GENERAL INDUSTRY SEGMENT

ENGINEERING MANUAL
Industrial Boilers

BE > THINK > INNOVATE >

GRUNDFOS

General.

The production of steam and hot water is one of the world's largest industries. Grundfos is pleased to be the preferred supplier of pumps for boiler systems for these industries.

Grundfos pumps are reliable, efficient and cover a vide performance range. As an experienced consultant in the implementation of boiler systems, we engage in a process of close partnership and dialogue to find the best solution for your system.

Grundfos is a global enterprise with a worldwide service network. When you need export or need on-the-spot advice in a particular part of the world, we have the technical expertise close by.

Boiler types.

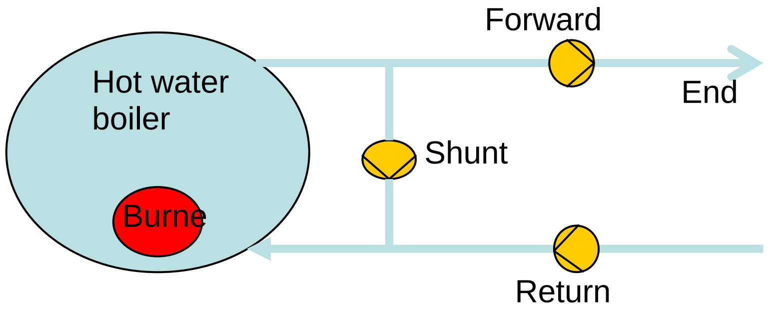
There are three main types of boilers:

- Hot water boiler
- Thermal oil boiler
- Steam boiler

The demands and the sizing of the pumps used for these boiler types are very different.

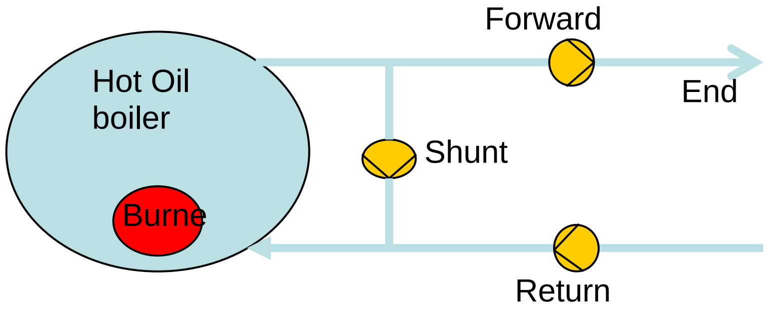
1. Hot water boiler

Hot water boilers are normally used in room and process heating. This kind of system is suitable for discharge temperatures up to 140°C. The advantage of hot water over steam is that energy loss is lower than with steam boilers.



2. Thermal oil boiler

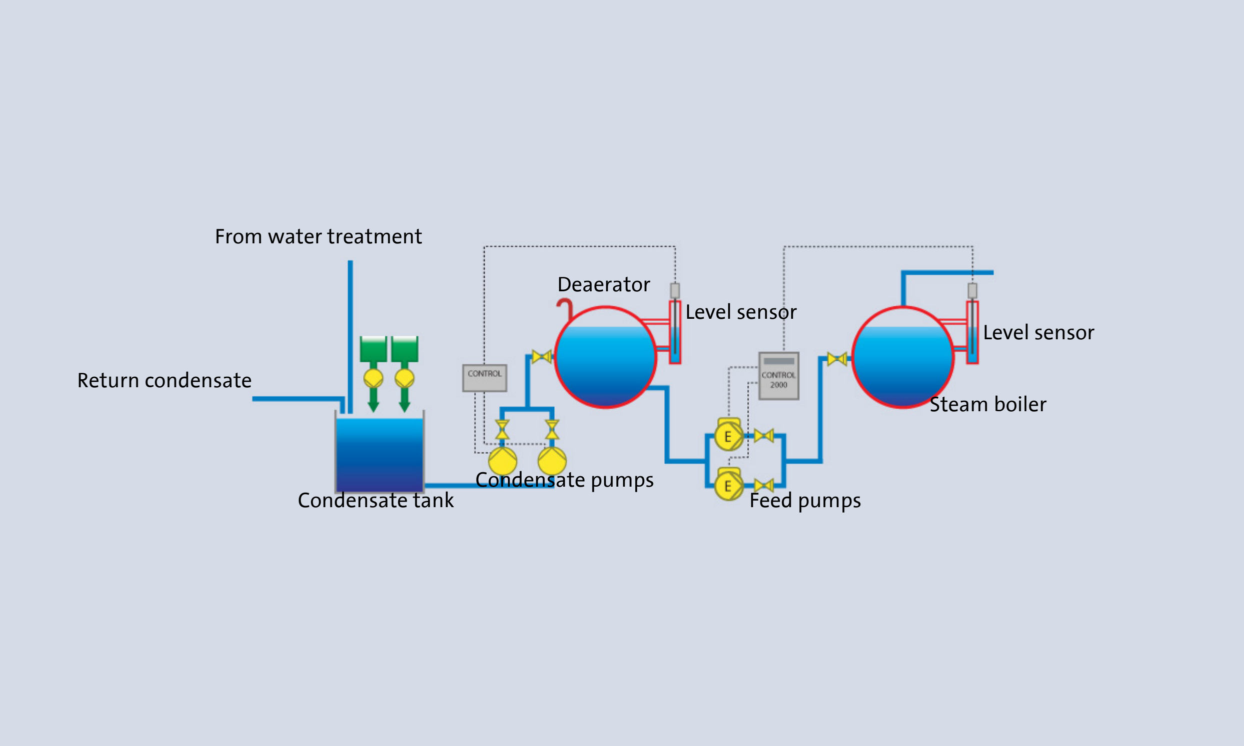
In hot oil boilers is used oil in stead of steam or water. The advantage with oil is that the system does not have to be pressurised above 100°C as with water and steam, but functions in atmospheric pressures of up to 300°C. In contrast, water requires a pressure of 85 bar to avoid evaporating. The construction of thermal oil boilers and systems is almost identical to that of hot water boilers.



3. Steam boiler

Steam is normally used in industrial process heating due to its high energy content. Steam is also used for cleaning applications and turbine-generation. The advantage of steam over hot water is its high energy content and ability to release energy during condensation. This also allows for very small heat exchangers.

Boiler system



Boiler components.

Deaerators/Condenser.

