Reviewing the operational safety of nuclear power plants

A report on the IAEA's international programmes

by Ferdinand L. Franzen

Although the rate of new orders for nuclear power plants is down dramatically and fewer plants are under construction, the number connected to the grid has steadily increased. This has prompted a shift of emphasis in nuclear safety from the design and construction of plants to their operation At the same time, there is growing recognition that mere compliance with regulatory requirements is not enough, that excellence in operational safety must be achieved for the public to support renewed expansion of nuclear power. For its part, the IAEA is continuing to develop programmes that can help its Member States and operating organizations achieve this goal Four of these — known by the acronyms OSART, OSIP, ASSET and IRS — are the subject of this article

OSART: Operational safety review teams

The Agency has traditionally provided advice and assistance to Member States in nuclear safety matters through expert missions. In 1982 the IAEA set up the OSART programme under which international expert teams make three-week in-depth reviews of operational safety practices at particular nuclear power plants Initially intended to complement technical assistance to developing countries, industrialized countries soon realized that they could also gain from OSART reviews. Invitations from these countries have outpaced those from developing countries, particularly in the aftermath of the Chernobyl accident An OSART review is not a design appraisal or a regulatory inspection to check compliance with national requirements, but an intensive exchange of information with operating organization staff on how to enhance safety performance

OSART missions usually addresses eight important areas of operational safety. (1) plant management, organization, and administration, (2) personnel training and qualification, (3) operation, (4) maintenance, (5) technical support, (6) radiation protection, (7) chemistry and (8) emergency planning and preparedness In comparing practices at one plant against those used successfully elsewhere, the OSART is results-oriented; that is, it does not urge a single proven approach but accepts alternative approaches that can contribute to plant management's quest for enhanced safety.

An OSART team has 10 to 12 experts representing a cumulative nuclear experience ranging from 100 to 200 years. External consultants are recruited from nuclear power plants, utilities, and regulatory authorities to provide specific expertise for particular reactors. The typical expert holds or has held a senior position in a nuclear power plant, with a total nuclear experience of 10 or more years. Team members from the IAEA staff ensure consistency among reviews. A typical mix is two-thirds non-IAEA members (half having previously participated) and one-third IAEA staff.

Members should have good investigative skills and a command of the OSART working language (English) and, if possible, some knowledge of the local language. In each review area, team members, having familiarized themselves with specific plant conditions through document study, examine operating results, observe personnel on work preparation and execution, and interview them to clarify impressions. Throughout the mission, each expert regularly informs his counterpart of his observations and conclusions. The daily progress is recorded and detailed technical notes are compiled. Summaries are also drafted to highlight the main conclusions reached. The latter form the basis for a presentation at the concluding meeting with the counterparts.

The team leader for each OSART, an IAEA staff member, is responsible for overall co-ordination and

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liaison with utility and plant management and the regulatory authority, for training team members, and for guidance to ensure a co-ordinated review process. The leader also prepares the OSART report after return to the IAEA's headquarters in Vienna for submission through official channels to the competent national authorities.

Written guidelines based on Agency *Safety Series* documents, applicable national rules, and OSART experience ensure consistency of reviews. They do not contain any criteria applicable to the review process but help the team focus on key elements of the plant's operational safety programme. Thus, each expert, after consulting with the rest of the team about current international practices, judges whether the objectives of such a programme are being met.

As of December 1987, 23 OSARTs have been carried out and their results have been reported in confidence to the competent national authorities. *(See accompanying table.)* Although a number of earlier reports have not been authorized for release, most of those since 1986 have been and are available through the Agency to interested parties.

In addition, a report in general terms on the main results of the first 18 OSARTs is now in preparation. In brief it can be said that all of these reviews confirmed that the nuclear power plants were being operated by experienced, dedicated staff fully aware of their responsibility for safety in operation.

