BOSCH
Invented for life

Expert Report

www.bosch-industrial.com

Avoidable loads on shell steam boiler systems

Dipl. Ing. Paul Köberlein, Bosch Industriekessel GmbH

Steam boiler systems are subject to various types of loading which can lead to varying degrees of stress on the boiler body. In addition to inadequate water quality, two main factors are of essential importance: the effects of design and settings and the effects of consumers. The following article describes the avoidable loads on boiler systems and provides the reader with an insight into the proper planning, construction and setting of systems right through to operation.

Saturated steam is used today as a heat-carrying medium in many different commercial and industrial companies in every sector of industry. In the food and beverage industry, heating, boiling and cleaning processes are supported, the textile industry uses the heat medium primarily for the further processing and finishing of fabrics, laundries and dry cleaners heat up washing machines or use the steam for smoothing and drying processes. In hospitals, ultra-clean steam is used to sterilise operating equipment, and steam supplies the adjoining large-scale kitchens or is used for humidification of the air conditioning system. The building materials industry needs saturated steam for many process, heating and drying procedures, such as the autoclaving of sand-limestone bricks. And in many other sectors, such as the paper and packaging industry, the chemical industry, pharmaceuticals and many more, steam is essential as a heat medium.

Most of these steam applications require saturated steam or slightly overheated steam with outputs of up to 200 t/h, pressures up to 30 bar and steam temperatures up to 300 °C. For generating steam, one or more gas- or oil-fired steam boilers is generally used in the structure as a shell boiler (Figure 1). In comparison to water pipe boiler systems these are by far the better alternative, in the relevant performance range, because they are cheaper to buy and to run.

Operating modern shell steam boiler systems is regarded as unproblematic nowadays. Nonetheless, these boilers are often subject to a series of problems – which are actually avoidable – which have a major influence on the safety and working life of these energy generators. In addition to inadequate water quality, two main factors are of essential importance: the effects of design and settings and the effects of consumers.

Inadequate water quality

Inadequate water quality, resulting in corrosion or the formation of deposits, is top of the list in the damage statistics. The results of this type of damage are generally known in the industry, and will therefore not be discussed in greater detail in this specialist report. „Poor“ water quality is often caused by one or all of the following:

- insufficient monitoring or testing of the necessary water parameters (Figure 1)
- lack of expertise
- misinterpretation of measured values or no reaction in the event of deviations

To avoid damage resulting from insufficient water quality, first of all, compliance with the water values specified by the water manufacturer (according to EN

Figure 1: Consequences of faulty hardness monitoring

12953 Part 10) is essential. In addition to using suitable water treatment components, attention must also be paid here to ensuring sufficient competence in the field of water analysis. It is recommend that fully automated analysis devices are installed, which will record and monitor all water parameters such as hardness, conductivity, pH and condensate purity (Figure 2). See Specialist Report 'Modern water treatment and water analysis'.

Effects of design and settings

Boiler output too high in relation to the steam output actually needed

This problem is often to be found in systems in which the steam consumption has been dramatically reduced through the loss of consumers or the subsequent use of any heat recovery potential that is available. But new systems can also be affected if, during planning, the simultaneity factors of the consumers were incorrectly evaluated or were calculated with excessively generous output reserves. The consequence of a steam take-off that is too low in relation to the boiler output is frequent switching on and off of the burner. This causes temperature changes that can be extreme, especially in the case of gas-fired boiler systems and long preventilation times.

Burners create temperatures between 1 400 and 1 700 °C in the furnace. During the furnace preventilation phase, which is prescribed before each burner ignition process, fresh air in taken in out of the boiler house. The low air temperatures of 20 – 30 °C cause the previously hot heating surfaces to cool down. After this, the burner ignites and is generally quickly given the signal to move to the highest load level. In extreme low-load phases, it is very often switched off again whilst it is still starting up and then – often too quickly afterwards – preventilated and ignited again.

The stress caused by the constant temperature changes during heating up and ventilation causes differences in the rate of expansion between the furnace and the boiler casing, which can lead to material fatigue over the course of time. In addition to increasing the system's susceptibility to damage, this operating system also has a negative effect on economic efficiency, since every preventilation process causes a considerable loss of heat.

