

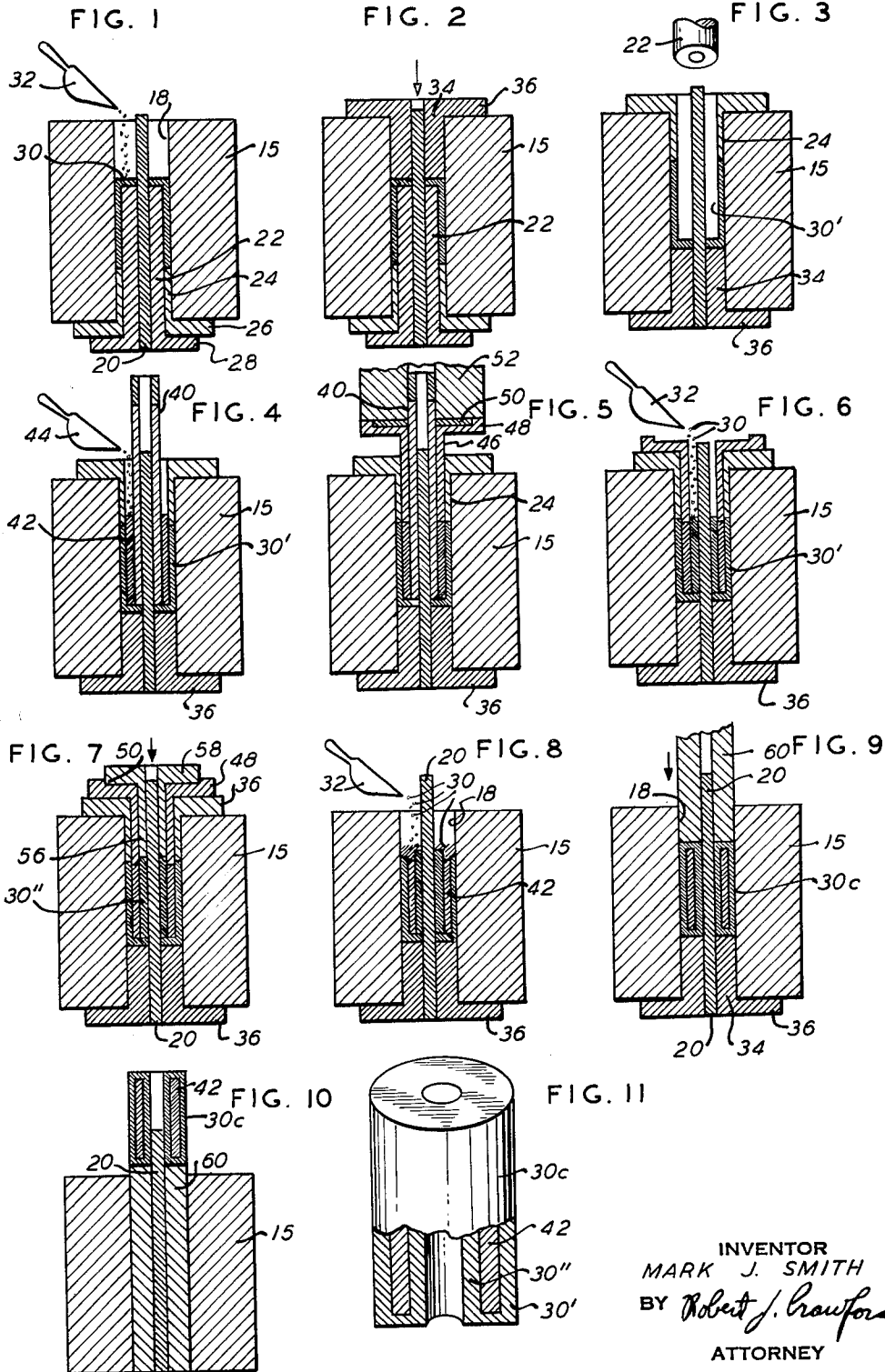
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M. J. SMITH

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FUEL ELEMENT MANUFACTURE

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FUEL ELEMENT MANUFACTURE

Mark J. Smith, Wilson, N.Y., assignor to Air Reduction Company, Incorporated, New York, N.Y., a corporation of New York

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This application is a continuation-in-part of applicant's prior copending application Serial No. 121,041, filed June 30, 1961, now Patent No. 3,158,547.

This invention relates to methods and apparatus for making encapsulated elements having a sleeve-shaped core that is surrounded by an encapsulating shell. The invention is intended particularly for manufacture, by fill-and-press steps, of a nuclear fuel element of annular cross section and having a sleeve-shaped nuclear core and a compacted shell or graphite encapsulating the core.

