OPERATOR's MANUAL

INSTALLATION
OPERATION
MAINTENANCE

DANSTOKER steam boilers

FUELS :

- **Oil • Gas • Biofuels**
- **Flue gases from engines and turbines**
- **Flue gases from combustion in grates, killns, incinerators and combustion chambers**

January 2003

Introduction

The boiler supplied to this heating plant has been manufactured on basis of the most up-to-date and proven construction principles, in compliance with the design code and approval standards agreed.

Thus, you have ample guarantee of having purchased a product where all conceivable efforts have been made to manufacture and supply a product of high quality and longevity.

However, the life of the boiler and its accessories is closely connected to and dependent on proper service and maintenance of the boiler plant. Therefore, provided constant, knowledgeable and competent control and service routines are applied, the running and functioning of the boiler and the equipment supplied by Danstoker will be safe and economical.

As manufacturer of the boiler we have in the following described some good and useful guidelines for the operation and maintenance of the boiler and the accessory equipment, supplied by us.

Many of these guidelines are intended as general advice and assistance, whereas others describe stipulated factors that unconditionally have to be observed – failure to do so will otherwise cause your right to present a valid complaint to Danstoker to lapse. **Consequently, it is of the utmost importance that this manual is studied carefully.**

With a view to prolonging the life of the boiler and in order to avoid costly boiler damage we shall therefore specifically draw your attention to the following paragraphs (however, not limited to these sections) :

- Paragraph 3.6 (Firing / Operation of the firing equipment)
- Paragraph 4.1 (Daily operation and maintenance)
- Paragraph 5 (Boiler and make-up water systems)

In this connection it should be noted that any equipment, included in the boiler plant and which has *not* been supplied or designed by **Danstoker a·s**, may have a major influence on the information provided in this manual. The information given herein does not replace specific instructions, if any, pertaining directly to such equipment or accessories, as those instructions shall have to be minutely observed.

Consequently, the personnel in charge of the operation and supervision of the plant (it is taken for granted that this personnel is properly and sufficiently qualified) is requested to thoroughly study the information given in this manual and to combine this information with that of other instructions, applicable to the entire plant in general.

In case you need further information, please do not hesitate to contact :

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Table of Contents

Installation

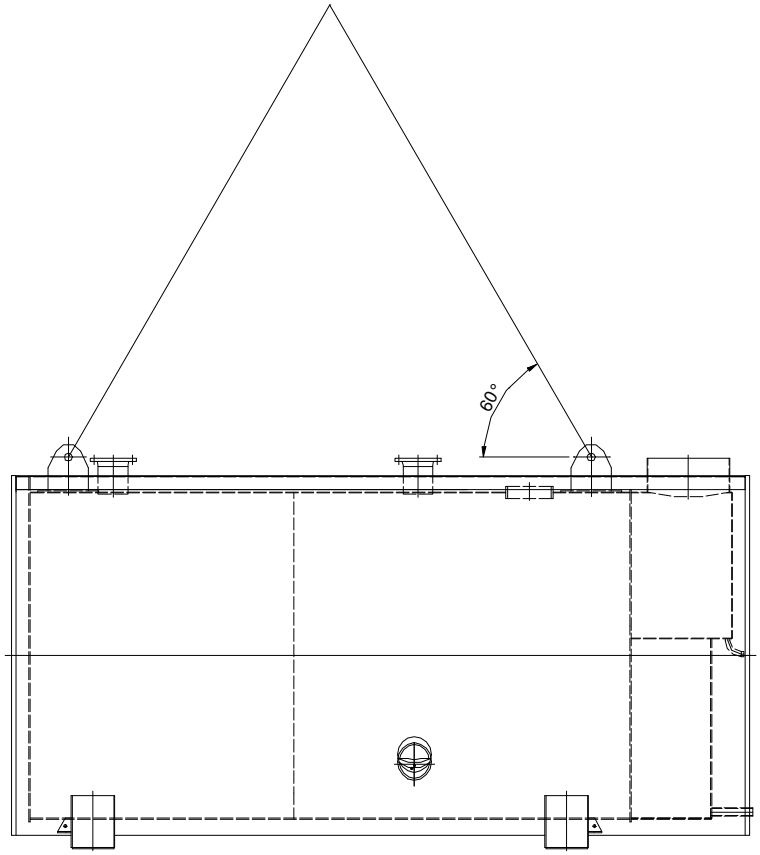
Boiler Foundation

A foundation cast in concrete or a steel foundation is to be erected at the place of installation. The foundation is to be made with a slight fall, thereby allowing all the water to be drained off throught the drain or blowdown valve. The foundation is to be dimensioned so as to comply with local rules and regulations applicable and must be sufficiently strong to bear the total load of the boiler (flooded weight!), of accessory equipment and, if any, of service platforms and galleries.
If not otherwise explicitly specified, the weight normally indicated by Danstoker is the weitght without water.
For your calculation of the total foundation load, you have to allow for the boiler weight inclusive of its water content as well as specific weights of the oil/gas burner or other combustion equipment, possibly a pre-heating blower placed at the boiler top, galleries, ladders, boiler mountings, piping systems, etc. Such additional weights will very acc. to the layout and extent of the specific installation.
The concrete foundation may be provided with steel foundation plates, on which the boiler saddles are to be secured by bolts, respectively should be allowed to move freely. In case sliding foil is used (to allow free movement) the thickness of same should be allowed for when deciding the level of the foundation plates.
As standard, Danstoker boilers provided with saddles/feet will be supplied with a piece of sliding foil (thickness 0.8 mm) in a dimension matching one boiler saddle. Please note that during transportation the sliding foil will be placed on or inside the boiler together with a cleaning brush and a socket wrench intended to tighten the cleaning and inspection doors.
For "box-type" boilers, where the entire bottom plate is calculated to be able to transfer the load from the boiler to a specially designed foundates (which is normally an integrated part of the combustion equipment), the requirement with regard to tightness between the boiler bottom and the foundation will be decisive for the choice of joint/packing material to be used.
After placing the boiler in its foundation, make sure to verify that the packing material is placed correctly.
Such packing material is ***not*** included in the normal boiler scope of supply, if not specifically stated.

Hoisting procedure for horizontal boilers

All Danstoker boilers are provided with two lifting/suspension eyes. The boiler is to be lifted from the transport vehicle by means of these lifting eyes, as illustrated in the drawing below, where the optimal lifting angle is 60° - this angle should be respected, only a few degrees deviation is permissible.
When using a lifting bar, this angle will be greater, which will be the optima solution when lifting very heavy boilers.
In this way the boiler may be carefully hoisted into position on its foundation.

Warning! Mortal danger! It is not allowed to pass or stay under the boiler while it is suspended.
The boiler is heavy, and it is very important that all necessary precautions have been taken to make sure that the hoisting may be carried out under safe and reliable conditions. Only professional and duly qualified personnel may be in charge of moving and transporting the boiler.

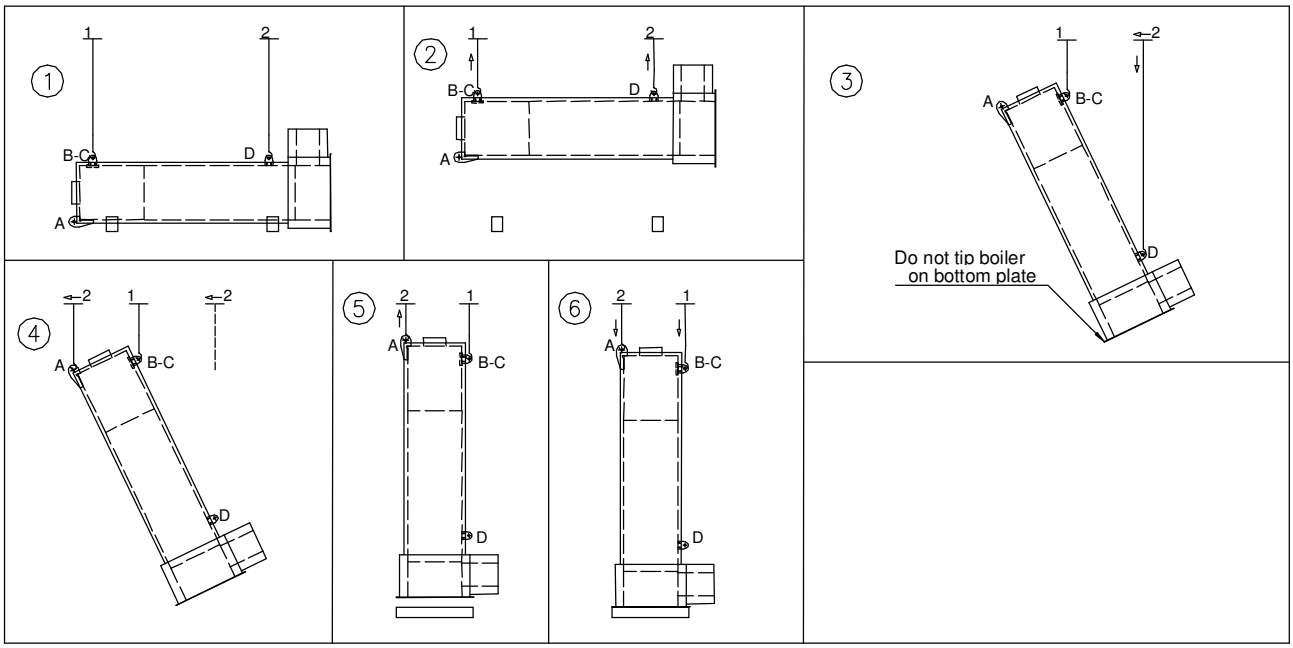


In case the boiler is to be moved over a plane surface, it may be rolled on roller-skates, to be placed under the saddles. Each saddle is provided with handling brackets. These brackets may be used to lift the boiler, but ONLY be means of a lifting jack. ***The brackets are NOT to be used for moving or lifting the boiler by means of a fork-lift truck or similar equipment.***

Hoisting procedure for <u>vertical</u> boilers

1. The vertical boiler is provided with 4 lifting eyes **(A, B, C og D).** When the boiler arrives on site on its specially designed transport saddles, the eye **(A)** is facing downwards, whereas the three other eyes are facing upwards **(B and C at the top of the boiler and D at the bottom of the boiler).** From this position the boiler is to be hoised by means of two separate cranes, where crane **(1)** is holding the two lifting eyes at the top **(B-C)** while the other crane **(2)** is holding the lifting eye at the bottom **(D)**.
2. Proceed to hoist the boiler off the truck. The special transport saddles are to be cut off or dismantled. Then lift the boiler so that it is free of the ground or the foundation, to allow the boiler to be tipped around.
3. The crane **(2)** holding the lifting eye at the bottom **(D)** is then to ease the wire or the chain until the boiler is hanging exclusively (by natural gravity) in the lifting eyes **(B-C)** at the top. It is important that simultaneously the crane **(2)** follows this movement horizontally in order not to create a lopsided or unbalanced pull, which might cause one of the cranes to tip over. The boiler is <u>under no circumstance</u> to rest on the bottom plate in this position, as it may result in deforming the bottom plate and/or the combustion chamber at the bottom of the boiler.
4. The crane **(2)** holding the bottom of the boiler is then to let go of the lifting eye **(D)**. Hereafter the crane **(2)** is to move to the opposite of the other crane **(1)** holding the boiler by the lifting eyes **(B-C)**. Crane **(2)** is then to hold the lifting eye **(A)**.
5. From this position the boiler is now ready to be hoisted into the final vertical angle, by having crane **(2)** pull the lifting eye **(A)**.

6. Once the boiler has been hoisted into its final positionning angle, both cranes are simultaneously and at the same speed to be eased, thereby allowing the boiler carefully to be placed on its concrete foundation.



Installation of the boiler and its accessory equipment

Any boiler may be installed only in such places and under such conditions that are complying with rules and regulations stipulated by the relevant local and/or national authorities in the country of installation. Here we are referring to for example the position and lay-out of the boiler room, access and exit conditions, accessibility for maintenance and service of the boiler (flue gas and water sides alike) and its accessory equipment.

