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00-23

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U.S. Nuclear Fuel Facilities Are Operating Safely, Independent Review Team Finds

WASHINGTON, D.C., May 8, 2000—U.S. uranium processing and fuel fabrication facilities are operating safely, according to a report released today by a special review team. The independent assessment, coordinated by the Nuclear Energy Institute, was requested by U.S. companies operating the facilities after last September's radiation accident that resulted in the death of two nuclear fuel plant workers in Tokaimura, Japan.

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Engineering and procedural safeguards for blending uranium fuel that would prevent an incident, such as the one at Tokaimura, are in place and used at the 10 nuclear fuel facilities operating in the United States, the report concludes. Members of the team today briefed the U.S. Nuclear Regulatory Commission on the findings of their seven-month project.

"The U.S. nuclear fuel industry is operating on the assumption that an accident can occur. This provides a sound basis for the continuing vigilance and the safe operating practices that we observed." said John C. Brons, a Nuclear Energy Institute executive who presented the report, entitled "Assessment of Nuclear Criticality Safety and Emergency Preparedness at U.S. Nuclear Fuel Plants" to the agency.

The review was conducted by Brons; special assistant to the president at NEI; independent consultant Robert M. Bernero, who was director of Nuclear Material Safety and Safeguards at the NRC; and James R. Clark, a JAI Corp. vice president with considerable operating experience in the nuclear fuel industry.

"Safety in operating fuel facilities is the industry's overriding focus," Brons said. "Workers at these facilities understand that they have the authority to stop plant processes for safety reasons."

All U.S. uranium processing and fuel fabrication facilities are regulated by the NRC. Brons said the review team "believes that these regulations and standards are observed and provide for fundamental criticality safety."

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Employees at the Tokaimura, Japan, fuel facility triggered the criticality, or nuclear chain reaction, on Sept. 30, 1999, by pouring excessive amounts of a liquid form of highly enriched uranium into a mixer. Radiation from the ensuing chain reaction has killed the two employees who suffered the most severe radiation exposure; a third employee also was injured. Hundreds of others, including residents immediately surrounding the Tokaimura facility, were exposed to elevated levels of radiation, though not at levels that would cause physical harm.

One of the contributing factors to the Tokaimura accident was insufficient training of workers on the potential for criticality—particularly when handling uranium enriched to 18.8 percent presence of the fissionable U-235 isotope—and its consequences. Neither of the operators who died had worked with the material before.

The report noted that processes are in place at U.S. fuel facilities to ensure that workers are experienced before being assigned to work independently. The report identified several opportunities to improve worker training, however.

In other areas that contributed to the Tokaimura accident, the review showed much stronger performance at U.S. facilities.

The facilities covered by the review are the five low-enriched uranium fabrication facilities operated by ABB Combustion Engineering in Hematite, Mo.; Framatome Cogema near Lynchburg, Va.; Global Nuclear Fuels in Wilmington, N.C.; Siemens in Richland, Wash., and Westinghouse in Columbia, S.C. Also, the team reviewed two high-enriched uranium fuel facilities owned and operated by BWX Technologies at Lynchburg, Va., and Nuclear Fuel Services in Erwin, Tenn. Also covered are the two gaseous diffusion plants owned and operated by U.S. Enrichment Corp. at Paducah, Ky., and Piketon, Ohio, and the uranium conversion facility in Metropolis, Ill., owned and operated by Honeywell.

Each assessment consisted of an on-site visit of one and one half to two days, preceded by the team's review of NRC inspection reports from the last two years. The review team focused on areas most important to criticality safety and emergency planning, including interviews with plant operators and other staff.

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The Nuclear Energy Institute is the nuclear energy industry's Washington-based policy organization. This news release and additional information about nuclear energy are available on NEI's Internet site at http://www.nei.org

Assessment of Nuclear Criticality Safety and Emergency Preparedness At U.S. Nuclear Fuel Plants

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for the

Nuclear Energy Institute

April 2000

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Executive Summary

The ten fuels processing facilities in the United States commissioned the Nuclear Energy Institute to conduct an independent assessment of their operations and practices in response to the nuclear criticality accident, which occurred on September 30, 1999, at a nuclear fuel conversion facility in Tokaimura, Japan. This initiative was undertaken in addition to any initiative undertaken by the individual facilities and was focused exclusively on the factors that the review team determined to be significant in shaping the environment that permitted the Tokaimura event to occur.

Overall, the review did not find any conditions of safety urgency requiring immediate attention. The team concluded that the facilities are operating safely.

During the course of its review, the team observed a number of instances at each facility where actual performance fell short of management expectations or of a standard that would be described as best practices. In each instance, the team provided its observations to the facility involved for its consideration and potential resolution or adoption. However, it should be noted that each facility visited contributed in some way to a virtual mosaic, which ultimately could be described as the "best practice" facility. Shortcomings and strengths considered, the review did not discover any deviation, practice or condition which compromised the nuclear safety of a facility.

Throughout the review process, the team observed a common belief on the part of the regulators, the managers, the engineers and the operators at all facilities that a criticality is possible and that it can happen "here." This is a positive contribution to continuing safety.

The prevailing view at the outset of this review was that the fuel cycle industry in the United States was regulated and operated on a firm safety foundation. Within the scope of the review, which was focused on the perceived contributing factors to the accident at Tokaimura, the assessment affirmed that view.

Introduction

On September 30, 1999, a criticality accident occurred at a uranium processing plant operated by the JCO Company, Ltd. in Tokai village, Ibaraki Prefecture, Japan. This report terms the occurrence as the Tokaimura event, or the Tokaimura accident. Appendix D provides a brief explanation of criticality and other industry specific terminology used in this report.

Early information received from public sources reported that the Tokaimura event involved several factors of interest and concern to the uranium processing industry worldwide. Specifically, the criticality resulted in severe exposure to three individuals, involved the public and emergency planning considerations, and involved chemical processes that are in common use worldwide. In addition, the event was technically unusual in that it was of an extended duration, which required active intervention to terminate the criticality.

Senior managers responsible for the operation of commercial uranium processing facilities (facilities) in the United States met with the Nuclear Energy Institute (NEI) during the week of October 4, 1999. They concluded that it would be valuable to conduct an overall review of the facilities using experienced, independent observers in addition to any special or routine reviews done by the individual facilities. NEI was tasked with management of an industry initiative to review all U.S. facilities for susceptibility to the conditions understood to be factors in the Tokaimura event. There was no intention to develop an authoritative evaluation of the Tokaimura event. Rather, the intention was to use the early information available from public sources to develop a comprehensive assessment of U.S. facilities.

NEI discussed the industry initiative with the Nuclear Regulatory Commission (NRC) and with the Administration. Both agreed that the industry initiative was an appropriate response to the Tokaimura event. An expectation was set that the review would result in a publicly available report that describes the Team's assessment of overall industry conditions in the relevant areas. This report is the fulfillment of that expectation.

The facilities covered by the assessment are the five low enriched uranium (LEU) fabrication facilities owned and operated by ABB Combustion Engineering, Framatome Cogema, Global Nuclear Fuels, Siemens and Westinghouse and the two high enriched uranium (HEU) fuel facilities owned and operated by BWX Technologies and Nuclear Fuel Services. These facilities are licensed by the NRC under 10CFR70. The two gaseous diffusion plants (GDP) owned and operated by USEC, which are certified by the NRC under 10 CFR76, were also included. In addition, the uranium conversion facility owned and operated by Honeywell was included at Honeywell's request. This facility is licensed by the NRC under 10 CFR40. A brief description of each of these facilities is included in Appendix A.

The characteristics sought in the experienced, independent observers were focused on management level experience in operations, regulation and the conduct of assessments. After appropriate search and discussion with the facilities, a special assessment team (referred herein as "Team") was formed to conduct the facility review. The Team consisted of Mr. Robert M. Bernero, Mr. John C. Brons and Mr. James R. Clark. Resumes of the individual team members are in Appendix B.

Scope and Focus

The Tokaimura event involved the relatively infrequent handling of uranium enriched to the intermediate level of 18.8% U-235. For U.S. commercial facilities, only the two HEU facilities are licensed for that level of enrichment. All other facilities are limited by their current licenses or certificates to lower enrichment levels. The Team concluded after a review of publicly available information that a number of other factors that were significant in shaping the environment for the Tokaimura event to occur appeared to be evident. They are:

1. ***A culture that permitted deviations from licensed procedures to respond to external pressures such as cost and schedule.*** At Tokaimura, a set of procedures defining the process involved in the accident was approved during the licensing of the facility. Had these procedures been followed, the likelihood of a criticality would have been substantially reduced. During the licensed life of the facility, pressures to reduce costs led to adoption of management-sanctioned procedures that were not in accordance with licensed conditions. The adoption of these procedures reflected a culture that was willing to sacrifice safety and regulatory due process for commercial expediency. At the time of the accidental criticality, the workers in response to schedule pressures employed a further shortcut over the unlicensed procedures, which greatly increased the risk.

2. *Tacit approval of procedural deviation by explicit involvement in unlicensed procedures and by routine willingness to deviate from "official" procedures.* Management and supervision created the initial set of inappropriate procedures but by practice did not insist that even those procedures be followed. Reportedly, operators frequently employed practices that were deviations from the promulgated procedures. Procedural use evolved to an "ad hoc" situation at Tokaimura.

3. *An insufficient criticality safety program, lacking appropriate use of the double contingency principle and maximum reliance on engineered controls.* The double contingency principle means that a criticality can occur only if two unlikely, independent events occur. Controls to prevent occurrence of such events are typically applied in a hierarchy of preference that values engineered controls over administrative controls. Engineered controls may be either passive or active but in either case are controls that are embedded in process hardware and do not require routine human intervention. Controls involving human intervention are termed administrative. At Tokaimura buckets were authorized in place of process-designed vessels to dissolve the U_3O_8 powder; this eliminated some designed-in mass and geometry control but maintained the use of geometrically safe storage columns. Actual practice avoided the use of the safe geometry storage columns through use of the precipitator tank to accumulate a large batch in a single vessel. Ultimately, the practices in place when the accident occurred avoided mass controls and geometry controls and added in an unfavorable reflection factor.

4. *Insufficient administrative controls, including change control, procedures for starting/restarting infrequent operations and configuration management.* Review of the Tokaimura event did not indicate any administrative method for management to assure themselves that the procedures in actual use were those that they had sanctioned. It is not clear that the administrative mechanisms provided the operators with a way to know whether or not the procedures in use were authorized either. The event also disclosed that the various changes involved (substitution of buckets, elimination of safe geometry vessels, shift to an operation performed very infrequently) did not receive any special review to ensure that intended safety margins were maintained.

5. *Insufficient training to workers on the potential for criticality, on the severe consequences of such an event and on adherence to procedures.* The actions of the operators indicated that they did not appreciate the impacts of handling material enriched to 18.8%. Results of interviews with the injured workers that were made publicly available indicated that they did not understand what criticality was and that they did not understand that many of the steps they had taken systematically eliminated barriers to criticality. Lacking this understanding, it is not surprising that they felt free to innovate to respond to schedule demands. It is normally expected that the operators actually performing work on the shop floor have experience to guide them in their understanding of procedures. In the case of this accident, neither of the operators had worked with this material before.