While no unacceptable risk for the environment or the public was found, the teams recommended practical ways to enhance operational safety. Additional suggestions either endorsed ongoing activities or aimed at more efficient performance. All plants visited were responsive to team proposals and actions often were initiated even before the missions were completed.

Significant differences were found among plants regarding the quality with which various important functions were being carried out. For example, the lack of a systematic, structured approach to ensure that each activity was carried out as intended led at some plants to inconsistent performance, and indicated a need for increased supervisory involvement and higher performance standards.

Each reviewed plant had some strong points that could be emulated by others. Thus, team members not only contributed their own expertise, but also took home ideas on other commendable practices. Many of the existing shortcomings identified by the team were already recognized and solutions had been proposed by operating staff. By incorporating these proposals, the team recommendations often were instrumental in getting the resources and management support needed to resolve the matter.

Thus far, OSARTs have visited pressurized-water reactors (PWRs), boiling-water reactors (BWRs) and pressure tube reactors (PTRs). OSARTS have been requested to magnox reactors and Soviet-designed VVERs, and there is the possibility of eventual visits to the remaining reactor types. The effectiveness of the OSART programme in expanding international co-operation in nuclear safety is reflected in the growing number of requests (1988: 12 to 15), and in the participation by experts and observers from a large number of countries. *(See accompanying table.)*

In 1988-89, the OSART programme, in responding to requests from the CSSR, Japan, Hungary, UK, and USSR, will have reached all areas of the world, East and West and industrialized and developing countries, further underlining the international character of nuclear safety. Experience indicates that this voluntary co-operation within the nuclear community is speeding up adoption of superior safety practices and raising the level of operational safety worldwide.

OSIP: Operational safety indicator programme

In support of the OSART programme, the Agency began in 1985 an effort to complement subjective judgements with objective, plant-specific data that could help team experts identify key areas for in-depth investigation, leaving less significant areas for more cursory treatment.

Development and application of operational safety indicators are closely interrelated in this programme, and they involve expert consultants active in this field. (Similar activities are being pursued in many countries operating nuclear power plants.)

One set of defined indicators addresses on-line activities, such as operation, surveillance, and maintenance, in terms of reactor safety, worker safety, environmental protection, and operating reliability. A second set addresses off-line activities, such as the processing of operating experience, including the identification of safety issues, analysis of direct and root causes, and implementation of safety upgrades.

As one example, reactor safety is broken down into overall indicators related to (1) safety significance of reported events; (2) safety margins in normal operation; (3) inoperability of and (4) reliability of safety functions; (5) unavailability of safety systems and components; (6) impact of human failures on the reliability of safety functions; (7) completion of and (8) effectiveness of surveillance testing of safety functions; (9) equipment ageing transients; and (10) corrosion fields. To supplement these and other overall indicators, more detailed indicators are available.

An exercise to validate the operational safety indicators was carried out at the Bruce nuclear generating station in Canada in December 1986. Since then, data for these indicators have been expressly compiled as part of the advance information for OSARTs to Pickering (Canada), Calvert Cliffs (USA), Philippsburg (Federal Republic of Germany), and Almaraz (Spain). The experience gained by OSART members and their plant counterparts is being used to improve this tool so that it can be referred to by OSART teams and by operating organizations to define and track key parameters of operational safety.

ASSET: Assessment of significant safety events team

A new IAEA service, ASSET, was established as a response to a recurrent finding of OSART missions to nuclear power plants: Failure of surveillance activities to identify incipient problems before they lead to equipment breakdown and lack of systematic analysis of the root causes of unusual events. Determination of the root causes should guide the revision of surveillance activities for increased effectiveness.

Upon the request of Member States, ASSET provides missions of experts in relevant technical disciplines, analytical techniques, and man-machine interface to investigate: (1) a particular event of safety significance, to assess the appropriateness and completeness of the corrective actions planned; (2) generic operational safety issues including particular events, human failures, surveillance activities, radiation doses, and waste production.

