THE REPUBLICAN ENERGY COMMITTEE OF THE SR OF SLOVENIA
LJUBLJANA, YUGOSLAVIA

NUCLEAR SAFETY ACTIVITIES
in
THE SR OF SLOVENIA
in
1 9 8 6

Ljubljana, June 1987

NUCLEAR SAFETY ACTIVITIES IN THE SR OF SLOVENIA IN 1986

Abstract

Currently Yugoslavia has one 632 MWe nuclear power plant (NPP) of PWR design, located at Krško in the Socialist Republic (SR) of Slovenia. Krško NPP, which is a two-loop plant, started power operation in 1981.

In general, reactor safety activities in the SR of Slovenia are mostly related to upgrading the safety of our Krško NPP and to developing capabilities for use in future units.

This report presents the nuclear safety related legislation and organization of the corresponding regulatory body, and the activities related to nuclear safety of the participating organizations in the SR of Slovenia in 1986.

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ABBREVIATIONS USED:

EGS	Elektrogospodarstvo Slovenije (Electricity Generating Board of Slovenia)
EIMV	"Milan Vidmar" Electrical Institute
IAEA	International Atomic Energy Agency
IBE	Inženirski biro Elektroprojekt
ICJT	Izobraževalni center za jedrsko tehnologijo (Nuclear Training Centre at the "Jožef Stefan" Institute)
IJS	"Jožef Stefan" Institute
IJS - RED	IJS Reactor Engineering Department
IMK	Institute for Metal Constructions
IRS	Incident Reporting System
JUGEL	Zajednica jugoslovenske elektroprivrede (Yugoslav Community of the Electricity Generating Boards)
NEK	Krško Nuclear Power Plant
NUKLIN	NUKLearni INstituti (Managing Community for the Research, Development and Peaceful Uses of Atomic Energy)
PRA	Probabilistic Risk Assessment
PSA	Probabilistic Safety Analysis
REI	Republiški energetski inšpektorat (Republican Energy Inspectorate)
RKE	Republican Energy Committee
RUŽV	Rudnik urana Žirovski vrh (Žirovski vrh Uranium Mine)
RBMK	Soviet Design of the Chernobyl NPP
SKEI	Yugoslav Federal Energy and Industry Committee
(US)NRC	(United States) Nuclear Regulatory Commission
2.SHJE group	working group preparing the second Slovene-Croatian nuclear power plant

A. ORGANIZATIONS AND LEGISLATION RELATED TO NUCLEAR SAFETY

With the coming into force of the federal "Act on Radiation Protection and the Safe Use of Nuclear Energy" (Federal Official Gazette No. 62/84, referred to hereinafter as the 1984 Act), Yugoslavia has a partly new organizational structure of the regulatory body, competent for nuclear safety. This competence is divided between the federal and the republic (and autonomous province) authorities.

1) Federal organization

a) Regulations:

Since nuclear safety is a matter of importance for the whole country, federal authorities regulate this field of activities. Thus, the FEDERAL ENERGY AND INDUSTRY COMMITTEE is authorized to enact four very important regulations for carrying into effect the nuclear safety provisions of the above mentioned 1984 Act, i.e.:

- Regulation of the conditions for siting, design, construction, commissioning and operation of nuclear facilities;
- Regulation of the format and contents of safety analysis reports for nuclear facilities;
- Regulation of qualifications, experience and training of personnel in nuclear facilities;
- Regulation of accounting and control of nuclear materials.

The FEDERAL COMMITTEE FOR LABOUR, HEALTH AND SOCIAL WELFARE is authorized to adopt several regulations concerning radiation protection in all fields where radiation sources are being applied (e.g. regulations of the national monitoring system for environmental radioactivity, of the disposal of radioactive waste, of the application of ionizing radiation sources for medical purposes, etc.).

b) Licensing:

Responsibility for licensing nuclear facilities in Yugoslavia lies with the authorities in the republics or autonomous provinces where the plant is to be located. However, to assure an assessment and overall control of nuclear safety questions important for the whole country, a federal COMMISSION FOR THE SAFETY OF NUCLEAR FACILITIES was established within the FEDERAL ENERGY AND INDUSTRY COMMITTEE. The competent authority in each

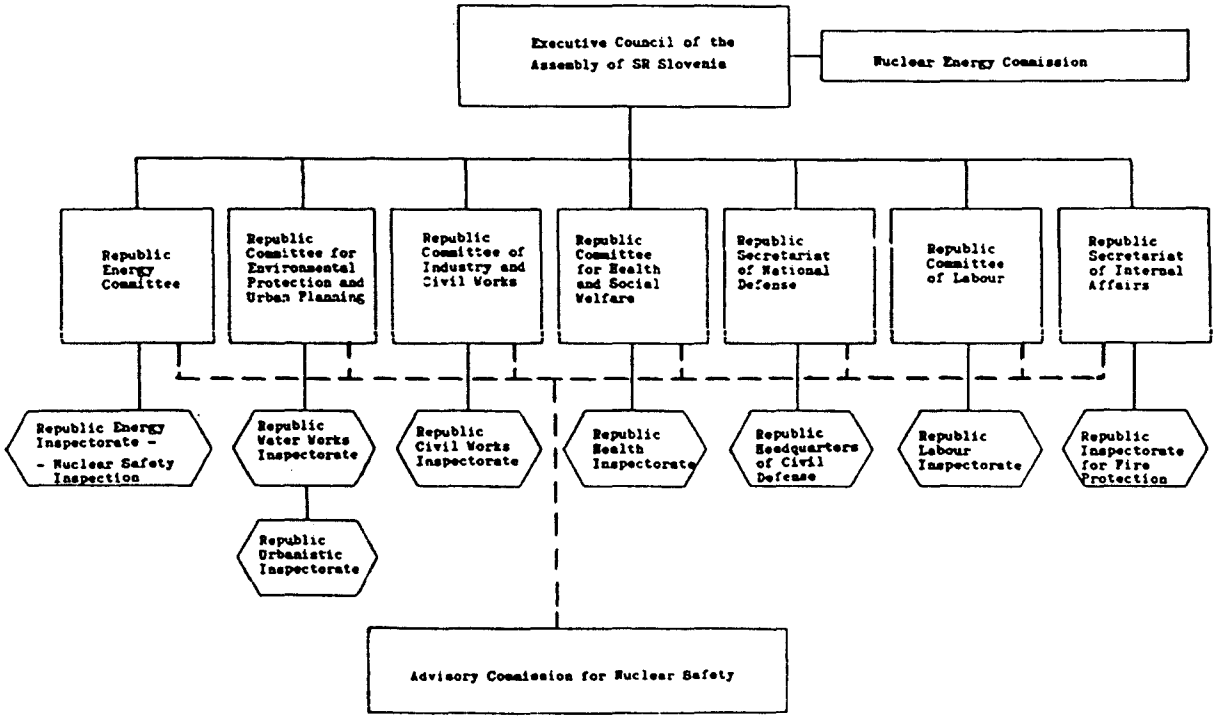
republic or province may issue licenses for the site, construction, commissioning and operation of a nuclear facility only if the Federal Commission has concurred that all the prescribed safety conditions have been met.

c) Inspections:

Inspections and enforcement of the 1984 Act are carried out by the competent bodies in each republic or autonomous province. However, in some cases, such as e.g. the implementation of international agreements, the use of standards and quality norms etc., the federal body has the right to define binding instructions to the competent republic or provincial bodies or even perform an activity if they failed to carry it out.

2) Regulatory structure in the SR of Slovenia

Regulatory authorities acting on matters related to nuclear safety in Slovenia are shown below.



Regulatory organization in the SR of Slovenia related to nuclear safety

At the level of the SRS, the competence to pass regulations for licensing and for inspection is described below within the separate presentations on various bodies and organizations. Generally speaking, nuclear safety in the SR of Slovenia is regulated by the republic's (198Ø) "Act on the Execution of Radiation Protection and Measures for the Safety of Nuclear Facilities" (Republic Official Gazette No. 28/8Ø). Due to the comprehensive and detailed provisions of the federal 1984 Act and Regulations, passed pursuant to it, there is little room left for the Republic's legislative activity. The most important legislative competence of the republic is the determination of the regulatory structure for the licensing and inspection activities. Furthermore, in detailing the general safety measures, prescribed by the federal 1984 Act, the SR of Slovenia adopts every 5 years a "Programme of Measures for Radiation Protection and Nuclear Safety". On this basis the competent administrative bodies of the SR of Slovenia, each in its own field of activity, by the end of every year prepare a detailed programme of general activities to be performed in the coming year. In the field of nuclear safety, this annual pogramme of general measures is financed by a special "Fund for nuclear safety" to which the budget of Slovenia and the 3 owners of nuclear facilities in Slovenia contribute on the basis of a social compact, signed in 1984. In this way general safety measures of interest for the whole republic of Slovenia are assured. Safety measures in each nuclear facility remain, of course, the responsibility of their operators.

The EXECUTIVE COUNCIL of the Assembly of the SR of Slovenia, i.e. the government, has very few direct functions related to nuclear safety. It adopts the already mentioned "Programme of Measures for Radiation Protection and Nuclear Safety" for a period of 5 years. It is also his direct competence to order the evacuation of the population in case of a nuclear accident or radiological emergency. Otherwise the various republican administrative authorities are acting within its structure.

Before describing the administrative authorities bearing responsibilities related to nuclear safety, three important special republican bodies have to be mentioned.

The NUCLEAR ENERGY COMMISSION advises the Executive Council on questions related to nuclear energy policy, development of the national nuclear programme and other general matters.

The ADVISORY COMMISSION FOR NUCLEAR SAFETY is the central experts' group in Slovenia, dealing with safety related questions and coordination among different governmental organs. It consists of representatives of governmental bodies and various research institutes. All questions concerning radiation protection and nuclear safety are passed to this commission. In the course of a licensing procedure, the competent administrative organs have to obtain an opinion from the Commission, before their decision is taken.

The REPUBLICAN HEADQUARTERS FOR CIVIL DEFENCE is responsible

for planning and executing the civil protective measures in case of national disasters and other significant emergencies, including nuclear accidents and radiation emergencies.

The REPUBLICAN ENERGY COMMITTEE is, within the limits of the federal regulations, authorized to adopt various regulations related also to nuclear safety (e.g. on regular reports on the operation of a nuclear facility etc.). Acting within its legal framework the REPUBLIC ENERGY INSPECTORATE is, according to the existing republic 198Ø Act, authorized to issue the commissioning permits for nuclear facilities. The REPUBLIC ENERGY INSPECTORATE has a NUCLEAR SAFETY INSPECTION which is responsible for inspecting the nuclear facility during construction and operation. In discharging their responsibilities, this inspection may, among other, discontinue the operation of a nuclear facility, if not all prescribed conditions have been met.

The REPUBLICAN COMMITTEE FOR ENVIRONMENTAL PROTECTION AND URBAN PLANNING is authorized to issue a site license for a nuclear facility. Through its REPUBLIC WATER WORKS INSPECTORATE and REPUBLICAN URBANISTIC INSPECTORATE, control over this part of the administrative procedure is executed.

The REPUBLICAN COMMITTEE FOR INDUSTRY AND CIVIL WORKS is competent for the rest of the licensing procedure. It issues the licenses for construction and for the operation of a nuclear facility, if all the prescribed conditions are met. The REPUBLICAN CIVIL WORKS INSPECTORATE has an authorization for inspections during the construction. The REPUBLICAN COMMITTEE OF HEALTH AND SOCIAL WELFARE is competent for the control of environmental radioactivity and the control of workers exposed to radiation. These tasks are realized through the REPUBLICAN HEALTH INSPECTORATE.

