I Asked 30,000 People in the Nuclear Industry about Safety Culture; This is What I Learned

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Abstract

Organizations in the nuclear industry place a high value on maintaining the safety of the workforce and community. Some of these organizations do a better job than others when it comes to developing and sustaining a healthy safety culture. We spent six years studying nuclear organizations to better understand the factors that influence safety culture. We used mixed methods to evaluate perceptions of safety culture in these organizations including administering a valid and reliable safety culture survey, conducting one-on-one interviews with managers, and facilitating focus groups with members of the workforce.

We analyzed the quantitative and qualitative data collected from more than 30,000 workers in U.S. based organizations. All of the organizations had a nuclear component to their operations. They operated nuclear reactors, processed nuclear materials, decontaminated and decommissioned buildings with radiological contamination, cleaned-up hazardous/mixed waste, and conducted basic science research and development. We talked to craft workers, technicians, engineers, scientific professionals, support personnel, production workers, supervisors and managers. We conducted extensive statistical analysis and learned that, with rare exception, there is a gap between the perceptions of managers and the workforce that they manage. Managers almost always have a more positive perception of safety culture than the people that are actually performing the work. It is not a question of whether there will be a gap; it is simply a matter of the magnitude of the gap.

We also learned through exploratory factor analysis that there is one dominant factor that accounted for almost all (75%) of the variance in the perceptions of safety culture. It was the behavior of the leaders, the decisions they made, and the systems they implemented that most influenced the workforce's perception of safety culture. Personal accountability for safety accounted for 14% of the variance, communication and reporting accounted for another 6%. Everything else accounted for the remaining 5%.

Management systems, decision making and behavior is the dominant factor and managers almost always have a more positive perception than the people that work for them. People that work in organizations where management exhibits positive decision-making and safety-related behaviors tend to have more positive perceptions of safety culture.

Based upon these results, we developed a theory that there were a few important factors on which management could focus on if they sought to influence the safety culture in their organization. Our experience and research suggests that management often fails to recognize five root causes of employee discontent. Employees seek:

- To be recognized as an individual
- To be respected
- A sense of stability
- Fairness
- To make a difference

Understanding the perceptions of the workforce is critical because perceptions influence attitudes, which contribute to behaviors that determine individual performance. An organization's performance is simply the sum of the performance of all of the members of that organization. To change an organization's safety

culture, interventions should target management behavior and decision making for the greatest return on investment.

Introduction

Safety culture research helps explain how an organization's shared beliefs, values, and attitudes may help or hinder safe performance. (Morrow, Koves, & Barnes, 2014) There is empirical evidence that as safety culture improves, so does safety performance. (Beus, Payne, Bergman, & Arther, 2010) (Morrow, Koves, & Barnes, 2014) (Christian, Bradley, Wallace, & Burke, 2009) (Wu, Chen, & Li, 2008) (Zohar 2000) This relationship suggests that the results of safety culture evaluations may serve as a leading indicator of safety performance and suggest areas for intervention before significant events occur. (Morrow, Koves, & Barnes, 2014) On a personal level, the leaders of organizations are interested in evaluating safety culture because they believe that if they can influence organizational culture and align it with their mental model, then organizational performance related to safety, security, quality, and productivity will be optimized thus yielding a competitive advantage.

Since 2011, safety culture programs have become institutionalized across the U.S. Department of Energy (DOE) and methods have become more rigorous and consistent. The Energy Facility Contractors Group (EFCOG), Integrated Safety Management and Quality Assurance Working Group developed guidance documents to help member organizations develop standardized methods and best practices for evaluating and sustaining healthy safety cultures. (Safety Culture / High Reliability Organization Task Group, 2015) (Safety Culture / High Reliability Organization Task Group, 2017) This paper reflects the aggregate results of safety culture evaluations conducted over a six-year period by Oak Ridge Associated Universities (ORAU). The evaluations were conducted within the DOE enterprise and the nuclear power industry.

