Technical Report

Dipl.-Wirtschaftsing. (FH), Dipl.-Informationswirt (FH)
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BOSCH
Invented for life

Saving energy - reducing costs - protecting the environment
Energy, cost and emission-saving solutions for shell steam boiler systems

The life expectancy of a boiler system is between 20 and 40 years. Typical efficiency gains achieved by replacing or modernising old systems is between 10 and 30 percent, depending on the initial situation. At current fuel costs, even extensive measures often pay for themselves in just a short time.

Energy-efficient optimisation potentials of the boiler/burner combination

If a steam boiler at a given load is balanced over the incoming and outgoing material and energy flows, the proportion of unusable energy soon becomes evident. Fuel, combustion air, feed water and electrical power (pumps and fans) are fed. Besides the usable thermal energy contained in the steam, other variables are flue gases at a specific temperature and with a certain oxygen content, possibly unburned fuel components, desalting and blow-down losses, losses from thermal radiation and thermal conduction at the boiler surface. These losses can be minimised by employing suitable measures.

Figure 1: Energy-efficient Bosch steam boiler Universal UL-S with integrated economizer and condensing heat exchanger

Reducing flue gas loss

Economizer and calorific heat exchangers

Energy is supplied to a conventional steam boiler system by combusting a fuel-air mixture. The heating surfaces (flame tubes and smoke tubes) emit heat to the water inside the boiler via thermal radiation, thermal conduction and convection. Not all the energy contained in the fuel is transferred to 100 %. Consequently, the flue gas temperatures are higher than the medium temperature of the boiler.

In order to use the considerable heat potential, economizers and often flue gas condensers can be connected downstream of the boilers. These units cool the hot flue gases to a certain temperature and, in return, preheat the feed water or other low-temperature water.

In the case of dry operation, the flue gases are cooled only to a temperature above the condensation temperature of the flue gases. As a result, the condensation energy contained therein is not used. Fuel cost savings of up to 7 % can be realised at full load.

If the flue gas temperature is reduced to below the condensation temperature, the condensation energy can also be used. Under the right framework conditions, a savings potential of up to 7 % more is possible in practical applications (figure 2).

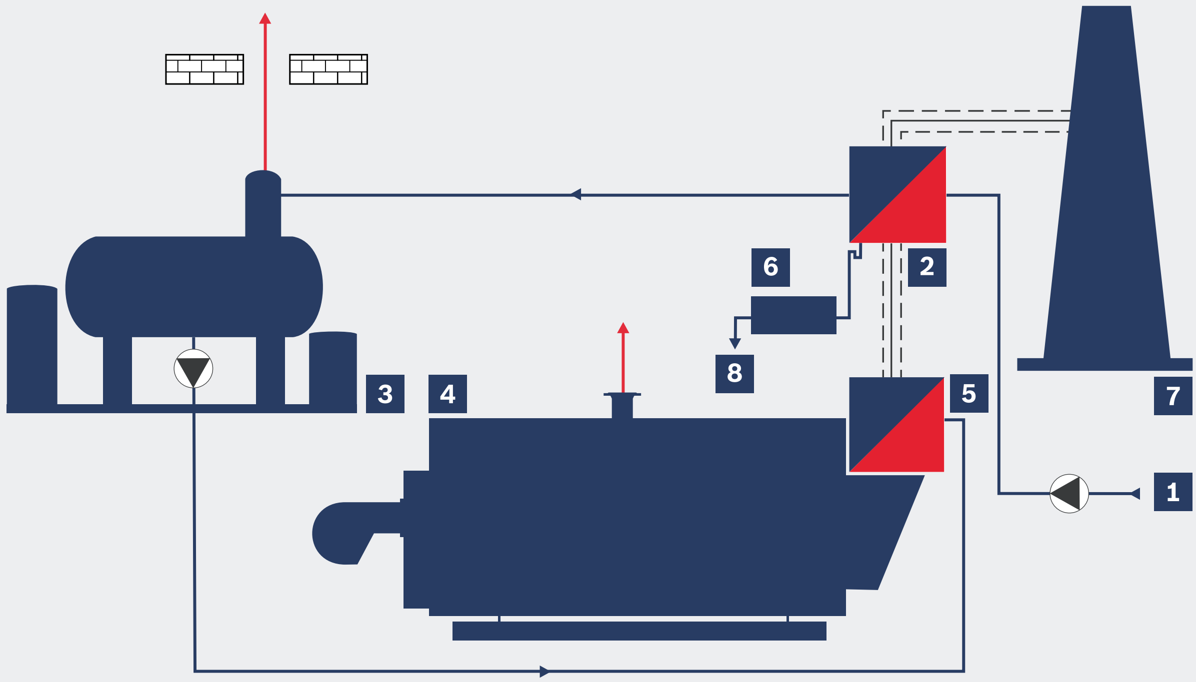
If the condensate rate of the steam boiler system is low (< 50 %), the requisite, cold make-up water flow rate is usually sufficient for using the flue gas condensation.

