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ORNL-TM-309

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## PREPARATION OF STOICHIOMETRIC URANIUM MONOCARBIDE CYLINDERS

D.T. Bourgette

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ORNL-TM-309

Contract No. W-7405-eng-26

METALS AND CERAMICS DIVISION

PREPARATION OF STOICHIOMETRIC URANIUM MONOCARBIDE CYLINDERS

D. T. Bourgette

Date Issued

001 - 4 1952

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Oak Ridge, Tennessee  
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## PREPARATION OF STOICHIOMETRIC URANIUM MONOCARBIDE CYLINDERS

D. T. Bourgette

### ABSTRACT

Employing a modified arc-melting technique, homogeneous cylinders of stoichiometric uranium monocarbide were consistently produced. The cylinders ranged in size from 0.25-in. diam by 1 in. long to 0.375-in. diam by 3 in. long. The top 10% of nearly all cylinders did, however, contain shrinkage voids that could not be eliminated. Uranium monocarbide buttons previously prepared by arc melting the elements were placed over a graphite-mold cavity, but in contact with copper in an argon-atmosphere arc furnace. When the uranium monocarbide charge became fully molten, it dropped into the cavity and solidified instantaneously. The measured densities of the arc-cast cylinders were 99.8% of theoretical with compositional limits of  $\pm 30$  ppm C.

The motivation for initiating this study was the need for pure stoichiometric uranium monocarbide radiation specimens and also the need for nonstoichiometric specimens containing controlled carbon concentrations. Therefore, throughout this study emphasis was placed on purity control of the starting material and furnace atmosphere, rate of power consumption, accuracy of weighing procedures, and arc-melting procedures. Variations in either of these preparational steps would result in an undesirable product.

## INTRODUCTION

Increased fuel temperatures and long-life fuel elements are economic advantages which predicate the continuing search for improved fuel materials. In addition, the obvious properties which are desired in a reactor fuel are dimensional and physical stability under irradiation, high uranium density, and high thermal conductivity. Further, the ability of the material to be readily fabricated into a form suitable for reactor application must be demonstrated. The Oak Ridge National Laboratory (ORNL) shares these interests in the evaluation of uranium carbides for use as a high-temperature reactor fuel.

Fuel materials used in present day reactors possess acceptable qualities for this particular application. Unalloyed uranium, uranium alloys,  $UO_2$ , and  $U_3O_8$  are being used with varying degrees of success. In all cases, however, an economic advantage would be realized if the fuel material could be operated at higher temperatures and for greater periods of time between replacement. Uranium monocarbide, a potential fuel material, offers considerable promise in meeting these requirements. In addition to its high uranium density, it is refractory, possesses good thermal conductivity,<sup>1</sup> and has a face-centered cubic structure<sup>2</sup> which theoretically is capable of offering resistance to radiation damage. Despite these advantages, there are several problems to the preparation and use of this compound as a nuclear fuel.

Although uranium carbides can be arc melted,<sup>3</sup> the author found that the stoichiometric composition (U-4.800 wt % C) was difficult to prepare because of its narrow composition limits and the time dependency of the carbon going into liquid solution. Further, uranium monocarbide reacts catastrophically with water or moisture in the

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<sup>1</sup>C. A. Smith and F. A. Rough, Properties of Uranium Monocarbide, NAA-SR-3625, p 12 (June 1, 1959).

<sup>2</sup>H. A. Saller and F. A. Rough, Compilation of U.S. and U. K. Uranium and Thorium Constitution Diagrams, BMI-1000, p 20 (June 1, 1955).

<sup>3</sup>R. J. Gray, W. C. Thurber, and C. K. H. DuBose, Preparation and Metallography of Arc-Melted Uranium Carbides, ORNL-2446 (December 27, 1957).

atmosphere,<sup>4</sup> and therefore, subsequent fabrication of fuel elements would present added handling problems. Before the potential of a suggested reactor fuel can be fully evaluated, there are a number of material properties that must be determined in addition to problems of inspection and handling. For the past two years investigators have been concerned with the preparation, physical- and mechanical-properties determination, and irradiation behavior of both the arc-cast uranium carbides and carbides prepared by powder metallurgy techniques.<sup>5</sup> However, the scope of the fuel element development program required the availability of crack-free, high-purity stoichiometric uranium monocarbide in shapes amenable to radiation and property determination studies. Therefore, using an arc-casting technique similar to the one developed at Battelle Memorial Institute,<sup>6</sup> a program with the objective of supplying the above mentioned uranium monocarbide shapes was initiated.

#### DEVELOPMENT WORK

##### Preparation of the Melting Stock

Freshly pickled uranium derby metal was nonconsumably arc melted a number of times and hot rolled from a salt bath at 750°C. The metal was then sheared, pickled in acid, and used as alloying stock with spectrographic carbon. Complete analysis of the alloying stock is given in Appendix A. Prearc melting with a water-cooled, tungsten-tip electrode improved the purity of the uranium melting stock by removal of the many volatile impurities.

##### Preparation of Stoichiometric Uranium Monocarbide

Past experience has shown that a nonconsumable arc-melting technique would be the optimum method for preparing high-purity stoichiometric uranium monocarbide. It appears that uranium monocarbide is highly reactive with most high-temperature materials at the elevated

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<sup>4</sup>Private communication with M. Bradley, Chemical Technology Division, Oak Ridge National Laboratory.

<sup>5</sup>Proceedings of the Uranium Carbide Meeting Held at Oak Ridge National Laboratory, December 1-2, 1960, TID-7603.

<sup>6</sup>A. C. Secrest, Jr., E. L. Foster, and R. F. Dickerson, Preparation and Properties of Uranium Monocarbide Castings, BMI-1309 (June 1959).

temperatures that are necessary for its preparation.<sup>7</sup> Therefore, a water-cooled copper hearth and a solid tungsten-tipped electrode were selected because this combination imparted the least contamination to the furnace charge. The copper pickup from the hearth was estimated at 4 ppm, and the tungsten contamination was so small that it was immeasurable. An added advantage of the cold-hearth arc-melting technique is that the high temperatures necessary can be attained and controlled.

Buttons of the proper size (100-400 g) were prepared by arc melting the spectrographic carbon and uranium sheet (0.20 in. thick) on a water-cooled copper hearth under a high-purity (< 4 ppm - total impurities) argon atmosphere of approximately 500 mm Hg. Prior to backfilling with argon, the furnace was evacuated to a pressure of 2 to  $4 \times 10^{-5}$  mm Hg. The arc was established by striking a tungsten peg with the electrode. The initial power input was always 200 amp at 25 v. When the uranium became molten, the power was slowly increased to 750 amp at 28 v over a 6- to 8-min period. It was found that when charging the stoichiometric amount (4.80 wt % C) of carbon, the charge had to be remelted subsequently 8 to 10 times to ensure complete dissolution of the carbon and melt homogeneity. A button-arc furnace illustrated in Fig. 1 was used to prepare four buttons with a single evacuation of the furnace. The electrode was used to turn the buttons over between melts. A 100-g Zr button used as an oxygen "getter" was melted prior to melting the uranium-carbon charge. Figure 2 illustrates the microstructure of a stoichiometric uranium monocarbide 300-g button. It was found that when using uranium metal containing 685 ppm C,  $UC_2$  would precipitate in the cast structure when the stoichiometric amount of carbon was charged. Therefore, several 100-g buttons were prepared in which the carbon content was varied by 30-ppm intervals in both the hypostoichiometric and hyperstoichiometric regions. An insight to the sensitivity of the stoichiometry and a feeling for how well the arc-melting procedure was being controlled were gained from these series of heats.

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<sup>7</sup>A. Strasser, Nucl. Eng. 5, 353-57 (1960).