Description of Methods

The evaluations were conducted by teams with expertise in executive leadership, safety management, industrial/organizational psychology, educational psychology, data science, biostatistics, and engineering. Evaluation methods were consistent with industry best practices and based upon the model of a healthy nuclear safety culture developed by the Nuclear Regulatory Commission (NRC) and Institute of Nuclear Power Operations (INPO) described in **Figure 1**. (Federal Register) (Institute of Nuclear Power Operations, 2013). All studies were approved by the DOE, Oak Ridge Institutional Review Board.

Survey Instrument

A survey instrument (questionnaire) was used to measure attitudes about and perceptions of the 10 traits of a healthy nuclear safety culture. The questionnaire consisted of 39 safety culture items, 1 quality control statement, and 6 demographic questions. Statements were grouped according to the 10 safety culture traits. All statements were worded so that respondents' agreement with each statement was desirable and suggestive of a healthier safety culture. A Likert-type, 5-point scale was used. Participants were asked to provide a single response to each statement using a 5-point Likert-type scale:

- Strongly Agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree

For the demographic questions, participants were provided the option "I prefer not to answer," to allow participants to abstain from responding to statements which they did not feel they were prepared to answer at the time. In addition, the survey asked participants to respond to one open ended question ("Do you have any other comments about the safety culture at the site?").

Traits of a Healthy Nuclear Safety Culture

1. **Leadership Safety Values and Actions**—Leaders demonstrate a commitment to safety in their decisions and behaviors
2. **Problem Identification and Resolution**—Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance
3. **Personal Accountability**—All individuals take personal responsibility for safety
4. **Work Processes**—The process of planning and controlling work activities is implemented so that safety is maintained
5. **Continuous Learning**—Opportunities to learn about ways to ensure safety are sought out and implemented
6. **Environment for Raising Concerns**—A safety conscious work environment is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination
7. **Effective Safety Communication**—Communications maintain a focus on safety
8. **Respectful Work Environment**—Trust and respect permeate the organization
9. **Questioning Attitude**—Individuals avoid complacency and continuously challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action
10. **Decision making** – Decisions that support or affect nuclear safety are systematic, rigorous, and thorough

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Figure 1. Traits of a healthy nuclear safety culture as defined by the NRC and INPO

Instrument Validity

Several measures were taken to establish the validity of the survey instrument. First, a construct validity table was prepared mapping the topic, domain, and constructs for each statement. Second, a panel of subject matter experts reviewed the statements, instrument structure, and construct validity table to determine if the instrument would adequately measure the subject. Statements were modified based on their feedback. Finally, the instrument was field tested to determine if the statements had content validity and if the structure of the instrument was appropriate. Statement structure and wording were modified based on feedback.

Instrument Reliability

The reliability of the instrument was measured using the internal consistency method. The internal consistency of the instrument, measured using Cronbach's Coefficient alpha, was calculated for the overall sample ($\alpha = .968$). A Cronbach's Coefficient alpha of $\alpha = .90$ or higher is generally considered to be reflective of a highly reliable survey instrument. Further, calculations confirmed that the survey would not be improved by removing any items from further analyses. Thus, the instrument was considered internally reliable and stable.

Survey Administration

Novi Survey®, a web-based application, was used to administer the surveys. The survey instrument was posted on a secure ORAU web site and field-tested for accessibility and functionality. A hard-copy option was also developed for workers who did not have ready access to a computer. Hard-copy surveys were

distributed and collected by ORAU personnel and scanned into a database using Remark® Software. Scanned data were checked for accuracy and completeness.

Survey participation was voluntary and participant time was on the clock (i.e., paid by the employer). Survey participants were not required to disclose their identity when completing the survey (i.e., no names, user identification, employee identification number, etc.). The entire workforce for each organization was invited and had equal opportunity to participate in the survey. A survey response rate of 50% was considered the minimum acceptable response rate for each organization. Demographic profiles of participants were compared to the entire workforce to establish representativeness.

Statistical Analysis

Results from the completed surveys were exported into Microsoft Excel®. The categorical responses on the Likert-type scale were converted to a numeric value: strongly agree = 5, agree = 4, neither agree nor disagree = 3, disagree = 2, strongly disagree = 1. Data quality checks were performed to assure data integrity. Microsoft Excel® files were exported into SAS® for statistical analysis. Descriptive statistics (mean, 95% lower confidence limit, 95% upper confidence limit, standard error of the mean) were calculated for each statement. Frequency response tables were created to compare the number of positive, negative and neutral responses for each item.

