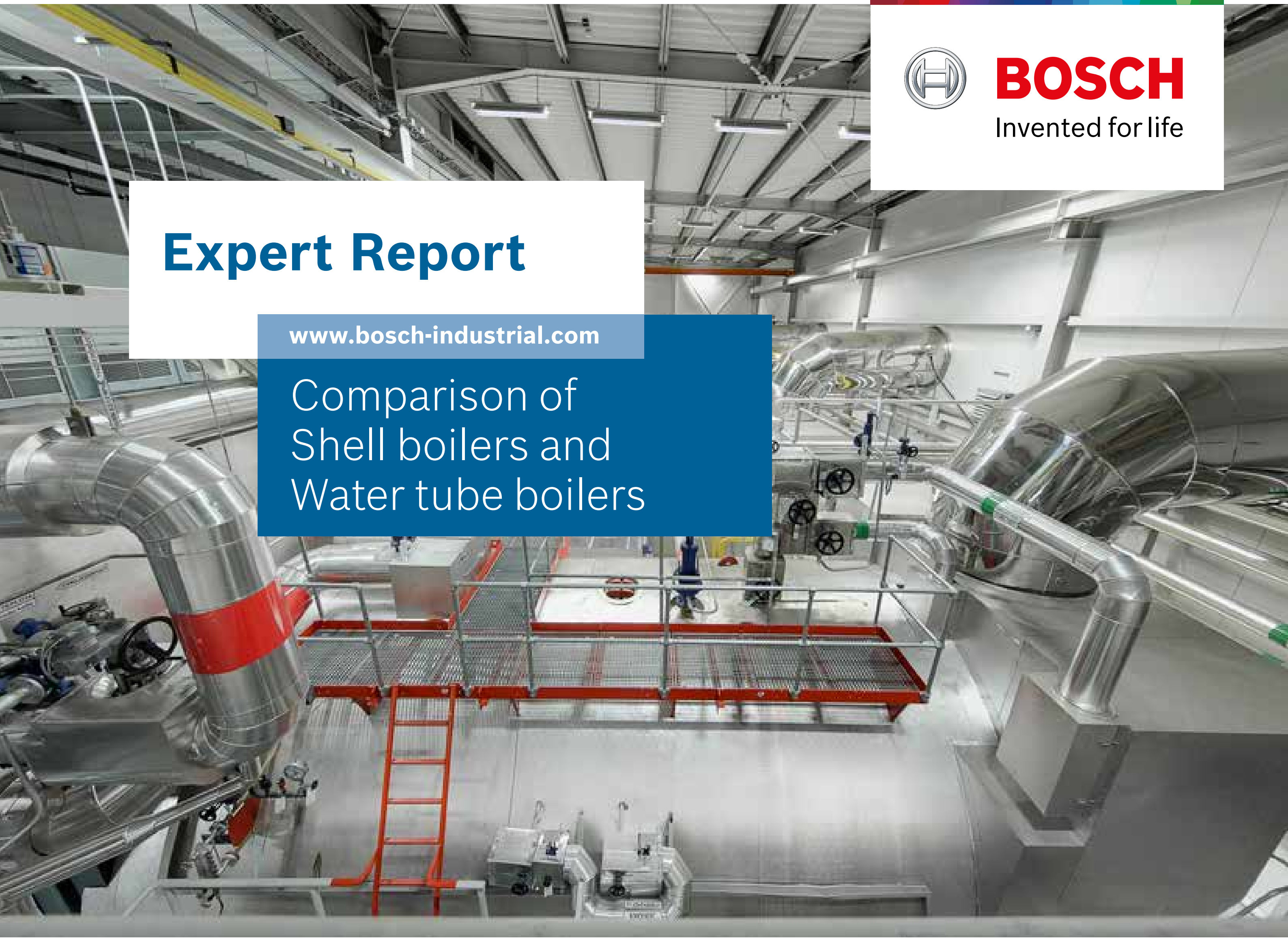

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Comparison of Shell boilers and Water tube boilers

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The industrial generation of steam looks back on more than 200 years of history. The first century is characterized exclusively by boilers which are comparable to today's shell boiler. In the year 1875 [1], i.e. 106 years after James Watt invented steam boiler and steam machine, the company Steinmüller designed the first water tube boiler.

