SHIP Egypt

Session 08

Heating Systems and optimisation

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Introduction (1)

- **This part of the training module develops the heating systems typically used in industries, which are hot water and steam production industrial boilers.**
- **The background recommended for the trainees is the knowledge on water and steam basic physical properties at different temperatures, what is the behavior of a general boiler-burner set, what is a heat exchanger and how is the regulation-control for these equipments.**

Introduction (2)

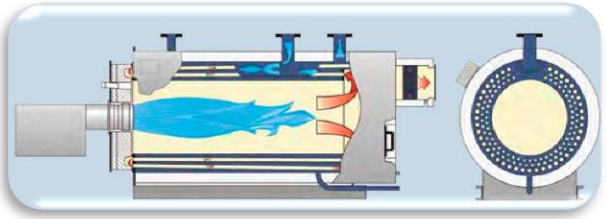
- **As heat production is related to many processes and energy subsystems in the industry, some information might be read also in other parts of the module (e.g. biomass boilers in the renewable energies section).**
- **The information provided doesn't focus on general operational and maintenance issues, but on which are the best technical and economic options to save energy and money at the industry by being more efficient, thus improving their competitiveness.**

Content

- **Brief introduction to heating systems**
- **Operational behaviours in steam boilers**
- **Efficiency improvements:**
  - Economizers
  - Heat recovery form purges of salts and sludges
  - Boiler envelope insulation
  - Three ways valves
  - Frequency variator in burner fan
  - O_2 control for efficiency
  - Water treatments and water supply modules
  - Condensates heat recovery
  - Steam storage module
  - Change in fuel and burner type
  - Change of complete boiler-burner
  - Control system
  - New boiler room
  - Heat production by CHP

Brief introduction to heating systems

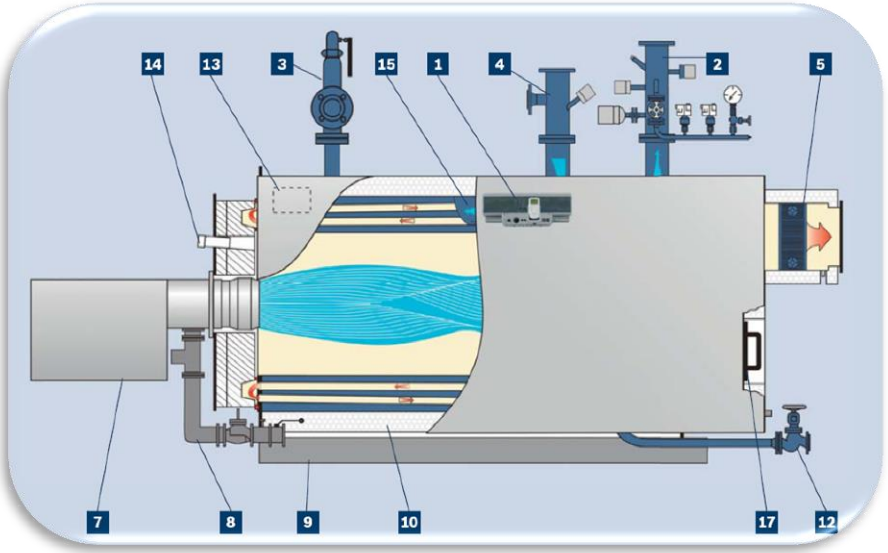
Source: Bosch



➢ Water boilers

⇨ Equipment level

- 1. Boiler Control system
- 2. Forward adapter connections (temperature limit and regulation, level regulator, level limiter, pressure indicator, pressure limiter, shutoff valve)
- 3. Full-lift safety valve
- 4. Return flow adapter piece
- 5. Flue gas heat exchanger
- 7. Burner
- 8. Gas regulation module
- 9. Base frame
- 10. Insulation with protective shell
- 12. Drain shut-off valve
- 13. Terminal Box
- 14. Sight hole
- 15. Injector device for inner temperature boosting
- 16. Inspection opening, flue gas side



Source: Bosch

Brief introduction to heating systems

➢ Water boilers

⇨ Boiler and boiler room general view

- **Set of 3 water boilers for industrial-scale hot water production. Each boiler 8 MW_{th}, with burner 10 MW_{th}**

Source: ESCAN s.l.

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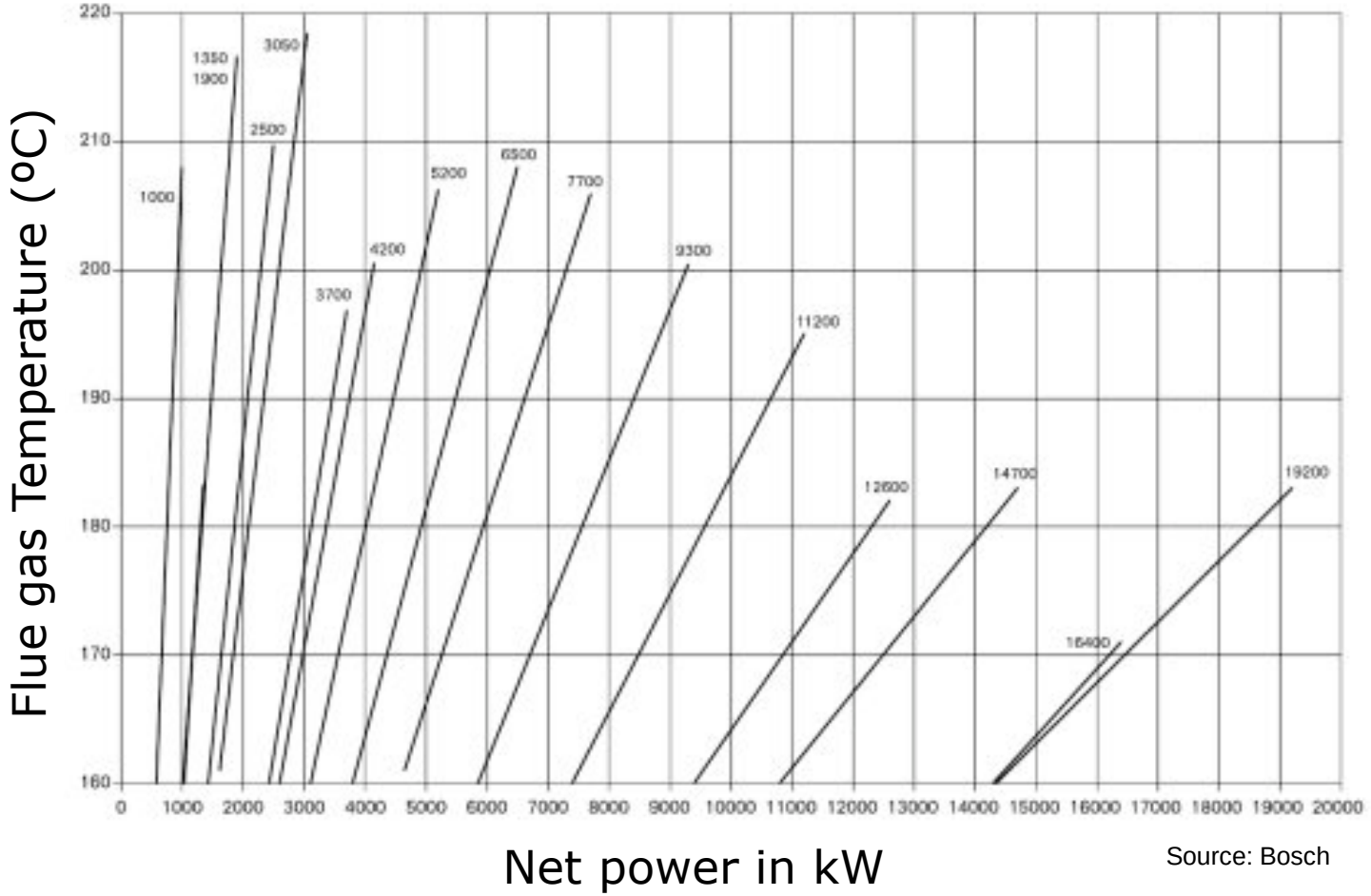
Brief introduction to heating systems

