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Human Factors in Nuclear Reactors' Accidents

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Definition of Human Factor

The interface between a machine and its operators in any industrial project is usually known as the human factor. Human and organizational factors are often considered as discrete variables in that they are commonly viewed as separate and identifiable issues in the cause of an event.

new requirements on the human operators:

The new systems require human operators to constantly adapt to new and unforeseen system and environmental demands. operators must be able to handle the `non-design' emergencies, because the system designers could not foresee all possible scenarios of failures and are not able to provide automatic safety devices for every contingency.

Micro and Macro-ergonomics

Human factors, also called ergonomics, is concerned with improving the productivity, health, safety, and comfort of people, and also with effective interaction between people, the technology they are using, and the environment in which both must operate. Human factors specialists call these collective sets "human-machine-environment systems."

Human factors at the micro level, micro-ergonomics, is focused on the human-machine system level and is concerned with the design of individual control panels, visual displays and workstations. Included are studies of human body sizes, known as anthropometric, human skills, cognitive capacity, human decision-making, information processing and error, etc.

Human factors at the macro level, macro-ergonomics, is focused on the overall people-technology system level and is concerned with the impact of technological systems on organizational, managerial, and personnel (sub-) systems.

Hnman Factors in Nuclear Reactors' Accidents

There are two main categories (classified according to the stage):

a) lack of human factors considerations at the (system) Design Stage; and

b) lack of human factors considerations at the (system) Operating Stage. The errors due to can be classified into the following errors:

1- procedural errors: such as errors in reading and implementing emergency operating procedures

2- cognitive errors: errors caused by faulty knowledge or reasoning during an event. Cognitive errors can be divided into four categories:

• Incorrect diagnosis of an accident situation and continuing despite information from the plant that contradicts the diagnosis.
•Changing a response decision without any technical basis.
• Limitations of short-term memory.
• Fail to recognise the differences between the plant's unfamiliar behaviour and their expectations.

human factor issues must be considered:

Task analysis
Personnel skills
Operator Training and Testing
Procedures
Control Room Design and Layout
Reporting
Equipment Design, Maintenance and Testing

Human system Interface (HSI):

Definition of HSI: 'A part of the nuclear power plant through which personnel interact to perform their functions and tasks.

The primary purpose of the HSI is to provide the operator with a means to monitor and control the plant and to restore it to a safe state when adverse conditions occur (it must include cognitive as well as physical aspects necessary for supporting performance.

The implementation of devices that successfully accomplish this objective would also satisfy six important human performance goals that all contribute to the safe and efficient operation of the plant: 1) reduce complexity, 2) reduce error and improve human reliability, 3) improve usability, 4) reduce operator workload, 5) support low variance among users, and 6) improve situation awareness.

The recommended selection of HSI consists of four criteria groups:

1. HSI technical characteristics, including architecture and functions, technology readiness, and regulatory considerations

2. Context of use (work domain context and operational context)

3. Usability: One of the most comprehensive methods to evaluate the usability of a device for an operational task is to apply the framework offered by ISO 9241-306:2008 ("Ergonomics of Human-System Interaction - Field assessment methods for electronic visual displays"2) (ISO, 2008). This standard helps the designer to define usability in terms of the "safety, effectiveness, efficiency, and satisfaction with which a specific user can use a specific system in a defined context."

Note that **"safety"** is not regarded as a separate attribute, but rather as an outcome of the correct application of the other three attributes.

• **Effectiveness:** The accuracy and completeness with which users achieve specified goals.
• **Efficiency:** The resources expended in relation to the accuracy and completeness with which users achieve goals.
• **Satisfaction:** Freedom from discomfort, and positive attitudes towards the use of the product.

4. Human performance and human-system interaction

Human factors in PSR:

The objective of the review of human factors is to determine the status of the various human factors that may affect the safe operation of the nuclear power plant. The scope of this safety factor is not only to review the status of management of the various human factors that could affect the safe operation of power plants, but it may also identify areas of human performance where such activities can significantly affect nuclear safety, if not addressed in the safety analysis area, and assess them against current standards and practices. The review takes into consideration aspects of human factors including: staff qualifications, hiring, and training of employees; employee performance enhancement programmes; employee concerns or ombudsman programme and also human-machine interface.