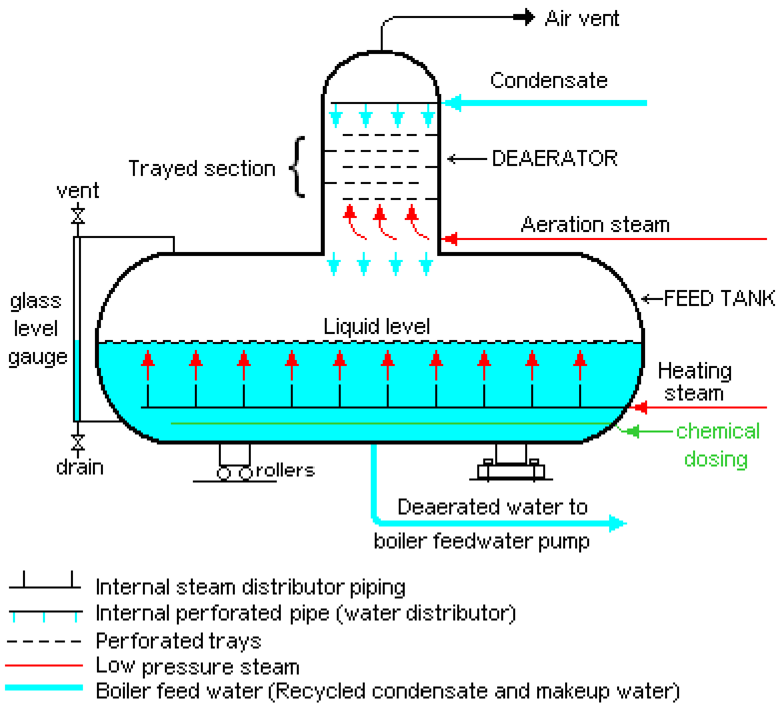
Deaerator and condenser tanks are only used in steam boiler systems and not in hot water and hot oil boil because here the fluid always is on liquid form. The construction of these two types of tanks is almost identical, but as their names suggest, they are used for different purposes.

Two primary principles are used with this form of tank design: thermal and vacuum. Which one depends on which type of boiler being used. Each principle also has different pump construction requirements.

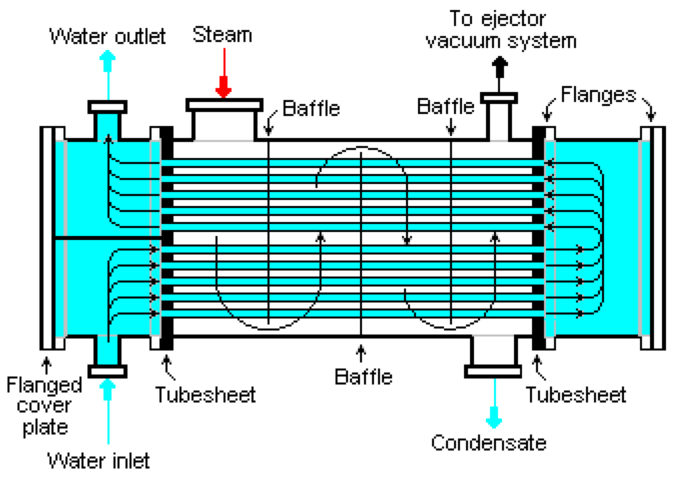
Thermo principle
A tank using the thermal principle is connected to the atmosphere. This design is normally used in smaller plants. Here, steam is used to maintain tank water temperature at around 105°C, which removes air from the water.

Vacuum principle
Here, an ejector pump is used to create a vacuum in the tank. This causes the tank water to start boiling because of the low temperature, which in turn removes air from the water. This principle is normally used for steam turbine applications.

Deaerator.
A deaerator is used to reduce oxygen (O^2) and carbonic acid (CO^2) levels in boiler feedwater to protect a boiler against corrosion. It is possible to reduce oxygen and carbonic acid levels to about < 0.02 mg/l of O_2 and 0 mg/l of CO_2, depending on deaerator construction.



Condenser.
A condenser ensures that all steam is condensed before being pumped back into the deaerator and on into the boiler. New treated water is normally fed into the condenser.

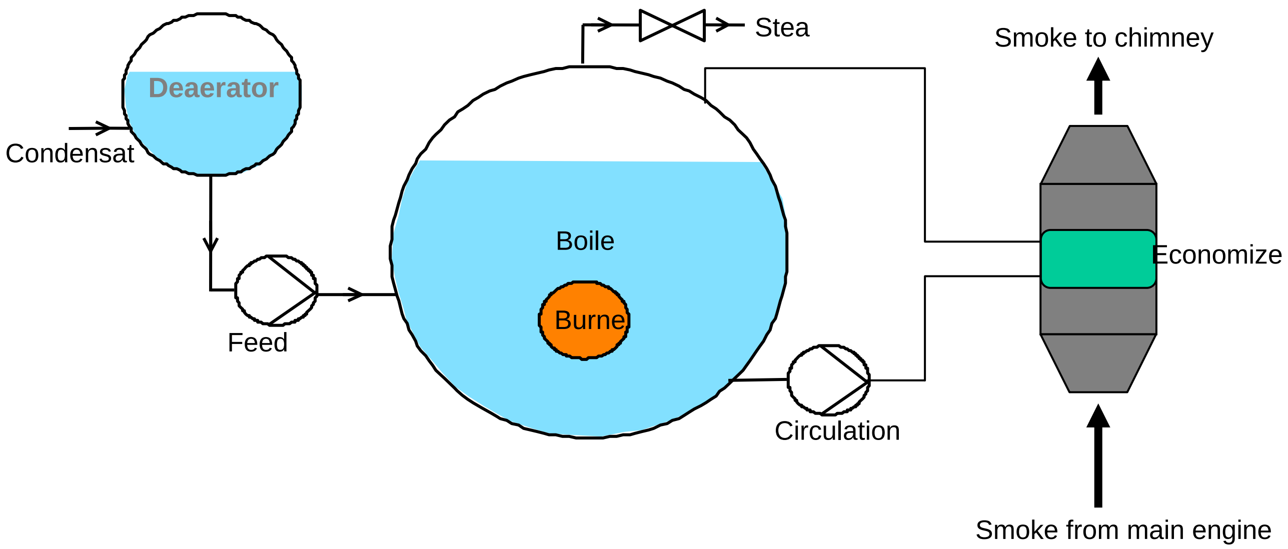


Economizer

Historically, economisers have only been used in large-scale power plants. However, the demand for more efficient boilers within industry and marine means that economisers are now far more commonplace.
An economiser is a heat exchanger that is placed in the exhaust from a boiler or in the exhaust funnel of the main engine of a ship.
Pump requirements differ greatly, depending on where the economiser is installed.

Economizer in the marine.

