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METHOD OF CASTING TUBULAR ARTICLES

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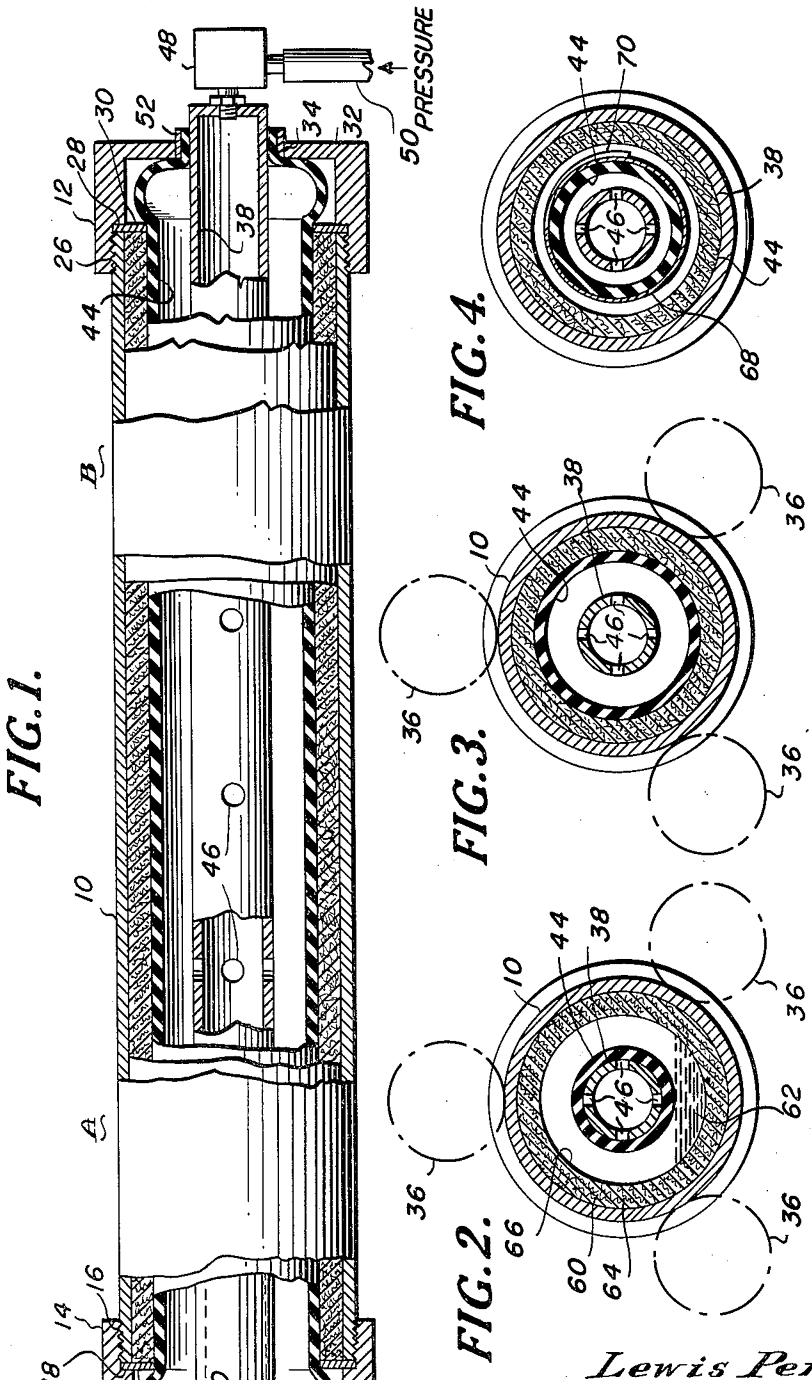

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

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1

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METHOD OF CASTING TUBULAR ARTICLES

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This invention pertains to the casting of so-called plastic articles having reinforcing fibers embedded therein. For example, the invention pertains to the casting of articles of liquid settable material such as thermosetting resins reinforced with a formation of fibers such as glass fibers. The invention pertains not only to methods of casting, but also to equipment therefor, and to the cast articles.

The invention particularly pertains to such casting by use of an expansible mandrel within a tubular mold, the expansible mandrel being employed for generating internal pressures outwardly on the liquid settable material and reinforcing formation.

