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HUMAN FACTORS INCLUSION PROPOSAL IN ‘REACTOR TRIP’ TO INCREASE SAFETY IN OPERATION

Antonio C. A. Vaz[1],Valdemir G. Rodrigues[2],Eduardo Y. Toyoda[3],Rajendra N. Saxena[4]

[1,2,3]Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN - SP)
Av. Professor Lineu Prestes, 2242.
05508-000 São Paulo, SP, Brazil
acavaz@ipen.br, vgrodri@ipen.br, eytoyoda@ipen.br, rnsaxena@ipen.br

ABSTRACT

A fundamental concept in nuclear reactor operation is that safety is the result of interactions between human, technological and organizational factors. The National Nuclear Energy Commission understands how human factors from psychological, physiological, behavioral and emotional origin can affect the reactor operation. For that reason, reactor operators are submitted to rigorous evaluations every year. When conducting case study during these sixty years of IEA-R1, three of them hypothetical and possible, related to the reactor operation illustrates the concern about the safety and security: Case 1- Operator had a stroke during reactor operation in the control room. Case 2- Operator suffered stress in traffic in his going to the reactor facility; when performing test in the emergency cooling system for reactor start up, he didn’t close a valve completely; changing the pool water technical quality causing a week delay in the reactor operation. Case 3- Operator just arrived to afternoon shift in the control room, after a few minutes his co-worker noticed that his cognition and behavior has changed, later in the hospital he was diagnosed with head cancer. This interdisciplinary work aims to include human factors of psychological, physiological and behavioral origin in 'reactor trip'. The ‘reactor trip’ (also known as ‘scram’) usually applies to technical factors to avoid high consequence event, are protection circuits that can assume the status of alert, hazard and essentially shut down the reactor automatically; when temperature, radioactivity, pressure, water flow, voltage and so on; are out of the operating limits. Technologies associated with neuroscience and psychological assessments such as: *Face Reader, Analogue Visual Mood Scale and Back Depression Inventory*; allows the evaluation of the operator in the control room. However, problems like described in the case study should be minimized. This interdisciplinary theoretical work is based on empirical doctoral thesis in progress.

1. INTRODUCTION

According IAEA, the programs for promoting global nuclear safety regime, Fig.1, include information exchanges, research and development, technical assistance for developing states, education and training, safety appraisal services, including evaluation of accidents and peer review [1].

Based on PhD research in progress, this work proposes to increase nuclear safety and security, including human factors of psychological, physiological and behavioral origins in the 'reactor trip’. Considering the same approach of human factor related in the James Reason [2] and HFACS- Human Factor Analysis Classification System [3] publications, this interdisciplinary research brings together an expert in human science and researchers from Research Reactor Center-CRPq, one of them reactor operator. The Chernobyl-Ukraine (1986) accident, Fukushima-Japan (2011) accident [4] and Germanwings-Flight 9225 (2015) accident [5] and its aftermath reinforced the need of theoretic and pragmatic studies over industrial and social resilience.