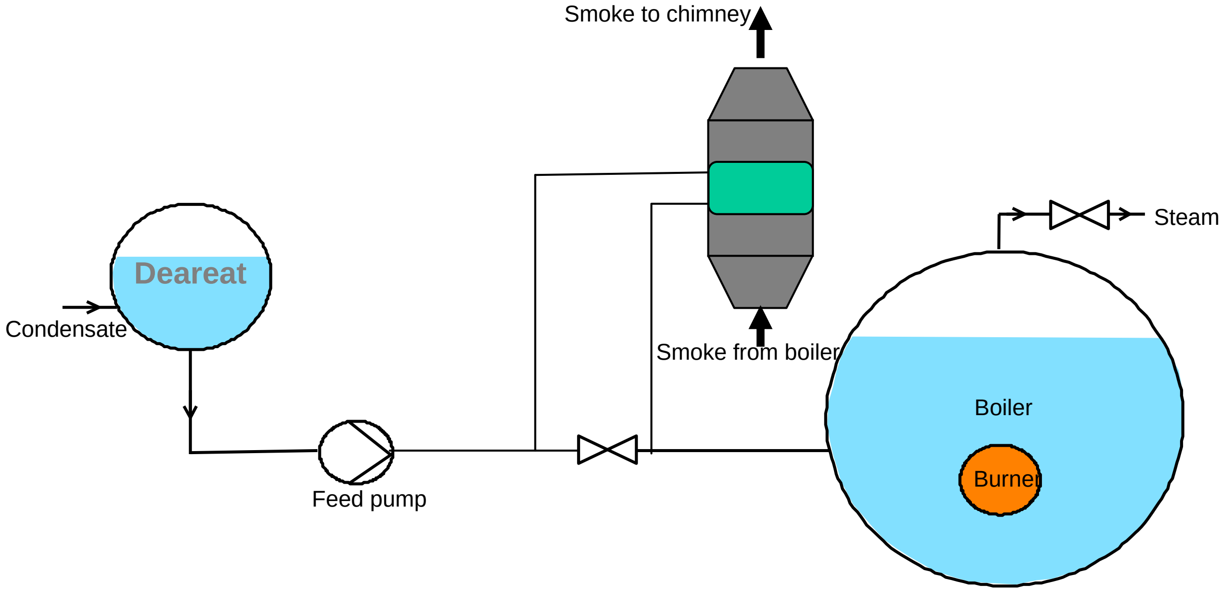
Referring to the diagram below, the circulation pump has to be sized to the pressure and temperature in the boiler, which can easily be 20 bar and 170°C. Because of this, economisers featuring air-cooled top and bearing flange may be required. The pump does not normally need to be capable of delivering a high differential pressure, as it only has to overcome the pressure loss in the plate heat exchanger (economiser).



Economizers in landbased boilers.

An economiser used with a boiler located on land uses the boiler's waste gases. The water circulated over the economiser is normally supplied by the main feed pump, but can also be fitted with its own circulation pump. The chimney will also include a bypass to allow waste gases to pass around the heat exchanger.

The construction differs from marine design as the waste gases released from the main engine of a ship is significantly greater. Energy produced by marine applications often allow for the generation of overheated steam fed directly from economiser and out in the piping.



Boiler pumps.

A range of pumps for different boiler applications exist. This section describes typical positioning of the different pumps and how they are controlled.
The most common boiler applications are boiler feed, condensate pumping, economiser circulation and shunt pumps.

Sub system pumps such as dosing and water treatment pumps also exist.

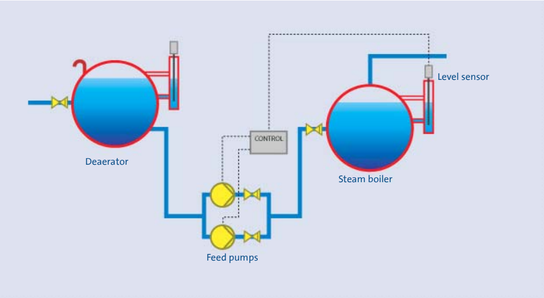
Boiler feed.

When we talk boiler feed there is normally 4 ways to do it.

- On/off control
- Via feed valve
- Via feed valve and variable speed
- Variable speed

They will all be described underneath here.

1. On/off control

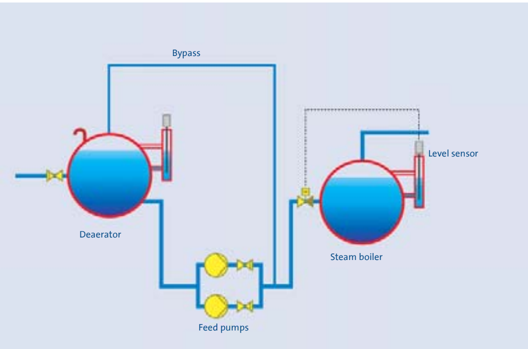


Function
In on/off control the feed pump is switched on/off via a level sensor or a differential pressure sensor. When the water level falls to the “Pump on” level, the pump starts pumping a large quantity of relatively cold water into the boiler. This will reduce the quantity of steam and cause the steam pressure to fall.

This is the reason why on/off control causes variations in steam production. It may also cause over-boiling in the boiler, which may cause water to enter into the system.

Benefits
> Inexpensive
> Simple to install
> No bypass

2. Via feed valve.



Function
In this type of system the water level in the boiler is controlled by a feed valve, which is controlled by a level sensor or a differential pressure transmitter positioned on the boiler.

The feed valve controls the water intake, which is adjusted according to steam consumption. This, however, requires that the feed pump is set to continuous operation.

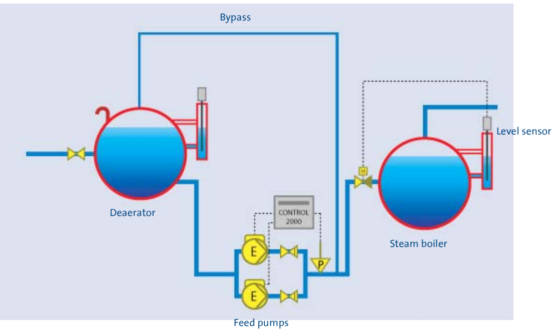
This system operates smoothly and is ideal for all types of steam boilers, both small and large, and will minimise the risk of over-boiling.

Benefits
> Boiler feeding adjusted according to steam consumption, as described.

Drawbacks
> The pump must be set to continuous operation (energy consumption)
> Bypass
> Feed valve is expensive
> Pressure loss across feed valve

Important
Remember to size bypass according to the CR data as to min. flow. It may be an idea to stop the pump at closed valve. This requires, however, a signal from the valve.

3. Via feed valve (variable speed)



Function
In this system the water level in the boiler is controlled by a feed valve, which is controlled by a level sensor or a differential pressure transmitter positioned on the boiler. The feed valve controls the water intake, which is adjusted according to steam consumption. This, however, requires that the feed pump is set to continuous operation. This system operates smoothly and is ideal for all types of steam boilers, both small and large, and will minimise the risk of over-boiling.

Benefits
> Boiler feeding adjusted according to steam consumption.
> Energy savings on pump operation.
> Constant differential pressure across feed valve

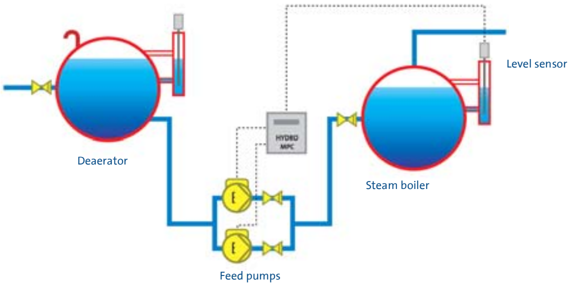
Drawbacks
> Bypass
> Feed valve is expensive
> Pressure loss across feed valve

Important
Requirements vary from one country to another as to the sizing of boiler feed pumps.

