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BOILER BOIL-OUT, BLOW-OUT AND CONSERVATION PROCEDURE

SIT WATER TREATMENT

Petr MUSIL | 14.10.2020

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1. INTRODUCTION

Purity of the pressure part surface of the boiler is of great importance to all boilers.

With increasing heat transfer, increasing steam pressures and the resulting higher steam saturation temperatures, the purity of the surface becomes more and more important.

Contamination at the pressure side of the boiler can result in damaged boiler tubing, or can result in carryover of loose particles into the steam system. These can then form deposits on the turbine blades or can cause damage to the superheater tubes.

Oil and grease from deposits on the boiler tubing surface form a barrier to heat transfer which may result in damage to these tubes due to local overheating. Especially with boiler functioning with natural circulation, which is the case with this type of tube banks.

Residues of oil may lead to foaming, which in its turn causes water to mix with the steam, resulting in unreliable water level readings and the formation of deposits in the superheater.

In order to remove oil, grease and rests of paint, the boiler is subject to a boil out to be carried out by a qualified commissioning engineer.

VYNCKE prefers an alkaline boil out procedure for chemical cleaning of the boiler. This procedure will be described below and shall consist of three stages:

1) Boiler flushing prior to hydrostatic test (post-erection boiler and pipelines rinsing).

2) Alkaline blow-out.

3) Blowing of the boiler and pipelines.

Other chemical cleaning methods could be followed, procedures for that are depending on the type of chemical cleaning.

2. BOILER FLUSHING AFTER ERECTION

In order to remove mechanical impurities (sand, loose scale, etc.), it is recommended to rinse all tubes of the steam - water cycle with water and downward flow.

If the downward flow cannot be obtained, we recommend to increase water velocity up to ca 1,5 m/s. In the first period of washing, the filtered raw water e.g. potable water can be used. The final washing stage shall be carried out with the use of the demineralized water (quality of the feed water). Rinsing can be considered satisfactory if water flowing out of the boiler does not contain distinct / visible impurities.

3. ALKALINE BOIL OUT

3.1. GENERAL

The alkaline boil out is a widely applied, common way of initial boiler cleaning. From a pure chemical point of view alkaline solutions are not capable of removing the most common iron oxides like hematite and magnetite as being present in new boilers. For this reason the appearance of the surface of a drum will show no significant change upon alkaline boil out.

The total effectiveness of the cleaning method is difficult to measure directly and is highly depending of a number of factors, not all in the hand of the commissioning engineer. The initial condition of the boiler with respect to the amounts of rust and/or mill scale present cannot be influenced. In addition large amounts of foreign material like sand or metal parts from mechanical activities (welding, drilling) are not removed with alkaline boil out and have to be removed from the system in a different way.

For an optimal result the commissioning engineer has to control the following three process parameters:

1. The alkaline condition during boil out (pH preferably > 10) serves two objectives: the removal of the organic fats and oils, and protection of the boiler inside wall for acid corrosion. It has to be considered that a boil out often is carried out using non-deaerated water in combination with air pockets in the system. In general, an unwanted situation with respect to corrosion which destructive effect will be amplified in neutral or acidic conditions.

2. The effectiveness of an alkaline boil out is strongly dependent on temperature. It can be assumed the boil out will have little to no effect if the temperature remains below 85 °C. An increased affectivity can be obtained by increasing the temperature. In practice the temperature has to be chosen at approx. 135 °C. Lower temperatures will require longer boil out times.

3. Time is the third process parameter influencing the quality of this cleaning technique. The solving of the organic deposits from the boiler is a time dependent process and therefore more complete with longer process time.

A boil out has to be performed one or two times during an uninterrupted period of 8 hours at the stated alkalinity and temperature (pH: 10, T: 100 - 135 °C min.).

The applied chemicals are responsible for two main effects: keep the pH at the desired value and provide a chemical condition in which the organic components will be and remain solved. The presence of Sodium Phosphate and Nitrate will minimize the existence of 'free' caustic, which is responsible for caustic embrittlement, a type of corrosion.

Due to liquid turbulence and the possible application of changing temperatures a certain part of loose or semi loose rust and mill scale will be removed from tube and drum walls. This material will be collected in areas with the lowest liquid velocities (drums, headers). These parts shall be carefully cleaned and flushed after boil out.

3.2. RESOURCES AND EQUIPMENT

The following manpower shall participate:

- Qualified commissioning engineer (1),
- Field boiler operator (1),
- DCS boiler operator (1),
- Fitters (2).

The following (temporary) equipment and/or systems shall be available:

- Temporary equipment as used for the steam flushing procedure for new boilers
- Spare manhole gaskets
- Pressure measurements drum and steam header (DCS)
- pH measuring after flushing
- Chemicals
- Cover sheeting
- Water for remedial washing and cleaning
- Safety clothes, signs and equipment
- Feed water system
- Drain system or disposal trucks
- Heat source: burner or GT/by-pass system
- Control and safeguarding system
- All other tools and equipment as required by the commissioning engineer

3.3. PREPARATION

Before supplying water and heat to the boiler the following conditions (but not limited to) have to be fulfilled.

