ASSESSMENT RESULTS OF THE INDONESIAN TRIGA SNF TO BE SHIPPED TO INEEL

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ABSTRACT

This paper describes the Training, Research, Isotope, General Atomics (TRIGA) spent nuclear fuel (SNF) examination performed by technical personnel from the Idaho National Engineering and Environmental Laboratory (INEEL) at the Bandung and Yogyakarta research reactor facilities in Indonesia. The examination was required before the SNF would be accepted for transportation to and storage at the INEEL. This paper delineates the Initial Preparations prior to the Indonesian foreign research reactor (FRR) fuel examination. The technical basis for the examination, the TRIGA SNF Acceptance Criteria, and the physical condition required for transportation, receipt and storage of the TRIGA SNF at the INEEL is explained. In addition to the initial preparations, preparation descriptions of the Work Plan For TRIGA Fuel Examination, the Underwater Examination Equipment used, and personnel Examination Team Training are included. Finally, the Fuel Examination and Results of the aluminum and stainless steel clad TRIGA fuel examination have been summarized. Lessons Learned from all the activities completed to date is provided in an addendum.

The initial preparations included: (1) coordination between the INEEL, FRR or Badan Tenaga Atom Nasional (BATAN), DOE-HQ, and the U. S. State Department and Embassy; (2) incorporating Savannah River Site (SRS) FRR experience and lessons learned; (3) collecting both FRR facility and spent fuel data, and issuing a radionuclide report (Radionuclide Mass Inventory, Activity, Decay Heat, and Dose Rate Parametric Data for TRIGA Spent Nuclear Fuels) needed for transportation and fuel acceptance at the INEEL; and (4) pre-examination work at the research reactor for the fuel examination.

INTRODUCTION

The return of United States origin foreign research reactor (FRR) fuel to the U.S. is founded in the Atoms for Peace initiative undertaken in the 1950s. The purpose of the initiative was to encourage peaceful use of nuclear technology worldwide. The agreement included conditions for the return of the U.S. origin nuclear material either at end-of-life or whenever the fuel was no longer needed. In 1978, the United States initiated the Reduced Enrichment for Research and Test Reactors (RERTR) program to reduce the inventory of high enriched uranium (HEU) fuel in civilian programs and promote the conversion of operable reactors to low enriched uranium (LEU) fuels. The program allowed the return of FRR HEU and LEU under an Off-Site Fuels Policy which expired for HEU in 1988 and for LEU in 1992. The March 1996, Record of Decision, based on the "Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel," reestablished this conditional return program of FRR spent nuclear fuel (SNF) enriched in the United States for fuel discharged within a ten year period and returned within a thirteen year period. As part of this decision, the INEEL was designated as the receiving site for TRIGA fuels from nineteen countries including Indonesia.

Plans for examination of the TRIGA fuel in Indonesia began in October 1996. The examination of TRIGA fuel in Bandung and Yogyakarta, Indonesia was conducted during May and June 1997. For the most part, the fuel inspected originated from the TRIGA research reactor located in Bandung.

INITIAL PREPARATIONS

Return of the Indonesian TRIGA fuel was initiated in October 1996 with the first Indonesian visit by U.S. Department of Energy (DOE) and DOE contractor personnel to provide introductions to and discussion of the SNF return program along with an initial assessment of the FRR fuel and facilities. INEEL and FRR personnel provided points of contact for BATAN with BATAN providing preliminary fuel data or projected availability, agreeing with the general terms of the FRR Program, and agreeing to host a fuel and facility assessment team visit. Routine e-mail and teleconferences were established between DOE/INEEL and BATAN personnel to address questions and provide information on facility status, personnel support, fuel availability for examination, and examination procedures. The U. S. Department of State and Embassy were also notified. Schedules were established for the INEEL team to examine the fuel and to assess the facilities for cutting, canning, loading and shipment of the fuel to the INEEL.

