



**INSTITUTO DE ENGENHARIA NUCLEAR**

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**Safety Culture of Complex Risky Systems. The Nuclear  
Engineering Institute Case Study**

por

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#### Resumo:

Análises de acidentes industriais demonstraram que a operação segura e confiável de processos que utilizam tecnologias complexas com alto grau de risco de acidente depende não apenas de fatores técnicos mas também de fatores humanos e fatores organizacionais. Após o acidente nuclear de Chernobyl, em 1986, a Agência Internacional de Energia Atômica, AIEA, estabeleceu o conceito de “Cultura de Segurança”, e deu início a um programa de avaliação e aprimoramento da cultura de segurança de organizações internacionais do setor nuclear. O Instituto de Engenharia Nuclear, IEN, é uma unidade de pesquisa e desenvolvimento tecnológico da Comissão Nacional de Energia Nuclear, CNEN, caracterizada como instalação nuclear e radiativa, onde são desenvolvidos processos que utilizam tecnologias complexas e de risco e/ou material radioativo. Como parte integrante de seu programa de gestão organizacional em busca da excelência, foi estabelecido o projeto de avaliação e aprimoramento da cultura de segurança, que segue as orientações da AIEA e é integrado ao processo de gestão segundo o modelo de excelência do Prêmio Nacional da Qualidade. Este trabalho descreve o projeto e apresenta os resultados obtidos na pesquisa inicial de avaliação da cultura de segurança do IEN realizada junto aos servidores, e as ações subsequentes.

#### Abstract:

*Analysis of industrial accidents have demonstrated that safe and reliable operation of complex industrial processes that use risky technology and/or hazard material depends not only on technical factors but on human and organizational factors as well. After the Chernobyl nuclear accident in 1986, the International Atomic Energy Agency established the safety culture concept and started a safety culture enhancement program within nuclear organizations worldwide. The Nuclear Engineering Institute, IEN, is a research and technological development unit of the Brazilian Nuclear Energy Commission, CNEN, characterized as a nuclear and radioactive installation where processes presenting risks to operators and to the environment are executed. In 1999, IEN started a management change program, aiming to achieve excellence of performance, based on the Model of Excellence of the National Quality Award, PNQ. IEN's safety culture project is based on IAEA methodology and has been incorporated to the organizational management process. This work presents IEN's safety culture project; the results obtained on the initial safety culture assessment and the following project actions.*

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## I. INTRODUCTION

As a learning process to understand the causes of big proportions industrial accidents, several scientists and international organizations have been analyzing industrial accidents that have caused impact not only on the front line operators and on the organization, but on the environment as well, affecting local society and, sometimes, spreading to regions and even continents. The nuclear power plants accidents of Three Mile Island, USA, in 1979 and Chernobyl, in old USSR, in 1986, the Union Carbide petrochemical industry accident, best known as Bhopal accident, in India, in 1984, and the Challenger space shuttle accident, USA, in 1986, among many others, have been analyzed. These analyses have demonstrated that safe and reliable operation of industrial processes based on complex and risky technology and/or that use hazard material, depend not only on technical factors related to the processes, but on issues related to human and organizational factors as well.

As results of this learning process, new methodologies for reliability and safety analysis of these industrial processes started to be developed, originating the development of the human factors approach, and more recently, organizational approaches have been proposed and utilized. These new approaches aim to complement the traditional engineering approach, based on technical factors only.

Reason [1] introduces three approaches for safety management: the person model, the engineering model, and the organizational model.

On the same Reason's approach, macro ergonomics [2] proposes that industrial organizations be analyzed under a sociotechnical approach composed of three basic dimensions: people, technology and organization, as presented in fig. 1. This approach considers the organization as a complex system with the following intrinsic attributes:

- Global result is bigger than the sum of the results of each part;
- There is interdependence among dimensions;
- The agents of the system are non-linear, such as their interactions;
- All relations occur dynamically, in the presence of uncertainties;
- Global results emerge as a consequence of the many system agents' interactions and in turn act as a feedback to these interactions.

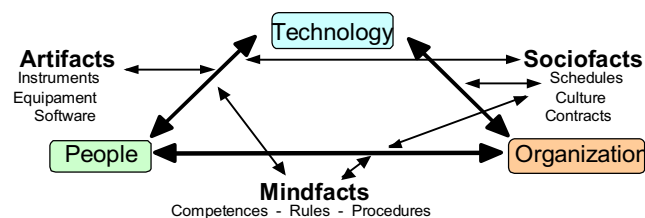


Figure 1. Sociotechnical Model of the Organizations, According to Macro Ergonomics.

