American Nuclear Society

WITHDRAWN

decay heat power in light water reactors

an American National Standard

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American National Standard for Decay Heat Power in Light Water Reactors

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American National Standard

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Foreword

(This Foreword is not a part of American National Standard for Decay Heat Power in Light Water Reactors, ANSI/ANS-5.1-1994.)

The ANS Nuclear Power Plant Standards Committee (NUPPSCO) approved a standard[1]* entitled "American National Standard for Decay Heat Power in Light Water Reactors" in October 1978. The standard was developed to fulfill a need for evaluations of fission reactor performance dependent upon knowledge of decay-heat power in the fuel elements. The standard replaced a 1971 Draft Standard[2] (see Appendix A).

Since the approval of the standard, new measurements of decay heat have been published.[3,4,5,6] In addition, improved nuclear data bases[7,8] have resulted in more precise summation calculations of decay heat. In 1991, comparisons of elements of the standard with results of the new measurements and the new summation calculations were published.[9] In that report, proposed improvements to the standard were outlined. Subsequent to this report, and in response to it, the tabular data in the tables entitled "Data for Standard Decay Heat Power" and associated uncertainties were reevaluated for the three fuel isotopes ^{235}U, ^{238}U, and ^{239}Pu, and evaluated for the fuel isotope ^{241}Pu. This revision thus includes the results of these new evaluations.

The revised standard is the same as the 1979 standard in that:

a. The standard prescribes fission product decay heat power and its uncertainty for reactor operating histories. Although the data adopted depend in part on the summation calculation method, the summation calculation itself is not chosen as the proposed standard.

b. The standard prescribes data that are applicable to Light Water Reactors (LWRs) of the type currently operating in the USA.

c. The standard prescribes the recoverable energy release rates from fission product decay but does not specify the spatial distribution of the deposition of the energy in reactor materials.

d. Decay heat power for ^{239}U and ^{239}Np are separately prescribed and are to be added to the fission product decay heat power.

e. In the standard, the uncertainty is expressed in a statistical sense as one standard deviation in a normal distribution.

f. The standard presents decay power for two irradiation conditions: (a) a fission pulse and (b) an irradiation of 10^{13} seconds to represent infinite reactor operation.

g. The effect of neutron capture in fission products during reactor operation is accounted for in the revised standard. An upper bound for the effect of neutron capture in fission products that provides conservative values of decay heat power is given for the case of a long operation of a ^{235}U fueled LWR at high neutron flux.

h. For cooling times greater than 10^5 seconds, the standard is based solely upon summation calculations.

i. The formulations are based upon the assumption that the energy release per fission during operation, Q_i, for each nuclide, is independent of time.

j. A method is prescribed for obtaining decay heat power for arbitrary reactor operating histories from the standard.

k. The decay heat power is related to the operating power of the reactor via the fission rate and the recoverable energy per fission during operation.

l. Decay heat power from activation products in reactor materials is not specified in the standard.

Features that distinguish the revised standard from the 1979 standard are:

a. The cooling-time region of validity has been extended to 10^{10} sec. In the 1979

* Numbers in parentheses refer to the Bibliography attached to this foreword.

standard the time region of validity was 10^9 sec.

b. Data are prescribed for decay heat power from fission products from fissioning of the major fissionable nuclides present in LWRs, i.e., ^{235}U, ^{239}Pu, and ^{241}Pu thermal, and ^{238}U fast, and methods are prescribed for evaluating the total fission product decay heat power from the data given for these specific fuel nuclides. The 1979 standard gave standard curves for ^{235}U and ^{239}Pu thermal, and ^{238}U fast.

c. The standard values adopted for ^{238}U are based upon an evaluation of new experimental data and summation calculations. In the 1979 standard, the values for ^{238}U were obtained solely from summation calculations.