To facilitate comparison between organizations, subscales were created for each safety culture trait. By design, each survey item was aligned with a safety culture trait. The mean scores for the statements aligned with a trait were averaged to create subscale scores for each trait. The subscales were then used to compare safety culture perceptions by demographic groups (i.e., work location, employer, etc.). Student's t-test and ANOVA were used to compare the mean scores between two groups. An alpha level of 0.01 was used to determine whether mean scores were significantly different. Exploratory factor analysis with varimax rotation was conducted to help understand the relationships between survey items and safety culture traits. Underlying factors were identified to explain and summarize the relationships between the survey items.

Stepwise linear regression analyses were performed to determine the impact of survey items (independent variable) on the perceptions of safety culture improvement (outcome of interest or dependent variable).

Focus Groups

A protocol was developed describing how semi-structured focus group interviews would be conducted for members of the workforce. A list of safety culture related questions was developed. Focus groups were designed to include 8 to 10 participants who were allowed to participate during their normal work hours. Stratified random sampling was employed by ORAU to select the individuals invited to participate in a focus group. Focus groups were conducted in private conference rooms by two trained ORAU facilitators. Personal identifiers were not attributed to the comments in order to maintain confidentiality. Notes from the focus groups were transcribed by the facilitators.

Management Interviews

A protocol was developed describing how semi-structured interviews of management representatives would be conducted. A list of safety culture related questions was developed. ORAU selected the senior managers to be interviewed. Each manager was interviewed individually in a private setting by a trained interviewer from ORAU. Notes from the interview were transcribed by the interviewer.

Qualitative Data Analysis

QDA Miner® was used for qualitative data analysis. A two-level coding manual based on the NRC and INPO safety culture traits and attributes was used. Analysis involved classifying focus group and interview statements as representative of one or more of the constructs of the 10 traits of a healthy safety culture. Data were summarized and patterns, relationships, and themes were identified. Statements

provided by survey participants in the open-ended item of the survey were coded and analyzed in a similar manner.

Results

Twenty-three safety culture evaluations were conducted from October 2012 through December 2017 for organizations with a nuclear mission. The total estimated population for these organizations was 32,454. Of those, 21,059 (65%) completed the survey; 1,022 (3.3%) participated in focus groups; and, 140 (0.4%) participated in management interviews. The demographic profile of the participants is described in **Table 1.**

We learned that, with rare exception, there is a gap between the perceptions of managers and the workforce that they manage. Managers almost always have a more positive perception of safety culture than the people that are actually performing the work. Our results suggest that it is not a question of whether there will be a gap; it is simply a matter of the magnitude of the gap. (**Figure 2**)

Table 1. Demographic profile of safety culture survey participants (2012-2017)

Tenure		
Category	Frequency	Percent
<2 Years	3158	15%
2-5 Years	3803	18%
6-10 Years	4338	21%
11-15 years	2470	12%
16-20 years	1117	5%
21-25 years	1623	8%
26-30 years	950	5%
>30 years	1808	9%
I prefer to not answer	1792	9%
Total	21059	1.0

Age		
Category	Frequency	Percent
<25 Years	252	1%
25-35 Years	2668	13%
36-45 Years	3459	16%
46-55 Years	5007	24%
>55 Years	5300	25%
I prefer to not answer	4373	21%
Total	21059	100%

Gender		
Category	Frequency	Percent
Male	12809	61%
Female	3966	19%
I prefer to not answer	4284	20%
Total	21059	100%

Manager or Supervisor		
Category	Frequency	Percent
Yes	4536	22%
No	14760	70%
I prefer to not answer	1763	8%
Total	21059	100%

Payroll Status		
Category	Frequency	Percent
Bargaining	2880	14%
Non-Bargaining	2013	10%
Salary	10259	49%
Hourly	1881	9%
I prefer to not answer	4026	19%
Total	21059	100%

