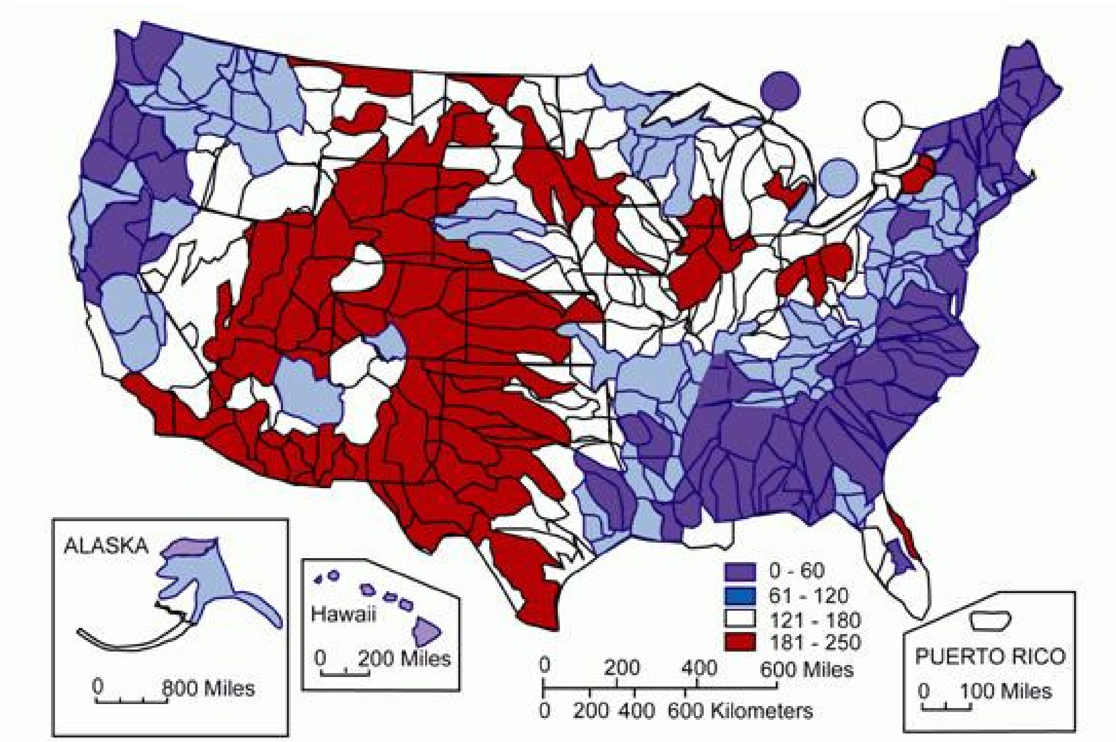
Energy cost reduction through online water quality monitoring
A White Paper from Gebrüder Heyl USA

Water quality monitoring is a vital step toward saving energy costs at any facility that utilizes boilers. Recent research has shown that better control of parameters such as water hardness, carbonate hardness and conductivity through online water quality monitoring can save facilities thousands of dollars annually in energy and down-time costs. Water quality monitoring can also greatly increase the functional life of a boiler, allowing for significant savings on capital equipment and investment.

According to the US Geological Survey, most regions in the United States are affected by hard water (see Graphic 1). The Great Lakes region, Alaska, Tennessee and parts of the Pacific Northwest suffer from moderately hard water, while the hardest water levels in the US can be found in Texas, New Mexico, Kansas, Arizona and southern California. However, hard or very hard water has been identified in some water sources throughout almost all regions of the country. This means that virtually any facility in the US could be vulnerable to incurring extra energy costs due to formation of lime scale in boilers and other negative effects of hard water.

Graphic 1: Concentration of Water Hardness in the USA as calcium carbonate, in mg/liter



Source: US Geological Survey. Mean hardness as calcium carbonate at NASQAN water-monitoring sites during the 1975 water year. Colors represent streamflow from the hydrologic-unit area. Map edited by USEPA, 2005. Modified from Briggs and others, 1977. **Note**: Major-ion chemistry in ground water is relatively stable and generally does not change over time. Although the map illustrates data from 1975, these data have been found to be accurate and useful in current assessments.

How does lime scale form?

