THE NEW SOLUTION OF THE AER6 BENCHMARK PROBLEM WITH ATHLET/BIPR8KN CODE PACKAGE

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ABSTRACT

The new solution of the sixth three - dimensional hexagonal dynamic AER benchmark problem obtained by the code package **ATHLET/BIPR8KN** is presented. The main differences from the previous one consist in applying the new model of the steam generator. A report contains the descriptions of the plant model, have been chosen for the solution of the benchmark problem. Models and approximations in use at the problem solution are given.

INTRODUCTION

The sixth three-dimensional hexagonal dynamic AER benchmark problems continues a series of the international benchmark problems defined during 1992-2000 in the frame of the international VVER cooperation forum AER. Some points, has not been considered in the previous benchmark problem are taken into accounts in current one. Some actuation of several safety related system are taken into consideration in this benchmark. There is not common neutron physical data and each participants of the benchmark problem use their own best-estimated neutron data. The fixed isothermal re-criticality temperature for nuclear data normalising is given. The response of the reactor core on the perturbation coming from the secondary side of the plant is investigated.

The initial event of the sixth AER benchmark is a double-ended break of the one main steam line. The break occurs in the end of cycle and full power conditions. Two of the most effective control rods are considered stuck in the upper position by the conservatism conditions. Coolant mixing in the lower and upper plenum is modelled. The full definition of the benchmark problem is presented in [1].

The new solution of the sixth tree- dimensional hexagonal dynamic AER benchmark problem obtained by code package ATHLET/BIPR8KN is presented. The main differences from the previous one consist in applying the new model of the steam generator. The description of the plant model, have been chosen for the solution of the benchmark problem, models and approximations in use at the problem solution are given

THE PLANT MODEL DESCRIPTION USED IN CALCULATION

Core model description

Due to the break asymmetric the full core configuration is to use. The used core map is shown on Figure 1. Hydraulically, the core modelled by 6 parallel channels (PIPE type object). The fuel assembly was modelled by 126 fuel rods, which were described as ROD type object divided in axial direction into 10 mesh points and in radial direction into 4 mesh points. Allocation of the fuel assemblies to the core sectors and thermal-hydraulic channels is presented on Figure 2.

For the preparation of the neutron physical data the code package KASSETA was used. The burn up calculation was fulfilled by BIPR8 code.

To receive the requested in the benchmark definition isothermal re-criticality temperature the turning of the cross sections of the absorption material were made. The adjustments were fulfilled by the multiplication of cross-sections of the absorption material on some correction factor. The results of the adjustments are shown in Table 1.

Table 1

Adjustment results

Parameter	State	
	Unadjusted	Adjusted
Keff, at zero power state, inlet temperature into the core 210 °C, all control rods except the two stuck are in lower position	0.97742	1.00023
Scram worth, ppm	6612	4155
Isothermal temperature coefficient at 210 °C, all control rods except the two stuck are in lower position, pcm/K	-	- 41.3

Primary and secondary side model

The input data for the modelling of the primary and secondary side of the reactor were based on the standard input set for the ATHLET programs for the VVER 440/213 project.

According to the benchmark definition the next objects were modelled in the plant scheme (Figure 3, 4):

- Reactor pressure vessel;
- Cold leg;
- Hot leg;

- Steam generator;
- Main steam line;
- Main steam header;
- Pressurizer system;
- Volume control system;
- High pressure injection system;
- Feed water system;

The primary circuit of the plant consists of the six separate loops. The principal scheme of the primary loop is shown on Figure 3. The reactor pressure vessel is divided into six parallel channels without any inter connections between channels. The exception is the down camera and upper plenum, where the mixing between channels is applied (Figure 5). The double FILL in the down camera and upper plenum branches models the turbulent mixing. The mixing occurs with the equal volumetric exchange between the neighbouring channels. Percent rate is according to the benchmark definition [1].

The secondary circuit of the reactor also consists of the six separate loops connected through the two main steam header. The principal scheme of the secondary circuit is shown on the Figure 4. Figure 6 shows the nodalization of the steam generator. The new model of the steam generator consist in:

- Down camera part;
- Lower camera;
- Heating up part;
- Separator with two connections. The first connection is to the down camera. The second to the steam space;
- Steam part;

This scheme of the steam generator allows imitating the internal coolant circulation and separation process. Two levels measure system of the steam generator is realised in this scheme. The first level is low range. It has the 600 mm base; the lower point of measurement is approximately 1.96 m from steam generator bottom. The operation of the steam generator level control system is based on the reading of this level. The second one is a high range level. It has the base by the all height of the steam generator. Feed water is described as a separate supply into each steam generator.

Break is realised as a double-ended break in the middle part of the main steam line 1. The mass flow rate through the break is determined on the base of the built in ATHLET one-dimensional critical discharge flow model.

All specified in the definition of the problem control signals have been modelled with the help of GCSM blocks.

