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Safety Culture in a Nuclear Installation

Reflections on its Assessment and Promotion

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Preface

Crucial to the safety of nuclear installations, besides the technical precautions, are the human and organisational aspects, particularly their interaction.

To cover such matters the International Atomic Energy Agency (IAEA) coined the term "Safety Culture", and over the past ten years has endeavoured to make the concept common currency and put it into practice. Based on international recommendations and its own experience as reference, the Swiss Nuclear Safety Commission (KSA) is similarly convinced that a sound Safety Culture makes a major contribution to nuclear safety. The present report is addressed to operators of nuclear installations, especially nuclear power plants, and reflects the thoughts of KSA on Safety Culture, its assessment and sustained encouragement.

Chapter 1 describes the current situation and the objectives. Chapter 2 defines, in line with IAEA, Safety Culture in relation to organisational and human considerations, and then distinguishes between three levels on which, from the standpoint of industrial psychology, Safety Culture may manifest itself among employees and units of the organisation. Chapter 3 deals with the essential elements of Safety Culture and their interaction under the conditions peculiar to a nuclear power plant. The main emphasis is on processes within the organisation – accordingly, the element "Organisation" is divided under 12 headings, each with its objective, possible difficulties and suggestions – and on the critical attitude towards occurrences and events, with the focal elements of evaluation: analysis, safety relevance, corrective action, documentation, organisational aspects and classification. In Chapter 4, tools for measuring Safety Culture are presented and, with the aid of selected examples, the experience gained and ways of evaluating and promoting it are discussed. This is followed by thoughts on the question of practical implementation. To conclude, recommendations on how to proceed are summarised in Chapter 5.

Safety Culture rests on many different factors. An attempt is made to outline the most important of them; a bibliography is added for further study. As yet there is no standard body of opinion on how Safety Culture should be evaluated and fostered, and investigation continues. Not least for this reason, the present paper makes no claim to completeness and is not be understood as a conclusive report, and certainly as no kind of directive. The intention of the document is rather to spur the operator of a nuclear installation into thinking specifically about Safety Culture. Operators of nuclear installations thus have wide latitude in adapting the assessment and promotion of Safety Culture to their particular requirements.

1 Objective

The safety of nuclear installations depends not only on technical precautions, but also on human and organisational aspects. Following the Chernobyl accident, the IAEA in 1986 coined the term "Safety Culture" in order to draw attention to the importance of human and organisational factors in the safe operation of nuclear installations; INSAG-3 [1]. In 1991 the term was defined by an International Nuclear Safety Advisory Group, and its practical implementation elucidated; INSAG-4 [2], - see Appendix A. As a consequence, those responsible for nuclear installations in many countries took up the subject of "Safety Culture", among them KSA, which on 20 January 1994 held a seminar with the aim of helping to foster Safety Culture in Switzerland's nuclear installations [3].

In the light of international recommendations and its own experience, KSA believes a good Safety Culture makes a major contribution to nuclear safety. It therefore uses this term in its statement on the application to grant a unlimited license with respect to time for the nuclear power plant Beznau II [4, page 55, 132, 137]:

"KSA deems Safety Culture to be of great significance to nuclear safety. It therefore recommends that the applicant endeavours to promote Safety Culture and undertakes an assessment."

The Federal Council imposed the following requirement [5, page 47]:

"The applicant shall by 31 December 1997 undertake a systematic review and evaluation of the Safety Culture in its organisation and submit it to the safety authorities."

In its statement on the application by Zwischenlager Würenlingen AG (ZWILAG) for permission to build and operate an interim storage facility for radioactive waste (ZZL), too, KSA expressly draws attention to Safety Culture [6, page 34, 35, 43]:

"It is expected that ZWILAG makes itself familiar with the elements of Safety Culture in nuclear installations... An essential element of Safety Culture, especially in the case of a new kind of installation such as the ZZL represents, is the feedback, processing and assimilation of experience."

The Federal Council imposed the following requirement [7, page 43]:

"The regulations applicable within the facility are also to include measures for promoting Safety Culture".

The IAEA Convention on Nuclear Safety of 1994 [8], which was also ratified by Switzerland, lays down in general terms the obligations of the legislature, public authorities and operators regarding the safety of existing and future nuclear installations. One important element is the promotion of Safety Culture.

This paper is addressed to operators of nuclear installations, particularly nuclear power plants, and presents thoughts by KSA on Safety Culture, its assessment and sustained encouragement with the aim of helping to put the KSA recommendations into practice. The main emphasis is on the organisation and its influence on staff as individuals or as members of teams.

It is the concern of KSA that Safety Culture be assessed and promoted within the comprehensible framework of a nuclear installation. The purpose of this document is to:

- consider elements deserving special attention;
- provide an aid for assessment and sustained promotion of Safety Culture;
- foster an institutionalised learning process directed at safety-minded behaviour.

2 Definitions and Terms

Safety Culture is a part of corporate culture, which in turn aims to promote the lasting success of an enterprise (Fuchs [3]). The IAEA defines Safety Culture in INSAG-4 [2] as follows:

"Safety Culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance".

Acknowledging the IAEA (INSAG-4 [2], art. 6, 12, 20, 59, 71, 72), KSA defines Safety Culture in the following manner [4, page 55]:

"The term "Safety Culture" denotes an underlying safety-oriented attitude at all hierarchical levels. Each individual staff member is required to be aware of his responsibility for safety, and to have the ability, means and authority to assume this responsibility.

Safety Culture comprises two main components. The first concerns the overriding responsibility of management to formulate and implement consistently a safety-orientated corporate philosophy, to create an appropriate organisational structure and to make available the necessary human and material resources. The second component embodies the attitude and conduct of personnel at all levels of the hierarchy and also communications between them".

As regards the attitude and work practices of each individual employee, the most important points are (INSAG-4 [2], art.59):

a questioning attitude
+
a rigorous and prudent approach
+
communication

If every person in a nuclear installation takes decisions and acts in this manner, the result will be a significant contribution to safety.

"Culture" is difficult to define, and hence there are many definitions. In the present context, culture is the totality of ideas, attitudes, values and perceptions characterising the organisation of life in a community.

For the purposes of this report, the following definition seems reasonable: Culture can be understood as a sphere of conduct that has been created by human beings. It includes goals, conventions, rules and injunctions which in normal circumstances guide behaviour. In ambiguous situations, culture serves as an additional aid to orientation; it thus has a steering and a navigating function. In this sense, Safety Culture ensures safety-conscious actions also in situations not amenable to concrete rules.

One can distinguish three levels on which corporate culture and hence also Safety Culture may manifest itself [9], [10]:

a) Artefacts

b) Social norms

c) Basic underlying assumptions

Circumstances on these three levels determine behaviour in specific situations. Conversely, they are influenced and changed by these situations.

Artefacts are the "visible" part of an enterprise, for example cleanliness and technical standard of the installation, the completeness of operating manuals, but also patterns of behaviour such as adherence to rules and regulations. It is thus a matter of appearances, of "image", and of concrete action.

Human actions are influenced by social norms. These decide "what one does" and "how one does it". They help the individual to perform his function in the group and influence relations between people and groups. They determine what kinds of behaviour are recognised as "acceptable" or "unacceptable".

The term "basic underlying assumptions" is used here in the sense of beliefs and convictions as to "how it is". These assumptions are often so deeply rooted that for those concerned it is hard to imagine thinking or acting "differently". They are commonly founded on actual experiences that have become taken for granted and felt to be "the truth".

More detailed comments on these terms from the industrial psychologist's viewpoint are to be found in Appendix B.

3 Elements of Safety Culture

3.1 Introduction

3.1.1 Peculiarities of Nuclear Power Plant Operation

As with all engineering constructions having an inherent capacity to cause hazards to people and environment, the safety of nuclear installations, here above all nuclear power plants (NPP), relies on the interaction of technical precautions, people's attitudes and actions, and on organisational measures.

Peculiar to the operation of a NPP are:

a) The reactor's very high radioactive inventory and hence inherently a very high potential danger for people and environment: absolute priority on safety.

b) Radiation zones when carrying out inspections, tests, maintenance, supervision and handling waste: importance of radiation protection.

c) Routine operation strictly regimented by technical and operational procedures: importance of regulations and discipline.

d) A broad spectrum of conceivable, but by experience rare, incidents: exceptional demands on operating personnel and on the man-machine interface, on the quality of emergency procedures in such an event and on the internal emergency organisation.

e) Complex and highly diverse technologies which must be kept at a high standard in the light of new knowledge: stringent demands on technical personnel, on a systematic approach and on the quality of equipment.

f) Primacy of safety in all nuclear installations: fertile ground for exchanging experience and for collaboration between their operating organisations.

g) Intensifying competition and increased pressure on cost in an electricity market on the verge of greater liberalisation: declining readiness to spend capital on preserving or improving safety, and a growing burden on personnel.

3.1.2 Insights from events

In the planning, construction and operation of NPPs there was early international recognition of the importance to safety of not only the technical, but also of the human and organisational aspects (man/technology/organisation = MTO). True, in many incidents, as with the serious accidents at Three Mile Island (1979) and Chernobyl (1986), a major cause lay in the inadequately thought-through design, but precisely in these two accidents the interplay of several MTO factors resulted in grievous damage to the reactor. This testifies to the need for an all-embracing vantage point with regard to the MTO, - see [3, Wilpert]: sociotechnical approach.

The operation of Switzerland's NPPs has so far been typified by high availability and only isolated events of significance in terms of safety. The importance of non-technical factors to nuclear safety is evident from the statistical evaluations of event reports that HSK carries out each year, using the IRS key (IRS = Incident Reporting System of the Nuclear Energy Agency (NEA) of the OECD and IAEA).

An analysis from 1993 [11] of the events in previous years identified for each event which among a number of root causes was the most significant. Since an event usually involves several factors acting together, pinpointing a single root cause may be problematical. The following figures for 197 events are therefore indicative only:

Unforeseen technical failure	37 %
Operator error	9 %
Maintenance and repair error	18 %
Management and organisational error	14 %
Design and manufacturing error	22 %

Various points are highlighted in [11]:

- In 90 % of the plant reports, technical failure is given as the observed cause; according to the figures above, the human factor as root cause accounts for 63 %.
- The spread of the human factor is surprising; only 9 % are operator errors, a high proportion of errors, 18 %, are due to maintenance and repair.
- Half of the 14 % management and organisational errors resulted from poor procedures, and the other half from shortcomings in the organisation and in the planning of work.
- The percentage spread for all Swiss NPPs is roughly the same, regardless of reactor type, size, manufacturer, years in service, number or average age of staff.

A more recent survey from 1996 [12] shows not only a sharp drop in the frequency of events over the past ten years, but also a decline in human error as the root cause. In the first three years of the period, this was the decisive cause in 70 % of cases, but in the last three years only 48 %. Despite the progress made, people's mistakes remain a major cause of incidents. However, it must be pointed out as well that human action as a rule does not cause incidents, rather it helps to prevent or remedy them; but there are no statistics available on this positive contribution.

After a brief comment on technical aspects, the following paragraphs examine more closely the human, and above all the organisational factors, because a sound organisation is the vital prerequisite for an optimum flourishing of human aptitudes and the full utilisation of technical capabilities.

3.2 Technical Aspects

Smoothly running, meticulously maintained technical equipment is an essential precondition for orderly and safe operation. Accordingly, Safety Culture is also reflected in attitudes to technical tasks and the care with which they are carried out: evaluation of occurrences, maintenance, surveillance tests, ageing programme (AÜP) and periodic safety review (PSÜ).

Among the objectives of AÜP and PSÜ are: comparison with the current state of the art, identifying possible weak points, and applying knowledge gained from particular events and new scientific findings.

The operating staff's duties are facilitated by technical measures which also serve to prevent wrong actions and to deal with incidents:

- fault-tolerant plant design;
- ergonomic design of control rooms and other man/machine interfaces;
- modern computer systems.

Especially with regard to minimising the radiation exposure of operating personnel, the arrangement and construction of the plant components in terms of radiation protection and ease of maintenance is very important.

Technical weak spots can be located by surveillance tests, by implementing experience from occurrences and from safety analyses, and remedied or circumvented by backfitting. Switzerland's plants have been backfitted to reach the latest technical standard by taking account of their own and worldwide experience and new knowledge.

3.3 Hierarchical Task Allocation

3.3.1 Corporate company

INSAG-4 [2] attributes great significance as regards Safety Culture to the corporate company of a NPP (similarly to the leading company of a partnership). The corporate company bears overall responsibility for the safe and economical operation of its NPP [4, section 5.2.1]. It assigns immediate responsibility for safe operation to its appointed plant manager, and makes sure that his freedom of action on safety matters is not hampered by economic considerations. Crucial factors in his selection, apart from suitable qualifications and experience, are a well-rounded character and the ability to lead and motivate his collaborators.

