CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Attendance at the International Conference and Workshop on Process Industry Incidents sponsored by the Center for Chemical Process Safety of the American Institute of Chemical Engineers.
(20.01402.671)

DATE/PLACE: October 3–6, 2000, Orlando, Florida

AUTHOR: D.D. Daruwalla

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AUTHOR: D.D. Daruwalla

PERSON PRESENT: D.D. Daruwalla, Center for Nuclear Waste Regulatory Analyses (CNWRA)

BACKGROUND AND PURPOSE OF TRIP:

The International Conference and Workshop on Process Industry Incidents sponsored by the Center for Chemical Process Safety of the American Institute of Chemical Engineers, was held on October 3–6, 2000, at Orlando, Florida. The conference attracted approximately 300 attendees from the United States and abroad. About 50 technical papers were presented, 5 workshops were conducted, and 6 short courses were offered.

The papers presented at this conference are published in a book titled Process Industry Incidents: Investigation Protocols, Case Histories, Lessons Learned; published by the Center for Chemical Process Safety. The author of this trip report has a copy of this book. The conference focused on the various tools and techniques currently employed in industry for the analysis of accidents and their causes. Actual industrial accidents were examined in detail to determine the root causes and the lessons learned. Regulatory agencies for health and safety from Europe and Asia participated in the proceedings, and this afforded an opportunity to learn about techniques currently employed in assuring health and safety abroad. The summary provided in this report is based on the author's attendance at selected sessions and brief notes taken during presentations on topics involving the safe design and operation of facilities which could be relevant to the Preclosure Safety Analysis (PCSA) of the High-Level Nuclear Waste Geologic Repository at Yucca Mountain (YM).

SUMMARY OF PERTINENT POINTS:

A brief summary of the papers and workshops relevant to the PCSA of the High-Level Nuclear Waste Geologic Repository at YM is provided below.

1. Valerie Barnes of Performance, Safety and Health Associates, Inc., Boalsburg, Pennsylvania, presented a paper titled Human Factors in Accident Investigation. In the past, Valerie has worked in developing

procedures for both the Nuclear Regulatory Commission (NRC) and the U.S. Department of Energy (DOE). Valerie indicated that human error plays a causal or contributing role in 50-80% of significant accidents, and her paper presented a framework for examining human factors and formulating effective corrective actions to prevent accidents. A software tool for understanding human contributors to accidents, and for trending human performance to ensure that appropriate corrective actions are being taken was briefly discussed. Schemes for classification of human errors were discussed, including the scheme for categorization of errors into 4 basic types: (1) errors of commission, in which incorrect actions were taken, (2) errors of omission, in which required actions were not taken, (3) extraneous acts, in which an action that was not required was taken, and (4) error-recovery opportunities, composed of actions that can recover previous errors. Other schemes divide errors into motor (e.g., a slip) and cognitive (e.g., a mental lapse). Rules-of-thumb for designing human-system interfaces to reduce the likelihood of errors were explained. The example of a fatal accident, at the Idaho National Engineering and Environmental Laboratory in which an unplanned activation of the CO_2 fire suppression system during electrical maintenance work resulted in one fatality and injury to several persons, was discussed to demonstrate how barriers that were in place had failed, while other key barriers which could have prevented the error were missing.

A four stage process for investigating human factors was proposed: (1) identify the nature of the mismatch between the human actions (or inactions) and the state of the task environment that produced the error, (2) identify barriers to the human error that were missing or failed, (3) identify the management systems responsible for maintaining those barriers, and (4) develop corrective actions to prevent same or similar accidents. The Human Factors Investigation Tool (HFIT) was used to address human factors in accident investigations based on this framework.

To a great extent, this same approach could be used in examining the DOE design of the Geologic Repository at YM for vulnerabilities with regards to human factors engineering. The paper lists several interesting references including NUREG–1624, Technical Basis and Implementation Guidelines for a Technique for Human Event Analysis.

The concepts of Human Factors Engineering were also discussed in detail in a paper entitled Premature Stopping Points for Determining the Root Cause of Human Error in Process Incident Investigations by Jack Philley of Det Norske Veritas (DNV), Houston, Texas. The paper examined underlying causes that result in employees frequently failing to follow established written procedures. It focused on the methodology for determining the true underlying root causes behind an incident, and then ensuring that the root cause finding is addressed by a recommendation to modify the system to implement a generic remedy. For example, it is not sufficient to use "failure to follow procedures" as a root cause finding. It is necessary to determine why the procedure was not followed, and then to come up with appropriate modifications to the system to effect a change.

