

SAFETY CULTURE IN THE NUCLEAR INDUSTRY

by

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INTRODUCTION

The concept of safety culture has received significant attention ever since the accident at Three Mile Island (TMI) highlighted the importance of management and organizational factors to the safety of nuclear power operations. The term "safety culture" was, however, first introduced in the aftermath of the Chernobyl accident by the International Nuclear Advisory Safety Group (INSAG) [Reference 1] to denote the complex of management and organizational factors that are important to safety. In a series of reports [References 1—3] issued after the Chernobyl accident, INSAG explicitly recognized the importance of an established safety culture to govern the actions and interactions of all individuals and organizations engaged in activities related to nuclear safety. INSAG further expanded on the concept by stating that "the phrase 'safety culture' refers to a very general matter, the personal dedication and accountability of all individuals engaged in any activity which has a bearing on the safety of nuclear power plants... starting with... their senior management." Although INSAG focused in significant detail on the policies and practices that are necessary to promote safety within the nuclear organization, INSAG made the critical observation that the importance is not just in the policies and practices themselves, but also in the environment of safety consciousness that they create.

The work of INSAG is important because it provided a general definition of safety culture that remains valid today. There also seems to be a general agreement in the nuclear community on the elements of safety culture. Elements commonly included at the organization level are senior management commitment to safety, organizational effectiveness, effective communications, organizational learning, and a working environment that rewards identifying safety issues. Elements commonly identified at the individual level include personal accountability, questioning attitude, and procedural adherence. Financial health of the organization and the impact of regulatory bodies are occasionally identified as external factors potentially affecting safety culture.

The Advisory Committee on Reactor Safeguards (ACRS) maintains a keen interest in the area of safety culture for a number of reasons, among which are the following:

1. Since the TMI and Chernobyl accidents, a clear consensus has developed in the nuclear industry that there is a strong link between the attitudes of management and workers toward safety and safety performance. The significant improvements in industry performance of the past 20 years are attributable, in part, to focused improvements in organizational elements that are generally associated with safety culture. The results of these focused improvements seem to confirm that a linkage exists and may be significant.
2. If, indeed, safety culture affects safety performance and if the linkage between elements of safety culture and safety performance could be established, the identification and monitoring of such elements could provide operators and regulators alike leading indicators of safety performance.
3. Currently, probabilistic safety analysis (PSA) models human error, but is not capable of modeling the effects of safety culture and other organizational factors on the frequency of unsafe acts and the probability of latent errors. Therefore, PSA is not able to model and quantify the effects of safety culture on safety performance. If safety culture attributes could be correlated with plant safety performance indicators, such as equipment failure rates or system unavailabilities, the impact of safety culture on risk metrics could be assessed and quantified.

In order to explore the current state of knowledge and identify areas where additional work would help to address the above issues, the ACRS recently completed a survey of the state-of-the-art in the area of safety culture. This work is documented in NUREG-1756 [Reference 4] and other papers [References 5 and 6].

NUREG-1756, "SAFETY CULTURE: A SURVEY OF THE STATE-OF-THE-ART"

NUREG-1756 documents an extensive review of literature that addresses the following questions:

- What is safety culture?
- How can it be measured?
- How is safety culture related to the safety of operations?
- How is safety culture related to the regulatory process?

NUREG-1756 explores the evolution of the definition of safety culture from its introduction by INSAG to the present. From the beginning, definitions of safety culture have always recognized both the management and organizational elements reflected in practices and procedures. The attitudinal elements affecting human performance are

fostered by the environment of safety consciousness created by those practices and procedures. The report identifies some of the attributes of safety culture proposed by different studies and describes the efforts made to model organizations and organizational outcomes. The report also recognizes work done by several international organizations, such as the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA), to identify performance indicators to gauge safety culture. Although much work has been documented in the area of safety culture, the report makes the following observations:

1. "INSAG work does not establish a link between safety culture and safety performance... A positive relationship is simply assumed."
2. "No performance indicators to gauge safety culture and its impact on safety of operations appear to have been identified and validated."