Since then, the development of water tube boilers took a dramatic course as far as capacity and pressure are concerned. In 1927, the first Benson boiler was taken into operation with a capacity of 30 t/h at 180 bar and 450 °C. In the sixties of our century, supercritical boiler with pressure beyond 350 bar and temperatures of more than 600 °C were designed. In 1970, the capacity limit was reached at 1 000 t/h. Only 5 years later, it was possible to manufacture water tube boilers with steam capacities of more than 2 000 t/h.

Such immense capacities and extreme steam parameters cannot be achieved with shell boilers due to the design principle. Howewer shell boilers still are being improved today. Some examples for this fact – initially started by Bosch Industriekessel GmbH – are the introduction of the three-pass boiler with internal, water- cooled reversing chamber in 1953, the development of the double-flue boiler (1956) or the failsafe water level probes (1977). Thus, steam outputs of up to 55 t/h are today being covered safely and economically almost exclusively by a single shell boiler. Depending on the size, pressure of up to 30 bar and superheated steam temperatures of up to 300 °C can be reched.

Figure 1 shows a modern shell boiler of twin furnace design. All of the above-mentioned aspects prove that both design principles have their justification. In general, it is neither sensible nor impossible to replace one design by the other in certain clearly defined cases. Sometimes, there are exceptions to this rule. The object of this essay is to provide arguments for such cases when both design principles can be applied: aspects of safety, operational aspects, physical characteristics and costs.

Safety

In some developing countries, i.e. in Asia as well as South America shell boilers are not widely spread. The local manufacturers of shell boiler produce in quality standards which do not meet the German standards at all. The same applies to safety equipment concerning excess pressure and water shortage. The safety standard is correspondingly low. For fear of the catastrophic consequences of a boiler explosion, the water tube design is being favoured due to the larger water contents of the shell boilers, sometimes also due to the very conservative attitude of some planners /engineering firms. Apart from the safety aspect, a decisive factor in the a.m. countries is the short service-life of the locally manufactured shell boilers.

In the former Federal Republic of Germany, the past 20 years render no reports of disastrous accidents in connection with shell boilers. Critical for this positive development was certainly the fail-safe probe system for the control and limitation of the water level 1977 and the introduction of Rules for the designimminent safety of shell boilers in 1985 [2]. Designimminent safety means giving up certain design principles (such as set-on boiler ends, girder stays for enforcement of ends), the unlimited possibility of inspecting the inside of the boiler and the provision of large spacing between boiler components of different temperatures.

Another important aspect was the introduction of the hydrostatic test with increased test pressure which is a simple, yet very reliable method of evaluating the condition and the safety of the shell boiler [3]. The above-mentioned rules and equipment made it possible to safely operate shell boilers in Germany without any major accidents for more than twenty years. This does not apply entirely other boiler design [4, 5]. Whenever quality in manufacturing and design is observed, shell boilers offer a high degree of safety and durability. Therefore, engineering firms and users should choose only such manufacturers who are in a position to present a large number of reference plants which have been operating safely and without damages for many years.

Aspects of Operation

This section of the essay deals with the requirements to water quality, maintenance and repeated safety checks.

The quality of boiler water and feed water is of great importance for steam boilers of any design. However, there are important, i.e. economic differences in the requirements to the water quality.

In case of water tube boilers, a saline operation is advisable for most types of construction [6]. For water tube boilers, saline stands for a conductivity of the boiler water of ≤ 2 000 μS /cm. Usually, for local heat fluxes > 250 kW/m², salt-free water is required in order to avoid blocking of the tubes, thus impeding the thermal transfer. These requirements can only be met by installing complicated and costly water treatment systems.

In principle, shell boilers can be operated with saline water (conductivity ≤ 6 000 μS/cm). Adverse effects of the boiler heating surfaces due to salt deposits does not occur. Simple water softening plants may be applied for water treatment. The type of water treatment is determined by economic aspects as well as by the quality of the water available. The decisive factor is the duration of amortization for high-quality water treatment systems which may result from the reduction of the desalting rates.

Another difference is the size in relation to the thermal capacity. Typically, shell boilers require less space at similar capacities required.

Maintenance can be performed much simpler in shell boilers as in water tube boilers. This is mostly due to the clearly lower efforts during start-up and shut-down as well as the easy access to the heating surfaces.