6. *Insufficient oversight, supervision or critical self-assessment, particularly with regard to inexperienced workers and unusual operations.* It should be assumed in any organization that there may be times when the work force either misunderstands or for some other reason performs in a way that is contrary to management expectations. This assumption should result in the establishment of programs to oversee operations, to identify deficient equipment and practices, and to establish methods to ensure that effective action results from the observations. Although information regarding JCO's internal practices was not available to the Team, it was assumed that a robust program of this nature would be a helpful feature to reduce the probability of failure and may not have been a part of routine practice prior to the event.

7. *Insufficient instrumentation to monitor the potential for criticality or personnel radiation safety.* At Tokaimura initial indications of the criticality were derived from off-site monitors. Worker dosimetry was insufficient to establish actual exposure during the event.

8. *Inadequate emergency planning measures, particularly with regard to termination of an extended event, timely notification and care of exposed personnel.* Communication between the facility and appropriate governmental agencies after the event was very difficult and, in some instances, untimely. Actions between governmental agencies were uncoordinated, and termination of the extended criticality was made more

difficult by failure to provide prior consideration for such an event. The management of emergency care for the severely irradiated individuals resulted in three moves before they reached a facility properly equipped to treat them.

9. ***Inadequate regulatory oversight.*** The regulatory agency associated with licensing of the facility did not conduct regular oversight activities. Visits were infrequent and not focused on licensed operations.

Based on these considerations, the foregoing statements identified in italics defined the scope and focus of the Team's review. (Subsequent authoritative evaluations of the Tokaimura event did not disclose any additional areas for review.) The Team prepared a document entitled "Assessment of Nuclear Criticality Safety and Emergency Preparedness at U.S. Nuclear Fuel Plants" that provided this information to the industry. The Team also prepared a protocol for conducting the assessment at each of the facilities to ensure uniformity and thoroughness. Both of these documents were delivered to the ten facilities by letter dated November 23, 1999. The documents are contained in Appendix C.

Assessment Methodology

The individual assessments were conducted in accordance with the protocol. Each assessment consisted of off-site preparation by the Team and an on-site visit of 1½ days to all facilities except for the two HEU facilities where the on-site visit was two days.

Prior to the on-site visit, the Team requested and received an advance package of information from each site that was used to provide specific background in a number of areas to be reviewed while the Team was on site. In addition, the Team reviewed NRC inspection reports for the two-year period preceding the Team's visit. These reports were available in the public document room.

The on site portion of the visit was begun with a presentation by facility management that responded to a detailed list of questions and topics included in the protocol document. This presentation was conducted in a highly interactive format as the Team probed the information presented.

Following the management presentation the Team participated in a facility tour consisting of areas of interest from the standpoint of criticality safety and emergency planning. In addition, the Team conducted a number of individual interviews of facility staff, focusing heavily on operators and their immediate supervisors. Where possible the Team spoke to staff from more than one shift.

At the conclusion of the first day, based on its observations and interviews, the Team advised each facility of three or more topics that individual team members would pursue in depth the following morning. The in-depth reviews allowed team members to focus more deeply on key issues to validate or correct the Team's initial observations and to consider items presented on the first day in greater detail.

After the in-depth reviews were completed, the Team prepared and delivered a debrief to the facility management.

Results—General

All uranium processing and fuel fabrication facilities in the United States are regulated by the NRC and committed to the same American National Standards Institute (ANSI) standards regarding the basic criteria for criticality safety. All of the facilities are committed to emergency planning under their specific regulations, 10CFR Parts 40, 70 and 76. The Team believes that these regulations and standards are observed and provide for fundamental criticality safety. The Team was committed to report to senior plant management any conditions of safety urgency that required immediate attention observed during the course of the review. The Team did not observe any such conditions at any of the ten facilities. The Team concluded that the facilities reviewed are operating safely.

Results—Contributing Factors

The assessment conducted by the Team was focused on nuclear criticality safety and emergency preparedness as defined and limited by contributing factors evident from public information about the Tokaimura event. The basis of the Team's observation was not the threshold of regulatory compliance or standards compliance that provide an adequate safety baseline but rather a higher standard of "best industry practice."

At the outset of the review process, "best industry practice" was based on the Team's collective experience.

As the review process continued, "best industry practice" became totally grounded in superior performance actually observed in one or more of the facilities.

*Note: The numbered **contributing factors** below appeared to shape the environment for the Tokaimura event. The Team's findings at the U.S. facilities were compared with these contributing factors.*

1. *A culture that permitted deviations from licensed procedures to respond to external pressures such as cost and schedule*

Observations

Although all of the U.S. facilities maintain some level of awareness on the shop floor and within the office areas of pertinent business goals or objectives, the Team did not observe any instance of a culture that emphasized those goals or objectives above safety or anywhere near it. Most production employees viewed the display of business goals as informative and helpful to understand priorities, but no one ascribed any dominant performance pressure to them. Employees at all of the facilities expressed their right to stop the process if they had any safety doubts or concerns. Operators appeared very confident that management would be very supportive of any decision that they made to stop while a safety concern was resolved.

Best Practices

At best practice facilities the Team observed a very positive culture in this regard, not just the absence of a negative culture. In the positive culture setting there was a high level of congruence between the expressions of management regarding safe work practices, use of procedures and the authority of the operators and the articulation of the same concepts by the operators and supporting management staffs.

2. *Tacit approval of procedural deviation by explicit involvement in unlicensed procedures and by routine willingness to deviate from "official" procedures*

Observations

As a matter of first priority in this area, the Team tested the methodology used at each facility to ensure that the procedures in use flow down from the licensed conditions and supporting safety analyses. The methods used at all facilities employed sufficient rigor to provide reasonable assurance that the operating procedures in use are consistent with licensed conditions. The Team did not observe any instances of shortcut or unanalyzed procedures.

The Team found that senior management at all facilities expressed their will and intention that operating staff adhere to procedures. Several facilities insisted that their standard of adherence was one of "verbatim compliance." Others expressed varied views of what was intended by procedural adherence. A few facilities had defined a hierarchy of procedural use dependent on the process or the specific nature of the steps being performed.

The Team also found that it was the will and intention of the operating levels of the organizations to adhere to procedures. Frequently, however, the actual use of procedures in the course of operating the facility did not match the stated standards of use described by management.

The processes employed are generally repetitive and automated. The Team concluded that procedures are being followed and that both management and operating staff are concerned about doing the work in accordance with procedures. The processes in the main, however, do not lend themselves to step-by-step following of procedures or by "verbatim compliance" as the Team understands that term. The difficulties that arise in the use of procedures are more attributable to differences of understanding between the procedure writers and the procedure users on the degree of latitude that the operator has in any part of the process.

Best Practices

At best practice facilities, management has carefully defined and communicated its expectation on how procedures are to be used. The definition has accounted for the realities of the process and the ability of the operators to access or refer to the procedures during their work. The definition also describes different standards to be employed during especially critical steps or when the procedure is infrequently performed. In some cases, operator aides have been authorized to assist the operators in compliance with the expected standards. At these facilities there is a high level of congruence in the understanding of the operators and the expectations of management. It is clear that the expectations are reinforced.

3. *An insufficient criticality safety program, lacking appropriate use of the double contingency principle and maximum reliance on engineered controls*

Observations

All facilities have adopted the ANSI standards that employ the double contingency principle for processes involving special nuclear material (SNM). Some elements of process at the GDP do not permit application of this principle, and the exceptions are recognized in their certificate. Specific focused requirements in the technical specifications applicable to these facilities compensate for any lack of ability to employ the principle in these areas.

Although all facilities adopt the ANSI standards for nuclear criticality safety (NCS), each individual facility has developed its own unique NCS strategy that is proposed in its license application for NRC approval. This case-by-case approach results in significant differences from plant to plant for reliance on mass or moderator control, in the application of mass thresholds for NCS calculations, and in the number of NCS controls for a process. Some facilities have an avowed policy of establishing "triple contingency controls" so that the least severe or most likely contingency occurrence would be an internally reportable event. The first level of reporting to the NRC would not be required until the second of three contingencies occurs.

Engineered controls are the expressed preference at all facilities. Most facilities have some process in place to systematically review administrative controls in use and where reasonable to replace them with engineered controls. Some facilities are using the integrated safety analysis (ISA) process very effectively to accomplish this goal of minimizing administrative controls.

Those facilities that have developed the ISA process more extensively report success, not so much in discovery of previously unrecognized risks, but in establishing a coherent consolidation of the safety design basis. It is this coherent design basis that can be used to weigh enhancements of safety controls and to assure that safety controls are systematically flowed down into operations.

Postings are used at all facilities to provide reminders at the point of need of criticality safety restrictions important to the operators and to the processes. Some facilities use them extensively. The Team noted that the impact and effectiveness of the postings is highly dependent on the care used in their preparation, the size print used, the language clarity and the location chosen.

Some facilities are reporting large numbers of "reportable" items under NRC Bulletin 91-01, which leads to a perception that criticality safety programs may be lax. In the Team's view, the real driver for the large numbers of items reported is the application of an overly conservative standard used to determine the scope and reportability of items at some facilities.

Best Practices

Best practice facilities are staffed with an adequate number of criticality safety engineers with job responsibilities that are undiluted by significant collateral duties. They are highly visible in the operating areas of the facility and well known to the operators and their supervision. Criticality safety surveillance is enhanced by cross training radiation protection personnel on shift to perform some nuclear safety surveillances. Any administrative controls in use are systematically challenged based on priorities established through aggressive use of the ISA and internal problem reports or operator input. Internal control limits are established that provide early warning of process deviations reportable under Bulletin 91-01. These early warning issues receive aggressive follow-up using the full range of the facility corrective action program. Postings are determined by the nuclear safety department and turned over to the operations department, which takes complete ownership for preparation and placement of the postings. External events such as the Tokaimura event result in a thorough review of the facility for applicability and lessons learned.

4. *Insufficient administrative controls, including change control, procedures for starting/restarting infrequent operations and configuration management*

Observations

All facilities employ some method to identify authorized changes to operating procedures and to assure that procedures in use are the latest revision. The Team observed varying degrees of rigor to be certain that operators are aware of the change and that outdated versions of the procedure are no longer available. Some facilities use primarily paper copies of procedures and control methods that are suitable to paper. Other facilities use computer-based systems and are moving toward elimination of "hard copy" procedure use. At most facilities changes are highlighted or marked in some distinctive way to facilitate recognition and awareness of change content.

Each facility has a satisfactory process for controlling changes to the physical plant and for start-up of new processes. In some instances the change control process is not "user friendly" in that it is difficult to verify and validate the entire record of change. Most facilities also re-initiate the change control process for previously approved systems that have been idle for extended periods or for processes that are used infrequently. Although this practice, which is commonly used in the facilities, is not required at most facilities, the Team believes that the probability of the Tokaimura event would have been reduced if it had been employed there.

Best Practices

Best practice facilities employ a centrally administered change control process for operating procedures that assures that old copies of the procedure are no longer available to operators once a change has been issued. Positive controls are in place to be confident that operators are informed of changes and trained in their significance before they are permitted to operate a process affected by change.

Best practice physical plant change control operates under an umbrella policy that specifies applicability to all equipment and processes related to nuclear safety. The policy also specifies that the change control requirements also apply to any previously approved system, even if unchanged, if it has been "out-of-service" for more than a designated time. The process is administered with a structured checklist that accompanies a proposed engineering change through a pre-established multi-disciplinary review and approval process that includes:

- an integrated safety analysis of the proposed change
- verification and validation of the change prior to implementation
- training of the appropriate personnel prior to initiation with SNM
- controlled distribution of revised procedures.

Document control is maintained on the entire record of the change, and management oversight review of proposed engineering changes at the onset, during project development and near completion is included.

