Blackpool:

More evidence on PSA

by Michael Cullingford

PSA is spreading widely throughout the world, with 30 IAEA Member States having active programmes in this area. The main reason for its popularity is that it offers insights critical in the safety decision-making process available from no other method. It allows power plant designers, regulators, and operators to discriminate between issues important to safety and those which are trivial. Although it is beneficial to perform a PSA to utilize the potential products available from such a study, it is especially important to realize that the PSA process itself is a valuable experience.

At the IAEA Seminar on Implications of Probabilistic Risk Assessment held earlier this year in Blackpool, United Kingdom, the uses of PSA in assisting decisions was the focus of many speakers. Among them was Prof. Leonard Konstantinov, Deputy Director General and Head of IAEA's Department of Nuclear Energy and Safety. He pointed out that the Agency uses the term Probabilistic Safety Assessment (PSA) for this subject area, since this more aptly describes its use.

Of the many useful insights resulting from a PSA, the probability of core melt, usually denoted by P_{cm}, is not the most meaningful. This point was emphasized by Prof. Konstantinov, who sounded a warning note when citing the P_{cm} results of the 22 PSAs that had been made by the end of 1983. He suggested that great caution should be exercised when comparing P_{cm} estimates for different plants because of their imprecision. This imprecision, from uncertainties, in the values of P_{cm} is attributable to differences both in the analytical methods used and in the design, operation, and site characteristics of the plants studied.

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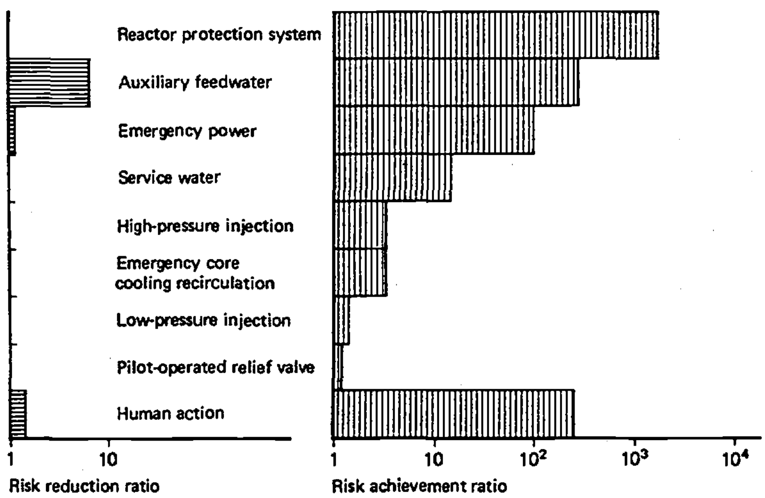
Potential uses of PSA

One of the most important contributions of PSA in nuclear safety is in identifying those accident sequences that contribute most to the P_{cm} for a particular plant. Such accident sequences are termed dominant accident sequences. Knowledge of the dominant accident sequences can be used to establish the relative importance of reactor systems. Prof. Konstantinov described this use of PSA by reference to the accompanying figure, which shows results for a specific plant.

The two important measures shown are the risk reduction ratio useful for assigning priorities to future improvements, and the risk achievement ratio. The risk reduction ratio is the factor by which P_{cm} could be reduced by improving a system's reliability. The risk achievement ratio is the factor by which P_{cm} would increase if the particular system was not operable. Although this example is a useful application to safety decisions, Prof. Konstantinov also pointed out the difficulties in obtaining such risk factors.



Risk reduction ratios (left-hand scale) and risk achievment ratios (right-hand scale) can be used in establishing the relative importance of reactor systems.

Safety evaluations and other benefits

The full benefits available from a PSA study often are not fully recognized. At the seminar many potential uses of PSA were described but only some of the papers reported actual experience.

The potential uses of PSA are summarized in the table. It is often the desire of the purchaser of a planned power plant to independently assess its safety. PSA is an effective tool for such a safety evaluation, whose benefits include identification of that data and its degree of preciseness necessary to assure a sound design.

From knowledge of risk-dominant accident sequences, important systems, components, and human errors may be identified. This information can be used in:

- Evaluation of the safety significance of abnormal incidents
- Operator training (including testing responses on simulators which incorporate accident sequences identified by a PSA)
- Improvement in designs
- Standards and regulations development
- Prioritizing time of plant inspectors to focus on safety-significant components, systems, and test and maintenance procedures
- Identifying uncertainties that are important and can form the basis of research priorities.