➢ Water boilers

⇨ Flue gas temperature – example efficient boilers



Source: Bosch

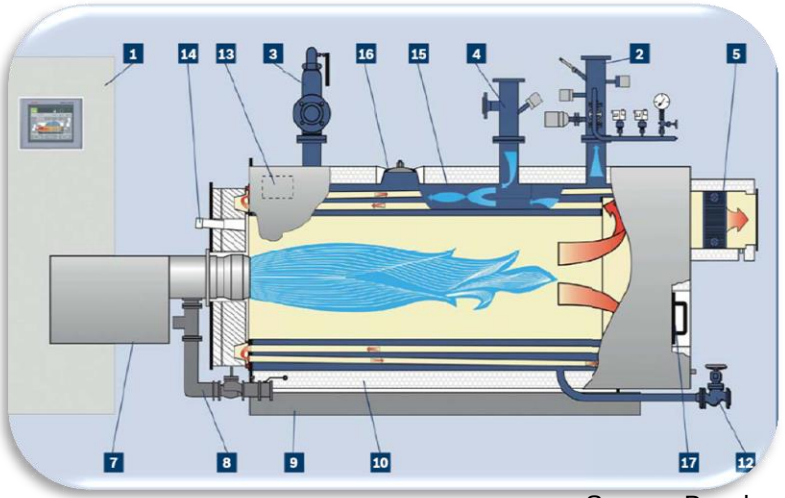
Brief introduction to heating systems

➢ Superheated water boilers

⇨ Equipment level

- 1. Boiler Control system
- 2. Forward adapter connections (temperature limit and regulation, level regulator, level limiter, pressure indicator, pressure limiter, shutoff valve)
- 3. Full-lift safety valve
- 4. Return flow adapter piece
- 5. Flue gas heat exchanger
- 7. Burner
- 8. Gas regulation module
- 9. Base frame
- 10. Insulation with protective shell
- 12. Drain shut-off valve
- 13. Terminal Box
- 14. Sight hole
- 15. Injector device for inner temperature boosting
- 17. Inspection opening, flue gas side

Source: Bosch



Source: Bosch

Brief introduction to heating systems

➢ Water Boilers and Overheated Water boilers

⇨ Some important characteristics in efficient water boilers include:

- **Effective 3-pass design**
- **Gas Heat Exchanger, reaching efficiency ratio up to 95 % and up to 105 % with condensing heat exchanger**
- **Effective thermal insulating materials with a high degree of efficiency**
- **Approved low return flow temperatures from 50 °C**
- **Suitable for efficient burners**
- **Pollutant reduced combustion due to the use of highly developed firing systems and careful matching of the best boiler/burner combination**
- **Lowest emissions for any fuel (liquid, gas, others)**
- **Robust, reliable and unsurpassed in its durability**
- **No burner minimum load level limit for keeping dry on the flue gas side**