As is fully developed in the copending application of Herbert D. Boggs, Serial No. 264,976, filed January 4, 1952, now Patent 2,785,442, and assigned to the assignee of the present invention, articles such as pipe may be successfully cast from liquid settable materials reinforced by suitable formation of fibers. For example, articles can be successfully cast from thermosetting resins reinforced with glass fibers. In the just-mentioned copending application, a formation of glass fibers, as in the form of a mat of relatively short fibers, a cloth of interwoven continuous fibers, overlaid layers of diagonally running continuous fibers, and other formations of fibers may be placed within a cylindrical mold. It is also proposed that short fibers may be introduced into a mold, to form the mat or formation therein. Once the formation of fibers is established within the mold, then a quantity of the liquid settable material in liquid form may be introduced, as by pouring into the mold or spraying thereinto. Thereafter, the mold is rotated about its longitudinal axis, and centrifugal forces distribute the liquid settable material evenly throughout the fiber formation. Curing action is then applied to the mold and contents, usually by externally applied heat. This causes the settable material to cure or gel; in other words, to harden. The result is excellent pipe without pores, so-called crazes and other defects.

The present invention constitutes an improvement over the just-mentioned casting techniques. Generally stated, the centrifugal forces mentioned in the preceding paragraph are augmented or replaced by forces applied internally of the mold to force the settable material and/or formation of fibers outwardly against the inner surfaces of the mold. In one major embodiment liquid settable material is poured or sprayed into the fiber formation which lines the mold, the mold is then rotated about its longitudinal axis to evenly distribute the liquid material, and then, when the material is evenly distributed, an expansible mandrel positioned centrally of the mold is expanded to exert force against the liquid material as it is at least partially cured. In another general version of the invention, it is proposed that the fiber formation be impregnated with powdered resin such as the phenolic resins. This will satisfy the requirement for even distribution of settable material throughout the formation and, when pressure is applied by means of the expanding mandrel technique, this pressure with the combination of heat will make the settable material flow and thereafter gel. In this method, it will not be necessary to spin the mold to distribute the settable material. Thus, articles may be molded without the aid

2

of centrifugal casting. It will be understood that further incidents of the invention are described hereinbelow.

Accordingly, it is a primary object of this invention to provide improved methods of casting reinforced articles from settable materials by exerting internal pressures outwardly against the inner surfaces of a mold.

It is a further object of the invention to so cast reinforced articles by providing a mass of liquid settable material within a mold in which a liner of fiber formations is present, spinning the mold about its longitudinal axis to evenly distribute the flowable material throughout the fiber formation, and then expanding a mandrel against the inner surfaces of the flowable material and formation while the material is set or cured.

It is a further object of the invention to provide within a mold a fiber reinforcement formation with powdered or otherwise liquefiable material evenly distributed throughout, applying internal pressures by use of an expansible mandrel and curing the settable material while pressures are thus applied.

Further objects and the entire scope of the invention will be in part obvious and in part expressly set forth in the following detailed description and discussion.

Illustrative embodiments of equipment for the practice of the invention and the method steps may be best understood by reference to the accompanying drawing, wherein:

FIGURE 1 shows a side elevational view partly in section of a pipe casting mold having a fiber reinforcing formation and expansible mandrel therein;

FIGURE 2 shows a cross-sectional view of the mold and contents of FIGURE 1 and a supply of liquid settable material lying therein;

FIGURE 3 shows a cross-sectional view of the mold and contents of FIGURE 1 with the mandrel expanded; and

FIGURE 4 shows a cross-sectional view of the mold and contents of FIGURE 1 with a sheet metal cover on the expansible mandrel.

Referring now to FIGURE 1, a cylindrical mold **10** is provided with end caps **12** and **14**. These caps may be of suitable material such as steel. The end cap **14** may be affixed to the mold **10** by threads **16**. An inwardly extending shoulder **18** is provided for clamping an annular ring **20** between the end of the mold **10** and the shoulder **18**. The end cap **14** is further characterized by an end wall **22** having an aperture **24** therein, this aperture being centrally located.

The end cap **12** may also be affixed to the mold **10** by threads **26**, this cap having an inwardly extending shoulder **28** for clamping another annular ring **30** between the cap and the end of the mold. Cap **12** has an inwardly extending end wall **32** having a relatively large aperture **34** located centrally thereof.

