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Organizational factors influencing human performance in nuclear power plants

*Report of a Technical Committee meeting
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IN NUCLEAR POWER PLANTS

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FOREWORD

In 1991 a Safety Series report on Safety Culture of the International Nuclear Safety Advisory Group (INSAG) was published as 75-INSAG-4 by the IAEA. This report deals with the concept of Safety Culture as it relates to organizations and individuals involved in the operations of nuclear power plants (NPPs).

Generally, the role of management and organization in assuring the safe operation of NPPs has been widely recognized and its importance accepted. However, the understanding of what constitutes effective management and organization in the area of safety is less developed than the understanding of most of the technical issues which plant operators and regulatory bodies are confronted with. The Technical Committee meeting provided a forum for a broad exchange of information on practices and experiences in the area of organization and management to accomplish operational safety in NPPs and thus enhance Safety Culture. This report and the papers presented at the meeting discuss those factors which influence and improve human performance covering both aspects, i.e. the basic requirements imposed on the operator and the ways of managerial support which enhance the reliable and safety oriented performance of operators.

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INTRODUCTION

In the early days of development the nuclear industry worldwide, and the nuclear safety regulators in particular, placed emphasis on design, hardware reliability, quality assurance/quality control (QA/QC) and placed only intuitive interest in human factors.

Human factors and ergonomics in the nuclear industry were an afterthought. Human reliability gained increased importance in the aftermath of the Three Mile Island (TMI) accident. The impact of organizational factors (the subject of the Technical Committee meeting) on nuclear safety is still in the early stages of research and development.

Studies of major accidents from a variety of industries indicate that they rarely arise from random failures of hardware, but instead arise from a combination of culture and latent human and organizational error together with hardware failures. The accident at the Three Mile Island NPP, for example, was partly a result of inadequate operator training, confusing operation procedures, and insufficient safety knowledge possessed by plant personnel. This combination turned a minor equipment failure into an accident. Studies of other major events that have occurred in the nuclear industry also reflect this cause-effect relationship between organization/management quality and hardware malfunction on operation errors.

The nuclear industry throughout the western world reacted vigorously to the lessons learned from TMI. In some countries, the reaction was even stronger than the one in the USA. In particular man-machine interface (MMI) issues, such as human factoring of procedures including use of simulators for their validation, were strongly emphasized.

Catastrophic accidents in other industries such as Challenger, Bhopal, and Exxon Valdez were partially attributable to design flaws. Known design deficiencies can be mastered by more restrictive operation, well trained crews, and above all by deeply ingrained safety culture. Operating conditions and the environment contributed to the Chernobyl, TMI and Bhopal accidents which all occurred during the night shift. Freezing environmental conditions played a part in the Challenger accident.

Organization and management factors played dominant roles in all of the catastrophes. Some salient organizational ingredients were lack of accident analyses, lack of risk analyses, lack of training, procedure violations, operator errors, no operating experience feedback, commercial pressures, no accident management training, no emergency planning, etc.

Additionally, actual experiences of collected and interpreted actuarial data from nuclear power operations further corroborate the significance of the human dimension. A summary of estimated contributions of "human errors" to system accidents, as suggested by some authors, could be as high as 70%.

Focus on hardware and assurance of hardware reliability has yielded remarkable results and an enviable track record. Now the nuclear establishment needs to refocus on assurance of the human dimension in a dynamic plant operational environment and a full understanding of organizational influences on nuclear safety.

While the continued emphasis should be on safety, it should be remembered that the primary goal for any nuclear utility is to produce electricity economically.

The National Energy Policy Act of 1992 (NEPA) began deregulation of the electric utility industry in the USA, creating a competitive climate heretofore unknown. This newly competitive electric energy market places severe competitive cost pressures on many nuclear power plants. Significant reductions in production costs are a necessity for the survival of some plants, and for improved profitability of all plants. Leaders in the nuclear industry realize that the thinking which got the field where it is today is not the thinking which will lead the industry to where it needs to be in the next century.

According to some authors, industries and organizations that are going to be able to compete today and survive must have four characteristics. They must be: (1) customer driven; (2) cost-effective; (3) fast and flexible; and (4) continuously improving. In the nuclear industry one important additional topic needs to be considered, namely nuclear safety. These challenges add a new dimension to the field of organizational factors.

1. HUMAN PERFORMANCE

1.1. INTRODUCTION

Successful NPP operation essentially means event free operation. The ultimate goal of the analysis of human performance is the prevention or at least the minimization of the occurrence of events. Quite often events are a result of inappropriate actions by the job performer and it is therefore imperative that he or she should develop adequate abilities and a proper mindset.

However such competency elements depend on the policies and support of the management systems for producing performance results of appropriate quality. In addition, competent individuals well supported by such organizational elements must be able to sustain their performance for the entire life span of the NPP, which would require continuous promotion of abilities and mindset.

Management must also demonstrate its performance and commitment by visible actions toward events reduction in all NPP decision making activities.

The three major components of human performance refer to:

- the response of individuals working within the framework and benefitting from the framework;
- the organizational elements;
- the strong lines of authority established based on determined values of the major components.

1.2. HUMAN COMPETENCE

The optimal performance of an individual is determined by a number of personal capacities such as:

- commitment to safety goals;
- job skills;
- quality orientation;
- problem solving mechanisms (stress tolerance, questioning attitude);

- interpersonal communication skills;
- awareness of the importance of fitness for duty.

These capacities are required from all individuals in all groups: direct operation, maintenance, quality assurance, training and auxiliary services.

In order to secure event-free operation the expectation from any individual would encompass:

- appropriate job performance in relation to execution of predetermined job tasks to the defined standards;
- problem solving skills with the term "problem" specifically understood as fundamental cause (root cause) for occurrences;
- conscious awareness of the quality goals set out for the job performance by management;
- producing quality results in teamwork and group performance.

1.3. ORGANIZATIONAL ELEMENTS

In order that a job performer with the required competencies produces quality performance, appropriate management systems must provide the necessary direction, resources and support.

The following systems relate to the organizational elements in this context:

- a system of policy communications must declare what the management is committed to and which are the corporate values and goals that are the priority of the organization;
- an appropriate line of authority that provides effective direction to the performer in keeping with the above values;
- information resources for quality in job performance, namely:
 - an appropriate training system
 - an effective supervision system
 - availability of up-to-date procedures;
- quality management tools and programmes:
 - human performance evaluation
 - self-assessment
 - a deficiency in work execution must be detected by verification checks and the results analysed in order to establish the root causes of such deficiencies.
 - keeping track of various modifications and corrective actions for follow up on preventive measures;
- the requirements of work place hygiene, the layout, the industrial safety provisions and ergonomics must support quality performance.

1.4. PROMOTIONAL ELEMENTS

The above quality performance needs to be rewarded so that it remains for a long period of time. Event free operation needs to be reinforced at all times, not only by providing the above systems but also by demonstrating actions that promote the following:

- a climate of trust and openness where reporting even a "near miss" would be a welcome step;
- clear rewards for event-free operation to the performers and the team including attributes such as adherence to procedures;
- identifying "self-checking", "double-checking", "auditing" as good practices for communication and supervision skills;
- performing root cause analysis on human factors;
- demonstration of values;
- preparing continually for internal/external assessments by peers, quality auditors, regulators and international evaluators.

2. REVIEW OF INCIDENTS

2.1. INTRODUCTION

Learning from experience is an important feature of living systems. Analysis of operational events is one of the sources of information for NPP operations.

Operational experience feedback is one of the most important tools for management to allocate resources. Resources can be used most effectively in the area of improvement of human performance because necessary hardware changes are generally limited.

There are many influences of organizational and individual origins which tend to conceal human errors. In a NPP this results in loss of information on near misses and minor events which are not required to be reported to the regulatory body. NPP organizations should have a programme to collect, analyse and disseminate operating experience concerning internal (within the plant) and external (national or international) events.

2.2. GENERAL CHARACTERISTICS OF EXISTING METHODOLOGIES

Events can be considered in two ways, either as individual or as a group of events. In both cases we need different tools for their analysis: root cause analysis for in-depth analysis of individual events, and epidemiological studies for analysis of groups of events.

There are several well known methods for analysis of individual events which will not be described in this document. However, few methodologies concerning organizational aspects based on analysis of individual events are available. Further, even fewer methodologies exist concerning organizational aspects in the epidemiological approach.

The "human part" of existing root cause analysis packages represents an engineering approach for individual event analysis (since most engineers prefer measurable facts, categorization and the usage of tools not requiring psychological expertise). Perhaps one of the reasons that the practical engineering approach has prevailed is that existing behavioural theories do not provide practical methodologies.

2.3. IMPACT OF THRESHOLD OF EVENTS INVESTIGATED ON LESSONS LEARNED

In general, there are several reporting systems both on a national (reporting inside the NPP, to the utility or to the regulatory body) and international level (incident reporting Systems of the IAEA, NEA, WANO, etc.) All these reporting systems have their own reporting criteria but the reporting threshold is not always clearly defined. For example, categories defined by the word "potential" by principle do not allow the definition of a threshold.

Reporting criteria should reflect both the causes and the consequences of the events, especially in the area of human and organizational factors. The effectiveness of epidemiological analyses of human performance and organizational aspects depends on maintaining the plant reporting threshold level as low as possible. Absence of criteria dealing with causes (in the area of human performance) makes the usage of the specific reporting system for the purpose of statistical analysis of human factors difficult and the conclusions unreliable.

To decrease the threshold to the level of near misses, management has to create an atmosphere of confidence which encourages staff to report problems.

There are several prerequisites for an efficient in-plant reporting and investigating system for the purpose of human performance and organizational factors analysis:

- It must be possible to trigger the event investigation process from diverse NPP work areas (including experts knowledgeable in human aspects investigation) and different responsibility levels.
- The decision to start the investigation should be independent of the initiating area.
- Experts performing the analyses should be independent of the initiating area.

2.4. CHARACTERISTIC OF AN INVESTIGATION GROUP

The group performing the investigation of events at the plant level should involve persons trained in applied psychology and organizational aspects. It should also be possible to include additional periodic reviews by external experts. Independent reviews of all event analyses reported in the plant by external peers on a regular basis are recommended.

2.5. TOOLS FOR ANALYSIS OF ORGANIZATIONAL FACTORS

Currently there is no known methodology to analyse organizational factors based on operational events. Existing methodologies only identify problem areas relating to some of the known organizational factors. Therefore the lists of organizational factors still need further extension, which also applies to definitions and applicable corrective (preventive)

measures. There is a need for the development of suitable guidelines for methods of analysis, the tools to be used and the corrective measures to be taken. In certain areas of organizational factors (role-responsibilities, communication, personnel selection, group climate) a wider use of questionnaires or interviews with skilled psychologists can be recommended.

Certain organizational problems are difficult to identify by analysis of individual events. For this purpose epidemiological studies are useful.

3. HUMAN FACTORS CONSIDERATIONS IN RISK ASSESSMENT AND EDUCATION

3.1. INTRODUCTION

The value of the contribution of human factors engineering (HFE) to the assessment and also reduction of risk in NPPs is gaining increasing recognition.

It can be said that human factors engineering embraces a very wide range of disciplines such as psychology, sociology, management, ergonomics, etc. The challenge facing any organization which is attempting to utilize human factors engineering is to do so in a systematic, cost-effective, results-oriented manner.

Today the situation is changing. There are some indicators that organizations (vendors, utilities, regulatory authorities, etc.) are forming multidisciplinary teams composed of experts on operations, instrumentation and control systems, and human factors. This approach is equally valid for existing facilities, retrofit applications or new designs. However for discussion purposes, the application of human factors for new designs will be described. Some examples of HFE team utilization include the design of Westinghouse AP-600, GE SBWR & ABWR, and CANDU-9.

3.2. HUMAN FACTORS CONTRIBUTION IN NEW NPPs

It has been revealed through event analysis that the human component in the past was not adequately considered in the design process which led to the implementation of non-ergonomic man-machine interface configurations.

It is anticipated that the correct application of HFE will provide the following advantages:

- designs which enhance safe operation,
- cost effective designs which are functional,
- designs within human capabilities and limitations,
- designs with tolerance to human errors,
- designs which minimize the need for retrofitting,
- introduction of new technologies with minimum risk,
- designs which facilitate commissioning and maintenance.

For guaranteeing these contributions from HFE it is necessary to formalize a design process in a specific and systematic plan referred to as a Human Factors Engineering Plan (HFEP).

It is essential that the HFEP be initiated in early design phases and be continued through the whole design phase.

3.3. HUMAN ENGINEERING DESIGN PROCESS

3.3.1. Composition of the design team

The human factors engineering design team should be composed of experienced individuals whose collective expertise covers a broad range of disciplines relevant to the design and implementation process. These disciplines will include technical project management, control and engineering, plant operations and architect engineering, as well as human factors engineering.

3.3.2. Design methodology and guidelines

A sound HFE design methodology will consist of the following key design activities, each of which must be formalized in an appropriate guideline document:

- Functional analysis
- Function allocation
- Task analysis
- Human system interface design
- Evaluation (verification & validation).

The design implementation requires the systematic application of the methodologies and guidelines mentioned above to assure the expected results.

The introduction of HFE in NPP designs is a new direction that will produce very useful results for the final design installation provided that the HFE techniques are thoroughly and consistently implemented.

3.4. CONTRIBUTION OF SOCIAL SCIENCES TO RISK ASSESSMENT AND REDUCTION

For a long time psychologists and other social researchers have studied human behaviour in fields other than nuclear. Therefore knowledge related to the limitations and capabilities of the human being is available which can certainly be applied in the areas of assessment, prevention or reduction of risk.

The social and psychological fields have also developed techniques and methodologies for obtaining reliable and valid data related to the influence of new man-machine interface designs which would be of value for knowing and understanding the real situation related to human performance in NPPs.

In addition social sciences have contributed to understanding human performance and this can be demonstrated by various examples.

Some authors have developed frameworks for cognitive behaviour which could be used by the analyst. Without a model of human performance as reference it may be very difficult to understand the problem areas and obtain good results. An example related to functional structure of human performance is given in Appendix I.

There are also studies related to limitations and capabilities of human motor behaviour, motivational aspects, leadership skills, etc.

Especially in the case of control room staff in nuclear power plants, there are many factors affecting their performance (see Appendix II). Knowledge from social areas is also available for assessing and mitigating human error, for example studies on mental workload or the influence of circadian rhythms in shift turnover and overtime.

However the situation is not optimal. It is necessary to do more research for refining or adapting some models. To know the real situation in a plant related to human factor problems (motivation, attitudes, safety cultures, leadership, etc.) specific plant data for analysis are required. A sign of good safety culture practices in NPP is their support of research and studies in the human factors domain.

These studies, as others in the technical area, require time and resources of which the NPP managers must be aware. However, the relevance of human actions, i.e. operator error and organizational and management errors, for the occurrence of events in NPPs is seen to be approximately 70%. In Appendix III types of human errors which can occur are described. This should be the motivating reason for plant managers to consider human factors in depth as solutions for plant operational and organizational problems.

4. ORGANIZATIONAL STRUCTURE

4.1. ORGANIZATIONAL DESIGN OF TASKS RELEVANT TO SAFETY

Complex systems such as a nuclear power plant require maximum orderliness in methods of operation. The work must be clearly defined, properly assigned, executed according to predetermined and written procedures, carefully recorded, regularly supervised, and the whole system readily corrected when necessary. A state of organizational confusion is frequently the root cause of many errors. It has been largely recognized that an accident is rarely due only to individual confusion, a single act or situation or decision, but is more frequently due to a chain of faults. An initial situation of organizational confusion about one or more human functions generates further malfunctions or faults and, what is worse, tolerates them because it makes them less visible. When human latent malfunctions present in the plant are joined in a critical situation, the chances of an event to occur will increase.

There are various aspects in safety organizational design that have to be considered for reliable functioning of the organizational structure. Safety criteria are necessary for:

- definition of the safety work in terms of identified technical tasks,
- organization of the safety work,
- dimensions of the operating organizational structure,
- assignment of the responsibility for the safety tasks,
- definition of all the tasks, technical and/or organizational, assigned to the various individual working positions of the structure,
- organizational procedures.

4.2. AUTOCORRECTIVE CHARACTERISTICS OF THE SAFETY ORGANIZATION

Events do not originate at the moment of the accident. They develop through the following phases:

- (i) The human malfunctions are in a latent state. They are insignificant, at the beginning stage, and can be seen as small tolerated root causes. They are preconditions for errors.
- (ii) The previous preconditions manifest themselves in the plant with clear symptoms. They may be small human malfunctions generally tolerated, that are not recorded or if recorded are not followed by any corrective measure. Sometimes they are major malfunctions that, having not generated an accident are not immediately followed by adequate measures. This is the level of the immediate causes of events, the causes generally recognized during the investigations. Indeed, this is only a symptom level and the measures taken at this level do not remove the root cause. This remains and can cause other accidents or future operational problems.
- (iii) A plurality of these minor malfunctions may, at one point in time, allow the state of the plant to drift from a safe condition to an uncontrolled condition. These malfunctions can manifest themselves in the plant as accidents or transients, safety systems missed interventions, anomalous radioactive releases to the environment, or anomalous radiation doses, and are recorded as events.

The autocorrective organizational system has to be capable of monitoring the organizational functioning at various levels along the vertical axes, with the necessary different sensitivities. Contained inside the various units is all the information on work and it is possible to reveal latent human malfunctions and suggest appropriate measures to correct errors in the initial phase of event developments. The autocorrective system has to function at the unit level, department level and plant level. It is essential that errors, when committed, be seen less as a matter of concern than as a source of experience from which benefit can be derived. Individuals have to be encouraged to identify, report and correct imperfections in their own work in order to help others as well as themselves to avert future problems. Only for repeated deficiency or gross negligence would managers have to take disciplinary measures. Nevertheless, sanctions should not be applied in such a way as to encourage the concealment of errors.

5. LINKAGE OF ORGANIZATIONAL ASPECTS TO PSA

The probabilistic safety assessment (PSA) has been used throughout the world for quantitative assessments of NPP safety. Incorporation of management and organizational factors is still in the development stage.

Organizational influences should be included in human reliability analysis (HRA) as a logical extension of the performance shaping factor (PSF) concept. Higher level influences may concurrently affect several "traditional PSFs" as well as introduce other direct influences on personnel performance, such as motivation and attitude.

Quantification of the probability of each accident sequence defined in an event tree requires assignment of probabilities of occurrence to many basic events representing failure of systems, components and human interactions. Under the initiating event (IE) and system

unavailability headings are types of basic events labeled "Equipment caused" and "Human caused". Human caused events are further divided into categories customary in the HRA literature.

Each of the basic events can be caused by various parts of a nuclear utility organization. The human caused events involve those plant personnel having hands-on interactions with the plant systems. These events deal with maintenance and operations department personnel.

Organizational influences flow from the external and corporate levels to the plant management and then to the functional groups in the plant. Even though personnel of the maintenance and operations departments may be the agents of failure, root causes may lie in organizational influences. Some of the organizational influences show up in measurements of PSFs such as the quality of man-machine interface (MMI), quality of procedures, or quality of training programmes. Other organizational factors are more subtle, e.g. the "climate" of the organization can affect general morale so that personnel do not pro-actively fulfill safety and availability goals or individual poor attitudes affect their "trainability" so they do not absorb important accident-related training. Similarly, uncertainty about management preferences on choices between emergency safety measures versus plant re-start capability can cause crew hesitation or failure to act at all.

Hundreds of organizational factors that are potentially related to reactor safety have been identified by various research groups. On the other hand, the data needed at different phases of the analysis process, e.g. to determine ratings for organizational factors, are not currently obtainable. The models presently used in PSAs don not cover all the possible effects of organizational factors. However, care must be exercised not to introduce a form of double counting.

Taken as a whole, a considerable level of R&D efforts and resources is still needed for development of a more applicable PSA methodology with advanced algorithms where the organizational factors can also be modelled more explicitly. On the other hand, due to the shortages in the methods to incorporate organizational factors into PSAs other complementary, non-probabilistic methods to assess organizational performance may be needed too.

6. INSTITUTION OF SOCIAL RESEARCH IN NUCLEAR POWER

6.1. THE ESTABLISHMENT OF A SPECIALIZED RESEARCH INSTITUTE IN JAPAN

Nuclear power is an important energy source for modern society, but it is a controversial issue as well. The problems that the nuclear power industry faces are related not only to technological issues concerning safety, but also to the nature of modern technological civilization, as a large and highly technical engineering system. Other major problems involve the image of nuclear power itself and public awareness.

All these aspects can be said to be a matter of the nature of modern technological civilization and its development. One of the unfortunate aspects of modern civilization is the striking imbalance between social/human sciences and natural science/technology that has progressed at a surprising speed. The problem of safety and reliability in nuclear power plants seems to be considerably influenced by this imbalance.

Therein lies the necessity of a specialized research institute. Consequently, the Kansai Electric Power Company, Ltd. established the Institute for Social Research within the Nuclear Safety System in 1992.

It is in recognition of these global and general concerns that concrete research activities were launched taking up local specific problems. Research programmes are conducted at four divisions at the Institute for Social Research within the Institute of Nuclear Safety System.

The first research division deals with the area of scientific management of workplace safety behaviour. This research is aimed at developing scales to assess safety behaviour and awareness and at testing the soundness and reliability of the scale.

The second research division explores the relationship between human/society and science/technology civilization. It intends to review a profile of citizens utilizing large-scale, highly-sophisticated technological systems, such as nuclear power plants.

The third research division plays a role in initiating studies in order to understand the interaction of the objectives of energy production, economic prosperity and ecological harmony, focusing on nuclear power generation which is becoming an increasingly important energy source.

The fourth research division engages in international comparative research related to our areas of interest. To initiate the above mentioned research activities, a research promotion council was established at the start of the operation of the institute.

Research on leadership was conducted at the first division in the Institute for Social Research. One of the core variables in organizational factors influencing human performance in nuclear power plants can be said to be the way human behaviour operates in workplaces. It has been demonstrated by research that leadership styles of first line and second line supervision in various workplaces in industries including nuclear power have influence on their employees' motivation for work, stresses and mental hygiene, thereby affecting their accident rates, turnover and work performance.

After more than thirty years devoted to trying to work out some new concept and method of measuring leadership, the leadership PM theory has been found to be most suitable.

Data were obtained directly from NPP at Kansai Electric Power Company in Osaka, Japan and on this basis scales to measure leadership behaviour were constructed. In the meantime, their validity and reliability was examined on a continuing basis.

These scales are applied in practice at the nuclear power plants of the Kansai Electric Power Company. To be specific, the leadership behaviour of shift supervisors and assistance managers of maintenance at the nuclear power plants is assessed on the basis of the ratings by their subordinates. The results of these ratings are fed back confidentially to the individual supervisors and managers of maintenance by staff from the Institute, who also provide them with individual counseling as necessary.

The ratings by subordinates are kept secret from the company's personnel manager or other officers who are involved in personnel management. These results are used only as support for edification of the individuals whose leadership behaviour has been rated by their subordinates.

Appendix I

FUNCTIONAL STRUCTURE OF PERSONNEL PERFORMANCE

1. EMOTIONAL

- Motivation - Attitudes
 - Moral
 - Social-psychological aspects: conformism. strong feeling of responsibility
 - Individual attitudes characteristics

2. RATIONAL

- Cognitive structure of personnel performance
 - Professional knowledge
 - Skills
 - Psychophysiological aspects of mental and memory actions, attention

3. PHYSICAL

- Motorics of actions in professional performance
 - Individual characteristics of emotional resistance, equanimity
 - Professional habits, motoric actions, automatisms
 - Psychophysiological aspects: rapidity, lability, flexibility, accuracy, exactitude, punctuality, precision of actions.

Resume: Individual structures include many variations of components

4. MANAGEMENT TOOLS

- Diagnostics
 - Establishment of requirements and criteria
 - Framework of control and testing
 - Organization of diagnostic processes and results
- Regulation
 - Shaping of vocationally significant personality characteristics; training and follow-up education
 - Personality-related psychological training
 - Regulation of social processes, conflict management, social-psychological training

Appendix II

MAIN CHARACTERISTICS OF OPERATING PERSONNEL PERFORMANCE

- A wide range of stress factors, from a routine to a high-tension and critical level;
- A high probability of instantaneous translation from routine action to highly active performance, i.e. a transition from observation or data search mode to decision making under conditions of time deficit and threat of error;
- An excessive responsibility for the actions and their implications;
- Faultless actions and decisions in emergency and actual threat to life situations;
- Team actions, where the performance of each operator is influenced by the team spirit in the shift;
- A high degree of professional preparedness to control sophisticated technological facilities and the people involved in operation management.

Appendix III

TYPES OF HUMAN ERRORS

Psychological analysis of NPP - personnel behaviour in pre-incident and post-incident situations shows that one or several of the following factors are involved in erroneous performance:

Errors at the psychophysiology level: apprehending information an operator did not notice/did not hear/did not see a signal or it seemed to him there was a signal; retarded response; inability to act in emergency;

Errors at the mental psychology/memory level: getting accustomed to stereotype situations/actions to prevent an adequate response to a new situation; low professional skills;

Errors at the motivation/attitudes psychology level: biased social values, lack of interest to work, low estimate of work importance; reluctance to risk one's life; formal attitude to one's job; lack of discipline; no sense of duty;

Errors at the personality psychology level: lack of will; reluctance to act reasonably in emergency; lack of communication skills; other worldly behaviour; emotional instability; lack of self control and other features which hinder performance and result in job quality decline;

Errors at the social psychology level: worthless moral value, reluctance to work in a group; pronounced conflict-mindedness in behaviour, inability to lead people.



DEVELOPMENT AND TEST OF A CLASSIFICATION SCHEME FOR HUMAN FACTORS IN INCIDENT REPORTS

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Abstract

The Research Center System Safety of the Berlin University of Technology conducted a research project on the analysis of Human Factors (HF) aspects in incident reported by German Nuclear Power Plants. Based on psychological theories and empirical studies a classification scheme was developed which permits the identification of human involvement in incidents. The classification scheme was applied in an epidemiological study to a selection of more than 600 HF - relevant incidents. The results allow insights into HF related problem areas. An additional study proved that the application of the classification scheme produces results which are reliable and independent from raters.

1 Introduction

This paper treats aspects of a research project on the analysis of human factor aspects in incidents reported by German Nuclear Power Plants. It describes the development and test of a classification scheme for the categorization of Human Factors (HF) in incident reports. The project was conducted by the Research Center System Safety (FSS), Berlin University of Technology and supported by the German Gesellschaft für Anlagen- und Reaktorsicherheit (GRS).

2 Classification Scheme

The project was an epidemiological study on Human Factors aspects in incident reports. In general, epidemiological studies using classification schemes to categorize relevant aspects. These studies are always based on reports about incidents only, not on the incidents themselves.

In order to compile a classification scheme which addresses the possible human role in incidents in a comprehensive way we looked at theories in different domains. These domains were:

- psychological theories of human error: we examined several human error theories and their proposals for error classification (Norman, 1981; Rasmussen, 1987; Reason, 1990; Rouse & Rouse, 1983),
- accident causation theories, which explicitly include human factors like the theory of Rasmussen (1982), Reason (1990) again,

- the concept of safety culture as it was introduced by the INSAG group (1991)
- the concept of group think of Janis (1989)

We then analyzed international epidemiological studies and their classification schemes:

- a study of the American NRC (Speaker, Voska and Lukas, 1983)
- a study for the French EDF (Leckner, 1987)
- a German study for the Federal Ministry of Radiation Protection (Hoffmann, 1984)
- and studies which were carried out by INPO (1983, 1984, 1985)

In its present form the classification scheme is divided into eight parts: general aspects, organizational aspects, personnel aspects, aspects of failure, aspects of causes and aspects of feedback.

- **The general aspects** include the time, the state of the system and operational phases, the locus, the affected parts, the characteristics of the component and the actors.
- **Organizational Aspects** cover interorganizational cooperation and, following the proposals of INSAG, aspects of safety culture.
- **Personnel aspects** focus on characteristics of the acting person and on group characteristics.
- **Processual factors** are the content and characteristic of the task, the level of task (according to Rasmussen), procedures for the task, information about the task, tools and safety devices.
- **Aspects of the failure** cover the trigger, the failure type and violations of rules/procedures.
- **Aspects of the causes** are the likely conditioning factors on the three Rasmussen levels communication, erroneous decision making and the level of information processing.
- **Aspects of feedback** focus on feedback characteristics, error consequence connection and on error discovery.
- The last group refers to factors of **external impacts** like lightening and flood.

After a pretest with some incident reports we simplified the classification system to a short version to be compatible with the data from the incident reports. This short version was implemented as a computer program for online classification

3 Analysis

In the last two decades more than 3000 incidents in NPPs in Germany were reported to the regulatory bodies. These reports are stored in a mainframe database. We had a look at these reports using descriptors from the reporting form and identified 16 descriptors which are more or less directly connected with human factors. Some examples of these descriptors are "wrong action", "action not in compliance with procedure" but also "measure of prevention: training."