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1. - TO RECTIFIERS
2. WATER INLET TO ELECTRODE
3. WATER OUTLET FROM ELECTRODE
4. POLISHED STAINLESS STEEL SLEEVE
5. SIGHT GLASS
6. DOUBLE O-RING SEAL
7. DOUBLE PLY BRONZE BELLOWS
8. WATER COOLING COILS
9. GAS INLET
10. COPPER FURNACE JACKET
11. TUNGSTEN TIPPED ELECTRODE
12. TUNGSTEN STARTING PEG
13. BUTTON CAVITIES
14. O-RING VACUUM SEAL
15. TO VACUUM PUMPS
16. COPPER HEARTH
17. HEARTH WATER COOLING
18. BRASS BASE PLATE
19. + TO RECTIFIERS

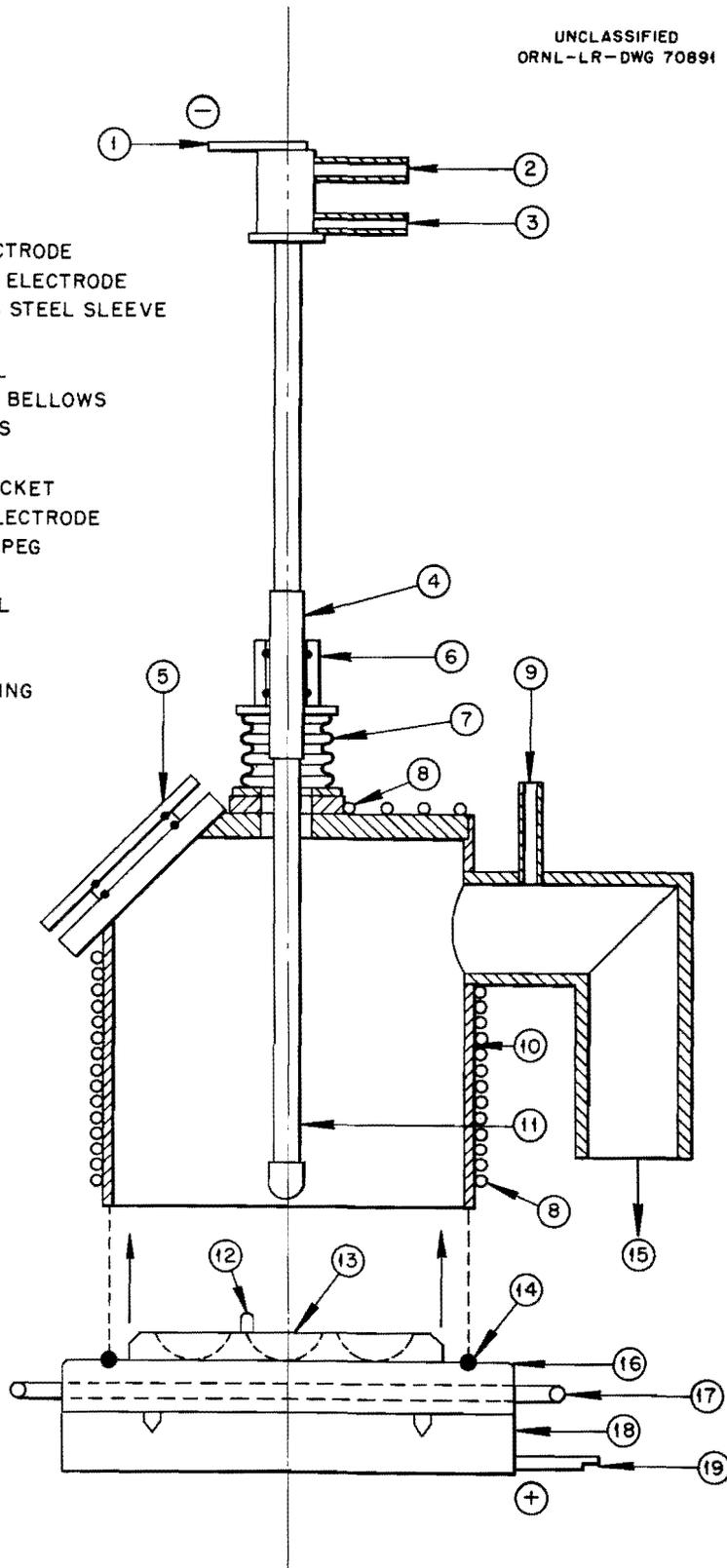


Fig. 1. Laboratory Nonconsumable Button-Arc Furnace.

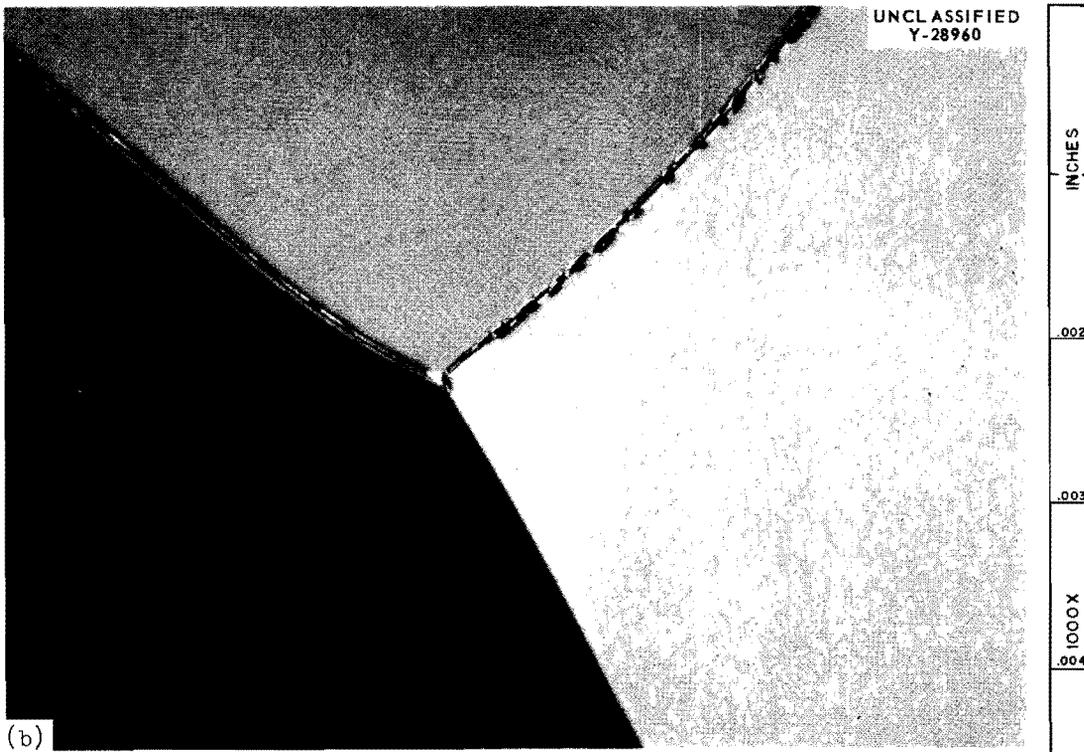
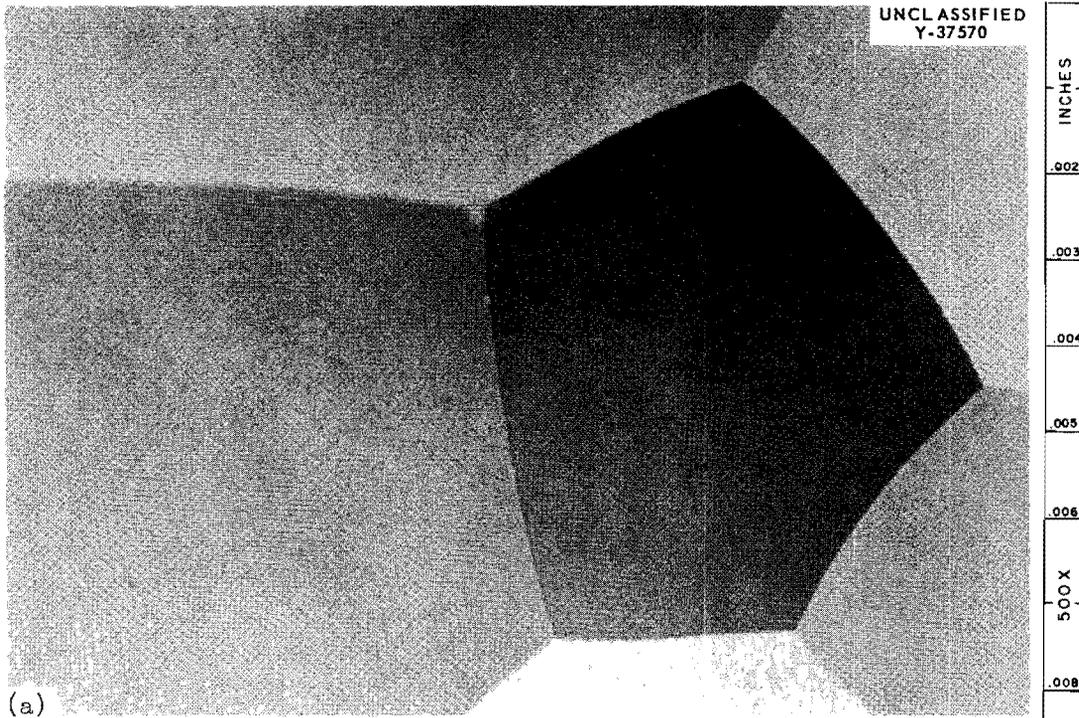