It is an object of the invention to provide an improved method for making encapsulated sleeve-shaped cores. Considerable difficulty was previously encountered in pre-forming parts of the encapsulating shell because the pre-formed part tended to collapse during the final or intermediate compression steps. In the prior art, efforts were made to pre-form a lower portion of the shell with a U-shaped section, but pre-forming of a portion of the shell in this manner is unsatisfactory.

It is an object of this invention to pre-form a portion of the shell with an outer cylindrical part attached to an end wall; to then place the core material within the outer part of the shell; and then provide an inner clearance into which inner shell material is compacted after the core material has been compacted. The shell is completed by forming an end over the exposed end of the core.

Another object is to provide improved apparatus for making encapsulated elements by fill-and-press steps; and the apparatus includes elements which apply the necessary compression force and reaction forces to compact the shell and core materials with a minimum number of operations.

Other objects, features and advantages of the invention will appear or be pointed out as the description proceeds.

In the drawing, forming a part hereof, in which like reference characters indicate corresponding parts in all the views:

FIGURES 1-9 are diagrammatic sectional views of apparatus made in accordance with this invention and illustrating the successive steps for making an encapsulated element in accordance with this invention;

FIGURE 10 is a view similar to the other figures, but showing the final step of ejecting the encapsulated element from the die chamber; and

FIGURE 11 is a greatly enlarged view, partly broken away and in section, showing the encapsulated element made by the process disclosed in the other views.

The apparatus shown in the drawing includes a die 15 having a cylindrical die chamber 18. A hole spindle 20 extends along the length of the die chamber 18 and is preferably co-axial therewith. A shell-forming plunger 22 fits around the hole spindle 20 but is of somewhat smaller diameter than the chamber 18. A shell-forming plunger collar 24 fills the clearance between the plunger 22 and the wall of the chamber 18 for a portion of the length of the chamber.

There is a flange 26 at the end of the collar 24 for limiting the extent to which the collar 24 can extend into the chamber 18. There is a similar flange 28 at the end of the shell-forming plunger 22 for limiting the extent to which this shell-forming plunger can extend into the die chamber 18.

With the flange 26 in contact with the end of the die 15, and the flange 28 pressed against the flange 26, the

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upper portion of the shell-forming plunger 22 extends beyond the end of the collar 24 for a distance equal to the desired depth of the shell that is to be formed in the die chamber 18.

5 Powdered shell material 30 is dropped into the upper end of the chamber 18 from a dispenser 32. This powdered material is preferably graphite with the conventional binder mixture used for encapsulating nuclear fuel cores; and the chamber 18 is filled to a level somewhat above the upper end of the shell-forming plunger 22.

10 A first tamping plunger 34 is then inserted into the end of the chamber 18. This tamping plunger 34 is of annular cross section so as to slide over the hole spindle 20; and the outer diameter of the plunger 34 fits into the chamber 18 with a sliding fit so as to move downwardly in the chamber as a piston. The bottom annular surface of the plunger 34 compacts the shell material 30 until a flange 36, at the upper end of the plunger 34, contacts with the end face of the die 15. The high pressure used for compacting the shell material is obtained by placing the die 15 and the plunger elements in a hydraulic press which applies force to the lower flange 28 and the upper flange 36. The amount of material dispensed to the chamber 18 is controlled so that the desired density is reached when the flanges 26, 28 and 36 prevent further movement of the plunger 34 toward the shell-forming plunger 22.

The assembly is then inverted into the position shown in FIGURE 3. In this position, the plunger 34 serves as a removable end piece closing the bottom of the die chamber 18. The outer shell-forming plunger 22 is removed with a rotary component of movement so as to leave a smooth inside surface on the shell, designated generally by the reference character 30'.

35 The shell-forming plunger collar 24 is left in position so as to confine the shell 30' against axial movement and to prevent axial displacement of the material of the shell by the plunger 22 as the latter is withdrawn.

40 A spacer 40 is then placed over the hole spindle 20 and is pushed down into contact with the end wall of the shell 30'. This spacer 40 has a radial wall thickness substantially equal to the radial thickness of the wall of the shell 30' because the purpose of the spacer 40 is to leave room for the subsequent introduction of material 45 to form the inner wall of the shell.

Core material 42 is then dropped into the clearance between the spacer 40 and the wall of the outer shell 30'. This core material 42 comes from a dispenser 44 and the amount of core material is controlled so that after compaction it will not be substantially higher than the top of the shell 30'. For making nuclear fuel cells, the core material 42 is a loaded matrix, but it is introduced into the die in powdered form.