Savannah River Site personnel had recently completed fuel examinations in Greece and were performing fuel examinations in several countries in South

America. A visit was made to Brazil by one of the team members to observe the SRS fuel examination. This visit and the numerous conference calls made with SRS to incorporate their experiences and lessons learned were invaluable in planning the fuel examination trip in Indonesia.

Original fabrication data and drawings of TRIGA fuel rods were obtained from General Atomics for all fuel shipped to Indonesia. Additional information on TRIGA fuels was obtained from the "Characterization of TRIGA Fuel" report[I]. As part of the overall INEEL Spent Nuclear Fuel Program, the "Radionuclide Mass Inventory, Activity, Decay Heat, and Dose Rate Parametric Data for TRIGA Spent Nuclear Fuels" report[II] was also issued providing these data estimates based on TRIGA fuel type, final burnup, decay time, and distance in air from fuel for dose rate calculations. This TRIGA SNF characterization report was also developed to: furnish data for the final repository; for radiological, dose, and heat and criticality assessments; licensing the NAC-LWT cask; and transport planning. The data presented in this last report may be used by the FRRs in completion of Appendix A, coupled with the Chicago 1997 RERTR Appendix A training, and will be useful to INEEL personnel in verification of information supplied by the FRRs.

FRR preparation work for the SNF examination was performed by a small team consisting of the BATAN Reactor Division, Radiation Protection, and Security staffs. Prior to arrival of the INEEL team, BATAN personnel selected and prepared areas where fuel examination equipment would be located and fuel examinations performed. The radiation exposure at the top of the storage pools was such that the permissible limit of 2.5 mR/hr was not exceeded. In Bandung, fuel was moved from the storage location to the examination pool. The TRIGA examination at the Yogyakarta facility was carried out in the same location where the SNF was stored (i.e., the bulk shielding storage tank). Fuel storage rack locations in the canals at the Indonesian facilities were adjusted to facilitate ease in fuel examination. The FRR equipment provided for this examination was the auxiliary cabling, electric power supply, and fuel handling tool; the tool consisted of a weight, stainless steel grapple mechanism, and flexible control cable having a reinforced rubber hose that extends between the handle and weight for transmitting the fuel element weight to the handle.

During this preparation period, (draft) fuel acceptance criteria and examination plans were developed, design and fabrication or selection of equipment was completed, and training of examination personnel was performed. Fuel data had to be gathered and compiled for the fuel to be examined. Facility information (including water quality data) was required to be able to plan the fuel examination. The receipt criteria (APPENDIX A) was developed to provide the starting basis for gathering fuel and FRR facility information concerning the TRIGA fuel to be shipped to the INEEL; APPENDIX A information is essential to developing INEEL technical basis documents, namely: criticality safety evaluation, environmental documentation, safety analysis reports, fuel characterization studies, and handling equipment criteria and designs. A detailed work plan was prepared for the fuel examination and microbial sampling processes and identifying required equipment to ensure the desired SNF data was obtained. A training plan was prepared to establish the proficiency necessary for the fuel examination team members to qualify as fuel examiners and microbial samplers.

Prior to departure from the INEEL, the equipment had to be packaged and shipped to Indonesia, required travel and shipment documentation was completed, and appropriate briefings were provided on security, health issues, and cultural awareness.

TRIGA SNF ACCEPTANCE CRITERIA

The fuel matrix of the aluminum and stainless steel (SS) clad TRIGA fuel is composed of an intrinsically brittle uranium-zirconium hydride[III] which has been subjected to thermal and nuclear conditions during reactor operation potentially causing micro fracture of the fuel. This condition could allow breakage into small particles should the fuel be physically impacted. Thus, the cladding provides the structural confinement boundary to prevent particle dispersion. The TRIGA SNF acceptance criteria at the INEEL was developed to ensure this confinement is maintained.

