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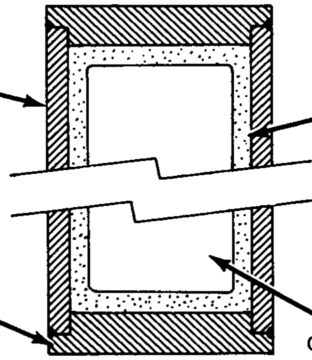
Fuel Element Concept for Long Life High Power Nuclear Reactors



It is possible to conservatively design nuclear reactor fuel elements with burnups that are an order of magnitude higher than can currently be achieved by conventional design practice. At the same time, these fuel elements have greater time-integrated power producing capacity per unit volume than has been achieved in the best conventional practice.

The proposed reactor fuel element design concept capitalizes on known design principles and previously observed behavior of nuclear fuel. The basic principles have been used in the design of various other fuel elements and tests have verified their validity. These principles and knowledge of behavior have not, however, been previously applied altogether in a fuel element design procedure.

This fuel element concept has the potential for: (a) increasing the operating life of reactor fuel, thus decreasing the operating cost of nuclear power plants; (b) increasing the power density of power reactors for a given core life with a consequent reduction in capital cost due to a more compact installation; and (c) making possible very compact high power long life reactors for mobile reactors where minimization of shield weight is important.

The life of almost all high power long life reactors is limited by the life of the fuel elements. The lifetime of fuel elements is generally limited by failure due to swelling of the fuel material or release of fission gases which generate high pressures within the fuel. The swelled fuel or high fission gas pressure then causes excessive growth or rupture of the fuel-clad material. In practice, excessive growth or rupture occurs when fuel burnup (in atoms fissured per heavy atoms present) reaches 1 to 3 percent.

The proposed fuel element design concept is simply a tube sealed at both ends that contains a layer of fuel and a large void space as shown in the figure. The fuel coats the inside surface of the tube with a layer that is thin enough so that it cannot exert significant forces on the tube due to thermal expansion or swelling. The only major force that the tube experiences is that due to the difference in pressure across the tube wall.

(continued overleaf)

The large void volume allows room for fission product gases that escape from the fuel. The burnup limit of the fuel element is determined when the tube can no longer contain the pressure that is built up by the fission gases. The larger the void volume fraction and the stronger the tube wall, the higher the burnup limit.

An important feature of the design is that it permits vapor fuel transport. By design, the fuel thickness for any particular application is selected to produce an inside fuel surface temperature high enough to yield significant vapor pressure. The inside fuel surface will therefore tend toward operation at a constant temperature independent of all operating conditions external to the fuel. Hot spots in the fuel, for example, are automatically eleminated by fuel vaporization from the hot zone. Likewise, cold spots are eliminated by selective condensation of fuel vapor onto the cold regions. The equilibrium fuel thickness distribution automatically reverts to that which produces a uniform inside fuel surface temperature. Elimination of hot spots means greater safety margins or increased fuel reliability and life.

Fuel vapor transport also results in lower fission gas pressure because the fission products are uniformly distributed over the entire fuel element length. The gas pressure is therefore the average pressure regardless of the burnup distribution along the length of the fuel. This increases fuel element life.

An additional feature is that the control of nuclear reactors using this fuel element concept may be simplified. Reactor fuel tends to be used up in the center portion of the pin at a more rapid rate than at the ends. The change in reactivity due to fuel usage must be compensated for by a control system. The vapor transport phenomena used in this concept moves fuel from the ends to the center to replace the used up fuel. This then reduces the reactivity change and hence less control system compensation is required. In addition, for any given allowable reactivity change over the lifetime of a reactor, the vapor transport fuel element will allow longer reactor life.

Notes:

1. The proposed fuel element design concept can be applied to any tube material, fuel, and fuel form.
2. Documentation is available from:
   Clearinghouse for Federal Scientific
   and Technical Information
   Springfield, Virginia 22151
   Price $3.00
   Reference: TSP69-10154
3. Technical questions may be directed to:
   Technology Utilization Officer
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Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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