We selected all cases which were classified at least in one of the 16 HF categories. So we obtained 678 cases. For an easier handling we downloaded these to a personal computer and arranged them into a combination of a relational database and freeform information retrieval system.

Because of time restraints we selected a random sample of 436 cases from a total of 678. The results refer to this sample. The course of the investigation is shown in figure 1.

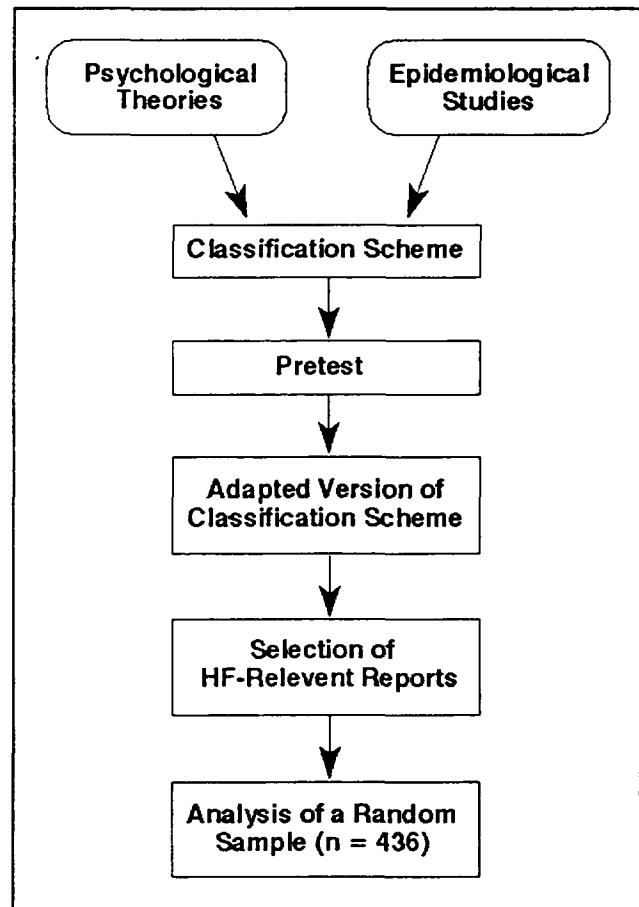


Figure 1: Course of the investigation

Then three raters were trained to analyze the narrative description of the event using the classification scheme. 20 cases, not part of our sample, were used as a warm up for the raters in order to standardize the ratings.

Each rater analyzed one third of the cases in our sample with one exception: For the computation of interrater reliability and retest reliability an identical random sample of 40 cases was analyzed twice (with a gap of 100 cases) by each rater, but only the first results of one (randomly chosen) rater were included in the overall analysis.

4 Results

Reliability

The overall interrater reliability and retest reliability were satisfying. Interrater reliability means that the results of the classification scheme are independent from the rater. Retest

reliability means, that the results of the scheme are stable. Analyzing the same reports after a period of time, produces similar results.

Category situation

In which situation did the events occur? This question is not trivial. Events are complex and often last over a period of time. We classified the situation of the first perceived indicators of an event.

- 45% occurred in a no power,
- 13% in a low power, and
- 42% in a normal operation situation

Actors

One very interesting result is, that in 20% of the cases outside firms are involved. In 83% of these cases there was a time lag between error and consequence. This means the contribution of outside firms to the so called latent errors (Reason, 1990) is relatively high. Latent errors differ in time and space from the actual event and therefore are harder to identify.

Information and feedback

In literature (for example INPO 1983, 1984, 1985) the influence of deficient procedures as latent errors is emphasized; we also found wrong or missing procedures contributed to the event in 22% of all cases. This is a strong evidence that there is a need to validate and test procedures.

Aspects of the error

In nearly half of the cases, the effect of the error is delayed, that means there is a time lag of more than 15 minutes between error and consequence. In one third of these cases you even find time lags of more than 8 hours. Most of these errors have to do with maintenance. Again we counted this as a strong evidence for latent errors.

5. Discussion

The results from the analysis of German Incidents provide valuable information, for instance concerning latent errors, the role of procedures. But epidemiological studies have an intrinsic problem: as reports are the database of studies like this, they are always dependent on the quality of the reports.

Our study identified some shortcomings of the German reporting system: HF aspects and aspects about organizational factors are rarely reported. Therefore, conclusions about HF and organizational factors are difficult to draw. To ensure the learning from experience for HF and organizational aspects both, the **reporting system** and the **event analysis** have to be improved in a way to include these aspects.

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EXPERIENCE WITH DIAGNOSIS OF ROOT CAUSES OF HUMAN PERFORMANCE PROBLEMS IN INDIAN NUCLEAR POWER PLANTS

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Abstract

Low capacity factor, in any NPP, is a result of high occurrence rates of significant events. A substantial portion of such occurrences is caused by "inappropriate action" due to inadequate human performance. To improve human performance we need first to do its evaluation. This paper describes the essential elements of the first basic step in that context : diagnosis or identification of the fundamental causes of human performance problems in Indian NPPs.

1. AN OVERVIEW OF HRD INITIATIVES TO REDUCE EVENTS

1.1. Background

Traditionally, in NPCIL, all reportable events were put to technical analysis, primarily to satisfy certain regulatory requirements e.g.

- to establish that technical specifications were followed, reactor tripped as per logic or
- to seek condonation of any technical specification violations and,
- to seek restart of the reactor

The technical analysis narrated sequence of events, gave symptoms leading to the occurrences and corrections that were mostly on symptoms. For example if a passing valve, a loose contact or an inadvertent switch operation caused a unit trip, the general belief was to consider all such as either unavoidable human errors or equipment deficiencies.

Organisation symptoms that are implied above were :

- (i) A first priority of getting the plant back on line as soon as possible - no time for root cause analysis (RCA)
- (ii) always reactive, seldom ahead of the game. Overloaded with responses to regulatory agencies
- (iii) incomplete problem solutions

Subsequently in 1991 thanks to the good practices documents supplied by the World Association of Nuclear Operators (WANO), and, later by the International Atomic Energy Agency (IAEA) that the concept of "root cause went into our conscious awareness . Since then, inhouse surveys, workshops and training sessions on root cause analysis (RCA) are in use for diagnosing the fundamental causes of our

outages and to arrive at a guideline for suitable corrective action plan for problem solving. In general, the NPP performance goal was stated as "not exceeding one outage per month." This defined the words "problem" and "problem solving".

The "problems" here meant occurrences in the NPP's with unacceptable consequences. Any diagnosis here needs systematic evaluation of equipment and human performance problems that led to such occurrences. Since the tendency earlier was to stop the investigation as soon as the symptoms were known, it became difficult for RCA facilitators to obtain from traditional reports, some representative data of the real (or root) causes. The following examples collected in 1990 will illustrate. It will be noticed that the tendency was to "jump to causes" before even attempting to understand "what exactly happened" with inconclusive analyses ending in words such as "human error", "spurious", "unknown" etc.

Example 2/1 Lack of questioning attitude

"On total loss of load, Reactor tripped on high primary coolant pressure. The station analysed the reason for high pressure trip and concluded that high primary coolant bleed flow, due to high feed flow was the "root cause" and that there was no spare bleed capacity to cope up with the transients of swelling due to load rejection."

Obviously, what the above did not explain were

- (i) why at all was the bleed flow too high and for the not-so-high valve opening indicated by the valve controller output milliamps? Valves were apparently leaking.
- (ii) by design, an anticipatory generator underpower relay contact, on load rejection should have relieved steam to atmosphere thus avoiding the high pressure trip. The reason why it failed to do so was not stated."

So what was lacking was "questioning attitude." But why ?

1.2. Organisational survey

A general attitude survey conducted through questionnaires and interviews of about a hundred station engineers established the following pointers to above question.

- (i) "poor work practices cause most events" as stated by 72% respondents
- (ii) "lack of accountability is the major reason for not pin-pointing root causes of events - stated by 30%, while another 25% said finding root causes are not encouraged as much as symptom corrections are. 20% said it was difficult to find out root causes and so they are not found

- (iii) to a question why plant personnel often quote design deficiency as the root cause, more than 50% stated "expert opinion to separate improper design from improper work practices as the root cause is not sought by authors of technical analysis.
- (iv) practically all 100% opined that pinpointing a name alongwith a human error that caused an event would lead to non-cooperation, union and even legal problems but the response from the work groups would be participative if we focussed on correcting factors that "sets them up to errors". So, the subject needs skilful handling.
- (v) About 50% noted our highly skilled staff do not possess in many areas the right attitude for proper task performance.
- (vi) About 60% stated equipment performance would improve if field training and QA procedures were improved.

In summary improvement of

- work practices
- accountability
- human factors
- attitudes
- quality programs

would be necessary for improvement in plant performances. But how and what exactly need be done ?

2. TRAINING INTERVENTIONS

It is hard to obtain real data (or root causes) on all above factors e.g. it is possible that the employees are psychologically detached from the corporations goals and missions and gaps develop between what he actually does in his job, and, what the company actually expects him to do. The corrective mechanism to such gaps is implementing certain training programs, so that a proper grid is created between the company and its employees on one side and the management on the other side. The benefit is data on real or root causes for inadequate human performance problems become available in a climate of trust in the training sessions - which are otherwise not available from formal reports. It will reveal where exactly management must act to change the work culture.

Accordingly, a series of training workshops and brainstorming sessions were designed and conducted first to generate awareness of RCA concepts and then to use follow up sessions to obtain data on real or root causes of a large number of events in NPCIL. The following gives bases of the design of such a training package.

2.1. Changing organisational culture

So, the management had to intervene to bring about an attitudinal change among the staff. The organisational culture is a product of management tolerance of certain

attitudes and practices that creep into the organisation over a period of time. Training is a mechanism through which, we felt, such attitudes and practices can be changed and corrected. For example employees need to be trained "to accept responsibility and "not pass the buck"

2.2. Selective training: problem solving skills

We can provide all the training in the world, but unless it provides a useful tool that improves job performance, it is a waste of time. The fundamental need or rationale for training our people is to make them effective problem solvers. So, our training must impart appropriate concepts, skills and most important an attitude towards effective problem solving. We need to bring out how the concepts of cause and effects define reality, how to use simple effective tools to help implement these concepts and to adopt a way of thinking that improves the ability to reason.

Training the entire workforce on problem solving was desirable, but would have been time consuming. We needed therefore, draw up priorities and identify employees, who were crucial to the performance of the basic goals of the company.

To enable employees to monitor their own quality performance, they learnt the technique of "Root Cause Analysis" which ultimately leads to the person who caused it. The second offshoot, and the main one is in the action to prevent recurrence of such faults. Quality performance is the key to improve productivity. The job will not have to be done twice. "Self-checking" as against close supervision was stressed as essential to avoid repeated failure with high productivity. Training programs addressed these needs specific to each job family in the NPP.

There was thus a primary need of reconditioning of mind across functions and level. The way of thinking had to be root cause, the culture had to be quality culture and the activities performance-focussed. An organisation development using primarily training "workshops" as a vehicle for change was decided upon by NPCIL for the reasons stated below.

2.3. Successful task performance: supervision and procedure

To minimise human performance problems, the performer must be provided all necessary information to correctly perform the task. The information can be provided through direct supervision, training or procedures, in suitable balance depending on the assigned task. Incorrect work practices were reported as major contributors to our human performance problems. Stated simply, this meant,

- people do not follow procedure
- error detection system is deficient.

A systematic analysis of the events would reveal whether increased supervision, additional training including on self-verification and/or revised procedures were needed to provide the needed information for correct task performance.

However, attitude development is a vital need to create and nurture the culture of correct work practice. The process of change to bring in cultural improvements needed a fundamental review of attitudinal factors.

2.4. Attitude plus ability: performance

An individual's performance in any organisation is the result of two factors : Ability and Attitude. These two factors, acting together constructively and, in balance produce the desired performance. Anyone of these factors, acting in isolation, will fail to achieve the desired results. For example, an I&C engineer who is enthused by his work on a digital control and protection system and wants to satisfy the operational needs in every way, but, does not know how to alter alarm setpoints or cannot explain consequences for its major component failures is likely to make a mess of the system. This is because he has poor ability, despite best attitude. Let us emphasise that ability is the basic and primary need. The ability aspect helps answer the employee's question : "what should I do and how should I do it"? Fortunately, we have a 35 year old tradition of technical training culture. But that was not enough. Because e.g. the vastly experienced I&C expert who knows every card and every procedure perfectly of the system, but finds his/her work as boring routine, is likely to go about in the work in casual or complacent manner - again making a mess of the system. The reason is in his/her perennial doubt through the question "why should I do it"? This lack of sense of purpose for the work possibly will bring all efforts or systems for ability building (like training, qualification, job rotations, special assignments) in the individual, to average, mediocre performance. Attitude development, at this point, must take over so that quality of performance improves. The quality will improve if we put back pride in his/her job and, most important, clearly and consistently articulate what the organisation stands for i.e. the corporate values of safety, quality and economic performance.

2.4.1 Pride in work

What causes, then, we figured out, lack of pride in an otherwise able or competent individual ? We have two answers. One, lack of role clarity on how (this) everyone's performance (or non-performance) affects the organisation; the second, lack of feedback and corrective action on individual's non-performance. Both factors are taken care of, if we can hold persons accountable for their work quality. In such a situation they quickly find out personal success leads to functional success. That leads them to the mindset and culture of "self assessment". But, since we operate a human system, we cannot rule out quality problems

like errors and failures. But we must go all out to prevent their recurrence - so we repeat, we must do root cause analysis. To do so, we must give precedence to information gathering and problem solving over summary justice. We thus needed to train persons to focus on how the system failed the person, rather than how person failed the system. We expected people to learn lessons from their experiences. We expected them to report, fearlessly, even non-consequential events. We expected them to follow the procedures for correct task performance.

3. CASE STUDIES AS DATA SOURCES

To sensitise station engineers to the root causes we developed training packages on the
(i) effective problem solving and
(ii) human performance enhancement
utilising initially cases reported via COG/WANO network. A large number of NPCIL events were then fully analysed and presented by our RCA trainers for generating more trainers all over NPCIL who were encouraged to present real-life cases from their experience with a view to arrive at the root causes.

As typical illustrations, we extract from such data sources the cases pertaining to the following diagnosis

- (i) Lack of verification culture
- (ii) Lack of adequate supervision
- (iii) Failure to follow procedures
- (iv) Inadequate communications

combined in some cases with either an external, or, internal performance shaping factor.

EXTRACTS

Example 3/1 Lack of verification culture

The Turbine Building field operator wanted to start the hydrazine pump and feed chemical to feedwater, but by oversight he started the phosphate pump. The pump was on for four hours till the next shift detected the error. This resulted in boiler conductivity shooting up beyond tech-spec limit.

In the past the tendency of most operators would be to merely blame the design for putting both switches close by. While this was certainly a human engineering problem, in a retraining session on "lessons learnt", the same operating staff admitted the root causes as inattention to the handswitches (HS), as also lack of self verification culture to check which pump had actually started, before leaving the workspot.*

Example 3/2 Inadequate supervision and on-job coaching

- (i) *Deaerator pegging steam pressure control valve had failed open which led to opening of relief valves in the deaerator. The field operator straightaway started closing the guard valve for the above. This reduced the deaerator pressure and NPSH to the Boiler Feed Pump which started cavitating. The control room engineer saved the pump.

Since there were no "consequences" station did not analyse it. (The cause was lack of training of the field operator as well as inadequate supervision as revealed in the training workshops deliberations.)

- (ii) On another occasion, the unit was in operation with the HP heater no.5 of the feedheating system on bypass mode for some maintenance. After maintenance work, when the heaters were valved in there was a drop in feedwater flow causing reactor trip on high primary coolant pressure. The cause was suspected as "equipment malfunction."

The event had recurred, including in some cases, leading to water hammer in feed lines.

The re-reviews revealed the operator was new in both cases and not aware of the need and procedure to do venting and gradual filling of the HP heater. Sudden filling of HP heater caused reduction in feed flow. Inadequate training and inadequate supervision were the root causes.

Example 3/3 Inadequate communication and noisy work place

Lack of communication, coupled with other external constraints such as noise as well as internal factors such as fatigue can cause serious consequences. As example, the following is extracted from the original station report (of 1991).

The unit was under startup. Operators were doing access control check in boiler room area. Suddenly the bleed cooler outlet temperature high alarm appeared and the primary coolant system got boxed up. Bleed cooler outlet temperature exceeded 100 degreeC. Immediately the Operators were contacted. The cooling water (Process Water) valves for the bleed cooler was found to be inadvertently closed by the operator and the same was immediately opened.

Note the word inadvertently. To get therefore to the real cause, a re-review was done in training workshops to get to the following facts.

*The operators were engaged in the task of putting access control in effect and final checking of all the accessible area during start up. It was understood that lack of communication was the main factor involved in this incident. The senior operator who instructed the junior operator to check the process water (PW) valves for bleed cooler, whether they are in fully open condition, had mistaken the

message and closed the valve. The communication between the operators was mostly in body language because of the loud background noise in boiler room. The junior operator who had closed the valve was staying back after the night shift and as per him, he was under physical strain. The senior operator failed to check and confirm whether his message was properly received and carried out by the other man."

Example 3/4 Inadequate communications and incorrect mindset

"The Control Room Engineer phoned up the field operator in unit-2 to switch off an Motor Control Centre BB-3 of unit-1 under shutdown (there were no operators on duty in unit-1). The field operator assumed there were no jobs in unit-1 and so switched off the MCC-BB-3 of operating unit-2. This tripped the oil purifier unnecessarily.

Since the event was traditionally "non-consequential" it was initially not analysed for its root cause. No wonder, that events similar to above kept recurring. Examples :

- (i) Unit-1 moderator system was to be shutdown, an operator was told verbally to rack out unit-1 moderator pump #1 circuit breaker. He approached the operating unit-2 moderator pump and isolated it.
- (ii) An I&C engineer instructed a senior tradesman to go to the reactor building and pull out the ion-chamber of the channel D of the triplicated Reactor Protective System. The senior tradesman heard this as Channel E and pulled out channel E ion-chamber.

In none of the above examples, there was any lack of knowledge or training deficiency. It was simply inadequate communication which together with "stress", "complacency", "preconditioning of mind" led to such extraneous acts. We provide an example of the latter.

Example 3/5 Inattention and failure to follow procedures

Two out of three trip logic of the Reactor Protective System allows one channel testing at a time. During routine surveillance test on Reactor Protective System one channel was tested for a parameter and left in tripped condition for checking other trip parameters. The field operator was advised to open Pressure Transmitter valve of this channel, but, he opened the valve of the other channel. This caused a unit trip on 2/3 logic. The cause was ascribed as "passing transmitter valve". In reality, there was a lack of attention to the details and non-adherence to step-by-step procedure.

Example 3/6 Time stress and failure to follow procedures

"For adding heavy water to the moderator system as a make up, there is a transfer tank with a capacity of two drums of D2O. In an incident, an operator wanted to add three drums in a shorter time and started simultaneous addition of D2O

from the drums to the transfer tank and also from the transfer tank to the system. However, both the transfer pumps tripped on fault. There was an overflow and spillage of tritiated D2O.

The cause was originally ascribed as "equipment failure". No reason was given for what caused both pumps trip and why spillage occurred.

However, the subsequent re-review in the workshops established the operator was under time stress to complete the addition before the end of his shift and so violated station instructions on avoiding simultaneous addition and transfer.

Example 3/7 Lack of pre and post job briefings and failure to follow procedure

Reluctance to use a procedure due to complacency and inadequate supervision of younger staff who do support tasks have been contributors to a significant number of events.

- (i) "A highly skilled tradesman, for example, may not use a step by step procedure for greasing of motors, nor, he will consider this as a job of a highly skilled worker. In a teamwork training follow up with one of our stations, the root cause for several motor bearings seizure was discussed. It was established that normally greasing is passed on to a new trainee maintainer who has no instruction to relate the existing bearing temperature to the required number of strokes of the grease gun and to wait and watch the change in temperature after greasing. As a result, overgreasing at times led to burning of motors. What is worse, the same unskilled tradesmen soon learnt the skill but was complacent about following or passing a procedure to the youngsters.
- (ii) a new maintainer was hurriedly instructed to "go and tighten some loose flange." There was no instruction on the size of the bolt, proper torque value, tightening sequence or limit of compression as in case of flexitallic gaskets. No wonder there was overtightening and leaks after a week of start-up.

We cannot certainly train our new people for use and adherence to procedures, if the supervisors do not follow the procedures in spirit.

4. IMPACT OF THE EFFORTS MADE

Improvements in an organisation initially are made in gradual steps in specific areas and our intention was to focus on how to sensitise and motivate station personnel to go into fundamental causes, to quality programs and to prevent recurrence of the events. Attitudinal change plays a pivotal role here and as a first step mental barriers to go to the root causes must vanish. The first taste of our success was in motivating station personnel to reanalyse all reported as well as unreported cases by themselves which not only improved their RCA skills for problem solving but also

provided valid data sources for diagnosing organisation problems in specific terms. The more measurable impact has been on the quality of reporting and analyses - pinpointing root causes now with pro-active approach. We reproduce two specific sample reports to illustrate this transformation.

Example 4/1 Problem well defined

"In one of our NPP's a persistent problem of the Emergency Diesel Generator tripping after an operation of 5 to 6 hours was being reported. Station noted the trip parameter was "CO₂ fire detector actuated" in every case and as the alarm used to clear shortly after the DG tripped, this was being described as spurious trip. Of late a RCA approach was taken. The experts were consulted who wired contacts of each individual detectors to the annunciator. It was found the CO₂ detector nearest to the Diesel Generator exhaust pipe used to give trip signal after prolonged operation. The detectors were then relocated away from the exhaust pipe.

The problem never repeated.

Example 4/2 Root cause mindset

During on power refuelling of coolant channel, three pairs of spent fuel bundles were received in downstream fuelling machine in auto mode. To receive the fourth spent fuel pair, the refuelling operator decided to use manual mode of operations using ram-B and ram-C, strokes in the upstream machine instead of using second ram extension as envisaged in Auto program. On completion of these operations, however, instead of ram B and ram C together reaching the required distance, ram-B stopped and was stalling at 160 cm (instead of reaching 225 cm). The operator suspected that the string length in channel was more than 12 bundle length. He confirmed from the fuel magazine location that one extra bundle had been left back in the channel. It was also suspected that the fuel string consisting of 13 bundles would have got loaded against downstream shield plug to a value higher than the safety limit

Action by the station

- (i) Iodine-131 content analysis in the primary coolant and the delayed neutron (failed fuel detection) monitoring system scan were done which revealed no abnormality. The I-131 value of spent fuel inspection bay water also remained below detectable level. All 12 bundles of this channel was replaced by fresh fuel bundles. After obtaining regulatory clearance the operation was continued.
- (ii) A root cause analysis done by station revealed "procedure not followed" as the root cause. The refuelling operator had stated that he believed, the use of manual operations would minimise reactor power disturbances. Also since the down stream operator had initiated Auto receive, one bundle

could be successfully discharged on auto into the magazine. The refuelling operator at this stage got the (wrong) impression that the receipt of both bundles of the fourth pair had been done successfully.

5. CONCLUDING REMARKS

First step in ensuring quality in management of NPP operation is to systematically find out the underlying causes of poor performance in general and human performance problems in particular. The organisation needs to be sensitised to identify them through proper training interventions, so that the second step of corrective action plans become successful. There are barriers to obtain data on real or root causes on human performance problems and they have been overcome by creating a forum in workshop setting whereby open and objective analyses have been performed voluntarily by station staff themselves. Such training interventions have proved useful in generating adequate management data on where interventions are necessary to bring in "pro-activity". This paper attempted the experience in India with such organisation diagnosis through workshops.

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**TWO IMPORTANT GENERAL ORGANIZATIONAL
FACTORS: THE ORGANIZATIONAL DESIGN OF THE
SAFETY WORK AND THE ORGANIZATION
AUTOCORRECTIVE SYSTEM**

*The italian way to improve them through
criteria for the safety organizational rules*

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Abstract

A complex reality, such as a nuclear power plant, requires the maximum order in the methods of operation. A state of "organizational confusion" is the frequent root cause of many errors. An initial situation of organizational confusion, about one or more human allocated functions, generates further malfunctions or lacks and, what is worse, tollerates them because it makes them less visible. Order in the operators society can be improved by improving the quality of the safety organizational design and can be maintained with an effective autocorrective system.

1. Introduction

Organizational and managerial factors influence human performance having conditioned the various subsystems that have a connection with the human system operating a plant.

Some systems (the personnel selection, the training, the staff assessment) determine the characteristics of the individual, of the single operator seen as " a component", how this human component fits the job.

Others systems (the interface man-machine, the operating and maintenance manual, operators-aids, the preventive maintenance, the technical specifications, the surveillance tests) influence the characteristics of the interrelation operators-plant.

Others more (the operators responsibilities system, the operators supervision system, the organizational procedures system) influence the characteristics of the interrelations man-man. They determine the functioning of the operators society on a plant.

About this last, and more general, aspects of the human system we intend to present our past experience in the work of improving the Italian NPPs Safety Organizational Rules, a utility's document required by the Italian law and that has to be approved by the Regulatory Body.

2. The Italian law and the Safety Organizational Rules for the NPPs

According to the Italian law the holder of the authorization or of the clearance certificate, before carrying out tests with irradiated fuel, including that of its insertion, must provide to the Regulatory Body the following documents:

- a) Final Safety Report;
- b) **Safety Organizational Rules;**
- c) Operational Manual;
- d) General Programme of tests with nuclear fuel or irradiated fuel;
- e) Results of the tests preceding the loading of fuel or of the insertion of irradiated fuel including those relating to pressurized containers designed to contain any radioactive substances;
- f) Organizational Chart,
- g) Technical Prescriptions.

The Safety Organizational Rules is a document which specifies the organization and functions, under both normal and exceptional conditions, of the staff responsible for the direction, operation and maintenance of a nuclear power plant, including the physical and medical supervision of protection at all stages, including those of start-up and operations.

Anyone not observing the Safety Organizational Rules is in Italy liable to up six months' imprisonment or to a fine.

The document has to be approved by the Regulatory Body after consultation with the Technical Commission.

The Regulatory Body has defined requisites for the contents of the Safety Organizational Rules.

3. Conceptual bases of the requisites for the contents of the Safety Organizational Rules

A few basilar concepts have guided the Italian Regulatory Body in writing the criteria for the approval of the utility's document.

A complex reality, such as a nuclear power plant, requires the maximum order in the methods of operation. The work must be clearly defined, properly assigned, executed accordingly predetermined and written procedures, carefully recorded, regularly supervised, and the whole system readily corrected when necessary. A state of "organizational confusion" is the frequent root cause of many errors. It has been largely recognized that an accident is rarely due only to "an individual confusion", a single act or situation or decision, but is more frequently due to a chain of lacks, in the design of the human system and in the supervisory system, which reduce the necessary support to human beings. An initial situation of organizational confusion, about one or more human functions, generates further malfunctions or lacks and, what is worse, tollerates them because it makes them less visible. When the human latent malfunctions, present on the plant, are joined in a critical situation, an accident will happen.

The whole operating organization may be seen as the great and diffused intelligence that must be always maintained in the condition to understand the operation of the whole plant and its safety. Order in the operators society can be improved by improving the quality of the safety organizational design and can be maintained with an effective autocorrective system.

In this paper we present the Italian translation of human factors concepts in practical criteria to improve Italian NPPs Safety Organizational Rules. Our criteria consider various aspects of the safety organizational design and of the autocorrective system. Some criteria could seem obvious but, observing the functioning of the human reality, we found they were not always followed.

4. Organizational design of safety

Our criteria for a reliable functioning of an organizational structure derive from the consideration of more general aspects:

- * definition of the safety work in terms of identified technical tasks;
- * organization of the safety work;
- * dimensions of the operating organizational structure;
- * assignement of the responsibility for the safety tasks;
- * definition of all the tasks, technical and/or organizational, assigned to the various individual working positions of the structure;
- * organizational procedures.

4.1 Definition of the safety work in terms of identified technical tasks

The safety objectives, written in the final safety report as safety functions enunciation, have to be translated, for both normal and abnormal conditions of the plant, in precise and concrete safety tasks or duties of immediate understanding for the operators. The plant conditions, assumed in the safety analysis, as safety physical and chemical limits of process parameters or as components and systems conditions limiting the operation, have to be well known to the operating organization. The bases of technical specifications must be understood by all those that have safety responsibilities. A course on transients and accidents analysis has to be in the training programme of reactor operators.