2. Mark Paradies of System Improvements, Inc., Knoxville, Tennessee, presented a paper titled Using Advanced Trending to Learn from Your Incident Statistics. Trending is an important tool for effecting safety improvements in any system or process. The value of the results achieved, however, will depend to a large extent on the ability of the analyst to detect real trends from the normal everyday variation in any process. The paper reviewed some of the common problems that cause people to misinterpret trends, and discussed two techniques, Pareto charting and process behavior charts to detect trends. Pareto charts can be used to identify a small number of key problems which, if fixed, would result in a

large improvement in the safety of the process. However, Pareto charting only works if there is a concentration of the problems into a small number of root causes. One could then focus on carrying out corrective actions in the small number of problem areas in order to effect a large improvement in the process. Another limitation of the Pareto chart is that it does not show how the data changes over time. To look for trends over time one has to construct and study a process behavior chart. This chart which originated from statistical process control, is composed of two graphs. The upper graph is a plot of the data (results), while the lower graph is the moving range derived from the data. The moving range is then used to derive the upper and lower process limits. These limits are then used to detect significant trends. If all the data falls between the upper and lower process limits, then even though there is variation in the system, there is no significant trend. Trending therefore can be used to properly analyze process safety data from accident statistics to identify best targets for improving safety in a process.

Many of the processes to be used at the Geologic Repository at YM are similar to processes used in the nuclear and mining industries. For example, removal of spent fuel assemblies from their transportation casks for repackaging into disposal containers is similar to spent fuel processing operations at nuclear power plants. Underground transport of disposal containers by rail bears similarities with operations in mining and subway transport systems. Accident data from these systems may be used in conjunction with advanced trending techniques such as those described above to identify potential problem areas, and this information may help with the review of the DOE design.

3. An incident database workshop was held during the conference. Speakers from the United States, Europe, and South Korea provided their particular insights on how their database systems are managed, how they can be accessed, potential to conduct trends analysis or predictive capability, lessons learned and many other relevant aspects. Two different types of databases used by regulatory agencies abroad were examined.

Christian Kirchsteiger from the European Commission (EC), Joint Research Council, Ispra, Italy discussed the MARS and SPIRS databases soon to be used throughout the European Union (EU) to manage hazards and reduce risk. The MARS consists of a self-standing sophisticated data management and analysis tool used to report and analyze industrial accidents in a standardized format, while SPIRS provides a map of all major hazardous industrial establishments in Europe together with information on their basic risk related characteristics. Together, the two systems can be used to support EC authorities and industry in their risk management related decision-making processes.

Soon-joong Kang of the Korea Occupational Safety and Health Agency made a presentation on an accident database developed by his agency in which accident data from 550 domestic and 800 foreign cases has been input and stored to date through communication with the Organization for Economic Co-operation and Development (OECD) and the EU. This database can be used for the generation of accident scenarios, risk assessment for the key elements of hazard analysis such as Hazard and Operability (HAZOP) and Fault Tree Analysis (FTA), and eventually the elimination of root causes. To increase the usefulness of the accident database, a GIS-based Integrated Risk Management System (IRMS) is being developed to integrate chemical plant hazards data with location information and provide risk contours. In addition an on-line data service system will be established this year which will provide Korean industry with worldwide accident information to be used in their accident prevention efforts. Figure 1 (attached), shows a graphical representation of the structure of the IRMS, and illustrates the role of accident database information in the generation of event scenarios for hazard analysis of a facility.

Information presented in the workshop will help with further development of the database for equipment failure rates in the PCSA tool. In addition, because many of the processes to be used at the Geologic Repository at YM are similar to processes used in the nuclear and mining industries (see item 2 above), an accident database module devoted to accidents which have occurred during the course of performing similar operations in the nuclear and mining industries, may be added to the PCSA tool to help with identification of potential problem areas. The information compiled in such a database would be useful during review of the DOE design.

4. A paper titled Risk Reduction by Learning from Incidents and Near-Misses was presented by Kurt A. Ruppert of Degussa-Huls, Frankfurt, Germany, in which an alternate way of defining risk was discussed. The German Chemical Industry Association (VCI) has set up a pilot program to optimize risk reduction by initiating and intensifying the process of learning from failures resulting from incidents and near-misses.