The REPUBLICAN COMMITTEE OF LABOUR, the REPUBLICAN SECRETARIAT OF INTERNAL AFFAIRS, and the REPUBLICAN SECRETARIAT OF NATIONAL DEFENCE perform actions relating to their competences.

These administrative bodies, in discharging their responsibilities, rely on the professional support of authorized organizations in technical matters. The AUTHORIZED ORGANIZATIONS which are listed in the Official Gazette perform important technical tasks related to nuclear safety and report annually to the competent administrative bodies.

At the beginning of 1987 an important reorganization of the regulatory body in the Socialist Republic of Slovenia was initiated. Up to now no specialized, exclusively competent and responsible regulatory body for nuclear safety existed as described above.

Activities in this field have been carried out by different committees and secretariats, by the Inspectorate for Nuclear Safety (in the framework of the Republican Energy Inspectorate under the Republican Energy Committee) and by the Advisory

Commission on Nuclear Safety. Above all the functions of promoting energy production and the function of surveillance over it had to be divided between different bodies. In due time it was found appropriate to improve this situation for various organizational, procedural and functional reasons. It was decided therefore to propose the establishment of a new body, the Republican Administration for Nuclear Safety. In April 1987 the Government of Slovenia approved an amendment to the 1980 "Act on the organization and sphere of activity of the Republic's Administrative Bodies" etc. (Official Gazette of the SRS No 50/80, 12/82, 9/85, 14/86) and passed it to the Assembly of the SR Slovenia. It is expected that the Assembly will discuss the issue in June and October 1987.

According to this Bill, the proposed Republican Administration for Nuclear Safety will be an independent, functionally autonomous body, dealing with all matters concerning nuclear safety, including legislative competences for Republican Regulations, some of the licensing procedures, enforcement and compliance assurance of the Federal and Republican legislation, inspections etc. It will be directly responsible to the Government and to the Assembly of the Socialist Republic of Slovenia.

If the enactment of the proposed Bill is realized in the way it is planned, a very important step will be taken and an old idea for the improvement of nuclear safety in Slovenia will be brought to life. In this way also the Agency's Code of Practice on Governmental Organization (SS No. 50-C-G), Section 3.1 will be implemented in the Socialist Republic of Slovenia.

3) Activities on the preparation of regulations

As already mentioned, pursuant to the 1984 Act, the Federal Energy and Industry Committee is authorized to adopt the following four regulations important to nuclear safety:

- the regulation of the conditions for siting, construction, commissioning and operation of nuclear facilities;
- the regulation of the contents of safety reports for nuclear facilities;
- the regulation of professional qualifications, experience and training of personnel in nuclear facilities;
- the regulation of accounting for and control of nuclear materials.

Drafts of all four regulations are being prepared by working groups from the SR of Slovenia. Through coordination by the "Jožef Stefan" Institute from Ljubljana, the drafts of the "Regulation of professional qualifications, experience and

training of personnel in nuclear facilities" and of the "Regulation of accounting for and control of nuclear materials" were completed and presented to federal authorities for approval. Also the working drafts of the "Regulation of the conditions for the siting, design, construction, commissioning and operation of nuclear facilities" and of the "Regulation of the format and contents of safety analysis reports for nuclear facilities" are being prepared in cooperation with experts from Slovenia.

In the field of radiation protection the Federal Committee for Labour, Health and Social Welfare adopted nine regulations. In Slovenia a working group was set up which contributed many useful amendments during the drafting of the mentioned regulations.

In the meantime, a formal procedure for the amendment of the Constitution of the Socialist Federative Republic of Yugoslavia was initiated. The amendments, which were proposed for other reasons, among other issues refer also to nuclear energy. Thus, it is proposed to establish an energy and radiation protection committee. In this way the draft proposal also formally entitles the Federal Assembly to adopt the entire substantial legislation in this field, a competence which until now, from the constitutional point of view, was not so clearly defined. It remains, however, up to the individual Republics and Provinces to adopt further legislation, necessary for the execution of the federal law.

It is expected that amendments to the Constitution, providing a clearer constitutional organization of the Federation, will not interfere with the 1984 Act.

After adopting several important supplementary Regulations, the 1984 Act is being more and more completed, providing a satisfactory legislative basis for all activities concerning nuclear safety and radiation protection. It is important to point out that it was the constant aim of the legislator to introduce through the 1984 Act, and especially through the regulations adopted on its basis, the principles and philosophy of the IAEA Safety Standards and Guides.

4) Activities of the Nuclear Safety Inspectorate

Introduction

The Nuclear Safety Inspection operates within the Republican Energy Inspectorate as concerns affairs subject to Republican authorities.

The 1984 Act provides a basis for the work of regulatory inspection. The major activities of inspection are connected with the following:

training of personnel in nuclear facilities" and of the "Regulation of accounting for and control of nuclear materials" were completed and presented to federal authorities for approval. Also the working drafts of the "Regulation of the conditions for the siting, design, construction, commissioning and operation of nuclear facilities" and of the "Regulation of the format and contents of safety analysis reports for nuclear facilities" are being prepared in cooperation with experts from Slovenia.

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Krško NPP reports:

- regular Krško NPP monthly reports
- report on radioactive release from Krško NPP
- report on changes of nuclear material in Krško NPP
- report on changes of nuclear material at Podgorica
- report on radiation dose rates in Krško NPP
- annual Krško NPP reports
- reports on exceeded releases of liquid or gaseous effluents

Krško NPP outages:

- plant outage from the electric grid
- violation of technical specification limitations
- unplanned plant shutdowns

Final Safety Analysis Reports:

- revisions of technical specifications
- final safety analysis report to Krško NPP
- index of operating procedures
- examinations of reactor vessel samples

Krško NPP repairs:

Measurements of the Krško NPP environment:

- programme of meteorological measurements
- radiological monitoring of the Krško NPP environment
- nonradiological monitoring of the Krško NPP environment

Reports from authorized and other organizations:

- annual reports of authorized organizations
- preparations for the construction of the 2nd Croatian - Slovene nuclear power plant

Confirmation and renewal of regulations:

- cooperation in elaborating proposals for regulations
- proposal for issuing regulations
- cooperation in changing regulations

Explanations:

- explanations concerning the competence of nuclear safety inspection
- opinions on regulations and their use in the field of nuclear safety

Professional examination and qualification of operational staff:

- cooperation in training programmes
- cooperation in qualification test commissions

There are a number of other activities that are covered by the following inspectorates:

- Republican Energy Inspectorate (within which the Nuclear Safety Inspectorate operates)

- Republican Sanitary Inspectorate which is connected with the Republican Health and Welfare Committee (their competence is radiation protection)

- Republican Water Inspectorate which is connected with the Environmental Protection and Urban Planning Committee (their competence is ecological monitoring of the Krško NPP environment, including temperature change of the river Sava, etc.).

With respect to fire protection, emergency planning and preparedness etc. there is also a close cooperation with the competent authorities at the republican level. The Nuclear Safety Inspectorate coordinates the various inspectorates' activities concerning the Krško NPP.

As the regulatory body is not self-sufficient in all technical areas relevant to inspection, it supplements its inspection programme through qualified and authorized consultant organizations. These are normally involved during all yearly outages for refuelling, when extensive maintenance is being done. Each year they give a written report to the regulatory body about their findings, safety assessments and recommendations. Their findings and recommendations then serve as a basis for the inspectors' activities in the future. In the case of the occurrence of an unusual event or finding, technical evaluations and studies are done by these institutions. The nuclear safety inspector can at any time request an extra meeting of Nuclear Safety Commission in order to have an urgent safety matter reviewed or to obtain additional advice. In particular, the Nuclear Safety Inspectorate took part in the following Krško NPP modifications:

- review of TMI documentation
- problems related to the steam generator
- SU-PA-12 test
- test operation of the cooling tower system
- reactor head deaeration
- modernization of the data processing system in Krško NPP

The Nuclear Safety Inspectorate cooperated in the following IAEA projects: the IAEA Incident Reporting System, the ASSET mission to Yugoslavia, and the PSA project (INT/Ø9/Ø63).

B. ACTIVITIES RELATED TO NUCLEAR SAFETY

Activities in the field of nuclear safety are performed by the Regulatory Body (see Section A of this report), Krško NPP personnel and the authorized organizations: IJS, EIMV, IMK, IBE and others.

Nominated representatives of the authorized institutions have cooperated in work performed by SKJV (Nuclear Safety Committee of the SR Slovenia) and in examination of NPP Krško operators.

Activities presented in chapters II to VII are focused mainly on the "Jožef Stefan" Institute, while activities of other authorized organizations are described in chapter VII.

I. NUCLEAR POWER PLANTS

1. Krško Nuclear Power Plant Operation in 1986

a) In 1986 the plant produced 3824.5 GWh of electric energy, which is 1.2% above the planned production. Generator on-line operation was 6561 hrs. By May 1987 the NPP Krško has supplied over 20.000 GWh to the grid.

Figure 1 shows monthly production of the Krško NPP in 1986

b) Thermal energy generated in 1986 was 11 671 379 MWh and the burnup was 9949 MWD/MTU.

c) Cumulative factors for unit service and availability after January 1,1983, when the startup tests were completed:

		1986	cumulative
Unit Availability Factor	(%)	74.9	74.5
Unit Capacity Factor	(%)	69.0	69.8
Unit Forced Outage Rate	(%)	1.3	3.5

Analysis of operating period	hours	%
Total time availability of operation	8760	100
Plant operating time	6561	74.9
Total outage time:	2199	25.1
- refuelling outage	1927	22
- planned shutdowns	155	1.8
- unplanned shutdowns	117	1.3

Figure 2 shows Krško NPP monthly time availabilities in 1986.

Visit of IAEA Safety Team

An IAEA Assessment of Safety Significant Events Team (ASSET) visited Yugoslavia's Krško nuclear power plant in November/December - the first such mission to be sent by the Agency to a member state. Yugoslavia had volunteered to make Krško available for the ASSET mission to test the assessment methods developed for the IAEA's nuclear safety programme. The authorized organizations IJS, EIMV, and IMK cooperated with the ASSET mission of IAEA experts.

