity of the pump is in order, adjust the pressure back to the required setting.
Note: It is impossible to check the condition of a pump without using the correct measuring instruments (vacuum gauge and pressure gauge).



What ought to be checked before a complaint is made about the oil pump?

It is not particularly comfortable when the pump refuses to work on a cold winter's day, and quite often the manufacturers of the pump become the subject of unkind thoughts. However, a few things ought to be checked before a seemingly hopeless pump is returned, because practical experience shows that nearly 50% of all pumps returned are in fact without defect.



For example, check to see:

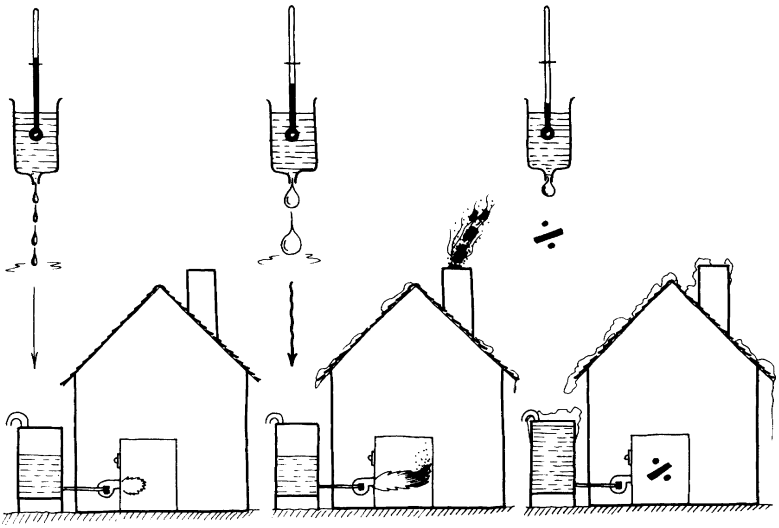
- if there is oil in the tank.
- that the pump shaft rotates. The coupling between pump and motor (perhaps the fan pulley) may need replacing.
- that the motor rotates in the right direction.
- that the pump speed is correct.
- if the shut-off valve on the suction line is closed, (it must be open).
- if the check valve on the suction side is stuck or fitted the wrong way round.
- if the suction and return lines have been swapped over.
- if the suction line has been crushed, (copper pipe installation).
- that the pump is set appropriately for one-pipe or two-pipe operation.
- that the pump capacity corresponds to the capacity of the burner.
- if there are leaks in the suction line, (use a clear plastic hose between line and pump)
- if the pump can suck, (use a vacuum gauge).
- if the pump can produce pressure, (use a pressure gauge).
- that the filter on the suction side is clean and the filter housing does not leak.
- that the various pipes are connected to the correct pump ports.
- if there is water in the oil. Smear water indicating paste on the dip stick. Insert the dip stick in the oil tank. If water is present the paste will change colour. If it does change colour, the tank needs cleaning out!

What significance have the oil characteristics?

Fuel oil is affected by the surrounding temperature. In cold weather it becomes more dense – in other words, its viscosity increases. Such a condition will show itself in combustion performance and may have unfortunate consequences on burner reliability.

Those installations where the oil is stored in an outdoor tank, and where some pipes are exposed, are especially prone to problems. How large the problems become is dependent on the temperature variations the oil is subjected to. With very low temperatures, paraffin separation can occur in the oil and can result in clogged filters.

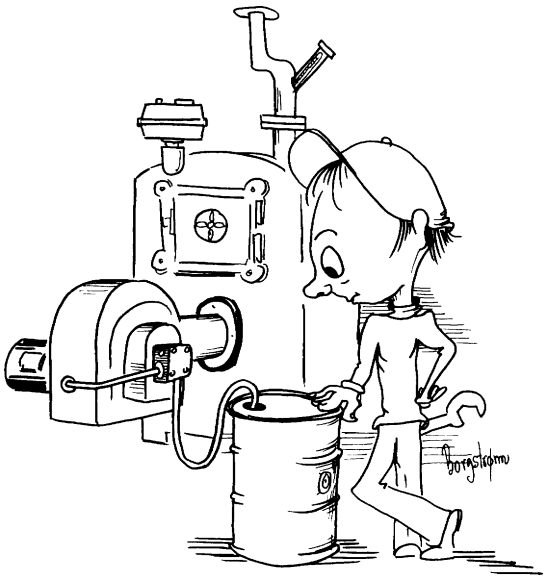
If the oil pump cannot draw oil from an outdoor tank, even though the temperature is around 0 °C, the cause can be condensed water in the tank which has become mixed with the oil. The oil itself does not freeze of course, but the water droplets do.



Will the pump be ruined if it is run on paraffin?

If the oil tank runs dry, the temptation is to use some other fuel to keep the burner going – paraffin for example. The gas-oil normally used in an oil burner is a little thicker than kerosene (it is more viscous) and the question arises, »can a pump withstand running on thin fuel?«.

Purely mechanically, there is nothing to prevent a Danfoss oil pump from running on kerosene instead of normal fuel oil: no damage will ensue. From the point of view of combustion however, in certain circumstances there will be noticeable changes because the use of a thinner fuel will change the nozzle capacity. This means burner readjustment, especially if the thinner fuel is in use for a prolonged period.



Note: In some countries the use of liquid fuel with a flame point lower than 55 °C is not permitted in oil burner installations. Therefore, in these countries, using kerosene must be considered an absolute short-term emergency measure.

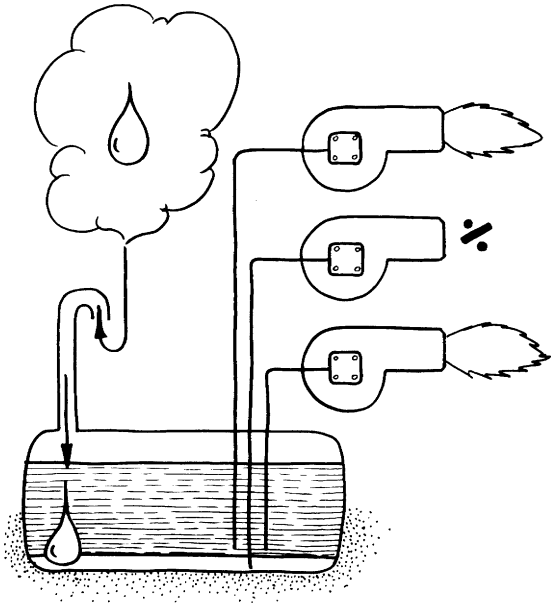
Why is it necessary to watch for water in the oil?

Fuel oil contains such a small amount of water that no operational malfunction will occur because of its presence. But, it should be remembered that when atmospheric air comes into contact with a cold oil tank the air content will condense and after a time collect at the bottom of the tank.

