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LOS ALAMOS SCIENTIFIC LABORATORY
OF THE UNIVERSITY OF CALIFORNIA • LOS ALAMOS NEW MEXICO

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QUARTERLY STATUS REPORT OF THE LASL
PLASMA THERMOCOUPLE DEVELOPMENT PROGRAM
FOR PERIOD ENDING MARCH 20, 1962
(Title Unclassified)

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APPLICATION-REACTOR EXPERIMENTS
(M-3679, 25th Ed.)

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IN-PILE EXPERIMENTS

Multiple Pin Cell

An experimental cell designed to study pin behavior over a long period and over a range of neutron fluxes has been constructed by utilizing an assembly of five $(\text{UC})_{0.3}(\text{ZrC})_{0.7}$ fuel pins arranged in series in nickel collector-pin base combinations. A threaded section on the nickel parts holds the individual components together to form a rod. There are no insulators, and the pins are shorted to the collector through the pin base. The series assembly rod is tightly fit with an aluminum sleeve which is capped at one end and opened to a large gas reservoir at the other. During the final stage of assembly, after bake out, approximately 10 torr of argon gas was introduced into the cell. The entire assembly is about 4 ft long and there are no connections to the reactor top.

There is no cesium in the multiple pin cell, and the argon filling is intended to retard pin evaporation in the same manner that cesium would. It is planned to leave the cell in the core for at least 1000 hr. After the irradiation time, the cell will be disassembled in the hot cell facility. Data concerning evaporation rates, changes in physical size, gas evolution, etc., should be obtained. Since the five pins in the assembly are located in different neutron flux regions, the data obtained will cover a wide range of environmental conditions.

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Calibration Run

Since there have been several minor changes in the vacuum environment cell, a re-run was made of an instrumental calibration mockup of this arrangement. Several cells have been run in the reactor since the calibration run of August 1961, including two cells which ran over 250 hr each. The calibration re-run, however, gave collector temperature markedly different from the August run. The γ -flux determinations are in fair agreement as measured by the cesium pod temperatures. The considerable difference in collector temperatures are not explained by the minor design changes since the August run. The γ -heating is negligible compared to the fission heating of the fuel pin so that the data indicate a substantial difference in the fission rates in the pins in the two experiments.

Close Spacing Cell

The electrically heated close spacing (or variable spacing) cell, referred to in LAMS-2658, p. 4, has been assembled (Fig. 1) and baking out is in progress. In addition to the features already described, others have been incorporated. A small sight-hole has been bored into the side of the emitter button so that reliable emitter temperatures can be obtained by pyrometric observation. The heat flow to the collector can be measured by two thermocouples placed at different depths in the solid portion of the collector, thus permitting estimates of cell efficiency to be made. The Ta emitter button has been sprayed with a layer of W about 5 mils thick. A side tube containing glass-encapsulated CsF has been added so that a comparison between W-Cs and W-CsF-Cs cell characteristics can be obtained. Heating (and cooling) of the cell body is accomplished primarily by passing hot silicone oil through tubes either brazed or welded to the cell body.

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Fig. 1. Close (Variable) Spacing Cell

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PLASMA THERMOCOUPLE CRITICAL ASSEMBLY

Construction has been completed of the Plasma Thermocouple Critical Assembly (PTCA), which includes 445 fuel elements and electrical controls for remote operation.

An outer stainless steel tube serves as a water-tight well for each element, and is secured to the fuel matrix base plate. The inner section is assembled as a unit, and is removable to facilitate loading of the Oy wires. Flexibility in the reactor core is therefore provided by the capability of varying the number and arrangement of fuel elements, and changing the fuel loading in each element. Twelve rotary drums with cadmium vanes located on the periphery of the core will be used for reactivity control and safety. Remote assembly of PTCA will be accomplished on Super Comet which is now wired and ready for installation in the Kiva.

PLASMA THERMOCOUPLE REACTOR CALCULATIONS

A parametric survey has been made of the characteristics of fast reactor systems in which the fuel elements consist of plasma thermocouple cells stacked end-to-end. The cells are assumed to be roughly similar to those currently in use for "in-pile" tests. It is postulated that the fuel elements are arranged in a hexagonal lattice, to form a cylindrical core, with coolant (NaK) flowing between the elements. There is no internal moderator in the system. Two types of emitter (fuel) pins have been considered: (a) carbide pins, consisting of 50 w/o ZrC and 50 w/o UC (93% enriched), and (b) metal pins, consisting of 58.4 w/o Mo and 41.6 w/o UO_2 (93% enriched). The pin diameters varied from 0.25 to 2 in. and the lengths from 1 to 18 in.; the postulated cesium gap was 0.040 in. Neutronic calculations have been made both for bare and reflected systems.

