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Research Reactor De-Fueling and Fuel Shipment

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Planning

Planning for the Georgia Institute of Technology Research Reactor operations during the 1996 Summer Olympic Games began in early 1995. Before any details could be outlined, several preliminary administrative decisions had to be agreed upon by state, city, and university officials. The two major administrative decisions involving the reactor were 1) the security level and requirements and 2) the fuel status of the reactor. While waiting for these decisions, informal planning was initiated by contacting persons potentially involved with reactor options (Department of Energy (DOE), contractors), persons experienced with de-fueling and shipment (University of Missouri, University of Rhode Island), and regulators (Nuclear Regulatory Commission (NRC), Georgia Department of Natural Resources (GDNR)).

The Georgia Tech Research Reactor (GTRR) was a heavy-water moderated and cooled reactor, fueled with high-enriched uranium. It was designed to produce a thermal neutron flux of greater than 10^{14} n/cm^2/sec at a power of 5 MW(t). The reactor was first licensed in 1964 with an engineered lifetime of thirty years. The reactor was intended for use in research applications and as a teaching facility for nuclear engineering students and reactor operators.

Approximately one year prior to the Olympics, the Georgia Tech administration decided that the GTRR fuel would be removed. In addition, a heightened, beyond regulatory requirements, security system was to be implemented.

Scheduling

Using the general administrative decisions as a goal, a critical path time line identifying specific objectives, technical decision points, and responsibilities were agreed upon through a series of staff meetings. Final agreement required three iterations of the time line and about one month of time. Major identified specific decision points included: 1) cask selection (several casks were considered), 2) reactor shut-down date, 3) fuel cool-down period, 4) available shipper/route approval dates, 5) available fuel receipt dates, and 6) projected dates for procedural approvals by the Georgia Tech Nuclear Safeguards Committee.

Even with an agreed critical path scheduling process, there were major perturbations. The first unexpected change in plans occurred as a result of Georgia Institute of Technology lawyers (without consultation with reactor staff) agreeing with NRC lawyers to a GTRR reactor shutdown date of 17 November 1995. The shutdown of the reactor had been planned for the end of the fall academic semester in December 1995. The announcement in October of a November shut down disrupted reactor training courses and research projects while producing a flurry of last minute use of the reactor.

A second major change in the critical path time line occurred when the cask selection process was made 60 days late. There were two shipping casks available, a DOE "BMI" cask and a cask made by Nuclear Assurance Corporation (NAC). In the interim, not knowing which cask was ultimately to be used, our staff was required to prepare procedures, establish routing and availability, obtain approvals, and complete training on both the NAC and the BMI casks.

The advantages of the BMI cask were: 1) its use only required the exchange of monies between DOE departments, (i.e., no need to go through external purchase requirements), 2) it involved an underwater transfer of fuel elements that could be done indoors in our fuel transfer pool, (i.e., considered safer and more secure), and 3) the cask was fully NRC certified for the GTRR fuel. The BMI cask had a major disadvantage since it could hold only 12 fuel elements. Thus, the removal of 25 elements would require three spent fuel shipments.

As an alternative, Nuclear Assurance Corporation (NAC) had an available cask that could hold all of the fuel elements in one shipment. But the NAC cask had the disadvantages of: 1) increased and external purchasing costs to DOE, 2) an "in-air" transfer of fuel elements that would have to be done outside the facility, and 3) the cask was not approved nor certified for the GTRR fuel. With extensive help from NAC, their cask was approved and certified in record time and the financial differences were resolved. The NAC cask was selected for the removal of the spent reactor fuel on the basis that it would require a single shipment.

The review and approval processes entailed numerous interactions with DOE, regulatory agencies and the Georgia Tech Nuclear Safeguards Committee. DOE was extensively involved with the provision of casks, cask certification, transportation, coordination with receiving facilities, documentation, and problem solving. The NRC was responsible for cask approvals and certification, route approvals, shipping date approvals, and Quality Assurance (QA) program approval in addition to their routine inspections. At the same time as fuel was being shipped, NRC was reviewing GTRR's request for reactor license extension involving both preliminary and final public hearings. With the de-fueling, Georgia Tech submitted a request to NRC to replace the high-enriched (HEU) fuel with low-enriched (LEU) fuel. Furthermore, NRC inspectors were on site throughout the year prior to the Olympics to observe staff training on procedures, trial runs, and ultimately the actual fuel movement. The state regulatory agencies of Georgia and South Carolina were involved in route selection, truck inspections, environmental monitoring during the in air fuel element transfer, and emergency planning and training. During the year, the Nuclear Safeguards Committee met on both a routine and "on-call" schedule to review and approve fuel-handling procedures. At each meeting, project status reports were presented, an open dialog maintained, and numerous suggestions incorporated in operational procedures.