All the safety tasks to reach the following main objectives have to be clearly precised:

- to maintain under control external discharges during normal operating conditions or planned operations;
- to maintain under control radiation doses of workers during normal operating conditions or planned operations;
- to maintain under control physical and chemical parameters of the process and the state of components, systems, materials and structure for minimizing the probability of transients and accidents;

- to maintain under control the conditions on the plant to assure that eventual accident have initial conditions not worse than those assumed in the safety analysis for minimizing the consequences of transients and accidents;

- to maintain the operators capacity to face transients and accident with sufficient and effective Event and Syntomatic procedures, learnt in class and on the simulator, for minimizing emergency consequences on the plant.

4.2 Definition of the organization of the safety work

A good definition of the safety technical work is not sufficient. The safety work has to be well organized and maintained under control. It is essential:

- * to maintain an integrated vision of the safety activity;
- * to assure information flows, along the vertical and orizzontal axis the structure, rapid, inaltered and without obstructions;
- * to coordinate the safety work done by different departments, units, individuals;
- * to assure sufficient and effective procedures and a careful implementation of them;
- * to assure personnel training and retraining on safety tasks;
- * to assure the due information to the regulatory body;
- * to assure the presence in Control Room of the licensed personnel requested by the law;
- * to maintain up-dated all the technical documentation on the plant;
- * to plan the emergency drills;
- * to assure effective procedures for the phisical protection of the plant.

4.3 Dimensions of the operating organizational structure

We do not intend to suggest a detailed organizational structure but only to fix some general safety criteria.

- * The division of the work along the orizontal axis of the organizational chart, in departments and units, has to ensure the capacity to have a sufficient specific competence;

- * Distinct supervisors have to assure a competent specialist supervision of the different departments or units;

- * An immediate and competent replacement of the plant manager or departments managers or units supervisors, during their absence periods, has to assure the management, supervisory and coordination functions, essential for the plant safety;

- * Great "supervisory ratio" along the vertical organizational axis and an organization lean with few hierarchical levels have to assure fast and correct information and an high safety visibility from the top of the structure;

- * Hierarchical autonomy of the training, quality assurance and radioprotection departments, from the operation department, has to assure a real their functioning;

- * Direct supervision of tasks that have a direct and immediate impact on the safety (control room, refuelling tasks, etc);

- * Limits to the continuous working hours, workloads not excessive;

4.4 Assignment of the responsibility for the safety tasks

The process of sub-division and assignement of the responsibility for the safety is a very critical one. Our criteria are the following:

- * To assign a responsibility for each task important for the safety and the radioprotection;

- * To assign responsibility to individuals and not to whole departements or units;

- * To assign each responsibility together with the necessary authority or functional independence, to implement safety controls and actions established by the Technical Prescriptions. This functional independence of operators, in their specific work, is necessary to assure a faster human response and an effective multiple barrier of the human element (operator, unit supervisor, department manager, plant manager) able to avoid common-mode human malfunctions, especially for tasks having an immediate impact on the safety of the plant;

- * To avoid, in the process of division and assignement, a pulverized responsibility, difficult to coordinate and to control;

* To distribute supervision responsibilities along the vertical axis of the organization chart in a logical and clear way;

* To assign each responsibility without ambiguity, without overlaps, avoiding shared responsibility, avoiding conflict, saying exactly the type of the assigned responsibility for the specific task (execution of the task, direct supervision of the task, indirect and successive supervision of the task);

* To assign responsibility to competent individuals;

* To avoid power abuses, to state clearly the limits of the managers authority;

* To regulate clearly transfers of responsibility, according predetermined rules.

4.5 Definition of all tasks, technical or/and organizational, assigned to each individual working position

It has been requested a clear picture of the assigned safety responsibilities through a detailed description of the individual working positions belonging to the organizational chart and being responsible of tasks relevant for the safety. In this way each working position knows all his responsibilities and those of each other working position.

In particular have been defined the following working positions:

* the plant manager;

* the assistant plant manager;

* the department managers; (operation, reactor physics, maintenance, chemistry, health physics, planning, spare parts management, documentation, training, security, quality assurance)

* the assistant department managers;

* the unit supervisors; (shift supervisors, mechanical, electrical, instrumentation and control, chemical and radiochemical, workers radioprotection, environment radioprotection,)

* each member of the shift.

As an example we report the Plant Manager safety tasks:

* to determine, to subdivide, to coordinate and to control the safety activities, done on the station and connected to its functioning;

- * to define clearly authority and responsibilities, of departments, units, committees, individuals, for all the activities important to plant safety, protection of individuals and public, protection of the environment, particularly the surveillance tests, required by the technical prescriptions;
- * to respect the corporate guidelines on the personnel qualification.
- * to ensure the existence of adequate programmes and effective operating procedures for all the activities important for the safety and the radioprotection;
- * to designate substitutes of department managers or unit supervisors during every their absence;
- * to give instructions for the substitutions of licensed operators so that maximum limits of working hours are respected;
- * to ensure effectiveness to the Quality Assurance program;
- * to authorize the restart of the plant after each shutdown;
- * to ensure that components, important for the safety, are not replaced by components with inferior characteristics;
- * to send to the regulatory body the second and the third notification on each anomalous event;
- * to apply for approval of the regulatory body to any proposed modification to the surveillance rules;
- * to give notification to the regulatory of any modification of the Operating and Maintenance Manual within 30 days;
- * to ensure that the Final Safety Report is maintained up to date;
- * to apply for approval of the regulatory body to the fuel loading and the next start of the plant;
- * to ensure, in case of accidental contamination or external irradiation, that workers exposed are immediately subjected to the appropriate decontamination procedures by the authorised doctor;
- * to plan the emergency drill;
- * to oversee the thermal effects on the environment;
- * to assure the control of the safety at plant, department and unit level.

4.6 Organizational procedures

Good interrelations among the operators working on a plant require the definition of the functional flow of safety activities involving more people and an optimal flow of information to the right person, without omissions, excessive delays, obstructions or alterations. Right

functional and information flows have to be assured by organizational procedures of the activities relevant for the safety. Among the main activities that have to follow specific procedures we cite:

- * Log-books compilation;
- * Shift turnover and transfer of responsibility;
- * Work permits;
- * Authorization for the surveillance tests
- * Management of the refuelling activity;
- * Extraordinary tests and experiences;
- * Temporary alterations of electrical circuits;
- * Management of plant modifications;
- * Management and book keeping of the radioactive sources;
- * Management of the documents;
- * Emission and distribution of operation orders;
- * Emission and management of licensee event reports;
- * Management of revisions of Final Safety Report;
- * Management of surveillance tests;
- * Management of measures and tests apparatus;
- * Management of the process computer;
- * Activity of the Advisory Council on Safety;
- * Transmission of information reports to the Authority Control;
- * Recycle of Operating Experience;
- * Activity for personnel reception;

5. Autocorrective characteristics of the safety organization

Events do not originate at the moment of the accident. They develop themselves through the following phases:

a) The human malfunctions are in a latent state. They are small and insignificant, at the beginning stage, and can be seen only recognizing each lack in the human system design, each bad habit in the operators behavior, each tolerated small root-cause of the human error.

Examples of these preconditions for errors are:

- * Safety tasks not defined clearly;
- * Safety Responsibilities not assigned properly;
- * Lack of procedures or of technical documentation;
- * Scarce qualities (correctness, completeness, comprehensibility) of existent procedures or of technical documentation;
- * Inadequate understanding of responsibilities;
- * Inadequate training programmes;
- * Inadequate trainees evaluation;

- * Inadequate supervision of the operators;
- * Inadequate hardware design;
- * Inadequate work programming;
- * Inadequate work conditions;
- * Inattention caused by scarce organization;
- * Inadequate communication intraorganization and interorganizations;
- * Individual carelessness, non compliance to the procedures;

b) The previous preconditions for errors manifest themselves on the plant with clear symptoms. They may be small human malfunctions, generally tolerated, that are not recorded or if recorded are not followed by any measure to correct them. Sometimes they are major malfunctions that, having not generated an accident, are nor immediately followed by adequate measures. This is the level of the immediate causes of events, the causes generally recognized during the investigations. Indeed this is only a symptom level, and the measures taken at this level do not remove the root cause, that remains and can cause many others accident or future operational problems. Examples of these are:

- * Incorrect or omitted actions in Control Room;
- * Unauthorized actions in Control Room or on the plant;
- * Inadequate electrical maintenance;
- * Inadequate mechanical maintenance;
- * Deliberate violations of technical Specifications;
- * Power abuses;
- * Arbitrary alterations of the state of the plant or of the logical circuits of the various systems;

c) A plurality of these minor malfunctions may, in any moment, drift the state of the plant from a safe condition to uncontrolled conditions, that manifest themselves on the plant and are recorded as events, which may be:

- * Accidents;
- * Transitories;
- * Safety systems missed interventions;

- * Anomalous radioactive releases to the environment;
- * Anomalous radiation doses;

We retain essential the presence of a safety organizational system, autocorrective and capable to monitor the organizational functioning at various levels along the vertical axis, with sensitivities different. Only inside the various units, there is all the information on the work and it is possible to reveal lacks of human system and suggest measures to correct errors in the initial phase of events development. In Italy has been requested an autocorrective system functioning at various levels: unit level, department level, plant level. It is essential that " errors, when committed, have to be seen less as a matter of concern than as a source of experience from which benefit can be derived. Individual have to be encouraged to identify, report and correct imperfections in their own work in order to help others as themselves to avert future problems. Only for repeated deficiency or gross negligence, managers have to take disciplinary measures. Nevertheless sanctions should not be applied in such a way as to encourage the concealment of errors.

- Unit level

On each specialistic unit of the departments, the Unit Supervisor has the responsibility to evaluate the collected data, to control both the good qualification and the behavior of his technicians, to assure the correct implementation of the procedures. He has to suggest an eventual need of : personnel training or immediate modifications of components of the plant and of operating procedures for a surer operation .

- Department level

On each department the Assistent manager has to analyze the results of tests and inspections made by the personnel of the department and observe the trend of the collected data with the scope to suggest eventual modifications of components of the plant, of operating procedures or of administrative procedures for a better operation.

- Plant level

On each plant is required an **Advisory Council on Safety** that has the following consultative functions defined by the Italian law:

- a) to give prior consideration to any proposed modifications to the plant or to part of it;
- b) to give prior consideration to any proposed modifications to the operating procedures of the plant;
- c) to give prior consideration to programmes of trials, tests, and operations of an abnormal kind to be carried out on the plant;
- d) to review periodically the overall operation of the plant, and express his view with eventual recommendations regard to safety and protection;
- e) to lay down the internal emergency drill for the plant and arrange for any necessary modifications in consultation with the Provincial Fire Service Headquarters;
- f) to assist the shift supervisor or the plant manager in the adoption of the measures which may be necessary to deal with any unusual conditions or abnormalities which may constitute a danger to persons or things.

6. Information reports to the Regulatory body

The correctness and completeness of the information send to the Regulatory body on each single event and on the semiannual operation, and the respect of the time in sending these reports are a significant index of the functioning of the safety organization.

In Italy is requested the following information:

6.1 Informative report on each event

The first notification has to be made by the shift supervisor as soon as possible, in any case within the next 24 hours. A phonogramme with informations on the state of the plant at the moment of the event, the description of what has happened, the safety measures taken, informations on the reasons and the causes which have determined the event.

The second notification has to be made the next workday by the plant manager with a telex to give more details on the event and the results of the first analisys of the event and a global evaluation.

The third notification has to be made within the next four weeks by the plant manager with a written detailed report.

6.2 Information report on each semiannual operation

The report has to contain:

- a discussion and an evaluation of the operation of the plant and the results of the periodic review made by the plant manager advisory council on safety.
- information on the capacity factor and a list of the principal maintenance works, information on the results of the surveillance tests;
- informations on radiation dose of workers engaged in radioactive area, specific maintenance works that cause a radiation dose greater than 5 mS-man, radiation and contamination levels in various rooms of the plant, information on the radwastes, total radiation to which all employee and contractor workers on the nuclear power station were exposed, and data on the environmental situation.
- information on nuclear fuel.

7. Conclusions

The safety commitment of NPPs operating organizations may be known observing many specific characteristics of the safety organizational design and the autocorrective system. The human reliability is high when many of the following safety organizational characteristics are present.

Specific organizational characteristics

- comprehensive vision of the safety;
- translation of the safety objectives in precise and concrete tasks of immediate understanding;
- coordination of the safety work at various levels of the structure;
- control of the safety works at more levels of the structure;
- competent technical supervision at departments level;
- competent substitutes for managers and supervisors during their absence periods;
- direct supervision of tasks having a direct and immediate impact on the safety (control room operators, refuelling operator, etc)
- sufficient and effective operating, maintenance, administrative and emergency procedures;

- plant specific simulator;
- training of the operators on the scenarios of the transients and accident analysis, on the technical prescriptions bases, on normal and emergency procedures;
- periodic retraining on emergency procedures;
- correct and fast information flow inside the operating organization;
- up-dated technical documentation;
- limits at the continuous work;
- very little overtime;
- maintenance department able to repair immediately components and systems;
- low radiation and contamination levels on the plant;
- record of all the events;
- ready investigation on all recorded events;
- deep investigation until the root cause of the events is known;
- provisions to avoid new, similar events;
- regular introduction of technical and organizational improvements to correct latent malfunctions, also if they have not produced consequences to the plant or to the personnel;
- fast and complete information to the Regulatory Body.

A few words about the italian NPPs situation

As you well know, as a consequence of the Chernobyl accident, a general public debate took place in Italy on the implications of the use of nuclear energy. The debate culminated in a referendum vote on nuclear matters in November 1987, whose results were interpreted by the political field as negative for the existing nuclear technology. The Government, with parliamentary approval, decided to shutdown indefinitely the 4 operating NPP's and to stop the 2 under construction.

In Italy the Regulatory body has been for several years the Directorate for Nuclear Safety and Health Protection (DISP) an autonomous branch of the National Committee for Energy, Environmental and New Technologies (ENEA). Accordingly a law approved by the Parliament in the 1994, DISP has become the core of a new governmental agency, denominated ANPA (National Agency for Environmental Protection), charged with other general duties related to environmental protection. Human factors represent one of the important areas on which ANPA will have to express evaluations. ANPA could become a reference point for the safety of other industrial sectors as the chemical one.

The author of this paper, before being charged with the work on Human Factors, has worked, as a resident inspector of the Italian Authority Control, on the Caorso NPP for six years.

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LEADERSHIP PM: THEORY AND PRACTICE

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Abstract

A leadership concept which is designed to overcome the limitations of the commonly used behavioral classification scheme is presented. In this PM concept, P stands for performance and M for maintenance. Measuring each characteristic on an axis between "high" and "low", four distinct types of leadership could be identified. The model was tested in laboratory studies and field surveys of different organizations.

1. PM Leadership concept

As a remedy, we developed the leadership PM concept which 1) allows multidimensional analysis, 2) can be operationally defined, 3) is itself value-neutral, 4) makes possible experimental research and statistical studies. Measuring leadership which is very much a group phenomenon, requires a group functional concept like PM concept (Misumi, 1985).

In the concept of PM, P stands for performance and represents the kind of leadership that is oriented towards achievement of the group's goal and problem solving. Being an abbreviation of maintenance, M stands for the kind of leadership that is oriented towards the group's self-preservation or maintenance and strengthening of the group process itself. These two conceptual elements (P and M) are similar to Bale's (1953) "task leader" and "emotional leader".

The concept of PM is a constructive concept to classify and organize the factors obtained from leadership at different levels. It is not merely a descriptive concept for the factors obtained from factor analysis, but is at a higher level of abstraction. Because of being abstract, PM concept applies

not only to industrial organizations, but also to many other social groups, P does not concern production only but also more general group goals or problem solving tasks. This is what principally distinguishes it from Blake Mouton's (1964) model.

In the case of PM concept, we consider P and M to be two axes on which the level of each type can be measured (high or low), thus obtaining four distinct types of leadership (see Figure 1). The validity of these four PM types was proved using correspondence analysis which was first developed by Guttman (1950) and later by Hayashi (1956).

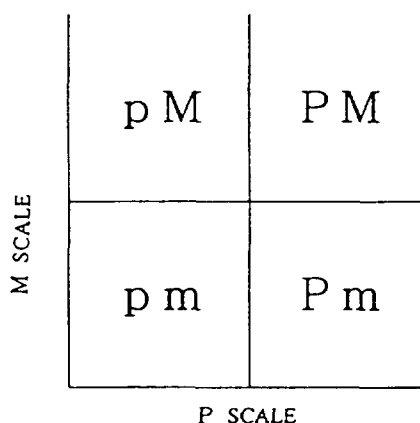


Fig.1. Conceptual representation of 4 patterns of P·M leadership behavior (Misumi, J. et al., 1964)

2. Early Validation of PM Leadership

Our research on the PM model consisted of both field surveys in different kinds of organizations and laboratory studies. Regarding measurement in the field, we found that evaluation by subordinates of their superiors was more valid than evaluation by superiors, peers or self. We, therefore, had subordinates evaluate the leadership of their superiors on the P and M dimensions.

Table 1
Factor loadings of main items on leadership

Items	Factor loadings		
	I	II	III
59 Make subordinates work to maximum capacity	.687	-.017	.203
57 Fussy about the amount of work	.670	-.172	.029
50 Fussy about regulations	.664	-.072	.001
58 Demand finishing a job within time limit	.639	.070	.065
51 Give orders and instructions	.546	.207	.198
60 Blame the poor job	.528	.113	-.121
74 Demand reporting on the progress of work	.466	.303	.175
86 Support subordinates	.071	.780	.085
96 Understand subordinates' standpoint	.079	.775	.229
92 Trust subordinates	.024	.753	-.003
109 Favor subordinates	.067	.742	-.050
82 Can talk to your superior without any hesitation	-.026	.722	.059
101 Concerned about subordinates' promotion, pay-raise, and so forth	.147	.713	.134
88 Show consideration for subordinates' personal problems	.132	.705	.150
94 Express appreciation for job well done	.058	.651	.129
104 Impartial to everyone in work group	-.143	.644	.164
95 Ask subordinates' opinion of how on-the-job problems should be solved	.049	.643	.121
85 Make efforts to fill your request when you request improvement of facilities	.110	.606	.333
81 Try to resolve unpleasant atmosphere	.233	.538	.338
87 Give subordinates jobs after considering their feelings	-.276	.478	.457
76 Work out detailed plans for accomplishment of goals	.229	.212	.635
75 No time is wasted because of inadequate planning and processing	.038	.333	.614
70 Inform of plans and contents of the work for the day	.254	.278	.607
52 Set time-limit for the completion of the work	.319	.299	.554
53 Indicate new method of solving the problem	.251	.489	.479
56 Show how to obtain knowledge necessary for the work	.295	.492	.472
61 Take proper steps for an emergency	.360	.451	.305
69 Know anything about the machinery and equipment you are in charge of	.255	.304	.458

To determine the level of P and M leadership for each subject, we first calculated the mean score of all subjects on each item of the two dimensions (P and M). As discussed by Misumi (1985), these P and M items, represented in Table 1, are the results of factor analysis. A leader whose score in P and M, is, for example, higher than the mean, is thought to provide a leadership of PM-type. A leader whose score is higher than the mean only in P dimension, is classified as providing a P-type (or Pm-type) leadership. When a leader's score is higher than the mean only in M dimension, he is referred to as a M-type (pM-type). When a leader obtains a score lower

than the mean in both dimensions, he is thought to provide a leadership of pm-type. this results in our final four-type classification: PM, P, M and pm.

To test the validity and reliability of these leadership categories in industrial organizations, we examined their relationship with some objective and cognitive variables such as productivity, accident rate, rate of turnover, job satisfaction, satisfaction with compensation, sense of belongingness to company and labor union, team work, meetings quality, mental hygiene, and performance norms. More than 300,000 subjects were surveyed. As indicated in Table 2, of the four types, PM-type was found to provide the best results, and pm-type the worst. In the long run, M-type ranks second, and in the short run, P-type ranks second. It is noteworthy that this order of effectiveness is not limited to businesses only, but is the same for educators (Misumi, Yoshizaki & Shinohara, 1977), government offices (Misumi, Shinohara & Sugiman, 1977), sports coaches (Misumi, 1985) and religious groups (Kaneko, 1986).

Table 2

The summary of comparison of the effectiveness of 4 patterns of P-M leadership behavior on various kinds of factors of work group (the figures of this table show the ranking of effectiveness in each factor) (Misumi, J. et al., 1972)

		Pattern of leadership behavior			
		P M	M	P	p m
Productivity	Long term	1	2	3	4
	Short term ^a	1	3	2	4
Accidents ^b	Long term	1	2	3	4
	Short term ^a	1	3	2	4
Turn over		1	2	3	4
Group norm for high performance		1	2 (3)	3 (2)	4
Job satisfaction (a narrow sense)		1	2	3	4
Satisfaction with salaries		1	2	3	4
Team work		1	2	3	4
Evaluation of work group meeting		1	2	3	4
Loyalty (belongingness) to	Company	1	2	3	4
	Labor union	1	2	3	4
Communication		1	2	3	4
Mental hygiene (excessive tension and anxiety)		1	2	3	4
Hostility to supervisor ^c		1	2	3	4
	(measured by SD method)				

a Including the data obtained by laboratory studies.

b Smaller figures indicate lower rate of accidents or turn over.

c Smaller figures indicate less hostility to supervisor.

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A RESEARCH FRAMEWORK OF ORGANIZATIONAL FACTORS ON SAFETY IN THE REPUBLIC OF KOREA

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Abstract

Korean nuclear society is yet unfamiliar with the topic, 'organizational factors on safety', while having shown lots of accomplishments in the area of physical and human factors on safety. However, recent large-scale accidents in other technological areas illustrate the importance of managing organizational factors on safety.

Recently Korea Atomic Energy Research Institute(KAERI) started paying attention to this topic and is trying to establish a future research framework of organizational factors on safety. This paper tries to explain overall direction of the framework.

Our framework, as managing organizational factors on safety, considers two kinds of areas: design of management systems, which implies a feed-forward system including organizational models; and operation of those systems, which implies a feedback system including management information and implementation systems.

Our framework also considers the evolution stage of a management system. Management systems evolve from visibility stage to optimization stage. To optimize a management system, we should be able to control the system. To control the system, we should be able to see how the system is going.

In addition, this paper tries to share some experience of KAERI on how organizational structure and culture affects organizational performance in R&D perspective.

1. Introduction

Recent large-scale accidents in other technological areas in Korea were largely due to institutional failures, rather than technical or human failures; for example,

lack of commitment effort on safety-related rules and procedures due to lack of safety-oriented organizational culture. There is growing need among people for systematic re-evaluation and re-establishment of all safety management systems. Managing organizational factors on safety is critical especially in Korea.

Korean government has been putting top priority on nuclear safety. However, Korean nuclear society is yet unfamiliar with 'organizational factors on safety', while having shown lots of accomplishments in studying physical and/or human factors on safety. Recently Korea Atomic Energy Research Institute(KAERI) started paying attention to this topic and is trying to establish a future research framework of organizational factors on safety. This paper tries to explain conceptual background and overall direction of the framework.

2. Current Status

2.1 Nuclear Power Program

Energy security is the primary concern of the energy policy in Korea. In order to meet increased demands for electricity, the Korean government has been committed to an ambitious nuclear power programme. Currently, 10 nuclear power plants(9 PWRs and 1 CANDU) are in commercial operation and 8 more units(5 PWRs and 3 CANDUs) are under construction. In addition, 5 more nuclear power plants are scheduled to be constructed by 2006. In 1994, 35.5 percent of nations electricity production was provided by nuclear power.

2.2 Nuclear R&D Program

In 1992, the Korean government established a 10 year long-term nuclear R&D program to advance the technological capability of Korea and establish self-sufficiency in the nuclear field by the beginning of the 21st century. This program includes the development of strategic key technologies leading to strong international competitiveness and the early establishment of advanced technology through a systematic development of basic technology. The program includes such

R&D areas as nuclear reactor technology, nuclear fuel cycle technology, radioactive waste management, nuclear safety improvement, basic technologies, radiation/radioisotope applications, nuclear power plant construction technology, and nuclear reactor operation technology.

Nuclear safety researches have been mainly performed at KAERI, largely in such perspectives as integrated nuclear safety assessment, severe accident analysis, human factors, and nuclear environmental analysis.

3. Research Framework of Organizational Factors

3.1 Research Orientation

We view organizational factors on safety as matters of management systems concerning NPPs. A management system here doesn't mean a management information system. It means the set of responsibilities of any decision maker bounded as a system. An organization is a management system, as a radio is an electric system or an axle a mechanical system.

Our research will consider all aspects of management systems concerning organizational factors on safety. Our research will focus on the full spectrum of the life cycle of management systems at all levels: the design of management systems that inherently lead to safe operation of NPPs, the implementation of those systems, and the maintenance of those systems. Often we forget or ignore the full life cycle of a management system, especially the maintenance side.

Our research will also consider the evolution aspect of a management system. Management systems evolve from visibility stage to optimization stage. To optimize a management system, we should be able to control the system. To control the system, we should be able to see how the system is going.

Our research will consider such levels of analysis as human operator level, plant level, corporate level, nuclear society level, and national level. Many research projects in the human operator level are in process in a human factors group at KAERI. Our research will begin from the plant level and eventually lead to the national level including social factors on safety.

3.2 Stakeholders

Our research will consider whole stakeholders and their relationships. Stakeholders are key players influencing organizational factors on safety, such as utility, regulatory bodies, technical organization, and public.

3.2.1 Utility

The utility is the most important player influencing organizational factors, which includes management and labor, headquarters and NPP sites. In Korea, Korea Electric Power Corporation(KEPCO) is the only utility company responsible for electricity generation and distribution, and it is running ten NPPs at four sites.

The utility's recognition and admission of organizational perspective on safety is crucial for data gathering and system implementation of our research.

3.2.2 Regulatory Bodies

Regulatory bodies also play a key role in determining and shaping organizational factors through regulation and interface with the utility.

In Korea, Ministry of Science and Technology(MOST) is responsible for nuclear safety regulation such as licensing and safety inspection, and Korea Institute for Nuclear Safety(KINS) provides technical and administrative support for MOST.

3.2.3 Technical Organization

Technical organizations play rather modest role for shaping organizational factors through recommendation to the utility and the regulatory body based on nuclear safety research including organizational factors.

In Korea, most of nuclear safety researches are being performed at KAERI. Since KAERI is maintaining national technical authority on nuclear safety with its technical experts, the utility and the regulatory body largely depend on and can't be able to ignore technical and organizational recommendations of KAERI.

3.2.4 Public

Recently the role of public in this picture is growing up with paradigm changes toward environmentalism and openness. Nuclear activities in many countries are in stagnation due to systematic anti-nuclear activities of non-governmental organizations (NGOs). Nowadays public acceptance is the key to pursue nuclear activities. Bad public acceptance on nuclear energy could even degrade the rationale of NPP personnel. Public has the power to affect the government, eventually the regulatory bodies and the utility, and hence is a key player in shaping organizational factors on safety.

3.3 A Framework for Organizational Factors

Our research borrows the concept of the management cube, explained in more detail in Appendix, to extract and categorize organizational factors in a normative sense and to assess a management system. The management cube comprise three axes in general terms: certainty of goals, completeness of beliefs about cause/effect relationships, and crystallization of value system. Management policies should pursue these three to enhance safety.

3.3.1 Certainty of Goals

To secure safe operation of NPPs, organizational goals for safety should be clear and certain, and NPP personnel should be well aware of those goals. Any conflict in organizational goals can affect the decisions of NPP personnel concerning safety. Therefore, consensus on organizational goals would be critical and the commitment to safety at corporate and plant level of the utility will increase the clarity of organizational goals for safety. Also Public and regulators could play important roles in this perspective.

3.3.2 Completeness of Beliefs about Cause/Effect Relationships

To secure safe operation of NPPs, decision makers concerned should have sound knowledge on the consequences of their decisions and enough relevant

information - so that they make correct and timely decisions. In addition to rules and procedures for safe operation of NPPs, there should be clear understanding of cause/effect relationship concerning decisions and their consequences. To enhance the understanding, training and education would be critical. Also information sharing between relevant organizations is important to correctly understand the decision environment. Technical organizations would play key roles in this perspective.

3.3.3 Crystallization of Value System

To secure safe operation of NPPs, there should be crystallized standards of desirability for safety; that is, a value system. Managers and NPP personnel should have clear understanding of what they get from their decisions and actions. Organizational culture plays an important role in this perspective. To crystallize the value system for safety, the establishment of a proper performance measurement and appraisal system would be critical.

4. Future Work

Our research is yet in a primitive stage. It will be performed in interdisciplinary approach, incorporating social science, management, safety engineering, systems engineering, information systems, etc. Our research, based on the framework described earlier, will proceed from extensive literature survey on theories, models, and tools. Afterwards, modeling(defining variables and their relationships), data gathering (including the development of measurement techniques), and test will be performed. Our research will include the implementation stage of the results of the study to actual organizations in NPPs. Currently we consider system dynamics as one of analysis tools for our research.