Risk has been traditionally defined as the possibility of harm, defined in terms of the probability of the harm during the lifetime of the facility and its anticipated severity. Risk can therefore be quantified as the product of the frequency (*F*) and consequence or severity (*S*) of a failure or incident.

$$R = F \cdot S$$

F can be further defined as a product of triggering sensitivity parameters *h* and the related preventive measures ψ.

$$^{*}F = h \cdot \psi$$

Where the triggering sensitivities are primarily material properties (e.g. explosive limits, flash point, pH value, reactivity, etc.) which have to be present for a failure to occur. These would determine the probability of occurrence by themselves if no preventative measures ($\psi = 1$) existed.

Similarly, the consequence or severity *S* can also be defined as a product of the specific dangerous material property *e* (e.g. maximum pressure, fire load, reaction enthalpy, toxicological concentration level or dose, etc.), the material inventory *M*, and the related mitigation measures Φ.

$$^{*}S = e \cdot M \cdot \Phi$$

The variables ψ and Φ correspond to weighting fractions, and incorporate all data for preventing and mitigating failures and dangerous incidents. In a safe facility, these variables will be significantly less than 1 (ψ and Φ << 1)

*NOTE: These equations will have to include normalizing factors to present frequency and severity in the appropriate units.

Accordingly, the new formulation of risk is:

$$R = (h \cdot \psi) \cdot (e \cdot M \cdot \Phi)$$

or
$$R = R_0 \cdot (\psi \cdot \Phi)$$

where
$$R_0 = h \cdot e \cdot M$$

Here, R_0 is the intrinsic or fundamental risk of the process. The parameters h or e or M have to be zero in order to make $R_0 = 0$.

This alternate interpretation of risk holds that the risk is composed of the fundamental risk R_0 and the technical and organizational preventative and mitigative measures. This achieves a decoupling between a risk component that is strictly related to the materials and the components that are related to preventative and mitigative measures.

This new interpretation of risk provides an alternative perspective to the methods to be used at the Geologic Repository at YM, where risk will be characterized in terms of frequency based catagories and dose limits (per the proposed 10 CFR Part 63).

The Table of Contents from the book titled Process Industry Incidents: Investigation Protocols, Case Histories, Lessons Learned; which was handed out to conference attendees has been attached as a source of additional information. It provides a complete list of the papers presented at the conference.

CONCLUSIONS:

Attending this conference was very useful in keeping current with ongoing worldwide advances in the techniques used for analysis of accidents in industry and their causes. The conference offered a good opportunity to gather information and generate discussion on topics involving the safe design and operation of facilities which could be relevant to the PCSA of the Geologic Repository at YM. In addition, since regulatory agencies for health & safety from Europe and Asia participated in the proceedings, this presented an opportunity to learn about techniques currently employed in assuring health and safety abroad. Specifically, attendance at this conference helped with the following:

1. Understanding human factor and human error issues with regards to incidents, including how to identify human factors involved and their underlying causes, and formulate effective corrective actions. A similar approach could be used in examining the DOE design of the Geologic Repository at YM for vulnerabilities with regards to human factors engineering.

2. How to use advanced trending techniques to learn from accident statistics to properly analyze process safety data. This can be used for identification of best targets for improving safety in a process.

   Since many of the processes to be used at the Geologic Repository at YM are similar to processes used in the nuclear and mining industries, accident data from these systems may be used in conjunction with advanced trending techniques to identify potential problem areas. This information may help with the review of the DOE design.

3. How to use incident databases to target prevention initiatives. Speakers from the United States, Canada, Korea, and the EU provided their particular insights on how these systems are managed, how they can be accessed, lessons learned and many other relevant aspects.

   Information presented will help with further development of the database for equipment failure rates in the PCSA tool. In addition, because many of the processes to be used at the Geologic Repository at YM are similar to processes used in the nuclear and mining industries, an accident database module devoted to accidents which have occurred during the course of performing similar operations in the nuclear and mining industries, may be added to the PCSA tool to help with identification of potential problem areas. The information compiled in such a database would be useful during review of the DOE design.

4. An alternate concept for defining risk was presented at one of the conference sessions. Under this definition, risk is the product of a) the intrinsic or fundamental risk of the process, and b) the robustness of the technical and administrative safety barriers applied to the process.

   This new interpretation of risk provides an alternative perspective to the methods to be used at the Geologic Repository at YM, where risk will be characterized in terms of frequency based catagories and dose limits (per the proposed 10 CFR Part 63).

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None.

RECOMMENDATIONS:

None.

