ON THE ROLE OF SAFETY CULTURE IN RISK-INFORMED REGULATION

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Abstract

There is a widespread belief that safety culture is an important contributor to safety of operations. The commonly accepted attributes of safety culture include good organizational communications, good organizational learning, and senior management commitment to safety. Safety culture may be particularly important in reducing latent errors in complex, well-defended systems. The role of regulatory bodies in fostering strong safety cultures remains unclear, and additional work is required to define the essential attributes of safety culture and to identify reliable performance indicators.

Note: The views expressed in this paper are the authors' and do not necessarily represent the views of the Advisory Committee on Reactor Safeguards.

1. Introduction

The importance of management and organization factors to nuclear facility safety was explicitly recognized in the aftermath of Three Mile Island. Following the Chernobyl accident, the International Nuclear Safety Advisory Group (INSAG) introduced the term 'safety culture' to represent the entirety of management and organization factors important to safety. Although INSAG intends that 'safety culture' capture all the management and organizational factors relevant to safe plant operation [1], many investigators use the term more narrowly. 'Safety culture' is often used to denote an element of organizational culture, which, in turn, is a component of the broader term 'management and organizational factors.'

The importance of organizational culture to the safety of operations has been established by studies in the chemical process industry, but similar data from nuclear power plants have been incomplete. Nonetheless, there is widespread belief that safety culture is an important indicator of, and contributor to, reactor safety.

2. The Concept of Safety Culture

Suggestions that 'culture' might help explain organizational behavior, and that management and organizational factors could influence safety performance, both predated INSAG's introduction of the term 'safety culture.' Ostram, et al.[2], note that "Heinrich's Domino Theory developed in the 1930s was based on the premise that a social environment conducive to accidents was the first of five dominos to fall in an accident sequence." Uttal [3] summarized the meaning of organizational culture as: a system of shared values (what is important) and beliefs (how things work) that interact with a company's people, organizational structures, and control systems to produce behavioral norms (the way we do things around here).

While the literature does not support a single definition of safety culture, there is some agreement on the organizational attributes that indicate a strong safety culture. In studying safety in the chemical process industry, Lee [4] found that the characteristics of low accident rate plants included a high level of communication, good organizational learning, a strong focus on safety by the organization at all levels, and a strong senior management commitment to safety. Lee started by identifying 19 attitudes toward safety, such as confidence in safety procedures, personal caution over risks, trust in the workforce, perceived clarity of safety rules, and satisfaction with work relationships. An attitude survey was designed to measure the degree to which individual workers reflected those attitudes. Using self reported accident rates as the safety metric, Lee found a strong correlation between 15 out of 19 of the factors (attitudes) and low accident rates.

During the 1990s, the NRC sponsored work at Brookhaven National Laboratory to look at the relationship between organizational factors and safety. Jacobs & Haber [5] developed a set of twenty management and organization factors, including coordination of work, communications, organizational culture, safety culture, goal prioritization and human resource allocation. The investigators reported successfully correlating particular factors, such as good communications, with particular safety metrics, such as a low number of human error events. Development of the underlying theory and design of the measurement process is well documented, but data collection appears to have been limited to one fossil power plant and two nuclear power plants.

3. Safety Culture and Human Error

The term 'human error' is generally understood to mean an unsafe act by a system operator. The consequences of such an act may or may not be severe, depending on other circumstances. Such circumstances are often the product of organizational factors that determine system response. In his taxonomy of human error, Reason [6] distinguishes between active errors, "whose effects are felt almost immediately," and latent errors, "whose adverse consequences may lie dormant within the system for a long time ..." Active errors are associated with system operators such as airplane pilots, air traffic controllers, or power plant control room personnel. Latent errors are associated with personnel removed from operations, such as designers and maintenance personnel.

Active errors, or unsafe acts, may interact with organizational factors and local workplace factors to create what Reason calls 'organizational accidents' [7]. The organizational factors and local workplace factors not only interact directly, but each may create latent condition pathways. Accidents with significant losses occur when all these conditions align in such a way that the defenses built into a system are overwhelmed.