The ASSET methodology comprises a five-step process: (1) review of an event, including detection and recovery actions; (2) "fault tree" analysis (series diagram) to identify precursor elements and direct cause; (3) "weakness tree" analysis (parallel diagram) to determine contributory elements or root causes, such as weaknesses in the surveillance activities on equipment, operator aids, and personnel qualification; (4) review of lessons learned on the elimination of direct cause and mitigation of root causes; and (5) check of planned or already implemented corrective actions and recommendation of appropriate modifications.

In the first ASSET mission, to the Krsko nuclear power plant in Yugoslavia in 1986, the team of experts in operations, analysis methodology, operating experience feedback, man-machine interface, and human factors investigated selected events of safety significance. These events included the loss of the second off-site power source; the inadvertent depressurization of the reactor coolant system; the leaking of the inner seal ring on the reactor vessel flange; the containment pressure increase due to instrument air leakage; and the malfunction of the diesel generator protection system. Also, a statistical analysis was carried out on the safety-related events reported to the regulatory authority in 1983, 1984, and 1985.

The ASSET team concluded appropriate actions were taken to correct the identified direct causes, usually by replacing failed elements and by revising maintenance procedures (where installation deficiencies were found) and operating procedures (where adverse exposure of sensitive components was found). However, as the team realized that correction of root causes was not comprehensive, additional suggestions were made on how to improve surveillance activities (for example, on instrumentation and control equipment) and operating experience feedback (including, for example, events affecting support systems). The development of emergency operating procedures was also discussed for coping with events such as station blackout, loss of service water, and loss of instrument air.

IRS: Incident reporting system

Unusual events are a major source of the operating experience feedback in the nuclear industry. These may include spontaneous failures of equipment, and deviations discovered through surveillance and maintenance activities. With more than 400 power reactors operating in Member States, these events occur regularly. Collection, evaluation, and dissemination of the lessons learned from these events is an important part of the continuing process of enhancing operational safety.

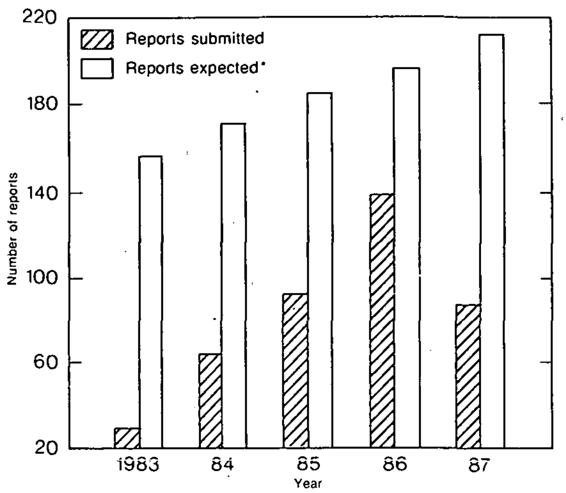
To facilitate worldwide, free exchange of information on safety-related events, the Agency, in co-operation with the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (NEA/OECD) operates an Incident Reporting System (IAEA-IRS). Member State co-ordinators submit national reports to the IAEA-IRS and receive copies of all other IAEA-IRS reports for further distribution. Arrangements are in place to ensure that the information exchanged is used for official purposes only.

The information communicated through this mechanism comprises basic information (event, utility/plant, date, reporting category); a narrative description of the event (system/component faults, previous events, consequences); a safety assessment; the corrective action taken or planned; (5) root causes and lessons learned; and a coded watchlist (to enable computerized storage and retrieval of key data).

The following reporting categories are distinguished: (1) release of radioactive material or exposure to radiation; (2) degradation of items important to safety; (3) deficiencies in design, construction, operation including maintenance and surveillance, quality assurance, or safety evaluation; (4) generic problems; (5) events requiring or leading to significant consequential actions; (6) events of potential safety significance; (7) unusual events of other man-made or natural origin directly or indirectly affecting safe operation; and (8) events that may attract significant public interest.

