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PROCESS FOR MAINTAINING STRAIGHTNESS IN EXTRUDED CERAMIC SECTIONS

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FIG. 1

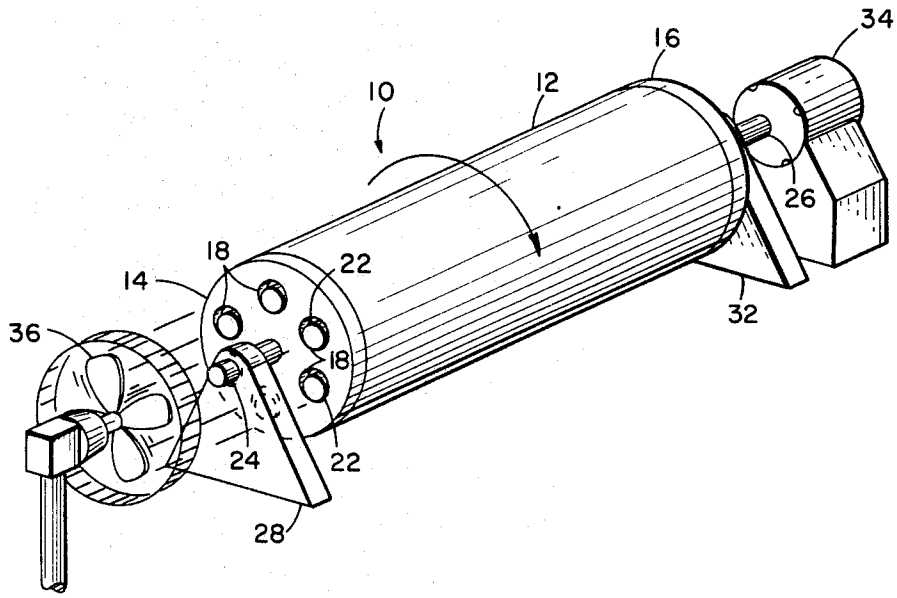
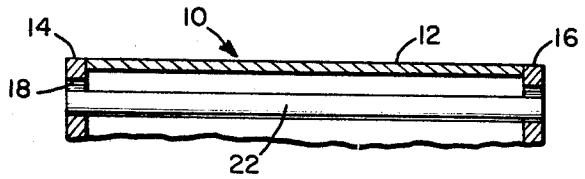


FIG. 2



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PROCESS FOR MAINTAINING STRAIGHTNESS IN EXTRUDED CERAMIC SECTIONS

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ABSTRACT OF THE DISCLOSURE

A method for drying extruded rod-like ceramic sections prior to sintering to reduce the degree of warping and out of roundness in the final product. During the drying step of preparing UO_2 extruded sections, the latter are mounted in a rotatable tube by way of over-sized circular holes in the supporting end plates. As the sections rotate with the tube, they also roll around in their supporting holes. Drying gas delivered to the sections is then applied uniformly over all surface areas of the sections.

Background of the invention

This invention was made in the course of, or under a contract with the United States Atomic Energy Commission.

In the preparation of certain types of extruded sections, such as extended cylindrical sections of UO_2 for use in nuclear fuel elements, it is necessary to maintain a high degree of straightness in the extruded sections during the drying and sintering cycle because of the strict dimensional requirements in their ultimate use as fuel elements. Drying prior to sintering is ordinarily accomplished by placing the extruded sections in an oven and maintaining a heated atmosphere until binder and moisture are evaporated.

For relatively short lengths of extruded sections of up to about four inches, bending or warping from the straight section in the range heretofore found to be present in the final product under existing methods of preparing the extruded sections were acceptable. If lengths beyond four inches are to be prepared, however, and this appears to be desirable in some situations, warping of the order of magnitude produced by previous methods produce results much less than satisfactory.

Summary of the invention

The present invention overcomes the aforementioned difficulties by permitting the preparation of extruded sections of the type herein described with far less warping that heretofore was thought to be possible in the final sintered sections by conventional methods of preparation. In accordance with this invention rod-like sections of ceramic UO_2 containing binder and plasticizer are dried in a revolving tube in order to expose all surface areas uniformly to the drying atmosphere. As a result of this method of drying, in which the sections are kept in continual motion, there is produced a sharply reduced bowing or warping and out of roundness in the final product of substantially greater length.

It is thus a principal object of this invention to provide a way of preparing extruded rod-like sections of reduced tendency to warp.

Other objects and advantages of this invention will be readily apparent from the following description of preferred embodiments of this invention.

Description of the drawing

FIG. 1 is an isometric view of preferred apparatus for carrying out the principles of this invention.

FIG. 2 shows a partial section along one of the extruded sections of FIG. 1.

Description of the preferred embodiments

In the preparation of fired extruded sections of UO_2 intended for loading into fuel rods for use in nuclear reactors, UO_2 in powdered form is blended with a binder and plasticizer, mixed together to the proper consistency, and loaded into an extrusion chamber. The mixture is then evacuated of air and extruded into the desired length and shape. The extruded sections are then dried in accordance with this invention as will be described below to remove the binder and any moisture present, and finally fired in a furnace to sinter the final product. This process of preparing extruded sections of UO_2, except for the unique way hereinafter described for drying the sections prior to sintering, is well known in the art.