In addition, rainwater often seeps into the tank because of a badly seal filling cap, etc. When the water in the bottom of the tank reaches such a level that the suction line begins to draw water there is a danger of the pump being damaged. It is therefore necessary to keep a check on the amount of water in the tank. A specially developed paste is available for the purpose; it changes colour to indicate the presence of water. The paste has to be smeared on the dip stick which is then inserted into the tank. If the paste changes colour there is water in the tank.

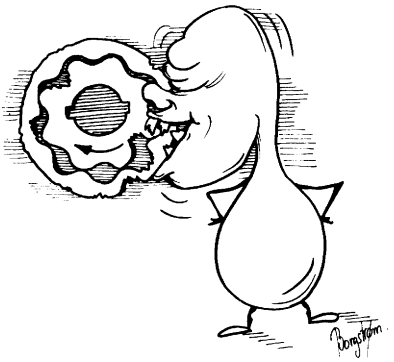
If the colour change takes place to a height of, for example, 3 - 4 cm on the dipstick, indicating the water level in the tank is 3 - 4 cm, then the water must be removed as soon as possible.

REMEMBER to ensure that the filling connector is leakproof.

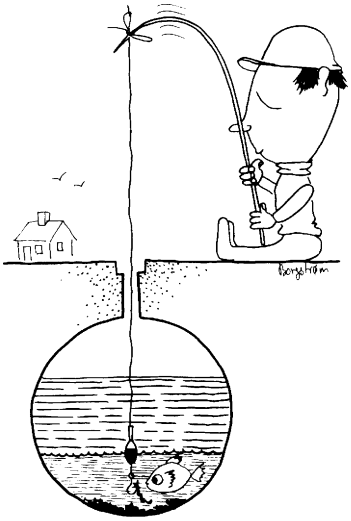


Note: If water is observed in the installation, the whole system must be cleaned out thoroughly. If more than one system is connected to the same tank, remember to check for water in each system. Air can be blown through the oil-carrying pipes and the separately fitted filters.

As far as the oil pump is concerned, a check must be made to see if it can still rotate. If it cannot, water has attacked the rotating and moving parts (which can be ruined by rust after only a few hours immersion in water).



Even if the pump can still be turned, it must be removed and run with the suction and return lines immersed in a vessel containing lubricating oil or pure fuel oil.
After the pump has been run like this for half an hour the water will have been rinsed out and the pump can be reinstalled.



When was the tank last cleaned out?

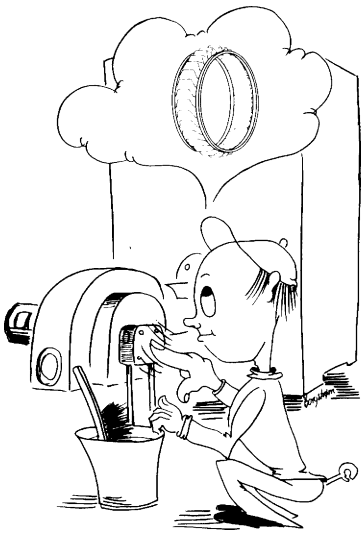
How should the oil filters be looked after?

On a domestic oil burner, in addition to the nozzle filter and the filter built into the oil pump, there should be a separate filter in the suction line immediately before the pump.

On large industrial burners, a filter must be installed in the suction line because large oil pumps and nozzles seldom have built in filters. Danfoss oil nozzles larger than 45 l/h (12,0 USgal/h) are not equipped with a filter, for instance.

As far as cleaning the filters is concerned, it is not good engineering practice to allow them to become so dirty that the burner stops. They should be cleaned at least once a year, more frequently if the amount of oil used warrants it. The gentlest way of cleaning a filter is washing it in kerosene, perhaps using a brush, and then blowing it through with compressed air. A *STEEL BRUSH* must not be used under any circumstances because it will damage the filter. *Woollen cloth* also should be avoided since it can leave threads and fluff in the filter.

During periodic maintenance work the suction line filter is not normally forgotten (perhaps because it is plainly visible), neither is the nozzle filter because it automatically becomes replaced when the nozzle is changed. However, care must be taken not to forget the built-in pump filter.



What happens if the suction and return lines are swapped over?

The result of mistakenly swapping over suction and return lines on a two-pipe system will depend on how the return line is mounted on the tank.

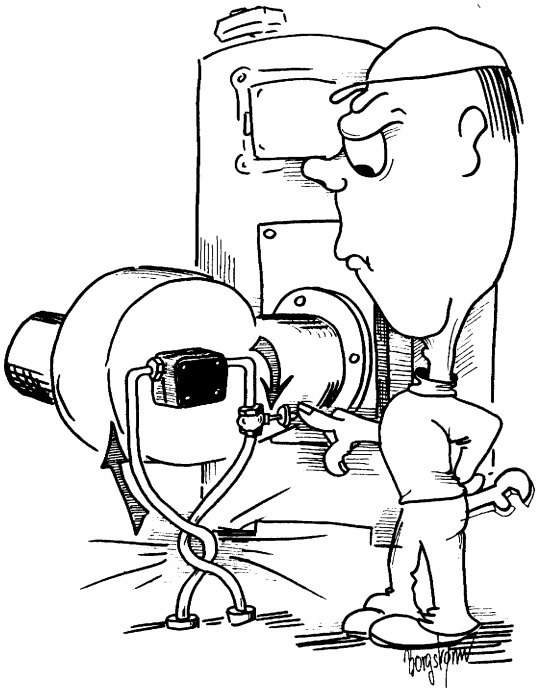
If the return line is led to the top of the tank

In this case, with the end of the pipe above the surface of the oil, the pump will suck air. This will not damage the pump, because the burner control will normally run to a lockout condition.

If the return line is led to the bottom of the tank, one of two things can happen

Shut-off valve open and no check valve in the suction line: The pump will simple draw oil through the immersed end of the suction line and send it back to the tank through the open valve.

Shut-off valve closed, check valve in the suction line: The pump will draw oil through the immersed end of the suction line but will be unable to send the excess oil back to the tank. Pressure in the pump may rise so violently that the shaft seal, and with it the pump, can be damaged.

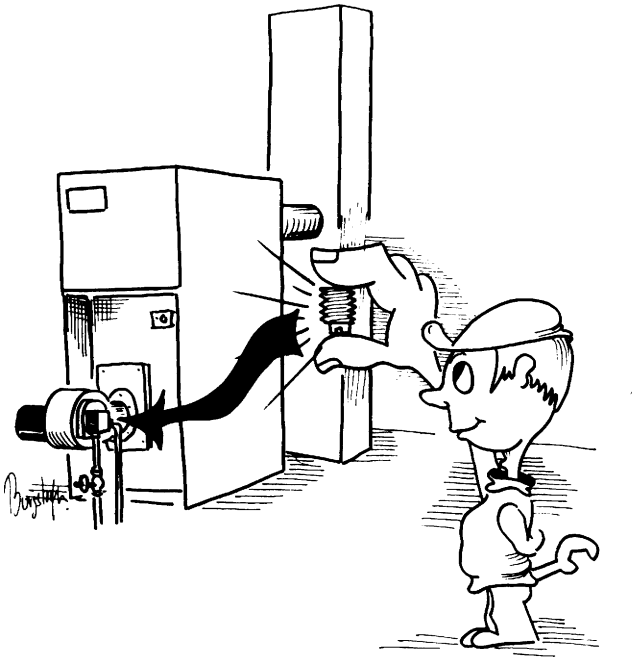


What happens if the two-pipe screw is fitted incorrectly?