RESULTS

The accident is initiated at 0 seconds, when the double ended break of the main steam line 1 is occurred. The change of the steam generator model has sufficient influence on the results (Figure 7, Figure 8). It causes the shift of the first power peak and larger secondary power return. This phenomenon can be explained by the behaviour of the steam generator power (Figure 10, Figure 11), steam generator level (Figure 12) and coolant temperature at the sector inlet (Figure 9).

CONCLUSION

❑ The change of the steam generator model has sufficient influence on the results. Main reason is the change of the heat exchange rate in the steam generator due to the internal circulation of the coolant and separation effect.

REFERENCES

1. S. Kliem, A. Seidel, U. Grundman „Definition of the sixth AER benchmark – main steam line break in NPP with VVER-440"

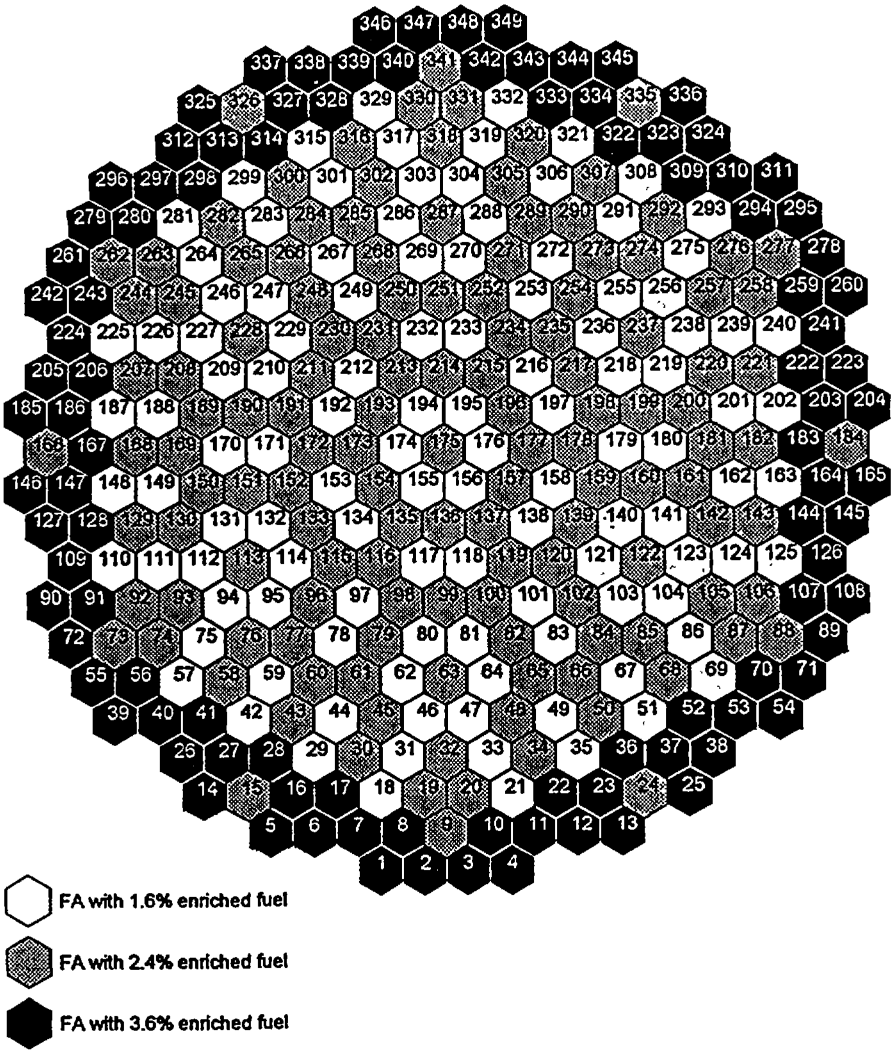


Figure 1. Core map

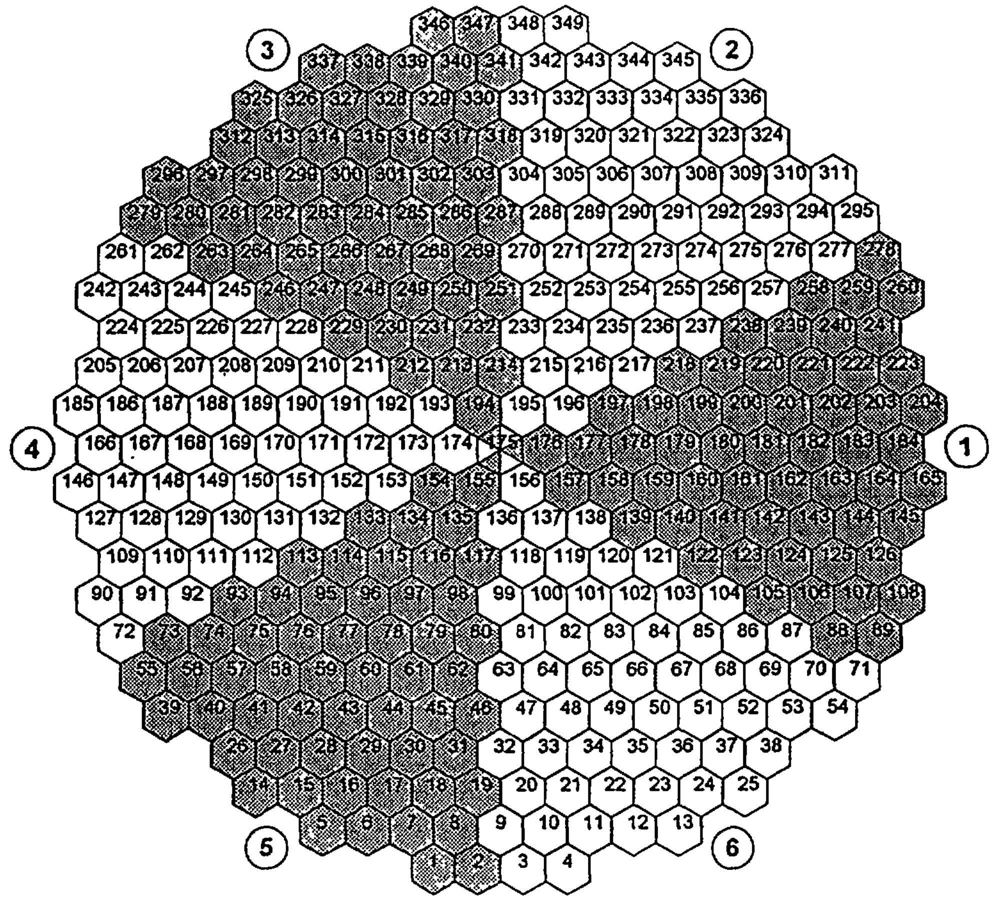
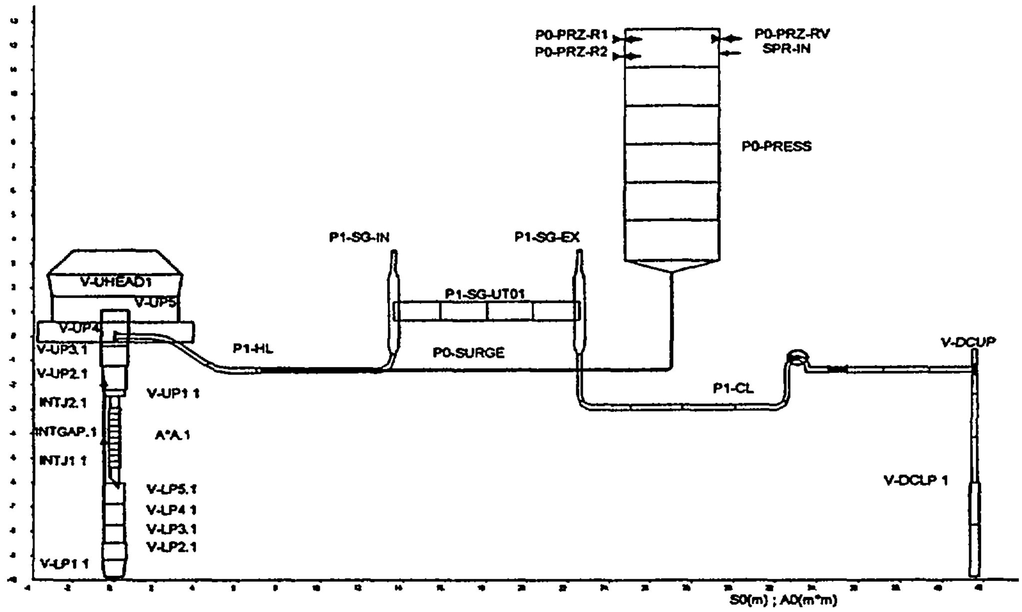
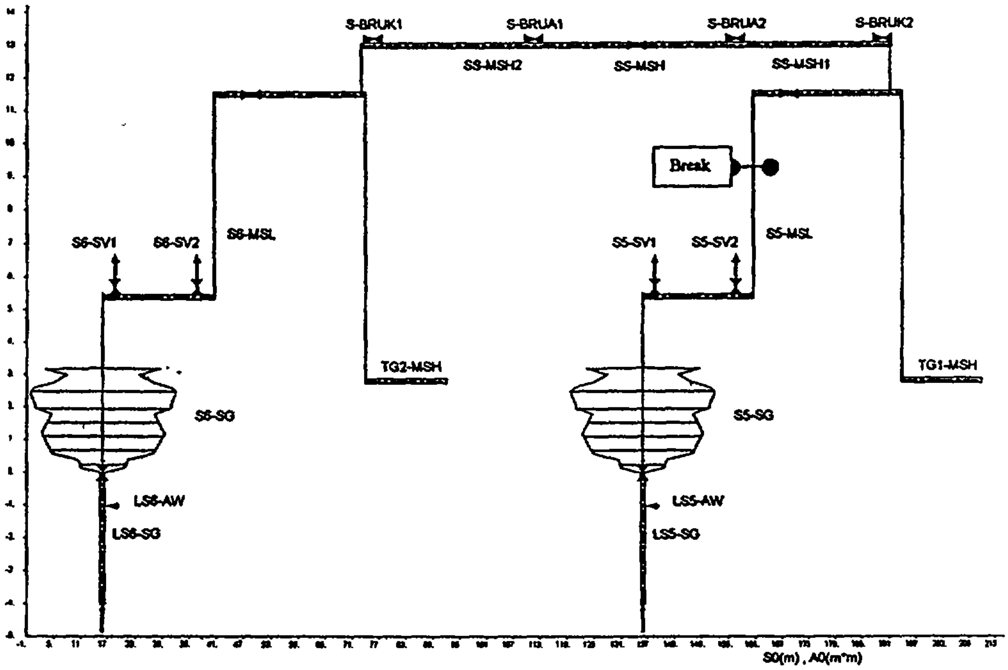