To achieve this, the following steps are recommended.
To achieve this, the following steps are recommended

- the installation of low-load controls which delay the immediate adjusting up after the burner start

Figure 2: Modern steam boiler system with fully automated water analysis and monitoring

- the use of performance regulators which enable the burner to be left in the low-load position for an unli mited period of time
- the use of burners with a high regulating range
- the modification of the burner capacity to actual requirements (i.e. burner modification or the provi sion of a burner with a smaller output range)

Insufficient pressure difference between burner switch-on and burner switch-off

As is already known, the performance of the steam boiler is regulated via the steam pressure measured in the boiler. If the level falls below the adjustable steam pressure $P_{Burner.on}$ the burner is switched on – if $P_{Burner.off}$ is exceeded, the burner is switched off.

If the spread between $P_{Burner.on}$ and $P_{Burner.off}$ is set too low, the consequences will be as follows:

- Frequent switching on and off caused by over-shooting of the pressure and thus to the tempera-ture change stresses described, with their negative consequences
- Of necessity, strict regulation parameters in the performance regulator in order to keep the setpoint value in a tight regulation range. The result, in addition to excessive wear on the control elements in the burner, is premature material fatigue of the heated walls

Experience has shown that with a set spread of 10 to 15 % between $P_{Burner.on}$ and $P_{Burner.off}$ (depending on the burner regulation and burner operating pressure) in relation to the boiler safeguard pressure, this prob-lem can be reliably avoided.

Performance regulator set too 'quickly'

Modern burner managers are able to variably specify the burner actuating time, i.e. the running time between the burner low load and high load position. At the same time, the reaction speed of the burner to setpoint value deviations can be influenced via the regulation parameters in the performance regulator. A shell boiler, with its high proportion of material and high water content, is a comparatively slow reacting system. Performance regulators that are set too 'quickly', possibly in combination with very short burner actuating times, lead to a rapidly rising heat entry in the flame tube. On the water side, this heat entry is removed primarily by steam bubbles which

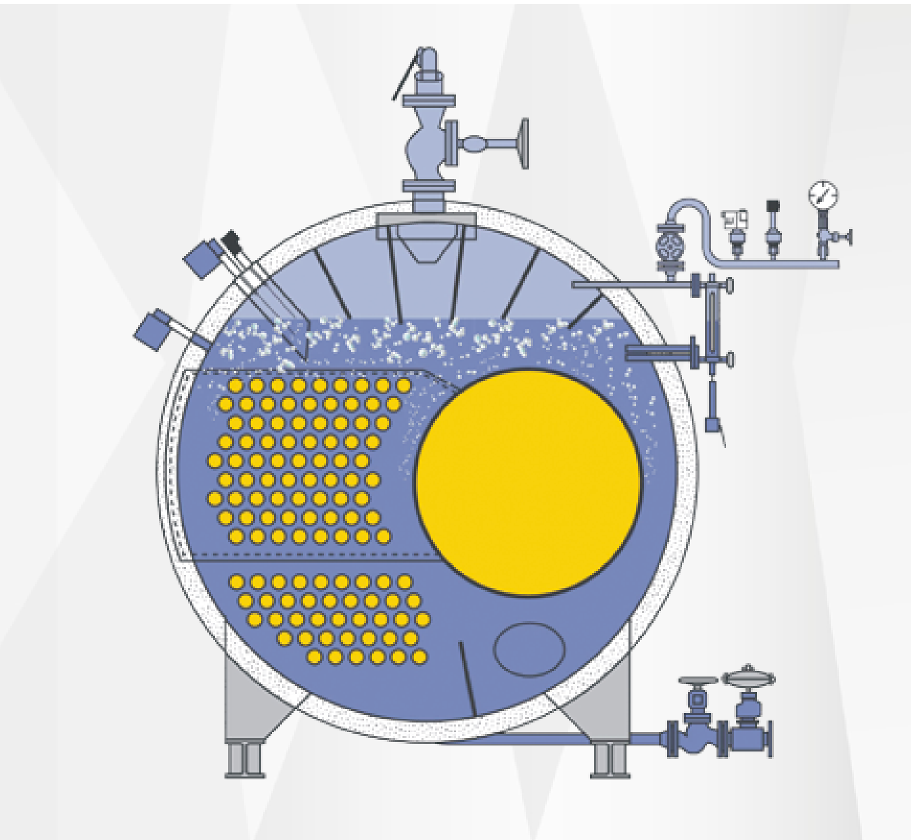

Figure 3: Diagram of heat removal at the heating surfaces under load through the formation of blisters

