WATER CHEMICAL REGIME OF STEAM GENERATORS OF NPP

DEFINITION OF WATER CHEMICAL REGIME (WCR)

Water chemical regime of NPP SG is the set of requirements to the content of different compounds in working fluid and coolant to ensure safe and reliable operation of steam generator. Usually, it concerns the concentrations of different components in water of the first and second circuits.

The incorrect water chemical regime could result into:

- **Extensive scaling of heat exchange surfaces;**
- **Intense silt formation in feed water and coolant pipelines;**
- **Intense corrosion of materials;**
- **Formation of residues damaging turbine and main circulation pump.**

Regulated parameters are acidity/alcalinity and general hardness as well as content of individual substances in water. The most common and important impurities are sodium, iron, copper, chlorines and oxygen.

The majority of recommendations for WCR are based on the practical experience of NPP operation.

PURPOSE OF WCR

The following tasks of WCR could be formulated:

- **Preventing intense erosion and corrosion wear of the elements of the second circuit;**
- **Decreasing of the scaling formation on the tube system;**
- **Decreasing of the number of the chemical cleansing;**
- **Decreasing in liquid water number.**

Earlier the WCR of the second circuit was complexed by using different materials – stainless steels for SG and turbine, carbonaseous steels – for pipelines and heaters, brass and copper – for condensers. Now all these materials were excluded except stainless alloys making WCR realization easier.

The main sources of impurities into the feed water are:

- **Additional water;**
- **Leakages of air and cooling water into condenser;**
- **Corrosion products removal.**

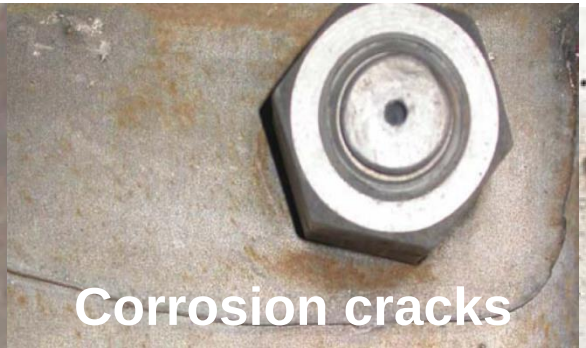
TYPES OF CORROSION

The two major types of corrosion could be distinguished:

- **General – is evenly distributed and unavoidable. Should be limited to ensure required duration of operation;**
- **Local – the corrosion localized in space. Could be pit-type, stress-type, gap-type. Strongly dependent on features of heat exchange and hydrodynamics of the flow.**

The low velocities (< 0,5 m/s) of the flow promotes pit corrosion due to formation of gas bubbles. The high velocities (>10 m/s) promote destruction of protective oxide layer and removal of corrosion products thus enhancing corrosion.

The first 200-1000 hour of SG operation connected to protective oxide layer formation thus corrosion rate during this time is higher.



REGULARITIES OF CORROSION IN SG

The fundamental studies on corrosion development for stainless alloys are following regularities of electrochemistry. General regularities are following:

1. **The removal rate of corrosion products from fatigue is dominant factor for its growth.**
2. **The decreasing of water pH value increases fatigue growth rate.**
3. **Increasing quality of water decreases growth rate of fatigue.**
4. **The presence of both chlorides and oxidizer in water results into surge in fatigue growth.**
5. **Both chlorine ions and anions are able to cause corrosion.**

The following activity row was formed:

$$SO_4 \approx Cl >> NO_3 >> CO_2 >> CO_3$$

The approximate equation for time of safe operation is following:

$$\log \tau = \log \tau_0 - 1{,}5 * \log C_{Cl} - 0{,}5 * \log C_{O2}$$

If the predicted time of reliable operation is shorted than design time then the concentrations of impurities should be decreased.