Figure 1: NPP Krško Electricity Production (3824.5 GWhr) In 1986

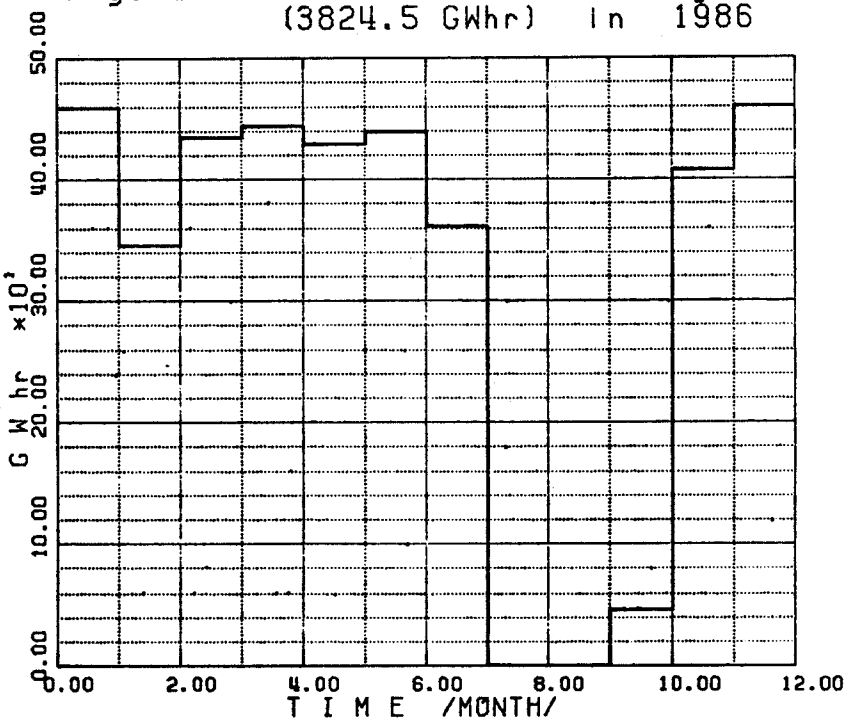


Figure 2: Availability Factor of the NPP Krško In 1986

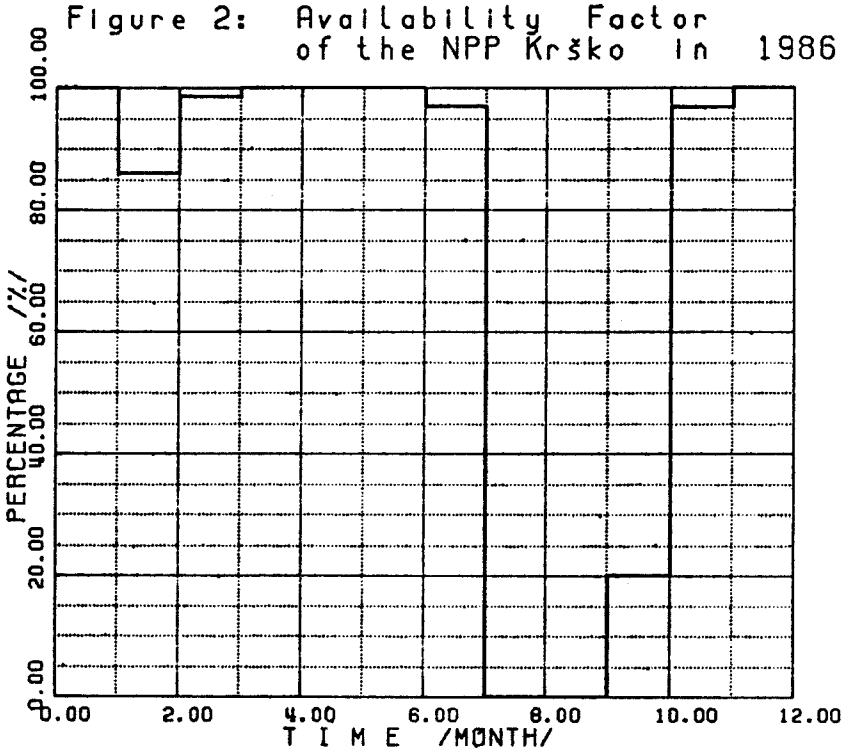


Table 1: Power reductions and shutdowns of the Krško NPP in 1986 more than 20% of the nominal power and for more than 4 hours

No.	Date	Type (1)	Duration (hours)	Cause (2)	Mode (3)	Remarks
1)	February 22-23	2	44	A	manual	
2)	Feb.24	2	9	A	manual	
3)	Feb.27 to Mar.01	1	51	A	R-regular	
4)	March 4	1	21	A	R-forced	power reduction
5)	March 14	1	9	A	R-forced	power reduction
6)	May 1-5	2	102	H	manual	power reduction
7)	July 9	1	18	A	R-regular	
8)	Aug.01 to Oct.24	2	2055	B,C	R-regular	refuelling, maintenance
9)	Oct.24	1	28	A	automatic	
10)	Nov.17	1	20	A	automatic	

Legend:

(1) 1 ..... Forced
2 ..... Scheduled (Planned)

(2) A: Equipment failure (description)
B: maintenance or testing
C: refuelling
D: regulatory body requirements
E: operator training, exams
F: administrative action (description)
G: operating error (description)
H: other (description)

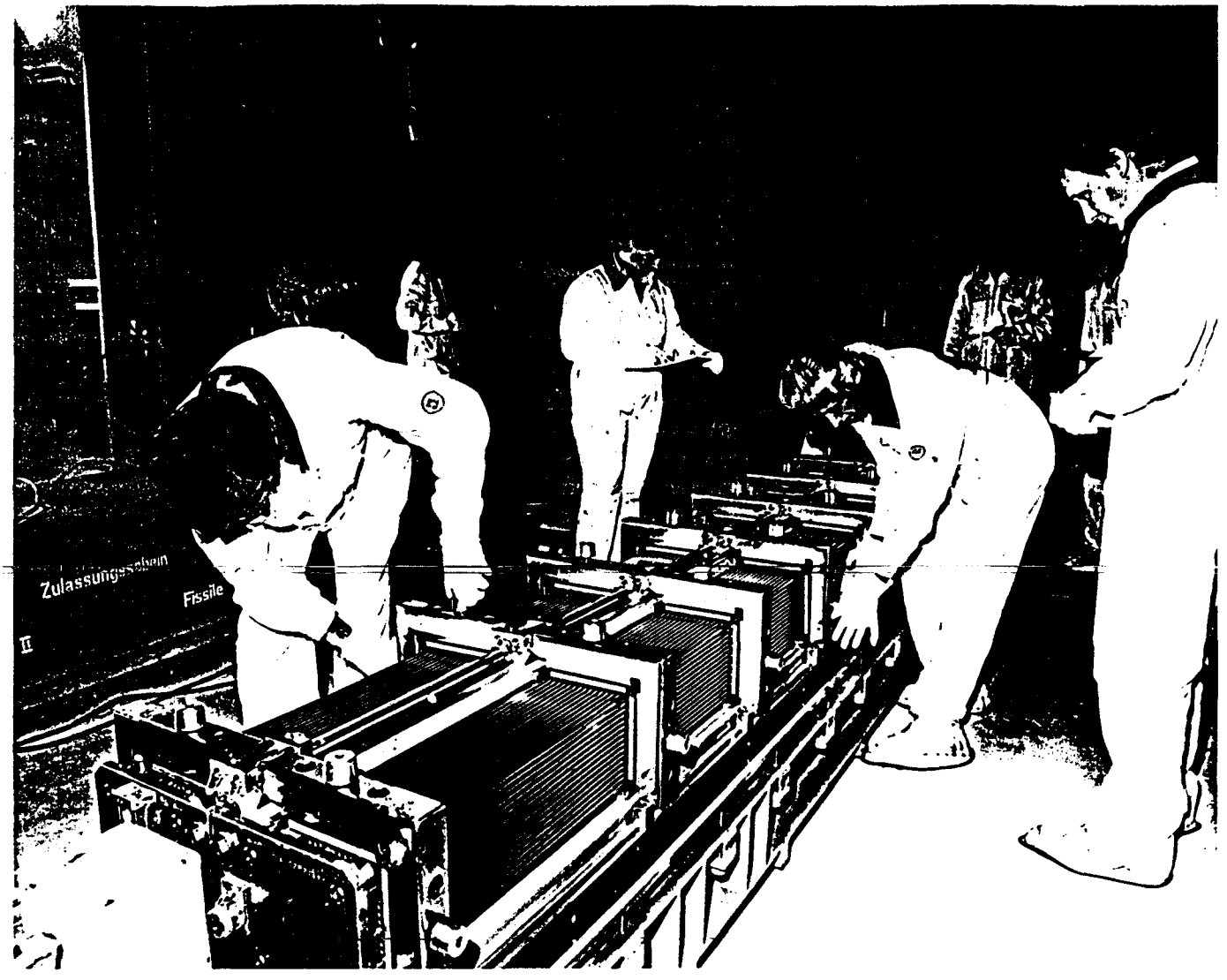
(3) Manual (regular)
Manual (forced)
Automatic
Other (description)

Table 2: DESCRIPTION OF PLANNED AND UNPLANNED SHUTDOWNS AND POWER REDUCTIONS BY MORE THAN 20% OF THE NOMINAL VALUE AND FOR MORE THAN 4 HOURS IN 1986

No.	Date	Duration	Description
1)	Feb.22 to Feb.23	44 hrs	The plant was manually shut down due to steam leakage on moisture separation lines of a high-pressure turbine part. Leakage was caused by tube erosion. Damaged parts were cut out and replaced.
2)	Feb.24	9 hrs	A repeated leakage on drain lines of a high-pressure part of a turbine. The plant was manually shut down.
3)	Feb.27	51 hrs	HD A and B pumps trip caused by HD control system failure and condensate leakage in sections D and C resulted in forced plant shutdown. HD LCV5126 valve repair and plant startup followed.
4)	Mar.4	21 hrs	Power reduction to 50% due to loss of flow across LCV 5126 and both HD pumps trip.
5)	Mar.14	9 hrs	Power reduction to 55% due to HD A pump trip and simultaneous repair of HD B pump.
6)	May 1-5	96 hrs	Power reduction to 50% on dispatcher's request No.356.
7)	Jul.9	18 hrs	Plant shutdown due to vacuum loss in a condenser. Safety pin of a "tapproge filter" was repaired and B condenser was cleaned.
8)	Aug.1 to Oct.24	2055 hrs	Annual refuelling outage, eddy current test of SG tubes, annealing of shot pinning parts of SG tubes.
9)	Oct.24	28 hrs	At lockout relay 86U activation for test purposes, there was no rapid switch over from M1 to MD1 bus. D/G1 started. Automatic reactor shutdown occurred. Due to steam leakage on turbine stop valve No.3 and due to the failure of isolation valve No.20141, uncontrolled cooling of the primary system occurred. Pressure drop in the secondary system activated the safety injection system. Termination of safety injection and event recovery according to the procedure followed.
10)	Nov.17	20 hrs	Feedwater control valve FCY 551 closed, which caused S/G1 level decrease and automatic plant shutdown.

2. Future Nuclear Power Plants

Preparatory work has been going on for the planned series of nuclear power plants to be built for the Yugoslav electricity grid up to the year 2000. JUGEL (Zajednica jugoslovenske elektroprivrede) has ordered a study of safety criteria to be applied for these nuclear power plants. The Reactor Engineering Division at the "Jožef Stefan" Institute has coordinated the effort in which several Yugoslav institutions took part and the resulting final report was published in 1986.



Unpacking of fuel in the Fuel Handling Building

II. SYSTEMATIC REVIEW AND RECORDING OF SAFETY RELATED ISSUES

1) Report on Safety Related Issues in 1986

Based on the "Programme of Measures for Radiation Protection and Nuclear Safety", the Regulatory Bodies of the Socialist Republic of Slovenia require a systematic review of selected safety related activities and independent evaluation of operational events in nuclear plants and facilities abroad and from the Krško NPP to be conducted and reported to them. This work is done by the "J.Stefan" Institute, located at the Reactor Centre at Podgorica, about 10 km from Ljubljana, assisted by the authorized institutions EIMV (Elektroinstitut "Milan Vidmar") and IMK (Institut za metalne konstrukcije) from Ljubljana.

In the report prepared for 1986 a description is given of the present status of regulatory codes, new designs, research activities and operating experience as regards nuclear safety abroad.