3.3.1. In general

- The boiler must be completely inspected; both the pressure part as well as the flue gas part, and all foreign items should be removed. Then the blind flanges, manholes and other openings at the flue gas part of the boiler must be closed. Fit gaskets.

- All the equipment to be used, including water and chemicals etc., should be checked and ready for use.
- The responsible operators have read and understood the procedures for filling, boil out etc. They are familiar with the operation of the installation. One day for instruction, checking the equipment and preparing the installation must be accounted for.
- All valves and cocks are tested for smooth operation and they are appropriately set.
- All, for this part of the starting-up procedure required, controls, safeties etc. are tested and approved for. Of great importance here are all the monitoring instruments in the control room and at the boiler.
- All relevant procedures are complete and present at the installation site.
- All legal and operational requirements are fulfilled and the necessary permits are present. In written form is laid down who is responsible for this aspect.
- All of the above mentioned conditions apply to the complete installation, thus for the boiler, burner, equipment to be operated by a third party etc.
- Boiler operation shall be manually.

3.3.2. Safety

- Barrier off area around and under steam drum.
- Only personnel involved in this operation is allowed in the immediate boiler area.
- Confirm that a sufficient flow of water is available for remedial washing and cleaning.
- Grating of drum platform at location of filling point to be covered with sheeting to prevent spilling to the lower area.
- Chemicals to be carried up to the steam drum in containers of max. 25 litres.

3.4. CHEMICAL INTRODUCTION ACTIVITIES

- Personal protective equipment to be worn. (goggles and plastic/rubber gloves as described in the product information.
- Chemicals to be poured into the drum carefully, to make sure that no chemicals will be spilled.
- After completion of filling the drum, manholes should be closed.
- Empty chemical drums should be dealt with as described in supplier's instruction.
- Sheeting on grating should be removed and cleaned by water flushing.
- Barriers to be removed.

3.5. CHEMICALS

For the alkaline boil-out the following chemicals shall be applied:

-	NaOH (Sodium Hydroxide)	2.0	kg/ m^3
-	Na_2NO_3 (Sodium Nitrate)	1.5	kg/ m^3
-	Na_3PO_4 (Sodium Phosphate)	1.0	kg/ m^3

Chemicals will be added into the drum one by one at a low temperature (maximum 50 °C) through the manhole. **Chemicals must be already prepared and present in form of liquid solution.**

The total amount to be added of each chemical has to be calculated from above table and is only depending of boiler part volumes:

Alternative compositions can be considered based on supplier's recommendations and procedures but will always be subject to approval of VYNCKE process department.

3.6. PROCEDURE

- Fill the boiler with warm or cold water up to about 100 mm below the level of the opened manhole in the drum. The temperature of the water should not exceed about 50 °C, because at higher temperatures the evaporation of the hot water will hinder the operator to add the chemicals. If the water has not yet reached this temperature, the temperature should be raised by extra heat input (gas turbine or burner).
- Add the required chemicals in the steam drums and close the manholes.
- Fill the steam drums with water until the boil out start-up level.
- Start the heat input, as per start-up procedure, and raise the pressure of the boiler slowly to the boil out pressure level.

3.6.1. Caution

The pH of the boiler water is very high, so be careful with opening the start-up/vent valve.

- At boil out pressure level the heat input shall be stopped (burner or diverter) or minimised (GT). To prevent condensation in the superheater the start-up valve shall be left slightly open.
- The drum level shall be maintained above the Low Alarm level. Boiler feed water shall be added as required.
- When the pressure drops to the boil out relief pressure level the heat input shall be introduced again to raise the pressure till the boil out pressure level. Repeat these steps for approximately 8 hours.

- After 8 hours the heat input can be stopped completely (if not already stopped) and the boiler should be drained completely as fast as possible. For an optimal effect it is preferable that the plant drain system shall be used and the disposals shall be mixed with wastewater. In case trucks will be used a cool down period will be required.
- After draining the boiler should be filled again with boiler feed water. The superheaters and boiler have to be flushed.
- The flushing of the boiler parts is complete when the pH of the drained water is equal to the pH of the boiler feed water.

3.6.2. Economiser and superheater

During the boil out procedure, economiser and superheater should be dealt with in the same way as during the start-up period. Therefore the procedure and precautions for the operation of the air cocks, drains, feed water valves etc., as called for in the start-up instruction or requirements, should be applied for during boil out.

3.6.3. Deaerator (integrated)

In case an integrated deaerator is installed the steam drums shall be filled and isolated from the feed water system to protect the boiler feed water pumps.

