METHODOLOGY FOR ASSESSMENT OF SAFETY RISK DUE TO POTENTIAL ACCIDENTS IN U.S. GASEOUS DIFFUSION PLANTS*

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ABSTRACT

Gaseous diffusion plants that operate in the United States represent a unique combination of nuclear and chemical hazards. Assessing and controlling the health, safety, and environmental risks that can result from natural phenomena events, process upset conditions, and operator errors require a unique methodology.

Such a methodology has been developed for the diffusion plants and is being utilized to assess and control the risk of operating the plants. A summary of the methodology developed to assess the unique safety risks at the U.S. gaseous diffusion plants is presented in this paper.

INTRODUCTION

The United States Department of Energy (DOE) currently operates two gaseous diffusion uranium enrichment plants at Portsmouth, Ohio, and Paducah, Kentucky. A third plant located at Oak Ridge, Tennessee, was operated from the early 1940s until 1985. The Oak Ridge Gaseous Diffusion Plant (GDP) was built in the early 1940s as part of the Manhattan Project during World War II. The three plants have successfully provided enrichment services for the United States and much of the free world for many years.

Diffusion plants are massive, the operating equipment is complex, and large amounts of uranium hexafluoride (UF_6) and other hazardous chemicals are handled at the sites. Obvious safety issues include nuclear criticality, UF_6 release, and exposure to various process chemicals. Assessment and control of health, safety, and environmental risks at the plants is a high priority, with particular emphasis placed on control of the unique radiological and chemical hazards.

As safety analysis practices and techniques have evolved, DOE has modified the safety techniques applied at the plants. Safety analysis documentation for the two operating plants was last updated and issued in 1985. The safety analysis effort is being upgraded using current requirements and techniques. Because the diffusion plants consist of nuclear operations and traditional chemical operations, a unique methodology is required to assess the risk of operating the plants in a manner that meets established DOE requirements.

The unique methodology selected for use in the Safety Analysis upgrade program includes several well known, state-of-the-art risk assessment techniques combined in a manner that is intended to be comprehensive, defendable, and cost-effective. The approach addresses the unique hazards that exist at the plants as well as specific consequences that can be caused by natural phenomena hazards. The approach involves three major sequential steps as shown in Fig. 1.

1. Hazards identification
2. Accident sequence development
3. Risk assessment

The product of the safety analysis is a set of Operational Safety Requirements (OSRs) that become strictly enforced limits on the operation of equipment. Operation in accordance to the limits of the OSRs will ensure that the operating risks remain within an acceptable range.

*Research sponsored by the U.S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