The corporate company is required to support the plant management in setting up an appropriate organisation structure with clearly allocated responsibilities, and see that the resources are available. It is important to define and promulgate the overall safety objectives (safety policy statement). The corporate company needs to establish its own ideas on how the objectives for its NPP are to be achieved.

In Switzerland, each corporate company operates only one NPP. This emphasizes the importance of exchanging experience and of cooperation between the plants at all levels. The corporate company must create favourable conditions for this to take place, and initiate and encourage shared activities between the plants.

3.3.2 Plant Management

Within the terms of its assigned immediate responsibility, the plant management creates the prerequisites (objectives, organisation, resources) for running the plant safely. Experience shows that the plant management's attitude and behaviour have a major influence on thework climate, in which the individual's talents should be allowed to grow, and hence on Safety Culture. For this reason, attention should be paid to personal qualities as early as when senior staff are hired.

Officially announcing the preeminence of safety (safety policy statement, see sections 3.3.1 and 3.4.2) and of safety objectives when appearing in public and at regular staff briefings is a necessary, but not sufficient precondition for a "living" awareness of safety at all levels. In its dealings with staff and the public, therefore, plant management should at every opportunity point up the capacity to cause hazards and the consequent safety objectives. Without such explanations and their constant repetition, "statements" are quickly seen as publicity exercises, and relegated to a drawer.

The required discipline means abiding by the procedures and limiting conditions. Deviations should happen only in exceptional cases and with the express approval of those in charge, when appropriate of the safety authority as well. Procedures are more closely obeyed, the better drafted they are, and even then only when those applying them understand their purpose.

Because of the largely uneventful course of everyday operation and the high availability, the danger of complacency is particularly acute. Maintaining watchfulness and due care therefore calls for special efforts to keep staff motivated. Especially important in promoting a good work climate are team spirit instead of "group think", along with professional friendliness, honesty and candour. The plant management can contribute to this by their personal commitment; for example by regularly appearing in the plant, and in direct personal contact by concerning themselves not only with resolving complex questions and evaluating events, but also with routine duties such as tests, maintenance or documentation. This approach by management fosters mutual trust. Personal contacts make it easier for superiors to judge their co-workers' jobs with their own eyes and to spot when things are amiss, such as key staff members permanently overworked, or frustration due to personal problems or insufficient resources. Identifying irritations and curing them straight away raises confidence in the management. Also, an adequate complement of experienced skilled staff makes deputising easier, and eases dependence on individual people.

Regular contacts and a busy exchange of experience at all levels with other nuclear power plants in Switzerland and abroad contribute to the Safety Culture. Plant management should actively support such endeavours.

3.3.3 Staff

Each individual staff member plays a part in Safety Culture. It is known from industrial practice that expertise and experience contribute greatly to the quality of work and to the work climate. These attributes therefore deserve close attention, besides personal character. One way to preserve an interest in work is to broaden and deepen the individual's knowledge. Learning about the nature and significance of what goes on in related subject areas boosts team spirit and instils an understanding for interdependency.

Experience tells us that good people perform best when their work is challenging. Through the commitment of their superiors they gain the confidence that these are behind them on difficult occasions, do not simply pass awkward tasks downwards and can openly admit to mistakes.

Thinking and doing incur the possibility of faults and errors. The danger is exacerbated both by overconfidence on the part of the individual and by "group think", i.e. meekly following collective opinions within the group [13].

It is stressed in INSAG-4 [2] that each individual should have a questioning attitude, scrutinising one's own mind set and performance together with those of the unit, and being open to suggestions from others. In view of the highly regulated but uneventful working environment, the call for a questioning attitude is very demanding, particularly for shift personnel. This critical approach should also be adopted towards proposed changes. Well-established matters that have proved their worth should be changed only after careful consideration; the new can contain unsuspected flaws.

The points mentioned in 3.3.1 c) and d) indicate the great importance of preserving technical skills, motivation and work climate. Reactor operators and shift supervisors reveal strengths and weaknesses in everyday situations and when dealing with problems. Simulator training offers further scope for improving and assessing the abilities of individuals and their performance in a team, especially when under stress. Proper attention must also be paid to the capabilities and conduct of the rest of the staff, particularly in technical support, in maintenance and supervision.

3.4 Organisation

3.4.1 General

Nuclear safety and the multiplicity of tasks impose severe demands on the organisation of a NPP. The organisation is required to establish conditions for optimum workflows and systematic, coherent structures for avoiding errors, for learning from experience and for addressing weaknesses, whether human, technical or organisational.

The implications of 3.3.1 f) provide a good starting point for establishing a solid organisation and good reason for learning from experience and knowledge gained from one's own plant and by operators of other NPPs, by manufacturers and international organisations. In the future, however, it cannot be ruled out that the increased pressure of competition will have adverse effects on the organisation and on the workforce, cf. 3.1.1 g).

Apart from a few references to the corporate company, this part of chapter 3 consides only the organisation and the activities within the NPP. Factors such as external circumstances and the authorities are addressed only in passing.

The framework of a safety-orientated organisation for a NPP can be set out as follows:

- Safety policy, i.e. the unambiguous attestation and publication that safety has the utmost priority, definition of corresponding objectives and monitoring of their attainment.
- Easily comprehended organisational structure and systematic, coherent quality management system; definition of duties and responsibilities with account taken of interfaces, particularly between line and staff functions.
- Appropriate human, financial and material resources for performing the duties and responsibilities.
- Basic and ongoing training matched to the job, also in-depth improvement of skills of staff having safety-related tasks; instruction and proper care of external personnel.
- Critical assessment of occurrences during operation and maintenance of one's own plant, application of experience from other plants; careful planning of repairs, modifications and other forms of improvement.
- Special attention to fundamental tasks such as plant surveillance, radiation protection, technical support, maintenance, industrial safety and emergency planning and preparedness. Of prime importance are a quality management system covering all aspects of safety and also a systematic safety review procedure, with tracking of associated advances in the state of design and technology.

Considered in the following sections are each of the organisational elements particularly relevant to Safety Culture. They are broadly arranged in the following manner:

Given first are the general IAEA recommendations, mainly as gleaned from INSAG-3 [1], INSAG-4 [2] and the OSART Guidelines [14].

A second part refers to possible difficulties in applying the IAEA recommendations in practice. These comments are based principally on the IAEA reports "OSART mission Leibstadt Nuclear Power Plant, 21 November to 8 December 1994" [15], "OSART mission to the Beznau Nuclear Power Plant, 13 November to 1 December 1995" [16] and "OSART mission highlights 1991-1992" [17].

The third part contains a number of suggestions which may help to alleviate the difficulties and to achieve the objectives. Useful here, in addition to our own experience, were the discussions with Leibstadt Nuclear Power Plant of 9 May 1996. These suggestions are intended as a spur to thoughts on plant-specific considerations.

3.4.2 Safety Objectives

On the subject of safety objectives (safety policy statement) the IAEA recommends that the corporate company and plant management declare throughout the organisation and publicly that safety has utmost priority, and demonstrate this by example [2, art. 20,33, 34].

Difficulties lie in the fact that safety objectives need to be formulated in concrete terms and if possible quantified, and communicated in an understandable form to every staff member so that they can take them into account in their daily work.

These are some suggestions which may help to achieve safety objectives:

- Plant management sets demanding objectives with regard to safety. From these each unit derives its yearly goals, monitors their attainment and, if necessary, redirects main emphasis.
- Failure to achieve these goals initiates a learning process, not only technical but also at the human/organisational level: analysis of weaknesses, making improvements, possibly agreeing new objectives.
- Staff are regularly informed by plant management about the general state of affairs, and about specific matters by their immediate superior.
- Plant management encourages a readiness to be actively involved in the international exchange of experience.

3.4.3 Collaboration between Organisation Units

The IAEA recommends an organisation having clear reporting lines and clearly defined interfaces between the organisation's units. For all safety-related matters, duties and responsibilities, competences and allocated resources are specified clearly and in detail (INSAG-4 [2], art. 25, 29, 30), [14, chap. 1].

The collaboration between organisation units occasionally presents difficulties because too little heed is taken of the consequences of one's own actions on others and on the plant, for example telling shift crews about current and forthcoming work being done in the plant.

Below are a few ideas on organisational measures which may help to ease these difficulties:

- The need for interdependence can be better understood by explaining the nature and significance of what goes on in related departments.
- With the aid of actual cases, staff from different parts of the organisation and external personnel who regularly work in the plant are trained in working together, particularly with regard to communication in the team and between teams.
- The definitions of tasks and their allocation to organisation units and individuals are periodically reviewed (job rotation)
- Employee appraisal places particular weight on aptitude for communication and teamwork.

3.4.4 Quality Management

Quality management (QM) is a core element in the organisation. High quality standards are a precondition for safety in a NPP.

By ratifying the IAEA Convention on Nuclear Safety [8], Switzerland undertakes to see that in Swiss NPPs quality assurance programmes are set up and implemented which ensure that all requirements pertinent to nuclear safety are complied with throughout the operational life of a plant.

The ground rules for building a QM system are laid down in standards. Comprehensive, systematic QM makes sure that, with accountabilities clearly assigned, all major safety-related procedural steps are factually and formally identified, planned, implemented and traceably documented. Hence it also forms the basis for making alterations and eventual improvements [18], and helps to reduce dependence on particular individuals.

Difficulties have been encountered with fitting existing elements into a comprehensive, systematic QM setup, and with assessing its effectiveness.

Some pointers which may help in achieving the objective:

- Plant management views QM as a core task. It defines which tasks are covered by the system, and how the effectiveness of the measures is verified and improved. When appropriate, it participates in audits.
- All documentation is regularly reviewed and updated.
- It is essential to quality and safety that the regulations are complied with. But comprehensive, systematic QM cannot be restricted to this. Especially in the case of complex situations, it ensures that the workflows in an organisation are treated as processes: problem identification and task analysis, the devising and implementation of solutions, assessment of their suitability, and feedback, with account taken of experience and current science and technology together with the results of safety analysis. When done systematically, with all aspects duly considered, the process can be expected to yield optimised, traceable results.
- Staff are familiar with the QM and QA rules and procedures, and contribute actively to the prevention of errors.

3.4.5 Operation

Being able to intervene directly, the operating crew are a central factor in the safe and reliable running of the plant.

A difficulty lies in sustaining a questioning attitude in highly regulated and generally trouble-free everyday operation.

Besides a questioning attitude to occurrences and observations, see section 3.5, the following suggested organisational measures can help to ensure safe operation:

- Up-to-date procedures and other documents are in readiness at all times for every operational situation and for possible anomalies. The use of these procedures is practised on the simulator.
- All activities such as inspections, repairs, overhauls and tests are performed according to defined procedures. These include analysis of the implications for plant safety. With special tests affecting the reactor, care must be taken that adequate safety margins are adhered to.
- Before restarting after an unscheduled scram, the plant's behaviour and the cause of the event must be systematically investigated.
- Cleanliness and good order, and the observance of personal safety and radiation protection guides are checked by regular rounds through the plant attended also by plant management.
- A picket on standby to assist the operating team quickly in the event of trouble. Well-trained and experienced picket engineers*) are of great value. Plant management and selected specialists can be reached with little delay.
- All staff and external personnel are sufficiently aware of the significance of their actions to the safety of the plant.
- Materials stored in the plant, particularly anything combustible, are reduced to a minimum.

3.4.6 Maintenance

The IAEA distinguishes between preventive (time-based), predicative (condition-based) and corrective maintenance as a prerequisite for safe and dependable operation of systems and components [14, section 4.3].

Difficulties may be encountered in optimising maintenance while weighing against each other the demands of radiation protection and safe plant operation.

The following suggestions may help to assure the quality of maintenance and at the same time minimise radiation exposure and the effect on running the plant:

- The work is documented, logged statistically and evaluated with the aim of optimising maintenance. The maintenance schedules are periodically reviewed on the basis of this work and recent knowledge.
- The volume of work on site is reduced by good planning and coordination. Training models, also on a 1:1 scale, help to improve the quality of work and reduce exposure to radiation.
- Computer-aided progressing of maintenance and general work assignments reduces sources of error and simplifies statistical evaluation.

*) A picket engineer is a fully qualified, licensed engineer who is on call to lead the control room shift in case of abnormal plant conditions.

- Not only regular staff but also external personnel are instructed and supervised on the subjects of industrial safety, radiation protection and, as necessary, the importance of the work as regards safety.
- The implications of maintenance work for safe plant operation are assessed, for example the fire hazard when welding.
- The checks carried out after maintenance are focused on functional capability under real operating conditions.

3.4.7 Technical Support

The term technical support denotes those technical and scientific tasks more of a fundamental nature which underpin operation. Calling for particular care according to IAEA are tests relevant to safety and also plant modifications, for which special safety analyses are recommended (INSAG-4 [2], art. 75, 76).

Efficient technical support covers a wide range of tasks and places severe demands on the knowledge and abilities of those staff engaged in it, and often requires coordination of their activities with those of other departments.