3.6.4. Post boil out activities

- When the boiler has cooled down, open all manholes and blind flanges of the bottom headers. Check the drum and the headers for possibly present rests of mud. If the boiler is not completely free of grease and oil, decide to boil out the boiler again.
- Flush the drum entirely clean with a fire hose. Let the water and possible loose parts flow through the drains / intermittent blow down connections. The quality of the flushing water used must be the same as or better then the feed water quality, see Requirements for water treatment and quality.
- Flush all bottom headers. Sludge and dirt that cannot be removed with flushing, should be dealt with by a scraper (a stick with a half-moon like blade connected at its end). If the building-out length next to the headers is not sufficient, then use scrapers, which can be disassembled, in two or more parts.
- Mount all flanges and manholes using new gaskets. Make sure that thread of bolts and nuts are supplied with a heat resistant anti sticking paste.
- After final inspection the boiler can be boxed up again and is ready for blowing-through of the superheater.

4. BLOWING OF THE BOILER AND PIPELINES

Blowing of the boiler shall be performed no later than 15 days after completion of chemical cleaning of the boiler pressure part. In case of any casual prolongation of this term, it is necessary to provide appropriate preservation of the boiler pressure part.

Blowing is a difficult and hazardous operation as dynamic and thermal impacts are forced in order to obtain adequate efficiency of the blowing. It shall be carried out under strict supervision of the equipment supplier and in full compliance with the suppliers` instructions.

This operation shall be performed in the boiler to be started for the first time, i.e. all measuring circuits, control systems, safety devices and interlocks have not been checked so far at high heat output boiler operation. Therefore servicing personnel with high qualifications shall be employed for the operation of equipment during the blowing process.

Blowing efficiency depends on:

- generation of steam with energy sufficient to remove mechanical impurities from the system
- generation of thermal stresses (within permissible limits) on tube internal surfaces, which facilitate tearing off impurities
- generation of thermal conditions facilitating the formation of permanent magnetic protective coat

In order to meet the above mentioned conditions, the following parameters shall be adequately selected:

- pressure in the boiler
- superheated steam temperature
- boiler capacity
- blowing cycle (duration and interval between successive blowings)

Detailed guidelines concerning the process of blowing will be worked up by the supplier of the complex blowing process.

General instructions resulting from boiler design and construction are indicated below.

Depending on local conditions there are two blowing methods possible:

- continuous method
- impact method

It is recommended to apply the continuous method if allowed by the auxiliary system of the boiler.

Flow measuring orifice on steam pipeline must be disassembled. Main steam gate valve shall be disassembled or prepared for the blowing process according to valve instruction.

4.1. CONTINUOUS METHOD

For this method, the boiler parameters required to achieve adequate blowing results, are obtained through gradual increase of steam capacity and pressure, and when they are obtained - to hold these parameters for a definite period of time.
Preparation of the boiler for firing up, increasing boiler parameters shall be carried out in conformity with Boiler Operating and Maintenance Manual. After the blowing operation, expansion and cooling down of the boiler shall be carried out.

4.1.1. Time of single blowing operation

Proper blowing process shall last for max. 20-25 minutes. This time is counted from reaching full blowing parameters by the boiler. These parameters, i.e. boiler capacity, steam temperature and pressure in the boiler must be kept during the whole indicated blowing time.

4.1.2. Interval between successive blowings, number of blowing operations

The interval between successive blowings shall normally last from 12-24 hours. This is a time necessary for expansion and cooling down of the boiler and storing demineralized water for performing the next blowing cycle.

The number of blowing cycles depends on the quality of boiler and pipelines cleaning operations carried out before.

In order to obtain proper results, the performance of min. 5 to 10 or more blowing cycles shall be taken into account.

4.1.3. Pressure in the boiler

Prior to the commencement of principal blowing, the boiler shall be started in conformity with instructions, discharging steam to the atmosphere.

At the final stage of boiler preparation for blowing, individual boiler parameters can be raised with maximum permissible rate. On completion of blowing the boiler shall be shutdown according to instructions.

4.1.4. Steam temperature

Steam temperature at boiler outlet shall be within the limits of maximum 350-400 °C.

4.1.5. Boiler capacity

In practice proper blowing shall be usually carried out with the capacity equal to 50 ÷ 80 % of rated capacity.

Assumed boiler capacity must ensure heat release of the furnace lower than rated heat release (i.e. with appropriate selection of the feed water temperature, superheated steam temperature and steam pressure) to ensure cooling of superheated steam down to the required value.

