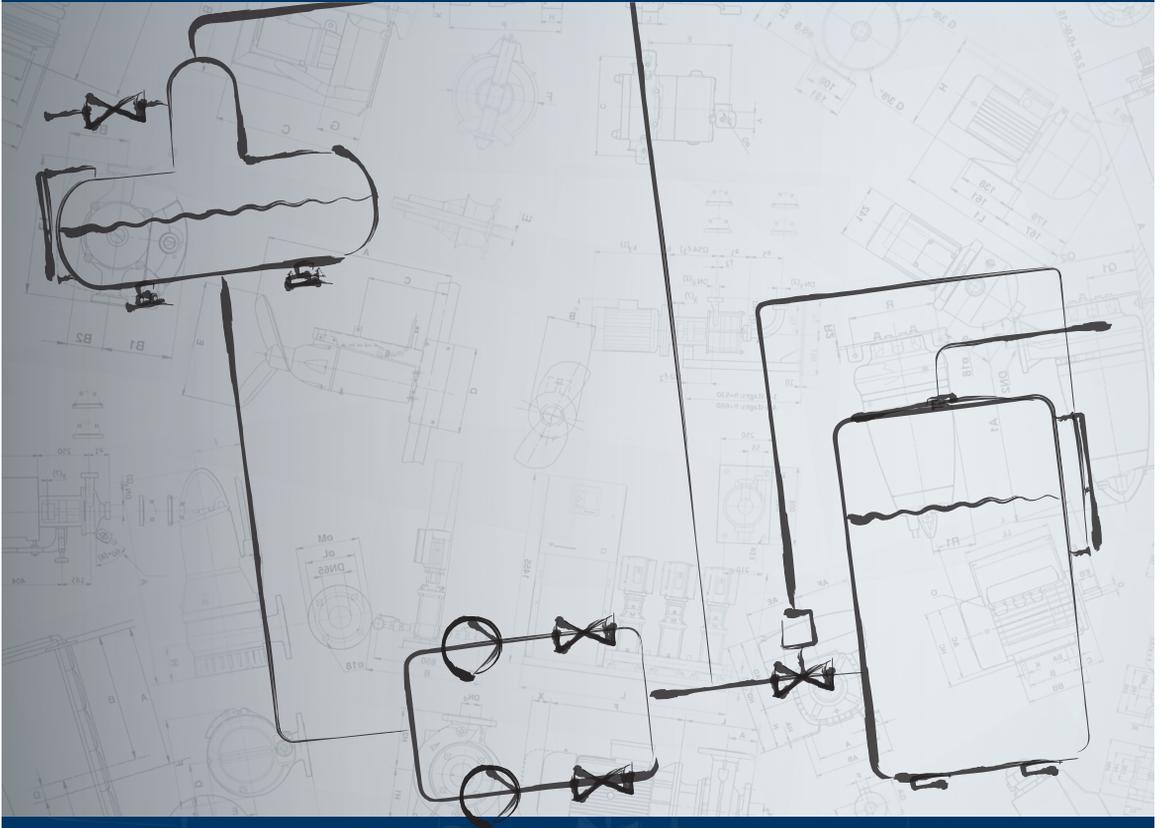


GRUNDFOS INDUSTRY



# ENGINEERING MANUAL Industrial Boilers

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GRUNDFOS 

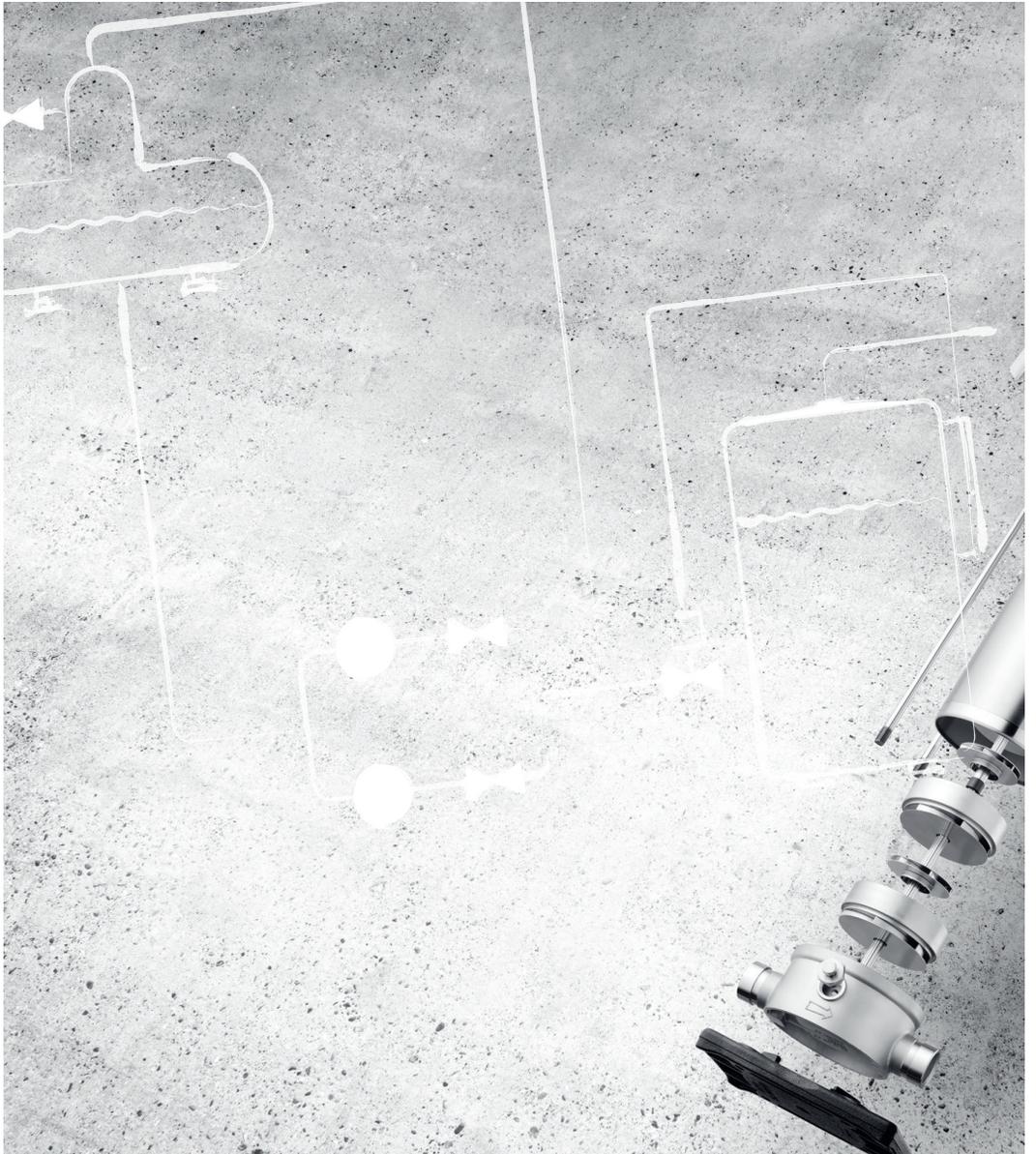


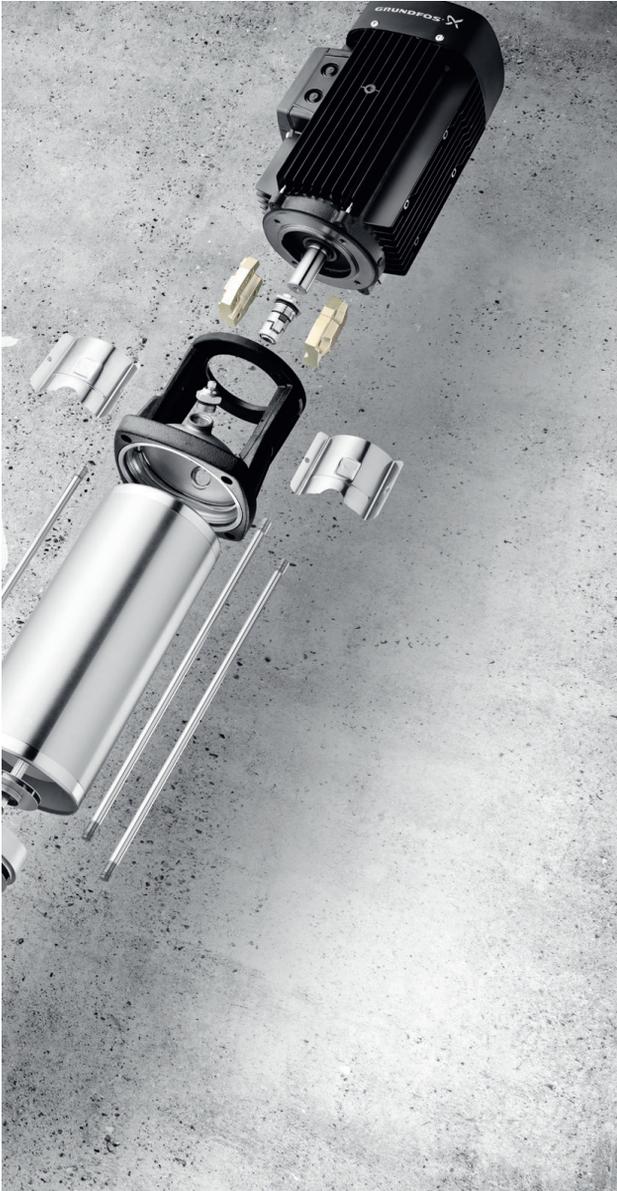
## **ENGINEERING MANUAL**

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## 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 wide 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 on-the-spot advice in a particular part of the world, we have the technical expertise close by.

### Boiler types

Three main boiler types exist:

- Hot water boiler
- Thermal oil boiler
- Steam boiler

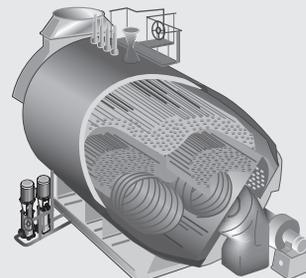
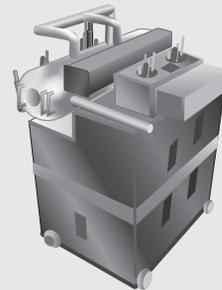
The demands and the sizing of the pumps used for these boiler types are very different. The inserted pictures at the right side show some of the typical boiler constructions used.

Here you can see a cut open drawing of the most common construction of a boiler used in the manufacturing industry. At the bottom you see the burner chambers, which are surrounded with water and at the top the smoke pipes. On the side of the boiler you can see the two feed water pumps. 

This construction is typically seen in the marine, but is also used in the manufacturing industry:



A typical boiler construction in the manufacturing industry:



### 1. Hot water boiler

Hot water boilers are normally used in room and building heating. These kinds of systems are suitable for discharge temperatures of up to 140°C. The advantage of hot water over steam is that the energy loss is much lower than with steam boilers. Figure 1 shows how the pumps are normally installed in a hot water boiler.