Two-pipe system

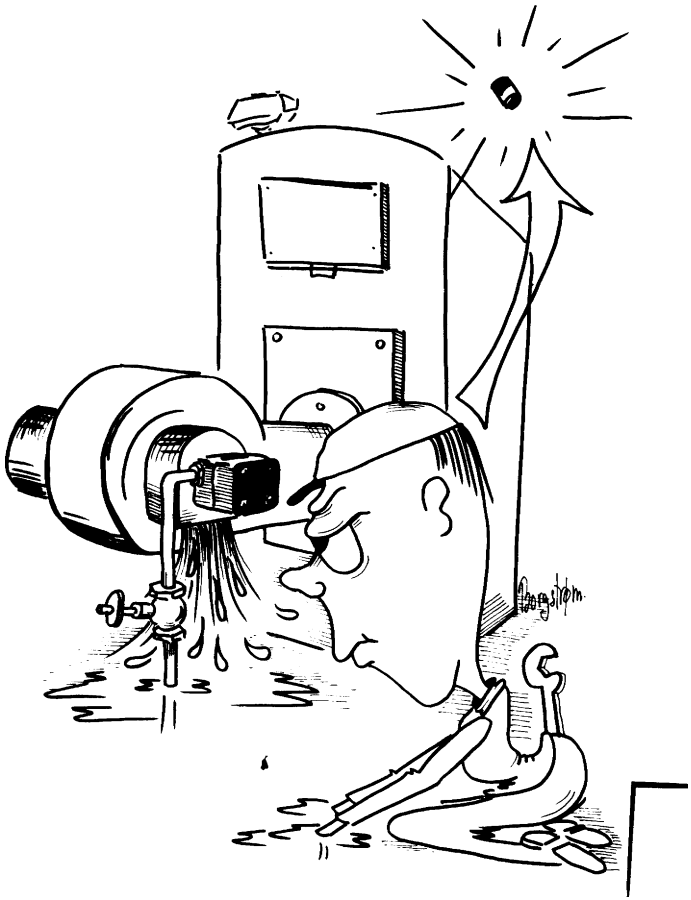
Forgetting this screw in the pump can result in the pump on a two-pipe system not sucking. Instead, the pump may draw air in through the return line so that the burner fails to start.

The pump will not be damaged by running without the screw, but because the suction and delivery sides of the pump are in direct connection it is doubtful if oil will ever reach the burner.



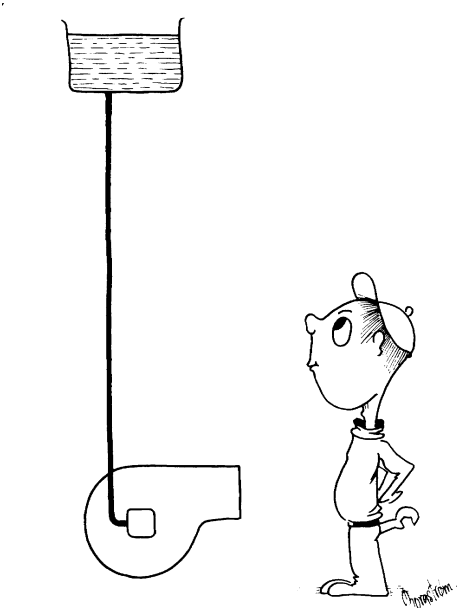
One-pipe system

The results of forgetting to remove the two-pipe screw when the pump is for use on a one-pipe system will be a little more tragic. Pressure in the nozzle line will rise violently and cause »excess dosing«, the pump shaft will eventually blow and cascade oil over the floor, and finally, the resulting reluctance of the motor to turn will damage the motor and perhaps burn it out.



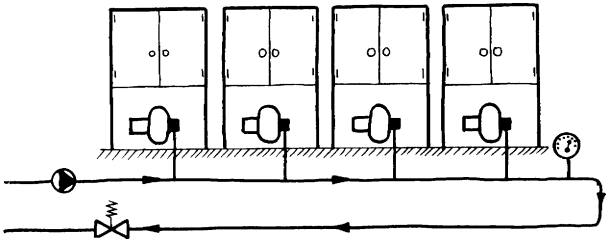
Should the pump suction side be subjected to pressure?

Local conditions may mean that the oil burner has to be positioned such a long way below the oil tank (for example, where a small auxiliary feed tank is used) that the suction side of the pump is subjected to pressure.



The same condition can apply where several oil burners are fed from a ring main. Danfoss oil pumps can operate with pressure on the suction side, but it is recommended that such a pressure is maintained constant so that pump output is constant. Max. pressure on the suction side is 2 bar (corresponding to approx. 25 m oil column).

On oil ring mains, pressure is held constant by the use of a spring-loaded regulating valve placed in the ring main after the oil burner connections. Large installations often employ a pressure-controlled motor valve to maintain constant oil pressure so that the suction side of the pumps are not subjected to a varying pressure when one or more of the burners starts or stops.



What are the risks in do-it-yourself pump dismantling?

Many have found out that dismantling an oil pump is not very difficult – it is putting it back together again that causes the trouble.
An oil pump consists of many parts, some of them small and easily lost. Therefore, the recommendation is to always limit dismantling as much as possible.



Finally, *regard technical literature with drawings of the pump down to its smallest detail as a help rather than a challenge.*

Why is it impossible to buy replacement gearwheel sets?

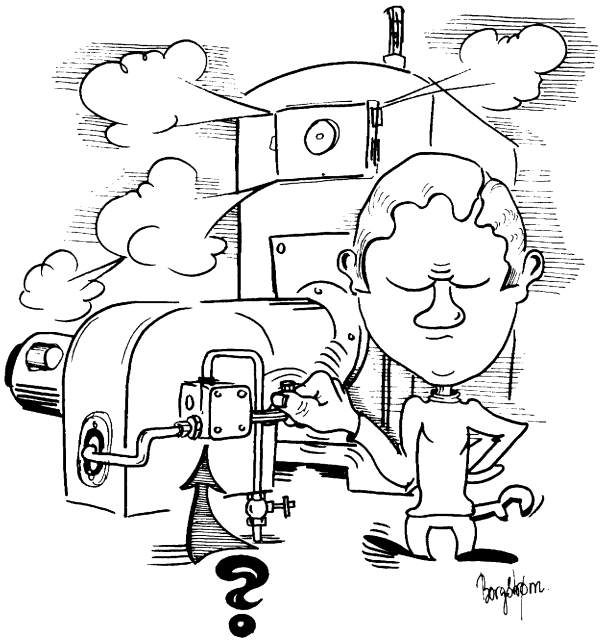
The gearwheel set is the heart of the pump.
One reason why Danfoss oil pumps have such uncommonly good suction and pressure characteristics lies in the precision and narrow tolerances used in the manufacture of the parts. Coupled with this, the special surface treatment the parts receive ensures that the pumps have a long working life.



