The Restart of L Reactor

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Abstract

L Reactor was returned to a fully operational condition, incorporating safety improvements and other modifications already in place in the three operating reactors. Restart criticality was achieved in October 1985. The reactor had been in a standby status from 1968 until 1980. Substantial repair, renovation, and new capital installation took place during the five-year restart effort. The peak work force was approximately 240 operations and 800 construction personnel. At the time, the project was the largest single Savannah River Plant (SRP) construction project since the original plant startup. This paper describes some of the problems and highlights of the unprecedented restart achievement.

Introduction

The reactor console operator made a small adjustment in control rod position, reviewed his nuclear instrumentation, then announced, "We are critical at low power." This quiet understatement symbolically marked the climax of an ambitious five-year effort to rescue the L-Reactor complex from a standby condition and restore it to full operational capability. This paper describes a few of the problems and highlights of that achievement, which culminated with restart criticality on October 31, 1985.

L Reactor was the third in the sequence of the five Savannah River Plant (SRP) production reactors to be brought on line during the original SRP startup. It began operating in mid 1954 and was operated until February 1968, when a reduced need for nuclear material for the U.S. defense program led to its retirement from service. It had been in a standby status for more than 12 years when the restart effort began in October 1980.

Need for Product

The Cold War and nuclear arms race between the United States and the Soviet Union were still in full swing in the late 1970s. Nuclear Weapons Stockpile memoranda prepared at that time showed that the U.S. production rate of weapons material was not sufficient to meet projected needs of the Defense Department. Some of the options that were considered to increase production included developing a new fuel assembly for the still-operating P, K, and C Reactors at SRP, restarting a Hanford reactor, recovering plutonium from commercial reactor spent fuel, and restarting L Reactor at SRP. The Department of Energy (DOE) used a review process consistent with the National Environmental Policy Act (NEPA), and ultimately selected L-Reactor restart as the preferred choice. Although the goal startup date was set as October 1983, there was no precedent for restarting a reactor after a 12-year shutdown. Funding of approximately $200 million was authorized for the entire project.

Ironically, it was President Jimmy Carter who authorized the program that ultimately led to L-Reactor restart. Only three years earlier (1977), President Carter had issued an executive order that prohibited reprocessing spent fuel from commercial nuclear power reactors, including plutonium recovery. President Carter compartmentalized these two executive actions as part of two completely separate technical and political issues.

Condition of L Area

Several sources describe L Area's official status following its 1968 shutdown as "standby", which Webster defines as "something that can be relied upon". In fact, L Area was not in good condition. After operating personnel completed their shutdown program in 1968, no significant maintenance was performed on any system. Equipment inside the main process building (Building 105-L) was protected from the sun and rain, but no temperature or humidity control was provided. However, most major process systems were intact because parts cannibalization had been discouraged during the standby period.

The initial group of restart personnel that arrived at the area on October 14, 1980, found primitive conditions. Outside support buildings and their contents had deteriorated, especially equipment made of carbon steel. The area was overgrown with weeds, grass, and small trees. Animals and birds occupied some of the buildings, including a family of bobcats in a maintenance shop and flocks of pigeons around Building 105-L. The first action the team found necessary was to set up electrical power, ventilation, and sanitary facilities (exterior portalets) for Building 704-L, simply to make the area habitable. These humble beginnings made it apparent to everyone that a long, difficult journey lay ahead.

Initial Major Issues

Several major issues had to be addressed immediately:

- What were the sources of manpower available to staff the project? Only a limited number of people could be transferred from the operating reactors without adversely impacting their operation. In fact, the project ultimately was staffed by a combination of transfers of a few experienced people from several plant departments, attrition from other plant areas, and new hires.
- What was the physical condition of the equipment? A few cursory inspections had been conducted to assure that restart was practical, but more detailed inspections were needed, and soon. Early decisions had to be made about what equipment could be repaired and what must be replaced.
- What management approach should be used to assure that all systems were accounted for and made operational on a practical, organized schedule? Key systems had to be identified to receive priority attention.

The Beginnings

Staffing was begun at once with an initial group of 12 handpicked people, all volunteers. The operations staff size ultimately peaked at about 240 people in 1983. Management of the restart team stressed from the outset that the project was unique and that everyone on the team had the opportunity to make a special contribution towards its success. New hires, in particular, could learn about SRP reactors as they took part in inspections and interacted with experienced staff members. Several of the new hires were female engineers, reflecting the national trend of increased involvement of females in the professional, technical workforce.

