Expert Report

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Output control of steam boilers

Introduction

Steam boiler output is usually controlled by regulating the burner heat output, using pressure as the reference value.

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Rapid output changes lead to a greater or lesser degree, depending on the boiler and burner design as well as on the control system, to serious breaches of the underpressure or overpressure limits. In case of burners which are controlled in stages, this can lead to undefined operating conditions.

To achieve a trouble-free, energy-saving, environmentally sound, low-wear and therefore cost-effective operation both of the boiler and its components, the selection of the correct design pressure of the boiler as well as its output are important factors.

In the following, the planner's responsibilities and selection criteria for the design pressure as well as the consequences of wrong pressure- and output selection will be pointed out.

Task of the planner

The planner of a boiler system must be made aware by the customer of the consumption criteria or he himself must be the boiler systems analyst for the areas of application in question.

In consultation with a competent boiler manufacturer, the optimum boiler design pressure as well as the boiler output can then be determined for the application in question, taking into account the customer's requirements as well as the burner control system.

This must also include the criteria based on the type of boiler construction, i.e. a prior decision about the boiler type – e.g. quick steam generator or shell boiler – must be made when selecting the boiler.

If a prior selection of the boiler type is not desired, the special conditions appertaining to quick steam generators make it necessary to have a significantly higher pressure requirement from the start, as well as assessing the possible output as accurately as possible.

This also has no adverse consequences for the shell boiler, although however it normally results in increased capital costs.

These costs are, however, generally recovered after approx. 2 to 3 years through the much more favourable operational characteristics. This aspect will be discussed in more detail later.

Selection of the design pressure (response pressure of the safety valve)

At the consuming system only a mixed pressure with plus and minus pressure tolerances is required (mean operating gauge pressure)

- Shell boiler with two-stage firing system:
  The response pressure of the safety valve should be at least 120 % of the required mean operating gauge pressure.
- Shell boiler with three-stage firing system:
  The response pressure of the safety valve should be at least 128 % of the required mean operating gauge pressure.
- Shell boiler with modulating firing system:
  The response pressure of the safety valve should be at least 120 % of the required mean operating gauge pressure.
- Quick-steam generator unit with two-stage firing system:
  The response pressure of the safety valve should be at least 150 % of the required mean operating gauge pressure.

The consuming system requires a minimum pressure
Maintaining a minimum pressure requires the selection of a markedly higher pressure level when determining the boiler values. The mean operating gauge pressure and consequently the safety valve response pressure must be raised above the minimum pressure sufficiently to ensure that the pressure does not drop below the required minimum value even in the case of sudden peak loads. For such requirements no generally valid statement can be made, and the design pressure must be fixed for each individual case.

Other requirements
A precision pressure control for the consuming system is not possible in the boiler; this must be achieved by means of a downline pressure governor (preferably immediately upstream of the consuming system) with the necessary pressure control accuracy. The boiler itself must, however, always supply an appropriately boosted steam pressure for this pressure governor, and it is important that pipework pressure losses between the boiler and the consuming system are taken into account as well.

As regards determining the output of individual boilers within multi-boiler installations, further criteria must be taken into account, which are described in a separate paper (Reference: Technical Report ‘Combining boiler and burner correctly’). The determination of the design pressure as well as of the distribution of output over the boilers is further affected by the need for a sequential control in multi-boiler plants, particularly when these plants are to be operated via the network pressure.

Effects of wrong initial pressure concept

If the boiler design pressure is too low, the following problems will occur:

- The minimum pressure cannot be safeguarded, with the result of pressure shortfalls and possible problems at the consuming systems.
- The mean operating pressure is not achieved – or too wide a deviation from the mean operating pressure becomes established.
- To achieve the smallest possible deviations from the specified values, the commissioning engineer is forced to set a narrow control range, which leads to a high ON/OFF switching frequency and frequently alternating burner operation.

This results in a high fault potential through excessively frequent ignition and potential ignition failure as well as excessive wear of boiler and burner components with considerable cost consequences.

Particularly subject to rapid wear in the burner area are the switching dependent components, such as ignition transformer, ignition electrodes, solenoid valves, servomotors and their limit switches as well as the automatic flame ignition and supervision device.

The energy consumption is increased by unnecessary purging losses. Repeated welding repairs on the pressure vessel become necessary through alternating temperature stresses.

The service life of the boiler is sometimes dramatically reduced. Apart from all these purely economic factors, such operating modes also cause increased stress to the environment, since during the startup and regulating stage the environmentally relevant values – particularly CO and NO_x – are significantly increased until the flame becomes stabilised.

