Fig. 1. Conceivably the lower values of specimens 1, 2, 11 and 12 can be accounted for on the basis of lower flux and lower burnup. If so, these specimens indicate that alloy content has little effect on growth rate.

Results of the experiment are inconclusive insofar as correlating chromium level, orientation, or mechanical or physical properties with irradiation induced dimensional instability. All preferredly oriented specimens increased in length; these increases ranged from 2 to 17 per cent. Nominal to relatively severe warping was observed. The surfaces of the preferredly oriented specimens were consistently smooth. Chromium additions do not appear to improve dimensional stability. Because of inaccuracies in flux measurements, it cannot be concluded that such additions have a deleterious effect on stability.

It is possible that limited changes in orientation, specimen temperature, flux level or, conceivably, composition have much more marked effects than anticipated. If this is the case, substantially more work must be done in controlling these variables. Pole figure X-ray data rather than "rho" values should be used; a more precise measurement of flux is required; and differences in flux level must be minimized. Only through such control will it be possible validly to evaluate composition effects.

Obviously, on the basis of the results obtained it is futile to advance a mechanism to explain the growth. The experiment was not sufficiently controlled to explain the results by twinning, diffusion or dislocation mechanisms.

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High Flux Reactors

The need for intense neutron sources for nuclear research has led to the construction of a large number of research reactors both in the United States and abroad. Several of the older reactors such as Bepo and the Brookhaven National Laboratory reactor are still in constant use, their low power density being compensated by large working volume and ease of operation. The swing in the opposite direction which started with the MTR concept has produced a number of small, high power density reactors used for both basic and applied research. Experience with the MTR has shown the need for greater working volume for engineering research. Only where the size of experimental equipment can be drastically limited can volume be sacrificed for higher flux. Thus, restrictions on volume can still be tolerated in a reactor designed exclusively for specified basic research experiments.

Criteria for the design of research reactors vary with energy spectrum requirements. Access to the fission spectrum in the reactor core is desirable for solid state physics experiments and here power density is the prime criterion. At lower energies, the strength of the neutron flux depends upon the ratio of power density to the slowing down power of the core. In a choice between equal coolants such as D_2O or H_2O, D_2O would obviously be the one chosen in this case.

The thermal neutron flux in a small reactor is that available in the reflector, since access to the core is difficult. The intensity of the thermal flux in the reflector depends primarily on the power output of the core. The choice of reflector is governed by core size. Ordinary water yields the greatest flux peak for neutron sources up to several inches in diameter but for high power reactors water is inferior to such reflectors as beryllium, graphite or heavy water. With increase in core size, the low absorption cross section of D_2O wins out over the smaller migration length of other moderators. This advantage is easily lost, however, if a D_2O reflector is overloaded with neutron absorbers and large beam holes.

Because of engineering problems associated with other reactor types, the heterogeneous D_2O or H_2O cooled system has invariably been the choice for high power density research reactors. It should be pointed out, however, that higher power density and lower slowing down power could be obtained with liquid metal coolants. Existing research reactors are well thermalized and generally of low critical mass although thermalization increases its xenon problems and the low mass increases fuel burn-up problems. Studies of nonthermal, heterogeneous, D_2O cooled reactors conducted at the Brookhaven National Laboratory indicate considerable advantage in this reactor concept.

Limitations on power density make it both difficult and costly to obtain steady neutron flux greater than 10^{15} neutrons/cm^2 sec. Higher flux can, however, be obtained for short intervals of time in uncooled reactors. In a water boiler reactor, for example, an integrated power density of about 0.3 Mw sec/liter is required to bring the core to its boiling point. In a neutron pulse lasting 1 sec the power density is already equal to that of the MTR, and the neutron flux could be greatly exceeded in shorter bursts. Integrated power density might reach 2 Mw sec/liter in a reactor core which could withstand a 1000°C rise in temperature.

The feasibility of pulsed reactors has been demonstrated for water moderated systems by the long series of experiments on BORAX, SPERT and KEWB. The homogeneous, graphite moderated system has been under consideration for kinetic experiments at the Argonne National Laboratory. Although the pulsed reactor has not yet been used as a basic research tool, it has some unique advantages for studies of nuclear reactions and radiation damage effects at high flux levels.

A pulsed D_2O water boiler would be particularly attractive for basic research work. A dilute solution of enriched uranium in a 1000 ft^3 tank of D_2O could sustain a pulse of 10^4 Mw sec and require as little as 3 kg of U^{235} for criticality. In this case, the integrated thermal flux in the core would reach 10^{17} neutrons/cm^2 during a single pulse. Thermal fluxes ranging from 10^{13} to 10^{17} neutrons/cm^2 sec could be obtained in a controlled neutron pulse lasting from 10^4 sec to 1 sec, respectively.

A possible high intensity source of neutrons which has not yet been effectively tapped is the delayed neutron precursors produced in thermal fission of U^{235} or fast fission of U^{238}. These fission products are inaccessible in solid fuel reactors but become available in bulk in liquid fuels and possibly in porous high temperature solid fuels. Delayed neutrons are produced at lower energies than prompt neutrons, which can be an advantage. Neutron densities possible depend on the energy release in prompt short range particles per delayed neutron. Although the absolute yield, decay scheme and even the identification of most of the delayed neutron precursors are not yet adequately established, it is clear that the precursors of 2, 6 or 22 sec half-life hold particular promise as small, high power density neutron sources.

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