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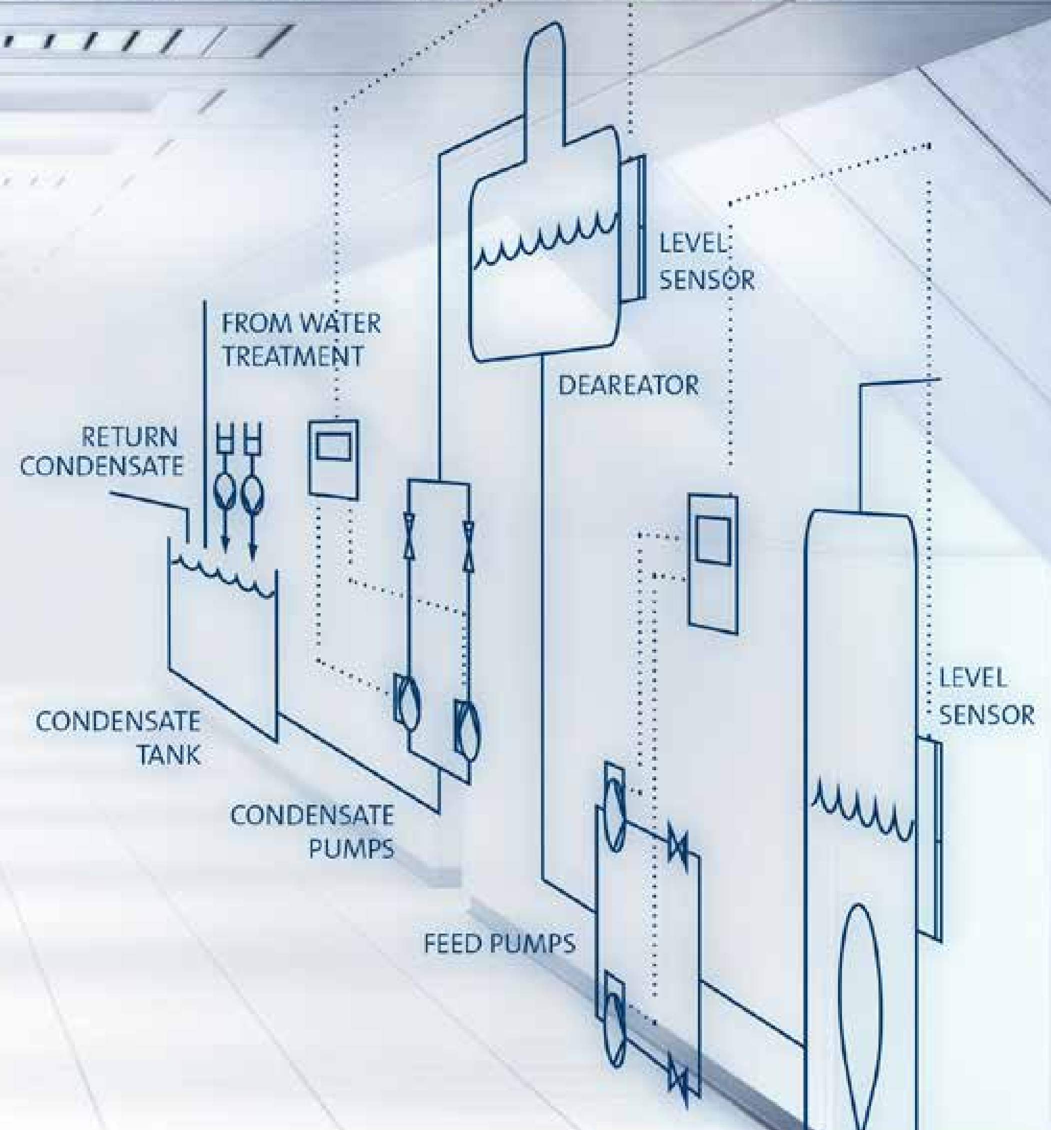
GRUNDFOS **INDUSTRY**
Boiler Feed Manual

BOILERS AND SYSTEMS



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ENGINEERING MANUAL

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 the 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

Five main boiler types exist:

- Hot water boiler
- Thermal oil boiler
- Steam boiler
- Steam generator
- Exhaust gas boiler

The demands and the sizing of the pumps used for these boiler types are very different.
Fig. 1 and 2 on the right show some of the typical boiler constructions used.

Fig. 3 is a cut-open drawing of the most common construction of a boiler used in the manufacturing industry. At the bottom the burner chambers are seen, which are surrounded with water and at the top the smoke pipes. On the side of the boiler the two feed water pumps are seen.

Fig. 1: A typical boiler construction in the manufacturing industry

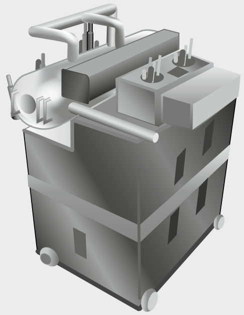
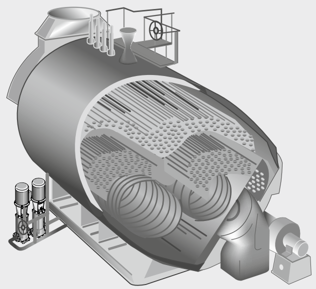


Fig. 2: This construction is typically seen in marine, but is also used in manufacturing industry

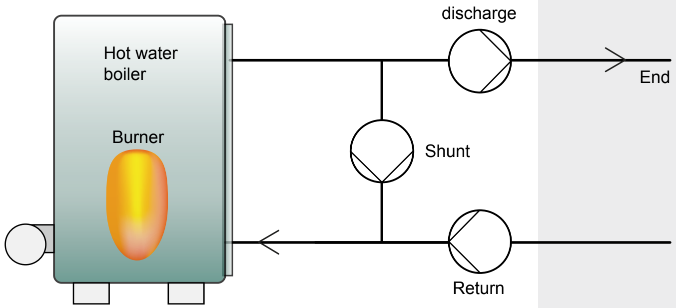
Fig. 3: The most common construction of a boiler used in the manufacturing industry



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. Fig. 4 shows how the pumps are normally installed in a hot water boiler.

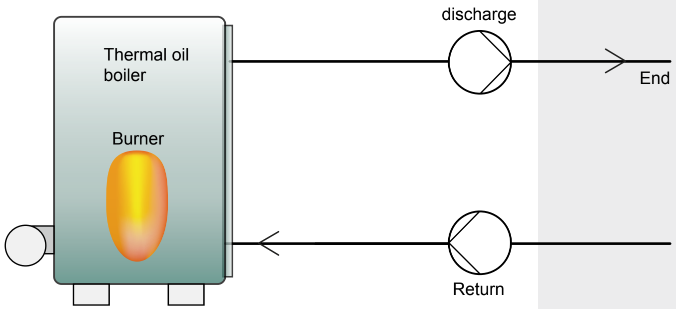
Fig. 4



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. Thermal 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 piping systems is almost identical to that of hot water boilers. So where the unique features of steam are not required, thermal oil can be a good alternative.

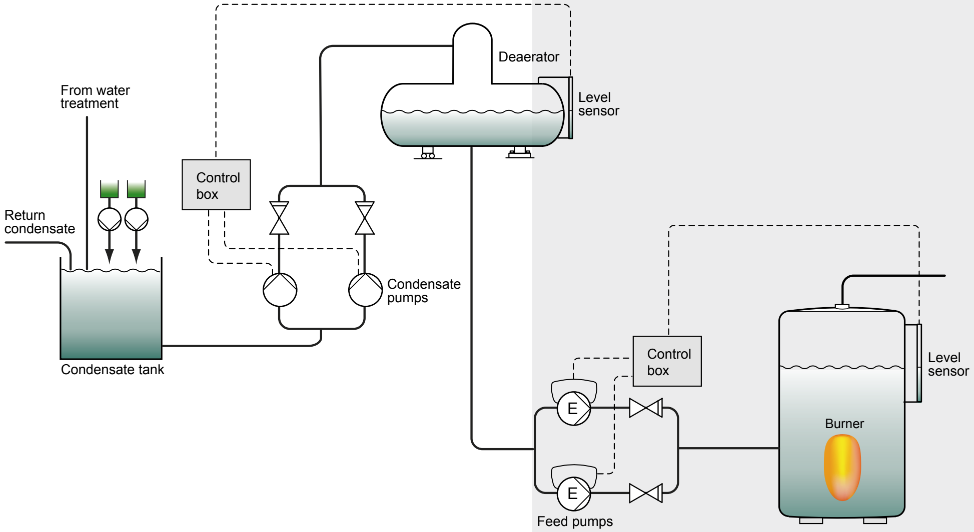
Fig. 5



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 operation. 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. And of course when talking sterilisation it is unique.

Fig. 6



Steam generator

In the steam generator, the feed water and steam are in principle passing through one long tube - designed as winded-up tube coils serially connected. In this long tube (tube coils), the feed water is heated up to the evaporation temperature in the first part and then evaporated in the second part. The intensity of the heat, the feed water flow and the size/length of the tube are adapted, so that the water is exactly fully evaporated at the exit of the tube. This ensures a very small water and steam volume (content of the pressure vessel). Thus there is no buffer in a steam generator, and is it temporary overloaded, i.e. beyond its nominal steam capacity - a separate buffer tank should be provided.

On Fig. 7 is shown a steam generator for the pharmaceutical industry where clean steam out of WFI water (WFI = Water for Injection) is produced. The WFI water is being heated by traditional steam.

The advantages using a steam generator compared to conventional steam boilers:

- Easy to operate - normally no requirement for boiler authorisation
- Rapid start-up and establishing full steam pressure
- Compact and easy to adapt in the existing machinery arrangement
- Price attractive - especially at low steam rates.

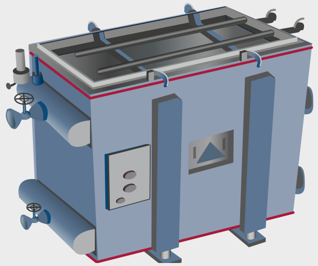
Fig. 7: Steam generator

Exhaust gas boiler

Steam can be produced not only by oil or gas-fired burners, but also by utilising the substantial amount of waste heat in hot flue gasses or exhaust air. The steam evapouration is done like the steam generators, and gives therefore a rapid acting and compact unit.

Utilisation of the waste heat in flue gas of the steam boiler / steam generator itself, is called either an economizer or an exhaust gas boiler. It can be used for preheating the feed water, but also for external purposes including preheating of make-up water, domestic water or central heating water.

Fig. 8: Exhaust gas boiler



Boiler house components

Deaerator

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.

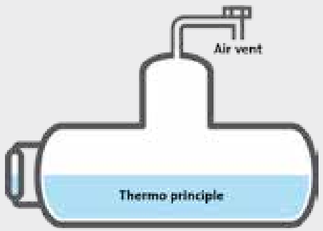
Two primary principles are used with this form of tank design; thermal and vacuum. The tank design used depends on the type of boiler being used. Each principle also has different pump construction requirements.

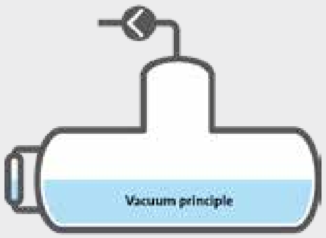
THERMAL PRINCIPLE

A tank using the thermal principle is connected to the atmosphere. 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. The air vent valve mounted on the Deaerator or condenser needs an opening pressure of approx. 0.2 bar. This provides a total pressure of 1.2 bar absolute. This means that the water will boil at a temperature higher than the usual 100˚C which is the normal boiling temperature 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 water to start boiling even at lower temperature than typical 60°C. This in turn removes air from the water. This principle is normally used in steam turbine applications.