Latent conditions may be sufficient to cause accidents. The prevalence of latent errors was identified in a recent study by the Idaho National Engineering and Environmental Laboratory (INEEL)[8]. INEEL analyzed 35 operating events and found that most identified errors were latent, with no immediate observable impact. The ratio of latent to active errors was 4:1.

The INEEL findings are supported by other analyses. In discussing a human performance improvement program at Duke Power Company, one Duke senior manager observed that "If you analyze an entire event, . . . you'll find it wasn't just one mistake - - it was five, six or seven mistakes that occurred and there weren't enough contingencies or barriers built in to prevent the event from happening [9]."

A systematic effort to improve human performance at Duke Power's McGuire, which addresses virtually the same factors identified by INSAG's model of safety culture, has produced significant improvements in station performance. The program was started in 1994 at McGuire when declining performance required correction, and management determined that station processes and programs were to blame. Since the program was initiated, refueling outage times at McGuire have been reduced from about 90 days to about 33 days, and capacity factors have increased from about 72% to about 89%.

4. A Regulatory Perspective

The Advisory Committee on the Safety of Nuclear Installations (ACSNI) identifies fostering safety culture as the next stage in the evolution of safety regulation [10]. They suggest that, "The regulators need to act in such a way as to encourage 'ownership' of safety by the whole staff of the licensee."

A theme that runs through the ACSNI study is that the most effective safety cultures will develop in less prescriptive regulatory structures. A subsequent report notes that, "It is recognized that there are a number of prescriptive regimes, such as the U.S. Nuclear Industry, where the encouragement of a positive safety culture is still essential. It is considered that those Operators with good Safety Cultures, within the US regulatory regime, tend to self-regulate around the constraints of the regulatory regime, to attain levels of safety which are beyond those minima specified in the regulations. The manner in which the Regulator can encourage such self regulation is not clear" [11].

This idea is explored in some detail in an earlier paper by Marcus [12], in which he examines the implementation of certain NRC requirements at several U.S. nuclear power plants. His conclusion was that, "... nuclear power plants with relatively poor safety records tended to respond in a rule-bound manner that perpetuated their poor safety performance and that nuclear power plants whose safety records were relatively strong tended to retain their autonomy, a response that reinforced their strong safety performance."

Current NRC programs to develop risk-informed regulatory processes and performance-based reactor oversight do not appear to be at odds with some degree of self-regulation. The new reactor oversight program [13] identifies a level of performance, as measured by a set of performance indicators, where regulatory involvement will be limited to a baseline inspection program. The program is structured around seven cornerstones of safety performance, each monitored by one or more performance indicators. In addition to the cornerstones, the staff has identified three "cross-cutting" elements associated with each cornerstone: human performance, safety-conscious work environment, and corrective action programs. There are currently no performance indicators associated with these cross-cutting issues. The NRC staff argues that, if risk-informed inspections and plant performance indicators show that cornerstone objectives are being met, then the associated human performance is also acceptable [13]. The ACSNI study group [10] concluded, however, that research is required to increase the number of validated culture and performance indicators available, and to establish the extent to which the indicators remain valid once they have been identified and used as indicators.

An issue that is important from a regulatory standpoint is assuring that root-cause analyses are sufficiently thorough to identify safety culture deficiencies and their impact on safety. Weil and Apostolakis [14] have extended traditional root-cause analyses to include work processes and Reason's model of human error [6]. They applied their methodology to a number of incidents and identified six of the twenty factors proposed by Jacobs and Haber [5] as being important: communications, formalization, goal prioritization, problem identification, roles and responsibilities, and technical knowledge. The basis for choosing these six was identifying factors that affected a large number of tasks and/or were often cited as contributing to errors. They also found that the significance of each factor must be assessed in the context of the tasks that constitute the work processes at the plant.

5. Conclusions

Reason [7] observes that the quality of both production and protection depend on the same organizational processes. However, "... the partnership between production and protection is rarely equal ... partly because the information relating to production is direct, continuous, and readily understood." By contrast, "... safe operations generate a constant - and hence relatively uninteresting - non-event outcome." Safety culture and the attributes associated with safety culture are important contributors to both system safety and system performance.

The suggested next step in understanding the relationship among safety culture, safety of operations, and safety regulation is to develop consensus on the essential attributes of safety culture, and to identify suitable performance indicators. Equally