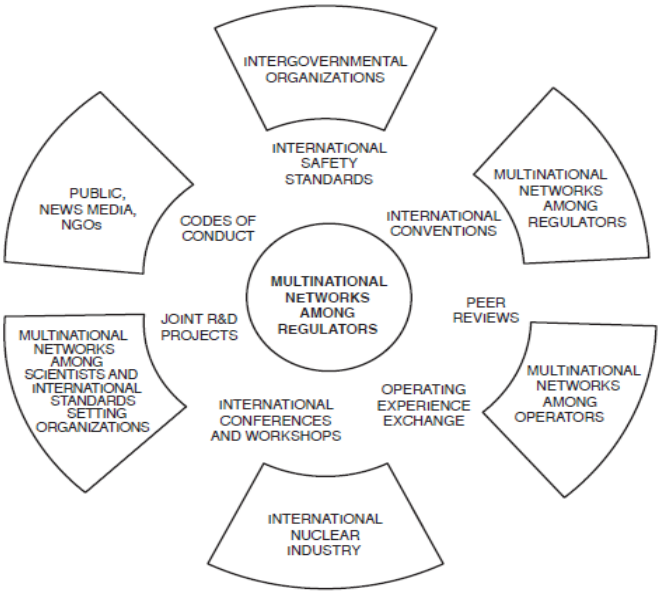


Figure 1: Main elements of the Global Nuclear Safety Regime

These new concepts of nuclear safety insist on the link between operating processes and social contingencies [6]. Investigations following these accidents brought the safety community to question the understanding of accidents solely based on operator’s behavior. TMI-U.S.A (1979) incident [7] operates an awareness of the influence of local workplace conditions on the operator’s performance. Reason’s cognitive models, Fig. 2, were then based on observations in nuclear reactor control rooms as case study of human behavior. The development of distinction between error theory intentional actions or unintentional actions and violations, is strongly linked to the development of nuclear energy and its safety culture. HFACS is heavily based upon James Reason's Swiss cheese model, Fig. 3, is a general human error framework originally developed and tested within the U.S. military as a tool for investigating and analyzing the human causes of aviation accidents [8]. However, according to Reason’s model of active and latent failures, such violation inducing situations (sabotage) are often set up by supervisory and management policies and practices. Such theories suggest that the best strategy for reducing violations by aircrew is to enforce the rules and to hold both the aircrew and their supervisors/organizations accountable. The terms active and latent as applied to errors were coined by James Reason. Active errors occur at the point of contact between a human and some aspect of a larger system, a human-machine interface. They are generally readily apparent, pushing an incorrect button, ignoring a warning light and almost always involve someone at the frontline. Latent errors, or latent conditions, in contrast, refer to less apparent failures of organization or design that contributed to the occurrence of errors or allowed them to cause harm to workers. Active failures are sometimes referred to errors at the sharp end are noticed first because they are consequent on the actions of the operator. Defense in depth is clearly mentioned in Swiss Cheese Model-SWC and it is the work philosophy of nuclear safety and security. It incorporates an accidental trajectory of accident opportunity which provides information on respective contributions of the psychologist and the engineer. They represent the organizational (managerial level) and human failures (unsafe acts): contribution of the psychologist. On the other hand, represent defense in depth as a block (set of defenses ensuring the system's integrity): it's the engineer contribution. Human variability may confuse the engineer (which partly explains the historical human error understanding of accidents).

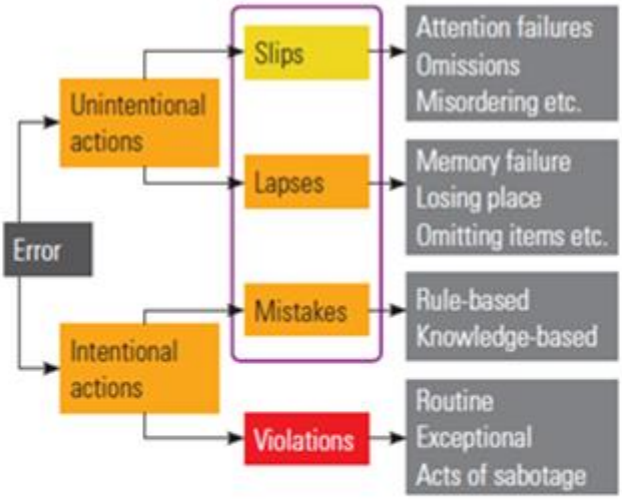


Figure 2: Unintentional and intentional actions

Technical and organizational sides of safety often confuse academic researchers. In the SCM, disciplines collaboration is used to display the complex interactions between humans and technology and therefore, emergent properties of system's security. Finally, the differences in graphical complexity between the theoretical and empirical models are to be noted.

Psychological characteristics and performance relativity are two important aspects of research of nuclear reactor operators. In order to obtain psychological characteristics and performance relativity, the relevant data of operators first need to be obtained. The acquisition of these data should be parallel and independent [9]. A new approach for finding the hazards of human errors, and not just their causes, in the nuclear industry is currently required. This is because finding causes of human errors is really impossible owing to the multiplicity of causes in each case. Thus, this study aims at identifying the relationships among human error hazards and determining the strategies for preventing human error events [10].

