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NPP UNUSUAL EVENTS:

DATA, ANALYSIS AND APPLICATION

by

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1. INTRODUCTION

For over 30 years the IAEA has served as a center for international co-operation on matters of nuclear safety. A strategy has been recently defined for combining analytical and practical elements to intensify the assistance to Member States and for building up a broad public confidence in nuclear technologies. This strategy is based on a dynamic approach to the following: advancing operational safety, reviewing safety issues, applying safety assessment techniques, promoting regulatory consistency, defining safety requirements for future nuclear installations, strengthening radiation protection infrastructures, managing radioactive wastes, improving public understanding of radiation and nuclear safety.

Within the IAEA's nuclear safety programme, high priority is given to operational safety. The concept of using reporting systems as focal points of safety experience feedback loops has now been in practice for more than 10 years. Reporting systems have brought and continue to bring benefits from the safety feedback process standpoint. The time has now come to strive for excellence.

The paper summarizes the status and explores future trends in some areas which are of particular importance to prevent NPP unusual events and to achieve common understanding with the public. International patters of assessing safety, monitoring safety level trends and using information on NPP unusual events to improve safety are specific subjects of the paper.

2. UNUSUAL EVENTS: DATA AND THEIR APPLICATIONS

The collection, interpretation and dissemination of operating experience is one of the fundamental, technical principles of nuclear safety. The advantages of pursuing this principle are widely acknowledged and relevant worldwide activity increases continually.

The IAEA is developing an integrated approach to draw safety significant lessons from operating experience for the nuclear community. The IAEA system on the feedback of operational safety experience from nuclear power plants consists of the following parts: Incident Reporting System (IRS) activity, Analysis of Safety Significant Event Team (ASSET) activity, Operational Safety Indicators Programme (OSIP) activity and Operational Safety Review Team (OSART) activity.

Information systems on unusual events occurring in NPPs are a specific means of utilizing operational safety experience. To date many national and international organizations set up and operate such systems. INPO and NRC systems in the USA, the EDF system in France, NEA/OECD, and IAEA systems are well-known examples of efforts to obtain feedback from unusual events in NPPs. Recently the new utility organization, the "World Association of Nuclear Operators" (WANO) has set up its own reporting system.

The IAEA-Incident Reporting System (IAEA-IRS) is an international focal point for NPP operating experience derived from unusual events. Official commencement of the IAEA-IRS was in 1983. To summarize the experience gained by this system in the seven years of its existence, it would be useful to begin with the definition: the IAEA-IRS is a cooperative network for collecting, handling, assessing and disseminating information on unusual events (i.e. deviations, incidents and accidents) occurring at nuclear power plants during operations, surveillance and maintenance activities.

An "unusual event" or simply "event" can be one occurrence or a sequence of related occurrences. A deviation is an event represented by discrepancies of deficiencies and discovered during maintenance, surveillance or operation (such as operational data collection, inspection, checking, testing) which could lead to an incident or an accident through technical or human failure. An incident is an event with no important damage to the plant or persons and includes: trip, unplanned shutdown, forced outage, violation of operational limits and conditions, radioactive release, personal contamination or irradiation. An incident may be a precursor to an accident. An accident is an event with significant damage to the plant or to persons.

The IAEA-IRS network consists of national and international parts; 25 countries with NPPs in operation participate in the system. The IAEA-IRS information flow is regulated by a set of reporting criteria (7 technical categories and 1 public-oriented category). Participants select events on the basis that these events have safety significance of general interest to the international nuclear community because important lessons can be learned. A report should not only be written when an event occurred but also when there is something important to share with colleagues. The indicative number of unusual events on which information is sent to the IAEA per year lies in the range of 0.5 to 1.0 times the number of nuclear power plants operating in the country. Today the number of records in the IAEA-IRS file is more than 1000.

There are three types of national reports in the IAEA-IRS: a preliminary report, a full report and a follow-up report. If the unusual event is considered to be highly significant to safety, a preliminary report shall be sent, consisting of a brief description and any preliminary assessment of the event. This report shall be sent as soon as possible, but in any case not later than one month after the event. A full report on an unusual event shall be sent within a period of three months. Follow-up reports shall be sent if it is necessary to add to or modify details previously supplied. These follow-up reports shall be sent as soon as practicable after additional information becomes available. Until now the IAEA-IRS file basically consists of full reports on unusual events, a small percentage (7%) of follow-up reports and a small number (12) of preliminary reports.

