SOLUTION OF THE FIFTH AER BENCHMARK WITH CODE PACKAGE ATLET/BIPR8KN

S.Danilin
M.Lizorkin
V Pekhterev

RRC " Kurchatov Institute ", Institute of Nuclear Reactors
Kurchatov Square 1, 123182 Moscow, Russia

ABSTRACT

The fifth three-dimensional hexagonal benchmark problem continues a series of the international benchmark problems defined during 1992-1996 in the international VVER co-operation forum AER. The initial event of the fifth AER benchmark is a symmetrical break in the middle part of the main steam header at the end of the first fuel cycle and under the hot shutdown condition with one stuck control rod group. The main difference from previous benchmark is that the system works of the primary and secondary sides are considered in this benchmark. The main aim of the benchmark is a calculation of the transient after the recriticality had achieved.

The solution of the fifth three-dimensional hexagonal dynamic AER benchmark problem obtained by code package ATHLET/BIPR8KN is presented. The report contains the description of the used reactor scheme including the description of the core, primary and secondary side. The amount of necessary tuning and tools of tuning to achieve a requested in the definition of the problem reference values are considered. Comparative analysis of the results obtained by using a different detalization schemes are carried out.

1. INTRODUCTION

The fifth three-dimensional hexagonal AER benchmark problems continues a series of the international benchmark problems defined during 1992-97 in the frame of the international VVER cooperation forum AER. The main difference from previous benchmarks is that the both primary and secondary side of the reactor are taken into account. 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 response of the reactor core on the perturbation coming from the secondary side of the plant are investigated.

The initial event of the fifth AER benchmark is a symmetrical break in the middle part of the main steam header. The break occurs in the end of cycle and hot shutdown conditions when all control rod groups are fully inserted into the core. One control rod group is considered stuck in the upper position by the conservatism conditions. The full definition of the benchmark problem is presented in [1].

The solution of the fifth tree- dimensional hexagonal dynamic AER benchmark problem obtained by code package ATHLET/BIPR8KN is presented. Comparative analysis of the results obtained by using a different nodalization schemes of the reactor plant are carried out.

2. THE REACTOR MODEL DESCRIPTION USED IN CALCULATION

2.1. Core model description

Symmetrical break allow to use the core configuration of 60 degree symmetry sector. The used core map is shown on Fig. 1. Each fuel assembly corresponds to the separate thermal hydraulic channel. Hydraulically the core was modeled by 59 parallel channels (PIPE type object). The fuel assembly was modeled 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.

For the preparation of the neutron physical data the code package KASSETA was used. The burn up calculation were fulfilled by BIPR8 code. The state of the reactor core at the end of the cycle before the break is presented in Table 1.

Table 1

Initial state of the core before break

Parameter	Value
Reactor power, MWt	10
Coolant inlet temperature, ^{o} C	260
Boron concentration, ppm	0.0
Cycle length, FPD	370.7
Subcriticality (unadjusted), pcm	-2620
Subcriticality (adjusted), pcm	-1534

The adjustment of the initial subcriticality of the core to the value which were suggested in the benchmark definition was performed by decreasing of the removal and absorption cross section of the absorber material for the fast group to correct the efficiency of the control rod group.

2.2. Primary and secondary side model

The input data for the modeling 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 modeled in the reactor scheme:

- 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;

Two calculation variants were considered for carrying out of the comparative analysis. These variants include the same core model but they are distinguished by different nodalization scheme of the primary and secondary side of the reactor.

The first calculation variant is a two loops scheme of the reactor plant. In this case the three loops on the each side of the reactor pressure vessel were combined to the one separate loop (Fig. 2). The nodalization of the main steam header for this scheme are shown on Fig. 3.

The second calculation variant is a four loops scheme of the reactor plant. In this case the two loops on the each side of the reactor pressure vessel were combined to the one separate loop and two loops were presented as a single one (Fig. 4). The nodalization of the main steam header for this scheme are shown on Fig. 5.

As could be seen from presented figures the symmetry of the scheme is achieved in both cases. This condition is important to guarantee the symmetry of the break. The main difference between schemes consist of the pressurizer connection. In the two loops scheme the pressurizer formally connected to the one loop but actual to the three one. In this case there is not possibility to connect it to the separate loop as requested in the benchmark definition. In the four loop scheme the pressurizer is connected to the separate loop as requested. The nodalization of the main steam header on the control volumes is the same in both cases. The initial parameters of the main objects of the scheme are also the same.

3. ANALYSIS OF THE OBTAINED RESULTS

The obtained results are shown on Fig. 6-23. Figures from 6 to 16 show a behavior of the global core parameters for the time of the transient. Figures from 17 to 23 show a behavior of the loop with pressurizer parameters for the same time.

The leak bring to the recriticality of the core and power peak due to average temperature decrease at the core inlet in consequence of the depressurization of all steam generators. The pressurizer, volume control system and feed water system switch on to correct the parameters of the primary and secondary side. The high pressure injection system is activated with 180 seconds delay according to the benchmark definition and stop the power increase.

Figure 6 is demonstrated the neutron power increase. As could be seen from the figure the maximum values of the neutron power obtained by both schemes are practically the same. But in the case of the four loop scheme the time shift are observed. This time shift is caused the more slow drop of the temperature at the core inlet obtained by using the four loop model (Fig. 13). This more slow drop of the temperature could be explained the next phenomenon which are observed by using the four loop model:

⇒ the higher values of the leak mass flow through the break (Fig. 16);

⇒ a bit smaller total core mass flow up to the peak (Fig. 11);

⇒ the higher values of the total power transferred to the secondary side of the U-tubes in the all steam generators (Fig. 23);

⇒ the smaller values of the upper plenum pressure (Fig. 8);

The higher values of the leak mass flow through the break (Fig. 16) is caused the solution sensitivity to the nodalization. It is meant that changing in the scheme (two loops to the four loops) by keeping the main steam header nodalization practically the same lead to the increase of the break mass flow rate and finally to the shift in the power peak. Obviously that the higher values of the total power transferred to the secondary side of the U-tubes in the all steam generators corresponds to the higher mass flow through the break.