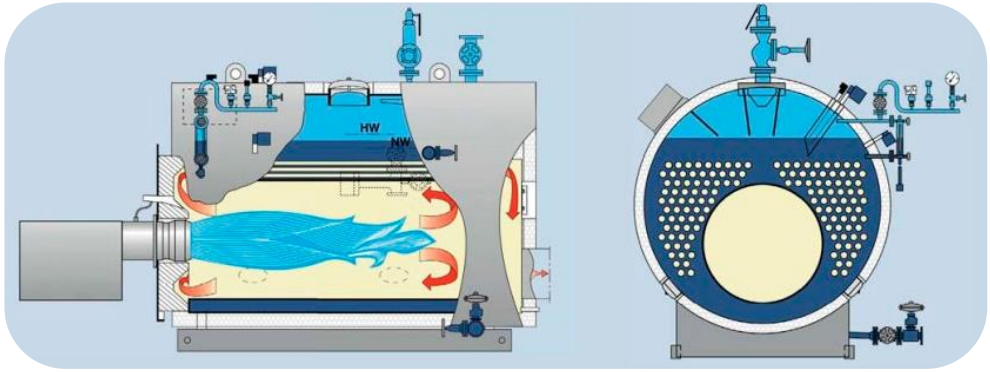
Brief introduction to heating systems

➢ Steam boilers

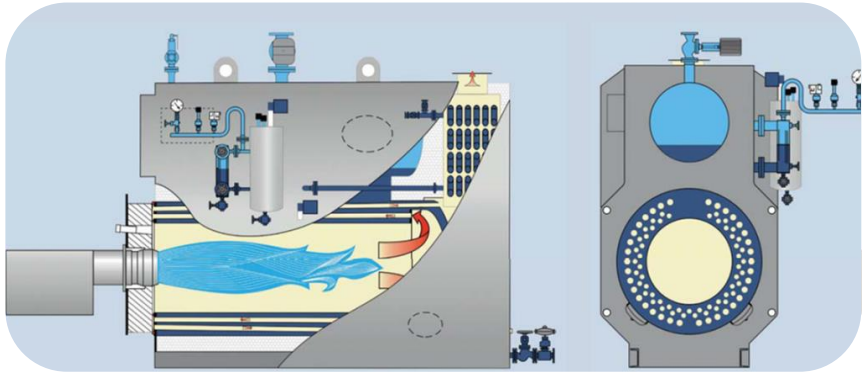
⇨ General view

Source: Bosch

Source: Bosch



Source: Bosch



Source: Bosch

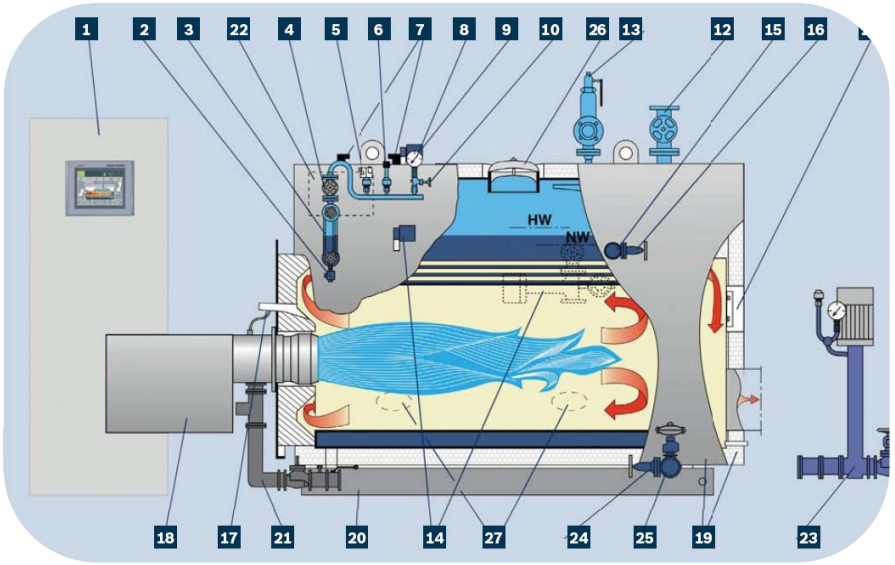
Brief introduction to heating systems

➢ Steam boilers

⇨ Equipment level

- 1. Boiler Control system
- 2. Blow-off tap
- 3. Reflective water level indicator
- 4. Manostat tube shut-off valve
- 5. Pressure limiter
- 8. Pressure gauge
- 10. Pressure gauge shut-off valve with testing flange
- 12. Steam removal valve
- 13. Full-lift safety valve
- 14. Fully automatic conductivity measurement and desalting
- 15. Feed water non-return valve
- 16. Feed water shut-off valve
- 17. Sight hole
- 18. Burner
- 19. Insulation with protective shell
- 20. Base frame
- 21. Gas regulation module
- 23. Pump module
- 26. Inspection opening, steam side
- 27. Inspection opening, water side
- 28. Inspection opening, flue gas side

Source: Bosch



Brief introduction to heating systems

- **Steam boilers**
  - Examples

Source: ESCAN s.l.

Brief introduction to heating systems

➢ Steam boilers

⇨ Some important characteristics in efficient water boilers include:

- **Effective 3-pass design**
- **High level of efficiency due to the integrated economizer**
- **Lowest emissions for any fuel (liquid, gas, others)**
- **Comprehensive series-wide basic equipment**
- **Intuitive touchscreen operation and SPC control**
- **Small space requirement due to its compact base area**
- **Simple installation and simple commissioning due to pre-parameterised boiler control**
- **Automatic start-up, standby and shutdowncontrol SUC**

Operational behaviors in steam boilers

➢ Low load operation

⇨ Effects:

- **Temporary burner load limitation**
- **Possible problems in switching loads**
- **Not possible to reduce load, then limits in regulation**

⇨ Too much power installed: possible solutions

- **Low burner load so might need to install a smaller burner**
- **An option is to connect additional consumers**

Operational behaviors in steam boilers

➢ Overloading operation

⇨ Effects:

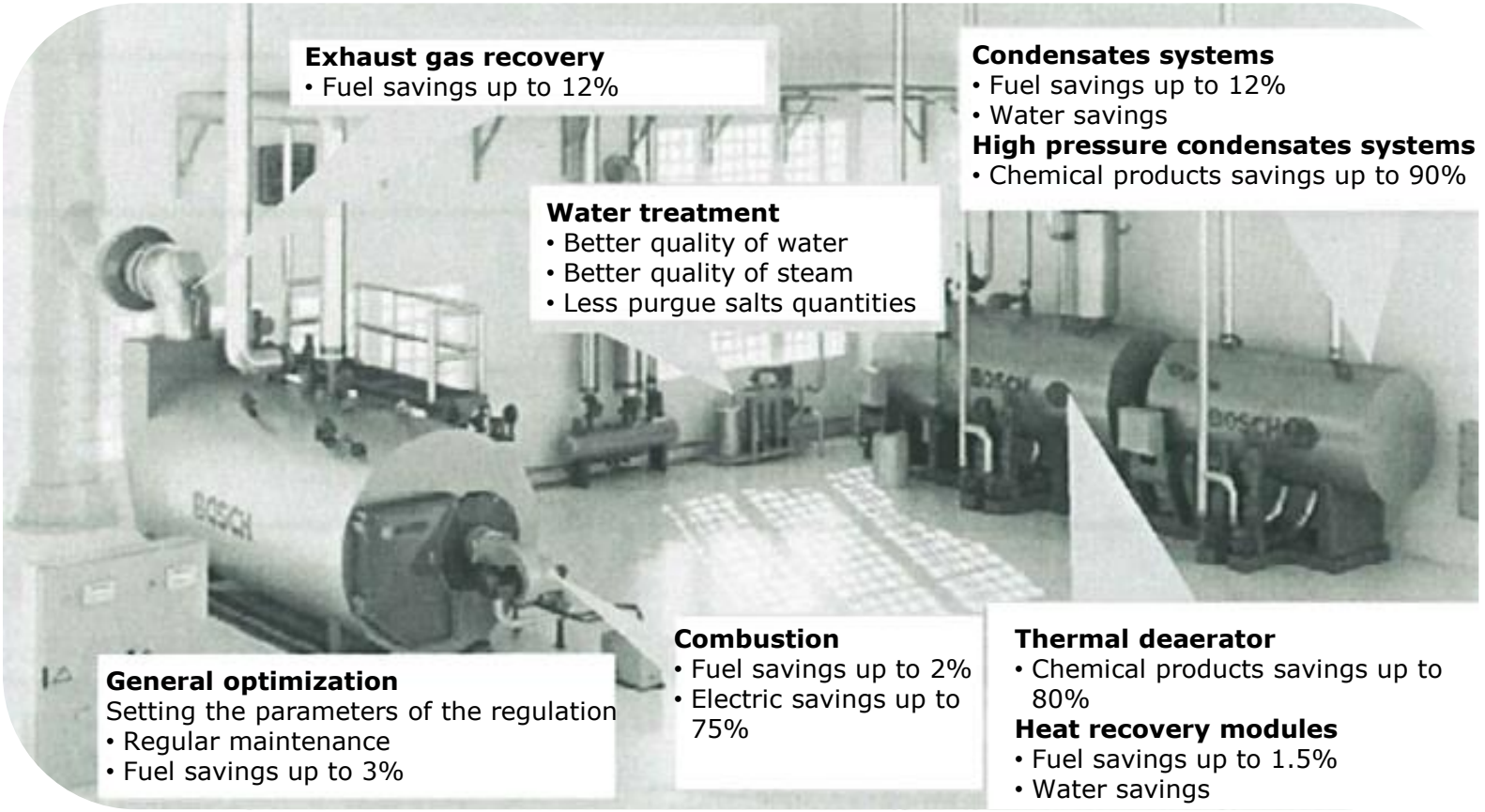
- **Low steam quality by entrained boiler water**
- **Salt deposits in some components**
- **Water impacts in ducts and valves**
- **Burner blocking due to lack of water**