Human factors are an umbrella term for the study of people's performance in their work and non work environments. The term human factors can mean many things to many people, and trying to understand all its implications can be daunting. Perhaps because the term is often used following human error of some type, it is easy to think of it negatively. However, human factors also include all the positive aspects of human performance: the unique things human beings do well. The primary focus of any human factors initiative is to improve safety and efficiency by reducing and managing human error made by individuals and organizations. Human factors are about understanding humans, behavior and performance. Then, from an operational perspective, applying that human factors knowledge to optimize the fit between people and the systems in which they work, to improve safety and performance [11]. Most accidents are attributed to human error, but in almost all cases the human error was the direct result of poor design [12]. The proposed teaching-learning method has been well accepted since it accelerates organizational learning and contributes with safety assurance in different contexts as civil and military aviation, shipping, railway, nuclear power plants, and chemical industries.

Reactor trip (also known as 'scram'), a nuclear reactor will "trip" meaning something happened that caused the reactor to automatically shut down to ensure safety. In other words, a trip means a plant is doing what it's supposed to do. Let's look at the term a bit more closely.

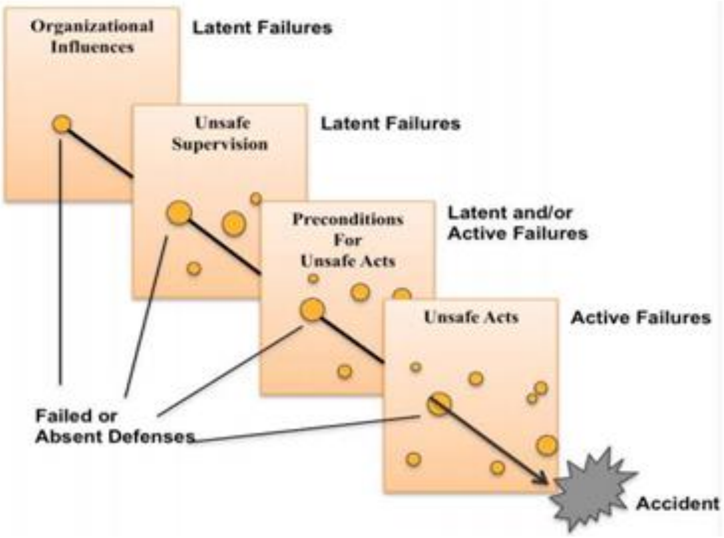


Figure 3: The swiss cheese model

Key operating parameters of a nuclear power plant, such as coolant temperature, reactor power level, and pressure are continuously monitored, to detect conditions that could lead to exceeding the plant's known safe operating limits, and possibly, to damaging the reactor core and releasing radiation to the environment. If any of these limits is exceeded, then the reactor is automatically shut down, in order to prevent core damage. In nuclear engineering terms, the automatic shutdown of a nuclear reactor is called a reactor trip or scram. A reactor trip causes all the control rods to insert into the reactor core, and shut down the plant in a very short time (about three seconds). The control rods are composed of chemical elements that absorb neutrons created by the fission process inside the reactor. They are placed methodically throughout the nuclear reactor as a means of control. For example, as the control rods are moved into the reactor, neutrons are absorbed by the control rods and the reactor power is decreased. Inserting them all at the same time shuts down the reactor. Control rods can also be inserted manually, if necessary. The plant operator then determines the reason for the trip remedies it and, when it's determined to be safe, restarts the reactor. So, while not common, a reactor trip is an important way to protect the components in a nuclear power plant from failing or becoming damaged [13].

A doctoral research on daily psychological evaluation in reactor operators is being carried out, which will provide important information for the development of this work. The last slice of J. Reason's Swiss cheese may appear with fewer holes. Before entering the reactor building and in the control room the operator will undergo a psychological, physiological and behavioral check that may prevent him from assuming his operator function, to prevent unsafe act of the operator.

