June 7, 1966 M. J. SMITH 3,255,279

FLASHLESS ENCAPSULATED SPHERE MANUFACTURE

Filed Oct. 13, 1964

FIG. 1

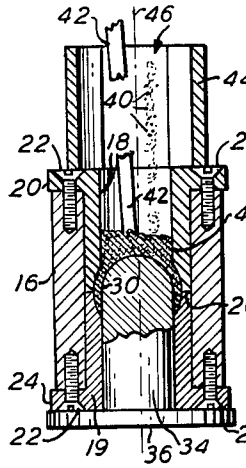


FIG. 2

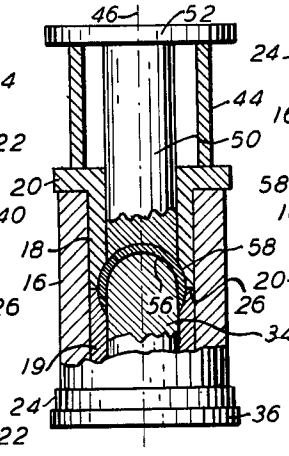


FIG. 3

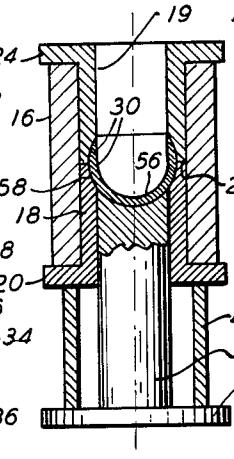


FIG. 4

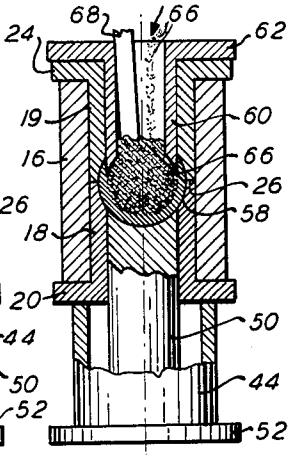


FIG. 5

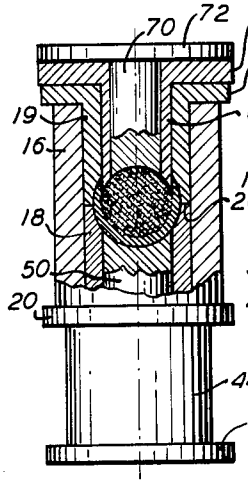


FIG. 6

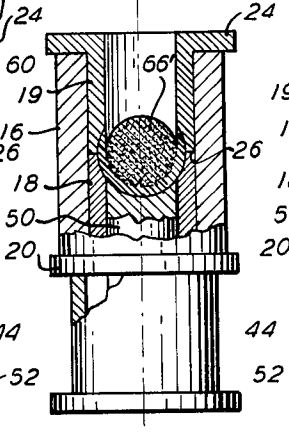


FIG. 7

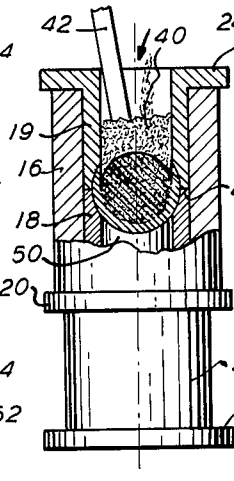


FIG. 8

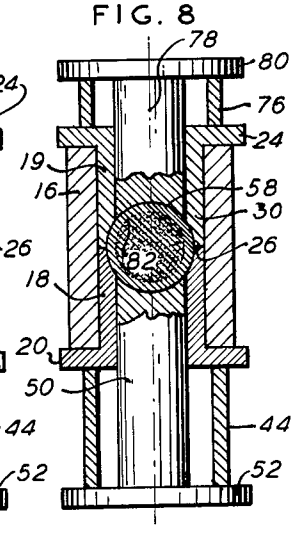
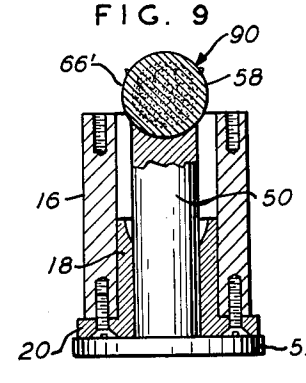