Effects of excessive planned output in comparison with the actual consumption

Here, too, serious errors are repeatedly found, namely that the individual boiler or the complete system is very frequently overdimensioned. This prevents the burner from operating beyond the minimum loads of its control range, which leads to frequent switching, severe pressure fluctuations and the other disadvantages mentioned above. Here, too, the quick steam generator in particular is disadvantaged vis-à-vis the shell boiler and a very accurate demand assessment and demand-related boiler output assessment must be made.

Example of an existing plant

The following example clearly illustrates the important economical disadvantages which can result from a wrong initial design concept or pressure setting:

Diagram 1 illustrates the pressure development before, and diagram 2 the pressure development after correction by the service engineer.

Basically, the installed boiler is considerably over-dimensioned and has a two-stage controlled burner.

Before the correction of the controller (diagram 1) the pressure differential when changing over from high – to low load and vice-versa was 1.6 bar g. The burner alternated 54 times per hour between high – and load.

Although after correction of the controller (diagram 2) the oscillation could be significantly reduced to 18 duty cycles per hour, the switching could not be eliminated because of the excessively high output of the burner in relation to the consumption.

The average expected service life of a fictitious part of this burner, on the assumption of 4000 operating hours per year and an expected service life of 175000 duty cycles, was when operating in accordance with diagram 1 less than one year and this was increased to approx. two and a half years when operating in accordance with diagram 2.

Obviously, this service life is still not satisfactory, but it can’t be significantly improved by changes to the pressure controller. Further improvements can only be achieved through an output reduction of the boiler.

In the case of the example, the burner would have to be replaced by a smaller one to obtain a better control range.

Diagram 1

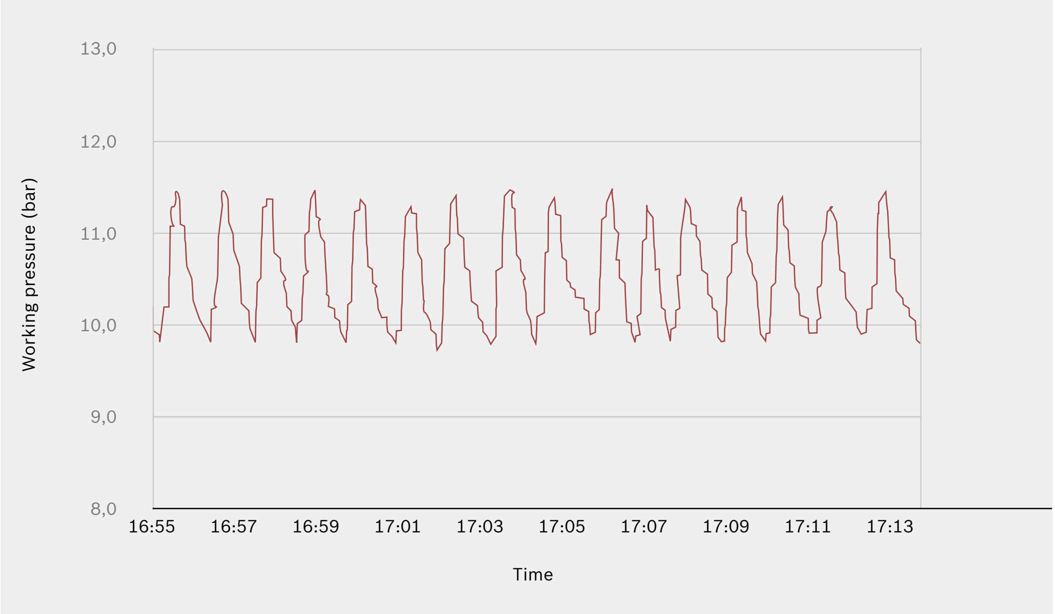
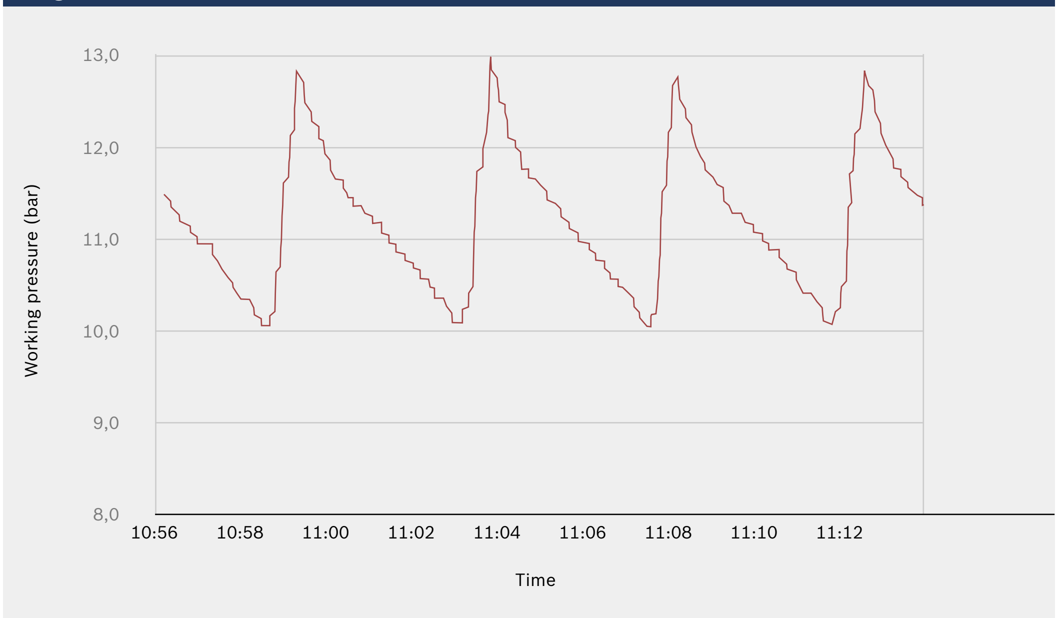