The critical mass of U^{235} and the corresponding total mass were found to decrease markedly with increasing fuel pin diameter; the values were also smaller for the carbide than for metal pins, since the former contain a larger proportion of U^{235} . The maximum practical pin diameter is limited by

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thermal conductivity effects, but there appears to be little neutronic advantage to be gained by going beyond 2 in. However, both the core mass and fuel mass in a bare reactor can be decreased in various other ways, e.g., by increasing the proportion of U^{235} in the fuel pins, decreasing the cross sectional area of the coolant channels, etc.

If a reflector of high density is used, there is no significant reduction in the total mass, but a reflector of low density, e.g., beryllium, produces a marked decrease in both total mass and mass of U^{235} . The optimum reflector thickness is related inversely to the pin diameter. The chief drawback to the reflected systems studied so far is the large ratio (about 3 or more to 1) between the maximum and minimum fission densities. The fission rates are high in the outer regions of the core because of the presence of thermalized neutrons returning from the reflector. A decrease in the proportion of fuel material near the edge is not sufficient to produce any great improvement in the fission density ratio and other methods, e.g., use of poisons, are being considered.

CESIUM PLASMA STUDIES

Electrical Resistivity

Measurements have been made of the electrical resistance of a cesium plasma at various plate temperatures and cesium pressures; from the data, the resistivity of the plasma was calculated. After applying a correction for the electron-ion contribution to the resistivity -- about 30% at 1880°K and less than 10% at lower temperatures -- the results were normalized to a pressure of 1 torr, by dividing by the square root of the cesium pressure. The electron-neutral contribution to the resistivity was thus found to range from 3.5×10^3 ohm-cm at 1120°K to 1.5 ohm-cm at 1880°K. By assuming that the electron-neutral conductivity can be expressed by the Chapman-Cowling equation, the ion-neutral collision cross section was determined as a function of temperature averaged over a Maxwellian distribution.

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Spectroscopic Studies

A window cell with a UC-ZrC emitter was built for the purpose of making a systematic study of the plasma spectrum in terms of the cell operating conditions. Because of difficulties experienced with the emitter, resulting in the introduction of debris into the cell (see page 8), no attempt was made at a detailed study with this cell. Instead, a further measurement of widths of plasma broadened lines was made, extending the range of 5×10^{13} to 3.3×10^{14} ions/cm³ covered previously up to 2×10^{15} ions/cm³. New results include lines of the sharp and diffuse series and constitute the first comparison of experiment and Griem's theory. Measured widths of the fundamental series lines were compared with Stone's theory which is already well-established. The measured ion density, obtained from an analysis of the radiative recombination continuum, was 1.87×10^{15} ions/cm³. For plasma conditions considered here, the line widths are expected to be directly proportional to ion density and insensitive to electron temperature.

FABRICATION STUDIES

Bonding of UC-ZrC Fuel Pins

A continuing problem exists in bonding UC-ZrC pins to the metal support known as a shoe. Shoes of molybdenum and niobium have been used, but delayed breakage has given considerable trouble in diagnosis. Initial evaluation indicated that brittleness in the bond diffusion region for Nb-Zr-UC:ZrC bonds as a source of trouble while Mo-Zr-UC:ZrC bonds with relatively thick diffusion regions appear to be more ductile and can accommodate the difference of expansion coefficients in molybdenum and UC:ZrC. Microhardness tests have shown that with niobium shoes the hardness of the bond is appreciably greater than with molybdenum. This difference probably accounts for the fact that thick bonds can be made with molybdenum at 2100°C which are less susceptible to cracking. Such bonds are difficult to fabricate and great care must be taken to cut the temperature just when the bond makes. Since 2100°C is well above the eutectic, complete disintegration occurs in a matter of seconds.

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Failure of UC-ZrC Emitters

Since frequent failures have occurred with UC-ZrC emitters made by pressing a mixture of UC and ZrC powder into a serrated tantalum disc, the problem has been subjected to a detailed study. It was found that considerable amounts of TaC were formed in the tantalum disc, presumably by tantalum reducing UC. The serrations near the edge of the disc were almost completely carbided, while those in the center were believed to have been both carbided and dissolved in the UC-ZrC. The operating temperature of the emitter, approximately 1900°C , is above the melting point of uranium but not above that of the carbides. It appears that the tantalum reduced the UC and the resulting uranium then melted and dropped onto the collector. The tantalum disc failed because of the formation of TaC which is brittle.

Metallized Ceramics

An evaluation has been completed of Al_2O_3 insulators which had been metallized by high-voltage nickel ion bombardment. The nickel thickness was about 10^{-5} in. when received. In several samples, the nickel thickness was increased by electrochemical deposition. Attempts were made to determine if these nickel coated ceramics could be brazed to nickel assemblies, using a copper-silver braze, with the objective of utilizing the procedure to make leak-tight joints. In all cases, however, it was found that the braze material penetrated beneath the nickel metallizing layer, so that there was no bonding to the ceramic.

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