Appendix : The Management Cube

The management cube, originally proposed by Thompson[1967] and improved by Sink[1986], provides a good starting point to deal with organizational factors on safety in an organization. Thompson[1967] proposed two frameworks on decision strategies and assessment techniques. His two frameworks contain three variables: preferences regarding outcomes, standards of desirability, and beliefs about cause/effect relationships. Sink[1985] integrated these two frameworks into the management cube as shown in Figure 1, which provides broad implications to the management process.

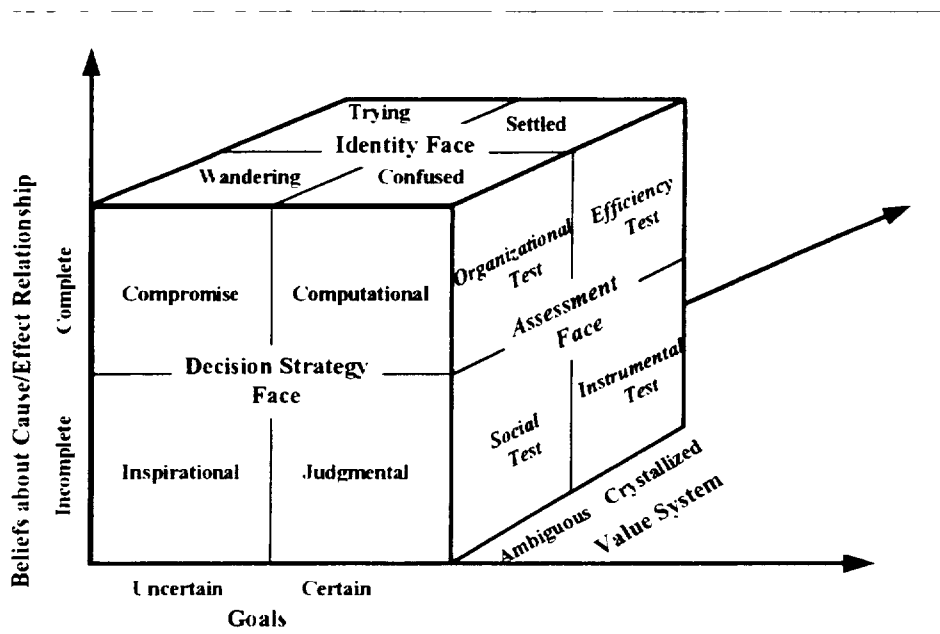


Figure 1 The Management Cube

Three Axes of the Cube

There are three axes in the cube. The first axis is about goals. Sink[1985] described it as clarity and consensus of goals, objectives, and activities for the work group, department, function, plant, firm, and so forth. Thompson[1967] originally depicted this axis as "preferences regarding possible outcomes." Desired outcomes here mean the goals of the organization, and preferences mean the

priorities of the goals. To enhance the discussion this axis is divided simply into two parts. The left part of the axis represents having uncertain goals or priorities of the goals and lacking the consensus on the goals. The right part of the axis represents having clarity and consensus with respect to goals.

The second axis is about beliefs about cause/effect relationships. Thompson[1967] dichotomized this axis into two parts: certain/complete and uncertain/incomplete. The bottom half of the axis represents uncertain/incomplete beliefs about cause/effect relationships. The top half of the axis represents certain/complete beliefs about knowledge or beliefs about the relationships.

The third axis is about the value system. Sink[1985] saw this axis as the extent or maturity of the development of performance measurement, evaluation, and control system; crystallization regarding the assessment criteria that will be or are used to evaluate and control the performance of the system being managed. Thompson[1967] originally depicted this axis as "standards of desirability" and asserted that cultures provide general standards of desirability. This axis is also divided into two parts: ambiguous and crystallized. The front part of the axis represents ambiguous value system including unclear assessment criteria. The back part of the axis represents crystallized value system including clear assessment criteria.

Three Faces of the Cube

There are three faces in the cube. The first face is formed by the two axes: goals and beliefs about cause/effect relationships. This face has four cells. Thompson[1976] put this face for describing the decision strategies. He suggested that each cell calls for different decision strategies. The decision here means the selection of actions through which the goals can be accomplished. If the goals are clear and cause/effect relationships are certain, computational strategies are required.

Sink[1985] suggested the preferred movement from cell to cell such as from cell (1,1) to cell (2,2), which means

driving the organization to clearly define the goals and then to learn and enhance the knowledge about the cause/effect relationships.

The second face is formed by the two axes: beliefs about cause/effect relationships and the value system. Thompson[1967] put this face for describing situations and types of assessment of actions. He suggested each cell calls for a different assessment technique.

- Cell (1,1) ; The cause/effect understanding is incomplete and the standards of desirability are ambiguous. People don't know how to accomplish the right things and the value system doesn't provide any guidance. This situation means an open system. The proper assessment technique is the social test by referent comparisons.

- Cell (1,2) ; The standards of desirability are crystallized but the cause/effect understanding is incomplete. People don't know how to accomplish their goals but they have crystallized value system. The proper assessment technique is the instrumental test based on effectiveness.

- Cell (2,1) ; The standards of desirability are ambiguous but the cause/effect relationships is complete. People know how to accomplish the goals but they don't have crystallized value system. The proper assessment technique is the organizational test based on quality and efficiency.

- Cell (2,2) ; The standards of desirability are crystallized and the cause/effect relationship understanding is complete. People know how to accomplish the goals and they have crystallized value system. The proper assessment technique is the efficiency test.

The third face is formed by the two axes : goals and value system. This face represents the identity of an organization.

- Cell (1,1) ; The goals are uncertain and the value system is ambiguous.

People are wandering because they are not sure what are their goals and what they get when they take some actions.

- Cell (1,2) ; The goals are uncertain but the standards of desirability are crystallized. People are trying to do something from which they are sure to get

some advantages even if they don't know what are their goals. Innovating organizations may be in this cell.

- Cell (2,1) ; The goals are certain but the standards of desirability are ambiguous. People are confused because they know their goals but they are not sure what they get when they accomplish their goals.

- Cell (2,2) ; The goals are certain and the standards of desirability are crystallized. People get the feeling of being settled because they know what are their goals and what they get when they accomplish their goals.

Eight Cells in the Cube

Each of the eight cells has a unique set of characteristics and hence a unique set of appropriate management strategies and behaviors relative to measurement, evaluation, control, and improvement.[Sink, 1985] Every organization places at a cell in the cube by design, purpose, intent, default, or by mistake.[Sink, 1985] For example, innovating organizations may place in cell (1,1,2). Their goals are often uncertain, they don't know the cause/effect relationships, but they maintain very strong culture so that the people in the organization be entrepreneurs. Note that these organizations can move to cell (2,1,2) by defining the goals clearly and making consensus through planning processes. But some organizations would stay in the cell (1,1,2) to motivate the creativity of their people. The cell (1,1,1) needs strong leadership. Small organizations which are dictated by a leader may place in the cell (1,1,1).

The position of an organization in the cube can be changed with the effort of the organization. There seems to be preferred direction on the movement among cells.

The Cube and the Management Process

Organizations make effort to move from one cell to the preferred cell or to stay at the current cell. This effort is the management process. For example, to

make goals clear and make consensus on the goals, organizations do the planning processes. To make the cause/effect relationships complete, they hire consultants, organize research teams or task forces, or construct the measurement system which can show the cause/effect relationships. To make the value system crystallized, they use strong leadership, emphasize the culture, or construct the evaluation and rewards system which can tell their people what they get when they accomplish their goals.

The cube also implies what the intervention and improvement effort should be. If an organization knows where it is in the cube, it can identify the direction of the effort. For example, suppose an organization is in the cell (1,1,1). Definitely the first step should be to make the goals clear and to make consensus on the goals, and hence the intervention effort should be focused on clarifying goals and making consensus. If an organization is in the cell (2,2,1), it requires a crystallized value system. Therefore, the intervention effort should be focused on establishing strong culture or constructing crystallized measurement, evaluation, and rewards system.

Another important point about the cube is that if an organization does not make any effort to stay in the cell, it may be moved to the cell it doesn't want. For example, if an organization in the cell (2,2,2) rewards wrong people or doesn't provide constant motivation, it would be moved to the cell (2,2,1) or in the worst case to the cell (1,1,1). The cube implies that constant improving effort should be maintained in the organization.

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REDUCTION OF RISK FACTORS FOR NUCLEAR POWER PLANTS DUE TO PERSONNEL PSYCHOLOGICAL DATA, INCLUDING ATTITUDE, MORALE AND MOTIVATION

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Abstract

The possibilities of reduction of risk factors for personnel activity and performance due to attitudes, motivation and moral are presented. Methodology and experience of psychology, sociopsychology, psychophysiology and sociology mistake sources are discussed. Authorization to job, stages of estimating occupational fitness and modules system of personnel psychological and sociopsychological training probabilistic are explained.

It is human error that causes of technology disasters and failures are most often attributed to. True, ignoring of human psyche capabilities and limitations and underestimation of individual characteristics and professional motivations of the operators who control industrial facilities of excessive unit power may result in grave implications. Thus a high level of safety and efficiency cannot be attained in nuclear power engineering unless two approaches to quality assurance (QA) are involved, viz:

-adaptation of technology to the limitations of human abilities;

-development of human abilities with respect to NPP working conditions.

Power engineers should work hand in hand with human factor specialists, to improve the safety of those NPP bays which are most personality-vulnerable:

1) Scientific advice of ergonomics and engineering psychology is introduced into the design of man-machine interfaces, NPP technologies, industrial engineering;

2) Human relationships are studied, conflicts are resolved;

3) Research into professional validity assessment, personnel selection, and staffing is made.

As defined in the Guide 50-SG-QA5 Rev.1 (1988), quality assurance is the planned and systematic actions which must be taken to enable NPP operation in accordance with the specified requirements. These requirements are stated in basic documents providing guidelines for the government-supervised regulation of NPP safety, site selection, design and operation issues. In this connection QA involves personnel management in that it is directly related to the thoroughness and degree of development of the guidelines for

personnel management, including those specifying vocational and personality requirements NPP staff must meet. The above should also refer to the procurement, construction, design, etc. personnel.

Qualification and personality requirements for the above-listed personnel types seem to be given an insufficiently clear-cut definition in respective Guide Series and need a further specification for every particular case. It seems relevant that IAEA and Member-States should pay a special attention to drawing normative regulations on the requirements to NPP staff psychological personality characteristics.

In fact every NPP failure emphasizes a high human responsibility and a big role of man in QA. Man can have a tremendous spectrum of capabilities and can often alleviate seemingly deadly situations in the facility one controls. However, one can also develop such a situation. The history of NPP incidents is abundant in such instances.

Psychological analysis of NPP - personnel behavior in pre-incident and post-incident situations shows that one or several of the following factors are involved in erroneous performance:

Errors at the psychophysiology level (apprehending information an operator did not notice / did not hear / did not see a signal or it seemed to him there was a signal; retarded response; inability to act in emergency);

Errors at the mental psychology / memory level (getting accustomed to stereotype situations / actions prevents an adequate response to a new situation; low professional skills);

Errors at the motivation / attitudes psychology level (biased social values, lack of interest to work, low estimate of work importance; reluctance to risk one's life; formal attitude to one's job; lack of discipline; no sense of duty);

Errors at the personality psychology level (lack of will; reluctance to act reasonably in emergency; uncommunicativeness; other-worldly behavior; emotional instability; lack of self-control and other features which hinder performance and result in job quality decline);

Errors at the social psychology level (worthless moral value system inability or reluctance work in a group; pronounced conflict-mindedness in behavior, inability to lead the people).

Those personnel characteristics which are respectively opposite to the above ones favourably affect the quality of NPP performance. The key errors characteristics and classification are represented in the table 1. This table is used of NPP incident analysts.

To reduce of risk factor for NPP through psychological requirements one could resort to stringent vocational selection on the basis of personality data. However, there is a rather significant ethic and legal issue which may not be by-passed in such a selection, since a personality is at stake. It is not in every country that psychologists are entitled to manpower selection and scree-

ning of those with potentially adverse psychological characteristics. However, even where it is a common practice, there are problems in NPP staffing. Professional requirements are still very stringent.

Tabl 1
For psychologist (NPP)

Mistake sources of Personnal. NPP. Inspection Methods

	Error sources	Slips, omission	Lapses, commission	Mistakes trick
P e r s o n a l i t y s t i c s	Vocationally significant personality characteristics			
	Psychophysiological characteristics			
	Professional attitudes, motivation, moral			
D i s p o s i t i o n	Character of mentality			
	Attention			
	Memory			
S o c i a l i n s	Managerial support of work and repose			
	Social-psychological climate			
	Social situation			

The following criteria of operator's successful performance, or performance qualities, were identified: appropriateness of actions under normal operating conditions and in potentially hazardous situations, correctness of operator's own decisions, active role in group decision making, self-control, prompt and precise actions in emergency situations. In emergency, of particular importance become in emergency such qualities as initiative, readiness to take actions to minimize accidental consequences, involvement in hazardous operations on eliminating consequences of an accident, creative approach to one's duties, resolution and courage, self-control, ability to take orders and sense of discipline. In order for high performance to be provided under normal operating conditions, members of NPP staff should, evidently, be physically fit, possess strong will-power and have motivation for accident-free operation of NPP as well as good technical and organizational training. Moreover, in critical conditions the sense of duty and high moral qualities of a personality play an increased role. All this points to exacting demands placed on members of NPP staff psychologically and emphasizes the need to carry out psychological selection in the industry (Fig. 1).

The selection criteria were identified by the method similar to functional-structural analysis. The structure of operator's performance under normal operating conditions was examined and a tentative list of requirements to members of occupational groups engaged in maintaining NPP control panels was made. This list was found to be generally in agreement with the results obtained by 16-factor questionnaire by R. Kattel, MMPI questionnaire as adapted by B. Berezin for non-clinical conditions of testing, pictograms for assessing propped memory, Rozenzweig's test and questionnaire used to determine inclination to risk taking by Schubert (RSK).

The study of operator's motivation and attitudes was done in two stages. At the first stage, which consisted of interviews and observation, we identified basic motives: cognitive, utilitarian, that of prestige, level of aspirations and avoidance of conflicts. At this stage the main attitudes in work were also distinguished: performing one's duty, appreciating social significance of one's work; attitudes aimed at career promotion, high quality, prompt and precise actions, social approval and high payment. At the second stage, a questionnaire of attitudes was used which allowed estimating the relative importance of each motive for performance and deriving a hierarchy of motives and attitudes for each individual. Averaged sample data can then be used as a reference point for giving description of a personality.

Motives and attitudes were compared with personality qualities using the results of the "questionnaire of attitudes" and checked against the data from the Kattel's questionnaire, MMPI and Rozenzweig's test. The data of the "questionnaire of attitudes" was supplemented with the estimates of inclination to risk by RSK and data of Rozenzweig's test assessing situational and operational attitudes (sets). Kattel's questionnaire and MMPI gave an idea of such components of examinee's social attitudes as commitment to job, adherence to social norms, pursuit of social approval etc.

Certain characteristics of operator's cognitive qualities, which were included in a suggested list of requirements, can be derived from quantitative and personality data of the pictogram test, MMPI scales and Kattel's factors.

In order to obtain information on personality qualities relevant to performance, we used the method of expert judgement. The judgement was done by those members of NPP staff who knew examinees well enough, specifically their executives and fellow-members of the shift.

All this allowed us to draw a fairly comprehensive picture of an examinee's personality. Basing on test results we made a psychological description of a person: a set of values and aspirations, motivation and attitudes, psychological health, moral qualities, development of will-power, personality traits, style of performance and communication etc. As personal data are collected, a file is formed which is later used for investigation purposes.

With the results of expert evaluation of performance qualities amassed, a data file on operators' performance qualities was formed. The results of tests in different samples (age, position, type of NPP, students and NPP staff) were compared and psychological qualities were checked against performance indicators with the use of methods of mathematical statistics and correlation analysis. To facilitate the research, an automated system of processing psychological data was used. The value of psychological analysis in occu

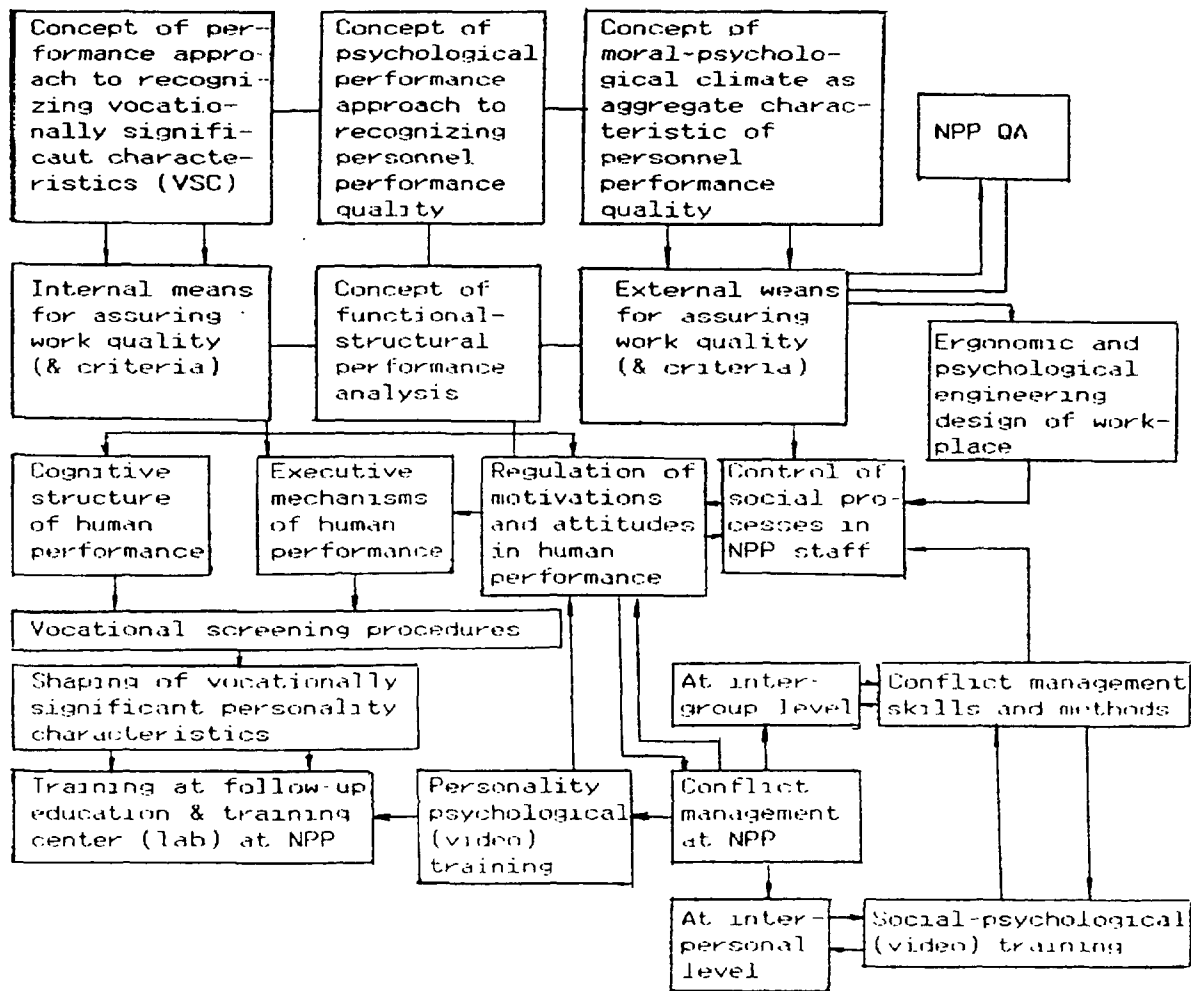


Fig. 1. Methodology of psychological support to human resources development

pational selection can be judged by prediction accuracy of conclusions on examinee's occupational aptitude. When investigating personality with the methods chosen, we did not merely aimed at describing individual differences. But also tried to find out how they affect person's behavior, both in normal and abnormal conditions. With a file of personal characteristics formed, a researcher is enabled to trace an examinee's behavior in different actual situations including emergency ones. Checking the results of psychological analysis (which allows drawing final report on professional aptitude) against the actual behavior of a person in emergency is the best validity test for professional selection method. The effectiveness of psychological methods as applied to personnel management in nuclear power engineering is the summation of the following components: minimizing wrong occupational choice and psychological preparedness of candidates for power engineering colleges, early diagnosis and inculcation of desired personal qualities, development of professionally relevant qualities by the time of college graduation, shortening the time of graduate's adaptation to job, eliminating mistakes in assignment to operative kinds of job, increasing NPP reliability by screening and selecting out misfits. The last component is sort of resultant and an indicator of effectiveness of man-power policy in terms of occupational selection and recruitment, personnel education and training.

Different methods of psychological analysis have varying effectiveness and this is also true when they are used in personnel management. The ultimate effectiveness of a method depends on whether the whole scheme of tasks is properly laid out and the procedure used is reliable. Moreover, the question arises as to applicability of some mathematical methods for assessing criteria to be used in selection as well as personnel management in general.

Conventionally personnel selection is defined as a scientifically substantiated authorization to specific work areas, with the practices aimed at finding the people who may be most easily trained and who can meet vocational requirements. However, since currently the number of entrants to the Power Departments of high school doesn't greatly exceed the number of vacancies, the very term "selection" seems, as it is, senseless. To ensure a high-quality training of personnel the methods and procedures of authorization to job must be oriented to diagnostics of personality state and an individual program of production of required personality characteristics. A package of psychological training modules has been developed in the USSR based on the idea that risk factors at NPPs may be reduced if the quality of personnel training is improved through the use of psychological personality data. A concept of vocational selection of NPP personnel has been developed, which includes not only comparative estimation of the required level of staff fitness and the actual one, but also a diagnostics program to study the factors deteriorating the fitness quality. Fig. 2 shows an algorithm of psychological testing aimed at the diagnostics of personality data and determination of risk factors involved into individual fitness. Thus, the results of psychological testing provide a basis for making a decision as to what practices should be used to train a particular person.

Psychodiagnostics will be efficient provided it is run within the frame work of investigation into social situation and social-psychological climate at NPP. Table 1 to effect a case-study program of investigating human factor used to obtain practical advice resulting in a high-quality NPP operation. Within the program a specific labor-consuming project was delineated, viz. the procedure of psychological and psychophysiological testing of would-be employees, and staff when having preventive medicals. In addition, the Departmental Laboratory "Prognoz" is also involved in the development of programs of psychophysiological and medical rehabilitation, of personnel's functional state control at work, and ergonomics programs.

As soon as the factors affecting the reliability and quality of NPP staff performance have been distinguished, the problem of psychological occupational selection may be approached as a solvable problem. A complex approach to its solution involves a time distribution and an account for the age-related psychological features of the personality formation and development. Fig. 3 shows a flow-diagram of the program module package for psychological and sociopsychological training of NPP personnel and higher school students majoring in nuclear-power engineering.

The package includes 7 modules. The first three ones have been developed for personnel management prior to employment at NPPs: at school, vocational school, college, higher school. Modules 4,6 and 7 are used at the

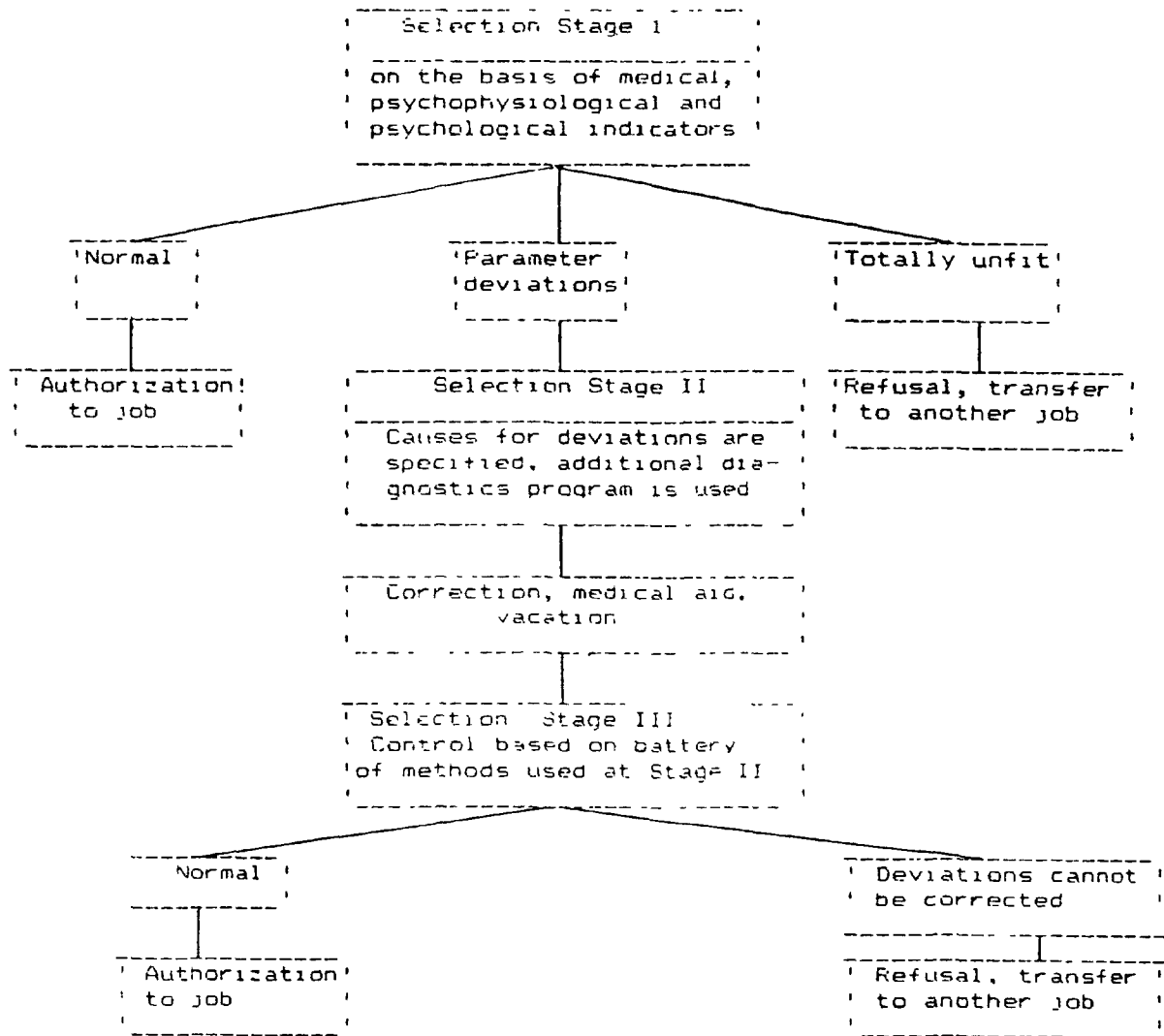


Fig. 2. Stages of estimating occupational fitness and authorization to job

stages at personnel training and refreshment at NPP: on-the-job tuition, education-and-training centers; and on a full-time basis: in education-and- training centers, institutes and departments of refreshment. Modules 3 and 4 are related to module 5 which includes the programs for training specific operator's functions of memory, attention and thinking.

Having no right to commit an error, an NPP operator must be nearly ideal. Operator's reference data include such perfect characteristics as stress- resistance, self-control, thoroughness, honesty, confidence, benevolence, self-dependence, as well as a healthy nervous system, high capacity for work and ability to rise to the task. By no means everyone can meet such rigorous requirements. It's this aspect that necessitates the system of NPP personnel training including the modules of psychological and sociopsychological training programs enabling one independently or with the help of a psychologist-tutor to improve one's personality characteristics and to raise them to a required development level.

Module 1	Module 2	Module 3	Module 4	Module 6	Module 7
Training in school	Diagnost. candidates for college admission	Development of professionally relevant qualities in college	Adaptation to NPP conditions	Career Promotion	Psychology of management
Occupational guidance and self-appraisal	Drawing-up of programmes of individual training	Diagnosis of dynamics of professionally relevant qualities	Control of functional condition	Personality training	Socio-psychological training
Personality training of teenagers	Construction of students groups in college			Socio-psychological training	Psychophysiological control
				Psychophysiological control	Medical testing
		Personality individual training			
Psycho-physiological professionally relevant qualities		Psychological professionally relevant qualities		Antiaccidental training	

Module 5

Fig. 3

The vocational selection methodology oriented to the personality development rather than to screening seems to be morally and ethically more substantiated, although one cannot exclude cases when a person has not to be authorized to job. These are the cases when any methods of medical rehabilitation, education, social psychology and psychology proper cannot correct those personality characteristics which contribute to the risk factors in NPP operation.

OA in NPP operation largely depends on the personnel culture level and on the scientific basis of the personnel management in the industry. In its turn the effectiveness of personnel management studies may be essentially improved if the experience gained by psychologists, social scientists, lawyers and managers of personnel management services of different countries is exchanged and pooled.



