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A Summary of the Hot Fuel Examination Facility's Neutron Radiography Reactor's First Eight Years

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A Summary of the Hot Fuel Examination Facility's Neutron Radiography Reactor's First Eight Years

The Neutron Radiography Reactor (NRAD) is located in the Hot Fuel Examination Facility (HFEF) at Argonne National Laboratory — West. HFEF comprises several large hot cells where both non-destructive and destructive examinations of highly irradiated reactor fuels are conducted in support of the LMFBR program. One of the non-destructive examination techniques utilized at HFEF is neutron radiography.

Neutron radiography is provided by the NRAD reactor facility, which is located beneath the HFEF/North main cell. The NRAD reactor is a TRIGA reactor and is presently operated at a steady state power level of 250 kW solely for neutron radiography and the development of radiography techniques. The facility is unique in that irradiated nuclear fuel specimens are radiographed in a vertical orientation on a high throughput basis. The NRAD facility reached initial criticality in October, 1977, and commenced radiography operations on February 23, 1978. Since that date, the facility has met all operational commitments and has had an availability factor of approximately 92%. During the time interval from October, 1977, through January, 1986, 1,072 MWh were accrued during 4,694 hours of reactor operation. A total of 10,700 individual radiographs were produced. Specimens radiographed included 5,350 individual irradiated reactor fuel rods, 62 irradiated reactor fuel subassemblies, and 59 irradiated fueled reactor test loops.

For the first seven years of operation the NRAD operating crew consisted of three members, one of whom was the Reactor Manager. All of the original crew were certified Reactor Supervisors. In 1984, the crew size was increased by the addition of a Reactor Operator. Presently, the crew consists of the Reactor Manager (whose primary responsibilities are program development), two Reactor Supervisors, one Reactor Operator, and a Reactor Operator trainee. Originally radiography technicians were provided by the HFEF Operations organization. Presently, the NRAD operating crew performs those duties in addition to their reactor operating duties.

Radiographs are primarily taken at the NRAD facility using the indirect, or transfer method, whereby radiographs of a specimen are obtained without having to place gamma radiation-sensitive film next to the specimen. Thus, radiographs of irradiated as well as unirradiated specimens may be obtained.

The development of radiography techniques has been an important continuing concern of the NRAD organization since its inception. For example, in keeping with the personnel radiation exposure policy of As Low As Reasonably Achievable (ALARA), which is in effect at the Argonne National Laboratory, foil handling equipment

and procedures were designed, fabricated, and developed by the NRAD crew to reduce the radiation exposure to radiography technicians. Much effort has also been expended in the development of radiographic dimensional analysis techniques. The results of these efforts will be published in a paper[1] to be presented by Mr. W. J. Richards at the Second World Conference on Neutron Radiography to be held in Paris, France, on June 16-19, 1986.

Techniques and procedures have been developed to perform track-etch radiography at the NRAD facility, which is a technique utilizing a cellulose nitrate type film in conjunction with a converter plate. The material on the converter plate emits alpha particles when it absorbs neutrons. The alpha particles that strike the cellulose nitrate film cause small holes or tracks on the film. Etching the film in a NaOH solution enlarges the holes or tracks on the film, creating a high resolution, low contrast image.

Neutron tomography is one of the more recent techniques being perfected at the NRAD facility. This is the process whereby axial radiographs are produced on film at many different angles, the visual information on the radiographs is digitized, and computer reconstructions of the data provide cross sectional replicas of the specimen. While tomography utilizing X-ray radiography or ultrasonics has been in use in the medical and industrial fields for a number of years, its adaptation to neutron radiography is relatively new.

The initial design of the NRAD facility provided a beam tube that extends beneath the HFEF/North main cell. The specimen tube extends from the beam tube upward into the hot cell. Thus, irradiated fuel specimens are radiographed in a vertical orientation without having to be removed from the hot cell environment. In the fall of 1981 a new beam tube was added to the facility. The new beam tube extends to a new radiography room where irradiated or unirradiated specimens are radiographed without having to be placed in the hot cell. The new beam tube has greatly extended the capability and utilization of the NRAD facility. Specimens from other facilities are routinely radiographed using the new beam tube.

To date, specimens from nine different reactor facilities have been radiographed at the NRAD facility in support of several research programs. The majority of the radiography performed at NRAD has been specimens irradiated in the Experimental Breeder Reactor-II (EBR-II). These include fuel rods, fuel subassemblies, blanket rods, blanket subassemblies, control rods and source rods. The research programs involved are the Integral Fast Reactor (IFR) program, the EBR-II driver fuel surveillance program, the DOE/PNC (Japanese Cooperative) program, and the space reactor (SP100) program. Many fuel rods and test loops irradiated in the Transient

Reactor Test Facility (TREAT) for the LMFBR safety tests have been radiographed at NRAD. Other TREAT specimens radiographed at NRAD include fuel rods and loops from the Light Water Reactor (LWR) safety test programs. The test trains from eight LMFBR Sodium Loop Safety Facility test (SLSF) irradiated in the Engineering Test Reactor (ETR) and subassemblies, fuel rods, and control materials from the Fast Flux Test Facility (FFTF) have also been radiographed at the NRAD facility. Severe Fuel Damage program (SFD) test assemblies for LWR safety studies were irradiated in the Power Burst Facility (PBF) and then brought to NRAD for neutron tomography. Tomography on the fourth and last of that series has just recently been completed. Tomography has also been performed on one of the SLSF test loops and on a mockup of a damaged Three Mile Island-2 (TMI-2) fuel bundle. Fuel, blanket, and reflector rods from the Shippingport Light Water Breeder Reactor (LWBR); fuel rods from the Loss of Fluid Test Facility (LOFT); and a fuel rod from the Texas A&M TRIGA reactor have also been radiographed in the NRAD facility.

Present plans for the NRAD reactor are to increase the operating power level from 250 kW to 1 MW in order to decrease radiography exposure times, which for tomography of large subassemblies are approximately 45 minutes. Increasing the operating power to 1 MW should decrease exposure times by at least one half. Presently, plans are being made to perform tomography on a fuel subassembly from the LOFT reactor that has a diagonal measurement of approximately twelve inches. Studies are also underway to identify other possible uses for the NRAD facility, such as activation analysis.

The first eight years have been busy ones for the NRAD facility. Many developments have been made and techniques developed in the field of indirect radiography. The facility has provided a valuable tool to many other research and development organizations and programs. It is felt that the usefulness of the facility will continue to develop in the future.

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[1] Radiography Experiments at EBR-II, W. J. Richards, H. A. Larson, paper to be published at the Second World Conference on Neutron Radiography, Paris, France, June, 1986.