CURRENT ACTIVITIES AND FUTURE TRENDS IN RELIABILITY ANALYSIS AND PROBABILISTIC SAFETY ASSESSMENT IN HUNGARY

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Abstract

In Hungary reliability analysis /RA/ and probabilistic safety assessment /PSA/ of nuclear power plants was initiated 3 years ago. First, computer codes for automatic fault tree analysis /CAT,PREP/ and numerical evaluation /REMO, KITT1,2/ were adapted. Two main case studies - detailed availability/reliability calculation of diesel sets and analysis of safety systems influencing event sequences induced by large LOCA - were performed. Input failure data were taken from publications, a need for failure and reliability data bank was revealed.

Current and future activities involves

- setup of national data bank for WWER-440 units,
- full-scope level-I PSA of PAKS NPP in Hungary,
- operational safety assessment of particular problems at PAKS NPP.

In present article state of RA and PSA activities in Hungary, as well as main objectives of ongoing work are described. A need for international cooperation /for unified data collection of WWER-440 units/ and for IAEA support /within Interregional Program INT/9/063/ is emphasized.

1. CURRENT RELIABILITY CASE STUDIES

1.1 *General Aim of Activity and Organization of Work*

General aim of current national R/D *activity on PSA* is to solve problems concerning mainly operation and maintainance /less design/ of PAKS NPP, as well as safety decision [1,2] .

The activity is sponsored by the national authorities and regulatory bodies, mainly by the Ministry of Industry and the National Atomic Energy Commission.
Scientific and theoretical work is coordinated by the Institute for Electric Power Research /VEIKI/, in practical applications the PAKS NPP and the Hungarian Power Plant Design Company /ERŐTERV/ are involved. Close cooperation on methodological problems and field experience exchange has been carried out with Institute of Fuel and Energy Complex /VUPEK/, Bratislava, Czechoslovakia.

Currently available codes at VEIKI for the analysis are:

- CAT - for automatic construction of system fault trees from component decision tables,
- PREP - for deriving minimal cut/path sets from system fault trees,
- REMO - for numerical calculation of availability, reliability of components, minimal cut/path sets, and systems.
- KITT1,2

For computerized analysis IBM PC, IBM 4361 /VEIKI/, and R55 /Robotron,GDR-PAKS NPP/ computers are used.
Failure input data are currently taken from general international publications, but more and more field experience of PAKS NPP /presently of 5 reactor-years/ and other WWER-440 units are involved in the analysis.

During 1984-85 *two main case studies* have been carried out. First the availability/reliability of Hungarian Diesel system of PAKS II NPP was determined, currently the analysis of safety systems influencing event sequences of large LOCA primary event in PAKS I NPP is being performed.

1.2 *Analysis of the Diesel System of PAKS II NPP*

Main objective of availability/reliability analysis of Hungarian diesel system supplied for PKAS II NPP units was to verify its

ability to meet the requirements summarized as follows /see Fig.1/a/:

- joint availability/reliability of stand-by /SBY/, start-up /SUP/, and long-term operational /LTO/ phases should be 0,99,
- subsystems are monthly tested during stand-by period,
- time required for start-up phase is 150-170s,
- the diesel system involves three redundant sets of engines.