Fig. 2. Typical Microstructures of Arc-Cast Stoichiometric Uranium Monocarbide Illustrated at a Magnification of (a) 500 and (b) 1000 Diameters. Etchant:  $H_2O + HNO_3 + \text{acetic acid}$ . Reduced 13%.

### Shape-Casting Procedure

The above studies have shown that with certain modifications the conventional nonconsumable arc-melting technique could be used for preparing sound stoichiometric uranium monocarbide cylindrical specimens. It was demonstrated at Battelle Memorial Institute that, when massive copper or graphite molds were used, the castings cracked as a result of cooling too rapidly.<sup>6</sup> This was substantiated at ORNL; and further, it was learned that the graphite molds grossly contaminated the charge. Therefore, the copper mold was modified to meet the following objectives:

- (1) Decrease the total heat content by decreasing the mass of the mold.
- (2) Create a thermal barrier to radiation losses by flame spraying all external surfaces with  $\text{Al}_2\text{O}_3$ .
- (3) Create a thermal barrier to conduction losses by incorporation of inner-split insert molds.
- (4) Decrease the contact area between the copper block mold and the water-cooled base plate so that the total heat loss would be minimized.

Uranium monocarbide drop-cast into the modified mold exhibited fairly smooth surfaces; however, slight internal cracking of the casting still occurred because of the rapid cooling rate. A thin-walled niobium sleeve incorporated into the mold assembly proved satisfactory; surface conditions of the casting were acceptable and cooling was slow enough to prevent internal cracking. Niobium sleeve molds proved expensive and machining was time-consuming; therefore, graphite sleeve molds were substituted, and the results were acceptable because the molten charge was not allowed to come in contact with the graphite until after the charge had dropped into the mold cavity where solidification was instantaneous.

Using this type of thin-walled sleeve incorporated into the copper mold assembly, a technique was developed for producing cast specimens, 1/4 to 3/8 in. in diameter and up to 3 1/4 in. long. As illustrated in Fig. 3, the graphite sleeve mold is suspended in the cavity of the

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1. WATER COOLED TUNGSTEN TIPPED ELECTRODE
2. TUNGSTEN STARTING PEG
3. GRAPHITE SLEEVE MOLD
4. COPPER MOLD INSERTS
5. COPPER SUPPORT MOLD
6. SURFACES FLAME SPRAYED WITH  $Al_2O_3$
7. WATER COOLED BASE PLATE
8. O-RING - MATES WITH FURNACE JACKET - Fig. 1.
9. WATER CHANNELS

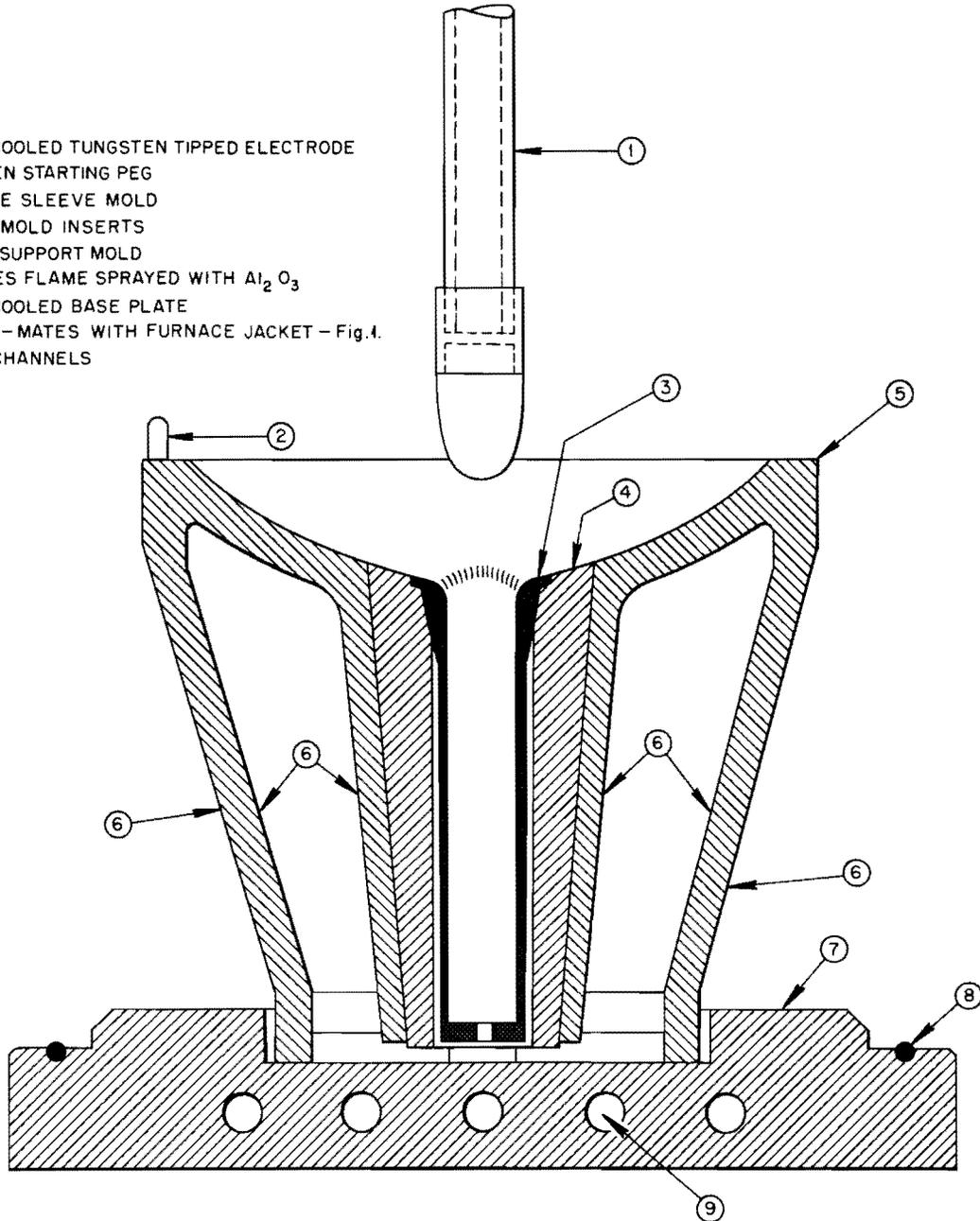


Fig. 3. Copper Mold Assembly with Graphite Sleeve Mold and Water-Cooled Base Plate.

copper split-mold inserts. The sleeve mold is held in place by a wedge fit and a small lip. The base plate and mold assembly illustrated in Fig. 3 fit inside the laboratory arc furnace illustrated in Fig. 1. In the technique developed, the precast arc-melted uranium monocarbide button rests within the cavity of the mold assembly directly over the mold opening. The steps involved in this shape-casting technique are as follows:

- (1) The arc-melting furnace is evacuated to a pressure of approximately  $3 \times 10^{-5}$  mm Hg.
- (2) It is backfilled with high-purity argon to a pressure of approximately 1/3 atm.
- (3) A low-intensity arc of 100 amp at 25 v is established and the outer mold is preheated for a period of 60 sec.
- (4) The uranium monocarbide buttons are preheated for a period of 30 sec.
- (5) The current is slowly increased to 700 amp at 28 v and simultaneously the arc is rotated until all but the bottom center of the button is molten.
  - (a) For the largest button, this requires approximately 90 sec.
- (6) The current is increased to 850 amp and held until the charge drops into the mold. This requires an additional 15 to 30 sec.
- (7) The power is slowly decreased while playing the arc around the top of the mold inserts and the furnace is immediately evacuated. When the low pressure kills the arc, the power is shut off to the electrode.
- (8) When the casting has cooled sufficiently so that it will not react with oxygen or water vapor in the atmosphere (usually one hour), argon is bled into the furnace to atmospheric pressure.
- (9) The casting is removed from the furnace and stored in a vacuum desiccator.

## RESULTS AND DISCUSSION

### Uranium Monocarbide Preparation

During the initial stages of this investigation, it became apparent that chemical analytical methods and x-ray techniques were not adequately sensitive to detect small changes in carbon variations (see Table 1). Therefore, metallographic examination and weight changes occurring during the melting cycle were used as means of bracketing the end composition of the arc-cast buttons.

To ascertain the effectiveness of the melting procedure on the homogeneity of the cast buttons and to gain insight on the compositional limits of uranium monocarbide, several 100-g carbide buttons in which the carbon content was varied by 30 ppm were prepared and evaluated. These results are tabulated in Table 1, and representative microstructures of each composition are illustrated in Fig. 4. Close inspection of the photomicrographs presented in Fig. 4 will show that small changes in the carbon concentration has induced the precipitation of second phases in small segregated areas. A small excess of carbon promoted the precipitation of  $UC_2$  over small areas of 2 to 4 grains, while a slight deficiency of carbon promoted the precipitation of alpha uranium within the grain-boundary regions. As the carbon concentration was increased, the acicular  $UC_2$  precipitate became larger, more clearly defined, and more densely populated, indicating an extremely carbon-sensitive reaction.

In an effort to account for the weight lost from the charge during the melting cycle and to determine changes in the furnace atmosphere, samples of the furnace atmosphere were collected subsequent to melting the zirconium "getter" and after melting the uranium-carbon charge. Table 2 lists the spectrographic results obtained from three separate runs wherein two 100-g charges were each remelted fifteen times.

Table 1. Effect of Composition and Melting Cycle on the Density and Weight Loss of Near Stoichiometric Uranium Monocarbide

Sample Identification	Intended Composition (wt %)	Analyzed Carbon (wt %)	X-Ray Results	Weight Change During Melting (g)	Measured Density (g/cc)
1-A	U-4.7900 C	4.69	UC only	-0.0048	13.731
2-A	U-4.7930 C	4.72	UC only	-0.0066	13.638
3-A	U-4.7960 C	4.71	UC only	-0.0035	13.629
5	U-4.8000 C	4.76	UC only	-0.0041	13.619
1-B	U-4.8030 C	4.71	UC only	-0.0009	13.607
2-B	U-4.8060 C	4.75	UC only	-0.0029	13.606
3-B	U-4.8100 C	4.78	UC only	-0.0027	13.589

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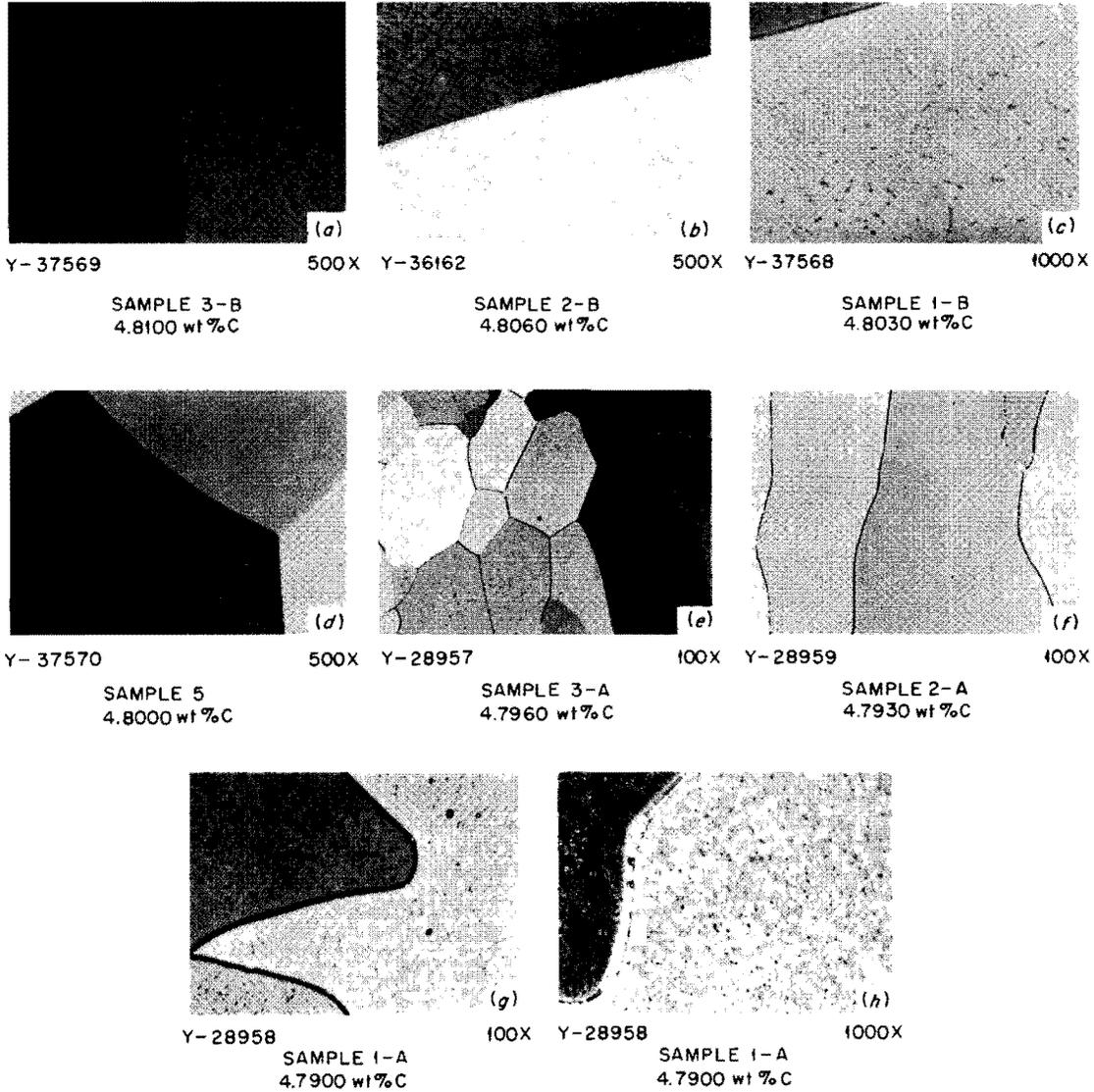


Fig. 4. As-Cast Uranium Monocarbide Matrix Containing Segregated Second Phases of  $UC_2$  and Alpha Uranium When the Carbon Content Is Varied by 30 ppm. Etchant: Equal parts  $H_2O + HNO_3 + CH_3COOH$ . Reduced 17%.