If the heart of the pump, the gearwheel set, plus the gearwheel cover plate, are subjected to overload all these parts must be replaced to restore the pump to working order again. Because of the narrow manufacturing tolerances, assembly and adjustment with accurate measuring equipment and a final check run, it therefore is not possible to supply separate gearwheels. Otherwise the final result would be an oil pump that didn't work satisfactorily.

What can happen if pump pressure is regulated without the use of a pressure gauge?

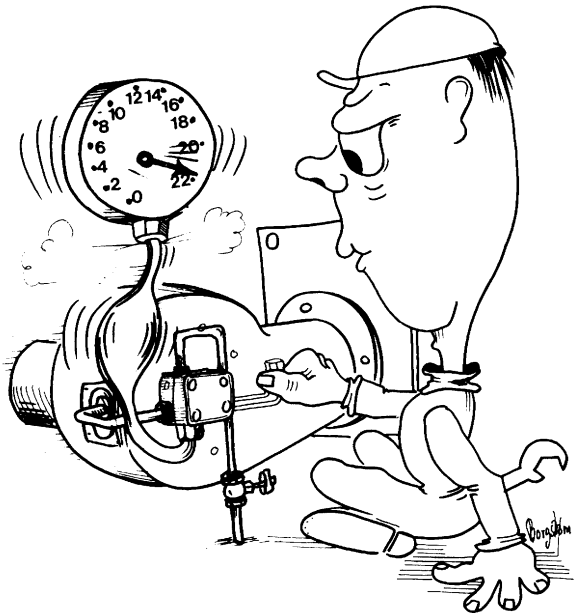
An oil burner is expected to give good combustion results. Correctly adjusted pressure for the nozzle is an essential factor for good efficiency.
It is therefore important to use a pressure gauge when adjusting the oil pressure. The oil pressure is a basic requirement to calculate the through put of a nozzle.



How much oil a nozzle gives at a pressure of 7 bar is stamped on the nozzle. By using the oil nozzle capacity curve, or a Danfoss nozzle calculator, it is possible to work out the oil supply at a given oil pressure.
If the oil pressure is increased without knowing the increase in oil volume, there is a risk that the boiler will be too small to handle the amount of heat produced. This will result in too high a flue gas temperature and, consequently, less efficiehcy. Knowing the oil pressure, and using the pump torque curve, the power requirement of the pump can also be worked out. This safeguards against the unintentional overloading of the burner motor.

How high an oil pressure can a pump withstand before damage occurs?

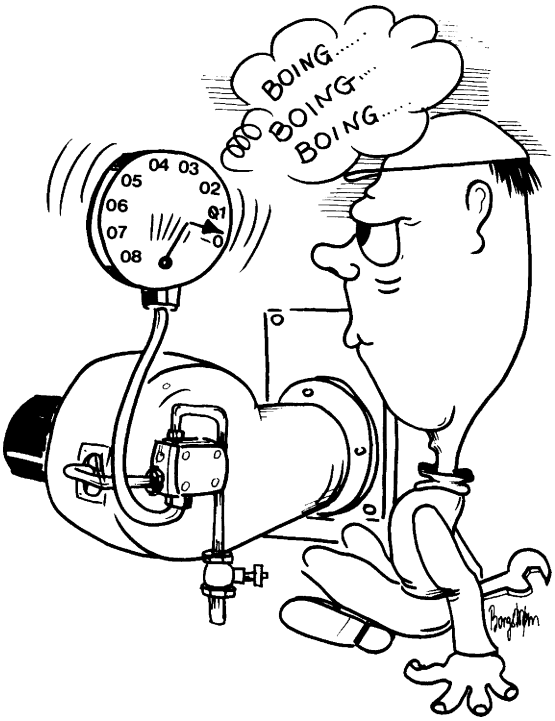
Investigations have shown that if the pressure setting screw is screwed right in, i.e. so that the spring becomes solid, pressure can easily rise to more than 50 bar. Experiments with a closed pressure regulating valve should therefore not be encouraged, for if the pump is fitted with a standard pressure gauge capable of withstanding up to about 25 bar it would most likely be blown up in the process.



Another result of operating with a closed regulating valve would certainly be that when the pressure climbed towards 50 bar any standard motor driving the pump would stall. That is because the pressure rise would drastically increase torque, up to two or three times the normal torque. Furthermore, the spring in the valve could be permanently deformed so making it unusable.
It is best then to abide by the »rules« and use the pressure regulating valve only as prescribed – to adjust pump pressure – always with a pressure gauge connected to the pump and always in accordance with the pump instructions.

What happens if a vacuum gauge is fitted on the delivery side of the pump?

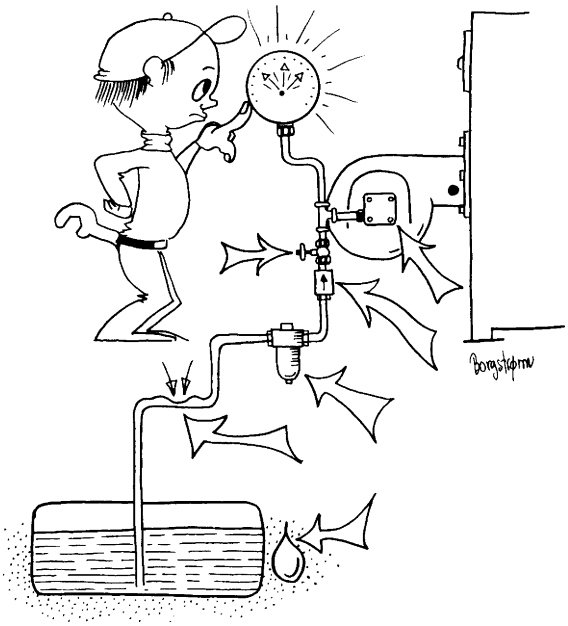
Even though the pump instructions clearly indicate which is the pressure or delivery side of the pump and which is its suction side, cases do occur where the vacuum gauge is connected to the delivery side. It is not hard to predict the result – THAT PRESSURE GAUGE WILL NEVER WORK AGAIN!



How can vacuum increase if the pump has not been tampered with?

The operational reliability of an oil burning installation is entirely dependent on whether the pump is able to draw oil from the tank. The higher the vacuum becomes, the more unreliable becomes the oil suction. Therefore, because a pump will not deliver oil even though it has good suction there may be a straightforward reason and it should not be sent for repair until a series of points have been checked, i.e.

- is the shut-off valve open?
- is the pump filter clean?
- is the separate filter clean?
- does the check valve stick?
- has the check valve been fitted the wrong way round?
- has the suction line been crushed?
- is the oil too cold?
- is there an obstruction in the suction line?