Among the conclusions cited in the report is the following:

"...There is a clear consensus in the field of safety management that worker attitudes toward safety make a difference. What is not clear is the mechanism by which attitudes, or safety culture, affect the safety of operations. Statistical evidence that unambiguously links safety culture or its specific attributes with the safety of operations is surprisingly rare, especially within the nuclear industry."

The report does not conclude that a linkage between safety culture and safety of operations cannot be established, or that performance indicators of safety culture cannot be identified. In fact, the report shows that such linkage and statistically valid performance indicators of operational safety have been identified in the chemical process industry. The report simply suggests that for commercial nuclear plants, further work needs to be done to explore these possibilities, including the establishment of a process to reach consensus on the essential attributes of safety culture and to identify suitable performance indicators.

SHOULD SAFETY CULTURE BE DIRECTLY REGULATED?

The NRC Revised Reactor Oversight Program

The U.S. Nuclear Regulatory Commission (NRC) has an interest in safety culture because it is now widely believed that there is a relationship between safety culture and safety of operations. Through policy statements, the Commission has clearly stated its expectation that each nuclear facility foster the development of a safety culture that ensures safe operations and establish a working environment that rewards the identification of safety issues. Inspection procedures direct the inspectors to evaluate areas that are elements of safety culture. The Commission has not gone further in regulating safety culture in a direct way. The main obstacle to further regulation is that many elements that are

important to safety culture are virtually inseparable from the management of the organization, and the NRC has been reluctant to regulate management functions in any way. Licensees are ultimately responsible for the safe operation of their facilities and must be allowed the latitude to achieve safety in their own way.

The NRC's Revised Reactor Oversight Program (ROP) [Reference 7] identifies a level of performance, as measured by a set of performance indicators, at which regulatory involvement is limited to a baseline inspection program. The performance indicators monitor seven cornerstones of safety performance. The four cornerstones for reactor safety are initiating events, mitigating systems, barrier integrity and emergency preparedness. In addition to the cornerstones, the program includes the following three "crosscutting" elements, which are part of each cornerstone:

- human performance
- management attention to safety and workers' ability to raise safety issues (safety-conscious work environment)
- finding and fixing problems (utility corrective action programs)

No performance indicators are associated with these crosscutting issues.

Currently, the vast majority of plants operate below the threshold that triggers an expanded inspection program. If one or more performance indicator(s) degrades, the NRC evaluates whether the degraded indicator(s) simply indicates an isolated event or suggests generic implications regarding the crosscutting issues of human performance, safety-conscious work environment, and the utility's corrective action program. To determine whether the degraded indicator(s) suggest(s) generic implications, this evaluation would question, for example, whether this is a repeat event, whether multiple layers of the organization were involved, or whether the event was self-identified. The program, therefore, evaluates elements of safety culture.

The problem is that the cornerstone performance indicator thresholds are set high enough that few plants experience degraded performance even in one performance indicator. By the time repeat events are noted, a significant cultural degradation could have occurred. Furthermore, cultural degradations are expected to be precursors of events and, thus should provide leading indications. Instead, in the current program, cultural degradation is implied by the occurrence of plant events or exceedance of indicator thresholds. If sufficiently objective indicators of safety culture could be identified, they could be monitored independently and could provide leading indications of degraded culture before plant events are experienced.

Is the ROP Effective in Identifying Safety Culture Problems?