Internationally established, 6 parts of the IRS report (basic information: country, NPP, title of event, abstract etc,; narrative description; safety assessment; root causes and corrective actions; lessons learned; coded watchlist) provide information to be used in the safety feedback process on the national and international levels.

During 1983-1990 a great deal was undertaken within the framework of the IAEA-IRS. On average 5-7 topical meetings on IRS issues took place annually. Subjects such as reviews, generic studies and specific analyses of IRS events, quality control, codification and computerization of IRS data, methodological aspects of event investigation, interactions with other corresponding systems and activities and possible improvement and development of the,IRS were considered at the IAEA-IRS meetings.

Worldwide social processes show that the public must be a party to technological communities (for example, the nuclear community). Today, the public is an additional driving force to improve safety. Nothing is more complicated and useful than to be able to answer the questions of the young generation and the public.

The present situation is characterized by the fact that experts are hesitant to provide the public with technical information, fearing that it would be misjudged. In turn, the public is concerned that the experts hide important information. Within the framework of the IRS, the IAEA is taking steps to increase the visibility of this system. It is necessary to recognize that developing an image, building up a profile and eventually forming some sort of relationship with the public target groups is definitely not something that can be done overnight. The quarterly reports on the operation of the IAEA-IRS and the trial implementation of the INES (International Nuclear Event Scale) are the starting points of a coordinated programme to achieve a common understanding of nuclear safety.

A typical content of IRS quarterly reports is the following: Introduction, General Statistics and Observations, Specific topics of IRS activity and Data Base News. Reviewing the characteristic of unusual events recent quarterly reports say that participants of the IAEA-IRS are sending information of safety significance. This information covers such problems as degradation of reactor coolant system pressure boundary, degradation of safety functions and systems and losses of off-site power. Participants reported that mechanical failures were the most often observed causes of unusual events (blockage, restriction obstruction, binding, break, rupture, cracks, weld failure, wear, fretting, lubrication problems, corrosion, erosion etc.). Electrical failure (short-circuit, faulty insulation, bad contact, disconnection, ground fault), hydraulic failure (water hammer, abnormal pressure, losses of fluid flow and pressure, gas binding etc.) and instrumental failure (false response, spurious signal, ,loss of signal etc.) are less in number groups of event causes.

While searching root causes of unusual events occurring in NPPs, there is a sound tendency to find these in the human factors area. Usually, national experts link human factors together with the following:

design deficiency (including modifications);
inspection, maintenance, testing deficiency;
manufacturing, construction or installation errors or deficiencies;
management organization or work planning deficiencies;
and procedural deficiency.

Information on unusual events received by the IAEA during the quarter under reviews (1990) indicates that NPP operation errors, violation of technical specifications, inadequate training among other factors are becoming less important than the aforementioned items or were not considered as appropriate areas to find root causes of unusual events.

Undoubtedly, national reports received will undergo further analysis, first of all with regard to safety significance, generic issues, appropriateness and completeness of corrective actions and lessons learned. To give an international perspective to IRS information and to prevent repetition of unusual (unfavourable) events in NPPs elsewhere are the main objectives of such analysis.

An "Interfacing Systems Loss of Coolant Accident" (ISLOCA) has been selected as a topical area for in-depth study in 1990. ISLOCA has been recognized as one of the precursors to core melt since the Reactor Safety Study (WASH-1400).

At the IAEA, the data base was used to search for events with interfacing LOCA aspects. Ten events were found. The national coordinators were requested to provide additional information. An expert meeting for this in-depth study is scheduled to take place in the third quarter of 1990 (Oct. 1990).

The prime aim of the International Nuclear Event Scale (INES) is to serve as a means for promptly and consistently communicating to the media and the public the safety significance of events reported at NPPs worldwide. This is why INES expresses the safety significance of events mainly in terms of hazard/severity. The scale was developed together with a user's manual and recommended for worldwide use on a trial basis for a period of one year. The INES Training Workshop took place in Vienna, 13-15 June 1990.