2. METHODS

The psychological, physiological and behavioral measures, obtained through individual evaluations of each reactor operator, will be analyzed and placed in databases. For these measures will be determined operating limits, which during the operation of the reactor will be correlated with the values measured at each hour of operation of the reactor, which will receive the status of normal, alert or danger. The HFACS framework provides a tool to assist in the investigation process and target training and prevention efforts. Investigators in nuclear industry are able to systematically identify active and latent failures within an organization that culminated in an accident. The goal of HFACS in nuclear industry is not to attribute blame; it is to understand the underlying causal factors that lead to an accident, Fig. 4.

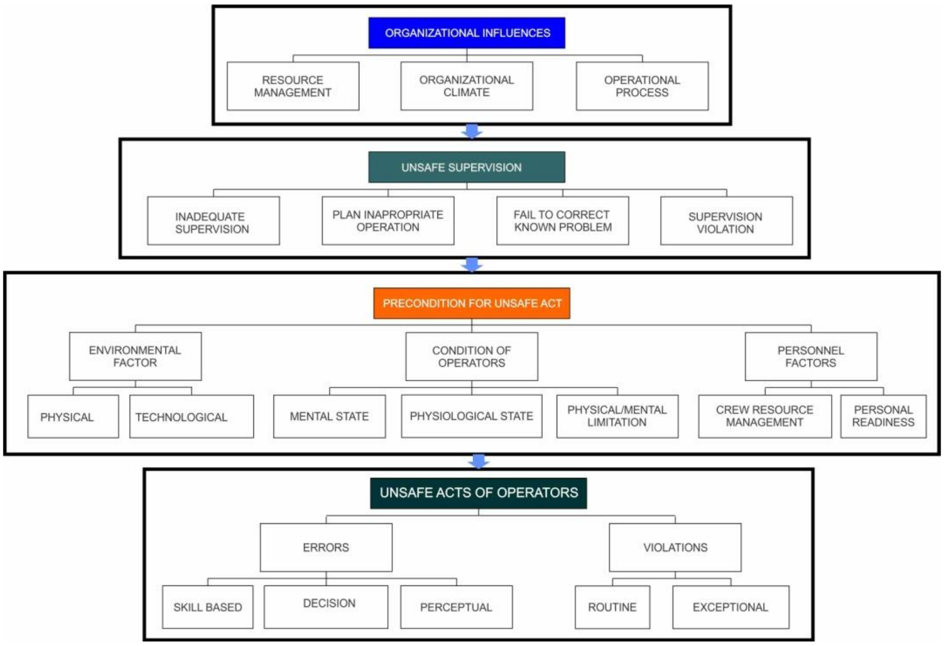


Figure 4: HFACS in nuclear industry

Case Study, three of them hypothetical and possible, related to the reactor operation illustrates the concern about the safety and security:

Case 1 - Operator had a stroke during reactor operation in the control room and his co-work shut-down the reactor.

Case 2 - Operator suffered stress in traffic in his going to the reactor facility; when performing test in the emergency cooling system for reactor start up, he didn't close a valve completely; changing the pool water technical quality causing a week delay in the reactor operation.

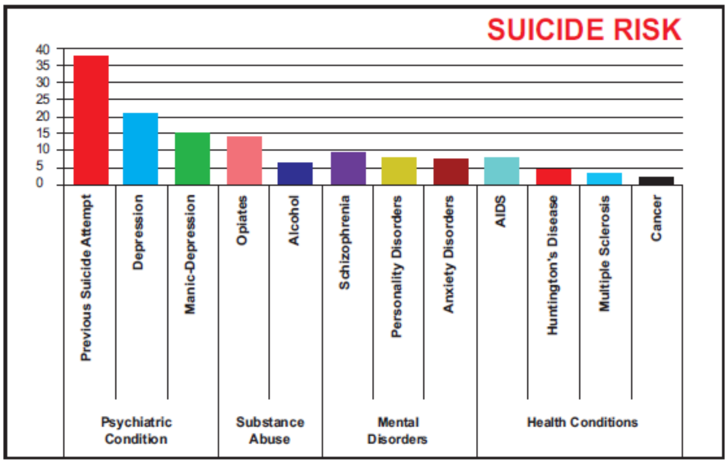
Case 3 - Operator just arrived to afternoon shift in the control room, after a few minutes his co-worker noticed that his cognition and behavior has changed. Later in the hospital he was diagnosed with head cancer.

