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TREAT NEUTRON-RADIOGRAPHY FACILITY*

by

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ABSTRACT

The TREAT reactor was built as a transient irradiation test reactor. By taking advantage of built-in system features, it was possible to add a neutron-radiography facility. This facility has been used over the years to radiograph a wide variety and large number of preirradiated fuel pins in many different configurations. Eight different specimen handling casks weighing up to 54.4 t (60 T) can be accommodated. Thermal, epithermal, and track-etch radiographs have been taken. Neutron-radiography service can be provided for specimens from other reactor facilities, and the capacity for storing preirradiated specimens also exists.

INTRODUCTION

The TREAT reactor(1) is located at Argonne National Laboratory's (ANL) Idaho site at the Idaho National Engineering Laboratory (INEL). The reactor has been performing transient irradiation experiments related to reactor safety for nearly 23 years. It also has been doing neutron radiography in the steady-state mode for 15 years.

The transfer technique has been used to obtain thousands of radiographs of a wide variety of reactor fuels ranging from small, unirradiated single pins to preirradiated 37-pin assemblies that required the removal of decay heat. Most of the radiography specimens are preirradiated and must be remotely handled. A number of different shielded casks are available to accommodate the various preirradiated specimens. Currently TREAT experiments are pre- and posttransient radiographed and experimental light water breeder fuel pins are radiographed as part of interim and postirradiation examinations.

TREAT REACTOR DESCRIPTION

The TREAT reactor is designed to operate primarily in a transient mode to perform experiments related to reactor safety. Various types of off-normal conditions can be simulated in a variety of reactor fuel elements in a wide range of coolant environments. The capability also exists to operate in the steady-state mode, which is used for neutron radiography.

The reactor is fueled with fully enriched, 18-micron-diameter UO_2 particles dispersed in graphite and clad in Zircaloy-3. The UO_2 and graphite mixture contains approximately 0.2% by weight of uranium with a uranium-to-carbon atom ratio of 1 to 10 000. This design, which provides a large, prompt negative temperature coefficient, results in a thermal neutron spectrum.

The reactor cavity can accommodate up to 361 fuel assemblies, each 10.1 cm (4 in.) square and in a square array. The cavity is radially enclosed by a 61-cm (2-ft)-thick graphite reflector and a 1.5-m (5-ft)-thick biological shield. Each fuel assembly has a 61-cm (2-ft) axial graphite-reflector section above and below the 1.2-m (4-ft)-long fuel section. The reactor core is custom loaded for each experiment, and the number of fuel assemblies loaded is normally 250 to 350. The assemblies are arranged in an approximately circular geometry, and the balance of the core cavity is filled with all-graphite reflector assemblies. An experiment or an unfueled mockup is placed in the center of the reactor. Because of the custom-loading feature and a wide variety of experiment types, the reactor core loadings used during radiography differ markedly. The current experimental program is exclusively in support of the Liquid Metal Fast Breeder Reactor (LMFBR) program. Figure 1 is a cutaway drawing of the reactor.

In the transient mode, the reactor operates for brief periods of times, up to 30 s, with the power level and energy release ranging up to 20 000 MW and 2200 MJ respectively. The quantities realized and the reactor's power-time profile during a given transient are determined by preprogramming an online, closed-loop control computer in accord with the in-core experiment requirements. All personnel move to the reactor control building, about 1 km (0.6 mi) from the reactor building, during transient operation.

In the steady-state mode, which is used for neutron radiography, the reactor can be operated at power levels up to 120 kW for indefinite periods of time. During such operation, personnel have access to the entire area outside the biological shielding to perform manipulative operations such as neutron radiography. The fission energy is removed from the reactor by an air-cooling system. A horizontal neutron beam is extracted from the core, and the manipulative operations are carried out from the main floor of the facility building.