5. ***Insufficient training to workers on the potential for criticality, on the severe consequences of such an event and on adherence to procedures***

Observations

All facilities provided information to their work force about the Tokaimura event; as a result there was general awareness of the accident and its consequences. Only a few facilities, however, used the event and the potential lessons learned aggressively to reinforce management expectations and standards. In general, interviews conducted by the Team revealed a weak understanding of the term criticality and an equally weak understanding of its consequences. Many operators understood criticality to have dire, life-threatening consequences but erroneously equated the cause of these consequences to an explosion. Operators were uniformly aware of the restrictions and controls under which they operate and were adamant in their need to adhere to those controls, but the training program had not provided sufficient understanding to retain the reasons for the controls. A few facilities were significant exceptions to this in that their work force exhibited a strong understanding of these key concepts.

General training is conducted at all facilities for all new employees shortly after the time of hire, and generally, the training is repeated or updated on a mandatory annual basis. In some cases the material presented for these general training courses was inordinately detailed and scientific. In other cases, the material used provided minimal understanding of the technical concepts. In the case of the few facilities where a strong understanding of key concepts exists, the information appears to have been acquired from sources other than the general or annual retraining such as handbooks or formal job specific criticality training.

About half of the facilities conduct more detailed training in the classroom on a task specific or job qualification specific basis.

Training is the responsibility of the training department at some facilities. Those facilities that have training departments usually conduct training on a more formal basis using learning objectives, lesson plans and objective measures to gauge success. Training staff tend to be beneficially engaged in the qualification process as well. In other facilities, training is a collateral responsibility of supervision, engineering or the criticality safety department.

Most of the qualification programs are relatively informal. The most common qualification process for operators involves on the job training (OJT), observation and approval/qualification by the first line supervisor. Some facilities use a much more formal process involving qualification cards, written tests, independent observers and practical factor check-offs. The Team was not able to discern any substantial differences in performance between the two systems. All but one of the facilities that used written tests as a part of the qualification process administered them as "closed book" even though all expected the procedures to be used during the course of operation. This appeared to the Team to represent inconsistent thinking. If the procedures are expected to be in active use during operations then the testing should be open book. If procedures are expected to be used only when some uncertainty exists, then closed book testing may be appropriate.

Some facilities assign permanent employees as the majority of the work force and rely on temporary employees for the remainder. The Team observed some uncertainties in the training and qualification management for temporary employees as compared with permanent employees.

Best Practices

The best practice facilities used the Tokaimura event aggressively to reinforce management expectations. The work force understands the physical phenomenon called criticality and is thoroughly aware of its severe consequences and how they occur. The work force also understands the physical principles associated with the various control factors in use at the facility.

Training is conducted to predetermined training objectives, and training results are measured to validate the achievement of objectives. Initial general training is backed up in six to eight weeks in recognition of the fact that, for a new hire, initial training is somewhat like " drinking from a fire hose." Annual retraining advances the general skill of the workforce rather than maintaining the entry level knowledge.

Qualification processes engage process engineers with the trainers and supervision to produce a quality product. Individuals assigned to observe OJT are themselves trained to observe the qualification process and act independently of any possible pressure to qualify people. Training material provided for operators captures potential operating lessons learned from the facility's own history and the industry at large. Individuals selected to train new operators are chosen for their training skills as well as their qualification credentials.

6. *Insufficient oversight, supervision or critical self-assessment particularly with regard to inexperienced workers and unusual operations*

Observations

Strong, beneficial involvement by first line supervision in operations was evident at all facilities. At most facilities, day-to-day close involvement of the criticality safety engineering staff with plant operations was also evident. At some facilities, process engineers and radiological technicians contributed to a healthy oversight process by involvement in various oversight roles such as conducting periodic surveillances of compliance with criticality safety postings.

All facilities conducted periodic audits related to criticality safety and operations as required by their licenses or certificates. At many facilities, however, the distinctions between oversight techniques that test compliance and those that seek opportunities for improvement or adherence to expectations were poorly defined. Requirements that would be better satisfied by formal compliance-based audits were frequently performed in an informal manner. Programs aimed at improvement opportunities were often conducted by the same individuals, month after month. The observations derived from these reviews frequently fit a predictable mold of benign deficiencies and seldom led to substantive opportunities for improvement.

Administrative corrective action programs are employed at all facilities to trend observations and to track items to closure. Many of the programs were highly compartmented, however. For example, NRC observations would be tracked in one program while a different program was used for internal observations. In some cases there were several corrective action programs tracking items derived by various sources. Often more attention and emphasis was given to NRC observations than those derived internally or independently with less regard for the significance of the observation. The diffuse nature of these programs tended to reduce their effectiveness.

Best Practices

Best practice facilities exhibit a substantial involvement by first-line management on the shop floor every day. This is supplemented by the active engagement of process and maintenance engineers and others such as the radiological technicians who have been specially trained to make observations regarding quality and safety of operations. Where appropriate, check lists are provided to guide these observations.

A balanced mix of audits, which formally test compliance; surveillances, which test conformance to expectations; and management walk-throughs, which seek opportunities for improvement, is employed. The results of these efforts together with those of outside agencies and other independent sources are tracked and trended in a comprehensive system. In addition, all individuals at the facility are free to contribute observations or identify problems. High percentages of the observations are identified by people actually involved in the process. Programmatic results are analyzed by management for the effectiveness and timeliness of prior corrective actions.

7. *Insufficient instrumentation to monitor the potential for criticality or personnel radiation safety*

Observations

Both instrumentation to monitor for criticality and personnel dosimetry are appropriate. On-site instrumentation provides proper coverage of all areas on site handling SNM to detect criticality. Alarm condition notification is accomplished by both audible and visual means. Dosimetry provided to workers is appropriate to monitor for routine exposure and also contains the ability to record accident exposures.

Instrumentation to monitor for criticality is available at most emergency control facilities in the form of instrument location and alarm/not alarm condition. Facilities rely on trained monitoring teams with hand-held instruments to monitor post alarm conditions. One facility has the capability to monitor criticality accident alarm system instrumentation for continuous readings after it has alarmed.

Best Practices

The Team's review focused on important fundamentals in this area such as coverage and sensitivity of instrumentation and dosimetry. The Team was able to conclude that all facilities were fully satisfactory with respect to this contributing factor. The review was not of sufficient scope to identify or evaluate best practices.

8. *Inadequate emergency planning measures particularly with regard to termination of an extended event, timely notification and care of exposed personnel*

Observations

All facilities have active emergency plans, which are exercised routinely on-site and periodically with support organizations off-site. The exercises cover the full range of site emergencies including criticality (except, of course, at Honeywell where no risk of criticality exists). Written agreement with local emergency organizations, fire, police, and hospitals are in place to support emergency operations. Facilities on-site to coordinate activities and communicate with off-site agencies and organizations are in place. Some facilities are very elaborate. On-site work force and visitors are trained in actions to be taken in response to various site emergency conditions.

Most facilities have relatively large sites that result in very low risk to the public especially with respect to a criticality. Risk to the off-site public is typically process or chemical risk. The principal risk at these facilities is to the on-site workers, radiation risk mostly from accidental criticality and process safety risk mostly from chemicals. Appropriate emphasis is given in emergency plan drills and exercises to risks associated with criticalities, chemical upsets or fire on-site.

Some facilities include extended criticalities in their repertoire of drills; others do not. Few facilities have given full consideration to options that may be used to terminate an extended criticality and the logistics to employ them. All facilities have considered the medical management of contaminated individuals but few have considered the management of highly irradiated individuals and the logistics to deliver them to appropriate facilities.

Best Practices

Best practice facilities maintain an active emergency planning organization that works closely with community emergency organizations on a mutual support basis. These arrangements are documented in written agreements and include a scope of services that encompasses the worst-case support situations. Arrangements are in place to guide community assistance forces who respond to plant emergencies on an off-hours basis. Community forces have been trained in special circumstances that may apply, such as fire fighting without the use of water in certain areas. Drills and exercises span the full range of emergency situations that may be encountered on-site, and full consideration of the worst-case situation has been applied. Routine training and drills emphasize events with the highest probability.

Emergency planning facilities are equipped with all necessary communication equipment, and backup equipment is available and tested. Meteorological information and accurate maps of the surrounding community are available. The emergency control facility itself will be habitable during an extended criticality, or an alternate site is available. Appropriate facility drawings are available at the emergency control center to allow planning of remedial actions in the event of an accident that renders access to the scene dangerous.

9. *Inadequate regulatory oversight*

Observations

All of the facilities reviewed receive adequate regulatory oversight from the NRC. The regulatory presence varies appreciably from one facility to another. The two HEU facilities have a single resident inspector as well as periodic inspections by NRC headquarters and regional staff. The two GDP have two resident inspectors each, and are frequently inspected by NRC headquarters and regional staff. The five LEU fuel fabrication plants do not have permanent resident inspectors but are periodically inspected by NRC headquarters and regional staff in a consistent pattern with changes to reflect unique conditions such as start-up of a new process. The single uranium conversion plant receives more than adequate regulatory oversight, roughly equivalent to the level applied to a fuel fabrication plant. NRC oversight is responsive to special circumstances such as the installation of new processes or labor disputes.

A healthy, respectful relationship with the regulators was apparent at all of the plants reviewed, especially with the resident inspectors at the four plants that have them. The GDP seem to receive the most intense level of regulatory oversight. The Team recognizes that these very large facilities came under NRC regulation only in the past several years of their very long operating lives, a basis for intense effort to establish the regulatory system under Part 76, unique to these plants. With the management systems now in place at the GDP, the continued intensity of regulation may be disproportionate to risk.

The evolution of NRC's licensing (and certification) process is evident. There is gradual adoption of ISA and a longer, 10-year license term. The scope and content of license conditions vary from plant to plant. Individual licensees are developing improvements in safety management systems, such as graded criticality safety limits, use of performance indicators, etc. The unique characteristics of these plants, even within a class, pose a challenge for evolution of a balanced regulatory regime that will require a continuing cooperative effort between the industry and the NRC.

Results—Integrated

The review process brought about by the Tokaimura event provided what appears to be a unique opportunity for a small group of people, the Team, to have full and very cooperative access to all commercial domestic fuel cycle facilities in one relatively short window of time. This was a unique opportunity to conduct a safety review at all of these facilities using the same scope and approach. The Team is quite conscious of the limited scope of its reviews and the short time for conducting each one. The typical review had the Team spending only about 15-20 hours in each plant. Nevertheless, this unique opportunity has enabled the Team to form some observations and conclusions that go beyond the scope of the review process itself. These additional observations are offered by the Team, conscious of our limitations, in the hope of providing further value to the ten facilities and to the NRC.

Competition and Consolidation

Portions of the industry were once a monopoly; the government-run GDPs were at one time virtually the only source of uranium enrichment. Other portions have long been independent competitors. The former monopoly portions are now challenged by available product from new sources, imposing competitive pressures where none previously existed. The competitive portions are participating in a global consolidation effort that provides new pressures. Overall, the industry is of strategic interest to the country. The time of transition is one for caution and clear focus on fundamentals.

Proprietary considerations have caused the facilities to be very guarded in sharing operating practices. To some extent that notion is reinforced by various securities and exchange rules in effect in the present context because of merger and acquisition activity. This report refers to a number of "best practices." It is interesting to note that each facility visited contributed in some way to the best practices mosaic. The Team believes that the best practices cited in this report do not have anything to do with proprietary processes.