Remember to size bypass according to the CR/CV data as to min. flow.
It may be an idea to stop the pump at closed valve. This requires, however, a signal from the valve.
Find out whether variable speed control of both pumps is required, as this increases expenses, but does not provide the same flexibility as to alternating pump operation.
Due to poor inlet pressure the CR(N) Low NPSH may be a fine solution.

Accessories required
Possibly Control 2000, pressure transmitter.

4. Without feed valve



Function
In this system the water level in the boiler is controlled directly by the variable speed pumps without using a feed valve. The pumps are controlled by a level sensor or a differential pressure transmitter positioned on the boiler. This way the water intake is controlled according to steam consumption. This system operates smoothly and is ideal for all types of steam boilers, both small and large, and will minimise the risk of over-boiling.

Benefits
> As described, boiler feeding adjusted according to steam consumption
> Energy savings on pump operation
> No pressure loss across feed valve
> Money earned equal to the price of an expensive feed valve

Drawback
> Requires precise and qualified start-up.

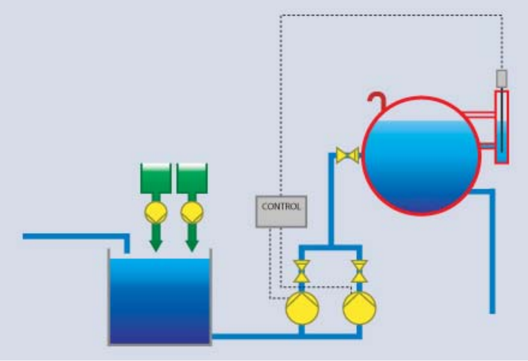
Important
A non-return valve must be installed on the suction pipe of the boiler.

A minimum frequency must be defined ensuring that the pump can always overcome the pressure in the boiler. It must be ensured that the pump stops when steam consumption is zero.

Accessories required
Possibly Hydro MPC.

Condensat pump

1. Condensate pumping on/off



Function
The pumps must move the feed water from the condensate tank to the deaerator. This system is typically on/off-controlled via a level sensor positioned in the deaerator.

Benefits
Inexpensive and simple to install

Important
Requirements vary from one country to another as to the sizing of condensate pumps (two pumps must always back up each other 100 %, requirements as to over-sizing, etc).

As the distance to the deaerator is typically only between 2-5 m, the pump must have the smallest head possible.

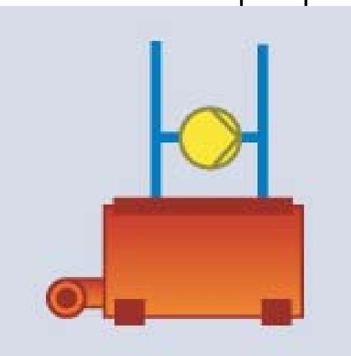
The pump is typically located right next to the condensate tank. The water temperature can be up to 95°C, and, therefore, cavitation may cause problems in this type of system. Consequently, a customised CR Low NPSH is a fine choice.

Accessories required
Dosing pumps and water treatment system.

Shunt pump.

The demands to a shunt pump are normally high flow and very low head. Because of that the shunt pump is normally maid with a 4 pol or 6 pol motor to get head down. Shunt pumps is normally single stage pumps.

1. On/off shunt pump



Function

The shunt pump must ensure that the return temperature to the boiler is not getting too low. If the differential temperature is high it will stress the boiler. The pump must be sized according to the lowest return temperature, meaning that it is over-sized most of the time.

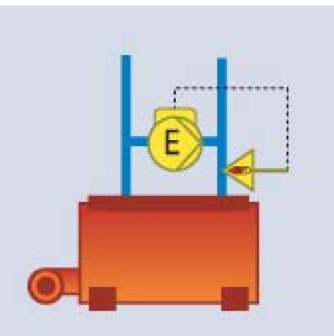
Benefits

> Inexpensive and simple to install
> Safe operation (few components)

Important

Information about the right return-pipe temperature to be obtained from the boiler manufacturer.

2. Variable shunt pump



Function

The pump must ensure that the return temperature to the boiler is not getting too low. If the differential temperature is high it will stress the boiler. A variable speed pump may be the right choice for this type of pump application. The pump must be installed with a temperature sensor registering the return temperature to the boiler, thereby ensuring a constant temperature.

Benefits

> Always constant return temperature
> Energy savings

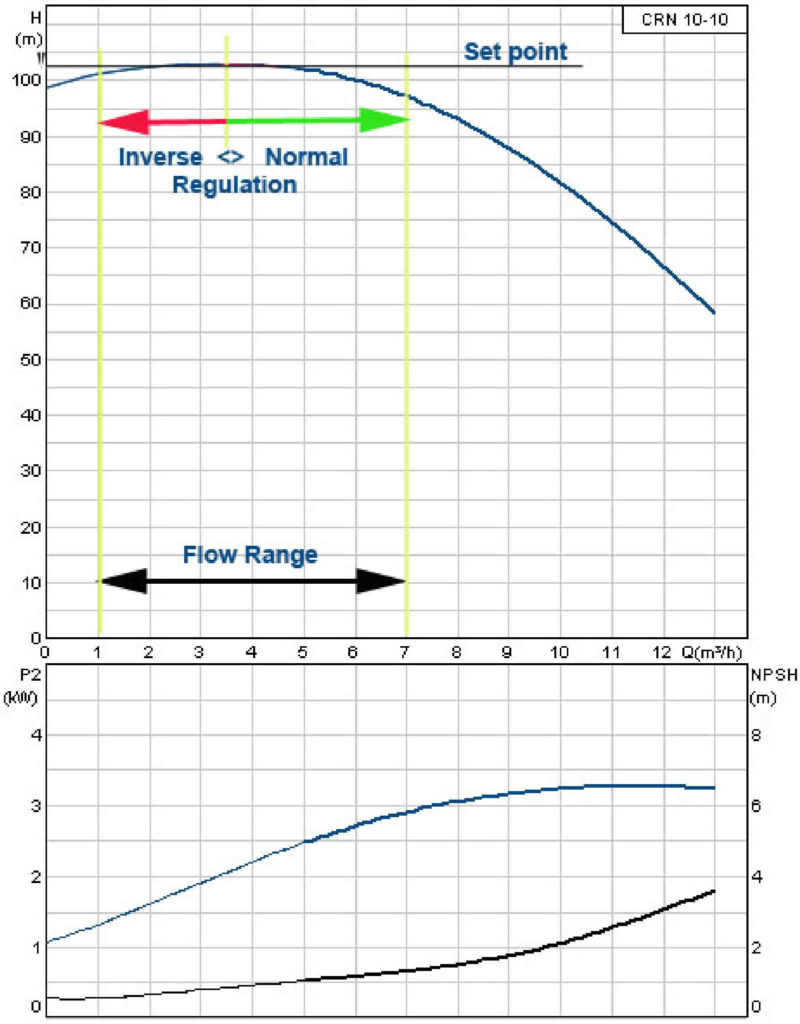
Important
Information about the right return temperature to be obtained from the boiler manufacturer.