Referring to FIGURE 2, three spaced rolls **36** are indicated in chain line, as convenient means for supporting the mold **10** for rotation about its longitudinal axis. The support and rotation of molds for centrifugal casting are fully developed in the above-mentioned copending application of Herbert D. Boggs, to which reference is now made for such details. It will be understood that lengthwise of mold **10**, as for example in the general vicinity of areas A and B as shown in FIGURE 1, sets of rolls **36** may be provided. Rotation of the mold and end caps may be provided by driving one or more of the rolls **36**, or by driving the mold directly by suitable coupling to a power source.

Reference character **38** designates what may be conveniently termed a mandrel core, this being for example, a tube extending generally from the end cap **12** to the end cap **14**. At the end cap **14** the mandrel core **38** is provided with a centrally extending lug **40** having a tapered end 42. The lug 40 is arranged to fit freely but snugly in the aperture 24 at the end wall 22 of end cap 14. The purpose of this arrangement is to maintain the mandrel core centrally within the mold 10. The tapered end 42 will permit some tolerance in originally inserting the mandrel core and finding the aperture 24.

The mandrel core 38 is surrounded by a resilient member 44 which forms an expansible mandrel. In FIGURE 1 the mandrel is shown expanded, as is also the case in FIGURE 3. In FIGURE 2 the mandrel is shown collapsed onto the mandrel core 38. The mandrel core 38 is provided with one or more apertures 46 and at the end of the mandrel core at end cap 12 a rotary fluid coupling joint 48 is provided for introducing fluid pressure into the mandrel core 38 from suitable pressure source connected to tube 50.

At each end of the mandrel core 38 the mandrel 44 may be attached by any convenient means, as by bonding to the core 38 or utilizing bands 52 clamped about the outer surface of the mandrel. Any convenient means for thus affixing the membrane to the mandrel core in these regions is suitable and no particular limitation to the illustrated arrangement is intended.

It now will be apparent that when fluid pressure is applied within the mandrel core 38 it will be transmitted through apertures 46 and will expand the mandrel 44 outwardly against the inner surface of the mold or against the inner surface of any material lining the mold. The mandrel 44 may be collapsed onto the mandrel core 38, as shown in FIGURE 2, either by virtue of its own resiliency, or by application of negative pressure, viz., vacuum within the mandrel core 38.

With the membrane collapsed onto the mandrel core 38, the aperture 34 in the end cap 12 may be of sufficient size to permit the insertion of the mandrel thereinto. However, no particular limitation to this technique is intended. It will be obvious that a mandrel may be first inserted before an end cap corresponding to cap 12 is applied, and then the cap placed thereon to maintain the mandrel within the mold. Variations of the suggested technique will be apparent to those skilled in the art.

Referring primarily to FIGURE 2, a condition is shown wherein a formation designated 60 of reinforcing fibers is present as a liner within the mold 10. The nature of these liners is fully developed in the above-mentioned copending application of Herbert D. Boggs and further elaboration in this application is thought to be unnecessary. It is assumed in FIGURE 2 that the mold is not in rotation and a pool 62 of a settable or curable material in liquid form is shown lying in the bottom of the mold. This is a situation which will obtain when a measured supply of liquid material is inserted into the mold, preliminary to spinning the mold.

It will be apparent that the end wall 22 of end cap 14 and the end wall 32 of end cap 12 will serve as an outer dam to maintain a quantity of liquid such as pool 62 within the mold before rotation is begun. Additionally, the technique for loading the liquid into the mold may be such that it does not flow readily to the end areas, but is lumped, so to speak, near the center of the mold.

The previously mentioned annular rings 20 and 30 are of internal diameter substantially the expected inner dimension of the cast article for reasons which will become apparent.

Starting with the condition which obtains in FIGURE 2, when the mold is now rotated about its longitudinal axis, centrifugal forces will develop which will distribute the liquid material evenly about the circumference and length of the mold 10. It will further be understood that the liquid material permeates into the fiber reinforcement formation, substantially filling all voids therein which exist between the fibers or bundles thereof. An intimate and even mixture of resin and reinforcements results, all as has been fully developed in the above-mentioned copending application of Herbert D. Boggs.