Storage of aluminum clad fuel in water can lead to increased corrosion (e.g., galvanic attack) of the aluminum cladding should a pin hole or crack develop in the cladding. If the fuel storage water quality is good, less than 1 μS, the galvanic corrosion potential is minimal. This results in a potential for significant cladding corrosion from the inside out making external visual observations unreliable to quantifiably determine the structural integrity of the cladding. (Alternate methods of inspection such as the eddy current technique and ultrasonic thickness measurements could be used to evaluate the loss of material, but were found to be too costly to implement at the FRR.) Therefore, for maintaining a confinement boundary, perforations of aluminum clad TRIGA fuel due to pitting, or perforations for either aluminum or stainless steel clad TRIGA fuel due to cracking or mechanical damage were determined to be unacceptable; perforations of stainless steel clad TRIGA fuel due to pitting are considered acceptable unless located randomly over greater than ten percent of the cladding surface or localized such that structural integrity is suspect. Corrosion in the form of polyps or heavy scale/oxide stains on either aluminum or stainless steel clad fuel is considered unacceptable. Also unacceptable are visual indications of abnormal thermal stresses that could result in cladding failure, namely; blistering, bowing or bulging of the fuel in excess of 100 mils as determined by insertion of the fuel into a Go, No-Go gauge.

This criteria is currently being evaluated by an independent committee consisting of cask vendors, fuel experts, and site receivers based on their requirements for fuel confinement and contamination containment. Failure to meet the acceptance criteria was not the basis rejecting the shipment of TRIGA SNF to the INEEL but the basis for requiring TRIGA fuel to be packaged prior to shipment for maintaining the confinement boundary.

While not a condition of SNF acceptance, results of microbial sampling are used to determine if organisms associated with possible corrosion of fuel cladding materials exist in the water or on the surfaces of the storage pool. Results will be retained for possible later consideration of long term effects when TRIGA SNF is placed in a final repository.

WORK PLAN FOR TRIGA FUEL EXAMINATION

The Work Plan for examination of TRIGA fuel was developed based upon visual examination methods and implemented the draft SNF acceptance criteria established to ensure the integrity of TRIGA fuel would be maintained during transport to and handling at the INEEL. Included in this plan are: instructions covering the fuel examination process and microbial sampling, equipment requirements, and personnel training requirements. Qualification of fuel examiners involved work plan training (a video taped mock-up training made available to FRRs for review of the examination process).

Fuel examination instructions included equipment setup, functional testing, and general positioning of the equipment in the fuel examination pool plus written and audio/visual documentation requirements for the condition of each fuel rod by sector. The instructions also address requirements for positive identification of each fuel rod as well as the dimensional and straightness checks utilizing the vertical scale or examination station and the Go, No-Go gauge.

The serial number, fuel type, cladding type, length of the can or fuel rod, and examination notes of each piece of fuel was recorded and mapped on data sheets using a sector format. This allowed identification of any pits, cracks, or deformations/damage to be identified by location and sector as the fuel was rotated and examined end to end.

The microbial sampling instructions requested microbial evaluation of the storage facility water, surfaces within the storage pools, and the fuel cladding. In addition to desired sampling locations, the sampling instructions describe the sampling process and analysis involving handling of samples, inoculation of culture media, documentation requirements, and interpretation of results.

UNDERWATER EXAMINATION EQUIPMENT

Underwater fuel examination equipment design was based upon INEEL Idaho Chemical Processing Plant (ICPP) experience. State of the art SVHS underwater camera equipment was selected to improve the marginal quality over standard VHS underwater camera equipment currently used at ICPP. The examination camera system incorporates a moderate telephoto capability and a pan and tilt option. This allows to zoom for closeup focus or full sequential coverage of the fuel and for positioning the camera head. Resolution of the SVHS equipment allowed viewing of pits less than 0.25 cm diameter to be identified approximately six feet from the camera head. Figure 1 shows the camera head and auxiliary lighting. To provide contrast to surface areas, the camera was fitted with two lights having adjustable light intensity. A second light source containing two adjustable lights were mounted on a separate pole and positioned independently to provide additional back lighting and contrast control.