Placing the boiler on its foundation

At the top the boiler is provided with 2 lifting eyes, allowing the boiler to be easily lifted into position on its foundation by means of a crane. If a crane cannot be used, it is possible to roll the boiler into position by means of transport rollers.
The boiler is furthermore provided with handling brackets, suitable to facilitate the final handling and adjustment, once the boiler has been placed on its foundation.
The boiler is to be placed level on the foundation (on its transverse and longitudinal axes alike) - however, if applicable, possibly with a slight fall towards the bottom blow-down valve.

Securing the boiler on its foundation

With a view to allowing a lengthwise expansion of the boiler, it is **essential that the rear boiler saddle can move freely** on the foundation. This will be ensured by placing the rear boiler saddle on sliding foil and by securing the front boiler saddle to the foundation - by means of welding or bolts.
In case of special conditions at the place of installation, it may prove necessary to secure the rear boiler saddle and instead allow the front boiler saddle to move freely.
The lengthwise expansion between the centres of the boiler saddles may be calculated according to the following formula:

$\Delta L \cong$ $L \times 1.2 \times (T_2 - T_1) / 1000$ [mm] where

L = center distance between the boiler saddles [m]
T_2 = the boiler's max. permissible operation temperature [°C]
T_1 = the boiler's temperature in cold condition [°C]

Fitting of boiler mountings, control and safety equipment

The boiler is to be provided with boiler mountings and control and safety equipment, as required by law in the country of installation.
The boiler mountings must be of a good quality and reliable and suitable for the actual operation conditions in terms of material and design and furthermore they are to comply with the requirements stipulated by the relevant national boiler authority.
When fitting boiler mountings and other accessory equipment, make sure that all packing surfaces and threaded connections are properly lubricated in graphite, dissolved in oil, or with another heat-resistant lubricant.

IMPORTANT !! **We draw your attention to the fact that it may prove necessary to adapt the equipment described, in order to make it comply with specific national regulations in the country of installation.**

Safety valves

The safety valves must be type-approved for use in the specific country of installation, and the blow-off capacity must at the set release pressure be approved according to current regulations, applicable in the country of installation.
The safety valves constituting the last link in the system providing protection against excessive pressure in the boiler plant, it is extremely important to make sure that the mounting onto the boiler and connection to the blow-off pipe is carried out correctly and with care.
The safety valves will normally be provided with protection houses on inlet and outlet. Only once the valves have been mounted on the boiler (ready to be connected to the piping), are you to remove these houses together with the protection of the lever arm.
If applicable, you are kindly referred to further special instructions provided by the manufacturer of the safety valves.

Service platform and ladder

The design and scope of supply of service platforms and ladders, if any, must comply with local rules and regulations applicable. In case the boiler is exposed to loads from platforms and ladders, it is important to make sure that the areas concerned are sufficiently strong to bear such loads.

Boiler connections

Once the boiler has been correctly erected on its foundation, you may proceed to establish the boiler connections, piping and ducting.
In general it applies to all such connections that they are to be carried out in accordance with national and/or local rules and regulations.

PLEASE NOTE : The branch connections of the boiler are under no circumstances to be exposed to external loads, forces or moments!

Connection to the chimney

The boiler is connected to the chimney via the flue gas duct, which may be connected to the boiler either by means of a welded joint or if necessary be means of a flexible connection with a view to making compensation for the thermal expansion of the flue duct and possible movements in relation to the chimney.

Connection to the distribution system

Connection to the distribution system is to be established in such a manner that no movements of the piping will affect the boiler's inlet and outlet branch sockets. If necessary, flexible connections shall have to be installed in order to compensate for any thermal expansion and movements of the piping system.

Connection to the blowdown / draining system

In connection with inspections and/or repairs of the boiler, and in case the boiler is taken out of operation, it may be required to drain off the boiler water. The draining-off should always be carried out in a manner not likely to expose the operation personnel or other persons to any inconvenience or danger. Normally the drained-off water cannot be re-used and shall therefore be led to the draining well.

Normally, water with temperatures exceeding 35 °C is not allowed to be discharged into the public sewage system on a continuous basis. Consequently, it is recommended to conduct the draining of water via a blowdown tank or a well, thereby allowing the temperature of the drained-off water to be reduced by means of external cooling water or stone.

It is very important that the blowdown system is established in such a manner that the boiler's drain branches are not exposed excessively to the effect of surges and/or the thermal lengthwise expansion of the blowdown piping.
In steam boiler applications equipped with more boilers, the piping from each boiler's blowdown valve is to led and connected separately to the blowdown tank.

IMPORTANT !! **We draw your attention to the fact that all regulations, stipulated by the local authorities in the country of installation specifically with regard to disposal of water to the sewage system, always are to be complied with.**

Connection to the blow-off piping from safety valves

The safety valves are to be mounted in such a manner that no vibrations, nor static, dynamic or thermal loads from the blow-off piping (and the silencer, if applicable) can be transferred to the safety valves. It must be ensured that blowing-off from the safety valves is allowed to take place in a safe manner, and the blow-off piping is normally to be led into open air (provided with proper frost protection).
The blow-off piping from the safety valves is to be established with a fall of minimum 0.5% and carried out so as not to cause formation of water pockets. In the immediate vicinity of the safety valves, a drain point is to be established in the blow-off pipimg by means of an unclosable tell-tale pipe, led to a suitable place in the boiler room where any leaks will be detected immediately.
In case the blow-off piping is ended vertically, closable drains may be established as well.

Furthermore, the blow-off piping is to be made so that the counter-pressure during the blowing-off does not exceed the permissible pressure of the valve.

Installation of pumps and piping

Feed water pumps

Feed water pumps are to be installed on a concrete foundation, sufficiently high to secure that the pumps will not be ruined in case the floor is flooded. Furthermore, the foundation should be big enough to allow sufficient space for correct connection and normal maintenance of pipings, valves and other necessary equipment.
For the position and mounting of feed water pumps due consideration should be given to the normal lowest water level in the deaerator tank during operation, thereby making it possible to comply with the minimum inlet pressure at the suction branch of the pump, stipulated by the pump manufacturer – normally approx. minimum 0,3 bar. The suction piping from the deaerator tank is to be led (with a fall) towards the feed water pump and with the fewest possible bends.

Feed water piping

When mounting feed water pumps and the feed water piping, it must be secured that no harmful effects are transferred to the pump(s) from piping and valves. Piping systems of a certain length should be properly supported before and after the feed water pump.
Any unacceptable noise from the feed water pump(s) may be damped by mounting compensators close to the pump's inlet and outlet and/or by placing the pump(s) on vabritation absorbing material.
In plants where the feed water is supplied by automatic starts/stops of the feed water pumps, it is very important to secure piping bends, on account of the fact that these starts/stops have a tendency to cause chock effects (water hammer effects) in the piping system.

PLEASE NOTE: **In case a modulating feed water valve, which can be closed completely during operation, is used in the feed water system, a feedback-connection to the deaerator tank should be established, dimensioned for the required minimum flow, stipulated by the pump manufacturer, with a view to safeguarding the pump against damage.**

Piping

In case more boilers are connected to a common steam supply network, proper precautions must be taken to secure that it is not possible, by incorrect operation, defective closing valves or otherwise, for feed water, condensate or the like to penetrate into steam boilers, accessible for inspection in the steam side.
This may be avoided be removing a suitable piece of piping, by insertion of blind flanges or by fitting 2 closing valves, with an intermediate drain of suitable size, intended to funtion as a so-called tell-tale device.

PLEASE NOTE !! **All piping is to be dimensioned, manufactured, mounted and controlled in compliance with rules and regulations, stipulated by the relevant national authorities.**

When determining the layout and construction of the piping system, the following circumstances should be considered :

- All piping complete with valves and fittings must be appropriately placed and supported so as to allow thermal expansion and contraction, without exposing the system to excessive loads.

All steam piping must be provided with appropriate draining facilities. Where possible, the steam piping should be established with a fall of approx. 1.5% to 3% in the flow direction, with a view to avoiding possible entrainment of piping condensate. Draining points should be established in the piping at every 30 meters, and all low points and points immediately before rises in the piping should be provided with draining facilities.

- All piping deviations should originate from the top of the main steam piping with a view to securing a steam quality as dry as possible at the place of consumption.
- The piping should be adequately insulated in order to prevent causing damage (scalding) to the operation personnel, to avoid unnessary energy loss and in order to comply with the health-and-safety-at-work regulations applicable.

Installation of the blowdown tank

The purpose of the blowdown tank is to dispose of the blowdown water, deriving from the boiler, in a safe and appropriate manner. As blowdown of the boiler water is conducted with the explicite purpose of removing dirt and impurities from the water, **the blowdown water is not to be re-used and is to be led to a discharge well.**

PLEASE NOTE! We draw your attention to the fact that specific requirements, stipulated by the local authorities with regard to discharge of water to the sewerage system, are to be complied with.

It is very important to establish the blowdown line piping in such a manner that the blowdown branch sockets on the boiler are not exposed in any way to stress or loads from surges and/or lengthwise thermal expansion of the blowdown piping.

Installation of thermal deaerator

The deaerator tank is to be placed on a level and solid steel frame, thereby allowing maintenance of the necessary pressure - normally approx. 0.3 bar - at the suction branch of the boiler feed water pump, as prescribed by the pump manufacturer.
When designing the steel support, due consideration must be applied in order to allow for the lengthwise thermal expansion of the deaerator tank caused by temperature fluctuations. Therefore, only one of the tank's feet is to be secured by bolts, whereas the other should be allowed to move freely in relation to the surface of the steel support.
Mounting of the tank valves and fittings, regulation and safety equipment, etc., is to be carried out in accordance with separate instructions.

Installation of make-up water/condensate tank

The condensate tank is to be placed on a level and solid steel support, thereby allowing maintenance of the necessary pressure at the suction branch of the boiler make-up water pump, as prescribed by the pump manufacturer.
In plants provided with an open condensate tank, the pump is normally to be placed minimum approx. 1 metre lower than the lowest permissible water level inside the condensate tank.
When designing the steel support due consideration must be applied in order to allow for the lengthwise thermal expansion of the deaerator tank due to temperature fluctuations. Therefore, only one of the tanks feet is to be secured by bolts, whereas the other should be allowed to move freely in relation to the surface of the steel support.
Mounting of the tank valves and fittings, regulation and safety equipment, etc., is to be carried out in accordance with separate instructions.

The Flue Gas Duct

It is of vital importance that the entire flue gas ducting is designed optimally with a view to minimizing the flue gas resistance throughout the system, thereby being able to make considerable savings (electricity) with regard to operation costs of the preheater blower and/or the suction blower.
The flue gas duct - to be manufactured in materials suitable for the operational conditions available and for the fuel used - must be short and provided with as few bends as possible. All duct bendings should be made with a large radius - minimum 1½ times the diameter of the duct.

It goes without saying that any national or local authorities' stipulations with regard to layout, inspection and cleaning of the flue gas ducts should always be complied with.

Mounting

The duct is to be placed on solid supports, thereby preventing excessive loads to be transferred to neither boiler nor chimney. In order to prevent flue gases from leaking into the boiler room (in case of over-pressure combustion) it is recommendable to assemble and connect the flue gas ducting by way of welding. If necessary the connections are to be provided with flexible connections for compensation of the thermal expansion of the flue gas duct and thereby allowing a certain margin of movement in relation to the chimney.

Connection of measuring and regulation equipment

The ducting system is to be provided with an adequate number of correctly and appropriately placed muffs for measuring and regulating equipment normally used - however, it should also allow for equipment required for periodical control measurements.

Insulation

With regard to the safety and the comfort of the operation personnel and to the general environment in the boiler room, the flue gas duct duct should be adequately insulated and provided with proper casing in materials suitable for the installation.

The insulation and the casing should be made with due regard to the connections for the measuring and regulating equipment.

Any outdoor parts of the flue gas ducts should likewise be suitably insulated and clad in order to comply with the specific installation and operation conditions.

Start-up Procedure

Erection Supervision / Inspection

Prior to putting a new steam boiler plant into operation, it is normally required that the national authorities in the country of installation conduct an initial erection inspection of the entire plant.
In case it is desirable to run the boiler plant in unattended operation (normally surveillance every 24 hours) a specific authorisation to do so has to be granted by the relevant national authorities.
At the initial erection inspection the inspector verifies that the manufacture approval certificate, provided by the boiler-maker, is in order and that the prescriptions given with regard to boiler room layout, erection, operation, maintenance, all accessory equipment and piping have been properly observed.
As far as boilers in unattended operation are concerned, it must furthermore be verified that the documentation required is available.
Provided that no irregularities of any significance are found during this erection inspection, the findings shall be recorded in the boiler logbook , completed by a statement to the effect that permission to put the boiler into opertion has been granted.