The differences in the upper plenum pressure are explained by influence of the pressurizer connection. In the two loop scheme the pressurizer actual connect to the three loops and in the four loop scheme it connect to the separate one. These differences lead to the upper plenum pressure differences and to the different work of pressurizer (Fig. 9,10).

Fig. 15 illustrate the behavior of the maximum fuel pellet centerline temperature for the time of the transient. Obviously that the differences in the curves correspond to the differences in the neutron power peaks. Figures from 17 to 23 illustrate the behavior of the steam generator parameters for the time of the transient.

4. CONCLUSION

The following main conclusions could be done after the comparative analysis have been made:

- ☐ The both compared variants have described the behaviour of the main reactor parameters practically the same. Observed time shift in the neutron power and no large differences in other parameters of the reactor is a sequence of the different nodalization of the scheme and pressurizer connection.

- ☐ Solution of the benchmark is sensitive to the nodalization of the scheme. Although it do not bring to the quantity differences in the results it should be taken into account by real safety analysis calculation.

5. REFERENCE

1.S. Kliem " Definition of the fifth dynamic AER benchmark problem - a benchmark for coupled thermohydraulic / three - dimensional hexagonal neutron kinetic core model"

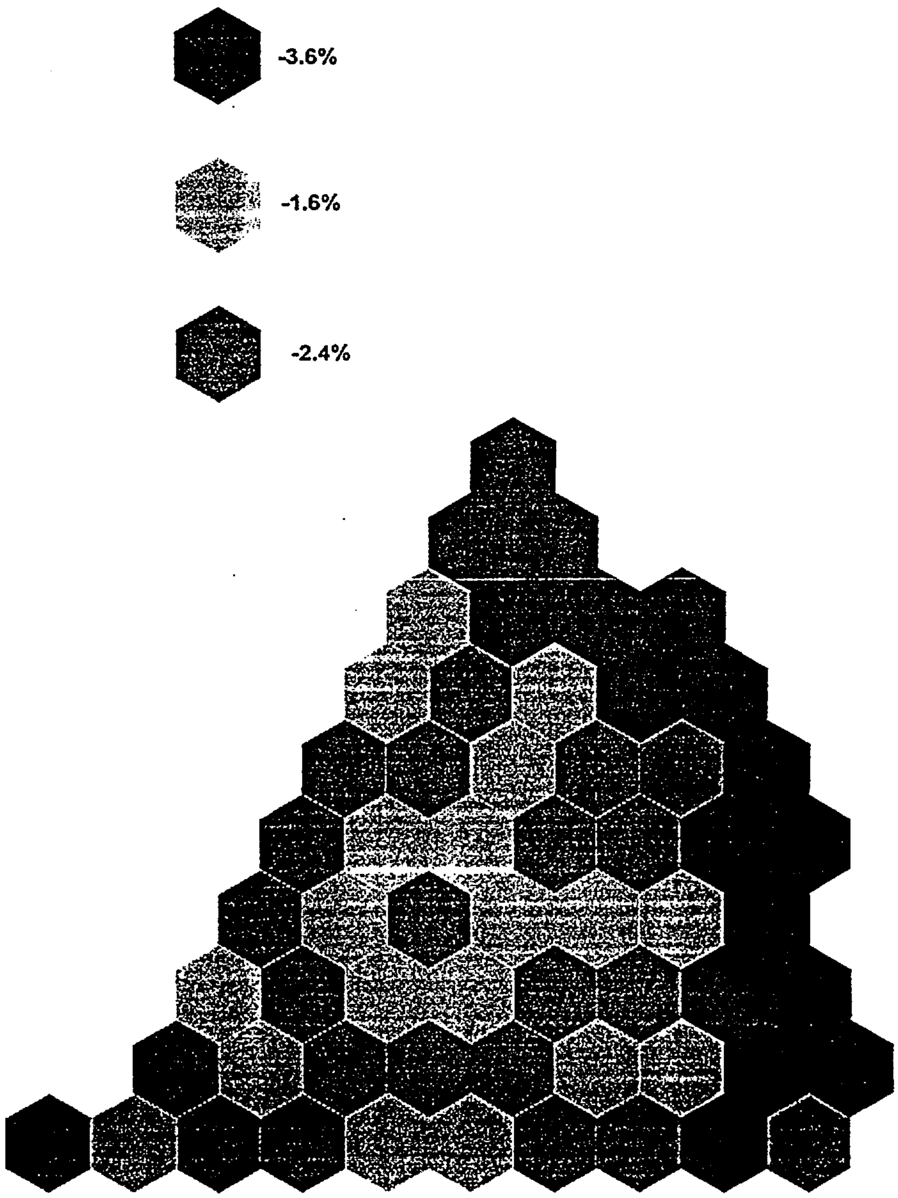

Fig. 1 Core configuration in 60 degree sector

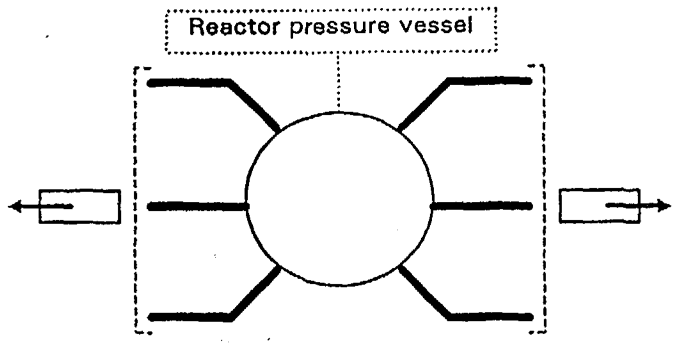

Fig. 2. Two loop scheme modeling

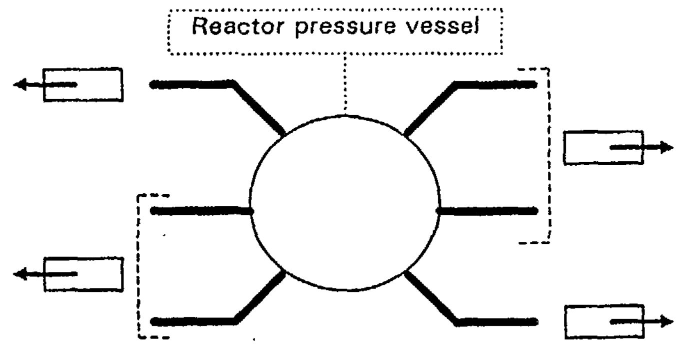

Fig. 4. Four loop scheme modeling

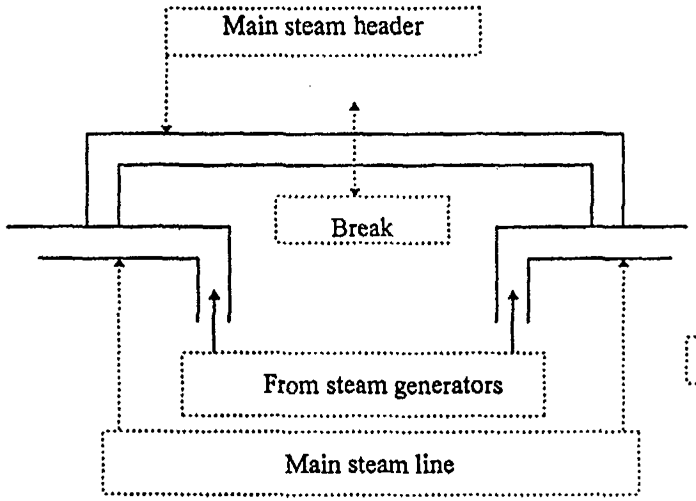

Fig. 3 Main steam header modeling for the two loop scheme

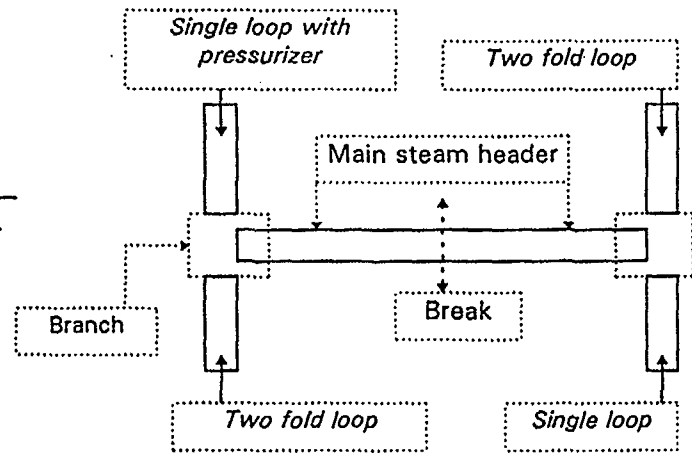