form and rise in the steam area (Figure 3). However, these steam bubbles form after a certain time delay. This causes brief local overheating and additional temperature change stresses, which in the long term speed up the process of material fatigue in the area of the heated boiler walls.

It is strongly recommended that commissioning is carried out by specialist staff, who will then set the burners and regulating systems.

Lack of sequence control concept in multiboiler systems

If multiboiler systems are not fitted with an automatic sequence control, the operating team has a major role to play. The members of the team must switch off boilers if the power take-off no longer justifies the operation of several boilers. If this does not happen, the consequences are as shown in diagram, by way of example. The chart shows that, over the entire period of time, the necessary steam requirement (blue) can be covered by Boiler 1 alone (red, with an output of 10 t/h). The frequent additions of Boiler 2 (green) with the temperature change stresses are thus completely superfluous.

In addition, the effect that the two boilers have on each other is clearly recognised. Whilst Boiler 1 (red) reduces it output, Boiler 2 (green) increases steam production and vice versa, i.e. the boilers are working 'against each other' and are pressurising each other alternately. The unimpeded transport of heat away from the heating surfaces can no longer be guaranteed.

A sequence control concept is therefore advisable even for boiler systems with two steam generators and is absolutely essential if there are three or more boilers in one boiler house. The type of sequence control (addition and disconnection of boilers as a function of volume or pressure) that is used will depend firstly on the number of boilers and secondly on what pressure fluctuations can be accepted on the consumer side. With sequence controls that are dependent on the volume of steam, the viable pressure fluctuation range can be kept much lower.

The following should also be noted:

- steam generators in multiboiler systems must be hydraulically separated from each other to prevent them influencing each other (e.g. using non-return valves)
- even at the planning stage, it should be borne in mind that secondary boilers must be fitted with a floor heating coil in order to avoid temperature layering of the boiler water during the heat maintenance phase.