At high condensation rates, the requisite make-up water flow rate is very low. However, as long as a hardness-free low-temperature water circuit is provided, the condensing technology can still be used. The released condensation heat can be used to heat up process water or support the heating system, for example.

Air preheating

In the case of new systems with an economizer, air preheating is an ideal efficiency-increasing measure if a flue gas condenser cannot be integrated for process-related reasons. With these systems, the flue gas temperature is reduced by preheating the combustion air.

Figure 2: Block diagram of a high-pressure steam boiler system with two flue gas heat exchanger stages (economizer/flue gas condenser)



- **1** Make-up water
- **2** Flue gas condenser
- **3** Water service module
- **4** Steam boiler
- **5** Economizer
- **6** Condensate neutralisation
- **7** Chimney
- **8** To the blow-down expansion module

Extremely simplified diagram

Various versions are available on the market. Bosch offers a standardised air preheating system for single-flame or double-flame tube boilers with duoblock burners. This system makes economic sense from boiler outputs of approx. five tonnes of steam per hour (figure 3).

Heat losses through desalting and blow-down water

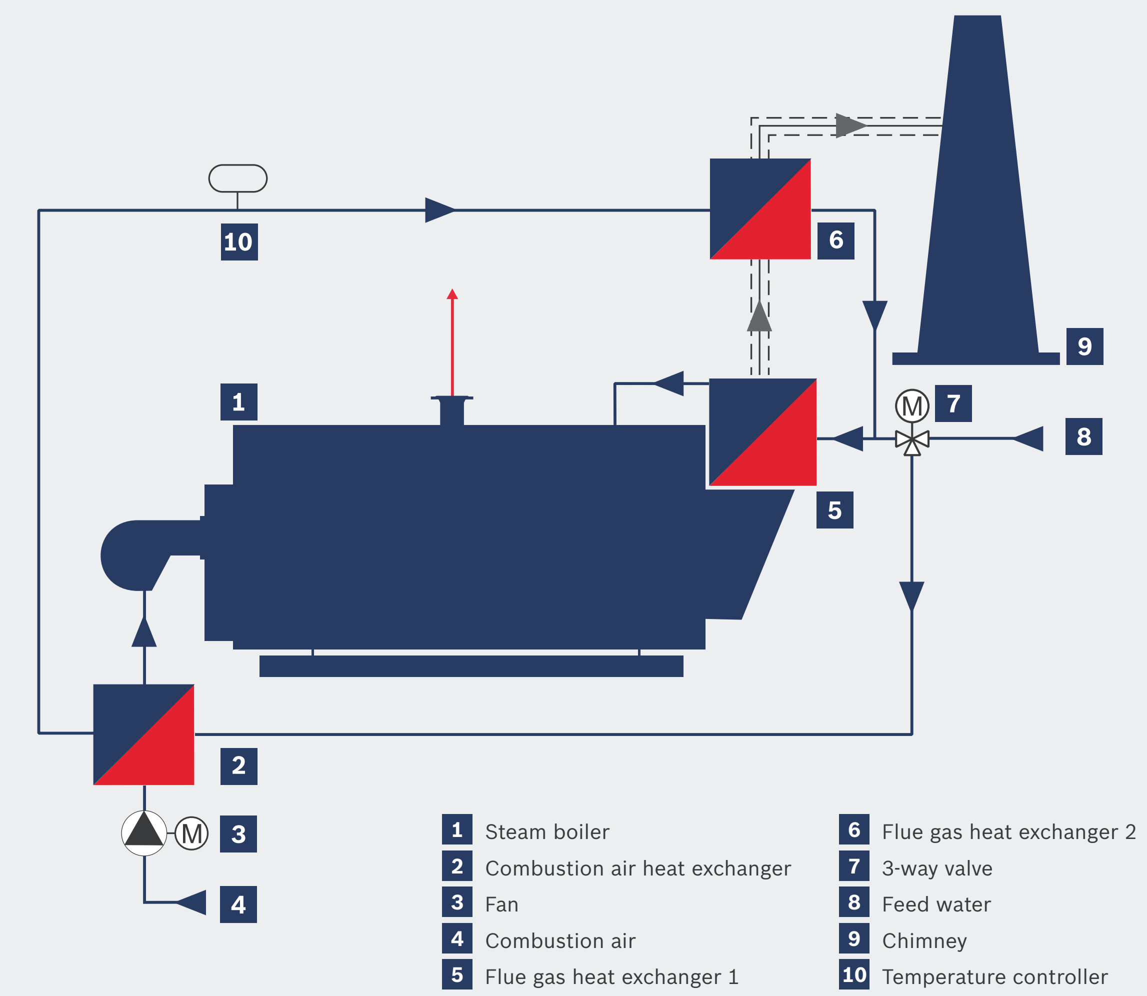
Owing to the principles involved, the concentration of all nonvolatile substances in the boiler water, such as salts for example, increases. An excessive salt content causes problems, including foaming of the boiler water and the negative consequences thereof, such as steam quality, water entrainment or uncontrolled low or high water level cut-outs. Therefore, the salt content of the boiler water must not exceed a defined threshold. The salt content is determined from the conductivity of the boiler water. Depending on this variable, a desalting control valve opens and the boiler water concentrated with salts is routed outside. The boiler is supplied with feed water again through the normal feed water control. The conductivity in the boiler water drops or is held at the permitted level.

