Proceedings of the Korean Nuclear Society Spring Meeting
Seoul, Korea, May 1998

Validation of the Excore Detector Module of PANBOX 2

Du Ill Kim, Jung Kil Kang, Sun Tack Hwang
Korea Nuclear Fuel Company

Yeong Il Kim
Korea Atomic Energy Research Institute

H. Finnemann, R. Böer
Siemens, KWU N, FRG

Abstruct

In the PANBOX 2 system an excore detector module simulating the excore signal responses during a short term transient is implemented in order to simulate the reaction of the flux detector and control system upon rapid power changes as it occurs e. g., in rod drop events. This module has been verified in the past by comparison calculations with the PANBOX 1 system. This report describes additional PANBOX 2 validation calculations which have been compared with experimental data measured at german plant KKG, cycle 1, for a rod drop event. In general, the PANBOX 2 results are in very good agreement with the KKG experiments. Therefore it is concluded that the excore detector model of PANBOX 2 is successfully validated.

1. Intrduction

The code system called PANBOX 2 has been developed at Siemens, KWU in Erlangen, FRG. PANBOX 2 is designed to calculate three-dimensional steady-state and transient full-core as well as part-core analyses. Neutronic and thermal-hydraulic modules can be coupled, evaluating the respective feedback mechanisms, or applied separately. Various options for efficient solution of the neutron diffusion equations are provided, as well as the capability to calculate coolant crossflow between channels in thermal hydraulics. Thus PANBOX 2 applications include high accuracy PWR core design and safety analyses also for events resulting in highly non-uniform power density distributions and/or low mass flow through the core /1/.

The reaction of the flux detector and control system upon rapid reactor power changes can be simulated with the PANBOX 2 system /2/. The excore model of PANBOX 2 has been verified within the PANBOX 2.3 verification process by comparison calculations with the PANBOX 1 system /3/. This report describes additional validation calculations which are compared with experimental data. They have been performed for a rod drop event because analyses of such transients require the evaluation of excore detector signals during the transient with respect to the occurrence of a reactor trip. The PANBOX 2 results are compared with the corresponding results obtained by experiments performed at nuclear power plant KKG in Grafenrheinfeld, FRG, Fig. 1, /4/.

2. Description of the Experiments

Experiments have been performed at plant KKG for cycle 1 and a burnup of 33 efpd. Rod C05, Fig. 1, has been dropped at HFP within 2.4 sec according to the falling curve given in Fig. 2. The other rod banks have been positioned as follows:

D10	= 64 cm	inserted
L+D	= 10 cm	inserted

The excore detector signals have been measured for the 4 radial detector positions both in the lower and upper core half, Fig. 1. The resulting signals as functions of time are referred as "uncalibrated" signals in Fig. 4-7.

3. Description of the PANBOX 2 Calculations

For PANBOX 2 calculations a neutronics data base NK_PWR has been generated starting from a SA90 calculation /5/ at a burnup of 33 efpd. Kinetics data have been generated with module KINDAT of SAV90. The following thermalhydraulic core boundary conditions have been used for cycle 1 and HFP conditions (3765 MW):

pressure	158 bar
inlet temperature	293.9 °C
inlet mass flow rate	3193.7 kg/m^2s

A rod drop analysis with the core simulator PANCOS of PANBOX 2 is generally performed by 2 steps:

(1) The first run requires control variable IWREXC>0 in the input block $WRITE. Additionally, the input block $EXCORE is read which describes the definition of excore detectors (Table 1.1). The steady-state and transient detector signals are written to file EXCORE_TAPE. The calculated power as a function of time is given in Fig. 3.

(2) Under control of IDEVAL=2, the second run serves as evaluation of the detector signals read from file EXCORE_TAPE. Therefore input block $CHEDSI is required, which contains the evaluation parameters according to the detection of occurrence of reactor trip (see Table 1.2). Please note, that these evaluation parameters have no influence on the generation and content of file EXCORE_PLOT which contains the excore signals as a function of time. These signals are nomalized to 1.0 at time t=0.0 for the sums of lower and upper detector values for each radial position.