A number of suggestions concerning technical support are given below:

- Plant management makes sure that sufficient qualified personnel are available for special technical and scientific tasks, and their continuous training is systematically pursued.
- Clear definition of the duties and competences of technical support positions and of demarcation lines with other positions.
- Systematic editing of test programs and specifications, with attention to the following questions: do the nature and extent of function tests cover all requirements? Are they conducted under conditions as representative as possible? Are the surveillance test programs appropriate or is there a need to use other test methods? Has account been taken of recent knowledge?
- Systematic evaluation of all test results with regard to ageing propensities, implications for surveillance tests or maintenance.
- Assessment of safety-related backfits, modifications, events and special tests, employing deterministic and probabilistic event and safety analyses.
- Backfit and plant modifications are systematically carried out and evaluated. Important aspects are: reason, present and initial requirements (regulations, specifications, safety report, etc.), new state-of-the-art knowledge, comparison of several alternatives, updating of documentation, smooth handover to operation and maintenance. In the case of modifications relevant to safety, the opinion of independent third parties (other operators, suppliers) is obtained.

3.4.8 Radiation Protection

The internationally applicable basic rules on radiation protection are well-known, but it can be observed in practice that radiation protection is not always integrated into work planning as an essential element.

Below are a few suggestions on organisational measures which may help to mitigate this difficulty:

- Challenging yearly targets are set for collective dose.
- To optimise work on the principle of ALARA, the radiation protection team is involved early in the work planning process.
- Data on local dose rates in the plant are continually updated.
- For specified tasks and for work in critical parts of the plant, accumulated doses and also work completed and planned are systematically recorded, evaluated and announced to staff.
- In the training of staff and external personnel, in-depth treatment is given to radiation protection as a key element in protecting health and for safety at the workplace.

3.4.9 Industrial Safety

The IAEA recommends measures aimed at ensuring adequate industrial safety at the workplace [14, section 1.5].

Certain difficulties arise in practice; on-site and accident insurance statistics are unsatisfactory for introducing targeted measures.

The measures suggested below can help to improve industrial safety:

- Plant management concerns itself not only with accidents, but also with near-misses, accident prevention and specific actions. Also meriting special attention is the question of what lessons for nuclear safety can be drawn from a comparative approach.
- Supervisors, staff and external personnel are trained in risk assessment before starting a job, and in recognising and minimising dangers at the work locations. Complex jobs are planned with particular care.
- The frequency of regular rounds through the plant are stepped up at times of increased activity, such as the annual overhaul.
- Before starting a job, the people doing it ascertain, as far as possible, that the components in question have been tagged out.

3.4.10 Attitudes of Staff

For the IAEA, the attitude to safety of each individual employee is crucially important. The most important elements are a deliberately questioning attitude, a rigorous and prudent approach, and the exchange of information and the documentation, - see chap. 2.

It can be difficult to sustain a questioning attitude in a strictly regulated and largely trouble-free work environment.

Below are a few suggested organisational measures which can help to ease this problem:

- Plant management calls for self-assessment at all levels, and lets staff know what conduct is expected of them in matters of safety.

- Staff are required to keep these expectations in mind during their daily work. Do I understand my task? What is the scope of my responsibility?
- Staff performance appraisal includes safety-awareness as a criterion.
- Mistakes are viewed as a starting point for discussion, instruction and improvements. The question is not: how could you do that?, but rather: how could that happen? Only repeated errors or negligent behaviour lead to disciplinary measures.
- Supervisors show that they are also open to their staff's everyday and seemingly trivial problems.
- Staff are encouraged to report even apparently insignificant observations.

3.4.11 Training

The IAEA considers thorough and systematic staff training as being central to safe plant operation, and recommends laying down appropriate measures in a training programme [14, chap. 2].

Experience has demonstrated the difficulty of setting up and implementing a consistent, systematic training programme which takes account both of the needs of specific groups and external personnel and those of the individuals (managers, specialists, new staff, instructors, measures attainment of objectives and evaluates the quality of instruction [19].

The following suggested measures can help to assuage these difficulties:

- In consultation with the staff, plant management identifies the training needs:
  - Sets up a consistent, systematic training programme which takes account of the needs both of all groups and of individuals, including management.
  - Prepares documentation for teaching, checking the achievement of learning goals, and evaluating the courses.
  - Defines the requirements profiles of the instructors who, if necessary, also undergo training in methods of teaching.
  - Periodically reviews and adapts the training programmes in the light of experience and recent advances.
- Supervisors and staff members monitor success.
- Special training programmes are created for external personnel. These cover, among other things, familiarisation with the plant and the relevant regulations.
- Steps are taken to ensure that the experience of the retiring generation is passed on in good time to those coming after.

3.4.12 Emergency Organisation

The IAEA recommends that the emergency organisation should reflect experience and the current circumstances, and that the readiness of all units involved in a real emergency should be assured at all times and regularly checked [14, chap. 8].

Difficulties have been encountered in exercises with the scenario, frequency and experience feedback, communications and cooperation with other affected units, the release of information to the public and the updating of emergency documentation.

These are a few suggestions for organisational measures which can help to ease these difficulties:

- The training programme for emergency crews is based on a long-term plan.
- Two emergency exercises a year, one plant internal and one with HSK involvement, appears to be appropriate. After each exercise a report is prepared containing agreed follow-up actions. The completion of such is assigned to the units concerned, and supervised.
- Emergency procedures are periodically reviewed with reference to the current situation in the light of experience from the exercises and from the simulator.
- The members of the emergency staff and the picket engineers are regularly trained in emergency management (including serious accidents and plant security), and brought into emergency exercises as trainees, or as part of the exercise supervision.

3.4.13 Safety Review, Internal Safety Review Committee (ISA)

The IAEA recommends that the safety review be carried out by a body independent of the power plant [1, art. 217].

In Swiss nuclear power plants, an internal safety review is conducted partly by the ISA. According to HSK Guideline R-17 [20], the ISA advises the plant manager on matters of nuclear safety. It is found that HSK Guideline R-17 is complied with, but the role of the ISA in different plants differs considerably. Precursors of events are discussed only in some instances and the inclusion of experts from outside happens only occasionally.

Below are a number of suggested measures which may be of benefit to the safety review:

- The ISA holds regular meetings, several times a year with a set agenda and additionally as necessary or requested.
- The ISA deals with all plant and document modifications pertaining to safety, also selected events or precursors and test programmes, including those which do not have to be submitted to the safety authority. It also assesses the emergency exercises and sees that any related follow-up action is carried out.
- ISA meetings are attended by specialists and picket engineers from within the plant as well as outside experts.
- The safety review takes account of experience and also the current status of international design and technology.
- The corporate company forms its own opinion on the safety of the plant.

3.5 Occurrences and Events

3.5.1 Introduction

In line with IAEA, the term "occurrence" denotes a deviation from normal operation or the discovery of shortcomings which directly or indirectly may impair nuclear safety. One or more occurrences, which can be caused by human agency (man), the technology or the organisation and their interaction, may eventually lead to a possibly notifiable "event". The thorough investigation and correction of the causes of occurrences reduces the likelihood of events.

To avoid repetition of similar occurrences and events either in one's own or in other plants, and in order to identify shortcomings, the IAEA recommends systematic in-depth analysis and announcement of the results in traceable form [14, chap. 5.3].

In practice it has been observed that the depth of analysis is often wanting: the evaluation methodology is too little known, analysis is not done systematically, and not all units of the organisation are involved. Evaluation is a key element of Safety Culture, and in the following is therefore considered in some detail.

In order to determine the causes, all occurrences relevant to safety, where appropriate also those outside the nuclear industry and those that result in near-misses, must be recognised as precursors or as indicating weak spots [3, Edmondson, Tanguy, Wilpert].

The present report is primarily concerned with occurrences and events in one's own plant. It is assumed, however, that events in other nuclear installations are also examined for their relevance to one's own.

3.5.2 Objective

The purpose of investigating occurrences and events is to:

- assess their relevance to safety;
- determine the direct causes and root causes;
- draw lessons from the event and its prehistory;
- take corrective action;
- maintain full, traceable records.

Definitions of causes:

- direct or observed cause: fault, action, omission or condition which gives rise directly to the occurrence.
- root cause: cause of a fundamental nature which, when corrected, prevents a repetition of the occurence.

With simple occurrences, the direct cause can simultaneously be the root cause.

3.5.3 Analysis

The principal elements of an evaluation are:

- A detailed description of what happened, with reference to prehistory, initial condition, sequence in terms of time and facts, behaviour of the installation, behaviour of the people involved and communications between them, application and suitability of existing regulations and a record of all facts and figures.
- Determine the adverse influences on operating and safety systems, i.e. identify parts of the installation which did not function as they should, also human actions which did not turn out as intended.
- The decisions taken by those involved, together with the underlying assumptions and expectations in the light of the technical and interpersonal circumstances.
- Check for unexpected phenomena, i.e. whether the assumptions on which the design was based were correct and/or vindicated.
- Identify the direct causes and root causes with account taken of all relevant MTO factors, expose any interdependencies and previously undetected weaknesses.
- Assess the circumstances peculiar to the case, the possible consequences and the generic significance to nuclear safety.
- Draw up proposals for remedial measures to be implemented at once or in the longer term.

The human element plays an important part not only in the course of an incident, but also in its evaluation, as the following shows.

Often people with different professional background and of different managerial levels are involved directly or indirectly in an event. If human error by people in the front line (reactor operators or maintenance personnel) is ascertained or suspected, the search for the root causes is frequently omitted. But these can lie elsewhere, perhaps way back in the past (manufacturers, preparation of operating manuals) or in the social or organisational environment (management, values and basic underlying assumptions) [3, Salm, Wilpert].

Human errors, and MTO interactions in general, are by experience more difficult to uncover than purely technical situations. Except in the case of repeated errors or negligent conduct, it is therefore more effective to ask the question: "How could that happen?", instead of "How could you do that?" [13]. The aim is that observations relating to safety are reported voluntarily and without delay, and mistakes freely admitted to. This can also be an indicator of the presence of Safety Culture.

Evaluation can also be hampered by people often having an instant explanation for what happened. If observations contradict their explanation, they are inclined to twist the observation, rather than query the explanation. Every analysis must therefore start with fully establishing the facts.

A comprehensive analysis can be very time-consuming; it is therefore advisable to carry out an early initial screening of the safety relevance, and in the analysis apply what Wilpert [3] calls "stop rules":

- when "the causal path cannot be pursued further owing to lack of information"
- when "a familiar abnormal event has been found which can be taken as a reasonable

explanation" (i.e. the event can be equated with a known and already analysed event);

- when "suitable corrective measures are available".

Care must be taken not to apply these stop rules too hastily: is the information really unobtainable? Is the similarity only superficial and apparent? Do the corrective measures go far enough?

There are several methods of analysis. The Assessment of Safety Significant Events Team (ASSET) [21], a service offered by the IAEA, is mentioned here as an example. ASSET examines mainly organisational weaknesses along the lines of:

Events arise from preceding
Occurrences caused by
Latent weaknesses, not eliminated in time by the
Plant surveillance system.

Attention is also drawn to the SVA training seminar "Ursachenanalyse von Störfällen in KKW" (root cause analysis of incidents in NPPs) 3 - 4 March 1994 and the SVA extension course "Der menschliche Faktor im KKW-Betrieb" (the human factor in NPP operation) of 23 - 25 October 1996.

The safety authorities do not prescribe the assessment methodology. The operator chooses the method appropriate to the nature of the event. Selected methods of root cause analysis are summarised in Appendix C.

3.5.4 Evaluation of Safety Relevance

For analysis purposes, a distinction is made between case-specific circumstances, the potential consequences and the generic significance to nuclear safety.

Case-Specific Circumstances

The following points must be considered: weaknesses that led to the failure; emissions to the environment; radiation exposure of personnel; coolability of the reactor core; integrity of the primary system; suitability of regulations and verification of the availability and effectiveness of safety and auxiliary systems.

Potential Consequences / Generic Significance

Assessing the potential consequences and generic significance of occurrences and events calls for an approach which can be both deterministic and probabilistic. These deliberations are directed chiefly at the weakening of defence in depth.

Important considerations when assessing the safety relevance are:

- Man/machine aspects such as ergonomic design.
- Man/organisation aspects such as completeness and correctness of regulations, spheres of responsibility, maintenance and testing practices; social norms and basic underlying assumptions that impede safety-related action (examples are the non-observance of technical specifications, failure to question routines, hasty diagnoses and decisions, and

weaknesses in communication).

- Technical aspects such as common-cause (common-mode) faults or recurrent faults in the same component, the transferability of faults to other parts of the installation; unexpected phenomena in the behaviour of the installation or of materials, shortcomings in design and execution.
- Inclusion of similar occurrences and events in one's own installation or other installations.
- The consequences when assuming one additional technical fault or human error.
- The course of the event under different operating conditions (nighttime and weekend, startup and shutdown, out of service, full load, different stage in the fuel cycle).