In the field of codes and regulations the report describes the USA Regulation of Advanced Nuclear Power Plants and USA Safety goals for the operation of nuclear power plants (Statement of policy, 10 CFR 50).

An overview of advanced designs and of reactor safety research is included. The IAEA index on reactor safety research, as run in member states, is shortly described. So is INSAG (International Nuclear Safety Advisory Group, IAEA) activity and the situation in the TMI-2 NPP in the USA.

As regards the operational events the following operational events were analysed:

- loss of on-site power supply and water hammer in the San Onofre 1 NPP (Nov. 21, 1985),
- loss of DC power supply to the control system and the subcooling transient in the Rancho Seco NPP (Dec. 26, 1985),
- UF6 release in Sequoyah Fuel Corporation (Jan. 4, 1986),
- the accident at the Chernobyl nuclear power station, Unit 4, (April 26,1986), and
- the operational transient in THTR-300 at the Hamm Uentrop NPP (May 1986)

The annual US NRC report and the IAEA report on nuclear safety activities in 1985 are presented in detail. Finally, a discussion on the authorized organizations and the quality assurance in nuclear installations with respect to the Yugoslav regulations is given.

2) Post Chernobyl Accident Activities

Immediately after the occurrence of the accident in the Chernobyl NPP, the division staff have elaborated a safety analysis of characteristics of RBMK reactors and estimated the probable events and consequences.

With the CRAC-2 code the upper limit of the expected acute consequences was assessed for whole body and thyroid doses, the source term being taken as the steam explosion scenarium in the PWR (1A accident) and assuming a direct wind from the site to our country.

Later, as the question of the radioactive cloud rise at the Chernobyl site was open, its effects on acute irradiation of thyroid, total bone marrow, lower large intestine, lungs and the whole body were studied, again with the help of CRAC-2, in great detail. Some of the results are presented in Figures 3, 4 and 5.

From the calculation of partial doses to individual organs, the influence of the release height on lung dose is shown in Figure 3. At a fixed release height, dose magnitudes as received by the whole body, bone marrow, lower large intestine, lungs and thyroid, are shown in Figure 4. The three contributions from the radioactive cloud, from the contaminated ground and from inhalation of contaminated air to the total marrow dose are presented in Figure 5.

3) Safety Related Library

All documents collected by local institutions which are related to nuclear safety are centrally registered by the help of the IJS DIS program package. Records include the following items: date of publication, language, signature, author, title, place of publication, publisher, institution, type of document, keywords and remarks. In this way all documents can be found if only one of the above mentioned items is given to the computer. The list of documents is being updated monthly and the information on the latest documents is distributed to all parties of the Agreement on Exchange of Information. The list of documents presently contains more than 5000 records which are classified according to the institutions where they are located. At present the Safety Documentation Library covers publications collected by IJS, EIMV, IMK and partially by NEK and RKE.

Figure 3: ACUTE EFFECTS FROM EARLY EXPOSURE. LUNG DOSE /In sieverts/, RELEASE FROM HEIGHT H.

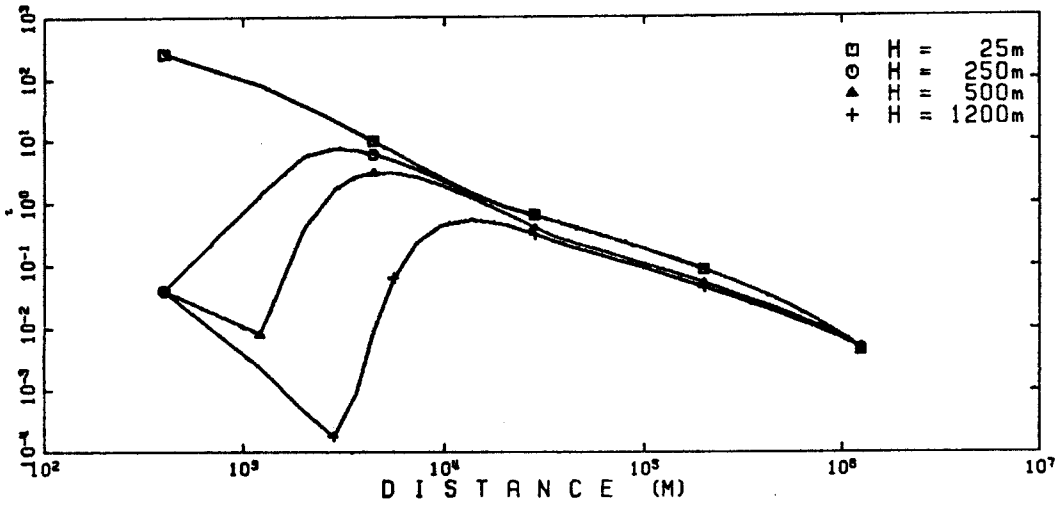


Figure 4: ACUTE EFFECTS FROM EARLY EXPOSURE. DOSE /Sv/ TO INDIVIDUAL ORGANS. RELEASE FROM 500m.

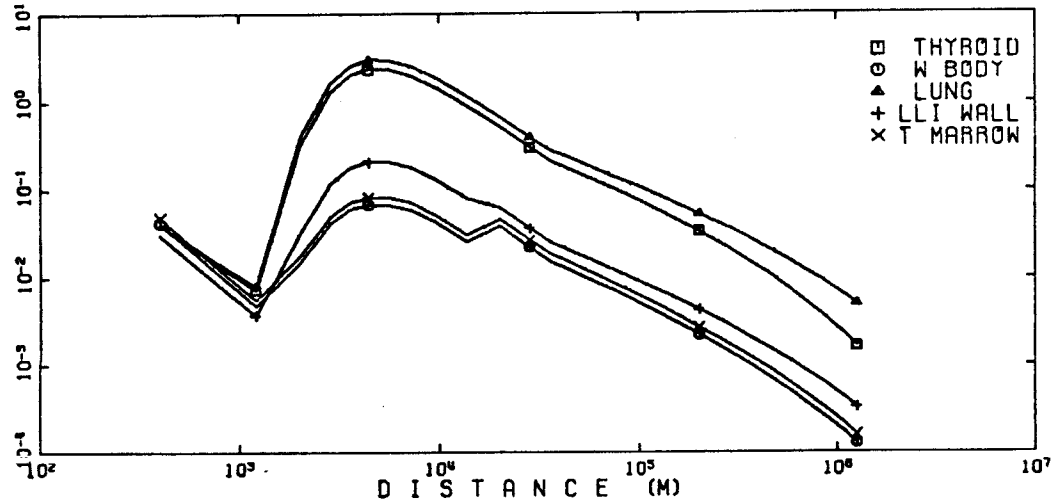
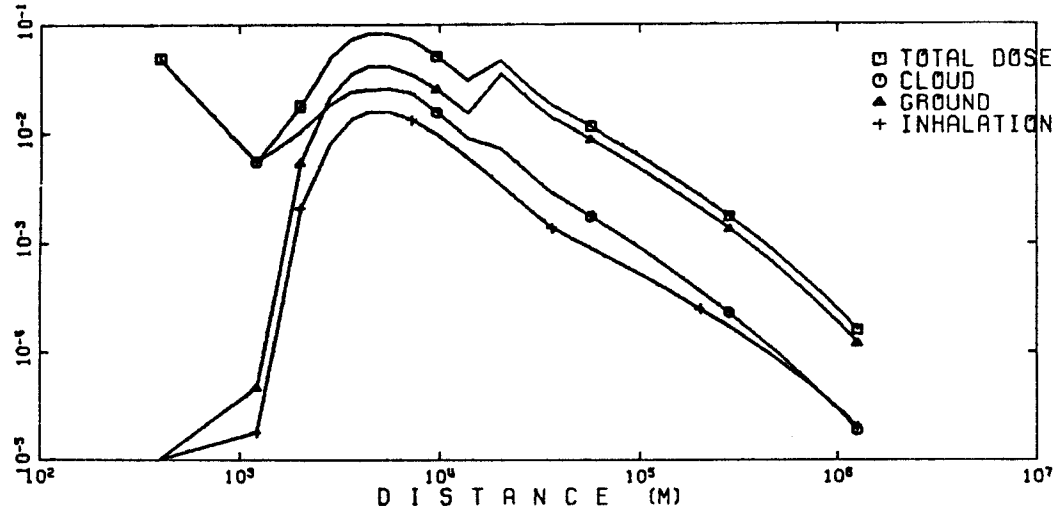


Figure 5: ACUTE EFFECTS FROM EARLY EXPOSURE. CONTRIBUTIONS TO THE T MARROW DOSE/Sv/. RELEASE FROM 500m.



III. PROBABILISTIC SAFETY ANALYSIS (PSA) PROGRAMS

Probabilistic Safety Analysis (PSA) is defined as the application of probabilistic risk analysis to safety decisions. PSA can be of use in various fields of investigation - standards and regulation development, siting of plants, operator training, risk comparison, design optimization, safety modifications, operating procedures, test and maintenance procedures, safety goals and plant availability.

Probabilistic risk assessments can be performed at different levels, depending on the objectives of the study and the availability of time and manpower. These three discrete levels are the following:

Level 1: System analysis
Level 2: Systems and containment analysis
Level 3: Systems, containment and consequence analysis.

An analysis of external events may be included in any of these levels. The external events that are selected for the analysis depend on the site, but they include such events as plant fires, internal and external floods and earthquakes.

1) Cooperation with IAEA on PSA projects

Yugoslavia has joined the Interregional IAEA project, INT/9/Ø63, Probabilistic Safety Analysis in late 1985. This project, locally coordinated by IJS, is performed jointly by different institutions from the SR of Slovenia and the SR of Croatia. Six institutions have been engaged altogether. The analysis comprises the evaluation of the importance and interaction of various plant systems and components, identification of accident sequences, deficiencies of design, of operating procedures and of test and maintenance work. The overall objective of this programme is to produce a probabilistic model of the Krško NPP which can be used by the utility and regulators in both safety and operational analysis of the plant.

The project scope is a level 1 PSA (according to NUREG-23ØØ). Specifically the project envisages:

- determining the core melt frequency from a comprehensive set of accident initiators internal to the plant, including Loss of Offsite Power.
- reporting dominant accident sequences, uncertainties, importance ranking of systems and failure modes.
- reporting specific contributions of 1E category to the total core melt frequency.