INES defines several levels of events, ranging from a functional or operational anomaly (Level 1) to a major nuclear accident with widespread health and environmental effects (Level 7). The safety significance is indicated in terms of an event's off-site impact, the on-site impact and the degradation of a plant's defence-in-depth. An event with no significance (according to the INES criteria) is classified as Below Scale (or Level Zero). An industrial accident or an event such as a fire or an earthquake that does not pose a radiological hazard is termed Out of Scale.

A start was made to classify IRS events according to INES. For example, of the 57 events reported to IAEA-IRS during the first quarter of 1990, 37 events were rated as zero or below for the criterion "defence in-depth", 13 events were rated as 1 on the scale, 6 events were on level 2 and 2 events on level 3. One event was rated as 3 on the scale for the criterion "on-site impact" because several workers received doses above the annual limit. There was no event classified with respect to the criterion "off-site impact".

One feasibility and several case studies were performed at the IAEA to find out what plant specific PSA can provide for the in-depth analysis of unusual events (based on examples of events reported to IAEA-IRS). IRS/PSA studies proved to be mutually beneficial. The knowledge acquired by structuring an event applying comprehensive PSA type logic is important in that it is conducive to identifying potential consequences not fully recognized in event analysis without PSA. In the third week of September a special experts meeting will be held to sum up IRS/PSA activity in Vienna.

3. UNUSUAL EVENTS: ANALYSIS AND RESULTS

Today, no task is more important than the development, acceptance and implementation of the international policy to prevent unusual events occurring in NPPs.

Undoubtedly, an essential element of the international prevention policy must be the methodology and practice of operating safety experience feedback which could provide answers to establish which problems exist in nuclear safety, how one should go about solving them to improve nuclear safety. The complex and ill-defined nature of the aforementioned methodology and practice, among other reasons, forces one to consider a step-by-step approach as being the most effective. Recently, the IAEA has been concentrating its efforts on two items of the safety feedback process: systematic methods of investigation/analysis of NPP events and of determination of the significance of unusual events from the operating safety experience feedback standpoint.

Despite all preventive measures, unusual events (incidents/accidents) still occur at NPPs. It is therefore of utmost importance to perform in-depth analysis of such events, to derive lessons and to feed them back to improve NPP safety. A method of root cause analysis based on the principle of latent weaknesses which are not eliminated in a timely fashion by the plant surveillance programme has been developed by IAEA-ASSET (the Assessment of Safety Significance Events Team). The ASSET approach addresses NPP policy for the prevention of unusual events, provides essential input to the methodology of safety experience feedback and is an example of a combination of analytical and practical elements. ASSET missions at NPPs such as Greifswald (GDR), Ignalina (USSR), KANUPP (Pakistan), Angra (Brazil), Krsko (Yugoslavia), ASSET workshops on significant events collected by the IAEA-IRS are facts that illustrate analytical and practical links.

A motto of the ASSET approach is that safe nuclear power plant is a plant without any incident. NPP unusual events are only the tip of the iceberg. Accidents and incidents result from event without meaningful impact on NPP operation (for example, events rated below INES) but not properly corrected (poor analysis and restoration) and the non-detected weaknesses that existed in the equipment, personnel and procedures (poor plant surveillance programme). Therefore safety culture implies an effective policy for prevention of NPP unusual events and plant surveillance programme is the ultimate barrier for prevention of accidents and incidents.

The ASSET method proposes predictive safety indicators as early warning signals to plant managers for prevention of unusual events. Predictive safety indicators should result from in-depth analysis of root causes of deviations that lead to consequences, categorized under 3 INES criteria (degradation of defence in-depth, on-site impact, off-site impact).

The indicators should first of all have the function of preventing and detecting possible negative phenomena at nuclear plants. In order to be effective, the indicators should recognize and foresee as early as possible the negative changes taking place in the systems and equipment significant to the operational safety of the plant as well as in the performance and prerequisites of the plant organization and management. On the other hand, it should also register the potential positive trends initiated by any changes made at the plant.

In order to meet these objectives, a number of developmental projects have been initiated worldwide. In addition to already widely used event and interval based methods, two distinguishable methods (although interconnected) have been proposed: reliability based approaches and risk based methods.

