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PIPE CASTING APPARATUS HAVING VIBRATING MEANS IN PHYSICALLY SEPARATED ADJACENCY TO THE CORE

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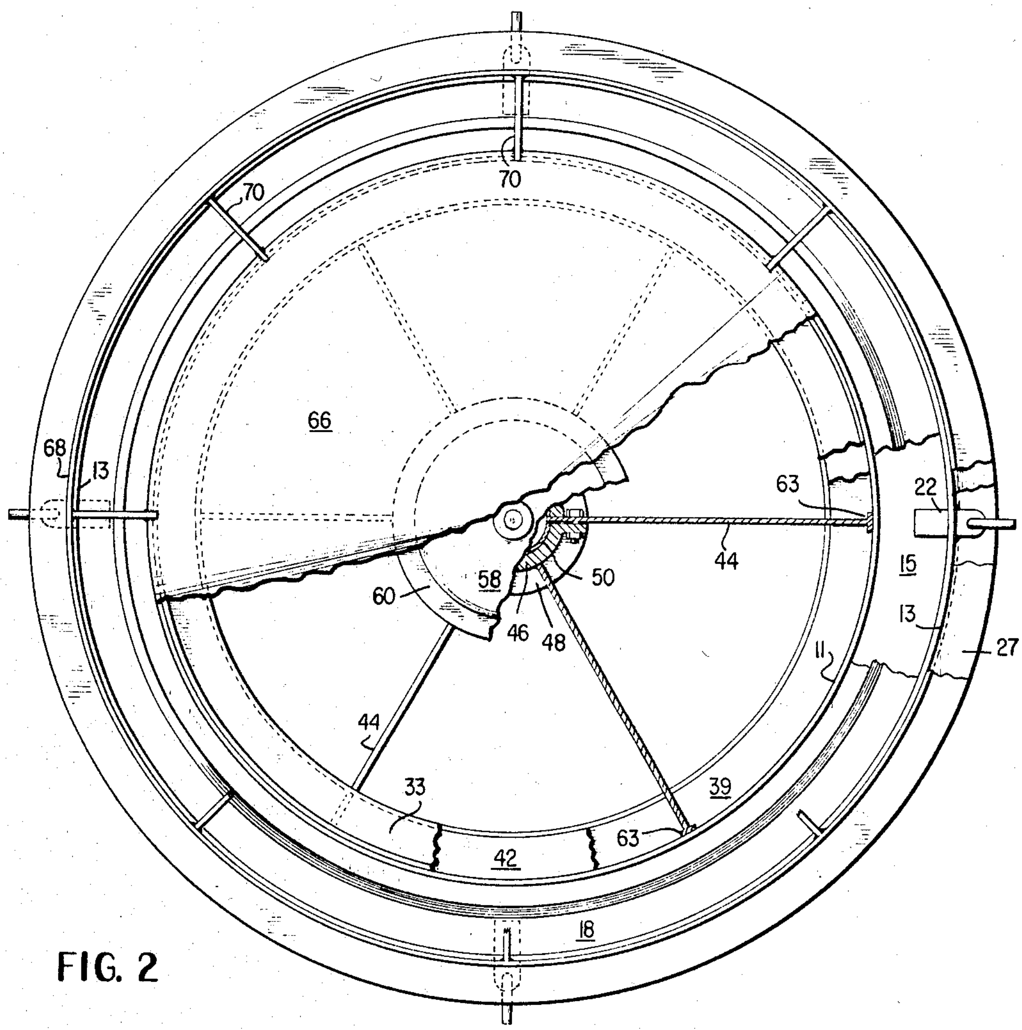