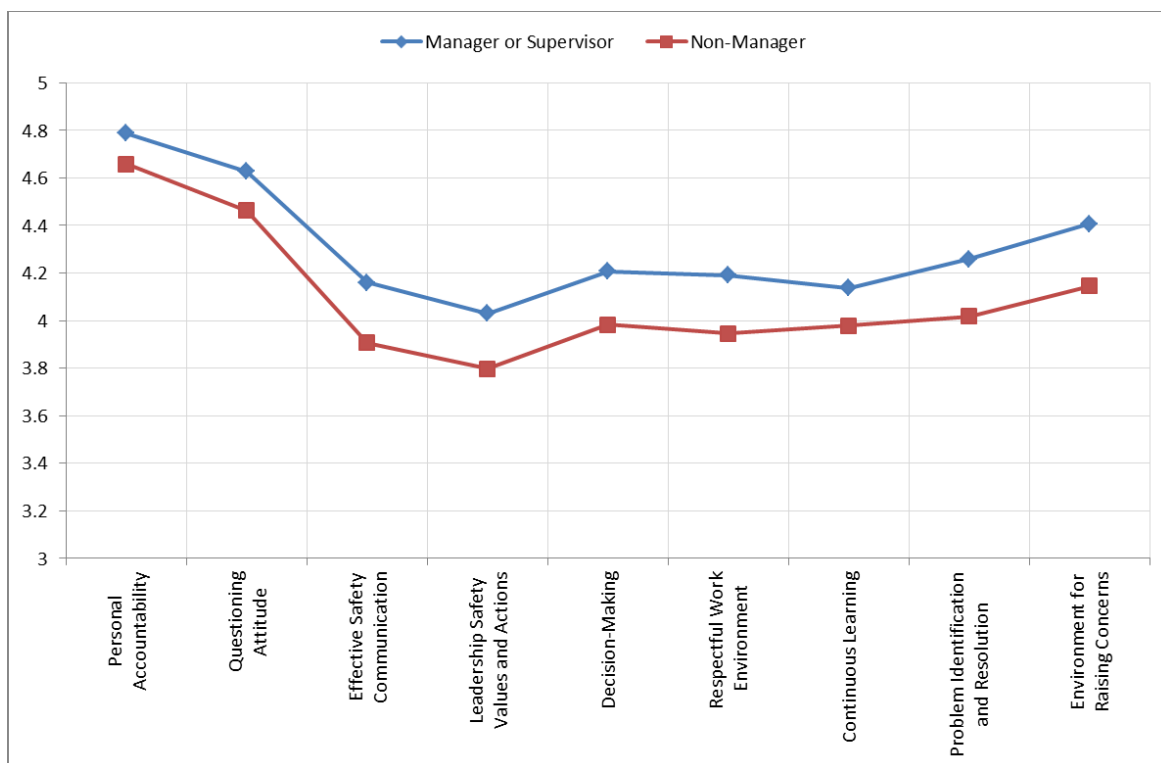| Department		
Category	Frequency	Percent
Administrative Support	3031	14%
ES&H and QA	2370	11%
IT	316	2%
Operation Support	2999	14%
Production	7117	34%
Other	3341	16%
I prefer to not answer	1885	9%
Total	21059	100%

Figure 2. Safety culture perceptions of managers compared to non-managers

The survey data was analyzed using exploratory factor analysis to help understand what factors explain the differences in safety culture perceptions. The analysis indicated that three underlying factors explained 95% of the common variance in the safety culture data. (**Table 2**) We found that there was one dominant factor that accounted for 75% of the variance. That was management systems, management decision-making, and leadership behavior. Survey items related to this factor included descriptors, such as:

- consistent decision-making related to safety,
- addressing safety issues in a timely manner, and
- leaders demonstrating their commitment to safety

Other factors in the analysis included personal accountability for safety (14% of the variance); communication and reporting of safety concerns (6% of the variance), and everything else (5% of the variance). (**Figure 3**)

The practical application of these results is explained as follows. If two people work for the same company and one has a very positive perception of safety culture and the other a very negative perception, why are their perceptions different? The results of these studies indicate that it was probably their experience with the company leaders, the leadership behaviors, the decisions made by leaders, and the management systems leadership installed that influenced the two different perceptions.