### 2. Thermal oil boiler

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



Fig. 1

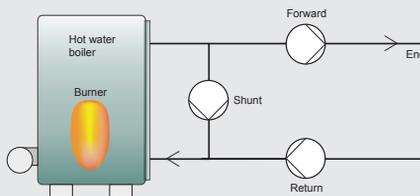


Fig. 2

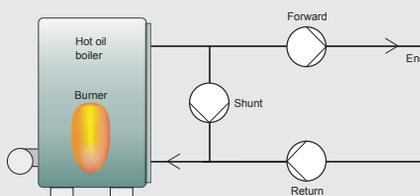
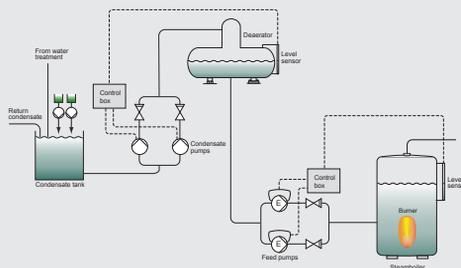


Fig. 3



## Boiler components

### Deaerators/Condenser

Deaerator and condenser tanks are only used in steam boiler systems and not in hot water and hot oil boilers as fluid is always in its liquid form. The construction of these two types of tanks is almost identical, but as their names indicate, they are used for different purposes. Two primary principles are used with this form of tank design; thermal and vacuum.

The tank design used depends on the type of boiler being used. Each principle also has different pump construction requirements.

**Thermal principle**

A tank using the thermal principle is connected to the atmosphere via a valve. This design is normally used in smaller plants. Here, steam is used to maintain the tank water temperature at around 105°C, which removes air from the water. A temperature of 105°C is needed because of the air vent valve mounted in the deaerator or condenser which needs an opening pressure of approx. 0.2 bar, which provides a total pressure of 1.2 bar absolute. This means that the water will boil at a temperature that is a little bit higher than the usual 100°C where water normally boils in atmospheric pressure. See also the vapour pressure table at the back of this manual. Besides the air vent valve, a vacuum breaker valve has also been mounted to ensure that vacuum never occurs in this tank type. If the vacuum valve was not mounted, vacuum could occur when cold make up water was added to the tank.

