A REPORT ON THE BEAM PORTS UTILIZATION OF THE TSING HUA OPEN POOL REACTOR

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ABSTRACT

Experiments utilizing The THOR beam ports are described. These experiments include:

a) fuel burnup determination by measuring the neutron age after collaiding with the bombarded elements,

b) determination of the thermal neutron spectrum by the chopper and time of flight technique,

c) capture gamma measurement,

d) ore analysis by the delayed neutron method and

e) fast neutron spectrum determination using a $^{6}Li_{3}$ neutron detector and the coincidence counting technique.

The Tsing Hua Open Pool Research Reactor (THOR) has been established in 1961 in the Republic of China. It has 6 beam ports and one through port. The beam ports are 6" in diameter and 8 ft in length, they are designated as E_1, E_2, E_3, W_1, W_2, and W_3, respectively.

The W_1 port has been used for nondestructive fuel burn up experiments[1] since 1967. A beam of neutrons of about 0.25 cm^2 cross section is collimated through a cement plug filling the port. A tank of water (or waterglass) is placed just in front of the port opening. A horizontal tube at the same height of the port is built into the tank so that the beam can be conducted right through the center of the tank. A rectangular tube is placed along the center line of the tank vertically. It crosses the horizontal tube at a right angle and it is lined with cadmium except where the beam meets the fuel element. A fuel element can be placed into this vertical tube and moved up and down so that different parts of the element can be exposed to the neutron beam.

The principle of this experiment is that fast neutrons from the beam port have a somehow higher Fermi age than those from the fission neutrons because they have interacted with the graphite reflector and the water. The thermal neutrons, while bombarding the fuel nuclei, will cause fissions. These interactions will in turn release fission neutrons which are of lower age than the neutrons from the beam port and are scattered into the tank medium. Thermal neutrons from the beam can not enter the tank medium because of the Cd lining. By comparing the distribution of the neutron slowing down density at 1.4 ev and that of the thermal neutron distribution due to a brand new fuel element and a used element, the fuel burnup can be calculated. The preliminary results from these experiments are fairly good.

The W-3 beam port has been used for measuring the thermal neutron spectrum as a standard student laboratory experiment [(2)]. The neutrons are conducted from the beam port by a collimator so that the beam cross section is about 1 cm^2. A high speed chopper with 10^4 rpm maximum speed is placed in front of the beam port, and a BF_3 counter is placed about 1 m away behind the chopper so that the thermal neutron beam is chopped into short pulses of about 50 μs widths with about 10000 μs separations. When the chopper is in operation, a triggering signal is produced each time when the cadmium sheets in the chopper are exactly parallel to the beam. These triggering signals are sent to a multichannel analyzer set-up for the time of flight measurement. The thermal neutrons from the burst made by the chopper consist of neutrons of various speeds but all flying toward the BF_3 counter. The BF_3 neutron counting output is fed into the analyzer thus neutrons with high speed will reach the counter earlier and be registered in the first few channels and those with low speed will be registered in the last ones. The system is set to work when the reactor is in full power. A collection of neutron counts for half an hour or so will result in a perfect Maxwell-Boltzmann distribution spectrum.

The E-3 beam port has been utilized in the past for capture gamma measurements [(3)]. A collimator with a hole about 1 cm^2 was inserted into the port. Proper shielding with paraffin and lead was placed to prevent stray gamma rays from interfering with the measurement. The neutron beam passed through a one meter long tube of 4 and 5 cms inner and outer diameter respectively. The space between the inner and outer diameter is filled with 6 LiF to prevent the scattered neutrons from reaching the detector. Fe and Pb targets were placed in the center of the tube and two 3" x 3" NaI (Tl) detectors were placed at a right angle 10 cm away from the target for coincidence counting. A TMC 256 channel analyzer was used to analyze the collected counts. The spectrum obtained was clear and satisfactory toward the high energy end from 6 Mev and up. Due to the poor resolution of the NaI(Tl) detector and the high Compton plateau, the overall data was considered rather poor. This could be improved by using a detector which has better resolution. The whole experimental system has been temporarily withheld due to lack of funds. It could be resumed whenever proper financial support is obtained.

The E_2 beam port was set up for analyzing minerals containing fissile and fissionable material by the delayed neutron method [4]; a pneumatic irradiation facility was built for this beam port. Containers containing prepared samples were sent to and withdrawn from the vicinity of the reactor core by a pneumatic system at the command of the experimenter. After exposing the sample to the reactor neutron radiation for a certain time, it was withdrawn. The sample, after the exposure, emits delayed neutrons if it contains fissile or fissionable elements. A bank of 6 BF_3 counters placed in a bulk of paraffin was designed for the neutron detection. For a sample with predetermined weight and a definite period of exposure, the amount of delayed neutrons detected determines the fissile material concentration of the mineral. Several years of operation proved that the system design was successful to accomplish our purpose. It is expected to obtain a more sophisticated facility, such as multiscaler, which will enable us not only to determine the concentration of the fissionable material but also to identify the proportion of existing isotopes. Neutron spectrum measurements of the beam from the E_1 beam port were performed [5]. A surface barrier lithium detector was used for this purpose. The reaction

$$ {}^{1}_{0}n + {}^{6}_{3}Li \longrightarrow {}^{4}_{2}He + {}^{3}_{1}H $$

was used for this measurement. The total energy of the products ${}^{4}_{2}He$ and ${}^{3}_{1}H$ was measured by coincidence counting of pulses caused by the alpha and the tritium particles in the detector. The energy is the sum of the energy released from the splitting of the compound nucleus ${}^{7}Li$ and that of the neutron. With the energy measurement and coincidence events collected from a TMC 400 channel analyzer, the spectrum of the neutrons from the beam port can be computed from the known cross section of ^{6}Li as a function of the neutron energy. Results of this experiment are given in reference [5].

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