The reliability based approach is generally system oriented and requires a preselection of systems (areas) which have high or dominant influence on NPP safety. The reliability based methods utilize somewhat simplified reliability models and imply operational data collected at the plant. One very promising development is the 'safety system unavailability trend indicator', which utilizes train level data on unavailabilities (different origin) and failures and processes this information to obtain trends which are statistically significant. Further development calls for refining the methodology to adequately address common cause potential and human errors disabling the system for methods to aggregate individual system indicators to obtain the safety measure at some higher level.

An aggregation of indicators is also an intermediate step towards risk based indicator development methods which are aiming to take a more holistic approach by concentrating on the plant as a whole rather than on its constituents. The risk based method should basically employ probabilistic models and structures that describe the stochastic nature of system performance. Again, the plant's operational data have to be collected, in some cases even to a broader extent than for reliability based indicators. The level of detail in the implementation of risk based methods may be different, but full scope (level 1), plant specific "living" PSA is seen as the highest objective. The ultimate goal would be a system which monitors in "real time" all the changes in plant operation, including configuration changes, and indicates the current safety level in comparison with a predetermined safety margin. Using "living" PSA models it should be possible to monitor and assess the trends in a high level safety measure (like core melt probability or radioactive release) which would then be the plant's top safety indicator to be used by plant/utility management as well as by the regulatory body.

According to the ASSET method, an NPP unusual event should be dismantled into occurrences. An occurrence is a failure of personnel, procedure or equipment to perform as expected. Several occurrences can usually be identified in the sequence of an event. Each occurrence requires in-depth analysis to identify its direct and root causes and to determine appropriate corrective actions. Effective enhancement of prevention of unusual events includes "repairs" and "remedies". "Repairs" address the root cause of the event by eliminating the deficiency of the plant surveillance programme and by mitigating the contributors to surveillance deficiency (surveillance policy and surveillance programme management).

Among means and techniques to prevent unexpected occurrences in a timely fashion Probabilistic Safety Assessment (PSA) techniques can provide information related to the spectrum of possible accidents for a particular nuclear power plant. Such information, when based on reliability data obtained from experience with that particular plant can be used to identify the most important accident sequences and their contribution to the probability of core damage. Once these are known, the main component and human contributors to safety are identified.

Changes in reliability of different components and systems can be further used to determine the safety level of the plant at any given time, to monitor the safety level of the plant up until the present and to predict from safety performance trending analysis, the safety level of the plant for some period of time in the future. PSA can therefore be particularly applicable to safety decisions related to the prevention of incidents.

Plant specific PSA knowledge has proven to be very useful in designing operator advisory systems or, recently, even in expert systems used as an operator tool. Although the examination of an actual incident occurrence at a plant shows that a PSA does not always treat the detail of any actual sequence (such details is often unnecessary for risk comparison and reliability purposes), PSA results, when coupled with general plant knowledge, results from simulator runs, maintenance and testing records, etc., have proved to form a sound knowledge base for operator advisory systems, which certainly play an extremely important role in the incident prevention mechanism.

With the rapid advancement of computer technology it has become possible to store and continuously update level-1 PSA on personal computers. This allows the updating of PSA results to take into account changes in plant configuration; the user can describe any plant configuration and receive updated risk information that reflects the plant's status at the time. It can prove to be a valuable decision-making tool for both operations personnel (control room and maintenance) and plant managers. It makes it possible to simulate the impact of certain operator actions on the safety level of the plant, before such actions are actually carried out, or to determine the safety implications of removing specific equipment combinations from service for testing and maintenance at a particular time. Plant managers can use this type of tool to decide where to focus their efforts to enhance the safety of their plant. It can be further used to identify important accident scenarios that should be stressed in operator training programmes and to identify beneficial changes to procedures or system design.

Another important area for utilizing PSA results in the assessment of safety significance of events or occurrences within the events analyzed. In this approach to incident analysis, the first step is structuring of the event sequence. It is of utmost importance to fully understand the event sequence including the operation of the systems involved as well as their intended function. A logical structuring of the event sequence is then accomplished in a PSA compatible way, which means the identification of systems and functions involved and the definition of the initiating event. The next step is the selection of an applicable PSA event tree and overlaying the structured event sequence on this PSA event tree. At this point the failed component(s) (equipment or human) should be located as a basic element in the fault trees of the chosen event sequence. In some cases, when the component is not found in the pre-established fault trees of the PSA, some reasonable compromise might need to be made as, for example, locating the faulty element in a larger component which is included in the PSA. The final step is the quantification of the event sequence meaning that probabilities of the basic occurrences that have really happened are changed to "1" which would result in a new top event unavailability figure, reflecting the plant degradation during the considered event sequence.