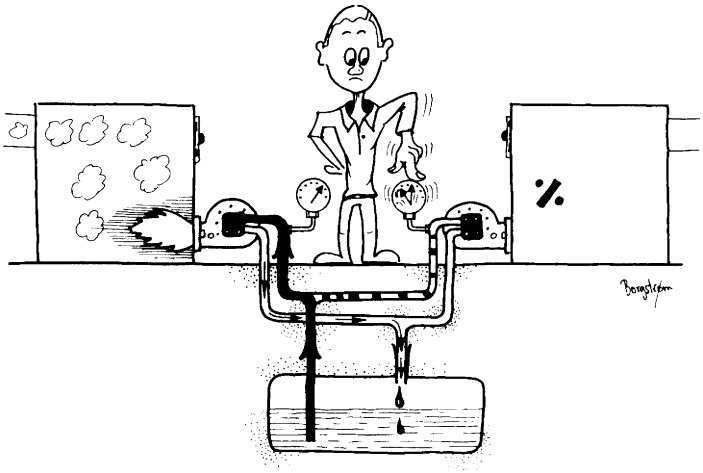


When resistance in a suction line rises, the vacuum rises. When vacuum reaches somewhere around –0.4 to –0.5 bar, air will be separated from the oil and the pump will begin to whine. A further rise in vacuum may, sooner or later, stop the oil supply.

As a rule, a high rate of air separation will show itself by violent fluctuations on the pressure gauge, perhaps on the vacuum gauge too.

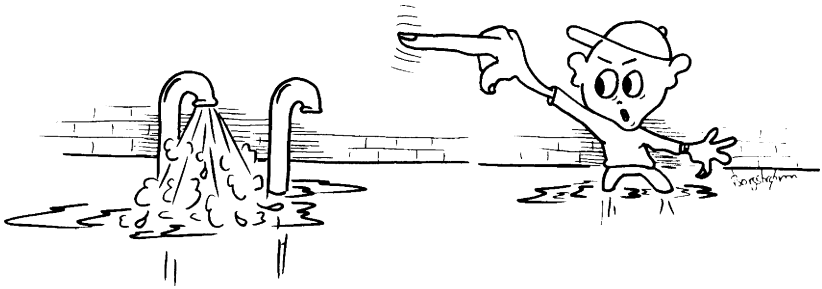
Can two pumps be allowed to draw on the same suction line?

It might perhaps be tempting to try to see if one suction line will serve two oil burners. Sadly, experience shows that the results are nearly always poor, even though the two pumps involved are brand new and the distance between tank and burner is the same in both cases. What invariably happens is that one pump »steals« oil from the other so that operation becomes quite unreliable.
Therefore each oil burner ought to have its own suction line, although there is nothing against a common return line – as long as its diameter is sufficiently large.
If the requirement is that several burners be supplied from one line, a pressure-regulated main line must be installed in which oil is circulated from the tank pass the oil burners and back to the tank with the aid of a separate circulation pump.

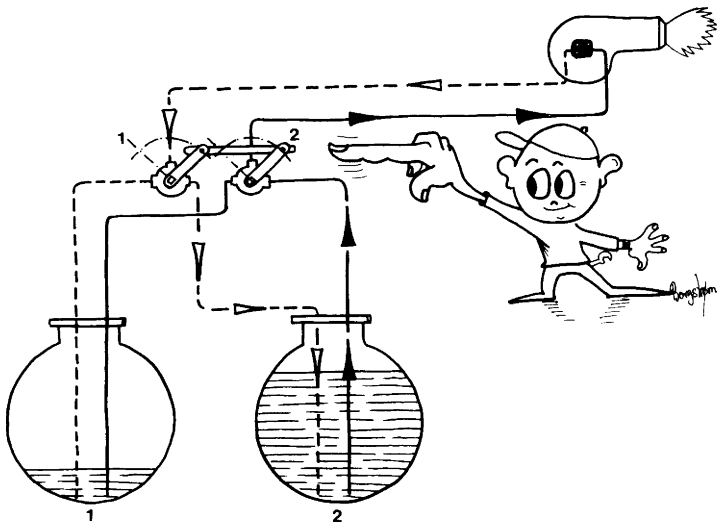


What about drawing oil from several oil tanks for one burner?

On an oil burning installation with more than one oil tank, serious mishaps can occur if when changing over from one tank to another, the suction line is changed over but changing over the return line is forgotten.

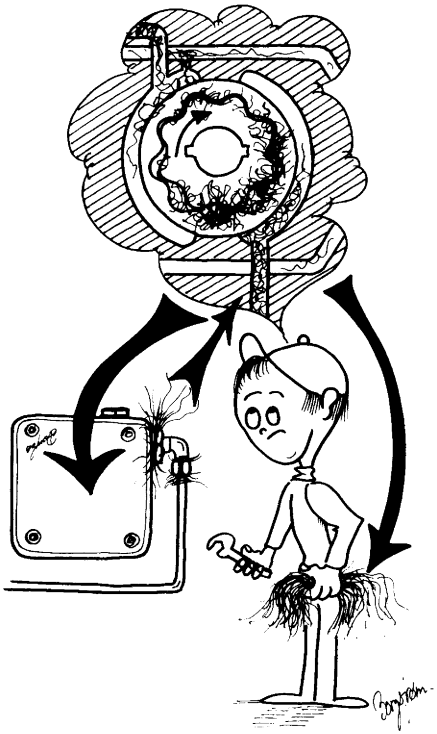


Linking the changeover valves as shown ensures that when oil is drawn from tank 2, excess oil is not returned to tank 1.



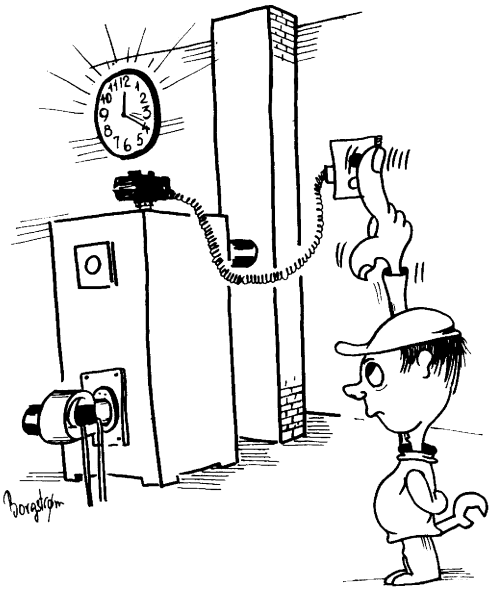
Nipples musk not leak – what is the method of sealing them?

Preconditions for obtaining a seal when making connections on suction and delivery lines are that the screw threads on nipples and unions match and that the sealing surfaces are not scratched or deformed.
If it is thought that packing materials are necessary to obtain an oil-tight joint, tape or joint paste can be used (providing, of course, it is resistant to oil).
PACKING YARN must not be used because loose threads will inevitably be sucked into the pump.