Diagram 2



Effects on cost

Diagram 3 shows the service life of a component as a function of the number of hourly duty cycles. The effect of the number of duty cycles on the service life can be clearly seen.

In a practical example this means that the solenoid of the gas solenoid valve with a spare parts price of approx. € 300, when operating in accordance with diagram 1, causes annual repair costs incl. labour (when replacement is carried out by the customer himself) of approx. € 500 – and when operating in accordance with diagram 2 approx. € 200 – each time without taking into account further costs for other parts replacements as well as for sending a service engineer, down-time, loss of business etc.

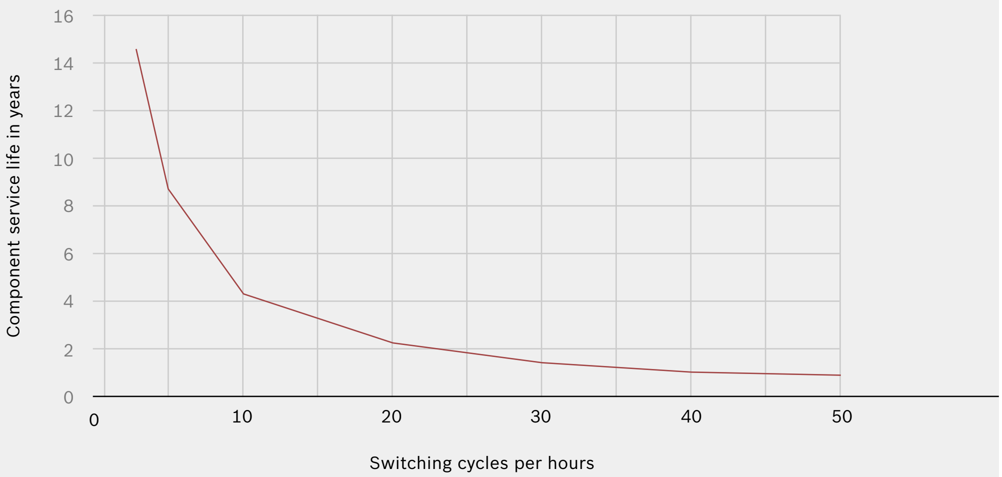
Summary

The explanations provided above show that determining the pressure safety margin and the boiler output are very important. Boiler systems analysts are urged to clarify these questions at an early stage with a competent boiler manufacturer who offers a broad range.

Bosch Industriekessel GmbH always equips their steam boilers with a meter which monitors the burner starts and enables the operator to recognise an unfavourable operating mode at an early stage.

Regular servicing (preferably quarterly) of the boiler plant by the supplier's qualified service technician, and matching the control system to the operational requirements of the customer, are both factors of equal importance for maintaining the value of the plant and minimising costs. However, errors made already at the planning stage are generally irreversible and to some extent considerably restrict the optimum use of boiler plants.

Diagram 3: Service life of components as a function of switching frequency



Assumptions: 4000 operating hours per year, average service life per component 175000 duty cycles

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