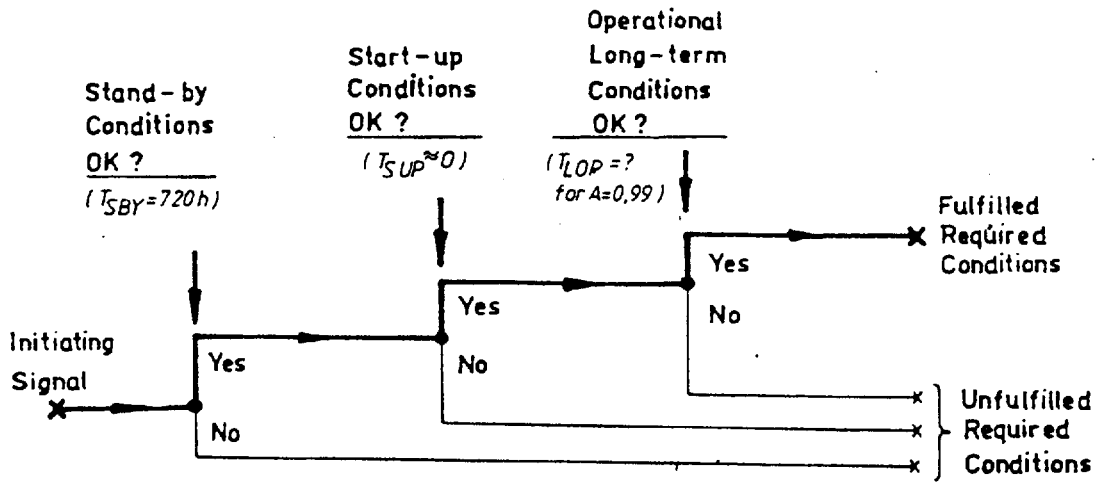

Fig. 1/a

During the analysis *three steps were completed* [3] :

- setup of an integrated system failure model* containing moduls of technological, electrical, and control/instrumentation subsystems for all three operational periods listed above,
- assembly of input data stack represented by component-related failure parameters, such as λ [1/h] failure rate, T_{rep} [h] repair time, and *P* failure probability,
- calculation of numerical system parameters.

Numerical results of 1DG and 3DG configurations are shown on Fig. 1/b. Main conclusions derived from these curves are as follows.

A. Stand-by availabilities for both 1DG and 3DG cases are high due to high-level repairability during this phase.

B. Start-up failure probability for 1DG is 3.10^{-2}, i.e. original requirement with one *DG* unit can not be met.

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* Part of the theoretical modelling work was sponsored by the IAEA within Research Contract No. 3210, see Ref. [4] .

