CORRECTIVE ACTION PROGRAM INSIGHTS FOR HRA

Pamela F. Nelson

Universidad Nacional Autónoma de México: Av. Universidad S/N, Mexico City, Mexico, pnelson_007@yahoo.com

Quantitative measures of human performance and reliability are fundamental in the support of nuclear power plant safety culture. These measures can be used not only for updating human reliability data, but also to quantify organizational performance factors. This paper is focused on human and organizational reliability, with the objective of developing a process to monitor and reduce the number of consequential errors in nuclear power plants. With this end in mind, this paper presents a new analysis method and associated capabilities to evaluate and predict organizational resilience levels of the nuclear power plant. It identifies the human and organizational errors associated with causes of consequential events. New leading performance indicators are developed that provide insights into organizational stress levels, leading to and facilitating the development of compensating measures to reduce stress levels (i.e., increase organizational resilience levels). Finally, some results from the data analysis are presented that could be applied to include organizational factors in the human error probabilities.

I. INTRODUCTION

The intent of this paper is to provide insights from Corrective Action Programs (CAP) that can be used for Human Reliability Analysis (HRA). The CAP programs referred to here are those that are structured in the US and Mexico, corresponding to a low level reporting system. That is, almost any event, mistake, error, deficiency is required to be reported into the CAP database. Different countries have different levels of reporting; if a country's reporting level is high level (e.g., only events that result in reactor trip) their database will not provide as much information or insights into precursors of consequential events. Consequential events are defined as those that are important to the plant, not necessarily to the regulator, such as plant trip, inadvertent actuation of safety systems, equipment isolation errors, etc.

Although HRA generally includes the quantification of human failure events (HFEs) that either precede or follow an initiating event, there is a class of HFEs that while a large contributor to reactor safety, is not typically quantified in HRA methods. These are the precursor events; that is, errors that did not lead to an accident or some of them do not even cause an initiating event; however, it is this kind of error, which, when aligned with other possible failures in the defenses, could lead to an accident.

II. CORRECTIVE ACTION PROGRAMS

There are large amounts of plant event data from the low level type of nuclear power plant CAP. The corrective action program is the primary mechanism where station employees and contractors identify problems and issues that need to be addressed. In most cases, items in the CAP are minor or administrative and planned events such as a work order that can also be identified through CAP. The CAP is intended to provide station personnel with a means to identify problems no matter how big or small and CAP also satisfies regulatory requirements for Problem Identification and Reporting processes. However, this data is not uniform from station to station and has not been assembled in a manner that is helpful to fully understand human error rates, their associated human error classification, and their risk significance. Although thousands of events are reported each year (most of which are administrative low level items and not risk significant), the classification is done differently at each plant, thus making difficult the formation of a generic database or any subsequent higher level analyses or research, such as that typically existing for equipment (e.g., Equipment Reliability Programs). For this reason alone, it is important to reactor safety to design a human error data base that provides the process, data and information to facilitate quantitative analyses and future human performance research, based on actual plant events as documented in Corrective Action Programs and other industry programs (e.g., NRC Licensee Event Reports, INPO Significant Operating Experience Reports). Once developed, such a database and associated computational algorithms could be maintained and updated to provide insightful trends into human performance and formal Human Reliability Analyses (HRA) not only on a plant specific basis but also on a fleet or industry basis. These are some of the goals of the ongoing research presented in this paper. This potentially could allow human error precursors to consequential operational events to be better identified and allow risk management methods to reduce the likelihood of events.

The CAP database contains a large number of events that have been caused in one way or another by human errors or deficiencies, ranging anywhere from an individual worker's slips or lapse to problems with management's prioritization of resources. This is concluded from the cause codes that are assigned to each event, which typically include causes corresponding to an individual performer, supervisors as well as management practices and decisions. The latter two of which could be considered more as organizational factors than human error. The assignment of the cause is performed after the responsible team at the plant has conducted the root cause analysis. The root cause analysis is performed on events that are considered significant; generally these correspond to events that cause consequential outcomes. In many plants these are known as significant conditions adverse to quality (SCAQ) as well as a group of less significant events; that is, those considered to be a condition adverse to quality on a station level. Only a subset of the most significant events are required to be reported to the regulator and are known as the Licensee Event Reports (LERs), in the case of the US Nuclear Regulatory Commission. There has been analysis done with the LERs, which are available to the public; but given the confidentiality of the station's CAP data, it has not been used as a database for HRA.