Table 2. Changes in the Gas Composition of the Furnace Atmosphere During Preparation of Uranium Monocarbide

Gaseous Species	Percent Change		
	Run No. 1	Run No. 2	Run No. 3
H <sub>2</sub>	+530.98	+75.0	+466.6
CH <sub>4</sub>	+276.50	+8.80	+111.5
H <sub>2</sub> O	+187.50	+75.58	+479.3
N <sub>2</sub> + CO*	+555.5	+1315.1	+2165.4
O <sub>2</sub>	+54.54	+86.4	+50.0
CO <sub>2</sub>	+4100	+1100.0	+7000
Ar	-0.42	-0.42	-0.61

\*95% (or greater) of any value from the chromatograph was CO.

The uranium used for these tests contained a low carbon concentration of approximately 40 to 50 ppm. The amount of carbon given to the formation of carbonaceous gases was exceedingly small and can, therefore, be neglected. For example, the amount of carbon involved in the formation of a 7000% increase in CO<sub>2</sub> (Run No. 3) was calculated to be  $2.737 \times 10^{-4}$  g. An example of this calculation is included in Appendix B. Therefore, the combined carbon lost by the formation of carbonaceous gases was negligible. The impurity carbon in the uranium, however, cannot be neglected. When charging 4.80 wt % C with uranium containing a carbon impurity of 830 ppm, a microstructure composed of a uranium monocarbide matrix containing large areas of the uranium dicarbide precipitate resulted. This behavior is illustrated in Fig. 5. It has been found that the greater the carbon impurity level the more difficult it is to attain the stoichiometric uranium monocarbide microstructure free of second phases.

#### Shape Casting

The initial cylinders cast into the solid copper mold exhibited severe cracking and roughened surfaces. The hollowed copper block mold design, incorporating split-mold inserts, created an interface that offered resistance to heat flow. The slower cooling rates that

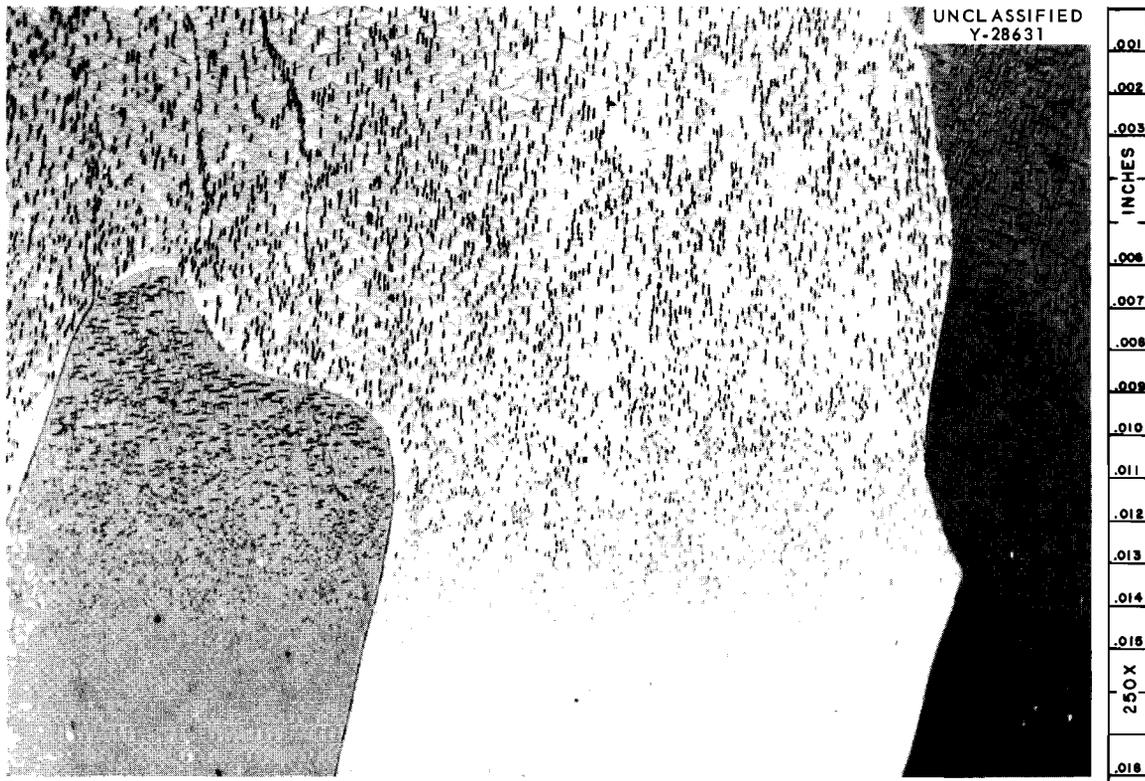


Fig. 5. Photomicrograph Illustrating Segregated Precipitation of  $UC_2$  in a Matrix of UC. Etchant:  $HNO_3 + H_2O + CH_3COOH$  - equal parts. Reduced 11%.

resulted produced cast uranium monocarbide cylinders containing only slight internal cracking. Incorporating inner mold sleeves of either niobium or graphite resulted in cast cylinders free of internal cracks and impurity contamination. Cylinders up to 0.375-in. diam by 3 in. long, prepared by the procedure earlier described, exhibited fairly smooth surfaces and were free of internal cracks. However, the top 10% of the cast cylinder contained closed shrinkage cavities due to simultaneous freezing of the exterior regions of the casting.

Even though high-quality uranium monocarbide cylinders 0.375-in. diam  $\times$  3 in. long were prepared, it is felt that larger cylinders possessing these same qualities could not be prepared by the technique described above. For example, all cast cylinders 0.500-in. diam  $\times$  3 in. long exhibited very rough surfaces and considerable porosity in the top 40% of the casting. The high power densities necessary to melt and adequately heat the button charge created sufficient force to violently agitate the molten charge and thereby prevented a smooth flow of melt into the sleeve mold cavity. The process could conceivably be scaled up; however, the use of larger button charges would result in small percent yields and high wastes.

Radiographs of arc-cast uranium monocarbide cylinders illustrating the results of the techniques studied are presented in Fig. 6. It was quite obvious that as the cooling rates were decreased due to the changes in mold design the integrity of the cast cylinders was greatly improved. Two typical cast cylinders are illustrated in Fig. 7; a representative cross-sectional microstructure of a stoichiometric uranium monocarbide cylinder is illustrated in Fig. 8. During the course of this study, many attempts were made to decrease the cooling rates of the cast cylinders. One such approach was the substitution of graphite split-mold inserts for the copper inserts. Uranium monocarbide button charges melted on the graphite surfaces and cast into the graphite cavity exhibited a greater propensity to deterioration under atmospheric conditions than did the cylinders that had been cast into copper inserts. For example, stoichiometric uranium monocarbide cylinders cast into both types of mold inserts were exposed to air for 17 hr. The room