Figure 2. Allocation of the fuel assemblies to the core sectors and thermal-hydraulic channels



PO-PRESS - Pressurizer
PO-SURGE - Surge line of the Pressurizer
PO-PRZ-RV - Pressurizer unloading valve
PO-PRZ-R1 - First safety valve of the Pressurizer
PO-PRZ-R2 - Second safety valve of the Pressurizer
V-DCUP - Down camera of the reactor
V-DCLP.1 - Lower plenum of the reactor vessel
V-LP1.1 ÷ V-LP5.1 - Space below the core
A*A.1 - Fuel assemblies
V-UP1.1 = V-UP3.1 - Space above the core
V-UP4 - Outlet mixing camera of the reactor
V-UP5 ÷ V-UHEAD - Space under reactor head
P1-HL - Hot leg
P1-CL Cold leg
P1-SG-IN - Inlet collector of the steam generator
P1-SG-UTO1 - U-tubes
P1-SG-EX - Outlet collector of the steam generator

Figure 3. Primary circuit of the plant



S-BRUK1	-	BRUK1
S-BRUK2	-	BRUK2
S-BRUA1	-	BRUA1
S-BRUA2	-	BRUA2
LS6-SG	-	Line of the feed water supply in steam generator 5
LS6-AW	-	Line of the feed water supply in steam generator 6
S6-SG	-	Steam generator volume by the secondary side
S6-SV1	-	First safety valve of the steam generator 6
S6-SV2	-	Second safety valve of the steam generator 6
S6-MSL	-	Main steam line 6
TG2-MSH	-	Steam collector before the turbine 2
(LS5-SG) + (TG1-MSH)	-	The same for the steam generator 5
SS-MSH2	-	Main steam header (common for SG 2, 4, 6)
SS-MSH1	-	Main steam header (common for SG 1, 3, 5)
SS-MSH	-	Main steam isolation valve