A boiler plant may normally be put in operation only after the relevant national authorities in the country of installation have conducted an erection inspection and subsequently have granted the necessary permission.

It is always the full responsibility of the boiler owner that the boiler plant and its control and safety equipment is in perfect working condition and in compliance with the regulations concerned - and that the operation personnel is sufficiently skilled and qualified and holds the necessary permits for operating and maintaining the boiler plant.

Inspection prior to commissioning / starting-up

Prior to starting up the boiler plant it is of vital importance to proceed to conducting a thorough visual inspection of all the components of the plant in order to secure a subsequent correct operation.
This inspection should comprise the following :

- Verification that all flange connections have been made with the correct feed moment.
- Verification that all inside surfaces are clean and that no objects have been left inside - for example cleaning tools or spare parts.
- Verification that all cleaning hatches and doors are closed and appropriately tightened.
- Verification that all pipe connections have been correctly connected and that protective covers, if any, have been removed.

PLEASE NOTE that all branch sockets on DANSTOKER boilers are protected with red plastic lids.

- Verification that all heat-affected areas are sufficiently insulated and that the insulation is intact everywhere.
- Verification that the safety valves are mounted as stipulated and that their drain and blow-off tubes are correctly connected.

WARNING ! Scalding risk from blow-off steam

It is important to ensure that drain pipes from the safety valves are carefully mounted and connected to a protected drain. Failure to do so may constitute a severe scalding risk to the operation personnel in case one of the safety valves should blow off steam directly - and unprotected - to the surroundings.

- Verification that the smoke damper, if any, is open.
- Verification that the inspection glass is appropriately tightened in open or closed position. Please note that the observation glass is always to be handled with care in order to avoid hurting the boiler operator – especially in over-pressure boiler plants – in case the glass might break. Whenever not used, the inspection glass should always be closed.
- Verification that sockets for draining off condensate likely to develop in the smokebox, the flue gas duct and in the chimney are in order.
- Verification that all the safety equipment mounted on the boiler has been correctly connected and is in perfect working condition.
- Verification that all electrical connections have been made correctly and that all electrical systems are working as intended.
- Verification that the combustion system and the combustion equipment is correctly mounted and has been tested mechanically.

Adjustment of electrodes for water level control

The number and the position of the various electrodes/probes will depend on the layout of the system as well as on the regulations stipulated by the national authorities in the country of installation.
The water level control system consists of a number of electrodes/probes mounted in flanges, placed on the boiler top - and perhaps also inside a water level flask (typically placed on the side of the boiler), provided with LW (low water) mark and water level indicators.
The lengths of the individual electrodes are adjusted by the boiler manufacturer to comply with the theoretical lengths, stipulated by current national regulations and general operation experiences – See Fig. 1: Adjustment of electrodes for water level control.

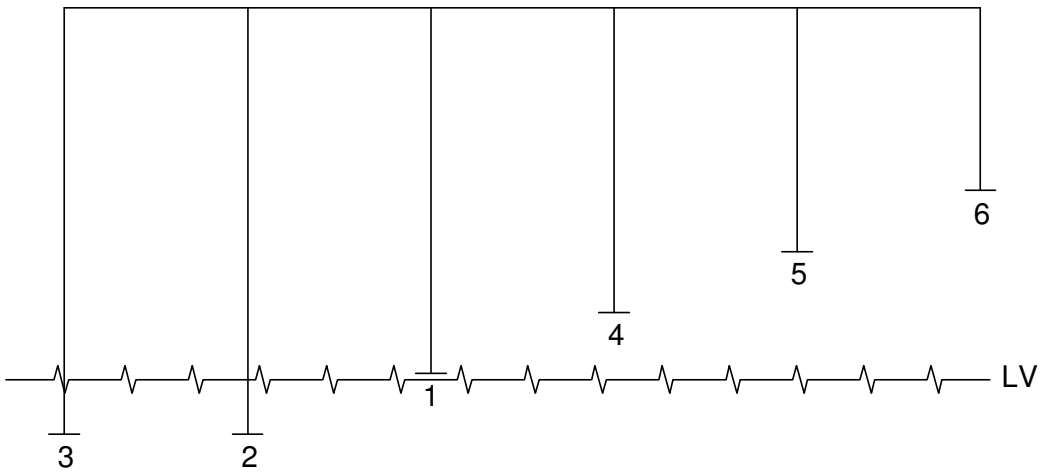


Figure: Adjustment of electrodes for water level control

Once the boiler has been erected on its foundation it may prove necessary to make a correction of the individual lengths of the electrodes - perhaps on basis of instructions provided by the national authority in connection with the erection supervision.
Adoption of the following procedure for shortening/adjustment of lengths of electrodes is recommended after having filled the boiler with appropriately treated boiler feed water :

Low water electrode :

(electrode No. 1)
The electrode is to be just free of the water surface, when the water level is flush with the L-W mark.

Low-low water electrode(s) :

(electrodes Nos. 2 and 3)
The electrodes shall be maximum 30 mm below the L-W mark. However, the water level shall at all times be visible in the water gauge glasses.

In case the feed water regulation is controlled by starts/stops of the boiler feed water pump :

Feed water - START (electrode No. 4)
The electrode should be 30 mm shorter than the low water electrode.
Feed water pump - STOP (electrode No. 5)
The electrode should be 60 mm shorter than the low water electrode.

In case the feed water regulation is controlled by a regulation valve :

Feed water regulation valve - OPEN (electrode No. 4)
The electrode to be 30 mm shorter than the low water electrode (electrode No. 1)
Feed water regulation valve - CLOSING (electrode No. 5)
The electrode to be 45 mm shorter than the low water electrode (electrode No. 1)
OPTION - overfilling electrode (electrode No. 6)
The electrode to be 120 mm shorter than the low water electrode (electrode No. 1)

When mounting the electrodes it should be verified that they are led correctly through their vibration supports.
Function test of the water level control system is to be conducted according to special instructions applicable.

Boiling-out / Cleaning of the boiler

The boiler is an all-welded construction and no lubricants have been used for the manufacture. Therefore, it is normally not necessary to conduct an alcalic boil-out of the boiler, unless there are specific requirements with regard to the purity of the boiler water from the outset. However, it is always recommendable to conduct a cleaning of the water circuit, prior to putting a new boiler into operation.
In case it is desirable to make sure that the boiler surfaces in the water and the steam side are completely clean, or in case the boiler during operation has been contaminated with fast or oils of any kind, it is recommendable to adopt the treatment described below.

PLEASE NOTE : Prior to starting the firing equipment in connection with the boiling-out, the proper permits to operate the boiler, issued by the relevant national authorities, must be available.

Inspection

The boiler to be inspected in the water and flue gas sides and any mislaid objects are to be removed.

Preparations

The boiler - and preferrably also the piping system - to be flushed with water, if possible by demineralized or softened water. New gaskets for the head hole and man hole covers shall be available for mounting after completion of the boiling-out.

Filling the boiler with water and chemicals

The boiler to be filled with demineralized or softened water to slightly above the L-W mark. Simultaneously chemicals are to be added through the upper man hole or though an available branch at the boiler top.

Chemicals to be used :

4 to 5 kg trisodium phosphate - Na_3PO_4 - per m^3 water.

The chemicals are to be dissolved - while stirring - in hot water before being fed into the boiler.

Shutting off the boiler

After the chemicals have been added, the man hole cover(s) and the steam and feed water valves are to be closed, whereas the manometer valve and air valve are to be kept open.

Firing

The firing is to be conducted at lowest load, equivalent to approx. 15% to 25% of max. nominal boiler rating and shall be conducted at a moderate phase, observing the following intervals :

1st hour: 5 minutes operation - 10 minutes stop

2nd hour : 10 minutes operation - 10 minutes stop

3rd hour : 15 minutes operation - 10 minutes stop

The air valve to be shut at approx. 1 to 1½ bar(o) boiler pressure, when pure steam escapes through the valve.

Hereafter, proceed continuous firing on lowest load until a boiler pressure of 5 bar(o) has been reached. Hold this pressure for a duration of approx. 8 hours - and subsequently stop the burner.

In case the firing process involves admission of hot flue gases to be led through the boiler, the firing will have to be conducted and adjusted - depending on the temperature of the flue gases - to the actual conditions, possibly regulated my means of a bypass damper.

In boilers intended to burn biomass there will normally be no problems in this respect, due to the fact that the firing equipment itself will require a gentle firing process.

Scumming, emptying

Provided the boiler is provided with a scum valve, proceed to conduct a thorough scumming through this valve.

Moreover, the water gauge glasses are to blown out in order to remove any dirt or deposits.

Finally, the boiler is to be emptied of water through the blowdown valves.

Cleaning

Once the boiler has been cooled down, proceed to open all handholes and/or manholes and to flush the boiler carefully from above, with the bottom blowdown valves in open position. The blowdown valves should not be activated until the boiler is completely clean, in order to avoid damage due to impurities.

If necessary, the bottom blowdown valves should be dismantled in order to remove any foreign matters.

Flushing of the boiler and the piping system should if possible be conducted by means of demineralized or softened water.

Final preparations

Proceed to mount new gaskets in head and man holes and subsequently carefully tighten these covers. Hereafter the boiler is ready to be put into operation, as described in section **Start-up of boiler plant (section 3).**

Please note !
In case the boiler is not put in operation immediately after the boiling-out, the procedures for "Preservation of boilers during standstill" (section 8) should be complied with.

Start-up of boiler plant

In general

The following instructions for starting a steam boiler from cold condition are intended as a guide, and control and regulation accessories are based on regulations stipuled in Denmark with regard to steam boilers and their accessory equipment.

CAUTION !
We draw your attention to the fact that it may prove necessary to adapt the equipment described in order to comply with national authorities' requirements in the country of installation.

The following points are to be verified prior to putting the plant in operation :

- Check the water level in the condensate/make-up water tank, in the deaerator tank as well as in the boiler. The water level should be just below normal operation level.
- Fill the boiler with appropriately treated water, complying with the requirements to the water quality, as stipulated in **Requirements to water quality** in Section 5. During the filling, the air in the boiler is to be scavenged through the air valve.
- Verify that the water treatment plant is ready for operation - and likewise check that the necessary chemicals are available in the dosing plant.
- Verify that the feed water quality complies with the values, stipulated in **Requirements to water quality** in Section 5.
- Check that the condensate/make-up water system is functionning correctly.
- Check that the feed water system is functionning correctly.
- Check that all valves are in correct start position, as stated below.
- Check that there are no signs of leakages.
- Verify that regulation and control panels are operational.

Position / Setting of valves during start-up

The setting (position) of valves is difficult to describe in general, due to the fact that it will depend on the layout chosen for the specific steam plant in question.
However, with the objective of preventing inappropriate temperature and pressure loads on the boiler, Danstoker has stipulated the following requirements with regard to correct setting of valves that must be observed - as a minimum - during start-up procedures of the boiler :

- Main steam valve — CLOSED
- Air valve — OPEN
- Check valve — OPEN
- Manometer valve — OPEN
- Valves of water-gauge armature – boiler side — OPEN
- Valves of water-gauge armature – for blow-down — CLOSED
- Bottom blow-down or draining valve(s) — CLOSED

Subsequently, you may proceed to start up the boiler as described in **Firing/Operation of firing equipment.**

Start-up of water treatment system

See special instructions for start-up of the water treatment unit.

Start-up of the make-up water system

The make-up water system may be supplied, designed and/or constructed by a supplier other than **Danstoker a·s.** Therefore, the following instructions are indicative only and merely serve as general information.
Prior to putting the boiler plant in operation, the make-up water system is to be operational.
When starting the make-up water system, the following points are to be checked and/or carried out :

- Check the raw water supply and the quality of the raw water as well.
- Verify that the water treatment system (softening unit or total desalting unit) is in operation.