**Organizational Approaches.** Focus of this work, IAEA [3] established in 1991 the “ Safety Culture” concept and developed a methodology for the assessment and enhancement of the safety culture, starting a program within international nuclear organizations, aiming to promote personal attitudes and behaviors that give overriding priority to all matters related to safety.

Reason [1] presents an approach based on his organizational model that perceives human error more as a consequence than as a cause and as symptoms that reveal the presence of latent conditions in the system. The model emphasizes the necessity for proactive measures of “safety health” and the need for continuous reforms of the system’s basic processes. This model has much in common with Total Quality Management. Indeed, it blurs the distinction between safety-related and quality-determining factors, while both are viewed as important for increasing the system’s intrinsic resistance to its operational hazards, and both are involved in organizational accidents.

Another organizational approach is the “Tripod Delta” methodology, developed at Leiden and Manchester Universities [4], that defines 11 organizational factors as determinants, named basic risky factors, which are submitted to an assessment process where the factors’ control level is considered an indicator of the quality of the organizational management process. This work presents IAEA safety culture concept and the description and partial results of IEN’ safety culture assessment and enhancement project.

## II. SAFETY CULTURE

Safety culture concept was initially issued by IAEA in 1986 in IAEA’s post-accident review meeting report of the Chernobyl accident. At that time its meaning was still under distinct interpretations and did not provide a guide to the assessment of the organizations’ safety culture. In 1991, through an international safety advisory group, IAEA defined safety culture concept in terms of the organizational framework in which people work and of the individual and group attitudes within this framework [3]. The concept has been defined in order to be practically used by the nuclear organizations (plant operators, research and development) as a basis for the assessment of the safety culture effectiveness and to identify opportunities for its enhancement. A methodology for the safety culture assessment has been developed, which is based on a task force inquiry to assess the organizational factors related to the safety commitment on the organizational politics level, on managers level and on individuals, as shown in fig. 2.

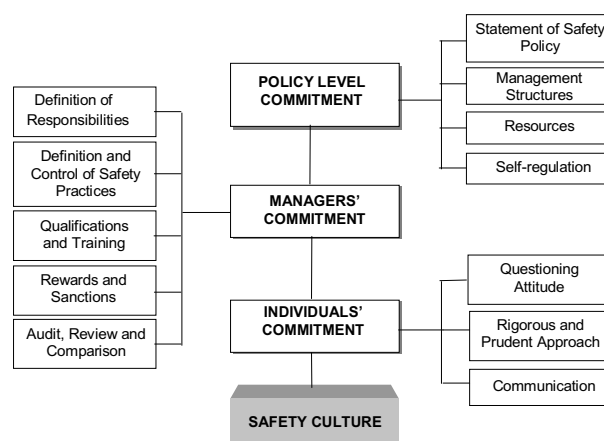


Figure 2. Aspects associated to the safety culture according to IAEA.

**IAEA's Safety Culture 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".

This definition remarks that safety culture relates both to organizations, concerning its style, and to individuals, concerning its personal attitudes and habits, and that although these matters are generally intangible, their qualities lead to tangible manifestations, and a principal requirement is the development of means to use the tangible manifestations to assess the associated basic underlying assumptions.

So, according to IAEA, safety culture requires two major components:

1. The necessary framework within the organization and is the responsibility of the management hierarchy;
2. The task force attitude in all organizational levels as a response to the framework and benefiting from it.

According to IAEA, the response of all those who search for excellence in safety is characterized by a questioning attitude plus a rigorous and prudent approach plus communication.

The search for excellence in nuclear organizations is directly connected to the safe operation of its processes. Christian Poindexter, chief executive officer of the Constellation Energy Group in USA, stressed the three golden rules to reach excellence that will always be applied to the field [12]:

1. Excellence starts with commitment to safety;
2. Excellence comes with practice;
3. Excellence is in the details.

This means that excellence of performance in the nuclear field depends definitely on the safety factor, and we can say that safety culture is safety's fundamental basic component.

**Organizational Culture.** According to Hofstede [5] there is no standard definition to the organizational culture concept, but most of the authors would agree that it is:

- Holistic: the whole is more than the sum of its parts;
- Historically determined: reflects organization's history;
- Related to anthropological studies: such as rituals and symbols;
- Socially built: created and preserved by the group of people that form the organization;
- Intangible: but to change it implies in tangible measures;
- Difficult to change: although there is no agreement on the level of difficulty.