In the described first run (1), the detector signals depend on the model parameters DETS1 and DETS2 which are used to roughly approximate the neutron transport from a node boundary to a detector position through water and steel by interpretation as removal cross sections /2/. In standard PANBOX 2 applications and now serving as the reference case A these cross sections have been defined in the past by PANBOX 2 user /6/ as

DETS1 = 0.18 cm^{-1} for the region between core boundary and core periphery and
DETS2 = 0.06 cm^{-1} for the region between core periphery and detector position,

respectively. To investigate also the dependency of the excore signals on the parameters DETS1 and DETS2, runs (1) and (2) have been repeated using the following alternative sets of values:

B)	DETS1 = 0.009	DETS2 = 0.03	(50 % of A)
C)	DETS1 = 0.018	DETS2 = 0.006	(10 % of A)
D)	DETS1 = 0.36	DETS2 = 0.12	(200 % of A)

4. Results

(1) Very good agreement between the PANCOS calculation and the KKG experiment is already achieved for case A comparing the calculated normalized excore detector signals with the uncalibrated measured values as Figs. 4-7 show.

(2) The agreement can be improved, when the uncalibrated measured values are calibrated to the calculated results for time t=0.0, as additionally plotted in Figs. 4-7.

(3) The influence of the model parameters DETS1 and DETS2 has been proven to be of less significance to the calculated detector signals as Figs. 8-11 for cases B, C, and D show. Therefore, the furthermore use of case A values in future PANBOX 2 rod drop analyses can be recommended.

5. Conclusion

The excore detector model pf PANBOX 2 has been successfully validated. PANBOX 2 results for the KKG rod drop transient have been compared with the corresponding experimental results. In general, PANBOX 2 results are very close to KKG results. Low influence of the PANBOX 2 model parameters on the excore detector signals have been observed.

References

/1/ R. Böer, R. Müller, H. Rascher
Code Manual PANBOX 2
WR KWU BT25/92/E516d, dated May 27, 1992

/2/ R. Böer
Specification and Implementation of the Excore Detector Simulation Model into PANBOX 2
WR KWU BT12/94/E371, dated Aug. 4, 1994

/3/ R. Böer, M. Grüner, J. Hüsken, C. Jackson, H. Rascher
Verification and Validation Summary for PANBOX 2.3
WR KWU BT12/94/E451, dated Oct. 7, 1994

/4/ Kernübersicht, Typ Grafenrheinfeld, R 222 E-32-3381, dated June 7, 1978

/5/ K. Koebke, G. Ambrosius, L. Hetzelt, S. Merk, H.-J. Winter
The Core Design Procedure SAV90 for Pressurized Water Reactors
Kerntechnik 57, Vol. 1, 1992, pp. 37 - 41

/6/ H. Bauer
Brennstoffenthalpieerhöhungen beim Störfall Steuerelementauswurf für Siemens-KWU DWR im Vergleich mit RIA-Experimenten,
Bearbeitungsdokumentation KWU BD/BT/13/94

Table 1.1 **Input Block $EXCORE**

see Fig. 1 or /4/

DETRAD	radius of detector positions measured from core center	380 cm
DETANG	angle of detector in first quadrant relative to x-axis of core-centered coordinate system	45 degrees
CORRAD	core radius	210.5 cm
DETS1	macroscopic removal cross section of water	case A-D
DETS2	macroscopic removal cross section of steel	case A-D

Table 1.2 **Record 1 of Input Block $CHEDSI**

BOLD	lower boundary for rate of detector signal change in percent of power BOPOW	-0.099 %
BOUP	upper boundary for rate of detector signal change in percent of power BOPOW	0.099 %
BOPOW	power to which the parameter BOLD and BOUP are related	3765 MW
TAU1	parameter 1 of impulse lag differential equation	2 sec
TAU2	parameter 2 of impulse lag differential equation	2 sec