Table 2. Factor Analysis loading values for safety culture survey participants (2012-2017)

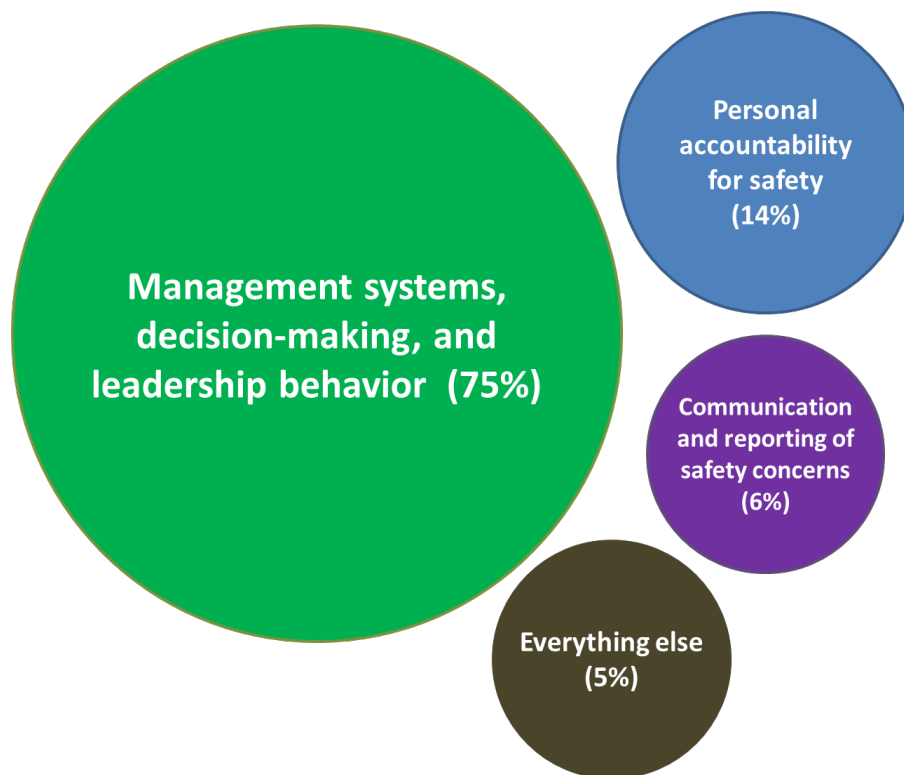| Factor 1 Management Systems		Factor 2 Personal Accountability		Factor 3 Safety Communication	
Statement	Loading	Statement	Loading	Statement	Loading
15	0.82	2	0.63	23	0.49
14	0.82	3	0.62	24	0.46
38	0.80	4	0.59	35	0.41
32	0.80	1	0.58	36	0.40
13	0.79	5	0.57	34	0.30
16	0.79	8	0.56	25	0.29
21	0.78	6	0.54		
20	0.77	7	0.51		
17	0.76				
34	0.76				
33	0.75				
39	0.75				