When the even distribution of liquid has been accomplished, the procedure may go on according to several variations. One manner of proceeding is to apply heat to the outside of the mold to bring the liquid material to a state of gel so that, if spinning is terminated, no further re-distribution of the settable material will result. When that point is reached, spinning may be terminated and the mandrel 44 then inflated to apply pressures against the formation and the liquid. In one manner of thinking, the pressures supplied by the mandrel replace the centrifugal forces otherwise applied. It will be apparent that pressures thus applied supplant pressures which could otherwise only be obtained by extremely high spinning speeds. Needless to say, it is a mechanical problem to spin heavy molds at high speeds without great wear and tear on the driving and supporting equipment.

Differing from the procedure outlined in the preceding paragraph, it is not necessary to stop the spinning once the liquid is evenly distributed. On the contrary, once the even distribution is reached, the mandrel 44 may be expanded while the spinning continues. In this case, the centrifugal forces present remain, and are augmented by the pressures applied by the expanded mandrel. While the spinning continues, the curing heat or other similar effect may be applied and the settable material will gel and harden.

The condition where the mandrel 44 is expanded against the formation with liquid evenly distributed therein, whether the mold is spinning or not, is shown in FIGURE 3.

An important aspect of the invention is the control of the amount of liquid in relation to the amount of reinforcement material so that the expanding mandrel will bottom on the inner surfaces of the fiber formation, rather than on the liquid material itself. This procedure leads to relatively thin-walled pipe which nevertheless has strength commensurate with thick-walled pipe. It may be pointed out that the reinforcement material is compressible to a substantial extent. That is, referring to FIGURE 2, for example, where the formation is shown as of a certain thickness, it can be assumed that if the mandrel in the absence of any liquid material, were to be expanded against the formation, the thickness could be reduced by a substantial amount, say, one-half. It has been found that for a given amount of reinforcement material, if it can be thus compressed and still a mixture of liquid and formation results, the pipe will be obtained with a correspondingly thin wall and yet will be as equally strong as pipe cast where the reinforcement cannot be compressed. Where centrifugal casting alone is employed, the specific gravity of the reinforcing fibers is generally less than the specific gravity of the liquid settable material. Therefore, the centrifugal forces will not force the reinforcement outwardly. Thus, the thickness of the reinforcement must be accepted generally as it is before spinning is begun or perhaps slightly less so due to centrifugal forces thereon and sufficient resin must be introduced to completely fill the radial dimension of the formation.

According to the procedure being described and claimed hereinbelow, the amount of liquid material introduced into the mold may be calculated, when addition of the reinforcing fibers is taken into account, to give a relatively thin-walled pipe. When the spinning is accomplished, the liquid material will be evenly distributed lengthwise and circumferentially, but will extend outwardly only to a radius designated, for example, by the dash line designated by reference character 64 in FIGURE 2. The mandrel 44 is then expanded and will first bottom on the inner surface designated 66 of the formation 60 as shown in FIGURE 2. However, continued expansion of the mandrel 44 will compress the formation inwardly until the mandrel also bottoms on the liquid material, or approximately so, in the vicinity of the dash line 64. It will now be apparent that a given amount of reinforcement has been forced to occupy a lesser space, and yet it is intimately surrounded by an even distribution of liquid material. Curing of the liquid material may now proceed. When powdered material is employed, the amount may be such as to provide the same compression features.

The end result of operation according to the preceding paragraph will leave some of the reinforcement fibers at the inner surface of the pipe, or possibly partially extending out of that surface. The reason for this result is that the fibers have moved inwardly only under the force of the mandrel 44 and will not proceed further inwardly. However, a smooth interior surface of the pipe may be readily accomplished by flushing the pipe (with the mandrel 44 collapsed or removed) with pure settable material.

Certain important benefits follow from the use of the expansible mandrel in accordance with all of the preceding discussion. One such benefit is that when working with certain resins, such as thermosetting resins and others, the mandrel 44 will hold in the styrene. This is a valuable feature, as will be appreciated by those skilled in the art.

