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LWRA Analysis of Inadvertent Closing of the Main Steam Isolation Valve in NPP Krško

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ABSTRACT

The paper describes the use of system code RELAP5/mod2 and analyzer code LWRA in analysis of inadvertent closing of the main steam isolation valve that happened in NPP Krško on September, 25 1995. Three cases were calculated in order to address different aspects of the modelled transient. This preliminary calculation showed that, even though the real plant behaviour was not completely reproduced, such kind of analysis can help to better understand plant behaviour and to identify important phenomena in the plant during transient. The results calculated by RELAP5 and LWRA were similar and both codes indicated lack of better understanding of the plant systems status. The LWRA was more than 5 times faster than real time.

INTRODUCTION

The computer codes for nuclear power plant safety analyses are verified and validated using the results of the transients performed on experimental facilities, and/or using results calculated by more accurate computer codes. The most appropriate way to adjust the model to the specific plant is comparison with the transient that really happened, so the model can be applied for the analyses of similar transients. That is the reason why, when certain transients happened, it is important to use the opportunity to evaluate the model of the plant.

The paper describes the use of simulator like code LWRA (Light Water Reactor Analyzer) and more detailed system code RELAP5/mod2 in analysis of inadvertent closing of the main steam isolation valve that happened in NPP Krško on September, 25 1995. Transients of this type do not lead to the extreme plant conditions, but can be used to check the model of control and protection system. Unfortunately, all data recorded on the plant information system were not available and only rough sequence of events was known, so we performed preliminary calculation. The final analysis and the comparison will be done in the future. One of our intentions was to explore capabilities of LWRA code to perform transient analysis in accurate and most effective way. If the accuracy of the LWRA results, checked against RELAP5 results and against available plant data, is verified, we can exploit full benefit of LWRA's easier input preparation, faster than real time calculation and on-line results presentation.

MATHEMATICAL MODEL OF THE PLANT

For the purpose of this analysis, the models for pressurizer level and pressure control, steam generator level control and turbine bypass (steam dump) system are included in already existing RELAP5/mod2 nodalization for NPP Krško. The standard RELAP5/mod2 nodalization for NPP Krsko is shown in Figure 1. Total number of used control volumes is 250 (167 on the primary side and 83 on the secondary side). The volumes are connected using 190 junctions on the primary side and 83 junctions on the secondary side (total number of junctions is 273). Total number of active heat structures on the primary side is 191 and corresponding number of the heat structures on the secondary side is 51. Of the total number of heat structures 12 heat structures are active heat structures (with heat input) and they are used to model reactor core. The heat input is table defined, taking into account change of the heat power during scram and decay heat generation after reactor scram. The model of the pressurizer level and pressure control system, as well as model of the steam generator level control system, are introduced in existing standard nodalization. Two additional trips are introduced to model SI actuation on low steam line pressure.

The steady state transient lasting 200 s was performed using new input deck. The results of the calculation were verified against standard criteria for initial conditions accuracy:

- error in net heat power exchanged in the system <1%,
- error in system pressure <0.5%,
- coolant temperature error <1%,
- error in primary water flow and in steam flow in SGs <1%,
- error in heat losses calculation <5%,
- error in total water mass in the system <1%.

The LWRA (Light Water Reactor Analyzer) code, which is plant analyser capable to analyse transients in PWRs and BWRs, is used to prepare another model for the NPP Krsko. The code is developed by Stanislav Fabic and it is based on older RETACT (REal Time Advanced Core Thermal Hydraulics) code, developed at Dynatrek, Inc. The thermal-hydraulic model of the code is classical 5 equation drift flux model with addition of separate conservation equation for mass of non-condensibles. The mass conservation equations are integrated for mass of vapor, mass of non-condensibles and mass of liquid. There are two energy conservation equations, one for gaseous phase (non-condensible and steam) and one for two-phase mixture. Only one momentum conservation equation, for the two-phase mixture is used. In the mixture momentum equation the phasic mass flow rates are expressed in terms of either mixture mass or mixture volumetric flow rate and the drift term. After solving for the mixture flow rate, the drift flux relations are employed to parse the mass flow rates of each fluid component. The mass and energy conservation equations are used to develop the calculation scheme based on one system pressure per region. The local fluid properties are assumed to be functions of the local enthalpy and the global pressure. The mass balances are combined to derive an integral expression for the local volumetric flow rate within each closed loop. More details about LWRA model can be found in ref. 5 and 6.