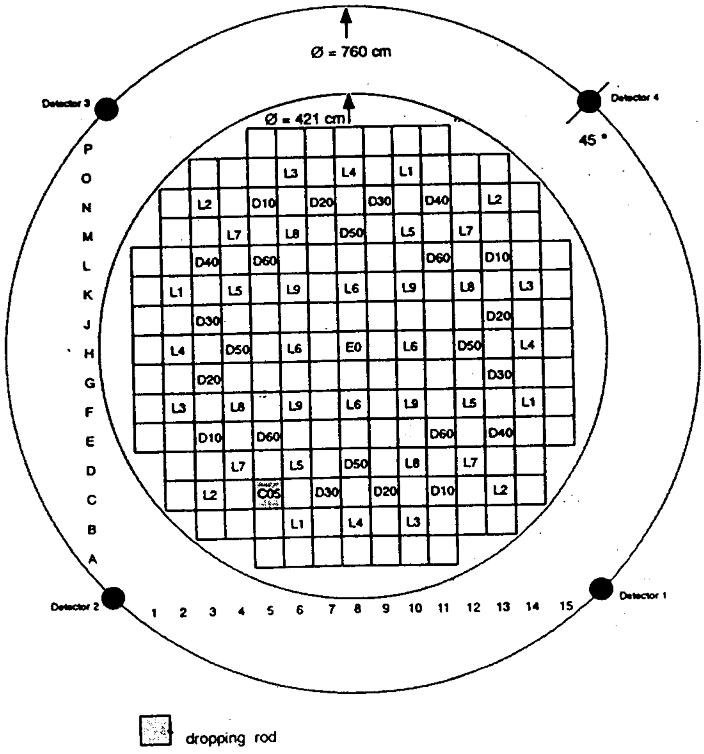

Fig. 1: Cross Section of Core KKG and Definition of Detector Positions in PANBOX 2