The Team believes that competition, consolidation, efficiency, safety and the strategic national interest will be served well if the facilities can find some way to share best practices and permit benchmarking in ways that do not betray proprietary interests.

The Facilities

The fuel cycle facilities reviewed cover the front end of the nuclear fuel cycle from the receipt of natural uranium oxide (U_3O_8) at the conversion facility to the shipment of completed fuel assemblies to the reactor users.

The conversion facility converts the natural U_3O_8 to natural UF_6; it does not handle enriched uranium (SNM). Although no risk of criticality exists, this facility was included in the review at its request because the chemical risks involved require emergency plan considerations. The other nine facilities accomplish the enrichment process, production of enriched uranium oxide powder, formation of the powder into ceramic pellets, loading of the pellets into fuel rods and, finally, assembly of the fuel rods into completed fuel assemblies for use in reactors. Facility product from the enrichment plants is typically in the form of UF_6. Fuel fabricators may deliver product in powder, pellet or fuel assembly form. All must maintain careful batch control for the enrichment assay to meet customer specifications and to maintain close Material Control and Accounting (10 CFR Part 74).

The fuel fabricators often hold substantial batches of material in interim storage for product blending and control. Product assay and quality receive great emphasis, as they should, but it takes additional effort to maintain comprehensive quality assurance for management and operations. These facilities are each a part of a worldwide network of nuclear fuel production that requires careful accounting for the condition of the supply materials received and the products shipped, as well as the containers used. The UF_6 and other products must be shipped in certified containers that require close surveillance and testing to meet requirements.

Risk and the Regulatory Process

The processes at these facilities are both chemical and physical. The conversion plant uses a chemical process to convert oxide to the UF_6 form. The enrichment plants use a physical process of pumping for pressurized selective diffusion of the UF_6 gas. The fabrication plants use chemical processes to produce the enriched oxide powder from the UF_6 and a succession of mechanical processes thereafter. Many of these mechanical processes are highly automated and, when viewed step-by-step, are relatively simple. Human involvement at any given stage tends to deal with a focused, repetitive portion of the process and is provided mainly for safety oversight, quality oversight, dealing with process upsets and handling of process input and output materials.

The principal accident risks at the conversion plant lie with potential release of large quantities of hazardous chemicals. At the enrichment plants, the hot UF_6 gas reacts vigorously with water, even moisture in the atmosphere, releasing hazardous chemicals, HF and UO_2F_2. If the UO_2F_2 particulate collects in one place, a critical mass may form. Criticality is avoided at these plants by controlling the size of the cylinders used to hold the UF_6, by controlling the possible buildup of deposits within the enrichment process and by avoiding collection areas where accidental UF_6 releases might collect. The fuel fabrication plants have risks associated with both the failure of the chemical processes and the possibility of criticality accident with large quantities of material in interim storage or the possible collection of process scrap residues to form a critical mass. Considering these risk characteristics and the layout of these plants, in the Team's view, risk to the off-site public is low and is typically process or chemical risk. The principal risk at these facilities is to the on-site workers, radiation risk mostly from accidental criticality and process safety risk mostly from chemical hazards. The harmful range of radiation from an accidental criticality is so limited that such an emergency can be managed at the site without major off-site protective measures. The risk profile is distinctly different from that of a nuclear reactor where risk to the off-site public from radioactive releases is the dominant concern.

The Team was surprised to find an apparent tendency to manage and to regulate these facilities as similar to reactors by both the management and the NRC. On the facility side, the Team observed emulation of reactor programs in administration of training and qualification, intentions for the use of procedures and elsewhere. On the regulatory side, the Team observed evidence of regulatory initiatives apparently modeled on reactor programs, such as the development of standard performance indicators. The regulatory process for these facilities is evidently evolving. The ISA is being introduced; license terms and application sequences are changing. Major licensee performance evaluations are being conducted by the NRC. Yet some of the licenses are still laden with special conditions as they were in the past. These license conditions are not always consistent. For example, some licensees are required to obtain a periodic external audit of their criticality safety program, while others are not. The direction and basis for risk-informed regulation of these facilities is not yet clear. There is, however, a clear opportunity for the industry and the NRC working together to enhance the regulatory paradigm as the NRC moves into risk-informed regulation in the fuel cycle area.

In the Team's view, it is important that the facilities be recognized and treated as they are, unique facilities with low and unique risk profiles. Expectations and programs should be directed at the realities of the processes being employed. Efficiency and safety will both be enhanced if the imposition of elaborate measures better suited to other enterprises is avoided. As much as each of these facilities is similar to the others, it is also sufficiently unique so that few "one size fits all" solutions are applicable.

Conclusions

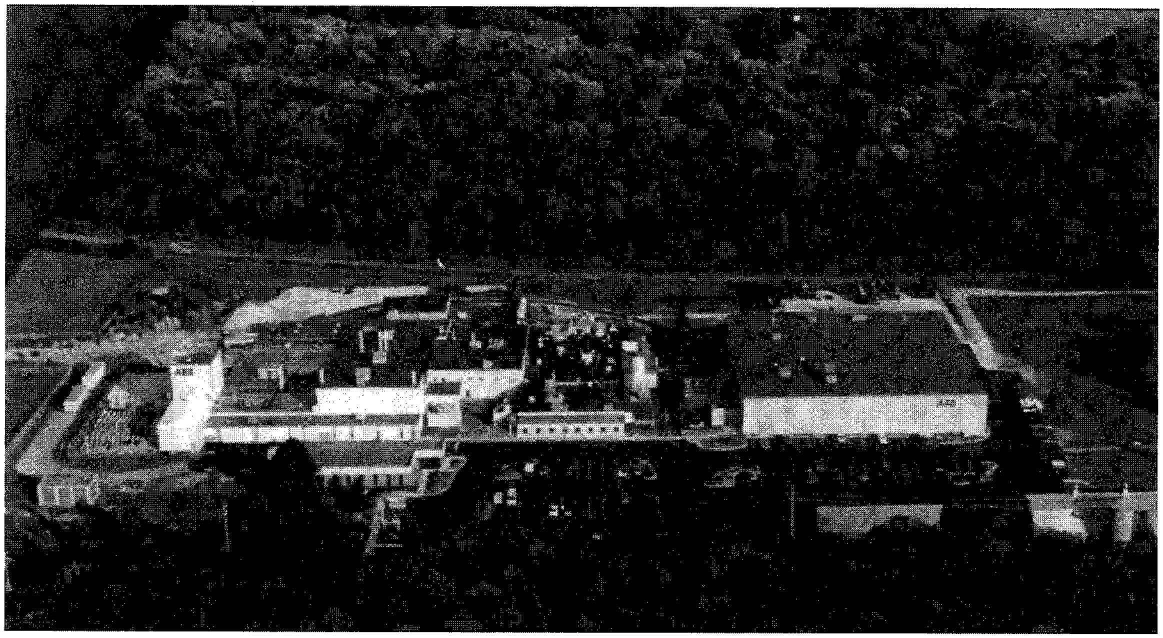
The Team did not observe any conditions during the course of its reviews or on-site visits of safety urgency requiring immediate attention.

During the course of its review, the Team observed a number of instances at each facility where actual performance fell short of management expectations or of a standard that would be described as best practices. In each instance, the Team provided its observations to the facility involved for its consideration and potential resolution or adoption. Similarly, as previously noted, each facility visited contributed in some way to the virtual mosaic which ultimately could be described as the "best practice" facility. Shortcomings and strengths considered, the Team did not encounter any deviation, practice or condition that compromised the nuclear safety of the facility.

Throughout its review process, the Team observed a common belief on the part of the regulators, the managers, the engineers and the operators that a criticality is possible and that it can happen "here." This is a positive contribution to continuing safety.

The prevailing view at the outset of this review was that the fuel cycle industry in the United States was regulated and operated on a firm safety foundation. Within the scope of its review as developed by a focus on the perceived contributing factors to the accident at Tokaimura, the Team affirms that view.

U.S. Fuels Processing Facilities



Facility: Hematite Nuclear Fuel Manufacturing

Owner: ABB CE

Type of facility: Fuel fabrication

Location: Hematite, Mo.

Description:

The Hematite Nuclear Fuel Manufacturing facility has been supplying fuel to the nuclear industry for more than 40 years. The current operation provides both boiling water reactor (BWR) and pressurized water reactor (PWR) fuel to domestic and international commercial power plants. The facility is located about 35 miles south of St. Louis.

The operation receives low enriched uranium hexafluoride and converts this material to uranium dioxide (UO_2) in a unique fluidized bed reaction vessel. The UO_2 is pressed into pellets, loaded into fuel assemblies and shipped to commercial customers.

The facility directly employs about 200 skilled operators, technicians and support staff.

Facility: Framatome Cogema Fuels

Owner: Framatome Technologies Group

Type of Facility: Fuel fabrication

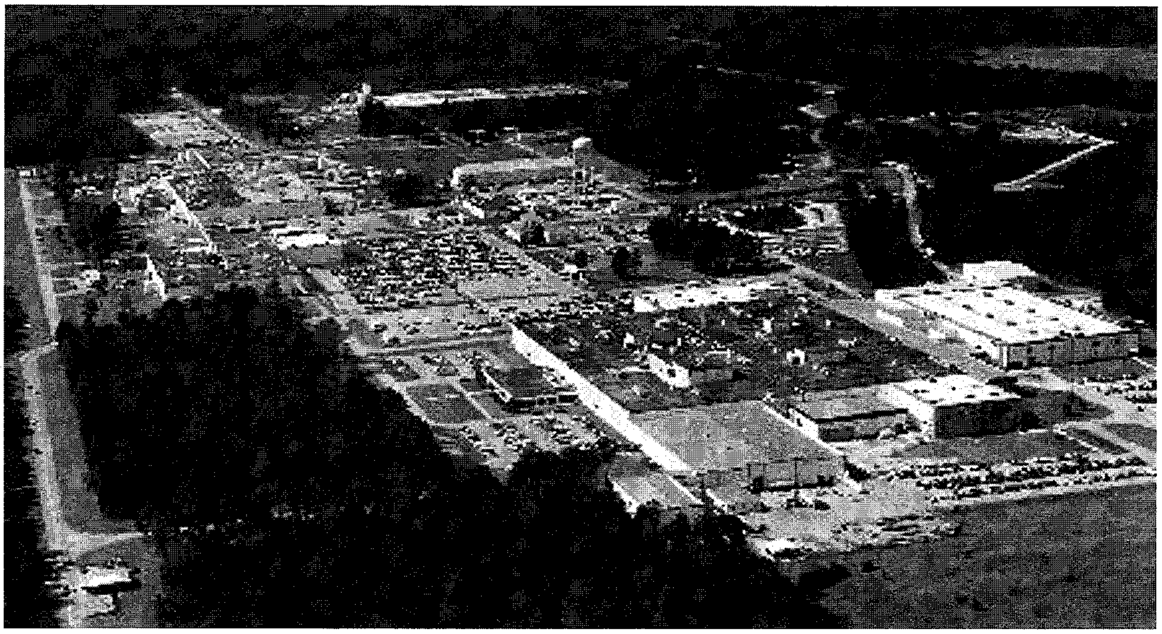
Location: Near Lynchburg, Va.

Description:

Framatome Cogema Fuels (FCF) manufactures high performance fuel for pressurized water reactors (PWRs) and offers services and products to help electric utilities improve nuclear plant performance while minimizing fuel-cycle costs. As a unit of Framatome Technologies Group, Framatome Cogema Fuels is part of a comprehensive nuclear plant services and technology products organization.