LWRA input deck for NPP Krško is developed using reduction of the standard RELAP5/mod2 input deck. Total number of control volumes in LWRA nodalization is 48. The volume numbers 1-6 and 7-12 are used for secondary side of steam generators, volume numbers 13-43 are representing primary system, number 44 and 45 are used for steam lines, Base deck ID: NEK18R01

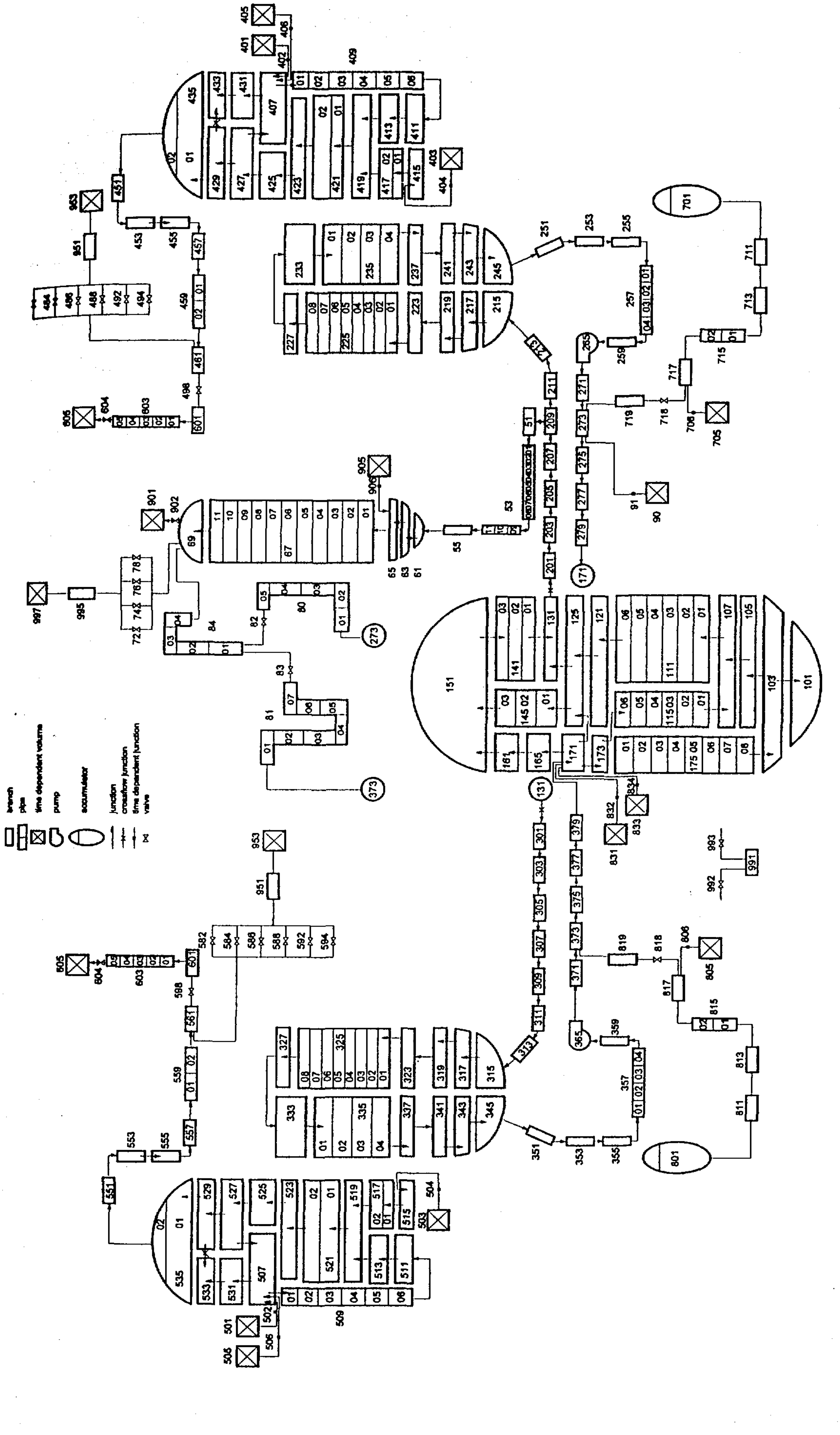

Figure 1. NPP Krško nodalization for RELAP5/mod2 calculation

46 for steam header, and volume numbers 47 and 48 are used for pressurizer relief tank and containment, respectively. The pumps are modelled using the same homologous head and torque curves as in the RELAP5/mod 2 code. Only small number of the heat structures is used in the model. There are 18 heat structures in the core (3 axial stacks of structures in each core volume) distributed in 3 radial zones to take into account power distribution used in reactivity weighting. The steam generators U-tubes are modelled with 10 heat structures in each steam generator. The pressure loss distributions within primary system and within recirculation loop in steam generators are calculated as the first approximation and loss coefficients have to be better tuned. The same is true for plant protection and control system, where some generic setpoints are used. In the steam generators only main feedwater is modelled in normal operation, without 70-30% feedwater split currently used in NPP Krsko. The steady state transient is performed to initialise the model. The fixed time step of 0.125 is used during 1000 s. Steady state results are verified against plant data and against RELAP5/mod2 calculation. Generally speaking, according to above mentioned standard accuracy criteria for initial conditions, good agreement is achieved for this preliminary stage in LWRA nodalization development. The pressure drop on steam generator secondary side has to be better calculated and that will give better results for secondary pressure and flow.

DESCRIPTION OF THE EVENT

The inadvertent closing of the main steam isolation valve happened in NPP Krško on September, 25 1995 at 10:22. The NPP was at full power. Due to the different SG plugging level, steam mass flow from the SG 2 and corresponding steam pressure were slightly higher than in the SG 1. After malfunction in control circuit of the main steam isolation valve (MSIV) 1, the flow from the steam generator was stopped and steam pressure increased up to 7.78 MPa. In the same time, due to the higher steam flow from the steam generator 2, the steam pressure decreased and SI signal was initiated at 5.4 MPa. Reactor scram, turbine trip and main feedwater isolation were actuated on SI signal. Due to the very short time (1.2 to 1.4 s) that passed between MSIV closure and reactor trip initiation, heat