Individual task #1
Steam Generators of Nuclear Power Plant

Topic 1. Heat balances and tQ - diagrams for NPP steam generators

Variants 1-13

Problem specification

Water-cooled saturated steam generator (SG) with natural circulation of the working fluid in evaporator (E).

Can have an economizer zone (EZ) (optional). The working fluid flows over the steam generator tubes on the outside; the coolant moves inside the tubes. The motion pattern of the coolant and the working fluid is a counter-flow.

The task is to:

- make an equation for the heat balance of the steam generator (find the thermal power $Q_{пг}$)
- calculate the total coolant flow G;
- draw a tQ – diagram;
- determine the coolant temperatures at the boundaries of the SG's characteristic elements;
- determine the minimum temperature difference in the evaporator $\Delta t_u^{мин}$;
- calculate the mean temperatures of the coolant, working fluid and the mean temperature differences in all the characteristic elements of the steam generator.

Notes:

- initial data are given in Table 1 (initial data for Task 1);
- pressure drops in the steam generator's elements are to be neglected;
- coolant temperatures at the boundaries of the SG characteristic elements are to be found through the equations of the respective heat balances;
- tQ – diagram is to be built to scale.

Table 1. Initial data for Task 1.

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Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13
SG type	saturated steam, natural circulation												
Coolant type	water	water	water	water	water	water	water	water	water	water	water	water	water
D_2, kg/s	300	200	275	175	180	220	225	200	400	240	190	205	230
p_1, MPa	15.5	16	17	15	12.3	11	15.7	11	15.7	15.5	12.3	11	16,5
t_1' , °C	320	330	335	320	300	292	322	300	330	325	305	300	320
t_1'', °C	289	295	290	280	269	260	295	270	295	288	269	270	270
p_2 , MPa	6.27	7	7	5.6	4.7	4.1	7.0	4.7	6.5	6.27	4.7	6.0	6
t_2'', °C	*ts*												
$t_{пв}$, °C	210	225	215	200	217	210	185	190	220	195	200	217	230
$\alpha_{пр}$, %	0.5	0.3	0.5	0.5	0.3	0.4	0.5	0.5	0.5	0.5	0.3	0.4	0,8
Cycle design	evaporator + economizer												

Questions to Task 1:

1. What specific zones is the heat exchange surface of a steam generator divided into?
2. Give a definition of *Economizer*.
3. Give a definition of *Evaporator*.
4. Give a definition of *Superheater*.
5. Give a definition of *Intermediate superheater*.
6. What element of the heat transfer surface is a compulsory part of the NPP steam generator?
7. How can you explain the necessity to maintain high pressure of the coolant in VVER reactors (PWR type)?
8. How can you explain the relatively low temperature of the working fluid's parameters in pressurized water steam generators?
9. How can you explain the low pressure of a liquid metal coolant in fast breeder reactors?
10. Is pressure of molten metal coolant lower than atmospheric? Why?
11. Why a high flow rate of a coolant is needed in NPP steam generators with pressurized water reactors (PWR, VVER)?
12. How is the thermal pattern with an economizer zone is practically realized in steam generators with saturated steam?
13. Give a definition to the term *Circulation water temperature*.
14. Give your explanation of how the setting of the minimum temperature difference in evaporator $\Delta t_{И}^{мин}$ affects the parameters of NPP in general?
15. What problems could be caused by low $\Delta t_{И}^{мин}$ value?
16. What problems could be caused by high $\Delta t_{И}^{мин}$ value?
17. How can you explain a big difference between the inlet and outlet temperatures of a liquid metal coolant in the steam generator of a NPP unit with a fast breeder reactor?
18. Why is the rising motion pattern of the working fluid in evaporator typically chosen for steam generators with liquid metal coolants?