At the present time there is a great temptation to consider a reporting system on unusual events occurring at nuclear power plants (NPPs) as a knowledge or an expert system which can act as an intelligent assistant to the nuclear community to use operational safety experience. Everyone would like to use such a system, especially as some expert systems have now moved from the laboratory stage into industrial environments. In other words, sophisticated problem-solving techniques which imitate human decision-making processes have been developed. Specific tools from this artificial intelligence domain have probably been used to analyse date collected on unusual events and the results obtained will be discussed at this specialist meeting.

With regard to the IAEA-IRS analysis activity, this consists of two main parts: the national investigation of unusual events in NPPs with following in-depth discussion thereof on an international level and the analysis of unusual event populations by international experts. The essence of this twofold process is one and the same - the resolution of analysis tasks by 'a human expert'. Expert groups use their own methodology and engineering judgement in the analysis of data. Moreover, mode of construction, working principles and requirements on the collection and assessment of the IAEA-IRS information greatly predetermine the results of IRS information analysis. I do not know of any studies which aim to analyse the bases of different reporting systems on unusual events and their influence on the results of assessment activity.

To day, the IAEA-IRS file contains over 1000 IRS reports; the average annual number of IRS inputs is approximately 200. IAEA-IRS reports have undergone a multiple screening process on national and international levels. Experience in some countries with NPPs in operation has shown that an average of 10 to 30 events per year per operating unit are reported. At present, more than 400 NPPs are in operation, which means that we receive only 1.5-4% of total information on unusual events. It is assumed that the purpose of selection is to identify events that have safety significance of general interest to the international nuclear community, because important lessons can be learned. However, safety significance and important lessons learned are very complex and are obscure, ill-defined concepts. Thus, under the aforementioned circumstances, it is natural that the IAEA-IRS file is a small, 'mixed set' of unusual events selected by various groups of experts. Undoubtedly, the advantage of this set is that it reflects the operational experience of a variety of nuclear power plants and different conditions in the world. However, the question to what extent IRS data collection can represent safety significant problems in unsolved as yet. That is why it is necessary to consider IRS reports only as detailed technical 'records' on unusual events in NPPs and to use expert knowledge in the reviewing-assessing process.

At the first phase of its existence (1983-1986), IAEA-IRS trends and patterns were determined from national assessments and discussions at international meetings. Tables I and II summarize these to a certain extent. A breakdown of the causes of unusual events reported and discussed is shown in Table I. The major contributors to the causes of incidents were design deficiency (18.7%), operational error (17.5%), corrosion (10.7%), maintenance deficiency or error (10.3%). The 16 problem areas which had an impact on plant operation or safety are tabulated in Table II.

IAEA-IRS activity now includes the following: 1) quality control of national reports to tailor the information contained in the reports to other conditions in different NPPs and countries; 2) regular in-depth discussion of recent IRS events among specialists to assess the safety significance of events and to draw general and specific lessons to be learned; 3) a systematic review of IRS data collection to group and assess IRS data from different IRS users' points of view; 4) performing IRS case studies, in particular using PSA methodology; 5) development of IRS guidelines and manuals to generalize IRS "Theory and Practice" and 6) a simulation of national and international cooperation in the field of information systems on unusual events to reinforce IRS activity and the effectiveness of feedback from operational experience. The ultimate goal of such activity is to develop the IAEA-IRS from a data collection and distribution system to a modern information source for significant applications in nuclear safety (human factor, PSA, public acceptance of nuclear energy, root causes and lessons from unusual events, gravity scale). In this respect, relevant steps are being undertaken to resolve IRS tasks with an interdisciplinary approach. It is planned that specialists from different domains of science and technology take active part in IAEA-IRS activity (for example: PSA experts, psychologists,journalists, sociologists).