FIG. 2

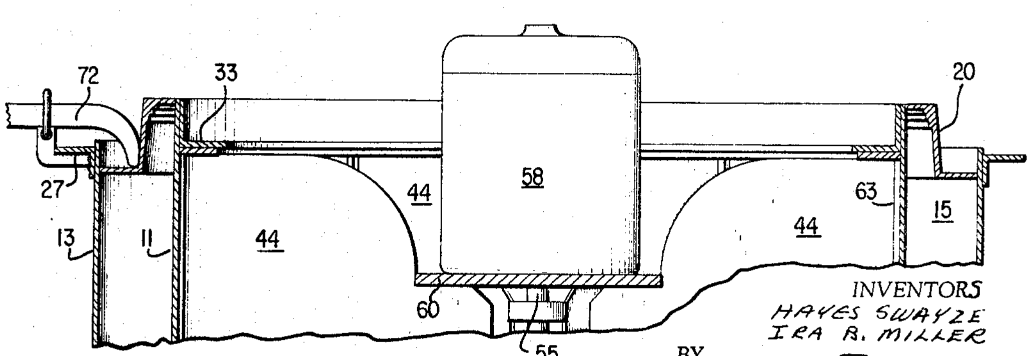

FIG. 3

INVENTORS
HAYES SWAYZE
IRA B. MILLER
BY Adams, Forward & McLean
ATTORNEYS.