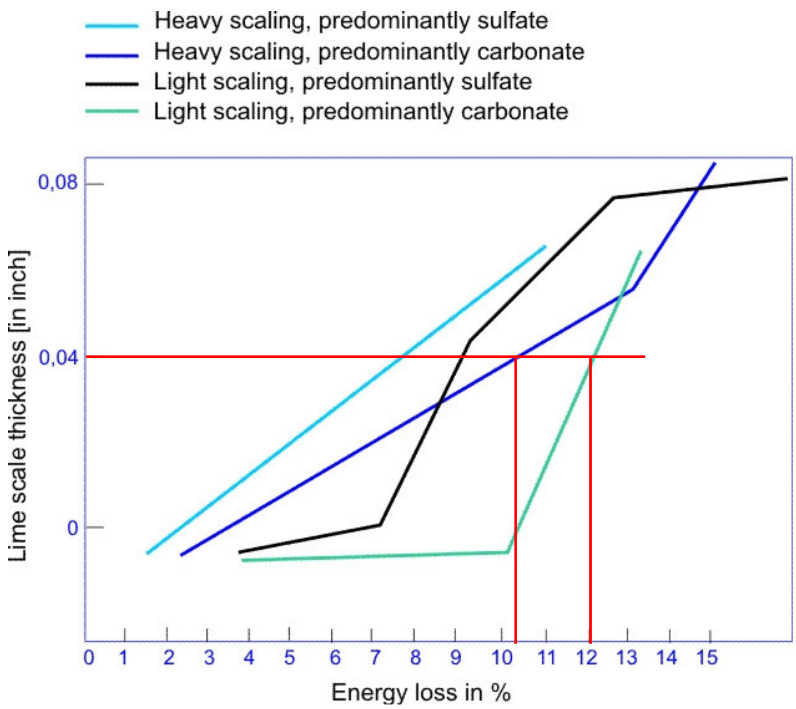
Lime scale is caused by calcium salts contained in hard water becoming soluble when heated inside of a boiler feed or condensate water stream. When calcium salts become soluble, they attach to the surface of metal that they come into contact with, forming a milky-colored, solid layer. In this way, lime scale builds up on the inside surfaces of the pipes and other metal parts of a boiler and its feed and condensate water streams. In addition, the likelihood of lime scale forming increases significantly with a rise in temperature.

What are the effects of lime scale?

Even in minimal amounts, lime scale reduces heat transmission, which leads to the immediate effect of a decrease in heating capacity - an important factor for energy costs. The reduction of the area inside the pipes also results in higher flow resistance. In addition, when it builds up, lime scale on heat transfer surfaces such as tubes may result in local overheating of the tube metal and the formation of cracks on the tube surfaces.

For instance, a layer of lime scale just 0.04 inches (1.0 mm) thick reduces the heat transfer coefficient of plate heat exchangers or tube heat exchangers by roughly 80%. This leads to a **reduction of heat transfer of up to 30%.** And even a seemingly insignificant layer of lime scale of just one-hundredth of an inch can ultimately result in an **increase in energy costs of approximately 12%.**

Graphic 2: Energy Loss Caused by Lime Scale



Source: Verein Deutscher Ingenieure (The Association German of Engineers), Guideline 2035

What happens in boilers in which feed water is not monitored?

Low heat transfer and thus relatively significant energy losses occur under the following operating conditions at a constant water hardness rate of just 2 ppm $CaCO_3$:

<u>Example: 15 t/h Boiler</u>

Condensate returns (45%)	238.4 ft^3/hr
Feedwater backfeed (55%)	291.3 ft^3/hr [1,748,076 ft^3/yr total]
Hours of operation	6000 hrs/year
Water hardness	2 ppm/m^3 = 2 g/m^3 $CaCO_3$
Heating surface	3,230 ft^2

At an input quantity of 200 lb of $CaCO_3$ (lime) annually and a heating surface of 3,230 ft^2, a lime scale layer of approximately 0.005 inches develops in the first year alone. This corresponds to around 2% additional energy costs.

→ **The additional costs of an electric power price of 2 cents per KWh add up to approx. $2,440/year**

With higher levels of water hardness, energy costs rise even more significantly:

Water Hardness	Lime scale/year	Additional energy costs*
2 ppm $CaCO_3$	0.005 in (0.1 mm)	$2,440 / yr
9 ppm $CaCO_3$	0.02 in (0.5 mm)	$6,100 / yr
18 ppm $CaCO_3$	0.04 in (1.0 mm)	$12,200 / yr

* At an electric power price of 2 cents /KWh

Monitoring boiler feedwater with a Gebrüder Heyl Testomat ECO analyzer prevents this additional energy usage. The return on investment of a Testomat ECO is thus realized after just one year. Return on an investment in the basic Testomat 808 analyzer model is realized even earlier.

Does water hardness have other effects on boiler performance?