4.1.6. Criteria

The criteria of selection of blowing parameters are following:

- coefficient of steam velocity increase in relation to nominal velocity "K_1",

$$K_1 \cong \frac{D_d}{D_{nom}} \bullet \frac{V_d}{V_{nom}} = 1{,}5 \div 2{,}5$$

where :

D_d - mass rate of flow during blowing [t/h]

V_d - steam specific volume during blowing [m^3/kg]

D_{nom} - mass rate of flow during nominal operating conditions [t/h]

V_{nom} - steam specific volume during nominal operating conditions [m^3/kg]

- interference (disturbance) coefficient (dynamic pressures ratio) "K_2"

$$K_2 = \frac{D_d^{\,2}}{D_{nom}^{\,2}} \bullet \frac{V_d}{V_{nom}} = 1{,}0\text{-}1{,}6$$

The above stated criteria K_1 and K_2 shall be met for individual steam superheater stages and steam pipelines with selected blowing parameters.

Basing on the preliminary evaluation, in order to meet the above mentioned criteria, the blowing parameters measured at the outlet steam piping should range as follows:

- blowing steam flow: 22 to 24 t/h
- blowing steam temperature: 350 to 400 °C
- blowing steam pressure: 18 to 20 bar(a)

Note:

The increase of above mentioned parameters should proceed simultaneously, i.e. the steam flow of 22 t/h should correspond to the blowing steam temperature of 350 °C and pressure of 18 bar(a) – the higher steam flow, the higher steam temperature and pressure.

4.2. IMPACT METHOD

If it is not possible to reach boiler parameters required for blowing using the continuous method, the impact method can be applied. At this method, boiler parameters (capacity) shall be raised as much as possible by means of the start-up burners, and then after extinguishing of the fire, the boiler shall be expanded rapidly by opening of the valve of the steam blow-out.

4.2.1. Time of a single blowing

The duration of the proper blowing process shall be limited to the initial period when boiler (pressure) expanding occurs.

4.2.2. Interval between successive blowings, number of blowing operations

See 4.1.2

4.2.3. Pressure in the boiler

Pressure in the boiler shall increase in conformity with guidelines stated in the Boiler Operating and Maintenance Manual. Pressure raising in the boiler shall be controlled by adequate opening of steam blow-out valve (and/or adequate heat release of start-up burners).

On reaching pressure in the drum of max 30 bar, the heat load of the boiler shall be released and the blow-out valve shall be completely opened.

As a consequence, the rapid boiler expansion will occur.

4.2.4. Steam temperature

Steam temperature during the whole process shall not exceed 350-400 °C.

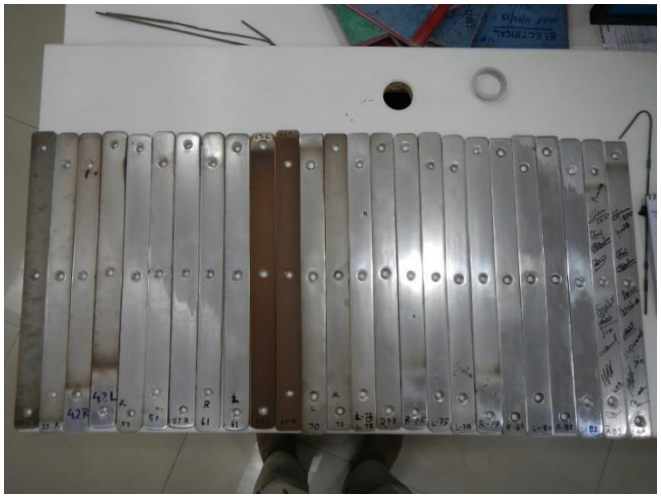
4.2.5. Criteria

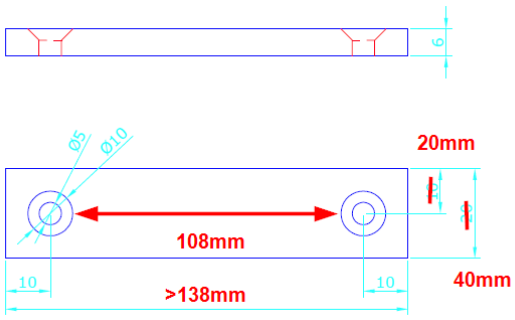
The criteria, i.e. the coefficient of steam velocity increase and interference coefficient are fulfilled as the result of rapid rise of steam quantity generated in the boiler and increasing its velocity because of boiler expansion.

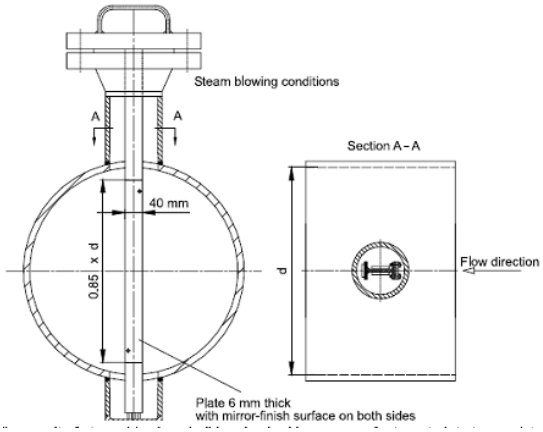
4.3. CHECKING OF BLOWING EFFECT

4.3.1. Checking of blowing effect – target plates

The quantity and size of solids entrained with steam shall be checked. This is recommended to be done by checking the number and size of dents on special copper plates intentionally inserted into the pipeline. These plates shall be placed before outlets from pipelines and are called target plates.