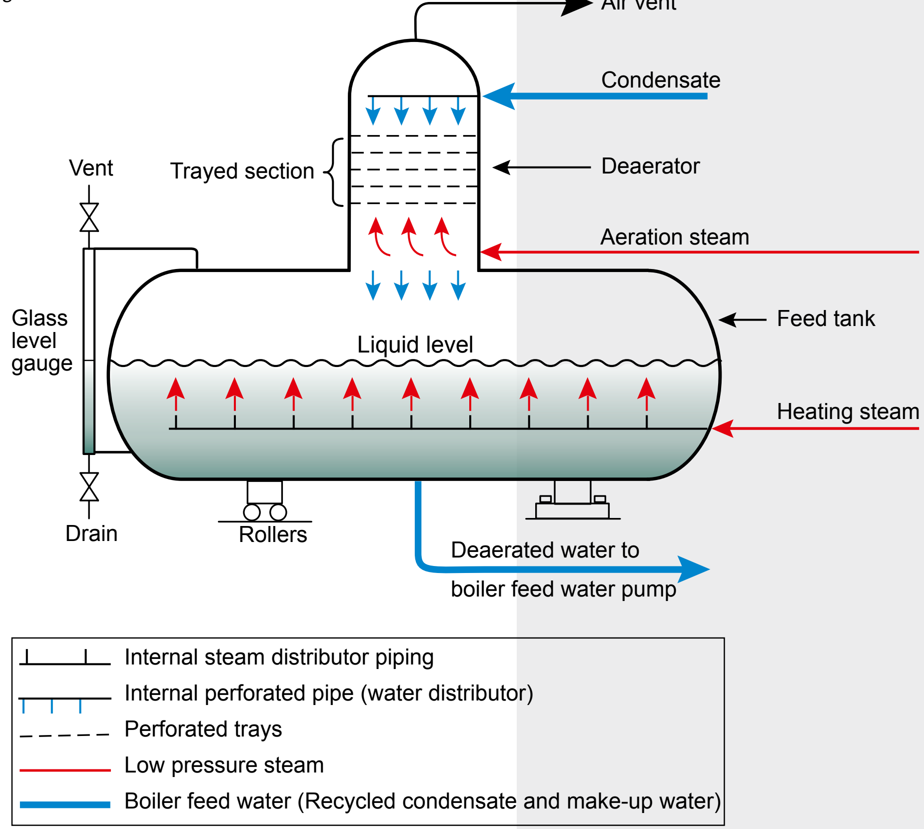




DEAERATOR

The most important task for the deaerator is to reduce the oxygen (O_2) and carbonic acid (H_2CO_3) levels in boiler feed water to protect the boiler against corrosion. It is possible to reduce the oxygen and carbonic acid levels to approx. < 0.02 mg/l of O_2 and 0 mg/l of CO_2, depending on the deaerator construction.

Fig. 9: Deaerator

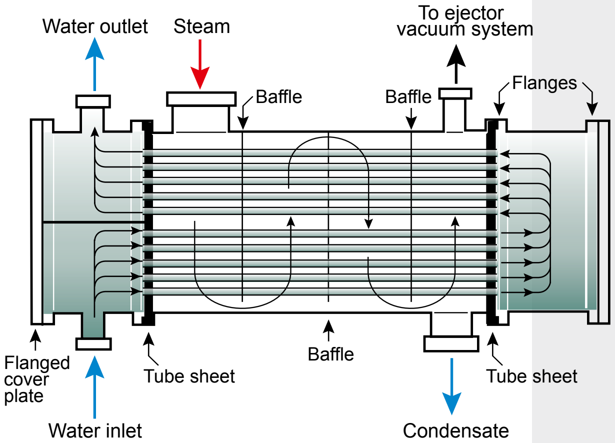


Over the last years it has become more and more normal just to use hot wells or water tanks with a water temperature of approx. 80°C instead of the deareators to get the oxygen out of the water. Instead of boiling the water in these tanks chemicals are dosed to remove the oxygen.

Condenser

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

Fig. 10: Condenser



Economizer

As mentioned earlier, the economizer is more or less the same as an exhaust gas boiler except it doesn't have its own steam chamber but uses the one in the boiler.

Talking economizers, there are normally two different ways of mounting depending whether it is installed on a land-based or marine-based boiler.

On the boiler located on land we use the boiler's flue gas as shown on the sketch. The water circulated above the economizer is normally supplied by the main feed pump, but can also be fitted with its own circulation pump, see Fig. 11 on the following page. The chimney will also include a bypass to allow waste gases to pass the heat exchanger.

Fig. 11

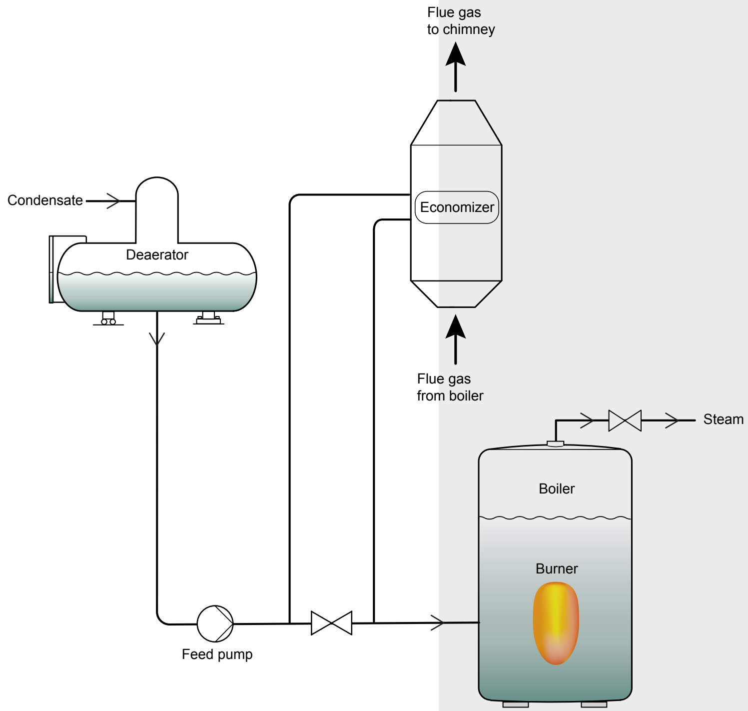
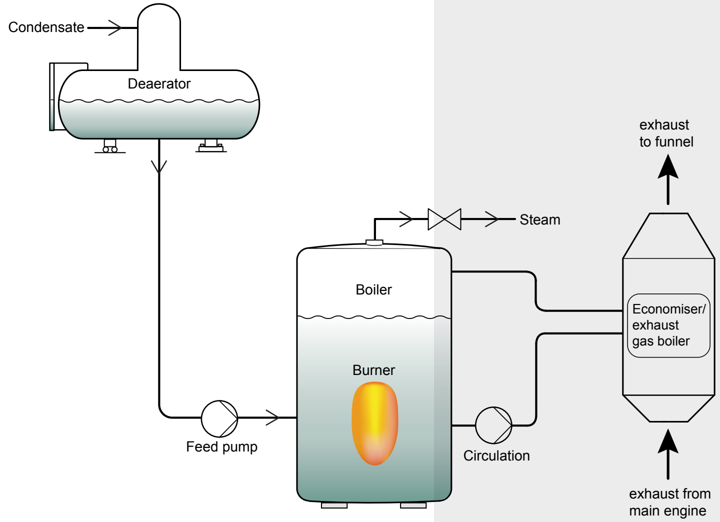


Fig. 12



The economizer on marine boilers differs from the land-based boilers because it is installed in the funnel on the main engine as waste gases released from that source are significantly greater. Energy produced by marine applications often allows for the generation of overheated steam fed directly from economizer and out into the piping.

Referring to the illustration in Fig. 12, the circulation pump has to be sized to the pressure and temperature in the boiler, which may easily be 20 bar and 170°C. Because of this, pumps 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 pipe heat exchanger (the economizer).

When installing an economizer it is very important to monitor, that the flue gas temperature in the economizer, ducts or chimney does not drop below the dew point temperature. If the flue gas condensates and the fuel contained any substances that turn into acids, the condensate will become very aggressive and possibly corrode the parts in contact. If condensation of flue gases is desired in order to reach higher thermal efficiency, please take contact to the fuel supplier for chemical analysis, and select materials for the parts, that can handle the acids.

Hot-well

The importance of the boiler feed tank, where boiler feed water and make-up water are mixed and stored and into which condensate is returned, is often underestimated. Most items in the boiler house are duplicated, but it is rare to have two feed tanks. This crucial item is often the last to be considered in the design process.

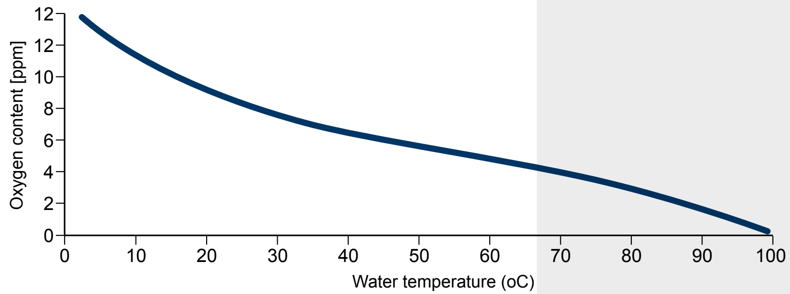
The feed tank is the major meeting place for cold make-up water and condensate return. It is best if

both, together with flash steam from the blow down system, flow through sparge pipes installed well below the water surface in the feed water tank. The sparge pipes must be made from stainless steel and be adequately supported.

OPERATING TEMPERATURE

It is important that the water in the feed tank is kept at a sufficiently high temperature to minimise the content of dissolved oxygen and other gases. The correlation between the water temperature and its oxygen content in a feed tank can be seen in Fig. 13.

Fig. 13: Water temperature versus oxygen content



If a high proportion of make-up water is used, heating the feed water can substantially reduce the amount of oxygen scavenging chemicals required.

Cost savings associated with reducing the dissolved oxygen in feed water by heating

Basis for calculation:

The standard dosing rate for sodium sulphite is 8 ppm per 1 ppm of dissolved oxygen.

It is usual to add an additional 4 ppm to maintain a reserve in the boiler.

Typical liquid catalysed sodium sulphite contains only 45% sodium sulphite.

Obviously a cost is involved in heating the feed tank, but since the water temperature would be increased by the same amount inside the boiler, this is not additional energy, only the same energy used in a different place.

The only real loss is the extra heat lost from the feed tank itself. Provided the feed tank is properly insulated, this extra heat loss will be insignificant.

An important additional saving is reducing the amount of sodium sulphite added to the boiler feed water. This will reduce the amount of bottom blowdown needed, and this saving will more than compensate for the small additional heat loss from the boiler feed tank.

To avoid damage to the boiler itself
The boiler undergoes thermal shock when cold water is introduced to the hot surfaces of the boiler wall and its tubes. Hotter feed water means a lower temperature difference and less risk of thermal shock.

To maintain the designed output
The lower the boiler feed water temperature, the more heat is required in the boiler to produce steam. It is important to maintain the feed tank temperature as high as possible, to maintain the required boiler output.

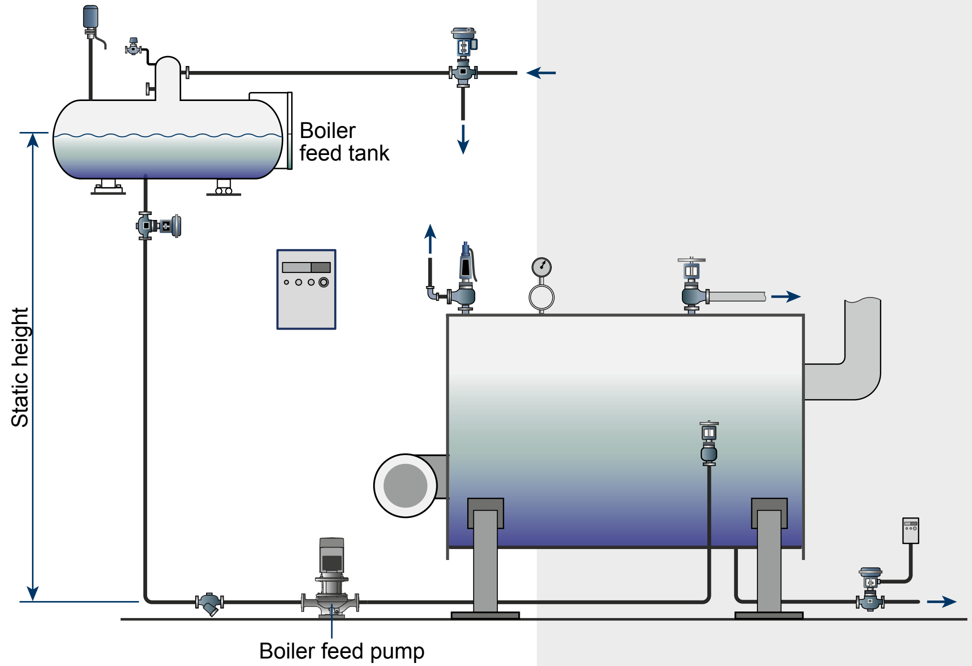
Cavitation of the boiler feed pump
Caution: very high condensate return rates (typically over 80%) may result in excessive feed water temperature, and cavitation in the feed pump.