In many systems, the desalting water is fed into the blow-down tank, and expands in the process. The expansion steam produced exits the open blow-down tank through the roof. The residual brine at 100 °C must then be cooled down to duct inlet temperature (in Germany 35 °C) by adding fresh or make-up water.

As a result, all the energy content of the brine is lost. In addition, fresh or make-up water must be added in order to reach the duct inlet temperature. The energy content of the desalting water is still enormous - the higher the operating pressure, the higher the temperature and hence the higher the energy loss.

Most of this heat loss can be recovered by means of a compact module. The hot boiler water brine expands - the expansion steam produced in the process helps heat up the feed water. A downstream heat exchanger cools the residual brine down to duct inlet temperature. The heat produced is used to preheat the make-up water (figure 4).

Figure 3: Block diagram of Bosch air preheating system



Extremely simplified diagram

Reducing the electrical power consumption with speed-controlled burner fans

An optimal fuel-air mixture is required for complete combustion. Industrial boiler systems are often run in partial load operation. In this case, both the fuel and the air feed are reduced.

However, even in partial load ranges, a combustion air fan without speed control will runs at 100 % of its rotational speed. The air volume fed in for combustion is controlled purely via air flaps. A high electrical power consumption occurs and deflagrates without use. If the air volume is changed primarily by modulating the speed of the fan, the power consumption in partial load ranges is significantly lower.

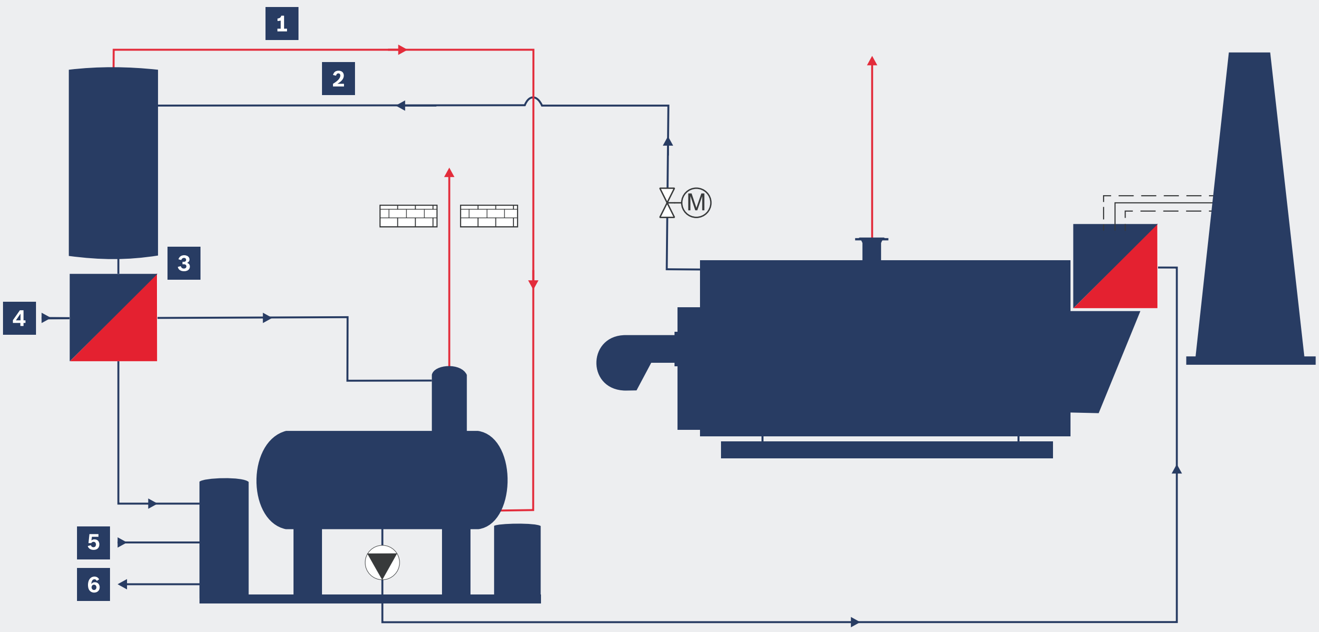
Noise development behaves similar to the power consumption reduction. All systems that are operated frequently in partial load ranges for prolonged periods should ideally be equipped with speed-controlled fans.