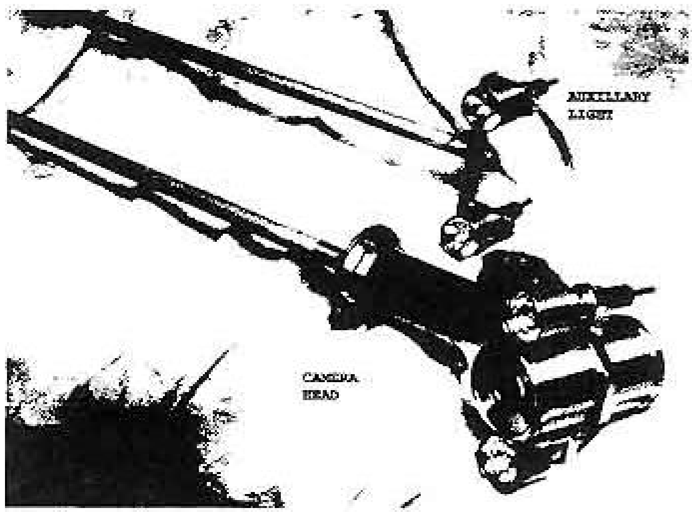

Figure 1 - Underwater Camera Head Assembly and Auxiliary Lighting

The underwater camera system has two monitors and an intercom system to provide communication between members of the examination team with voice recording capabilities on the SVHS recorder. These features allow for independent verification of visual observations. The system was designed with two SVHS recording tape decks which allowed obtaining a primary and a simultaneous back-up copy; the backup copy could then be retained by the FRR facility for their records. A power connection was also provided for a lap-top computer. Figures 2 and 3 are representations of the signal and power diagrams for equipment hookups.

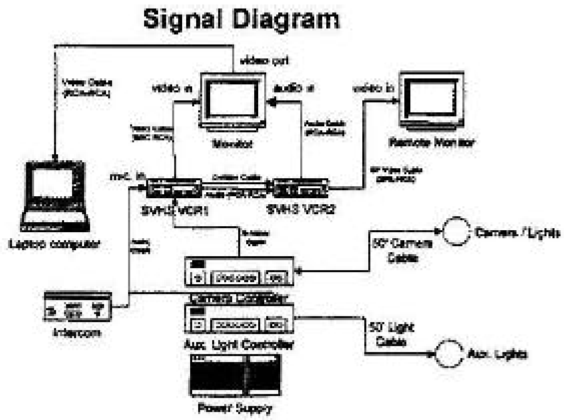

Figure 2 - Signal Diagram

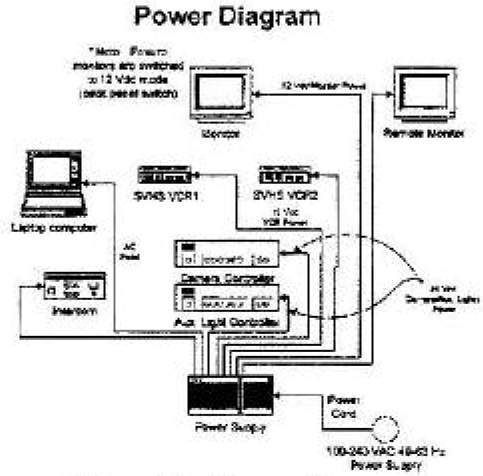

Figure 3 - Power Diagram

For system support equipment, general camera head location (vertical movement) was accomplished through use of a manually operated sliding clamp block to which the camera handling extension tube was attached. The sliding block was moved by a hand crank driven pulley system and allowed movement of the camera over a three foot span. Additional vertical range could be obtained by repositioning the camera handling extension tube in the sliding block clamp. A vertical scale or examination station and Go, No-Go gauge (see figure 4) respectively provided dimensional reference for documenting observations during fuel examination and allowed determination of the extent of bowing or swelling of a fuel rod by full insertion of the rod into the gauge beginning with the smallest of the five graduated tubes. Graduated holes drilled in the vertical scale or examination station provided comparison reference for estimating sizes of pitting, pin holes, or corrosion observed. A 35mm camera, 135 mm lens, and high speed film was also used to photograph each fuel element or can to provide an independent copy of the examination should the video tapes be lost or damaged during transit.

