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Dose Rates from Neutron Activation of Fusion Reactor Components

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Although it is generally recognized that activation problems will result from several of the large fusion experiments now planned or under construction, it appears that such problems may have to be faced even before such experiments operate. This consequence follows from the fact that neutral-beam design must necessarily precede applications by several years. A forthcoming upgrade program at LBL will require prolonged periods of testing of a deuterium 170-keV neutral beam at 65 A with a 10% duty factor. On a cold self-loaded beam dump, such a beam would generate 3.3-MeV neutrons at an instantaneous rate\(^1\) of about \(7.8 \times 10^{12}\) neutrons per second. Such a source can produce appreciable dose rates for personnel who must do maintenance work following a prolonged period of testing. A survey of several U.S. laboratories determined that there was no code readily available which could easily be adapted to CDC computers, and which would calculate the required dose rates. Thus, a decision was made to construct such a code, using the most modern libraries of neutron-cross-section and radioisotope-decay data available. Our code ACDOSI has been written in ANSI FORTRAN IV in order to make it readily adaptable at other installations.

In neutral-beam development, periods of testing usually average a few hours, separated by intervals of several hours required for maintenance or overnight shutdowns. ACDOSI calculates the average neutron source strength during the test periods from data supplied by the user, consisting of the deuteron instantaneous current and energy, the duty factor during the test period, the length of the test periods, the length of the interval between tests, and the number of test periods.
The calculation is based on measured neutron-production rates from self-loaded targets\textsuperscript{1} for the $^2\text{H}(d,n)^3\text{He}$ reaction, plus a correction for deuteron energies differing from 150 keV. Alternatively, ACDOS\textsubscript{1} makes provision for the user to directly enter the average neutron source strength, for other than neutral-beam-source applications.

To calculate the activation rates, ACDOS\textsubscript{1} requires the target nuclides to be specified as to atomic number, mass number, and total mass in kg. ACDOS\textsubscript{1} treats the targets as homogeneous and neglects neutron attenuation in the targets. Required input data also include a set of group fluxes which are normalized to unit neutron source strength, and a list of the corresponding group boundaries. ACDOS\textsubscript{1} calls on the ACTL library of experimental neutron cross sections\textsuperscript{2}, with up to 12 different reactions listed for each target nuclide. ACTL supplies information on product identification and half life for both excited-state and ground-state product nuclides. ACDOS\textsubscript{1} singles out for consideration, all product nuclides with half lives greater than 1 second. For each such product, ACDOS\textsubscript{1} determines a continuous range of cross sections by linear interpolation between experimental points. Then, the interpolated values are used to calculate the average flux-weighted cross sections for each group and each reaction.

In order to calculate activities, ACDOS\textsubscript{1} requires a set of up to 10 time points measured from the end of the last test period. For each product nuclide, ACDOS\textsubscript{1} computes the group-produced activity, and then the total for all groups, at the end of the final test period. The latter is then used to determine the activities at the user-specified times, and the results are printed out for each product nuclide.

To calculate dose rates, ACDOS\textsubscript{1} requires information about a simple geometrical approximation to the actual target. The user may specify either a spherical shell, in terms of the inner and outer radii, and the distance to the surface; or a cylinder, in terms of the radius and height, and the distance on axis to the surface. ACDOS\textsubscript{1} ignores attenuation of radiation within either of these solid figures. In
order to determine the gamma or annihilation radiation produced by each product nuclide, ACDOS1 calls on the decay-mode library LEVDEC, which is based on the more detailed library ENSL. LEVDEC also supplies the identity of the daughter nuclide. ACDOS1 searches to see whether the daughter nuclide is radioactive, and if so, assumes that its decay products appear instantaneously following the decay of the parent. ACDOS1 then makes use of an analytic approximation to the dose-rate-per-unit-flux tables to compute dose rates for the fluxes corresponding to the particular geometry specified. The results are printed out, for each product nuclide and in total, as a function of the specific times following the final test period.

ACDOS1 has been applied to the computation of dose rates from various components of TFTR neutral-beam sources, such as the beam dumps, accelerator structure, cryopumps, deflection magnet, and beamline as a whole. An improved version of ACDOS1, known as ACDOS2, is now under development, and will remove many of the approximations made in ACDOS1. We are indebted to Robert J. Howerton of LLNL for supplying the ACTL and LEVDEC libraries, and for much additional valuable advice.

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