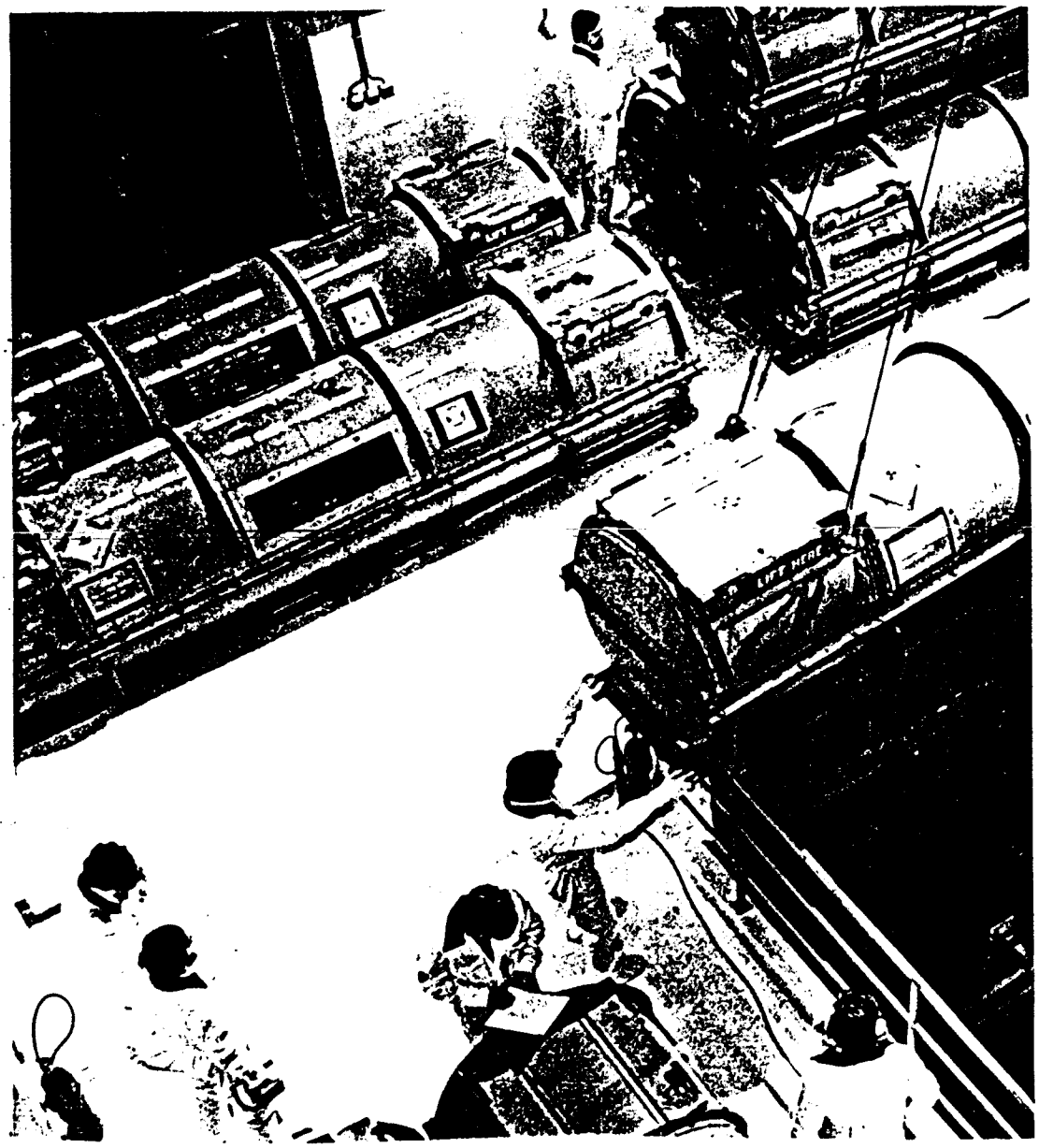
In parallel, the Reactor Engineering Division at the "J.Stefan"

Institute, is also participating in the IAEA coordinated programme on the use of PSA in safety analysis and on the development of risk criteria for the whole nuclear fuel cycle. The programme of work (Agency research contract No.3941/RB) is the following:

a) Detailed evaluation and comparison of code results for Main Feedwater System Reliability of the Krško NPP.

b) Probabilistic estimate of the possibility of further operation of the NPP after the loss of the second independent off-site power source introducing certain improvements.

The IAEA stimulates exchange of experiences in the area of PSA among the actively participating member states. Jožef Stefan Institute staff regularly participate in IAEA workshops.



2) Computer codes, data base and calculation of risk, reliability and availability of NPP systems

The current data base uses generic values of component failures as specified by foreign documentation (like the US Reactor Safety Study WASH 1400), and NREP (National Reliability Evaluation Program) NRC documents. It is planned to substitute these values gradually by the specific operational data from Krško NPP.

Recently, two accident sequences were evaluated in detail, triggered by a steam generator tube rupture and a small leak of the reactor coolant. In parallel, analyses on the system level were performed for safety and other systems that can mitigate consequences of the mentioned accidents.

Figure 6 shows the analysed event tree for the SG tube rupture accident.

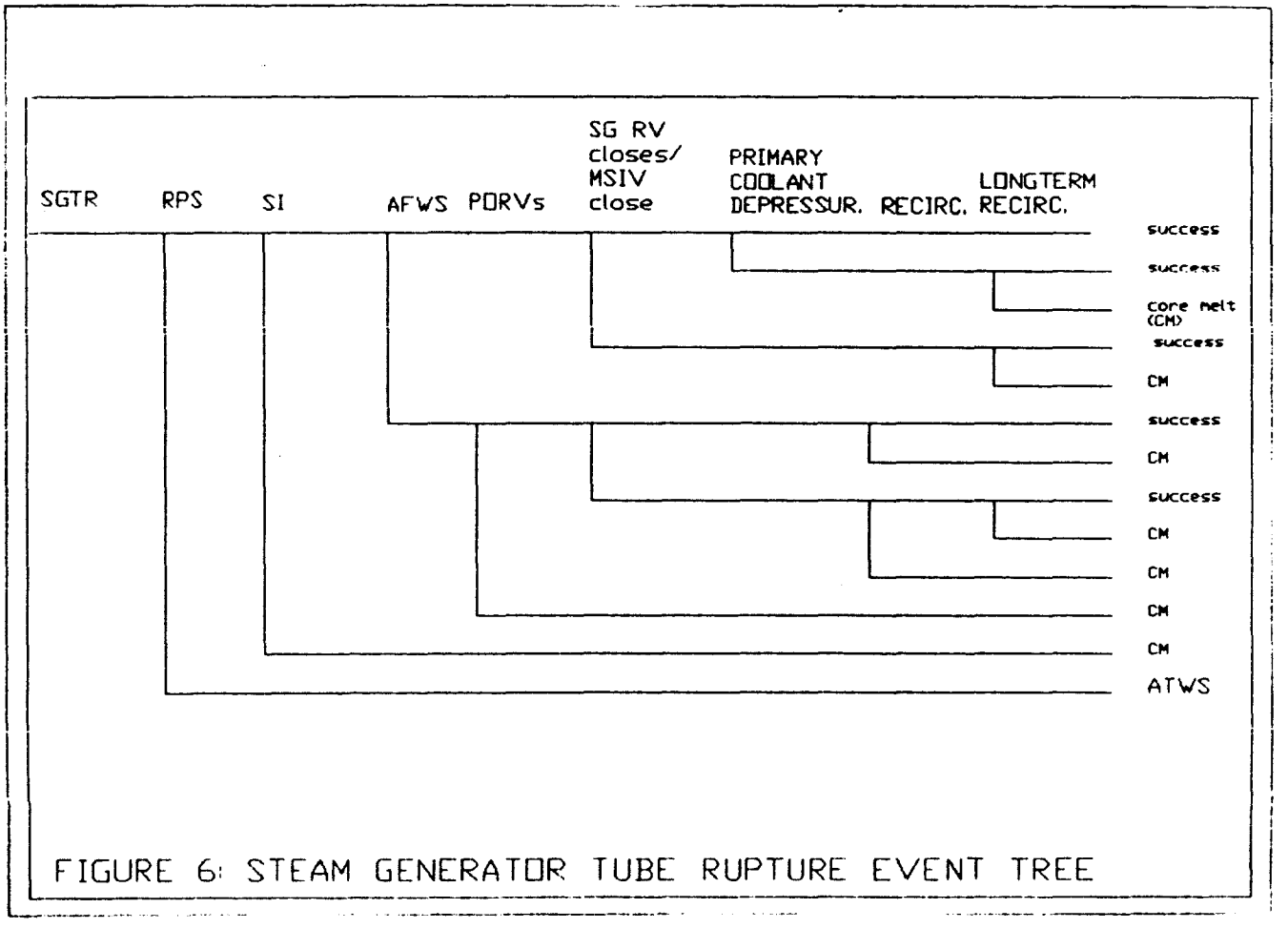


FIGURE 6: STEAM GENERATOR TUBE RUPTURE EVENT TREE

IV. PARTICIPATION IN THE IAEA INCIDENT REPORTING SYSTEM (IRS) AND SAFETY ASSESSMENT OF EVENTS IN NUCLEAR FACILITIES

With the rapidly increasing number of cumulative reactor years, the feedback of experience is becoming a valuable tool for enhancing the safety and reliability of nuclear power plants. Systematic reporting and evaluation of safety-related events can lead to the identification of necessary plant modifications and the development of improved plant procedures. To facilitate the exchange of experience, both the Nuclear Energy Agency of the OECD (OECD/NEA) and the IAEA have established Incident Reporting Systems (IRS) to collect and examine events submitted by national organizations. National coordinators screen all events, passing on the most significant. Yugoslavia has joined IRS, the national coordinator being the Republican Energy Inspectorate of the SR of Slovenia.

In establishing the national reporting system, the Republican Energy Inspectorate is being assisted by the "Jožef Stefan" Institute which has developed a computer-aided data base on incidents in nuclear power plants. The data base is organized on a personal computer. Simple searching and grouping of certain types of incidents is possible. The data base was enlarged by 22 new reports from the NEA/IAEA meeting in Paris, September 1986. Further enlargement of the IRS library is envisaged as reports on many incidents became available in December 1986.

All events are described on forms according to IRS. In addition to incident causes, the consequences and corrective actions are included. Safety assessment and categorization are made using American National Standards (ANS) and considering IAEA recommendations. The ANS classification from the Final Safety Analysis Report having four categories of incidents, according to their frequency and probability of radiation exposure to the environment) and the IAEA Guide to a National System for Collecting, Assessing and Disseminating Information on Safety Related Events in NPPs which classifies seven categories of incidents were used. Depending on the category the incidents are then selected for reports to regulatory bodies.

V. DEVELOPMENT AND MAINTENANCE OF COMPUTER CODES FOR DETERMINISTIC SAFETY ANALYSES

Reactor Engineering Department staff at the "Jožef Stefan" Institute are continuing their research in the field of nuclear energy with particular attention to the safety of nuclear installations and power plants. The basic fields of research comprise deterministic and probabilistic safety analysis, heat and mass transfer, two-phase coolant flow, dynamic behaviour of systems and plant components during transients, and structural analyses of components and constructions.

The work was focused on the analyses of structural, operational and safety characteristics of nuclear power plants and on the improvement of computer codes for the performance of these analyses. The staff have developed their own codes or installed and tested other computer programs used for safety analyses and for the reliability and availability assessment of systems and equipment. For these purposes, intensive work started on the transfer of the RELAP5/MOD1 code from CDC and IBM environment to VAX, and independently, to transfer test programs for the performance on the array processor CSPI MAP642Ø.

Deterministic safety analyses enable the calculation of thermal and hydrodynamic conditions in cases of assumed accidents and transients. The department staff has performed these analyses on the basis of the models prepared in previous years for assumed accident conditions in the Krško NPP. A large part of these efforts was directed towards the analysis of steam generator tube plugging impact on the normal and the transient operation of the Krško NPP.

A large break loss-of-coolant accident was calculated using the conservative evaluation model and the computer code RELAP4/MOD6. The results of the preliminary analysis showed the relative rise of the maximum cladding temperature depending on the plugging rate (Fig. 7). The results also showed what peaking factor production is necessary to compensate the critical conditions caused by plugging (Fig. 8).