Analysing an event by means of PSA can help in assessing the safety relevance (remaining safety margin) and in checking the completeness and correctness of PSA, and also in assessing remedial measures. The PSA must be adapted if necessary to recently gained knowledge ("living PSA").

The Nuclear Regulatory Commission (NRC) evaluates events quantitatively as part of its "Accident Sequence Precursor (ASP) Program" [22]. The NRC has established criteria for events to be investigated in detail.

3.5.5 Corrective Action

The purpose of any corrective action is to remedy the direct causes and root causes.

Some suggested aids to making soundly based decisions regarding corrective action:

- Where possible, several alternative solutions of a technical and/or organisational nature are considered. The arguments for and against the measures are ascertained and weighed up. Preference is given to solutions which have proved effective in the past.
- When the measures are complex, a safety review by an independent agency is advisable.
- Particularly in the case of changes which affect the reactor system, it is advisable to obtain the opinion of the reactor supplier and of operators of similar installations.

When the corrections have been made, their effectiveness is checked. As mentioned in section 3.4.7, systematically updating the documentation is especially important.

3.5.6 Reporting

Careful and systematic reporting is of key importance. Experience shows that the obligation to put down on paper fully and systematically the findings of analysis and the reasons for decisions is of great assistance in understanding the full context and in carefully balancing the decisions.

In the reports, the aspects dealt with so far should be presented in such a way that they can be followed not only within the plant, but by everyone to whom they are addressed. They should also contain positive experience acquired in identifying, intercepting and overcoming the situation. For occurences or shortcomings which require no detailed investigation, a short description and documentation is sufficient, so that they can also be statistically evaluated later.

The systematic preparation of reports helps in the timely exposure of hitherto unknown weaknesses and of trends, simplifies comparison with previous occurrences and events, and generally fosters a critical attitude towards one's own work and the safety status of the installation. The reports must therefore be circulated not only to those directly affected and the decisionmakers, but to all specialists in the plant. Staff in general must also be informed in a suitable manner.

Informing third parties adds to the exchange of information, but they can draw benefit only from complete information. Reports by the NRC, for example, state the manufacturers and types of defective components.

The safety authorities use the Incident Reporting System (IRS) of IAEA and NEA. With the passage of time, the IRS has evolved into a valuable source of information for generic studies.

3.5.7 Organisational Aspects

Below are a number of suggested organisational measures:

- Plant management defines the principles and the trigger point for an in-depth analysis of occurrences and events, taking into account precursors and events in other installations. It monitors the achievement of goals.
- Based on these principles, procedures are drawn up for the flow of information, the method of analysis, reporting, corrective action, the informing of staff and for training.
- Systematic reporting requires in-house rules on the content of reports and on how they are compiled and approved. Also recommended is the creation in the plant of a central editorial office which, among other things, watches over the uniformity, completeness and traceability of the reports (also for third parties) and sees that the rules are obeyed.
- Analysis calls for suitably trained and experienced people; as far as possible, these are not directly involved in the occurrence. The composition of the analysis team is matched to the subject matter of what happened; the leader of the team is trained in questioning techniques and methods of analysis. It is beneficial to use or consult specialists for the interactions between technical, human and organisational factors.
- For the final assessment of the analysis and the corrective action assigned to the plant management, an independent review is recommended.
- A hotline gives every staff member the possibility of presenting safety-related matters to plant management, whether openly or anonymously.
- Close collaboration between the operators of Switzerland's NPPs at different levels can help to improve the methodology and to reveal weaknesses, especially in the human/organisation sphere.

3.5.8 INES Classification of Events

The classification of events in nuclear installations on the International Nuclear Event Scale (INES) [23] is intended mainly for informing the public. This scale, drawn up by the IAEA and the NEA, grades events by their relevance for the installation and environment. Besides a rating 0 for events not important in safety terms, but nonetheless not trivial, it distinguishes seven stages in all, from "anomaly" (1) to "major accident" (7); a violation of the principles of Safety Culture raises the rating by one stage.

The authorities demand that the INES be used for events in Swiss installations as well [24]. The HSK Guideline R-15 "Berichterstattung über den Betrieb von Kernkraftwerken" [24] works from different premises and is much more finely graded at the bottom end of the INES.

3.5.9 Summary

1. The careful and systematic evaluation of occurrences and events, the system of reporting and the exchange of experience are characteristic features of the Safety Culture in a nuclear power plant.

2. Essential elements of an analysis are:

- Description of the course of the event, recording and verifying all human, technical and organisational data and facts;
- Checking for adverse influences on operating and safety systems, also for unexpected phenomena;
- Identifying the direct causes and root causes by means of systematic analyses, including social norms and basic underlying assumptions;
- Assessing the particular circumstances and the potential consequences, also the generic significance to nuclear safety.

Every occurrence and event in one's own plant (and where appropriate in other plants as well) must be investigated. Breadth and depth of the investigation depend on the safety relevance and complexity.

3. The purpose of corrective action is to remedy the direct and root causes. It is advisable to analyse a number of alternative solutions, and if necessary obtain advice from outside.

4. The analysis findings must be traceably recorded by means of a systematic reporting procedure. The report forms the basis for deciding on corrective action, simplifies the identification of trends and in general fosters among operating personnel a safety-awareness and a critical attitude towards one's own work and one's own plant. It also serves as a means of informing managers and the safety authorities and of exchanging experience.

5. A prior condition for a systematic approach is the creation of a suitable organisational structure and the involvement of specialists.

6. Close collaboration between the operators of Switzerland's nuclear installations at different levels can help to improve the methodology and to reveal weaknesses, especially in the human/organisational sphere.

4 Identification, Assessment and Promotion of Safety Culture

4.1 Tools for Measuring Safety Culture

Existing and suggested measuring tools are summarised briefly below.

4.1.1 Indicators

Since 1991 the World Association of Nuclear Operators (WANO) conducts an annual worldwide survey of selected data from NPP operators, the "WANO Performance Indicators" [25]. With this the operators can rank their particular plant and identify trends. The WANO indicators cover availability figures and safety-related data such as the number of unscheduled reactor scrams and the unavailability of safety systems.

Good WANO indicators over a prolonged period and in their entirety are a sign that Safety Culture is present, but give no insight into the reasons why, and are no yardstick for judging the quality of the processes taking place in the plant or the responses of individual and groups in actual situations.

Major operator organisations in western countries have established further indicators for use in-house which also recognise safety-related efforts, for example the number of suggestions acted upon or the number of inspections and meetings on the subject of safety. Other possibilities might be the voluntary reporting of errors or near-misses, or the initiative shown by staff in making safety improvements.

4.1.2 Existing Evaluation Methods

So far, surveys have been done mostly with questionnaires and interviews. The questions are often very general, i.e. insufficiently related to real situations, and are concerned primarily with working conditions, emphasis placed on safety and ways of avoiding mistakes. Questions aimed specifically at examining the behaviour of an individual or group in an actual situation under the conditions prevailing in the plant, are usually lacking. Some examples:

- The questionnaire "Zur eigenen Arbeitstätigkeit und zum Umgang mit Sicherheit" devised by the Industrial Psychology Department (IfAP) at ETH Zurich asks how much time is spent on safety-relevant activities (maintenance, etc.) and under stressful working conditions (pressure of time, etc.), and about safety standards [26].
- The appendix to INSAG-4 [2] contains some 150 questions covering the whole gamut - government, safety authority, corporate company, operating organisation, plant staff, nuclear research and power plant design.
- The ASCOT Guidelines of the IAEA [27] split the questions of INSAG-4 into subquestions and provide practical indicators of the presence of Safety Culture. They are a good foundation on which to compile a plant-specific questionnaire for self-assessment. The ASCOT advisory service is willing to present its technique in seminars.

- There are a number of commercial methods for preventing losses, and hence suitable for evaluating and promoting safety. One example is the "International Safety Rating System" (ISRS) [3], [28] used by the operator of UK nuclear power plants (see section 4.2.2). It consists of 20 elements divided into questions which can be answered with yes or no. Comparing with best international practice provides an assessment and thus an overall verdict on Safety Culture. Each element includes the statement of goals, rules to be observed, responsibilities and work procedures.

In order to go deeper than the customary interrogation by questionnaire and interview, Prof. Semmer, who holds the chair of industrial and organisational psychology at Berne University, proposes a "situational approach" [29], [30], as experience shows that questions not sufficiently related to situations do not alone achieve the required result. The situational approach takes as its starting point a situation connected with safety. The various aspects (initial situation, thoughts/fears, actions/non-actions, communication) are discussed with the individual or the group. The findings concern all aspects of dealing with a concrete situation (ergonomic, technical, motivational, cognitive, social aspects [12]). They allow comparison between individuals/groups with similar tasks, uncover weaknesses, yield a verdict on Safety Culture, and can be used for training purposes.

The process is divided into three stages:

a) Gathering of "situations"

Concrete, plant-related situations are obtained, for example, from previous experiences linked with safety. Editing these into a situational questionnaire is very time-consuming and requires interdisciplinary collaboration (people familiar with the methodology, specialists on human factors, power plant experts). In favourable instances, working up individual situations can result in a general framework which is useful for analysing future situations.

b) Questioning of individuals/groups

Staff, individually or in groups, have these "prototype" situations presented to them by a team trained in questioning techniques, and are then questioned on them. The results are recorded.

c) Evaluation of the questioning

The purpose of evaluation is, on the one hand, to make judgements on the points mentioned (comparison, weaknesses, Safety Culture, training), but on the other, it is also used for improving and refining the instruments, of the situational approach in particular.

With the situational approach, not only interpreting and dealing with a concrete situation is important; equally significant is the registering of social norms and basic underlying assumptions that directly influence the interpretation and action taken. These include safety-awareness, a thought-through response, communication, training, stress, experience of the plant organisation and the quality of regulations and working aids. Intrusion into the private sphere of participants is not usually necessary.

Appendix D contains examples of the situational approach. As part of a research assignment, the intention is to work with the plants on developing an additional instrument for assessing Safety Culture.

4.2 Examples of Assessment

The assessment systems used in a sample list of nuclear power plants in other countries are briefly summarised below.

4.2.1 International Atomic Energy-Agency (IAEA)

Assessing elements of Safety Culture forms part of missions by the "Operational Safety Review Team" (OSART). The IAEA report "OSART mission highlights 1991-1992" [17] outlines the most important points; recommendations, suggestions, good performance and good examples are collected in a database.

OSART examines in depth the organisational and operational aspects considered specifically in the present report in section 3.4. Treated in less detail are the factors "man" and "machine" and also occurrences. The object of the OSART mission's interdisciplinary blend of expertise, its stay of several weeks in the plant and its contacts with managers and staff is to reach a balanced assessment. OSART demands a considerable effort by the plant as regards preparation, implementation and response afterwards. The execution of recommendations and suggestions is checked by a follow-up mission about 18 months later. Experience shows that a favourable assessment by OSART also indicates the existence of Safety Culture in matters of organisation.

OSART is an external assessment tied to a particular point in time. However, many recommendations are to be viewed as ongoing tasks, the execution of which needs regular checking and improving. The purpose of OSART is thus to set in motion a process of regular self-assessment which also covers important elements of Safety Culture. The peer reviews of the WANO and INPO (Institute of Nuclear Power Operators) follow basically the same pattern as OSART, but in general do not cover every area, and report only to the body commissioning the reviews.

4.2.2 Nuclear Electric (UK)

Nuclear Electric (NE) has compared practices in UK nuclear power plants with the requirements of INSAG-4 [2], and found the principal elements are covered. Deserving particular mention are:

- All NE nuclear power plants are inspected by the Institute of Nuclear Power Operators (INPO), and some of them by WANO.
- In each plant there is an engineer responsible for evaluating events and exchanging experience with other plants.
- Indicators additional to those of WANO are measured in every plant.
- NE has been using the ISRS, see section 4.1.2, since 1990. NE rates ISRS as a proven tool with which a NPP can assess and promote its safety independently.

A need for action has been found in the case of self-monitoring. Staff are trained in special courses suited to their grade. The theme "stop, think, act, review" (STAR) is the subject of a campaign. Other efforts are aimed at integrating Safety Culture into the quality improvement programme. NE's experience in recent years has been that productivity gains and cost reductions run in parallel with improvements to the safety indicators [3], [28], [31].

4.2.3 Electricité de France (EDF, France)

Over the years, each plant has evolved its own organisational mould and corporate culture. There are a range of instruments for assessing safety, e.g. in-house "missions sûretéqualité", "visites sûreté retour de l'experience" with employees from other EDF plants, and finally EDF inspections. These missions are currently being supplemented by the self-assessment element ("auto-évaluation"); individuals are responsible for their actions and are expected to assess them critically and make the necessary corredions. For example, information gaps on changing shifts were discovered and remedied. A greater exchange of information between plants is demanded, in order to determine the best working practice.

In its Nuclear Safety Report 1995, EDF states that decisive factors in substantially improving Safety Culture are its safety promotion programmes directed at staff of all levels, also the regulations and good practice and its experience-feedback instrument "REX" for systematising root cause analysis in the plants. Like earlier annual reports, this report represents and describes "living safety culture". It illustrates how to analyse operation systematically and learn accordingly [32], [33].