balance in the primary system was only temporarily disturbed and there was no heatup of the coolant. In the meantime the MSIV was closed on low steam pressure signal in steam line 2 and steam pressure in SG 2 started to increase. The pressures in both SGs were stabilised bellow SG PORV set point around 50 s after transient initiation. All conditions in the plant were stable. Only first part of the transient was analysed.

RESULTS

The calculation started from 100 % power, with the same conditions in both steam generators (18 % U-tube plugging in both steam generators). MSIV 1 was closed and 500 s of transient was calculated.

The following cases were first calculated using RELAP5/mod2 in order to address different aspects of the modelled transient:

1. *Main steam isolation valve 2 closes at the beginning of the transient,*
2. *Main steam isolation valve 2 does not close at all,*
3. *Main steam isolation valve 2 closes at the beginning of the transient with the assumption of leak through the both main steam isolation valves.*

SI signal was registered around 1.5 s after MSIV 1 closure. In the first case the MSIV 2 closed on low steam pressure around 2.4 after transient initiation (closure time is between and 5 s). Steam pressure in both SGs is shown in Figure 2. The pressure increases after closure of the valves till SG PORV set point. The combined capacity of the PORV and safety valves is large enough to stop the pressure increase and cool the primary side. Characteristic cycling of the valves can be identified on Figure 2. The reactor scram was initiated early in the transient but combined effect of the decreasing reactor power and accumulated heat was resulted in PORV opening in order to establish heat balance in the plant. In real situation there were no actuation of the valves and that suggest that our calculation wasn't able to reproduce real data.

The next case was started with assumption that there was no closure of the MSIV 2. This assumption was used to define two bounding cases for this transient and to explore possible deficiencies in the mathematical model, and to explain difference between measured data and calculation. In this case the pressure increase in both steam generators started after MSIV 1 closure, like in the previous case, but due to fact that MSIV 2 was opened, the primary side was cooled and power imbalance was smaller. Due to the smaller power imbalance pressure increase reached the point where one steam generator is enough to transfer heat power from the primary side after reactor scram. The maximum pressure is higher in isolated steam generator, but both pressures are more or less constant after 200 s of transient (Figure 3). Almost constant steam flow from the steam generator 2 was established after auxiliary feedwater flow initiation.