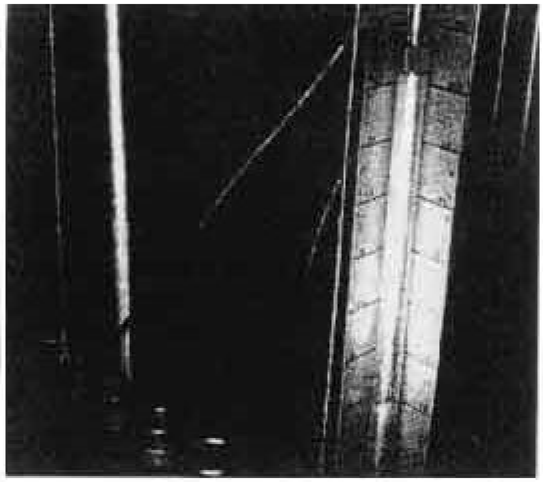

Figure 4. Reference and Go, No-Go Gauges

A microbial sampling kit containing sterile swabs, bottles of sterile water for sample preparations, bottles containing culture solutions, gloves, alcohol, syringes, operating tools, and sample documentation forms was provided for each facility. Three types of culture media were included to determine if acid producing microbes, sulfate reducing bacteria, or heterotrophic microbes exist in the fuel storage environment.

Additional equipment included sectional extension tubes and hanger brackets for underwater equipment, a modular equipment stand, hand tools for equipment assembly and maintenance, spare lights, and sealing tape. Backup spare video equipment was also included for components that were not easily repaired and unavailable at the FRR. All equipment with the exception of the 35mm camera and lap-top computers, which were hand carried, was packaged into two large overpack containers for transport.

EXAMINATION TEAM TRAINING

INEEL fuel examination personnel were selected based on education and previous fuel handling or examination experience. Training was conducted by qualified instructors to a quality assurance approved training plan. The initial training session was held in a dry mockup facility to familiarize personnel with the setup and operation of the underwater video and lighting systems, and to ensure work plan instructions were adequate. This training session allowed team members to identify deficiencies in and modifications required to the equipment and work plan. A mockup of a TRIGA fuel rod with various intentional defects (e.g., pits, scratches, and simulated corrosion product) was used to ensure personnel and equipment could readily detect and identify conditions expected during actual fuel examinations.

Following work plan revisions, equipment modifications, and correction of equipment deficiencies, a second training session was held in an available tank to check the underwater operation of the video camera and lighting equipment. Prior to departure of the examination team for Indonesia, a final fuel examination training session covered all examination requirements from unpacking, setup, and packing.

Training for microbial sampling provided hands-on familiarization with sampling equipment, obtaining samples, sample preparation and inoculation of cultures, and interpretation of results. Also discussed were documentation requirements and techniques to avoid sample contamination.

FUEL EXAMINATION AND RESULTS

The Bandung facility was selected for the beginning fuel examination. BATAN provided personnel for handling the fuel and performing radiological monitoring and control. The examination team performed a facility assessment noting area and facility access, handling equipment, hot cell capabilities, and overall storage pool conditions for later fuel packaging and cask handling/loading considerations. Then the fuel examination equipment was set up adjacent to the examination pool and according to the work plan, the microbial sampling of the pool water, pool structural surfaces, and fuel cladding was conducted followed by the fuel examination. Upon completion of the examination, the equipment was decontaminated, packaged, and transported to Yogyakarta where this sequence was repeated except that the examination equipment was transported to the U. S.