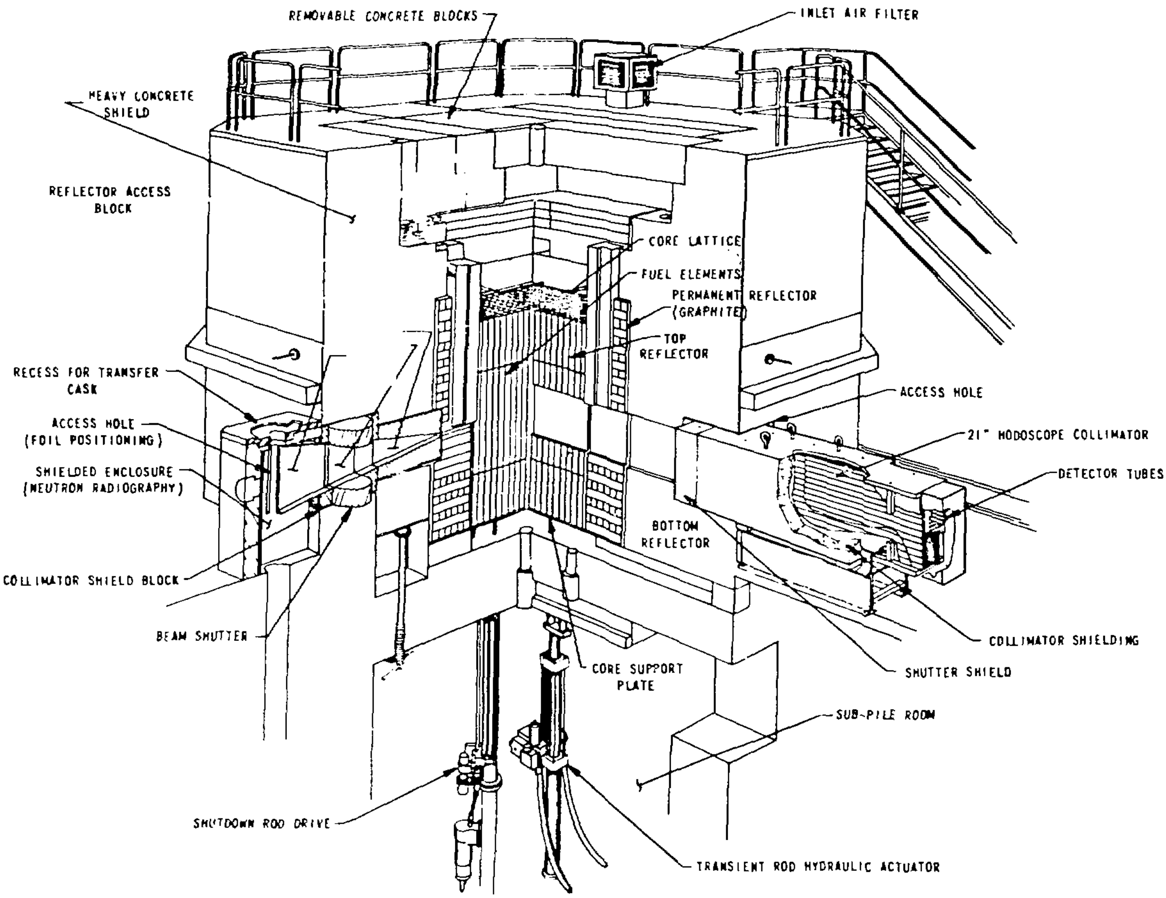

Fig. 1. Cutaway Drawing of TREAT Reactor

The neutron radiography facility was added 15 years ago by taking advantage of an opening through the radial reflector and biological shielding. Normally the reactor is operated at 80 kW for a few hours while a specimen is being radiographed.

RADIOGRAPHY SYSTEM DESCRIPTION

The heart of the radiography facility is a 2.57-m (101-in.)-long boral-lined segmented divergent collimator. It extends from the outer edge of the core cavity, through the 0.6-m (2-ft)-dia rotating neutron shutter filled with 30 wt% boric acid in Santowax R (a mixture of terphenyls), and into a U-shaped radiation shield. The collimator has vertical length over diameter (L/D) of 30 and a horizontal L/D of 60. The collimator has a 4.8-cm (1.9-in.)-wide by 9.9-cm (3.9-in.)-high opening adjacent to the core and a 14-cm (5.5-in.)-wide by 48.3-cm

(19-in.)-high opening adjacent to the radiography specimen. Horizontal beam divergence is 0.6 degrees, and the vertical beam divergence is 3.8 degrees.

