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STUDIES OF THERMIONIC MATERIALS FOR SPACE POWER APPLICATIONS. Dec 63.

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STUDIES OF THERMIONIC MATERIALS
FOR SPACE POWER APPLICATIONS

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Contract NAS 3-4165

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Work done by

Members of the Thermionic
Direct Conversion Group and
the Fission Product Heat Group

The work carried out under Contract NAS 3-4115 during December, 1963 is summarized as follows:

1. Fabrication Development

1.1 UC-ZrC Fuels

Isostatic Pressing Development

Isostatic pressing has been developed to a point where pressing UC-ZrC cylinders of any desired L/D ratio to uniform density and pore distribution is a routine practice. To demonstrate the versatility of the method, other shapes, such as tubes, thimbles, and spheres, were pressed and sintered from tungsten and UC-ZrC powders. Success was attained in producing bodies of each of the above shapes. The most difficult part was the design of the isostatic mold to prevent spring back of the mold from damaging the pressed part and to allow easy filling of the mold.

Also, machining of 0.55 in. x 1.55 in. x 1.1 in. slabs (or more properly "slivers") from isostatically pressed 90UC-10ZrC bodies for a 2°/o heat emitter showed that these specimens were much less prone to breakage during machining than those previously prepared by ordinary cold-pressing techniques.

Pore Control in UC-ZrC Fuel Specimens

Prior to this reporting period, studies in controlling the pore structure of UC-ZrC have been of an exploratory nature in attempting to get a handle on which particle size fraction gives a fast acting, stable open pore type structure. This month, based on results previously overseen and the above improvements in isostatic pressing, a more systematic approach to planning for a given pore structure, namely, the accessible pore area for optimum fission gas release has been started.

A study was begun to determine what effect particle size has on the resulting density and true surface area of isostatically pressed and sintered UC-ZrC specimens of 90UC-10ZrC and 50UC-50ZrC fabricated under identical conditions except for particle size and proportions (using four different powder fractions) are now being fabricated for surface area evaluations. In the table below is a brief summary of specimens of each UC-ZrC compositions which have been prepared and evaluated to date. All of the specimens listed were isostatically pressed (30,000 psi) and sintered at 1900°C. The specimens were characterized by BET measurements and by microscopic examinations.

Table 1-1

| Particle Size | Sintered Density | Roughness Factor determined by BET* |
|---|---|---|
| -65μ/+50μ | | ~50 |
| -44μ/+20μ | | ~110 |
| -44μ/+10μ | | ~160 |

*Roughness factor is the ratio of true surface area to geometric area.

Specimens of 90UC-10ZrC composition are currently being prepared of -44μ/+20μ powder fraction. Sintering will be otherwise made exactly as the specimens listed above. Density and pore area determinations will be made and compared with the above. It is hoped that the -44μ/+20μ powder fraction will result in specimens having a density in the neighborhood of 92% with a more favorable pore distribution.

A BET roughness factor measurement was also made on a 90UC-10ZrC specimen prepared from -44μ/+10μ powder fraction by isostatic pressing and sintering at 2000°C. The sintered density was 91% T.D. The BET roughness factor was measured to be ~270. Specimens of 90UC-10ZrC composition will also be prepared using fabrication exactly the same as for the above specimen.

nitrogen temperature) [illegible] indicated by the fact that the surface area of sample $A_1$-1 is so small that the BET Kr adsorption has been proved to be inadequate. Mercury porosimetry and microstructure examination of sample $A_1$-1 will follow the measurement of its surface area.