Start-up of the feed water system

The feed water system may be supplied, designed and/or constructed by a supplier other than **Danstoker a·s.** Therefore, the following instructions are indicative only and merely serve as general information.
Prior to putting the boiler plant in operation, the feed water system must be operational.
When starting the feed water system, the following points are to be checked and/or carried out :

- Check the water level in the make-up water tank.
- Check that the water level regulation of the make-up water tank functions so that the water supply from the condensate/make-up water tank is sufficient to maintain the appropriate water level. Also check that the feed water pump will stop at too low water level in the make-up water tank.
- Start the make-up water system, if not already in operation.
- Check the temperature in the make-up and feed water tanks, thereby ensuring a feed water supply with the correct temperature to the boiler.
- Verify that the water level in the boiler is just below normal water level.
- Verify that the automatic water level regulation on the boiler/feed-water tank is functionning. For smaller boilers the type of regulation may be ON/OFF by means of starts/stops of the feed water pump. For larger boilers the feed water regulation should be conducted on a modulating basis.
- Check that the air valve on the boiler is open.
- Start the feed water pump against closed valve on the pressure side. The valves on the suction side must be kept open – supply make-up water to the feed water pump and scavange sufficiently. Starting the feed water pump must be done in compliance with the separate instructions applicable. ***Important: There must be sufficient flow over the pump to secure proper cooling of the pump!***
- Proceed to slowly open the closing valve on the pressure side of the feed water pump.

IMPORTANT! In case a feed water regulation valve is mounted on the pipe connection to the boiler, it must be secured that the required minimum flow through the pump in operation, stipulated by the manufacturer of the pump, can be observed, in order to avoid cavitation and damage of the pump.

This may be secured either by establishing an overflow connection from the pressure side before the regulation valve, thereby allowing the water to circulate back to the deaerator, or by providing the regulation valve with a limit switch, intended to stop the feed water pump at the correct maximum water level in the boiler.

Firing / Operation of the firing equipment

Definition of firing equipment (burner)

As the Danstoker boilers are often used in applications designed specifically for the client's individual purposes, the expression of ***FIRING EQUIPMENT (burner)*** used in this manual may apply to a large variety of firing methods and combustion principles.
As examples we could mention oil and gas burners, dual fuel burners, turbines and engines, combustion of various kinds in killns, incinerators, combustion chambers and combustion on grates.
This variety of combustion equipment may call for special attention, whenever the issue is firing and start-up procedures, interruption of the firing, maintenance, etc.

In general

The longevity of the boiler depends among other things on the number of boiler starts. In this connection an average of max. 1000 cold starts and max. 10,000 warm starts may be expected in the course of a 20-year lifetime, with operation loads ranging between 40% and 100%.
Furthermore, it is a fact that the longer time the boiler is allowed for each single start and the slowlier the boiler is released from minimum to maximum nominal load, the longer the life of the boiler will be.
With a view to securing a gradual and uniform heating of the boiler material and the refractory lining alike, and with a view to avoiding excessive temperature stress in the boiler body (and thereby the risk of causing cracks, fissures and leakages on account of different dilation co-efficients of the boiler material) it is of the utmost importance to observe and comply with the instructions given in the following.
Typical damage in case the boiler is fired excessively fast may be the development of cracks and fissures in tube and stay weldings at the first pass (reversing chamber and rear tube plate). Such damage is caused by the longitudinal dilation of the furnace, due to the fact that the furnace material, when firing the boiler excessively fast, will dilate faster than the other parts of the boiler.

Please note : The Danstoker warranty obligations shall lapse in case any damage to the boiler is contributable to the fact that the boiler was heated excessively fast!

We distinguish between 3 start-up situations - namely :

- **The initial firing**
- **Firing a COLD boiler**
- **Firing a HOT boiler**

The initial firing

The procedure for the initial firing is applicable to all types of steam boilers. For steam boilers provided with refractory lining – i.e. for ex-ample oil/gas fired boilers provided with refractory-lined burner plates (refractory cement or clay) as well as for all other steam boilers provided with refractory lining of some kind – specific requirements may apply with regard to the initial firing in order to allow for a sufficient and adequate drying process of the refractory lining in question.
Thus, with a view to achieving a homogeneous heating of the boiler and the refractory lining, if any, the initial firing of a new boiler must be conducted on lowest burner load – i.e. approx. 15% to 25% of the maximum nominal load.
The firing may under no circumstances be faster than stipulated in the paragraph on **Firing a COLD boiler** – i.e. :

1st hour :	5 minutes operation	10 minutes stop
2nd hour :	10 minutes operation	10 minutes stop
3rd hour :	15 minutes operation	10 minutes stop

4th hour and following hours :

Continue the firing on lowest load until the operation pressure has been achieved or until the boiler pressure has increased to approx. 6 baro. Subsequently, you may increase within approx. one hour the burner load to maximum nominal load.

Bottom blow-down

By means of the bottom blow-down valve(s) boiler water should be drained off during the entire firing process. The purpose of the blowdown is to remove the cold water and deposits, if any, from the boiler bottom. Simultaneously, the blowdown will cause the boiler pressure to decrease, thereby provoking a priming effect that will improve the water circulation and thereby contribute to equalizing the temperature difference of the various parts of the boiler.

Temperature difference

The temperature difference between the bottom blow-down branch and the lowest connection pipe for the water gauge armature is not to exceed 20 °C. In case of excessive temperature difference, the firing must be stopped until the temperature has again been equalized.

Firing a COLD boiler

The definition of a **COLD BOILER** is a boiler that has been out of operation for more than 3 days and consequently has been cooled down to under approx. 50 °C.
Firing of a cold boiler must be conducted at lowest load – i.e. 15% to 25% of nominal maximum load.
Boiler water is to be drained off (through the blowdown valve) throughout the firing process.
The purpose of the blowdown is to remove the cold water and deposits, if any, from the boiler bottom. Simultaneously, the blowdown will cause the boiler pressure to decrease, thereby provoking a priming effect that will improve the water circulation.
The temperature difference between the bottom blow-down branch and the lowest connection pipe for the water gauge armature is not to exceed 20 °C. In case of excessive temperature difference, the firing must be stopped until the temperature has again been equalized.

If it is not possible to drain off water during the firing process, the following intervals must – ***without fail*** - be complied with :

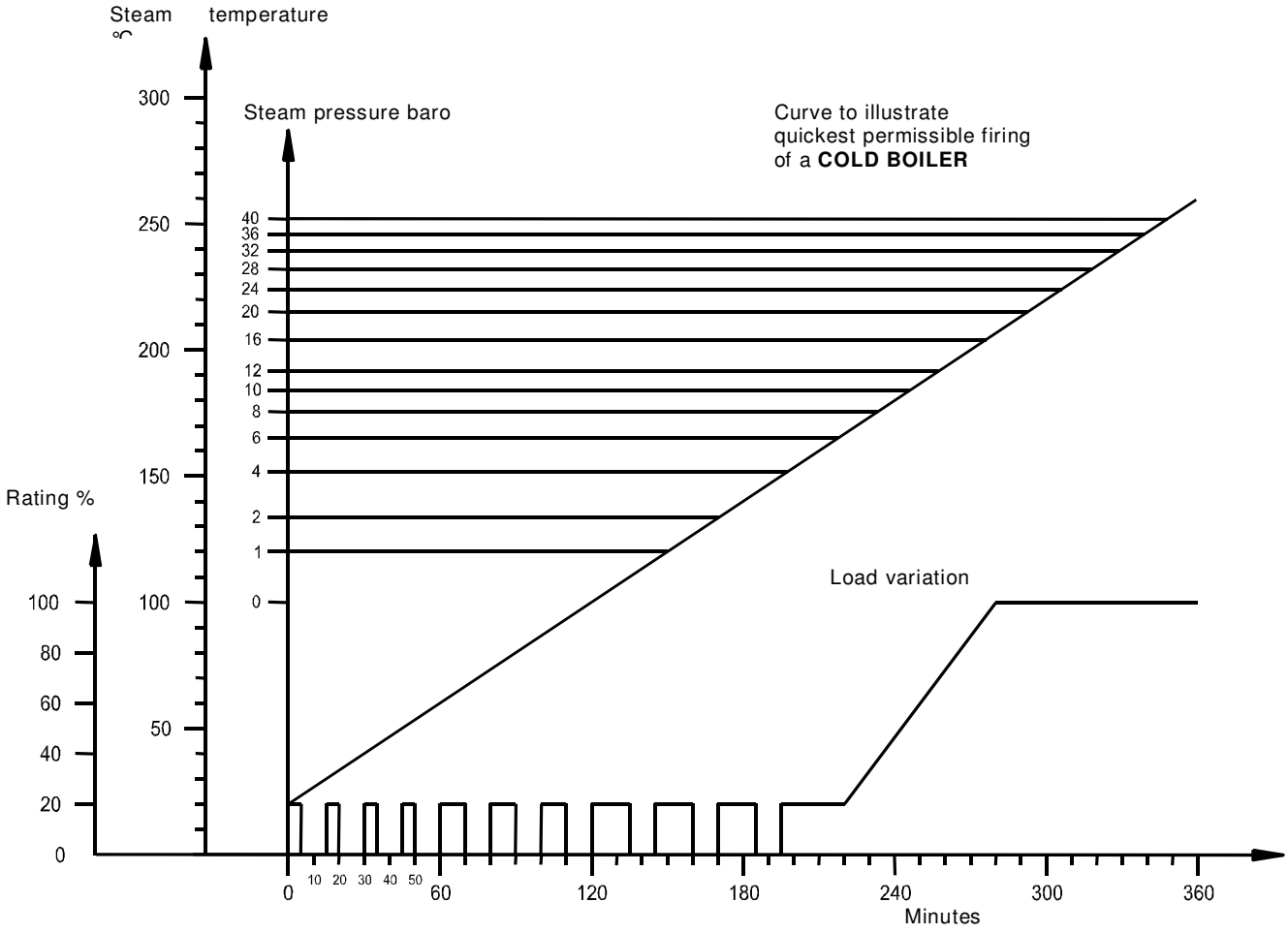
1st hour :	5 minutes operation	10 minutes stop
2nd hour :	10 minutes operation	10 minutes stop
3rd hour :	15 minutes operation	10 minutes stop

4th hour and following hours :

Continue the firing on lowest load until the operation pressure has been achieved.

Quickest permissible firing of a cold boiler

The duration of firing a COLD boiler till operation pressure has been achieved should not be less than 4 to 6 hours, depending on the operation pressure.
You are kindly referred to the start-up curve below, which applies to the firing of a COLD boiler.