⇨ Overloading types and solutions:

Punctuall Overloads		Overloads due to Low power installed
Necessary for the process	Not necessary for the process	All
* Use a steam collector * Use of the storage capacity of the boiler * Modify regulation	* Overloading protection * Water separator	* Increase load capacity: -Increase burner power -Install additional boiler * Use heat recovery systems

Efficiency Improvements

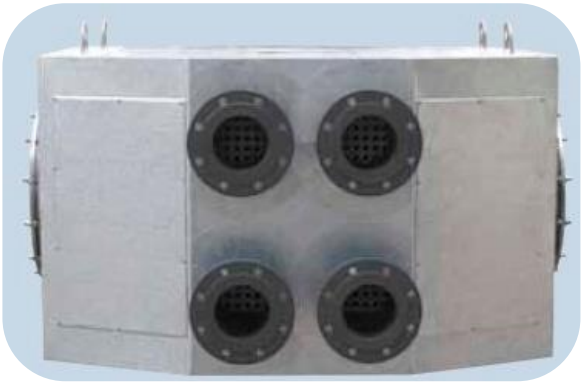
➢ INDUSTRIAL BOILERS



Source: Bosch

Efficiency Improvements

- **Economizer in hot water and superheated water boilers**
  - Description:
    - **Reduction of the exhaust combustion gas.**
    - **Increasing efficiency due to heat exchange.**
    - **Could be used for condensating technology for the exhaust gas.**

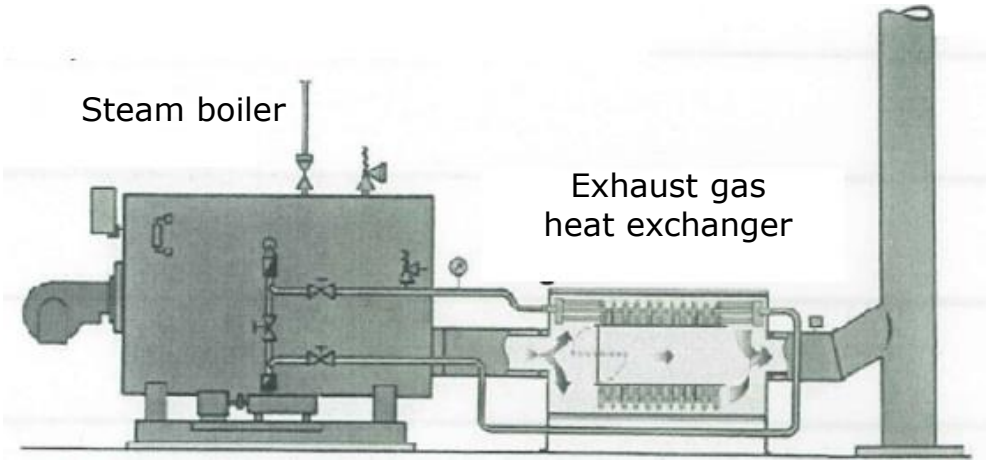


Source: Bosch

  - Design:
    - **Usually intalled behind the boiler, at the exhaust gas output, with conexion fittings**
  - Advantages:
    - **Increase energy efficiency, fuel savings and reduction of exhaust gas temperature**
    - **Increase the production of heat with the same boiler**
    - **Easy updating of the existing systems**

Efficiency Improvements

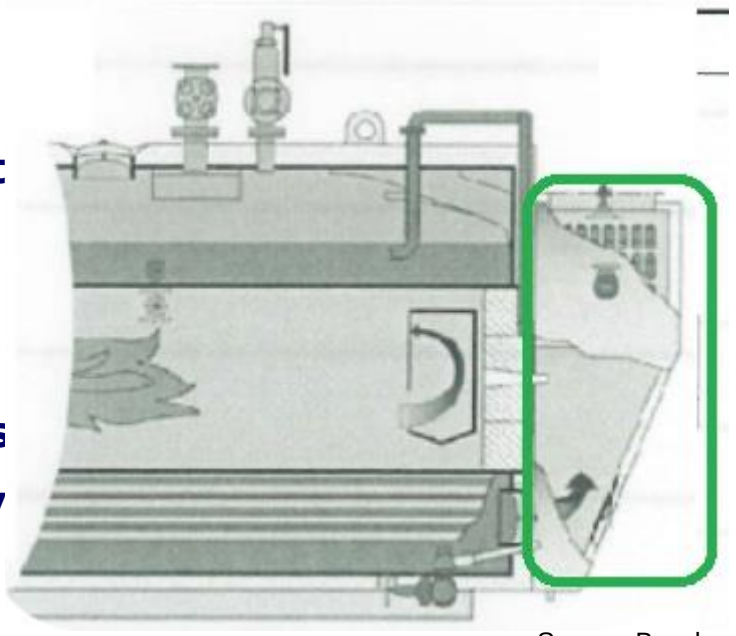
- **Economizer in hot water and superheated water boilers**
  - ⇨ Economizer (Heat Exchanger)
    - **Fuel savings up to 5%**
    - **Continuous regulation of the exhaust gas temperature**
    - **Cold start without working below the dew point**
    - **Horizonal or vertical assembly**