For this paper, we had the possibility to analyze two plant's CAP databases in detail, as well as others to a lesser degree. The Plant A database contains more than 140,000 events in 10 years, 17,050 of which have cause codes assigned to them. For plant B, of the 37,000 events reported in 10 years, there were approximately 19,000 events in the database with cause codes. Some insights from the first database have enabled the development of several tools and are documented in several papers written by the author. [1,2,3,4,5] The insights from plants A and B are summarized in this presentation.

III. HUMAN AND ORGANIZATIONAL RELIABILITY ANALYSIS

Originally, I had been approached by plant A to risk-inform maintenance procedures. The thought was that the risk informing could be a relatively simple task; however, once began, the realization was that it was not so simple and several other tasks were needed first. Before anything else, it was necessary to look at how to develop data for pre-initiator HFEs (e.g., HFEs during test and maintenance) in an HRA. In this case, we refer specifically to pre-initiators, referring to HFEs that occur before an initiating event. During this process, the development of a leading performance indicator and tools for reducing the frequency of consequential events became the focus. More work is required to validate both the indicator capability as well as the frequency reduction of consequential events by using the tool. Another area that supports HRA development is to perform research to find ways to incorporate organizational factors into HRA. This is discussed in a paper presented at this PSAM conference and will be summarized during this presentation.

We are talking about events that do not cause a nuclear safety event (i.e., a core damaging event); however, their consequential cost is high due to lost generation, equipment damaged due to maintenance human errors (e.g., improper/incorrect lubrication), radiological cleanup and associated costs, lost time accidents, and equipment/plant damage due to inappropriate operation of equipment (e.g., flooding a room by opening a wrong valve, etc.). In addition, generally in conventional probabilistic safety assessments (PSAs), human actions leading to initiating events, i.e., unplanned reactor trips or power reductions, have not been modeled explicitly. Maintenance human errors are modeled in PSA in order to determine system unavailability.[6,7] Laakso, Pyy & Reiman[7] and Pyy[8] introduced an analysis of maintenance human failures and their effects, and discussed their safety significance from the PSA point of view; however, the effects and safety significance of maintenance related human failures mainly included equipment unavailability or equipment malfunction, very few were related to unplanned reactor trips. But, there is a growing need to analyze the mechanism associated with human-induced unplanned reactor trips and the organizational constraints and characteristics associated with often performed maintenance and testing activities leading to consequential human errors such as unplanned reactor trips, in order to provide a basis for managing maintenance and operations related human errors as well as to incorporate human-induced initiators more explicitly in PSA models.[9] Kim[10] defines a method for the identification of human-induced initiating events in low power and shutdown because he mentions that most conventional PSAs typically assume that the frequency of initiating events already includes human-induced initiating events. Sometimes, human-induced initiating events may not be dealt with in the full power PSA because of their infrequent occurrence.

Along these lines, maintenance and testing (e.g., surveillance testing) of reactor systems are important causes of unplanned reactor trips, turbine trips, down-power events, inadvertent system actuations, damage to the plant equipment and even harm to workers and possibly to the public. For this reason it is essential to find ways to reduce undesired events. Although HRA analyzes human errors and their probabilities for PRA, there are several limitations. This analysis only considers errors on components that are modeled in the PRA. Also, the research and in-depth analysis has been concentrated on the human errors after an initiating event presents itself (i.e., post-initiator). The end state considered is generally core melt or large, early release. In addition, human errors are usually classified into three types: pre-initiator human actions, human errors that cause initiating events and, post-initiating event human actions.

Type C analysis is the center of many present HRA research projects as well as nearly all of the HRAs that have been done for commercial plants. Type B events are typically considered to be included in the initiating event frequency. Finally, Type A errors are included in the HRA, that is, actions that can be performed erroneously and cause an equipment misalignment or miscalibration; however, these events are usually found to be not risk significant for PSA purposes and thus not highly scrutinized in the review processes. They can, in fact, be highly risk significant from the perspective of a consequential operational event which is the point being emphasized by nuclear oversight organizations such as INPO.