Figure 4. Secondary circuit of the plant

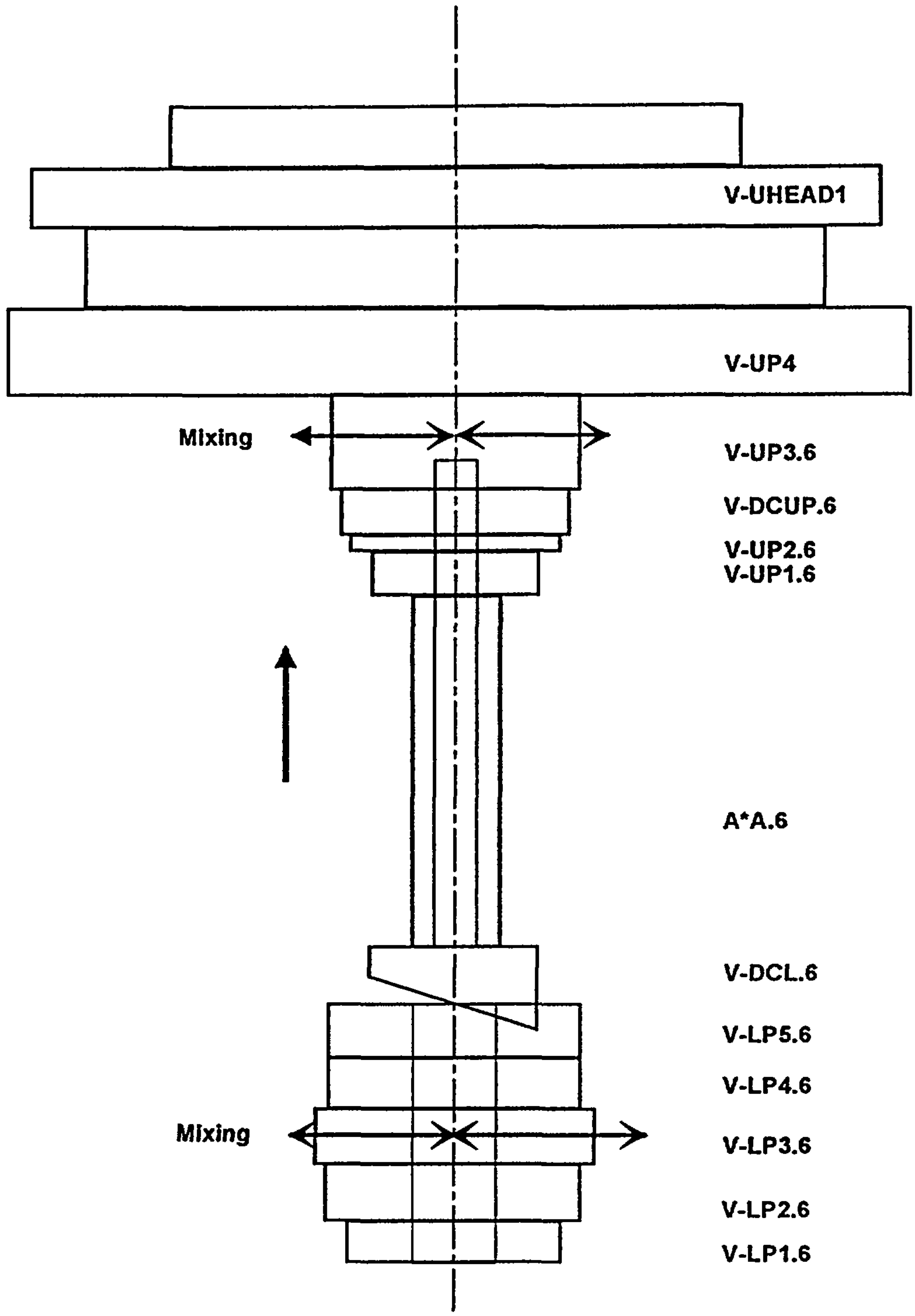


Figure 5. Nodalization of the reactor pressure vessel (sized, one channel is shown)

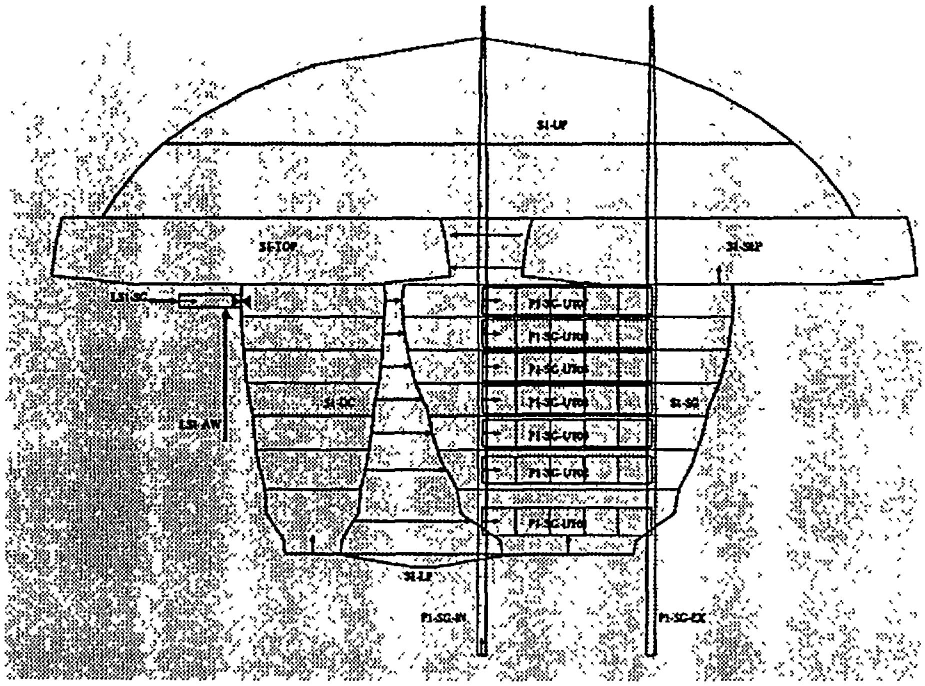


Figure 6. Nodalization of the steam generator (sized)