ANALYSIS OF MANAGEMENT STRUCTURES AT RUSSIAN NUCLEAR POWER PLANTS CURRENTLY IN OPERATION

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Abstract

At present organizational management structures at Russian NPPs have a well defined division character where the main elements are industrial technology divisions that fulfill operation, repair/maintenance and operating management functions. The administrative management structure is related to the necessities given by the main elements and can be presented in three levels: top level management, i.e. director, chief engineer and their deputies; ancillary support functional departments; industrial/technological divisions. The paper gives the detailed composition of the organizational management structures in all three levels for 8 NPPs located in Russia and discusses the results of a diagnostical analysis based on examination of documents, inspection of management structures, comparative analysis of existing and recommended organizational management structures and interviews with the top management of all NPPs analyzed.

1 INTRODUCTION

Character of management activity in framework of nuclear energy specificity for management levels is defined by necessary trustworthiness, timely decision making and access to current information.

In case separate management elements can not take into account all the variety of factors, influencing on decision making process owing to objective reasons, redistribution of functions between the levels of management hierarchy takes place. The consequence of this redistribution is the expansion of NPPs economical independence.

On order to carry out presented analysis the following elements of diagnostical analysis were used:

- examination of regulatory documents, regulatory authority organization principles of management structures;
- inspection of existing management structures at Russian NPPs;
- discovery of functional elements and magnitude of fulfilled functions by existing structural elements;
- comparative analysis of existing and recommended organizational management structures;
- identification of superfluous elements in organizational management structures;
- interviewing of NPP's top management.

2 ANALYSIS OF ADMINISTRATIVE MANAGEMENT STRUCTURES

At present organizational management structures at Russian NPPs have well-defined division character where the main elements are industrial technological divisions that fulfil operation, repair and operating management functions. Administrative management structure is conditioned by the necessity of these functions realization by the main elements.

Table 1 shows distribution of functions between main NPP divisions.

Data presented by Table 1 show that some contiguity zones occur when main divisions realize management functions (equipment management, repair, operating management and maintenance). So it is necessary to co-ordinate the realization of functions. In order to do it functional departments (industrial - technological, for preparedness and carrying out of repair, for material - technical supply, for automatic control systems and others) and functional leaders (deputies of chief engineer for operation, for repair, for nuclear safety and others) exist.

Administrative management structure may be presented by three levels:

- I level - top level management, i.e. director, chief engineer and their deputies;
- II level - ancillary support functional departments (agricultural, transporation, schools, etc.);
- III level - industrial / technological divisions.

Figures 1, 2, 3, 4 present an example of the organization structure of Novovoronezhskaya NPP.

I LEVEL

Director is the first administrative leader at NPP and he organizes management of NPP in industrial and social areas.

Chief engineer is the first deputy of director. He organizes management of NPP industrial activity.

As a rule director has deputies for economics, common affairs, for personnel and social affairs, for confidentiality, for capital construction. These deputies organize management in social sphere and in administrative economical activity including the following functions:

- to provide NPP with man-power resources;
- to provide NPP with financial resources;
- to provide NPP with material resources;
- to organize accounting, to execute financial operations;
- to provide legal support;

Table 1

Distribution of functions between main NPP divisions

Division	Reactor equipment				Turbine equipment				Generator equipment			
	Main		Auxiliary		Main		Auxiliary		Main		Auxiliary	
	ME	EE	ME	EE	ME	EE	ME	EE	ME	EE	ME	EE
RD	0,0M	0,0M	0,0M	0,0M								
TD					0,0M	0,0M	0,0M	0,0M			0,0M	0,0M
ED		0,R		0,R		0,R		0,R	0,0M,R	0,0M,R	0,0M,R	0,0M,R
C&ID	0,R	0,R	0,R	0,R	0,R	0,R	0,R	0,R	0,R	0,R	0,R	0,R
CD	0,0M,R		0,0M,R		0,0M,R		0,0M,R		0,0M,R	0,0M,R	0,0M,R	0,0M,R
CRD	R		R		R		R				R	

ME - Mechanical Equipment

ETE - Electrical Equipment

O - Operation

OM - Operating Management

R - Repair

RD - Reactor Division

TD - Turbine Division

ED - Electrical Division

C&ID - Control and Instrumentation Division

CD - Chemical Division

CRD - Division for Centralized Repair

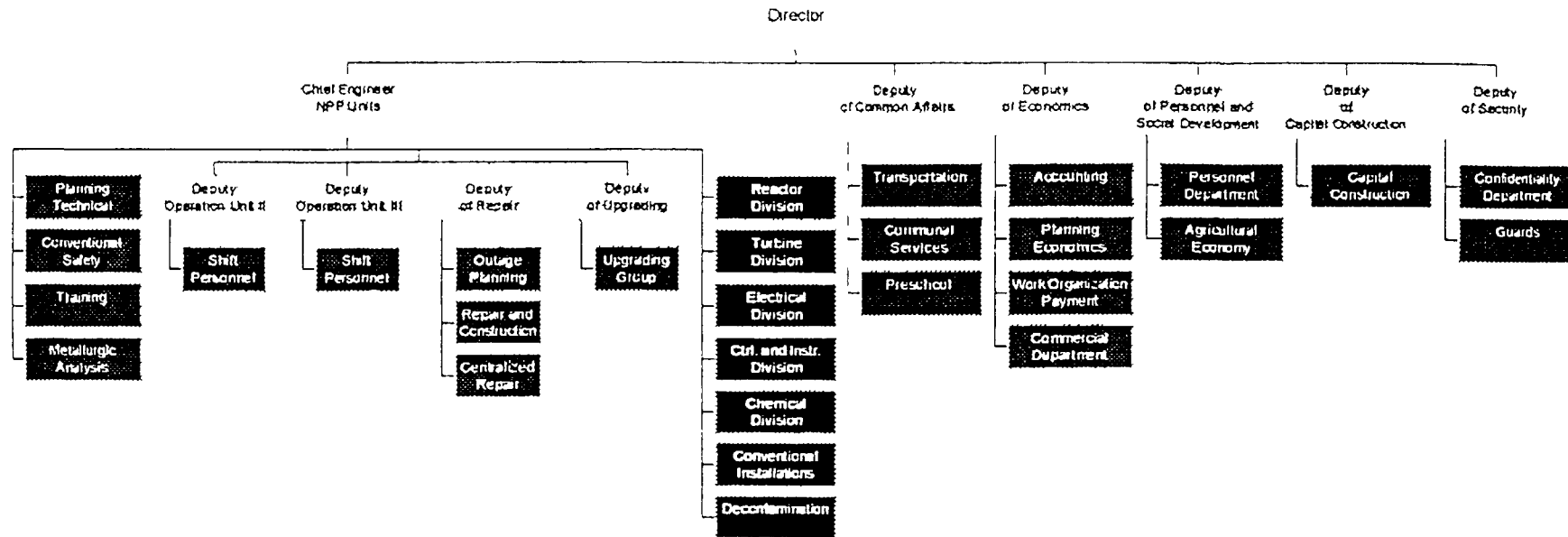


Figure 1. Organization example (Novovoronezhskaya NPP)

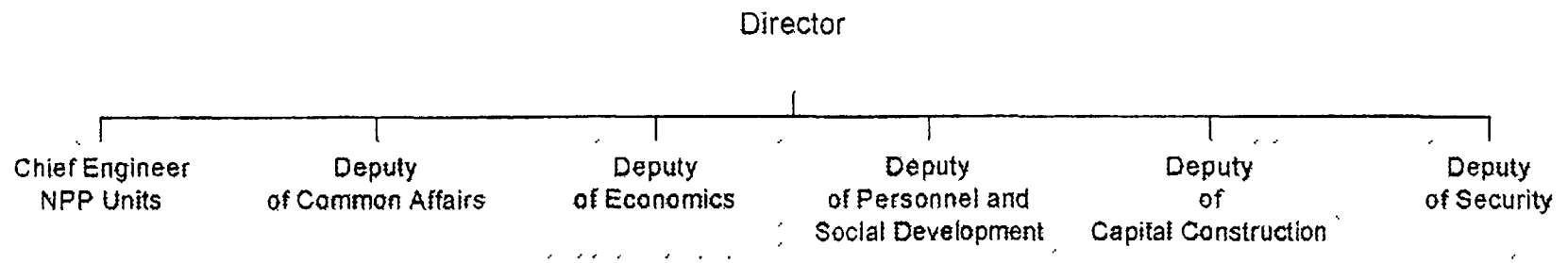


Figure 2. Top management of the NPP organization.

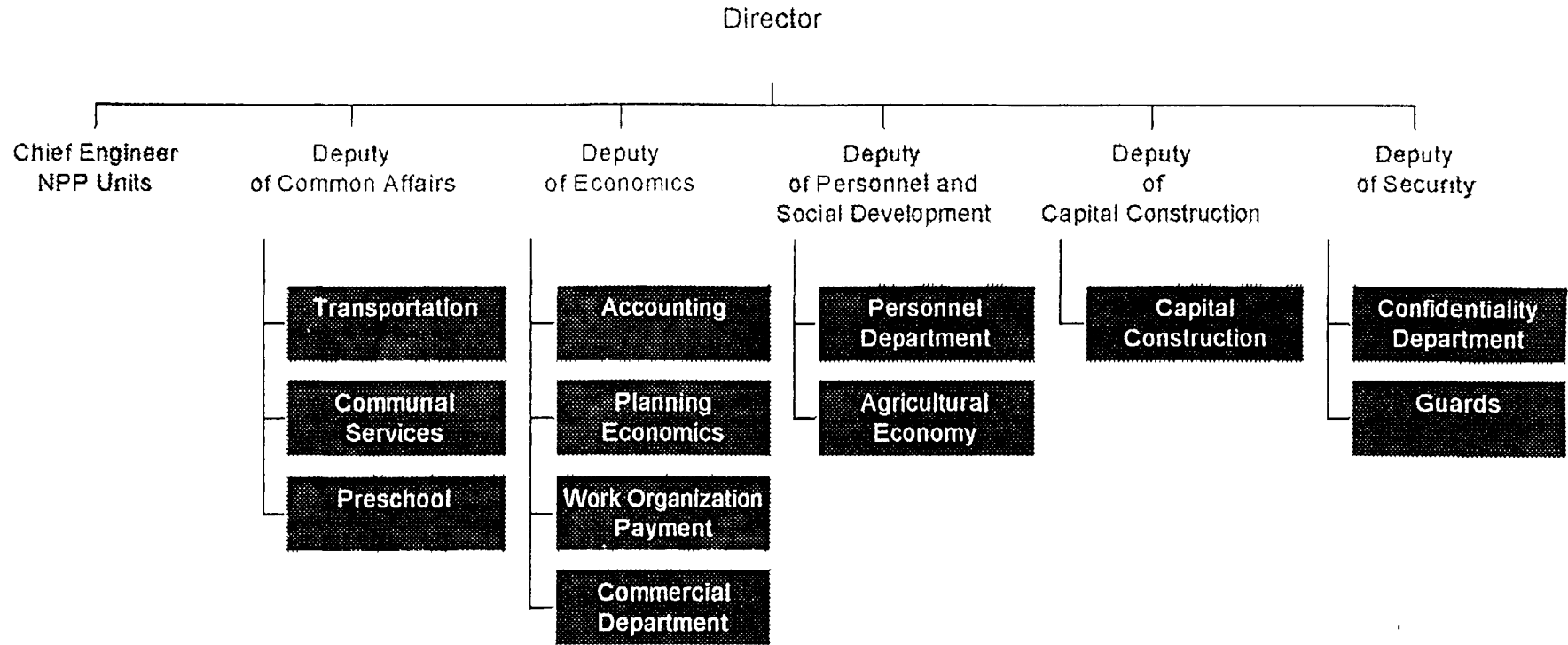


Figure 3. Organization of the community.

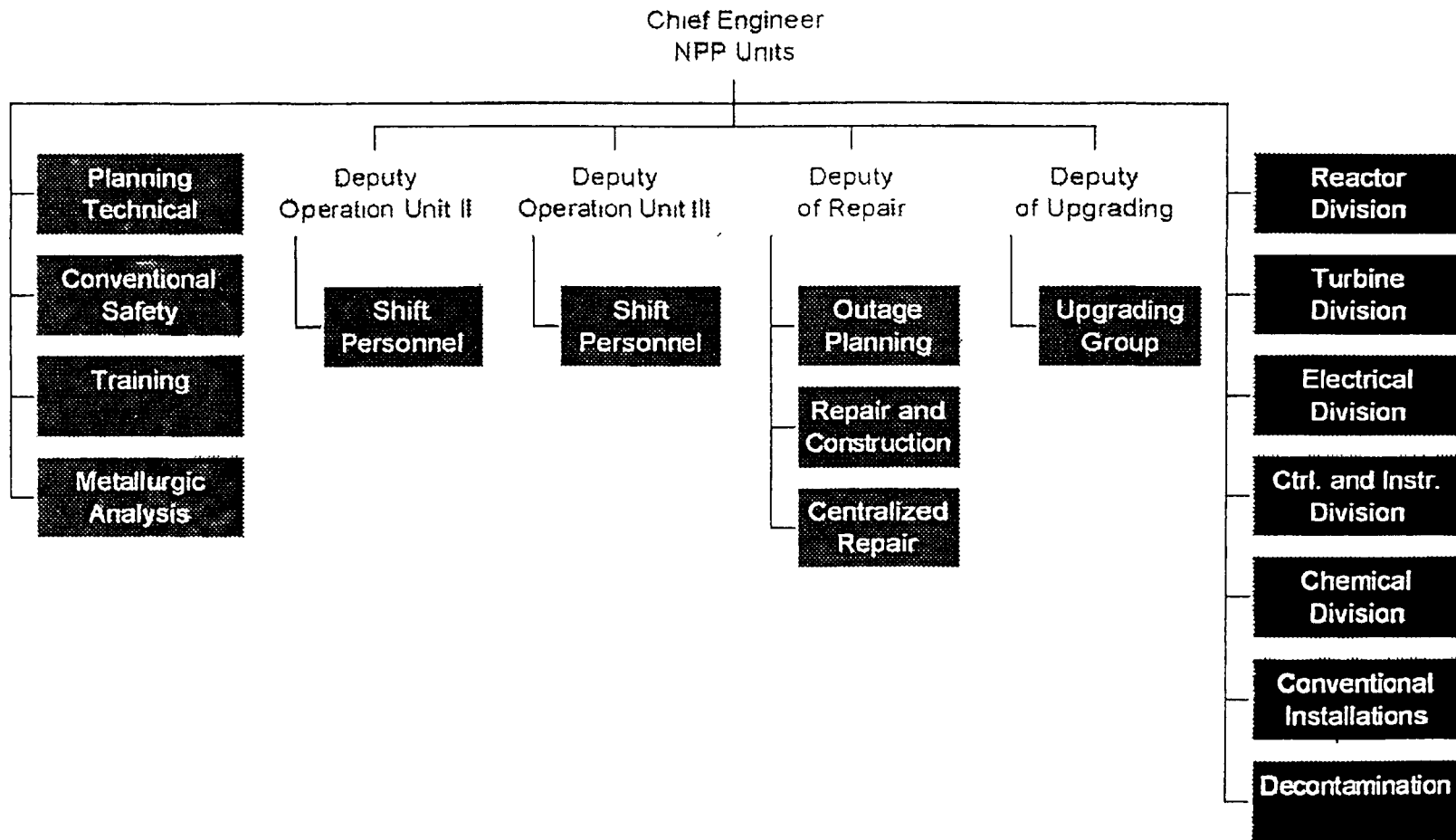


Figure 4. Administrative organization of the NPP Units.

- to provide security of NPP, of government and commercial secret, to organize NPP access;
- to provide economical service;
- to provide the social development of NPP;
- to organize business correspondence.

Table 2 presents staff of director deputies at NPPs currently in operation.

Specificity of NPPs social sphere, different approaches to industrial development, different NPP designs condition existence of such support service elements in management structures as communal economy, municipal transport, heat and electrical supply, water-pipes and sewerage economy and others and also the existence of such untraditional for nuclear energy services as agricultural economy, pre-school institutions, fish economy, social cultural objects, flower economy and others. Number of these services depends on quantity and structure of social sphere objects which are on NPPs balance.

Analysis of existing administrative management structures permits to define the following tendencies in the development of NPPs social sphere:

- social sphere has no complex programme of development which outstrips industrial development programme. So it conditions the expansion of uneffective work and management, unreasonable increase of quantity of plants and organizations providing the functioning of social sphere;
- industrial development has always higher priority than social development. Common source of financial support implies that social problems are solved with a low priority and this is the reason of social sphere arrearage behind industrial one and it leads to falling-off in social economical situation in NPPs towns where NPP is the dominating (or only one) employer and financial source;
- division of the responsibility of social aspects between I level managers (director, deputy of director for common affairs, deputy of director for personnel and social affairs) prevents the promotion of complex social programs.

Table 3 shows the departments which report to two traditional deputies of director in existing management structures at operating NPPs.

Material-technical provision is most important part of industrial-economical activity at NPP, so number of NPPs (Balakovskaya, Kola, Kalininskaya) carries out a set of measurements, devoted to improvement of management structures of supply departments. The approaches were different but the aim was to concentrate supply functions.

Chief engineer has a set of deputies who organize management of industrial activity at NPP. As a rule the main functions of this activity are the following:

- to provide equipment management;
- to provide repair management;
- to provide management of nuclear / radiation safety;
- to provide qualitative technological processes.

Table 2

Staff of director's deputies at Russian NPPs currently in operation

Deputy of director	NPP with WWR reactor				NPP with RBMK- reactor		BN-600	EGP-6
	Balakovskaya 4x1000	Kalininskaya 2x1000	Kola 4x440	Novovoronezhskaya	Kurskaya 4x1000	Smolenskaya 3x1000	Beloyarskaya 1x600	Bilibinskaya 4x12
for common affairs	+	+	+	+	+	+	+	+
for economics	+	+	+	+	+	-	-	-
for personnel and social development	+	+	-	+	+	+	+	+
for capital construction	+	+	+	+	+	+	+	+
for confidentiality	+	+	+	+	+	+	+	+
for safety	+	-	+	-	-	-	-	-
for agriculture	+	-	+	-	+	+	-	-
for social affairs	-	-	+	-	-	-	-	-
for external economical connections	+	-	-	-	-	-	-	-
assistant for common affairs	-	-	-	-	-	-	-	-
assistant for personnel	-	-	+	-	-	-	-	-
assistant for civil protection	-	-	+	-	-	-	-	-
assistant for legal affairs	+	-	-	-	+	-	+	-
assistant for public relation	+	-	-	-	-	-	-	-

Departments reporting to two traditional deputies of director at operating Russian NPPs

Deputy of director	Name of NPP	TPD	RCH	ACE	SD	CMD	PSI	S	ITS	HE	SDD	TDD
for common affairs	Balakovskaya	+	-	-	-	-	+	-	-	-	-	+
	Kalininskaya	-	-	-	-	-	-	-	-	-	-	-
	Kola	+	-	-	-	-	+	-	-	+	-	-
	Novovoronezhskaya	+	-	-	-	+	+	-	-	-	-	-
	Kurskaya	+	+	-	-	+	-	-	-	+	-	-
	Smolenskaya	+	+	-	-	+	-	-	-	-	-	+
	Beloyarskaya	+	+	+	+	-	-	-	-	-	-	-
	Bilibinskaya	+	-	-	-	+	-	-	-	+	-	-
for personnel and social development	Balakovskaya	-	-	-	-	+	-	-	-	-	+	-
	Kalininskaya	+	-	+	-	+	+	-	+	-	-	-
	Kola	-	-	-	-	-	-	-	-	-	-	-
	Novovoronezhskaya	-	-	+	-	-	-	-	-	-	-	-
	Kurskaya	-	-	-	-	+	-	-	-	-	-	-
	Smolenskaya	-	-	-	-	-	+	-	-	-	-	+
	Beloyarskaya	-	-	-	-	+	+	+	-	-	-	-
	Bilibinskaya	-	-	-	-	-	+	-	-	-	-	-

TPD Transporation Department
 RCD Repair Construction Department
 ACE Agricultural Economy
 SD Department for Supply
 CMD Communal Department
 PSI Pre-School Institutions
 MS Medical Support
 ITS Industrial Technical Schools
 HE Hotel Economy
 SDD Department for Social Development
 TDD Trade Department

Also some posts of chief engineer deputies exist and their functions are to organize the management of concrete elements of technological process.

Table 4 presents a staff of chief engineer deputies at Russian NPPs.

Interviews of NPP staff showed that the number and qualification of chief engineer deputies depends on following factors:

- competence of chief engineers and their traditional deputies for operation and repair;
- structure of main NPP equipment;
- 1st level managers are not financially interested to decrease the management expenditures.

Double reporting of industrial technological structures is layed in guiding documents (statements about structural department) that mention the reporting to director - in administrative-economical activity and to chief engineer - in industrial activity.

Since chief engineers of NPP have a number of functional deputies, so industrial technological structures (divisions, departments, laboratories) get at these posts leaders for the decision of questions which are at the competence of these persons.

II LEVEL

II level of NPP administrative management structure is presented by ancillary support departments which are the structural elements that fulfil local functions.

In existing schemes of NPP administrative management functional departments have different reporting to functional and line leaders (see Table 5).

Table 5 shows that II level of administrative structure consists of a lot of departments (often these departments are rather small) that are under wardship of functional leaders. The greatest part of these departments report to director and chief engineer.

Existing practice, personnel policy and structure of salaries at operating NPPs lead to concentration of high skilled specialists in technological and industrial divisions.

At the same time employees of functional departments whose main task to co-ordinate and provide the work of technological divisions in order to reach industrial goals have no sufficient qualification and competence required for successful accomplishment of the functions of these departments.

Arised situation leads to transferring of technological divisions into "natural economy" that concentrate not only the traditional for NPP technological divisions functions but also duplicate functions of departments. The result of this phenomena is a large volume of uneffective work and consequently increase in man-power.

Deputies of chief engineer at operating Russian NPPs

Deputy of chief engineer	NPP with WWR reactors				NPP with reactor	RBMK-	BN-600	EGP-6
	Balakovskaya 4x1000	Kalininskaya 2x1000	Kola 4x440	Novovoronezhskaya	Kurskaya 4x1000	Smolenskaya 3x1000	Beloyarskaya 1x600	Bulibinskaya 4x12
1. for operation	+++	++	+	++	++	++	+++	+
2. for repair	+	+	+	+	+	+	+	+
3. for safety and reliability	-	+	-	-	+	+	-	+
4. for scientific work	-	-	-	-	-	-	+	-
5. for automatic control systems	-	+	-	-	-	-	-	-
6. for upgrading	-	+	+	+	+	+	-	+
7. for new units	-	-	+	-	-	-	-	-
8. for operation of electrical equipment	+	-	+	-	-	-	-	-
9. for quality of assembling	+	-	-	-	+	-	-	-
10. for personnel training	+	-	-	-	-	-	-	-
11. for operational preparedness	-	-	-	-	+	-	-	-

Table 5

Submission of functional department at operating Russian NPPs

Post	Balakovskaya	Kalininskaya	Kola	Novovoronezhskaya	Kurskaya	Smolenskaya	Beloyarskaya	Bilibinskaya
Director	AD II depart. Office IID		AD II depart. Editorial office		AD PED WO&PD CCD ECCD Lawyer	AD PED WO&D Lawyer	AD PED ASSICL II depar. Lawyer	AD PED Lawyer Civil protection
Chief engineer	PTD STID LP&TSD ACSD	PTD	PTD STID E&TD LM	PTD LP&TSD E&TD LM	PTD LP&TSD E&TD LM	PTD Insp. E&TD LM	PTD Insp. LP&TSD E&TD LM	PTD Insp. LP&TSD E&TD
Deputy of director for economics	PED WO&PD	PED WO&PD AD Commercial department Lawyer	PED WO&PD Juridical group	PED WO&PD		-	-	-
Deputy of director for personnel and social development	PD SDD CMD	PD Office AED TPD CMD ACE PSI ITS	PD SDD	PD ACE	PD SDD S&CAD	PD PSI	PD PSI CMD	PD PSI
Deputy of director for confidentially	I depart. Security	I depart. Security	I depart. Security	I depart. Security	I depart. Security	I depart. Security	I depart. Security	I depart. Security

Post	Balakovskaya	Kalininskaya	Kola	Novovoronezhskaya	Kurskaya	Smolenskaya	Beloyarskaya	Bilibinskaya
Deputy of director for capital construction	CCD	CCD	CCD	CCD	CCD	CCD	CCD	CCD
Deputy of director for safety	NSD LM	-	NSD	-	-	-	-	-
Deputy of chief engineer for operation	Duty staff	Duty staff E&TD	Duty staff	Duty staff	Duty staff	Duty staff	Duty staff	Duty staff
Deputy of chief engineer for repair	PPRD	PPRD RCD LM	RCD	PPRD RCD CRD	PPRD	PPRD CRD	CRD	PPRD RCD CRD
Deputy of chief engineer for safety	-	NSD RSD LP&TSD	-	-	NSD ACSD	NSD LP&TSD LM ACSD	-	NSD LM
Deputy of chief engineer for ACS	-	ACSD	-	-	-	-	-	-
Deputy of chief engineer for electrical equipment operation	ACSD	-		-	-	-	-	-
Deputy of chief engineer for upgrading	-	Reconstruction group			Reconstruction group		-	-
Deputy of chief engineer for science	-	-	-	-	-	-	NSD STD	-

Post	Balakovskaya	Kalininskaya	Kola	Novovoronezhskaya	Kurskaya	Smolenskaya	Beloyarskaya	Bilibinskaya
Deputy of chief engineer for personnel training	E&TD	-	-	-	-	-	-	-

- | | | | |
|-------|--|-------|---|
| AD | Accounting Department | CMD | Communal Department |
| IID | Information Inquiry Department | AED | Administrative Economical Department |
| PED | Plan Economical Department | TPD | Transportation Department |
| WO&PD | Work Organization and Payment Department | ACE | Agricultural Economy |
| CCD | Department for Capital Construction | PSI | Pre-School Institutions |
| ECCD | Department for External Commercial Communications | ITS | Industrial Technical Schools |
| ASICL | Laboratory of Automatic Systems for Industrial Control | S&CAD | Department of Social and Communal Affairs |
| PTD | Plan Technological Department | NSD | Nuclear Safety Department |
| STID | Department of Scientific and Technical Information | PPRD | Department for Plan Preventive Repair |
| ACSD | Department of Automatic Control Systems | RCD | Repair Construction Department |
| E&TD | Department of Staff Exercise and Training | CRD | Division for Centralized Repair |
| LM | Laboratory of Metals | STD | Scientific Technical Department |
| SDD | Department for Social Development | | |

As an example at some NPPs where organization and execution of equipment repair are carried out by centralized plant services, operation divisions (reactor division, turbine division) have their own structures and teams of workers for repair preparedness and execution because (questioning materials) qualification and competence of PPRD employees don't allow to form acceptable plan of repair. Repair staff of CRH and attracted contracted organizations can not operatively respond to arising needs concerning small repairs which decrease the reliability of main equipment operation.

Insufficient personnel competence and disadvantages of administrative management structures are compensated by increase of man-power providing repair management and execution.

Therefore the first main disadvantage of the II level of administrative management structure is low qualification of ancillary support department employees and as a result the functions of these departments have to be fulfilled by technological divisions themselves and as a result number of technological divisions staffs increases.

Another disadvantage of the II level of existing administrative structure is dispersion of functions designated to one task between different independent departments that frequently report to different functional leaders. As an example problems of NPP safe operation are solved by LP&TSD, NSD, RSD, laboratories and inspections. Such type of structure doesn't promote an establishment of balance between procedure provision of NPP safety and operated equipment (programmes for supervision, improvement of procedures, personnel training) and also such type of structure doesn't permit to solve the problem of NPP safety complexly.

III LEVEL

III level of administrative management structure is presented by technological industrial divisions which may be divided on main and auxiliary divisions.

Main divisions that realize the basic industrial functions are the following:

- reactor division;
- turbine division;
- electrical division;
- control & instrumentation division;
- chemical division.

Auxiliary divisions are the following:

- division for centralized repair;
- repair construction department;
- fanning and conditioning division;
- heat supply and underground communication division;
- hydrotechnical division;
- decontamination division.

The reasons of main and auxiliary divisions existence in administrative management structure are the following:

- different infrastructures of NPPs location;
- different departmental belonging of NPPs during their commissioning;
- difference of NPPs designs;
- different conceptions of equipment repair;
- different concepts of equipment operation.

Table 6 presents the variation of existing divisions in management administrative structures at operating Russian NPPs.