Framatome Cogema Fuel's products and services consist primarily of the design and fabrication of nuclear fuel assemblies, components and incore instruments. FCF provides engineering and field service support to nuclear utilities and is part of teams working with the Department of Energy to design the waste package for the proposed repository at Yucca Mountain in Nevada and to dispose of weapons grade plutonium by use as commercial nuclear fuel.

Backed by the global resources of Framatome and Cogema, FCF fuel designs provide effective solutions to current and anticipated demands for high performance and reliability. FCF's advanced fuels feature superior debris resistance, high resistance to corrosion, and fuel rod and structure designs for 18- and 24-month fuel cycles.



Facility/Owner: Global Nuclear Fuel

Type of Facility: Fuel fabrication

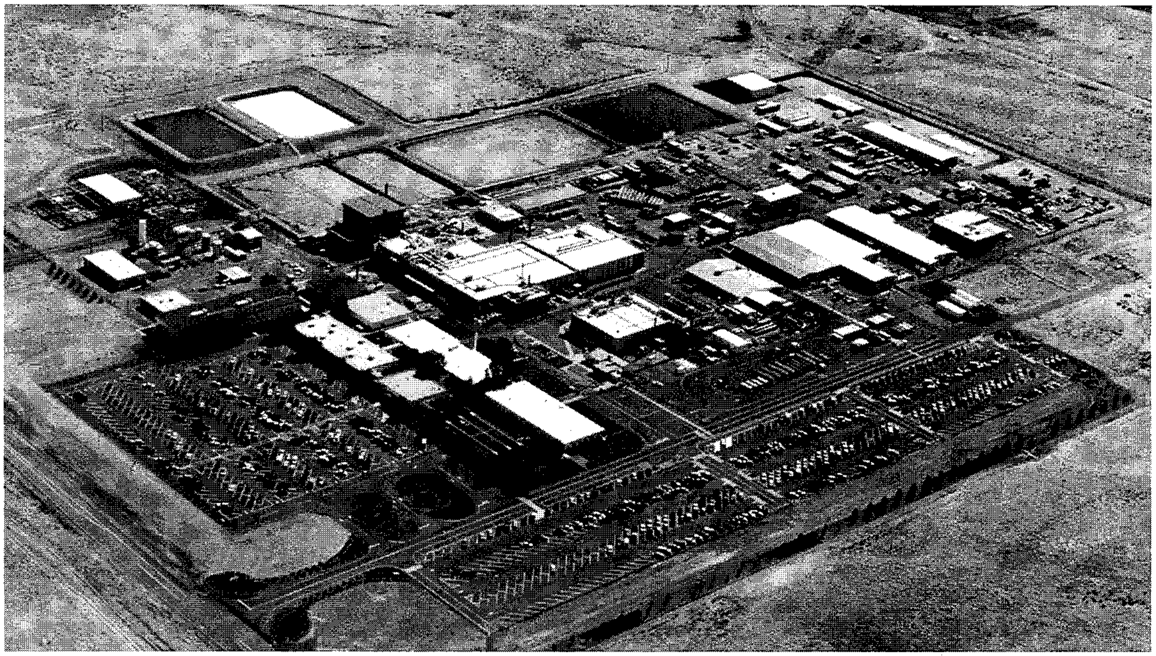
Location: Near Wilmington, N.C.

Description:

The Global Nuclear Fuel (GNF) facility is GNF's U.S. manufacturing site for boiling water reactor (BWR) fuel assemblies and other reactor related components. These products are used in the operation of commercial nuclear reactors supplying public electrical power.

The nuclear operations utilize very low enriched uranium (less than or equal to 5% U-235) from feed material to finished fuel assemblies. The processes are a combination of chemical and mechanical operations.

In addition, on-site non-nuclear manufacturing produces components for fuel assemblies and other reactor core resident parts.



Facility/Owner: Siemens Power Corporation

Type of facility: Fuel fabrication

Location: Richland, Wash.

Description:

Siemens Power Corporation (SPC) produces ATRIUM[1] fuel assemblies for boiling water reactors (BWR) and high thermal performance fuel assemblies for pressurized water reactors (PWR). Fuel assemblies are fabricated at the Richland engineering and manufacturing facility. The plant has a bundle assembly capacity of 700 metric tons of uranium (MTU) per year. With a capacity of 1,200 MTU per year, SPC's patented and environmentally friendly method of converting feed uranium hexafluoride (UF_6) to uranium dioxide (UO_2) has the highest capacity of any "dry" conversion facility in the world.

SPC is one of the largest suppliers of nuclear fuel in the United States, having designed, manufactured and delivered more than 35,000 fuel assemblies (more than four million fuel rods) to 50 nuclear power plants in the United States, Germany, Taiwan, Belgium, France, Mexico and Japan. Together, SPC and Siemens KWU's Nuclear Fuel Cycle Division in Germany have supplied fuel and reactor services to more than 100 nuclear power plants worldwide.

SPC provides other nuclear plant services, including digital instrumentation and control systems, chemical cleaning and decontamination services, and personnel dosimetry products.

SPC employs about 750 people at its Richland engineering/manufacturing facility and sales offices in Bellevue, Wash., and Alpharetta, Ga.

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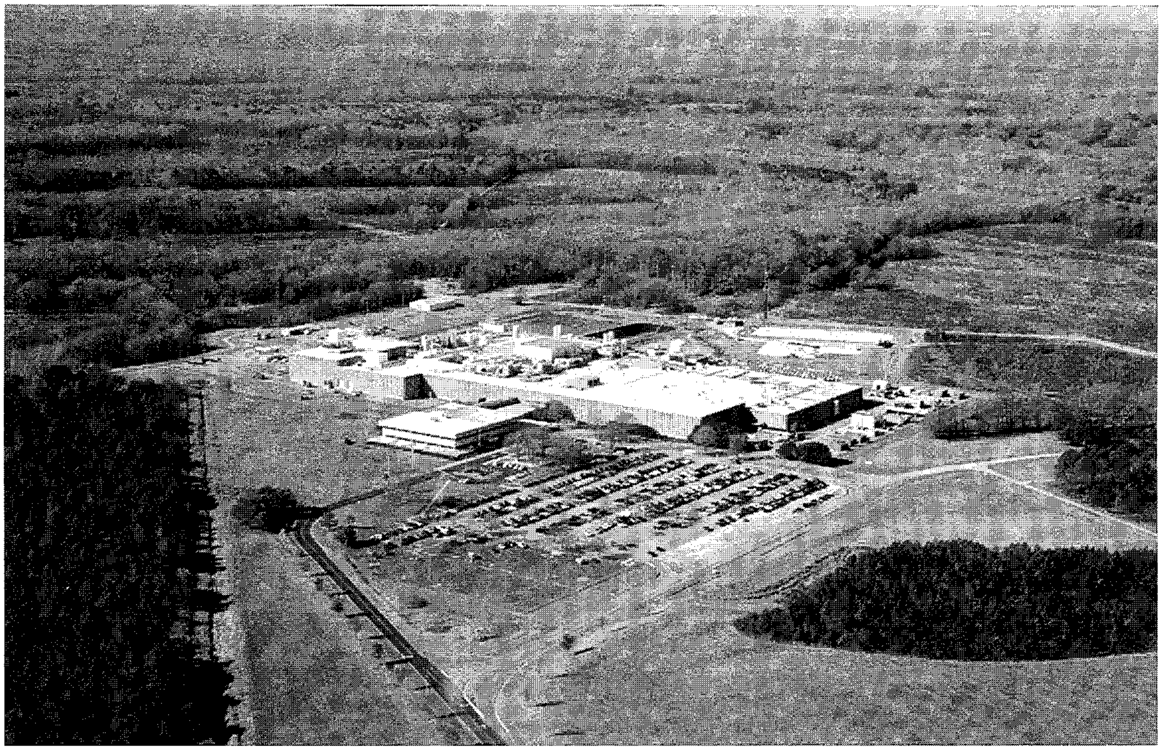
[1]ATRIUM is a trademark of Seimens



Facility: Columbia Site

Owner: Westinghouse

Type of facility: Fuel fabrication

Location: Columbia, S.C.

Description:

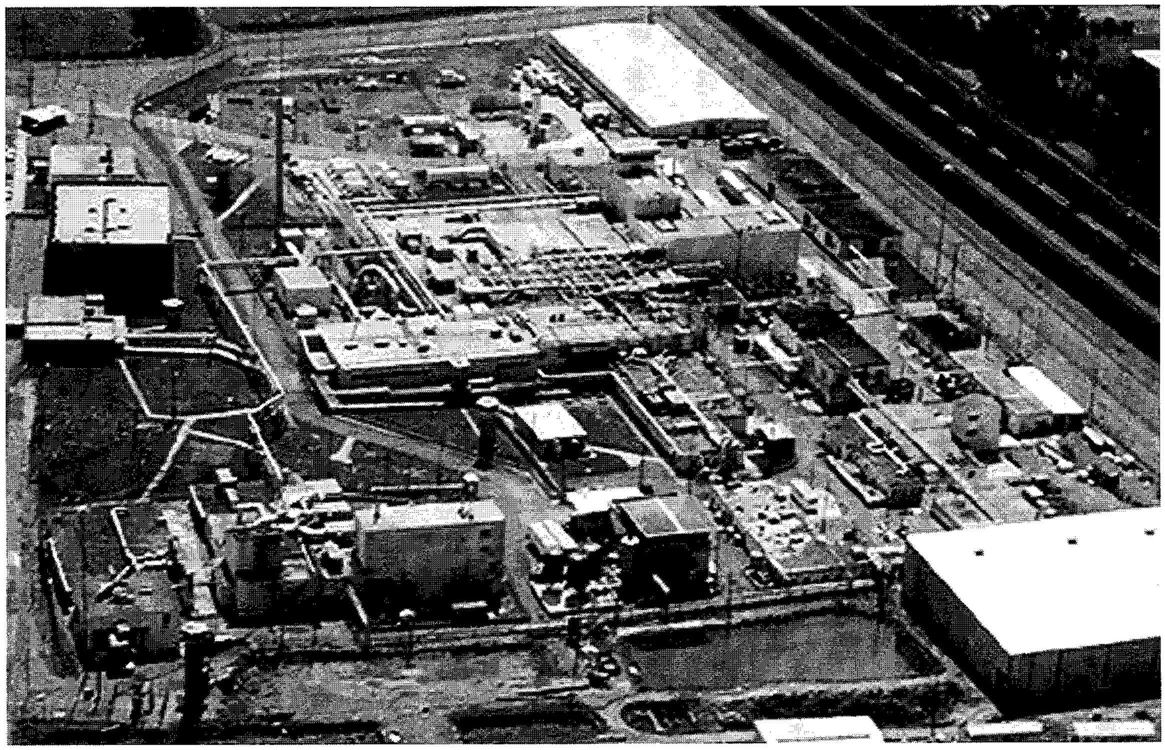
The Columbia Site is part of the Westinghouse Electric Company's Nuclear Fuel Business Unit and is the largest facility of its kind in the world. The complex, in operation since 1969, covers 1,155 acres and includes 550,000 square feet of manufacturing and office space.

The nuclear fuel fabricated at the facility is used in commercial reactors worldwide to generate electricity. Fuel and fuel-related products are exported to Belgium, Brazil, Czech Republic, France, Japan, Slovenia, South Korea, Spain, Sweden, Taiwan and the United Kingdom. About 9 percent of U.S. electricity comes from nuclear fuel manufactured by Westinghouse in Columbia.