Not only does water hardness lead to additional costs through energy losses due to calcium salt-based lime scale build-up, but it can also lead to even more harmful build-up of scale deposits from a combination of factors. Silicates, sulfate and calcium phosphate in boiler feedwater can all lead to deposits on heat transfer surfaces. The presence of an excessive amount of any one of these substances in boiler feedwater can lead to costs of up to approx. $27,000 per year. When these factors combine to form scale build-ups, the costs due to energy loss, de-scaling operations and further potential damage to the boiler and related equipment can be enormous.

Energy losses due to build-up of calcium-carbonate, sulfate and calcium-phosphate:

Build-up of 0.04 inches	Energy loss	Oil or gas usage
Ca-Carbonate	~ 11%	18,823 ft^3 / yr
Sulfate	~ 9%	15,397 ft^3 / yr
Ca-Phosphate	~ 4.5%	7,699 ft^3 / yr

Do down-times for boiler maintenance really affect typical operating costs?

Plant down-times are an essential cost factor in the decision to better monitor water quality with an online analyzer. Plants or facilities have to be shut down when a boiler needs to be cleaned. This occurs more frequently if water hardness has lead to increased lime scaling. Plant operators and facility managers can significantly lower these costs through monitoring water hardness with a Testomat 2000, Testomat ECO or Testomat 808.

Down-times	Frequency	Days / year	Production losses*
Without hardness monitoring	approx. 2-3 times/year	approx. 8-12	approx. $15,000 – 90,000
With hardness monitoring	1 time/year	approx. 4	approx. $6,300

* Based on a 15t saturated steam boiler in industrial usage

→ **The testing of water hardness in heating systems and boilers helps to maximize the cost-effectiveness of your plant**

Are there other factors that should be monitored in order to maintain boiler performance?

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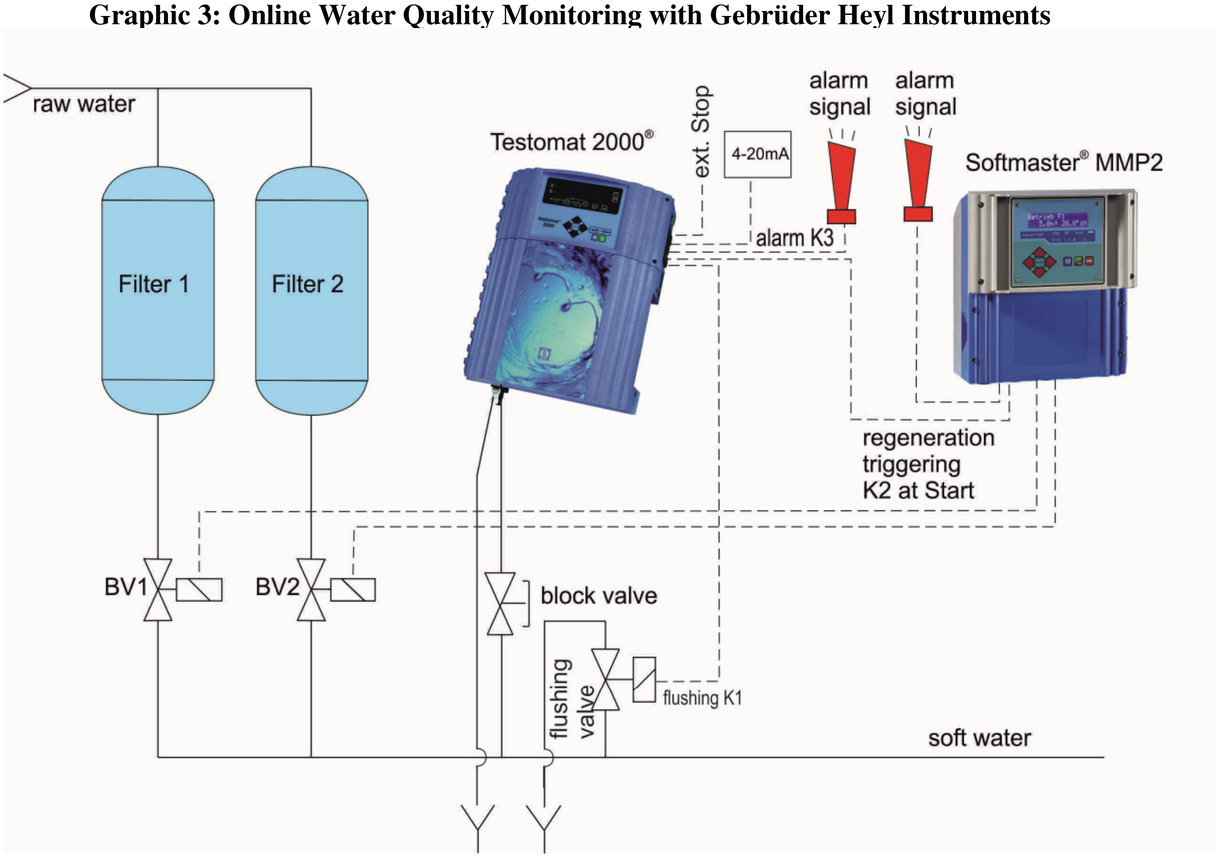
During steam generation, dissolved salt remains in the water and increases the salt concentration in the feed water, especially on the water's surface.