So, Hofstede defines organizational culture as the collective mind program that distinguishes the members of one organization from those of another. To change the organizational culture implies that most inter-personal relations shall be re-negotiated. Therefore, if new tasks or a new organizational environment compel this re-negotiation, there will be a good chance that the unwanted aspects of the old culture may disappear.

According to Schein [6] the organizational culture elements must be organized in three levels, as shown in fig. 3.

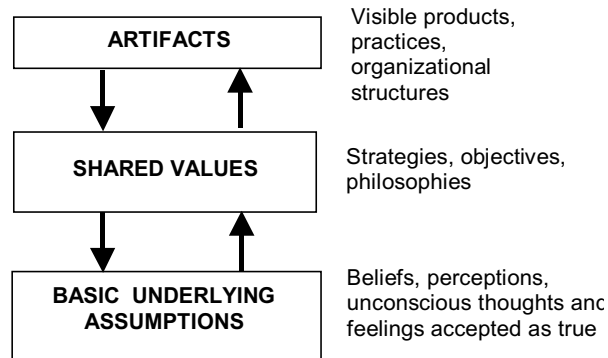


Figure 3. Culture levels, according to Schein (1985)

### III. IAEA'S SAFETY CULTURE ASSESSMENT AND ENHANCEMENT METHODOLOGY

IAEA, as the maximum organization, on the world level, to promote the pacific and safe use of nuclear energy, has established a program that aims to aware the international nuclear organizations of the need and importance to have an effective safety culture, offering consultant support to those that join the program. In Brazil, Eletronuclear, the holding and operator of nuclear power plants Angra I and II, has joined the program and assessed its safety culture in 1999 [7].

IAEA's methodology consists on the establishment of a project by the organization, composed of:

1. High level management commitment to start a safety culture enhancement program;
2. Decision to assess the present safety culture;
3. Definition of: the organizational factors to be assessed, the data analysis method, and the assessment instrument;
4. Establishment of the strategy for communication and awareness of all organizational sectors about the importance of the project;
5. Safety culture assessment by the organizational task force;
6. Communication of results and next steps of the project;
7. Preparedness and implementation of improvement action plans;
8. Safety culture re-assessment around 18 months later.

The project must count, on a decisive way, with the organization high-level management commitment and with a coordination team responsible for the implementation of the several activities of the project, counting with IAEA's support through the *Assessment of Safety Culture Operating Team. (ASCOT)*.

#### IV. IEN's SAFETY CULTURE PROJECT

The Nuclear Engineering Institute is a research and technological development unit of the Brazilian Nuclear Energy Commission, CNEN, characterized as a nuclear and radioactive installation, where processes based on complex risky technology that utilize nuclear or radioactive materials are developed, such as the operation of the Argonaut nuclear research reactor, the operation of the particle accelerator cyclotron type, CV-28, and the management and storage of industrial radioactive waste from the states of Rio de Janeiro and Espírito Santo, besides the development of chemical processes related to the nuclear fuel cycle [8]. All these processes need to attend to several requirements related to operational safety and environmental control so that their operation and installations can be certified by CNEN and in order to get the operational license from the Brazilian environmental control institute, IBAMA.

In 1999, IEN started a management change program [9] aiming to reach its 2005 vision: "to be a research and technological development center of excellence recognized in the country by its effective contributions to the improvement of society quality of life". This program consists on the implementation of a quality management process based on the Model of Excellence of the National Quality Award, PNQ [10] and on the Balanced Scorecard methodology [11]. PNQ model stresses the incorporation of the excellence fundamentals to the organization's practices by the establishment of a non-prescriptive set of requirements to the 26 items distributed in its seven criteria of excellence. The level of attendance by the organization to these requirements, as a function of the organizational practices, reflects the degree of excellence reached by the organization. This model considers that the evolution towards excellence is a function of the organizational learning, obtained through the continuous evaluation of the organization's management system, comparing to excellence references of practices and results as benchmarking, and the consequent implementation of improvements and innovations to the management practices. The balanced scorecard methodology is used to control the organizational strategies by defining a set of performance indicators, and to transform them into to operational plans of actions.