If water close to boiling point enters a pump, it is liable to flash to steam at the low pressure area at the eye of the pump impeller. If this happens, bubbles of steam are formed as the pressure drops below the water vapour pressure. When the pressure rises again, these bubbles will collapse and water flows into the resulting cavity at a very high velocity.

This is known as 'cavitation'; it is noisy and can seriously damage the pump.

To avoid this problem, it is essential to provide the best possible Net Positive Suction Head (NPSH) to the pump so that the static pressure is as high as possible. This is greatly aided by locating the feed tank as high as possible above the boiler, and generously sizing the suction pipework to the feed pump (Fig. 14).

Fig. 14: NPSH above feed pump



Make-up water
Cold water from the water treatment plant makes up any water losses in the system.

Many water treatment plants need a substantial flow in order to achieve optimum performance. A 'trickle' flow as a result of a modulating control into the feed tank can, for example, have an adverse effect on the performance of a softener. For this reason a small plastic or galvanised steel cold make-up tank is often fitted. The flow from the softener is controlled 'on / off' into the make-up tank. From there a modulating valve controls its flow into the feed tank.

This type of installation leads to 'smoother' operation of the boiler plant. To avoid the relatively cold make-up water sinking directly to the bottom of the tank (where it will be drawn directly into the boiler feed water line), and to ensure uniform temperature distribution, it is common practice to sparge the make-up water into the feed tank at a higher level.

Water level transmitter
In all steam boilers it is of utmost importance to have a constant water level in order to have a safe boiler operation and to maintain a good steam quality.
The steam boiler is normally equipped with the following transmitters:

SAFETY
- Low low level, burner shut down.
- Low level alarm.
- High level alarm.

CONTROL
- Low level, pump start.
- High level, pump stop.

The control level transmitter can also be a modulating type which can work according to the following principles:

- Conductivity probes.
- Float control.
- Differential pressure cells.

The level transmitters can be placed directly in the boiler shell or in external chambers.

The water level detected will always deviate from the actual water level in the boiler. How much it deviates depends on boiler construction and sensor placement.

The use of the different control systems is described in detail under section "Boiler systems".

Level control valve and actuators
The level control valve actuator receives a level signal from the level transmitter and, in response, moves the valve to a position that corresponds to the signal. The actuator moves the valve stem and adjusts the flow depending on the valve characteristic. The valve characteristic depends on valve design and will not be described further in this literature.

CONTROL VALVE SIZING
In order to size a valve for a water application, the following must be known:
- Volumetric flow rate through the valve
- Differential pressure across the valve

Talking valve capacities they are generally measured in terms of K_v. More specifically, K_{vs} relates to the pass area of the valve when fully open, whilst K_{vr} relates to the pass area of the valve required by the application.

The simplified equation for pressure drop when pumping water is expressed like this:

$$V = K_v\sqrt{\Delta P}$$

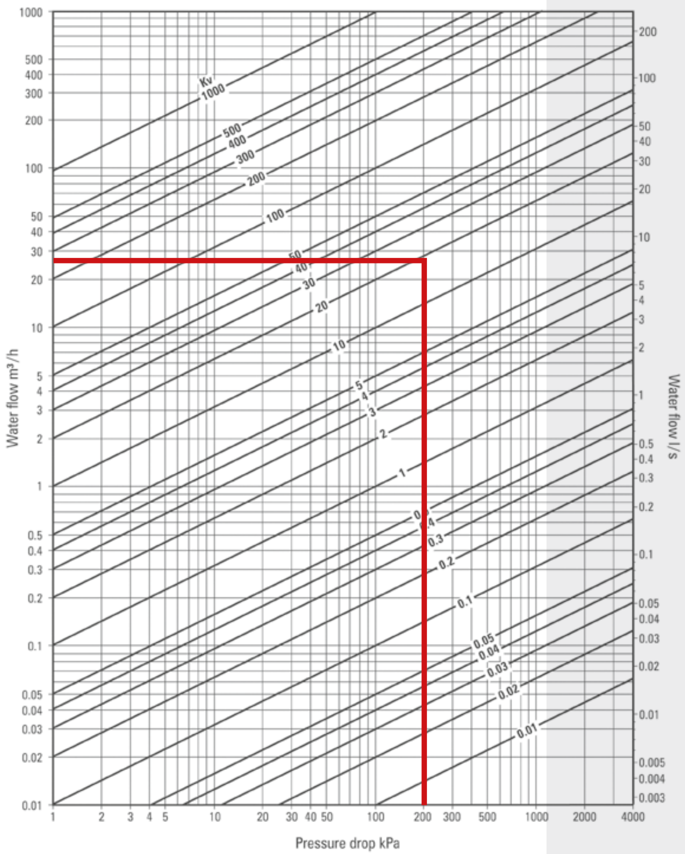
he K_v value for the valve can then be determined:

$$K_v = \frac{V}{\sqrt{\Delta P}}$$

For a boiler application, with a flow of 26 m^3/h including safety factors and the request for 2 bar pressure drop over the control valve, the K_v value is 18.3 which in practice is a K_v of 20.

The values can also be found in a K_v chart:

Fig. 15 (Source: www.spiraxsarco.com)



Boiler systems

Pumps

A large range of pumps can be used for boiler applications depending on type of boiler and where used in the application.

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, economizer circulation and shunt pumps.

Sub-system pumps, such as dosing and water treatment pumps, are also used but will not be described in this literature.

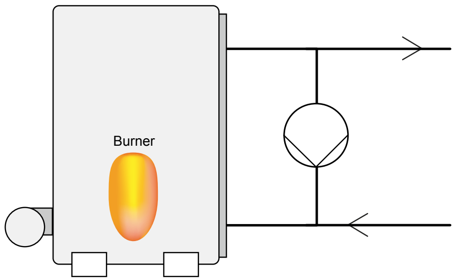
Hot water boiler

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.

On/off shunt pump

Fig. 16



FUNCTION

The shunt pump must ensure that the return temperature to the boiler does not become too low. If the differential temperature between the return pipe and the forward pipe varies too much it will give a huge stress on the boiler structure. The pump must be sized according to the lowest return temperature, meaning it is over-sized most of the time.

BENEFITS

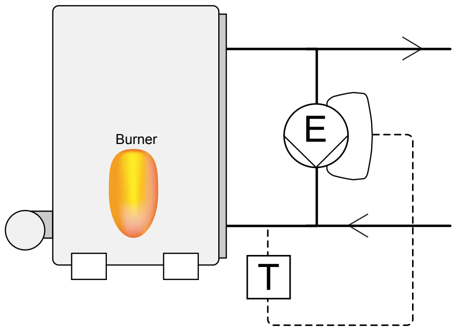
- Inexpensive and easy to install
- Safe operation (few components)

IMPORTANT!

- Information about correct return-pipe temperature to be obtained from boiler manufacturer.
- Same load on boiler to keep same differential temperature.

Shunt pump with variable speed

Fig. 17



FUNCTION

The shunt pump must ensure that the return temperature to the boiler does not become too low. If the differential temperature between the return pipe and the forward pipe varies too much it will give a huge stress on the boiler structure. 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 no matter the load on the system
- Energy savings

IMPORTANT!

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

ACCESSORIES REQUIRED

Temperature sensor, R100/Grundfos Go

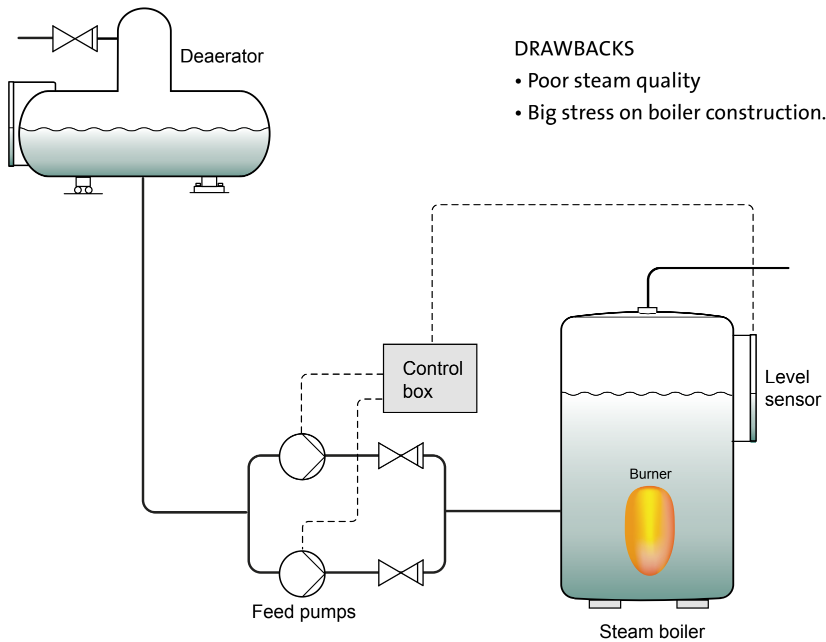
Steam boiler

Steam boiler feeding can normally take place in below 4 ways:

- On/off control
- Through feed valve (with and without bypass)
- Through feed valve and variable speed (with and without bypass)
- Variable speed

The 4 methods mentioned above are the most common and will be described in the following. Please be aware that you can easily find a mix of the 4 systems.

Fig. 18: On/off control



On/off control

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
- Big stress on boiler construction.

Through feed valve

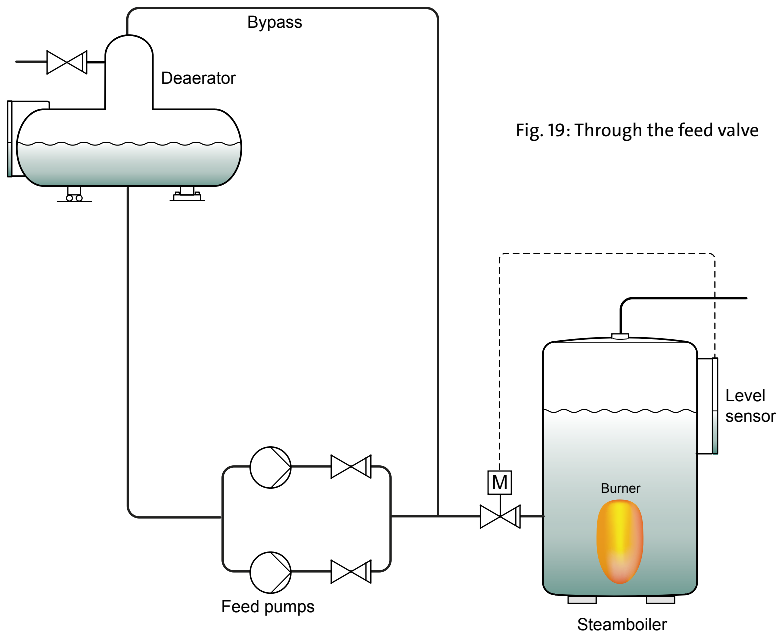


Fig. 19: Through the feed valve

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 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.
Normally there are to ways to make the bypass, either with a valve or an orifice. If it is a valve it is normally controlled that it will start to open when the regulation valve is closed to a certain level. This to avoid the continuously energy loss you would have if it was open all the time.