Operations

The de-fueling and shipment of the GTRR irradiated fuel involved five major steps:

1. Transfer of fuel assemblies from the reactor to the fuel storage pool
2. Removal of the lower top shield plug from the fuel assembly
3. Cutting the active elements out of the fuel assembly
4. Transfer of elements to shipping cask
5. Shipping of the active HEU elements to DOE.

After a predetermined fuel cool down period of 90 days the fuel assemblies were moved one at a time from the reactor vessel to the storage pool using a transfer cask. From inside the cask, a grapple connected to a winch was lowered and attached to each assembly (See Fig. 1). The assembly was then raised up into the cask and allowed to drip-dry. A drawer at the bottom of the cask was then closed and the cask was placed on a cart. The cart was then towed from the containment facility into an adjacent high bay facility, which housed the fuel storage pool. The cask was partially lowered into the pool to provide sufficient shielding, and the assembly was lowered into the pool (See Fig. 2). Twenty-five transfers were made, at approximately two fuel transfers per day.

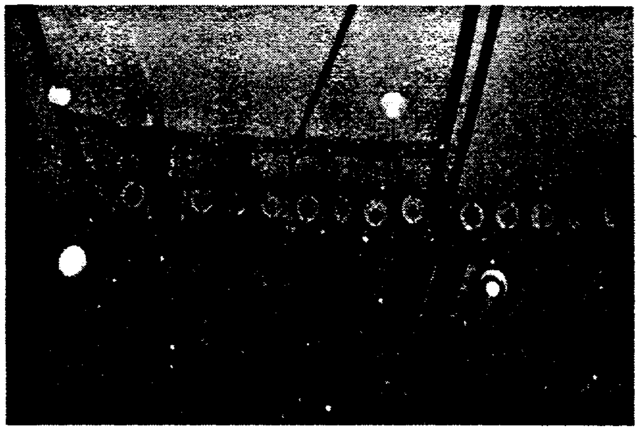
Figure 1 (left) shows the transfer cask being positioned to remove a fuel assembly from the reactor. The grapple can be seen sticking out just below the cask.

Figure 2 (right) shows a fuel assembly being lowered into the storage pool. The water in the pool provided sufficient shielding so that radiation levels were at or near background levels.

Other than the potential for direct radiation exposure, the only health physics problem to arise was the gradual increase in tritium concentration in the fuel storage pool. The tritium concentration in the pool reached a maximum of 4.6×10^4 Bq L^{-1}. The tritium was attributed to activated heavy water affixed to the surface of the fuel assemblies. Even with a 20-minute hold time to allow the fuel assembly to drain thoroughly as it was removed from the reactor, the amount of tritium carried over to the pool was significant. Twice daily monitoring of the fuel storage pool water was initiated. With the last shipment of fuel from the reactor, pool monitoring was reduced to a weekly schedule.

The fuel assembly, when in the reactor, was shielded on top by a 1.25 meter long upper, non-attached, top shield plug. In addition, attached to each fuel assembly was a one-meter long lower top shield plug (LTSP). The bottom end of the lower top shield plug contained the majority of induced activation products resulting from reactor use. The LTSP had to be removed from each assembly to permit the assembly to be remotely moved into the hot cell for cutting. To remove the lower top plug shield a special assembly holder was fabricated. This holder sat on the bottom of the pool with sufficient height to keep the attachment area two feet under the water for shielding purposes. One at a time, each assembly was carefully transferred to the pool assembly holder. While in the holder, a reactor operator reached into the pool down to the attachment area, unscrewed three bolts and clipped two thermocouple wires. A bucket was attached to the holder to catch the bolts and thermocouple wires. This significantly decreased the time it took to remove the LTSP. The lower top shield plug was then removed from the storage pool and returned to the reactor containment building. The remaining assembly was returned to the fuel storage rack (see Fig. 3) in the pool. With extensive training and limiting exposure time, radiation exposure to the reactor operator was minimized. Radiation exposure levels to the extremities were approximately 2.5 mSv hr^{-1} and 0.1 mSv hr^{-1} at the operator's head. The thick pool wall shielded the whole body of the reactor operator.