FIG. 9



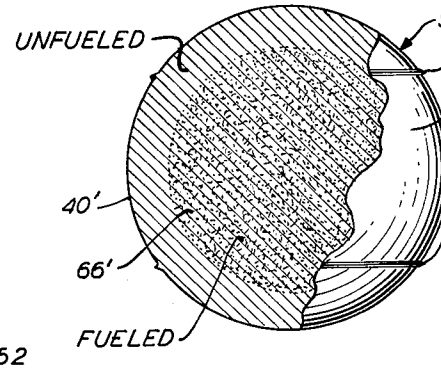


FIG. 10

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FLASHLESS ENCAPSULATED SPHERE MANUFACTURE

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11 Claims. (Cl. 264—.5)

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 flashless encapsulated sphere manufacture.

The conventional spherical elements, such as produced for nuclear fuel, are produced with a ridge or flash at the equator which often makes the shell have an excessive radius so as to require its removal by tumbling, grinding, or machining of the shell which is a time consuming and costly step. This flash originates by virtue of the die and plunger configuration. It is obvious that such a flash will be produced upon final pressing with conventional plungers that come together within the die body cavity. The plunger cavities can never be exact hemispheres since this would produce a feather edge on the plungers at the equator of the sphere. These edges would flare out and destroy the desired configuration, and this would also cause binding. In practice, therefore, the cavities are always somewhat less than hemispherical with the edge flattened to provide the strength required. Flash is the natural result of this design.

It is an object of the present invention to provide an improved method of making spheres without a flash, and with a smooth spherical surface at the equator of each sphere. Another object is to provide a method of compressing a spherical encapsulation in a die with pressure applied over less than half of the surface of the sphere, and to bring the movable part of the die into contact with less than a hemisphere of the surface while other parts of the die restrain the remainder of the material to the desired spherical shape.

It is another object of the invention to provide improved apparatus for making encapsulated spheres. The preferred embodiment of the invention provides a die assembly with die parts that are continuously in contact during the molding operation to confine the sphere at its equator, and with a movable die element that compresses material to form the upper part of the sphere above the equatorial zone that is confined by the continuously-contacting parts at the equator region.

This invention provides combinations of die parts that cooperate to obtain a flashless encapsulated element without adding any substantial increase in the labor required for the manufacture. Aside from the assembly of some extra elements in the die, there are no additional steps in the process over what is required in the manufacture of encapsulated spheres by conventional methods.

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 through 9 are views, mostly in section, showing apparatus for making encapsulated spheres and illustrating the successive steps in the manufacture; and

FIGURE 10 is a cross section of a completed encapsulated sphere made in accordance with the method illustrated in FIGURES 1–9.

The apparatus illustrated in the drawing includes a die assembly having a molding cylinder **16** with upper and lower plunger cylinders **18** and **19**, respectively. The upper plunger cylinder **18** has a flange **20** which extends

across the upper end of the molding cylinder **16** and which is secured to the molding cylinder by screws **22** passing through the flange and threaded into the cylinder **16**. A similar flange **24** of the plunger cylinder **19** is attached to the lower end of the molding cylinder **16** by other screws **22**.

The plunger cylinders **18** and **19** have confronting end faces **26** which contact with one another at a mid region along the length of the molding cylinder **16**. The outside surfaces of the plunger cylinders **18** and **19**, inward from their flanges **20** and **24**, respectively, are cylindrical throughout their full length and fit into the cylindrical opening which extends throughout the length of the molding cylinder **16**. This fit is preferably a running fit so that one or the other of the plunger cylinders **18** and **19** can be conveniently removed at the end of a molding operation to release the sphere from the mold assembly.

The inside surfaces of the plunger cylinders **18** and **19** are cylindrical throughout most of their length but they have spherical zone surfaces **30** adjacent to the end faces **26**. These zone surfaces **30** meet at the end faces **26** to form a continuous equatorial zone for the mold and there can be no flash between the confronting end faces **26** because these faces are brought into intimate contact before any mold material is introduced into the mold assembly.