Source: Bosch

Efficiency Improvements

- **Economizer in hot water and superheated water boilers**
  - ⇨ Economizer (Heat Exchanger) – Type 2: Integrated Economizer
    - **High efficiency system**
    - **Integrated into the exhaust gas chamber of the boiler**
    - **Heating recovery 5-7%**
    - **Exhaust gas loss < 5%**
    - **Smaller space requirements**
    - **Assembled in boiler Factory ready for connection, tested and insulated**
    - **No additional bed is needed**



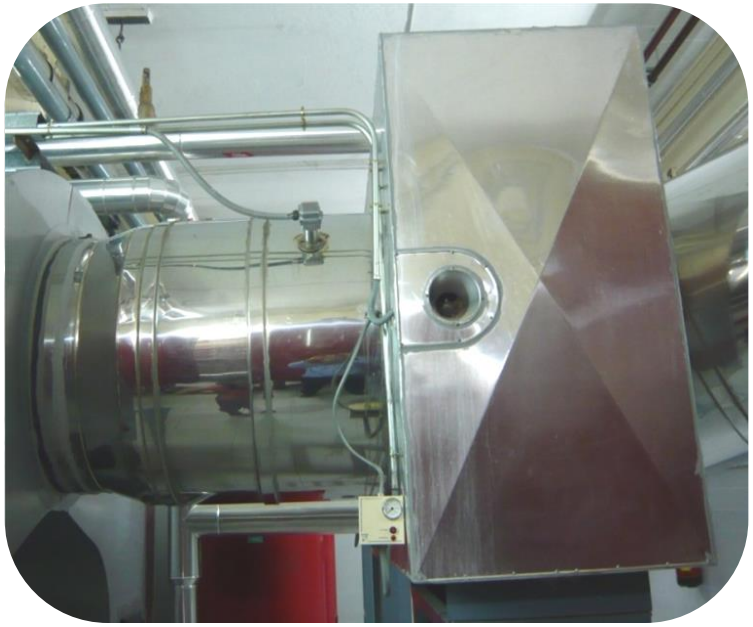
Source: Bosch

  - ⇨ Warning: not all boilers can use all heat recovery equipment. It is needed to asses the specific case.

Efficiency Improvements

- **Economizer in hot water boilers**
  - ⇨ Examples of real life economizers

Side-wiew
Source: ESCAN s.l.



Side-view
Source: ESCAN s.l.

Bottom view
Source: ESCAN s.l.

Efficiency Improvements

➢ Economizer in steam boilers

- ⇨ Energy savings thanks to the temperature rectuction of the exhaust gas through heating the water returned to the system.
- ⇨ These economizers have a very efficient heating surfaces that take advantage of these heating potential thus increasing the boiler efficiency

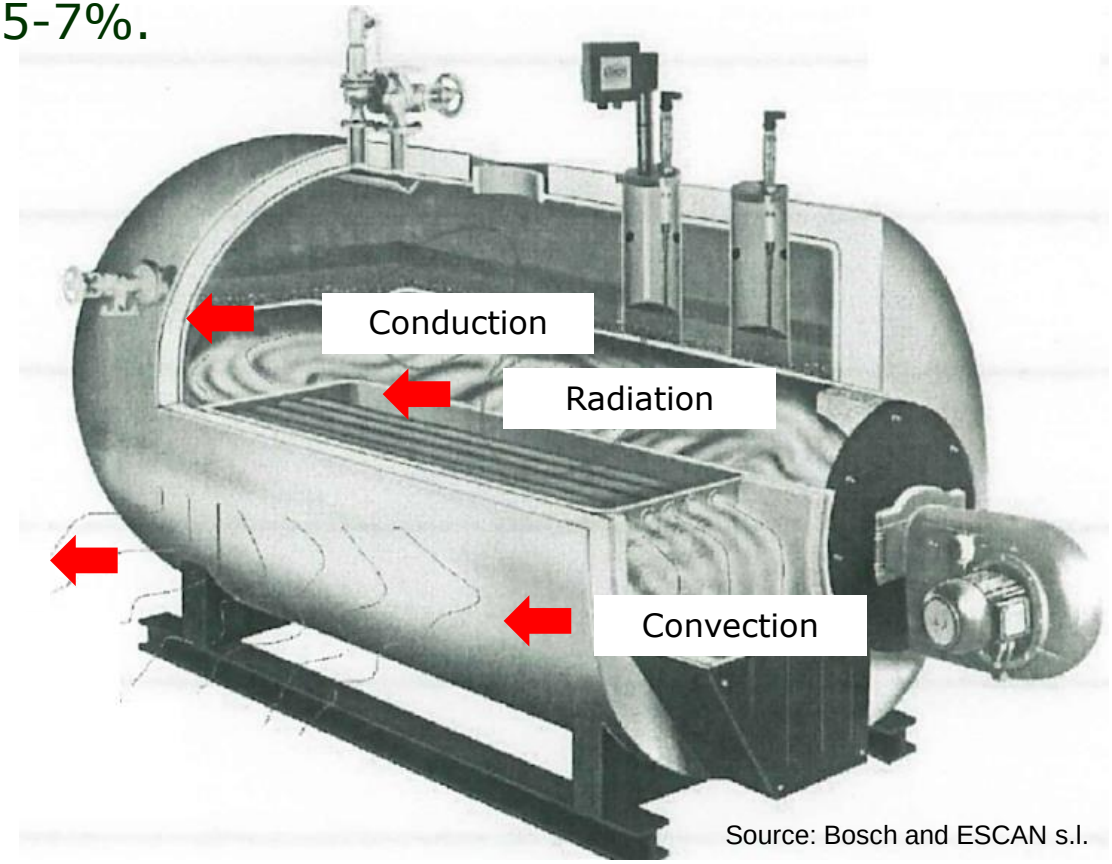
Source: Bosch

- ⇨ Design:
  - **The steam is gathered in the lower part and passes – to the upper part – through the heat exchanger for the heat recovery.**
- ⇨ Advantages:
  - **Increases efficiency and reduces fuel consumption**
  - **Improvement and easy updating of the existing systems**