An additional concern regarding the effectiveness of the ROP performance indicators in identifying cultural problems is that the industry has used these indicators to monitor safety system performance since the 1980s. Therefore, the industry has developed significant experience in managing a plant's performance so that it scores well on these indicators. In addition, the implementation of the Maintenance Rule and the ability to perform online maintenance of much of the equipment monitored by the indicators further allows the operator to focus its attention on these systems, away from the schedule pressure experienced during shutdown for refueling. It is noteworthy that several facilities that were subjected to intense regulatory scrutiny during the 1990s had not exhibited significant degraded performance, as measured by these indicators, prior to regulatory intervention.

past history

This concern regarding the proper selection and number of validated culture and performance indicators, and the extent to which the indicators remain valid once they have been identified and used as indicators, was raised by the Advisory Committee on the Safety of Nuclear Installations (ACSNI) in its 1993 report to the United Kingdom Health and Safety Executive (HSE) [Reference 8]. Along the line of thought developed by ACSNI, one could contend that the ROP performance indicators are not well-suited to identify safety culture issues. Monitoring performance in more complex situations in which the organization is forced to manage the proper balance between safety and economics, such as shutdowns for refueling, could provide better triggers for assessing the culture of the organization.

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Some senior managers of operating plants have expressed concern regarding the pressure they experience from peers and management alike to complete refueling outages in ever shorter time. From that perspective, one might question whether some recent instances of inspections that failed to identify component degradation, including the extensive head corrosion at the Davis-Besse Nuclear Power Station, might possibly relate to the pressure to expedite inspection activities in order to restart the reactor on the planned, fast schedule. Conditions experienced under the pressure of outage schedules are more likely to create the kind of latent errors and conditions that are of major concern with safety culture [References 9 and 10], than the unreliability or unavailability of safety systems monitored by the ROP performance indicators. Rapid decisions to be made in these situations regarding inspection findings or whether repairs are needed before restart are more likely to expose the true culture of the organization. Recent experience with failure of passive components may suggest some reorientation of the oversight process from its current focus on safety systems.

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outage schedule
pressure
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Can Metrics Monitored by the Plants Provide Indicators of Safety Culture?

U.S. nuclear plant operators routinely monitor and trend a substantial amount of performance data. Some of these data provide direct insight into the safety culture of the organization, but typically, no effort is made to organize them under the umbrella of "safety culture."

Among the programs that are most reflective of the culture of the organization is the "corrective action program." Under this program, which is implemented at all nuclear plants, any individual who identifies a defect, nonconformance, or discrepancy with established requirements is required to promptly report the finding to plant management. Plant management assigns the responsible organization to evaluate the issue and recommend the appropriate resolution. Typically, each issue is assigned a significance level that will affect the level of action and schedule for resolution. Safety and regulatory significant issues require "root-cause" analyses to identify the fundamental causes and actions required to prevent recurrence. The corrective action program has become the central process through which issues are raised, evaluated, and resolved and, thus, provides a significant window on the effectiveness of management and the attitudes of plant personnel toward safety.

The NRC's current ROP evaluates plant corrective action programs under the crosscutting issue of "finding and fixing problems." The corrective action programs, however, are much more than just a measure of how good the plant organization is at finding and fixing problems. Elements of the program and their metrics provide clear insights on management attitudes and responsiveness to employees who raise concerns, as well as the appropriateness of the threshold for accepting new issues, the extent of work backlog and the adequacy of the workforce to perform it within schedule, the adequacy of root-cause analyses, and the questioning attitude of the plant staff. These metrics are, in many ways, metrics of "Safety Culture." Plant management and the NRC use these metrics extensively to monitor recovery of plant organizations from poor performance. Some of these metrics could provide effective performance indicators of elements of safety culture and provide leading indications of safety performance.

At least one utility in the United States, namely, Northeast Utilities, integrated the insights from the corrective action program with other plant metrics under a structural umbrella of "Safety Culture" proposed by IAEA [Reference 11], to trend and monitor the recovery of its nuclear program in the 1990s.

Under the umbrella of safety culture, the following indicators were monitored:

- Safety-conscious work environment ✓
- Radiation protection ✓
- Challenges to operations ✓
- Human performance ✓

- Licensing and design compliance ✓
- Procedure compliance and quality
- Quality of maintenance
- Oversight
- Corrective action effectiveness
- Effective operating experience

Many parameters were monitored and integrated to provide a numerical score for each indicator and for the overall safety culture index. The index was used for trending performance and proved to be a useful indicator.