REQUIREMENTS FOR NPP WATER

Parameter	Feed water		Blowdown water	
	Old	New	Old	New
pH*	9±0,2	9,5±0,1	8,8±0,3	9,3±0,2
Specific electric conductivity of H+ sample, μS/cm	0,3	0,15	5,0	1,5
Fe, μg/kg	15	10	-	-
Cu**, μg/kg	3	1	-	-
Cl, μg/kg	-	-	100	50
Na, μg/kg	-	-	300	100
SO_x, μg/kg	-	-	200	50
O_2***, μg/kg	10	10	-	-
N_2H_6O, μg/kg	>40	>20	-	-
Organic, μg/kg	100	200	-	-

*** The high pH promotes general corrosion, but limits local corrosion. The high pH is recommended for feed water.**

**** After last heater.**

***** After deaerator.**

MEANS OF WCR REALIZATION

The WCR realization is complex task connected to many features of power unit operation: tightness of condenser, means of water treatment, parameters of deaeration, chemical cleansing, blowdown and frequency of periodical washing.

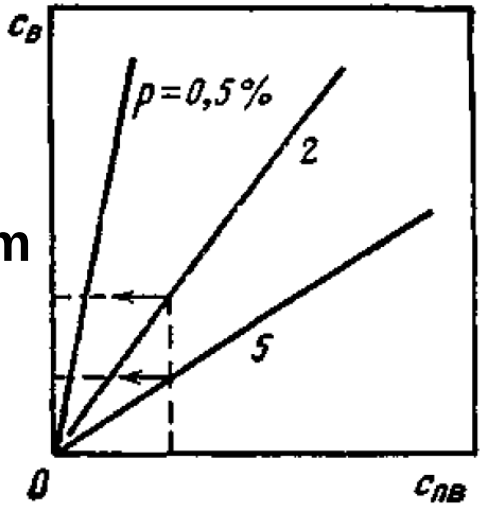
There are blowdown of two types: continuous and periodic.

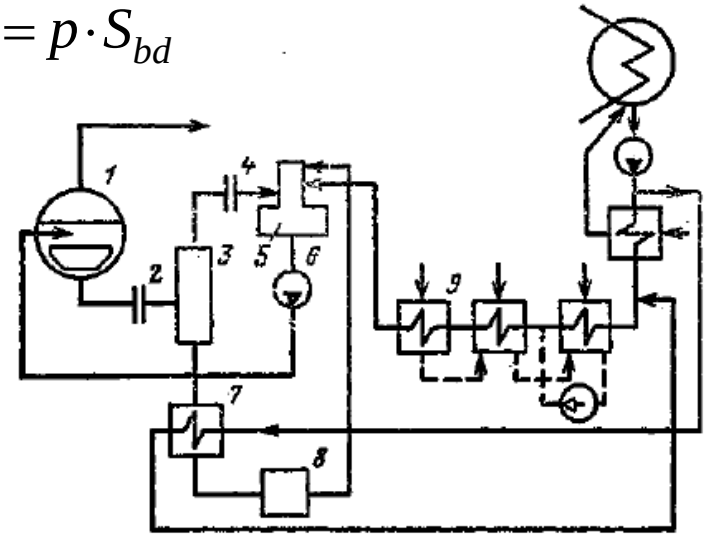
The continuous blowdown – removal of contaminated feed water from so-called salt-sections of SG. It's calculated according to following equation:

$$q \cdot S_{cool} + \alpha_{add} \cdot S_{add} + (1+\alpha_{ss}) \cdot S_{st} + p \cdot S_{bd.cl} = (1+\alpha_{nn}) \cdot S_{st} + \alpha_{add} \cdot S_{st} + p \cdot S_{bd}$$

$$q \cdot S_{cool} + \alpha_{add} \cdot S_{add} + p \cdot S_{bd.cl} = p \cdot S_{bd}$$

The periodic blowdown is needed for removal of solid impurities.
It is realized from bottom parts of SG.