The Westinghouse Columbia Site often exceeds regulatory requirements for waste management and reduction, and nuclear material control, and has been recognized several times by the National Safety Council for its commitment to safety.

The Columbia Site is ISO 9001-certified and is committed to continuous improvement in its products and processes. The Product Assurance organization performs independent inspection as appropriate and is responsible for final product release.

Formerly known as the Commercial Nuclear Fuel Division, the Nuclear Fuel Business Unit was expanded and renamed in 1999.



Facility/Owner: Nuclear Fuel Services, Inc.

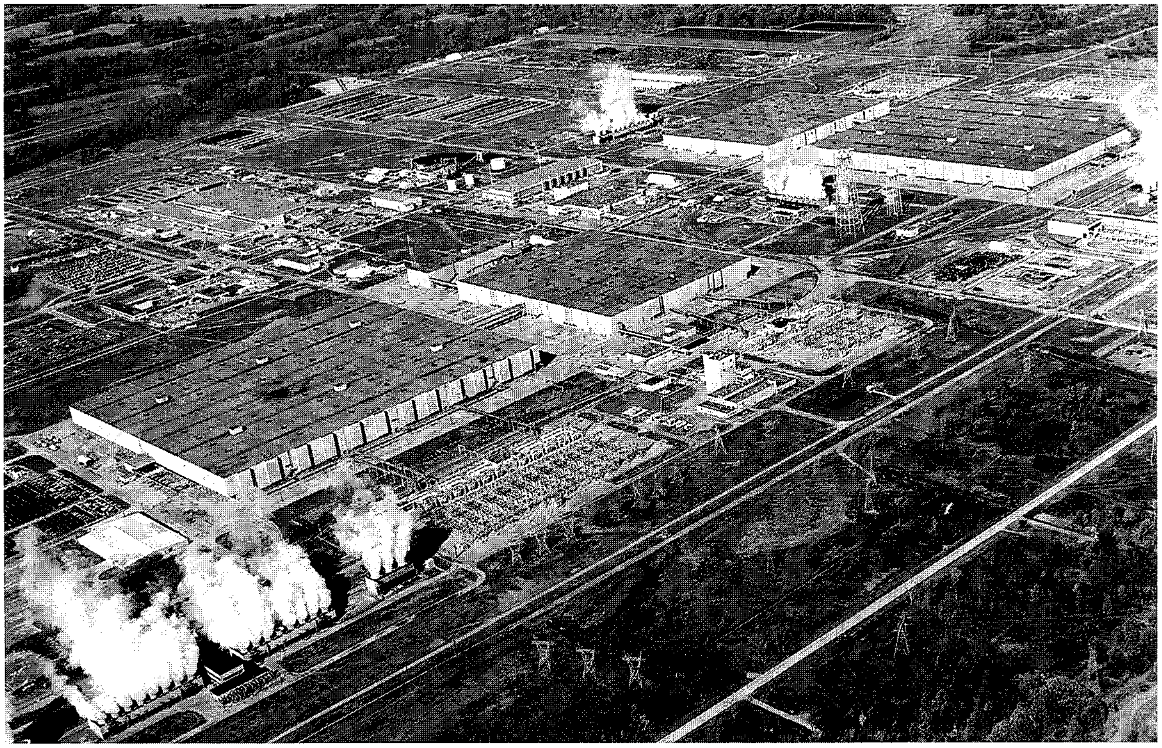
Type of facility: Fabrication of special nuclear materials

Location: Erwin, Tenn.

Description:

Nuclear Fuel Services, Inc. (NFS) has been a Nuclear Regulatory Commission licensed owner/operator of special nuclear materials processing facilities for more than 42 years. The company is headquartered in Erwin, Tenn., on a privately owned 62-acre site. The site includes a 22-acre high security nuclear processing facility with more than 20 buildings housing the equipment for processing and fabrication of special nuclear materials, decontamination and decommissioning systems, research and development laboratories, bulk chemical storage and warehouse facilities, wastewater treatment processes, and administrative offices.

At its Erwin facilities, NFS manufactures highly enriched uranium fuel materials for the U. S. Navy. NFS is also engaged in significant decontamination and decommissioning activities at the Erwin site. NFS's work force consists of more than 600 workers, professionals, administrators and contract employees.



Facility: Paducah Uranium Enrichment Plant

Owner: USEC

Type of facility: Uranium enrichment

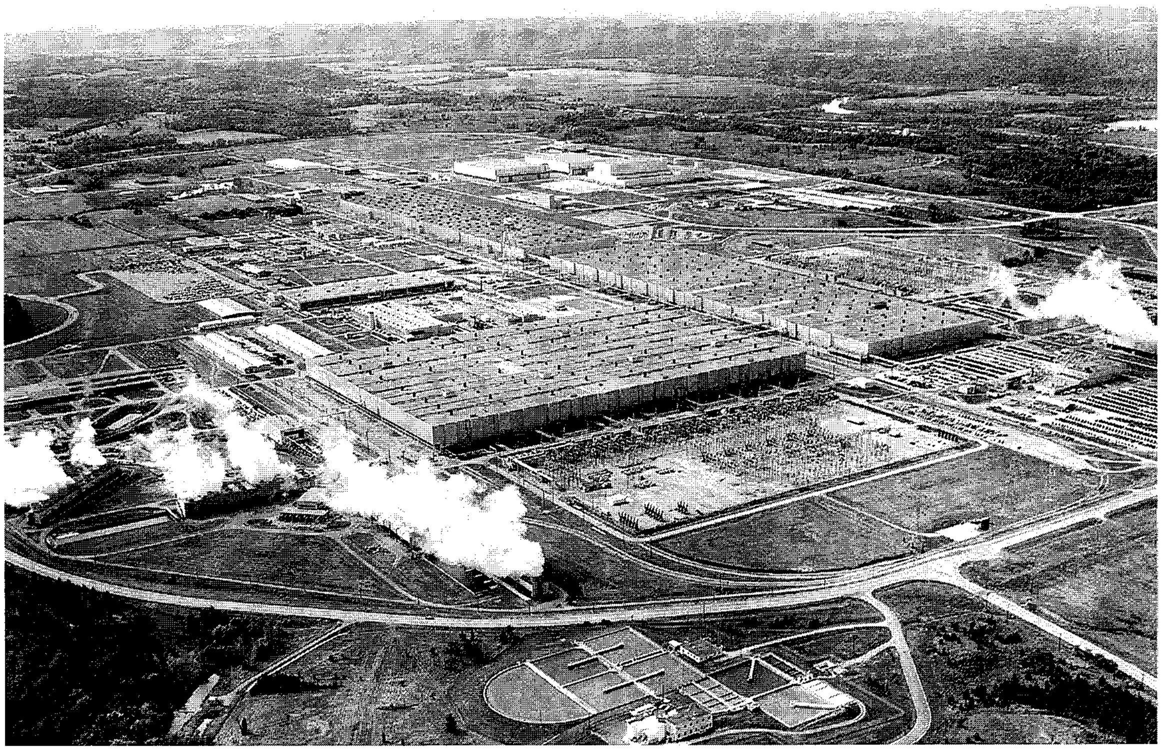
Location: Paducah, Ky.

Description:

The Paducah Uranium Enrichment Plant is operated by the United States Enrichment Corporation, a wholly owned subsidiary of USEC Inc. The plant enriches uranium by a gaseous diffusion process for use as fuel in commercial nuclear power plants worldwide.

The facility began production in 1952 and operated almost exclusively for national defense purposes until 1969. Today, USEC leases the plant from the U.S. Department of Energy and employs approximately 1,700 people. The facility enriches natural uranium from less than 1% U-235 to 2.75% U-235. Then the material is shipped to Paducah's sister plant near Portsmouth, Ohio, for enrichment to approximately 4% to 5% U-235, to fit customers' requirements for nuclear power plants.

The Paducah plant covers a fenced area of about 750 acres, 74 of which contain process buildings under roof that include nearly 1,800 enrichment stages. The plant has a design capacity of 11.3 million SWU per year. SWU stands for separative work unit, the industry standard for measuring uranium enrichment services.



Facility: Portsmouth Uranium Enrichment Plant

Owner: USEC

Type of facility: Uranium enrichment

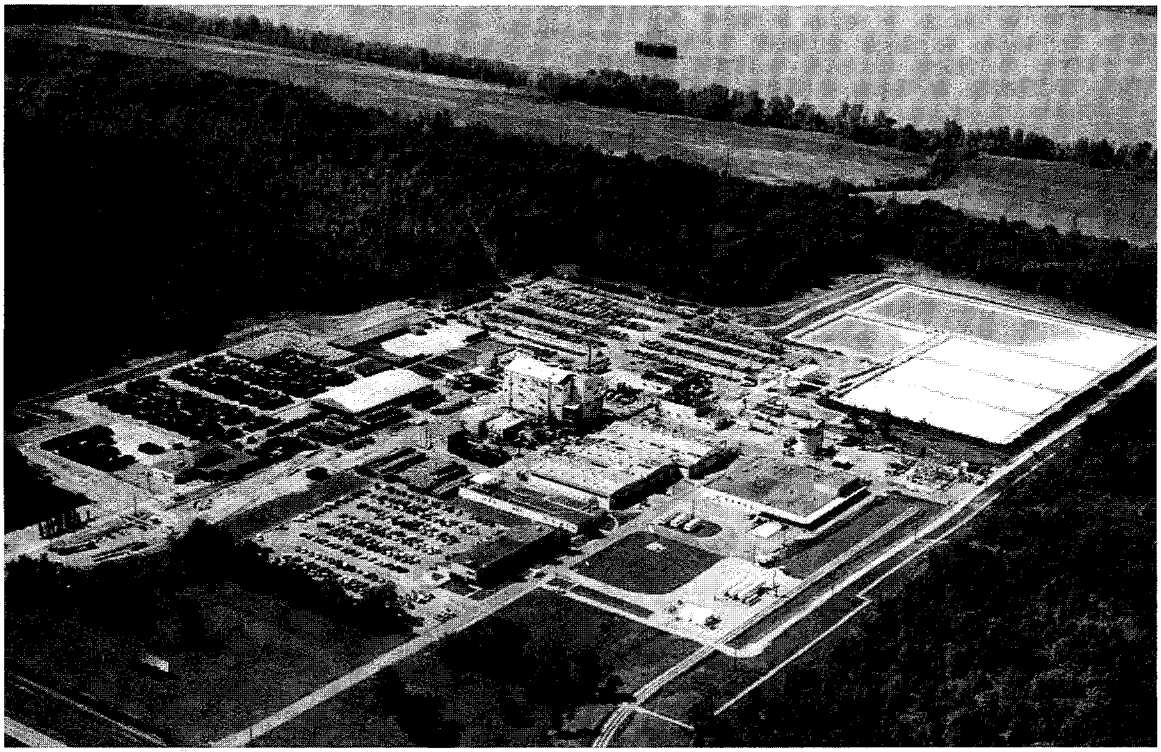
Location: Piketon, Ohio

Description:

The Portsmouth Uranium Enrichment Plant is operated by the United States Enrichment Corporation, a wholly owned subsidiary of USEC Inc. Located near Portsmouth, Ohio, the plant enriches uranium by a gaseous diffusion process for use as fuel in commercial nuclear power plants worldwide.