The group was named the "L Startup Project Team" (LSPT) with emphasis on "team". The LSPT mission from Day 1 was

- on time
- under budget
- no injuries

The project logo was a phoenix, a mythological bird consumed by fire only to be reborn and spring up again from its own ashes. The logo adorned the cover page of most documents prepared by LSPT personnel and was painted on a huge sign hung conspicuously from the highest elevation of the reactor building. A concerted effort was made to maintain a high level of morale throughout the restart effort.

The LSPT organization was arranged into four major groups, Design Liaison, Operations, Works Engineering, and Design & Technical. The function of these groups was much like that of SRP departments having similar names. However, under the Project Management Team (PMT) system pioneered by Du Pont at Victoria, Texas, all LSPT personnel reported to a single superintendent whose office was in L Area. This arrangement, a new concept for SRP, proved to be effective in the decision-making process and contributed significantly to the ultimate success of the project. Engineering Department Design and Construction personnel operated under a separate chain of command.

Early decisions were made to define major areas of responsibility. Most design and construction work was to be done by the Du Pont Engineering Department, based on requirements and specifications provided by LSPT. Also, LSPT would provide for liaison among the other groups as well as provide overall technical support. For funding accountability, restart work was divided into "capital" for new equipment and "cost" for repair or renovation of existing equipment.

The management approach used to attack the project was to divide the complex into 28 design areas and assign responsibility for each design area to one or more engineers. Several documents would be prepared for each design area. Each document would have a specific purpose and objective, and the full set would comprise a consistent approach in achieving the restart of all systems. The documents included:

- Work Scope − a short description of the work required to restore the system to service.
- Basic Data Report − a technical description of the system. (The basic data report concept was not invented for the restart of L Reactor. It was widely used by Du Pont to document the requirements for new equipment or systems).
- Quality Assurance Assessment − an evaluation of critical parts of the system that would require special attention and control in implementing the new SRP QA program.
- Quality Assurance Action Plan − the vehicle for ensuring that the specifications were met.
- Job Plan − a detailed procedure that ensured a system was in a safe condition to be worked on and was returned to a safe operable condition after work was completed.

The preparation of these documents often served as a learning process, as the engineer found it necessary to research, review, and fully understand his/her system before publishing the report. Preliminary scopes of work for each design area and a schedule were provided to DOE and the Du Pont Engineering Department by December 1980. The project was underway.

Equipment Inspections

Detailed equipment inspections were begun as soon as it was safe for personnel to enter the process areas. The Equipment Engineering Section of SRP conducted many of the inspections. The results were needed early to determine which systems would require the most attention. Several techniques were used, including visual, dye penetrant measurements, ultrasonic thickness measurements, and eddy current testing. In many cases, specialized apparatus was built to conduct a satisfactory examination.

No major surprises or disappointments arose from the inspections. In fact, much of the equipment was in better condition than expected considering the lack of maintenance. About 30 specific recommendations were made for repair, replacement, or overhaul of equipment, including the following examples:

- Purchase new heat exchangers.
- Replace all carbon steel cooling water pipes having diameters of 6 inches or less.
- Remove deposits of aluminum nitrate from the reactor vessel and effluent nozzles.
- Remove all asbestos insulation from the area.

The LSPT Effort

The preparation of Basic Data reports and QA Assessments began early in 1981. These reports were reviewed, revised, and approved for release. The approved versions of Basic Data reports were transmitted to the Engineering Department late in 1981. QA Action Plans were ultimately issued by the Engineering Department to specify requirements during design, procurement, and construction of new capital equipment.

Planning and scheduling were heavily emphasized throughout the restart effort using computer programs, graphs, charts, and countless dreary planning meetings. Critical-path schedules and work-accomplished charts were updated daily. Some difficulty was experienced in developing work schedules that were mutually agreed upon by LSPT and the Engineering Department.

Each design area has its own history of document preparation, inspection, restoration, and testing. It would be impossible to describe such details in this brief paper. As a substitute for this detail, the reader might simply try to visualize about 240 operations people and 800 construction people at one site, hard at work for almost 3 years in a construction zone. An enormous amount of reports and documents was generated. As expected, there were some delays, some milestones not met, and some disappointments, but there was never any serious doubt about the final outcome. The objective was to bring all these systems together, ready for safe, reliable operation.

Renovation of most systems was complete by late 1983 but environmental issues would delay nuclear operation until 1985. Operational tests were not complete. Management decided to assimilate the respective divisions of LSPT into existing SRP departments. The LSPT organization formally ceased to exist on September 1, 1983. Responsibility for outstanding punch-list items and final systems testing was transferred to the respective SRP departments. Cost accounting records show that $186 million had been spent on the project, compared to the $214 million authorized.