Fig. 5 Main steam header modeling for four loop scheme

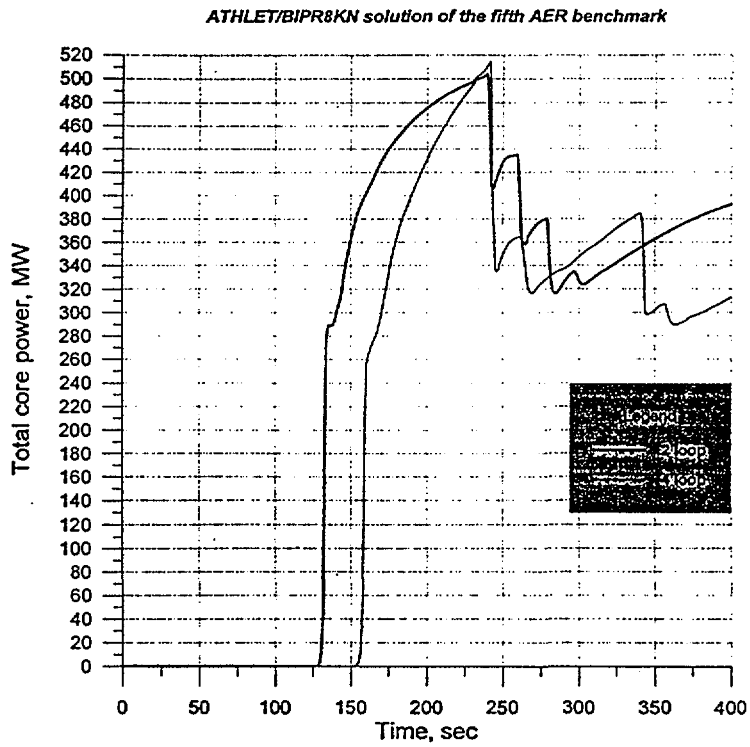

Fig 6. Total core power versus time

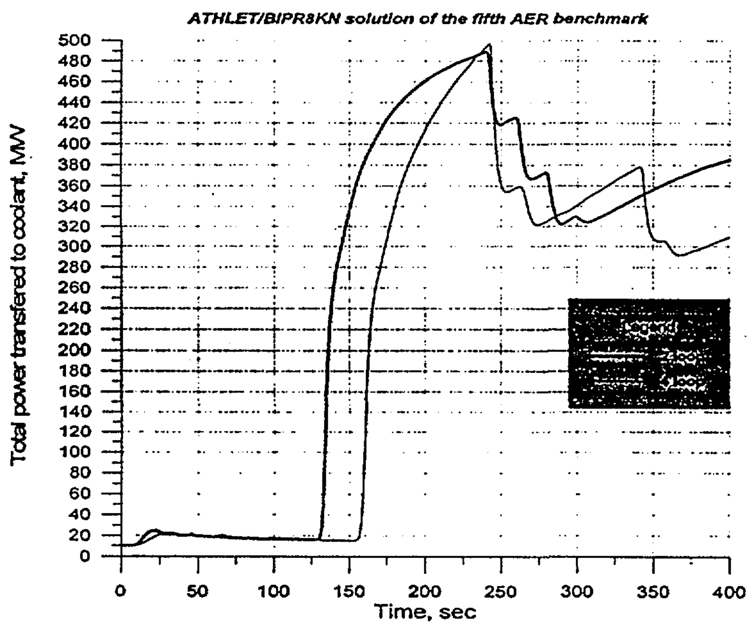

Fig 7. Total power transferred to coolant versus time

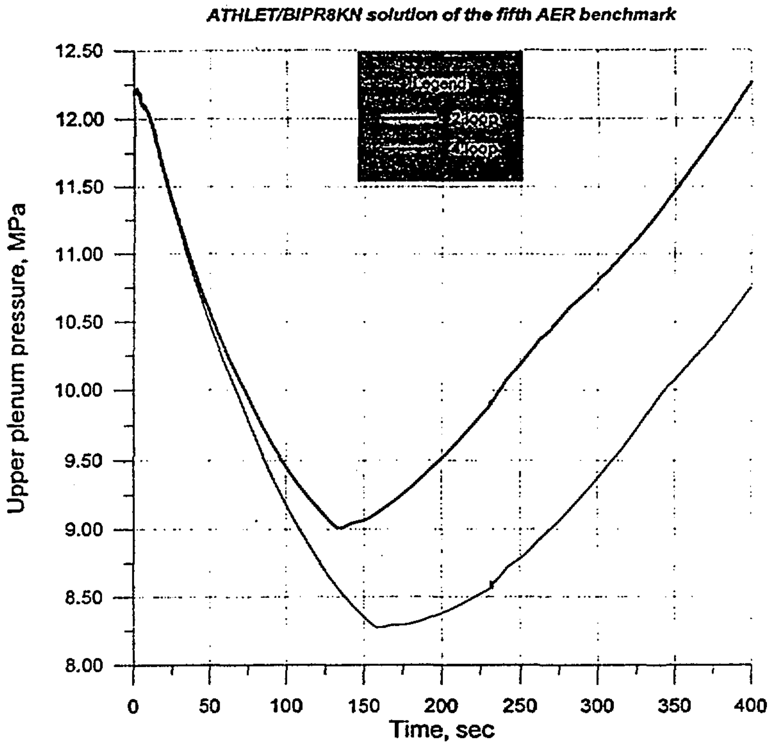

Fig .8 Upper plenum pressure, measured at the hot leg elevation versus time

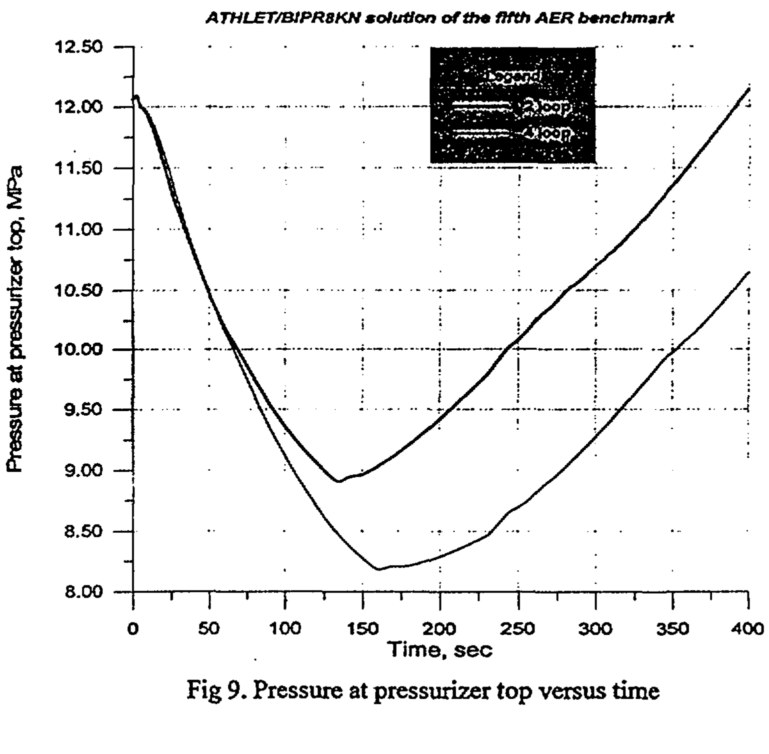

Fig 9. Pressure at pressurizer top versus time

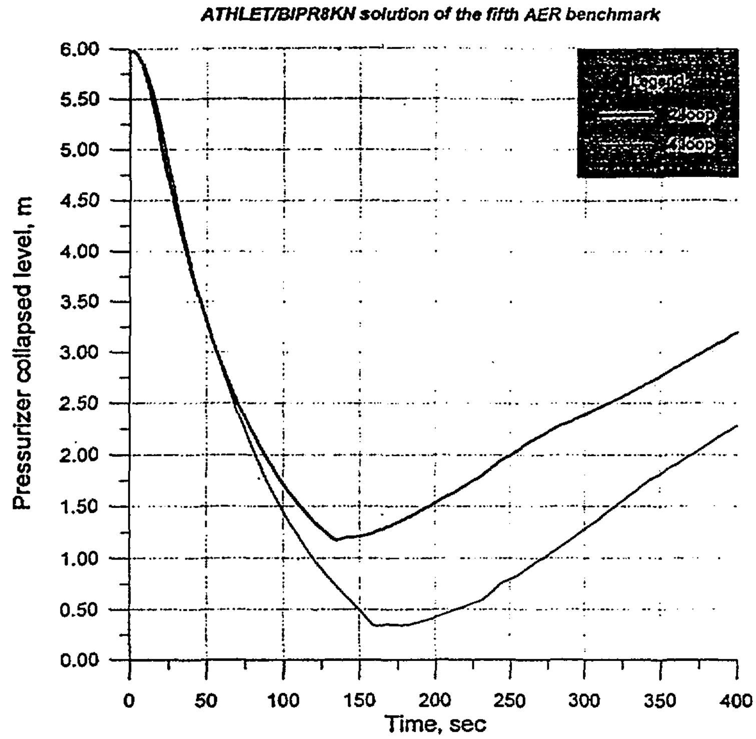

Fig 10. Pressurizer collapsed level versus time

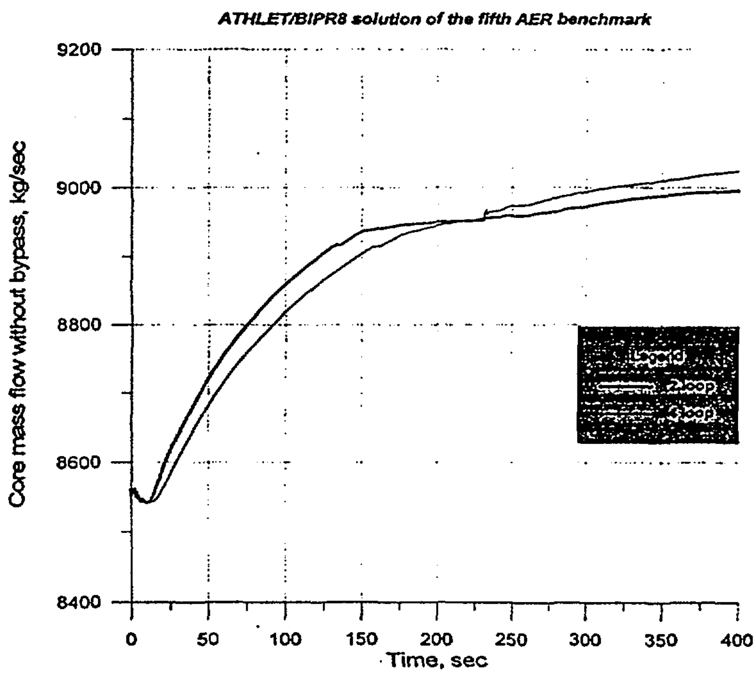

Fig 11. Core mass flow without bypass versus time