Major Human Factors Causes of the Three Mile Island Accident

The lack of human factors considerations at the design stage:

1-The TMI's control room: It was poorly designed with problems including:

•controls located far from instrument displays that showed the condition of the system; cumbersome and inconsistent instruments that often looked identical and were placed side-by-side, but controlled widely differing functions;
•instrument readings that were difficult to read
•contradictory systems of lights, levers or knobs -lever up may have closed a valve, while pulling another lever down may have closed another one.
•there was no direct way or any designated indicator to read the exact water level in the reactor core. This was partly responsible for one of the most significant errors by the operators: they cut back and failed to maintain the high pressure injection (HPI) system. Furthermore, the HPI throttle valves were operated from a front panel while the HPI flow indicator was on a back panel and could not be read from the throttle valve operating position.
•In the control room of TMI, there were three audible alarms sounding and more than 1,600 lights blinking at the time of accident. The TMI operators had to literally turn off alarms and shut down the warning lights.

2-The lack of proper operators training in general, and "stress training" in particular, was a major contributor to the TMI accident. It was a critical human factors consideration that should have been paid attention to at the design stage of the TMI. In other words, the TMI operators were only trained to handle the discrete events and not to deal with `multiple-failure' accidents. These accidents were not simulated in the training.

3- The organizational factors: Some typical (generic) problems were due to the hierarchical organizational structure, such as problems of mismatches in the response times at the different levels in the hierarchy, and of information overload (cf., Meshkati, 1991).

The operating stage's problems

In spite of existing of a numerous instances of misjudgment by the operators but it may seen to be less significant in this accident comparable with the design errors.

Major Human Factors Causes of the Chernobyl Accident

Lack of human factors considerations at the design stage:

1- the designers did not foresee the awkward and silly actions by the operators
2- faults in the concept of the reactor (inherent safety not built-in);
3- faults in the engineering implementation of that concept (insufficient safeguard systems); and
4- failure to understand the man-machine interface
5- the shutdown system was, in the event of the accident, inadequate, and might in fact have exacerbated the accident, rather than terminated it;
6- there were no physical controls to prevent the staff from operating the reactor in its unstable regime or with safeguard systems seriously disabled or degraded,
7- there were no fire-drills, no adequate instrumentation and alarms to warn and alert the operators of the danger.
8- The lack of proper training, as well as deficiencies in qualifications of operating personnel
9- deficiencies in the plant organization and management

The principal `managers' who ran and conducted the test at Chernobyl which caused the accident "were electrical engineers from Moscow. The man in charge, an electrical engineer, was not a specialist in reactor plants"

The lack of human factors considerations at the operating stage:

•A sequence of human errors turned some weaknesses in the reactor's design into deadly flaws.
•Six important safety devices were "deliberately" disconnected on the night of 25); the most important of which, the Emergency Core Cooling System (ECCS) was made inoperative. And the reactor was deliberately and improperly run below 20% power.

Major Human Factors in Fukushima:

1- Operators' lack of knowledge about and practice with the emergency systems.
2-The ERC support was more difficult to provide than expected due to the conditions of the emergency.
3-The ERC had difficulty managing the supervision of the three reactors simultaneously.
4-The idea of using fire trucks came up early, but its implementation was delayed while attempting the other possibilities and understanding the procedures.
5- The uncertainty and the lack of foresight about this specific accident were also highlighted in the number of decisions that had to be made during the emergency response because they had not been considered beforehand.
6- Those farther away from the danger, in the TEPCO headquarters and in the Prime Minister's office, seemed to have greater difficulty dealing with uncertainty.

Conclusions

Many serious accidents have primarily been attributed to Human Factors. Humman factor considerations shoud be taken into account during design stage, regulations, and in PSR.

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