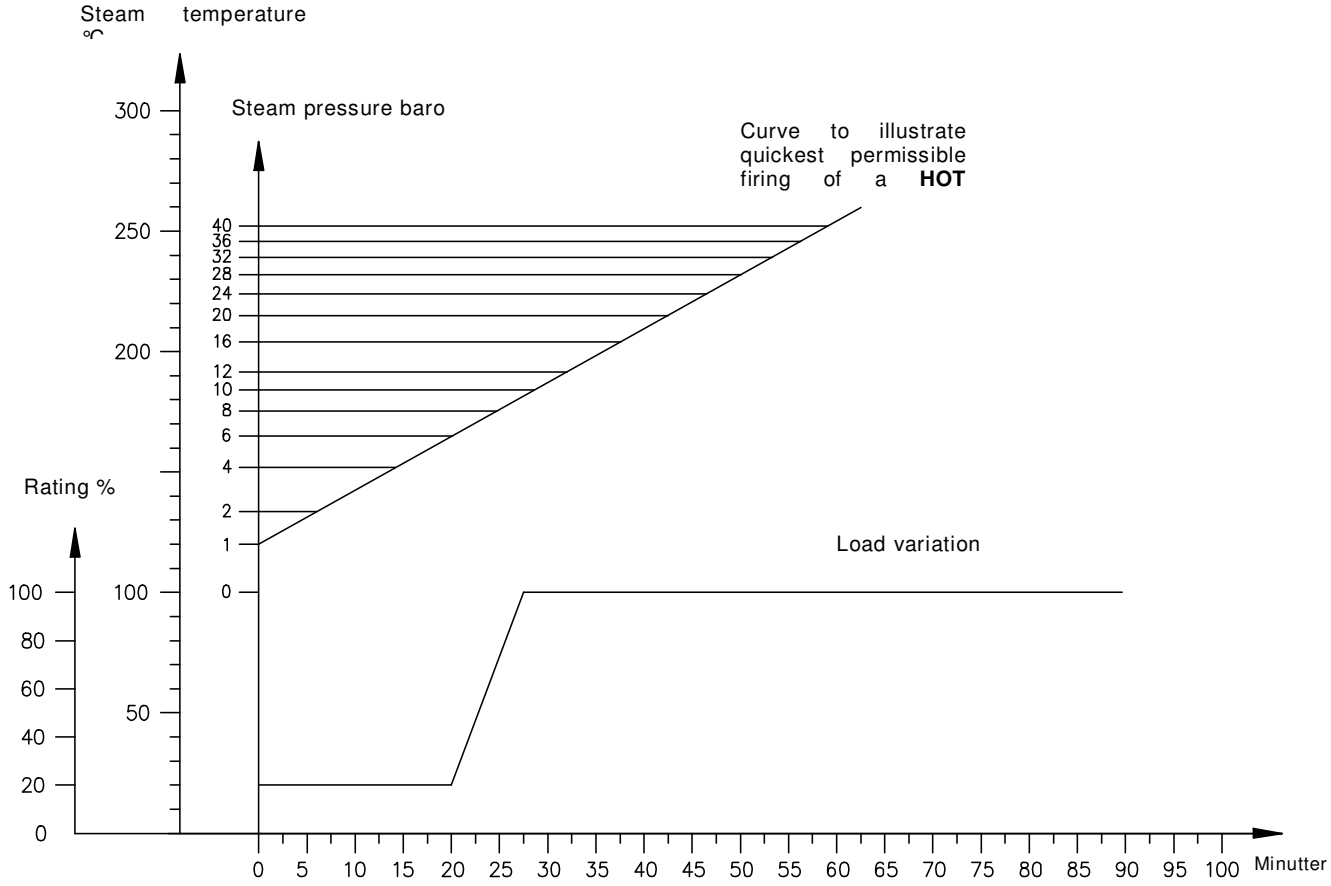


Firing a HOT boiler

The definition of a **HOT BOILER** is a boiler, which is kept under a pressure over 1 baro – i.e. holding a water temperature of over approx. 120 °C.

Quickest permissible firing of a HOT boiler

The firing of a HOT boiler should be contucted at a load of 15% to 25% of maximum nominal rating for a duration of minimum 20 minutes, until the pressure has increased to approx. 6 baro.
Hereafter the firing equipment may be released for maximum load in the course of 5 to 10 minutes.
You are kindly referred to the start-up curve below, which applies to the firing of a HOT boiler.



Controls to be made when starting up the boiler – In general

Control of condensate water

The water vapours, which will develop during the firing, will during th start-up procedure as well as in the first period of operation to a large extent condensate in the boiler tubes, until these tubes have been completely heated. Consequently, it is very important to verify that the draining facilities in the smoke-box, smoke ducts and in the chimney are operational, thereby minimizing the risk of corrosion.
All drains from the flue gas system must be provided with a water trap or another facility to separate the boiler's flue gas circuit from the outside. The separation should be examined at regular intervals – however, always in connection with momentary stop of the firing equipment.

Bottom blowdown

The blowdown removed the cold water and sludge and deposits, if any, from the boiler bottom. Simultaneously, the blowdown will create a decrease of pressure in the boiler, thereby provoking a priming effect, likely to improve the water circulation.

Control of the water level

During the start-up process the water level in the boiler will increase on account of the cubic expansion of the water. If the water level has risen, the bottom blowdown valve should be activated briefly in order thereby to reduce the amount of water in the boiler to slightly under the normal water level. In this manner it will be avoided that water and foam will be swept along together with the steam, whenever the steam valve opens, and which would cause a great risk that valves and accessories fitted on the steam line would be damaged.

Connection to the steam line

When the operation pressure has been achieved, the main steam valve is to be opened **slowly**, due to the fact that a sudden pressure decrease, as a result of the steam release, will make the water swell and cause large steam bubbles in the upper water level.
When starting the boiler (and the steam line) from cold, special attention should be given to the amount of condensate, which will develop when heating the steam piping. Provided efficient draining of the condensate has not been established, extensive water hammer effects may appear whenever the steam valve is opened completely.

After-tightening

When – during the firing of the boiler – the temperature and the pressure start to rise in the boiler and once the operation pressure has been achieved, you may proceed to look for possible leakages
Verify that all flange connections, the valves' packing boxes as well as hand, head and man holes, etc. fit tightly. It is particularly important to make this check when the boiler is being put in operation for the first time or when it has been stopped for a prolonged period of time.
If a leakage is found, after-tightening of flange connections and the like should be made immediately, provided it is evaluated that they can be tightened without stopping the boiler plant. If need be, the firing load should be reduced, thereby ensuring that that pressure will not rise while the tightening is being carried out.
Uncessary violence or power should not be applied when making the tightening in order to avoid damaging the packing material or the bolts.
Hatches and joints on the air and flue gas ducting should likewise be checked with regard to leakages.

Stop of the steam boiler plant

When stopping the boiler plant in connection with weekends, holidays, inspections, etc. it is equally important (as when starting the boiler) to allow the boiler material to be cooled down slowly and gradually with a view to avoiding causing damage to the boiler material.

You are kindly referred to the paragraph **Stop for normal inspection and maintenance of the boiler** (Section 4) with regard to the quickest permissible cooling down of the boiler.

During operation

Daily Operation and Maintenance

It is of vital importance that the boiler rating is adjusted so as to correspond to the varying steam requirements of the boiler plant, without exposing the boiler unit to extremely low or extremely high loads. Thereby a much greater operational safety and a considerably more economical operation may be achieved.

Once the boiler has been put into operation, it must be kept under pressure until the next inspection or another stop. However, it is advisable to reduce the pressure, whenever the boiler is out of operation with a view to minimizing the chimney and the radiation loss.

The fuel heat input (the fuel quantity) is to be adjusted according to the instructions for the firing unit in question and is to be adjusted to the steam requirement with a view to achieving an **even and homogenous transfer of energy** from the boiler's heating surfaces to the boiler water.
The boiler is not to be used for burning other types of fuel than those agreed and specified for this particular supply, unless an analysis has been made of the fuel and its possible corrosive effects on the materials that have been used for the manufacture of the boiler and/or the combustion equipment.
Likewise the combustion air used in the boiler plant must not contain particles or be contaminated by other agents, likely to have a deteriorating or corrosive effect on the boiler or other parts of the combustion plant.
If necessary, appropriate precautions and counter-measures should be adopted.

Danstoker cannot be made responsible for any chemical and/or temperature-related deterioration of the materials of the boiler and the combustion plant, nor for any consequence of burning unsuitable fuels. Moreover, Danstoker is not responsible for any fatigue failure in the materials, caused by pressure fluctuations.

With a view to minimizing the risk of corrosion, the smoke temperature must never be lower than the temperatures stated below :

MINIMUM flue gas temperatures

Combustion of **BIO-GAS**	160 °C
Combustion of **NATURAL GAS**	120 °C
Combustion of **LIGHT FUEL OIL** (max. sulphur content : 0,5 %)	120 °C
Combustion of **FUEL OIL** (max. sulphur content : 0,5 %)	120 °C
Combustion of **FUEL OIL** (max. sulphur content: 2,5%)	170 °C
Combustion of **WOOD** (max. moisture content 15%)	120 °C
Combustion of **WOOD** (max. moisture content 30%)	120 °C
Combustion of **WOOD** (moisture content over 30 %)	120 °C
Combustion of **STRAW**	120 °C

⇨ Minimum feed water temperature : 105 °C.

The safety equipment of the boiler should be checked daily according to current regulations. You are kindly referred to separate instructions, if any.
Water analyses are to be made on a daily basis, and if necessary the chemical dosing and the blowdown quantities are to be adjusted accordingly, in order to ensure that the boiler water at all times complies with the prescribed requirements with regard to water quality.

The combustion must be checked on a daily basis by visual inspection and furthermore analysis measurements of the flue gas should preferrably be conducted. In case of any irregularities, the combustion must immediately be adjusted accordingly.
The inspection glass (the viewer) should only be activated at low burner load in order to prevent damage on the glass and/or the packing. When not used, the inspection glass must always be tightened in closed position. If the glass should break when in open position (in over-pressure boilers), it may cause severe damage to the plastic-covered plates.
In case of leakages from stuffing boxes and flange packings these should be tightened immediately, as the packing surfaces are otherwise worn excessively.
Cleaning and inspection covers are to be checked at regular intervals, and if necessary tightened. They must fit completely tight, otherwise the resulting leakages are likely to discolour and damage the cover plates.

Stop of the boiler

Operation situations may occur where it will prove necessary to stop the boiler for shorter or longer periods of time.

Normal boiler stops

In applications where the boiler is intended to generate steam only for a part of the day and/or only on normal working days, the boiler is usually stopped by modulating the burner slowly down to minimum load.
Hereafter the following procedure is to be complied with :

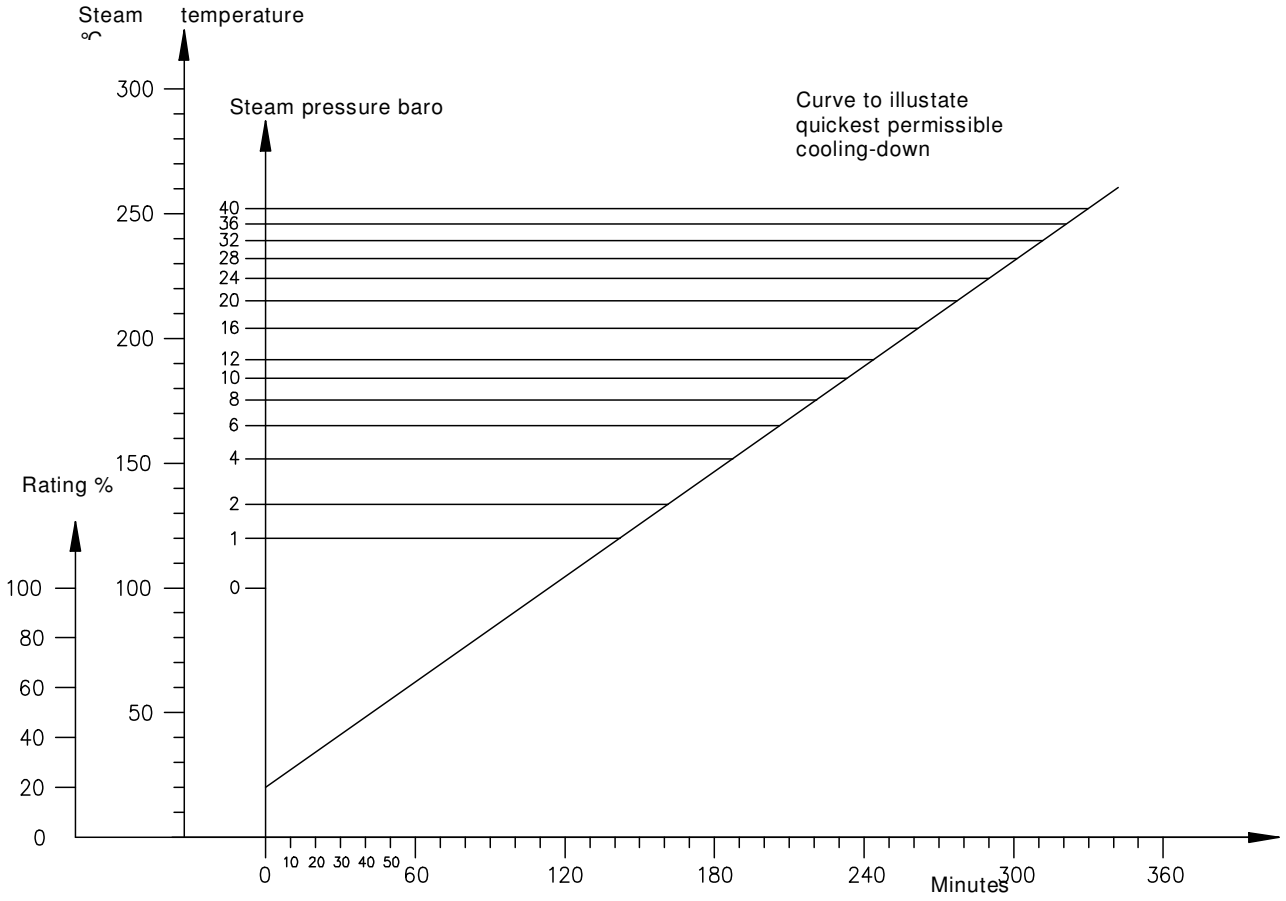
- The firing and the energy supply alike (oil, gas, biofuel, hot flue gases) is to be stopped by switching the firing control into "OFF" position.
- In installations equipped with a single boiler, the oil supply aggregate is stopped. In heavy-fuel fired plants, however, the circulation shoud be continued in case there is a risk that the oil may harden in the piping system. If the normal heating media (steam or hot water) is not available, the electrical preheater must be coupled in.
- The feed water supply is to be stopped by switching of feed water pump regulation into "OFF" position. Simultaneously the closing valve at the feed water tank is to be closed.
- The make-up water supply is to be stopped by switching of make-up water pump regulation into "OFF" position. Simultaneously the closing valve at the make-up water tank is to be closed.
- The control for automatic desalting and bottom blowdown systems to be switched off. The respective closing valves to be closed.
- The steam valve on the boiler is to be closed.