Accessories required
Temperature sensor, R100.

What Grundfos offers.

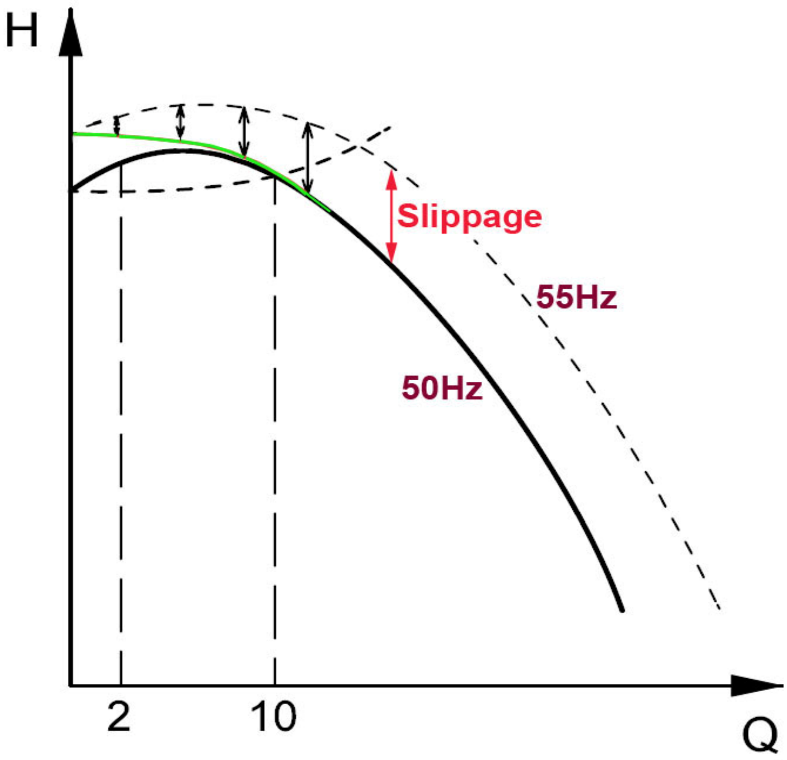
1. E pump solutions.

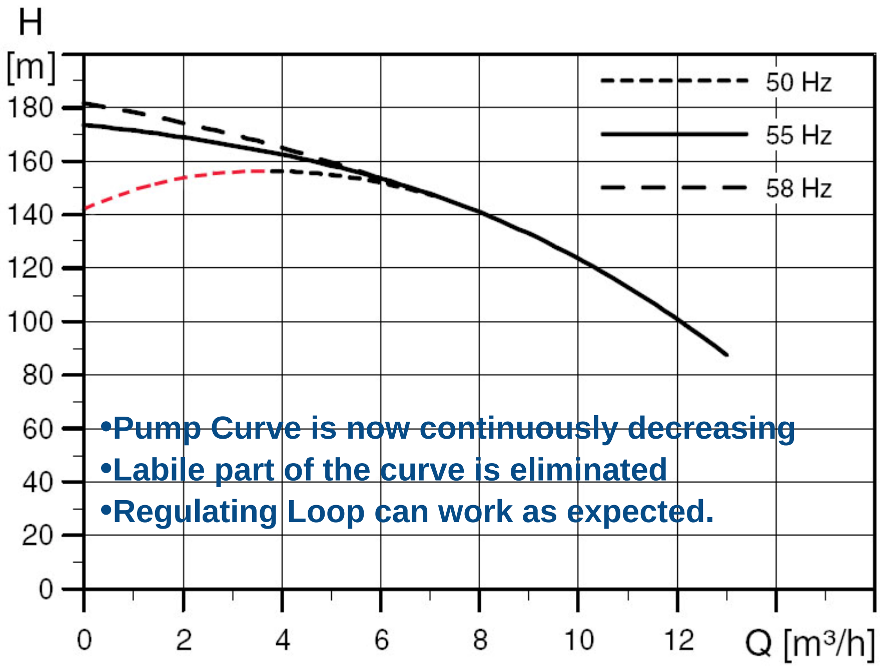
With Grundfos E-solution it is possible to optimise the feed pumps with the software. The reason you want to do that can be because the pump curve is labile. See the curve below to see how the curve looks and what problems it can give.



As you can see on the curve it is possible to have 2 different flows on the same set point. Put another way, normal regulation of the pump is required on one part of the curve, i.e. greater flow and more speed, while on the other, inverse regulation is needed, i.e. less flow and more speed. A normal regulator is not capable of controlling both and will become very unstable, which can lead to poor steam quality.

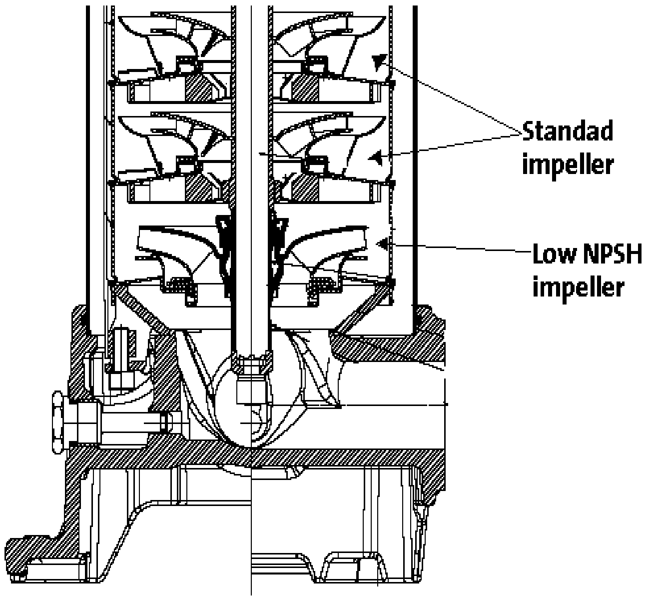
Grundfos e-solutions can be upgraded to address this type of problem, by increasing the frequency to 55 Hz and increasing the motor slip. The motor automatically adjusts when it falls under the labile point of the curve. See the chart below.

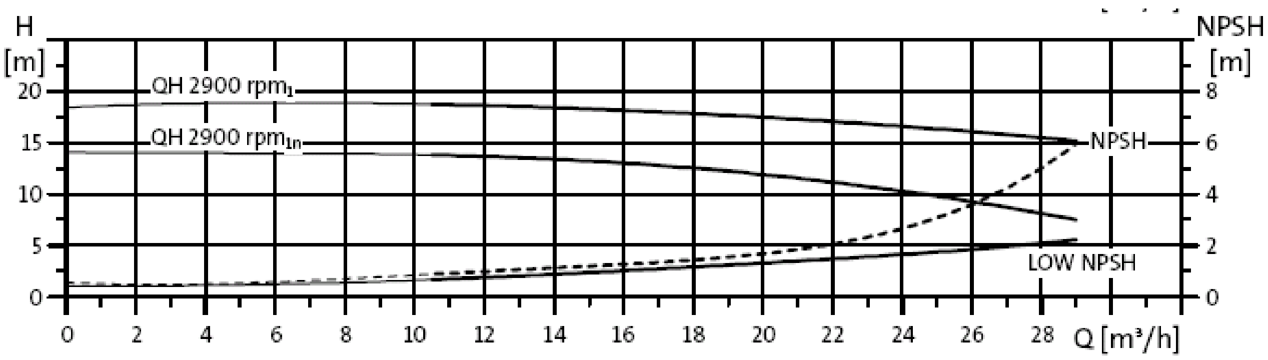




The labile curve is not a problem in all boiler plants. Normally it is or can bee a problem if the feed pumps is placed close to the boiler, with a little friction loss as a result. Because of this you normally never see the problem in the marine ore other places where the pumps and boiler are placed far away from each other.