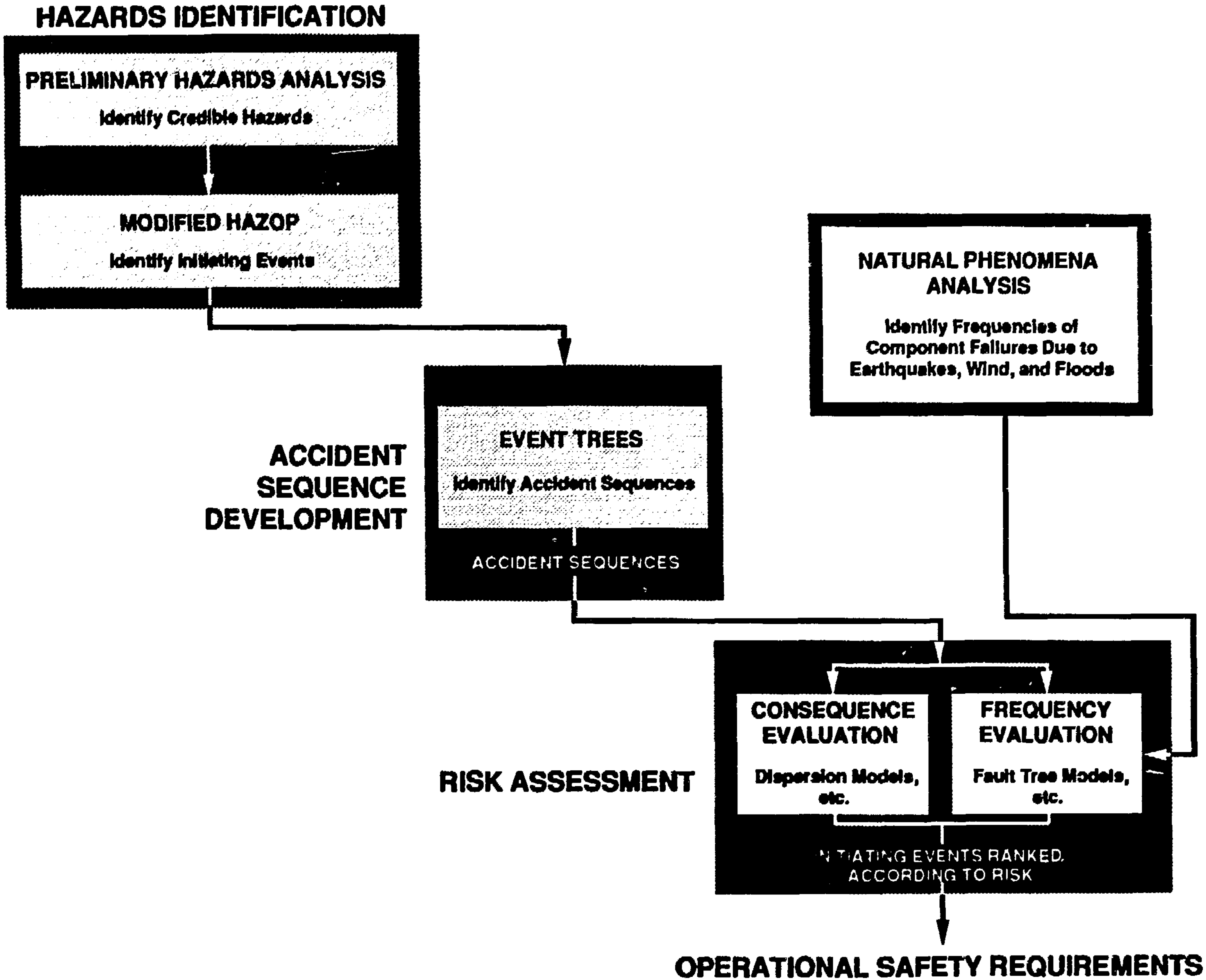

Fig. 1. Methodology for analysis of accidents in U.S. gaseous diffusion plants.

The Safety Analysis Upgrade document describes the systems and programs which ensure that the OSRs are properly implemented and controlled. After this document is issued and approved by DOE, it will be updated as necessary to reflect changes in equipment and systems that affect safety.

SAFETY ANALYSIS REPORTS

The U.S. Department of Energy places strong emphasis on operating safety at all of its facilities. As a result, the overall safety programs include many different aspects of safety analysis and control. As a way of concentrating the safety program, the nonstandard industrial hazards at each plant are evaluated and documented. The Safety Analysis Report (SAR) is one portion of this overall safety program. While standard industrial hazards will be identified and documented as part of the GDP SARs, other aspects of the overall safety program will address specific handling of these hazards.

The SARs for the diffusion plants will include risks related to health, safety, and the environment; however, they will not include considerations of economic impacts such as lost production or damage to equipment. Natural phenomena hazards are included; sabotage is not included.

These diffusion plants are owned by the U.S. government and managed by contractors who operate the facilities for an annual fee. For many years the Oak Ridge and Paducah plants were operated by Union Carbide Corporation, Nuclear Division, and the Portsmouth plant was operated by Goodyear Atomic Corporation. The current managing contractor for the GDPs is Martin Marietta Energy Systems, Inc. DOE and its predecessor organizations (Atomic Energy Commission and Energy Research and Development Administration), provides orders and guidance to the operating contractors covering areas such as safety documentation.

The DOE Field Office, Oak Ridge, which is responsible for the operation of the GDPs as well as other facilities, has provided a guidance document for the preparation of SARs [1]. The guidance document is being used in preparation of the upgraded GDP SARs. This guidance emphasizes the use of risk assessment techniques in addition to "traditional" considerations such as meeting design criteria and evaluating worst-case scenarios. The specific implementation of the accident analysis portion of the SAR has been documented [2].

HAZARDS IDENTIFICATION

Comprehensive identification of all hazards is the goal of the hazards identification process. On the basis of the results of a top level preliminary hazard screening step, the various buildings and systems of a diffusion plant are divided into 12 specific groups for ease of record keeping. The basic approach places first priority on facilities where UF_6 in liquid form is handled and places second priority on facilities where UF_6 in gaseous or solid form is handled. Other miscellaneous facilities are third priority.