Hereafter, the boiler may be left in this condition until next normal start-up.

Stop for normal boiler inspection and maintenance

In case the boiler is taken out of operation with a view to conducting normal periodic inspections and maintenance, it may prove necessary to accellerate the cooling down of the boiler in order to provide access to the flue gas and water circuits within a reasonable period of time.
However, it is of vital importance to conduct the cooling-down gradually and not in a sudden manner, in order to prevent excessive and harmful material stress, likely to cause damage to the boiler construction.
The cooling down should be conducted at a maximum rate of approximately 2 °C per minute.

Quickest permissible cooling-down of the boiler



You are recommended to apply the following procedure :

- The firing and the energy supply alike (oil, gas, biofuel, hot flue gases) is to be stopped by switching the firing control into "OFF" position.
- In applications with a single boiler the oil supply aggregate is to be stopped. In heavy-fuel fired plants, however, the circulation should be maintained in case there is a risk that the oil will harden in the piping system. If the normal heating media (steam or hot water) is not available, the electrical preheater should be coupled in.
- In boiler plants burning solid fuel, endeavours must be made with a view to minimizing the amount of unburnt fuel in the boiler whenever the fuel supply is stopped - subsequently, the burning out should be accomplished by means of a combustion air fan, running at reduced capacity. When the burning-out is sufficiently advanced, the combustion air fan is to be stopped altogether, and the final combustion continues by means of the air that the smoke exhauster alone will supply to the fuel. In case the draft conditions are sufficient to remove the remaining smoke, you may proceed to stop the smoke exhauster completely.
- The steam valve on the boiler to be closed.
- The control for automatic desalting and bottom blowdown system to be switched off.
- Proceed to decrease the pressure in the boiler gradually by repeatedly and briefly activating the bottom blowdown valve.
- The switch for the feed water pump to be put in ”MANUAL” position. Repeatedly and briefly feed water may be pumped into the boiler in order thereby to reduce the boiler water temperature and to contribute to accellerate the cooling down process.

- For boilers, fitted with an oil or a gas burner, the burner is to be swung out of the burner front plate, if possible. Likewise the inspection door in the boiler rear end is to be opened. In this manner there will be a further cooling of the boiler water from the flue gas side and/or the boiler construction due to the draft of air thereby achieved. An important condition for doing so, however, is the fact that the boiler flue outlet is led separately from the boiler to the chimney.
- For boilers, fitted with a combustion aggregate for solid fuel or oil/gas burners with separate combustion air fans, this fan may furthermore be utilized for ventilating the smoke circuit of the boiler - and thereby contributing to a uniform and gradual cooling.
- Once the boiler pressure has been reduced to approx. 1 baro, the air valve may be opened.
- The feed water supply is to be stopped by switching the feed water control into "OFF" position. Simultaneously the closing valve at the feed water tank is to be closed.
- The make-up water supply is to be stopped by switching the make-up water control into "OFF" position. Simultaneously the closing valve at the make-up water tank is to be closed.
- Once the permissible temperature for discharging the boiler water to e.g. the municipal sewerage system has been achieved, you may proceed to open the bottom drain valve and drain off all the water.
- Once the boiler has been emptied, close the bottom drain valve(s). Prior to closing the drain valve(s), you may flush the boiler in the water circuit with cold water through the hand, head or man holes, in order to remove possible remains of impurities and sludge.

Emergency stops

In the course of operation, certain dangerous situations may occur, which will call for an immediate stop of the boiler - a so-called emergency stop. In case such situations occur, the boiler plant is stopped by activating the emergency stop, that is required to be available in the control panel and/or on several other suitable places in the boiler room, in compliance with the current regulations applicable to emergency stops in the country of installation.
After activating the emergency stop the closing valves are to be closed, in case this can be done without causing any risk to the operation personnel. Any further actions and measures to be adopted will depend on the specific reasons for the emergency stop.

The following situations may necessitate an emergency stop of the boiler plant :

- Development of sudden circumstances of unknown origin - such as abnormal sounds (rumbling, knocking) or movements from the boiler plant.
- In case traces of overheating or deformation in parts of the boiler construction are registered.
- Explosion of fire-tubes and/or the furnace.
- Failures in the safety equipment, which cannot be exchanged or repaired during normal operation.
- Failures in the feed water system, causing the feed water supply to the boiler to be obstructed.
- In case of breaks or leakages that cannot not immediately be eliminated and in case of failures in the make-up water system, which will stop the necessary make-up water supply to the boiler.
- In case of fire danger or actual fire in the fuel supply.
- In case of power failure, causing the combustion not to start automatically again.
- In case of the pressure rising above or falling below the normal level in the boiler and the piping system.

The national authorities in the country of installation shall be summoned immediately after discovery of any conditions likely to have an effect on the safety of the plant. Prior to the arrival on site of a representative from the authority in question you may not proceed to conduct any modification or clearing/removal operations of the damage or its immediate environment, unless it is imperative to do so with a view to saving lives or to prevent additional accidents, loss or damage.

Operation journal / Logbook

Once the system has achieved normal operating conditions, proceed to check and record all process parameters, such as pressure and temperatures in the system.
These data will provide the operators with valuable information, used as reference values when comparing process data with actual values obtained when the installation was new - with a clean system and clean tubes.
Furthermore, all unnormal situations that may occur are to be recorded in the logbook, a fact that may prove of great importance with a view to establishing on a later occasion the reason(s) for - for example - boiler damage or other irregularities.
Enclosed with this manual (at the back) you will find suggested layouts of such LOGBOOKS for :

- **Operation journal - DAILY RECORDS (boiler parametres)**
- **Operation journal - DAILY RECORDS (water quality)**

Boiler and make-up water systems

In general

Boiler water

Impurities in the boiler feed and make-up water affect not only the efficiency of the boiler plant, but also the safety of same - consequently this issue is of major concern to the operating personnel, and it deserves special focus and attention.

The problems, which will inevitably arise, in case untreated or insufficiently treated water is used in a steam plant, may appear already within a very short time of operation !!

The typical problems would be :

- Formation of scale and deposits on the heating surfaces in the boiler.
-

In case any trace of scale is found in the boiler, your right to present a valid claim to Danstoker shall lapse.

- Deposits of sludge and rust, which - in connection with the oxygen content of the water - will result in pitting under these deposits. Furthermore, other plant components outside the boiler are likely to be damaged if similar impurities are deposited there.
- Oxygen corrosion on boiler parts as well as in the piping, tanks and other parts outside the boiler.
- Corrosion in the boiler and in other parts of the installation on account of an excessively high salt content in the feed water.
- Excessive use of sodium hydroxide for adjustment of the pH-value may cause stress corrosion cracking (or caustic embrittlement) in the form of typical micro cracks/fissures.

The main objective of treating the water properly that is fed into a steam plant, is therefore :

- **To prevent impurities from entering the system altogether.**
- **To eliminate the harmful effects of these impurities, if any.**

The undesirable impurities usually find their way into the steam system via the feed and make-up water system. Without a correct treatment of the water (mechanical and/or chemical), the risk of provoking scale formation and corrosion in the boiler system and its accessory equipment will be unacceptably high.

In the following are stipulated requirements to the quality of the water in steam applications. These requirements are based on the requirements stipulated in the German TRD 611 code and on extensive experiences from steam generating systems.

PLEASE NOTE :
Failure to observe the requirements stipulated below with regard to water quality will cause the Danstoker warranty obligations to lapse !!

REQUIREMENTS TO WATER QUALITY

FEED WATER and BOILER WATER in fire-tube boilers generating saturated steam

FEED WATER						
GENERAL CONDITIONS: **THE WATER MUST BE CLEAR AND FREE FROM ODOUR AND UNDISSOLVED SOLIDS**						
Quality classification		**Salty**		**Partly saltfree**		**Saltfree**
		< 0,5 ≤ 22		≤ 22	≤ 44	≤ 44
Conductivity at 25 °C	µS/cm	< 500	< 500	5 – 50	5 – 50	< 0.2
pH-value at 25 °C (*)		> 9	> 9	> 9	> 9	> 9
Oxygen O_2	mg/l	< 0.02	< 0.02	< 0.02	< 0.02	< 0.01
Total hardness (Ca + Mg)	mmol/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.005
Total iron content, Fe	mg/l	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Total copper content, Cu	mg/l	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Oil and fat content	mg/l	< 1	< 1	< 1	< 1	< 1

BOILER WATER						
GENERAL CONDITIONS: **THE WATER MUST BE CLEAR AND FREE FROM ODOUR AND UNDISSOLVED SOLIDS**						
Quality classification		**Salty**		**Partly saltfree**		**Saltfree**
		< 0,5 ≤ 22		≤ 22	≤ 44	≤ 44
Conductivity at 25 °C	µS/cm	< 8000	< 4000	< 3000	< 1500	< 50
pH-value at 25 °C (*)		10.5-12.0	10.0-11.8	10.5-11.5	10.0-11.0	9.5-10.5
Phosphate (PO_4)	mg/l	5 – 20	5 – 15	7.5 – 15	7.5 – 15	10 – 20
Silicic acid (S_iO_2)	mg/l	< 160	< 120	< 100	< 30	< 4

(*) It is recommended that the pH-value is adjusted with Na_3PO_4. Only use NaOH in those cases where the required pH-value cannot be reached with Na_3PO_4 alone.

In principle the above requirements are indentical to the recommendations given in the German TRD 611 code. Besides the requirements are based on many years of operation experiences.

Danstoker cannot in any way be held responsible for the chemical and/or temperature-related deterioration of the boiler materials - nor for the consequences of the use of boiler and feed water that does not comply with the requirements stated above !!

Treatment of make-up water

The treatment of make-up water is a form of preventive treatment. The purer the make-up water is, the less problems will arise in connection with the boiler water treatment - and thereby allowing you to avoid possible operation problems in the future.

- With a view to determining the required form of preventive treatment, it is essential to have the raw water source properly investigated and the water thoroughly analysed.
- The required treatment depends not only on the desired quality of the water, but also on the composition of the raw water itself.

CAUTION !
It is important to have the raw water analysed at regular intervals and not only rely on the initial/original water analysis. The conditions may change and the composition of impurities may change accordingly.

Formation of scale

The formation of scale on the heating surfaces of the boiler will result in a reduction of the boiler efficiency on account of the impaired heat transfer, again resulting in a deterioration of the operation economy.
Depending on the composition of the raw water the scale may - in addition to calcium carbonate - also contain silicate compounds, iron and cobber oxides. These salts may cause development of scale on the fire-tube walls and on other steel surfaces - unless appropriate counter-measures are initiated in the form of treatment of the make-up water.
However, the main concern in connection with scale is the risk of excessive heating of the water-cooled surfaces of the boiler.
The boiler boiler water functions as a cooling media for the tubes, and as the scale deposits have a low heat transfer coefficient, the formation of scale will result in a lower cooling efficiency and cause the temperature of the fire-tube material to increase.

PLEASE NOTE: Your right to present a valid claim to Danstoker shall lapse, whenever scale is found in the boiler !

Consequently, the scale-developing agents **must be removed** from the make-up water by means of a softening unit - or alternatively by means of a desalting unit.
The water treatment system chosen must be dimensioned so as to be able to treat as a minimum the water supply required for the generation of the nominal steam rating – possibly slightly over-dimensioned in order to compensate for the amount of steam, escaping from leaks, if any, in the entire system.