Behaviour of the steam generator pressure in the real case was somewhere between pressures calculated in the first and the second case. In the real case there was no PORV actuation and MSIV was closed. The pressure increase was limited with both pressures staying close together after initial transient (measured value of the pressure in SG 1 was slightly higher). The heat balance, calculated in the mathematical model, indicates that such kind of behaviour was possible only if some additional mechanism of steam generators cooling, not addressed in the original model, exists. The third calculation was started with working assumption that there is a leakage in the steam generators after MSIV isolation. Assumed values of the leakage were 15 kg/s for first steam generator and 5 kg/s for second steam generator. The greater mass flow in the first steam generator was used because that was the only way to have smaller pressure in steam generator 1 which was isolated first. The calculated pressure is shown in Figure 4. These results show that it is possible to reproduce real pressure behaviour if the real values of the flow outside steam generators are known, that means if the real boundary conditions in the plan are known. In that case, the model will be able to calculate accurate values of the plant parameters.

The first LWRA calculation was performed without any intervention. The behaviour of the secondary pressures is similar to behaviour of the measured pressures. Calculated pressure peak in SG 1 is higher than in real situation, and pressure drop in SG 2 after MSIV closure is larger. Both things are caused by the delay in SI signal initiation, due to lack of derivative effect in steam line pressure signal conditioning. During the transient opening of the SG PORV number 1 is calculated.

The steam generator pressures are taken as the representative variables for comparison of the calculated and measured results. The pressures calculated by LWRA, by RELAP5/mod2 and measured in the plant are plotted in Figure 5. In RELAP5 calculation there is no pressure drop in SG #2. LWRA calculated pressure drop is too large. RELAP5 calculates too low pressure peak in SG #1 and LWRA calculates too high pressure. The rate of pressure increase in both calculation is lower than it is measured in the plant. Both codes calculate similar pressure after first 100 s of transient and pressures are slightly increasing. In the plant pressure is decreasing indicating additional cooling of the plant. When some leakage is specified on the MSIVs or some additional loss of the steam from steam generators is specified the peak pressure increase is decreased and it is possible to get pressure decrease in both steam generators in second part of the transient.

CONCLUSION

It could be concluded that the behaviour of the transient depends on the time of low steam line pressure signal initiation and corresponding SI signal generation, as well as on the time and duration of MSIV 2 closure and possible loss of the steam from isolated steam generators. The control and protection system of the plant performed as designed and the plant is brought into the safe shutdown operation without any consequences.

This preliminary calculation shows that, even though the real plant behaviour was not calculated, such kind of analysis can help to understand plant behaviour and to identify important phenomena at the plant during transient. In normal analysis of the event, performed by the plant staff, such things are usually not addressed because of lack of adequate analytical tool. In most cases main goal is only to answer if there were any safety problems and if systems and equipment performed as requested. Both, the RELAP5/mod2 and LWRA, codes calculate similar results, and for this class of accidents, after proper boundary conditions will be defined, both codes can give results close to plant data. The LWRA calculation time (5 times faster than real time on Pentium 133 MHz) is at least for order of magnitude shorter than RELAP5 calculation time. The code is easy to use with possibility of changes in transient scenario and in set point values during the calculation. The preparation of input values is simpler and the code can be used in situation when we have not enough data to describe the plant.

REFERENCES

[1] NEK Updated Safety Analyses Report, Krško 1994.

[2] NEK Technical Specifications, rev. 41, Krško 1995

[3] Precautions, Limitations and Setpoints for Nuclear Steam Supply System, Rev. 10, 1994.

[4] RELAP5/mod2 Users Manual, H.G. Ransom et al., NUREG/CD 4312, EGG-2396, Idaho National Laboratory, INEL, August 1985.