Sample $A_1$-2 is [illegible] for the determination of its vacuum rates of vaporizati

To the determination of the true surface area of samples $A_1$-2, $A_1$-3, $A_1$-4 and $A_2$-1 two methods have been followed to deduce the true surface area of these samples from the adsorption results. The first is to take the amount of Kr atoms adsorbed at the point where the adsorption curve changes to a straight line as that for monolayer adsorption (see Fig. [illegible]). In the other method [illegible] is to plot $\left[\frac{p}{p_0}\right]$ versus $\frac{p}{p_0}$ and to evaluate the amount of

$$\left[v\left(1-\frac{p}{p_0}\right)\right]$$

[illegible] adsorption [illegible] and then [illegible] surface [illegible] of [illegible] at [illegible] temperature. [illegible] the two methods agree fairly well for [illegible] other. The true surface areas of these samples, expressed in [illegible] represent [illegible] of the data derived by these two methods.

[illegible] this [illegible] on the sintered toughness [illegible] samples [illegible] appreciably [illegible] although the [illegible] $A_1$-1 [illegible] than that of $A_1$-2 [illegible] set. It is possible that these samples may [illegible] even though their densities are different. [illegible] these samples may provide an answer. Such studies will be made after determination of the vaporization rates of these samples.

to the [illegible]-70ZrO2 samples listed in Table [illegible] were [illegible] quantities are being prepared for similar [illegible]

Fractional Fission Product Release from UO2-ZrO2

[illegible] measurements[1] of the release of $Xe^{133}$, $I^{131}$, $Te^{132}$ and [illegible] in the hot-pressed high density (~[illegible] bonus) 30UO2-70ZrO2 at 1600°C and $A_1$-3 at 1900°C.

[illegible] measurements have been made on sample $A_2$-2 at 1400°C. [illegible] hot-pressed and sintered 30UO2-70ZrO2 [illegible] irradiated to $10^{19}$ fissions/cm³. $A_2$-2 was thermally stabilized at 2000°C for a period of 20 hours and has a specific surface area of 0.5 cm²/gm and a surface roughness factor of 236 (see Table 2-1). The analyzed composition is 29.38%UO2-70.62%ZrO2. The release data are shown in Table 2-2 and [illegible]

The [illegible] in Table 2-2 can be summarized as follows:

[illegible] the overall release and the total release for sample $A_2$-2 is [illegible] higher than that of the more dense samples $A_1$-2 and $A_2$-3. At the end of 98 hours at 1600°C, the $Xe^{133}$, $I^{131}$, $Te^{132}$ and $Ba^{140}$ released are about 50%, 60%, 65% and 8% respectively, as compared to 0.2 - [illegible] for sample $A_1$-2 at the same temperature in 96.5 hours. [illegible] a large part of the release [illegible] the first 2.0 hours. For [illegible] of burst[illegible] [illegible] the [illegible] sample $A_2$-2 [illegible] the [illegible] [illegible] release data were [illegible] the basis [illegible] [illegible] burst of xenon gas [illegible] the [illegible] [illegible] released by a true diffusional process. The equation for fractional release





[illegible]

$$\frac{D}{a^2} = \frac{}{}$$

where [illegible] = fraction [illegible] in the particle

$D' = D/a^2$

D = [illegible]

a = the effective radius of the [illegible] UO2-ZrO2 [illegible]

[illegible] make up the [illegible] $\frac{}{}$

where [illegible] density of sample in terms of fraction of theoretical density, and S = true surface area of sample in [illegible]

t = time of annealing, at [illegible]

This equation represents Fick's law of [illegible] quite accurately from an assumption of [illegible] for radius at [illegible] an initially uniform concentration [illegible] [illegible] at [illegible] $(D')(t) \leq 0.03$

| [illegible] | [illegible] | [illegible] |
|---|---|---|
| 2.75 | [illegible] | [illegible] |
| 40 | [illegible] | [illegible] |
| 46 | [illegible] | [illegible] |
| 72 | [illegible] | [illegible] |
| 98 | [illegible] | [illegible] |

$$\sqrt{[illegible]}$$

[illegible] [illegible] constituent for $Xe^{133}$ in [illegible] [illegible] shown and S/V [illegible] available for the diffusional [illegible]

[illegible] 1600°C, [illegible]

$$[illegible] = [illegible] \left(\frac{10}{[illegible]}\right)$$