BENEFITS
• Boiler feed adjusted according to steam consumption, as described.

DRAWBACKS
• The pump must be set to continuous operation (energy consumption)
• Bypass, creates an unnecessary energy loss.
• The feed valve is expensive
• Pressure loss across the feed valve

IMPORTANT!
Remember to size bypass according to the CR pump's min. flow, which is 10% of the 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.

Through feed valve and variable speed

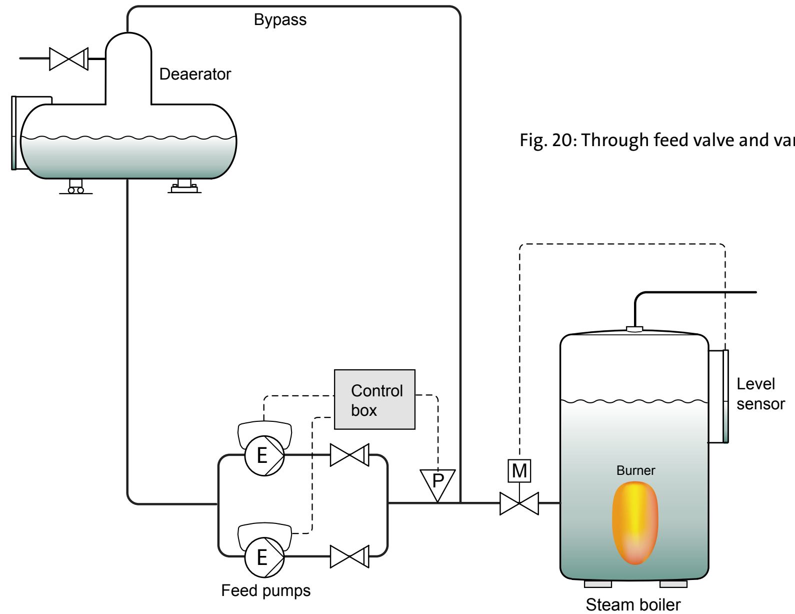


Fig. 20: Through feed valve and variable speed

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 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.
Normally there are two ways to make the bypass, either with a valve or an orifice. If it is a valve it is normally controlled so that will start to open when the regulation valve is closed to a certain level. This to avoid the continuously energy loss you would have if it was open all the time.

BENEFITS
• Boiler feed adjusted according to steam consumption
• Energy savings on pump operation
• Constant differential pressure across the feed valve

DRAWBACKS
• Bypass, with energy loss
• 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.

Variable speed

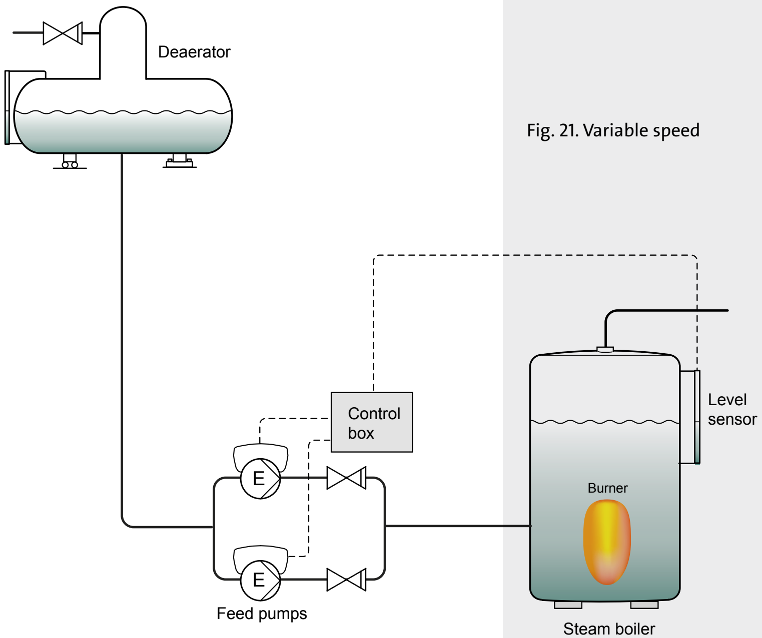


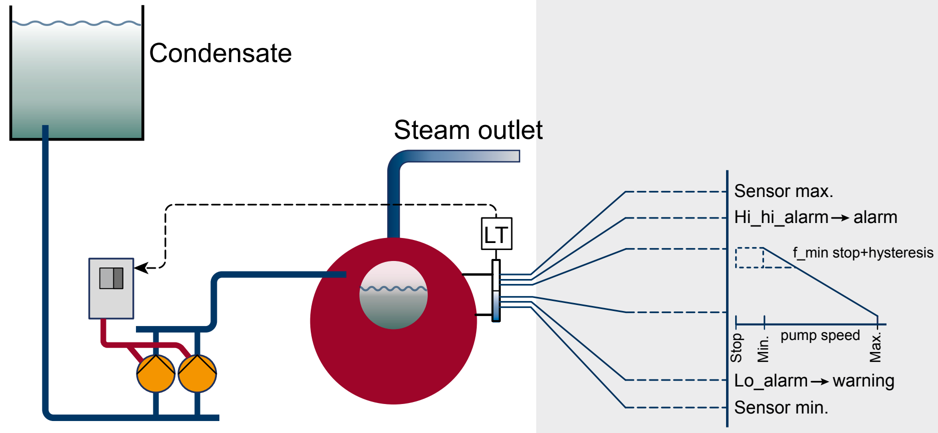
Fig. 21. Variable speed

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.

REGULATION LOOP
The regulation loop has to be set up precisely so the level will be as accurate as needed and the pump will stop if no water is needed.

Boiler feed pump is usually in a duty/stand-by configuration, as shown on the sketch (Fig. 22).

Fig. 22



Energy

By control of the level in the boiler directly with the variable speed pumps you also have the most energy-efficient way of making boiler feeding. There is no unnecessary flow in a bypass and the continuous pressure loss over the control valve is eliminated.

Doing a simple calculation on how big the energy loss actually is, often is quite surprising.
As an example: Standard steam boiler application, with a steam production of 20 m^3/h, and a pressure loss over the valve at 5 bar.
The load profile of the boiler is divided into 5 periods, the following calculations can be made:
100% load = 20 m^3/h in 1752 hours a year
75 % load = 15 m^3/h in 1752 hours a year
50 % load = 10 m^3/h in 1752 hours a year
25 % load = 5 m^3/h in 1752 hours a year
And stopped in the rest 1752 hours a year

Fig. 23

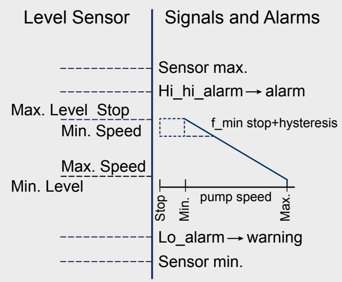


Fig. 24

$$P_{1\,at\,100\%} = \frac{Q \cdot h \cdot 2.72 \cdot hours}{\eta_{motor} \cdot \eta_{pump}} = \frac{20 \cdot 50 \cdot 2.72 \cdot 1752}{0.9 \cdot 0.8} = 6{,}618 kW/h$$

$$P_{1\,at\,75\%} = \frac{Q \cdot h \cdot 2.72 \cdot hours}{\eta_{motor} \cdot \eta_{pump}} = \frac{15 \cdot 50 \cdot 2.72 \cdot 1752}{0.9 \cdot 0.8} = 4{,}964 kW/h$$

$$P_{1\,at\,50\%} = \frac{Q \cdot h \cdot 2.72 \cdot hours}{\eta_{motor} \cdot \eta_{pump}} = \frac{10 \cdot 50 \cdot 2.72 \cdot 1752}{0.9 \cdot 0.8} = 3{,}309 kW/h$$

$$P_{1\,at\,25\%} = \frac{Q \cdot h \cdot 2.72 \cdot hours}{\eta_{motor} \cdot \eta_{pump}} = \frac{5 \cdot 50 \cdot 2.72 \cdot 1752}{0.9 \cdot 0.8} = 1{,}655 kW/h$$

$$\text{Yearly energy savings:} \qquad = \underline{16{,}546 \text{ kW/h a year}}$$

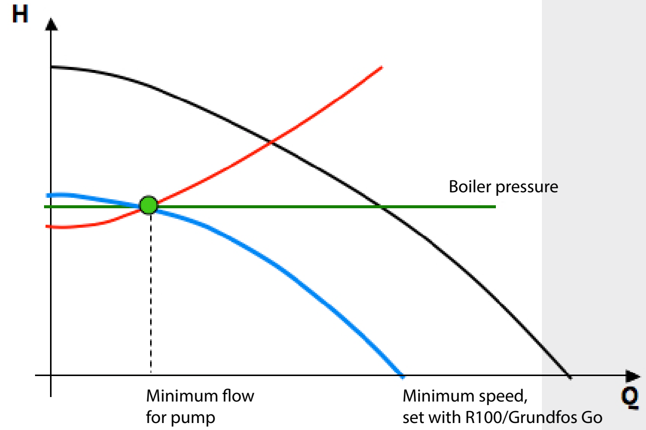
And remember the savings above are without the loss saved in the bypass end.

BENEFITS
• As described, boiler feeding adjusted 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, and its maintenance costs.

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.

Fig. 25



• It must be ensured that the pump stops when steam consumption is zero. May for instance be carried out with a high level switch from the boiler.
• The regulator area may be small. If the 4-20mA level sensor is for example 2 metres and regulation takes place in an area of just 20 cm corresponding to app. 2 mA, then the regulation gab will be very narrow.
• 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 system

Feed water

The importance of correct feed-water treatment for economic operation and for extending life of boiler and equipment cannot be over emphasized. Feed-water treatment is essential in boilers, feedsystems, etc., more particularly in modern boilers of a high evaporative rate. (The faster a steam boiler or generator will convert water to steam, the more rapidly the solids in the water will concentrate). So, large and small water-tube boilers, the typical fire-tube packaged boiler, and steam generators are all examples of this in varying degrees. As all untreated waters carry natural salts, they have to be treated to prevent scale forming.

The three main reasons for water treatment are:

• Prevention of corrosion in feed boiler, steam and condensate systems.
• Elimination of scale.
• Economic boiler operation without carry-over.

CORROSION will reduce metal thickness of tubes or shell. Result: pressure must be reduced and finally boiler condemned.

SCALE reduces the heat flow from fire side to water. Result: higher gas temperature is needed to maintain the same heat transfer and the efficiency of the boiler will drop due to higher losses through the flue gasses.

CARRY-OVER is a collective term to describe the entrainment of a relatively small quantity of boiler water solids with the steam. Carryover occurs as a result of either foaming or priming, or by a combination of both. Foaming is the formation of bubbles on the surface of the boiler resulting in the throwing over of slugs of boiler water with the steam. This is similar to the 'bumping' experienced when water is boiled in an open vessel.

Fig. 26

Impurity	Effect on a boiler
Dissolved gases	Corrosion
Calcium and magnesium salts	These salts are the " hardness in the boiler " Some salts can also cause corrosion
Silica	Can form a very hard scale
Suspended and dissolved solids	Contribute to or cause carryover

DISSOLVED GASES

The two gases which cause corrosion are oxygen and carbon dioxide. The carbon dioxide does so simply by dissolving in the water and forming a weak carbonic acid which attacks the metal in feed systems, boiler or condensate systems. Oxygen is present in all waters, so that red iron oxide forms on a mild steel surface immersed in water. This rusting or, as we call it, corrosion triunes until the metal is corroded away. If the amount of oxygen in the water is restricted, the oxide film does not form so readily; but instead, the surface of the steel tarnishes. This tarnish is usually the development of a thin film of iron oxide on the metal surface which is not so fully oxidized as the red iron oxide, and is more dense, thus tending to resist further corrosive attack. In water of increasing alkalinity, the oxide film becomes more stable and gives more protection to the steel, but until a definite alkalinity is reached, it still tends to break down in selective areas, where pits will develop.