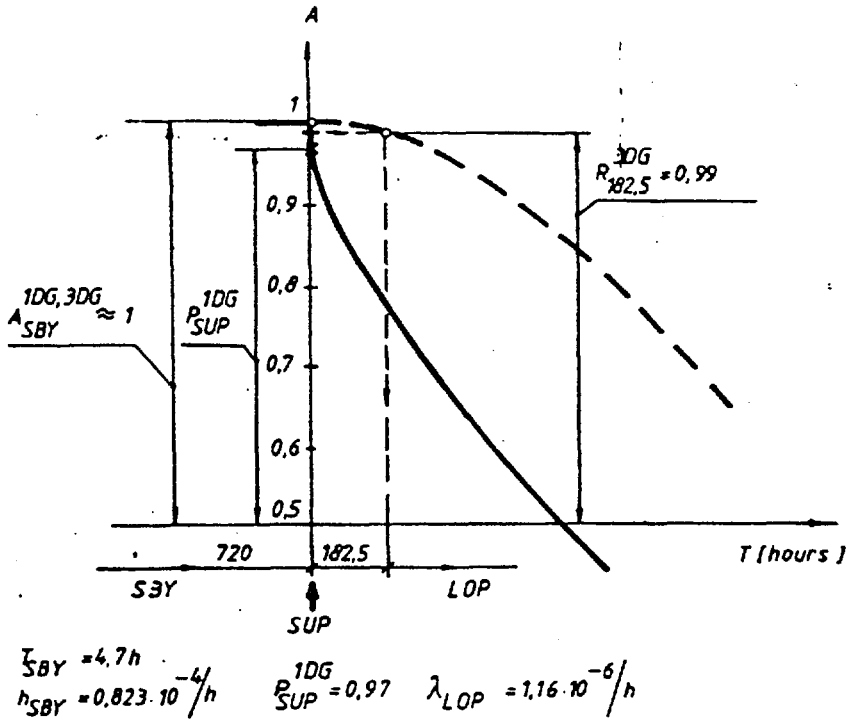


Fig. 1/b

Diesel Generator Availability Factors

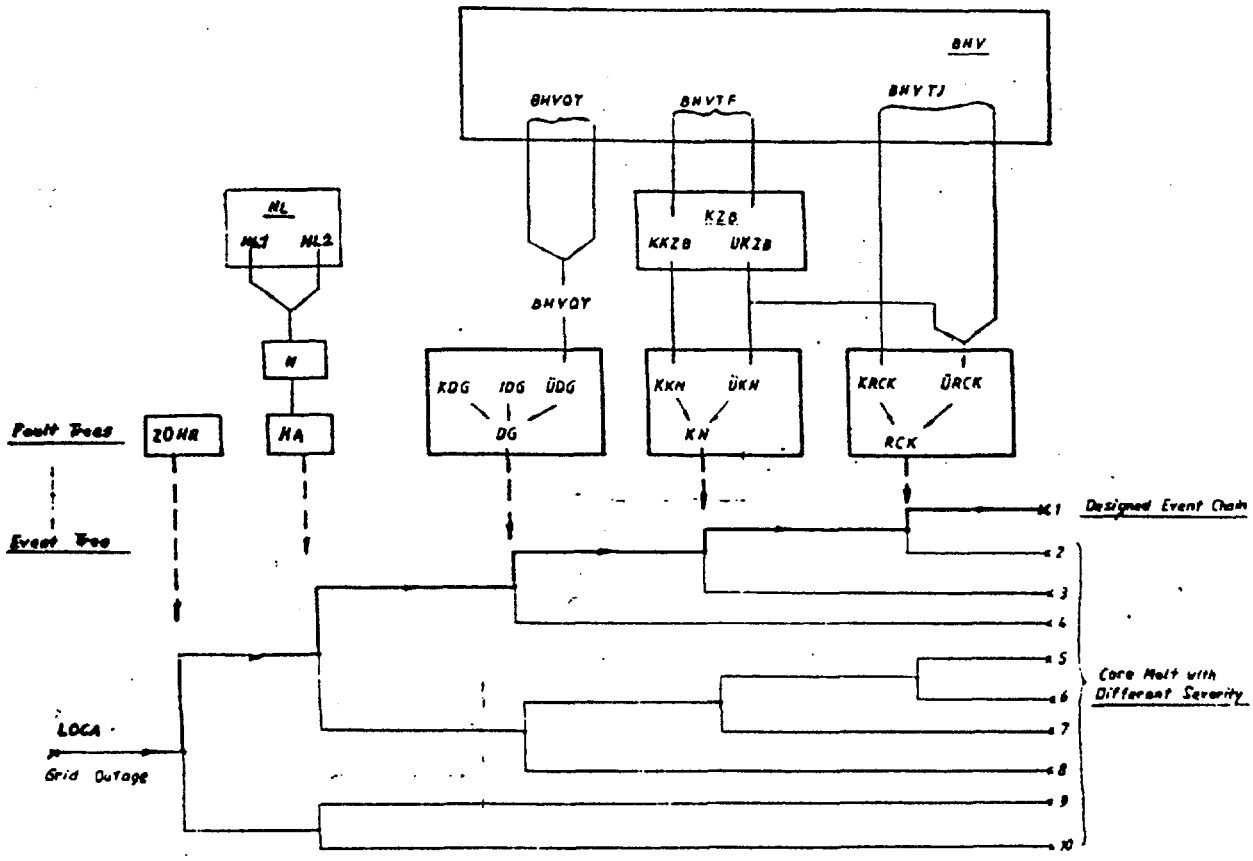
C. Complex availability/reliability factor of higher then 0,99 value can be achieved, if three redundant diesel sets, monthly tests /$T_{SBY} \leq 720h$/, and less than one week operation /$T_{LTO} \leq 182,5h$/ are considered.

As a summary, calculations verified that the Hungarian diesel system supplied for PKS II NPP meets the requirements set up by the Soviet general plant designer within operational conditions listed above.