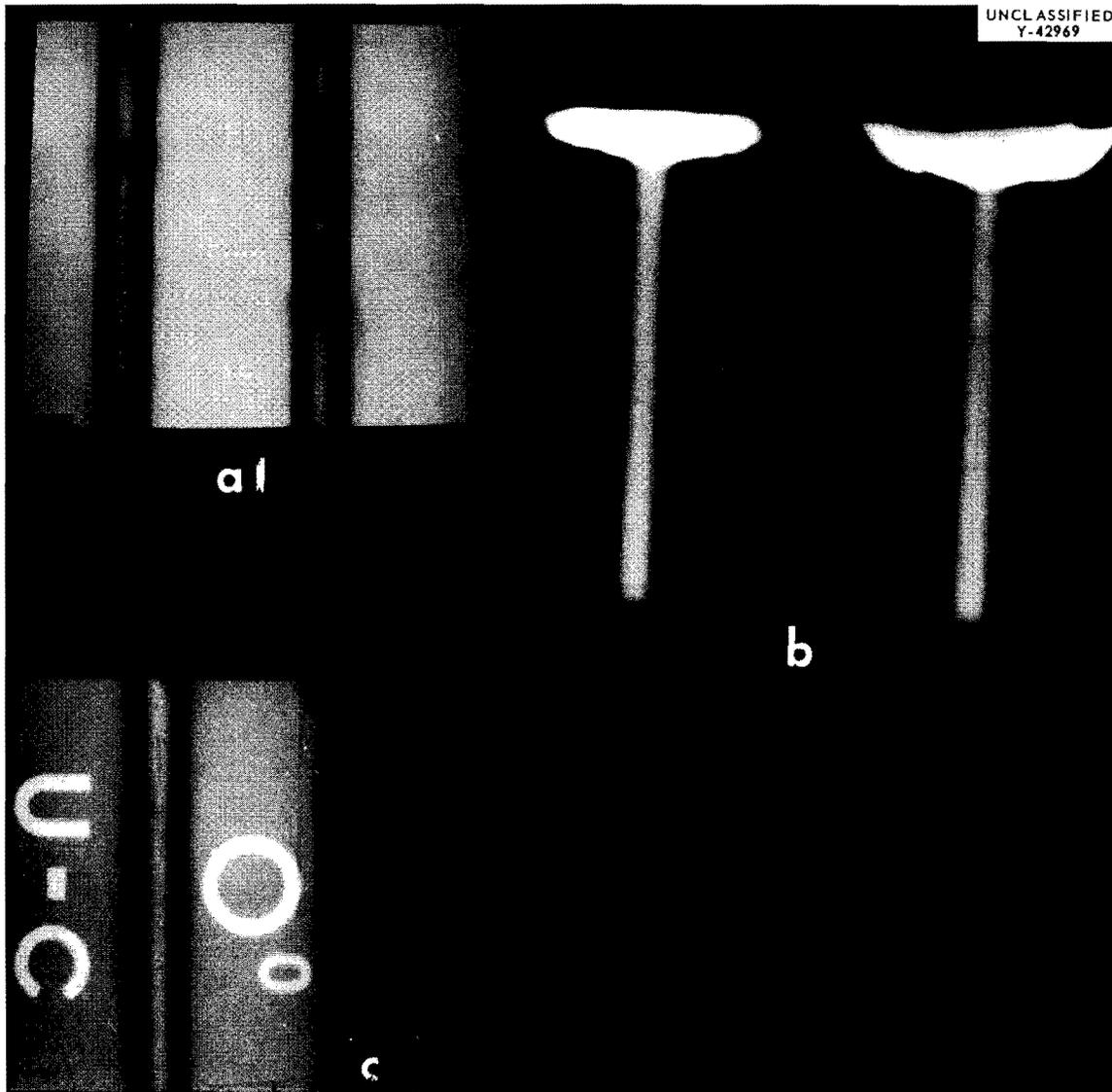


Fig. 6. Radiographs Illustrating the Casting Integrity Resulting from (a) a Solid Copper Mold, (b) a Hollowed Copper Mold Utilizing "Split-Mold Inserts," and (c) a Hollowed Copper Mold Employing an Inner Sleeve Mold in Conjunction with the Split-Mold Inserts. Reduced 22%.

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Fig. 7. Arc-Cast Uranium Monocarbide Cylinders Illustrating the Two Extreme Surface Conditions.

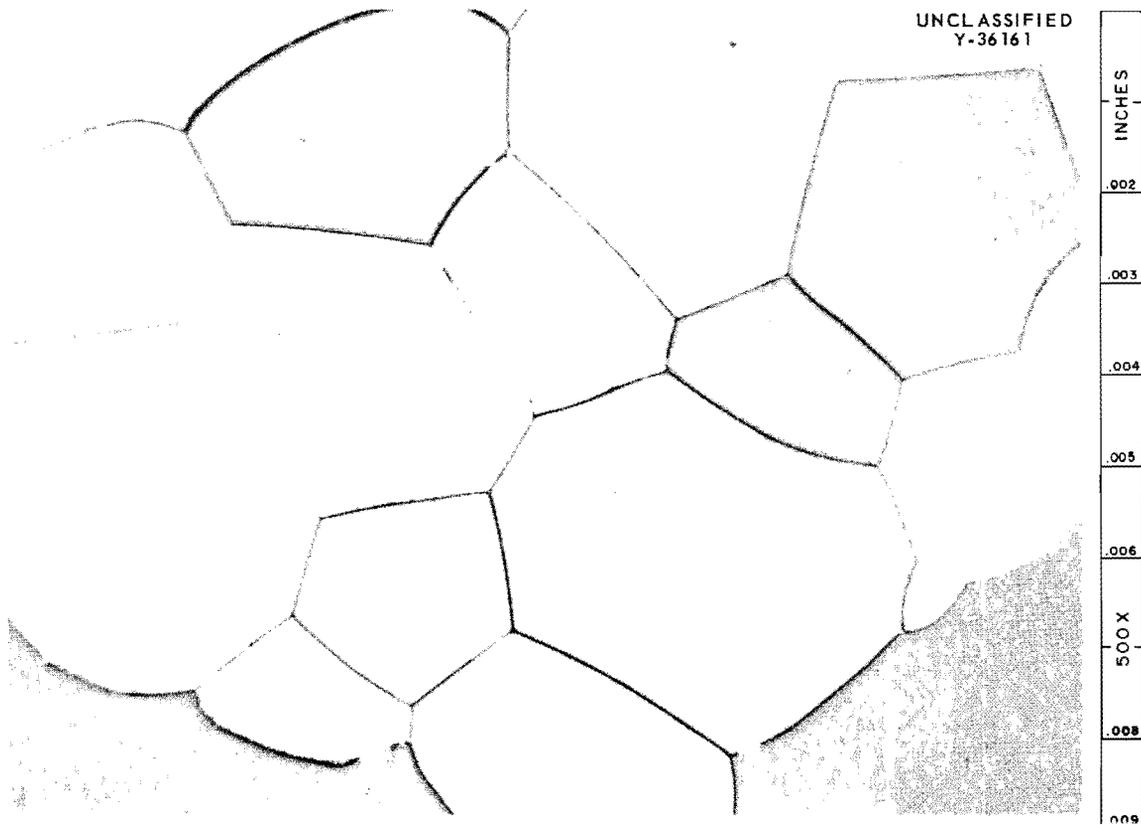


Fig. 8. Typical Cross-Sectional Microstructure of a Stoichiometric Uranium Monocarbide Cast Cylinder. Etchant:  $\text{H}_2\text{O} + \text{HNO}_3 + \text{CH}_3\text{COOH}$ . 500X. Reduced 7%.

temperature varied between 23 and 27°C; the humidity varied between 53 and 76%. Cylinders cast into the graphite mold inserts lost approximately 36% of their weight. This weight loss is attributed to the formation and simultaneous spallation of uranium oxides. The cylinders cast into the copper exhibited no weight loss or change in physical appearance.

Measured densities of the uranium monocarbide button charges and the subsequently cast cylinders, cast both in graphite and copper mold inserts, showed that greater deviations occurred in the uranium monocarbide that had been drop-cast from the graphite surfaces. The density results are tabulated in Table 3. Figure 9 illustrates the microstructure of a uranium monocarbide cylinder that had been cast into the graphite split-mold inserts. Notice the precipitation of a fine phase which could not be absolutely identified; however, it is postulated that this precipitate is uranium dicarbide in a uranium monocarbide matrix.

Table 3. Changes in the Measured Densities of Uranium Monocarbide Remelted in Copper or Graphite Split Molds

Button Number	Initial Button Density (g/cc)	Density of Shapes		Percent Deviation
		Remelted in Copper	Remelted in Graphite	
1	13.618	13.613		-0.036
2	13.592	13.589		-0.022
3	13.609	13.600		-0.066
4	13.587		13.515	-0.529
5	13.632		13.528	-0.762
6	13.619		13.531	-0.646



Fig. 9. Microstructure of Stoichiometric UC Which Had Been Remelted in a Graphite Mold. Notice the fine precipitate. Etchant:  $H_2O + HNO_3 + CH_3COOH$  - equal parts. 250X. Reduced 7%.

## CONCLUSIONS

1. Small research quantities of stoichiometric uranium monocarbide free of preparational impurities can be repeatedly made by direct arc melting of uranium metal and spectrographic carbon, provided the following conditions are observed:

(a) Uranium metal having a carbon impurity content of less than 50 ppm is used or higher impurity levels are considered as part of the carbon charge.