Efficiency Improvements

➢ Boiler envelope insulation

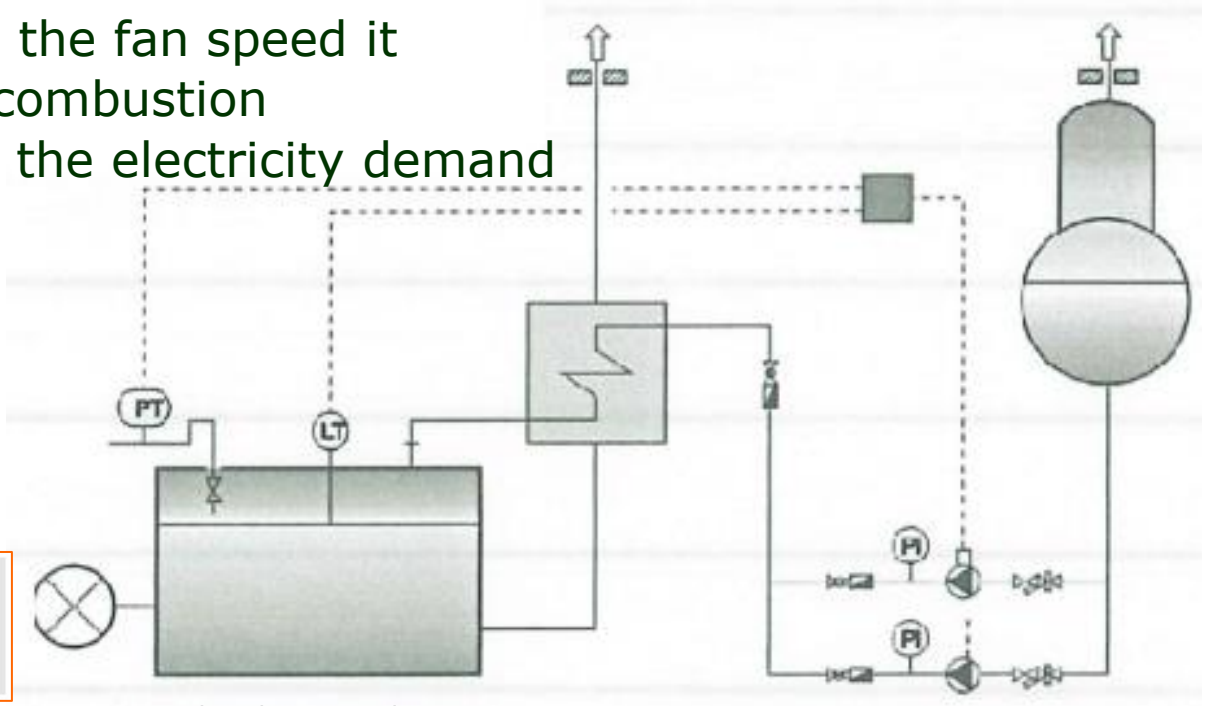
- ⇨ For modern industrial boilers with efficient insulation, the typical looses are 2-3%
- ⇨ In old boilers or bad insulated this might increase up to 5-7%.



Source: Bosch and ESCAN s.l.

Efficiency Improvements

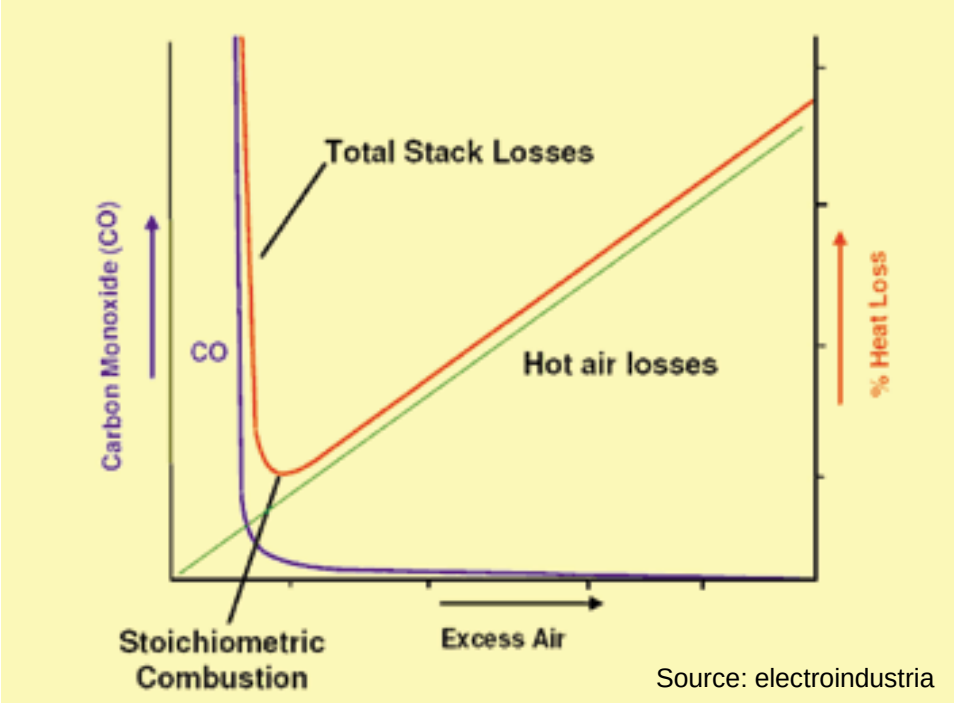
- **Frequency variator in burner fan**
  - An electronic device that controls the fun and provides electricity savings
  - A frequency converter can vary the speed of a fan or pump, which allows to control variable flow and pressure. Also it quickly adapts the speed of a fan or a pump to new flow or system pressure.
  - By reducing the fan speed it reduce the combustion air flow and the electricity demand



Source: Bosch and ESCAN s.l.