1.3. *Large LOCA Event Tree Analysis*

Primary objective of availability analysis of safety systems influencing event sequences induced by large LOCA primary event is to predict core melt probability for this case and to identify subsystems of highest partial contributions.

During analysis the same three steps as for the diesel study are applied.



Notation:

ZUHR - Control System/for DG and LP ECCS Start-up/
HA - Hydroaccumulators/Passive ECCS/
KN - Low Pressure Emergency Core Cooling System
/KKN - during Stand-by; UKN - during Operation/
RCK - Long-term Heat Removal System
/KRCK - during Stand-by, IDG - during Start-up,
UDG - during Operation/
N - Nitrogen System/during Stand-by/
NL - Compressed Air System/for Air Operated Valves, during Stand-by/
KZB - Intermediate Cooling System/for LP ECC Pump/
/KKZB - during Stand-by, UKZB - during Operation/
BHV - Safety Cooling System
/BHVQY - for Diesel Generator System
BHVTF - for Intermediate Cooling System
BHVTJ - for Long-term Heat Removal System/

Fig. 2
Large LOCA Event-Tree

The probabilistic model was set up in a combined event tree/fault tree from - see Fig.2. In the event tree nine essential event chains resulting core melt are identified, within the analysis five basic branch points, i.e. five main safety systems are involved. Altogether 21 subsystem fault trees containing primary failures of C/I, electrical, and technological components were developed. Presently

data collection and numerical probability calculation are going on, the complete case study is to be finished by Dec. 1985.

Limitations during modelling work are given by currently available codes as follows:

- components with repair and with constant failure rate can be considered,
- no uncertainity analysis and no common mode failure modelling are being carried out,
- human reliability and periodic inspection have been partially considered.

2. RELIABILITY DATA BANK FOR PAKS NPP

2.1. *General Objectives*

The *primary objective* of the Reliability Data Bank /RDB/ is to collect and process failure statistics, as well as store and make available failure and reliability parameters for components and systems of Hungarian NPP units of WWER-440 types [5] .

It is expected that such objective will make it possible to

- asses and improve the reliability of components and systems. As in Hungary imported NPP units are under construction, the enhancement of designs is of less significance and the RDB is basicly concerned with operational reliability factors,
- identify most frequent and significant failure modes. Importance of failures can be characterized by failure rates and induced consequences on higher system level. RDB parameters are designed to characterize and identify weakest points of operating units,
- evaluate failure trends and determine maintainance activity. Failure parameters provide data for long-term determination of optimum test periods and inspection strategy,

- support complex safety and reliability analysis. Failure and reliability parameters are input data for probabilistic safety and risk analysis more and more required by licensing and regulatory agencies in Hungary, too.

The RDB produces failure and reliability parameters of selected components and systems. The *scope of systems and components* is under classification, first ones are to be reported which are handled by the Safety-Related Event Reporting Data Base /see Section 2.3/.

2.2. *Integration of National and International Data Bases*

As WWER-440 units have been operating in several other countries since years, failure and reliability data used for RA and PSA applications are to be stored on data banks set up on national and international level - see Fig.3.