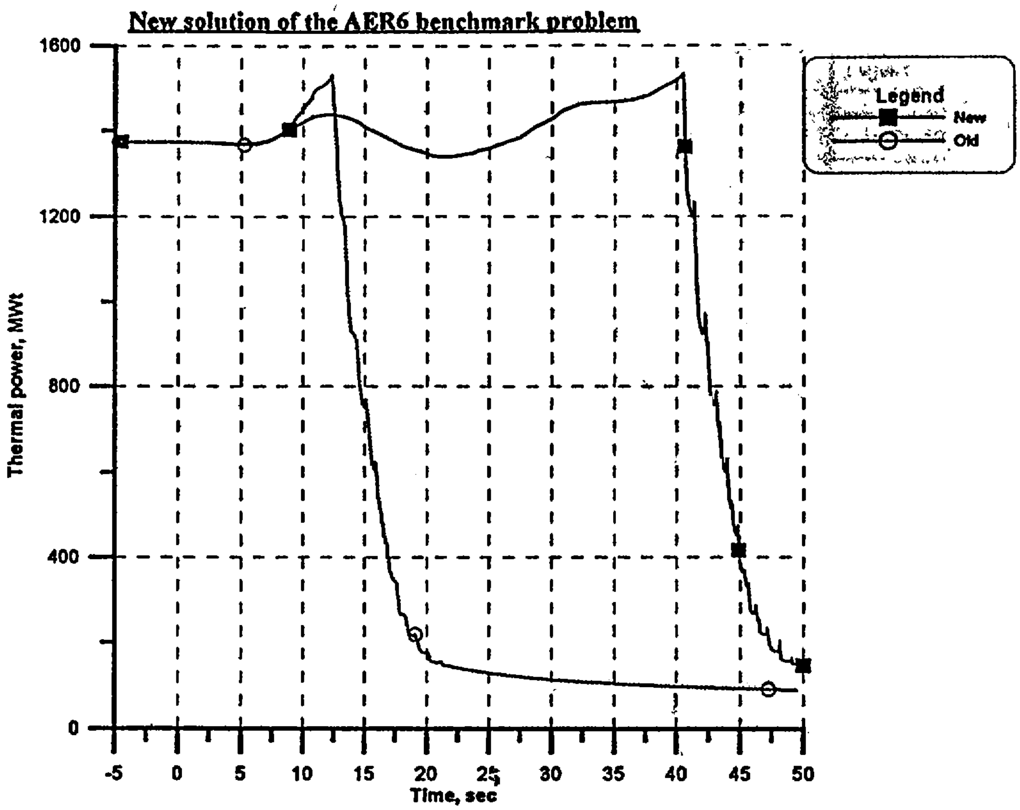


Figure 7. Thermal power versus time

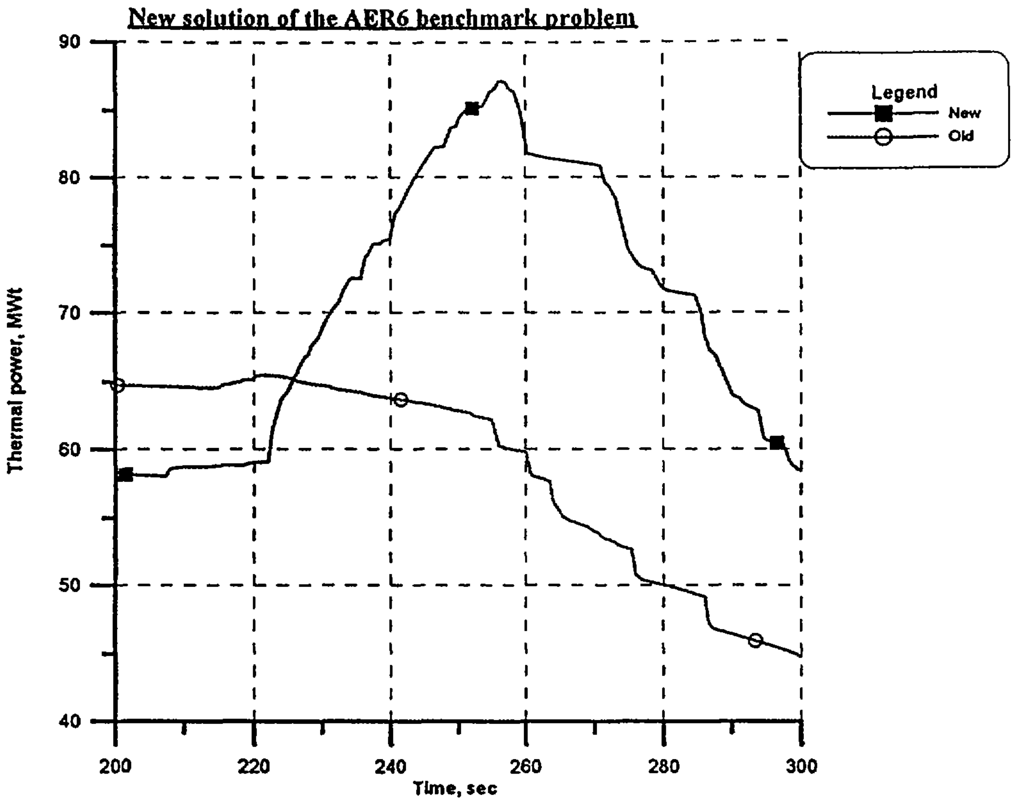


Figure 8. Thermal power versus time (sized)