IEN's safety culture project has the following objectives:

- To incorporate the safety culture assessment to the organizational management process;
- To accomplish an initial safety culture assessment by the organizational task force, based on IAEA's methodology utilized by Eletronuclear;
- To review the safety culture assessment methodology of Eletronuclear;
- To establish and implement actions plans to the safety culture continuous improvement;
- To periodically assess the safety culture.

The integration of this project to the organizational management process results in the attendance to the two major safety culture requirements established by IAEA, where on the organizational level, the PNQ criteria of excellence provide the basic framework, and on the individuals level, the personal attitudes may be influenced by the new organizational practices, which are defined according to the safety culture assessment results, in order to improve the organizational factors identified as critical.

According to Hofstede [5], in his research performed between 1985 e 1987 under the auspices of the Institute for Research on Intercultural Cooperation, IRIC, in the Netherlands, that covered twenty units from ten different organizations, the cultural differences on the level of

the organizations reside more in the practices and less in the values, and consequently the shared perceptions of the organizational routine practices may be considered as the center of the organizational culture. There is no doubt that founders and leaders values contribute to the organizational culture, but the way culture affects organizational staff is through the shared practices, remarks Hofstede, which means that the mind program of the organization's members, or, the basic underlying assumptions, may be modified by the introduction of new management practices in the organization. According to Schein [6], when the members of the organization get a shared perception of the good results achieved by the new practices introduced, the value gradually starts a process of cognitive transformation into a belief, and ultimately into an assumption. As the values begin to be taken for granted, they become unconsciously accepted, therefore, modifying the underlying assumptions. Morgan [13] comments that many aspects of the organizational culture are based on routine aspects of the daily practices. It happens because these aspects define the socially built stage in relation to which the present organization's actors' generation brings life to its culture. Routine plays an incredible role in case one wants to understand how one organization works when no one is watching it, Morgan remarks.

Therefore, the culture, the daily practices and the results of the organization, or, the culture and the organizational management are inter-related, as shown by fig. 4, where the management process is embedded in the culture of the organization. The broken lines between the culture and the management process represent that this inter-relation happens under the complexity approach, characterized by the following attributes:

- Inability to predict: system is sensitive to initial conditions; one must adopt the planning as learning style;
- Inability to control: it is not possible to control what happens to the system;
- Edge of chaos: it is on this region that system changes have more possibility to occur;
- Self-organization and emergence: ordered patterns that emerge simply as a result of the relationships and interactions of the constituent agents, and in turn affect these relationship and interactions;
- Ability to influence: the privileged emergent patterns called "attractors" may be influenced, at least when system agents' are human beings.

Considering the organization as a complex sociotechnical system, whose agents are human beings, complex as well, Seel [14] defines organizational culture as the emergent result of the continuing negotiations about values, meanings and proprieties among the members of the organization and with its environment.

Under this context, organizational culture changing interventions must avoid the conventional approach that believes that it is possible, in a controlled way, to change organizational culture from one state to another previously planned. This leads us to move away from "planned changes" type of intervention toward "facilitated changes" type of intervention.



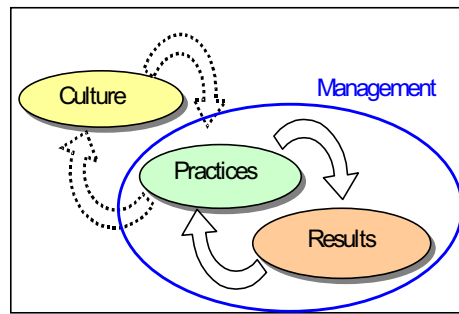


Figure 4. Inter-relationship between organizational culture and management.

Through the implementation of new practices in the organization the culture stability will somehow be affected, and therefore facilitating changes to occur which will compose dynamic and continuously the new culture, which, in turn, will affect the management process. The change agents, who are those persons that consciously participate of the changing intervention, together with the organization's leadership, act continuously on the system as regulators agents. This implies to the change agents a permanent alertness condition toward the system.

Our thesis is that the integration of the safety culture project to the organizational management process, and the use of the model of excellence of PNQ as the basis to the management process, may provide some degree of "governability" to the system, reducing the involved complexity, once the PNQ model provides an holistic organizational analysis, through its criteria requirements. The results of the successive safety culture assessment lead to the identification of the critical organizational factors that, together with the continuous learning process, shall be improved and along time shall provide continuous improvements to the system.