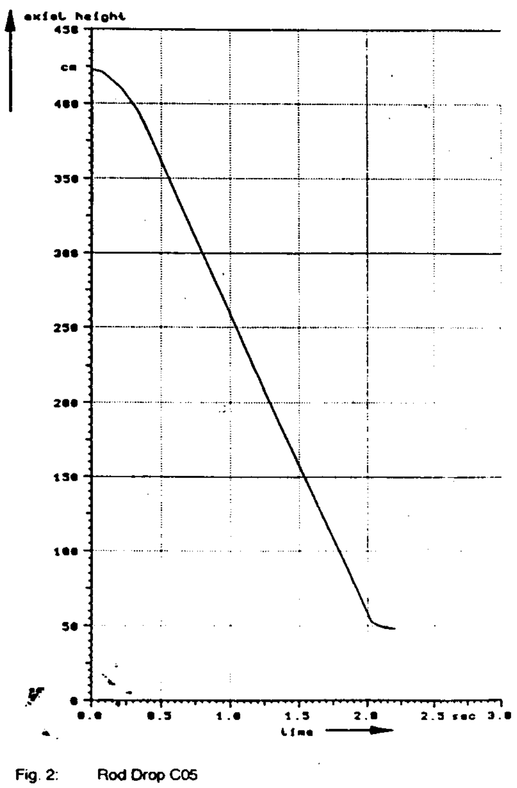

Fig. 2: Rod Drop C05

Position of Dropping Rod C05 as Function of Time

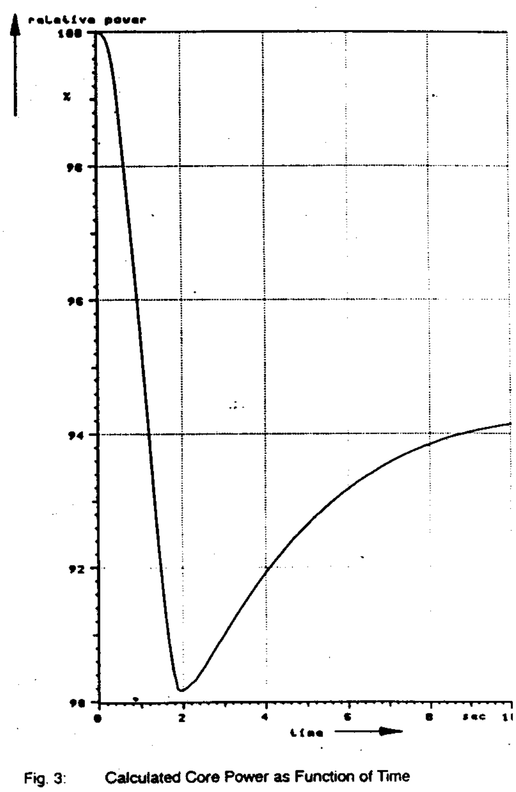

Fig. 3: Calculated Core Power as Function of Time

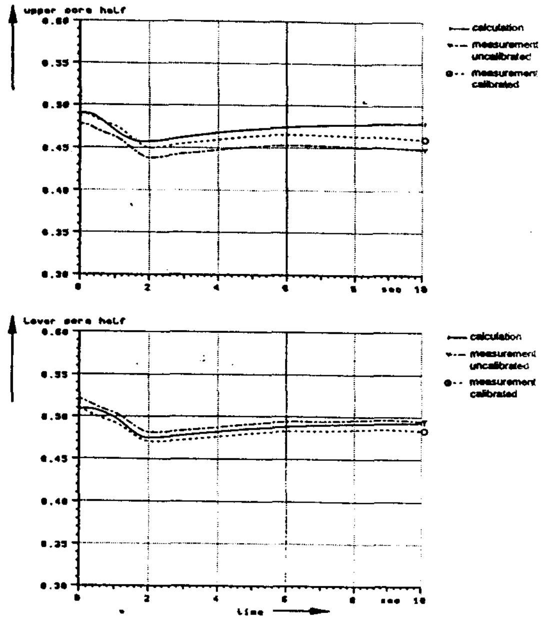

Fig. 4: Rod Drop C05
Excore Detector Signals for Case A Parameters
Detector 1

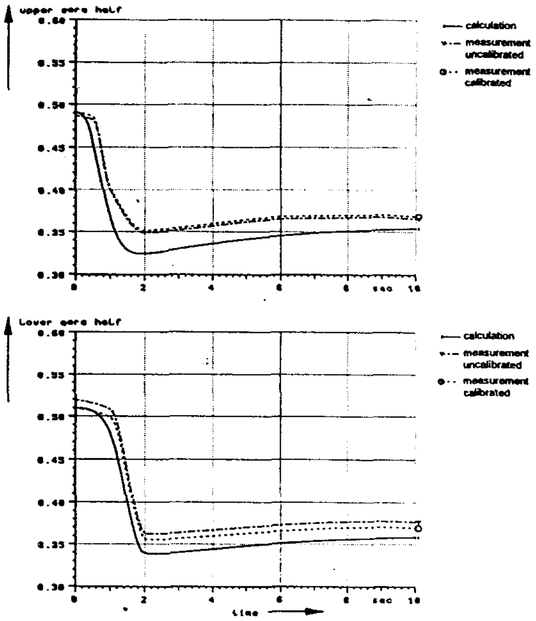

Fig. 5: Rod Drop C05
Excore Detector Signals for Case A Parameters
Detector 2

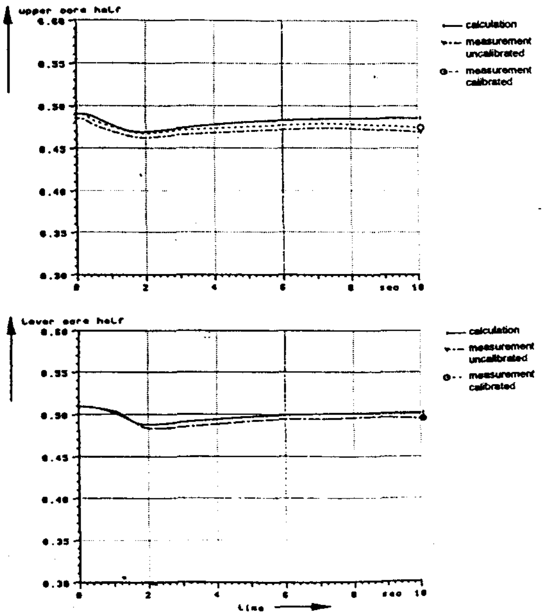

Fig. 6: Rod Drop C05
Excore Detector Signals for Case A Parameters
Detector 3

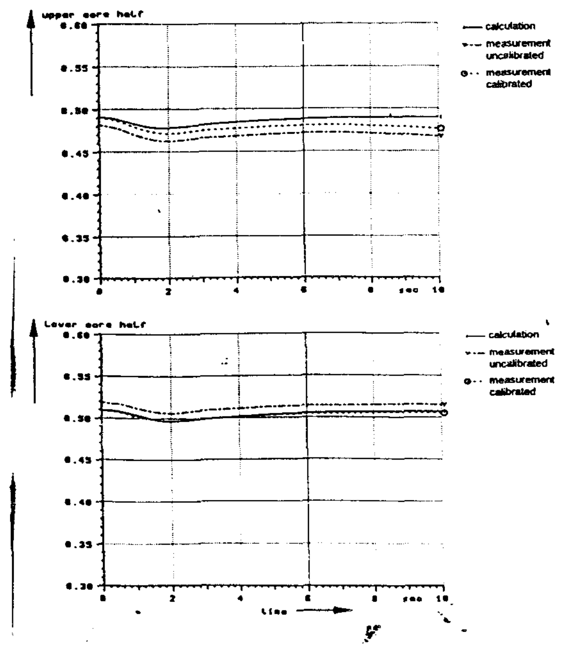