Reducing firing-side losses caused by too much excess air

Stoichiometric combustion is the ideal combustion technology. This is the case when all fuel molecules react completely with the airborne oxygen. Insufficient airborne oxygen produces carbon monoxide - a highly-toxic gas. Too much airborne oxygen creates an energy inefficiency. Therefore, an optimised burner setting is desirable. Due to air pressure, air temperature and air humidity fluctuations on the one hand and fluctuating fuel quality on the other, a certain amount of excess air over the theoretical optimum must be set as a safeguard.

To be able to operate the systems closer to the optimal operating point, continuous measuring and control equipment is required. An O_2 control comprises essentially an oxygen probe installed in

Figure 4: Schematic diagram brine expansion and cooling processes



- **1** Expansion steam
- **2** Boiler water brine
- **3** Expansion and heat recovery module
- **4** Make-up water
- **5** Cooling water
- **6** to the drain

Extremely simplified diagram

the flue gas flow, plus control device. It continually records the residual oxygen content in the flue gas and transmits the signal to the burner control, which re-adjusts the required air volume.

For some years now, combination electrodes (O_2 and CO) have also been available. Together with a CO measurement, the added air volume can be moved closer to the CO threshold (figure 5).

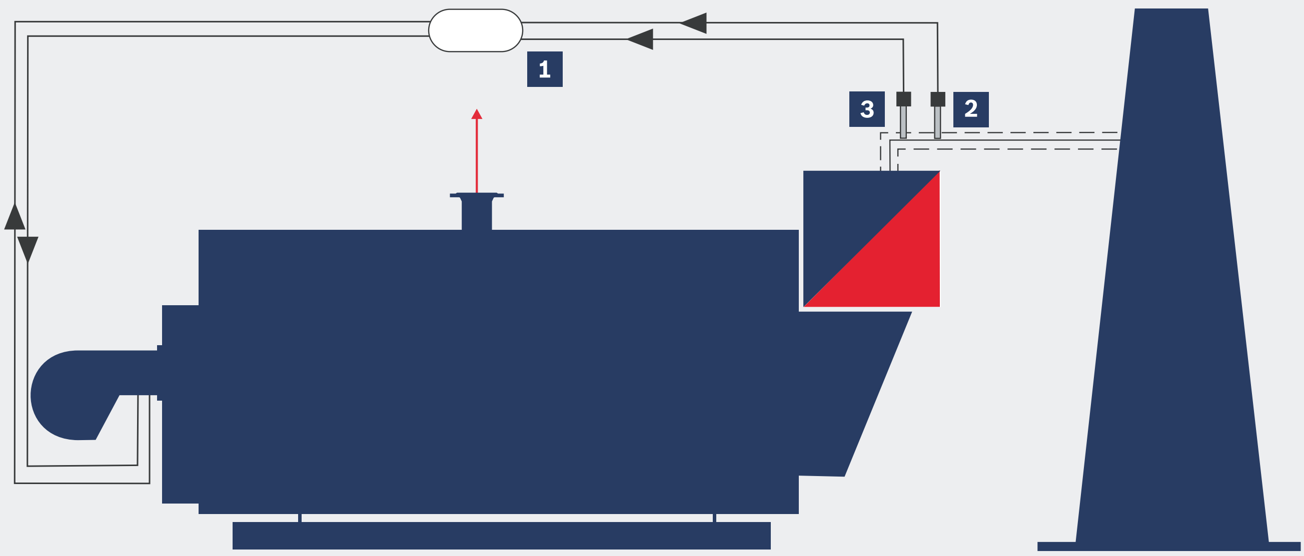
Reducing the process-related heat losses by pre-ventilating the flue gas paths

Before each burner start, it is important to ensure that there are no ignitable mixtures in the flue gas paths. In practice, this is achieved by so-called „pre-ventilation“. Instead of the flame igniting first, the combustion air fan starts up and forces cold ambient air through the flue gas paths, which are normally hot. A triple air exchange, which can result in a significant energy loss, is specified.

Accordingly, unnecessary burner starts must be avoided. A number of different factors influence the starting behaviour of the firing mechanisms, the causes and potential solutions include:

- over-dimensioned boiler systems
  Solutions: Adjust rated output by modifying or replacing the firing system
- unfavourable burner control ranges
  Solutions: Modifying or replacing the firing system
- poorly adjusted plants
  Solutions: Adjust control characteristics, increase spread of burner switch-on and switch-off pressures
- high spread between peak load and base load on consumer side
  Solutions: Restructuring or time staggering of consumers in order to achieve a more even power distribution; use of firing systems with high control ranges; in case of temporary consumption peaks, use of steam accumulators; use of multi-boiler systems

Figure 5: Schematic diagram O_2 and CO control



1 Control
2 Oxygen sensor
3 Carbon monoxide sensor

Extremely simplified diagram

Reducing losses caused by thermal conduction and thermal radiation at the boiler surface

Losses caused by thermal radiation and thermal conduction depend on proper insulation, the total surface and the operating temperature. Therefore, the manufacturers design the boiler systems to be as compact as possible, use highly-effective insulators and provide inspection chambers with removable insulating elements.