An excessive concentration of salt leads to build-up of a solid crust, weaker heat transfer, boiler corrosion and build-up of foam. The foam can be carried away with the steam and interfere with the downstream plant.

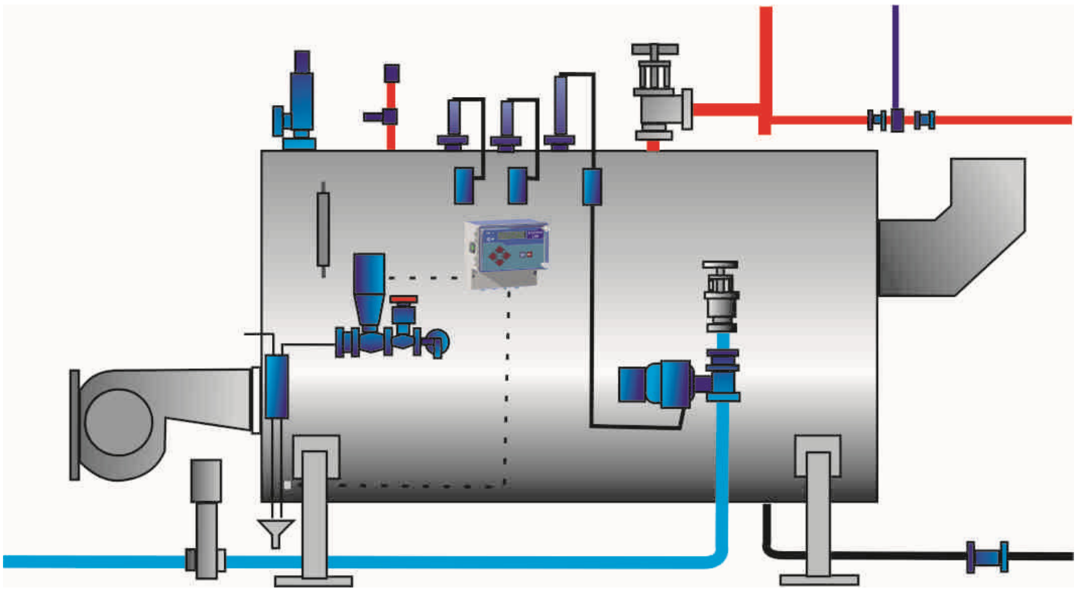
How do Gebrüder Heyl instruments help control boiler water quality?

The Testomat analyzes feed water hardness on a quantity- or time-controlled basis. When high hardness levels are exceeded, the Testomat sends a signal to the Softmaster MMP2 and the Softmaster will change the filter and regenerate depleted filter. Both devices send signals to a main control unit over a 4-20 mA interface. Both devices have alarm signal outputs in case of unexpected events (e.g. low water pressure, low filter capacity etc.).

Graphic 3: Online Water Quality Monitoring with Gebrüder Heyl Instruments



In order to avoid corrosion due to salt, the conductivity level of the feed water is monitored with a EcoControl EC Dos Desalt conductivity monitoring device. The boiler water with high concentration of salt will get discharged and water will fed in as needed to maintain the correct level of salinity.



How can the water treatment process best be improved through online analyzers?

Plant operators and facilities managers can increase the efficiency of the boiler water softening process through continuous water quality monitoring. Water quality monitoring allows operators to detect whether the chemical tank contains the correct level of salt and ensure that the regeneration process is running correctly.

Combining the Testomat 2000, Softmaster MMP2 and EcoControl EC Dos Desalt leads to less waste water, lower salt usage and cost savings through lower energy demand.

Which types of businesses can save on energy costs through monitoring water quality with online analyzers?

Application examples for low-pressure boilers:

- Commercial bakeries
- Meat processing facilities
- Steam heaters
- Commercial laundry facilities

High-pressure steam generators are built as large-volume boilers with an acceptable operating pressure of 1 to 25 bar.

Application examples for high-pressure boilers:

- Food and beverage industry (breweries, dairies)
- Pulp & paper industry
- Pharmaceutical industry
- Building materials industry

Sources

US Geological Survey

Verein Deutscher Ingenieure (The Association German of Engineers), Guideline 2035

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