SIGNATURES:

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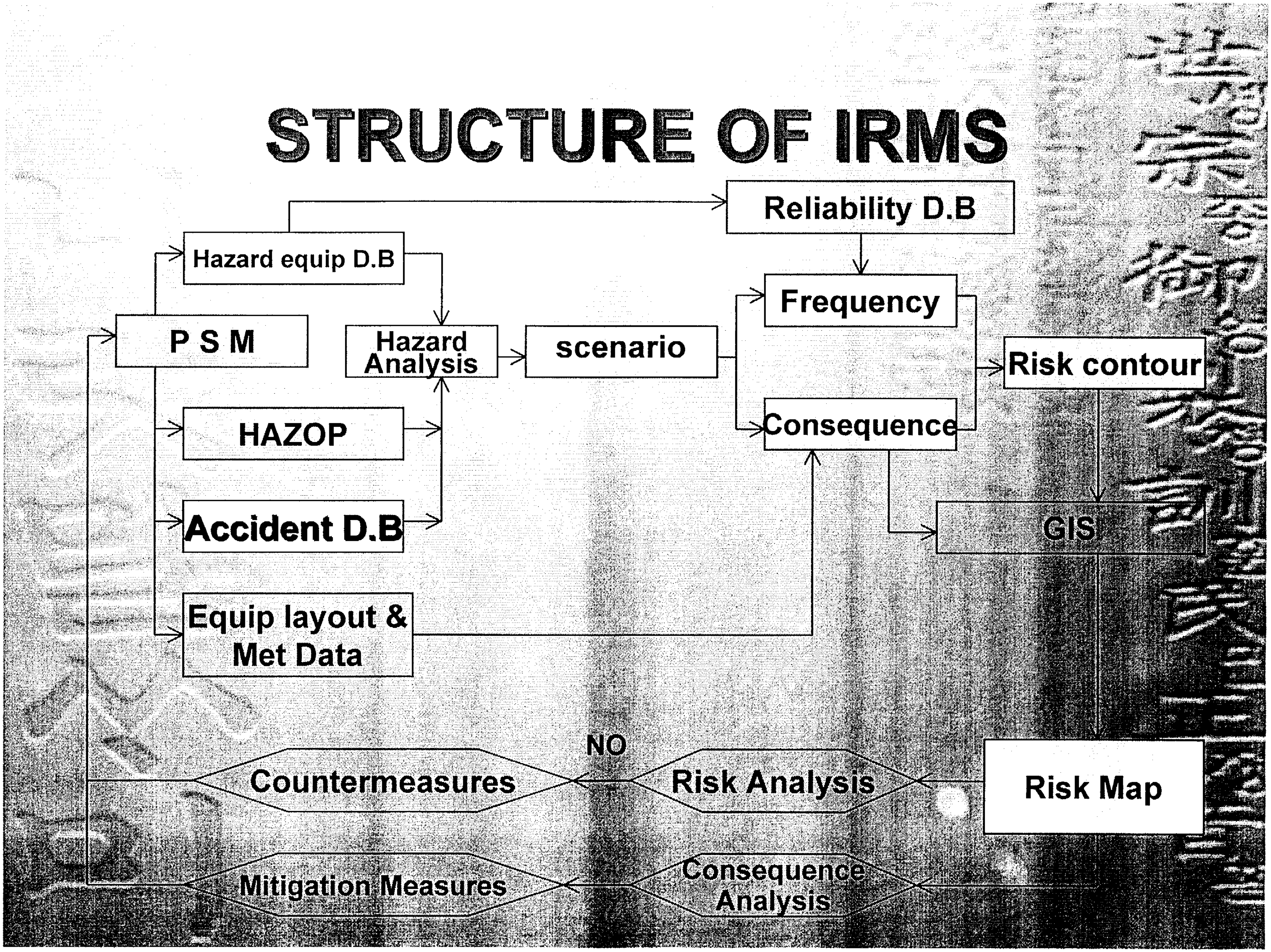
STRUCTURE OF IRMS
Reliability D.B
Hazard equip D.B
Frequency
P S M
Hazard Analysis
scenario
Risk contour
HAZOP
Consequence
Accident D.B
GIS
Equip layout & Met Data
NO
Countermeasures
Risk Analysis
Risk Map
Mitigation Measures
Consequence Analysis

Figure 1

CENTER FOR CHEMICAL PROCESS SAFETY
INTERNATIONAL CONFERENCE AND WORKSHOP

Process Industry Incidents
Investigation Protocols
Case Histories
Lessons Learned

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U.S. Chemical Safety and Hazard Investigation Board

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