Energy-efficient optimisation potentials within the boiler system

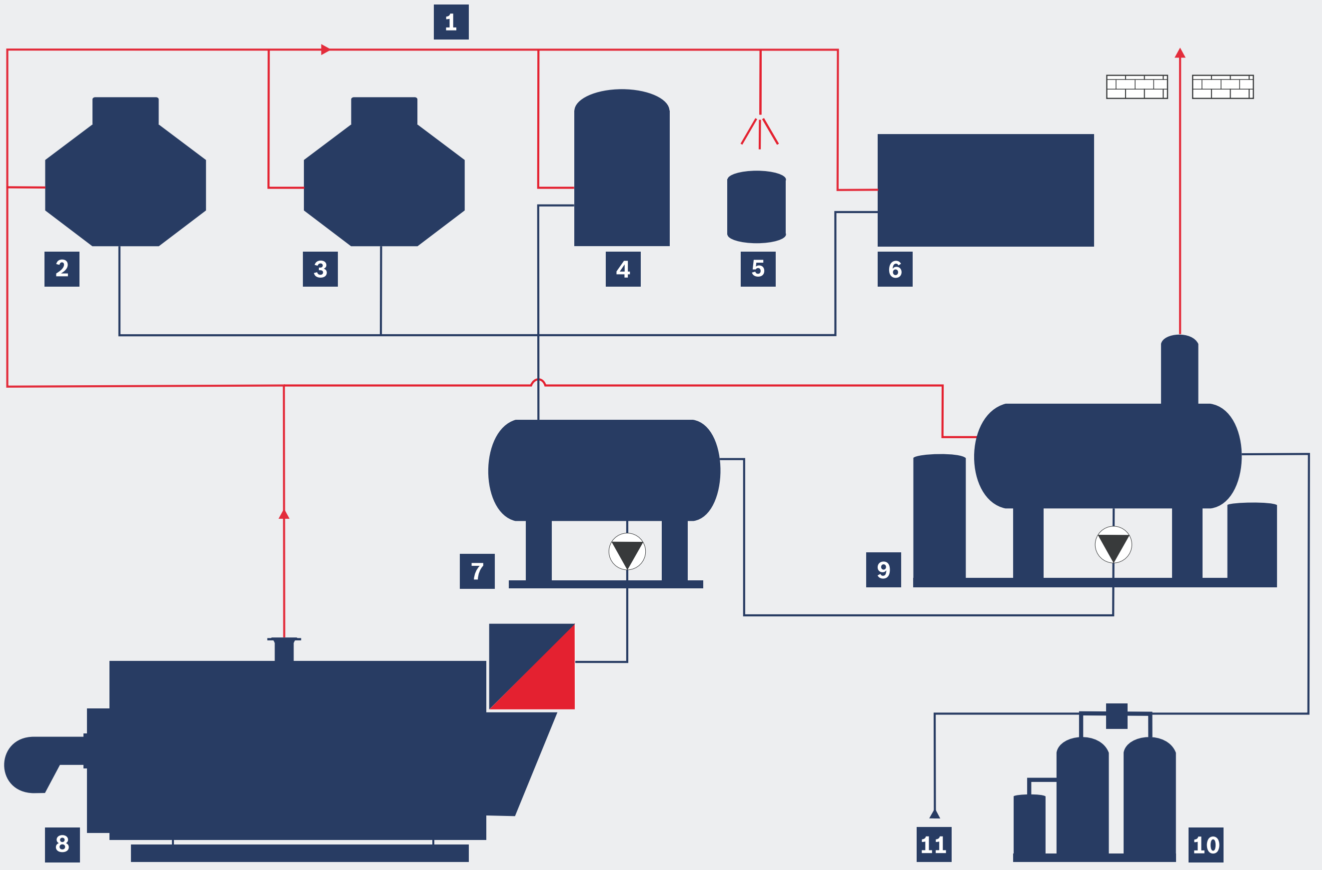
Heat recovery from condensate

Condensate should be returned wherever possible. At a high condensate yield, less fresh water needs to be treated using energy. A return is ruled out only if the condensate is contaminated by impurities. High-pressure condensate modules can absorb high condensate flows, without intermediate storage of losses or with the intermediate storage of low losses, and return them to the plant if required. The higher the condensate pressure, the higher the savings over pressureless, open, condensate returns. Up to 12 % energy losses through expansion steam can be avoided. Other advantages are created by reducing the chemical consumption for water treatment, reduced desalting and blow-down rates and a lower corrosion rate in the condensate system (figure 6).