Why is it often necessary to start a newly-installed oil burner four or five times before the pump becomes primed?

For the technician who is not used to the starting-up routine, the fact that it may be necessary to carry out four or five start attempts before the pump »catches« oil can be both irritating and surprising.
The reason why several start attempts are necessary is that the longer the suction line is and the larger its diameter, the more air it will contain. If the suction line is not filled with oil prior to starting, it is left to the pump to draw the air out before catching hold of the oil. This can take a little time.



Even if everything seems to be exactly as it should, there are a number of useful checks that can be made if the frustration becomes too great.

- Is there oil in the tank? Or perhaps the tank lies a long way from the burner.
- Is the suction line connected to the correct pump port? Check with the pump instructions. Is it a one-pipe or two-pipe system?
- Have the suction and return lines been swapped over?
- Does the pump rotate? Perhaps the coupling between motor and pump is defective or incorrectly assembled.
- If the pump rotates, is the speed right?
- Does the pump suck at all? Fit a vacuum gauge to the pump, close the valve on the suction line, start the pump and let it run for a short time. The vacuum should come up to about –0.5 to –0.7 bar.

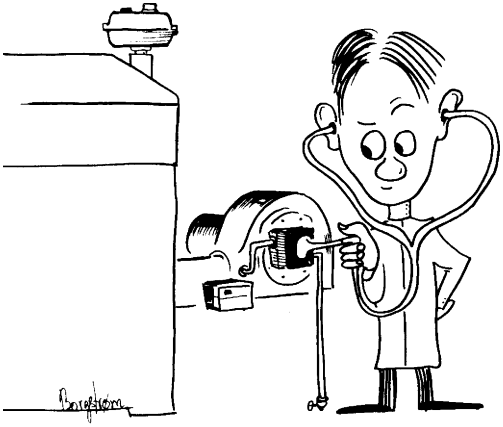
Pump problems

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Pump will not rotate

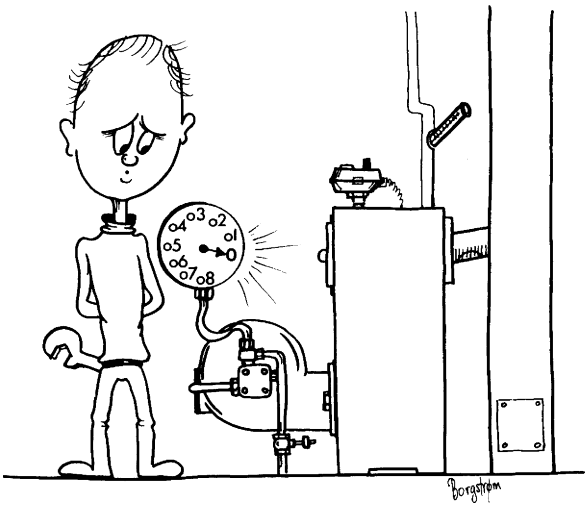
The familiar sound an oil burner makes when it is in operation is reassuring, to the extent that no sound for a prolonged period indicates that something is wrong. In order to find the reason, the following points may be checked.
After having made all the normal checks – oil starvation, closed or blocked valves, air in the system, dirty filter and nozzle, low pressure and vacuum, etc. – without success, the feeling might be that the pump should be sent back for repair. Before doing so however, there is one more thing to check:
Is the pump in fact being driven by the motor coupling/fan pulley?
The coupling or pulley could be defective or could have worked itself loose. Such a malfunction does not necessarily indicate its presence by undue noise.



Pump will not suck

As has been said previously, the operation of a plant is entirely dependent on the ability of the pump to draw oil from the tank. If the occasion arises where the pump will or cannot suck, the first thing to do is to fit a vacuum gauge to the pump, (see pump instructions). If the vacuum gauge registers 0 bar when the plant is started there are one or two points to check:

- Does the pump shaft rotate, or is it only the motor that turns? The coupling between pump and motor may be defective or assembled incorrectly.
- If the pump shaft does rotate, is the direction of rotation and speed correct?

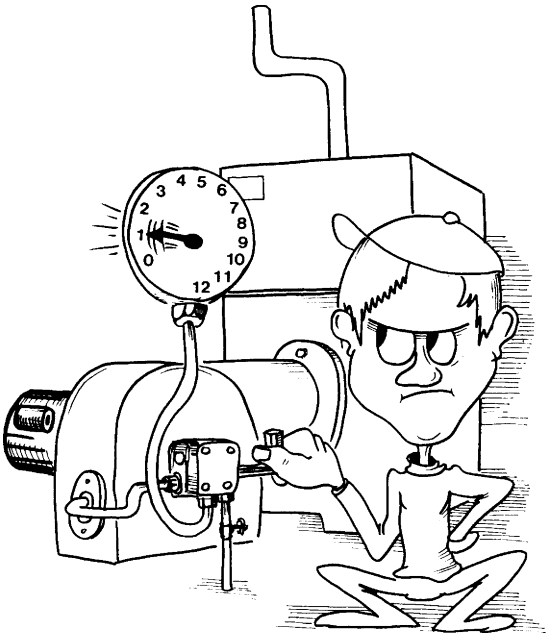


It is as well to make sure that the vacuum gauge used in the above test is in working order and that it is connected to the appropriate pump port.
If no vacuum gauge is available, a preliminary test can be made on the pump by seeing if it will suck oil from a container placed by the side of the pump. Another check should be made if the pump has been dismantled for filter cleaning: make sure that the pump cover has been replaced and tightened correctly so that it forms a seal with the pump housing.

Pump pressure cannot be regulated

If the pump pressure cannot be regulated, or if the pressure gauge deviates, the reason can be:

- Coupling between motor and oil pump defective, (no pressure reading on the gauge).
- Pressure gauge defective.
- Pressure gauge incorrectly fitted.
- Pressure regulating valve defective or clogged. If this is the case, the pressure gauge will show either constant high pressure or constant low pressure.
- Air in the oil. This will produce oscillating pressure gauge readings.
- Wrong type of pump, i.e. capacity too small in relation to nozzle capacity. Here, the pressure gauge will show too low a pressure.
- Worn gearwheel set. The pump will be unable to build up sufficient pressure.
- Oil too thin. When oil viscosity falls, nozzle capacity also falls.
- Is pump suitable for kerosene application.



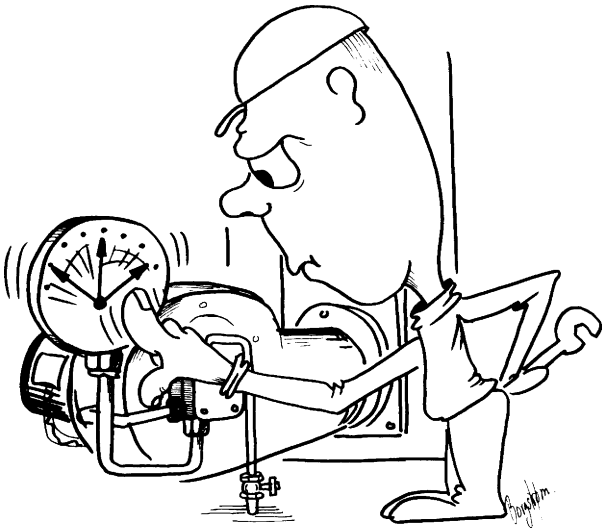
Pump pressure oscillates

Pump pressure variations can produce poor combustion since the oil volume as well as the atomizing pattern will change.