The next step in the operation was to cut the active elements out of the fuel assembly. The 2.2-meter long fuel assembly has a 60-cm active element area located approximately 25 cm from the assembly base. Both the BMI and NAC casks were limited in only being able to accommodate fuel elements less than 64 cm in length. A jig was developed and placed in the hot cell to hold the fuel assembly in a fixed horizontal position. Two automated hacksaws were pre-positioned on the jig to give a 1.5-cm edge on either end of the element. Two "master-slave" manipulator arms were used to operate the hacksaws from outside the hot cell. After training on several dummy assemblies, each irradiated assembly was moved from its storage rack in the pool to a transfer chute and raised from the pool directly into the hot cell.



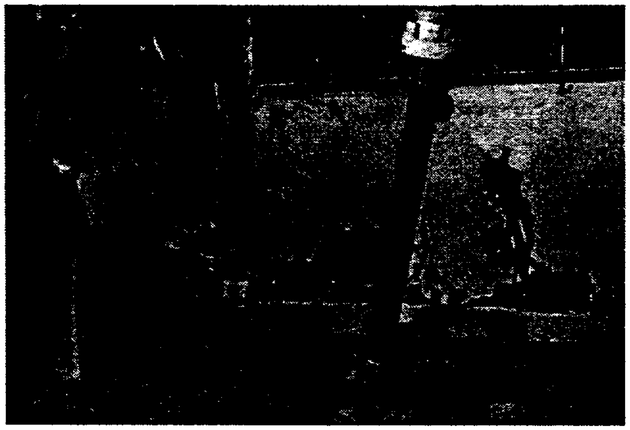


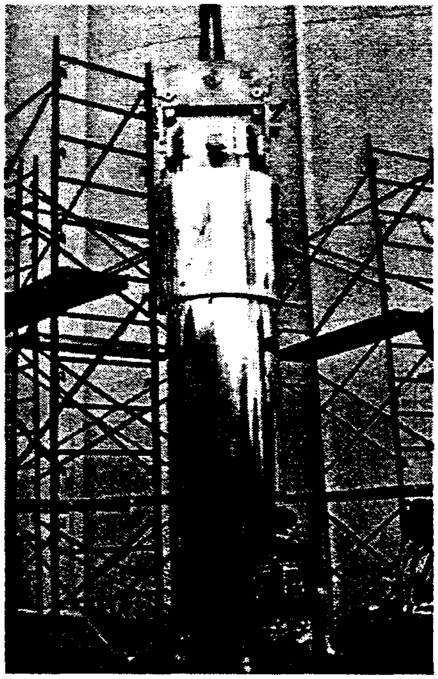
Figure 3 (above left) shows the fuel rack against the wall of the pool. The second assembly from the left still has a lower top shield plug still attached.

Figure 4 (above right) shows a fuel assembly being cut in the hot cell. The "master-slave" manipulators were used to handle the assembly and to start the motor-driven cutting process.

In the hot cell, the assembly was labeled and positioned in place. Both ends of the assembly were then sawed off (See Fig. 4). The active fuel element was returned to the storage pool and placed inside one of four baskets (See Fig. 5). An audit team kept track of the location and identification of all the assemblies and elements. Assemblies and element locations were predetermined by three independent criticality calculations. Health physics concerns involved with the cutting operations included: 1) breaking of the hacksaw blades, 2) hacksaw blade direction going astray and perhaps cutting into the element, 3) the accumulation of radioactive hacksaw "dust", and 3) the accumulation of radioactive waste in the hot cell. Our experienced reactor operators remotely replaced hacksaw blades when broken and remotely adjusted saw blade direction when the direction began to stray. A vacuum cleaner with a HEPA filter exhaust was used to collect the dust and shavings from the cutting process. Shielded waste buckets in the hot cell minimized the radiation dose from the cut ends of the assemblies. However, the recovery and clean up of the hot cell after the operation contributed a significant fraction of the total radiation exposure to staff health physicists (about 0.5 mSv).

Figure 5 (above) shows two of the baskets containing the cutout fuel elements.

Figure 6 (right) is the NAC shipping cask.