Figure 3. Results of exploratory factor analysis

Discussion

An employee fulfilment model called the "Blue Cube" was developed by one the authors (Dr. Smith). The model suggests that when employees are unhappy and disengaged, it is the result of failure to satisfy one or more of five basic conditions. When these five conditions are fulfilled, their perceptions and attitudes are more positive, their behavior is more desirable, and their performance is more likely to meet or exceed expectations. The data from these safety culture evaluations support this notion. (**Figure 4**)
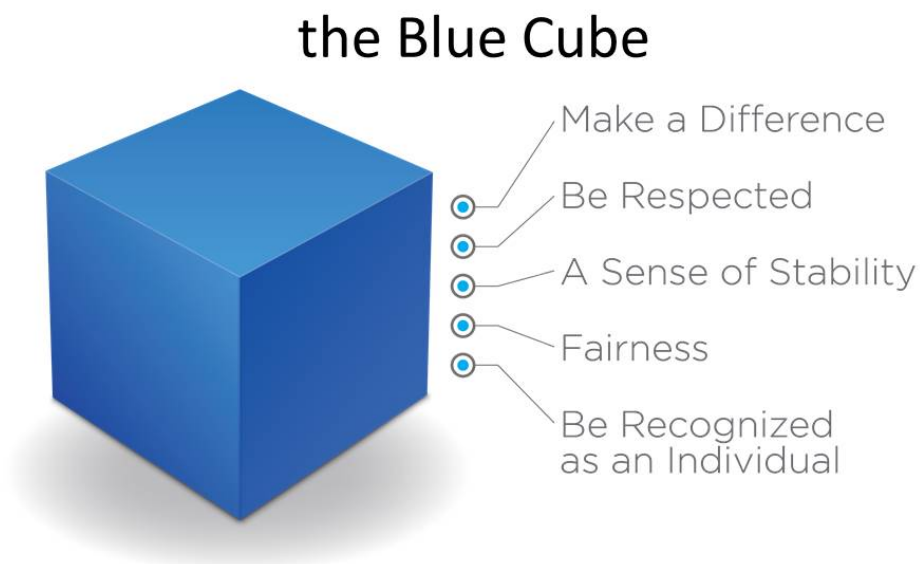

Figure 4. The five dimensions of employee fulfillment

Dimension 1 – Be recognized as an individual. People want to be recognized as an individual. They want managers to get to know their unique talents and acknowledge their contributions to the organization. The workforce is saying to management. I don't know you. You don't know me. I never see you except when something bad happens. How could you possibly know what contribution I am making to the organization?

> **"Management does not consider us experts. They take recommendations from people that have no practical experience in the field. They should trust our training, knowledge, and experience. We might actually know something."**

Dimension 2 – Be respected. People want to be shown respect by being included in the conversation. They want managers to ask for their input. They want to know about changes before they are implemented. They may have ideas to make things better if someone will just ask. The workforce is saying to management: at least ask us what we think. Don't make big changes that affect us without getting some input from us. And, if you say you want us to ask questions you have to mean it. Don't get angry and defensive when we question something. We really are just trying to make things better.

> **"People in this group are not treated with respect. My manager has a 'Napoleon syndrome' and will tell you, 'If you don't like it here, McDonald's is hiring.' We're treated like children."**

Dimension 3 – Sense of Stability. People want to know what to expect, especially when they are surrounded by change. This provides them with a sense of stability in their work life. The workforce is saying to management: We all know and expect change to occur but it is difficult for some of us. Just keep us informed and tell us the truth. Don't say one thing when you mean something else.

> **"They had an informational meeting to allay our fears about the changes and it was supposed to be positive. People were there to answer questions, but none of the questions were ever answered. People left those meetings in shock."**

> **"There isn't a lot of communication from upper management to us. They want you to know certain things, but they don't tell you all of it."**

Dimension 4 – Fairness. In order for the workforce to have a sense of fairness, explain to them the reasons behind decisions. The workforce is saying to management: If you explain to me the reasons why decisions are made the way they are, I can accept that. I may not agree with the decision but at least I understand why you did what you did.

Dimension 5 – Make a Difference. Most people want to make a difference. They want to be part of the solution. Few people wake up with the thought, "Today, I just want to be average." We believe that the vast majority of people really want to be successful. The workforce is saying to management: If I understand the bigger picture and see how I fit in, I will be more engaged and contribute more to the team. If you keep me in the dark, I will do my job, but nothing more.

> **"We have a high level of performance, and we do very high hazard work. We're at 3 million safe hours, our productivity is great, and we're well under budget. There is pressure to sustain that. I remind everybody, there is a reason why teams don't win six or seven super bowls in a row. Sustainment is brutally hard."**

Conclusions

Based on the results of this study, it is concluded that:
- The dominant factor in determining safety culture is leadership behavior, the decisions made by leaders, and the management systems installed by leaders.
- There is a gap between the perceptions of management and the workforce with management almost always having a much more positive perception than the people they lead.
- Managers can close the gap in safety culture perception by practicing the principles in the employee fulfillment model described in this paper.

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