Possible reasons are:

- Air in the oil as a consequence of leaks or too high a vacuum in the suction line, (half-closed shut-off valve, blocked filter, blocked check valve in the suction line, crushed suction line, etc.).
- Dirt in the pump pressure regulating valve.
- Defective spring in the pump pressure valve.
- Pump/motor coupling slip, i.e. speed variations.

Note: On an installation with a ring main where several burners are supplied from one pump, pressure variations can occur if the pressure regulating valve (which maintains constant pressure in the ring main) is defective. (See section »Should the pump suction side be subjected to pressure?«).



Pump nozzle cut-off ineffective

An oil burner starts and stops about ten or twelve thousand times a year. If the nozzle cut-off is ineffective the boiler will become very sooty internally. Oil pumps having a cut-off function are designed to cut off oil to the nozzle when revolutions per minute are still high, so that combustion air from the fan is sufficient to ensure a soot-free stop.
Cut-off or closing is effected by a solenoid valve installed in the nozzle line or incorporated in the pump.

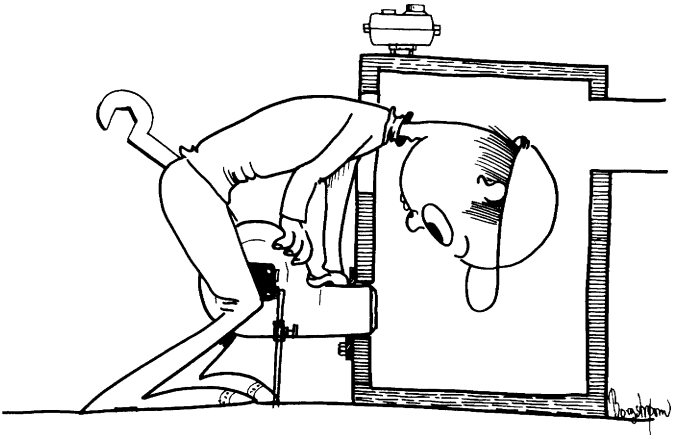
The reasons for poor cut-off can be as follows:

- Air build-up in the nozzle line, or perhaps in the nozzle or between nozzle and nozzle holder.
- Dirt in the hydraulic cut-off valve, or a defective spring/diaphragm.
- Dirt in the nozzle line solenoid valve.



No oil from the pump

Burner mounted on boiler, piping carefully installed and connected, water on, wiring complete, oil tank full, and.....nothing!



After five or six attempts to start the plant, irritation must give way to a logical fault-finding procedure to find out why not a drop of oil is reaching the nozzle:

- Open the valve on the section line.
- Bleed the pump in accordance with the instructions.
- Fit pressure gauge and vacuum gauge to the pump to check pressure and vacuum.
- Check the coupling between motor and pump.
- Start the burner and check the pump direction of rotation.
- Check the pump installation (one-pipe or two-pipe system). If there is still no sign of oil at the nozzle, check:
- to see that the suction and return lines have not been swapped over.
- that the solenoid valve operates, or if appropriate, why it does not operate.
- that the oil nozzle is not blocked.
- that the check valve in the suction line is not the wrong way round.
- that the suction line does not leak and that it has not been crushed flat.

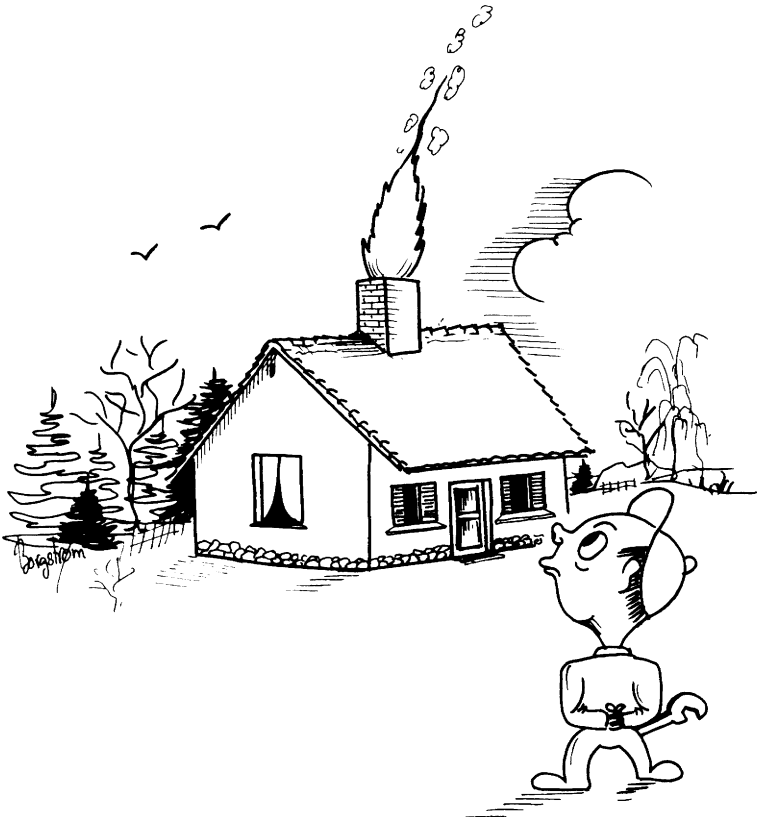
Note: Oil may have been supplied to the nozzle at some time during this procedure and may lie unburnt in the combustion chamber. Subsequent ignition will cause this oil to evaporate and may lead to a near-explosive start.

REMEMBER to vent the boiler if a number of unsuccessful starts have been attempted without oil ignition. This is even more important when the boiler is hot because of the higher rate of oil evaporation than with a cold boiler.

More oil than normal from the pump

Perhaps the oil supply is greater than is considered normal, i.e. the flame appears to be larger than expected; check the following:

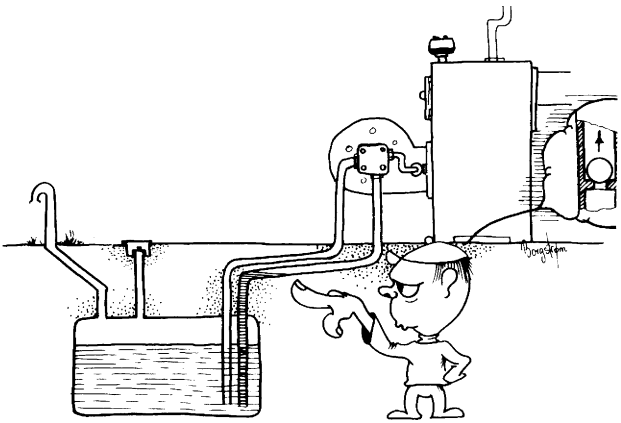
- Oil pressure. It may be too high as a consequence of attempts to make adjustments without using a pressure gauge.
- Pump regulating valve. If this is blocked by dirt too high a pressure may be created which, in turn, may lead to too much oil at the nozzle.
- The oil nozzle. Perhaps the wrong size has been fitted, e.g. a 5.0 USgal/h nozzle instead of a 0.5 USgal/h nozzle.