Sludge and rust deposits

The suspended particles may be found in a variety of forms and must be removed from the raw water, provided the raw water is to be used as make-up water.
Organic matters and micro-organisms must likewise be removed from the raw water, provided the raw water is to be used as make-up water.
The matters that we wish to remove often consist of very small particles, and consequently they must be collected into larger particles by adding special chemicals to the water - i.e. by means of the so-called **flocking**. Subsequently, it will be possible to remove these particles - either by flotation or sedimentation. Any small particles, if any, still remaining in the water can be removed by leading the water through an open sand filter.

Dissolved gases (oxygen, carbon dioxide, nitrogen)

The raw water (tap water) contains oxygen, free carbon dioxide and nitrogen, all agents present in the form of dissolved gases.

The oxygen - which constitutes approx. 20% of the dissolved gases - is undesirable in the steam system, as it **may cause severe corrosion** on metal and alloys, used in the boiler plant. Tap water with a temperature of 8 °C may contain up to approx. 11 mg of oxygen per litre water - however, the normal content is approx. 9 mg/litre.
Under sludge deposits on for example the furnace, reversing chambers and smoke tubes, where only a part of the steel surface is covered, the oxygenous water may cause pitting. **Pitting develops very fast** and constitutes the most serious type of corrosion inside a boiler.
Therefore, the oxygen must be removed from the water by thermal or chemical deaeration.
The thermal deaeration may take place in a deaerator tank, in which the make-up water will be heated to approx. 105 °C, while being under a pressure of approx. 0.2 baro. In this process the content of oxygen in the water may normally be reduced to 0.02 mg/l.
Any still remaining oxygen is to be removed by adding chemicals to the make-up water, before it is subsequently pumped into the steam system.
Carbon dioxides normally do not constitute a severe problem in connection with make-up water for steam generating systems, as a conditioning of the water to hold a pH-value between 9 and 10 will convert free carbon dioxide to sodium carbonate.
Nitrogen - which constitutes approx. 80% of the dissolved gases - is not in itself corrosive, however, as it is not possible to remove the oxygen selectively, the deaerator is to be so dimensioned that also the nitrogen is removed.

Dissolved salts

Dissolved salts, chlorides (NaCl, $MgCl_2$), sulphates ($MgSO_4$, $CaSO_4$) and carbonates ($CaCO_3$) - which may enter the boiler with untreated make-up water, must also be removed in order to prevent the formation of scale and corrosion in the system.
This removal may take place by adopting one of the following methods - i.e. by **ion exchange** or by **reverse osmosis**.
A typical **ion exchange unit** consists of a very sour cation exchanger and a very basic anion exchanger, a regeneration equipment with hydrochloric acid and a sodium hydrate tank as well as a neutralization unit, which will neutralize any excess of acid and base from the regeneration liquids, before the water is lead to the sewege system.
A **reverse osmosis unit** (RO-unit) is primarily used whenever reduction of the salt content in the water is of vital importance. The pureness of the permeate depends on the quality of the raw water which is to be treated.
Reverse osmosis is a membrane separation process which, by means of a high water pressure, is capable of separating (rejecting) the dissolved salts (ions) contained in the raw water and letting the clean water molecules pass through the membrane.
In reality it is the water molecules that are removed from the dissolved salts and not, as is known from ion exchange, the ions that are removed from the water.
The dissolved salts are removed almost 100% and the pores of the membranes are so small that even micro-organisms like bacteria and pyrogenics cannot penetrate. The treated, purified water (the permeate) is collected in the reservoir tank of the plant, and from here it will be pumped to the user installation. The ""fouled" water (the concentrate) will be led to sewer.
The decision as to which type of unit to use depends on 3 conditions :

- The quality of the raw water
- Environmental conditions - i.e. handling of acids and lye as well as discharge to the sewege system
- Economical optimization

All in all - the advantages achieved by using saltfree make-up water (as compared to using only softened make-up water) will normally by far outweigh the slightly higher expenses incurred.

Addition/Dosing of chemicals

The importance of applying a correct water treatment method and the addition of chemicals cannot be overestimated !!

The best way of dosing the chemicals into the system is by means of a suitable – 100% reliable - and infinitely variable dosing unit.

The use of unreliable equipment of poor or dubious quality may have the implication that insufficient quantities of chemicals will be added to the system for prolonged periods of time - during which period the treatment will be entirely inappropriate. This may lead to the onset of corrosion in the boiler and subsequently considerable repair costs that far outweigh the cost of a reliable chemical dosing equipment.

Bottom blowdown of the boiler

When heat or steam is generated in a boiler the concentration of heavy impurities and dissolved contaminants will increase at the bottom of the boiler, on account of the fact that this place offers the best conditions for a sedimentation of these particles due to the reletively low velocity of the boiler water.

With a view to preventing this concentration from causing corrosion or excessive heating of the boiler material, it is necessary at regular intervals to drain off a certain amount of water from the boiler – i.e. to blowdown the boiler. This “boiler blowdown” therefore constitutes an essential part of the general control routines with regard to the overall boiler water treatment.

Taking of water samples

In order to ensure proper operating conditions it is imperative that the exact quality of the boiler water - and the water composition as well - is known from day to day, in order that the necessary measures and treatment may be applied immediately with a view to correcting and setting right any unsatisfactory and undesirable conditions. It is therefore extremely important - **at regular intervals** - to take out samples of the water used in the steam plant.

1. Take out samples of the raw water used - **every week.**
2. On **a daily basis**, proceed to take samples of :
    - The make-up water
    - The feed water
    - The boiler water

The necessary information about the quality of the water is obtained by means of a few simple tests, which are conducted on the samples taken.

<u>The following tests shall be made</u> :

- pH value of the boiler water
- Hardness of the feed water
- Conductivity of the boiler water
- The O_2% or alternatively the excess of oxygen-binding agents in the boiler water

You are kindly referred to the enclosed **Operation Journal (Daily records – Water quality)** that you will find at the back of this manual.

Water Sampling procedure

When taking water samples for analysis, the following procedure is recommended :

1. Clean the water sample bottle to be used.
   For repeated samples from the same water source, it is recommendable to use the same bottle for the samples.
2. Open the cooling water to the sample cooler.
3. Gradually open the sample test valve. Flush the cooler and piping with a high flow rate until sample flow is hot.
4. Reduce the flow rate to about 200 to 500 ml/minute.
5. Take the water sample when the temperature of the water is below 25 °C.
6. Rinse the sample bottle three times with sample water before filling it.
   The bottle shall always be filled to the top and sealed immediately.
   The bottle shall remain sealed until the analysis can be performed.
7. After taking the sample, close the sample inlet valve first, and then proceed to close the cooling water inlet valve.

Boiler inspection and service

In general

There is only very little maintenance to be performed on the boiler itself. The necessary and appropriate inspections are mentioned in the following.
If desirable, you may enter into a Service Agreement with the Danstoker Service department in order to have Danstoker conduct the more extensive periodic inspections (see the Introduction).
Please note that ***NO*** alterations and/or repairs of the boiler unit during the warranty period may be undertaken without the prior written permission of Danstoker a-s.

Failure to observe this stipulation will cause Danstoker's warranty obligations to lapse.

Alterations and repairs undertaken **after** the warranty period has expired, may only be performed by companies and personnel, duly skilled and licensed to manufacture pressure vessels or to carry out work on pressure vessels.
It is recommended that the operator/owner contacts Danstoker a-s prior to commencing repair works anywhere on the pressurised part of the steam boiler.

In case the boiler is damaged considerably during operation, the local inspection authority should be advised accordingly, prior to making any attemps to repair the boiler.

Daily inspections

The following inspections should - **as a minimum** (however, depending of the local authority) - be performed on a **daily basis**, and preferably at least once every shift :

- The combustion system shall be controlled - and in case of an unbalanced or unsteady combustion - the system must be adjusted accordingly.
- The safety equipment of the boiler should be checked according to current regulations. See separate instructions, if any, on this subject.
- Water analyses must made on a daily basis, and if necessary the chemical dosing and the blowdown quantities are to be adjusted accordingly to ensure that the boiler water complies at all times with the prescribed requirements.
- Check and record the smoke outlet temperature after the boiler. In plants equipped with an economiser, the smoke gas temperature between the economiser and the boiler should likewise be noted.
- Check all connections and piping for leakages.
- Check the chemical dosing equipment.
- Take the necessary water samples and perform an analysis. Record the results of these tests.
- The water-gauge sight glasses must be blown out on a daily basis. See special instructions.
- The inspection glass (the viewer) should only be operated with care in order to prevent damages on the glass and/or the packing. When not used, the inspection glass must always be tightened in closed position.
- The inspection glass is always to be tightened when in closed position. If the glass breaks in open position it will cause severe damage on the cover plates.
- Check and record the make-up water temperature as well as the pressure and temperature of the feed water.
- Verify that the feed water pump unit is functionning correctly. In this connection you are kindly referred to specific instructions provided by the pump manufacturer.
- Check and record the steam pressure.
- In boilers with steam superheating, also check and record the steam temperature.

- Verify that the condensate pump (make-up water) is functionning correctly. In this connection you are kindly referred to specific instructions provided by the pump manufacturer.
- Verify that the deaerator unit is functionning correctly. In this connection you are kindly referred to specific instructions provided by the manufacturer.

Soot control

Once the boiler has been in operation for a certain period of time, soot deposits will inevitably build up in the boiler tubes. An excess of unburnt fuel may also cause soot deposits to stick to the tube surfaces. This is most likely to happen during operation on low loads and with low smoke temperatures.
The quantity of soot and deposits largely depends on factors such as the type of fuel used, the degree of purity of the flue gases, the smoke temperature, time in operation, etc.
The required frequency of soot removal varies from plant to plant, and exact guidelines cannot be provided – however, see the brief instructions below.
The cleaning may be conducted manually, and Danstoker a·s provides with the boiler a cleaning brush, suitable for the dimension of the smoke tubes.
However, it may prove a great advantage to conduct the cleaning by means of **automatic cleaning equipment**, on account of the fact that the cleaning may be conducted while the boiler is in operation – without inconvenient operation stops. Danstoker can supply such equipment, i.e. **the *DANBLAST* chock blast system** – please contact us for documentation and a price quote.

Soot cleaning intervals

The following method of checking whether the boiler needs to be cleaned is recommended :

- **Check the flue gas temperature.**
  If the smoke outlet temperature after the boiler has increased by 20 °C above the normal value for a clean boiler, the boiler needs cleaning.

- **Check the flue gas resistance.**
  If the flue gas resistance has increased above the normal value for a clean boiler, the intervals between cleanings of the flue gas side must be shortened. The flue gas resistance may be measured by means of a simple U-tube gauge, which is connected to the furnace or the combustion chamber of the boiler and the flue gas duct after the boiler.

Please note! An increase of the flue gas resistance is normally insufficient to provide precise indication on the amount of soot deposits on the fire tubes' internal surfaces.

- **Visual control**
  At regular intervals proceed to inspect the smoke tubes visually with regard to soot deposits. If excessive amounts of soot have accumulated, the tubes must be cleaned. Such inspections are particularly important to conduct whenever the quality of the fuel used has been modified.

Tending and maintenance

The boiler's flue gas circuit

By making daily inspections and records of the combustion it will be possible to register that the flue gas temperature rises concurrently with the sooting-up of the fire tubes. With an increase of the flue gas temperature of approx. 20 °C the tubes should be cleaned, as the increased flue gas temperature will result in a deteriorated firing economy.

When the boiler is taken out of operation it should be slowly run down in load, prior to being stopped and cooled down (see section 4).

It is recommended to cover up the firing aggregate in order to protect it against soot and other impurities.

The actual cleaning may be conducted with a rotating brush or with a hand brush and vacuum cleaner. With a view to obtaining optimal cleaning, it is essential that the brush fits closely in the tubes. The most efficient result is achieved when the cleaning is done immediately after the boiler has been taken out of operation and while it is still hot and dry.

Under certain conditions it will be possible to establish an automatic soot-cleaning device (air, ultrasound or the like) (Danstoker automatic soot cleaning equipment, type *DANBLAST* – please see paragraph 6.3 Soot control). Thereby, it will be possible to run continuously without having to take the boiler out of operation to clean the flue gas circuit.

After cleaning of the flue gas circuit has been completed, the soot must immediately be removed from the furnace, combustion chamber, reversing chambers and the smoke-box.