(b) A water-cooled tungsten-tipped electrode is used in conjunction with a water-cooled copper hearth to minimize contamination.

(c) A vacuum of at least  $5 \times 10^{-5}$  mm Hg is obtained before the arc furnace is backfilled with high-purity argon.

(d) Charge constituents are weighed accurately to the fourth decimal place.

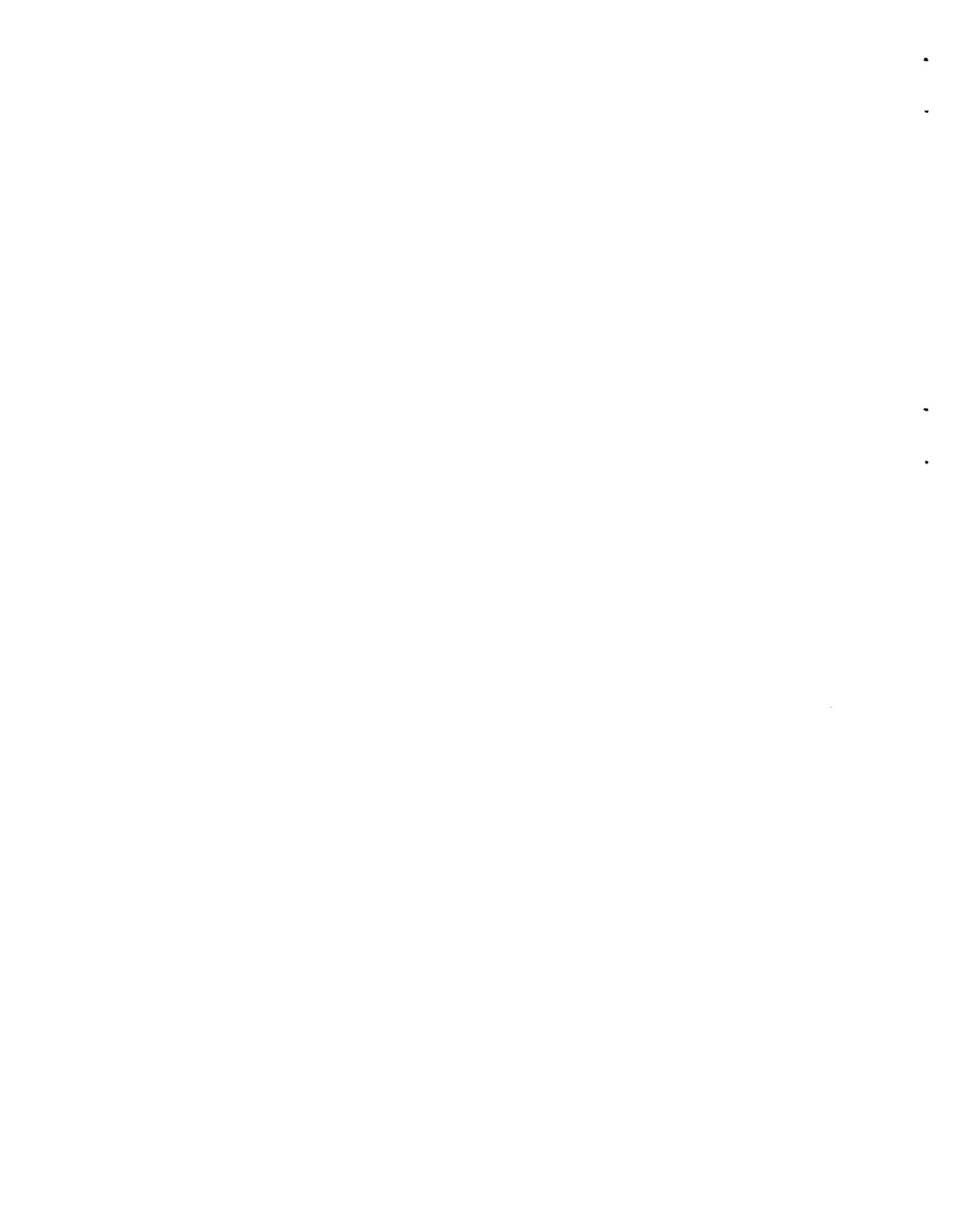
2. Stoichiometric uranium monocarbide is sensitive to small changes in the carbon concentration.

3. Remelting stoichiometric uranium monocarbide in contact with graphite, if only for short-time intervals (1 to 2 min), results in sufficient carbon contamination to lower the density and alter the microstructure of the original composition.

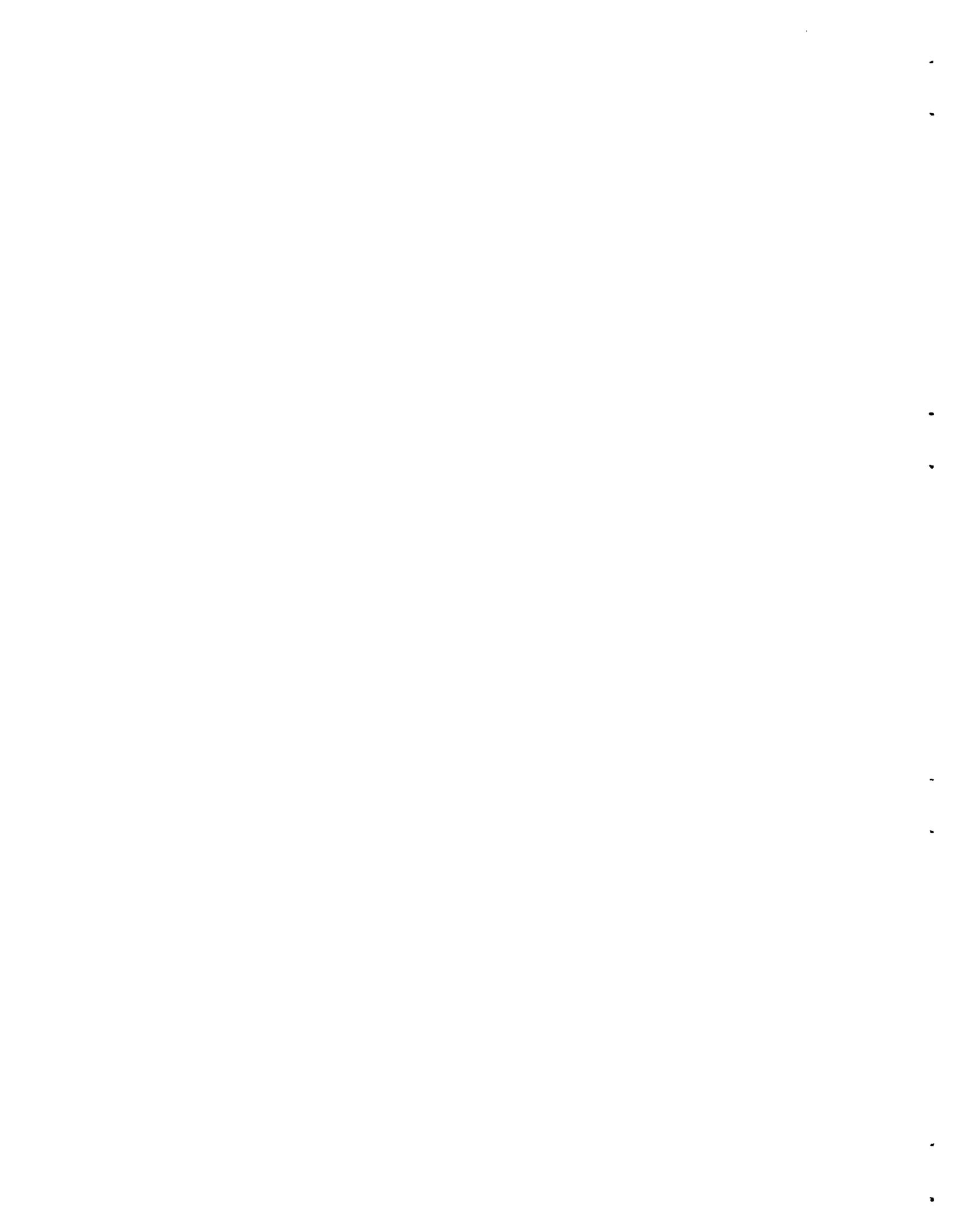
4. Remelting stoichiometric uranium monocarbide into cylindrical shapes free of contamination is possible when using graphite sleeve molds, provided the molten charge does not come into contact with the graphite prior to its dropping into the sleeve mold.