**Vacuum principle**

Here an ejector pump is used to create a vacuum in the tank. This causes the tank water to start boiling even at low temperatures. This in turn removes air from the water. This principle is normally used in steam turbine applications.

**Deaerators (Fig. 4)**

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

**Condensers (Fig. 5)**

A condenser ensures that all steam is condensed before being pumped back into the deaerator and then

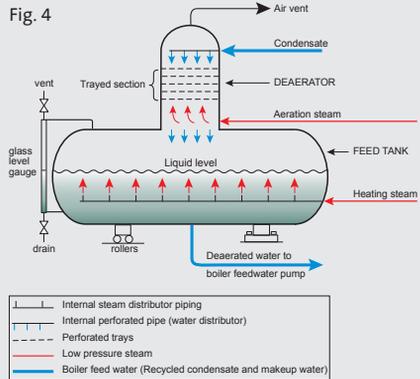
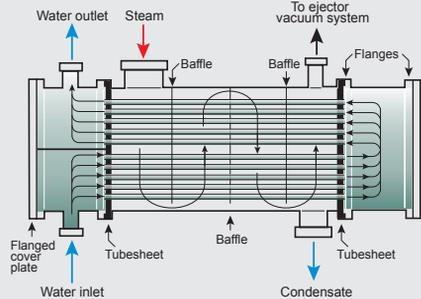


Fig. 5



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 the manufacturing industry and marine industry means that economisers are now far more commonplace.

An economiser is a heat exchanger 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 (FIG. 6)

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).

#### ECONOMISERS IN LAND BASED BOILERS (FIG. 7)

An economiser used with a boiler located on land uses the boiler's waste gases. The water circulated above the economiser is normally supplied by the main feed pump, but can also be fitted with its own circulation pump see Fig. 7. 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 are significantly greater. Energy produced by marine applications often allow for the generation of overheated steam fed directly from economiser and out into the piping.



Fig. 6

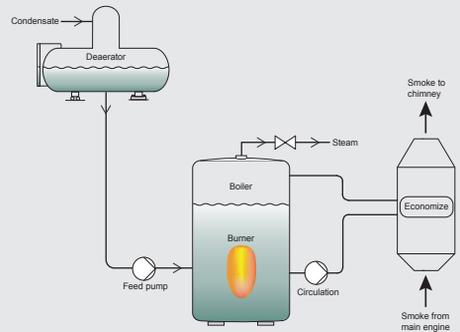
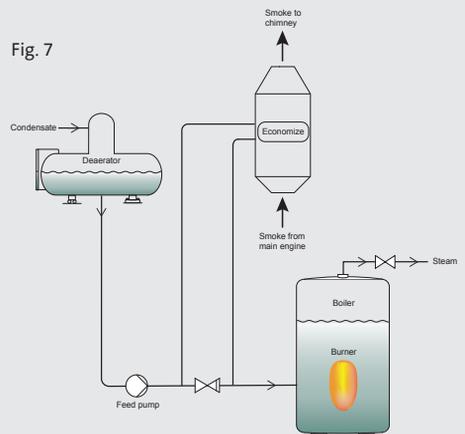


Fig. 7



**Boiler pumps**

A range of pumps for different boiler applications exist. This section describes the typical positioning of the various 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**

Boiler feeding can normally take place in the following 4 ways:

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

All 4 methods will be described in the following.

**1. On/off control (Fig. 8)**

**Function**

In on/off control the feed pump is switched on/off through 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 the system.

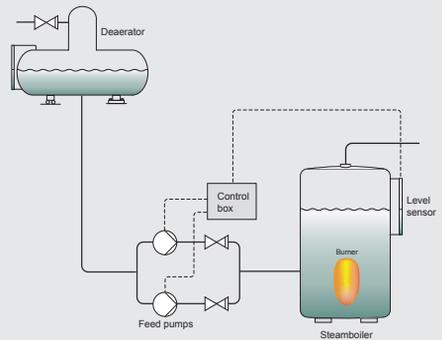
**Benefits**

- Inexpensive
- Easy to install
- No bypass

**Drawbacks**

- Poor steam quality

Fig. 8



## 2. Through feed valve (Fig. 9)

### 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 the 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
- The feed valve is expensive
- Pressure loss across the feed valve

### Important!

Remember to size bypass according to the CR pumps min. flow which is 10 % of nominal flow for the pump. It may be an idea to stop the pump when the valve is closed. This requires, however, a signal from the valve.

## 3. Through feed valve, variable speed. (Fig. 10)

### 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 the 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,



Fig. 9

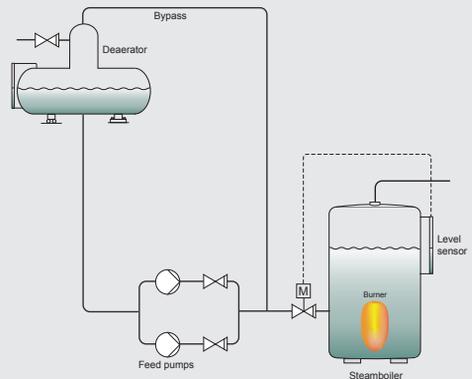
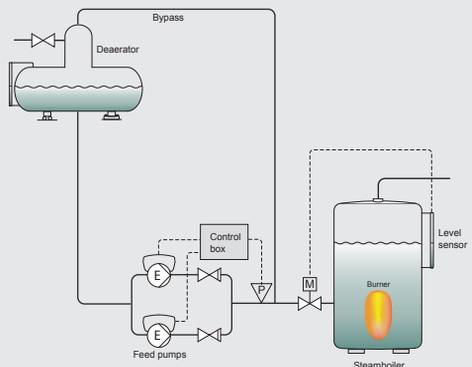


Fig. 10



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 the feed valve

**Drawbacks**

- Bypass
- The feed valve is expensive
- Pressure loss across the feed valve

**Important!**

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

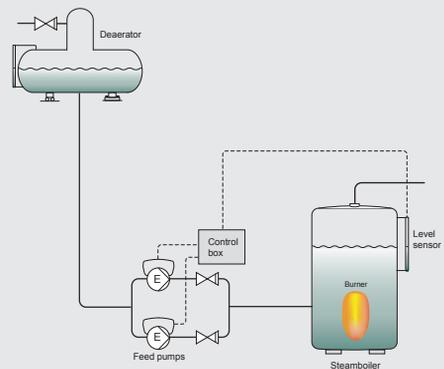
Remember to size bypass according to the CR/CV data as well as to min. flow. It may be an idea to stop the pump when the valve is closed. This requires, however, a signal from the valve. Find out whether variable speed control of both pumps is required as this increases expenses, but does not provide the same flexibility as to alternating the pump operation.