[5] S. Fabic, Users Manual (Rev. 1.0) for LWR Plant Analyzer, December 1994

[6] D. Grgić, R. Sešo, M. Prah, NPP Krško Modelling Using LWRA Code, 3rd NSS Regional Meeting, September 16-19 1996., Portorož, Slovenia

[7] ESP-1.2.012 RELAP5 Transient Analysis Procedure, Krško 1995.

[8] NEK RELAP5/mod2 Nodalization Notebook, NEK ESD TR 13/95, Rev.0, Krško 1995.

[9] NEK RELAP5/mod2 Steady State Technical Report, NEK ESD TR 14/95, Rev.0, Krško 1995.

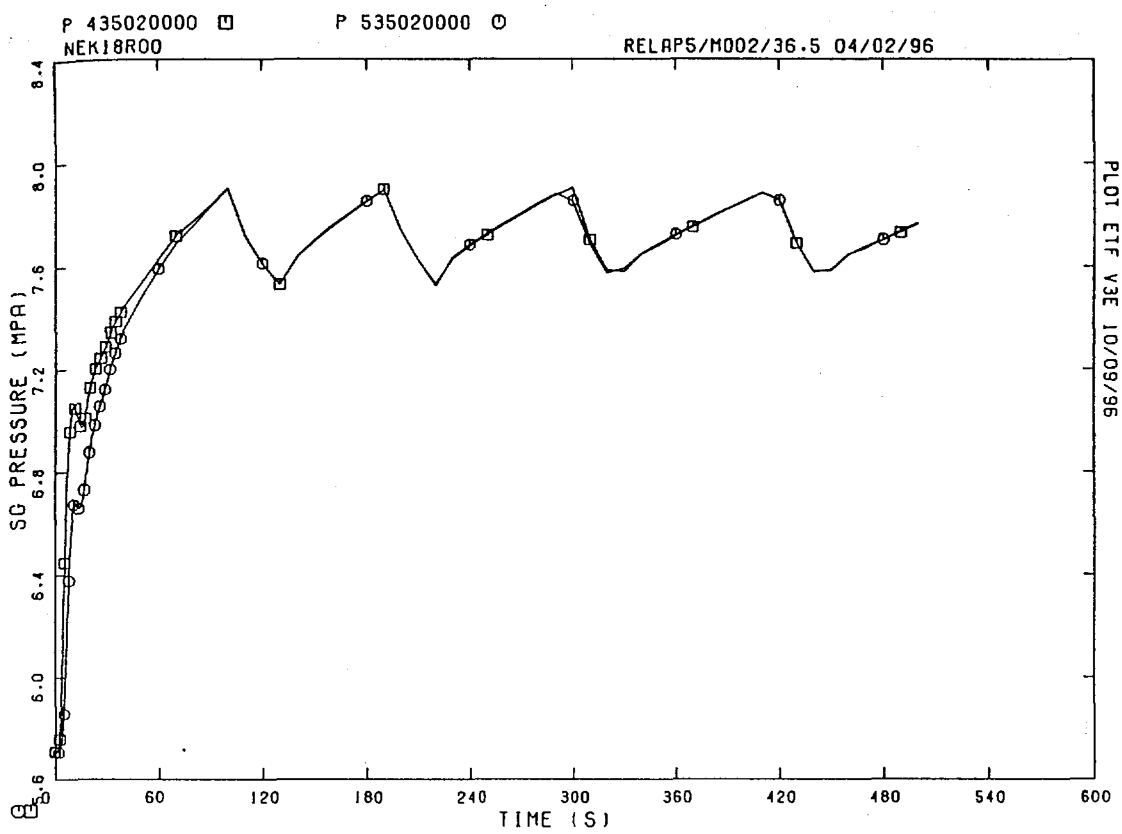

Figure 2. SG pressure behaviour in case when MSIV 2 is closed

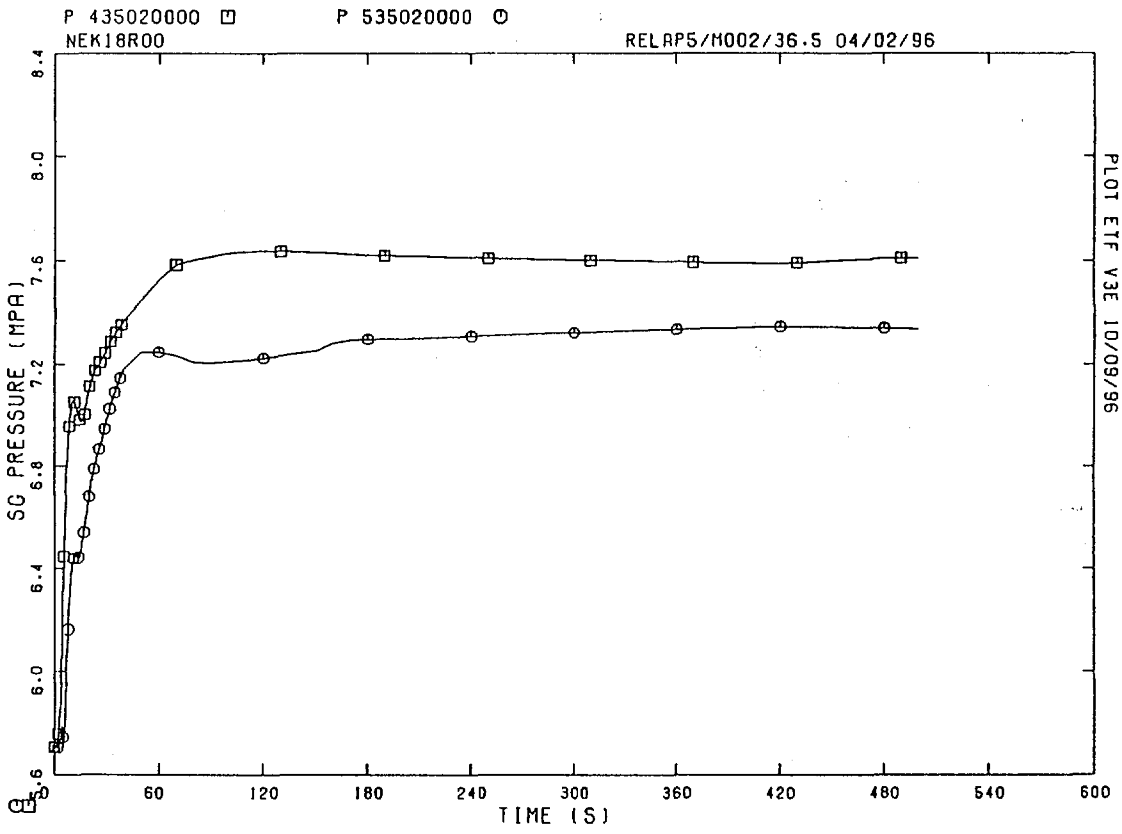