Heat recovery from exhaust vapour

In order to prevent corrosion in the systems, carbon dioxide and oxygen must be removed from the boiler feed water. This is achieved primarily through thermal processes in the so-called full degassing systems. The softened make-up water is very quickly heated by steam. The solubility of the gases decreases as the

Figure 6: High-pressure condensate system using a brewery as an example



1 High-pressure steam line
2 Mash kettle
3 Wort kettle
4 Hot water heater
5 Barel cleaning
6 Bottle cleaning
7 Condensate service module
8 Steam boiler
9 Water service module
10 Water treatment module
11 Untreated water

Extremely simplified diagram

temperature rises and at 100 °C is approximately zero, whereby the dissolved gases exit the system together with a small plume of steam (exhaust vapour) through the roof.

The energy loss through the exhaust vapour can be significantly reduced in two ways:

One option is to use a vapour cooler. In the vapour cooler, the steam is condensed by means of a heat exchanger which, in return, preheats the softened make-up water before it reaches the feed water tank.

A second option is to continuously monitor the oxygen content in the feed water tank. A valve is inserted into the exhaust vapour flow behind the steam aperture. This valve is opened by the control only if the degasification function is required. This is always the case when make-up water is fed in or the oxygen content in the feed water tank is too high.

Energy optimisation by means of regular care, maintenance and monitoring

Effective care and maintenance of boiler systems pays off. Deposits cause an increased flue gas temperature, resulting in significant energy losses. A one-millimetre thick calcium-carbonate deposit on the flame and smoke tubes, caused by inadequate maintenance of an ion exchange system for example, reduces efficiency by up to 15 %.

With modern systems, the water circuits can now be monitored and controlled by automated processes. And so gradually deteriorating efficiency or even damage caused by inadequate water quality are a thing of the past.

Energy optimisation with modern boiler and system controls

The energy-efficient optimisation of complex systems calls for high data transparency. Modern systems continuously record and evaluate a high number of operating states, operating data and measured values and show the results in a meaningful manner. This permits an early reaction to deteriorating efficiency (figure 7).

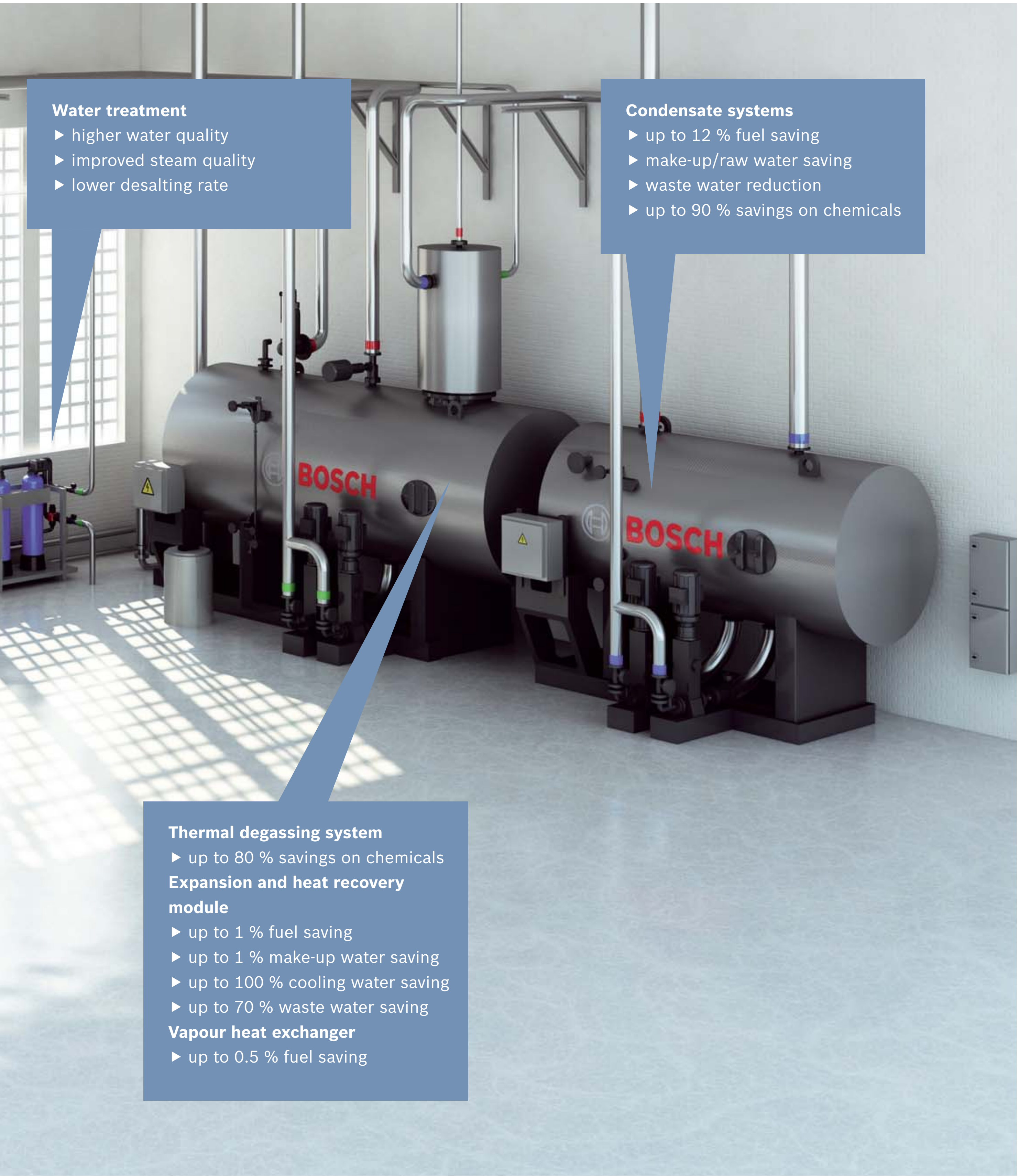
Figure 7: Bosch boiler control with Condition Monitoring basic for consistently high efficiency and availability