Additionally, during discussions on the safety of a proposed facility, the PSA for that plant can serve as the focus of questions leading to a more efficient resolution of the expressed concerns. An interesting example of this aspect was covered in a paper describing the use of PSA in the licensing process for the planned UK pressurized-water reactor Sizewell "B".

Cost-effectiveness also is being used in many regulatory decisions by maximizing the ratio of risk reduced over the cost of the risk reduction.

Finally, the PSA serves as a benchmark risk and methodology model for operational decisions and eventual demonstration of compliance with safety goals. Such a plant-specific PSA model can be used for safety decisions throughout the lifetime of the plant. The plant PSA model will have increasing impact with time since plant operational data fed back into the model will reduce uncertainties and allow more reliance on numbers.

Actual experience in the use of PSA was described in papers on optimization of system design, technical specifications, maintenance outages, and a decision involving optimal allocation of resources among several power plants under construction.

Potential products from a PSA and some possible uses

Product	Use
• Data specifications	• Safety evaluation of plant design
• Major contributors to risk (accident sequences, importance of systems, components, human actions)	• Incident evaluation, operator training; Focus standards and regulations on areas significant to safety; Optimize time of plant inspectors
• Weaknesses in plant design or operation	• Improved designs, backfitting
• Major contributors to the uncertainties	• Prioritization of research
• System for involvement	• Efficient public dialogue
• Cost effectiveness	• Regulatory decisions
• Overall risk plus methodology	• Operations, compliance with safety goals, deeper understanding of safety issues

Treatment of uncertainties

The seminar dwelt at length on ways of handling the uncertainties inherent in PSA in its current stage of development. Even though many benefits are resulting from PSA studies that include large uncertainties, reduction in, and better ways of treating, uncertainties are desirable.

Uncertainties generally stem from three sources — parameter variation (data), modelling, and incompleteness. Parameter variation includes failure rates of conventional pieces of equipment (pumps, valves, pipes, vessels), human failure rates, and spatial and temporal changes of basic properties. With the exception of human error, the uncertainties due to parameter variation are relatively small because of the large body of experience. The failure rates of unique pieces of equipment usually can be extrapolated from other similar equipment.

Methods for analysing uncertainties associated with data variability are reasonably mature. Those available for estimating uncertainties in basic data and propagating them through the analysis differ in philosophical approaches, yet they may produce similar results, particularly when the data base is large.

Uncertainties because of modelling assumptions are usually addressed through sensitivity studies that show the variation in results with different models. Those models showing the biggest changes are candidates for closer scrutiny and perhaps further research.

Human errors are important in operation, control, maintenance, and testing of equipment in practically any industrial activity. In the cases of the airline and chemical industries, it has been estimated that human interaction has contributed in as many as 90% of the accidents. Human interactions are a major source of uncertainty in PSA because people may perceive different actions to be correct, performance varies from one person to another, actions are independent, and errors of commission, as well as omission, can be made.

Future trends and conclusions

It is expected that in the future the trend to use partial PSAs for safety decisions will continue. However, it will be necessary to better incorporate plant operational experience into plant-specific PSAs to continuously improve the effectiveness of PSA models. More emphasis will be given to an improved modeling of human performance. On the other hand, PSA results themselves can improve human performance by utilization in on-line expert systems to aid the operator in coping with incidents.

Already, PSA is reaching a level of maturity such that some analytical approaches could be standardized.

At the Blackpool seminar, the panel included (from left) F. Allen (UK), M.C. Cullingford (IAEA), H.J. Gittus (UK), L.V. Konstantinov (IAEA Deputy Director General heading the Department of Nuclear Energy and Safety), M. Hayns (UK), J.A. Peat (UK), and H. Bakhoum (IAEA).

Reduction of uncertainties in quantitative risk results will enable better integration of PSA into safety criteria and licensing processes. It is clear from experience gained with PSA over the last 10 years that it is necessary to use these methods to complement the deterministic safety criteria.

PSA offers critical safety-related insights which can be gained through no other procedures. This is because improvements in a plant should be directed to those areas which could have both an important impact on a potentially serious accident and a high probability of failure. Safety evaluations not based on PSA may identify parts of a plant possessing only one or neither of these characteristics.

Evaluation of abnormal events is an important area that can benefit from PSA application. The IAEA can benefit its Member States by providing information and appropriate resources to implement PSA for improved safety decision-making.