During the DOE/INEEL Indonesian visit, FRR personnel provided the latest draft of their Appendix A, Spent Nuclear Transfer Data Form input which had been nearly completed prior to the visit. The data was collectively reviewed by the INEEL team and FRR personnel with any items remaining for completing the form identified. The INEEL team provided the references and drawings from General Atomics, the Tomsio report[I], and the Sterbentz report[II] to aid in completion of the form. Copies of the examination data sheets, videos, and photographs were provided for the BATAN facility records noting that this documentation and results of the fuel examination provided most of the missing information. Remaining significant issues include:

- Burnup calculations need to be verified or are still required for a few TRIGA elements.
- Source document references need to be included to satisfy Quality Assurance requirements for the information provided.

Indonesian FRR TRIGA fuel was evaluated based upon the ability to maintain fuel integrity during transport to and handling at the INEEL. Fifty standard stainless steel TRIGA rods were examined in Bandung of which zero were determined to require packaging prior to shipment. Seventy-five standard TRIGA rods (66 aluminum and 9 stainless steel) were examined in Yogyakarta of which one was determined to require packaging prior to shipment, thirty-five require no packaging, and for thirty-nine the packaging requirements are waiting upon the conclusions of the independent criteria committee previously described. The microbial sampling results showed that in the Bandung storage pool, only the acid generating and heterotrophic microbes existed while all types of microbes existed in the Yogyakarta storage pool.

Fuel examination Figures 5, 6, and 7 present problems with aluminum clad TRIGA fuel, namely; pitting, bulging, and a heavy oxide. Stainless steel clad TRIGA in good condition (see Figure 8) can be compared to fuel examination Figures 9 and 10 which respectively present pitting and heavy deposit SS cladding problems.