CALCIUM AND MAGNESIUM SALTS

There are two forms of hardness; temporary and permanent. Temporary hardness is due to bicarbonates of calcium and magnesium which breaking to carbonates when the water has boiled. In the boiler the following chemical reaction takes place : Calcium bicarbonate + heat. Calcium carbonate + carbon dioxide + water. Calcium and magnesium bicarbonate are soluble in water but carbonates are insoluble and therefore precipitate as a fine white powder. This precipitate will bake unto the heating surface of a boiler and form a scale.

Permanent hardness is due to calcium and magnesium sulphates, chlorides and nitrates, and these salts cannot be removed by boiling. However, under boiler conditions (resulting in successive concentrations of these hardness salts) the solubility of these salts is soon exceeded and they deposit on the hottest part of the heating surface. The salts of magnesium that form permanent hardness sometimes tend to cause corrosion instead of hard scale formation, e.g. magnesium chloride in an untreated boiler hydrolyses to form corrosive hydrochloric acid.

SILICA

Silica forms scale in a similar way to the permanent hardness salts. When the scale formed is a mixture of silica, calcium and magnesium salts, it is very hard and therefore presents a difficult problem at inspection time.

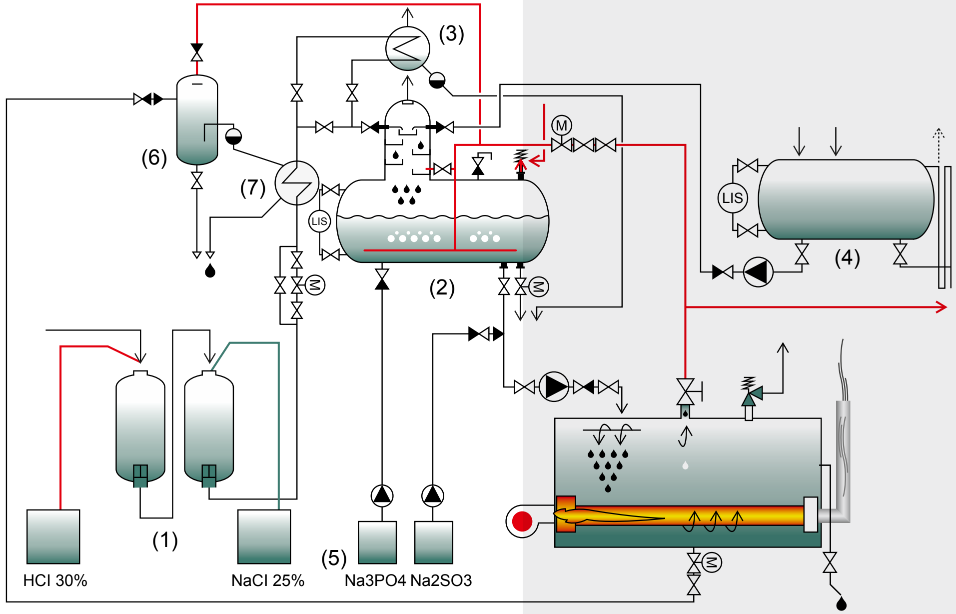
THE SUSPENDED AND DISSOLVED SOLIDS

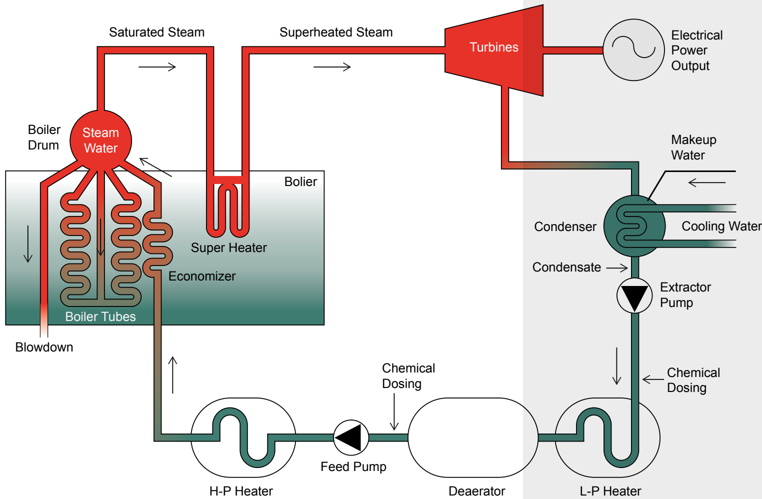
The suspended and dissolved solids cause foaming by becoming absorbed unto the walls of individual bubbles so that small bubbles, instead of coalescing to form large ones and bursting early, repel one another and build up a large volume of small bubbles. If these bubbles burst near the steam outlet, the spray is taken over with the steam. If the bubbles do not burst high in the steam space, the foam can be drawn over with the steam.

The composition of boiler feed water must be such that the impurities in it can be concentrated a reasonable number of times inside the boiler, without exceeding the tolerance limits of the particular boiler design. If the feed water does not meet these requirements it must be pre-treated to remove impurities. The impurities need not be completely removed in all cases, however, since chemical treatment inside the boiler can effectively and economically counteract them.

Where to dose what

Depending on the chemical and its purpose, there are different application points in the boiler system; high-pressure and low-pressure parts can be identified in the following diagrams.





TREATMENTS APPLIED

We can differentiate between two types of treatment:

• **External treatment**: Reduction or removal of impurities from water outside the boiler. In general, external treatment is used when the amount of one or more of the feed water impurities exceed the tolerances of the given boiler system. There are many types of external treatment (softening, evaporation, deaeration, membrane contractors etc.), which can be used to tailor feed water to a particular system.

• **Internal treatment:** Conditioning of impurities within the boiler system. The reactions occur either in the feed lines or in the boiler proper. Internal treatment may be used alone or in conjunction with external treatment. Its purpose is to properly react with feed water hardness, condition sludge, scavenge oxygen and prevent boiler water foaming.

EXTERNAL TREATMENT

It is generally agreed that on steam boilers, the principal feed water treatment should, where possible, be external to the boiler. Depending on the boiler operating pressure and the water requirements, the treatment applied may vary. General guidelines include:

Operating pressure	Treatment applied
<450 psi	Sodium zeolite softening to remove calcium hardness Lime precipitation for silica and hardness removal
450 – 900 psi	Demineralisation to remove calcium, magnesium and sodium hardness
>900 psi	Electrodialysis reversal (EDR) and Reverse Osmosis for high-purity water

The following table shows the quality of water required as the boiler's operating pressure increases.

Boiler steam pressure (psi)	Maximum TDS (ppm)	Maximum alkalinity (ppm)	Maximum hardness (ppm)
Low – 300	3500	700	<20
300 – 450	3000	600	0
451 – 600	2500	500	0
600 – 750	2000	400	0
750 – 900	1500	300	0
900 – 1000	1250	250	0
1000 – 1500	1000	200	0
1500 – 2000	750	150	0
2000 – 3000	150	100	0

Typical requirements for power generation of feed water:

Parameter	Recommended value
Specific conductivity	100 (212
Sodium and potassium	< 10 µg/kg (10 parts/billion)
Silica	< 20 µg/kg
Iron	< 20 µg/kg
Copper	< 3 µg/kg
Carbon	< 200 µg/kg
6000 (19685.04ft)	81.3 (178.3
8000 (26246.72ft)	75.5 (167.9

External water treatment technologies applied can be listed as (ordered from the lowest quality product obtained to the highest quality product):

• Lime – soda softening – with lime softening, hydrated lime (calcium hydroxide) reacts with calcium and magnesium bicarbonates to form a removable sludge. This reduces the alkaline (temporary) hardness. Lime/soda (soda ash) softening reduces non-alkaline (permanent) hardness by chemical reaction.
• Ion exchange – by far the most widely used method of water treatment for shell boilers producing saturated steam.
• Reverse Osmosis

Processes applied for an external boiler feed treatment (depending on the level of water purity):
• Water softening
• Dealkalisation: Removes more TDS than the classic water softening.
• Demineralisation: Used for very high pressure boilers such as those in power stations.

In many cases external treatment of the water supply is not necessary and the water can be treated only by internal methods.

INTERNAL TREATMENT
Internal treatment can constitute the unique treatment when boilers operate at low or moderate pressures, when large amounts of condensed steam are used for feed water, or when high-quality raw water is available. This treatment comprises the dosing of chemicals which in turn will help to:
1. React with any feed-water hardness and prevent it from precipitating on the boiler metal as scale. Scale inhibitors are used with this purpose.
2. Condition any suspended matter such as hardness sludge or iron oxide in the boiler and make it non-adherent to the boiler metal; Scale inhibitors are also used for this purpose.
3. Provide antifoam protection to allow a reasonable concentration of dissolved and suspended solids in the boiler water without foam carry-over; antifoamers are applied.
4. Eliminate oxygen from the water and provide enough alkalinity to prevent boiler corrosion. Corrosion inhibitors are dosed.

In addition, as supplementary measures an internal treatment should prevent corrosion and scaling of the feed water system and protect against corrosion in the steam condensate systems.

Feed water, i.e. treated make-up water mixed with condensate returns, can be treated to remove oxygen. This can be done through a feed water heater, deaerator, or economiser. Often oxygen scavengers may be added to further reduce oxygen.

Further treatment:
Special attention must be paid to steam and condensate treatment, as the steam will leave behind most chemicals. Special volatilising chemicals are added to travel with the steam and protect condensate lines from corrosion. This can be through pH control or a filming agent. Some corrosion inhibitors are injected directly in condensate lines. Antifoam agents may also be added to prevent carry-over of dissolved materials with steam.

Chemicals used
During the conditioning process – which is an essential complement to the water treatment program – specific doses of conditioning products are added to the water. The commonly used products include:
• Phosphates-dispersants, polyphosphates-dispersants (scale inhibitors): reacting with the alkalinity of boiler water, these products neutralize the hardness of water by forming tricalcium phosphate, and insoluble compound that can be disposed and blow down on a continuous basis or periodically through the bottom of the boiler.
• Natural and synthetic dispersants (scale inhibitors): increase the dispersive properties of the conditioning products. They can be:
• Natural polymers: lignosulphonates, tannins
• Synthetic polymers: polyacrilates, maleic acrylate copolymer, maleic styrene copolymer, polystyrene sulphonates etc.
• Sequestering agents: such as inorganic phosphates, which act as inhibitors and implement a threshold effect.
• Oxygen scavengers: sodium sulphite, tannis, hydrazine, hydroquinone/progallol-based derivatives, hydroxylamine derivatives, hydroxylamine derivatives, ascorbic acid derivatives, etc. These scavengers, catalysed or not, reduce the oxides and dissolved oxygen and may also passivate metal surfaces. The choice of product and the dose required will depend on whether a deaerating heater is used.

• Antifoaming or anti-priming agents: mixture of surface-active agents that modify the surface tension of a liquid, remove foam and prevent the carry-over of fine water particles in the steam.

Available technologies
Pumps:

Process	Equipment	Grundfos products	Comments
Boiler feeding	Multi-stage centrifugal pump (low NPSH)	CR pump with modified software	Case story: CRN 64-2 with Air-Cooled Top for boiler feeding at high temperature in Indonesia Case story: CR32 and CR45 for boiler feeding allow energy saving efficiency up to 40%.
Condensate recirculation	Centrifugal pumps	CR, NB/NK, MTR	
	Inline pumps	Paco VLS	
	End-suction pumps	Paco LF	
	Canned style pumps	Peerless Hydroline	
Oxygen removal	Dosing pumps	SMART Digital, DME	
Phosphate dosing	Mechanical dosing pumps	DMH	Phosphate buffers the water to minimize pH fluctuation. It also precipitates calcium or magnesium into a soft deposit rather than a hard scale. Additionally, it helps to promote the protective layer on boiler metal surfaces. However, phosphate forms sludge as it reacts with hardness; blow-down or other procedures should be established to remove the sludge during a routine boiler shutdown.