In general, unless they face the situation that confronted Northeast Utilities in 1996, utilities are reluctant to develop and share with the regulator such transparent measures of safety culture. The example of Northeast Utilities is important because it demonstrates that plant information, which is available and routinely collected by the operator, can provide significant performance indications of safety culture. It is important to understand the extent to which plant management data is made available to, and utilized by, the regulatory bodies of the other quadripartite countries to monitor plant safety culture.

Does Safety Culture Need To Be Regulated?

Operating and safety performance of nuclear power plants have been steadily improving through the years. The nuclear industry has effectively addressed the lessons learned from the TMI and Chernobyl events. The industry views itself as mature, safe, and capable of managing its own culture and performance. The U.S. nuclear industry is undergoing a phase of consolidation into nuclear groups that have the resources and capability to operate their plants with high professional standards at high performance levels. The question, then, is whether there is a problem with the safety culture at power plants that would justify a stepped up effort to directly regulate safety culture.

The ACSNI study of safety culture (previously referenced) noted that the most effective safety cultures develop in less-prescriptive regulatory structures. They stated "the most impressive achievements appear in companies where the pressure for safety has been generated within the organization, apparently independent of external standards" [Reference 8]. We can add that best industry practices have often been the result of successful initiatives of individual utilities, while overregulation tends to lead to uniformity and striving to meet minimum requirements.

On the other hand, even at the current level of industry maturity, we are confronted with events such as the recent reactor vessel head corrosion identified so belatedly at the Davis-Besse Nuclear Power Plant. Problems subsequently identified in other programmatic areas suggest that these may not be isolated events, but the result of a generally degraded plant safety culture. The head degradation was so severe that a major

accident could have resulted and was possibly imminent. If, indeed, the true cause of such an event proves to be degradation of the facility's safety culture, is it acceptable that the reactor oversight program has to wait for an event of such significance to occur before its true root cause, degraded culture, is identified? This event seems to make the case for the need to better understand the issues driving the culture of nuclear power plants and to strive to identify effective performance indicators of resulting latent conditions that would provide leading, rather than lagging, indications of future plant problems.

MODELING OF SAFETY CULTURE IN PROBABILISTIC SAFETY ANALYSIS (PSA)

Given the significant impact of human performance on plant risk, the ACRS believes that it is essential that the contribution of cultural factors to human performance be understood and modeled in PSA. The review of the state-of-the-art documented in NUREG-1756 leads to the conclusion that, to date, a quantitative relationship has not been fully developed and validated between the elements of safety culture and safety performance that could be used to model the effects of safety culture in PSA. The NRC has recently developed a technique for human event analysis, known as ATHEANA [Reference 12], which includes a search process for human failure events and detailed search processes for "error-forcing" context. The effects of safety culture could be modeled as part of the error-forcing context; however, this capability of ATHEANA has not yet been fully tested and validated.

The Swedish Nuclear Power Inspectorate (SKI) sponsored a study [Reference 13] that used an expert elicitation process to select performance indicators of safety culture and expected values of the indicators for a full range of safety culture conditions. The proposed methodology includes an algorithm for quantifying the impact of the performance indicators on risk metrics. This approach could be promising, but needs to be further explored and validated.

CAN INFORMATION ON SAFETY CULTURE BE TRANSFERRED FROM ONE COUNTRY TO ANOTHER?

In our review of safety culture, we have found that the implicit assumption is typically made that safety culture experience is transferable from country to country. Safety culture is as much attitudinal as it is structural. Therefore, before lessons learned in one country can be utilized in a different country, it is important to question how and how much the safety culture at any given facility is affected by the cultural characteristics of the country in which the facility is located.

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