The same applies to the subject of repeated checks. For shell boilers which are produced in accordance with the a.m. regulations for designinherent safety a very simple, clear and economic system has proven itself: i.e. visual inspection of the relevant boiler components following a hydrostatic test under increased test pressure, please also refer to [3]. This allows for an almost total renunciation to non-destructive testing such as ultra-sonic tests. For water tube boilers, the hydrostatic testing with increased test pressure has not caught on for several reasons which should not be discussed in this essay. Moreover, many areas of a typical water tube boiler are not accessible for visual inspections (insulated areas). Therefore, the extensive use of ultra-sonic testing and such is required.

Figure 1: High-pressure shell boiler, twin-furnace design, 35 t/h, 16 bar

Figure 2: 100 MW hot water – water tube boiler during transport

Physical Characteristics

In the following, some aspects will be discussed which result directly from the respective design principle: water contents, accumulations, partial-load characteristics.

In relation to the thermal capacity generated, a shell-type boiler has a much higher water contents than a water tube boiler. Therefore, the shell-type boiler is more robust towards load fluctuations or load demands, which temporarily exceed the rated boiler capacity. Except for a short-term increase of the steam wetness, no other effects are to be expected; especially negative influence on the thermal transfer is not expected. This ‘amicable behaviour’ is not characteristic for the water tube boiler by nature of its design. Pressure fluctuations will also inevitably influence the occuring changes in density.

Apart from the mentioned advantages, the large water volume of a shell boiler also has some drawbacks considering the cold start behaviour. The time interval which passes until steam is available from the boiler is clearly longer than in water tube boilers with comparable pressure and capacity. Additionally, each cold start of a shell boiler causes a higher mechanical stress than stationary regular operation [reference note cold start]. This leads to the conclusion that in shell boilers, cold starts should be carried out as carefull as possible.

Due to the lower water contents, the water tube may be used in varions countries as a so-called ‘product boiler’, i.e. installation can be performed much easier [7].

An essential factor for the durability of steam boilers is the number of burner starts. Decisive for this fact is – apart from the suitable adjustment of boiler/system – also the low load level which can be produced by the boiler. In case of superheatedsteam- generating water tube boilers of certain designs, this low load corresponds to the smallest thermal capacity given by the burner. In water tube boilers, the burner low load can usually not be projected to the boiler since the reduction of the water-side mass flows negatively influence the thermal transfer, causing undesired burn-out effects in the range of high heat fluxes.

Costs and Time

As long as certain requirements can be covered by several shelltype boilers, the selection of a shell boiler is the more economic alternative – provided the level of manufacturing costs as well as quality are comparable. Moreover, as a rule, the delivery times as well as the periods required for assembly of the plant are shorter.

Usually, shell boilers offer a slightly higher degree of efficiency than water tube boilers at comparable waste gas temperature and waste gas composition due to lower radiation and line losses. This can also be easily maintained during operation due the facilitated maintenance, i.e. also in operation, the shell-type boiler is characterized by an increase in economy.

Criteria	Shell Boilers	Water Tube Boilers
Water quality	lower requiremens, saline operation possible	high requirements, salt-free operation required
Maintenance	easy cleaning	more costly
Repeated testing	simple, inspection following hydrostatic testing, extensive non-destructive testing such as ultra-sonic testing only rarely required and only to a low extent	ultra-sonic testing required in addition to hydrostatic test, i.e. time-consuming and costly
Costs at comparable level of manufacturing costs and quality	lower	higher
Efficiency	higher, easy to maintain	lower, more difficult to maintain during operation
Partial load characteristics	Burner control ratio can be Exploited when falling-short of min. load burner can be shut-down without any problems	In case of certain designs, partial load must be limited, burner cannot bei switched off-hand
Water contents	higher due to design principle	lower
Accumulation capacity	due to the high water volume, not susceptible to pressure and load fluctuations	susceptible to load and pressure fluctuations resulting form the process
Delivery time	shorter	longer
Space requirement	low	high
Period required for assembly, initial start-up	short	longer

Summary
Usually, the application ranges of shell boilers and water tube boilers are clearly divided. It is simply impossible to use a shelltype steam boiler for the generation of 1 000 t/h steam at 180 bar and 450 °C. Up to a range of approx. 200 t/h, 30 bar and 300 °C, one or more shell boilers are generally the better choice due to the fact that they are cheaper in purchase and operation. Modern manufacturing processes and regulations regarding the designinherent safety allow for a high safety level and durability. The aforegoing aspects are summarized briefly in the table following below.

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