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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 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.

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.

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.
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.

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.
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 (O₂) and carbonic acid (H₂CO₃) 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 O₂ and 0 mg/l of CO₂, 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 deaerators 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.
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](image)

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, $K_v$ relates to the pass area of the valve when fully open, whilst $K_p$ 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:
The Kv value for the valve can then be determined:

\[ V = K_v \sqrt{\Delta P} \]

The Kv value for the valve can then be determined:

\[ K_v = \frac{V}{\sqrt{\Delta P}} \]

For a boiler application, with a flow of 26 m³/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)

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### 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.

---

**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.

**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.

**ACCESSORIES REQUIRED**
Temperature sensor, R100/Grundfos Go
Through 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 two ways to make the bypass, either with a valve or an orifice. If it is a valve it is normally controlled so 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 to avoid the continuously energy loss you would have if it was open all the time.

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.
**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.

---

**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 m³/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 m³/h in 1752 hours a year
- 75% load = 15 m³/h in 1752 hours a year
- 50% load = 10 m³/h in 1752 hours a year
- 25% load = 5 m³/h in 1752 hours a year

And stopped in the rest 1752 hours a year
**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.

**AND REMEMBER THE SAVINGS ABOVE ARE WITHOUT THE LOSS SAVED IN THE BYPASS END.**

**Fig. 24**

- 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 gap 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 gases.

**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

**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

---

**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
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.

**Steam traps**
The duty of a steam trap is to discharge condensate while not permitting the escape of live steam. No steam system is complete without that crucial component ‘the steam trap’ (or trap). This is the most important link in the condensate loop because it connects steam usage with condensate return.

A steam trap quite literally ‘purges’ condensate, (as well as air and other incondensable gases), out of the system, allowing steam to reach its destination in as dry a state/condition as possible to perform its task efficiently and economically.

The quantity of condensate a steam trap has to deal with may vary considerably. It may have to discharge condensate at steam temperature (i.e. as soon as it forms in the steam space) or it may be required to discharge below steam temperature, giving up some of its ‘sensible heat’ in the process.

The pressures at which steam traps can operate may be anywhere from vacuum to well over a hundred bar. To suit these varied conditions there are many different types, each having their own advantages and disadvantages. Experience shows that steam traps work most efficiently when their characteristics are matched to that of the application. It is imperative that the correct trap is selected to carry out a given function under given conditions. At first sight it may not seem obvious what these conditions are. They may involve variations in operating pressure, heat load or condensate pressure. Steam traps may be subjected to extremes of temperature or even water hammer. They may need to be resistant to corrosion or dirt. Whatever the conditions, correct steam trap selection is important to system efficiency.

It will become clear that one type of steam trap cannot possibly be the correct choice for all applications.

**How steam traps operate**
There are three basic types of steam trap into which all variations fall, all three are classified by International Standard ISO 6704:1982.

**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 ‘inver-
ted 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 wa-
ter quantity corresponding to the allowable steam out-
put 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 men-
tioned 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.

\[
q_{\text{Boiler}} = 20 \text{ tons/hour} \\
\rho_{\text{Boiler}} = 12.5 \text{ bar} \\
\rho_{\text{Boiler, operating}} = 10 \text{ bar} \\
\text{Temp. } = 175^\circ C
\]

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.

\[
Q_{\text{Boiler}} = \frac{20 \times 10^3}{955.2} = 20.9 \text{ m}^3/\text{h} \\
\rho_{\text{Boiler}} = \frac{12.5 \times 10^3}{955.2 \times 9.81} = 133.4 \text{ m} \\
\rho_{\text{Boiler, operating}} = \frac{10 \times 10^3}{955.2 \times 9.81} = 106.7 \text{ m}
\]

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

\[
Q_{\text{Pump max}} = 1.25 \times Q_{\text{Boiler}} = 1.25 \times 20.9 = 26.1 \text{ m}^3/\text{h} \\
Q_{\text{Pump continuous}} = 1.15 \times Q_{\text{Boiler}} = 1.15 \times 20.9 = 24.0 \text{ m}^3/\text{h} \\
h_{\text{Pump}} = 1.1 \times h_{\text{Boiler}} = 1.1 \times 133.4 = 146.7 \text{ m}
\]

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 NPSHₐ value has to be calculated.

NPSHₐ = Pressure AVAILABLE to the pump from the system.

NPSHₐ = Pressure REQUIRED from the pump to avoid cavitation.

To avoid pump cavitation, the following has to be accomplished, NPSHₐ > NPSHₐ:

NPSHₐ = hₐ - hₐ - hₐ ± hₕ - hₙ

NPSHₐ = Pressure available at inlet of pump.

hₐ = Atmospheric and deaerator operating pressure at pump site.

hₐ = Friction loss in suction pipe.

hₜ = Vapour pressure of liquid.

hₕ = Height between water level in deaerator and suction side of pump.

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

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

\[ NPSHₐ = \frac{P}{p \cdot g} - \frac{\rho p}{g} + \frac{h_t}{g} - h_v = \frac{(1.01325 + 0.15355) \cdot 10^5}{955.2 \cdot 9.81} - 2 \cdot \frac{1.1668 \cdot 10^5}{955.2 \cdot 9.81} + 5 \cdot 1 = 2.0\text{m} \]

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 hₐ and the hₙ 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:

NPSHₐ = hₜ - hₕ - hₙ

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 NPSHₐ 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.
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.

E-Solutions
E-solutions are the Grundfos term for motors equipped with internal, MGE, or external, CUE, variable frequency drive.

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.
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.
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.

**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
• 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.

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.

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. See 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 (ρ)= 955.2 kg/m³

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/s².

\[
h_{boiler} = \frac{p_{boiler}}{\rho \cdot g} = \frac{12.5 \times 10^5}{955.2 \times 9.81} = 133.4 \text{mWC}
\]

**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.

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

<table>
<thead>
<tr>
<th>Certificate</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certificate of compliance with the order</td>
<td>According to EN 10204, 2.1 Grundfos document certifying that the pump supplied is in compliance with the order specifications.</td>
</tr>
<tr>
<td>Test certificate. Non-specific inspection and testing</td>
<td>According to EN 10204, 2.2. Certificate with inspection and test results of a non-specific pump.</td>
</tr>
</tbody>
</table>
| 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. Certificate from the surveyor is included. We offer the following inspection certificates:  
- Lloyd’s Register of Shipping (LRS)  
- Det Norske Veritas (DNV)  
- Germanischer Lloyd (GL)  
- Bureau Veritas (BV)  
- American Bureau of Shipping (ABS)  
- Registro Italiano Navale Apertura (RINA)  
- China Classification Society (CCS)  
- Russian Maritime Register of Shipping (RS)  
- Biro Klassifikasjons Indonésia (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. |
| Electroplished pump | Confirms that the specific pump has been electroplished. 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”. |