A forming plunger **34** is introduced into the plunger cylinder **19**. This forming plunger **34** has a bottom flange **36** which contacts with the flange **24** to limit movement of the forming plunger into the die assembly. The outside surface of the plunger **34** is cylindrical up to the beginning of the zone surface **30** of the plunger cylinder **19**. At this level, the diameter of the forming plunger decreases somewhat and then continues with cylindrical contour to the level of the confronting faces **26**. Above this level, the forming plunger **34** is hemispherical.

Molding material **40** for the encapsulation is dropped into the mold assembly through the open upper end of the plunger cylinder **18**, as shown in FIGURE 1. This material **40** drops down into the space between the upper end of the plunger **34** and the spherical zone surfaces **30** of the plunger cylinders **18** and **19**. In order to insure uniform distribution of the material **40** into the space, the material is preferably tamped with a tamper **42**.

Enough material **40** is dropped into the die assembly to completely cover the upper end of the forming plunger **34** and to compensate for the compression to which the material **40** is subjected in the next step.

A plunger spacer **44** is placed on top of the flange **20** in a position generally concentric with the center axis **46** of the plunger cylinders **18** and **19**.

FIGURE 2 shows the next step in the process. A bottom plunger **50** is introduced into the plunger cylinder **18** and is pushed downwardly into the plunger cylinder to compress the encapsulated material **40**. This bottom plunger **50** is cylindrical and the portion which extends into the plunger cylinder **18** fits closely with a running fit in the cylinder.

The die assembly is then subjected to pressure, such as that of a hydraulic press, to force the bottom plunger **50** downward in the plunger cylinder **18** until a flange **52**, at the upper end of the plunger **50**, strikes against the plunger spacer **44**. The parts are of such length that when the flange **52** abuts against the plunger spacer **44**, the end face of the plunger **50** is exactly even with the upper limit of the spherical zone surface **30** of the plunger cylinder **18**.

The plunger **50** has an end face **56** which is an area of a sphere and which completes a hemispherical surface when combined with the spherical zone surface **30** of the plunger cylinder **18**.

Thus the compression step illustrated in FIGURE 2 compresses the material **40** into a shell **58** which is hemi-

spherical both inside and outside above the level of the faces **26**, and which has a cylindrical inside surface below the level of the confronting faces **26**.

The die assembly is then turned upside down into the position shown in FIGURE 3. The forming plunger **34** is removed, preferably with a rotational movement, so as to leave a smooth inside surface in the shell **58**.

FIGURE 4 shows the next step in the process. A tamping shield **60** is introduced into the plunger cylinder **19**. This tamping shield has an outside surface similar to that of the forming plunger **34** so that it fits with a running fit in the plunger cylinder **19** and it contacts with the cylindrical inside surface of the shell **58**. The tamping shield **60** has a flange **62** at its upper end; and this flange **62** contacts with the flange **24** of the plunger cylinder **19** to limit the extent to which the tamping shield **60** extends into the shell **58**. An end face **64** of the tamping shield **60** is a spherical zone surface and forms a continuation of the hemispherical inside surface of the shell **58**.

Core material **66** is dropped into the die assembly through the open top of the tamping shield **60** and this core material is preferably distributed uniformly into the shell **58** by a tamper **68**. The core material, which contains nuclear fuel when making an encapsulated nuclear fuel element, is supplied in sufficient quantity to completely fill the shell **58** and to leave additional material in the tamping shield **60** to compensate for the subsequent compression of the core material in the next step of the process.

FIGURE 5 shows a tamping plunger **70** having a cylindrical portion which fits into the tamping shield **60** with a running fit. A flange **72** forming the upper portion of the tamping plunger **70**, comes in contact with the flange **62** of the tamping shield **60** to limit the downward movement of the tamping plunger in the die assembly.