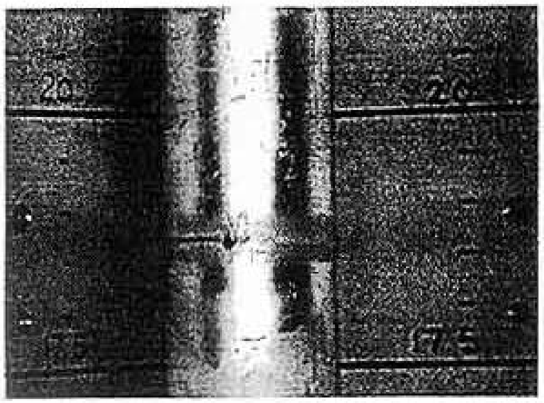

Figure 5 - Cladding Pit on Al TRIGA Rod

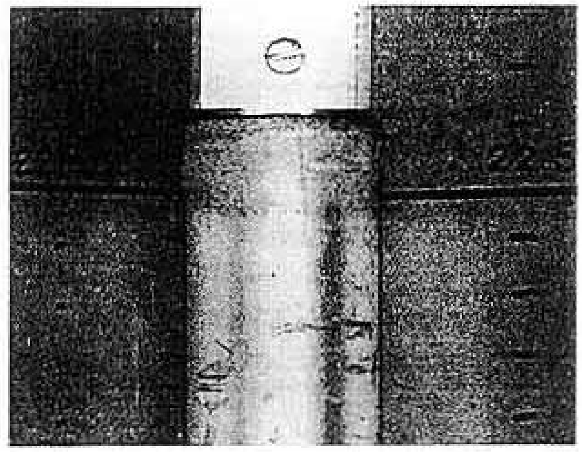

Figure 6 - Bulged Al Clad TRIGA Rod

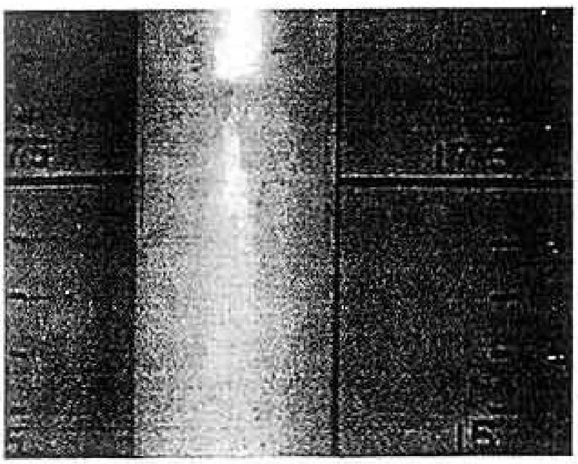

Figure 7 -Heavy Oxide on Al Clad TRIGA Rod

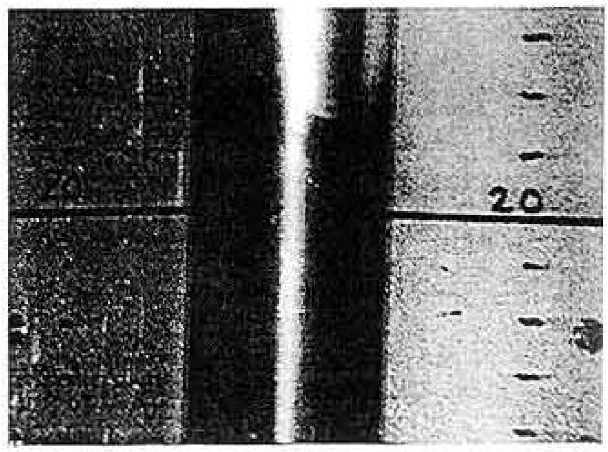

Figure 8 - SS Clad TRIGA Rod in Good Condition

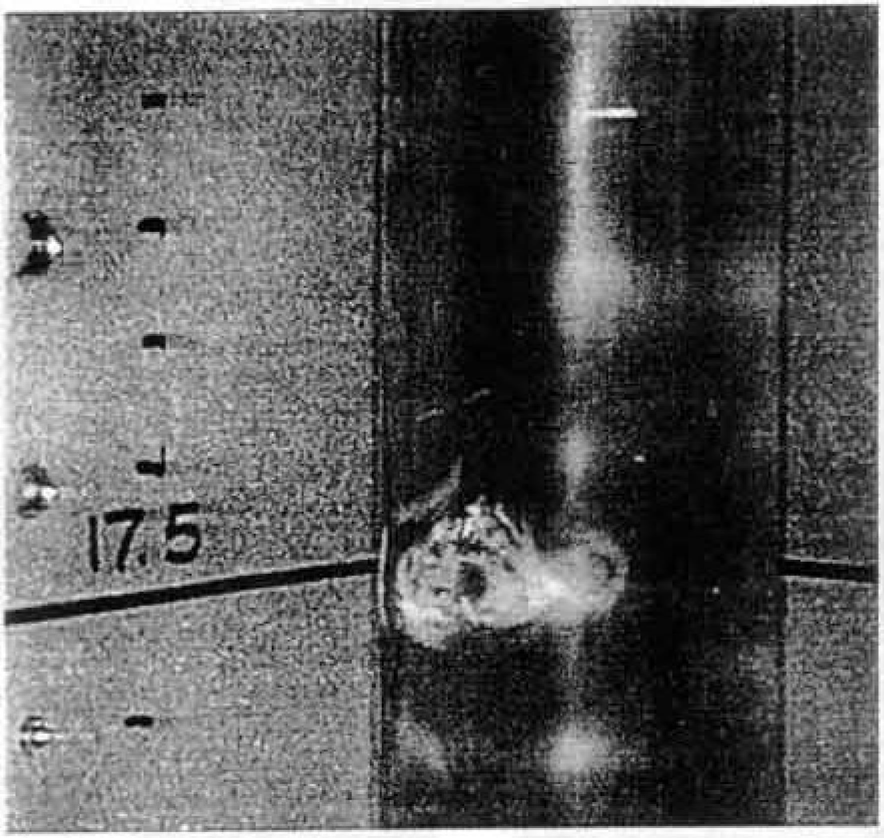

Figure 9 -Cladding Pit on SS Clad TRIGA Rod

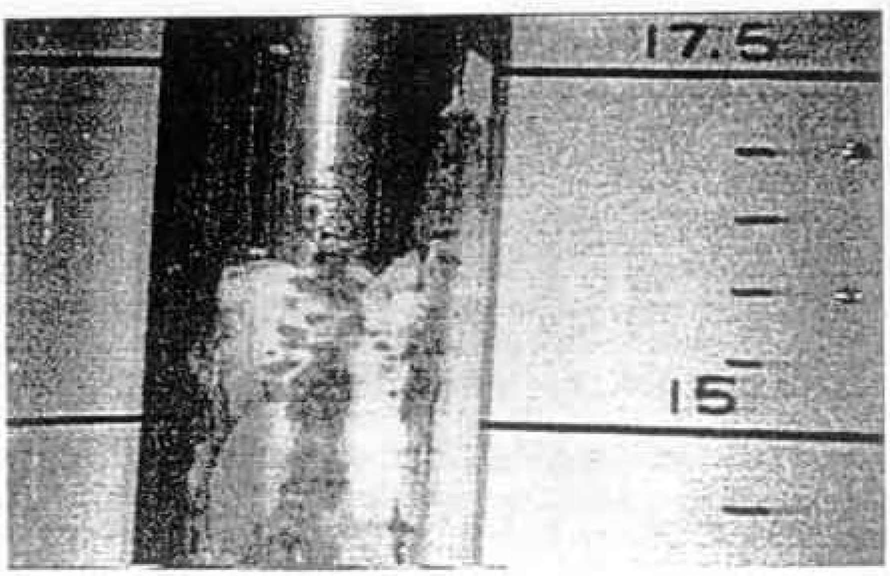

Figure 10 - Heavy Deposit on SS Clad TRIGA Rod

REFERENCES

I. Report, N. Tomsio, “Characterization of TRIGA Fuel.” General Atomics GA-C18542, October 1986.

II. J.W. Sterbentz, “Radionuclide Mass Inventory, Activity, Decay Heat, and Dose Rate Parametric Data for TRIGA Spent Nuclear Fuels,” Lockheed Martin Idaho Technologies Co. INEL-96/0482, March 1997.

III. Book, William M. Mueller, James P. Blackledge, George G. Libowitz, “Metal Hydrides,” Academic Press New York and London 1968, Library of Congress Card Number 68-26681, pg. 313.

ADDENDUM: LESSONS LEARNED

The examination equipment and process used during this TRIGA fuel assessment had been previously evaluated during the mockup phase. Field use identified some areas which could be modified thus enhancing future fuel examinations. The main items identified are listed below.

- Provide video recorders with on/off indicators other than the orange and red combination. These colors are not sufficiently different to immediately recognize if either video tape is full (i.e., no recording is being performed)..

- Provide a time counter on the SVHS video recorder. Record start and stop times for each fuel piece examined.