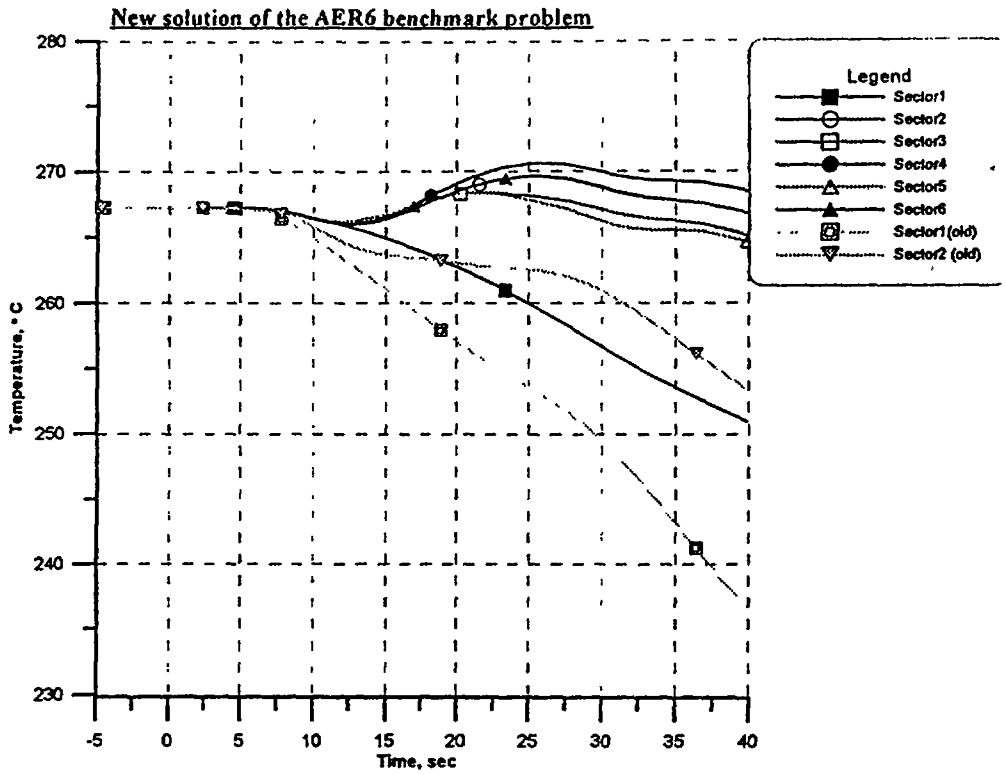


Figure 9. Coolant temperature at the inlet of the sectors

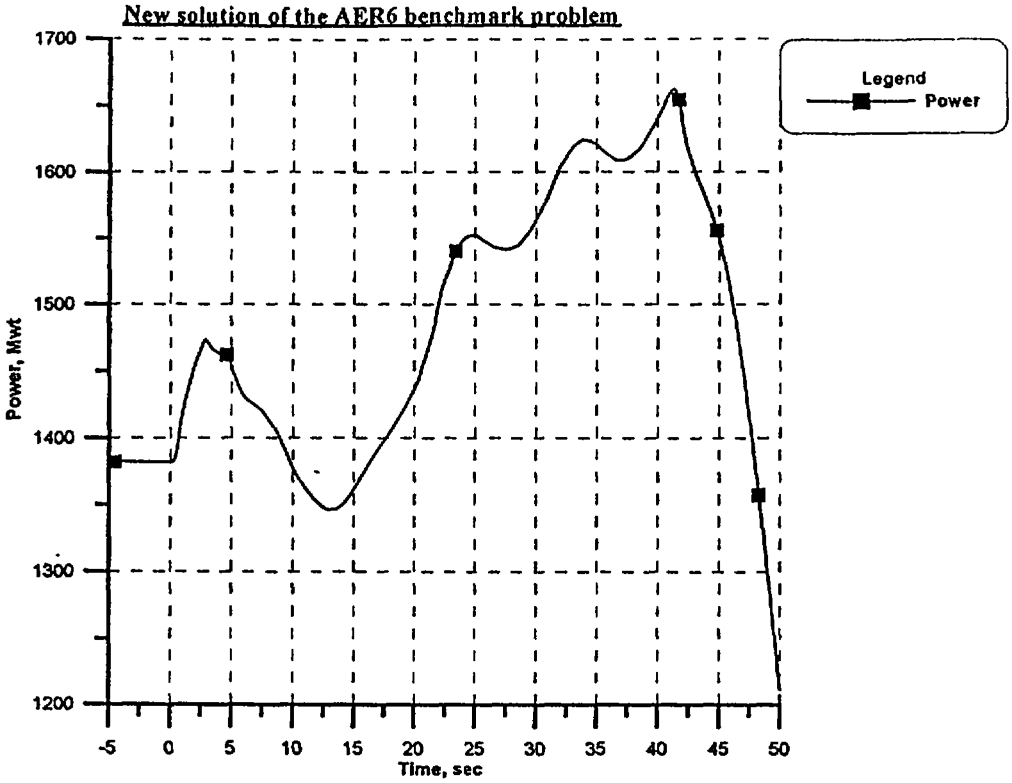


Figure 10. Sum power of the steam generator