TYPES OF STEAM TRAP

• Thermostatic (operated by changes in fluid temperature) – The temperature of saturated steam is determined by its pressure. In the steam space, steam gives up its enthalpy of evaporation (heat), producing condensate at steam temperature. As a result of any further heat loss, the temperature of the condensate will fall. A thermostatic trap will pass condensate when this lower temperature is sensed. As steam reaches the trap, the temperature increases and the trap closes.

• Mechanical (operated by changes in fluid density) – This range of steam traps operates by sensing the difference in density between steam and condensate. These steam traps include 'ball float traps' and 'inverted bucket traps'. In the 'ball float trap', the ball rises in the presence of condensate, opening a valve which passes the denser condensate. With the 'inverted bucket trap', the inverted bucket floats when steam reaches the trap and rises to shut the valve. Both are essentially 'mechanical' in their method of operation.

• Thermodynamic (operated by changes in fluid dynamics) – Thermodynamic steam traps rely partly on the formation of flash steam from condensate. This group includes 'thermodynamic', 'disc', 'impulse' and 'labyrinth' steam traps.

Also loosely included in this type are 'fixed orifice traps', which cannot be clearly defined as automatic devices as they are simply a fixed diameter hole set to pass a calculated amount of condensate under one set of conditions.

All rely on the fact that hot condensate, released under dynamic pressure, will flash-off to give a mixture of steam and water.

Pump sizing

In the EU, the EN 12952-7 norm has to be used when sizing pumps. However, please check the 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%.

(So in basic the pump size must be 25% larger than what is mentioned on the boiler nameplate, when it comes to flow. Remember to add the amount of water in the bypass. The amount can be controlled by an orifice or by control valve which might be open at the same time as the regulation valve)

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.

(So in basic the pump size must be 10% larger than mentioned on the boiler nameplate, when it comes to pres-

sure. Remember to add the pressure loss in regulation valve and pipes between pump and boiler.)

Besides the rules and regulations above, you cannot just read the flow and pressure on the boiler nameplate and use this data to size the pump. This is because of the high temperature of the water and hereby the lower density of the pumped water. See the example below.

Be aware that pumps in boiler applications are not 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, see fig. 28.

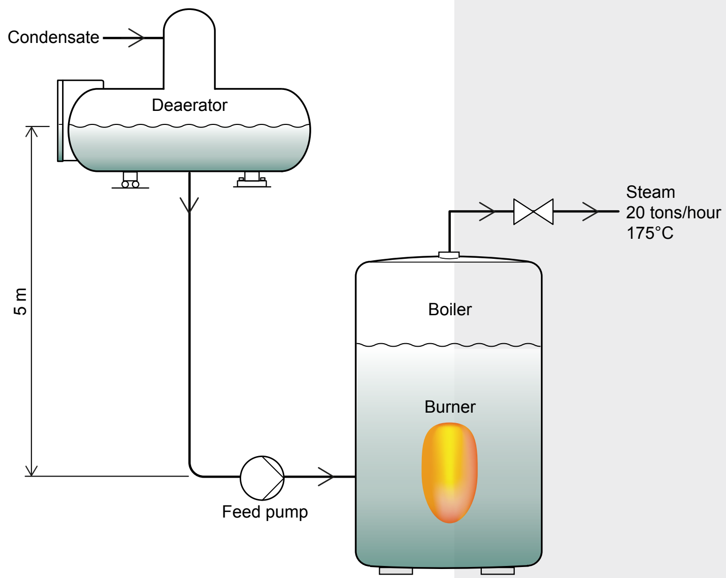
Q_{Boiler} = 20 tons/hour

$P_{Boiler\ max}$ = 12.5 bar

$P_{Boiler\ operating}$ = 10 bar

Temp. = 175°C

Fig. 27



It is seen on the illustration above, that 175°C mentioned on the nameplate is the temperature of the steam in the outlet of the boiler. This information, however, is of no use, as the pump never registers what happens in the boiler. **When sizing, always use the temperature in the deaerator**.

From the vapour table the following data of water at **a temp. of 104°C is given**.

Density (rho)= 955.2 kg/m³

Vapour pressure = 1.1668 bar

First the data from the nameplate have to be converted into m³/h and mWC, which can be used in the sizing.

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

$$h_{Boiler} = \frac{p_{Boiler}}{\rho \cdot g} = \frac{12.5 \cdot 10^5}{955.2 \cdot 9.81} = 133.4 m$$

$$h_{Operating} = \frac{p_{Boiler}}{\rho \cdot g} = \frac{10 \cdot 10^5}{955.2 \cdot 9.81} = 106.7 m$$

Apply safety factors from EN 12952-7, flow and head becomes as specified below.

$Q_{Pump\ max}$	= 1.25 x Q_{Boiler}	= 1.25 x 20.9	= **26.1 m³/h**
$Q_{Pump\ continuous}$	= 1.15 x Q_{Boiler}	= 1.15 x 20.9	= **24.0 m³/h**
h_{Pump}	= 1.1 x h_{Boiler}	= 1.1 x 133.4	= **146.7 m**

In the example the pressure drop in regulation valve and flow in bypass has not been taken into consideration.

All values are now calculated and the pump can be chosen. Please note that the pump does not have to handle both flow and pressure with safety factors at the same time.

It should be carried out as shown below and in fig 29.

Situation 1:
Flow 26.1 m³/h with safety factor at 133.4 m

Situation 2:
Head 146.7 m with safety factor at 20.9 m³/h

From these situations the following pump is chosen as it can handle both situations.

Now the pump is selected but before ordering, the $NPSH_A$ value has to be calculated.

$NPSH_A$ = Pressure AVAILABLE to the pump from the system.

$NPSH_R$ = Pressure REQUIRED from the pump to avoid cavitation.

To avoid pump cavitation, the following has to be accomplished, $NPSH_A > NPSH_R$

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

$NPSH_A$ = Pressure available at inlet of pump.

h_b = Atmospheric and deaerator operating pressure at pump site.

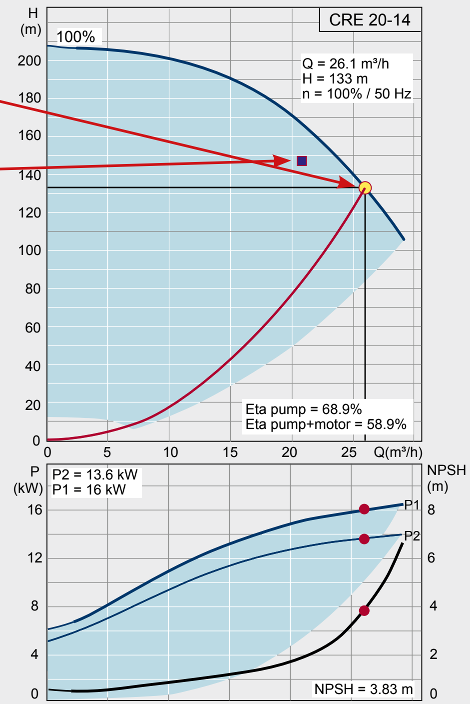
h_f = Friction loss in suction pipe.

h_v = Vapour pressure of liquid.

h_{geo} = Height between water level in deaerator and suction side of pump.

h_s = Safety factor. Normally estimated between 0.5 and 1 m.

Fig. 28



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

$$NPSH_A = \frac{p}{p \cdot g} - h_f - \frac{p}{p \cdot g} - h_{geo} - h_s = \frac{(1.01325 + 0.15355) \cdot 10^5}{955.2 \cdot 9.81} - 2 - \frac{1.1668 \cdot 10^5}{955.2 \cdot 9.81} + 5 - 1 = 2.0m$$

As mentioned earlier the density of 104°C water must be used as this is what the pump meets.
However, taking another look at the formula it is obvious that the h_b and the h_v equalize each other. The reason is that the water in the deaerator is normally kept at the boiling point.

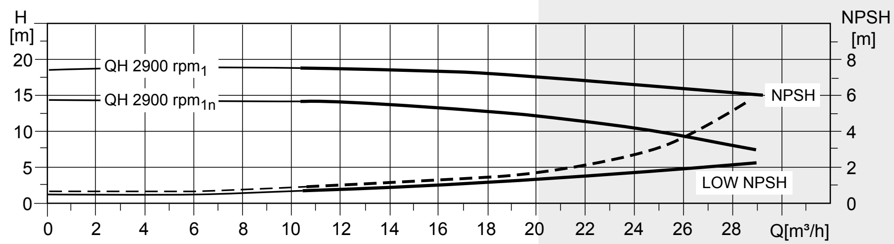
This phenomenon will always occur in a boiler system and because of that, the formula can be simplified:

$NPSH_A = h_f - \pm h_{geo} - h_s$

Instead of using boiling to drive the oxygen out of the water, it is possible to add chemicals instead. In that type of application the water is heated to approx. 80°C instead.

The application gives an $NPSH_A$ at 2 m, and the selected pump has a NPSH-value way above that. Due to this it is necessary to look at the low NPSH versions of the pumps, see fig. 29.

Fig. 29



As the curve shows, this pump can be used in a low NPSH version.
A pump to do the job has been found, fig. 31. Put in the actual duty point and it looks alright, but if it is compared to the pump with 2 impellers less, the latter looks even better, fig. 32. However, please be aware if the pump with 12 impellers is chosen, it must run over-synchronous to reach the duty point according to the EN norm. The choice depends on the application and requests.

Fig. 30

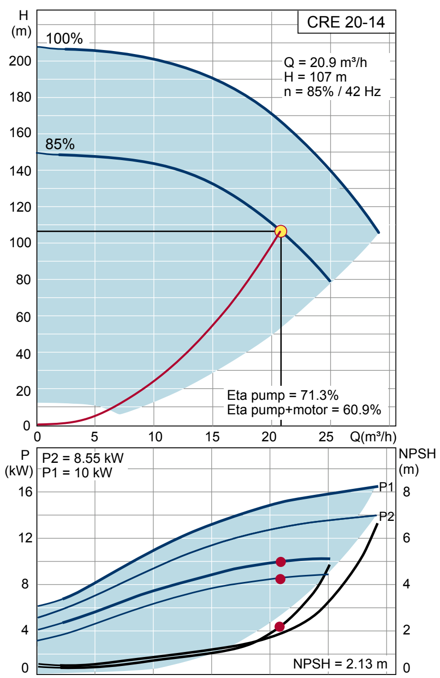
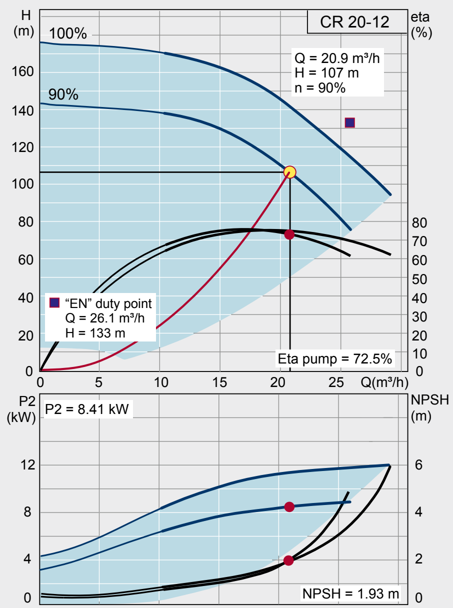


Fig. 31



Grundfos iSOLUTIONS

Grundfos iSOLUTIONS

Grundfos iSOLUTIONS is bringing intelligence into the complete pumping process. Grundfos iSOLUTIONS takes a holistic approach to the pump control and utilises the intelligence to reduce the number of control valves and unnecessary energy consumption.

GENERAL BENEFITS

1. Energy saving

• Reduced Life Cycle Cost and reduced CO_2 emission

2. Increased comfort

• Reduced noise from installation,
• Constant pressure
• No water hammering

3. Make processes work

• Adapts automatically to changes in system
• Control and regulation of critical parameters

4. Reduced total system cost

• Speed controlled pumps can make some valves etc. unnecessary
• Reduced installation and commissioning costs

5. Protection of pump, motor and electronics

• Reduced stress on motor, pump and system
• Overload protection of motor and electronics

PUMP CURVE COMPENSATION

In boiler feed the pumps are often operating at low flow and still at full boiler pressure. When these conditions are present centrifugal pumps have some limitations in their natural performance as the pump curve gets unstable in the low flow area. This gets even more explicit when the load curve is flat, like in boiler feed, and that is a regulating challenge. See fig. 32 and 33.