In accordance with fulfilled functions industrial divisions may be divided into operation:

- reactor division;
- turbine division;
- chemical division;

repair:

- division for centralized repair;
- repair construction department;

divisions combining operation and repair functions:

- electrical division;
- control and instrumentation division;
- hydrotechnical division;
- heat supply and underground communications division.

Internal structure of divisions is full of small departments and as a result has a lot of leaders (chief foremen and foremen); working places in divisions are duplicated due to bad work of horizontal communications.

Other reason that doesn't permit to decrease staff quantity during organizational measurements is insufficient NPP provision by control and instrumentation means. As a result people have to work instead of instruments carrying out a lot of work manually.

The same thing may be said about NPPs provision with technical means of automatic control systems which allow to decide tasks of material technical supply, economics, accounts, work normalization, metrological provision, etc.

Above mentioned reasons and other factors during last years provide stable tendency to increase industrial staff number at operating NPPs. The consequence of this thing is increase of staff coefficient and rise of produced energy price.

Table 7 presents data for staff number and staff coefficients at operating NPPs.

Table 6

Variation of divisions in administrative management structures at operating Russian NPPs

Divisions	N P P							
	Balakovskaya	Kalininskaya	Kola	Novovoronezhskaya	Kurskaya	Smolenskaya	Beloyarskaya	Bulibinskaya
RD	++	+	+	+	+	+	+	-
TD	++	+	+	++	+	+	+	-
ED	+	+	+	+	+	+	+	+
C&ID	+	+	+	+	+	+	+	+
CD	+	+	+	+	+	+	+	-
CRD	+	+	+	++	+	+	+	+
F&CD	+	+	-	-	-	-	+	-
HTD	-	-	-	-	+	+	-	-
CID	+	-	-	+	+	+	+	+
DCD	+	+	+	+	+	+	+	-
RCD	+	+	+	+	+	+	+	+
TPD	-	-	+	-	-	+	-	-
ATD	-	+	+	+	+	+	+	+
RTD	-	-	-	+	-	-	+	+

RD Reactor Division
 TD Turbine Division
 ED Electrical Division
 C&ID Control and Instrumentation Division
 CD Chemical Division
 F&CD Fanning and Conditioning Division

HTD Hydrotechnical Division
 CID Heat Supply and Underground Communications Division
 DCD Decontamination Division
 RCD Repair-Construction Department
 A&TD Adjustments and Test Division
 TPD Transportation Department
 RTD Reactor-Turbine Division

Table 7

Staff number and staff coefficient at operating Russian NPPs

NPP	Prescribed power, MVt	Staff number			Staff coefficient		
		1991	1992	1993	1991	1992	1993
Balakovskaya	3000	3379	3591	3573	1,12	1,2	1,25
Kalininskaya	2000	2668	2930	3100	1,33	1,46	1,55
Kola	1760	2431	2528	2517	1,38	1,44	1,43
Novovoronezhskaya	1834	3415	3609	3635	1,55	1,96	1,98
Kurskaya	4000	4774	5487	5584	1,19	1,37	1,39
Smolenskaya	3000	3545	4070	4275	1,18	1,35	1,42
Beloyarskaya	600	1841	1883	1874	3,06	3,14	3,12
Bilibinskaya	48	657	729	718	13,68	15,18	14,95

3 ANALYSIS OF OPERATING MANAGEMENT STRUCTURES

The main functions of operating management is the continuous care about NPP systems.

Managers of shift staff are responsible for NPP operation:

- dispatcher of NPP;
- director of NPP;
- shift supervisor of NPP unit;
- deputy shift supervisor of NPP unit

Organizational principles reflected in the orders of Ministry of Energy permit to realize operating service by five shifts for personnel of main divisions with unhealthy conditions of work and by four shifts for the rest operating staff. Hereby the reserve shift exists which compensates the waste of working time of permanent shift staff, conditioned by necessity of physical staff rehabilitations, vocations, staff illnesses, etc.

The main function of NPP shift staff is operating the main and auxiliary systems in order to maintain or to change power level in accordance with dispatcher's schedule. Shift staff is divided on separate divisions according to division sign.

Deviations from the operating management structures prescribed by Ministry of Energy are the result of the following factors:

- individuality of every NPP design;
- different level of interdivision and interplant cooperation;
- different development level of systems or components;
- restrictions in staff recruitment and staff qualification.

Shift supervisors (duty engineers) of technological divisions realize management of shift staff.

Thus shift staff of NPP has double reporting that is shown in simplified form at Figure 5.

Figure 5 presents scheme of NPP shift staff reporting.

Such structure has positive and negative sides.

The advantage that is shift staff of technological divisions (ED, C&LD, CD) has cooperative connections with repair staff of these divisions and this fact influences positively on increase shift staff skill level and also it fact helps to solve the common for shift and repair problems on the division level.

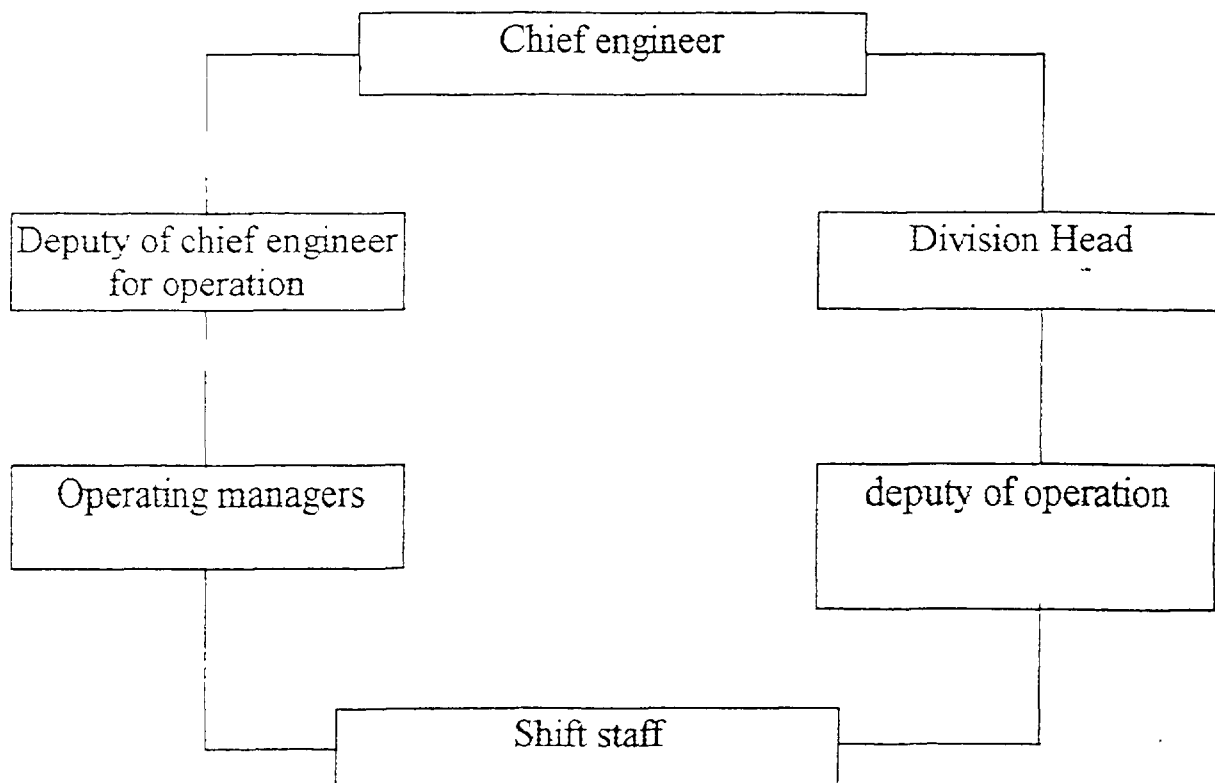


Figure 5. Organizational chart of NPP shift staff reporting.

The disadvantages of the division principle of operating management are the following:

- shift staff has no control nor surveillance on the systems during commissioning and have therefore no influence on potential safety issues;
- absence of shift staffs functional co-operative leads to an increase in staff number;
- information flow about the systems state from divisions to department heads is not completed and complex.

Under such kind of plan system PPRD is not able to provide all the divisions with valuable and convenient for all the divisions complex repair plan.

Analysis of the results of management staff questioning showed that the most part of respondents on all the management levels consider that management structure with the division of repair and operation functions from one side and operating management and maintenance functions from the other side is more expedient and effective.

Figure 6 presents the scheme of functional distribution and interaction between NPP divisions under operating management.

Presence of zones of shift staff mutual functioning decreases complexity of operating management task and it leads to increase of staff actions non-coordination and to reduction of equipment operation safety.

Analysis of leadership questioning showed that majority of respondents consider the creation of NPP operating management structure where operating staff is indivisible association with indivisible leadership, more expedient and more effective.

4 CONCLUSIONS

Management structures at operating NPPs do not satisfy the principles, recommended by the scientific organization of labour:

- management standard for the I level managers is rather exceeded. Number of management subjects (department, division, functional leaders) submitted directly to chief engineer in administrative management structures of operating NPPs is 12-17;
- one-man management as a basic principle of management is absent in organization of management of technological divisions (ED, C&ID, CD) that fulfil repair, operation and operating management functions. It is the reason that departments get excluding each other orders of different priority and as a result it leads to reduction of NPP operation safety and reliability. All the divisions have multifunctional reporting. Number of functional connections "leader - executor" depends on the number of functional deputies of the I level managers:
- industrial technological divisions that nominally are the equipment keepers have no all the rights and responsibility sufficient for successful economic activity. As a rule tendency to give technological divisions large volume of rights and responsibility (self-dependence in material and financial chargment, in forming of technical and personnel policy, etc.) leads to more significant break of technical policy, to increase of unreclaimed material resources storages, to increase in man-power, to increase of ineffective work use.

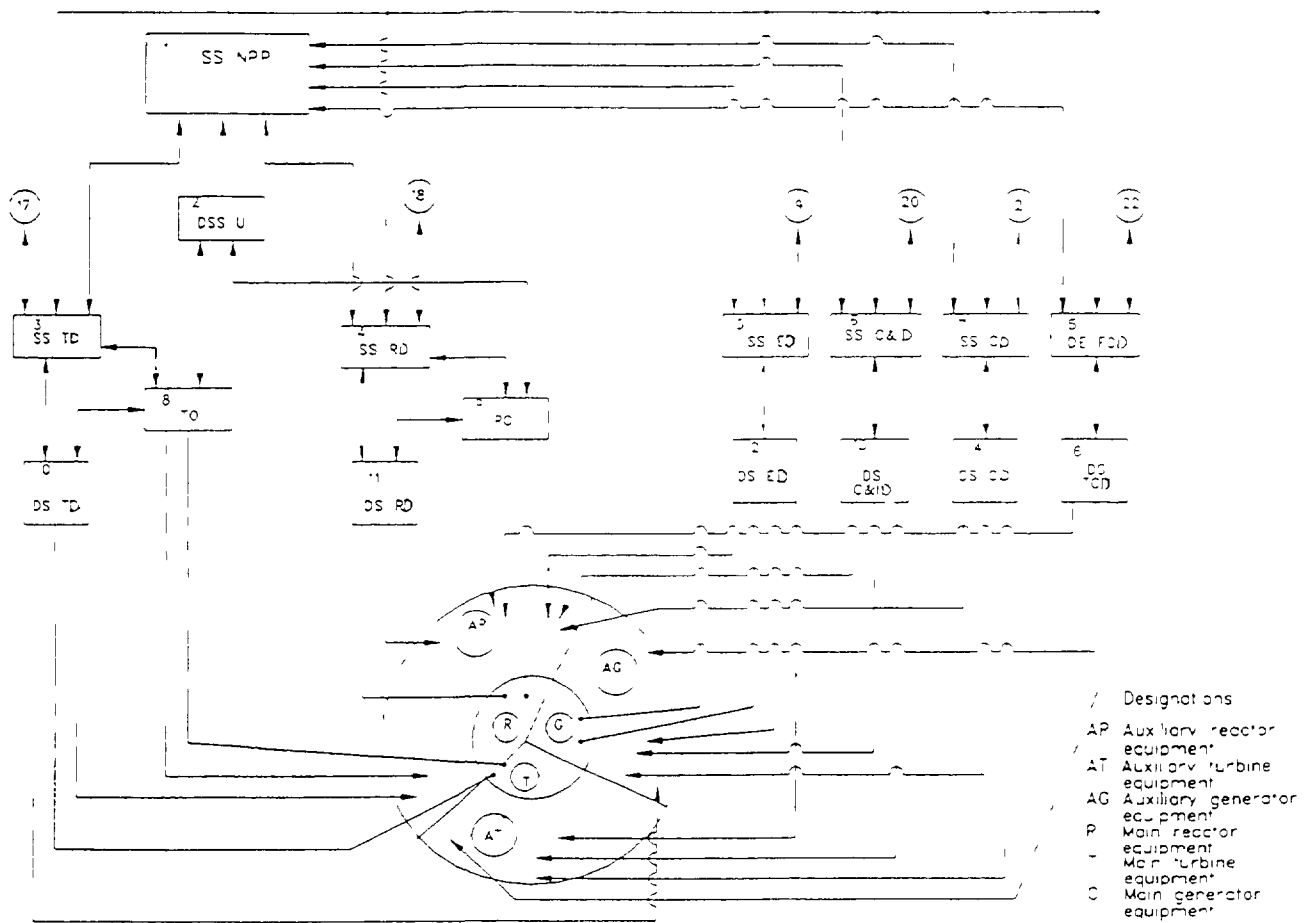


Figure 6. Scheme of functional distribution and interactions between NPP divisions.

Abbreviations for Figure 6

SS NPP	Shift Supervisor of NPP
DSS U	Deputy of NPP Unit Shift Supervisor
SS TD	Shift Supervisor of Turbine Division
SS RD	Shift Supervisor of Reactor Division
SS ED	Shift Supervisor of Electrical Division
SS C&ID	Shift Supervisor of Control and Instrumentation Division
SS CD	Shift Supervisor of Chemical Division
TO	Turbine Operator
RO	Reactor Operator
DS TD	Duty Staff of Turbine Division
DS RD	Duty Staff of Reactor Division
DS ED	Duty Staff of Electrical Division
DS C&ID	Duty Staff of Control and Instrumentation Division
DS CD	Duty Staff of Chemical Division
DE ECD	Duty Engineer of Fanning and Conditioning Division
DS FCD	Duty Staff of Fanning and Conditioning Division

Designation on the figure 6

Main functions of NPP operating management

1 - 2	Direction about schedule of power load Direction about operating plan of equipment operation during shift duration General management.
2 - 1	Information about operating state of main equipment.
1 - 4	General management of shift staff of reactor division. Direction about operating plan of equipment operation during shift duration.
4 - 1	Information about operation of auxiliary systems and main reactor equipment.
1 - 3	General management of shift staff of turbine division Directions about operating plan of equipment operation during shift duration.
3 - 1	Information about operation of auxiliary systems and main turbine equipment.

Designation
on the figure 6

Main functions of NPP operating management

1 5	General management of shift staff of electrical division Direction about schedule of power load Direction about operating plan of equipment operation during shift duration
5 1	Information about operation of main and auxiliary equipment of electrical division
1 6	General management of shift staff of control and instrumentation division
6 1	Information about operation of auxiliary systems of main equipment
1 7	General management of shift staff of chemical division Direction about operating plan of equipment operation during shift duration
7 1	Information about operation mode of auxiliary systems of main equipment
3 4 5 6 7	Divisions interactions directing on state changes of main and auxiliary equipment
2 8	Direction about schedule of power load
2 9	Direction about operating plan of equipment operation during shift duration To supervise changes of main equipment operation mode
9 2	Information about operating state of main reactor equipment
8 2	Information about operating state of main turbine equipment
3 8	Instructions dealing with mode conducting and with specific features of equipment operation Directions about switching in the schemes of auxiliary systems To supervise changes of operation mode of main and auxiliary turbine equipment
9 - 3	Information about operation of main and auxiliary turbine equipment
3 10	Directions about concrete tasks dealing with execution of operating maintenance To supervise work of shift staff Instructions dealing with tasks execution
10 3	Information about operation of main and auxiliary equipment
9 10	Operating directions about manipulations with the equipment that is not under turbine operator control
10 9	Information about operation of main and auxiliary equipment
4 9	Instructions dealing with mode conducting and with specific features of equipment operation Directions about switchings in schemes of auxiliary systems To supervise changes of operation mode of main and auxiliary reactor equipment
9 4	Information about operation and operating state of main and auxiliary reactor equipment
9 11	Operating directions concerning manipulations with the equipment that is not under reactor operator control
11 9	Information about operation and operating state of main and auxiliary equipment
4 11	Directions concerning concrete tasks dealing with execution of operating maintenance To supervise work of shift staff Instructions concerning tasks execution
11 4	Information about operation of main and auxiliary reactor equipment
5 12	Directions concerning concrete tasks dealing with the execution of operating maintenance
6 13	To supervise work of shift staff
7 14	Instructions concerning tasks execution
15 16	Information about operation and operating state of main and auxiliary equipment of technological divisions
12 5	
13 - 6	
14 7	
16 15	
1 15	General management of shift staff of fanning and conditioning division Directions concerning operating plan of equipment operation during shift duration
15 1	Information about operation mode of fan and conditioning systems
3 17	Information about state of operated equipment.
4 -18	Information about defined failures and deviations from normal operation of equipment.
5 -19	
6 20	
7 21	
15 22	
17 3	Administrative management of shift staff of division
19 5	Demands to change operating state of equipment
20 6	Information about fulfilled repair of equipment and operation abilities of equipment
21 7	
22 15	

For repairs operating NPPs use both its own personnel and personnel of their contractors. NPPs administration can compare the expenditures of repair performed by its own forces and by contractors. It becomes clear that repair performed by NPP own forces is cheaper and more effective because cost of hired worker is higher than cost of NPPs worker under equal productivity. These comparisons evidently impel NPP administration to create in structure of NPP mighty repair departments which may provide completely repair of NPP equipment.

However NPP administration even under existence of powerful repair base doesn't refuse from the service of contractors by the following reasons:

- large time interval between reservation of equipment and spare parts for repair performance and beginning of repair itself and also because of impossibility of prompt (in extraordinary cases) purchase of equipment and spare parts by NPP without contractors participation;
- imperfection of perspective planning.

It brings to the fact that in order to buy some critical equipment and materials (cables, devices, tubes and others) NPP has to pay not only for bought things themselves but also for assembling work that is not fulfilled by contractors.

Creation of mighty repair structures that can not be used completely during interrepair cycles stipulates for uneffective utilization of high skilled specialists; creation of working places that are used only seasonally; increase of staff coefficient; increase of load on social sphere that leads to deterioration of social climate in the towns where NPPs are placed.

However economical situation in the country arised in such a way that at present energy branch has unloaded repair and construction organizations that compete for receipt of contracts and it presupposes improvement of service, of repair quality and decrease of their cost (or slowing down of cost rise tendency).

Dispersion of nuclear, technical, radiation and fire safety problems between different departments (RSD, NSD, LP&TSD, technical inspectorate, etc.) makes very difficult complex decision of NPP technological processes safety provision.

Dispersion of functions of social objects management between I level leaders (director, deputy of director for personnel and social development) doesn't promote to complex decision of social sphere development.

Operating management structures at operating NPPs are realized in accordance with principle of division of NPP equipment management responsibility between technological divisions.

Shift staff of technological divisions has double reporting:

- to leadering shift staff on the line of operating management;
- to leadership of technological division on the line of administrative management.

Technological equipment of NPP consists of complex systems. Their separate elements are in disposal of different technological divisions. Information about operation state of equipment from shift staff comes by two ways:

- to operating leadership;
- to leadership of technological divisions.

Operating leadership analyses coming information and makes decisions about the current operation ability in the boundaries of its competence.

Leadership of technological division gets information from shift staff (only about complex system), makes decision about operation of equipment that is under this technological division supervision and creates repair plan of its part of complex system.

General system plans for equipment repair during plan preventive repair are developed later on base of technological divisions plans and then are handed in technological divisions for execution.

This system of repair planning and organization is unadequate. The reasons are the following:

- dispersion of complex information about state of technological systems on the first stage of its forming;
- insufficient qualification of PPRD employees that doesn't permit to create and to improve repair plans of technological divisions;
- disconnection of technological divisions which is conditioned by NPP management structure;
- unclear interpretation of notions "customer" and "executor".

As a consequence of unsatisfactory planning and organization of repair there are delays in terms of repair campaigns, groundless waste of resources, reliability deterioration, power underproduction.

Administrative reporting of shift staff to leadership of technological division leads to reduction of qualitative equipment commissioning probability.

Shift staff has to stop commissioning of equipment after repair defining its insufficient quality for long operation. However unreliable equipment may be put into operation because it is profitable to administration of technological division by some local interest (mostly shift staff of technological divisions depends on division administration but not on operative leadership).

During further operation insignificant latent failure may be resulted by severe accident.

Thus the reduction of pre-start operation verification of equipment conditioned by double reporting of shift is resulted by deterioration of NPP reliability.

Division of shift staff in accordance with division sign doesn't create desire to decrease shift staff number, promotes the development of conflicts between duty shift staffs of different departments in zones of responsibility delimitation.

Inquest of NPP leadership confirms unperspectiveness of exist practice and personnel polity in NPPs management structures. Majority of opinions of all levels respondents persuade to organize functional (without divisions) management structure with potent functional departments that are able to form current and perspective policy.

LIST OF ABBREVIATION

ACE	Agricultural Economy
ACS	Automatic Control Systems
ACSD	Department of Automatic Control Systems
AD	Accounting Department
AED	Administrative Economical Department
ASICL	Laboratory of Automatic Systems for Industrial Control
A&TD	Adjustments and Test Division
CCD	Departement for Capital Construction
CD	Chemical Division
CID	Conventional Installation Division
CMD	Communal Department
CRD	Division for Centralized Repair
C&ID	Control and Instrumentation Division
DCD	Decontamination Division
DE ECD	Duty Engineer of Fanning and Conditioning Division
DS CD	Duty Staff of Chemical Division
DS C&ID	Duty Staff of Control and Instrumentation Division
DS ED	Duty Staff of Electrical Division
DS FCD	Duty Staff of Fanning and Conditioning Division
DS RD	Duty Staff of Reactor Division
DSS U	Deputy of NPP Unit Shift Supervisor
DS TD	Duty Staff of Turbine Division
ECCD	Deparment for External Commercial Communications
ED	Electrical Division
ETE	Electro-Technical Equipment
E&TD	Department of Staff Exercise and Training
F&CD	Fanning and Conditioning Division
HE	Hotel Economy
HS&UCD	Heat Supply and Underground Communications Division
HTD	HydroTechnical Division
IID	Information Inquiry Department
ITS	Industrial Technical Schools

LM	Laboratory of Metals
LP&TSD	Department of Labour Protection and Technical Safety
MS	Medical Support
NPP	Nuclear Power Plant
NSD	Department of Nuclear Safety
O	Operation
OM	Operating Management
PD	Personnel Department
PED	Planning Economical Department
PPRD	Department for Plan Preventive Repair
PSI	Pre-School Institutions
PTD	Planning Technological Department
R	Repair
RCD	Repair Construction Department
RD	Reactor Division
RO	Reactor Operator
RSD	Department of Radiation Safety
RTD	Reactor Turbine Division
SD	Department for Supply
SDD	Department of Social Development
SS CD	Shift Supervisor of Chemical Division
SS C&ID	Shift Supervisor of Control and Instrumentation Division
SS ED	Shift Supervisor of Electrical Division
SS NPP	Shift Supervisor of NPP
SS RD	Shift Supervisor of Reactor Division
SS TD	Shift Supervisor of Turbine Division
STD	Scientific Technical Department
STID	Department of Scientific and Technical Information
S&CAD	Department of Social and Communal Affairs
TD	Turbine Division
TDD	Trade Department
TE	Technological Equipment
TO	Turbine Operator
TPD	Transportation Department
WO&PD	Work Organization and Payment Department

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MMI: THE MAN-MAN INTERFACE

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Abstract

An investigation on human performance and job satisfaction of individuals was performed in all Swiss Nuclear Power Plants in 1980/81. The objective of the study was to identify and to remove potential deficiencies that may have a negative impact on the safety of the plants in order to prevent severe nuclear accidents in Switzerland. The analysis indicated a good performance of the plants' staff. No severe deficiencies were recognized but some areas were identified with a potential for improvement. A recent review of the report indicated the lack of communication as a common cause for some of the recognized problems. Possible reasons for the problem and recommendations for solutions are discussed.

INTRODUCTION

In the follow up of the TMI-accident, it has become apparent that the Man Machine Interface (MMI) i.e. the alarm representation, the plant performance information systems etc. has to be improved. At the same time it was recognized that there was also a potential to improve performance on the human side e.g. to improve training, cognitive skills etc.

The Swiss Federal Council decided to have a closer look at the Swiss Nuclear Power Plants in order to evaluate their safety performance and to identify appropriate measures to prevent accidents in Switzerland which could be like the one at TMI.

The Swiss Federal Nuclear Safety Inspectorate (HSK) was asked to investigate technical aspects of the plants but also to evaluate the human performance of those personnel who have a high influence on the safety of the Swiss Nuclear Power Plants.

A working group was formed, consisting of 8 representatives of the 4 Swiss NPPs (3 in operation, 1 still under construction at that time), 2 psychologists from the Institute for Applied Psychology in Zurich (IAP) and 2 members from the HSK. The group developed an investigation programme, based on a questionnaire.

The aim of the programme was, to verify 3 hypotheses:

1. The management of Swiss NPPs satisfies the requirements for safe operation.
2. Attitudes necessary in accident situations have to be present also during normal operation.
3. The attitudes of individuals are determined by different factors:
 - technical factors
 - human relations
 - personal factors

this implies that a rational behaviour always has an emotional background.

The investigation was performed during 1981/1982. The hypotheses were confirmed and the results showed no explicit need for improvement.

More than ten years later the report has been reviewed from both a distant and also a different point of view and some additional findings identified.

THE INVESTIGATION PROGRAMME

PREPARATION

The investigation was intended to include groups of personnel that have a significant influence on the safety of NPPs. They were identified as

1. Managers (Plant Manager, Department Heads, Section Heads): 35 individuals
2. Emergency staff: 9 individuals (some of whom are a member of group 1)
3. Shift Supervisors and Picket-Engineers (safety engineers): 47 individuals
4. Licensed Operators (63 individuals)

The investigation group created a draft questionnaire which had to undergo a test run with members of the evaluation group (1). The results were fed back into the questionnaire which was modified accordingly.

DATA ACQUISITION

The investigation of all the groups took place during 1980/1981.

Before starting the action, some introductory statements clarified the intent and the seriousness of the investigation:

- the interviews will have no direct consequences to the individual
- the interviews are not a qualification process of the individuals nor a psychological test
- every open and frank answer is an essential contribution to the safety of the plant
- the whole investigation will be performed on an serious, neutral and anonymous basis.

QUESTIONNAIRE

CONTENT

The questionnaire was structured in order to address different areas of management and operation listed below. The individuals had to indicate the relevance of the issue (weight) and how they feel it is realized at the NPP (rating).

TECHNICAL ISSUES

need of individuals for training
evaluation of training
evaluation of the technical competence
quality of the review process on procedures
information processing in the team
time resources
ergonomy in the plant

PERSONAL / INDIVIDUAL ISSUES

- personal satisfaction
(job security, salary, relationship to chief and colleagues, career development, opportunities for personal development, appreciation ...)
- need for more competence and knowledge
(training, instructions, methods ...)

- personal responsibilities
- responsibility of other team members
- personal self assessment

MANAGEMENT ISSUES

- knowledge about the managements' objectives and their implementation
- application of technical competence of individuals
- distribution of competence within the team
- personal competence
- collaboration with the chief
- supervision by the chief
- satisfaction with the management style
- information transfer on safety relevant issues
- critical operational situations
 - personal experience
 - behaviour of the chief
 - behaviour of the Picket Engineer

TEAM ISSUES

- team characteristics / distribution of responsibility
- team integration
- personal work load within the team
- behavioural changes for different tasks

ORGANIZATIONAL ISSUES

- work environment (working place, cleanliness, workload, physical environment, stress, shift schedule, communication)
- picket organization
- security measures
- performance of the organization
- personal satisfaction
 - (general, with present position)
- prerequisites for satisfaction

COMPANY ISSUES

- procedure to replace vacant position
- increased requirements on the individual due to organizational and environmental changes
- needs for internal training (e.g. requirement of the regulatory body, motivation, operational need ...)

ANALYSIS

The analysis of the questionnaire tried to identify general and common properties of all NPPs, properties within individual NPPs, general properties of the different functional groups and properties of the different functional groups at each NPP.

RESULTS

As an overall result, no severe behavioural or organizational deficiencies with an impact on the safety of the plants could be identified. There was no immediate need for improvement in any area. At the one plant under construction, within the crew waiting already a longer time for startup, some indications of a lower motivation could be recognized.