Fig. 7: REFLOOD CLADDING TEMPERATURE OF THE HOT PIN AT ELEVATION 2.59m (EM DECL 0.4, 0%, 10% t.p., Fq=2.22)

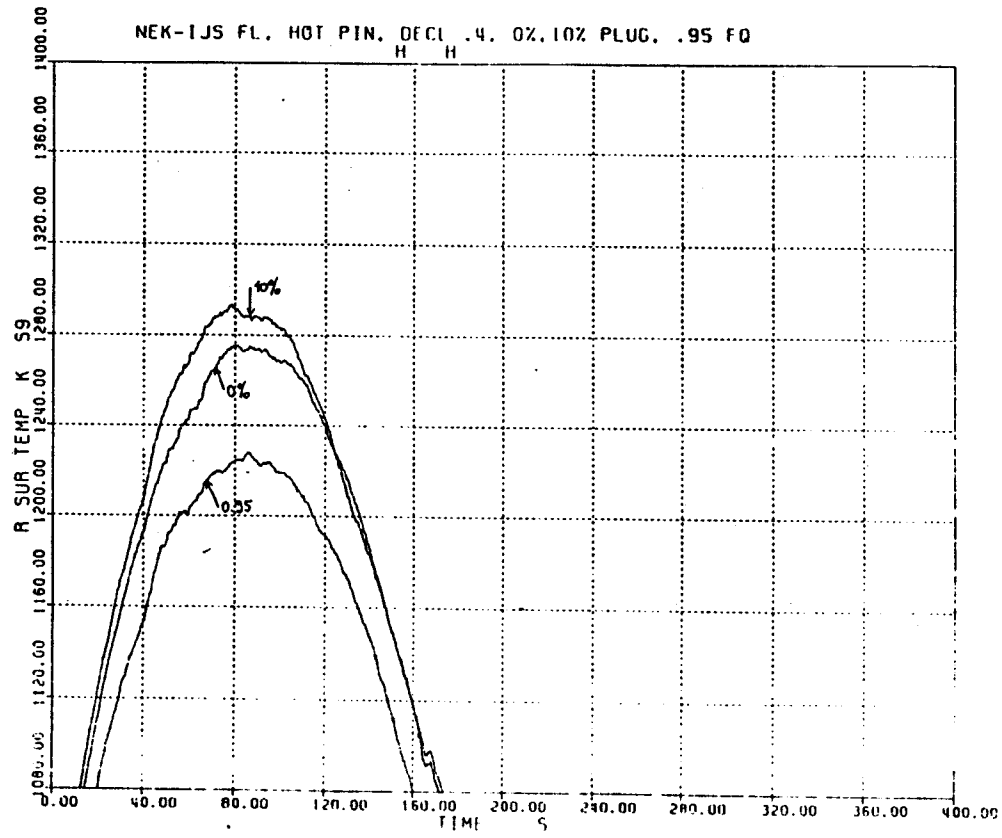
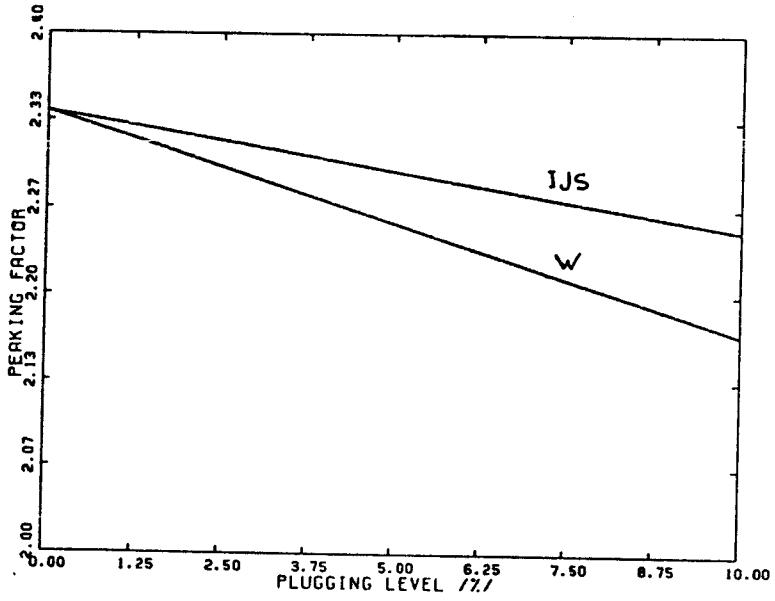


Figure 8: REQUIRED PEAKING FACTOR DECREASE



With the help of the RELAP4/MOD6 code a standard problem was analysed which is performed under the sponsorship of the International Atomic Energy Agency and is based on the PMK-NVH nuclear plant model from Hungary. (An experiment was performed on the PMK NVH facility simulating SB LOCA on the VVER power plants.) Analysis of the calculated results showed good agreement with the measured data.

The division staff has developed two new computer programs: SMUP-Ø5 and MS-Ø1. The former analyses the steady-state model of the U-tube steam generator with a preheater of the Westinghouse-D4 type, while the latter is used to determine the steady-state model of the main steamline with turbine control valves. The purpose of these models is the analysis and determination of new operating conditions in the primary and the secondary system under various conditions resulting from modifications or changes to the primary or the secondary system. The model was also used to analyse the steam generator tube plugging effects on the parameters of the primary and the secondary side during normal operation. Fig. 9 shows its effect on the additional necessary opening of the steam turbine control valves for operation at nominal power.

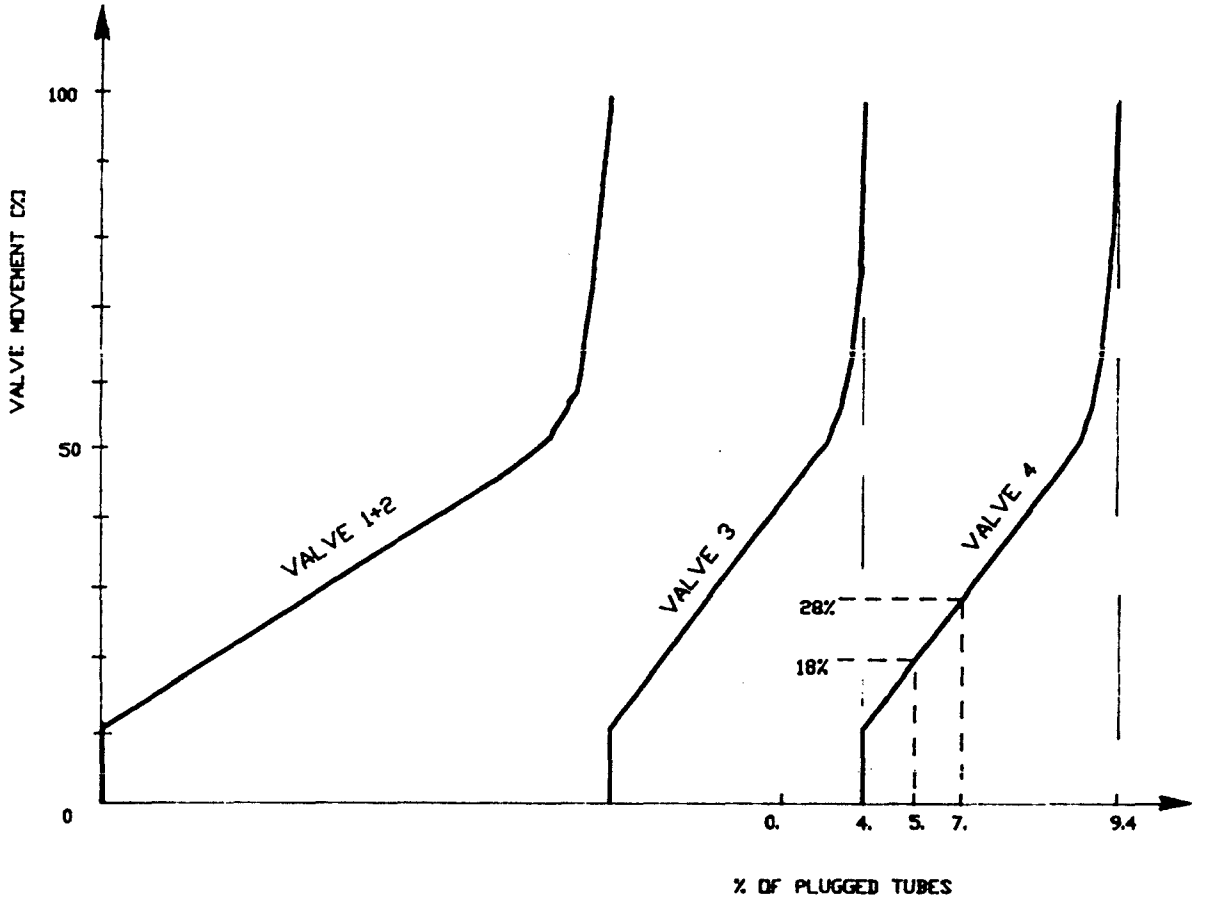
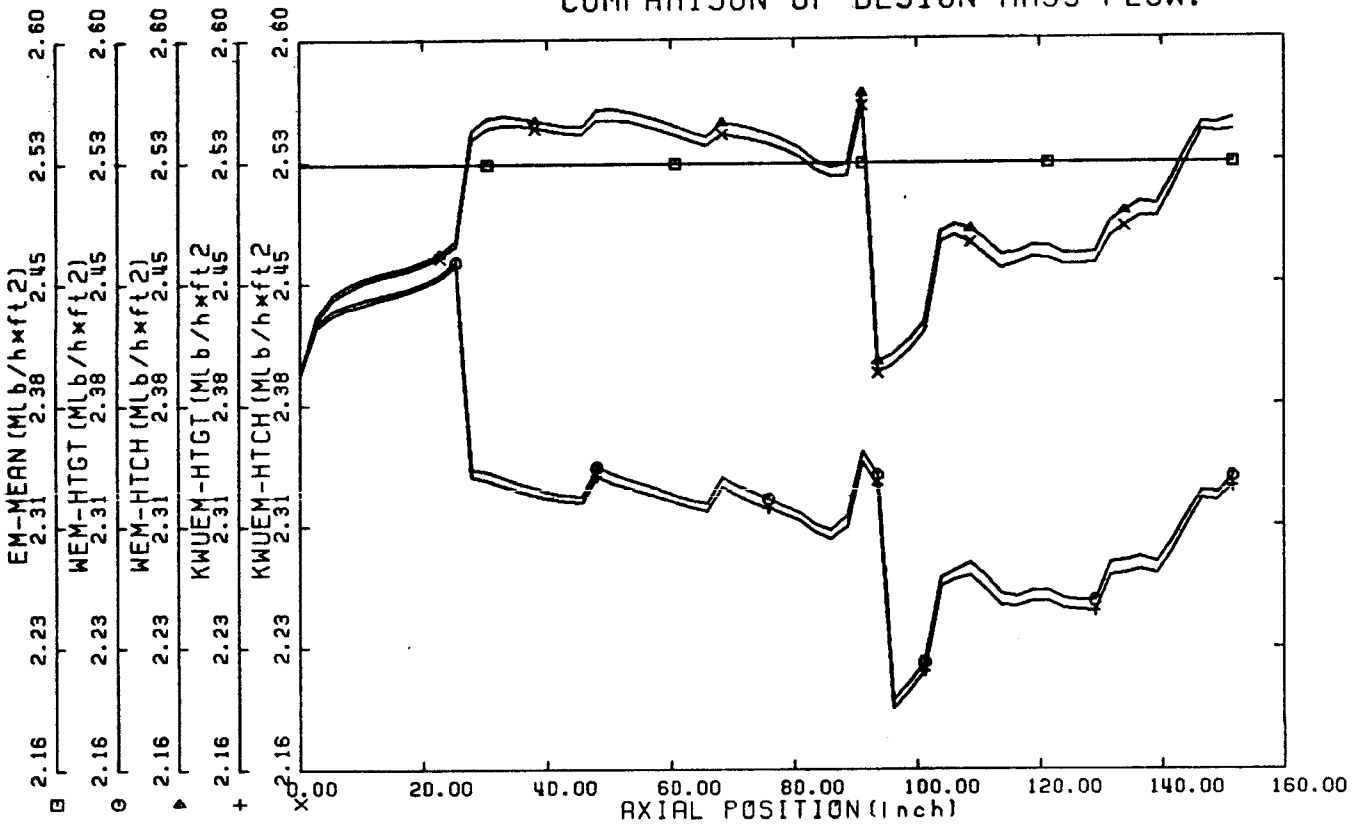


Fig. 9: ADDITIONAL NECESSARY OPENING OF TURBINE CONTROL VALVES No.3 and 4 DUE TO PLUGGING OF SG TUBES

For the purposes of evaluating core capability, the staff has developed a model for the design calculation of the reactor core thermal-hydraulics by using the COBRA-III-C computer code. Departure from the minimum boiling ratio was analysed depending on the design power history distributions, and on the type of core (KWU,W). Krško NPP uses W and KWU fuel elements. Figures 10 to 12 show some results of this calculation: mass flow, void fractions and the minimal DNBR along the different hot subchannels.