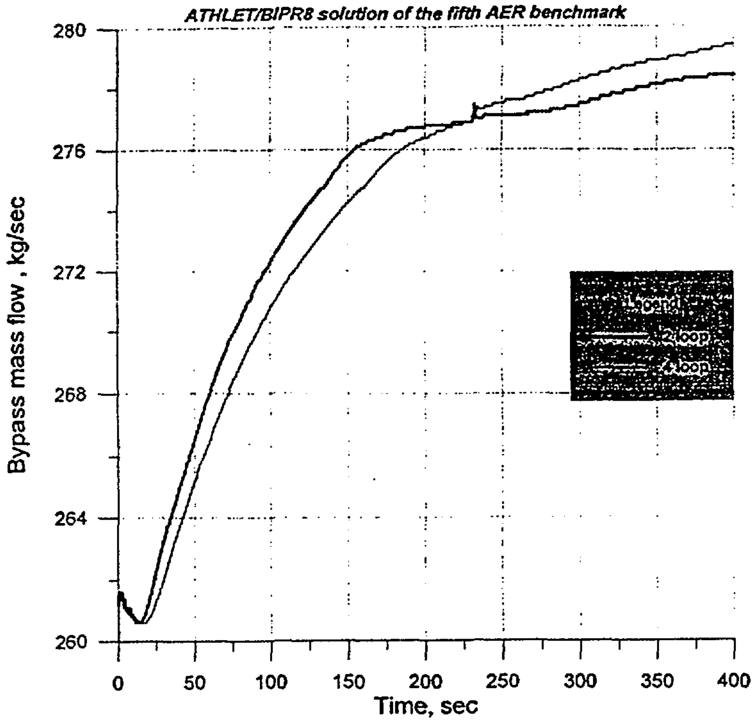

Fig. 12. Bypass mass flow rate versus time

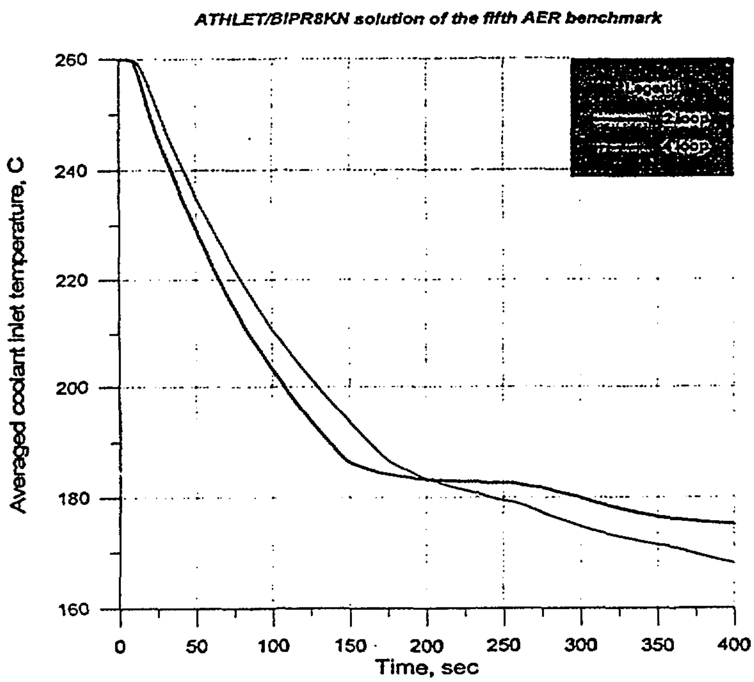

Fig 13. Averaged coolant temperature at the core inlet versus time

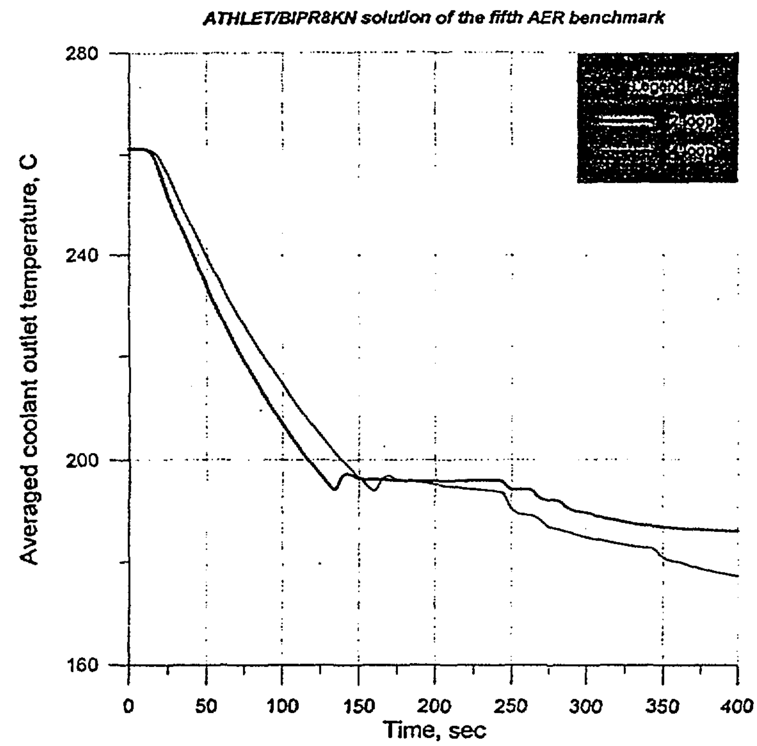

Fig 14. Averaged coolant temperature at the core outlet versus time

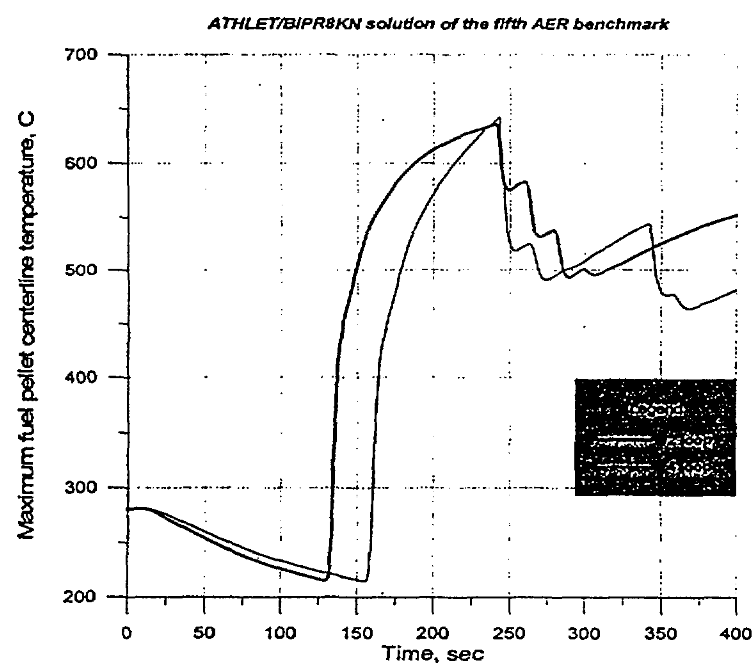

Fig 15. Maximum fuel pellet centreline temperature versus time

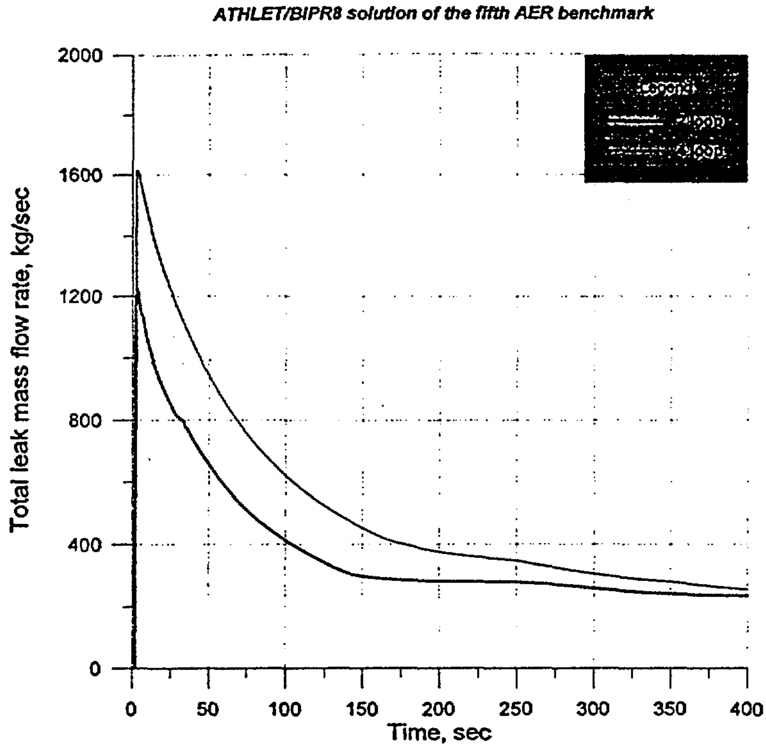

Fig 16. Total leak mass flow rate versus time

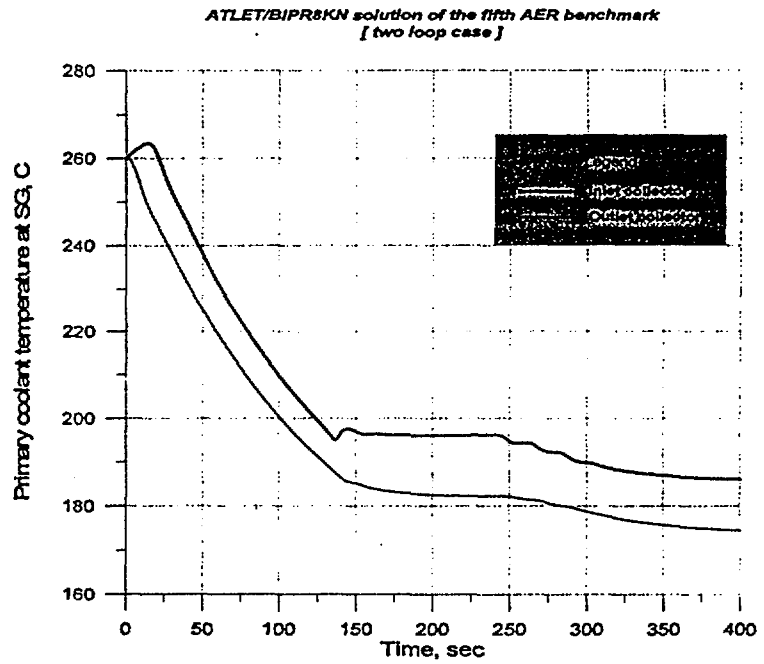

Fig 17. Coolant temperature at steam generator versus time(loop with pressurizer)