Other points worth noting are:

- Examples of recent promotion programmes are the "observatoire sûreté/disponibilité", under which events are examined for evidence of conflict between safety and availability, and the "démarches prestataires" for systematically verifying the deliveries and performance of third parties.
- EDF gathers plant-specific indicators. Graphics show the interactions between different indicators, including those between availability and safety-relevant events.
- The Conseil de la Sûreté Nucléaire, a panel providing dialogue between Direction Générale and the Directions Opérationelles, renders an important contribution in that nuclear safety is given proper emphasis when deciding corporate policy and carrying it through.
- In the period 1992/95, the proportion of "significant" events submitted to root cause analysis rose from 10 % to more than 80 %.

4.2.4 Koeberg NPP (South Africa)

In 1992 the Koeberg nuclear power plant responded to missions by WANO, OSART and ASCOT by putting a staff member in charge of promoting Safety Culture. Besides clarifying work flows and identifying safety-relevant processes, special attention is focused on fostering Safety Culture. Systematic training is based on the following elements:

- To launch the "safety awareness" campaign, 1000 employees attended a 4-day seminar;

a 1-day refresher course was held in 1994.

- On-the-spot self-monitoring was encouraged with the aid of a campaign (posters, overprinting of office supplies) under the slogan "STAR" (stop, think, act, review).
- Monthly and yearly prizes were given for notable STAR achievements. Improvements in quality were rewarded quarterly. The winners of these competitions qualified for the plant management's annual award.
- Certain WANO indicators and the plant's own indicators were posted, together with the set targets, at central locations in the plant.
- A bulletin with news from the plant and other installations appears twice a month
- An anonymous in-house telephone has been set up for reporting worries about safety.

The management of Koeberg is of the opinion that overall performance has improved dramatically over the past two years, set off by the Safety Culture campaign [34].

4.2.5 Sydkraft (Sweden)

In 1993 the Sydkraft power company invited a former director of the Swedish nuclear safety inspectorate (SKi) to study the Safety Culture at its plants Barsebäck (2 units) and Oskarshamn (3 units). His brief was: what is the present state of Safety Culture within the company, among the nuclear plant management and the staff? What steps need to be taken in the short and longer term in order to improve the Safety Culture? The study was carried out between June 1993 and March 1994.

The following points regarding methodology merit attention:

- A varied group of experts was assembled: 2 nuclear specialists, 2 aerospace experts and 1 specialist on off-shore oil recovery, while the secretary was provided by a management consultancy.
- In all, some 10 % of the work force were included in the study.
- 35 informal interviews were conducted with senior staff and subject specialists.
- The secretary on his own held 130 systematic interviews, each lasting an hour, with operations and maintenance personnel and also with suppliers. The questionnaire was formulated according to activity: operations more than 50 questions, maintenance 40 questions, suppliers 30 questions.
- The plants were inspected by experts.
- Relevant documents were reviewed.
- Opinions were obtained from regulatory bodies and independent experts.

Based on the information acquired, the result of the study was a report which specifically pinpoints strengths and weaknesses, and suggests improvements [35].

4.3 Self-Assessment

Methods of assessment are described in section 4.2. An IAEA publication [36] judges self-assessment of Safety Culture to be much more effective than assessment by outsiders or inspections by the regulatory authorities. The following points are stated in favour of objective self-assessment by the organisation:

- Assessment is done by people working in the plant who know the organisation, procedures and problems.
- Assessment is tailored to actual requirements and can be done repeatedly.
- There is an awareness of weak spots and an incentive to cure them.
- Things can be said openly since the findings stay in the plant and remain confidential.

A precondition for self-assessment of the organisation is that the necessary questioning attitude prevails despite routine and good results. If this element is absent or beginning to flag, outside assessment may be called for.

4.4 Aspects of Practical Implementation

It has been shown in the foregoing that instruments for assessing and promoting Safety Culture in nuclear installations are being developed and applied. It is important that these instruments and how they are used are adapted to the cultural environment and particular circumstances in the plant concerned. The adaptation process can be far from straightforward and requires close cooperation between those familiar with the instruments, experts on human and organisational factors and specialists from within the plant. The learning process while going for the goal of assessing Safety Culture can itself help to achieve that goal.

The following questions can be useful as a starting point for considering Safety Culture in a specific plant:

- What is the present situation judged to be (strengths, weaknesses)?
- Which approach will most readily provide a deeper insight?
- What measures will produce improvements in the short/longer term?

4.4.1 Extent and Depth

Safety Culture concerns the entire organisation. Its investigation therefore involves as many staff as possible, although the depth of enquiry will vary widely, depending on the relevance to safety.

The number of people included in the survey, and also the instruments used, depend on a given group's influence on safety. The greater the safety relevance, the larger the sample should be, up to involvement of all the group's members, and the more exacting, too, are the demands on the method of investigation and on the assessment team. Broadly speaking, one can differentiate between two categories:

- Groups having an indirect influence on safety (e.g. parts of the administration, some technical areas); survey by simple questionnaire.

- Groups having a direct influence on safety (e.g. management, operations, maintenance, possibly outside firms); survey with questionnaires tailored to activities and safety, as well as situational interviews.

In the case of groups with a direct influence on safety it must be decided whether the group as whole is involved in the survey - which allows conclusions on group dynamics and work climate - or whether, to preserve anonymity, the members are questioned individually.

4.4.2 Composition of Team .

Section 4.2 gives examples of outside assessment and self-assessment. Section 4.3 includes statements by the IAEA on self-assessment. Both approaches are acceptable, provided the requisite preconditions are satisfied.

Self-assessment is carried out by a resident in-house team. As well as the specialists from the plant, it may well be necessary or beneficial to enlist the help of former members of the organisation and of outside experts on human and organisational factors, together with people versed in the methods of assessment (consultancies, universities, IAEA).

Outside assessment is conducted by a team of external specialists assisted by representatives of the plant. Candidates are again the specialist functions mentioned above and also past organisation members, whereby it is important that the team is well-balanced.

4.4.3 Time Scale

It is advisable to complete the survey within a few months so that all concerned have the same boundary conditions. To be recommended is a pilot run in order to improve and refine the instruments and also to reconsider the scope and detail of the survey.

4.4.4 Repetition of Assessment

A reassessment should be considered periodically or whenever a justification exists (accumulation of occurrences, serious incident).

5 Recommendation

This report presents reflections by KSA on the assessment and promotion of Safety Culture in a nuclear installation. It makes no claim to be exhaustive and is to be taken neither as a final document nor as a guide or directive on practical implementation. The intention of the report is rather to stir the operator into assembling his own thoughts, calling upon his and others' experiences in dealing with problems of the technology, the organisation and of the personnel.

The following questions can be useful as a starting point for considering Safety Culture in a specific plant:

- What is the present situation judged to be (strengths, weaknesses)?
- Which approach will most readily provide a deeper insight?
- What measures will produce improvements in the short/longer term?

Within these terms, KSA recommends that operators of nuclear installations should take steps to acquire a comprehensive picture of the Safety Culture in their organisations; the involvement of outside experts is likely to be of advantage. A detailed report to the safety authorities is not necessary, though they should be informed of the adopted approach, important findings and any implications. This will allow the safety authority to be convinced of the operator's efforts with regard to Safety Culture, and at the same time contribute to its own assessment derived from plant reports and contacts.

The cultivation and assessment of Safety Culture is fundamentally the operator's job. It is a matter of examining the daily routine for its relevance to Safety Culture. In this way a continuing process should be set in motion or fostered which reinforces the basic attitude towards safety at all levels of the hierarchy; the aim is a living Safety Culture established through institutionalised learning.

A reassessment should be considered periodically or whenever a justification exists.

This document was approved by KSA at its 357th meeting on 25 February 1997, and is also supported by HSK.

Appendix A: Excerpt from INSAG-4 [2]

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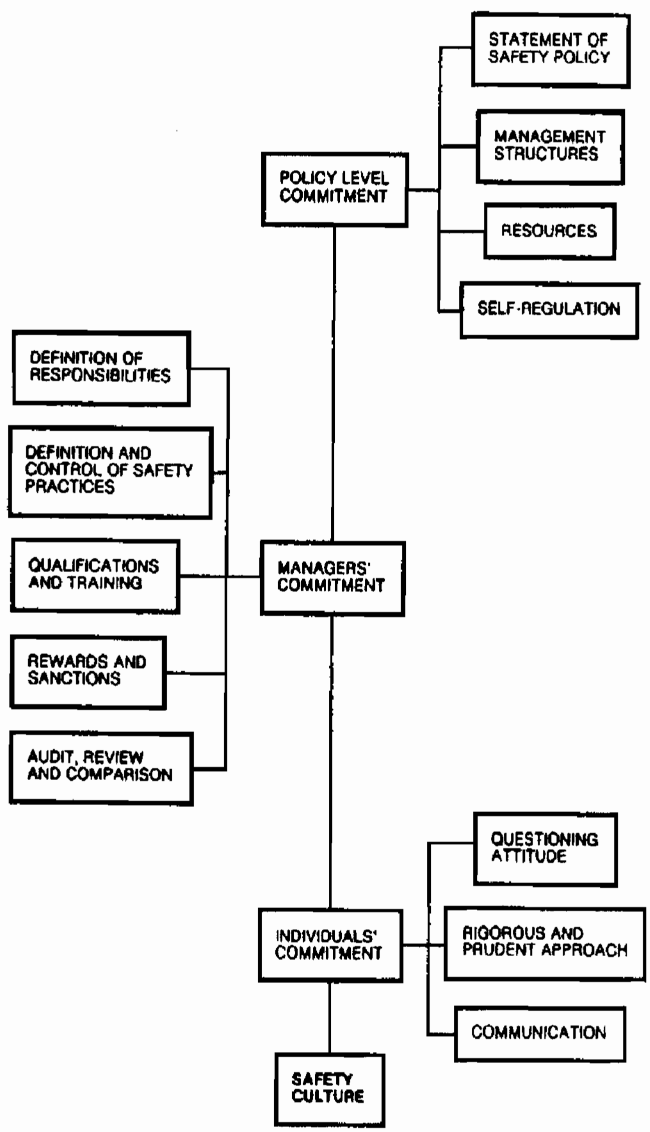

FIG. 1. Illustration of the presentation of safety culture.

3. UNIVERSAL FEATURES OF SAFETY CULTURE

11. In all types of activities, for organizations and for individuals at all levels, attention to safety involves many elements:

— *Individual awareness* of the importance of safety.
— *Knowledge and competence*, conferred by training and instruction of personnel and by their self-education.
— *Commitment*, requiring demonstration at senior management level of the high priority of safety and adoption by individuals of the common goal of safety.
— *Motivation*, through leadership, the setting of objectives and systems of rewards and sanctions, and through individuals' self-generated attitudes.
— *Supervision*, including audit and review practices, with readiness to respond to individuals' questioning attitudes.
— *Responsibility*, through formal assignment and description of duties and their understanding by individuals.

12. *Safety Culture has two general components. The first is the necessary framework within an organization and is the responsibility of the management hierarchy. The second is the attitude of staff at all levels in responding to and benefiting from the framework.*

13. These components are dealt with separately under the headings of Requirements at Policy Level (Section 3.1) and Requirements on Managers (Section 3.2) and Response of Individuals (Section 3.3). Since Safety Culture particularly concerns individual performance, and since many individuals carry safety responsibilities, Section 3.3 is especially important.

14. Figure 1 illustrates the major components of Safety Culture, relating the text headings to this overall scheme.

15. *In keeping with the practice of INSAG-3,* **throughout the report the presentation is in accordance with the assumption that the practices are in current use.** *The sense of the usage is that the circumstances described are those which this report seeks to promote.*

3.1. REQUIREMENTS AT POLICY LEVEL

16. *In any important activity, the manner in which people act is conditioned by requirements set at a high level. The highest level affecting nuclear plant safety is the legislative level, at which the national basis for Safety Culture is set.*

17. Governments discharge their responsibilities to regulate the safety of nuclear plants and other potentially hazardous installations and activities in order to protect individuals, the public at large and the environment. Legislation is backed by the necessary advisory and regulatory bodies, which have sufficient staff, funding and powers to perform their duties and the freedom to do so without undue interference. In this way, national climates are fostered in which attention to safety is a matter of everyday concern. Governments also encourage international exchanges aimed at safety improvements and seek to minimize any commercial or political impediments to such exchanges.

18. *Within an organization, similar considerations apply. Policies promoted at a high level create the working environment and condition individual behaviour.*

19. Safety policies and their detailed implementation vary depending on the nature of the organization and the activities of its staff, but important common features can be defined. Sections 3.1.1 to 3.1.5 show how such commitment at the policy level is declared and supported.