- Test all head sets for internal noise interference to minimize feedback and noise during the audible recording of examination data.

- Provide electrical shielding of the lighting rheostats on the controller to reduce noise during recording.

- Use smaller lockable shipping crates for the examination equipment. This will facilitate easier shipping and handling at fuel examination locations.

- Just prior to travel, FRRs generate the radiological survey maps of all the areas which have been, are existing, or suspected of contamination in which INEEL personnel will work.

- Discuss with FRR personnel the needs or requirements to secure, protect, and control the fuel assessment data and fuel shipment information.

- For the pulley used to manipulate the video camera position, the equipment hangers for attaching this to the stand or FRR facility support need to be larger to accommodate a 6.25 cm tube/pipe diameter as well as some type of insert/filler to allow accommodating a much smaller tube/pipe diameter - a robust design.

- Some of the TRIGA aluminum rod serial numbers were on the lifting device (e.g. pintel) such that the fuel handling tool covered the serial number; mainly the older fuels. These numbers were extremely difficult to read since there was some marring by the tool. To verify such a serial number, a stand allowing release of the tool head was necessary to locate the fuel rod near the examination equipment.

- Modify the referencing gauge to allow multiple orientations for video camera viewing; even to allow separate deployment.

- Use a lighter material of construction for and possibly reduce the number of tubes on the Go, No-Go gauge.