MEANS OF WCR REALIZATION

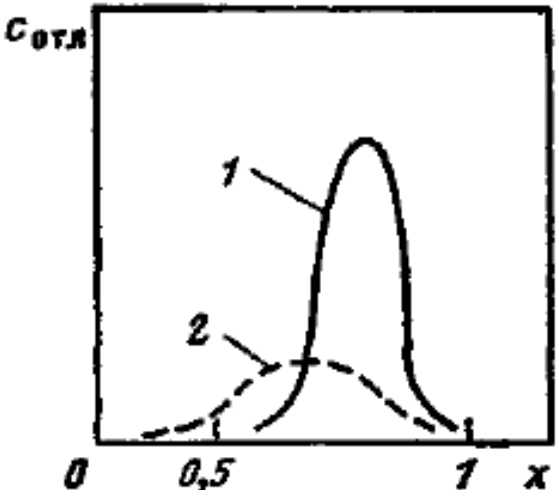
For once-through SG the blowdown realization is impossible. For such steam generators the WCR is realized by means of periodical removal of scaling formed:

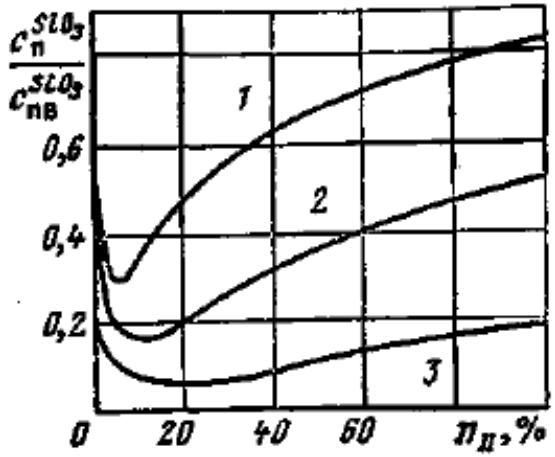
$$\tau = \left(\Omega_{sc}\right)_{perm} / \left(3{,}6 \cdot 10^{-3} \cdot D \cdot \Delta S_{fw}\right)$$

$$\left(1 - q - \alpha_{add}\right) \cdot S_k + q \cdot S_{cool} + \alpha_{add} \cdot S_{add} = S_{fw}$$

$$\Delta S_{fw} = S_{fw} - S_{st}$$

$$\Omega_{sc} = \delta_{add} \cdot F \cdot \rho$$





The allowed thickness of scaling is determined from conditions of reaching permissible temperature of tube material.

If the cleansing period will be too short (less than 1 year), the required quality of feed water could be obtained by presented earlier equation.

WATER CLEANSING REGIME

The following solutions are possible for water cleansing:

1. **Water-sodium cationization;**
2. **Salt removal without silica removal;**
3. **Salt removal with silica removal;**
4. **Evaporating cleansing.**

Corrective water treatment by hydrazine (to suppress oxygen) and ammonia (to suppress carbon dioxide).

$$N_2H_4 + O_2 \rightarrow N_2 + 2H_2O; \qquad NH_4OH + CO_2 \rightleftharpoons NH_4HCO_3;$$
$$N_2H_4 \cdot H_2SO_4 + O_2 + NaOH \rightarrow N_2 + 4H_2O + Na_2SO_4. \qquad NH_4HCO_3 + NH_4OH \rightleftharpoons (NH_4)_2CO_3 + H_2O.$$

dd[illegible] $Ca_{10}(PO_4)_6OH_2$ in form of non-adhesive slag.

Another solution is using $C_{10}H_{14}N_2Na_2O_8$ (trilon B) as additive to salt-free water in order to prevent iron oxides deposition on the heat exchange surface of high pressure SG.

However, the realization of WCR without correcting additives is possible if the feed water has low hardness.

All modern NPP utilize hydrazine treatment combined with condensate cleansing.

THANKS FOR ATTENTION!