**4. Without feed valve (Fig. 11)**

**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 the 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.

Fig. 11





### Benefits

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

### Drawback

- Requires precise and qualified start-up

### Important!

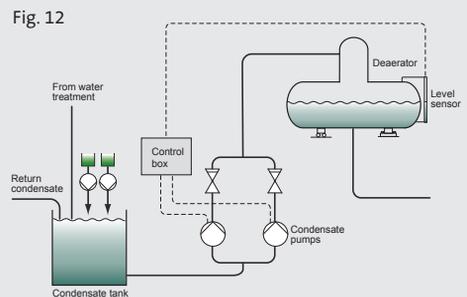
- A minimum frequency must be defined ensuring that the pump can always overcome the pressure in the boiler, and supply the minimum flow for the pump. May be carried out with the “min. curve” option for the pump.
- It must be ensured that the pump stops when steam consumption is zero. May e.g. be carried out with a high level switch from the boiler.
- The regulator area may be small. If the level sensor e.g. is 2 metres and regulation takes place in an area of just 20 cm corresponding to approx. 2 mA, if the level sensor is 4-20 mA.
- The level signal is normally inverted. This means that if you get 20 mA from the level sensor, the boiler is full and then the pump should stop instead of speeding up.

## CONDENSATE PUMPS

### 1. Condensate pumping on/off (Fig. 12)

#### Function

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



**Benefits**

Inexpensive and easy to install

**Important!**

Requirements vary from one country to another as regards the sizing of condensate pumps (two pumps must always back each other up 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 may 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 requirements of a shunt pump are normally high flow and very low head. The shunt pump is therefore normally made with a 4-pole or 6- pole motor to get the head down. Shunt pumps are normally single stage pumps.

1. On/off shunt pump (Fig. 13)

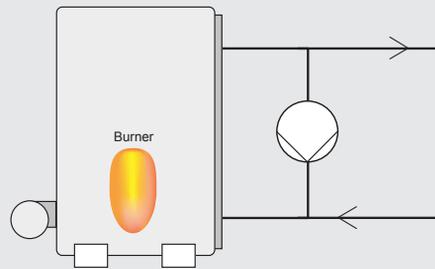
**Function**

The shunt pump must ensure that the return temperature to the boiler does not become 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 easy to install
- Safe operation (few components)

Fig. 13



### **Important!**

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

## 2. Variable shunt pump (Fig. 14)

### **Function**

The pump must ensure that the return temperature to the boiler does not become too low. If the differential temperature is high it will stress the boiler. A variable speed pump may be the correct 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!**

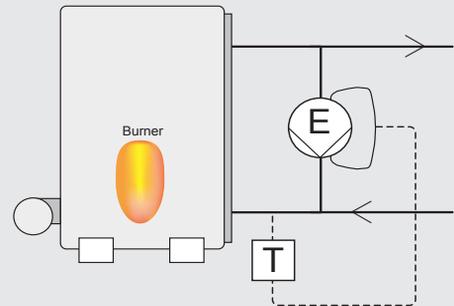
Information about the correct return temperature to be obtained from the boiler manufacturer.

### **Accessories required**

Temperature sensor, R100.



Fig. 14







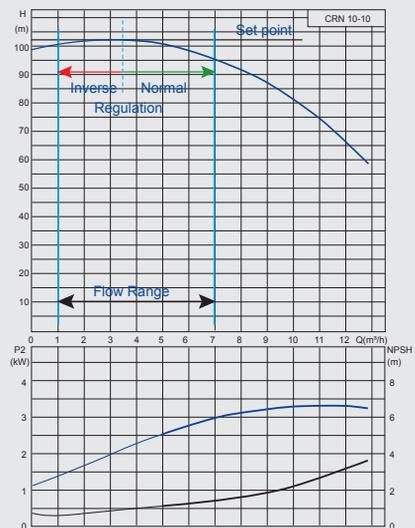
## What Grundfos offers

### 1. E pump solutions

With Grundfos E-solution it is possible to optimise the feed pumps with the software. Feed pump optimisation by means of software is used, e.g. because the pump curve is labile. See the curve on fig. 15 for an overview of the curve and what problems it may cause.

As seen from the curve, it is possible to have 2 different flows on the same set point. Put differently, 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 a poor steam quality.

Fig. 15



Grundfos E-solutions may 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 below the labile point of the curve. See fig. 16.

The labile curve is not a problem in all boiler plants. Normally it is or can be a problem if the feed pumps are located close to the boiler with a small friction loss as a result. You would therefore normally never see this problem in the marine industry or in 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 construct the pump with an oversized inlet chamber. See fig. 17 where you can also see the result of a low NPSH impeller and what effect it has on the NPSH value.

Fig. 17

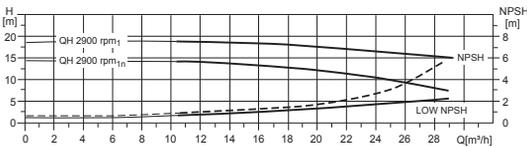
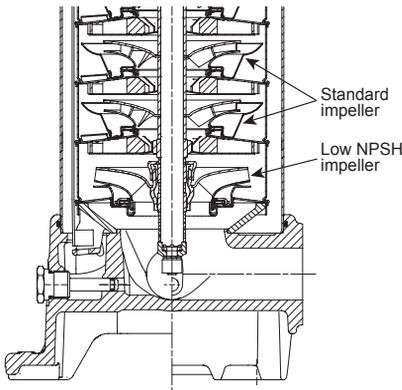
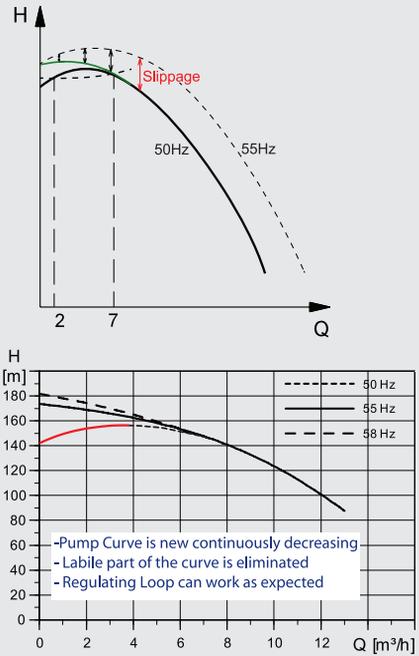


Fig. 16



### 3. Air-cooled top (Fig. 18)

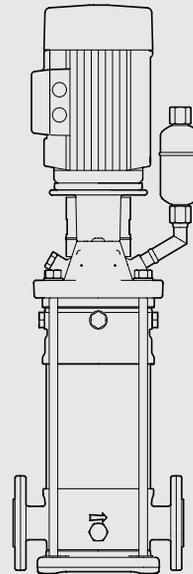
The air-cooled top solution is used with water temperatures above 120°C and up to 180°C. For oil up to 240°C.



