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The importance of water volume in steam boilers

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A large volume of water in the boiler can hardly serve as a reserve it only creates energy losses. Too little water in the boiler leads to pressure fluctuations and impairs steam quality. A correctly calculated water volume is therefore an important performance criterion when selecting a boiler. However, top priority must be given to a sufficient steam space and a burner control system with short furnace purging time.

Boiler designs are very often assessed according to their water content. Contradictory arguments often arise here. For example, it is said in favour of a low water volume that unnecessary water reserve results in long heating-up times and additional shutdown energy losses. This argument is supported by manufacturers of quick-steam generators and by companies which are active in the heating boiler sector. Also, some users are in favour of boilers with low water contents. A large water volume is to some extent favoured by companies which build shell boilers. They emphasize that, for example, this makes the boilers react more flexibly to demand changes and certain steam reserves are provided in this way.

A large water volume used to have important safety implications

To be able to assess the importance of the water volume correctly, the development of the last 60 years must be taken into account. At a time in which steam boilers were fired with solid fuels, the water volume was of quite vital importance. Since water controland limiting arrangements were not present, the fuel was charged by hand and the municipal water supply did not always work reliably, it was an essential safety requirement for steam boilers to maintain a sufficient water reserve in case the fresh water supply would fail just when the glowing fire was at its maximum. In these case the heat released by the fuel had to be drawn off and turned into steam by the excess water available. It was for this purpose also necessary to provide sufficiently large water tanks.

Since the fifties, coal firing has been largely replaced by oil firing. During this transition, all safety considerations which were usual for steam boilers with slow control response solid fuel firing were also transferred to oil or gas fired installations. The important fact that in the case of oil firing, which has quick control responses, the heat supply to the boiler can be stopped within a second, was not taken into account. Furthermore, modern water level control- and monitoring systems, which have come into use in the meantime, virtually eliminate any danger of overheating damage as a result of water failure.

Regardless of this development, however, boilers with large water reserves were still preferred.

Patent brought flexibility during fluctations

In the course of the sixties, progressive manufacturers reduced the water volumes of their boilers to a sensible level, which ensures sufficient flexibility during load fluctuations, but prevents or substantially reduces unnecessary additional losses during start-up, shut-down and run-down. Particular importance was here attached to the steam space volume, since the steam space should be designed as large and optimally as possible, which also applies to the steam generating surface and the height of the steam space.

The different designs I to III show internally arranged, rear wet-back reversing chambers of a boiler. Design III represents an optimum, since a low water volume, a large fire tube diameter and a large steam space are achieved. The design is based on a Bosch Industriekessel GmbH (formerly Loos) patent of the fifties and has since then proved itself in over 50 000 boilers.

Modern steam boilers with quick-response firing control have a reduced specific water volume (at lowest permissible water level) of 1 – 1.4 m^3 per 1 t_{steam}/h. In special cases, boilers with up to 10 to 25 % higher specific water volume are, however, still used.

For moderate steam needs below 1.5 t_{steam}/h, there are specially designed process boilers which fall considerably below the abovementioned standard value of the specific water capacity (approx. 0.75), to be able to take advantage of easements in statutory installation regulations. These steam boilers, too, have been extremely successful in practice, despite the low specific water capacity.

Figure 1: Section of a modern three pass shell boiler with low specific water volume

Heating coil allows rapid steam generation

The quick-steam generator as a boiler with an extremely low water volume has its advantage in the quick availability of steam and in low shut-down losses. These advantages are however paid for by strong pressure fluctuations during larger demand changes and by a relatively high water content in the steam. For this reason, quick-steam generators are generally only used profitably if they offer in the lower steam boiler sector certain reliefs in legal supervision requirements and if no special requirements have to be met by the steam quality. Apart from that, the boiler capacity must with the quick-steam generator be very accurately matched to the actual consumption, since otherwise high switching frequencies of the firing system would occur, which would lead to rapid wear, soot accumulation, energy loss etc.

Important criterion: minimal furnace purging time

How small the influence of decreased pressure is on the steam capacity can be illustrated by the following example: In a boiler which is operated at 9 bar, only 8.5 kg steam can be gained from 1 m³ water volume by reducing the boiler pressure by 1 bar. This shows clearly that water volume can hardly be considered as a latent steam reserve. The amount of steam present in the steam space can in the case of sudden demand peaks no longer be appreciably increased via postevaporation through pressure reduction. Apart from that, pressure reduction is as a rule not accepted, but constant pressure is asked for.

Output peaks can only effectively be realized through the burner control. In this respect the controllability of the burner must be accorded special importance when it comes to sudden changes in demand. As regards the burner controls the burner operating time must be as long as possible and the cost-intensive furnace purging time as short as possible.

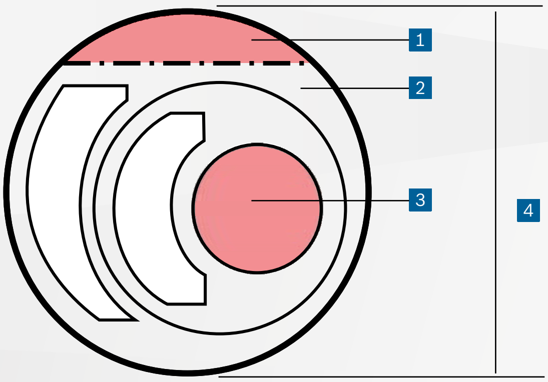
Urgently recommended is also the installation of lowload controls and time pulse counters for recording the burner switching periods.

Each furnace purging period is particulary counterproductive as regards rapid demand changes and demand adaptations of a boiler. When selecting boilers, this criterion should therefore be specially noted and steam boilers given preference which can be operated with reduced furnace purging times. Appropriate test reports and confirmation by the boiler manufacturer should be made available in this respect.

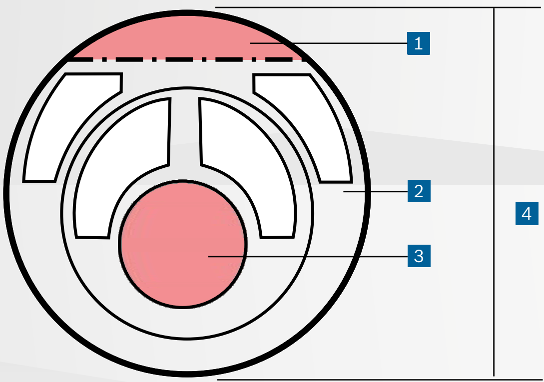
The designs I and II have the same characteristics:

1 small steam space
2 large water volume
3 small fire tube
4 large external dimensions

Boiler design I



Boiler design II



A progressive version is design III:

1 large steam space
2 reduced water volume
3 large fire tube
4 small external dimensions

Boiler design III

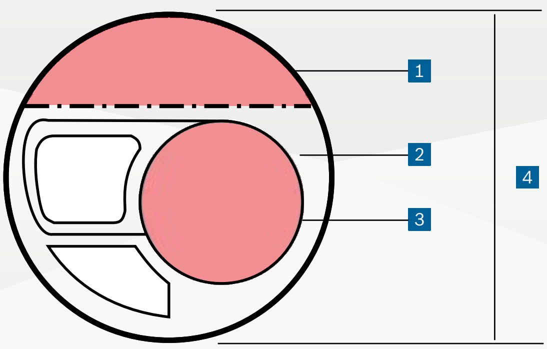


Figure 2: Three boiler designs, each with internal, rear wet-back reversing chamber

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