3.1.1. Statements of safety policy

20. *An organization pursuing activities with a bearing on nuclear plant safety makes its responsibilities well known and understood in a safety policy statement. This statement is provided as guidance to staff, and to declare the organization's objectives and the public commitment of corporate management to nuclear plant safety.*

21. Safety policy statements by different bodies with differing functions vary in both form and content. An operating organization has full and formal responsibility for the safety of its nuclear plants. Its safety policy statement is clear and is provided to all staff. This statement declares a commitment to excellent performance in all activities important for the safety of nuclear plants, making it plain that nuclear plant safety has the utmost priority, overriding if necessary the demands of production or project schedules.

22. A regulatory body has a weighty influence on the safety of nuclear plants within its purview and an effective Safety Culture pervades its own organization and its staff. The basis is again set down in a safety policy statement. This makes a commitment to implement legislation and to act to promote plant safety and the protection of individuals and the public, and to protect the environment.

23. Supporting organizations, which include those responsible for design, manufacture, construction and research, influence greatly the safety of nuclear

plants. Their primary responsibility is for quality of the product, whether this is a design or a manufactured component, installed equipment, a safety report or software development, or any other output important to safety. The basis for Safety Culture in such an organization is the directive establishing policy and practices to achieve quality, and thereby to meet the safety objectives of the future operator.

3.1.2. Management structures

24. *Implementation of these safety policies requires that accountability in safety matters is clear.*

25. The detailed way in which this is achieved depends on the role of the organization, but one key requirement is common to all: strong lines of authority are established for those matters bearing on nuclear plant safety, by means of clear reporting lines and few and simple interfaces, supported by the definition and documentation of duties.

26. The formal responsibility for plant safety lies with the operating organizations and the delegated authority with the plant manager. In the contributing organizations, the equivalent requirement is to ensure by management structure and definition of duties that responsibility for the quality of the product is well defined.

27. *Large organizations with significant impact on nuclear plant safety provide independent internal management units with responsibility for the surveillance of nuclear safety activities.*

28. In operating organizations, these units have the role of scrutinizing safety practices at the plant. They report at a senior management level, ensuring the integration of safety responsibilities into the management chain with a prominence matching that of other main functions. Supporting organizations adopt similar methods to achieve product quality, involving audit and review practices with arrangements for reporting at a senior level.

3.1.3. Resources

29. *Adequate resources are devoted to safety.*

30. Sufficient experienced staff are available, supplemented as necessary by consultants or contractors, so that duties relevant to nuclear plant safety may be carried out without undue haste or pressure. Staffing policies ensure that competent individuals can advance through the key posts. Training of staff is recognized as vital and the necessary resources are devoted to it. Funding is sufficient to ensure that staff

in all safety related tasks have available to them the necessary equipment, facilities and supporting technical infrastructure. The working environment for such staff is conducive to the effective performance of their duties.

3.1.4. Self-regulation

31. *As a matter of policy, all organizations arrange for regular review of those of their practices that contribute to nuclear plant safety.*

32. This includes, for example, staff appointments and training, the feedback of operating experience, and the control of design changes, plant modifications and operating procedures. The intent is to bring fresh judgement to bear and to allow new approaches to be suggested by involving fully competent individuals or bodies outside the normal chain of command. Such arrangements are promoted as natural and helpful aids to the practitioners, and they avoid the appearance of a punitive search for shortcomings.

3.1.5. Commitment

33. *Paragraphs 16–32 cover activities which define the working environment and which require corporate level commitment for success. This commitment is publicly asserted and well known, shows the stance of corporate management in relation to its social responsibilities, and demonstrates also an organization's willingness to be open in safety matters.*

34. On a personal basis, managers at the most senior level demonstrate their commitment by their attention to regular review of the processes that bear on nuclear safety, by taking direct interest in the more significant questions of nuclear safety or product quality as they arise, and by frequent citation of the importance of safety and quality in communications to staff. In particular, nuclear plant safety is an important agenda item at meetings of boards of operating organizations.

3.2. REQUIREMENTS ON MANAGERS

35. *The attitudes of individuals are greatly influenced by their working environment. The key to an effective Safety Culture in individuals is found in the practices moulding the environment and fostering attitudes conducive to safety. It is the responsibility of managers to institute such practices in accordance with their organization's safety policy and objectives.*

36. The requirements so placed on managers are discussed in the following. Except as specifically indicated, the comments apply to all organizations engaged in activities affecting nuclear safety.

3.2.1. Definition of responsibilities

37. *Discharge of individual responsibilities is facilitated by unique and clear lines of authority.*

38. The responsibility assigned to individuals is defined and documented in sufficient detail to prevent ambiguity. The collective definitions of the authority and responsibility of individuals are reviewed to ensure that there are no omissions or overlaps and no problems of shared responsibilities. Definitions of responsibility are approved at a higher level of authority. Managers ensure that individuals understand not only their own responsibilities but also those of their immediate colleagues and of their management unit, and how these responsibilities complement those of other groups. This requirement for careful definition of responsibilities applies with special force to operating organizations since they carry the formal responsibility for plant safety. The delegated responsibility of the plant manager for the safety of the plant is given particular emphasis.

39. Since operating organizations carry the formal responsibility for the safety of operating plants, they have a further obligation. This is the duty to assure themselves, by means of third parties if necessary, that other organizations whose activities contribute to the technical basis of plant safety discharge their responsibilities satisfactorily.

3.2.2. Definition and control of working practices

40. *Managers ensure that work on matters related to nuclear safety is carried out in a rigorous manner.*

41. While the necessity is obvious in operating organizations, the requirements for product quality in supporting organizations call for similar attention. The necessary basis is generally a hierarchy of up to date documents ranging from policy directives to detailed working procedures. These procedures are clear and unambiguous and they form an integral series. The documents receive formal scrutiny, checking and testing under the organizations' quality assurance arrangements, and formal means are adopted for their control.

42. Managers ensure that tasks are carried out as defined. They institute systems for supervision and control and insist upon orderliness and good housekeeping.

3.2.3. Qualifications and training

43. *Managers ensure that their staff are fully competent for their duties.*

44. Selection and appointment procedures establish satisfactory initial qualifications of personnel in terms of intellect and education. Any necessary training and periodic retraining are provided. The assessment of technical competence is an integral part of training programmes. For critical tasks in plant operations, judgement of fitness for duties includes physical and psychological considerations.

45. *Instruction instils more than technical skills or familiarity with detailed procedures to be followed rigorously. These essential requirements are supplemented by broader training, sufficient to ensure that individuals understand the significance of their duties and the consequences of mistakes arising from misconceptions or lack of diligence.*

46. Without this additional understanding, nuclear safety issues arising may not receive the attention they warrant or wrong actions may be taken, out of lack of comprehension of the risks involved.

3.2.4. Rewards and sanctions

47. *Ultimately, satisfactory practice depends on the behaviour of individuals, as influenced by motivation and attitudes, both personal and group. Managers encourage and praise and seek to provide tangible reward for particularly commendable attitudes in safety matters.*

48. Importantly, at operating plants, systems of reward do not encourage high plant output levels if this prejudices safety. Incentives are therefore not based on production levels alone but are also related to safety performance.

49. Errors, when committed, are seen less as a matter of concern than as a source of experience from which benefit can be derived. Individuals are encouraged to identify, report and correct imperfections in their own work in order to help others as well as themselves to avert future problems. When necessary, they are assisted to improve their subsequent performance.

50. Nevertheless, for repeated deficiency or gross negligence, managers accept their responsibility for taking disciplinary measures, since safety may otherwise be prejudiced. There is, however, a delicate balance. Sanctions are not applied in such a way as to encourage the concealment of errors.

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3.2.5. Audit, review and comparison

51. *Managerial responsibilities include the implementation of a range of monitoring practices which go beyond the implementation of quality assurance measures and include, for example, regular reviews of training programmes, staff appointment procedures, working practices, document control and quality assurance systems.*

52. These practices depend on the activities of the organization. In design, manufacturing and operating organizations, they include scrutiny of the means by which design or engineering changes are controlled. In the plant operational context, they include scrutiny of changes to operating parameters, maintenance requirements, modifications to plant, plant configuration control and any non-routine operation of the plant.

53. By these means, the working of safety management systems is checked by internal processes. It is good practice to augment such processes by calling on experts from functions other than that concerned or from outside the organization. This ensures the availability of broadly based views and experience, provides a basis for emulation and encourages the introduction of good practices that have been adopted elsewhere.

54. Managers make arrangements to benefit from all sources of relevant experience, research, technical developments, operational data and events of safety significance, all of which are carefully evaluated in their own contexts.

3.2.6. Commitment

55. In these ways, managers demonstrate their commitment to Safety Culture and encourage it in others. The practices identified structure the environment in which people work. The attitude of mind that produces satisfactory performance by people in groups or as individuals is fostered by demands for orderly work, by clarity of understanding of duties, by rewards and any necessary sanctions, and by the invitation of external scrutiny.

56. *It is the task of managers to ensure that their staff respond to and benefit from this established framework of practices and, by attitude and example, to ensure that their staff are continuously motivated towards high levels of personal performance in their duties.*

3.3. RESPONSE OF INDIVIDUALS

57. *Sections 3.1 and 3.2 present the means by which the framework is set for an effective Safety Culture and emphasize the responsibilities of management. As is pointed out in the introduction to these sections, it is the task of staff at all levels to respond to and benefit from this framework.*

58. The question remains: How? To emphasize this key question, what follows is set out in a different style. It is expressed in terms most relevant to operating staff since they bear the most direct responsibility, though in different ways the points apply to all persons with duties important to nuclear safety.

59. *The response of all those who strive for excellence in matters affecting nuclear safety is characterized by:*

A QUESTIONING ATTITUDE

plus

A RIGOROUS AND PRUDENT APPROACH

plus

COMMUNICATION

The result will be a major contribution to:

SAFETY

60. Before an individual begins any safety related task, his or her *questioning attitude* raises issues such as those listed in the following:

- Do I understand the task?
- What are my responsibilities?
- How do they relate to safety?
- Do I have the necessary knowledge to proceed?
- What are the responsibilities of others?
- Are there any unusual circumstances?
- Do I need any assistance?

— What can go wrong?
— What could be the consequences of failure or error?
— What should be done to prevent failures?
— What do I do if a fault occurs?

In the case of relatively routine tasks, for which the individual has been fully trained, question and answer will be automatic to a large extent. For tasks with a novel content, the thought process becomes more deliberate. New and unusual tasks which have an important safety content will be the subject of written procedures clarifying these matters.

61. Individuals adopt a *rigorous and prudent approach*. This involves:

— understanding the work procedures;
— complying with the procedures;
— being alert for the unexpected;
— stopping and thinking if a problem arises;
— seeking help if necessary;
— devoting attention to orderliness, timeliness and housekeeping;
— proceeding with deliberate care;
— forgoing shortcuts.

62. Individuals recognize that a *communicative* approach is essential to safety. This involves:

— obtaining useful information from others;
— transmitting information to others;
— reporting on and documenting results of work, both routine and unusual;
— suggesting new safety initiatives.

63. A questioning attitude, a rigorous and prudent approach, and necessary communication are all aspects of an effective Safety Culture in individuals. The product contributes to a high level of safety and generates a personal pride in dealing with important tasks in a professional manner.

Appendix B: Artefacts, Values and Basic Underlying Assumptions

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Artefacts and Behaviours [9]

Artefacts are the "visible" part of an enterprise, for example cleanliness and technical standard of the installation, the completeness of operating manuals, but also patterns of behaviour such as adherence to rules and regulations. It is thus a matter of appearances, of "image", and of concrete action.

Fundamental to artefacts is that they can be observed. However, artefacts allow only limited inferences to be drawn on what lies behind them, since they can have many different causes. As a rule therefore, it is not permissible to assess corporate culture from artefacts alone.

Values (Social Norms [9])

Social norms are among the influencing factors that underlie observable forms of behaviour. They decide to a large extent "what one does" and "how one does it". They determine what kinds of conduct are deemed to be "good/bad", "acceptable/unacceptable", "sensible/senseless". They help the individual to perform his function within the enterprise and the group, and influence dealings between people and groups.[1]

Social norms are not to be equated with official rules and regulations such as those laid down in standard procedures, technical specifications, manuals or mission statements. They are often more a question of "unwritten laws". They regulate how much work one does in a group, for example, in that members who in the eyes of the group perform too much or too little are dubbed "rate buster" or "free rider" [37]. Such norms can by all means diverge from the official, written norms, even contradict them.

> Thus, someone who checks again that a displayed piece of information is correct, despite the fact that everything is "obviously" all right, is written off as nervous and over-cautious - notwithstanding the official norm that safety always has "top priority".

Social norms are upheld by means of "sanctions". Their violation is punished, for instance by being exposed, made to look ridiculous, rejected or ostracised. Their observance brings recognition, popularity or prestige. The deciding factor here is the behaviour model provided

[1] A distinction is often made between "values" and "social norms". Values are general concepts of what is worth aspiring to, or not. They thus have the function of general "guiding principles" constituting the basis for more concrete "codes of behaviour", in other words social norms. But in a given case it is often hard to make the distinction; we have therefore dispensed with this distinction so as not to complicate the discussion unnecessarily.