1st level: Start page with the button "Condition Monitoring"

2nd level: Selection menu with four areas: operation monitor, function values, consumption values and measurement values

3rd level: Detailed view with optical display in form of "traffic light function"

Figure 8: Energy-efficient optimisation potentials on a steam boiler system



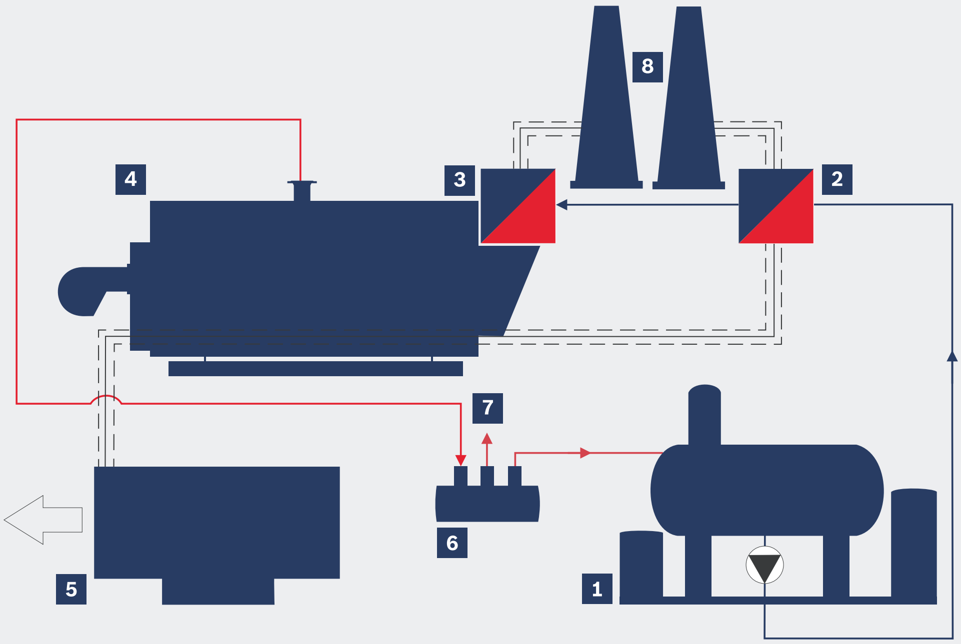
Summary of the savings potentials on the steam boiler system

Rising energy costs allow measures that would have been inconceivable a few years ago to be profitable. In many cases, hiher initial investment costs are returned many times over by the high fuel saving over the running times of the systems.

Often, the simplest of actions, such as changing the control parameters for example, can create an enormous effect.

Maintaining and checking the system for energy efficiency at regular intervals is recommended. The user benefits from consistently high energy efficiency, longevity and reliability of its system.

Figure 9: Hydraulic integration of a CHP unit and a self-fired shell steam boiler into the process steam generation system



- **1** Water service module
- **2** Flue gas heat exchanger
- **3** Economizer
- **4** 4-pass steam boiler
- **5** CHP
- **6** Distributer
- **7** Consumer
- **8** Chimney