The Portsmouth facility began production in 1955 and operated almost exclusively for national defense purposes until 1969. Today, USEC leases the facility from the U.S. Department of Energy and employs about 2,000 people. The plant enriches product that has been shipped from its sister plant at Paducah, Ky. (The Paducah plant enriches uranium from less than 1% U-235 to 2.75% U-235, and Portsmouth completes the enrichment to 4% to 5%, as required by customers for use in commercial power plants.)

The Portsmouth facility covers a fenced area of about 640 acres, 93 of which contain process buildings under roof that include about 2,100 enrichment stages. The plant has a design capacity of 7.4 million SWU per year. SWU stands for separative work unit, the industry standard for measuring uranium enrichment services.



Facility: Metropolis Works

Owner: Honeywell International Inc.

Type of facility: Uranium conversion

Location: Metropolis, Ill.

Description:

Metropolis Works converts uranium ore concentrates to uranium hexafluoride. The Honeywell facility has been one of the world's leading suppliers of chemical conversion services to nuclear utilities. The plant employs the dry fluoride volatility process, which provides a distilling capability. Uranium hexafluoride after passing the distillation system is the highest quality product in the industry. The raw materials hydrofluoric acid, ammonia and fluorine are utilized to produce uranium hexafluoride. Hydrofluoric acid and ammonia are stored in large quantities at the site. Fluorine is produced on site by the electrolytic decomposition of hexafluoride.

The facility is located on 1,000 acres, of which 60 acres are fenced for plant operations. It employs 350 people.

Production facilities for sulfur hexafluoride, iodine pentafluoride, and antimony pentafluoride are also available at Metropolis Works. These products require fluorine for their synthesis. Sulfur hexafluoride is used in the utility industry as an insulating gas; iodine pentafluoride and antimony pentafluoride are used in the carpet industry.

Review Team Resumes

Robert M. Bernero

Mr. Bernero currently serves as an independent consultant to the U.S. Department of Energy and to some commercial nuclear facilities, including USEC.

1972-1995
U.S. Atomic Energy Commission/U.S. Nuclear Regulatory Commission

Mr. Bernero entered nuclear regulatory service as a licensing project manager for power reactors, in reactor regulation, and a nuclear fuel reprocessing plant, in the Office of Nuclear Material Safety and Safeguards (NMSS). He entered management in NMSS as the chief, Fuel Reprocessing and Recycle Branch.

He later served as assistant director for material safety standards in the Office of Standards Development, as a manager in the Three Mile Island Inquiry, and as director, Division of Risk Analysis in the Office of Research. He returned to the Office of Nuclear Reactor Regulation as director, Division of Systems Integration, and director, Division of Boiling Water Reactor Licensing.

In 1987 Mr. Bernero returned to NMSS where he served as deputy director for two years and director for six years, until his retirement.

1959-1972
General Electric Company

Mr. Bernero served as a design, construction and test engineer for naval reactors at the Knolls Atomic Power Laboratory. He also served as a project engineer, system engineer, and design section manager for space nuclear power systems at the GE Space Division.

Mr. Bernero holds a bachelor of arts degree from St. Mary of the Lake in Illinois (1952), a bachelor of science degree in chemical engineering from the University of Illinois (1959), and a master of science degree in chemical engineering from Rensselaer Polytechnic Institute (1961).

John C. Brons

Mr. Brons currently serves as special assistant to Joe Colvin, president of the Nuclear Energy Institute.

1994-1998

Commonwealth Edison

Mr. Brons served as vice president, nuclear support with responsibility for corporate support services (except engineering) for 12 nuclear units. Significant collateral assignments included site vice president at the LaSalle station (3 months) and site vice president at Zion (1 year).

1980-1994

New York Power Authority

Mr. Brons served NYPA as president and chief operating officer, executive vice president and chief nuclear officer with additional responsibility for engineering and nuclear fuel supply, senior vice president/chief nuclear officer with responsibility for both the Indian Point 3 (PWR) and the James A. FitzPatrick (BWR) plants, and resident manager at Indian Point 3. From 1989 to 1994, he had a concurrent assignment as executive vice president of the Long Island Power Authority with responsibility for decommissioning, defueling and dismantling the Shoreham nuclear power plant, reporting to the governor of New York.

1959–1980

U.S. Navy

Following graduation from the U.S. Naval Academy, Mr. Brons served in destroyers for three years and then in the submarine force for the remaining 18 years. Key assignments included chief engineer of a first of class nuclear attack submarine during construction and initial operation, Executive Officer of a nuclear propulsion training unit, Commanding Officer of a nuclear attack submarine, Submarine Division Commander/Deputy Squadron Commander and Senior Member of the Atlantic Fleet Nuclear Propulsion Examining Board.

Mr. Brons holds a bachelor of science degree from the U.S. Naval Academy (1959), a master of science degree (management) from Rensselaer Polytechnic Institute (1970) and is a graduate of the Harvard Business School Advanced Management Program.

James R. Clark

Mr. Clark currently serves as vice president and senior consultant of JAI Corporation.

1991-Present

JAI Corporation (formerly E. R. Johnson Associates)

Mr. Clark is vice president and senior consultant, who as part of the management and operating contractor team for the U.S. Department of Energy's Office of Civilian Radioactive Waste Management, manages the M&O Waste Management and Program Office Support departments. Previously, Mr. Clark managed the M&O Waste Acceptance & Transportation Department. He also performs nuclear safety audits and readiness reviews of nuclear facilities and operations for industrial clients.

1966-1991

Nuclear Fuel Services Inc.

From 1987-1991, Mr. Clark was senior vice president in charge of the decommissioning of NFS' obsolete facilities and the design and construction of a modern facility for the recovery of highly enriched uranium from scrap. From 1984-1987, he was vice president, manufacturing of NFS' naval fuel material production facility at Erwin, Tenn. This facility is the sole supplier of highly enriched uranium fuel material to the U.S. Navy. Prior to these assignments, Mr. Clark served as technical services manager for the first commercial nuclear fuel reprocessing plant (West Valley, N.Y.), where he managed the nuclear safety evaluations for the receipt, storage, processing and shipment of hundreds of metric tons of special nuclear material.

1960-1966

Martin Company

Mr. Clark served as field engineer for PM-3A Nuclear Power Plant at McMurdo Sound Antarctica and the MH-1A Nuclear Power Plant dockside trials.

Mr. Clark holds a bachelor of chemical engineering degree from Villanova University (1959), a masters of nuclear engineering from MIT (1965), and a master of business administration degree from State University of New York (1972).

Enclosure to NEI letter dated November 23, 1999

ASSESSMENT OF NUCLEAR CRITICALITY SAFETY AND EMERGENCY PREPAREDNESS AT U.S. NUCLEAR FUEL PLANTS

Introduction

On September 30, 1999, an accidental nuclear criticality occurred at the Tokaimura complex in Japan. The conditions of the event sustained the critical reaction for some time before it was stopped. Currently available information indicates that strict controls to prevent accidental criticality were not in place, and there is evidence that radiation monitoring within the plant was inadequate. The accidental criticality was sustained for hours due to the configuration of the system in which it occurred. There were apparent serious problems in emergency preparedness both for response to onsite accidents and for public notification and protection. The pattern of problems evident suggests that an accidental nuclear criticality was not considered a credible event by the Tokaimura facility operators or their regulator. Investigation of this accident will undoubtedly proceed for many months in order to examine all the details of the event and discover all the lessons that can be learned from it. Meanwhile, it is prudent for each similar facility in the U.S. industry to undergo an independent assessment, in addition to its internal reviews, with regard to these problem areas to ensure that the risk of such an occurrence here is acceptably low.

The Nuclear Energy Institute (NEI) has sponsored the formation of a special assessment team (Team) to synthesize currently available information about the Japanese accident, and to perform an assessment of these specific areas at each of the ten plants. The Team will work cooperatively with NEI's Facility Operations Committee (FOC) representing the ten U.S. licensed fuel cycle facilities.

The Team will apply a standard of best industry practices in performing the assessments. The Team will also strive to achieve uniformity and thoroughness of the assessments relative to any susceptibility of U.S. facilities to the conditions understood to be factors in the Japanese accident.

Facilities Covered By the Assessment

All five LEU fuel fabrication facilities (GE, W, ABB, Siemens, Framatome), both HEU fuel fabrication facilities (BWXT, NFS), Allied-Signal Uranium Conversion Facility, and the Paducah and Portsmouth Gaseous Diffusion Plants.

Assessment Team Composition

The Team will consist of three individuals with broad experience in regulation, process operations, administrative controls, criticality, training and general management. They are Mr. Robert M. Bernero, Mr. John C. Brons, and Mr. James R. Clark.

Legal counsel for the Team will be provided by Mr. Robert Bishop, NEI's General Counsel.

Principal Tasks To Be Performed by the Assessment Team

Review information available on the circumstances, apparent causes and contributing factors of the Tokaimura event.

Prepare a well-defined plan for the conduct of the review to be conducted at each of the facilities that is limited in scope to that necessary to include susceptibility to the apparent causes and contributing factors in the Tokaimura event. The Team shall consider the apparent cause analysis provided by members of the FOC in determining its review plan. (The review plan has been completed and is this document.)

Review appropriate information from the participating facilities on equipment, procedures, training programs, internal audits, and NRC inspections. This effort will focus on those documents that are likely to provide insights into whether the apparent causes/contributing factors of the Tokaimura event exist in the domestic fuel cycle industry.

Conduct individual plant visits at each site (est. 1-2 days each) to obtain additional information, as needed, on relevant equipment, procedures and programs and to assess the status of implementation of those procedures and programs.

Brief plant management on individual plant observations via exit meetings, and later as necessary if additional insights gained by the overall review warrant it.

Prepare a report, to be made publicly available, which presents the results of the assessment on an industry-wide basis. Be available to brief the NRC on the results of the assessment.

Identification of Causes/Contributing Factors

Although it may be some time before the "official" investigation of the accident at Tokaimura is completed and released to the public, it appears that sufficient information is available to define broadly stated apparent causes and contributing factors. It is abundantly clear from the facts of the accident itself and its impact on the human beings involved that neither the management nor the workers involved had sufficient appreciation of the potential for an inadvertent criticality. Beyond that the following apparent causes and contributing factors have been identified from a study of publicly available information:

- A culture that permitted deviations from licensed procedures to respond to external pressures such as cost and schedule.

- Tacit approval of procedural deviation by explicit involvement in unlicensed procedures and by routine willingness to deviate from "official" procedures.
- An insufficient criticality safety program, lacking appropriate use of the double contingency principle and maximum reliance on engineered controls.
- Insufficient administrative controls, including change control, procedures for starting/restarting infrequent operations and configuration management.
- Insufficient training to workers on the potential for criticality, on the severe consequences of such an event and on adherence to procedures.
- Insufficient oversight, supervision or critical self-assessment particularly with regard to inexperienced workers and unusual operations.
- Insufficient instrumentation to monitor the potential for criticality or personnel radiation safety.
- Inadequate emergency planning measures particularly with regard to termination of an extended event, timely notification and care of exposed personnel.
- Inadequate regulatory oversight.

Areas of Inquiry

The team will focus the scope of its review at each facility to assess susceptibility (as applicable) to the foregoing list of apparent causes and contributing factors.

Assessment Report Content

- Introduction and Purpose of the Assessment.
- Team Composition/Experience.
- Methodology.
- Facts and Background. Summary of nature of Tokaimura event, including the nature of the plant, its processes and safety controls to the extent that this information is publicly available.
- Identification of Apparent Causes/Contributing Factors.
- Assessment of Domestic Industry Against Each Identified Apparent Cause/Contributing Factor. Determination of potential vulnerabilities/lack thereof and bases for determinations.
- Recommendations. Areas for improvement – recommendations for changes to reduce potential vulnerabilities.
- Conclusions.