55 FIGURE 5 shows the next step in the method. A second tamping plunger 46 surrounds the spacer 40 and fits within the shell-forming plunger 22. This second tamping plunger 46 has a flange 48 at its upper end with a center depression 50 for centering a spacer 52 against which hydraulic pressure is exerted when compacting the core material 42.

60 The spacers 52 and 40 are then removed, but the second tamping plunger 46 is left in place to prevent displacement of the core material as the spacer 40 is withdrawn. A combined rotational and axial movement of the spacer 40 is used to leave a smooth surface on the inside of the core material.

70 Additional shell material 30 is then supplied from the dispenser 32 into the clearance left by the removal of the spacer 40. This shell material extends down into contact with the bottom wall of the outer shell 30' and sufficient additional shell material 30 is added so that

when compacted, it will approximately reach the top level of the compacted core material 42 and the shell 30'.

FIGURE 7 shows the step of compacting the core material to form the inner shell, designated generally by the reference character 30''. This compaction for the inner shell is performed with a third tamping plunger 56 which is of annular cross section and fits around the hole spindle 20 and within the second tamping plunger 46. The third tamping plunger 56 has a flange 58 for limiting its downward movement in the hydraulic press. This flange 58 preferably fits within the center depression 50 of the flange 48. The outer shell and the core material are held in their compacted positions by the bottom surface of the collar 24 and the second tamping plunger 46 during the compaction of the inner shell 30''.

All of the elements in the chamber 18 above the shell and core are then removed, preferably with an initial rotation so as to obtain a clean cleavage between the bottom surfaces of these elements and the shell and core material within the die chamber 18.

FIGURE 8 shows additional shell material 30 being deposited in the die chamber 18 from the dispenser 32. This additional shell material covers the entire upper end of the outer and inner shell 30' and 30'', respectively, and the upper end of the core material 42.

A fourth tamping plunger 60, which fits over the hole spindle 20, moves downwardly into the chamber 18 as a piston and completes the forming of the shell. The completed shell is designated by the reference character 30c.

After compacting the final end wall of the shell 30c, the die 15 is again inverted, the plunger 34 removed, and the tamping plunger 60 is pushed up to eject the shell 30c and the encapsulated core material 42 from the die.

The method described makes possible the encapsulation of a sleeve-shaped core with a shell having a wall of substantially uniform thickness throughout and with as much compaction as desired for both the shell and the core.

The preferred embodiment of the invention has been illustrated and described, but changes and modifications can be made and some features used in different combinations without departing from the invention as defined in the claims.

I claim:

1. The method of making an encapsulated tubular element including
 - (a) depositing powdered encapsulating material in a die chamber around a hole spindle and around an outer shell-forming plunger located along a portion of the length of the spindle, with both the spindle and the plunger centrally located along the axis of the die chamber and spaced from the wall of the chamber,
 - (b) filling the space around the plunger and beyond the top of the plunger along a length of the hole spindle beyond the plunger with shell-forming material,
 - (c) compacting the shell-forming material under axially-exerted pressure,
 - (d) inverting the die chamber and the compacted material contained therein,
 - (e) removing the plunger and replacing it with a spacer of less radial width than the plunger so as to leave a new clearance between the compacted material and the spacer,
 - (f) depositing in the new clearance core material to be encapsulated,
 - (g) compacting the core material,
 - (h) then withdrawing the spacer to leave an inner clearance between the core material and the hole spindle,
 - (i) depositing additional encapsulating material in the inner clearance,

(j) and compacting the additional encapsulating material to complete the shell.

2. The method described in claim 1 including rotating the shell-forming plunger and spacer as they are withdrawn from contact with the compacted material that contacts with the plunger and spacer so as to avoid axial dislodgement of the compacted material.

3. The method described in claim 1 including compacting the core material to a level at least as low as the upper limit of the previously-compacted encapsulating material which surrounds the core material.

4. The method described in claim 1 including compacting the outer encapsulating material by pressure of an annular surface spanning the space between the wall of the die chamber and the peripheral surface of the hole spindle, compacting the core material by pressure of an annular surface spanning the space between the spacer and the outer shell material and while holding the material of the outer shell compacted by mechanical confinement at both ends and around its periphery.

5. The method described in claim 4 including compacting the inner shell material by pressure of an annular surface, spanning the space between the core and the hole spindle and while both the core and the outer shell material are held compacted by a mechanical confinement at both ends.