The specimen being radiographed is placed inside the U-shaped radiation shield(2). This shield is designed to attenuate radiation coming from preirradiated experimental fuel being radiographed as well as the neutron beam coming out of the reactor. The 33-cm (13-in.)-thick shield is filled with lead shot and mineral oil with supplementary shielding outside the U-shaped enclosure. A shielded handling cask containing the specimen is lowered out of the handling cask to the proper elevation for radiography. Figure 2 shows the radiography shield with a TREAT handling cask in position for specimen radiography. A 34-cm (13.4-in.)-inside-diameter by 3.8-m (12.5-ft)-long pipe has been cast into the floor to permit radiographing long specimens. The enclosure rests on the main floor and is supported by a concrete foundation extending down to bedrock; this allows casks weighing as much as 54.4 t (60 T) to be placed on top of the enclosure.

Fig. 2. A TREAT Handling Cask in Position on the Radiography Shield for Specimen Radiography

The transfer foil is placed in an aluminum mounting fixture outside of the shield, a shield door is opened by a motor drive, and the mounting fixture and foil is motor driven behind the specimen. The neutron shutter is opened and closed by a drive cylinder operated by compressed air and under the control of a timer mechanism.

Normally dysprosium foils are used, but resonance radiographs can also be taken. To demonstrate this capability, track-etch radiographs have been taken with the assistance of personnel from the Neutron Radiography (NRAD) facility in ANL's Hot Fuel Examination Facility. With the core loadings currently in use, a total neutron flux of approximately 5 x 10^8 n/cm^2 s is realized with the thermal flux of 2.8 x 10^8 n/cm^2 s @ 65 kW power level.

RADIOGRAPHY SYSTEM CAPABILITY

Since the TREAT radiography system became operational 15 years ago, over six thousand radiographs have been taken. For a number of years it was the only neutron radiography facility at the INEL and has radiographed preirradiated fuel specimens from the Engineering Test Reactor, the Advanced Test Reactor, the Power Burst Facility, the Chalk River Reactor, the Experimental Breeder Reactor II, as well as TREAT experiments. Before the operation of the NRAD facility, TREAT was providing over 700 radiographs per year. Currently about one-tenth that number of radiographs are taken annually; TREAT's prime mission is the transient irradiation of liquid metal fast breeder reactor fuel experiments.

Small specimens, such as a single unirradiated fuel pin, are mounted on an aluminum support structure and positioned in the radiography facility without the use of a handling cask. TREAT experiments normally contain preirradiated fuel pins thus requiring the use of either one of two shielded handling casks. Preirradiated fuel specimens from other reactors also require the use of shielded shipping and handling casks. In some cases the shipping cask is also used as the handling cask. In other cases the specimens must be transferred from the shipping cask into a handling cask. Storage capability also exists using below-grade fuel-storage pits at the facility. When the storage is used, a number of specimens can be received or shipped over a period of time with a relatively large number of specimens radiographed during one day.

To accommodate eight different handling casks, steel adapter plates are used between the cask and the shielding enclosure. The adapter plates are approximately 1 m (3 ft) in diameter and position the casks so the specimen is properly positioned horizontally in the neutron beam. The various handling casks have specimen-elevation-indicating devices which permit proper vertical positioning. This feature is particularly important for specimens that are several meters long. The radiography facility is serviced by two different overhead bridge cranes. The maximum hook capacity being 54.4 t (60 T).

The most complex specimen radiographed to date was a preirradiated 37-pin assembly that required the removal of decay heat. Removal of the decay heat was required during transport to and from the ANL Hot Fuel Examination Facility as well as before, during, and after radiography at TREAT. The handling mechanism was further complicated by the need to rotationally align the assembly so that the rows of pins were aligned parallel to the neutron beam for six different rotational positions.

Recent modifications increased the shielding effectiveness of the U-shaped enclosure, replaced the below-grade tube so that longer and larger diameter specimens could be accommodated, replaced the foundation so that 54.4 t (60-T) casks could be set on the radiography enclosure, and installed a 54.4 t (60-T) crane.

REFERENCES

(1) FREUND, G. A., ELIAS, P., MACFARLANE, D. R., GEIR, J. D., and BOLAND, J. F., Design Summary Report on the Transient Reactor Test Facility, TREAT, ANL-6034, Argonne National Laboratory (1960).

(2) HARRISON, L. J., CONANT, R. M., and MOURING, R. W., Improvements in Neutron Radiography Equipment at TREAT, Proc. of 25th Conf. on Remote Systems Tech. (1977).

(3) TAYLOR, D. S., HARRISON, L. J., and WHITE, J. R., Neutron Radiography of a Grid-Type Subassembly, Proc. of 23rd Conf. on Remote Systems Tech. (1975).