After the plants are divided into groups of facilities, each group is the subject of a Preliminary Hazards Analysis (PHA). The PHA provides a systematic review of the hazards that exist in the facility. This review is conducted by a team of accident analysts in coordination with knowledgeable plant process, management, engineering, and safety personnel. After the hazards for a selected facility are identified, the standard industrial hazards are determined, documented, and maintained for possible additional analysis by other safety programs. The nonstandard hazards are reviewed, and those judged to be significant are carried forward for further analysis. The nonstandard hazards judged to be insignificant are identified and documented.

The significant hazards are used as input to the second step of the hazards identification process, which is a modified Hazards and Operability (HAZOP) Study. The HAZOP technique was developed and widely used by the chemical industry, and it is recognized as an effective method for hazards identification and analysis. The traditional HAZOP process is modified in that the level of detail is generally limited to the system and subsystem, instead of the component level. The basic structure of the HAZOP process is retained, including use of guide words and component-level analysis where necessary. The HAZOP study also involves interaction between a team of safety analysts and knowledgeable plant personnel. The product of the modified HAZOP study is a list of potential initiating events. The initiating events are screened to identify those that are judged to be significant. The significant initiating events are identified for further analysis. The initiating events judged to be insignificant are identified and documented.

Initiating events judged to be insignificant will be subjected to an independent review to confirm that their contribution to the overall plant risk is acceptably low. Any initiating events judged by the independent review team to be significant will be added to those already identified for more detailed analysis.

At the completion of the hazards identification process, a list of significant initiating events is carried forward into the accident sequence development step.

ACCIDENT SEQUENCE DEVELOPMENT

Accident sequences will be developed using Event Tree Analysis (ETA). This method considers all combinations of successes and failures of response systems and operator actions that are designed to prevent or mitigate the consequence of the initiating event. Human-error-analysis methods will be used to define and quantify operator failure probabilities for initiating events and mitigating actions.

Development of event trees is accomplished in cooperation with plant personnel in team work sessions. A product of ETA is a graphical depiction of the accident scenarios, making it easy to understand the importance of the various mitigating actions involved in each accident scenario.

After the accident scenarios are developed, the safety systems will be identified. Safety systems will consist of operator and hardware systems that are necessary and sufficient to maintain an acceptably low risk of operation.

RISK ASSESSMENT

The third major step in the accident analysis methodology is to quantitatively assess the risk of each accident sequence. Evaluation of risk involves a two-step process to determine consequences and frequencies.

Consequences of each accident scenario will be estimated, based on operating experience, industry data, and physical and mathematical models. Specifically, a plume analysis dispersion computer model, developed at Oak Ridge National Laboratory, will be used to predict the dispersion of UF_6. Commercial dispersion codes will be used for other chemical releases. The results of modeling the consequences by using these codes will be utilized to identify the expected impact to people and the environment. Both on-site and off-site impacts will be evaluated.

The frequency of each accident scenario will be estimated using Fault Tree Analysis (FTA). The frequency of occurrence of each initiating event and the probability of failure of each mitigating action will be estimated based on FTA, plant experience, and industry data.

Natural phenomena events are an important subset of initiating events that are analyzed in this methodology. A comprehensive effort is underway to determine the frequency of earthquakes, winds, and floods in the plant areas that can cause equipment failures. The result of the natural phenomena analysis is a set of damage curves for equipment and structures in the diffusion plants. Both the frequency of equipment damage and the magnitude of the damage to the equipment is identified from these curves. This damage information is then used as input to the fault tree analysis to identify the frequency of the initiating events and the probability of failure of the mitigating actions when natural phenomena events cause the process upset condition.

After the consequences and frequencies of each accident scenario are estimated, they will be combined to establish the risk associated with each accident scenario. These estimated risks can then be ranked according to magnitude of risk. This risk ranking will be useful in selecting appropriate actions to evaluate and maintain the operating risk of the plants at an acceptable level.

OPERATIONAL SAFETY REQUIREMENTS

The results of the risk assessment are used to identify safety class items and establish specific operating limits and procedures. OSRs are established for the equipment and control systems, both hardware and administrative. Detailed procedures are then written to meet the requirements of the OSRs.

SUMMARY

The accident analysis methodology that is being implemented in the U.S. gaseous diffusion plants provides systematic identification of hazards, development of accident sequences, assessment of risks, and establishment of OSRs to ensure that operating risks remain within an acceptable range.

REFERENCES

[1] U.S. DEPARTMENT OF ENERGY, OAK RIDGE OPERATIONS, *Guidance for Preparation of Safety Analysis Reports*, DOE/OR-901, Oak Ridge, Tennessee, USA (1989).

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