A highly complimentary letter of appreciation was written by Richard Denise, acting DOE manager at SRP, to Gerald Curtin, vice president of Du Pont Petrochemicals Department. The letter commended all those who contributed to the success and safety of the project, recognizing that it was the largest single construction effort at SRP since the original startup in the early 1950s. Members of the LSPT team still feel a sense of pride to have been part of the project.

Environmental Issues

An enormous amount of time and energy was expended to address the many environmental issues that were raised about the restart of L Reactor. The final resolution of these issues had far-reaching implications and would later prove to have adverse effects on reactor operation. One major point of contention involved “thermal mitigation,” or reducing the environmental effects of the heated cooling water as it left the area.

In 1982, DOE published an environmental assessment on the proposed restart of L Reactor, with a finding of No Significant Impact. Subsequently, several environmental concerns were raised by groups such as the Natural Resources Defense Council (NRDC) and the Attorney General’s office in South Carolina. A lawsuit was filed in November 1982 to require the preparation of a detailed environmental impact statement (EIS) before startup. DOE committed to preparing the EIS, and a Notice of Intent was filed in July 1983.

The EIS process ran the full gamut of document preparation, hearings, and solicitation for comments before the extent of system modifications required for compliance was known. A significant requirement was the construction of a 1000-acre lake near the L-Reactor outfall to receive the cooling water discharge. The reactor was to be operated in such a way that a temperature of 90 degrees F or less was maintained in about half of the lake. Allegedly, this condition would contribute toward establishing a balanced biological community in and around the lake three to five years after operation was resumed.

This extensive involvement of federal and state agencies was unprecedented in SRP history. These included the federal Environmental Protection Agency (EPA) and the South Carolina Department of Health and Environmental Control (SCDHEC). The process that evolved during the L-Reactor restart project would impact strongly on the way these same agencies would conduct similar business in the future. The point of regulation had been moved from the plant boundary and the Savannah River to areas within the SRP site itself.

Special Capital Systems

Several new systems were installed in P, K, and C Areas during the L-Reactor standby period and had to be built especially for L Area. These systems included:

- The M-2 console – a hard-wired logic system to determine the need for light water addition to the fuel in the event of a severe process water leak.
- Computer-based systems for control rod operations, flow and temperature monitoring, and selective fuel charge/discharge operations.
- Diagnosis of Multiple Alarms (DMA) – a computer-based system that assisted control room operators in interpreting and prioritizing alarm messages before taking corrective action during emergency situations.
- Improved emergency cooling system and water removal system.

In addition, the procurement of the 12 process water/cooling water heat exchangers deserves comment. Examinations of the original L-Area and R-Area heat exchangers revealed that many were in poor condition, and repair would not be cost effective. Consequently, bids were let for the purchase of new units. After no bids were received from U.S. firms to build the shells and heads, contracts were awarded to Mitsui Engineering and Hitachi Engineering in Japan. One might not expect that a country in which two cities had been devastated by U.S. nuclear weapons 35 years earlier would choose to be part of the U.S. nuclear weapons program, even for a profit. The new heat exchangers were delivered on time and operated satisfactorily. Their design incorporated improvements to reduce the probability of tube failure and leakage.

Problem Areas

Two examples of systems where unusual problems were encountered were the fuel assembly charge/discharge (C&D) machines and the disassembly area basin.

- The C&D machines and associated hardware were highly complex devices used for remote transfer of new fuel assemblies and other components to the reactor, and transfer of irradiated assemblies away from the reactor to underwater storage. The machines in P, K, and C Areas had been modified several times by separate projects during the 12-year L-Reactor outage, but there were no as-built drawings in October 1980. The only workable approach for the L-Reactor restart was to modify the machines sequentially for each project and accept the inefficiency that occurred.
- Renovation of the disassembly basins was also a challenge. (The basins were used to store irradiated materials after discharge). They had been kept full of water during the L-Reactor standby period. A thick layer of sludge covered the floor bottom, with several miscellaneous radioactive components buried in it. As the water was drained and the walls dried, care had to be exercised that contaminants did not become airborne. Also, adequate shielding had to be maintained for irradiated materials on the floor. After many months of tedious, careful cleanup, the basins were finally emptied, scraped, and repainted.

An additional, chronic problem that proved troublesome in several systems was availability of correct as-built drawings and schematics specific to L Area. The system engineers often found it necessary to verify or update the prints by field inspection.