Thus a supervisor who frequently speaks of the "top priority" of safety, yet ignores specific violations of this official norm, makes fun of existing rules or indeed sets a poor example himself, will undermine the official norms, even though he is always talking about them.

mainly by colleagues and superiors, and the reactions to rule infringement or compliance - but not the mere declaration, the official "pronouncement" of norms.

The mechanisms governing the observance of social norms can be very subtle. The suggestion of getting the picket engineer here now, does not have to meet with forceful disagreement. A drawn-out "If you think so..." can be enough to give the suggester the impression that he is felt to be unsure, lacking confidence and incompetent if he wants to fetch the picket engineer for such a minor problem. Nor must sanctions actually be applied; it suffices if those concerned fear them. In the extreme case it may even happen that out of fear of exposure something is not done which most of those involved believe to be sensible - for instance when many think the boss should be got out of bed, but no one says so because they are afraid of making fools of themselves if the problem later turns out to be harmless.

Actual experiences and their evaluation by the people involved play a crucial role in the forming and preserving of social norms. This is especially so with situations which are ambiguous. It can have different consequences:

a) Social norms will vary between individuals, organisational units and organisations, depending on experiences and their evaluation. To some degree this is normal and unavoidable. But if crass contradictions arise, this can lead to problems.

a) To the extent that social norms become established through experience in specific situations, they are often not consciously registered as a "general" norm, but are stored in the memory "together" with the corresponding, situation-related information. They can therefore often be recalled only with difficulty unless the situational aspects are activated in the memory at the same time. And even then they may be hard to put into words - much as we can see that a sentence is wrong without being able to state correctly the grammar rule that has been broken.

a) A social norm rarely applies as sole arbiter. More usual is that there are several norms which as a rule do not interfere with each other, but may clash in certain situations. In the field of safety, for example, it has to be decided whether a risk is great enough for additional precautionary measures to be necessary, or so small that extra precautions might be seen as a "anxiety" reaction.

   If the people involved are convinced that a situation is acceptably safe and in line with regulations although the corresponding instrument is not working, this may mean that someone who suggests looking into the matter can expect to appear stupid. (It does not matter whether this fear is justified or not. As described above, such fears can even result in failure to take actions which most of those concerned think sensible, but do not suggest for fear of being made to look silly!)

   There can also be social norms which govern to what extent superiors are informed about problems. The edict "talk frankly about mistakes" can conflict with the social norm "thou shalt not split on colleagues" and in many actual situations even be cancelled out.

Social norms thus exist in differing degrees of general applicability: some are very general, others are tied more to specific situational characteristics. Knowing the general norms is important because they define the boundaries of action. However, they do not necessarily allow behaviour to be predicted in situations which call for a decision between mutually contradictory norms. For this, a knowledge of situation-specific social norms is important.

Accordingly, an interrogation aimed at determining social norms cannot be restricted to general questions. Rather, concrete situations must be brought in so as to gain an idea of which norms apply in which situation.

Basic Underlying Assumptions [9]

The term "basic underlying assumptions" is used here in the sense of barely conscious beliefs and convictions as to "how it is". These assumptions are often so deeply rooted that for those concerned it is hard to imagine thinking or acting "differently". They are commonly founded on actual experiences that have become taken for granted and felt to be "the truth". They concern the "right" interpretation of a situation, its causes and further development, the likely consequences of certain actions and interventions, etc. Examples of such basic underlying assumptions can be:

- Some safety regulations contribute much, others little, to safety; certain regulations can on occasion be harmlessly circumvented.
- Some indicated evidence can be trusted less (or more) than one's own instinct.

Like social norms, basic assumptions are influenced by empirical models and concrete experiences. Here too, divergent, indeed contradictory, fundamental attitudes can exist among individuals and among different groups.

Once established, basic underlying assumptions are usually little discussed and seldom critically queried. As with social norms, these assumptions do not necessarily apply in the same way in every situation. It is perfectly possible for an assumption to be activated in one situation, and not in another. Sometimes they can be so strongly associated with particular situations that they emerge into consciousness above all when one is in such situations or when they are the subject of thoughts, imaginings or conversation, whereas without this situational reference one is not immediately aware of them.

The Role of Social Norms and Basic Underlying Assumptions in Motivation

Basic underlying assumptions influence behaviour in close relationship with social norms. The value-expectation theory starts from the premise that the decision for or against a particular action depends largely on what advantages or disadvantages one expects from that action (or its omission).

Two aspects play a part here:

a) With what probability are which consequences expected from an action (or its omission) (expectation component)?

a) What value is given to these (value component)?

In the "value-expectation calculation", the (subjective!) probabilities of various desirable consequences (benefit, advantage) and undesirable consequences (cost, disadvantage, harm) are weighed against each other [38]. The balance of this calculation then determines the motivation. Social norms and basic underlying assumptions influence this calculation in different ways:

> An estimation (basic underlying assumption) that one's own intuition is more reliable than a given reading leads possibly to the surmise (expectation) that continuing in normal operation is not dangerous, resulting in little motivation to take extra precautions. If to this is added the social norm that in the case of minimal risk an additional safety measure is a manifestation of over-anxiety, there arises the expectation of making oneself ridiculous in front of the others (negative valuation). The balance of the calculation (low probability of damage if operation continues, high probability of appearing over-anxious ["social damage"]) would in this instance argue clearly against taking additional safety precautions.

In order to be able to judge behaviour in concrete situations, therefore, it is important to be familiar with the value-expectation calculation and the social norms and basic underlying assumptions that influence it.

Appendix C: Summary of Root Cause Analysis Methods

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WORKING MATERIAL

REVIEW OF EXPERIENCE WITH ROOT CAUSE ANALYSIS OF INCIDENTS

REPORT OF A TECHNICAL COMMITTEE MEETING
ORGANIZED BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY
AND HELD IN
VIENNA, NOVEMBER 22 - 26 1993

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2. REVIEW OF EXISTING ROOT CAUSE METHODOLOGIES

2.1. OBJECTIVES

The objectives of this chapter are to examine the root cause methodologies and determine the positive and limiting aspects of each and in addition to advise when each methodology should be adopted.

These objectives enabled wide ranging discussions about the various techniques and methodologies described during the initial stages of the TCM.

The group quickly recognized that differences in definitions between ASSET and other methodologies created difficulties in understanding the methodologies. Although the membership of the group was drawn from practitioners in the various methodologies, there were limitations in the comprehensive comparison of techniques due to the each individual's basic philosophy and limited knowledge in more than one technique.

2.2. STRENGTHS AND LIMITATIONS

The techniques reviewed included the following:

Task Analysis
Change Analysis
Barrier Analysis
Event and Causal Factor Charting (ECFC)
Fault tree analysis
ASSET (Assessment of Safety Significant Events Team)
HPES (Human Performance Enhancement system)
MTO (Man - Technology - Organisation)
AEB (Accident Evolution and Barrier Function Analysis)
MORT (Management Oversight and Risk Tree analysis)
HPIP (Human Performance Investigation Process)
AORS (Abnormal Occurrence Reporting System)

The strengths and weaknesses described in the INPO Good Practice on Root Cause analysis (OE-907 INPO 90-004) were used as a starting point and in order to benefit from previous review activities.

2.2.1. Task Analysis

Description

Task analysis is a technique that can be used on many types of investigation. One of the first priorities when beginning an investigation is to determine as much as possible about the activity that was being performed. This will require a review of work documents, logs, manuals etc to determine what the task was and how it

was performed. This process is a task analysis and may be done in two ways, either by reference to the plant documentation or by reviewing the task as it is being performed by direct observation or interview. Frequently it is a combination of the two. There are many variations of the process available.

Strengths:

- Makes the investigator familiar with the approved and actual method of performing the task
- Identifies possible contributors to the event
- Helps to identify deviations from the normal way of doing the task
- Helps to identify barriers

Limitations:

- Can be time consuming
- Most effective when performed in conjunction with staff normally responsible for the task
- Rarely used independently

2.2.2. Change Analysis

Description

Change analysis compares the previous trouble free activity with the event to identify differences. These differences are evaluated to see how they contributed to the event.

Strengths:

- Good starting point
- Generates questions
- Simple to use
- Useful in evaluating equipment failures
- Good addition to the ECFC technique

Limitations:

- Usually produces more questions than answers
- Gradual changes and the compounding of changes can be overlooked
- Danger of incorrectly defining the change
- Must be used in conjunction with other techniques

2.2.3. Barrier Analysis

Description

Barriers are devices employed to protect equipment and people, and enhance the safety and performance of the man-machine system. They can be physical or administrative in form and are erected to ensure consistent and desired behaviour by plant and personnel. A single barrier is rarely relied upon. Barrier analysis is a method that seeks to identify such barriers and determine those which either failed or were absent. The failure of a number of barriers in series can create a situation that can result in an event. The group recognised that the ASSET methodology includes one particular type of barrier analysis.

Strengths:

- Helps to identify probable causal factors
- Can be used independently or within an integrated system (ECFC)

Limitations:

- Requires some familiarity with the philosophy to be effective
- Danger of not recognising all failed barriers
- Danger of having a too restrictive concept of a barrier without addressing its quality and depth

2.2.4. Event And Causal Factor Charting

Description

An events and causal factors chart (ECFC) is a graphically displayed flow chart of an entire event. The basis of an ECFC is the sequence of events plotted on a time line. Beginning and end points are selected to capture all essential information pertinent to the situation. As an event line is established, additional situational features such as related conditions, secondary events and presumptions are added.

Probable casual factors become evident as the chart is developed. Often causal factors that were not obvious at the outset become evident through this technique.

An ECFC provides an excellent opportunity to graphically display barriers, changes, causes and effects and human performance interactions.

Strengths:

- Organises data
- Develops investigation and provides a cause orientated explanation.

- Helps to ensure objectivity
- Very concise story of what happened and how it happened
- Easy to understand and communicate with those not familiar with the technique.(i.e. management and operators)
- Very flexible guidelines
- Provides a broad picture
- Utilises the concept of cause and effect
- Computer programs exist to produce ECFCs charts.

Limitations:

- Requires up-front information to start
- Can be time consuming
- Rarely stands alone and greatly enhanced by superimposed barrier and change analysis
- Flexibility can be a limitation if used by inexperienced analyst
- Requires practice to use effectively
- Does not specify or limit scope of analysis

2.2.5. Fault Tree Analysis

Description

This is a systematic approach, similar to the MORT process, that may be used when the problem is known but the causes are not clear. It uses a set of questions to help direct the investigator to the causes. Numerous commercial variants are available.

Strengths:

- Can be used with limited training
- Useful in solving programmatic problems
- A simplified version of MORT
- Gives structure to an event
- Pin points logical connections

Limitations:

- May only identify area of cause
- Potentially superficial
- Can cause tunnel vision and limit the identification of other contributors

2.2.6. ASSET (Assessment of Safety Significant Events Team)

Description

The root cause analysis methodology developed to support the IAEA ASSET Services programme, seeks, by consideration of NPP safety performance, to advise how the NPP management can enhance the nuclear safety of the plant. The process involves a diverse international group of experts who review the events that have occurred at the NPP, identify the pending safety issues and after analysing events representative of the safety issues advise how the NPP management could enhance aspects of their management systems to further enhance the prevention of incidents. The process is described in IAEA-TECDOC-632 but has developed beyond the currently published handbook. Incidents occur and recur because preventive measures are not reliable. Root causes are clearly defined as the answer to the question: why was it not prevented? Root causes are the deficiencies at the NPP to eliminate the plant latent weaknesses by timely detection (surveillance programme) and prompt restoration (feedback programme). (NB The ASSET views surveillance in a very broad sense). The methodology arises from the needs of the ASSET team to quickly assess the management latent weaknesses and associated root causes. It has been subsequently used as a framework for plant event investigation and analysis in order to determine direct and root causes.

Strengths:

- Freely available for all member states to use
- Used numerous times in ASSET missions and by NPPs in the preparation to receive an ASSET mission.
- Has a degree of international recognition
- Provides a structure and methodology for disparate teams
- Output is directed at NPP management, the utility and the regulator
- Can provide focussed corrective actions
- Can be applied quickly by ASSET mission process
- Defined limit of application is within the NPP and hence recommended corrective actions are directed specifically within the plant. The plant is given no excuse
- Developed to target organisational problems
- Human performance aspects are considered as important as equipment and procedural failures
- Has an IAEA manual describing the process
- Training courses on the ASSET analysis procedures are available and were already conducted on request in 23 out of the 30 countries operating NPPs.