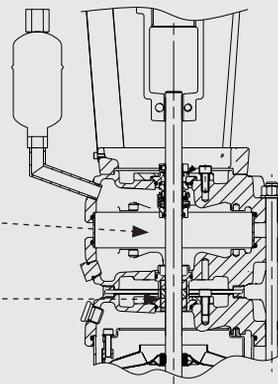
The air-cooled top **separates the seal chamber from the pump** by an air-cooled chamber, generating an insulating effect similar to that of a thermos.

Via a **narrow passage between the pump and the air-cooled top**, a small quantity of the pumped liquid ensures that the seal chamber is always filled with liquid.

Fig. 18



Air cooled top



#### 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 during standby. As the diagram in fig. 19 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.

Fig. 19

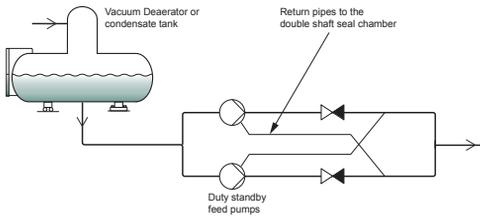
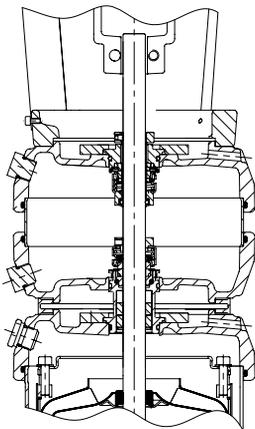


Illustration of a pump top with a double shaft seal arrangement in fig. 20.

Fig. 20



Instead of the pump with a double shaft seal arrangement, one with a magnetically-driven shaft can

CRN 150 pump with Double shaft seal :



also be used. See more in the Grundfos catalogue Custom-built pumps.

### 5. Bearing flange (Fig. 21)

If the 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.

### Boiler problems

When discussing problems with boilers and pumps that break down, some topics keep recurring. Some of them are mentioned here.

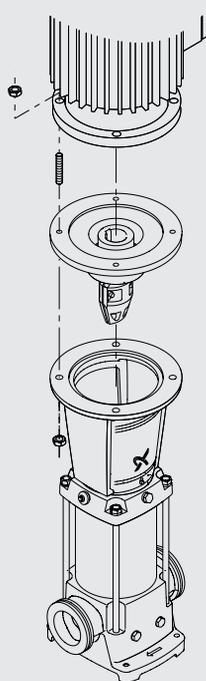
#### BOTTOM BLOW DOWN

A problem we often see in the boiler business is cavitation due to bottom blow down of the boiler. A bottom blow down is when water is let out from the water reservoir in the bottom of the boiler. The reason for doing this blow down is that suspended solids in the water can be kept in suspension as long as the boiler water is agitated, but as soon as the agitation stops, the suspended solids will fall to the bottom of the boiler. If the solids are not removed, they will accumulate and, given time, will inhibit the heat transfer from the boiler fire tubes, which will overheat or even fail.

The normal method of removing this sludge is through short, sharp blasts using a relatively large valve at the bottom of the boiler. The objective is to allow the sludge time to redistribute itself so that more may be removed at the next blow down.

The duration and frequency of the blow down vary from the different boiler manufacturers.

Fig. 21



The pump problem starts when the blow down time is so long that the pressure in the boiler starts to fall. This will or can result in the feed pump running out of curve which means that the required NPSH value for the pump will increase dramatically. And this results in cavitation and over time break down of the pump.

### WEEKEND SHOT DOWN

Many of our customers have productions that stops in the weekend. This means that they also stop the steam production over the weekend and only keep the boiler at a minimum temperature to be ready to start up again. How they choose to carry out this standby period is very different from customer to customer, but often a little amount of steam is recycled from the boiler to the deaerator to keep that heated as well. From time to time they then start the boiler to correct the levels in the boiler and deaerator and this may cause problems both with cavitation and water hammer. Cavitation due to a lower pressure in the boiler than normal and water hammer due to the column of water in the pump being cooled down at standstill as it is not insulated. And when the pump is subsequently started you send a column of "cold" water through the pipes resulting in water hammer in the system.

### PRODUCTION CHANGES

Often we see that the production changes over time so they sometimes use larger amounts of steam than the data available to us during sizing of the boiler. This may result in two small pumps; meaning that we run with two big flows in the pumps and because of this, a bigger NPSH is required.

Often the customers also have different operation patterns than they inform us about when we size the feed pumps. For example we had a customer who once a month used steam for an hour to clean his turbines. This resulted in such high pressure drops in the boiler that the pump cavitated an hour every month.

## DOSING

Normally no problems arise due to the way the chemicals used are being dosed into the water. But from time to time we have seen an increase in tear of the impeller if the chemicals are being dosed directly in front of the feed pumps. This is because the concentration can be very high in the pump due to the chemicals not having been mixed properly before passing the pump.

If it is a large CR with bronze bearing it is important to keep the PH value in the boiler water below 10 as it will otherwise tear down the bronze. It is usually not a problem as the boiler manufacturer also has an interest in keeping the PH value at approx. 8-9. Be aware that if NH<sub>3</sub> is added to lower the PH value, the NH<sub>3</sub> will also tear down the bronze.

## FEED PUMP START-UP

When the pumps are being started, you have to take the following two things into consideration.

If the pump is equipped with a frequency converter, it is important that the pump starts at such high speed that it delivers a higher pressure than the one in the boiler. If not, it will be like running against closed valves until it overcomes that pressure. This can result in a burned shaft seal.

If the ramp up time is set to 0 sec., the water column in the inlet of the pump has been shown to having been torn apart and some sort of vacuum pockets have been created. When that pocket collapses again or the water column catches up, it creates some sort of water hammer with a very high pressure. This phenomenon happens very fast and pressure peaks above 120 bar have been found. This pressure peak can destroy all sensors in the inlet of the pump and at the same time lift the chamber stack in the pump so explosively that the motor bearings can be damaged.