Efficiency Improvements

- **O_2 Control**
  - ⇨ Continuous optimization of combustion. Continuous control of the necessary O_2 for the burning



  - ⇨ Measure and control device which allows the control of the right feeding air needed to optimize combustion, reducing losses

Efficiency Improvements

➢ Water treatment

- ⇨ Water analyzer: Achieve better quality of the water
- ⇨ It controls:
  - **The feed water pH value**
  - **The O_2 content in the feed water**
  - **Additional residual water hardness**
  - **Boiler water pH**
- ⇨ Advantages:
  - **Reduction of the use of dosage agents**
  - **Better security thanks to the measurement results correctly analyzed**
  - **Time savings thanks to the automatic measurement**
  - **Reduction of losses from salt water and sludge through a dosage depending on the needs**
  - **Further reduction of water metering agents and steam heating due to salt water and sludge losses are lower**

Source: Bosch

Efficiency Improvements

- **Condensates heat recovery - Efficient condensate systems**
  - ⇨ Problems in the condensate discharge and transport due to it being in two phases (flash steam with condensate):
    - **Wrong sized pipes**
    - **Unacceptable mixing of the two phases speeds**
    - **Improper selection of the type of purge valve**
    - **Efficiency loss in the exchangers for backward condensates**
    - **Leaks in pipes for corrosion, erosion or water hammer**
    - **Installation mistakes**
    - **Confluence of several pipes in an only one condensate pipe**
    - **Condensate elevation downstream the purge valve**

Efficiency Improvements

➢ Condensates heat recovery

- ⇨ Module available as condensate reservoir pressure and non-pressure
- ⇨ To accumulate condensates from vapour's consummers

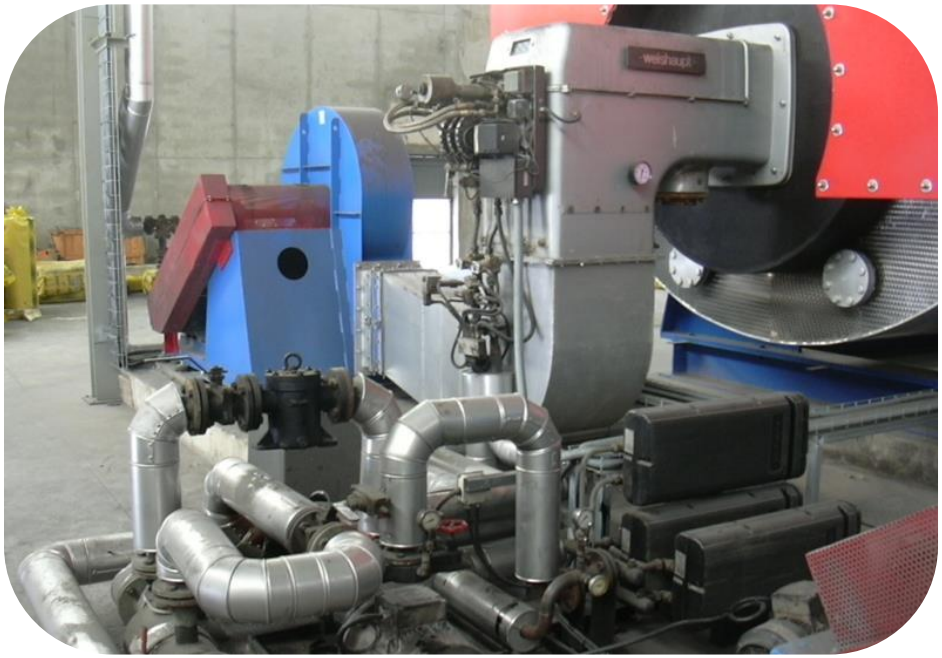
- ⇨ Advantages:
  - **Additional water reduction**
  - **Energy reduction for thermal outgassing**
  - **Any demand on the feed height**
  - **No loss on expansion vapour**
  - **Reduced flow from salts and sludge purgues**
  - **Low corrosion risk**

Source: Bosch

Efficiency Improvements

- **Fuel and dual – fuel burners**
  - ⇨ Examples of real life burners in food industry

Source: ESCAN s.l.



Efficiency Improvements

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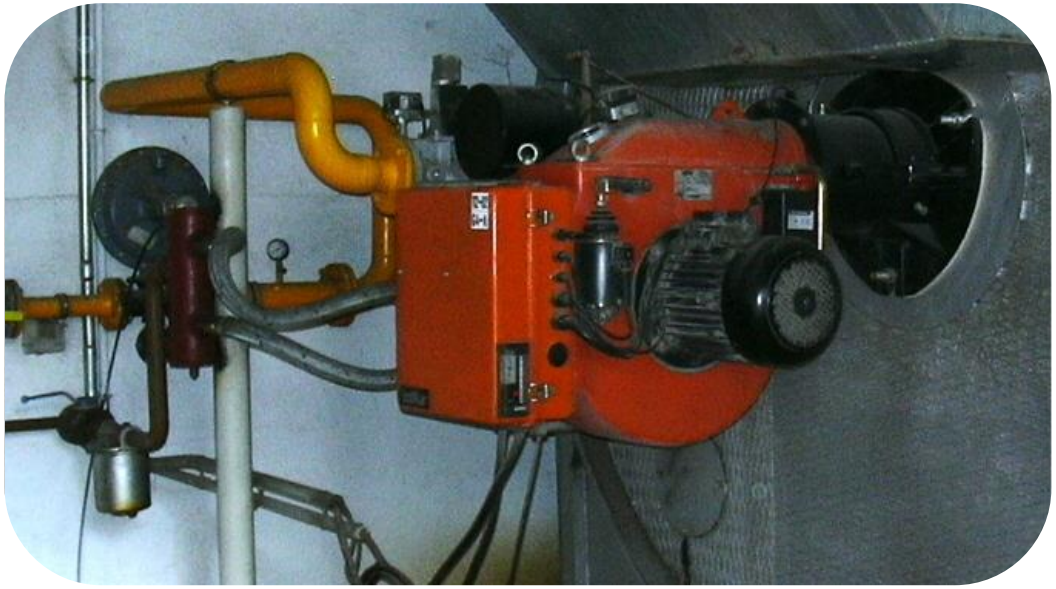
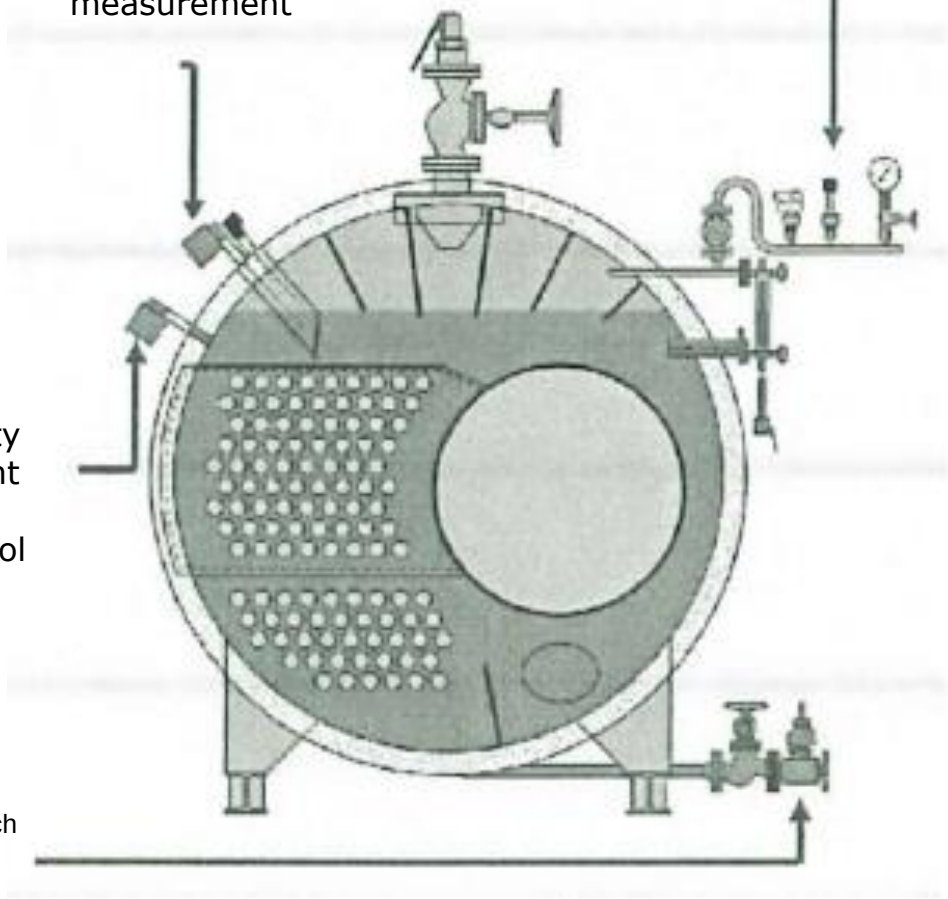