Extremely simplified diagram

Efficiency increase by combining various thermotechnologies

Combined heat and power

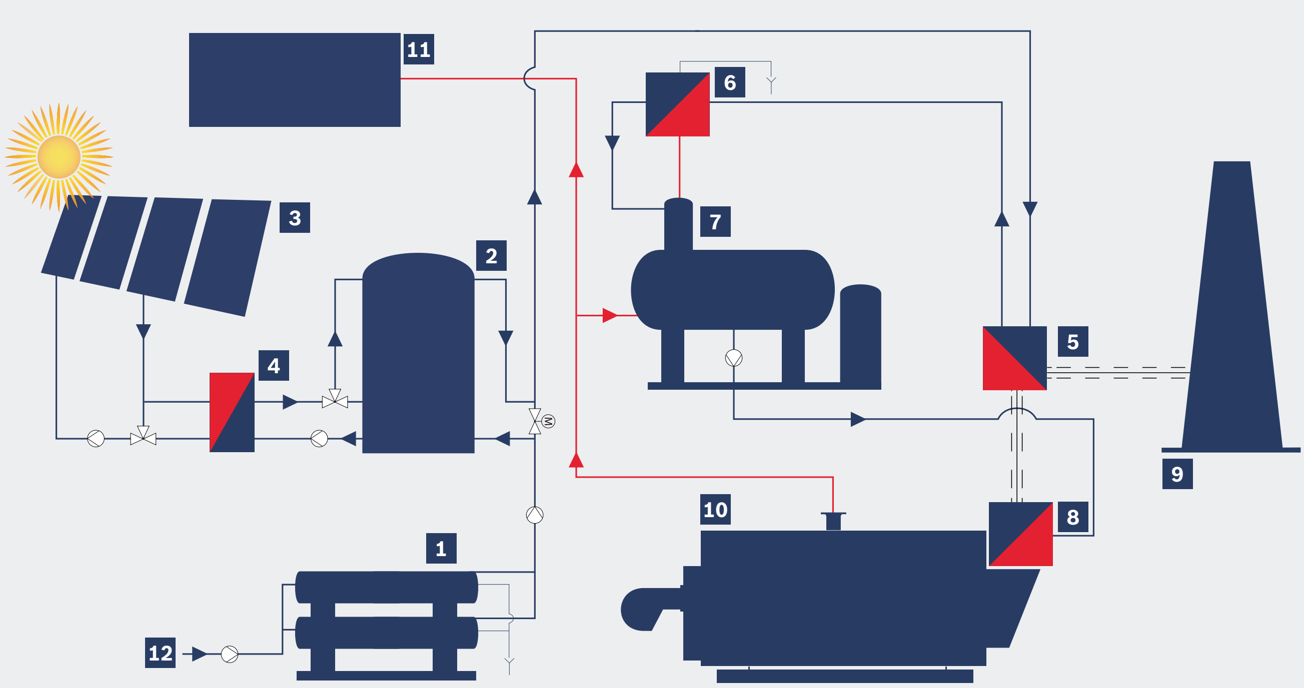
The use of combined heat and power systems in the commercial or industrial sectors can provide a viable alternative. A gas turbine or a combined heat and power unit (CHP) generates the electrical power - a downstream waste heat boiler system uses the hot flue gases from the upstream combustion processes to efficiently generate thermal or process heat.

The spread between the price of fuel and electricity, the system capacity utilisation and, in certain countries, also the government funding, are factors affecting profitability. Such systems are the ideal solution for numerous industrial users that require heat and power for their production facilities around the clock.

Heat recovery steam boiler
When modernising existing systems, a pure heat recovery boiler is often the best choice. The existing steam boiler is used as a peak load boiler, the base load is generated by the heat recovery generator by using the hot flue gases of a CHP.

Self-fired shell boiler with waste heat usage
The hot water or steam generator with waste heat usage is a con-ventional 3-pass boiler with an integrated, additional fourth smoke tube pass. The hot flue gases from the upstream processes are routed through this pass in order to support the steam or hot water generation process. The additional peak load boiler, which is necessary with pure waste heat boilers, can usually be dispensed with due to the own firing system. Investment costs, space require-ments and upgrade complexity are drastically reduced. Often the ideal solution when re-designing the energy control centre (figure 9).

Figure 10: Example of hydraulic integration of a solar thermal energy unit into the process steam generation system



- **1** Osmosis plant
- **2** Heat storage tank
- **3** Solar thermal system
- **4** Heat exchanger
- **5** Condensing heat exchanger
- **6** Vapour cooler
- **7** Water service module
- **8** Economizer
- **9** Chimney
- **10** Steam boiler
- **11** Production
- **12** Fresh water

Extremely simplified diagram

Process steam generation with solar-thermal support

Combinations with solar thermal energy can also be an effective solution for steam boiler systems with a high make-up water requirement. Treated make-up water preheated with solar energy. Additional energy is fed to the steam generator and high-pressure saturated steam is produced.

Under the correct framework conditions, an economic and environmentally-friendly energy supply can be guaranteed by such a system combination (figure 10).

Conclusion

The most diverse concepts can be applied to guarantee an economic energy supply, depending on initial situation, size and the chronological sequence of the distributed output. Rising energy costs allow measures that would have been inconceivable a few years ago to be profitable. Higher initial investment costs are often returned many times over by the high fuel saving over the running times of the systems.

Checking existing systems for energy efficiency at regular intervals is recommended. Often, the simplest of measures, such as changing the control parameters for example, can create an enormous effect.

Maintenance and service of the systems should not be neglected. It is recommended that the systems are maintained and readjusted every quarter or at least every six months. The user benefits from consistently high energy efficiency, longevity and reliability of its system.

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