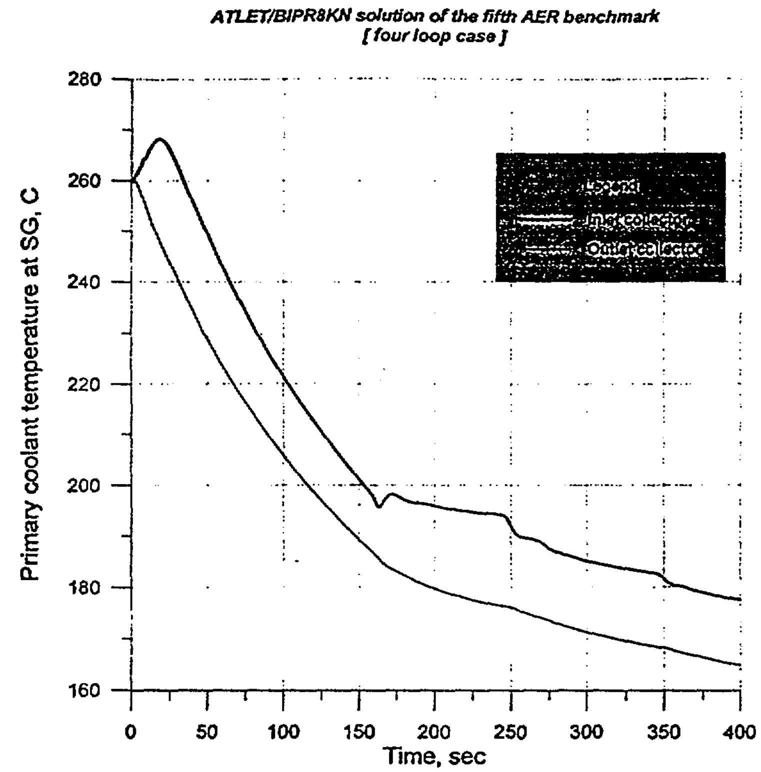

Fig 18. Coolant temperature at steam generator versus time(loop with pressurizer)

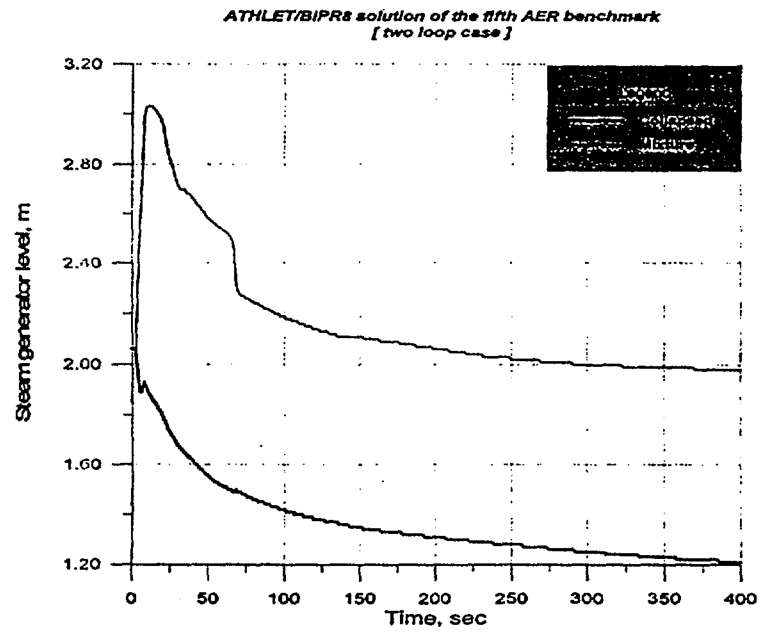

Fig 19. Steam generator level versus time (loop with pressurizer)

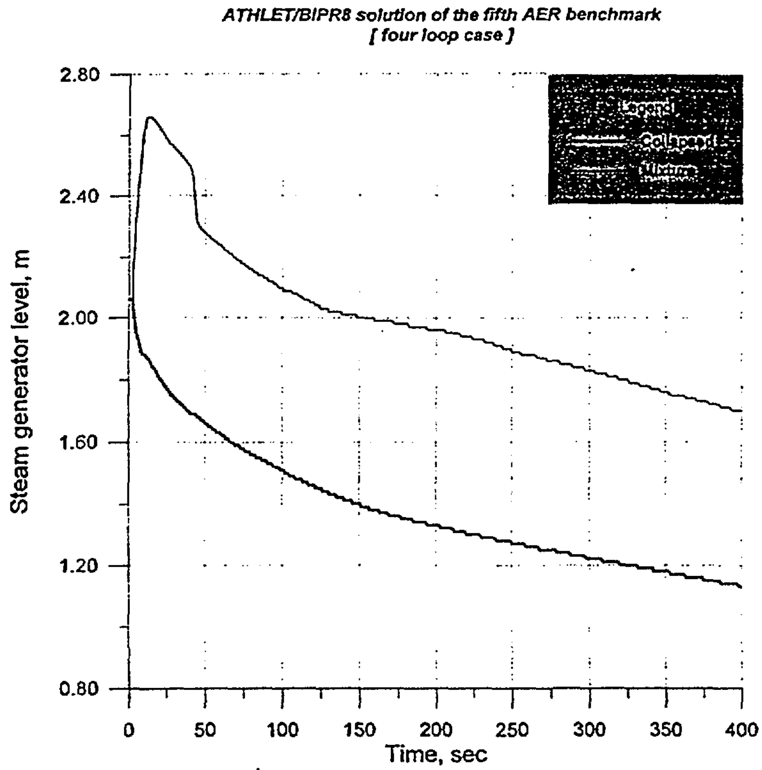

Fig 20. Steam generator level versus time (loop with pressurizer)