Target plate: KC054007 / V135218

As a criterion of proper blowing effect – there should be assumed an amount of dents.

Allowed amount and sizes of dents must follow the turbine supplier requirements.

4.3.2. Inspection of K_1 and K_2 coefficients

Steam parameters at outlet of individual surfaces of steam superheaters and on pipelines shall be recorded during every blowing and the flow through the boiler shall be determined from the balance or measurement in order to check K_1 and K_2 coefficients. These coefficients shall be no lower than indicated in paragraph 4.1.6

At final blowing, K_1 and K_2 coefficients cannot be lower than coefficients of former blowings.

4.4. CONDITIONS LIMITING THE BLOWING PROCESS

4.4.1. Boiler auxiliary equipment

All boiler auxiliaries taking part in the blowing process have to be subjected to individual tests and shall have efficient operating systems of controls, signalling, interlocks and safety devices.

4.4.2. Boiler auxiliary systems

All systems including boiler auxiliary systems taking part in the blowing process, for instance the furnace system, start-up oil burner system, slag and ash removal systems, combustion air system, air steam preheating system, steam temperature control system, drain and vent systems, boiler feeding system, auxiliary systems in the turbine hall necessary for boiler operation, have to be subjected to individual tests and shall have efficient operating systems of controls, signalling and safety devices.

4.4.3. Measurements

Practically, all measuring instruments installed on the boiler pressure part and in the combustion system shall be in operational efficiency before starting the blowing process.

4.4.4. Recording of measurement results

Prior to commencement of blowing, measuring instruments have to be started definitely to record at least the following parameters:

- feed water quantity
- feed water temperature
- pressure in the drum
- steam pressure behind the boiler
- feed water pressure
- water level in the drum
- steam temperature

- measurements necessary for combustion process control.

4.4.5. Interlocks and safety devices

Interlocks and safety devices associated with the project, for the boiler, furnace system and auxiliary equipment taking part in the blowing process have to be started prior to the commencement of the blowing process.

4.5. BLOWING PROCESS PROCEDURE

- Provisional pipeline system for blowing of the boiler and pipelines shall be inspected by an inspecting commission and released for operation in form of an official record.
- On completion of boiler chemical cleaning and prior to blowing the following elements have to be installed: flow measuring orifices (for measurement of feed water flow and steam flow – if it is permitted by the orifice supplier).
- Preparation of the boiler for starting shall be performed according to the boiler manual, taking into account additional activities resulting from preparation of provisional connections for blowing of pipelines.
- The rate of raising parameters, running the furnace, steam discharge from the boiler and other operational activities shall be in conformity with requirements of adequate instructions.
- Inspection of boiler elongations shall be performed at pressures in the drum 1 bar; 5 bar and at the blowing pressure.
- When raising pressure in the boiler pay attention to the fact that steam discharge from the boiler shall not be lower than indicated in boiler start-up diagrams for a given pressure.
- Steam pressure and temperature at boiler outlet shall be kept at constant level during blowing.
- Permissible steam temperatures behind individual stages of steam superheater cannot be exceeded during blowing - as indicated in the Boiler Operating and Maintenance Manual.
- After completion of the blowing process, the boiler shall be shutdown according to guidelines of the Boiler Operating and Maintenance Manual.
- Completion of the blowing process shall be confirmed in a report.
- Readings of basic parameters of individual blowing cycles shall be attached to the blowing report.

4.6. BOILER PREPARATION FOR NORMAL – CONTINUOUS OPERATION

- After shut-down of the boiler all provisional installations installed for the blowing operation shall be removed as well as devices which had been removed for blowing only, should be reinstalled to make the boiler complete and ready for operation.
- Before the boiler is started-up and put into continuous operation, remove all temporary positioning elements from boiler parts.
- Depending on the expected period between the blowing and next start-up of the boiler, the proper method of boiler preservation shall be adopted.

5. BOILER CONSERVATION PROCEDURE

5.1. STEAM BOILERS CORROSION DURING OUTAGE CONDITIONS

In case of a longer or shorter scheduled outage of the boiler island, there are some basic measures that should be taken into account for protecting the boiler against corrosion which is likely to occur during outage periods.