6. The method described in claim 5 including removing the compacting force from one end of the inner core material, and the mechanical confinement from the same end of the core material and outer shell, and then covering those ends with encapsulating material and compacting it over the full radial width of both ends to complete the shell.

7. The method of making an encapsulated tubular element in a cylindrical die chamber that has a hole spindle extending along the longitudinal axis of the die chamber, which method comprises

- (a) closing the bottom of the die chamber,
- (b) filling the die chamber with powdered shell material up to a predetermined level while holding the core material radially spaced from the hole spindle,
- (c) placing additional shell material in the chamber on top of the other shell material and across the full radial width of the die chamber from the wall thereof to the periphery of the hole spindle,
- (d) compacting the shell material in the die chamber by pressure applied by a surface spanning the space between the wall of the chamber and the periphery of the hole spindle,
- (e) inverting the die chamber,
- (f) confining the compacted material in one end by the surface with which the material was compacted,
- (g) confining the other end of the compacted material across its radial width while placing powdered core material into the space in the shell which was formed by originally spacing the shell material from the hole spindle,
- (h) maintaining a moderate spacing of the core material from the hole spindle while filling the shell with the core material to a predetermined level,
- (i) then compacting the core material by pressure of an annular surface spanning the exposed top surface of the core material,
- (j) restraining the compacted core material against axial dislodgement,
- (k) placing shell material in the space left between the core material and the hole spindle during the filling with core material,
- (l) compacting the shell material which is placed around the hole spindle by force of an annular surface,
- (m) withdrawing that annular surface of the confining force from the core material and the outer shell material while providing a rotary component of motion during the withdrawing of the confining surfaces,

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- (n) placing additional shell material in the die chamber above the end limits of the outer shell, core material and inner shell material,
- (o) compacting the additional shell material, all of the compacting being done under high pressure,
- (p) and then ejecting the core material and its surrounding shell from the die chamber.
8. The method of encapsulating a sleeve-shaped core of material, which method comprises
- (a) forming an outer shell and an end wall of the shell by placing powdered shell-forming material in a space of tubular cross section closed at one end,
- (b) compacting the shell-forming material in the space,
- (c) and after the compacting of the shell material, increasing the radial width of the space at the inside thereof to leave a clearance between the compacted shell material and the inner radial limit of the space,
- (d) filling this clearance with the material to be encapsulated so as to form that material into a sleeve-shaped core,
- (e) again widening the space at the radial inside part of said space to leave a new clearance between the sleeve-shaped core and the inner radial limit of the space,
- (f) filling this new clearance with shell-forming material,
- (g) compacting the shell-forming material to form an inside of the shell, and
- (h) completing the shell by compacting other shell material that covers one end of the inner and outer parts of the shell and that spans the end of the sleeve-shaped core.
9. Apparatus for encapsulating a sleeve-shaped core including
- (a) a die having a cylindrical chamber open at both ends,
- (b) a removable end piece closing one end of the chamber and forming a bottom of the chamber,
- (c) a hole spindle coaxial with the chamber and extending through the bottom end piece,
- (d) a shell-forming plunger that fits around the hole spindle to fill the chamber radially outward to an outer clearance when an outer shell is to be formed in said clearance,
- (e) a first sleeve-shaped tamping plunger that fits the cylindrical chamber,

- (f) a spacer that fits around the hole spindle to fill a portion of the chamber that is reserved for an inner shell, said spacer serving to hold core material away from the hole spindle while spacing core material in the chamber,
- (g) a second sleeve-shaped tamping plunger that fits through the first tamping plunger and into the space between the first tamping plunger and said spacer,
- (h) and a third tamping plunger that fits over the hole spindle and within the second tamping plunger.
10. The apparatus described in claim 9 including a fourth sleeve-shaped tamping plunger that fits into the chamber and that spans the full radial width of the chamber from the hole spindle to the cylindrical wall of the chamber.
11. The apparatus described in claim 9 including a flange at the upper end of the second tamping plunger and means on the flange for holding one end of the spacer in a centered position with respect to the cylindrical chamber.
12. The apparatus described in claim 9 including flanges at the upper ends of all of the tamping plungers for limiting their downward movement into the die chamber.
13. The apparatus described in claim 9 including the shell-forming plunger having an opening therein for receiving the hole spindle to maintain the hole spindle in a centered position in the cylindrical chamber, and the first tamping plunger also having an opening therein for receiving the hole spindle for maintaining the hole spindle in a centered position in the chamber after the shell-forming plunger has been removed from the die chamber.

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REUBEN EPSTEIN, *Primary Examiner*.L. DEWAYNE RUTLEDGE, CARL D. QUARFORTH,
Examiners.