Within all investigated groups, technical aspects had a high importance already for normal operation while human behavioural aspects were not treated with the same priority.

Today, many years after the completion of the project, a deeper insight into the analysis indicates that the reason for many of the low rated issues can be attributed to one common cause:

The **Man Man Interface, communication.**

CONCLUSIONS:

Poor communication is not a specific problem of NPPs but also applies to many other organizations, especially to those operating within a technical field.

Three areas of communication may be addressed:

- a) communication between individuals
- b) communication within the line organization (top down and bottom up)
- d) interdepartmental communication

What is the reason for?

COMMUNICATION BETWEEN INDIVIDUALS

The reason of an individual to chose a certain profession is very much based on his character and on his attitudes. Many technical people are more introverted and do not show or develop the same communication skills that may be recognized within profession groups in less technically oriented organizations.

Additionally, during their career-development, there is no direct need for them to acquire or to develop such skills. Technical people may communicate very efficiently about technical issues but they may run into trouble while performing communication in normal human relationship in their daily work.

How can this be improved?

Engineers in management positions have to undergo basic and repeated management training.

All members of the staff (mainly technical people) have to be aware of the potential communication problems and an appropriate training has to be applied where necessary.

Informal events may foster the communication within individuals.

COMMUNICATION WITHIN THE LINE ORGANIZATION

Lack of official communication rules (regular reports and meetings with clearly defined content and objectives), lack of practice in communication (missing follow up of once introduced organizational measures), lack of a systematic review of the need for such rules.

How can top down and bottom up communication be improved?

Define clear ways and rules for official communication. Clearly define responsibilities and make decision processes transparent. Let people participate on decisions as far as possible.

LACK OF INTERDEPARTEMENTAL COMMUNICATION

NPPs usually have a strong vertical organization structure which is not very suitable for an efficient interdepartemental communication.

Areas of responsibility are almost predefined in a NPP (operation, electrical and mechanical maintenance, radioprotection, chemistry). They may be easily mapped onto a vertical organization structure. Additionally the organization of an NPP is very often grown historically, starting by the construction project and ending with the operational organization.

How can interdepartemental communication be improved?

Keep the organisation transparent. Create and maintain an open information policy, define and accept clear ways of communication. Implement or improve training on "how to perform within a matrix organization". Practice the matrix organization in interdepartemental projects.

WHAT HAS BEEN DONE?

In Swiss Nuclear Power Plants, the management but also all Picket Engineers and Shift Supervisors undergo a basic management training that addresses also team behaviour and of course communication. This training is repeated every several years. Communication problems are also addressed to operators during their classroom and simulator training based on observed situations, events in the own plant, international experience or findings from other industries.

It appears that the communication problem (that may have even a basic Swiss cultural background) is recognized at the powerplants and adequate measures have been taken to overcome it.

SAFETY CULTURE

INSAG-4 defines safety culture as "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".

Pointing to the individual three essential attributes:

- Questioning Attitude
- Rigorous and Prudent Approach
- **C o m m u n i c a t i o n**

Keeping the inherent and underlying problem of technical people in mind, and fighting against it with adequate measures like management and team training, will be a significant contribution to safety culture but also to a better understanding of decision processes within an organization, and as a consequence, a better motivation of individuals.



ANALYSIS OF HUMAN FACTORS IN INCIDENTS REPORTED BY SWISS NUCLEAR POWER PLANTS TO THE INSPECTORATE

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Abstract

197 reported incidents in Swiss Nuclear Power Plants were analyzed by a team of the Swiss Federal Nuclear Safety Inspectorate (HSK) using the OECD/NEA Incident Reporting System. The following conclusions could be drawn from this exercise. While the observed cause reported by the plant was "technical failure" in about 90% of the incidents, the HSK-Team identified for more than 60% of the incidents "human factors" as the root cause. When analyzing this root cause further it was shown that only a smaller contribution came from the side of the operators and the more important shares were caused by plant maintenance, vendors/constructors and plant management with procedural and organizational deficiencies. These findings demonstrate that root cause analysis of incidents by the IRS-Code is a most useful tool to analyze incidents and to find weak points in plant performance.

1. Introduction

The Swiss Federal Nuclear Safety Inspectorate (HSK) demands, that Swiss Nuclear Power Plants report all events or any findings in classified systems, that may have an impact on safety. The report should allow HSK to judge the safety significance. Class B refers to incidents or findings of „slight safety relevance. They are registered and evaluated to allow for an early detection of potential weaknesses“. Class B corresponds to level 0 on the International Nuclear Event Scale (INES) of IAEA and OECD/NEA.

The OECD/NEA-Incidents Reporting System (IRS) provides a structured code to analyse and classify incidents. In order

- to become familiar with the IRS-code utilisation,
- to distinguish between the observed, direct cause reported by the plant and the root cause of the incident,
- to find weaknesses in plant performance,

197 reported incidents from Swiss Nuclear Power Plants were analysed by an HSK-team, consisting of a chemist, a physicist and two mechanical engineers. Please note a) the technical background of the team and the absence of any special knowledge in „human factors“, b) the limited number of incidents analysed.

As an introduction **TABLE 1** reviews Swiss Nuclear Power Plants: years of operation, reactor size and type, vendor, further the number and average age of licensed staff. The differences in all aspects are remarkable.

TABLE 1: Overview of Swiss Nuclear Power Plants
(Licensed Staff, Number of Events, - Status 1991)

	KKB Beznau I + II	KKM Mühleberg	KKG Gösgen	KKL Leibstadt
In Operation	1969/1971	1971	1979	1984
Power (Mw _e)	350/350	320	920	942
Type	PWR	BWR	PWR	BWR
Vendor	W	GE	KWU	GE
Licensed Operating Staff	59	34	48	43
Average Age	45.9	47.3	43.6	37.8
Analysed Events	58	35	32	72
Period covered	1/86 - 12/92	4/83 - 12/92	10/81 - 12/92	2/87 - 12/92
Incidents per year	8.3	3.5	2.7	9.0

Concerning the number of incidents per year reported:

- Comparing the older plants KKB and KKM, for two reactors on one site the number doubles.
- Comparing the newer plants KKG and KKL, the first years of operation may be smooth or rough.

2. Observed Cause versus Root Cause

TABLE 2 compares the cause reported by the plant, the observed, direct cause, with the root cause found by the HSK-team.

TABLE 2: Human Factors in Observed Cause and in Root Cause
(Technical Failures Balance to 100 %)

	Observed Cause (%)	Root Cause (%)
KKB (PWR 1969/71)	10	60
KKM (BWR 1971)	9	71
KKG (PWR 1979)	9	72
KKL (BWR 1984)	15	57
TOTAL	12	63

- The observed cause is about 90 % „technical failure“. This means mainly mechanical or electrical failure; a few percents are attributed to chemical or core physics failure and to instrument failure.
- The root cause is in more than 60 % „human factors“, irrespective of the differences between the plants mentioned before.

3. Human factors

Considering the importance of the „human factor“ the IRS-code number 5.2.8 was used to analyse its many facets. See TABLE 3.

TABLE 3: Root Cause Analysis of Human Factors
Classification according to OECD/NEA-IRS-Code Number 5.2.8 (shortened)

- I Operator Error (5.2.8.4)**
 - Error of Omission (5.2.8.4.1)
 - Carelessness, confusion (5.2.8.4.2)
 - Cognitive Error (5.2.8.4.3)
 - Violation of Tech. Spec. (5.2.8.4.4)
- II Maintenance + Repair Error**
 - Inspection, Maintenance (5.2.8.5)
 - Repair, Testing (5.2.8.6)
- III Inadequate Training (5.2.8.9)**
- IV Management + Organisation Deficiency**
 - Procedure Deficiency (5.2.8.3)
 - Communication Problem (5.2.8.7)
 - Work planning Deficiency (5.2.8.8)
- V Design + Construction Deficiency**
 - Design Deficiency (5.2.8.1)
 - Construction Deficiency (5.2.8.2)

For practical purposes the code number is organised in 5 classes, each one addressing a special group or activity:

I Plant operator; II Plant maintenance; III Training; IV Plant management; V Vendor/constructor;

In TABLE 4 all incidents with „human factors“ as a root cause are classified:

TABLE 4: Root Cause Analysis, Classification of Human Factors
(Sum of Human Factors = 100 %)

	KKB PWR 69/71	KKM BWR 1971	KKG PWR 1979	KKL BWR 1984	TOTAL
I Operator Error	6	12	17	24	15
II Maintenance + Repair Error	26	36	26	27	28
III Inadequate Training	3	0	0	0	1
IV Management + Organisation Deficiency	37	20	13	12	21
V Design + Construction Deficiency	28	32	44	37	35

- All plants have a rather similar profile.
- Contrary to common opinion, the contribution of the plant operator is small (~ 15 %). Of importance are the shares from plant maintenance (~30 %) and from the external parties vendor/constructor (~35 %).
- Training seems to be adequate (~1 %).

- Plant management contributes a sizeable fraction (~20 %) which needs further discussion.
- In simplified terms the contributions to the root cause may be expressed as follows: Technical Failure 37 %, Human Factors 63 %. The human factors may be divided in two categories

Direct human factors (I + II + III)	28 %
Indirect human factors (IV + V)	35 %
Technical failure/Direct human factors/Indirect human factors	~1/3 : 1/3 : 1/3

4. Management deficiencies

TABLE 5 presents a breakdown of management factors for all plants:

TABLE 5: Root Cause Analysis, - Breakdown of Management + Organisation Deficiency (all Plants, Sum = 100 %)

Procedural Deficiency (Code 5.2.8.3)	46 %
Communication Problem or Error (Code 5.2.8.7)	8 %
Management, Organisation or Work Planning Deficiency(Code 5.2.8.8)	46 %

- Procedural deficiencies are most common (~45 %).
- Organisational factors are of importance (~45 %).
- Communication seems to be satisfactory (~10 %).

5. Summary and Conclusions

197 reported incidents in Swiss Nuclear Power Plants were analysed by a team of the Swiss Federal Nuclear Safety Inspectorate (HSK) using the OECD/NEA Incident Reporting System. This exercise led to the following conclusions:

- The IRS-code system is a most useful tool to analyse the root cause of incidents.
- The reported, observed cause by the plant is about 90 % „technical failure“, the root cause found by the HSK-team is about 60 % „human factors“.
- The root cause „human factors“ shows only a small contribution from the operator (~15 %); more important are the shares of plant maintenance (~30 %) and of vendor/constructor (~35 %).
- Plant management contributes the balance (~20 %). The main factors are procedural deficiencies (~10 %) and organisational deficiencies (~10 %).
- Communication in the plant and training of licensed staff seems to be adequate.
- Expressed in simplified terms, the contributions to the root cause are as follows: Technical failure 1/3, direct human factors (operator + maintenance) 1/3, indirect human factors (plant management + vendor/constructor) 1/3.

As demonstrated, root cause analysis of incidents by the IRS-Code is a most useful tool to find weak points in plant performance. It is recommended that each plant (possibly a central agency)

performs root cause analysis for selected incidents. The experts team should include a „human factors specialist“ (possibly from the outside). The aim of the incident analysis is a) to arrive at a clear understanding of all aspects; b) to propose appropriate actions to prevent recurrence; c) to improve overall plant performance.

Acknowledgement

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A SITUATIONAL APPROACH TO THE MEASUREMENT OF SAFETY CULTURE

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Abstract

Values and social norms are the main target of most approaches to the study of safety culture and many existing survey methodologies directly ask for these norms and values. However, a number of considerations point to the dangers of limiting the evaluation of safety culture to the analysis of these responses. Therefore the necessity is stressed to also consider how actual situations activate norms and behaviours. This relates to the fact that in any given situation both aspects of the appraisal of reality are present: the objective definition of the situation and its personal evaluation. The latter not only reflects the "official" norms and values but also "basic underlying assumptions". The situational approach introduced in this paper confronts people with situations which contain a dilemma with conflicting social norms and where various costs and benefits are associated with different types of behaviour. In addition, the prerequisites and limitations of the situational approach are discussed.

Culture, norms, and situations

One can define Organizational Culture as „a pattern of basic assumptions ... (of the) correct way to perceive, think and feel ...“ (Schein, 1990). This culture is a product of a long learning process, during which a group or an organization develops accepted ways of dealing with its problems. The function of culture is to coordinate the actions of its members by aligning or coordinating their perceptions, thoughts, feelings, and actions. A stable culture can be very comforting to the individual member. It reduces uncertainty by giving interpretation and meaning to events and actions. This anxiety-reducing function of culture is one of the reasons why it is so difficult to change an existing culture, because change may result in a – temporarily – increase of uncertainty (Schein, 1990).

Safety culture is seen as an important factor for an effective safety regime in nuclear power plants. The interest for such an „exotic“ concept like culture is driven by the insight that not everything can be governed by formal regulations and prescriptions (International nuclear safety advisory group (INSAG, 1991).

Culture helps the individual in its appraisal of reality. This appraisal is twofold, consisting of an interpretation of reality — how it is —, and a comparison of this interpretation with a „norm“ — „how it should be“. Directly or indirectly, this appraisal leads to observable „products“ in terms of actual behavior and/or artifacts which are often products of earlier behavior.

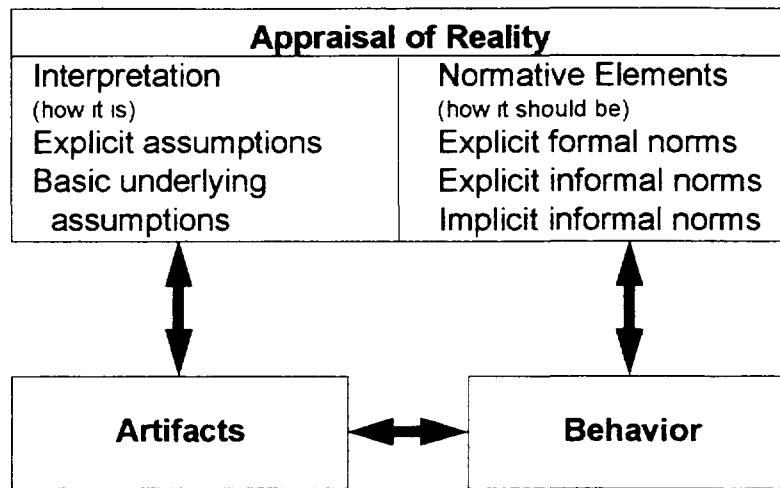


Figure 1 Interrelation of appraisal of reality, artifacts, and behavior

One can distinguish three levels of culture: (a) observable artifacts, (b) values, and (c) basic underlying assumptions (Schein, 1985).

Artifacts and behavior are the first things an outsider can see, feel and hear upon entering an organization. This category includes everything visible — dress codes or tidiness of the workplace as well as availability of manuals, company records, products and annual reports. The main problems with artifacts is – as Schein warns – that they are hard to decipher accurately (Schein, 1985).

Values and social norms are the main target of many approaches to the study of safety culture. Many existing instruments directly ask for such norms and values. One example is the IfAP Security Survey, developed at the Institute of Work Psychology at the Swiss Federal Institute of Technology (Grote and Künzler, 1993). It contains items like „In the case of a conflict, security has priority over production“ or „For each step in the working process it is clear who is responsible.“ The respondents are asked, how „true“ such statements are. In a similar vein, the „Idaho Safety Norm Survey“ (Ostrom, Wilhelmsen et al., 1993) asks for personal norms of safety with items like „In our company, the employees are aware of their part in safety“.

Such questions are very important and indispensable for the assessment of Safety Culture. A number of considerations, however, point to the dangers of limiting oneself to the evaluation of safety culture by directly assessing norms.

1. Not all values and social norms are „official“. Groups have informal norms and values, and these may well be in conflict with official norms (or with the norms of other groups).

Both scientific studies and daily experience, for instance, suggests the existence of "production norms" in teams. They regulate the amount of work that is considered legitimate ("a fair day's work"). If someone produces significantly more („rate buster“) or less („chiseler“) he or she is sanctioned by the group. Similarly, a norm of group-solidarity may forbid to "squeal" which in our case would imply reporting to management possible security problems caused by other members (or even the supervisor) of the group.

Such group norms modify, and may even undermine, the way in which organizational norms are implemented. Such (local) social norms will not show up easily in surveys, and special care has to be taken to unravel them. With regard to safety, such an unofficial social norm could be „Don't be a coward“, „Don't make a fool of yourself“, etc. (In the Swiss construction industry there is a term ("Sicherheitsstündeler") which may best be translated as "safety-fanatic"; needless to add that this term is derogative in meaning.)

2. The organization and its representatives may well communicate conflicting norms. Official policy papers and speeches may state that „security has an overriding priority“ (cf. (International nuclear safety advisory group [INSAG], 1991, p. 1), but everyday behavior of managers may contradict this. Typically, this actual behavior will have more impact than the officially espoused values.

Thus, if a plant manager displays signs of strong irritation in response to a delay in reactor startup, this may well shift the priorities of the team in favor of speed rather than safety, even if this same manager repeatedly emphasizes the absolute priority of safety concerns. These things can happen in a very subtle way, as when a manager praises his team for meeting a deadline that could only be met by taking short cuts and by bending rules...

It is these „theories in use“ that are most important, and not proclamations.

3. Many social norms are very difficult to describe verbally. Just as many people can detect a grammatical error yet may be unable to describe the underlying rule, many norms cannot easily be described but can only be activated in concrete situations, usually by detecting violations of these norms.
4. Social norms are general prescriptions how to do things „right“. Concrete situations, however, typically involve several norms which have to be balanced.

This problem is probably best exemplified by the behavior of children. They often irritate and embarrass adults by insisting on the social norms that they have been taught. Parents scolding their children for publicly saying "Look, Mom, doesn't this man look funny?" may well be confronted with a reply like "But you told me that I should always tell the truth!", because the child has not yet learned to balance the norms of truthfulness and politeness.

In a similar vein, norms of being productive and of being safe, while certainly compatible in the long run, may well conflict in the short run, requiring a balancing decision from operators.

5. Behavior is governed by many calculations about the desirability and probability of various outcomes. They involve social norms (which may, as pointed out, be conflicting) but also calculations of personal gains, losses, and costs.

To take an example from everyday social life again, many of us have a strong social norm of helping. Nevertheless, many will hesitate to help a man lying in the street in poor cloths and smelling from alcohol, because they instantly calculate the costs of getting involved. There are many documented cases of victims of traffic accidents that have not been helped, even many people witnessing a person being physically attacked often do not intervene. Yet,

when questioned, many of them undoubtedly will endorse the value of helping others when they need help, even though they will not help in many situations.

Similarly, it is easy to agree to the general notion that „Security is topmost priority“, but it may be quite difficult to call the plant manager in the middle of the night in an ambiguous situation which may involve safety risks but also might turn out to be completely harmless and, in the latter case, carry the risk of looking like a fool who cannot master such a situation...

So, norms are one thing, but applying them in concrete situations where so many additional considerations come up, may be quite another one.

6. Not only need norms be balanced with other norms as well as with all kinds of costs and benefits associated with specific behaviors. In many cases it may even not be evident to an individual or a group that a given norm is relevant in a given situation. For example, it is well known that the risks associated with certain actions tend to be underestimated if these actions have been carried out successfully many times (e.g. Reason, 1990). This may lead to the assumption that danger "does not really exist" — or, if so, only for beginners but not for experienced people. Similarly, if a crew feels certain about a diagnosis (e.g. that temperature is okay despite a display signalling temperature to be too high because this signal has been signalling too high values on several occasions), it will perceive things to be "normal".

In these cases, situations may not be defined as situations where safety is an issue. Safety norms may, therefore, not become salient in the minds of the people involved. Only in hindsight, after it has become clear that safety *was* an issue, it looks like it must have been "natural" to activate safety norms in this situation. But in the situation, other issues are salient, such as efficiency; these issues include self-definitions, or identities (e.g. "experienced, non-anxious operator"). That different situations activate different goals, norms, and identities, has been seen as leading to "situational ethics" where norms are violated because they do not appear relevant to the situation at hand (Cropanzano, James, & Citera, 1993).

All this points to the necessity to consider the *situation* and its definition, and all the complex implications for the activation of quite different, and potentially conflicting, social norms, for costs and benefits involved in different behaviors.

It remains, of course, important to directly ask for organizational and social norms. But a thorough investigation of Security Culture must go a step further. It must try to find out how *actual situations* activate norms.

In any given situation both aspects of the appraisal of reality are active: the definition of a situation and its evaluation. Apart from "official" norms and values, it is the „basic underlying assumptions“ which are of utmost importance for these processes. Basic underlying assumptions are defined as „taken-for-granted, underlying, usually unconscious assumptions that determine *perceptions*, thought processes, feelings and behavior.“ (Schein, 1990, p. 112, italics added). They often are so deeply rooted that they are rarely spoken about in the organization, and often people are even not aware that they are operating (this is meant by the term *Unconscious*). Especially important is their influence

on the perception and definition of reality. It is impossible to cope with all information that presents itself at every second in our life. We need rules tell us what to attend to and what to ignore. Assumptions can develop in different ways. Often they are based on experiences or on tradition. Such assumptions could be: „My boss gets very angry if I call him in the middle of the night“. Or „Of these two instruments, one is more reliable than the other one, so, if they contradict, the second one must be broken.“ „I am the only one in our team who does not exactly know how to ...“ These assumptions sometimes seem so obvious and self-evident that they are never tested. So it seems that one aspect of Safety Culture would be that such assumptions are discussed and tested (questioning attitude!). This also means that a very good communication (culture) must be established.

The situational approach

Many social norms, and especially the basic underlying assumption are not „so clear in the open“ that they can be uncovered through direct questions. To take into the consideration the fact that values and assumption express themselves in situation we propose a situational approach. In such an approach, people are not directly questioned about values or norms but are confronted with situations that contain a dilemma, that is conflicting social norms and various costs and benefits associated with different types of behavior. They are asked what they would in such a situation, what they think others would do, how they would expect others to react to their own behavior, etc. (cf. Eder & Ferris, 1989).

Consider the following example for a control room operator (the following examples are for illustratory purposes only. To construct an instrument we would have to collect real situations first).

Situation 1

Imagine you have to restart the reactor after a SCRAM. You have only 20 minutes left to do this, after that period you will have to wait for two days because of the xenon build-up. A number of security checks are advisable. It is unclear whether they can be done in such a short time.

- What do you do?
- How do you proceed?
- What would the others think of your reaction?

The answers could be analyzed with respect to safety procedures, knowledge of regulations, assessment of the riskiness of the situation, conflicting norms or values.

Such a situation could then be further developed in order to assess more specific questions. One such question might be how difficult decisions of this type are taken in the team, whether everybody's opinion is asked for, if dissenting voices are likely, how they are dealt with, etc.

Situation 2

Imagine you have to restart the reactor after a SCRAM. You have only 20 minutes left to do this, after that period you will have to wait for two days because of the xenon build up. A number of security checks are advisable. It is unclear whether they can be done in such a short time.

The shift supervisor decides to give it a try, even though he has to drop a security check. Experience shows that this check is not really necessary because it has always been OK.

- Do you agree with the supervisor's decision?
- Do you think the other members of the team would agree with the decision?
- How would you react if someone raised doubts about the decision?

A further variant may explicitly introduce the aspect of group pressure:

Situation 3

Imagine you have to restart the reactor after a SCRAM. You have only 20 minutes left to do this, after that period you will have to wait for two days because of the xenon build up. A number of security checks are advisable. It is unclear whether they can be done in such a short time.

The shift supervisor decides to give it a try, even though he has to drop a security check. Everybody knows that this check is not really necessary because it has always been OK

The whole team therefore supports the supervisor. But you have your doubts.

- Will you raise your doubts?
- What reaction do you expect from your supervisors and your colleagues?
- Would you insist if they ridicule you, doubt your competence, or the like?

Through this type of questions, the - often implicit - social norms and basic underlying assumptions may be activated through the situational context. Special attention should be given to aspects which involve threats to one's self-worth and positive identity, as in situations where someone might fear to look foolish, anxious, incompetent, stubborn, and the like.

Possible answers to these scenarios can have different formats. The answer may be left to the people being asked (free format). From such answers one often gets important information as to what are the important aspects of the situation for the individual, what associations come up, etc. The disadvantage is that free-format answers are difficult to compare across individuals, groups, or organizations. This is easier in multiple-choice formats, as in the following example.

Possible Answers to Situation 2

1. I have my doubts, but is HIS responsibility
2. I have my doubts, but protests are useless
3. I think he is wrong and I tell him that
4.

Of course, a combination of both is possible, e.g. starting with open answers and then ask for other possibilities which have not been mentioned spontaneously.

Such interviews can be conducted with individuals as well as with groups. The form does not necessarily have to involve interviews; after some experience with this type of assessment it seems quite possible to develop "situational questionnaires" as well.

Describing typical situations: the critical incident interview

The quality of such situational interviews depends to a large extent on the quality of the situations that they are based on. Only to the extent that these situations can be regarded as prototypical for the situations that people encounter, only to the extent that they entail real dilemmata that are accepted by people as realistic, can they yield informative answers. Determining such situations is, therefore, crucial.

Typically, such situational questions are based on the method of "critical incidents" (Flanagan, 1954). Various people with experience in this field are interviewed about incidents that were "critical" in the sense that something did go wrong or almost went wrong. (This does not necessarily pertain to dramatic failures such as accidents; smaller events which may be possible precursors at also of interest!). People are then asked about the characteristics of this situation, how it developed, how people reacted to it, what actions made the situation to wrong or turn worse or, if the situation was mastered, exactly what actions were responsible for this mastery. Actions not taken, such as a group where many members have doubts but do not communicate them, would be included as well, as well as individual thoughts and feelings involved.

With extensive interviewing (combined with observation), a number of situations would be collected. Their descriptions would then have to be discussed with experts (such as operators, supervisors, security personnel etc.), yielding a collection of situations that seem prototypical and realistic both in content and

wording. Similarly, possible reactions of various people or groups would be discussed with these experts in order to reach a collection of answers which may be used in multiple choice alternatives or as probes in interviews.

Prerequisites and limitations of the situational approach

It is evident that the development of instruments based on the situational approach requires a carefully planned effort as well as considerable skill of those who develop it. Expertise in interviewing and behavior observation is, therefore, indispensable, as is experience with the field. A collaboration of social scientists and technical experts seems, therefore, advisable, as well as a collaboration of people within an organization with experts from outside.

Just as any type of questionnaire or interview method, this type of assessment is, of course, subject to responses which are "socially desirable" and thus give a positively distorted view. Besides careful wording of questions and skillful application of interview procedures a climate of trust between those questioning and those being questioned is, therefore, indispensable. Apart from these "validity" issues, however, the situational approach may be an important tool for self-assessment, provoking reflection and communication about the implementation of safety considerations and the adequacy of assumptions that are assumed by everybody to be true.

Finally, this approach is not meant to replace other approaches. Interviews and questionnaires that directly ask for norms, assumptions, and habits, remain important, as well as the analysis of indicators such as incident reports, plant availability, or the like. Given that norms, goals, etc. are activated by and interpreted in the light of specific situations, however, a situational approach seems an important complement to other methods of assessing safety culture.

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RELATIONSHIP BETWEEN ORGANIZATIONAL FACTORS, SAFETY CULTURE AND PSA IN NUCLEAR POWER PLANT OPERATIONS

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Abstract

There are four nuclear safety imperatives or "4Ms": machine (hardware, design, QA/QC), milieu (operating conditions, environment, natural phenomena), man (human reliability) and management (organizational and management influences). Nuclear safety evaluations as well as evolution of its most powerful tool, Probabilistic Safety Assessment (PSA), followed chronologically the 4M constituents. The nuclear industry worldwide, and the nuclear safety regulators in particular, have been preoccupied with the first M almost to the point of obsession with belated and only intuitive interest in the third and fourth M (human dimension). Human factors or ergonomics in the nuclear industry was an afterthought. Human reliability was essentially born in the aftermath of the Three Mile Island (TMI) accident. Impact of organizational factors on nuclear safety is only in the early stages of R&D. This paper describes some of the concepts being pursued by APG to link organizational factors and safety culture to Human Reliability Analysis (HRA) and to integrate such into probabilistic safety assessment (PSA), e.g.[APG, 1993].

BACKGROUND

In the aftermath of TMI, which was not so much with hardware as with how the hardware was employed or not employed, thousands of hardware changes were proposed and many of peripheral public risk impact implemented costing the rate payers billions of dollars. In the aftermath of Chernobyl, which has more to do with safety culture and less with design flaws, western world, with some exceptions, perceives RBMKs as hopelessly flawed in design, construction and maintenance amounting to a view that "a good RBMK is a dead RBMK". The western world perceives, with more exceptions, even Soviet built 440MWe VVERs as inadequate despite their outstanding inherent safety characteristics and a remarkable operating record.