The principal corrosion-effecting factors are:

- humid air
- condensate
- water containing oxygen
- water containing chloride
- wet acidic deposits

Practically, the risk of corrosion may be avoided:

ON WATER SIDE:

- in dry air with relative humidity lower than 35 to 40% as well as in case of oxides deposits without salt contents
- with nitrogen without free O_2
- with oxygen-free, treated feed water, with pH value > 10

ON FLUE GAS SIDE:

- With very thin and dry deposits

Shutdown of the steam boiler shall be a reason to conservation. The choice of conservation method shall be made on the basis of selection criteria mentioned below.

Frequent or long-lasting outage periods may cause considerable damage, unless the boiler is adequately preserved using the appropriate conservation method. In case of the steam boiler unscheduled outage without this protection (e.g. urgent repair works), adequate measures should be taken to reduce the duration of this period as much as possible.

5.2. CONSERVATION METHOD SELECTION CRITERIA

The selection of boiler conservation method shall be based on outage conditions, thus the choice of this method depends on the following factors:

- whether or not the steam boiler could be held up under pressure
- whether or not atmospheric factors affect boiler during outage
- whether or not the boiler is considered as a standby unit
- whether it is to be connected to the power network at previously determined moment
- whether negative temperature conditions are likely to occur within the boiler area (thus excluding wet conservation methods – risk of water freezing)
- are the tubes fouled by considerable internal deposits (i.e. inside the tubes).

In case of considerable fouling by internal deposits, wet conservation methods shall be excluded as the effect of chemical reactions between internal deposits and metal surface is difficult to assess. If such a need arises, the circulation system shall be subjected to chemical cleaning.

The most important criteria applicable to the selection of conservation method are presented below:

- Estimated duration of outage
- Repairs to be carried out on pressure parts or flue gas pass
- Estimated time period needed to achieve start-up readiness
- Operating conditions:
    - feed water quality
    - feed water reserve (amount of stored water)
    - possibility of discharging / removal of conservation solutions before start-up
    - auxiliary systems readiness status: e.g. feed water pumps, filling system, water treatment station, chemical dosing station, hot air generators, etc.
- Internal deposits
- Deposits located on the flue gas side

5.3. CONSERVATION METHODS

5.3.1. Steam – water circuit

A. Dry conservation. Boiler open to the atmosphere

B. Dry conservation with overpressure

C. Dry conservation with dried air

D. Wet conservation at room temperature with overpressure in the boiler tubular system

5.3.2. Flue gas side

A. Maintaining of dry deposits by heating

B. Wet cleaning with drying

5.3.3. Mechanical and electrical equipment

A. Application of protective paint layers or anti-corrosion protective oil layers

B. Plastic foil wrapping combined with application of chemical desiccant media

C. Avoiding of dew point condensation, especially at control cabinets and hermetically enclosed switches using venting or heating

All these methods are described further in the following sections.

5.4. CONSERVATION APPLICATION

5.4.1. Steam – water circuit

A. Dry conservation – boiler open to the atmosphere

This method of conservation shall be avoided whenever possible. Generally, it is applied in case of urgent repairs or risk of freezing with no nitrogen available.

The whole system shall be completely dewatered – i.e. all heating surfaces and pipelines shall be drained out.

Since salt residues are hygroscopic and force corrosion, the boiler water shall be desalinated before evaporator draining to achieve the salt content in the water close to that one of the feeding water. It can also be achieved by means of complete evaporator blowdown, followed by filling of evaporator with demineralized water quality (feedwater) and further draining of the boiler, preferably after raising the pressure up to 2 bar.

Complete elimination of water (humidity) from tubes inside is practically impossible to achieve, even if the system is drained at residual pressure of 2 to 3 bar and water is evaporated due to the action of accumulated heat. Remaining water (humidity) shall be evaporated to the highest possible extent by means of introduction of supplementary heat to the boiler (hot air delivered through the furnace system).

The steam–water circuit shall be dried within maximum 48 hours.

The care shall be taken to drain fittings, impulse pipes for measurement devices, water gauges, pressure gauge connections, etc. since these devices are very essential in respect of their complete draining.

Variable ambient temperatures may cause a risk of dew point condensation especially in the areas without air flow. That is why all openings such as: drum manhole openings, vents, etc. shall be left open.

Additionally, the system may be dried using dry compressed air or dried air coming from the fan.

Reliable anticorrosive protection may be achieved with metal temperatures ranging from c.a. 5 to 15 °C above the ambient temperature. The heating may be carried out using one of the following methods:

- feeding of furnace chamber with hot air coming from steam air heaters (or other air heating devices)
- blowing of hot air into the steam / water system

Hot air blown into the system shall be heated up to obtain the final humidity value of c.a. 40% of relative humidity:

Required minimum heating values of air for various initial relative humidity values of air are presented below:

- at 50% of relative humidity c.a. 4 °C heating
- at 70% of relative humidity c.a. 10 °C heating
- at 90% of relative humidity c.a. 15 °C heating
- at 100% of relative humidity c.a. 17 °C heating

Using hot air for conservation purposes, one shall bear in mind that heating of air can only cause the reduction of relative and not absolute humidity. Hot air with low relative humidity can absorb considerable amounts of water but further cooling down in outside ducts or lower temperature elements may result in dew point condensation.