Before describing results of IAEA-IRS analysis activity at the second phase (1987-1990) it is necessary to note that an essential part of experts' analysis activity depended on the experts' knowledge/engineering judgement regarding operational safety experience problems. Moreover, in analysing IAEA-IRS information, no formal methods of assessment of the quality of the experts, of conducting expertise and of treatment of experts' assessments were used.

Reviewing the IAEA-IRS data collection, experts found the following trends and patterns. Over half of the incidents screened involved human error. Problems identified were high sensitivity of safety equipment to human error, reliance on oral communication, lack of safety consciousness, training of auxiliary operators and maintenance personnel and operator motivation during routine walkdowns.

About one quarter of the events screened involved engineered safety equipment failures. Recurrence of failures was caused by lack of feedback to designers from operational experience, lack of complete understanding of the failure mechanisms involved due to lack of indepth analysis of events, inadequacy and incomprehensiveness of surveillance programmes (including testing) partially due to a lack of monitoring the means and shortcomings in preventive maintenance programmes.

Unexpected behaviour of systems, component and materials continued to occur. Several deficiencies reported to the IRS were discovered by surveillance programmes. Reviews of event reports showed that adequate surveillance programmes could have prevented other events. Some events, such as a reported water hammer and interaction of the resulting water leak with electrical power distribution systems, an event of the interdependency of AC and DC power systems, and a reported loss of all AC power, were not anticipated by either designers or utilities.

Deficiencies in design or during construction, such as unsealed penetrations, led to potentially severe system interactions in the case of events with flooding. It seems that protection of electrical or electronic cabinets against water dripping was not always provided and is still lacking. Such deficiencies, up till now, have not been sufficiently recognized, as no formal surveillance activities dealt with this area.

The design of some support systems did not always receive the same level of care as the major components of the plants. Loss of compressed air including instrument air has in some cases jeopardized the containment function. An insufficient design was sometimes followed by insufficient surveillance activities leading to the occurrence and recurrence of events.

Corrective actions taken by the plant staff were mostly of a remedial nature, addressing immediate requirements rather than preventing recurrence. To ensure the competence of operating staff, in order to guarantee sound judgement and decision-making, would also be to contribute to a permanent solution of unresolved problems.

Lessons learned were often applied only in the area where findings had been made and incidents had occurred. The application of these lessons to other systems or areas in which the same type of failure could have safety implications should be done more systematically. The diversity of plant types and design does not pose any difficulty in identifying generic lessons. It is more difficult to improve the use of international information related to trivial or less severe, known incidents. That is why incidents still recurred, even on the same plant, although the most well-known incidents or accidents generally led to significant modifications at many plants.

The above listed general observations made by international experts groups, of course, were based on in-depth analysis of reported events and their causes. The length of this paper only permits the presentation of some of the results of such in-depth analysis. They are as follows.

In the IAEA-IRS data collection there is a group of events which can be classified as internal events: internal flooding due to leaks, fire fighting systems actuation or water dripping. This group represents a sample of consequences of unexpected paths of water in a nuclear installation. Although precautions are taken at the design stage to cope with major events such as LOCA, the occurrence of more trivial water spilling have not received sufficient attention. The design of the penetrations sealing is sometimes weak, and the installation is not always complete during the construction phase.

The review of all events reported in the IRS identified a large number of occurrences related to the integrity of primary heat transport systems, steam generator tube failures, fuel integrity and thermal-hydraulic phenomena. It is recognized that, in all these areas, problems have been identified and documented and efforts are continuing towards successful resolutions. Nevertheless, the problems in the following four specific areas deserve additional attention: failure of reactor internal components due to stress corrosion cracking, fuel integrity terminal transients, degradation of pressure boundaries due to mechanical failures, and steam generator tube failures. In the cases of stress corrosion cracking of reactor internal components 1) extreme care must be taken in the selection of materials to be used in a potentially corrosive environment; 2) the design must consider the effects of thermal stresses and fluid loads during operation, as well as the residual stresses in components, and minimize the creation of high stress points in the components. Other factors to be considered in seeking improvements must be 1) the comprehensiveness of in-service inspection programmes for suspect components and 2) quality control in the manufacture of components and in their fabrication and installation. A review and analysis of the direct causes of the thermo-hydraulic phenomena group indicated the following root causes for the events: 1) weaknesses in surveillance of equipment performance; 2) a possible weakness in the surveillance of personal performance.