## Pumps and sizing

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

### Cavitation

If the water in the deaerator or the condensate tank has a high temperature, it is difficult to pump without causing the pump to cavitate. The higher the temperature, the more likely cavitation is to occur. This is because you have to “pull” in the water in the first impeller and as a result the pressure will fall a little and the water will start to evaporate. When the pressure is rising through the impeller and the small steam bobbles are starting to implode and become water again, this is called cavitation.

Because of this problem, the deaerator / condensate tank is often placed several metres above the pump inlet to ensure as high an inlet pressure as possible. The pump can be 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 EU, the EN 12952-7 norm has to be used when sizing pumps. However, please check the factor requirements in your local country.

### FLOW SAFETY FACTOR ACCORDING TO EN 12952-7

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 may be necessary.

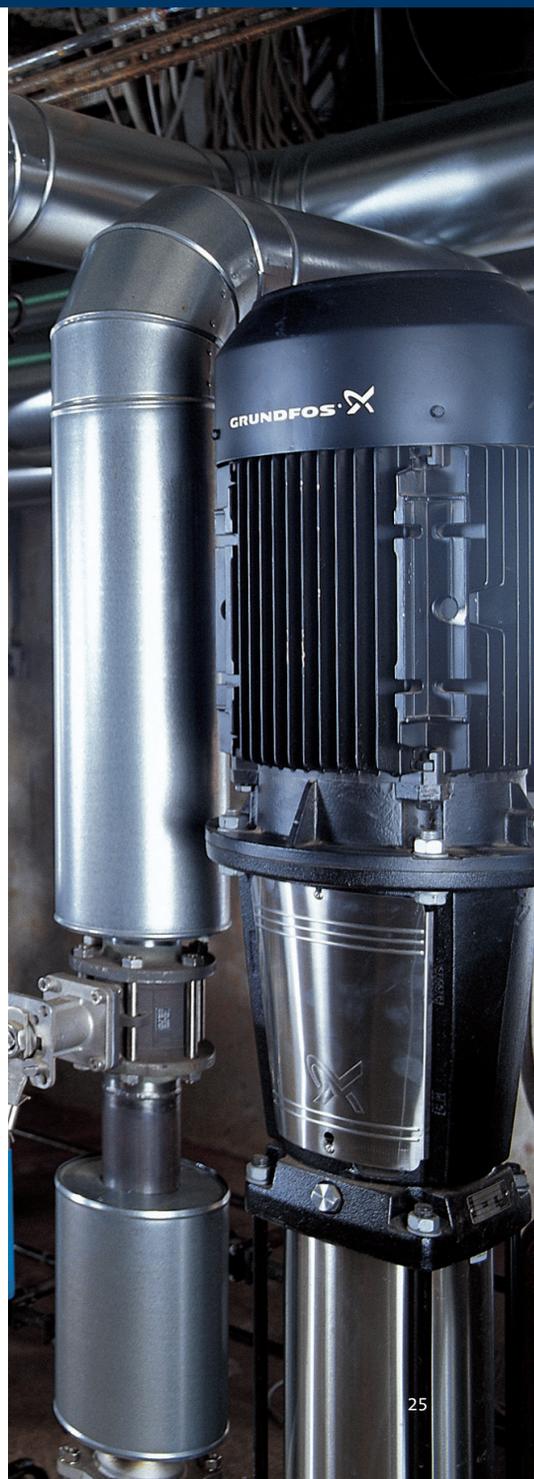
Where boiler waters are constantly blown down in volumes exceeding 5 % of the allowable steam output, the feed pump capacity shall be increased by the corresponding percentage e.g., if the blow down is 8 % of the allowable steam output, the feed pump capacity shall be increased by 8 %.

### PRESSURE SAFETY FACTOR ACCORDING TO EN 12952-7

The feed pump shall be capable of supplying the steam boiler with both the feed water quantity at maximum allowable pressure as specified above and the feed water quantity corresponding to the allowable steam output 1.1 times the allowable working pressure.

*In some countries you are allowed to reduce the 10 % if the security valve is of a certain size. Please check the local rules and regulations.*

Besides the rules and regulations above, you cannot 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 lower density of the pumped water. See the example below.



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

**EXAMPLE OF FLOW AND HEAD CALCULATION**

The following information is taken from the boiler nameplate in fig. 22.

- $Q_{Boiler} = 20 \text{ tons/hour}$
- $P_{Boiler \text{ max}} = 12.5 \text{ bar}$
- $P_{Boiler \text{ operating}} = 10 \text{ bar}$
- $\text{Temp.} = 175^\circ \text{C}$

As you can see from the illustration above, the  $175^\circ\text{C}$  mentioned on the nameplate is the temperature on the steam in the outlet from the boiler. This information however is of no use as the pump never registers 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. of  $104^\circ\text{C}$** .  
 Density ( $\rho$ )=  $955.2 \text{ kg/m}^3$   
 Vapour pressure =  $1.1668 \text{ bar}$

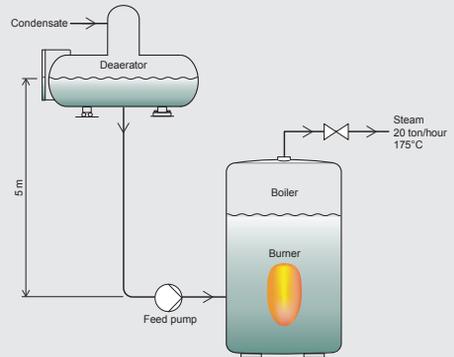
First we must calculate the data from the nameplate to  $\text{m}^3/\text{h}$  and  $\text{mVs}$  that can be used in the sizing.

$$Q_{Boiler} = \frac{Q_{Boiler}}{\rho} = \frac{20 \cdot 10^3}{955.2} = 20.9 \text{m}^3 / \text{h}$$

$$h_{Boiler} = \frac{P_{Boiler}}{\rho \cdot g} = \frac{12.5 \cdot 10^5}{955.2 \cdot 9.81} = 133.4 \text{mVs}$$

$$h_{Operating} = \frac{P_{Boiler}}{\rho \cdot g} = \frac{10 \cdot 10^5}{955.2 \cdot 9.81} = 106.7 \text{mVs}$$

Fig. 22





When we then apply the safety factors from EN 12952-7, we get the flow and head as specified below.

$$Q_{\text{Pump max}} = 1.25 \times Q_{\text{Boiler}} = 1.25 \times 20.9 = \mathbf{26.1 \text{ m}^3/\text{h}}$$

$$Q_{\text{Pump continuous}} = 1.15 \times Q_{\text{boiler}} = 1.15 \times 20.9 = \mathbf{24.0 \text{ m}^3/\text{h}}$$

$$h_{\text{Pump}} = 1.1 \times h_{\text{boiler}} = 1.1 \times 133.4 = \mathbf{146.7 \text{ mVs}}$$

All values are now calculated so we can start to choose the pump. Please notice that the pumps do not have to handle both the flow and pressure at the same time. It should be carried out as shown below and in fig 23.