Figure 3. SG pressure behaviour in case when MSIV 2 is open

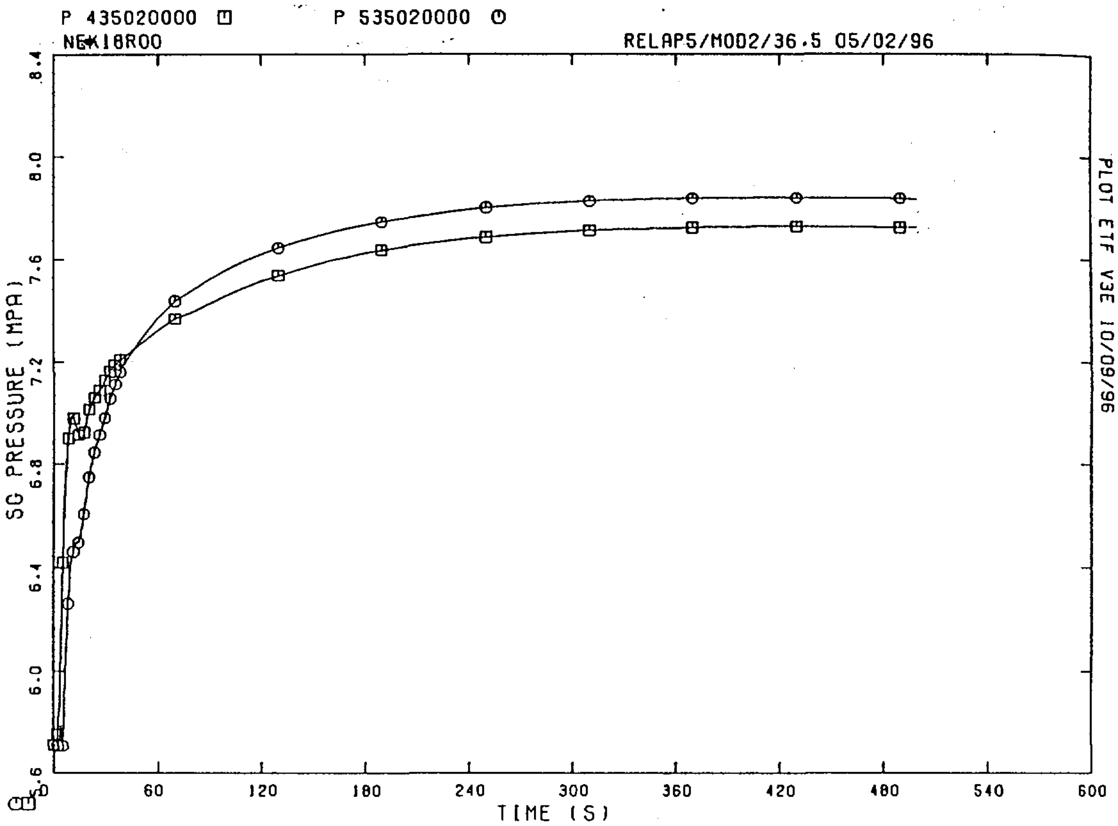

Figure 4. SG pressure behaviour in case when MSIV 2 is closed and leakage is taken into account

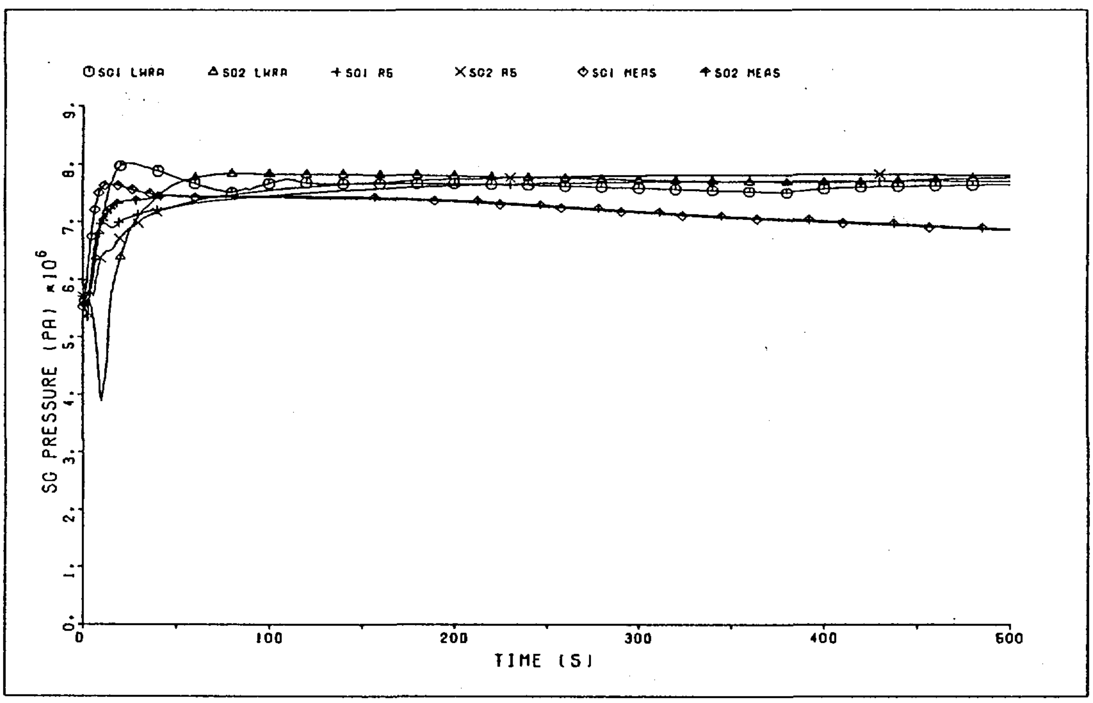

Figure 5. Comparison of the SG pressures calculated by LWRA and RELAP5 and measured in the plant