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VENUS

A Two-Dimensional LMFBR Disassembly Computer Program

1. Name of Code: VENUS.[1]

2. Computer and Programming Language: Written in FORTRAN IV for the IBM 360/75 using the standard OS/360 system and FORTRAN H compiler.

3. Nature of Physical Problem Solved: VENUS computes the power, energy release, and space-time (r-z geometry) history of the temperature, pressure, density, and material motion of a liquid metal fast breeder reactor (LMFBR) during a disassembly excursion. Reactivity feedback due to Doppler broadening and motion of the reactor material is accounted for.

4. Method of Solution: The power and energy release are calculated using the point kinetics formulation of Kaganove with up to six delayed neutron groups.[2] The reactivity is a combination of an input driving function and feedback effects due to Doppler broadening and material motion. An adiabatic model is used to calculate the temperature increase throughout the reactor, based on an initial temperature distribution and power profile provided as input. These temperatures are, in turn, converted to fuel pressures via an energy dependent or energy-density dependent equation-of-state (EOS). In nonfueled regions, pressures are calculated by a simple compression model. The code is structured such that the user can readily add a new EOS if the EOS in the program is not applicable or suitable to the user's requirement. The material motion that results from the pressure buildup is calculated by a direct finite difference solution of a set of two-dimensional (r-z) hydrodynamics equations. This is done in Lagrangian coordinates using a modified version of Kolsky's[3] method. The reactivity change associated with this motion is calculated by first-order perturbation theory. The displacements are also used to adjust the fuel densities as required for the density dependent equation-of-state. An automatic time-step-size selection scheme is provided to control the numerical accuracy of the calculations.[4]

5. Restrictions on the Complexity of the Problem: The code is written so that the dimensions of the storage arrays can be readily changed to accommodate a broad range of problem sizes. In the base version, the total number of mesh points is restricted such that

$$(N_r + 3)(N_z + 3) < 700 \quad .$$

N_r and N_z are the total number of mesh intervals in the r and z directions. The total number of spatial regions used in the mockup is restricted to 20. The program requires about 375K bytes (4 bytes = short word, 8 bytes = long word) of storage with these restrictions. If the available storage is more than 375K, the above restrictions can be relaxed accordingly.

6. Typical Machine Time: The machine time is highly dependent on the nature of the excursion. Typical problems require from 3 to 15 min of IBM 360/75 CPU time, with some cases taking up to 30 min.

7. Unusual Features of the Code: VENUS has the following two distinct advantages over Bethe-Tait type analyses[5-8]:

   a. Because conservation of mass and momentum are explicitly taken into account in the VENUS program, the assumption that the pressure can be calculated by ignoring any change in density during an excursion used in Bethe-Tait type analyses is no longer needed. Since the density is computed explicitly as a function of time, an energy-density-dependent equation-of-state can be employed readily.

   b. The use of Lagrangian coordinates in the VENUS program provides detailed information on the motion of the reactor material during an excursion. This information is essential to the basic understanding of the mechanism of an accident and to the assessment of possible damage to the surrounding structures.

8. Related and Auxiliary Programs: Two auxiliary graphical output programs are available. One is designed for use with the IBM 2280,[9] and the other is for the S-C 4060.[10]

9. Status: In use.

10. Machine Requirements: The base version requires about 400K bytes of storage to execute on an IBM 360. One reason for the rather large storage requirements is that most of the data are stored in double precision. If the code was converted for use on a computer with a more accurate single-precision word size than the IBM 360, it should be possible to use single-precision storage. This would result in decreasing the word storage requirements by about 40%. One peripheral storage device is needed if the graphical output option is used.

11. Material Available: The code, documentation, and a sample problem are available from the Argonne Code Center at Argonne National Laboratory. The code and sample problem require about 3500 cards. For additional information, contact either William T. Sha, Argonne National Laboratory, Argonne, Illinois 60439, or J. F. Jackson, Argonne National Laboratory, Idaho Falls, Idaho 83401.

12. *Acknowledgment:* This work was performed under the auspices of the U.S. Atomic Energy Commission.

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