The lower end of the tamping plunger **70** is a spherical area and forms a continuation of the spherical surface on the end face of the tamping shield **60**. The die assembly is then subjected to pressure, such as by a hydraulic press, to force the tamping plunger **70** downward to its limit of travel, and this compresses the core material **66** into a sphere, as shown in FIGURE 5. The completed sphere is indicated by the reference character **66'**.

The tamping plunger **70** and tamping shield **60** are then removed from the die assembly, leaving the upper portion of the core sphere **66'** exposed, as shown in FIGURE 6. Additional encapsulating material **40** is then dropped into the die assembly through the upper end of the forming plunger **19**, as shown in FIGURE 7. The tamper **42** is preferably used to obtain more uniform distribution of the material **40** in the plunger cylinder **19**.

A plunger spacer **76** is then placed on top of the flange **24** and a top plunger **78** is introduced into the plunger cylinder **19**. A flange **80** at the upper end of the plunger **78** limits downward movement of the plunger **78** The plunger **78** fits into the cylindrical portion of the plunger cylinder **19**, as in the case of the other elements, with a running fit; and there is an end face **82** at the lower end of the plunger **78**. This end face **82** is a spherical area which matches with the spherical zone surface **30** of the plunger cylinder **19** to complete a hemispherical surface.

The die assembly with the parts shown in FIGURE 8 is subjected to pressure, as from a hydraulic press, to bring the top plunger **78** into its lowermost position, as illustrated in FIGURE 8. This completes the molding of the encapsulated sphere, the encapsulation being indicated by the reference character **40'**.

In order to release the sphere from the die assembly, the screws **22**, which connect the plunger cylinder **24** to the molding cylinder **16**, are removed. The plunger cylinder **19** is then removed, together with the plunger spacer **76** and top plunger **78**. The plunger spacer **44** is also

removed, there being a break in the circumference of this spacer **44** to permit it to be withdrawn transversely from its position between the flanges **20** and **52**. The bottom plunger **50** is then pushed upwardly until its flange **52** comes in contact with the flange **20** and this leaves the encapsulated sphere, designated by the reference character **90**, in the position shown in FIGURE 9, where it can be readily removed from the die assembly.

FIGURE 10 is an enlarged cross-sectional view of the sphere **90**. Although the outside surface of the core **66'** and the encapsulation **40'** may be perfectly spherical surfaces, it sometimes occurs in practice that there is a slight ridge **94** at the locations where the end faces of the plungers **50** and **78** merge with the spherical zone surfaces **30** of the plunger cylinders **18** and **19**. These ridges, when they do occur, are hardly noticeable and the size of the ridge **94** is exaggerated in the drawing for clearer illustration.

Even where the ridge is pronounced, it does not approach a flash, as experienced in previous methods of making encapsulated spheres, and it is easily removable by tumbling, if removal is desired.

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

I claim:

1. The method of making a sphere in a die having a relatively fixed portion and a plunger movable toward and from the relatively fixed portion, which method comprises confining a mass of material in the die with the material confined to a lower hemisphere and a portion of an upper hemisphere above the equator by contact with the relatively fixed portion of the die, compressing the mass to a final shape by pressure of the movable portion of the die applied over a spherical area equal to the remaining portion of the upper hemisphere while bringing the movable portion of the die into position to register with the portion of the upper hemisphere that is confined by the relatively fixed portion of the die, and then separating parts of the die at a location of a full diameter of the sphere and removing the sphere from the die.

2. The method described in claim **1** including first forming a hollow shell over the entire spherical surface of the relatively fixed portion of the die, then filling the hollow shell with an internal core material, applying additional shell material over the core, then compressing the additional shell material with the movable portion of the die to complete the encapsulation of the core.

3. The method described in claim **2** including forming the hollow shell with a hemispherical inside surface and a cylindrical opening at the top of the shell, mechanically confining the cylindrical opening against inward collapse while supplying the core material to the space within the shell, and then withdrawing the mechanical confinement before completing the forming of the sphere.