Health Protection and Safety

The potential for unusual health protection or safety incidents was high in L Area during restart. Health Protection and Safety programs were implemented to minimize radiation exposure and prevent injury. When water or instrument lines were opened for the first time, personnel were required to wear plastic suits supplied with breathing air. Similar care was taken as each new system was inspected. As a result, the number of tritium uptake and skin contamination cases was kept at an acceptably low level. A fire brigade and an emergency rescue team were established.

Some examples of unique jobs are:

- Welding or cutting cooling water lines that might contain methane, an explosive gas
- The odious task of removing 12 years of pigeon fecal waste from the stack area
- The high radiation environment created during the removal of irradiated sleeves and plugs from the reactor tank top
- The extensive use of special paint containing xylene
- Removing asbestos from several systems.

Some unusual safety-related situations did arise, often related to the co-occupancy of facilities by LSPT and Construction personnel. Both groups had full-time safety engineers assigned to the project. From January 1981 through September 1983, no operations employee sustained a Restricted Workday or Lost Workday class injury. Construction sustained two Lost Workday Cases early in the restart, then remarkably accumulated 2.5 million injury-free exposure hours through September 1983. The safety performance during the restart effort was outstanding.

Contingency Tests

The restart schedule was revised drastically after the requirement to prepare a full EIS was imposed. To exploit the availability of this time, several special "contingency tests" were planned and conducted. The intent of the tests was to learn more about the behavior of key systems during abnormal conditions. The test results would be applicable to all SRP reactors. Examples of the tests are:

- Confinement Heat Removal (CHR) − several below-grade rooms were intentionally flooded with about two feet of water using the emergency addition systems. The test objective was to demonstrate that emergency coolant could be supplied and removed by the existing systems. The test was successful.
- Plenum Level/Gradient − hydraulic pressures were measured in the primary system at reduced flow conditions. The data were used to calculate the flow available to fuel assemblies during emergency situations when the coolant flow might be very low.
- Ventilation − airflow data were taken in the air plenums at the filter compartments to assist in optimizing the removal of contaminants from the reactor room air.

Final Preparations

Slowly, finally, all parts of the project began to come together. The copier machine ran constantly and the document storage room overflowed with reports. Operations groups prepared and conducted functional tests of all the systems to demonstrate operational readiness. Extensive training sessions were held for reactor operators and supervisors. QA work was completed, audited, and approved. DOE teams conducted operational readiness reviews. A startup assessment committee consisting of over 50 SRP and Savannah River Laboratory engineers reviewed the status of all systems to assure satisfactory completion of all outstanding work items. The Management Oversight Committee issued an approval report, contingent on the successful completion of a few tests.

By late October 1985, all the formal authorizations necessary for nuclear startup were finally in place.

Reactor nuclear startup was an anticlimax compared to the rush of activity that preceded it. With few dignitaries in attendance, low power criticality was achieved at 4:42 p.m., October 31, 1985. All the reports, meetings, tests, and hard work were finally rewarded by a successful restart. As fate would have it, the new Phoenix was born on a Halloween night.

Epilogue

An ideal follow-up to a story about the successful restart of L Reactor would be to report that the reactor was operated for several years at the expected powers of 2000 MW or greater. However, that is not the case. During winter operation, L Reactor did achieve power levels as high as 2700 MW, limited by conventional thermal/hydraulic limits. However, during hot, summertime operation, the L-Lake temperature limit of 90 degrees F often restricted power to a few hundred megawatts. This extreme, seasonally dependent variation in power became the routine form of operation until the final shutdown in June 1988. Fortunately, the achievement of successfully restoring L Reactor to operational readiness is undiminished by its final operating history.

Biography

Thomas Gorrell received a BS degree in physics from Penn State in June 1953, and was part of the initial startup activity at SRP. His first work assignment was with the Process Development Pile (PDP). In October 1953, the PDP was made critical with a Mark I fuel charge replicating the first R-Reactor charge. (R Reactor was the first of the five [R,P,L,K, and C] reactors to be operated, beginning in December 1953.)

Following a tour of duty with Reactor Technology in R, C, and L Areas, Mr. Gorrell joined the physics group of the Heavy Water Components Test Reactor.

In 1981, he joined the LSPT group and took part in the initial restart activities.

Mr. Gorrell's final work assignment in 1988-1989 was to act as liaison between Du Pont management and the incoming Westinghouse management who conducted an independent safety review of the SRP reactors. He retired as a research associate in March 1989, when Du Pont completed its contractual obligations at SRP.

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