Limitations:

- Has a different terminology and definition of root cause as compared with other techniques.
- Because the method, apart from identifying weaknesses in equipment personnel and procedures, also identifies deficiencies in management and policy regarding prevention of incidents, it takes knowledgeable staff with practical experience to do the analyses.
- Manual is not current and is difficult to follow.
- Limited guidance is given in event data capture and refinement during the analysis
- When used as a framework for event investigation by NPPs some required basic skills/methods are not identified. This is obviated during missions by the experience and terms of reference of the team of experts

2.2.7. HPES (Human Performance Enhancement System)

Description

The HPES system is a methodology that draws together a number of basic investigative processes. HPES assumes that people want to perform well and by behaviour modification via better management controls and an enhanced work place, human factor related events can be reduced.
The techniques encompassed within the HPES package include:

Task Analysis
Change Analysis
Barrier Analysis
Event and Causal Factor Charting (ECFC)
Behavioral analysis
Situational analysis
Interviewing

The HPES package is the result of many years of development and is used in various forms inside the nuclear community and similar event analysis methodology and techniques are in use by several other organisations including the civil aviation industry.(INPO HPES Coordinators Manual INPO 86-016 & HPES Program INPO 90-005)

Strengths:

- Provides a toolbox of techniques
- Proven methodology used worldwide
- Flexible to apply
- Addresses human performance and provides a guide in behavioral analysis
- Training courses and handbooks available

Limitations:

- Focussed corrective actions dependent on experience of the analyst (as true for other methodologies)
- Requires experience and training to apply effectively (as true for other methodologies)
- The process does not specifically identify organisational issues though these can be determined.

2.2.8. MTO (Man - Technology - Organisation)

Description

MTO does not describe a specific method. Rather it is a general concept (or knowledge domain) applied to safety which stress the importance of focusing on the interaction between man, technology and the organisation. However, within this knowledge domain specific methods have been developed. In particular a modified version of HPES has been adopted by the Swedish nuclear industry.(This is often referred to as MTO-analysis by the Swedish nuclear industry).

Because MTO strongly focuses on the context surrounding event analysis it stresses such things as:

- the importance of giving Human Factors knowledge when an event analysis technique is introduced;
- the importance of organising event analysis in such a way that event analysis teams receive support
- the importance of a "mentor system" of training so new team members of the analysis team can be introduced in a practical way.

Strengths:

- Describes the context of event analysis in terms of necessary background knowledge and organisation structure needed for successful implementation.
- Has a strong connection to human factors.

Limitations:

- Because a modified HPES technique is used, the limitations of the specific techniques applied (i.e. barrier analysis, ECFC, and change analysis) are apparent (see other sections of this chapter).

2.2.9. AEB (Accident Evolution and Barrier Function Analysis)

Description

The AEB method models the interaction between human and technical systems. In particular it models the failures and errors in the interaction leading to an incident or accident. An AEB analysis consists of three main parts (1) the narrative of the accident, (2) the AEB flow chart model of human and system errors and failures, and (3) the barrier function analysis. In contrast to a tree representation of the contributing factors to barrier function failures, this method implies that failures and failing barrier functions are analysed in AEB analyses at successively more detailed levels.

In the AEB model those errors and malfunctions which lead to an incident and ultimately to an accident are modelled in the flow chart in boxes of failures, malfunctions and errors. Each link between two successive failures is analysed with regard to failing or missing barrier functions. Barrier function systems can be both human and technical. The flow chart model in AEB only models errors and deviations and does not give an account of the sequences of all events in the accident. AEB is shorter and more focused on errors and less complete in relation to the narrative of an event.

Strengths:

- Free to use
- Formalises the links between human performance and technology
- Uses barrier function analysis in a more graphical way
- Particularly focused on failures and errors

Limitations:

- Not widely used and under development, hence little practical application on NPPs so far.
- Does not present all the data in the AEB main flowchart and hence runs the risk of missing potential relevant contributory factors represnted in the narrative.
- Manual only in Swedish

2.2.10. MORT (Management Oversight and Risk Tree Analysis)

Description

MORT is a comprehensive analytical procedure that provides a disciplined method for determining the causes and contributory factors of incidents and accidents. The method consists of a fault tree together with a long series of interrelated questions. The MORT process is based on the energy trace and barrier analysis. (Ref MORT Safety Assurance Systems - Johnson WG 1980)

Strengths:

- Free to use and proven methodology
- Comprehensive manual and training courses
- Looks to the whole management structure
- Uses detailed fault tree
- Flexible (can use part of fault tree for small events)
- Up to 1500 potential causal factors
- Uses barrier analysis
- Identifies the 'assumed' risks taken by management
- Computerised versions are available

Limitations:

- Requires experience to use
- Not appropriate for use by NPP staff in routine investigative duties
- Complicated
- Time consuming due to extensive task analysis

2.2.11. HPIP (Human Performance Investigation Process)

Description

The Human Performance Investigation process is a method developed for the NRC for the investigation of events that involve human performance issues at NPPs. HPIP leads the investigator through the techniques to perform an in-depth investigation of human contributors to an event. HPIP also provides six investigative modules (Procedures, Training, Verbal Communications, Organisational Factors, Human Engineering and Supervision) for determining the root causes of human performance related events (NUREG/CR-5455).

Strengths:

- Similar to HPES
- Simplified fault trees are easy to use
- Training on HPIP minimal if users are experienced in basic techniques

Limitations:

- Very new and no established track record

2.2.12. AORS (Abnormal Occurrence Reporting System)

Description

AORS is a methodology to analyse and provide feedback on operational events. Cause analysis is a routine process within the AORS. Data preparation for the computerised data bank is incorporated in the process of analysis. It incorporates the ASSET methodology. The AORS splits an event into its occurrences and has routine identification of causes for each of its occurrences to determine its safety significance.

Strengths:

- Incorporates other techniques
- Closely linked with event database

Limitations:

- Closing the loop of experience feedback needs additional managerial arrangements
- Requires other indepth analysis of significant events
- Not widely used

2.3. APPROPRIATE APPLICATION

The application of the methodologies described above is dependant upon many factors.

In particular:

ASSET is appropriate for use by the IAEA in the application of the ASSET missions to NPPs as well as for use by NPPs on a routine basis. In both cases the ASSET method, if applied by knowledgeable and experienced staff, quickly details recognizable causes on more than one level of responsibility, thus making it possible to address each of these levels of responsibility with well selected practical corrective measures.

HPES is viewed as a very useful tool but may be too comprehensive as a tool for a quick management overview of events

MORT was considered applicable for complex event analysis but too complex for general NPP event analysis.

2.4. GENERAL OBSERVATIONS

The group considered that all the techniques reviewed had strengths and limitations and did not seek to criticise any one methodology or philosophy.

Some members of the group considered that a development of a universal methodology would be of benefit, for instance the development of a hybrid. This was not the majority view, however a standardisation of definitions was considered essential.

The importance of all NPPs management to recognise the need for a methodology could not be over emphasised. However, the group considered that the methodology should be determined by the NPP and NOT be prescribed by the regulator.

The weaknesses of any adopted methodology should be recognised and any benefits of other systems used to enhance the skills and tools available to the NPP event investigation and analysis teams. In any case, it is advantageous to have the knowledge about other methodology even if not regularly used.

The most important aspect was, however, believed to be the provision of appropriate resources and support by NPP management.

Appendix D: Examples for the Situational Approach

Prof. Dr. N. Semmer, Professor of Industrial and Organisational Psychology, University of Berne

Some examples of questions for the situational interview are given below.

Example A: Control room of a research reactor

Case No. 1

Imagine you have to restart the reactor following a scram. However, you only have 20 minutes. Otherwise, because of the xenon build-up, there will have to be a wait of two days before starting up again.

What do you do? How do you proceed?

How the situation is presented can be varied in different ways, depending on what is to be assessed. If the focus is on *communication,* for instance, the example could be expanded as follows:

Case No. 2

Imagine you have to restart the reactor following a scram. However, you only have 20 minutes. Otherwise, because of the xenon build-up, there will have to be a wait of two days before starting up again. The shift supervisor decides it is feasible, if need be one will just have to leave out one of the tests that are normally done. This is unnecessary anyway, he says; everyone knows that all is OK in this respect.

What do you do? How do you react?

The interviewees' reactions, i.e. their replies to this situation, can be stated freely or in the form of multiple-choice answers. Possible answers to Case No. 2 could be as follows:

Possible answers to Case No. 2

1. I say nothing. I think that is reasonable.
2. I say nothing. Even so, I have my doubts, but it's his responsibility after all.
3. I don't think that's right, I say nothing, there's no point in protesting.
4. I don't think that's right and I say so, loud and clear.

Such a scenario can be further developed in a number of ways, according to what aspect is being considered. One could envisage, for example, that the person concerned expresses his doubts and is then put down as a "worry guts" by a colleague. Again his reaction is asked for.

Equally, one could ask how, in the interviewee's opinion, his colleagues / superiors would be likely to react.

With some situational questions, the interviewee could even be engaged in a little roleplaying with the interviewer, for example the shift supervisor or another member of the group, taking part.

The answers could be assessed by experts from different viewpoints. These might include: correct estimation of risk, value placed on safety, adequate clarification of the situation, adequate communication, etc.

Example B: Plant management

In the morning a reactor-water pipe outside the primary containment springs a serious leak. Based on the anticipated repair time of about an hour, the radiation protection people estimate a collective dose of 10 mSv for the maintenance crew. By cutting back power output the collective dose can be reduced proportionately. The load dispatching centre needs the power urgently at the moment, otherwise it will have to buy expensive energy from elsewhere, and suggests not lowering output until after 10 p.m.

Questions to the plant management

How do you go about reaching your decision?

Which criteria will you include in your decision?

Questions to the picket engineer or other persons concerned

How do you think the plant management would proceed?

How do you think the individual members of the plant management will decide if there is any uncertainty?

Example C: Picket engineer

The plant shut down during the night, owing to a spurious trip. The shift is not sure whether the plant behaved as it should. You can check that the plant's transient response was correct only be referring to computer records. You find you cannot retrieve theserecords. You could phone the specialist, then the records would be available for scrutiny in about 2 hours. Any delay in startup will inevitably mean that because of the expected xenon transient, full power can no longer be attained.

Questions to the picket engineer

What is the most effective decision?

What are the reasons for this decision?

Question to the shift supervisor

How do you think the majority of picket engineers will behave in this situation?

Question to the plant management

What would you decide if the picket engineer phones you?

Possible answers

1. I would give the go-ahead to start the plant without analysing the computer printouts.
2. I would phone the specialist and accept a 2-hour delay in startup.
3. I would inform the supervisor and leave the decision to him.

Example D: Field operator

Shortly before starting up after the annual overhaul you check the valves in the primary containment. There you find that a temporary ladder has already been removed, preventing access to one valve which can therefore no longer be checked.

Question to the field operator
What do you do?

Possible answers

1. I fetch a ladder and try to check the valve setting.
2. I inform the shift supervisor at once and ask him what I should do.
3. I do not check the valve because I know a field operator will be doing a final check.

Questions to the shift supervisor
How do you think your field operators will react?
What do you decide when the field operator phones you?

Example E: Maintenance mechanic

You have been told to dismantle reactor-water clean-up pump 1. At the location there is a high dose rate; the radiation protection people instruct you to work quickly. The shift has given clearance for the job. You discover that the seal water valve has not been closed and has no locking tag, so the pump is possibly still under pressure.

Question to the mechanic
How do you react?

Possible answers

1. I trust that the valve is safe and start to work.
2. I close the seal water valve.
3. I tell the shift supervisor what I have discovered.
4. I carefully loosen the flange and check for pressure.

Questions to the shift supervisor
How do you think the mechanic will react?
How do you react when the mechanic phones?

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Abbreviations

ALARA	As Low As Reasonably Achievable
ASCOT	Assessment of Safety Culture in Organisations Team (IAEO)
ASP	Accident Sequence Precursor
ASSET	Assessment of Safety Significant Events Team (IAEO)
AÜP	Ageing Programme
EDF	Electricité de France
HSK	Swiss Federal Nuclear Safety Inspectorate
IAEA	International Atomic Energy Agency
IfAP	Institut für Arbeitspsychologie der ETH Zürich
INES	International Nuclear Event Scale (IAEO und NEA)
INPO	Institute of Nuclear Power Operators (USA)
INSAG	International Nuclear Safety Advisory Group (IAEO)
IRS	Incident Reporting System (IAEO und NEA)
ISA	Internal Safety Review Committee
ISRS	International Safety Rating System
KSA	Swiss Federal Nuclear Safety Commission
MTO	Man/Technology/Organisation
NE	Nuclear Electric (NE)
NEA	Nuclear Energy Agency (OECD)
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission (USA)
OECD	Organisation of Economic Cooperation and Development
OSART	Operational Safety Review Team (IAEO)
PSA	Probabilistic Safety Assessment
PSÜ	Periodic Safety Review
QA	Quality Assurance
QM	Quality Management
SKi	Swedish Nuclear Power Inspectorate
SUVA	Schweizerische Unfallversicherungsanstalt
WANO	World Association of Nuclear Operators
ZWILAG	Zwischenlager Würenlingen AG
ZZL	Zentrales Zwischenlager der ZWILAG