Fig. 32

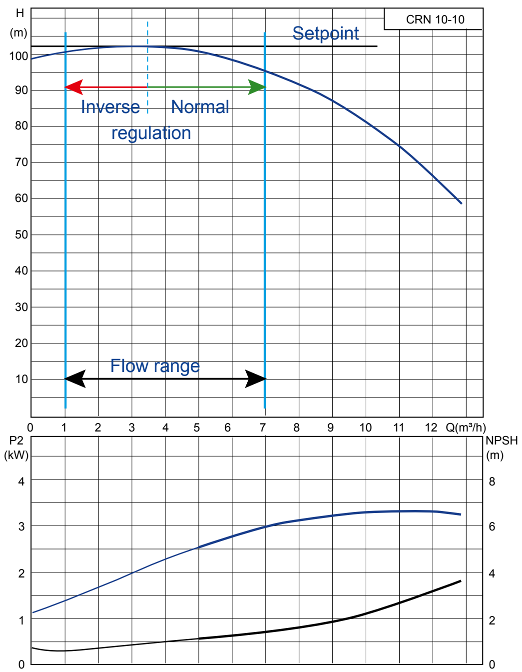
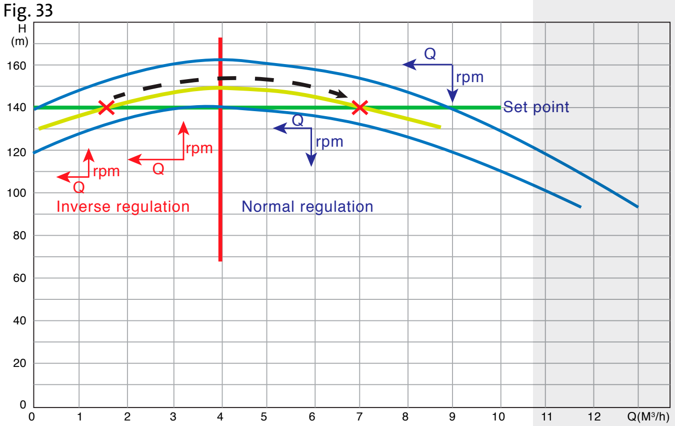


Fig. 33



As a special function in the Grundfos frequency converter. it is possible to compensate for this phenomenon by altering the internal motor control.

The maximum RPM of the motor is increased to 55 Hz, or 58 Hz if required, and at the same time the slippage of the motor is increased.
When the pump is running at low load, due to low flow, the speed of the pump is high. When the flow increases the load increases and because of the larger slippage the pump speed will decrease and fold back to the original pump curve at 50 Hz, even though the motor is still running 55 Hz. See fig. 34.

The pump curve is now continuously decreasing and the instable part of the pump curve is eliminated.

More important: The regulating loop can work as expected. See fig. 35.

Air-cooled top

As mentioned in passage Economizer, the boiler feed pumps are sometimes installed so that they meet the boiler pressure and temperature. These temperatures are sometimes higher than what the shaft seals can handle.

The solution can be an air-cooled top.
A CR pump equipped with air-cooled top can handle temperatures of 180°C in water and 240°C in thermal oil.

The air-cooled top separates the seal chamber from the pump by an air-cooled chamber, generating an insulating effect similar to that of thermos. The cooling air from the motor keeps the chamber cooled down.
Via a small gap at the shaft from the pump to the air-cooled top, a small quantity of the pumped liquid ensures that the seal chamber is always filled with liquid.

Fig. 34

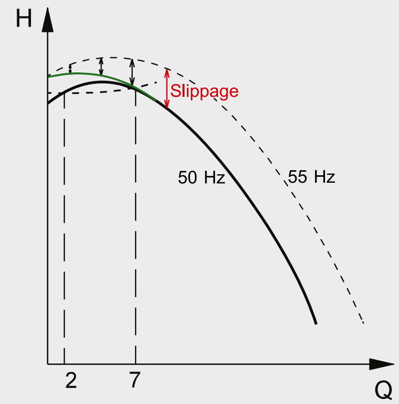
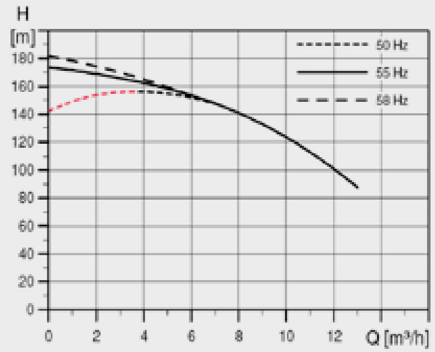


Fig. 35



The air-cooled top solution is a "stand alone" pump meaning no external liquid is needed to cool down the shaft seal.

Low NPSH

The CR Low NPSH is actually a standard pump provided with an oversize impeller in the first stage. The oversize impeller has a larger eye than the standard impeller and therefore better capable of handling poor inlet pressure and hot water.

The Low NPSH can handle the same operating pressure and temperature as the standard CR pumps.

MAGdrive

Double shaft seal or Magdrive

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 operate parallel as duty standby pumps. Here, there is a risk that the standby pump may let air through the shaft seal due to 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.

Double seal

Can be applied in hot water installations, i.e. economizer applications, where the quench liquid is used for cooling shaft seal surfaces.

Can also be applied in vacuum installations where it is necessary to ensure, that air does not enter the condensate.

Fig. 36 Air cooled top

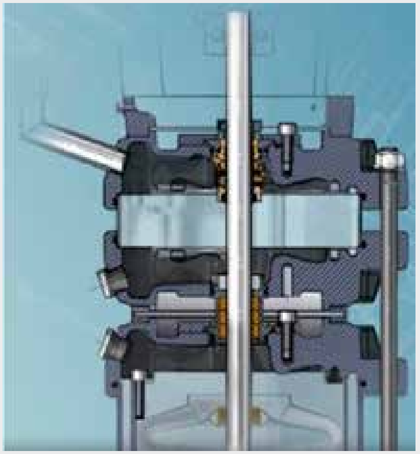
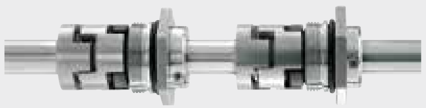


Fig. 37 Double seal



Bearing flange

The bearing flange is an additional flange with an oversize ball bearing to absorb axial forces in both directions.
The bearing flange ensures long life time when running conditions are rough.

The typical use of bearing flanges:

• When the pump is equipped with standard motor the bearing flange can compensate for the hydraulic forces from pump, ensuring an acceptable lifetime on motor bearings which are not dedicated for pump applications.
• When the pump is run with higher inlet pressure than the maximum pressure recommended.

MP 204

If the pumps in the boiler system are without frequency converters it is important to protect them in another way. For that, Grundfos has developed the MP 204, which is an intelligent motor protection, that not only protects the motor but also tells something about the performance of the pump/motor.

The features that it can measure are among others:

• Load issue.
• Power supply.
• Temperature.
• Ground fault.

CUE

If the E-solution mentioned earlier, is not appropriate, with the frequency converter installed directly on the motor, or the motor power is too high for an "on board" solution, Grundfos also has a wall-mounted frequency converter, the CUE.

Key benefits by CUE compared to standard VLT:

• Very easy start-up wizard

Fig. 38: Bearing flange

Fig. 39: MP 204

Fig. 40: CUE

- GRUNDFOS graphical display
- Well-known GRUNDFOS E-pump functionality as standard
- Pre-programmed for GRUNDFOS pumps
- RFI filter (C1) for domestic areas included for:
  – 1 x 200-240V – all sizes
  – 3 x 200-240V – all sizes
  – 3 x 380-500V – up to / including 90kW
- RFI filter (C2 or C3) for industrial areas included for all remaining sizes and voltages
- Bearing supervision as standard (for standard motors with re-lubrication facilities)
- Standstill heating possibilities (for motors in condensing areas)
- GRUNDFOS GENIbus as standard

CIM/CIU:

CIM/CIU products are products developed by Grundfos so electronic solutions mentioned earlier, such as the MGE motor, MP204 and CUE can communicate with the rest of the control world. The CIM/CIU gateways can translate the Grundfos fieldbus to all other standard fieldbus types used in the market for example Profibus, Modbus and Lon. The CIM/CIU products are built in two versions; one for wall-mounting and one as add-on card. Add-ons are for a limited series of products.

Monitor

The Grundfos CR Monitor is a product that takes early warning to a new level. Normally, when we talk monitoring systems there is nothing between 'All okay' and 'ALARM!' but the CR Monitor deals with that and introduces 'Warning'. This warning gives you time to act to prevent unnecessary power loss and breakdown and most importantly to prevent production loss due to lack of steam production. This new, automated supervision tool can foresee efficiency drop, pump failure and prevent cavitation in inline centrifugal pump installations. And especially caviation problems which in the end will lead to efficiency drop and a broken pumps are faults we see most often in boiler feed installations.

Fig. 41: CIM/CIU

Fig. 42: Monitor

The main tasks of CR Monitor is, as mentioned earlier, surveillance, surveillance, surveillance – and simple communication. Despite the complexity that makes the unit possible, the system only communicates on three levels: 'All okay', 'Warning' and 'ALARM'. The latter two are accompanied by plain language interpretations of the data that trigger the warning.

Cavitation prevention

Without all standard measurings and the intelligent efficiency measuring it also measures how close the installation is to cavitation. Normally the first sign of cavitation which meets the pump is the disconcerting sound of 'gravel' from the pump.
And especially in boiler feed applications where there is always a risk of cavitation (sometimes impossible to avoid), the CR Monitor can constantly report on the available NPSH at any given moment. And not only that: if you have had cavitation because a fault or another unnormal operation pattern of the boiler has happened the CR Monitor can immediately tell by the efficiency monitoring if the cavitation has harmed the pump. So said in another way ***CR Monitor can give peace of mind***.

Power-saving

By monitoring the pump efficiency, it is possible to assess the state of the pump hydraulics. So not only if you have faults in the system but also if you just have simple wear of the pump hydraulic, the CR Monitor will warn you before the pump completely stops. And efficiency monitoring becomes a decision-making tool. So once a certain efficiency drop has been reached, the decision can be made to service the pump, restoring its original capacity.

It can also be a question of getting the most for your maintenance time and money. There's no point in servicing a pump every 12 months if it does not need it. So, ***fundamentally it monitors that the efficiency is at its best around the clock regardless of duty point.***

Some of the unique advantages and selling points are mentioned below.