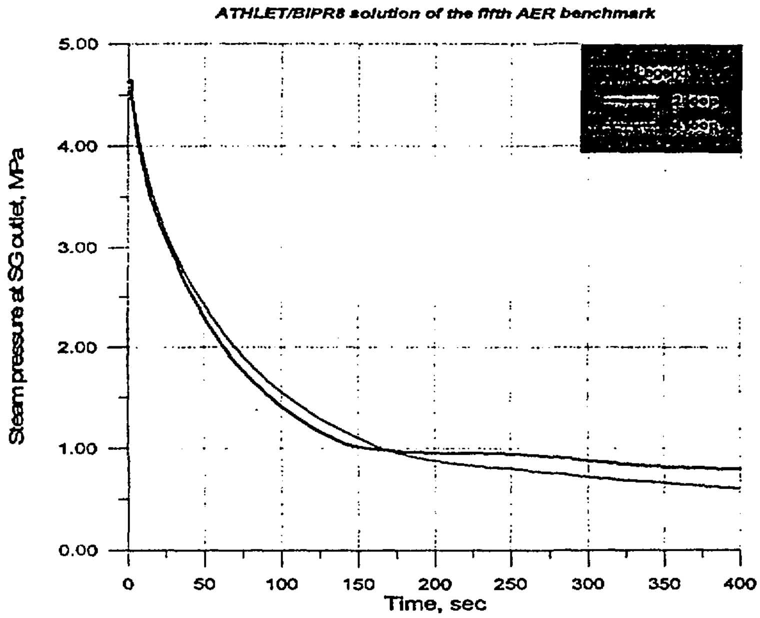

Fig 21. Steam pressure at the steam generator outlet versus time (loop with pressurizer)

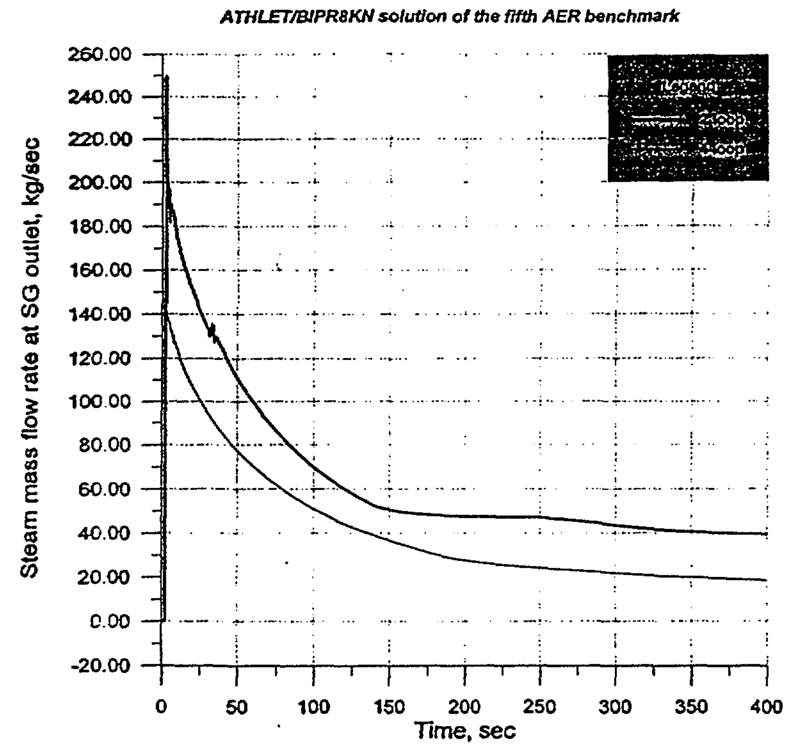

Fig 22. Steam mass flow rate at the steam generator outlet versus time (loop with pressurizer)

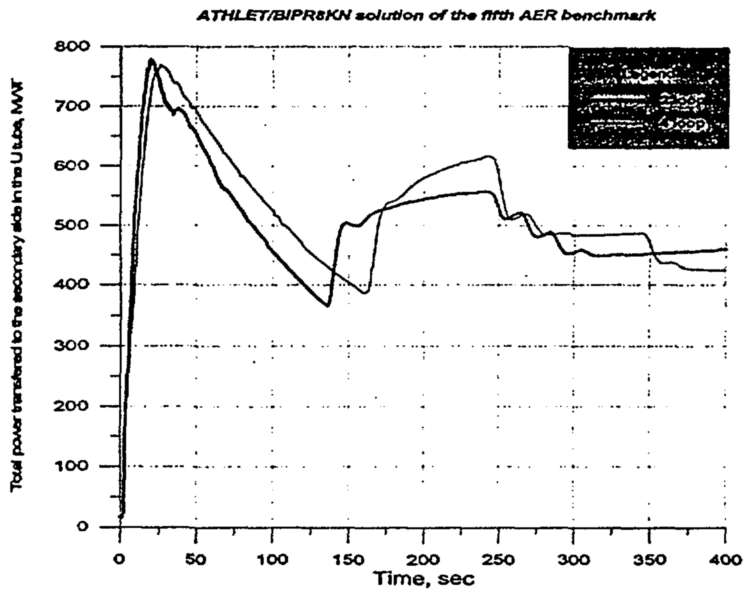

Fig 23. Total power transferred to the secondary side in the U-tubes for all steam generators (loop with pressurizer)