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Today, I would like to provide for you an overview of results of recent neutron research projects that NRC has sponsored and a brief summary of ongoing and future research projects involving personnel neutron dosimetry and neutron measurement programs.

Newly Completed Research

In 1980 several studies were completed. The viewgraph (A) will provide you with report numbers and addresses for obtaining copies.

1) Subtask A of a large research program was conducted by Bill Endres et. al at Battelle Pacific Northwest Laboratory. Results of the study are published in NUREG/CR-1769. This study was sponsored

   a) to determine with available instruments the neutron energy spectra inside containment and any locations outside containment where workers might be exposed, and

   b) to measure the response of personnel dosimeters that are under development or currently in use at nuclear power plants in the U.S.

Neutron spectra measurements of dosimeter responses to exposures at six commercial nuclear plants were studied. (Five PWR's designed by 3 manufacturers and a BWR.) Results of neutron spectral measurement indicate average or effective neutron energies below 100 keV at all locations studied inside containment of pressurized water reactor (PWR) power plants. The neutron energies were somewhat higher near containment penetrations at a boiling water reactor (BWR) power plant. Neutron spectra were obtained using Bonner multisphere and ^{3}He proportional counter spectrometer systems. The ^{3}He proportional counter spectrometer was used to help define the spectra between 20 keV and 1 MeV more precisely. Most dose producing neutrons were found to have energies between 25 and 500 keV, averaging 50 to 100 keV at most locations inside PWR containment. The neutron energy spectra outside shield penetrations at the BWR plant were somewhat higher in energy; average energies fo 150 to 250 keV were determined with the Bonner multisphere spectrometer.

Dose-equivalent rates were determined at selected locations with a tissue equivalent proportional counter (TEPC) by analysis of event size or energy lost spectra. Quality factors, as currently defined, were determined from analysis of these spectra.

Dose-equivalent rates inside containment but outside various shield walls varied from 1 to 40 mrem/hr and increased to several rem/hr near the reactor cavity.

Dose-equivalent rates measured with ^{252}Cf or PuBe calibrated SNOOPY and RASCAL portable monitoring instruments were usually found to over-respond by a factor of 1.5 to 2.0 when compared to the dose equivalent rates determined by the multi-sphere spectrometer and the TEPC.

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This figure shows the spectra from a PWR taken with ^{3}H spectrometer. Initially this spectra looked suspicious, but we now believe that recent calculations which take into account the thick iron shielding will provide this spectra. This spectra is also very similar to the recently revised Hiroshima bomb spectra being reexamined by George Kerr at ORNL.

Dosimeters including NTA, polycarbonate film, CR-39 monomer film, and 3 designs of TLD-albedo dosimeters were placed on water phantoms at selected locations at each power plant in the reactor containment. The NTA film and polycarbonate track etch dosimeters failed to respond above the levels needed for positive indication of dose, which can be attributed to energy thresholds higher than the energies of most neutrons in the measured spectra. The NTA film did not record the exposure to neutron radiation even when the estimated dose equivalents were greater than 1 rem.

In this study, CR-39 showed no response to neutrons where the integrated dose equivalent was less than or equal to 100 mrem. At moderate exposures of 100 to 1000 mrem, the CR-39 indicated only 25% to 50% of the expected dose equivalent. Tracks in CR-39 film are etched by an electrochemical process which has not yet been perfected. At the present time, CR-39 does not appear to be an entirely satisfactory neutron dosimeter for reactor applications but many of the current problems may be corrected in the near future. The CR-39 track etch dosimeter also showed a low response (50% or less) when calibrated with an unmoderated ^{252}Cf neutron source.

All three types of TLD-albedo neutron dosimeters used in this study showed a high response to the neutron spectra inside reactor containment. All three types also required a spectral response correction to enable more accurate interpretation of exposure to neutrons. The TLD-albedo systems were found to be the only dosimeters with the required sensitivity for use as a personnel neutron dosimeter within the reactor containment spectra.

A forthcoming publication, NUREG/CR-2233, reports on efforts by National Bureau of Standards and by Battelle.

This report includes: 1) a discussion of dosimeter and remmeter calibrations performed using a D_2O moderated ^{252}Cf source. Use of the Cf source is recommended at power plants. 2) The threshold response of NTA film was investigated and found to be approximately 1.2 MeV although some response was indicated at 600 kev. It is therefore not recommended for use at reactors. 3) The edge effect created by placing the sensitive elements of albedo dosimeters close to the phantom edge is minimal if the sensitive elements are more than 7 cm from the phantom edge.

The later portion of the report examines performance of several types of neutron dosimeters to actual reactor spectra. The exposures were conducted at locations in one BWR and two PWR plants where the neutron spectra had been measured during previous studies. These measurements were essentially performed to examine the

response and precision of several types of neutron dosimeters. Dosimeters were exposed in sets of five, in most cases, to allow an accurate determination of the response. Albedo dosimeters generally were found to have a high response to the neutrons inside reactor containment; NTA and polycarbonate track etch films showed minimal response. Cr-39 monomer plastic showed some promise and is still under development.

Current Research

Current on-going research includes a continuation of the neutron dosimetry work at Battelle's PNL. Subtask B consists of measurements of the response of various neutron dosimeters to mono-energetic neutrons produced by a Van de Graaff generator. The neutron energy range is from 100 to 500 kev. Future exposures will also be conducted at the NBS reactor using filtered neutron beams with energies of 25 and 144 kev beams.