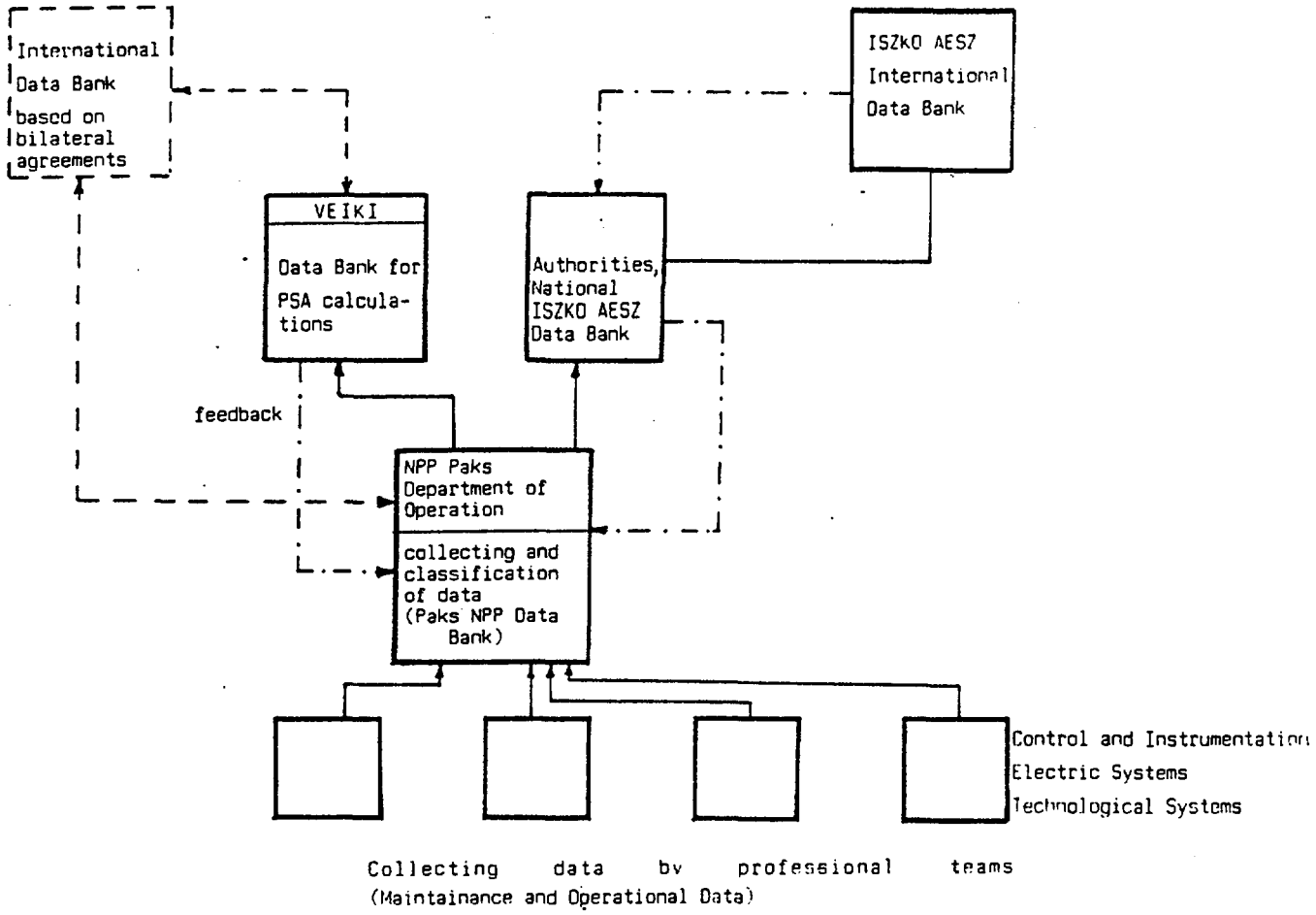


Fig.3.
Relation of Internal
and International Data Bases

The *primary national data bank* is to be set up at PAKS Nuclear Power Plant, which forms the single nuclear station at Hungary in the near future /until 2000 its planned total capacity is 8x440 MW_e/. Input failure statistics are gathered and reported by professional teams of control and instrumentation, electric power, and technological sections. Reported data are pre-evaluated by the operational section of the plant, and stored on the main plant-wide off-line data-evaluation computer. Stored data are transferred to VEIKI and different authorities for further evaluation, as well as are used for unit operational purposes. VEIKI coordinates and performs required RA and PSA studies, main results are fed back for operational use .