0il returns to tank during shut down

If oil is able to flow back to the tank during burner shut down, the burner control box will frequently have time to stop the burner sequence before the pump has drawn sufficient oil for starting, i.e. lock out will occur.
Air in the oil system provides the reason why oil flows back to the tank during shut down. All the oil in the suction line flowing back to the tank during this period indicates a leak large enough to make it difficult for the pump to draw any oil at all.
In practice, if the leak is not very substantial and the shut down period not very long, the pump will be able to draw enough oil before the control box stops the burner. Should the shut down period become longer because of reduced heat demands however, the pump may not be able to recover the quantity of oil that flows back to the tank, i.e. in the time available on restart before lock out takes place.
To prevent such unfortunate operational disturbances a check valve in the suction line, the return line, or both, is recommended. If a check valve is fitted in the suction line, it is worth remembering that it will increase the resistance in the line and thus increase the amount of vacuum the pump must exert. Therefore, in cases where the oil tank is a long way from and a long way below the burner, it may be preferable to fit the check valve in the return line to avoid air separation caused by vacuum in the suction line becoming too high. Under all circumstances steps must be taken to ensure that all screwed connections have been properly made to prevent air from entering the system. Additionally, it is important that both suction and return lines are immersed to an equal depth in the lank to ensure that the oil column in each pipe is the same.

Note: To obtain the best level of reliability when fitting check valves, use only good quality units. Inferior check valves will often create more problems than they solve.



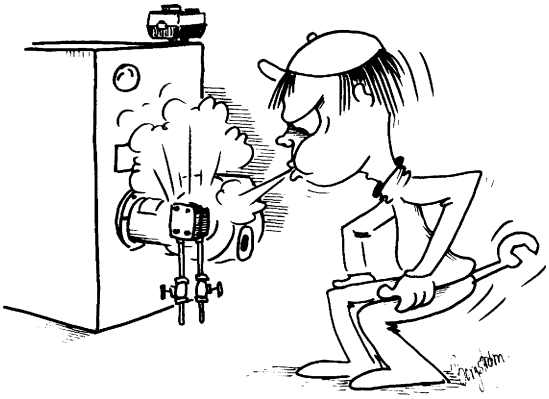
Pump overheats

lf the pump becomes hotter than normal it may be a sign of serious trouble and should be examined immediately.

The fault may again lie in the coupling. If it is too long it may exert an end force on the pump shaft. This force will be transferred into the pump and create to high a load between pump and pump housing. The consequense will be heat generation. The same defect may occur if several makes of coupling are available at the time of repair and replacements are made with parts of a different length.

Too large a pump on a one-pipe system, e.g. a 100 l/h (26 USgal/h) pump on a plant with a 2 l/h (5 USgal/h) nozzle, will also generate heat because the same oil will be in circulation all the time - only 2 l/h (5 USgal/h) new oil being introduced into the system to cool the pump. (The reverse happens on a two-pipe system, nearly all of the pump capacity being returned to the tank so that new oil is constantly being circulated to cool the pump).

An internally dirty pump, one which is well on the way to a seize-up, will produce friction and certainly create an abnormal amount of heat.

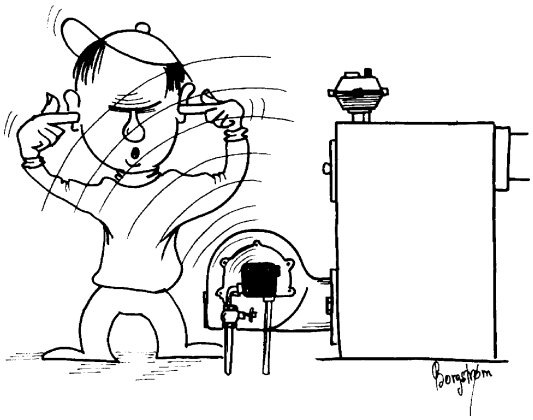


Pump whines or makes a crackling noise

When shortly after starting, a gradually increasing whine comes from the pump the most probable reason is that a valve in the suction line is still closed. This valve will produce such a high vacuum in the suction line that air will separate from the oil and the pump will begin to shriek in protest. Depending to some extent on temperature and viscosity, the pump will begin to whine at about –0.5 bar (vacuum) in the suction line. This can damage the pump, therefore the valve should be opened immediately.

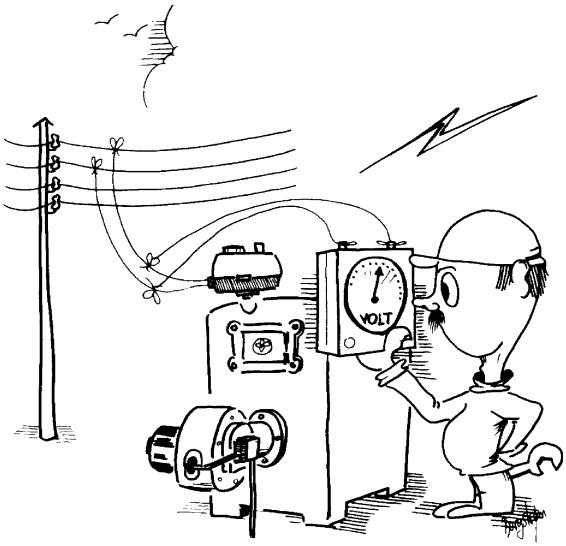
A similar condition, with high vacuum and whine, can occur if the oil filter in the suction line is clogged; if the check valve in the suction line has stuck in its closed position; or if the suction line has been crushed flat. Other factors producing pump whine are: a wrongly dimensioned suction line (the internal diameter is too small for the length), also an excesive, suction height, and perhaps dirt in the suction line.

Air bubbles from a leaking suction line can easily produce a crackling noise in the pump. Such a defect can be confirmed by fitting a pressure gauge to the pump – air bubbles will cause it to jump or flutter. In other words: low vacuum and a jittery pressure gauge indicate a leak in the suction line.



Voltage drop

Voltage supply varies from region to region, but although »Voltage drop« has been included under »Pump problems« the pump on an oil burner is not a particularly voltage-sensitive unit.
Only for pumps with built-in solenoid valves is there a limit to the permissible voltage variation. That is to say, Danfoss controls and electrical components for oil burners will operate with from 10% over voltage to 15% under voltage.
As far as the electric motor is concerned, there are also certain limits and since, normally, pumps are driven by electric motor it can be said that oil pump operation is affected indirectly by voltage variations.



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