Unusual events can be characterized in respect of their relevance to safety and frequency of occurrence as follows: Events unrelated to safety — 0.5 to 1 per week; safety-related events — 0.5 to 1 per month; events of safety significance — 0.5 to 1 per year. These figures are long-term averages and not necessarily representative for an individual unit. But they may convey the insight that only a fraction of all events to be analysed by a nuclear power plant/utility is reportable to the national information system (second and last group of events) and an even smaller fraction (last group only) to the IAEA-IRS. Thus, the more than 400 reports in the system as of October 1987 constituted only a small subset of other national or regional reporting system data.

Unusual events of safety significance reported to the IAEA-IRS



* Estimated based on number of power reactors operating × 0.5 per year

During the past years the IAEA-IRS has grown from a clearinghouse for information on incidents and accidents into a co-operative network for collecting, handling, assessing, and disseminating information on deviations, incidents, and accidents at nuclear power plants. Deviations discovered through surveillance and maintenance activities are included.

A technical committee representing the participating Member States oversees efforts to improve the system and to optimize its use in operating experience feedback. The committee meets at least once per year to discuss events which were reported for generally applicable conclusions and to make appropriate recommendations to operating organizations and regulatory authorities for implementation. It may also report on events that were found to be of special interest internationally. A review of the reports in the systems's first three years (1983 to 1985) found that:

National participation in the IAEA-IRS (as of December 1987)

Type of participation	
Full:	Argentina; Brazil; Bulgaria; CSSR; Finland; German Democratic Republic; Hungary; India; Republic of Korea; Netherlands; Pakistan; Spain; UK; USSR; and Yugoslavia
Through NEA-IRS:	Belgium; Canada; France; Federal Republic of Germany; Italy; Sweden; Switzerland; and USA
Through meetings:	Japan
Expected: (when plants become operational)	Mexico; Philippines

- Reporting quality was uneven, particularly regarding event description, root cause identification, discussion of impact on plant operation, and corrective action taken.
- Only 8% of the events reported were considered of "high" safety significance and 22% were of "medium" significance.
- Principal causes were design deficiency (18.7%) and operational error (17.5%).
- The leading effect on plant operation was reactor trips (53.2%).
- The dominant type of failure was single failure (40.1%) with multiple failures or common-cause failure less frequent.

An assessment of the events of high safety significance confirmed the following as important safety issues: system interaction by flooding or spraying with water; electrical system interaction; multiple failure in different systems; common-cause failures; maintenance errors; and operator actions. However, the assessment required considerable engineering judgement because of the limited database (a total of 169 initial and 29 follow-up reports), the large variation in the report quality, the diversity of reactor types, and varying operational practices.

In its first 5 years of operation, the IAEA-IRS has reached almost full participation. All but two Member States with operating nuclear power plants now participate either directly or through the NEA-IRS. In addition, it has established close co-operation with the NEA-IRS and developed a solid infrastructure to support further improvements. Among high-priority issues for the future are improving the reporting quality (a prerequisite for any thorough assessment) and promoting a more complete reporting of unusual events of safety significance.

Regular in-depth discussion of events reported to the IAEA-IRS among specialists appears indispensable to assess the safety significance, to determine the lessons to be learned, and to evaluate their broader applicability. Additional guidelines and manuals may also be needed to match the intent and reality of the IAEA-IRS, to assist in widening its use, to check for trends, and to serve specific interests. Growing international co-operation in the feedback of operating experience is needed as a way to avoid duplication of efforts, to allow access to as much data as possible, and to strengthen assessment capability worldwide.

Close co-operation

The four Agency programmes briefly summarized here reflect the preparedness of Member States to co-operate more closely in matters of nuclear safety. While the OSART programme has become the most visible and rapidly expanding one, all four programmes are expected to continue for the foreseeable future, supporting each other, and becoming more refined, efficient, and adaptable to changing demands.