**IEN's Initial Safety Culture Assessment.** This assessment has been based on IAEA's orientations and on the instrument utilized by Eletronuclear, that has counted with IAEA support. The same 22 organizational factors have been assessed and the same data analysis methodology has been utilized. The assessment was performed by IEN's staff, with previous communication of its objectives and strategic importance. The participation was anonymous in order to assure freedom of expression, and data gathering has been made through specific meeting with each Division separately.

Table 1 presents the classification of safety culture and organizational factors indexes, according to the obtained percentage levels.

## V. RESULTS

A total of 214 filled formularies have been received, corresponding to 73% of IEN's staff. This level of participation has been considered representative. Safety culture indexes have been obtained considering all assessment data. We understand that scratched or not properly filled formularies is part of IEN's cultural aspects, and therefore, must be considered in the results.

TABLE 1. Classification of IEN’s safety culture and organizational factors indexes

Index (%)	Classification
Above 85	Very Good
Between [75 e 85)	Good
Between [65 e 75)	Satisfactory
Between [50 and 65)	Regular
Below 50	Unsatisfactory

Fig. 5 presents the global safety culture index, as well as its segmentation by sex and educational level. One can observe that in all cases the index obtained is classified as “REGULAR”.

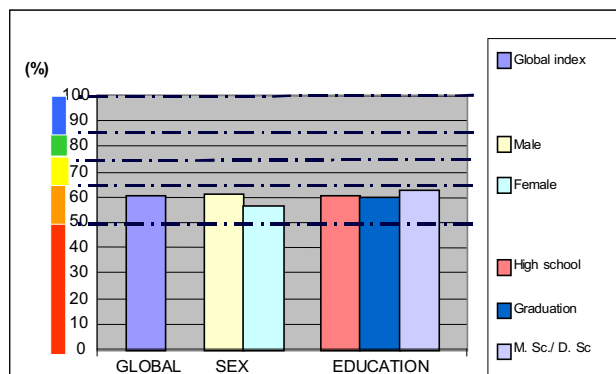


Figure 5. IEN’s safety culture indexes.

Fig. 6 presents the results for each of the 22 organizational factors assessed, whose classification is shown in table 2. We can identify that factors F7, F10, F17 and F21, respectively, Relationship to Licensing and Regulatory Body, Quality of Documentation and Procedures, Adequate Resources Allocation, and Organizational Evolution Through Learning, are the most critical.

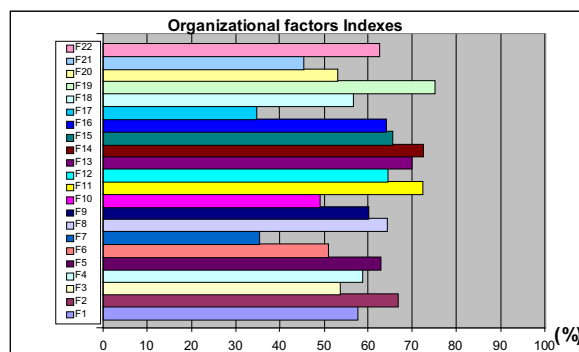


Figure 6. Organizational factors indexes.

TABLE 2. Classification of each of the 22 assessed organizational factors

Classification	Organizational Factors
Unsatisfactory	F7. Relationship to licensing and regulatory body / F10. Quality of documents and procedures / F17. Adequate resources allocation / F21. Organizational evolution through learning
Regular	F1. High-level management commitment to safety / F3. High priority to safety / F4. Systematic approach to safety / F5. Importance of safety on the organization's strategic plan / F6. Lack of conflicts between production and safety / F8. Proactive and long term perspective / F9. Management of changes / F12. Qualified and well dimensioned personnel / F16. Good working conditions related to execution time, workload and stress / F18. Collaboration and teamwork / F20. Management of conflicts / F22. Commitment to performance and rewards
Satisfactory	F2. Evident leadership / F11. Fulfillment of regulations and procedures / F13. Well defined tasks and responsibilities / F14. Transparency and communication / F15. Motivation and satisfaction at work / F19. Error treatment at work

These results have been largely divulged and commented in all levels of the Institute, and have been discussed in a round table during IEN's 2001 Internal Week of Accident Prevention (*SIPAT*). The REGULAR safety culture index obtained reflects the need and points out the importance of this project, in order to help IEN to reach its 2005 defined vision.

As the continuation of this work, a safety culture enhancement plan, based on the assessment results will be implemented, in order to establish new organizational management practices and procedures that may lead to the improvement of the most critical organizational factors assessed.

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