In addition, structural analysis of fuel rods was conducted with FRAPCON-2 and the thermal-mechanical response studied during reactor operation.

Figure 10: CORE THERMOHYDRAULIC DESIGN MODEL. COMPARISON OF DESIGN MASS FLOW.



□ WES. model - mean flow in 25 central fuel assemblies
○ WES. model - hot thimble subchannel
△ WES. model - hot typical subchannel
+ WES.- KWU. mixed core model - hot thimble subchannel
× WES.- KWU. mixed core model - hot typical subchannel

Figure 11: CORE THERMOHYDRAULIC DESIGN MODEL.
COMPARISON OF VOID FRACTIONS.

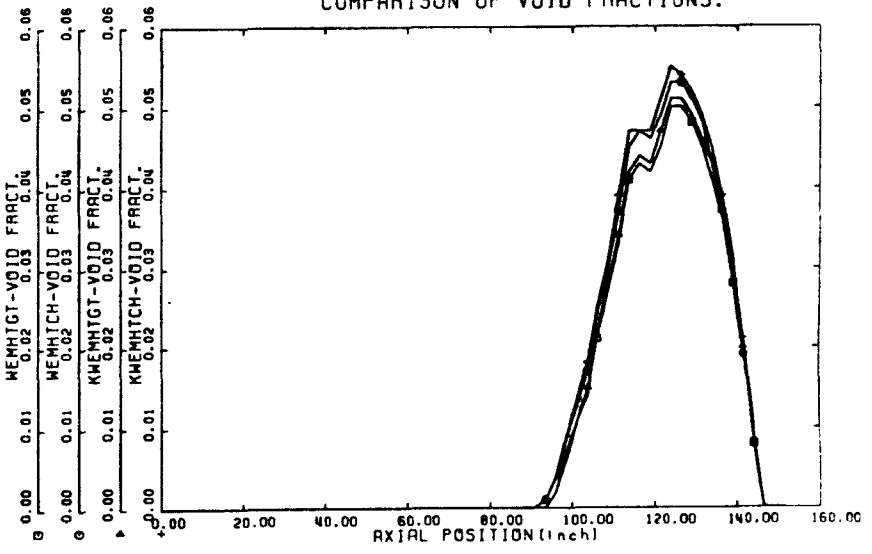
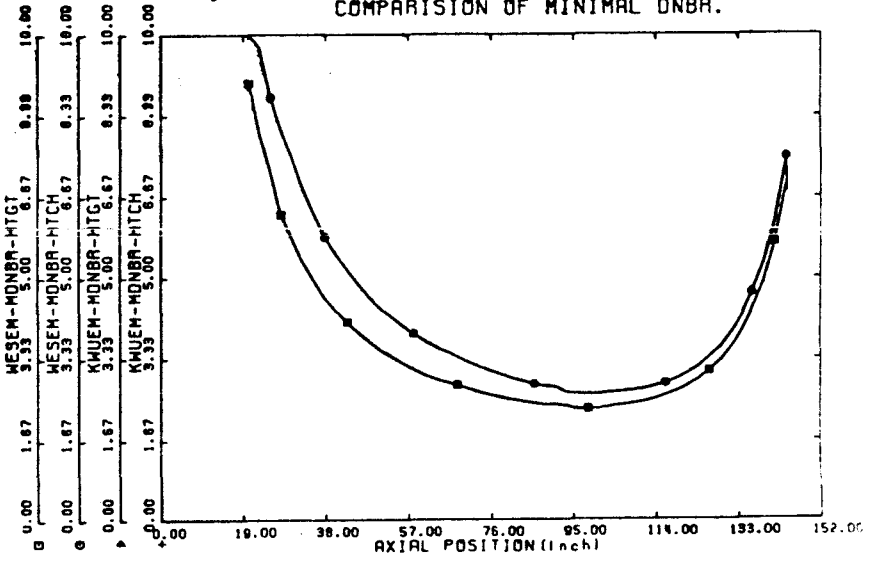


Figure 12: CORE THERMOHYDRAULIC DESIGN MODEL.
COMPARISION OF MINIMAL DNBR.



□ WES. model - hot thimble subchannel
○ WES. model - hot typical subchannel
△ WES.- KWU. mixed core model - hot thimble subchannel
+ WES.- KWU. mixed core model - hot typical subchannel

With RELAP5/MOD1, cycle 19, steam generator tube plugging effects were studied for two very important assumed accidents: small-break loss-of-coolant and the rupture of one or more tubes in a steam generator. Some of the results obtained are shown in Figs. 13 to 16.

With this programme the staff has joined the international standard problem ISP-20, which is performed under the auspices of the OECD and represents the analysis of an actual event in the Belgian Doel nuclear power plant - a steam generator tube rupture. The effects of 10% plugging were obtained for break sizes equivalent to 1", 3" and 5" SG tube pipes.

In the field of transient analysis close cooperation has continued with the Elektrotehnički fakultet (Faculty of Electric Engineering) in Zagreb and with Gesellschaft fuer Reaktorsicherheit in Garching. The ALMOD computer code has been improved jointly, so that it is now capable of simulating non-symmetric phenomena in multi-loop plants. The modified ALMOD code was verified with the calculations of startup tests and with the results of measurements in the Krško NPP.