A quantitative method for establishing the contribution of human performance and reliability to consequential operational events leading to, but prior to an initiating event is needed to quantitatively correlate human performance and reliability of often repeated tasks and activities to operational events considered undesirable during nuclear power plant operation leading to, but prior to, an initiating event. It is important to establish quantitative measures of human performance and reliability (i.e., figures-of-merit) prior to the occurrence of an initiating event, as well as to provide a method to evaluate organizational and operational practices and processes (i.e., procedures) to assess the risk contribution of those activities leading to initiating events.

Human performance and human reliability focused risk informed performance indicators are needed to monitor consequential human performance trends and measure effectiveness of station processes, procedures, and corrective actions. This could be a basis for a systematic approach for establishing the risk significance of procedural related human actions (i.e., procedure risk profiling) performed at nuclear power stations (e.g., Operations and Maintenance organizations). In order to tackle this need, a human performance monitoring and tracking methodology and tool that can be deployed to nuclear plant organizations for the purposes of quantitatively measuring and monitoring human performance events and trends for the purposes of reducing the occurrence of consequential human errors (i.e., prior to the initiating event) was developed and will be described briefly in this presentation.

IV. CONCLUSIONS

Safety is the highest priority issue at nuclear power stations and one of the most important contributors to assuring safety is improving human performance. Due to the increase of significant operational events in recent years, [10] there was a need to develop and deploy risk informed solutions that can be applied to procedures / work instructions to ensure that the right level of detail and human factor engineering principles are applied to critical activities to reduce the likelihood of active and latent errors that challenge reactor safety and equipment reliability, in effect, increase safety culture at nuclear power plants.

In fact, Magwood[11] writes that safety culture has been identified as having played an important role in allowing precursor conditions at Fukushima to go unaddressed. Ensuring nuclear reactor safety is not only a question of physical protection against all credible threats, enhancing robustness of important safety systems and increasing redundancy of back-up power and water cooling systems, but also one of making certain that qualified and trained staff are supported by effective procedures. However, these assets are valued only in an organizational culture that places a premium on ensuring high levels of safety, or implementing what is called an effective 'nuclear safety culture'. In recognition of the importance of such factors, this paper presents an approach to enhancing organizational resilience so that staff is better able to respond under increasing organizational stress due to an excess of work activities.

Due to regulatory requirements for Problem Identification and Resolution (PI&R) programs, nuclear power plants have large amounts of plant event data. This data exists in several areas but is comprehensively contained in plant specific Corrective Action Programs (CAP). The regulatory requirement for PI&R programs was due to the overarching importance of reactor safety. PI&R Programs (i.e., CAP) provide the base experiential data to enable NPPs to design methods to track and trend events in order to provide a process to facilitate quantitative trending analyses, provide feedback and lessons learned from plant experience, and to provide a tracking mechanism for correct actions and enhancements. NPP programs relative to specific and industry operating experience are based on actual plant events as documented in Corrective Action Programs and other industry programs (e.g., NRC Licensee Event Reports, INPO Significant Operating Experience Reports). For this paper, it was determined that once developed such a database and associated computational algorithms could be maintained and updated by plant personnel to provide insightful trends into human performance and also provide formal data sources for Human Reliability Analyses (HRA) not only on a plant specific basis but also on a fleet or industry basis. The methods described in this presentation will allow human error precursors to consequential operational events to be better identified and allow implementation of risk management methods to reduce the likelihood of events.

During the development of this study, it became apparent in the analysis of the CAP database that the majority of the condition reports were caused by combinations of organizational and individual errors. When a condition report item identified the occurrence of an equipment failure, the level of the condition report severity level assignment increased. While many databases exist for reporting equipment failures, the human performance aspect is often times not emphasized, except when it is directly related to the equipment failure. The analysis of the CAP database provided many insights into the importance of considering all organizational and individual errors as precursors to more severe outcomes and the necessity to include these factors in a quantitative tool developed for plant use. The presentation of this work describes the analysis of the data contained in the CAP database, the development of a plant specific resilience curve and leading performance indicator and discusses future work.

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