B. Dry conservation with overpressure

Dry conservation with overpressure is usually carried out using nitrogen (residual oxygen contents max. 0,01%).

After the boiler shut-down and cooling down to the level of feed water temperature, the whole boiler (including superheater) shall be filled with completely treated feed water, and then, if the salt content in the boiler water is less than 5 µS/cm – filled with nitrogen. Otherwise, complete water blowdown shall be carried out and after that, the boiler refilled with the feed water shall operate for c.a. half an hour at 5 bar pressure with evacuation of steam, in order to remove the air that entered the system. Then the whole boiler shall be filled with feed water.

Gaseous nitrogen source shall be connected at the highest point of the unit (i.e. drum vent), thus removal of water from the boiler will result in filling of the boiler with nitrogen. Nitrogen overpressure shall be maintained at a minimum level of 2 mbar (7 mbar, if possible) and continuously supervised.

Nitrogen consumption depends on tightness of shut-off fittings and it is difficult to foresee.

C. Dry conservation with dried air

Removal of remaining water and the conservation process of the boiler pressure part with the use of dried air is becoming more and more popular.

Air drying methods include:

- cooling and separation of water by condensation (refrigerator principle)
- compression of air up to a few bars followed by condensate separation
- regenerative chemical drying

Air dryness value shall be verified using hygrometer.

Drying of humid tubular systems with dry air is a long-lasting process. It is due to the remnants of water to be preliminary evaporated by, e.g. heat accumulated in the boiler or by means of the vacuum pump to be connected to the boiler.

During further conservation of the tubular system, a slight overpressure, i.e. 1 – 2 mbar, is sufficient.

The conservation with dry air is highly reliable in case of relative humidity of dried air not exceeding 35 – 40% at ambient temperature (including tubular system).

The advantage of this method comprises the possibility of interrupting the process at any moment, e.g. in order to carry out necessary repairs.

D. Wet conservation at ambient temperature with overpressure in boiler tubular system

Effective wet conservation can only be carried out while the boiler steam–water system is held up under overpressure.

Shortly before the boiler shut-down, the boiler water shall be subjected to desalination so as to achieve the conductivity less than 5 μS/cm.

If it is impossible to achieve this value, by means of intensive desalination (continuous blowdown), the boiler water shall be drained out of the boiler. Afterwards, the boiler shall be refilled up to the drum normal water level or completely (i.e. including superheater), depending on the chosen conservation method as described below.

a) Conservation with visible water level

If the conductivity below 5 μS/cm can be reached by means of desalination, the boiler shall be shutdown for outage.

If refilling of the boiler with water is necessary, then after reaching the normal water level in the drum, the boiler shall be heated up to obtain the pressure of c.a. 5 bar. The boiler shall be held up under this pressure for c.a. 30 minutes and then shutdown for outage.

Hermetically closed boiler shall be cooled down to achieve the pressure of c.a. 5 bar and gaseous nitrogen shall be introduced to the boiler pressure section (e.g. via drum connection or superheater outlet vent connection). Nitrogen pressure reducing valve shall be set to c.a. 1,4 bar.

Filling with nitrogen starts when boiler pressure drops below nitrogen pressure value.

Nitrogen piping diameter shall be so selected that duration of filling does not exceed one hour at gas flow velocity amounting to 50 m/s.

After complete cooling of the boiler, the condensate formed in superheater tubes and steam piping shall be removed.

Overpressure ranging from 2 to 10 mbar is sufficient for conservation purposes.

Alkalinity of the boiler water shall be maintained at the highest possible level, recommended for the boiler water. Alkalinity shall be verified on a regular basis. Generally, the supply of hydrazine is provided at the highest level, i.e. 300 mg/kg. Inadequate quality of the boiler water may be improved by its partial replacement.

b) Conservation with filled superheater

The boiler shall be completely – i.e. including superheaters - filled with water.

When the boiler is full of water (i.e. water flows out through all air vents), vent valves should be closed and then the source of gaseous nitrogen supply shall be connected to the highest point of the system, i.e. drum vent.

In order to compensate thermal swelling of water, an adequate gaseous space shall be provided. It can be achieved by removing a certain amount of water.

Nitrogen overpressure shall be held up and verified at minimum level of 2 mbar (10 mbar, if possible).

In some specific cases, gaseous nitrogen can be replaced with water under pressure, e.g. low pressure condensate or feed water coming from a deaerator.