The *international data bank* is covered by the so-called ISZKO AESZ joint data acquisition system of CMEA countries. Failure and reliability data of PAKS NPP are reported to this system by the Hungarian authorities and the national ISSZKO AESZ institution. Requirements for this international ISZKO AESZ system were defined some years ago, these requirements are basicly considered during specification of the PAKS NPP reliability data bank, too. As scope of data to be reported to ISZKO AESZ system does fully not cover information needed for full-scope PSA applications /ISZKO AESZ means Information System on Quality of NPP Equipments/, the PAKS reliability data bank will include a wilder range of input failure data. To make possible efficient RA and PSA analysis of WWER-440 type systems, in addition to the information available from ISZKO AESZ sources, bilateral interchange of experiences gained at other CMEA countries /e.g. at Czechoslovakia/ becomes necessary, too.

2.3. *Scope of Input/Output Data*

The internal Reliability DB of PAKS NPP is to be used for evaluation and store of failure and reliability parameters of its main equipments and systems which are essential for increasing the unit operational safety and for optimal scheduling of maintainance activity.

Basic input to the Reliability DB are the operational failure information from Event Reporting DB and repair data from Maintainance DB /on control/instrumentation, electric power and

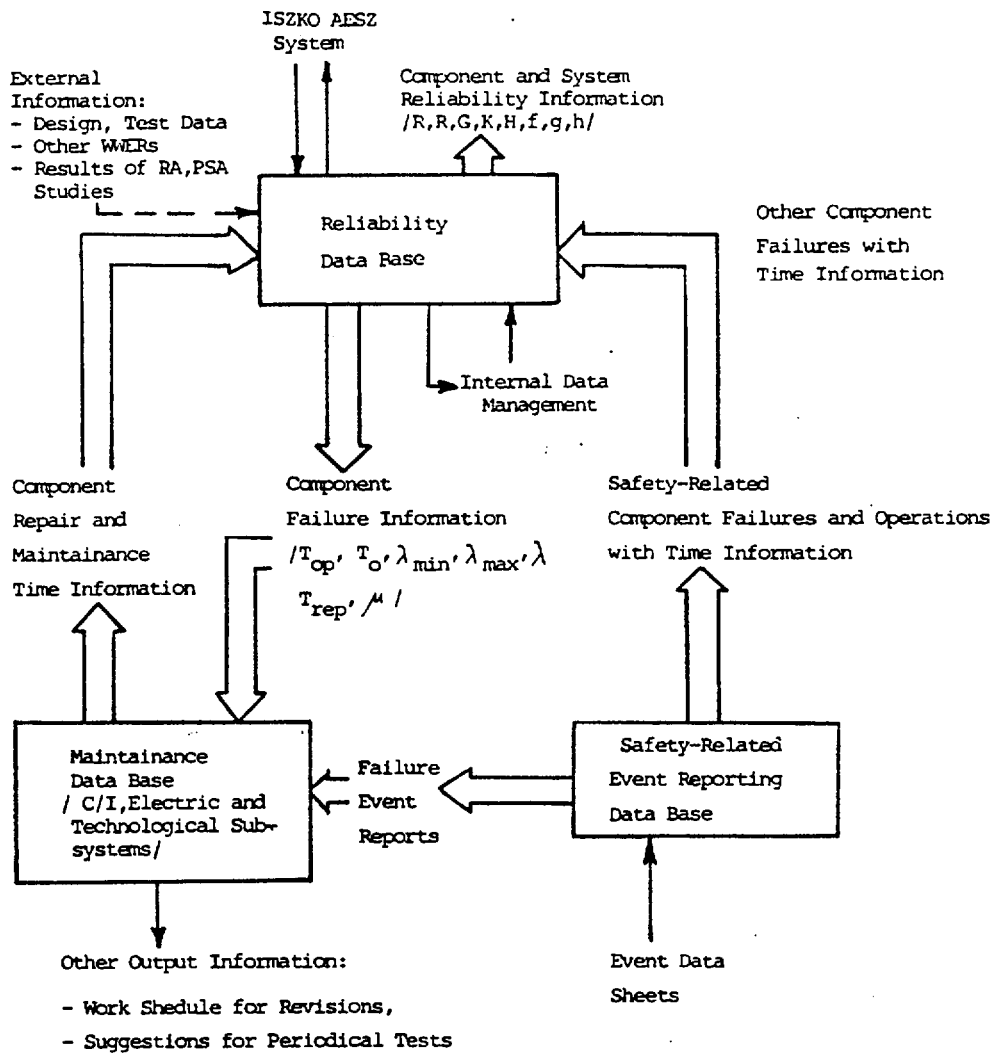


Fig.4.
Relation of Internal
Off-line Data Bases

technological systems/ - see Fig.4. In both cases information is supplied on data sheets. Coded and stored information contains data on plant state and its perturbation /rate and duration of power changes/, disturbed component and system identification, cause of failures, repair and maintainance activities, e.t.c. Calendar time information is of basic importance /listed data are to be directly transferred to ISZKO AESZ, too/. As in the Event Reporting DB only safety-related data are handled, other essential component failures are to be individually announced to the Reliability DB.

Output data from Reliability DB for maintainance and operational purposes contain

- *failure information*, which is related to component-level, i.e. to equipments. Operational data basicly involves mean

operational time and failure rate, repair data comprises mean repair time and repair intensity,

- *reliability information* is related both to components and systems. Evaluated parameters are failure probability, reliability, repairability, availability, repair function and several density functions.

