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Avoidable stresses in hot water boiler installations

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Low- and high-pressure hot water boiler installations for space heating are subject to a number of stresses which result in a greater or lesser stress on the boiler body.
Two main factors must be considered:
1. Effects produced by the system
2. Effects produced by the operation of the burner

Effects produced by the system

The system-side effects are imposed on the boiler and, as a rule, cannot be influenced by the boiler manufacturer and supplier. As negative influencing factors, the following can be listed.

Unfavourable water conditions resulting in corrosion or the formation of deposits

These effects are regarded as generally known and damage through unsuitable water regimes can be reliably prevented by commercial water treatment installations as well as chemical closing-devices, provided that the water quality is monitored in accordance with the specified values.

Boiler flow difficulties as a result of insufficient boiler flow rate caused by system-side pump and control valve settings

In case of insufficient flow through the hot water boiler, e.g. when the system pump is simultaneously acting as boiler circulating pump and flow is reduced as a function of load or

pressure via the speed control resp. if the system control valves suppress a water flow towards the boiler, sluggish flow conditions may arise in the boiler. These favour local overheating and steam void formation.

In addition, this may lead to faults in the thermostats and temperature limiters, since the sensors are not exposed to sufficient flow, and mixed temperatures, which to some extent far exceed the safe temperature, occur as a result of streaming.

For this reason, a forced flow of the boiler during burner operation must be absolutely ensured. The minimum flow amounts to 25 %, related to the maximum boiler capacity and a temperature difference between supply and return flow of 20 K.

Excessive spread between the circulated heating system water returning to the boiler and the boiler exit temperature

Excessive temperature differences between the water returning from the heating system and the water heated by the boiler and released into the central heating flow always result in expansion and thermal stresses within the boiler.

Permanent damage may arise if the differences between flow and return temperature change frequently, and this in proportion to the value of these differences and rates of change. These effects can be counteracted by a return temperature control system which maintains a fixed minimum return temperature respectively which safeguards that a max. temperature difference between supply and return flow is not exceeded.

Excessively low boiler water return temperature

Insufficient boiler water return temperatures below the dewpoint temperature of the fuel used can lead to water precipitation in the flue gas passages with the result of corrosion, blocked flue ducts etc. This also applies to the cold start of the boiler resp. the plant.

Falling short of the minimum return temperature specified by the boiler manufacturer can, as described, be reliably prevented by the appropriate arrangements, if correctly planned and designed.

During cold start of the boiler or the plant, it is essential to make sure that especially the boiler will be heated up at low burner capacity and full water flow in the boiler circuit; only after reaching the admissible return flow temperature, the boiler should be connected to the system. When connecting the boiler to the system, adherence of the boiler return flow temperature must be observed. This process can be automatised by means of the a.m. return flow temperature control.

Pressure fluctuations as a result of shortcomings in the system-side pressure maintenance

Through appropriate arrangements in the system, the system pressure should be kept as constant as possible and the pressure level needed for the complete system must also be ensured at all operating conditions to prevent the generation of steam. Wrong operation of stop valves or unfavourable behaviour of system pressure regulating elements may lead to considerable pressure fluctuations which affect the boiler walls and lead to permanent damage on exposed areas of the boiler.

It must also be considered that the system pressure has a certain safety margin (20 %) to the safety valve trip pressure in order to avoid an unintentional response of the max. pressure control resp. the safety valve.

Excessive differences between operating pressure with corresponding saturated steam temperature and the actual supply temperature

Because hot water boilers do not regulate their operating pressure through their own heat input, as is for example the case with steam boiler water temperature and the corresponding saturated steam temperature.

Due to the geodesic conditions of a hot water system it is often necessary to apply a relatively high system pressure despite relatively low hot water flow temperatures.

The high system pressure determines the wall thicknesses of the boiler, which increase with higher design pressures. With increasing material thickness, the wall thickness temperatures of the heated components may also increase, particulary under unfavourable operating conditions and as a result of deposit formation in the case of incorrect water flow layout, which then leads to additional stresses due to the lower elasticity of the pressure vessel.

In combination with frequently changing burner starting and stopping intervals this can lead to longterm contractions and expansions and after a certain number of load changes to the fatigue of components.

In addition, a discharge of steam voids from the heating surfaces by imposed exernal pressure can no longer take place unimpeded, so that the steam voids adhering to and growing on the heating surfaces lead additionally to consider-able local temperature increases.

For all the above mentioned reasons the temperature safety margin should indeed be set with a sufficient difference from the required operating temperature, but additional reserves beyond the operationally necessary values should be avoided when determining the pressure.

The temperature safety margin should therefore be at least 20 °C below the applicable saturated steam temperature – of the design pressure – (in the case of high-pressure hot water boilers).

In the case of boilers group IV, i.e. high-pressure hot water boilers, particular attention must however be paid to these aspects because of the mandatory dimensioning and design regulations.

For applications with very high static pressures, e.g. in multistorey buildings, TV towers as well as in mountainous terrain, the introduction of heat exchangers is recommended to counteract the static effects on the boiler and therefore allow a pressure application which corresponds to the saturated steam temperature.

Unfavourable influences on space heating control systems

Since hot water boiler installations are mainly used for space heating, e.g. in the case of district heating systems supplying several blocks of flats, these blocks of flats generally have control sub-stations for the temperature control within the flats etc. Coordinating these control sub-stations with the heat supply station is important because with the generally fitted weathergoverned energy- saving controls the heating temperature is lowered during the night by timers in the heating circuit, which then, when several control units switch over simultaneously, leads to a suddenly rising heat demand.