SURVEILLANCE OF MOTOR AND PUMP:

- Efficiency (no unnecessary power loss)
- Under/overvoltage
- Overheating
- Too high power consumption
- Bearing surveillance
- Protection against dry-running
- Cavitation prevention

SYSTEM AND LIQUID SURVEILLANCE:

- Process out of range
- Liquid temperature
- Pressure
- Flow
- Aux analogue input

REDUCE MAINTENANCE AND STOCK:

- Periodic maintenance is history
- No unnecessary maintenance.
- Reduction of spare parts on stock
- Reduction of man hours to service
- Regular manual pump inspection is history
- Unexpected downtime is reduced to an absolute minimum.
- CR Monitor provides supervision 24/7/365

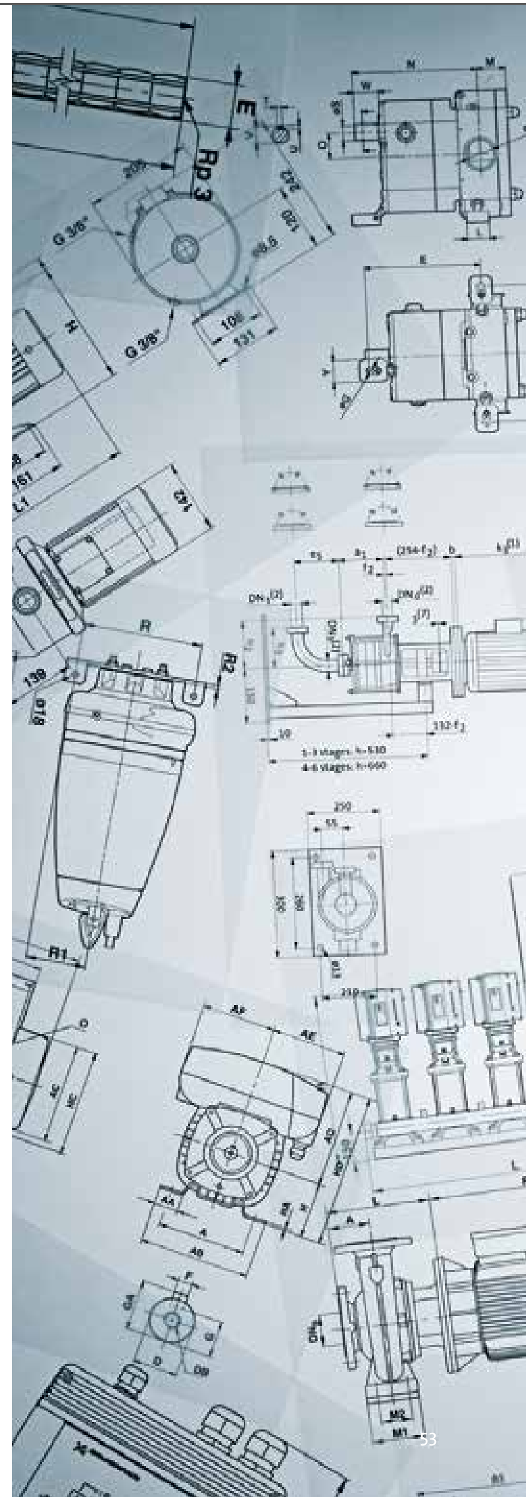
Level control condensate

Traditionally, float controls have been used for this application. Modern controls use level probes, which will give an output signal to modulate a control valve. Not only does this type of system require less maintenance but, with the use of an appropriate controller, a single probe may incorporate level alarms and remote indicating devices.

Level probes can be arranged to signal high water level, the normal working (or control) water level, and low water level. The signals from the probe can be linked to a control valve on the cold water make-up supply. The probe is fitted with a protection tube inside the feed tank to protect it from turbulence, which can result in false readings.

Water level indicator

A local level indicator or water level gauge glass on the feed tank is recommended, allowing the viewing of the contents for confirmation purposes, and for commissioning level probes.

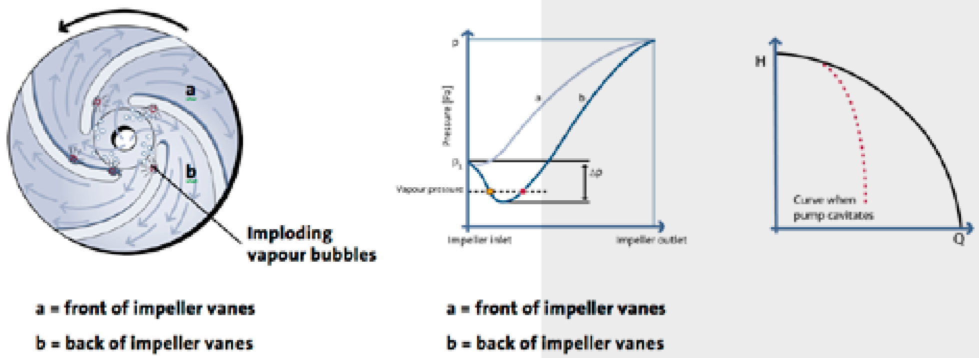


Theory/problems

Cavitation

Since 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 will occur. This is because the pump has to "pull" the water in the first impeller and as a result, the pressure will drop a little and the water will start to evaporate. When the pressure is rising through the impeller and the small steam bobbles begin to implode and return to liquid form, it 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 to reduce the pump's NPSH value. See more under sizing of pumps.

Fig. 43



Water hammer

Water hammer (or, more generally, fluid hammer) is a pressure surge or wave resulting when a fluid (usually a liquid but sometimes also a gas) in motion is forced to stop or change direction suddenly (momentum change). Water hammer commonly occurs when a valve is closed suddenly at the end of a pipeline system, and a pressure wave propagates in the pipe. It may also be known as hydraulic shock.

This pressure wave can cause major problems, from noise and vibration to pipe collapse. It is possible to reduce the effects of the water hammer pulses with accumulators and other features.

Water hammer in boiler feed applications normally happens when interchanging between the duty/standby pumps. The water in the standby pump is often cold and when the column of cold water hits the warm part, water hammer can occur. It can also occur between the pump and the boiler if valves are being closed fast, for example when changing from bypass to filling the boiler.

Column separation

Column separation is a phenomenon that can occur in a boiler feed application between deaerator and the pumps. It happens if the pressure in the pipeline drops rapidly to the vapour pressure of the liquid, the liquid will vaporise and a "bubble" of vapour will form in the pipeline. This is most likely to occur if knees or valves (changes in pipe slope) are installed in the piping. When pressure later increases above vapour pressure of the liquid, the vapour in the bubble returns to a liquid state leaving a vacuum in the space formerly occupied by the vapour. The liquid on either side of the vacuum is then accelerated into this space by the pressure difference. The collision of the two columns of liquid, (or of one liquid column if at a closed end,) results in water hammer and causes a large and nearly instantaneous rise in 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.

BLOWDOWN / SKIMMING

A problem often seen in boiler applications is cavitation due to bottom blowdown of the boiler. A bottom blowdown is when water is let out from the water reservoir in the bottom of the boiler. The reason for doing this blowdown 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 blowdown.

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

The pump problem starts when the blowdown 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, meaning that the required NPSH value for the pump increases dramatically. And this results in cavitation and over time breakdown of the pump.

SAFETY VALVE

The safety valve is a very important fitting. Its function is to protect the boiler shell from over-pressure and subsequent explosion.

Always ensure that local standards are complied with.

The following standards are examples:

BS 6759 in the UK, for materials, design and construction of safety valves.

BS 2790 in the UK, for the design and manufacture of shell boilers of welded construction.

EN ISO 4126 Continental Europe, General requirements for safety valves.

Please see manufacturers' material for detailed dimensioning and installation instructions.

WEEKEND SHUT-DOWN

A lot of steam boiler applications have weekend shut-down. This means that the steam production is stopped during the weekend and the boiler is kept at a lower temperature but still ready for start-up again. How they choose to carry out this standby period varies 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 the boiler is started 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.

STEAM CONSUMPTION CHANGES

Often the steam consumption changes over time and sometimes the production of steam is larger than stated on the boiler nameplate and hence the data available for Grundfos during sizing of the boiler feed pumps. This may result in too small pumps; meaning that the pumps run with too large flow and because of this, a higher NPSH is required.

An example is a customer that once a month used steam for an hour to clean the turbines at the site. This resulted in very large pressure drops in the boiler and the result was that the pump cavitated that 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 an increase in tear of the impeller is seen. That happens when the chemicals are dosed directly in front of the feed pumps. This is because the concentration can be very high in the pump due to the chemicals having not been mixed properly before

entering 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 NH3 is added to lower the PH-value, the NH3 will also tear down the bronze.

Using the Grundfos Digital Dosing will eliminate the tear problems as the dosing pump will dose continuously and ensure that no excessive chemical levels occur.

FEED PUMP START-UP
Before the pumps are started, the following two things have to be taken 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 pressure in the boiler. If not, it will be like running against closed valves until the pump 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 seen torn apart and some sort of vacuum pockets have been created.
Se paragraph Column separation.

FAQ

How do I avoid cavitation?
You must ensure that the pressure level at the suction side of the pump is higher than the vapour pressure of the water. Net Positive Suction Head (NPSH) available must be higher than NPSH required. See section ”Pump sizing”.

How do I convert from bar to mWC?
In order to convert you need to know the temperature of the water as density varies with temperature. From the vapour table, the following data of water at a temperature of 104°C is given.
Density (rho)= 955.2 kg/m^3
The nameplate indicates a maximum boiler pressure of 12.5 bar and the value has to be in Pascal.
The force of gravity g is 9.81 m/s^2.

$$h_{Boiler} = \frac{p_{Boiler}}{\rho \cdot g} = \frac{12.5 \cdot 10^5}{955.2 \cdot 9.81} = 133.4 mWC$$

What precautions do I need to take when living at high altitude?
If the deaerator is operated at the boiling point, no special precautions are necessary. The lower the pressure, the less oxygen can be dissolved in the feed water, which actually enhances deaeration. The precautions to avoid cavitation are the same as in section ”Pump sizing”. See table below for boiling temperatures.

Fig 44: Table based on the standard sea-level atmospheric pressure of 101.3 kPa:

Altitude, m	Boiling point of water, °C
0 (0ft)	100 (212 °F)
300 (984.25ft)	99.1 (210.3°F)
600 (1968.5ft)	98.1 (208.5 °F)
1000 (3280.8ft)	96.8 (206.2 °F)
2000 (6561.68ft)	93.3 (199.9 °F)
4000 (13123.36ft)	87.3 (189.1 °F)
6000 (19685.04ft)	81.3 (178.3 °F)
8000 (26246.72ft)	75.5 (167.9 °F)

Certificates

Certificates

Certificate	Description
Certificate of compliance with the order	According to EN 10204, 2.1. Grundfos document certifying that the pump supplied is in compliance with the order specifications.
Test certificate. Non-specific inspection and testing	According to EN 10204, 2.2. Certificate with inspection and test results of a non-specific pump.
Inspection certificate 3.1	Grundfos document certifying that the pump supplied is in compliance with the order specifications. Inspection and test results are mentioned in the certificate.
Inspection certificate	Grundfos document certifying that the pump supplied is in compliance with the order specifications. Inspection and test results are mentioned in the certificate. Certificate from the surveyor is included. We offer the following inspection certificates: • Lloyds Register of Shipping (LRS) • Det Norske Veritas (DNV) • Germanischer Lloyd (GL) • Bureau Veritas (BV) • American Bureau of Shipping (ABS) • Registro Italiano Navale Agenture (RINA) • China Classification Society (CCS) • Russian maritime register of Shipping (RS) • Biro Klassifikasio Indonesia (BKI) • United States Coast Guard (USCG) • Nippon Kaiji Koykai (NKK)
Standard test report	Certifies that the main components of the specific pump are manufactured by Grundfos, and that the pump has been QH-tested, inspected and conforms to the full requirements of the appropriate catalogues, drawings and specifications.
Material specification report	Certifies the material used for the main components of the specific pump.
Material specification report with certificate from raw material supplier	Certifies the material used for the main components of the specific pump. A material certificate, EN 10204, 3.1, will be supplied for each main component.
Duty-point verification report	Certifies a test point specified by the customer. Issued according to ISO 9906 concerning "Duty point verification".
Surface-roughness	Shows the measured roughness of the cast pump base of the specific pump. The report indicates the values measured at the base inlet and outlet according to ISO 1302.
Vibration report	Vibration report indicating the values measured during the performance test of the specific pump according to ISO 10816.
Motor test report	Shows the performance test of the specific motor, including power output, current, temperature, stator windings resistance and insulation test.
Cleaned and dried pump	Confirms that the specific pump has been cleaned and dried, and how it was done.
Electropolished pump	Confirms that the specific pump has been electropolished. The maximum surface roughness is specified in the report.
ATEX-approved pump	Confirms that the specific pump is ATEX-approved according to the EU directive 94/9/EC, the "ATEX directive".

Vapour pressure p and density of water at different temperatures

t[°C]	T[K]	P[bar]	[kg/m³]	t[°C]	T[K]	P[bar]	[kg/m³]	t[°C]	T[K]	P[bar]	[kg/m³]
0	273.15	0.00611	0999.8					138	411.15	3.414	927.6
1	274.15	0.00657	0999.9	61	334.15	0.2086	982.6	140	413.15	3.614	925.8
2	275.15	0.00706	0999.9	62	335.15	0.2184	982.1	145	418.15	4.155	921.4
3	276.15	0.00758	0999.9	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	39.776	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