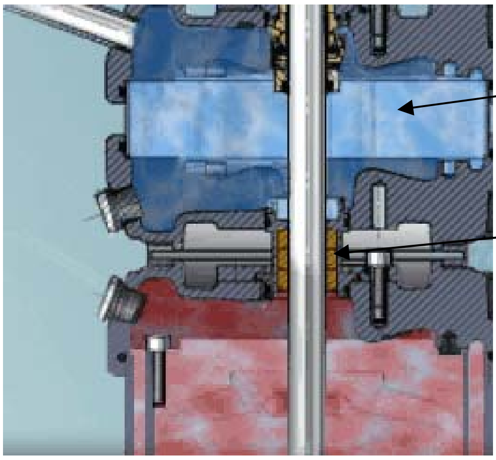
2. NPSH
To improve the NPSH curves on the CR pump range you can make the pump with an oversized inlet chamber. See the picture below, you can also see the result of a low NPSH impeller and what affect it has on the NPSH value.





3. Air cooled top

The air cooled top solution is used when you have water temperatures above 120 °C and up till 180°C. For oil it is up to 240°C.



The air-cooled top separates the seal chamber from the pump by an air cooled chamber, generating an insulating effect similar to that of a thermos.
Via a narrow passage between the pump and the air-cooled top, a small quantity of the pumped liquid insure that the seal chamber always is filled with liquid.

4. Double shaft seal / Mag-Drive

The double shaft seal or Mag-Drive is used where ingress of air through the shaft seal may occur. This phenomenon can occur when a set of duty standby pumps pump water from a vacuum tank, which can lead to air ingress into the pump when in standby. As the diagram below illustrates, this can be addressed by transferring some of the water from the pressurised side of the non-return valves back into the chamber between the double shaft seals.

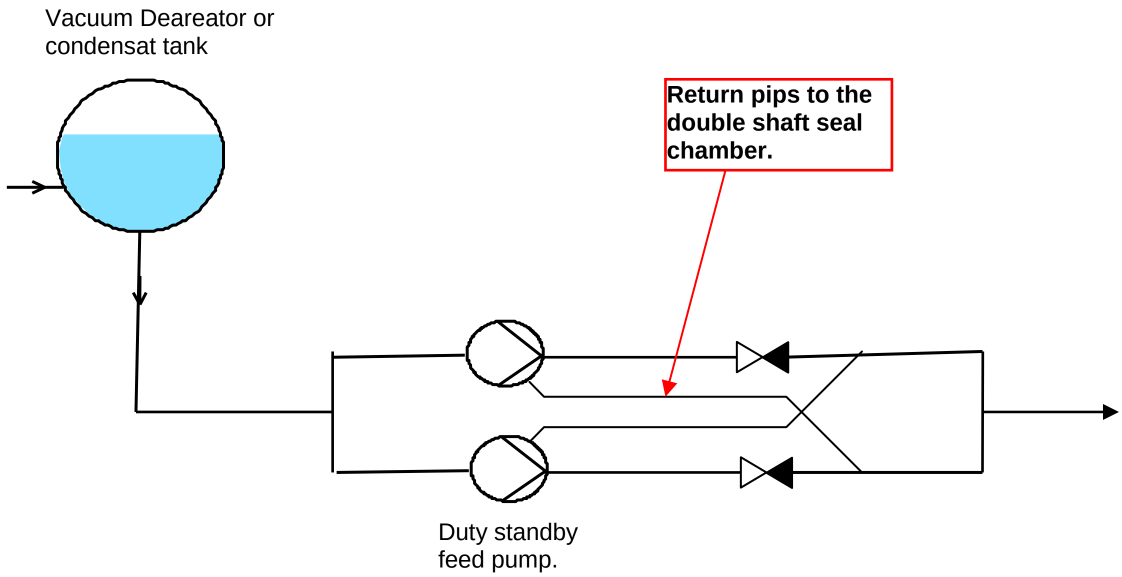
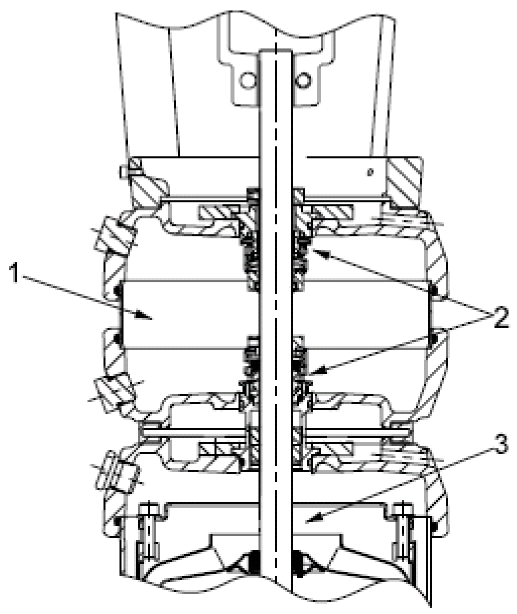


Illustration of a pump top with double shaft seal arrangement.

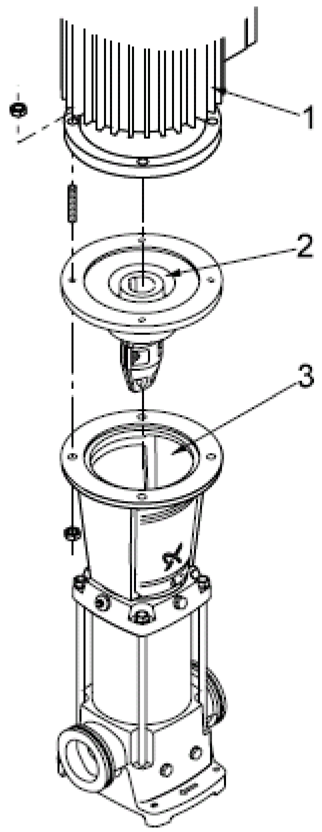


In stead of the pump with a double shaft seal arrangement, , one with a magnetically-driven shaft can also be used.

See more in the Grundfos catalogue Custom built pumps.

5. Bearing flange

If inlet pressure is high, as with an economiser pump in a marine boiler installation, you may need to consider fitting a bearing flange.