4. The method of making a sphere from a compressible mix, which method comprises confining a space with two different spherical zone surfaces that abut with one another around a great circle of a sphere, confining the lower portion of the space over a surface that forms with one of the zone surfaces a hemisphere, filling the space with the compressible mix and with some of the mix extending beyond the upper limit of one of the zone surfaces, compressing the mix into the space by moving another spherical surface towards said space and into position to form with the other of the spherical zone surfaces the other hemisphere whereby said space comprises a complete sphere, removing the confining surfaces including the separating of two different spherical zone surfaces where they abut one another around the great circle, and removing the completed sphere from the space.

5. The method of making a spherical encapsulated nuclear fuel element which comprises confining a space

between an inner surface that is cylindrical below a center plane and hemispherical above said plane and an outer surface made up of two separate areas, each of which is a spherical zone on a different side of a great circle that lies in said plane, the centers of the zones being coincident with the center of said hemisphere leaving the space with the cylindrical opening at the end of the space adjacent to the hemisphere, filling the space with encapsulating material through said cylindrical opening, tamping the encapsulating material and then compressing it by the application of force applied over a spherical surface that is advanced toward the hemispherical inner surface across the full cross section of the cylindrical opening until the advancing spherical surface reaches the end of the cylindrical opening and forms with the upper zoned surface an outer hemispherical surface of the space with a compacted shell of encapsulating material within the space, inverting the space and removing said inner surface so as to leave the shell hollow and with a cylindrical opening at its upper part, mechanically restraining the sides of the cylindrical opening through the shell while filling the shell with a measured amount of core material having nuclear fuel therein, compacting the core material with a concave surface that forms with the inside of the shell a complete spherical surface for the core, then withdrawing the core-compacting force and the mechanical restraint from the sides of the cylindrical opening into the shell, placing additional encapsulating material over the exposed portion of the core, and then compacting it by pressure of a spherical surface over what was the cylindrical opening through the shell and by this final compaction bringing the outside surface of the shell substantially flush with the adjacent spherical zone to give the shell a spherical outside surface over its entire area.

6. Apparatus for making encapsulated spherical elements including a molding cylinder having a cylindrical chamber therein, upper and lower plunger cylinders that fit within the molding cylinder with a sliding fit, the upper and lower plunger cylinders having confronting faces that abut with one another and each of said plunger cylinders having a somewhat larger cross section at the end which abuts the other plunger cylinder, each of the larger cross sections having a spherical zoned surface that meets that of the other plunger cylinder at a great circle, a forming plunger having a cylindrical portion that fits the inside of the lower plunger cylinder up to the top of said lower plunger cylinder, a hemispherical upper end on the forming plunger which extends above the lower end of the upper plunger cylinder, and another plunger that slides in the upper plunger cylinder for compacting encapsulating shell material against the upper part of the forming cylinder, the other plunger having a lower face that is a spherical surface which is concentric with the hemisphere of the forming plunger when the lower face of said other plunger moves down into a position even with the upper end of the spherical zoned surface of the upper plunger cylinder.

7. The apparatus described in claim 6 including the molding cylinder being invertible and the forming plunger being removable to leave a partially formed shell within the holding cylinder with a cylindrical opening through the shell where the forming cylinder is withdrawn.

8. The apparatus described in claim 7 including a shield that fits into the inverted lower plunger cylinder and that extends down through the cylindrical opening in the shell, abutment surfaces that limit the extent to which the shield fits into the shell, the end face of the shield being a spherical zoned surface that comes substantially flush with the spherical surface of the inside of the shell when said abutment surfaces are in contact.

9. The apparatus described in claim 8 including a tamping plunger that slides up and down in the shield as a piston and that has an end face for compacting core material which is dropped into the shield through the shield, said end face being a spherical surface that forms a continuation of the spherical surface of the zone on the end face of the shield.

10. The apparatus described in claim 9 including a final tamping plunger that follows the shield and the tamping plunger that slides in the shield, the final tamping plunger being of a size to slide in one of the plunger cylinders as a piston and having an end face that is a spherical surface and that forms a hemisphere with the spherical zone surface of its plunger cylinder.

11. The apparatus described in claim 10 including all of the plunger cylinders and tamping plungers having flanges that limit the extent to which they extend into the molding cylinder, and detachable fastening means for connecting the plunger cylinders with the molding cylinder.

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