d. The standard values adopted for ^{241}Pu are based upon evaluation of experimental data and summation calculations. The 1979 standard did not give a separate set of values and prescribed that ^{235}U values should be used for contributions from all other fissioning actinides other than ^{239}Pu and ^{238}U.

e. Standard values and uncertainties for pulse thermal fission ^{235}U have been revised for times after shutdown of 1.0, 1.5, and 2.0 sec, based upon a recently published evaluation by Tobias[10] of all available experimental data for ^{235}U. These changes involve increases of decay heat power of 16.2%, 8.0%, and 3.3%, respectively. Corresponding uncertainties have been reduced for these values from those given in the 1979 standard, also based on the Tobias evaluation.

f. Standard values and uncertainties for pulse thermal fission of ^{235}U have been revised for times after shutdown larger than 1.5×10^9 sec. These changes reflect improved nuclear data and uncertainties used in summation calculations for long-lived fission products, principally ^{99}Tc and ^{126}Sn.

g. Standard uncertainties for pulse thermal fission of ^{239}Pu have been revised for times after shutdown of 1.0, 1.5, 2.0, and between 20 and 15,000 sec, based on the Tobias evaluation[10] of all available experimental data for ^{239}Pu, as well as the excellent agreement of the experimental results of Akiyama et al.[5] with the results of Dickens et al.[3]

h. Standard values and uncertainties for pulse thermal fission of ^{239}Pu have been revised for times after shutdown greater than 5×10^9 sec, reflecting improved nuclear data and uncertainties used in summation calculations for long-lived fission products, principally ^{99}Tc and ^{126}Sn.

Since the evaluation of the literature performed by the ANS-5.1 Working Group leading to the 1979 version of the standard, some new publications have appeared that report additional experimental results, summation calculations, and evaluation efforts. Experimental results of Dickens et al.,[3] Baumung,[4] Akiyama et al.,[5] and Johansson[6] have been published. Tobias[10] has reported on results of least-squares analyses involving all data for ^{235}U and ^{239}Pu. New evaluations of fission-product yields[7] and nuclear data[8] have been utilized in summation calculations. Summation calculations by Ryman et al.[11] for long cooling times in support of a U.S. Nuclear Regulatory Commission Guide[12] on spent fuel storage are in good agreement with data predicted by the 1979 Standard; the Guide accepts the use of the 1979 Standard in its cooling-time region of validity. Isotope inventory codes[13] that use summation techniques to predict decay heat power have been subjected to a controlled intercomparison[14] and found to provide essentially equivalent results.

Comparisons of the 1979 Standard with recent measurements[4-6] and with three recent foreign decay heat power standards or proposed standards[15,16,17] have been presented by Dickens et al.[9] Dickens et al. made seven recommendations for near-term improvements to the standard; four are included in this revised standard. These four recommendations are:

a. For ^{235}U thermal fission standard, extension to 10^{10} sec.

b. For ^{239}Pu thermal fission standard, extension to 10^{10} sec and improved uncertainties.

c. For ^{238}U fast fission, revision of standard based upon a new evaluation of experimental and calculated data; extension to 10^{10} sec.

d. For ^{241}Pu thermal fission standard, a complete separate data set.

Further revisions of the standard are planned to:

a. Improve the capture effect specification.
b. Include contributions from actinides not already included.
c. Specify total recoverable energy Q for major elements.
d. Separate beta- and gamma-ray components.
e. Complete separate data sets for other fuel elements and other neutron energies.

Items a, b, and c were included in the recommendations for near-term improvements to the standard by Dickens et al.[9]

The formal presentation of the revised standard is the same as for the 1979 Standard, thus allowing ease in upgrading computer programs as requested by the users of the 1979 Standard.

Relationship to other standards

Fission-product yields and uncertainties used in summation calculations for the revised standard are consistent with ANS-19.8, "Standard Fission-product Yields for ^{235}U, ^{238}U, and ^{239}Pu" (in draft form).

The 1979 Standard ANSI/ANS-5.1[1] is superseded by the present revision.

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