Future Research

Future research plans include:

1. Continuation of the neutron dosimetry project at Battelle. Subtask C will investigate more fully the ^{3}He spectrometer system which can be used by reactor health physicists to determine neutron spectra inside reactor containment. This will aid the plant health physicist 1) in the proper interpretation of personnel neutron dosimetry results 2) in determining changes in the neutron spectrum and 3) in evaluating the effectiveness of shielding changes after the plant is modified, for whatever reason.

2. Further work is also planned to more fully study the response of albedo and CR-39 dosimeters.

3. Another project which should be of interest to everyone will correlate the large amount of data obtained from neutron spectra and dose equivalent rates conducted by both PNL and the Environmental Measurements Laboratory (EML) at 16 nuclear power plants. While much of the data has been reported, it is not in a useful form and needs to be re-evaluated. This data should provide information on the relationships of the neutron spectra on: the ratio of 9" to 3" Bonner sphere responses; the neutron-gamma dose rate ratios; the personnel dosimeter response; and the monitoring instrument response.

4. Future work at NBS will examine the PNL and EML data to determine the best way of obtaining neutron dose equivalent data which will entail 1) investigating the best way to calibrate, and interpret the readings of a 9" spherical rem meter, and estimate the error inherent in this method 2) NBS will also examine the 9" to 3" sphere ratio to be used in obtaining a dosimeter calibration factor, and will measure other ratios. These will be compared with the measured dosimeter responses and the true dose equivalent to determine the dosimeter calibration factor as a function of sphere ratio. 3) Finally NBS will finalize the characterization of the ^{252}Cf source as an NBS standard neutron field to permit accurate calibration of instruments used in neutron fields.

At this time I will entertain questions.

NUREG/CR-1769

NUREG/CR-2233 (Available in August 1981)

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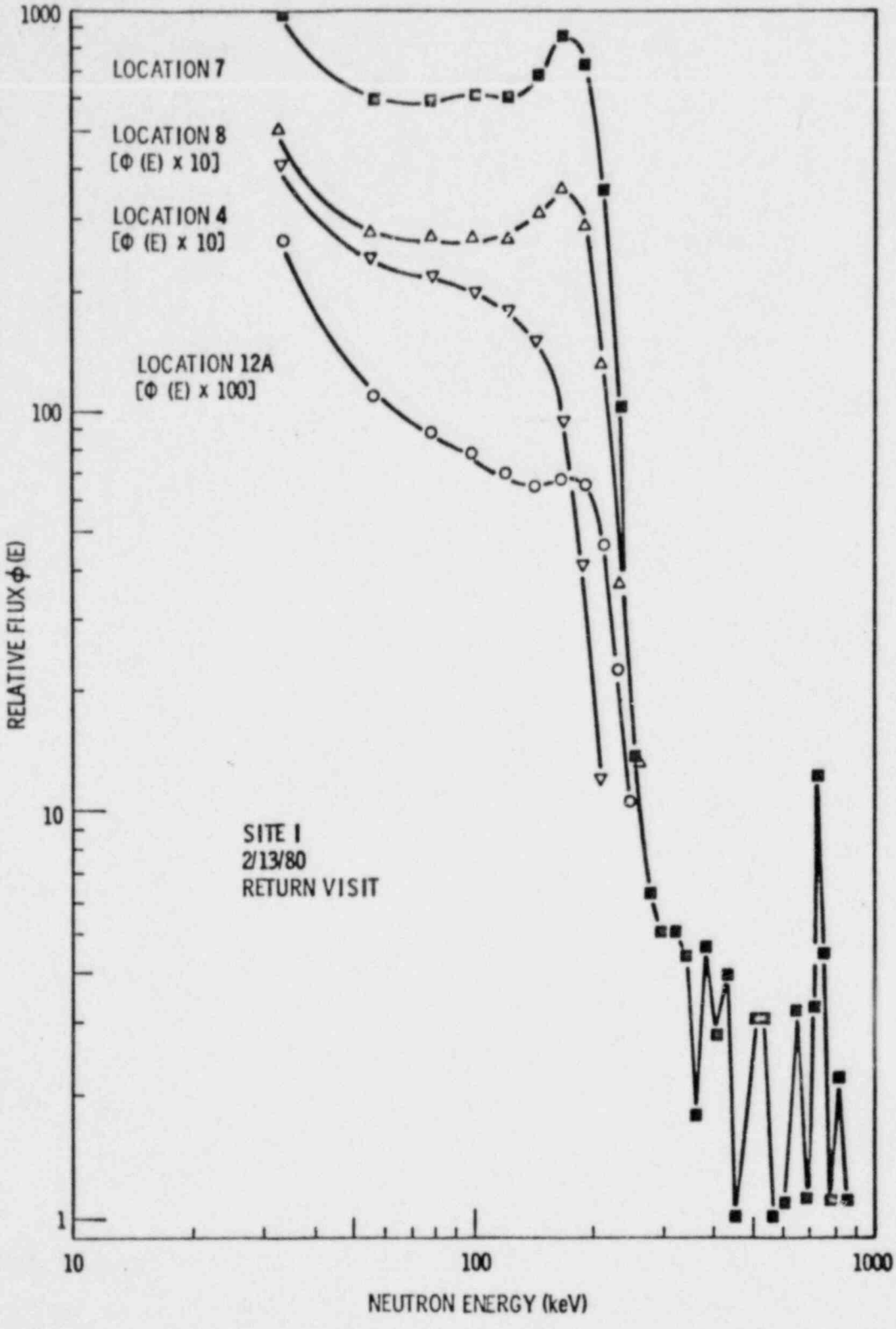

FIGURE 3.7. Neutron Energy Spectra Measured by the ^{3}He Spectrometer Inside the Containment Vessel of a Pressurized Water Reactor at Site I

 Viewgraph B