Components and systems involved in Reliability DB are classified as "non-repairable", "immidiately repairable", and "repairable within limited time interval" ones. Interpreted and reported failure and reliability parameters for listed classes are summarized in Table 1.

Table 1.
List of Output Failure and Reliability Parameters

Component Failure Parameters

T_{op} [hours]	- Mean Operation Time
T_o [hours]	- Mean Initial Operation Time
λ [1/hours]	- Failure Rate
λ_{min}, λ_{max} [1/hours]	- Failure Rate Confidence Bounds
T_{rep} [hours]	- Mean Repair Rate
μ [1/hours]	- Repair Intensity

Component and System Reliability Parameters

$F(t)$	- Failure Probability
$R(t)$	- Reliability
$G(t)^2$	- Repairability
$K(t)^2$	- Availability
$H(t)^2$	- Repair Function
$f(t)$ [1/hours]	- Operation Time Density Function
$g(t)^2$ [1/hours]	- Repair Time Density Function
$h(t)^1$ [1/hours]	- Repair Density Function

Parameters marked cannot be interpreted:
(1) - for non-repairable components or systems
(2) - for non-repairable or immidiately repairable components or systems

3. FUTURE ACTIVITIES ON PSA

A 5 years' national R/D program on PSA of PAKS NPP is to be started in 1986. Organisation of this activity with be the same as currently introduced /scientific coordinator: VEIKI, participants: PAKS NPP, ERŐTERV/. Three main objectives are foreseen.

A. *Setup of reliability data bank* for WWER-440 units,
Basic ideas and requirements are described in previous section. Software organisation work is to be finished by the end of 1986, computerized data collection is to be started from 1987.

B. *Full-scope level-I PSA* of PAKS NPP.

In addition to present large LOCA study, other event sequences initiated by further primary events and resulting core melt top event are to be analysed.
For this purpose more advanced computer codes /with importance sampling, periodic inspection consideration/ are to be installed.

Participation in the IAEA's interregional program on PSA /INT/9/063/ has officially been reported and considered as valuable contribution to the national activity in Hungary.

C. *Operational safety assessment of particular problems* at PAKS NPP .

Beside full-scope PSA special studies related to particular systems of the plant are planned, e.g.
- development of optimal supervisory strategy of safety systems,
- calculation of allowable maintainance period of equipments in systems of different importance,
- comparative reliability study of electric power supply by external grid and by plant diesel generators.

The information to be gained from these calculations makes possible to increase the electric energy production of the plant with high level operational safety.

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