**Situation 1.:** Flow 26.1 m<sup>3</sup>/h at 133.4 mVs

**Situation 2.:** Head 146.7 mVs at 20.9 m<sup>3</sup>/h

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

Now we have a pump that can do the job, but before ordering we have calculate the NPSH value.

To avoid pump cavitation,  
 $NPSH_{\text{system}} - NPSH_{\text{pump}}$

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

$NPSH_{\text{system}}$  = Is the pressure available at the inlet of the pump.

$h_b$  = Atmospheric pressure at the pump site.

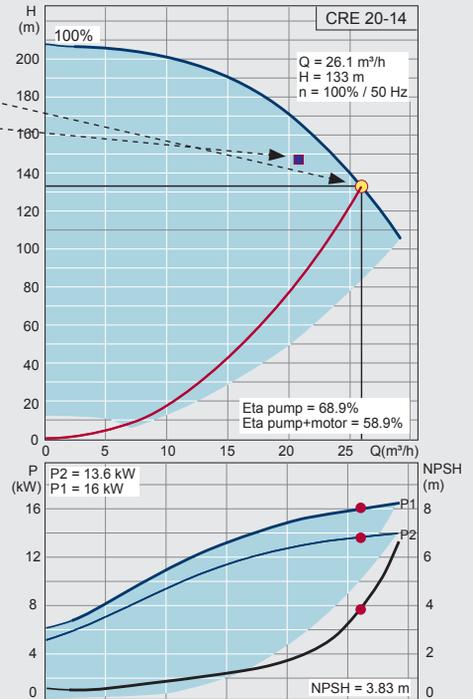
$h_f$  = Friction loss in the suction pipe.

$h_v$  = Vapour pressure of the liquid.

$h_{\text{geo}}$  = Vapour pressure of the liquid.

$h_s$  = Safety factor. Normally varies between 0.5 and 1 m.

Fig. 23



**Example:** : With the value from earlier and the tank placed 5 m above the pumps, the following formula is found:

$$h_{\text{system}} = \frac{p}{\rho \cdot g} - h_f - \frac{p}{\rho \cdot g} - h_{\text{geo}} - h_s =$$

$$\frac{1.25 \cdot 10^5}{955.2 \cdot 9.81} - 2 - \frac{1.25 \cdot 10^5}{955.2 \cdot 9.81} + 5 - 1 = 2.0 \text{ mVs}$$

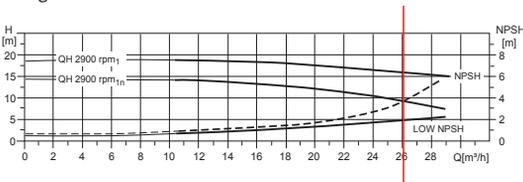
As written earlier it is the density of 104°C water we are using as this is what the pump registers. But when we take another look at the formula we will see that the hb and the hv offset each other. This is because the water in the deaerator always is kept at the boiling point.

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

$$\text{NPSH}_{\text{system}} = h_f - \pm h_{\text{geo}} - h_s$$

So now we have a NPSH<sub>system</sub> on 2 mVs, and the two selected pumps have NPSH values way above that. Because of this we will now look at the low NPSH versions of the pumps, see fig 24.

Fig. 24





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

We have now found a pump that can handle the job, fig. 25. If we try to put in the actual duty point it looks alright, but if we compare it with a pump with 2 less impellers it is looking even better, fig. 26. But please notice that if we choose the pump with 12 impellers, it must run over synchronous to reach the duty point according to the EN norm. Which one you choose is up to you.

Fig. 25

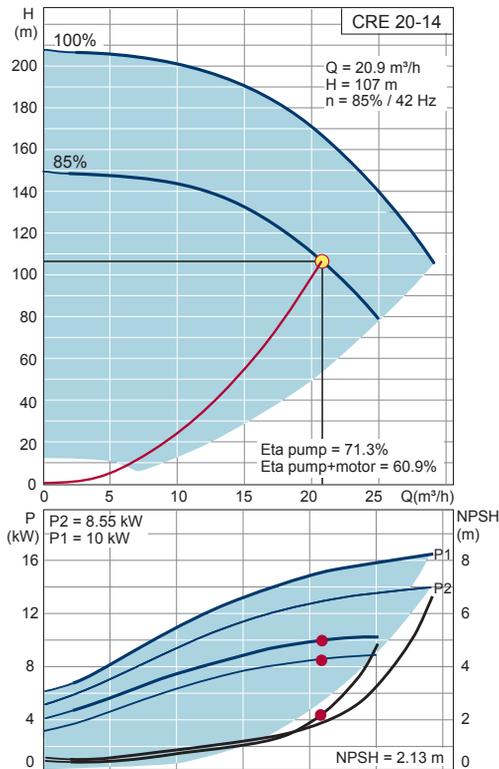
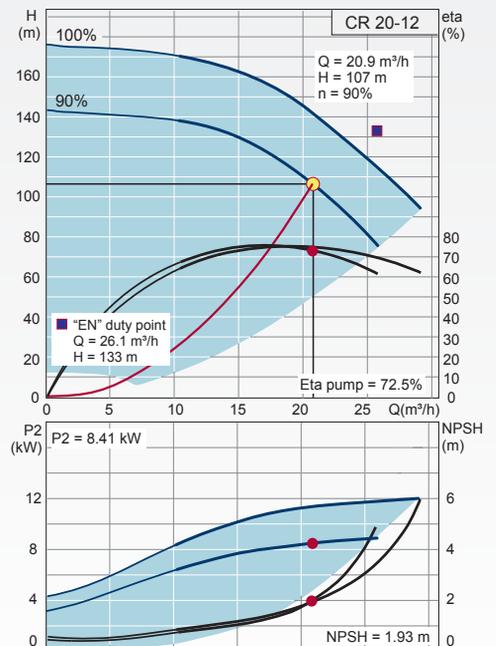


Fig. 26



Vapour table

Vapour pressure and density of water at different temperatures

This table shows the vapour pressure  $p$  [bar] and the density  $\rho$  [kg/m<sup>3</sup>] of water at different temperatures  $t$  [°C]. Likewise, the table shows the corresponding absolute temperature  $T$  [K].