A bearing flange is an additional flange with an oversize ball bearing to absorb axial forces in both directions. The coupling part of the flange ensures optimum alignment.

Pumps and sizing.

Before sizing your pumps, the following three factors need to be considered:

Cavitation.
When you in the Deaerator ore condensate tank has water with a high temperature it is difficult to pump without the pump will cavitat. The higher the liquid , the more likely cavitation is to occur. This is because you in the first impeller have to “pull” in the water and as a result the pressure will fall a little bit and the water will start to evaporate. When the pressure is rising through the impeller and the small steam bobbles is starting to implode and become water again it’s called cavitation.
Because of this problem the Deaerator/condensate tank is often placed several meters above the pump inlet to ensure a high as possible inlet pressure. And the pump is made with a special first stage design that reduces the pump’s NPSH value. See more under sizing of pumps.

Shaft seal or Mag-Drive.
For feed pumps pumping from a vacuum tank, there is a risk of air infiltration to the pump through the shaft seal. This phenomenon occurs when two feed pumps are running in parallel as duty standby pumps. Here, there is a risk that the standby pump may let air through the shaft seal due to the vacuum in the deaerator/condensate tank. This problem can be addressed by installing pumps with a double shaft seal arrangement with barrier water or a Mag-Drive pump. Read more about our custom-built pumps in the Grundfos catalogue.

Sizing.

In the European union there is a norm EN 12952-7 there has to be used in the sizing of the pumps. But you always have to check what the factors are in your country.

<u>Flow safety factor according to EN 12952-7</u>
The feed pump capacity shall correspond at least to 1,25 times the allowable steam output of all steam boilers. For safety reasons 1,15 times of maximum continuous rating is enough. For availability and difference in service conditions a greater margin can be necessary.

Where boiler waters is constantly blown down in volumes exceeding 5 % of the allowable steam output, the feed pump capacity shall be increased by the corresponding percentage e.g., if the blow down is 8 % of the allowable steam output, the feed pump capacity shall be increased by 8%.

<u>Pressure safety factor according to EN 12952-7</u>
The feed pump shall be capable of supplying to the steam boiler both the feedwater quantities at maximum allowable pressure as specified above and the feedwater quantity corresponding to the allowable steam output 1,1 times the allowable working pressure.

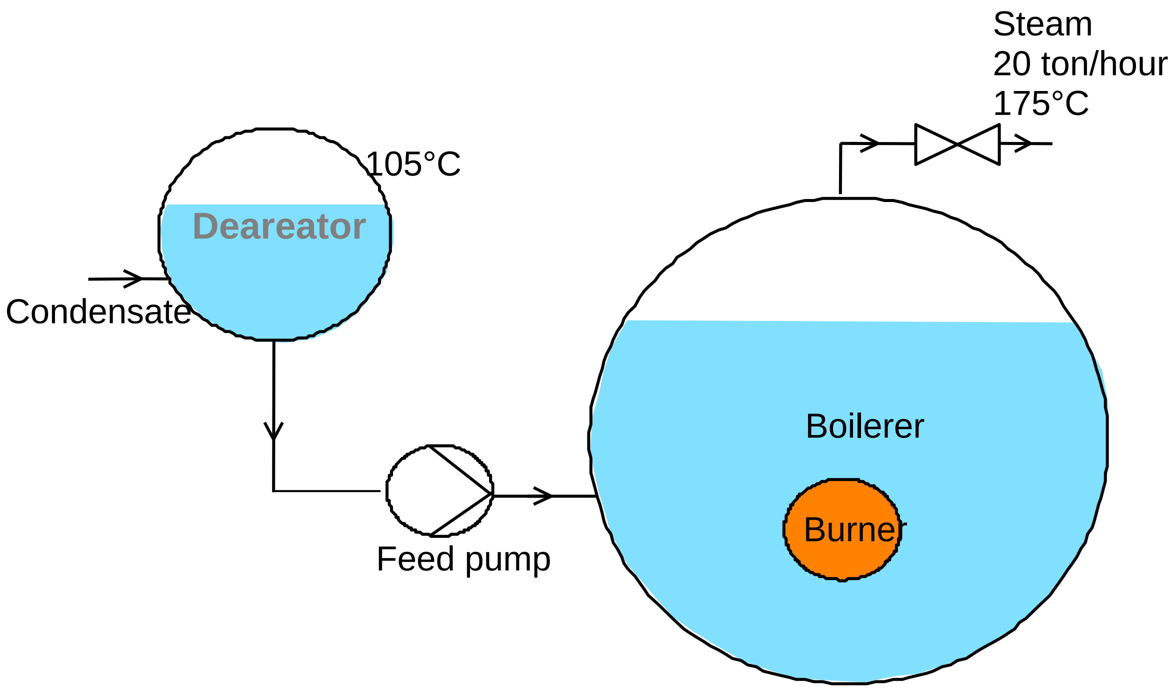
In some country’s your allowed to reduce the 10 % if the security valve has a certain size. Check local rules.

Besides the rules above you cant just read the flow and pressure on the nameplate off the boiler, and use this data to size the pump. This is because of the high temperature on the water and hereby the lover density of the pumped water. See the example below.

Be aware that pumps in boiler applications is not a part of the Pressure equipment directive 97/23/EC (PED) according to guideline 1/11.

Example for calculating flow and head.

From the boiler nameplate we have the following information's.
Q_{Boiler} = 20 tons/hour
$P_{Boiler\ max}$ = 12,5 bar
$P_{Boiler\ drift}$ = 10 bar
Temp. = 175° C



As you can see on the sketch above the 175°C mentioned on the nameplate is the temperature on the steam in the outlet from the boiler. So this you cant use to anything because the pump never sees it. **When sizing you must always use the temperature in the deaerator.**

From the vapour table we have following data on water with a
temp. on 105°C.
Density (rho)= 955,2 kg/m3
vapour pressure = 1,1668 bar

First we must calculate the data from the nameplate to some m^3/h and some mVs that we can use in the sizing.

$$Q_{Boiler} = \frac{Q_{Boiler}}{\rho} = \frac{20 \cdot 10^3}{955,2} = 20,9 m^3 / h$$

$$h_{Boiler} = \frac{p_{Boiler}}{\rho \cdot g} = \frac{12,5 \cdot 10^5}{955,2 \cdot 9,81} = 133,4 mVs$$

$$h_{Drift} = \frac{p_{Boiler}}{\rho \cdot g} = \frac{10 \cdot 10^5}{955,2 \cdot 9,81} = 106,7 mVs$$

When we then use the safety factors from EN 12952-7 we get the flow and head as belove.