This is not to suggest that the U.S. nuclear industry and the Nuclear Regulatory Commission (NRC) did not react to the lessons learned from TMI and Chernobyl [e.g. Murley, 1990]. The nuclear industry established Institute for Nuclear Power Operations (INPO) which gave dignity to nuclear operations as a separate discipline. The NRC instituted inspection programs as well as a regulatory activity named Systematic Assessment of Licensee Performance (SALP). With the basic research belatedly initiated due to hardware preoccupations, both INPO and the NRC developed approaches, such as SALP, were essentially intuitive rather than based on sound research in the field of behavioral sciences. Hence, organizational influences on nuclear safety remain in the intuitive domain.

Anatomies of catastrophic accidents (e.g. Chernobyl, Bhopal, Challenger, AMOCO Cadiz, Piper Alpha, Exxon Valdez, etc) corroborate conclusively the APG's 4M theory.

Accidents at Chernobyl, TMI-2, Challenger, Bhopal, Exxon Valdez are partially attributable to design flaws ("Machine"). Known design deficiencies can be mastered by more restrictive operation, well trained crews and above all by deeply ingrained safety culture. "Milieux" contributed to Chernobyl, TMI-2, and Bhopal accidents which occurred during the night shift. Freezing environmental conditions played a part in the Challenger accident.

"Man", to a lesser extent, and "Management", to a greater degree, played dominant roles in all of the catastrophes mentioned. Some salient organizational ingredients were: lack of accident analyses, lack of risk analyses, lack of training, procedure violations, operator errors, no operating experience feedback, commercial pressures, no accident management training, no emergency planning, etc.

Additionally, actual experiences of collected and interpreted actuarial data from nuclear power operations further corroborate the significance of the human dimension (the 3rd and 4th M). A summary of estimated contributions of "human errors" to system accidents, reproduced from [Hollnagel, 1994] in Table 1, suggests that the contribution could be as high as 90%.

Focus on machine and assurance of machine has yielded remarkable results and an enviable track record. Now the nuclear establishment needs to refocus on assurance of human dimension in a dynamic plant operational environment and adequate understanding of organizational influences on nuclear safety. It should become the most pressing nuclear safety research issue.

TABLE 1

Estimated contribution of "human errors" to system accidents [Hollnagel, 1994]

Source	Single estimate	Double estimate		Domain
	(%)	Low (%)	High (%)	
Shapero et al (1960)	-	20	50	Weapon systems
LeVan (1960)	-	23	45	Aerospace
Robinson (1970)	25	-	-	General
Rasmussen (1973)	-	20	30	General
Hagen (1976)	-	10	15	NPP Total Failures
Christensen et al , (1981)	-	50	70	Electronic equipment (human initiated)
Christensen et al , (1981)	-	60	70	Aircraft maintenance (total failures)
Christensen et al , (1981)	-	20	53	Missile system maintenance (total failures)
INPO (1984)	44	-	-	Nuclear
INPO (1985)	52	-	-	Nuclear
Trager (1985)	60	-	-	Nuclear
Bellamy et al (1988)	59	-	-	Process Control
Guardian (1990)	75	-	-	Air transport
Swain (1990)	90	-	-	General

ORGANIZATIONAL FACTORS

The primary goal for any nuclear utility organization is to produce safe and economic electricity.

The National Energy Policy Act of 1992 (NEPA) began deregulation of the electric utility industry in the U.S., creating a competitive climate heretofore never known. This newly competitive electric energy market places severe competitive cost pressures on many nuclear power plants. Significant reductions in production costs are a necessity for survival at some

plants, and for improved profitability at all plants. Leaders in the nuclear industry realize that the thinking that got the field where it is today is not the thinking that will lead the industry to where it needs to be in the next century.

Industries and organizations that are going to be able to compete today and survive must have four characteristics: (1) Customer driven; (2) Cost-effective; (3) Fast and Flexible; and (4) Continuously improving [Blanchard, 1993]. In the nuclear industry one overriding ingredient must be added to this list: Nuclear Safety. Head-on competition with natural gas and coal, as alternatives to electricity generation, is a brutal reality. These new economic challenges add a new dimension to the field of organizational factors.

Organizational theory suggests that virtually every sanctioned activity occurring at an operating nuclear power plant stems from policies and decisions, organizational structures, and programs enacted by the plant management, corporate management or external regulators. Whether a utility is oriented towards production, safety, the efficacy and the degree of "ownership" or commitment of staff to organizational goals and values are reflections of the organizational culture.

What determines an organizational culture is a unique blend of policies, values, attitudes, practices, myths, history, self-image, which simply becomes: "the way things are done" or the way business is conducted" in a particular utility. What differentiates one utility from another is the organizational culture and ability to permeate this culture down through the whole organization.

Organizational culture within a utility can be broken down into: (a) Corporate culture; (b) Nuclear operations culture; (c) Nuclear plant culture; and (d) Employee attitudes. In case of a strictly nuclear utility, corporate and nuclear operations culture are one of the same. In any human endeavor, the manner in which people act is conditioned by requirements set a top level, i.e. Chief Executive Officer (CEO). Policies promoted at a CEO level create the working environment and condition behavior of individuals in the trenches.

Westrum [1988] has identified the characteristics of safe organizational behavior as generative, calculative, or pathogenic. Generative organizations are those that accomplish high levels of success. Hazards are identified and removed by lower level personnel empowered to seek out and eliminate problems. Calculative organizations perform functions by the book in conventional ways, meeting safety and regulatory requirements but rarely exceeding them. Pathogenic organizations consider safety regulations as barriers to production. As illustrated below, categories such as Westrum's can be linked to quantification of human error rates of plant personnel.

A safety policy statement declares a commitment and constant focus to excellent performance in all areas important to nuclear safety, making it abundantly clear to all employees that nuclear safety has the utmost priority, overriding if necessary the demands of production and schedules. A dramatic demonstration was the plant manager's decision to shut down the second unit of Turkey Point in Florida during a peak holiday season when a safety issue forced the first unit to shut down. An effective way of communicating the CEO's message is via clearly defining the company's mission/objectives/core values and maintaining consistent emphasis on safety as the highest priority, and remaining constant and unchanging with time. CEO's conviction and ability to communicate determine to a greater degree whether a particular nuclear utility can be characterized as generative, calculative or pathogenic.

SAFETY CULTURE

The aspect of overriding mentioned above, which is a very subtle one and represents a fine line between production and safety, led IAEA's INSAG-4 [INSAG, 1991] to offer the following definition: "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". To assist member states to assess safety culture in the nuclear industry, IAEA developed the ASCOT guidelines [IAEA, 1983] (Note, APG participated in ASCOT development.)

Nuclear weapons programs, both in the U.S. and the former Soviet Union, have failed to override the demands of production and schedules. Nuclear utilities in the Western World have, by and large, succeeded. In the U.S. the success has, however, been accompanied with high costs which are now prohibitive and cannot be sustained. The authors see a solution by virtue of a shift to risk culture. This subject is addressed in our Vienna paper [Joksimovich, 1995].

We postulate that the safety culture is a derivative of the larger concept of organizational culture briefly discussed above. As such, it is amenable to conceptual modelling. A team consisting of a behavioral scientist from Blanchard Training and Development Company (BTD) and nuclear safety engineers from APG, arrived at a framework and working models.

The framework, as depicted in Fig.1, consists of an input, organizational behavioral core and an output. This represents one way of looking into dynamics of the utility organizational structure as well as processes taking place within.

The organizational behavioral core represents the interactions of managerial and individual behaviors that shape the overall organizational culture. The organizational characteristics can be measured with various instruments (e.g., [Wilson, 1981]) and quantified on various scales, such as Westrum's. The organization is connected to the outside world through business, regulatory and community influences. Output variables are the dependent variables that reflect the achievements of the organization. These are measures of success in meeting the goals and objectives set by corporate and plant management in terms of safety, plant performance and control of costs.

The external influences, corporate goals and attitudes are filtered to the level of individual workers or work groups. The individual workers, such as maintenance personnel or control room operators may commit various "unsafe acts" [Reason, 1990] that tend to defeat or penetrate the multiple barrier of protection against accidents. The likelihood of "unsafe acts" being committed systematically is the result of the complex interaction of the organizational influences and the relative susceptibility of individuals to react positively or negatively to such influences. Organizational accidents happen when latent or unrevealed flaws combine with a triggering event to breach or degrade the built-in multiple system defenses. Of interest to PSA is how to quantify the effects of such organizational influences on human error rates of plant personnel.

For the framework depicted in Fig.1, one of the output variables considered by APG is personnel behavior, which is described by four categories:

- (a) Supportive Pro-Active (individuals do what is expected from them and take initiative to do more);
- (b) Supportive Reactive (individuals try to do what is expected from them but little more);

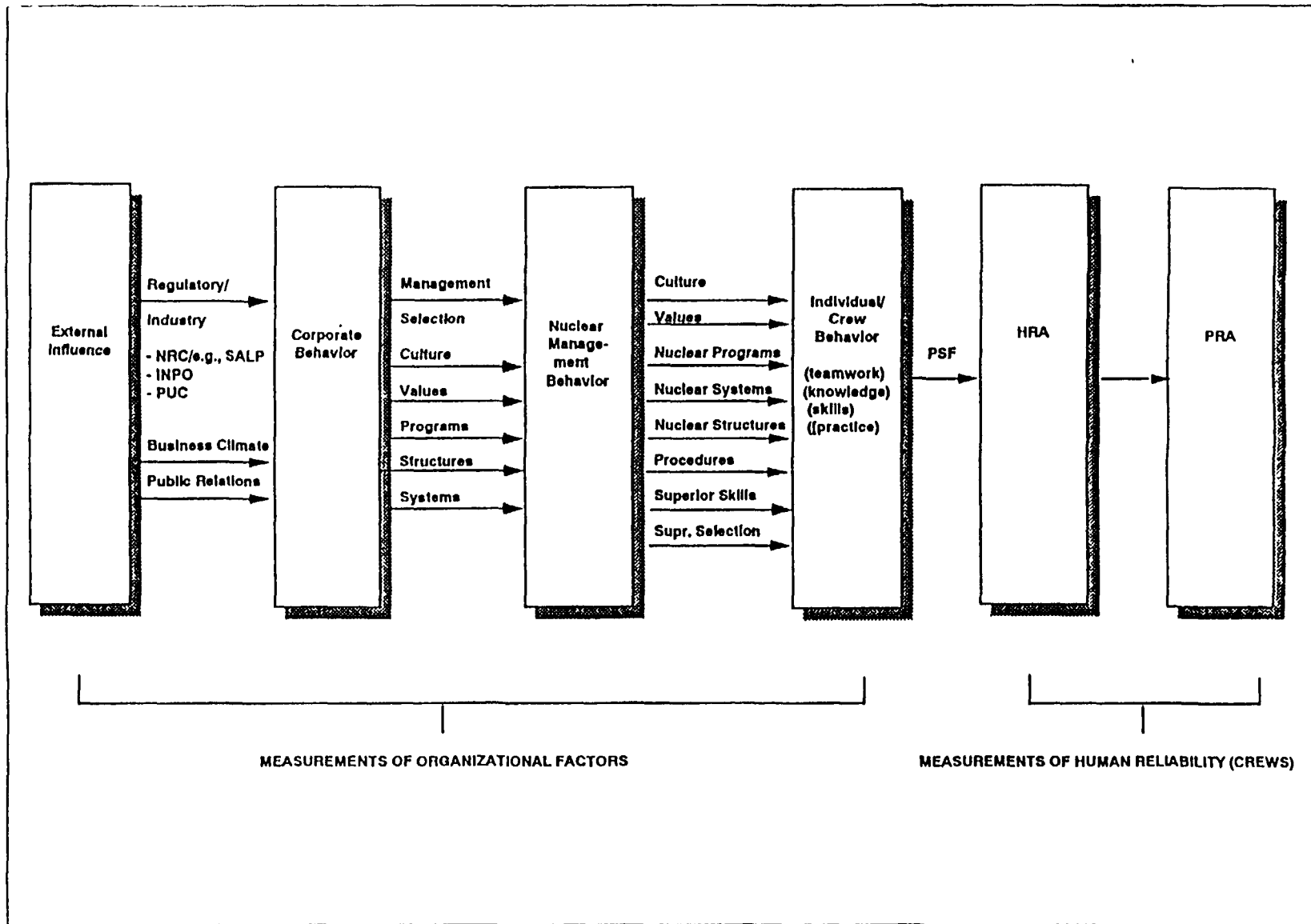


Figure 1 Framework Linking Organizational Factors to PRA

(c) Non-supportive Reactive (individuals resist doing required tasks deliberately omit some tasks); and

(d) Non-supportive Proactive (individuals take deliberate, deleterious or unsafe acts).

It should be noted that some behavioral scientists use the term "compliant" instead of "supportive". In the nuclear industry the term "non-compliant" is typically associated with the regulatory matters that require enforcement.

The APG hypothesis is that the four categories represent increasing probabilities for committing "unsafe acts" intentionally or unintentionally. These are complex interactions between behavioral tendencies of the individuals (including their personalities and value structures), the moderating effects of the individual's technical knowledge and safety commitments, as well as the work environment including the supervisory control. The behavioral categories not only affect an individual's performance on-the-job but also his willingness to be trained. The preponderance of supportive behaviors over non-supportive ones is expected to improve personnel reliability and reduce likelihood of committing unsafe acts. All in all, safety culture of an organization is predicated on a composite of individuals which make up a utility organization.

According to Dr. Zigarmi of BTG, in the general business environment such as at a manufacturing plant, a typical census distribution of personnel output variables is approximately as follows: (a) Non-supportive proactive (~2%); (b) Non-supportive reactive (~40%); (c) Supportive reactive (~40%); and supportive proactive (~18%).

Through application of organizational factors instruments and interpretation of results, the census of nuclear utility personnel within each of the categories of output variables can be measured. To our knowledge, no such measurement has been performed yet in the nuclear utility setting.

An alternative approach for assessing output variables is to use the concepts of Human Reliability Analysis (HRA). In the HRA technology, the relative probabilities of human errors among different situations or task contexts are scaled according to a number of "performance shaping factors" (PSFs) that act directly on an operating crew in the control room or on individuals like maintenance technicians. A logical extension of the PSF concept is to include organizational influences in HRA models (a safety culture PSF), which are in turn incorporated into the plant PSA models.

LINKAGE TO PSA

A schematic representation of a simplified event tree/fault tree logic model for a given initiating event (IE) is displayed in upper part of Fig.2. The lower part of the figure depicts several typical organizational units of an operating plant compatible with the framework as displayed in Fig.1. Causal links are illustrated between the two parts of the figure.

Quantification of the probability of each accident sequence defined in an event tree requires assignment of probabilities of occurrence to many basic events representing failure of systems, components and human interactions (HIs). Under the IE and system unavailability headings are types of basic events labeled "Equipment caused" and "Human caused". "Human caused" events are further divided into categories customary in the HRA literature.

Each of the basic events can be caused by various parts of a nuclear utility organization. The "human" caused events involve those plant personnel having hands-on interactions with the plant

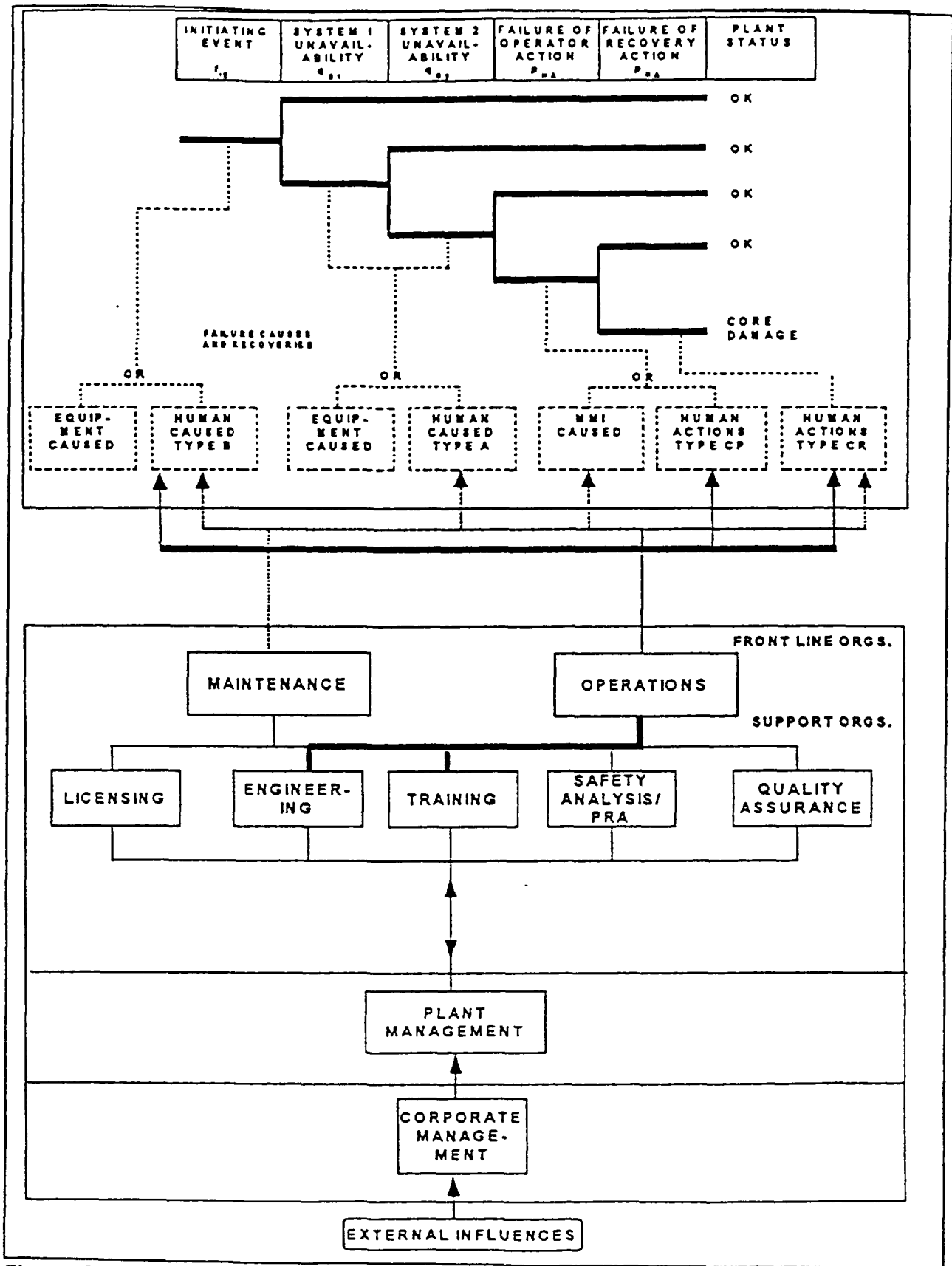


Figure 2 Representative Event Tree Illustrating Linkage to Organizational Factors

systems. In the figure, these events are represented with direct links to "Front Line" organizations- the maintenance and operations department personnel.

The lower part depicts an inverted hierarchy of the organizational units. Organizational influences flow from the external and corporate levels to the plant management and then to the functional groups in the plant. Even though the front-line personnel may be the agents of failure, root causes may lie in organizational influences.

Fig.3 provides an example for a conceptual application of "output variables" for the maintenance front line organization represented in Fig.2.

Plants A and B are postulated to have different distributions (or census) of personnel behavioral categories among their maintenance personnel. Subsequently, a hypothetical distribution of conditional probabilities of committing a maintenance error for various behavioral categories were postulated. The product of histograms A and B results in outcome depicted in frame C. Likewise, the products of histograms B and D yield the outcome depicted in frame E. The bottom line, measured by "mean values" differs by almost a factor of 2. The heart of the matter is that, on the average, maintenance workers at Plant B are expected to commit fewer errors than their counterparts at Plant A.

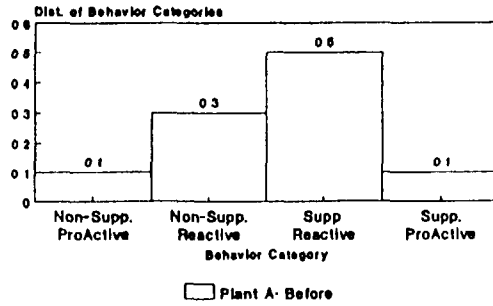
Fig.4 illustrates a schematic for the hierarchical linkage of organizational influences on reliability of control room operating crew.

The left-hand chart presents time-reliability curves (TRCs) derived by APG from data collected at three different BWR simulators with licensed operating crews [ORE, 1990]. On the ordinate is non-response probability while elapsed time is shown on the abscissa. For the sake of illustration, data for an anticipated transient with failure to scram (ATWS) scenario are presented when the HI is the timely initiation of the standby liquid control system (SLCS) after diagnosing the ATWS condition. The differences between the TRCs reflect the integral effects of different organizational influences on a) safety vs. production (e.g., crews are confident that management supports early injection of boron into the reactor in an apparent ATWS situation); b) providing high-quality procedures, operator aids, and control room design; and c) high-quality and effective training program.

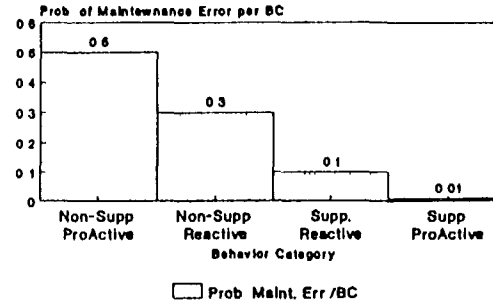
The vertical line through the TRCs represents the "time window", at representative 600 secs, which is a time by which SLCS should be initiated. The intersection of the vertical line and the respective curves yield the probability that crews of respective BWRs will respond in allotted time, i.e. this is termed the non-response probability.

For the sake of illustration, the right-hand chart is a cross-plot of the values of non-response probabilities of three BWRs vs. organizational factor ratings for the plants which have been assigned arbitrarily based on our observations and judgements for the respective plants (i.e., actual measurements of organizational factors were not available at the time the simulator measurements were taken). The "organizational factor rating" is a numerical representation along a suitable scale, e.g., a "Westrum" scale. We encourage further R&D to obtain measured organizational factors and operating crew performance in order to verify and/or quantify the correlation illustrated.

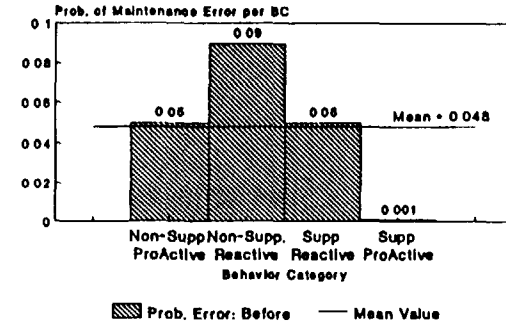
Frame A: Hypothetical distribution of behavior categories (BCs) at Plant A before change in organizational factors



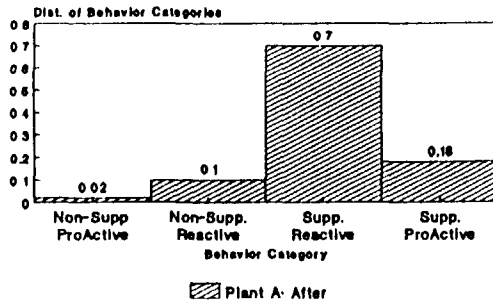
Frame B: Hypothetical probability of maintenance error for each behavior category



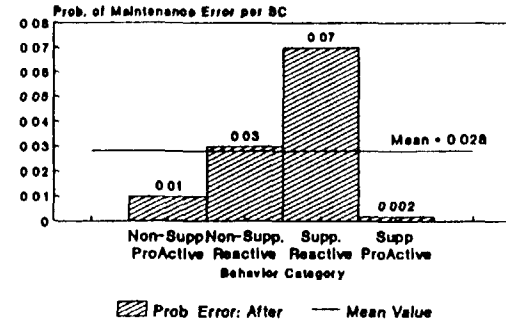
Frame C: Weighted probability of maintenance error at Plant A: Before



Frame D: Hypothetical distribution of behavior categories (BCs) at Plant A after change in organizational factors



Frame E: Weighted probability of maintenance error at Plant A: After



Assume Same Before and After

FIGURE 3 ILLUSTRATION OF EFFECT OF BEHAVIOR CATEGORIES ON PROBABILITY OF HUMAN ERROR

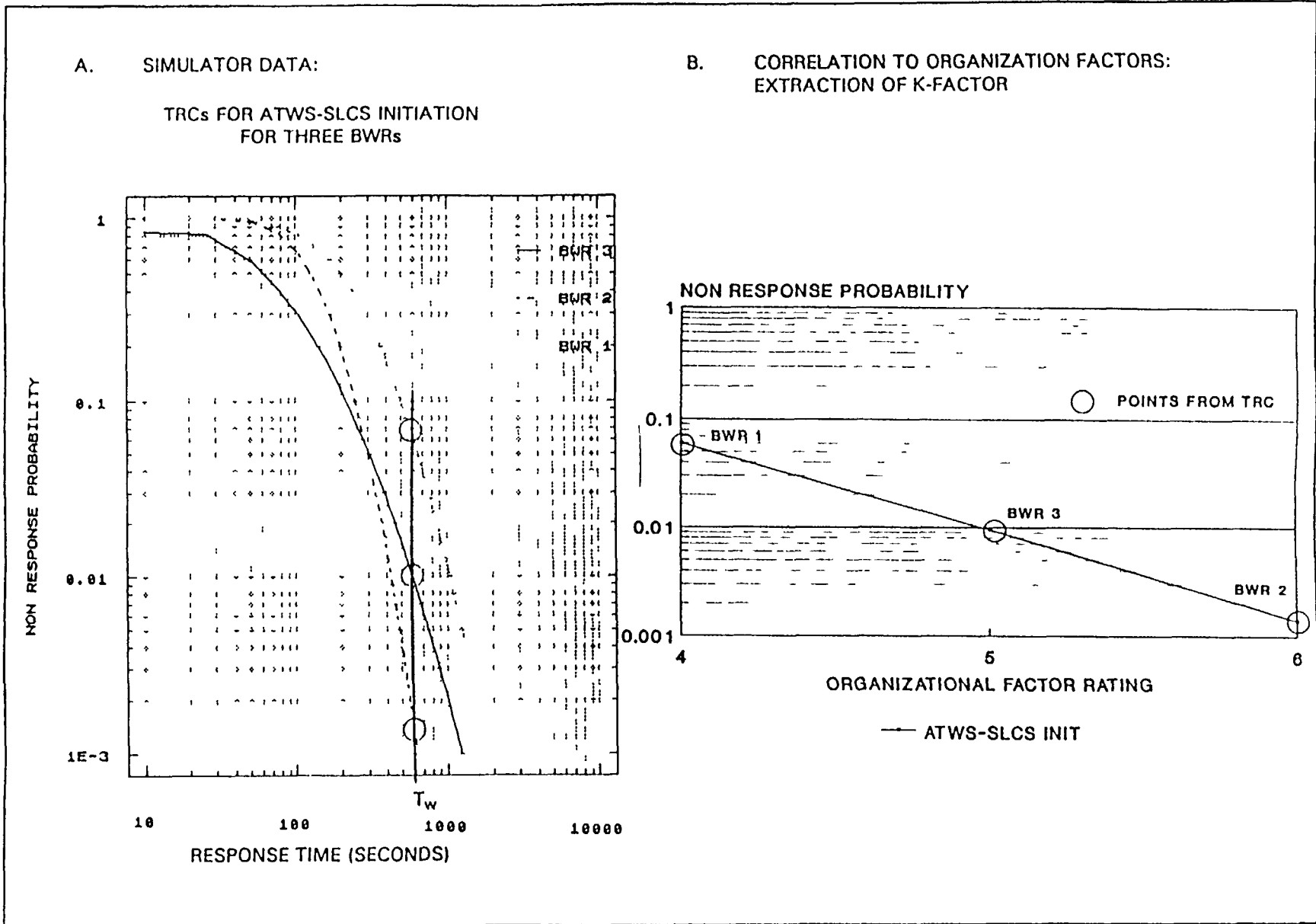


Figure 4 Framework Linking Organizational Factors to PRA

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ACRONYMS

ATWS	-	Anticipated Transient With Failure to Scram
BTD	-	Blanchard Training and Development Company
CEO	-	Chief Executive Officer
HIs	-	Human Interactions
HRA	-	Human Reliability Analysis
IE	-	Initiating Event
INPO	-	Institute for Nuclear Power Operations
NEPA	-	National Energy Policy Act
NRC	-	Nuclear Regulatory Commission
PSA	-	Probabilistic Safety Assessment
PSFs	-	Performance Shaping Factors
QA/QC	-	Quality Assurance/Quality Control
SALP	-	Systematic Assessment of Licensee Performance
SLCS	-	Standby Liquid Control System
TMI	-	Three Mile Island
TRCs	-	Time-Reliability Curves

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