Efficiency Improvements

➢ Control system improvement

-Steam measurement - Steam limitation - Power regulation

water level measurement



- Conductivity measurement - Sludge purgue control

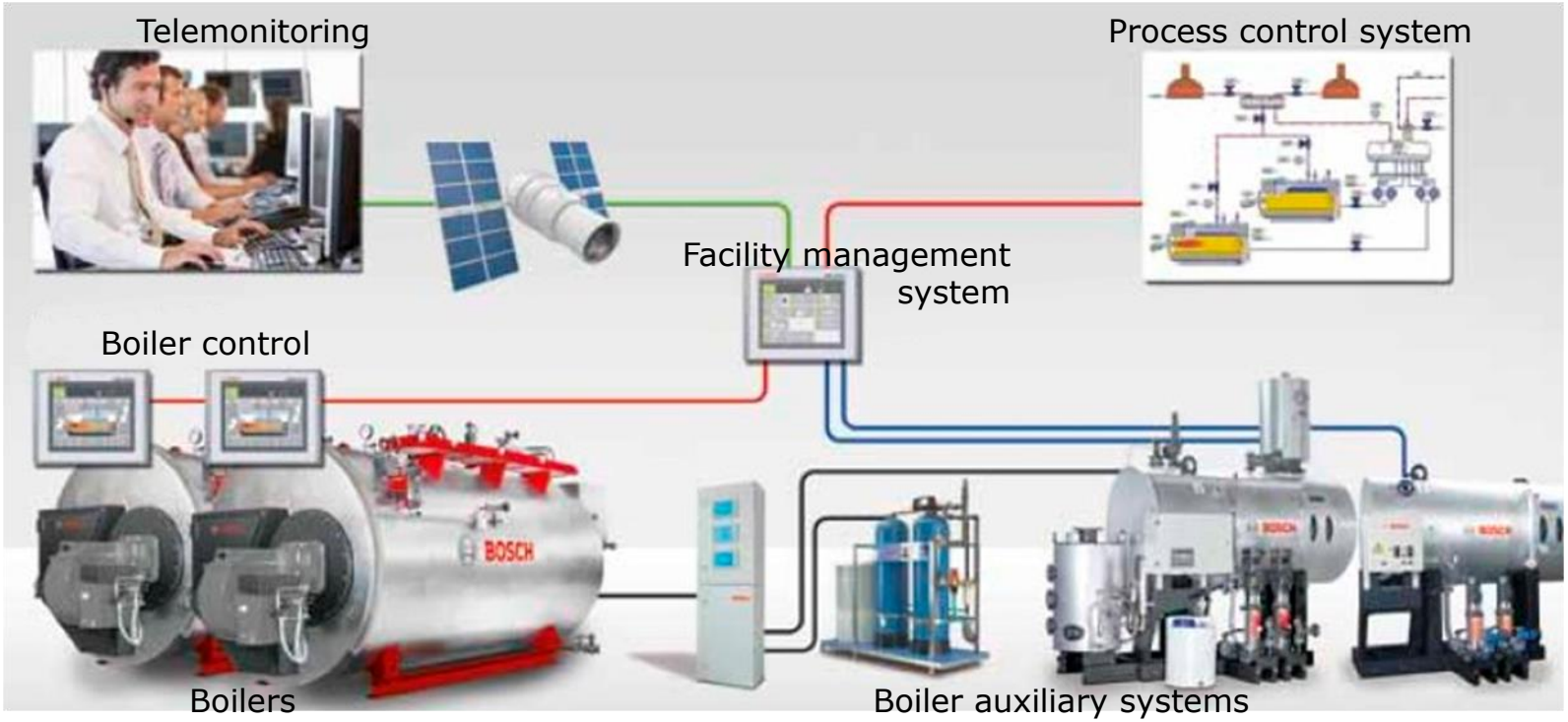
Source: Bosch

Efficiency Improvements

➢ Control system improvement

⇨ Modules for feeding boilers

- **Management system installation**



Source: Bosch

Quick calculation

- **Hot water boiler efficiency**
  - ⇨ Calculate losses (qA)
  - ⇨ Radiation losses 0.8%
  - ⇨ Desalination and other losses 1.2%
- **Formula based on SIEGERT:**

$$qA = (t_A - tL)\frac{A_2}{(21 - O_2)} + B$$

t_A…Flue gas temp [K]

t_L…air temperature [K]

O_2…oxygen content flue gas [%]

A_2…specific fuel factor natural gas H = 0.6440

B…specific fuel factor natural gas H = 0.0111

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