"Safety" Issues

Any issue of safety significance identified by the team will be reported promptly to the senior manager present of the facility being reviewed. After any appropriate discussion, the facility will disposition the information as required by its procedures and the Code of Federal Regulations. If an assertion or allegation of unsafe practices arises during the course of the review or the interviews conducted, the Team will disposition the information to the facility program for handling allegations (if any) or to senior management with appropriate regard for the identity of the individual who provided the information or the privacy of the information.

Schedule

Plant reviews will be scheduled so that the Team can complete its final report and be ready to present its findings to the industry and the public no later than the end of the first quarter, 2000.

Protocol for Assessment of Nuclear Criticality Safety and Emergency Preparedness at U.S. Nuclear Fuel Plants

I. Preparations For Team Review

The Team provides in Section II below a list of topics and questions that are related to determination of the susceptibility of a US facility to the events which occurred at the JCO facility in Tokaimura, Japan on September 30, 1999. These topics and questions address the nuclear criticality safety, emergency preparedness and general safety management systems that are the focus of the Team review. The first step in the conduct of the Team review is a comprehensive but concise presentation by the facility management that includes discussion of these topics and questions as well as any other matters the management considers germane. After the presentation the Team will conduct a review tailored to the subject plant, including specific discussions with personnel from key organizations, plant tour and interviews with a number of plant staff.

The facility management is requested to provide the following documentation in advance of the Team visit to assist the Team members for effective conduct of the review:

- The principal organization chart(s) for the facility staff.
- The results of any self-assessment, quality assurance review or audit that may have been conducted in the aftermath of the of operations.
- Any performance indicators that may be in use at the facility relative to process and administrative controls associated with safety and, in particular, the risk of criticality. Provide past data for such performance indicators as may exist for at least the past two years unless the indicator has not been in use that long. The Team does not wish to receive any proprietary productivity performance data, unless it is directly related to safety performance.

In preparing documentation for use by the review Team and in presentations, the plant should make all practical efforts to avoid the use of classified or proprietary information.

II. Management Presentation at the Outset of the Plant Review

Facility management will provide the review Team a presentation that includes discussion of the following topics and questions:

Nuclear Criticality Safety.

- What is the policy basis for recognition of process points that, lacking adequate administrative or physical controls, could result in criticality? What standards are in place that describe the extent of the controls, in form and depth, intended to preclude criticality?
- How are the policy basis and standards documented and communicated?

- Describe the administrative processes in place to insure that procedures in use comport to the policy basis/standards.
- Describe any special considerations in place to heighten sensitivity to processes which involve shifts from favorable to less favorable or unfavorable geometry control.
- Describe any controls in place to insure exclusion of material or equipment which could result in the ability to violate criticality safety limits (e.g. cleaning buckets).
- Describe the training process which supports employee awareness of criticality considerations, criticality hazards, process operations, necessity for procedure adherence, installed monitoring equipment, measures available to terminate unplanned criticality.
- Describe any process or practice in use at the facility which makes use of "near miss" information. How is this information used to support training and continued awareness of criticality safety?
- Describe the installed and operable systems for area radiation monitoring and detection of a criticality.
- Describe the standards used for criticality accident alarm systems.
- Describe the standards for individual worker dosimetry.
- Describe processes in place to monitor the effectiveness of:
    - Administrative controls that translate policy/standards to shop documents
    - Conduct of operations, including fitness for duty
    - Training

Accident Response and Emergency Preparedness

- Describe emergency plan considerations for the facility and how they are exercised.
- Is the call list for emergency response current? When was it last verified?
- Describe the facility arrangements for offsite assistance or cooperation in the event of chemical accidents, nuclear accidents, fires and other emergencies.
- Do any of the possible chemical releases or accidental criticalities have the potential to be sustained for hours? How is this reflected in emergency response planning and training?

Management Systems

- Describe the facility's system for problem reporting and tracking.
- Describe the facility's system for evaluating and acting on safety problems that have been reported.
- Describe the facility's corrective action process. Is it a uniform program for all identified deficiencies or is it variable, dependent on the identifier of the deficiency (e.g. self, regulatory oversight, industry experience, etc.) or the nature of the deficiency (e.g. administrative, process oriented, criticality related, etc.)? Does the corrective action process have a mechanism to highlight repetitive deficiencies?
- Describe the qualification/re-qualification process for supervisors/workers engaged in the performance of processes involving risk of criticality. How does management track the currency of proficiency/qualification of employees assigned work in these areas?

- Describe the management philosophy regarding the use of and adherence to procedures in the execution of process (i.e. verbatim compliance, two-man rule, reader worker, skill of the craft, general guidance, a combination of these or other approaches dependent on the process being controlled, etc.)
- Discuss factors which are known to affect human behavior in the course of operations. Such factors include:
  - Incentive plans
  - Production Goals
  - Efficiency / Quality employee involvement efforts
  - Process variability, custom manufacture, batch sizes, enrichment levels
  - Suggestion programs
  - Safety consciousness
  - Bargaining agreements
  - Working hours / shift schedules / overtime
- Provide a management level discussion of independent assessments / regulatory inspections conducted in the past two years that have included a specific focus area of operations that involve risk of criticality or serious accident.

III. In-Depth Review

Each member of the Team will meet with a member of the facility staff for a more in-depth review of certain topics. This part of the review will require about 1½ hours. Each facility will be notified in advance of the areas selected for in-depth review. Candidate areas are training, corrective action program, emergency planning, self-assessment activity, configuration management, etc.

IV. Facility Tour

A tour of relevant areas of the facility to show key processes related to criticality risk, monitoring equipment, emergency plan arrangements and other features useful to understanding reduced susceptibility to risk of criticality or the ability to terminate criticality will be provided to the entire Team.

V. Interviews

Each Team member will interview 3 – 4 employees from each facility to probe for general awareness of criticality issues, training efficacy, understanding of administrative controls, emergency plan considerations, etc. Interviewees will be selected from all levels of the work force who can be expected to be available during the time of the team's visit. Selections will be made from availability lists provided at the outset of the review visit. Where necessary, to avoid interruptions to production schedules the Team will make itself available before or after shift. All interviews will be conducted on a non-attribution basis. Any data derived from the interview will be presented only in a summary fashion. Bargaining unit members may be accompanied by union representation if desired.

VI. Debrief

At the conclusion of the visit the team will caucus as needed to coordinate observations. After the caucus the team will provide a debrief of its observations relative to the facility. It is expected that a limited number of the facility staff and, exclusively facility staff, will participate in the debrief. The review Team will provide a written summary of the Debrief as soon as possible after the Debrief based on its field notes. It is expected that the NRC Resident Inspector or assigned Senior Inspector will not attend the Debrief but will be given access at the site to review the written summary. Plant management should take notes at the debrief and determine whether further interactions with the review Team are needed.

VII. General Report

The review team will prepare an overall report summarizing its observations and conclusions relative to the entire industry once all of the visits have been completed. The final report will not cite specific review results from any facility. The report will be presented to the NRC and be made public. A representative of the team will be pleased to return to the facility and provide a local report of the same material presented to the NRC at any facility that desires it. The public would be welcome at any such briefing conducted if desired by local management.

Nuclear Energy and Criticality:
An Explanation

Energy is produced when atoms are split in a process called *fission*. The word fission simply means splitting. The most common atom used to support the fission process for the production of electricity is uranium.Uranium, like all atoms, comes in several different sizes. The sizes vary by the number of neutral, sub-atomic particles that are a part of the atom. The neutral, sub-atomic particles are called ***neutrons***. The technical term for distinguishing the different sizes of the same atom is ***isotope***. Uranium—containing several sizes or isotopes—is found naturally in the earth. Over 99% of it is uranium-238 (U-238 in shorthand), where the number 238 refers to the total number of neutrons and protons in the atom. In uranium the number of ***protons***, which is a different sub-atomic particle, is always the same. A small amount of natural uranium is the isotope uranium-235 (U-235). This size uranium atom has three fewer neutrons than the much more abundant U-238.

In nuclear energy small differences can be very important. In this case, U-235 can be split and release energy, where the much more commonly found U-238 cannot be split. One of the early steps in the production of nuclear fuel from uranium, right after the conversion of refined natural ore to a suitable chemical form for further processing, is to concentrate (enrich) the amount of U-235 present.

The natural uranium coming from the conversion plant contains over 99% U-238 and less than 1% U-235. The enrichment process concentrates the small amount of U-235 to higher percentages by selectively discarding a fraction of the U-238. Typically, the fuel used to produce electricity is enriched to between 3.5% and 5% U-235. Some research and special reactors use higher enrichment percentages. The higher the enrichment, the more U-235 is available to fission and to produce energy. As the enrichment percentage rises, the greater the care and the more precautions that must be taken when handling and storing it. Uranium enriched to 5% is considered "low enrichment." It is riskier to handle than natural uranium but has a very low risk compared to uranium enriched to what are termed intermediate and high levels.

When a U-235 atom splits, it breaks up into several smaller parts and it gives off energy. The parts given off are two or more smaller atoms, some neutrons and other forms of nuclear radiation, in the form of particles or pure energy. The neutrons are very important. Not only do they distinguish one isotope from another, but they can be the source of additional splitting, or fission. If one of the neutrons given off from the first fission encounters another U-235 atom, it will cause it to split also giving off more neutrons, more small atoms, more energy and more radiation.

What happens to the neutrons is very important. If the neutron, which is moving at a high speed, moves away from the U-235, it cannot cause another fission. This is called ***leakage***. If, on the other hand, the neutron encounters materials that cause it to slow down, it will be near the U-235 for a longer period of time, which increases its chances for causing another fission. Other materials act like mirrors for neutrons, causing them to be reflected, which could direct them back at the U-235, providing another chance for them to cause fission instead of leaking.

Each fission produces, on average, more than one neutron. Averages are used because although each fission is a little different, there are so many atoms involved that the "averages" are very predictable. If, on average, the neutrons released from one fission cause less than one additional fission, the number of fissions will be decreasing and the process is said to be ***subcritical***. If, on average, the neutrons released by each fission cause exactly one more fission, the number of fissions will be staying exactly the same and the process is said to be ***critical***. If, on average, each fission causes more than one additional fission, the number of fissions will be increasing and the process is said to be ***supercritical***.

Because atoms are very small and there are countless numbers of them very close together, this process can proceed very quickly and involve very large numbers of atoms that are being split—releasing energy, more neutrons and radiation.

A number of things can be done to be sure that the conditions do not exist for the process to be critical (or supercritical) in a fuel processing facility. One is to limit the number of U-235 atoms present in any one area. This can be done by controlling the mass of uranium being processed or by controlling the enrichment level. Another is to make it easier for neutrons to leak. This can be done by spacing storage areas for uranium apart from each other or by storing the uranium in special containers such as tall, narrow cylinders. The latter method is called ***geometry control***.

Another form of control is to eliminate or minimize the presence of material that can slow the neutrons down. This is called ***moderator control***. Similarly, a restriction on materials that act like mirrors for neutrons is called ***reflector control***.

In a fuel processing facility, the object of all of these controls is to prevent criticality. If a criticality occurs, significant amounts of radiation can be released in a very short period of time.

The amounts of radiation released can easily be deadly to any human being nearby. The radiation, however, spreads out like ripples in a pool and will have a greatly reduced effect on people more than a few yards from the criticality.