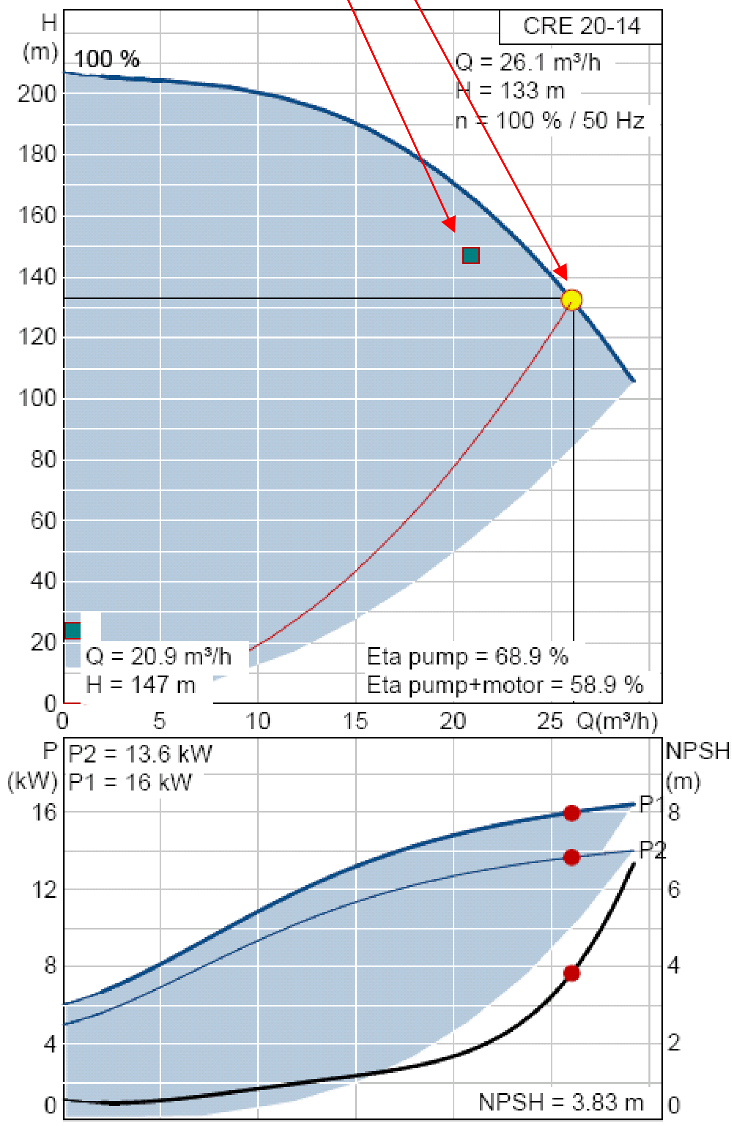
$Q_{Pump\ max}$ = 1,25 x Q_{Boiler} =1,25 x 22,4 = **26,1 m3/h**
$Q_{Pump\ continuous}$ = 1,15 x Q_{boiler} = 1,15 x 22,4 = **25,8 m3/h**
h_{Pump} = 1,1 x h_{boiler} = 1,1 x 133,4 = **146,7 mVs**

All values are now calculated so we can start to choose the pump. Be aware that the pumps don't have to do both the flow and pressure at the same time. But as showed belove.

Situation 1.: Flow 26,1 m^3/h at 133,4 mVs

Situation 2.: Head 146,7 mVs at 20,9 m^3/h

From these situations we choose the following pump because the pump is capable of doing both situations.



Now we have 2 pumps that can do the job, but before we order we have to do a calculation on the NPSH value.

To avoid cavitation in the pump, $NPSH_{system} > NPSH_{pump}$

$NPSH_{system} = h_b - h_f - h_v \pm h_{geo} - h_s$

$NPSH_{system}$ = Is the pressure available on the inlet of the pump.
h_b = Atmospheric pressure at the pump site.
h_f = Friction loss in the suction pipe.
h_v = Vapour pressure of the liquid.
h_{geo} = Vapour pressure of the liquid.
h_s = Safety factor. Normally varies between 0,5 and 1 m.

Example: With the value from earlier and the tank placed 5 m above the pumps we will get the following formula.

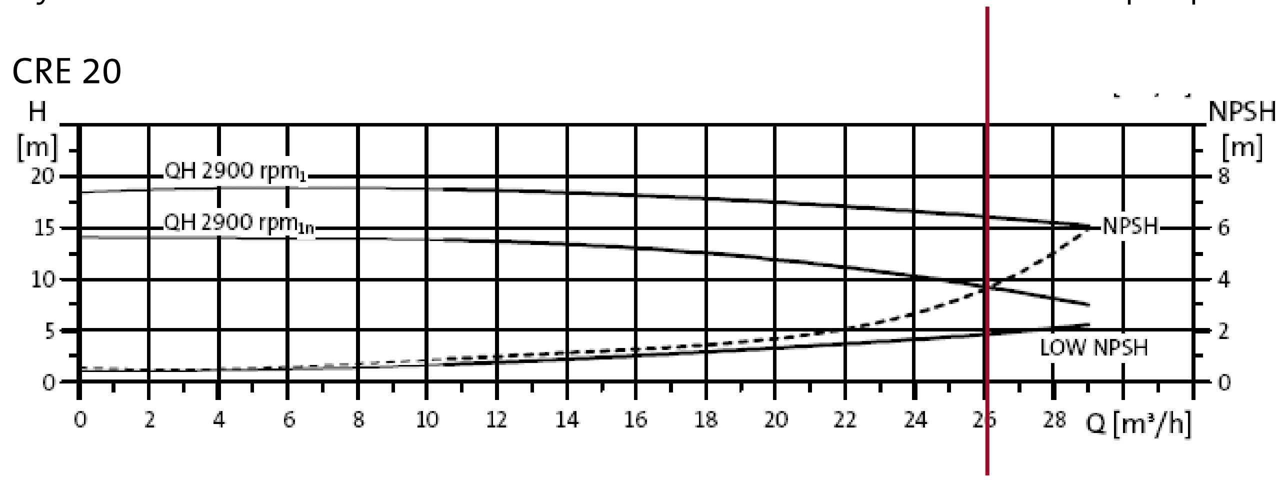
$$h_{system} = \frac{p}{\rho \cdot g} - h_f - \frac{p}{\rho \cdot g} - h_{geo} - h_s = \frac{1,25 \cdot 10^5}{953,7 \cdot 9,81} - 2 - \frac{1,25 \cdot 10^5}{953,7 \cdot 9,81} + 5 - 1 = 2,0mVs$$

As written earlier it is the density on 105°C water we are using because it is that the pump is feeling.
But when we look at the formula again will we see that the h_b and the h_v take out each other. This is because the water in the Deaerator always is kept on the boiling point.

This phenomenon will always occur in a boiler system and because of that we can reduce the formula to the following.

$NPSH_{system} = h_f - \pm h_{geo} - h_s$

So now we have a $NPSH_{system}$ on 2 mVs, and the to pumps we have chosen has NPSH values way above that. Because of this we will now look at the low NPSH versions of the pumps.



As we can see on the curve this pump can bee used in a low NPSH version.

We have now found a pump that can due the job. If we try to put in the actual duty point it looks alright but if we compare it with on with 2 less impellers it's looking even better. But be aware that if we choose the on with 12 impellers it must run over synchronous to reach the duty point according to the EN norm. Which on you choose is up to you.