It is then necessary to coordinate such control circuits and to introduce time delays, so that extreme peak loads are avoided at the district heating station. An uncoordinated operation of the heat control substations with the various heat generation possibilities can lead to extreme boiler loads and to the occurrence of operating conditions and damage as described.

Effects produced by the burner operation

Excessive burner output in relation to the actually required peak boiler output

A high burner output results in the boilers being frequently switched on and off according to the burner control range. This caus es temperature changes which, particulary in the case of gasfired boilers and long pre-ventilation times, can be extreme.

Burners generate temperatures of 1 700 – 1 900 °C in the combustion chamber. In the furnace purging phase before ignition, the introduction of ambient air from the boiler room at usually 20 – 30°C will cool the previously hot boiler walls and the water temperature, too, will be lowered by the flushing and cooling process.

During the subsequent re-ignition of the burner, the latter generally increases its output and is very often in extreme low-load phases during the run-up process switched off again with subsequently, often immediately, occurring restarting. The permanent thermal shock stress between flame and purging leads to expansion differences between combustion chamber and boiler shell, which can in the course of time lead to permanent damage. Therefore, burner cylces of < 4 per hour should be aimed at.
This behaviour can be counteracted:

- by the installation of low-load controls, which prevent a run-up of the burner,
- by using burners with wide control ranges and
- by adapting the effectively needed boiler output to the actual demands.

Too close temperature difference setting between burner shut-off and burner restart

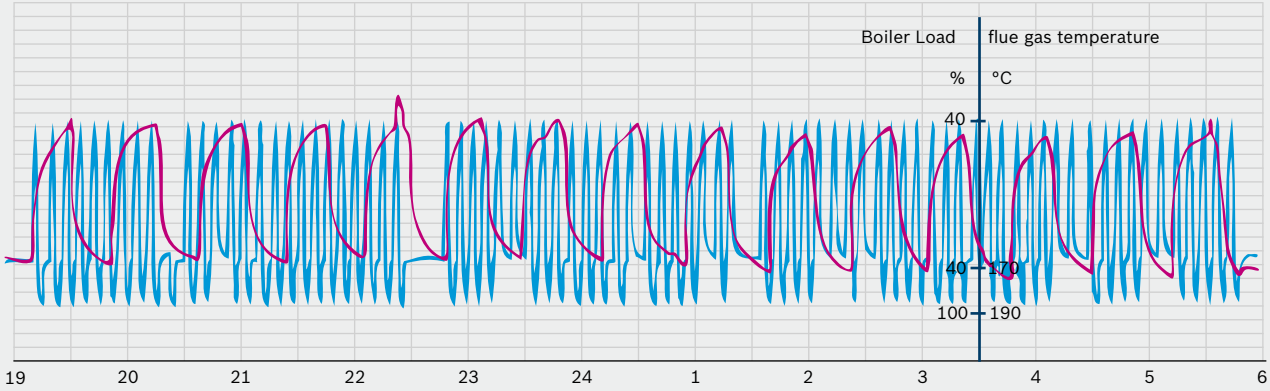
Temperature controllers or temperature sensors must be set or designed with a sufficient spread between burner start and burner shut-off. The spread between burner ON and burner OFF should ideally be at least 6 – 10 °C, to prevent too frequent starting and stopping through temperature over-shoot or when switching off through undercooling as a result of post-ventilation. Insufficient temperature differences between burner start and burner stop result in a very frequent switching on and off of the burner with the above mentioned thermal shock stresses in the combustion chamber and the consequent permanent damage.

Unfavourable burner regulating behaviour through excessively quick up- and down regulation of the burner

Excessively quick load change rates in the control of the burner can also have unfavourable effects on the durability of the boiler walls, as mentioned above.

Before the correction (blue): boiler operating uneconomically
Characteristics: on-off burner control; burner start interval approx. 7.5 minutes with each time 35 seconds purging time; temperature-governed stress reversal of the boiler in this case unnecessarily high

After the correction (pink): boiler operating economically
Characteristics: on-off burner control, low-load controlled during the night; burner start interval approx. 44 minutes with each time 35 seconds purging time; temperature-governed stress reversal of the boiler in this case reduced to a fatigue-free level



Operational diagrams of gas-fired high-pressure hot water boilers before as well as after correction of its load behaviour in the low-load phase between 7.00 p.m. and 6.00 a.m.

Parallel operation of serveral boiler units, although the heat output is much too low for the total of the boilers operated

Here, the operators have an important part to play: they have to switch off the boilers when the heat output of several boilers is no longer justified.

Heat supply stations must already at the planning stage be dimensioned for the actual operating conditions, so that it is very advisable to provide correspondingly dimensioned low-load boilers for the summer months, which allow a sufficiently long burner run phase even at high outdoor temperatures.

Further improvements can be achieved through the installation of sequential control systems. It must here be taken into account, however, that a sufficient temperature range must be available, so that the sequential control can be unequivocally actuated.

Boiler installations equipped with sequential control can as regards the temperature safety margin only be operated at reduced output temperature, which must be taken into account already at the planning stage.

Sequential control also results in greater temperature differences between the individual operating phases. In order to avoice this, it is recommended – especially in plants with more than 2 boilers – to realize an automated sequence control while integrating a measuring device for the total heat quantity.

Summary

The possible causes of avoidable boiler stresses mentioned above make it clear that we are here dealing with an extremely complex subject.

This ranges from planning via execution and up to the operation of the plants. Obviously, this brief account of problems relating to hot water operation cannot claim to be complete.

Because of the complexity of the subject, hot water installations must be planned by capable, experienced specialist companies, since many of the possible faults can already be avoided at the planning stage. An important part is also played by the quality of the components used, starting with the boiler, the firing system and the other system components. Of great importance is also the method of operation as well as the maintenance and supervision of the plant as a whole by the operating personnel.

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