Nuclear Assurance Corporation (NAC) provided a trained staff to transfer the elements from the storage pool to the NAC cask and to load the shipping cask onto the transport vehicle. The NAC cask (See Fig. 6) could hold a total of five baskets. A special transfer cask was loaded into the fuel storage pool, the basket placed in the transfer cask and then the cask removed from the fuel storage pool. The transfer cask was then placed on a special cart and moved out of the facility to an open area. There a crane was used to lift the transfer cask from the cart to the top of the vertically positioned NAC cask. The transfer cask was then attached to the shipping cask and the basket was lowered into place. The procedure was practiced with an empty basket prior to the actual operation. After all of the baskets containing the fuel elements were in the NAC cask, the transfer cask was disengaged for the last time and the NAC cask capped. The cask was then moved into a horizontal position, placed on the trailer bed of the transport truck, enclosed, secured, and surveyed. Shipping, routing, security preparations, and notification of regulatory and governmental agencies were made and the truck made a successful delivery of the cask to Savannah River DOE operations. Accompanying the truck in separate vehicles were an armed guard provided by the Georgia Public Service Commission, representatives from Georgia's Department of Natural Resources Radiation Protection Program, and an NRC security inspector.

In addition to usual health physics operations, several health physics concerns were addressed. The fuel baskets provided were designed to fit the transfer cask and the shipping cask. The baskets as received were contaminated with cesium-137. Numerous attempts were made to decontaminate the baskets prior to placing them in the fuel storage pool. Although surface contamination was completely removed, the contamination continued to "bleed" ^{137}Cs from the alloy. This led to low levels of ^{137}Cs in the fuel storage pool and special handling operations for the baskets. In addition, there were permissible levels of "loose" radioactive contamination on the casks. Thus the casks had to be wrapped in protective plastic during all air operations. Finally, there was significant radiation streaming from the mating slit between the transfer cask and the shipping cask (on the order of 0.5 Sv hr^{-1}). Fortunately, the baskets passed the slit very quickly and, thus, radiation exposure was minimal during the transfer process (maximum whole-body dose of 0.4 mSv). Georgia Department of Natural Resources independently monitored radiation exposures at the GTRR site boundary during the transfer operations and reported slightly elevated levels of direct radiation (about 0.04 mSv above ambient quarterly results).

Procedures

Eight specific procedures were developed to carry out the reactor de-fueling project. The individual procedures developed are identified and described in Table 1. In addition, all staff members received five hours of emergency training and participated in a half-day emergency exercise. The exercise scenario involved a potential worse case incident of a fuel element (greater than 1 Sv hr^{-1} @ contact) dropping out of its shielded cask during the transfer operations. The exercise was graded by NRC and provided all personnel with a better understanding of the potential hazards associated with de-fueling a nuclear reactor.

Table 1

Procedure #	Title	Comments
1500	Irradiated Fuel Transfer To Storage Pool	Provided a method for the efficient and safe transfer of irradiated fuel from the GTRR to the storage pool.
1501	Lower Top Shield Plug Removal from Irradiated Fuel Elements	Provided a method for removing the lower top shield plug from irradiated fuel elements.
1505	Preparation of Irradiated Fuel for Off-Site Shipment	Provided detailed procedures for the preparation of irradiated fuel for shipment to the Savannah River Site.
1506	Physical Protection of Irradiated Fuel in Transit	Assured the proper implementation of a physical protection system for irradiated reactor fuel in transit.
1507	Emergency Threats to Irradiated Fuel in Transit	Provided procedure for response to potential emergency threats to irradiated fuel in transit.
1510	Cask Maintenance, Inspections and Tests.	Provided a method for maintaining and inspecting the shipping cask and to meet the requirements of the Georgia Institute of Technology and 10 CFR part 71 Quality Assurance Programs.
1511	Cask Operating Procedure	Provided the requisite steps essential to loading and unloading the cask.
1512	Irradiated Fuel Shipment by NAC-LWT Cask	Provided the necessary steps for shipping GTRR's HEU fuel using the NAC cask.

Conclusions

Even with well established and agreed upon goals, plans, and procedures, one must expect changes, perturbations and localized contamination associated with de-fueling a nuclear reactor. Key to the successful de-fueling operations was thorough planning, team understanding and communication, and adequate personnel to respond to unexpected events.

References

1. Georgia Department of Natural Resources Environmental Protection Division, "Environmental Radiation Surveillance Report, 1995-1996".