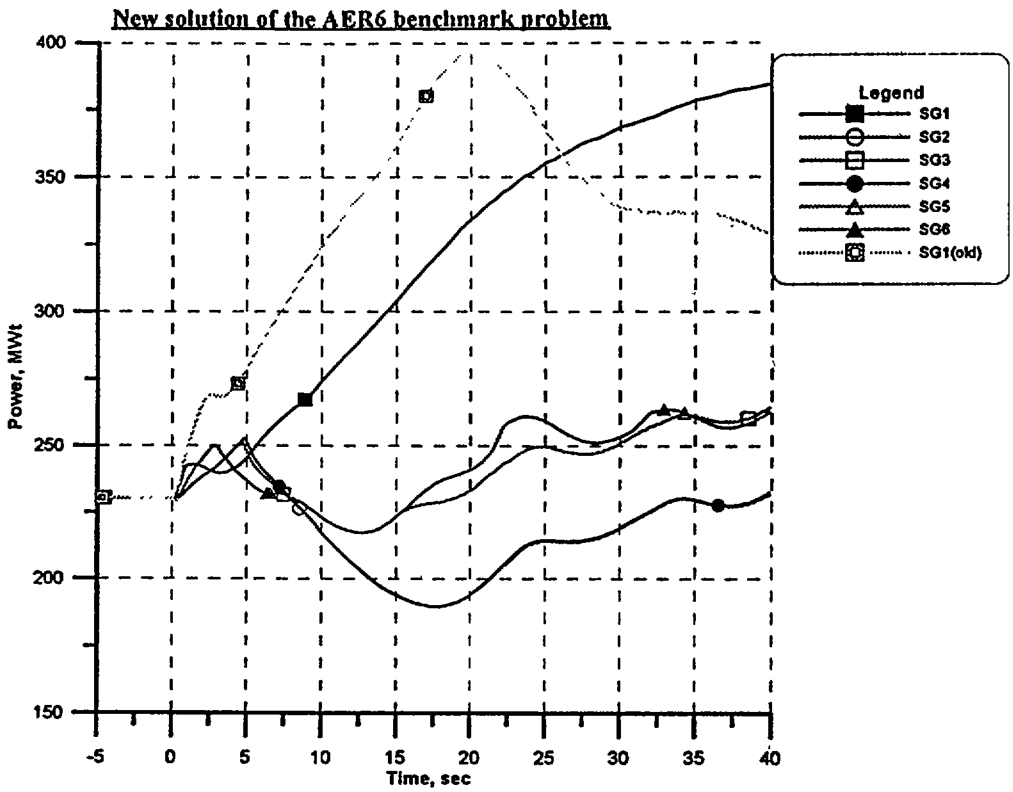


Figure 11. Power of the steam generator

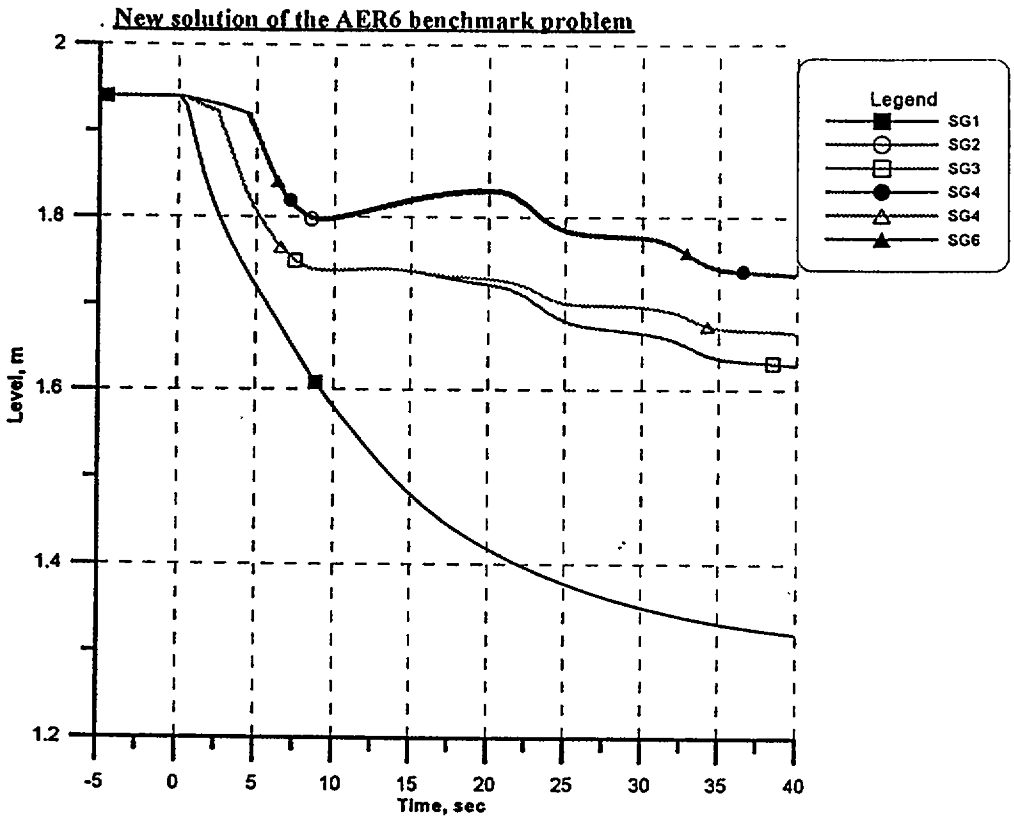


Figure 12. Steam generator level