It may be further desirable to give the mandrel 44 an element of longitudinal rigidity. Referring now to FIGURE 4, which shows the mandrel 44 partially expanded, it is proposed that a sheath of thin resilient metal 68 be wrapped about the mandrel 44, extending the length of the mold 10, this sheath to be overlapped considerably as at 70 and pre-stressed to follow the mandrel down to its collapsed position on the core 38. Thus, when fluid pressure is applied within the mandrel, the sheath 68 will expand, the expansion resulting in a diminishing of the overlapping area 70. This explanation is thought to make it clear that the same internal pressures are applied as without the sheath and yet the sheath provides some longitudinal rigidity.

It is assumed that the importance of the step of spinning the mold preliminary to expanding the mandrel, or at least in conjunction with the expanding of the mandrel will be appreciated. However, it is pointed out that if a procedure is started with a pool of liquid 62 as shown in FIGURE 2, and only the mandrel is expanded without other steps, i.e., spinning being performed to distribute the liquid material, the liquid will not be distributed concentric with the axis of the mold. On the contrary, while the mandrel may expand in the form of a cylinder, that cylinder may be eccentric with the mold.

As is apparent from the foregoing, the spinning step is of importance in evenly distributing the liquid material throughout the fiber reinforcement formation, before the mandrel 44 is expanded. The spinning step may be dispensed with according to the invention where the formation has evenly distributed therein a quantity of material in powdered form, which may, under application of heat, become a liquid after the mandrel is separated to then flow and then subsequently set under the force of the mandrel 44 alone.

The lug 40 may be splined or otherwise keyed to the end wall 22 of end cap 14 for preventing relative rotation between the mandrel core 38 and the mold.

As previously mentioned, the supply of liquid settable material may be introduced into the mold in any convenient fashion. In most instances, it will be desired to introduce the material into the mold before the mandrel assembly is introduced. The liquid material may be permitted to remain as a pool in the bottom of the mold, or the mold may actually be spun before introduction of the mandrel, to generally distribute the liquid material. The rotation may be then stopped, the mandrel inserted, and the mandrel then expanded with or without spinning, all as described.

The mandrel 44 may be of any suitable resilient material, such as rubber, synthetic rubber or the several flexible resilient plastics now known by those skilled in the art to be available. It is further contemplated that a disposable resilient mandrel may be used—to be discarded after one use.

Rather than introduction of pressure through a rotating joint, a cartridge or the like containing fluid under pressure may be placed within the mandrel core 38, or as a replacement thereon, with means for releasing the pressure externally at the desired moment.

The foregoing detailed description is given only for purposes of illustration, and the scope of the invention is to be determined from the appended claims.

What is claimed is:

1. The method of casting fibrously reinforced tubular articles of settable material comprising: introducing a tubular formation of fibrous reinforcing material into a horizontally disposed tubular mold mounted for rotation about its longitudinal axis; introducing a measure of settable material into the mold; spinning the mold and its contents to evenly distribute the settable material through the reinforcing material; inserting a radially inflatable expansible mandrel into the lumen defined by the mold and its contents; inflating the expansible mandrel to bring its peripheral surface into contact with the contents of the mold; further expanding the mandrel against the inner surface of the contents of the mold while the mold is spinning; and curing the settable material to at least a non-flowable state while the mandrel is so applied.

2. A method as in claim 1 wherein the amount of settable material introduced into the mold when distributed is of lesser radial thickness than the fibrous formation, the arrangement being such that the mandrel when expanded can first botton on the fibrous formation and compress same to a point whereat the mandrel will also bottom on the liquid settable material.

3. The method of casting fibrously reinforced tubular articles of settable material comprising: introducing a tubular formation of fibrous reinforcing material into a horizontally disposed tubular mold mounted for rotation about its longitudinal axis; introducing a measure of settable material into the mold while the mold is spinning; spinning the mold and its contents to evenly distribute the settable material through the reinforcing material; inserting a radially inflatable expansible mandrel into the lumen defined by the mold and its contents; inflating the expansible mandrel to bring its peripheral surface into contact with the contents of the mold; further expanding the mandrel against the inner surface of the contents of the mold while the mold is spinning; and curing the settable material to at least a non-flowable state while the mandrel is so applied.

4. A method as in claim 3 wherein the amount of settable material introduced into the mold when distributed is of lesser radial thickness than the fibrous formation, the arrangement being such that the mandrel when expanded can first bottom on the fibrous formation and compress the same to a point whereat the mandrel will also bottom on the liquid settable material.

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