Referring to the figures, revolving dryer **10** consists of an elongated tube **12** having a pair of end identical plates **14** and **16**. Plate **14** is provided with a plurality of openings **18** to support the ends of extruded sections **22** of circular cross-section. The opposite ends of the latter are supported in similar fashion by similar openings (not shown) in end plate **16**. In addition, extending from each of plates **14** and **16** are shaft extensions **24** and **26**, respectively, mounted on supports **28** and **32**, respectively, for permitting the rotation of tube **12**. Shaft **26** extends for coupling to a motor unit **34** which provides the power for rotating tube **12**.

Shown somewhat schematically is a blower **36** whose purpose is to direct a stream of the drying atmosphere through and around tube **12** where openings (i.e. **18** in plate **14**) are oversized to permit circulation through the interior of tube **12** as well as to permit sections **22** to roll around during rotation. Dryer **10** is located within an environment such as a room or a large chamber wherein the atmosphere may be controlled at the desirable consistency, temperature and pressure. In the examples described below, the drying atmosphere consisted of air at a temperature of about 22° C., at substantially atmospheric pressure with blower **36** consisting of a ¼ H.P. fan located at a distance of about two feet from the upstream end of dryer **10**.

In the utilization of the dryer shown, fuel rods **22**, following extrusion, are placed within tube **12** as illustrated, and the latter is rotated while fan **36** is operated to produce a steady flow of drying atmosphere through and around tube **12**. Straightness in rods **22** is accomplished, it is believed, by introducing uniform stresses in the outer layers of the green extrusions during the drying cycle through the simultaneous rolling and rotating sequence of extrusions **22** arising from the rotation of tube **12**.

Several extrusions of UO_2 were made in accordance with the principles of this invention, a few of which are listed in the following table:

TABLE

	Sample		
	1	2	3
Weight of UO_2, grams	4,000	4,000	4,000
Weight of binder (ammonium alginate), grams	30	30	30
Weight of plasticizer (glycerine) grams	240	240	240
Water content (initial percent) WH_2O/WUO_2	15	19	19
Extrusion load, lbs	125,000	125,000	125,000
Moisture content of Extrusion, w/o	8.28	9.04	15.6
Green density, percent T.D.	39.2	41.6	43.9
Fired density, percent T.D.	85.2	89.6	87.2

Rotational speeds for tube **12** were within the range of 15 r.p.m. to 3 r.p.m. It was found that better results were produced by beginning the drying process at the high end of the rotational speed range and gradually reducing the

speed to the low end of the range as the drying process was completed. This effect is believed to be the result of the characteristics of the green sections which are more plastic and likely to take a set whereas a reduction in speed is desirable later as the extrusions have acquired some green strength and greater advantage can be taken of a smoother flow and distribution of the drying atmosphere.

In each of the above samples, for extruded rods of six inch lengths, bending from the straight section was within about 0.015 inch. This compares to bending of 0.040 to .050 inch for lengths of about four inches for the same extrusion process except that the rods are dried by placing them in a drying oven and not rolled and rotated in accordance with this invention. Thus, it is seen that the present invention reduces bowing by about ⅓ for lengths of about 50% longer than previously obtained. This represents a significant improvement which makes it possible to utilize fuel rods of much greater length than heretofore was thought to be possible.

A feature of the invention is that the rolling action permits positive control of the drying sequence as the rate of surface exposure changes and the evaporation rate can be controlled by varying the speed of revolution, heat input and drying atmosphere. The temperature, pressure and moisture content of the atmosphere can be made to be other than ambient air if desired, fan **36** can be operated to give any desired rate of gas flow, and motor **34** can be used to alter the rolling rate for optimum or desired conditions. Another important advantage of this invention is that the rotational speed of tube **12** can be varied to suit the particular circumstances and the characteristics of the green extrusions.

Fuller details and information on this type of process for producing extended and sintered powdered UO_2 ceramic sections is described in "Symposium on Power Packed UO_2 Fuel Elements," CEND–153, Nov. 30–Dec. 1, 1961.

It is thus seen that there has been provided an improved way of producing extruded sections of improved straightness with a minimum of out of roundness. While only preferred embodiments of the invention have been described, it is understood that many variations thereof are possible

without departing from the principles of this invention. For example, tube **12** may be provided with additional openings both in the end plates and in the outer wall, if desired. Furthermore, tube **12** can be provided with the heating coils to aid the drying process and also to burn out the binder thus combining, if desired, drying and presintering of the sections. While only circular sections have been described, other than circular can be dried if some rounding tendency can be tolerated. Hence the invention is not to be limited in scope by the preceding description but only by that of the following claims.

I claim:

1. In a process of preparing solid extruded sections of circular cross-section from ingredients consisting of a mixture of a powdered principal material, binder, and plasticizer having the steps of blending the ingredients, mixing said ingredients to the proper consistency, extruding the mixture into at least one extruded section, exposing the section to a drying atmosphere, and sintering the dried section, the improvement comprising, during the step of drying, supporting said section at the ends thereof for unrestrained rolling, and rotating and rolling said section simultaneously to introduce uniform outer surface area exposure to the drying atmosphere for reducing the extent of warping present in the section after sintering, the rate of rotation being decreased as said section is dried.

2. The process of claim **1** having a plurality of said sections, said sections being mounted for drying parallel to each other in a circumferential array about an axis which is the center of rotation of said array, each of said sections being free to roll while being rotated about the center of rotation.

3. The process of claim **2** wherein the starting materials include powdered UO_2 as the principal material.

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