5.5. FLUE GAS SIDE

Apart from ash, flue gases contain acid-forming combustion products. During boiler outage, highly hygroscopic sulphuric acid with initial concentration of c.a. 60 – 85% absorbs humidity from the air. Concentration of the acid decreases with the absorption of water. Sulphuric acid at 70% concentration does not attack steel so aggressively.

Sulphuric acid diluted below 70% considerably increases its corrosive properties.

Coarse ash deposits are dangerous because of their chemical composition (additional absorption of corrosive gases). That is why these deposits shall be removed before longer outage.

5.5.1. Drying of deposits by heating

If estimated outage period is short (e.g. several days) and deposits on heating surfaces are not large (e.g. boiler outage occurs shortly after mechanical cleaning of heating surfaces), it is recommended to heat the boiler with air of the temperature of c.a. 60 °C above the ambient temperature.

In case of extremely short outage periods, the air temperature can be lower but it is always recommended to hold up the air temperature at a level of 20 °C above the ambient temperature.

5.5.2. Washing and drying of heating surfaces on flue gas side

Cleaning of the flue gas side is carried out in order to remove both types of deposits from heating surfaces – i.e. ones which are water-soluble and others which can be removed preliminary only by means of chemical treatment. Application of this method requires the implementation of adequate installation or ordering this specific work at the professional company. Penetration of water (washing solution) into fissures of the brickwork or lining material and subsequent soaking shall be avoided. Critical areas can be easily protected by covering them with plastic foil, fissures can be sealed with the use of adhesive and sealing materials that remain flexible after drying.

During the initial cleaning with high pressure water or hot water, the care shall be taken so as to avoid the penetration of dust or steam to other plant sectors, due to the chimney draught.

Heating surfaces which are cleaned only with the raw water, are exposed to stronger corrosion. This risk can be reduced by using alkaline water for cleaning; the pH value should not exceed 12. Heated water has better washing properties than the cold one but it affects acidic corrosion.

That is why the duration of acidic washing phase at pH values of sewage water lower than 4 shall be possibly short and not exceed 5 hours.

The purposes of wet cleaning and conservation are found to be fulfilled when the sewage water pH value is between neutral and equal to the fresh washing solution pH value. Indicator paper verification is sufficient.

The equipment shall be dried directly after wet cleaning. It can be done using hot air blown into the furnace chamber. Usage of flue gas for this operation is prohibited.

Washed and dried heating surfaces with pH value between neutral and alkaline can be subjected to conservation with venting (shorter periods) or slight heating with air (longer periods).

Insert desiccant silica gel to extract the humidity from the air. The point of conservation is to avoid corrosion caused by humidity in air, so extracting the water is the primary goal. It requires a closed boiler with all doors and openings closed. Check periodically for the amount of remaining silica gel and refill if necessary. Change of color of the silica gel from blue to red will indicate a leakage → action needed (check for openings, close the doors…).

5.6. MECHANICAL AND ELECTRICAL EQUIPMENT

Boiler auxiliary elements as well as other auxiliary systems such as: mechanical equipment, furnace installation, drives, control equipment, etc. shall be subjected to conservation in accordance with their instruction manuals. Following considerations shall be taken into account:

- all outside elements shall be carefully cleaned and protected with protective paint layer
- all "naked" elements such as: shafts, bearings and others shall be cleaned; in case of longer break periods, the layer of anti-corrosion oil shall be applied
- particularly vulnerable elements shall be dismantled and individually protected against corrosion by e.g. wrapping with plastic foil (generally with hygroscopic chemicals)
- insulation of motors and cables can be affected by excessive moisture during outage, thus losing its protective properties; insulation shall be verified and dried by heating (if needed) before start-up

6. WATER QUALITY FOR FLUSHING, BOIL-OUT AND CONSERVATION

6.1. FLUSHING

Water with quality described in the table below shall be used. Deaeration is not necessary.

Austenitic and high-alloy ferritic components shall only be treated with de-ionised water.

		Plants exclusively made of low-alloy ferrites	Plants made of austenites/high-alloy ferrites
Conductivity difference	µS/cm	< 20 (1)	< 2
Chlorides (Cl-)	mg/l	-	< 0,2
Iron (total Fe)	mg/l	-	< 0,5
Solids	mg/l	< 5	< 1
pH value @ 25°C		6,5 – 9,5	-
• Where the inlet conductivity exceeds 400 µS/cm, the maximum conductivity difference shall be + 5%.			

6.2. ALKALINE BOIL-OUT

The water used shall be treated (at least softened tap water) and deaerated feedwater. Where demineralized water is used, the sole use of sodium hydroxide (caustic soda solution) should be avoided due to the risk of sodium hydroxide accumulation in the crevices which may lead to stress-corrosion cracking. As experience has shown, the water demand will be 4 to 5 times the water volume referred to normal water level.

6.3. CONSERVATION

Same quality as for the alkaline boil-out.