Vapour pressure $p$ and density $\rho$ of water at different temperatures											
$t$ [°C]	$T$ [K]	$P$ [bar]	$\rho$ [kg/m <sup>3</sup> ]	$t$ [°C]	$T$ [K]	$P$ [bar]	$\rho$ [kg/m <sup>3</sup> ]	$t$ [°C]	$T$ [K]	$P$ [bar]	$\rho$ [kg/m <sup>3</sup> ]
0	273.15	0.00611	999.8					138	411.15	3.414	927.6
1	274.15	0.00657	999.9	61	334.15	0.2086	982.6	140	413.15	3.614	925.8
2	275.15	0.00706	999.9	62	335.15	0.2184	982.1	145	418.15	4.155	921.4
3	276.15	0.00758	999.9	63	336.15	0.2286	981.6	150	423.15	4.760	916.8
4	277.15	0.00813	1000.0	64	337.15	0.2391	981.1				
5	278.15	0.00872	1000.0	65	338.15	0.2501	980.5	155	428.15	5.433	912.1
6	279.15	0.00935	1000.0	66	339.15	0.2615	979.9	160	433.15	6.181	907.3
7	280.15	0.01001	999.9	67	340.15	0.2733	979.3	165	438.15	7.008	902.4
8	281.15	0.01072	999.9	68	341.15	0.2856	978.8	170	443.15	7.920	897.3
9	282.15	0.01147	999.8	69	342.15	0.2984	978.2	175	448.15	8.924	892.1
10	283.15	0.01227	999.7	70	343.15	0.3116	977.7				
								180	453.15	10.027	886.9
11	284.15	0.01312	999.7	71	344.15	0.3253	977.0	185	458.15	11.233	881.5
12	285.15	0.01401	999.6	72	345.15	0.3396	976.5	190	463.15	12.551	876.0
13	286.15	0.01497	999.4	73	346.15	0.3543	976.0	195	468.15	13.987	870.4
14	287.15	0.01597	999.3	74	347.15	0.3696	975.3	200	473.15	15.50	864.7
15	288.15	0.01704	999.2	75	348.15	0.3855	974.8				
16	289.15	0.01817	999.0	76	349.15	0.4019	974.1	205	478.15	17.243	858.8
17	290.15	0.01936	998.8	77	350.15	0.4189	973.5	210	483.15	19.077	852.8
18	291.15	0.02062	998.7	78	351.15	0.4365	972.9	215	488.15	21.060	846.7
19	292.15	0.02196	998.5	79	352.15	0.4547	972.3	220	493.15	23.198	840.3
20	293.15	0.02337	998.3	80	353.15	0.4736	971.6	225	498.15	25.501	833.9
21	294.15	0.02485	998.1	81	354.15	0.4931	971.0	230	503.15	27.976	827.3
22	295.15	0.02642	997.8	82	355.15	0.5133	970.4	235	508.15	30.632	820.5
23	296.15	0.02808	997.6	83	356.15	0.5342	969.7	240	513.15	33.478	813.6
24	297.15	0.02982	997.4	84	357.15	0.5557	969.1	245	518.15	36.523	806.5
25	298.15	0.03166	997.1	85	358.15	0.5780	968.4	250	523.15	39.779	799.2
26	299.15	0.03360	996.8	86	359.15	0.6011	967.8	255	528.15	43.246	791.6
27	300.15	0.03564	996.6	87	360.15	0.6249	967.1				
28	301.15	0.03778	996.3	88	361.15	0.6495	966.5	260	533.15	46.943	783.9
29	302.15	0.04004	996.0	89	362.15	0.6749	965.8	265	538.15	50.877	775.9
30	303.15	0.04241	995.7	90	363.15	0.7011	965.2	270	543.15	55.058	767.8
								275	548.15	59.496	759.3
31	304.15	0.04491	995.4	91	364.15	0.7281	964.4	280	553.15	64.202	750.5
32	305.15	0.04753	995.1	92	365.15	0.7561	963.8				
33	306.15	0.05029	994.7	93	366.15	0.7849	963.0	285	558.15	69.186	741.5
34	307.15	0.05318	994.4	94	367.15	0.8146	962.4	290	563.15	74.461	732.1
35	308.15	0.05622	994.0	95	368.15	0.8453	961.6	295	568.15	80.037	722.3
36	309.15	0.05940	993.7	96	369.15	0.8769	961.0	300	573.15	85.927	712.2
37	310.15	0.06274	993.3	97	370.15	0.9094	960.2	305	578.15	92.144	701.7
38	311.15	0.06624	993.0	98	371.15	0.9430	959.6	310	583.15	98.700	690.6
39	312.15	0.06991	992.7	99	372.15	0.9776	958.6				
40	313.15	0.07375	992.3	100	373.15	1.0133	958.1	315	588.15	105.61	679.1
								320	593.15	112.89	666.9
41	314.15	0.07777	991.9	102	375.15	1.0878	956.7	325	598.15	120.56	654.1
42	315.15	0.08198	991.5	104	377.15	1.1668	955.2	330	603.15	128.63	640.4
43	316.15	0.08639	991.1	106	379.15	1.2504	953.7	340	613.15	146.05	610.2
44	317.15	0.09100	990.7	108	381.15	1.3390	952.2				
45	318.15	0.09582	990.2	110	383.15	1.4327	950.7	350	623.15	165.35	574.3
46	319.15	0.10086	989.8					360	633.15	186.75	527.5
47	320.15	0.10612	989.4	112	385.15	1.5316	949.1				
48	321.15	0.11162	988.9	114	387.15	1.6362	947.6	370	643.15	210.54	451.8
49	322.15	0.11736	988.4	116	389.15	1.7465	946.0	374.15	647.30	221.2	315.4
50	323.15	0.12335	988.0	118	391.15	1.8628	944.5				
				120	393.15	1.9854	942.9				
51	324.15	0.12961	987.6								
52	325.15	0.13613	987.1	122	395.15	2.1145	941.2				
53	326.15	0.14293	986.6	124	397.15	2.2504	939.6				
54	327.15	0.15002	986.2	126	399.15	2.3933	937.9				
55	328.15	0.15741	985.7	128	401.15	2.5435	936.2				
56	329.15	0.16511	985.2	130	403.15	2.7013	934.6				
57	330.15	0.17313	984.6								
58	331.15	0.18147	984.2	132	405.15	2.8670	932.8				
59	332.15	0.19016	983.7	134	407.15	3.041	931.1				
60	333.15	0.19920	983.2	136	409.15	3.223	929.4				



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Being responsible is our foundation  
Thinking ahead makes it possible  
Innovation is the essence

**GRUNDFOS A/S**  
Poul Due Jensens Vej 7  
DK-8850 Bjerringbro  
[www.grundfos.com](http://www.grundfos.com)

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