IMPORTANT !!
Water and steam cleaning of the flue gas circuit should not be conducted as part of the ordinary daily routine, unless the boiler is specifically designed for cleaning with water or steam and unless a prior agreement with Danstoker a-s or a relevant institute has been made. Special instructions will apply in case of cleaning with water and/or steam.

In connection with the cleaning, the heating surfaces of the boiler should be inspected for corrosion damage and/or leakages. Likewise the refractory lining, if any, should be checked.

At least once a year the boiler should be inspected everywhere in the flue gas circuit with regard to possible corrosion damage and leakages. Likewise it should be verified that the refractory lining, if any, is still intact.

This inspection could be conducted by the **Danstoker Service** Department (see the Introduction) – please contact us for further particulars.

In case corrosion damage is found on the heating surfaces, you are recommended to proceed to conduct an ultrasound examination of the material for evaluation of the boiler's reliability of operation.

The water circuit

At least once a year the boiler should be inspected thoroughly in the water circuit.
This inspection could be conducted by the **Danstoker Service** Department (see the Introduction) – please contact us for further particulars.

The inspection should involve the following :

- The boiler is to be emptied of water.
- Man, head and hand hole covers are to be removed and cleaning plugs, if any, are to be dismounted.
- The boiler is then to be thoroughly flushed everywhere in the water circuit.
- Hereafter the boiler is to be inspected in the water circuit to the extent possible.
- Particles at the bottom of the boiler may be removed by means of a wet-sucker.
- In case hard deposits of scale on the heating surfaces are found the boiler should immediately be submitted to an acid de-scaling treatment. This treatment is always to be conducted by a recognized company, duly skilled and authorized to perform this type of treatment.

It is a fact that as little as 0.5 mm scale will reduce the efficiency of the boiler, and at the same time the existence of scale may cause costly boiler damage.

In case any trace of scale is found in the boiler, your right to present a valid claim to Danstoker a-s shall lapse.

- The water treatment plant should be checked.
- Feeding of make-up water after the cleaning should be done cautiously and slowly - and of course with appropriately treated water.
- The outside of the boiler should be checked for leakages from man hole covers, valves, flanges, drain pipes and the like. Any damage or irregularities should be set right immediately.

Start-up of the boiler after the inspection shall be conducted as described in **Start-up of the Boiler Plant** (section 3).

Preservation during lay-ups (idle periods)

In general

When a boiler is taken out of operation for a shorter or longer period of time, severe corrosion damage may develop in the water and the flue gas circuits alike during the standstill period – unless appropriate measures and preparations are made and that the boiler is inspected at regular intervals with a view to reducing the risk of corrosion on the internal surfaces.

The boiler must be kept clean and as dry as possible. All external surfaces must be protected against corrosion caused by leaking valves and flanges.
An appropriate preservation of the boiler constitutes the best protection against corrosion damage, otherwise likely to develop during a longer standstill period.

We distinguish between 3 types of preservation (lay-ups) - i.e. :

1. **Wet preservation (wet lay-ups) (hereunder Nitrogen Preservation)**
2. **Dry preservation (dry lay-ups)**
3. **Use of VCI**

A boiler, which is removed from service for a prolonged period of time, must be properly protected against corrosion. First proceed to clean the boiler thoroughly in the flue gas and the water circuits – then subsequently the boiler is to be filled with water (wet lay-up) or the boiler is to be drained off altogether (dry lay-up).
A dry lay-up – or VCI preservation (see below) is the best solution in case the boiler is shut down for more than 1 to 2 months.
For short-term shut-downs, the wet lay-up, or alternatively nitrogen preservation, will be suitable or even preferrable, due to the fact that it will be possible to start up the boiler somewhat faster than is the case with dry lay-ups.
It is recommended to apply one of the lay-up methods described in the following.

Wet preservation (lay-ups) of boilers

Wet lay-up of the boiler requires fewer preparations, the boiler may rapidly be put back into service, and the protection of the boiler's water side is sufficient. This method can safely be used during shorter - and frost-free! – shut-down periods.

It is recommended to adopt the following procedure :

- Run the boiler slowly down to minimum load, whereafter the burner is stopped.
- Close the boiler's connections to the steam system.
- Subsequently cool down the boiler until the boiler water has reached the permissible temperature for discharging it into the municipal sewerage system.
- Open the drain valve(s) cautiously, once the pressure in the boiler has decreased to approx. 1 barg. All the water contained in the boiler is to be drained off.
- Empty the boiler and inspect it carefully everywhere. In case any sludge, scale or other deposits are found, proceed to clean the boiler as described in **The Water Circuit** above.
- Close the drain valves.
- The air valve should remain open.
- Fill the boiler completely with softened water and add 0.5 litres of a 30% solution of soda lye and 200 g of sodium sulphite per m^3 of water.
- Scavenge the boiler continuously while filling water into the system in order to ensure that all air is removed from the boiler's internal areas.
- Maintain a hydrostatic pressure of approx. 0.2 barg in the boiler

during the shut-down period. To achieve this, the boiler removed from service can be fitted with an expansion tank, installed and connected as high as possible (f ex. an air vent valve).

Maintaining the water level in the boiler

The water level in the expansion tank should be checked regularly, and if the water level falls, more softened and treated water should be added to the boiler.
Adding water to the system should be conducted in such a way that the risk of air pocket formation is eliminated.

Water Circulation in the boiler

To ensure that the chemicals are not used up locally it is recommended to establish a circulation system, by using a small pump to circulate the boiler water. The pump is intended to ensure that the treated water from the bottom of the boiler is pumped back into the system at a connection point placed between the boiler and the expansion tank. The pump should be activated a couple of hours each week.

Water samples

If the circulation piping is provided with a test cock, water samples may be taken and, after analysis, used to verify whether the water treatment is still sufficient or whether more chemicals have to be added to the system.

The boiler water is to be kept alkaline in order to provide the necessary corrosion protection.

If the pH-value is too low (below 10) sodium hydroxide should be added, and if the surplus of sulphite falls below 100 mg/litre another 100 g of sodium sulphite per m^3 of water should be added.

Starting up the boiler after wet lay-ups

If no other work has been performed on the boiler that would require the boiler to be started according to the instructions for the initial firing of the boiler (for example renewal of the refractory lining), the boiler should be started according to the normal start-up procedures – see section 3.

Flue Gas Circuit

The flue gas circuit must be clean and dry in a boiler that is removed from service.

Soot deposits - in the smoke tubes and in other areas exposed to the flue gases - are likely to cause corrosion when absorbing humidity from the air, especially when burning sulphurous fuels.

It is therefore of the utmost importance that all surfaces in the flue gas circuit are as clean and dry as possible under the given conditions.
The flue gas outlet should be covered up when the boiler is shut down.

Nitrogen preservation

This method is actually a variant of the ordinary “wet lay-up”, as the method implies keeping the boiler filled with boiler water, to which an oxygen-binding agent (100 to 200 g sulphite per m^3 of boiler water) has been added.

Instead of filling the boiler completely with boiler water, some of the normal steam drum is to be filled with nitrogen through a pressure regulating valve from a nitrogen bottle. The pressure regulating valve will provide the combined facilities of (1) correct dosing of nitrogen during cooling down and (2) maintaining an over-pressure in the boiler of approx. 0.2 barg.

When starting up the boiler again the supply of nitrogen is shut off and the boiler may immediatley after be fired/started up in compliance with the normal start-up procedures.

The nitrogen trapped inside the boiler will subsequently evaporate into the steam system, where it will cause no problems whatsoever.

Dry lay-up of boilers

The water side

The boiler is to be emptied of water and subsequently inspected thoroughly. If any sludge, scale or other types of deposits are found, proceed to clean the boiler as described in **The water circuit** (section 7).

The flue gas side

The preservation of the flue gas sides is carried out by cleaning the flue gas circuit thoroughly while the boiler is still warm, and by keeping the boiler’s flue gas side completely dry during the shut-down period.

The following procedure is recommended :

- Remove all loose deposits in the flue gas circuit (use a rotating brush and a vacuum cleaner).
- Soak/soften surfaces with hard deposits.
- The softening and subsequent washing out should be done using alkaline or basic water.
- Hard deposits that cannot be removed after softening and washing out are to be removed with mechanical cleaning equipment. When firing fuel oil, such deposits are normally vanadium coatings that tend to build up at the entrance to the first smoke tube pass of the boiler.

CAUTION !!
If the furnace is provided with refractory lining it may become wet, and consequently there is a latent risk of corrosion on the underlying surfaces. However, this risk will be minimized if the refractory lining is sufficiently dried, e.g. by keeping the boiler heated for an appropriate period of time. The heating may be achieved by circulating hot water from another boiler or by blowing heated air through the boiler.

- In order to neutralize any remains of acid, the cleaned flue gas surfaces should be given a light coating of powdery calcium or magnesite.
- It is essential that the chemical used is applied as a very fine power to secure a good adherence and an even distribution on the surfaces. This will provide the most effective neutralization of the acid deposits. Insert the chemical through the burner opening and if possible let the natural chimney draft distribute it inside the boiler.

- If - for some reason - it is difficult or undesirable to use chemicals (as a powder), ordinary lime water can be used instead.
- Minimize the chimney draft as much as possible. Close the smoke outlet tightly, thereby preventing smoke from being drawn back into the boiler.
- If the boiler is placed in a non-heated room or in a place with a high humidity, it will be necessary to take special precautions to keep the air in the boiler dry.
- This can be achieved by placing bags of blue silica-gel inside the boiler. Blue silica-gel will turn red, once it has absorbed humidity. Silica-gel that has absorbed humidity may be re-used after having been dried at 100 to 120 °C for approx. 3 hours. After drying it will regain its original blue colour.
- Silica-gel is used to avoid condensate to develop in boilers that have been sealed tight.
- The flue gas circuit should be inspected at regular intervals, for example once a month. Special measures should be taken to detect traces of corrosion, and simultaneously the silica-gel (if applied) should be examined.
- An alternative method to keep the boiler dry is to use an air drying device, which blows dried air into the boiler at a low over-pressure of 0.5 to 1 mm WC.
- The solution to use a blower to blow heated air through the boiler is suitable in boilers that cannot be properly sealed - especially in older furnace and fire-tube boilers, intended for under-pressure operation.

Use of VCI (Volatile or Vaporized Corrosion Inhibitors)

An alternative method to the ordinary long-term wet lay-up would be to apply so-called 3-phase inhibitors - VCI – which are chemical compounds with corrosion-inhibiting properties. The VCI will provide a 3-phase protection of the metal surfaces – i.e. :

- vapour phase
- water phase
- boundary water√vapour phase

by forming a protective film that inhibits the electrochemical reaction of water and air on the metal surfaces and simultaneously providing a repulsive shield against the water and oxygen molecules.

Therefore, the method may with great advantage be applied for wet and dry lay-ups alike.

With a view to making the right choise of inhibitors and lay-up methods, specialized companies should be consulted in matters relating to shut-downs of the boiler.

OPERATION JOURNAL

Daily Records (boiler parametres)

Boiler No.		Boiler manufacturer		
Boiler type		Max. rating	T/H	KW
Identification No.		Year of manufac.		

Month	
Year	

Date	Hour	Init.	Boiler rating / Burner load	Hours of operation	Operation pressure	Temp. after superheater	Feed water temperature	Fuel flow (oil / gas)	Fuel consumption	Flue gas temp. after boiler	Pressure after boiler	O_2 content	Flue gas temp. before super-heater	Flue gas temp. after ECO	Pressure after ECO	Ambient temperature
			t/h %	h	baro	℃	℃	m^3/h kg/h	m^3- kg	℃	mbar	%	℃	℃	mbar	℃
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OPERATION JOURNAL

Daily Records (Water Quality)

Boiler No.		Boiler manufacturer	
Boiler type		Max. boiler rating	t/h kW
Identification No.		Year of manufacture	

			FEED WATER										BOILER WATER			
Month			Feed water meter	Feed water temperature	Water sample temperature	General appearance, smell	Conductivity	PH-value	O_2 content	Total hardness (Ca + Mg)	Total iron content (Fe)	Total cobber content (Cu)	Conductivity	PH-value	Phosfate (PO_4)	Silicic acid
Year																
Date	Hour	Init.	m^3	°C	°C	-	µS/cm	-	%	mmol/l	mg/l	mg/l	µS/cm	-	mg/l	mg/l
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