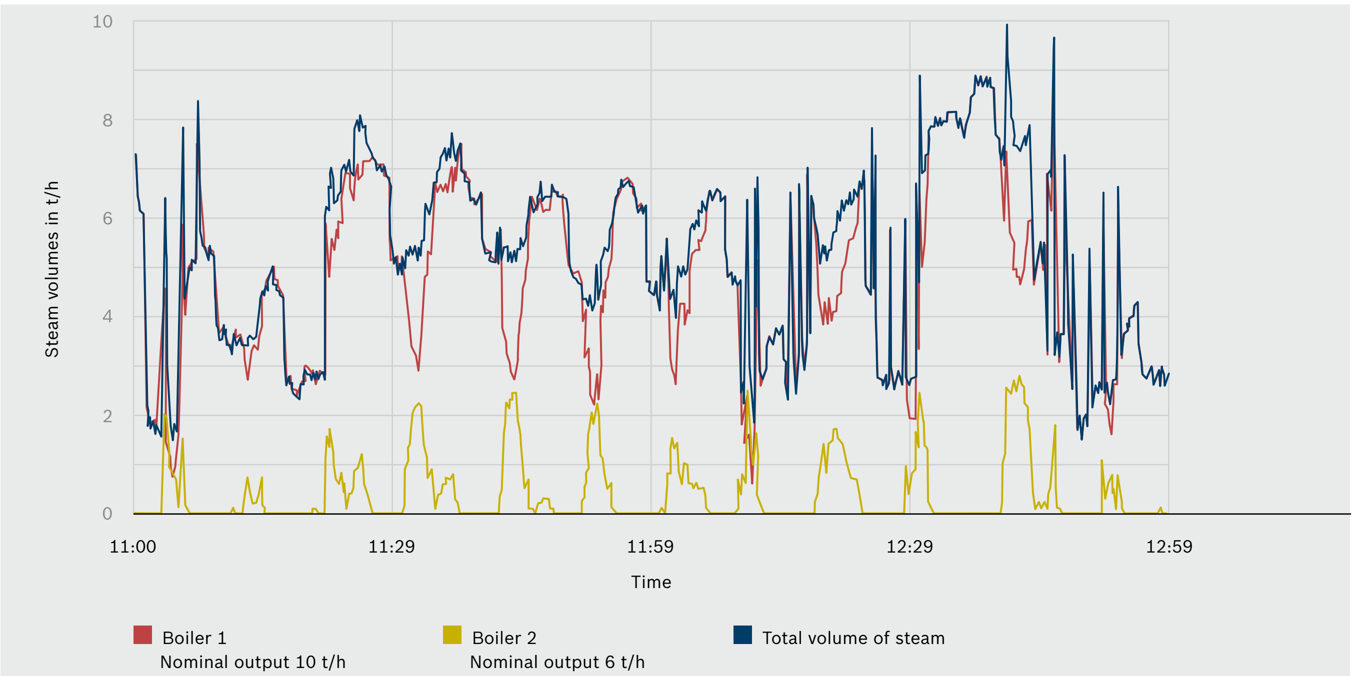

Diagram 1: Record of steam output in a boiler system with 2 steam generators without sequence control concept

Effects of consumers

Frequent start-up from cold state

Starting up the system from the cold state represents the greatest mechanical load on the boiler body. (See 'Cold starting of shell boilers') The reason is the greater temperature difference between the flame tube and boiler casing at the cold start compared with standard operation at operating temperature. The flame tube thrust (difference between change in length of the boiler casing and the flame tube) is higher during the start-up process, which leads to considerable additional strains which the boiler body has to deal with. This problem is even more acute if, during the start-up procedure, steam bubbles cannot form or can only form to a limited extent, which is the case, for example, if the steam removal valve is closed. The natural circulation that normally exists in the steam boiler (Figure 4) does not occur, resulting in tempe rature layering in the boiler (cold at the bottom, hot at the top) with additional thermal stresses. In the case of very frequent cold starts, these extreme changeover stresses can lead to cracking of the material, or, in the worse case, to complete failure of the system.

The following should be noted if the start-up load is to be reduced:

- start-up from cold state to operating temperature with the smallest possible burner load
- During the start-up procedure, a small quantity of steam should always be able to flow off in order to start the natural circulation through pushing up the steam bubbles.
- Ideally, the system should be fitted with an automatic start-up switch, which regulates burner operation and load removal as a function of water temperature and pressure so that stresses are kept to a minimum

Long periods on stand-by

During heat maintenance or stand-by operation (e.g. in multiboiler operation, if the secondary boiler is not required), the boiler cannot give off any steam. Depending on the control concept, either the steam removal valve is closed or the secondary boiler is run