## ACKNOWLEDGMENTS

The author wishes to extend appreciation and thanks to L. Queener of the Melting Laboratory for his help in preparing and melting the charges of uranium carbides and to J. Lockett of the Metallography Group for his assistance in the immediate and rapid preparation of the metallographic specimens.



APPENDIX A



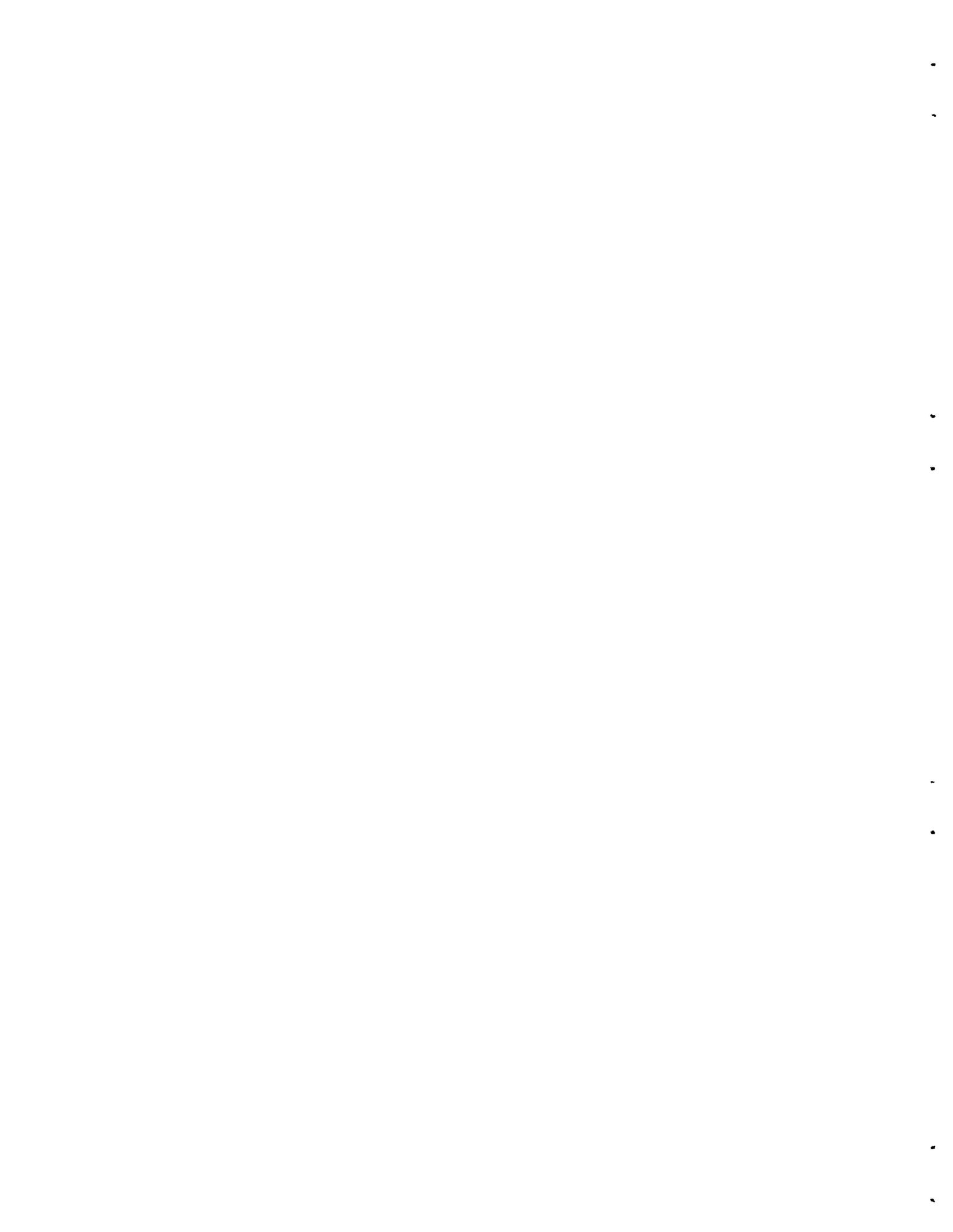
ANALYTICAL ANALYSIS OF THE ALLOYING STOCK

Element	Uranium		Carbon
	Before Arc Melting	After Arc Melting	
C	< 50 ppm	36 ppm	Remainder
B	< 0.24	< 0.1	
N	< 75	< 50	
O	< 200	74	
Ag	< 0.1	< 0.1	
Al	5	< 0.2	
Ba	N.D.* < 5	< 0.1	
Be	N.D.* < 0.5	< 0.02	
Bi	N.D.* < 1	N.D.* < 1.0	
Ca	22	< 0.05	
Cd	0.20	0.03	
Mn	6	0.10	
Ce	< 5	N.D.*	
Cu	37	21	
Fe	68	59	0.40 ppm
Ni	170	52	
Mg	20	0.014	0.10
P	< 10	8	
Si	20	15	0.30
Sn	4	0.02	
Zn	43	4.0	
H	16	11	
U	Remainder	Remainder	

\*N.D. - Not detected.



APPENDIX B



Calculation used to estimate the amount of carbon given up by the melt in the formation of a 7000% increase in CO<sub>2</sub>.

(A) Given Parameters:

- (1) Reference temperature - 294.5°K
- (2) Reference pressure - 983.5 mm Hg
- (3) Volume of system - 6101.55 cm<sup>3</sup>
- (4) Mass spectrometer analysis (vol % CO<sub>2</sub>)
  - a. Prior to melting the uranium monocarbide charge - 0.0001
  - b. Subsequent to melting the uranium monocarbide charge - 0.0071

(B) Method of Calculation:

- (1) Basic equations used
  - a.  $PV = nRT$
  - b.  $V_{\text{total}} = V_{\text{CO}_2} + V_2 + V_3 + \dots$   
where
    - P = system pressure - atm
    - V = system volume - liters
    - n = moles of gas
    - R = gas constant - 0.082
    - T = absolute temperature - °K

From Eqs. a. and b. above, it can be shown that

$$V_{\text{CO}_2} = \frac{n_{\text{CO}_2}}{n_{\text{total}} v_{\text{total}}}$$

where:

$V_{\text{CO}_2}$  = volume of CO<sub>2</sub>

$n_{\text{CO}_2}$  = moles of CO<sub>2</sub>

$n_{\text{total}}$  = total moles of gas present

$$\therefore \frac{n_{\text{CO}_2}}{n_{\text{total}}} = \frac{V_{\text{CO}_2}}{V_{\text{total}}} = 7.0 \times 10^{-5}$$

Now from  $PV = nRT$

$$n_{\text{total}} = \frac{PV}{RT}$$

$$\therefore n_{\text{CO}_2} = \frac{(7 \times 10^{-5})(PV)}{RT}$$

$$n_{\text{CO}_2} = (7 \times 10^{-5})(6.10155) \left( \frac{983.5}{760} \right) = 2.28 \times 10^{-5}$$
$$(0.082)(294.5)$$

$$\therefore \text{wt}_{\text{CO}_2} = 44.011 (2.28 \times 10^{-5}) = 1.003 \times 10^{-3} \text{ g CO}_2$$

and

$$\therefore \text{wt}_{\text{C}} = \frac{12.011}{44.011} (1.003 \times 10^{-3}) = 2.737 \times 10^{-4} \text{ g C}$$

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