According the HFACS, case study is presented in Table -1.

Table 1: Human factor analyze

	Organizational Influences	**Unsafe Supervision**	**Preconditions for Unsafe Acts**	**Unsafe Acts of Operators**
Case-1	Not Applicable	Not Applicable	Adverse Physiological States	Not Applicable
Case-2	Not Applicable	Not Applicable	Adverse Mental States	Perceptual Errors/Violation
Case-3	Not Applicable	Not Applicable	Adverse Physiological States	Not Applicable

There is a tight relationship between psychological characteristics and performance among people in risky occupations. People with high performance usually have good cooperation, calmness, psychological health, and proactive. It´s necessary to offer operators comfortable working environment to improve their performance and ensure safety [11]. In medicine it is public and well-known that abnormalities of psychological, physiological and behavioral order emit signs that can be interpreted and diagnosed, this allows that through analysis it is possible to create parameters to be connected to the reactor trip, in order to reduce the risk of operation of the reactor. Technologies such as face reader and psychological, physiological and behavioral assessments that measure heart rate, skin temperature, facial expressions, brain waves, collaborate to perform this work, making measurable symptoms like Anxiety, depression, insomnia, poor personal hygiene, hyperactivity, stress, strange behavior, illusion and suicide, Fig. 5.



Clare Harris and Barraclough

Figure 5: Suicide risk for psychological, physiological and behavioral disturbs

3. CONCLUSIONS

The nuclear safety community regulators, operators and owners generally tend not to favor the concept of global governance with respect to their enterprise. Their philosophy is that the principal responsibility for nuclear safety lies with the operator of the nuclear facility. National governments set the policy frame work and establish legislation and regulation within which the operators are obliged to act. A major breach of physical security, such as sabotage of a nuclear reactor, could pose serious safety risks [14]. The international nuclear security regime is nowhere near as extensive, advanced or entrenched as the regime for nuclear safety. There are fewer treaties, a less widely accepted set of recommended security principles and practices, little collaboration between nuclear plant operators worldwide, as in the case of World Association of Nuclear Operators (WANO) for nuclear safety, practically no peer review and an abiding sense that nuclear security is too sensitive an issue to be subject to global governance.’ The extent of the overlap between safety, security and nonproliferation is, however, increasingly recognized. Common principles, for instance, are seen to apply to safety and security, such as the philosophy of “defense in depth” [15]. Nuclear reactors and other nuclear facilities must meet two broad safety requirements: A nuclear safety requirement that the facilities be safe to operate with a very small probability of accidents; and a radiation safety requirement that the radiation exposures in normal operation be below certain limits for both personnel and for members of the public. Data will be obtained through operators evaluations related to alcohol consumption, drugs, blood pressure, deficit of attention, concentration, body temperature, stress, depression, pain expression, etc. Compared to measures performed on operators in the control room may assume the status of alert, hazard and essentially shut down the reactor automatically after data combination. It can be interpreted as a threat to the operator health or to the reactor facility. This study is being carried out in the reactor IEA-R1, research reactor of the swimming pool type that works in the power of 5MW. Located in the University of São Paulo campus, region of the city where the population density is huge. The reactor started up in 1958, and in these sixty-one years of operation it is considered to be an intrinsically safe reactor. The results of this study can be applied in the selection and training of new reactor operators, an activity that with the development of the nuclear industry should increase greatly. With the application of human psychological, behavioral and physiological factors in the 'reactor trip' it is expected that the safety of the reactor and the operators will be increased, since measures such as heart pressure, heart rate, body temperature, adrenaline level, stress, mood , anxiety and depression, should anticipate the diagnosis of future problems. Nuclear reactor operation, because it is considered high-risk activities as well as other activities related to means of transport, medicine and petrochemical industries. It is important to point out that the average age of the operators that go through this study is over 50 years, which will offer some peculiarities that should be considered in the result. Nuclear reactor accidents constitute an epitome of low-probability but high-consequence risks. Brazil needs to contribute actively, to the international development of a nuclear security policy. Studies reveal that with new procedures used in medicine, psychology and neurology associated with technology it is possible to determine the threats before the facts.

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