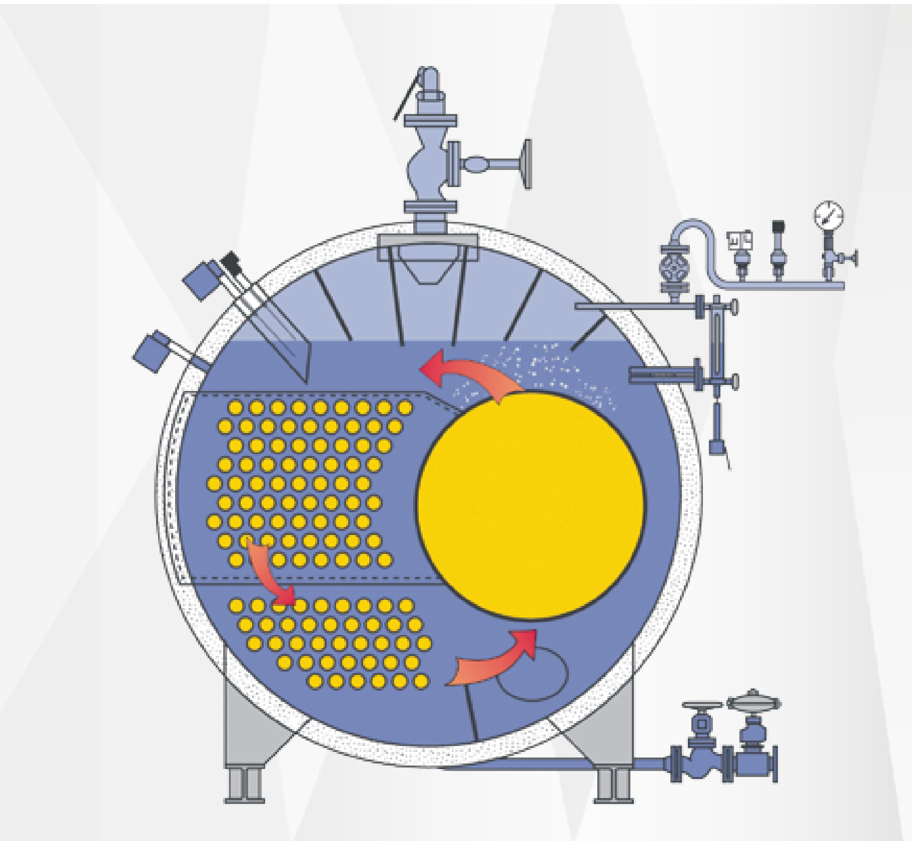

Figure 4: Diagram of the natural circulation within the boiler

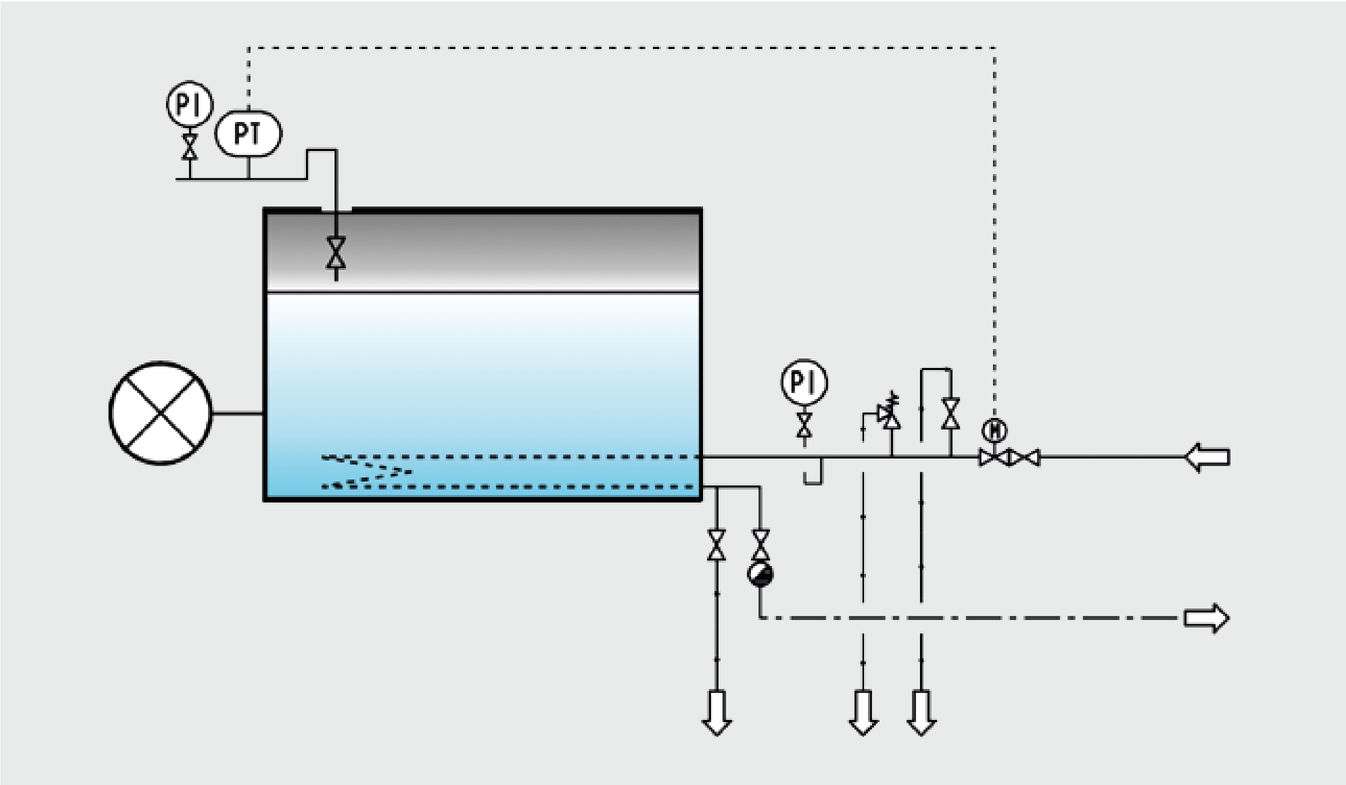

Figure 5: Diagram of a regulated floor heating coil

at a lower pressure than the prevailing network pressure. The burners only come on sporadically in this operating mode, in order to balance out losses from heat conduction and radiation. If this state is maintained over any length of time (> 3 days), temperature layering starts to occur in the boiler. If boilers that are kept warm in this way are then switched to normal operation, the high operating pressure (hot upper area) makes it seem as if a boiler is available immediately. The boiler control will then apply a high burner load to this boiler in a very short time if there is a corresponding requirement. As a result of the temperature layers in the boiler, extreme thermal stresses will then occur.

This can be prevented by the installation of heat maintenance coils (Figure 5) in the floor of the boiler. Steam heating of this heating coil is from underneath, which means that harmful temperature layering in the boiler are reliably avoided. To ensure that this solution can be implemented, however, a multiboiler system or a reliable supply of external steam is essential.

Pressure fluctuations caused by marked output fluctuations

With marked load changes, i.e. if load changes occur quickly, resulting in marked pressure fluctuations, unfavourable flow states can occur in the boiler. The steam bubble formation that is necessary to remove heat from the heat surfaces can slow down, or lead to many smaller bubbles joining together to form larger steam bubbles, which do not separate immediately from the heated surfaces and thus encourage local overheating. For this reason, special measures are required for boiler systems which supply consumers with extremely fluctuating loads, in order to limit the pressure fluctuations in the boiler independently of the consumer units. This can be achieved, for example, by:

- Increased boiler safeguarding on the pressure side and integration of a reducer station bet ween the boiler and the consumers