A large group of events was associated with engineered safety features. It was found that events occurred due to failure of "components" such as pilot operated relief of safety valves, check valves, pumps, turbine driven pumps, spring operated safety valves, failure of "system", such as main steam isolation valves, control rod systems, reactor trip breakers, residual heat removal systems during cold shutdown, emergency core cooling systems, auxiliary feedwater systems and due to loss of redundant or diverse systems by common mode or common cause mechanisms.

Last but not least, from the analysis of information of the IRS reports and the determination of direct causes of events involving "human factor", five areas were identified as being major contributors. These were as follows: a) errors of omission, which include the lack of a procedure, or the inadequacy of a procedure; b) errors of omission, including failures to follow procedures; c) errors in diagnosis or incorrect response; d) communication problems; e) operator awareness and/or vigilance.

Data collection on unusual events at NPPs and their analysis represent two interlinked sides of a single process. The more intensive the use of modern techniques simulating and supporting human decision-making processes, the more highly developed and more effective are the requirements for data collection. It is high time now to create a special logical frame for analysis activity to deal with unusual events at NPPs. This will bring a great impetus to the improvement of operational safety experience feedback.

4. CONCLUSIVE REMARKS

Nuclear safety is an international issue. The role of the International Atomic Energy Agency is growing because it offers not only a center for contact and exchange between East and West, North and South, but also because it is a practical instrument through which international cooperation on matters of nuclear energy and safety can be promoted and implemented within countries.

The task of ensuring that all nuclear technologies worldwide are safe and well-regulated is crucial for mankind to choose its energy strategy. Harmonization and unification of countries' efforts and resources call for a new dimension in international cooperation. Prevention of accidents in the nuclear industry using operating safety experience feedback has a high priority in this respect.

From my personal point of view the following recommendations can be made on how to achieve the next stage of the use of unusual events information to improve NPP safety:-

- the unification of intermediate points and the development of a user friendly environment in the safety experience feedback loop;
- generalization of a methodology for the experience feedback process, paying special attention to the methods of unusual event analysis and the determination of the significance/importance of events from selected points of view;
- reduction of the threshold for reporting in both the qualitative and quantitive sense; a) a report should not only be written when an event occurred but also when there is something important to share with colleagues; b) more knowledge about the most safety significant events will lower the reporting threshold;

- priority must be given to the final stages of the operating safety experience feedback process (completeness and appropriateness of lessons learnt and corrective actions, development of decision making rules and implementation of long and short term corrective actions in practice to close the feedback loop);
- more rational distribution of man-power and financial resources on national and international levels, combining analytical and practical elements of the feedback process;
- consideration of the public as an additional driving force to improve safety: more transparency and visibility

Always there is a room for improvement but everyone should remember that it is easier said than done and the best is oftentimes the enemy of the good.

TABLE I

Distribution of the Causes of IAEA-IRS Incidents

Cause of Incident	Percentage
Design deficiency or error	18.7
Operational error	17.5
Corrosion	10.7
Maintenance deficiency or error	10.3
Installation deficiency or error	8.0
Other fluid hydraulic effects	7.6
Ageing	7.2
Causes external to the plant	5.6
Fabrication deficiency or error	4.0
Procedural deficiency or error	4.0
Environmental influence	2.4
Violation of operating technical specifications	2.0
Loose parts	2.0

TABLE II

Problem Areas in Plant Operation of Safety

Problem Area	Percentage of Incidents
Failure in Reactor Protection System	2.5
Problems with Reactivity Control Systems	5.8
Loss of Both Main and Auxiliary Feedwater Systems	5.0
Loss of Off-Site and/or On-Site Power	9.9
Problems with Relief and Safety Valves	10.7
Problems with Other Valves	5.8
Leakages from Reactor Coolant Systems	17.3
Defects in Reactor Coolant System Pressure Boundary	5.0
Thermal Shock Conditions on Reactor Pressure Vessel	4.1
Problems with Reactor Coolant Pumps	4.1
Problems with Engineered Safety Features	5.0
Degradation of Containment Functions	8.3
Problems with Diesel Generators	5.8
Fires	3.3
Degradation in Spent Fuel Cooling	1.6
Flooding of Equipment	5.8