Figure 13: NPP KRSKO OPERATIONAL SAFETY DURING SGTR ACCIDENT-RELAP5/MOD1 CALCULATION

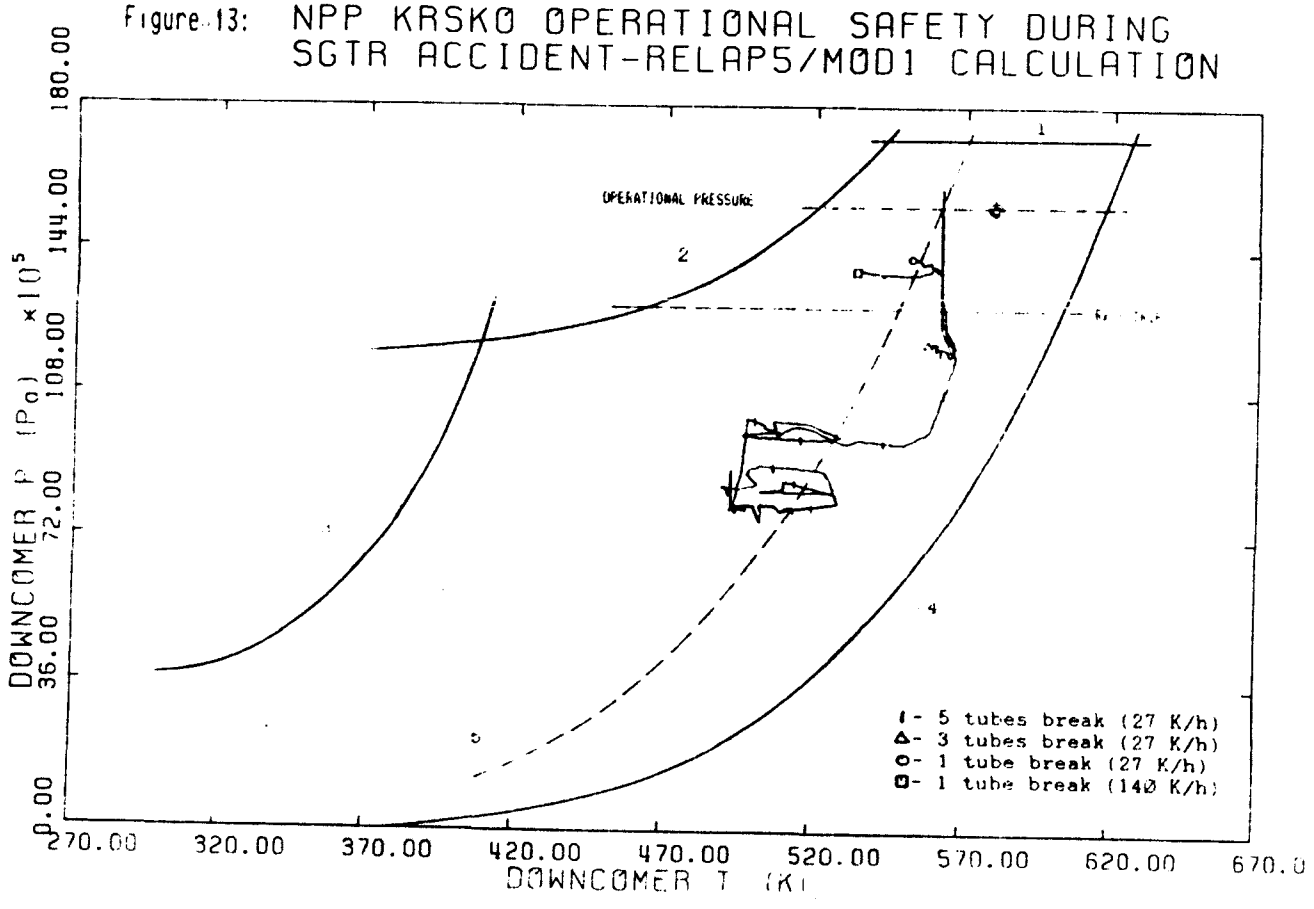


Fig. 14: PARAMETRIC STUDY OF SGTR ACCIDENT DONE WITH RELAP5/MOD1 CODE

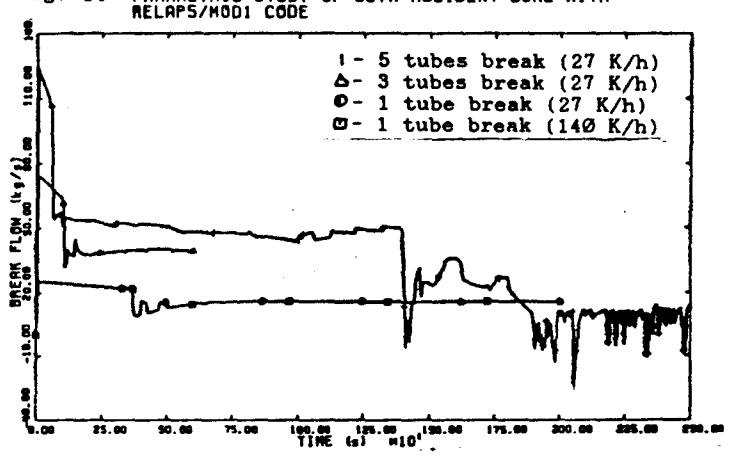


Fig. 15: PARAMETRIC STUDY OF SGTR ACCIDENT DONE WITH RELAP5/MOD1 CODE

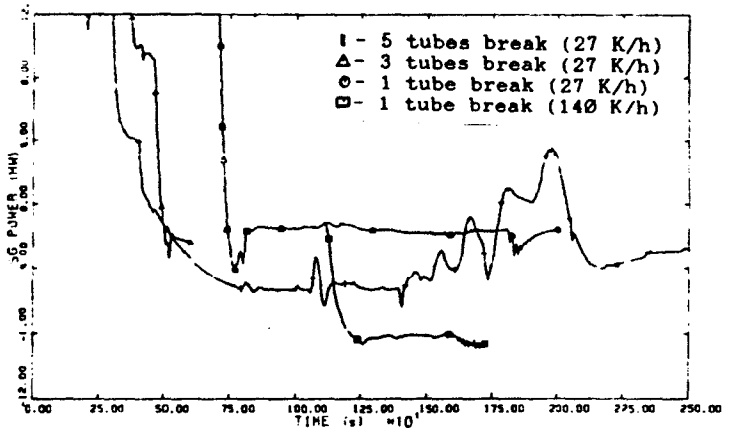
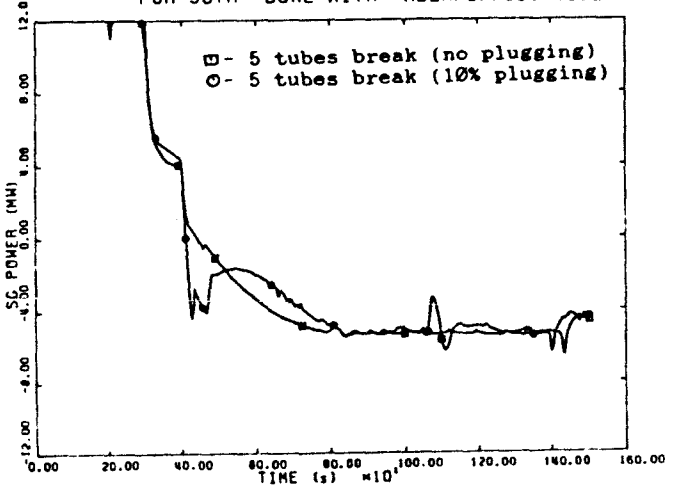


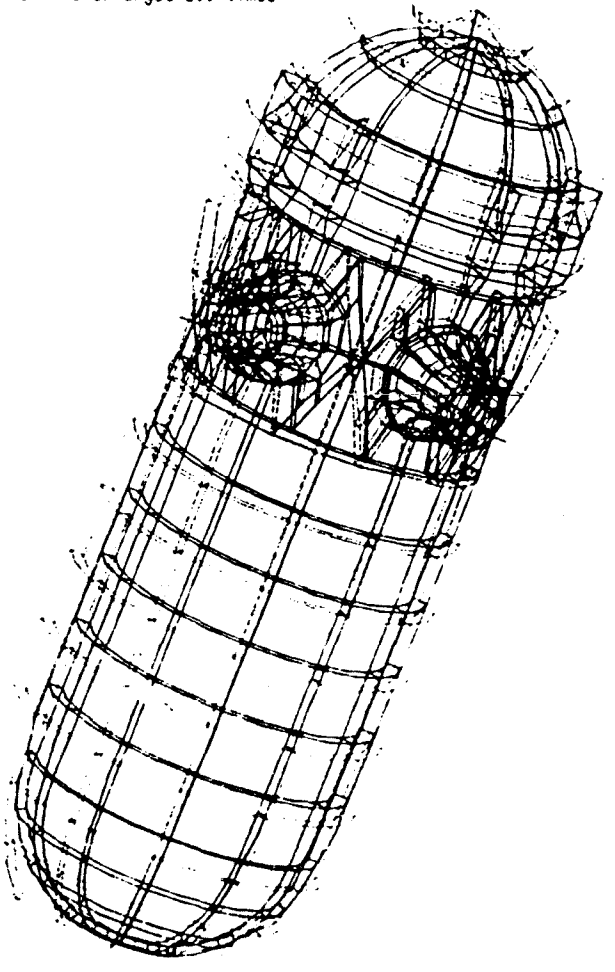
Fig. 16: NPP KRSKO RESPONSE ON U-TUBE PLUGGING FOR SGTR DONE WITH RELAP5/MOD1 CODE



The department staff have successfully transferred to VAX the SAP-IV computer program, used for the analyses of various kinds of constructions, components and pipes. It uses the finite element method for static and dynamic structural analyses of elasticity. The program was supplemented by subroutines for space plotting of the geometry of components and deformations, see Fig.17. First test calculations of the reactor vessel head vent have been run. A test model was made of a three-dimensional, thick-wall pressure vessel of a nuclear reactor.

In cooperation with the University of Erlangen, FRG, they continued to develop program for determining the non-steady state temperatures of fuel pellet axially-symmetric problems with fractures and melting by a self-adaptive mesh grid using the boundary element method.

Figure 17: REACTOR PRESSURE VESSEL, 3-D, SYMMETRIC
Initial mesh
Deformed mesh due to internal pressure
Deformations enlarged 200 times



VI. TRAINING

In the framework of the Programme of measures for the protection against ionizing radiation and the programme of nuclear safety the Reactor Engineering Department at the "Jožef Stefan" Institute organized a technical seminar for the members of the operator licensing board. The seminar was held in Portorož from 13 to 15 October 1986.

The Nuclear Training Centre (ICJT) at the "Jožef Stefan" Institute organized a training course for professionals working in the field of nuclear power plant technology, entitled "Safety and Reliability of NPP Operation". The course was organized with the assistance of the IAEA and the Argonne National Laboratory (USA). Beside foreign lecturers, a number of domestic experts were invited to give lectures on selected topics. The course was conducted in two parts:

- Part 1: Probability Safety Analyses, May 19-30, 1986,
- Part 2: Prevention of Unusual Events, September 15 to October 10, 1986

In 1986, the ICJT of the "J.Stefan" Institute published several training manuals aiming at professional training of operators and other staff in a nuclear plant, and the staff in other organizations that work in the field of nuclear technology.

VII. ACTIVITIES OF OTHER AUTHORIZED ORGANIZATIONS

1) "MILAN VIDMAR" ELECTRICAL INSTITUTE (EIMV)

The "Milan Vidmar" Electrical Institute has cooperated, as every year, in the annual refuelling outage of the Krško NPP, where the staff has coordinated the work of other authorized organizations and performed QA/QC activities.

Representatives of the institute also participated in sessions of the technical commission for nuclear safety and cooperated with the ASSET mission at analysing events which caused an automatic reactor trip, and in analysing the problems of plant transformers and auxiliary diesel generators.

The Institute has quarterly conveyed information to IJS, REI and to IMK on relevant new publications, articles and other documents.

2) INSTITUTE FOR METAL CONSTRUCTIONS (IMK)

IMK is authorized for the following activities:

QA activities, measurements and inspection of quality and operational functions including non-destructive analyses and QA of supporting metal constructions and metal parts of the equipment, pressure pipes and vessels during construction, test operation and normal operation of nuclear plants and installations.

In 1986, work for the Krško NPP included activities in the framework of refuelling outage, inspection of manufacture and installation of the mechanical part of the reactor vessel head vent system, work on Q-list, cooperation in the ASSET project on leakage of RPV O-ring, and participation in the Portorož Meeting (Thermal Shock Issue). The Institute has collected documentation and evidence of safety in nuclear plants and installations, which is described in IMK reports. The IMK expert cooperated in the SKJV commission and cooperated in the group for updating regulations concerning nuclear safety.

3) IB ELEKTROPROJEKT (IBE) - Architect/Engineer

IBE is authorized for the following activities:

- preparation of investment and technical documentation for NPPs,
- construction management of NPPs and nuclear installations, inspection during construction, preoperational tests, test operation, including organization of QA for NPPs and installations during construction,
- inspection of investment and technical documentation for NPPs and installations,
- preparation of site documentation.

For the Krško NPP the IB Elektroprojekt participated in modifying and upgrading different systems and components. The staff has cooperated in the study of disposal of low and medium level radioactive wastes.

VIII. INTERNATIONAL CONTACTS, COOPERATION AND EXCHANGE OF INFORMATION

Contacts with the IAEA

All Slovene organizations working in the nuclear field have close contacts with IAEA, especially in the field of nuclear safety. This cooperation is also emphasized by IAEA technical assistance in developing and training for independent activity in the field of nuclear safety.

Information on IAEA activities is distributed in Yugoslavia by the Federal Energy and Industry Committee in Beograd (SKEI) and through the Republican Institution for International Scientific, Technical and Cultural Cooperation (ZAMTES). At a working level, the exchange of information is also going on through individual Yugoslav participants in various Agency projects and programmes.

Contacts with the IAEA include cooperation in projects, participation in conferences and workshops, scholarships, expert missions and technical assistance.

Contacts with NRC

In September 1985 USNRC and SKEI from Belgrade signed an "Agreement on Information Exchange and Cooperation Related to Nuclear Safety between the Yugoslav Federal Energy and Industry Committee and the US NRC". This agreement extended contacts between USNRC and IJS which were previously related mostly to the safe startup and operation of the Krško NPP.

Based on the Agreement signed between USNRC and SKEI it was suggested that the "Jožef Stefan" Institute should coordinate through NUKLIN association the execution of the Agreement for all who participate in the Yugoslav nuclear programme and who need information on NPP safety.

Compilation, ordering, and classification of NRC documents was focused on documents related to computer safety analyses, operating events, source terms, PSA, releases into the environment, problems concerning steam generators and selected news.

In 1986 the IJS has continued with a systematic classification and distribution of the compiled documentation. As a result of this work a systematic list of safety related documents at the "J.Stefan" Institute, the "Milan Vidmar" "Electrical Institute and "The Institute for Metal Constructions" was sent to parties of the Agreement and to some other interested work organizations.

Professional contacts which have been going on for a number of years are indispensible in order to disseminate current information concerning nuclear safety. The present scope of cooperation, though small, still presents a fair basis for continuation, extension and deepening.

Good information is one of the basic conditions for safe operation of our nuclear power plant, so only an adequate information system that will include all participants in the nuclear program will give satisfactory results.

Other international contacts are held with Gesselschaft fuer Reaktorsicherheit (Garching, FRG) with whom we cooperate in developing computer programs for transient analysis. The Reactor community at IJS maintains permanent contacts with the following foreign software centres: NEA Data Bank in Paris, National Energy Software Center in Argonne (USA), Radiation Shielding Information Center in Oak Ridge (USA) and with the IAEA Nuclear Data Section. In the framework of this cooperation, several programs and data bases have been exchanged.