- Integration of a steam store for load peaks
- A pressure maintenance device after the boiler, with a regulated steam removal valve, in order to protect the boiler from an excessive pressure loss

Summary

The avoided causes of boiler problems listed here show that this is a very complex topic. It stretches from planning through construction and setting to the operation of the boiler systems. A conclusive discussion of all the relevant problems is not possible within this framework.

Because of the material complexity of steam boiler systems, it is vital that the following points are noted:

- Steam boiler systems should only be planned by trained, experienced specialists, since many possi ble sources of problems can be avoided at this early stage
- The quality of the boilers, burners and boiler system components used is of decisive importance if the system is to run smoothly and without break downs
- The correct installation of the system requires a competent plant engineer with a knowledge of the interplay between the various boiler house components
- Operation and support by the operating staff are extremely important and have a decisive effect on the working life of the steam boiler system
- A maintenance and Remote service contract with the boiler manufacturer is always a major advantage

Bosch Industriekessel GmbH

Nuernberger Strasse 73
91710 Gunzenhausen
Germany
Tel. +49 9831 56253
Fax +49 9831 5692253
sales@bosch-industrial.com
Service Hotline +49 180 5667468*
Spare Parts Hotline +49 180 5010540*

Bosch Industriekessel Austria GmbH

Haldenweg 7
5500 Bischofshofen
Austria
Tel. +43 6462 2527300
Fax +43 6462 252766300
sales-at@bosch-industrial.com
Service Hotline +43 810 810300**
Spare Parts Hotline +49 180 5010540*

info@bosch-industrial.com
www.bosch-industrial.com
www.bosch-industrial.com/YouTube

* EUR 0.14/min from German landline; maximum mobile phone price: 0.42 Euro/min
** max. EUR 0.10/min from Austrian landline
Different charges may apply for calls from mobile networks and for international calls.