Fig. 7: Rod Drop C05
Excore Detector Signals for Case A Parameters
Detector 4

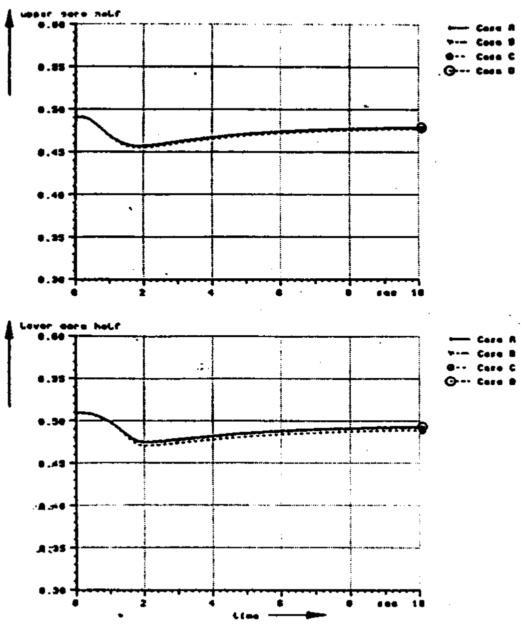

Fig. 8: Rod Drop C05
Calculated Excore Detector Signals for all Cases
Detector 1

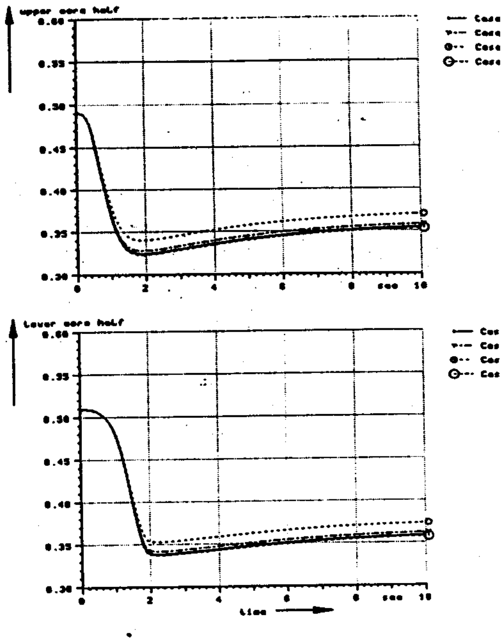

Fig. 9: Rod Drop C05
Calculated Excore Detector Signals for all Cases
Detector 2

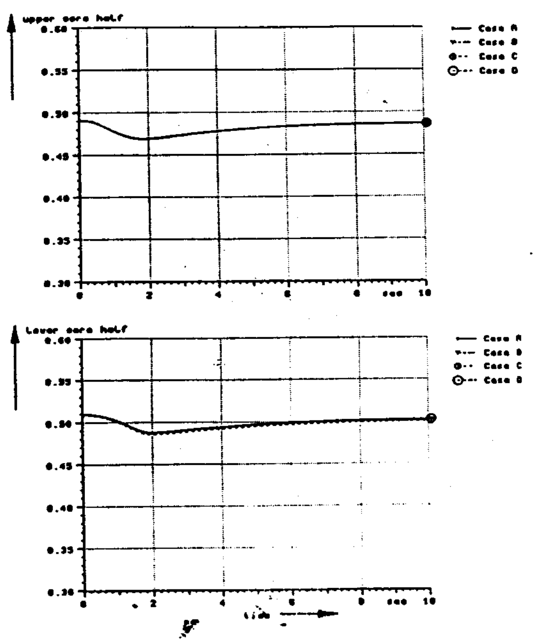

Fig. 10: Rod Drop C05
Calculated Excore Detector Signals for all Cases
Detector 3

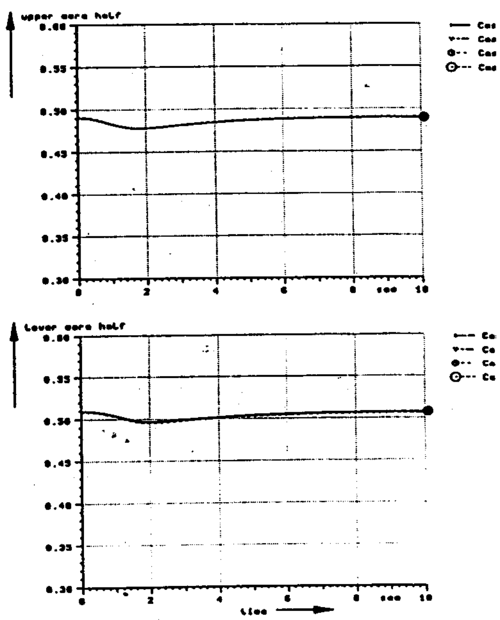

Fig. 11: Rod Drop C05
Calculated Excore Detector Signals for all Cases
Detector 4