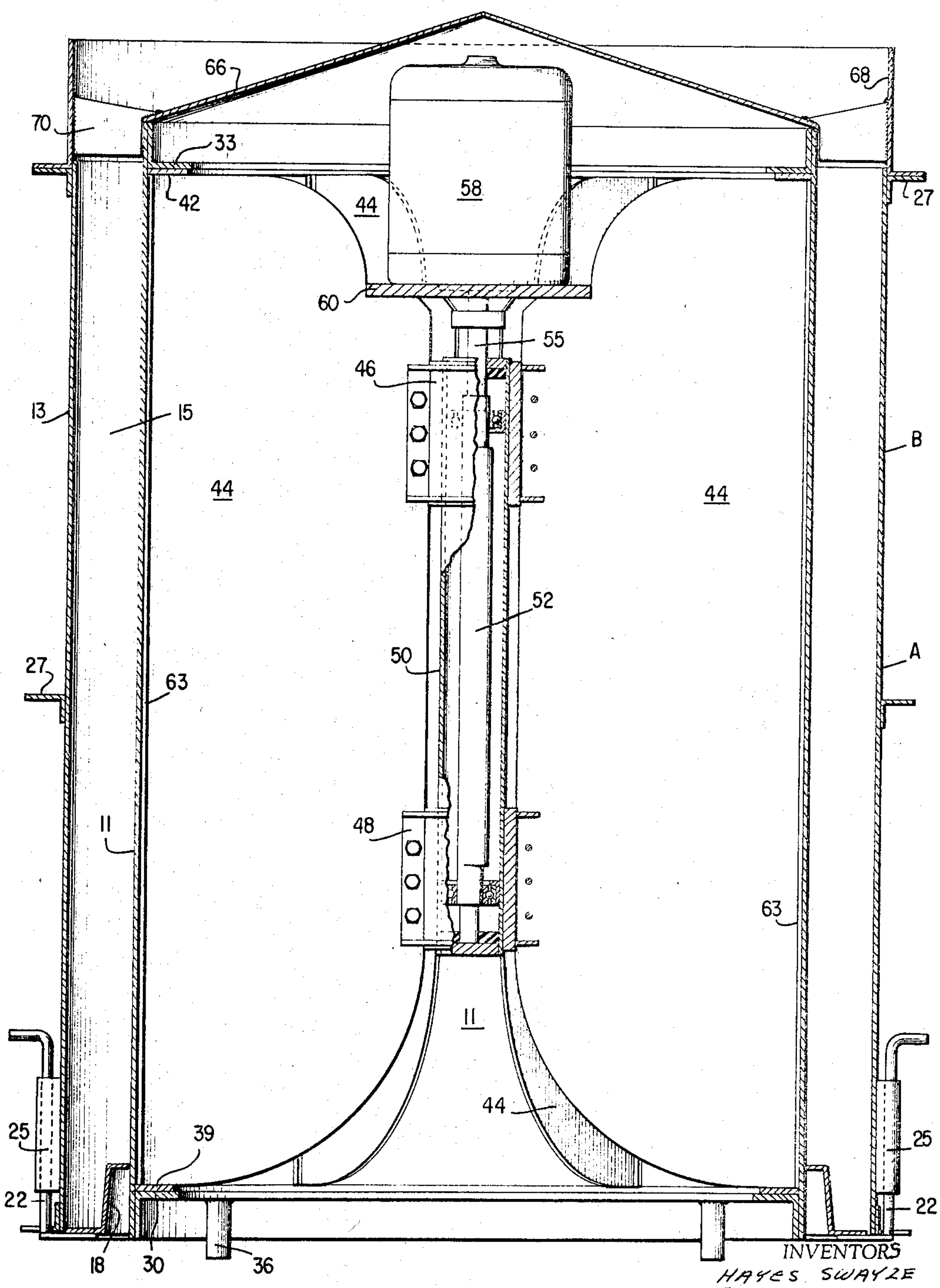

FIG 1

INVENTORS
HAYES SWAYZE
IRA B. MILLER
BY Adams Forward + McLean
ATTORNEYS.

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PIPE CASTING APPARATUS HAVING VIBRATING MEANS IN PHYSICALLY SEPARATED ADJACENCY TO THE CORE

Hayes Swayze, Columbus, Ohio, and Ira B. Miller, Albuquerque, N. Mex., assignors, by mesne assignments, to Hydro Conduit Corporation, Wilmington, Del., a corporation of Delaware

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This invention is a new method for casting hollow concrete members such as pipe, and an apparatus suitable for performing this method. Manufacturers of concrete pipe greatly prefer the "dry casting" technique, in which a cement mix of minimum water content is employed. Such methods are of particular value in the speed with which the cement sets to its permanent form, allowing removal of the mold, thus permitting the fabricator to cast a great deal more concrete pipe with a given inventory of forms. Since "dry mix" concrete does not have the ready-flow characteristics found in wetter concrete mixes, it is necessary to shake the mold to insure the spread of the cement mixture throughout the mold and throughout any reinforcing armatures or cages placed within the mold.

In this invention a "dry-mix" concrete formula is passed into a hollow, usually cylindrical, tubular mold while the inner surface of the mold or forming member is being vibrated at a plurality of locations on the interior of the molding zone. The invention resides in the provision, within the core which forms the inner surface of the molding zone, of a source of vibration closely adjacent the inner core surface so as to move in and out of contact with the interior core surface at a plurality of locations extending along the length of the molding zone and spaced around the inner periphery, the vibrating body being disconnected from the inner core surface at all locations but fitting sufficiently snugly within the core so that about 70–80 percent of the vibration energy is transmitted to the core, thereby imparting controlled bending movements to the core surface.

In accordance with the present invention the vibration frequency and amplitude at the point of application of the vibrations to the inner surface of the molding zone are controlled to provide adequate compaction of the concrete, that is, sufficient compaction that the concrete pipe will not fall apart on removal of the mold within a short time period, preferably not more than about three minutes overall. The compaction achieved during pouring, using the vibration technique of this invention will advantageously be such as to allow removal of the mold immediately after pouring without in any way harming the integrity of the hollow cast member. The compaction or consolidation of the plastic charge or concrete mass must be such that the finished pipe after 28 days meets specified compressive strength tests. An acceptable compressive strength is set at 4,000 p.s.i. at 28 days when using not less than 6 bags of cement per cubic yard of concrete (ASTM test C–39 [1962]). Steel-reinforced concrete pipes made according to the method of this invention meet ASTM Test Specifications C–14 and C–76.

The frequency of the vibrating body is maintained within the range about 40–100 cycles per second. The power and amplitude of vibration applied to the inner core surface is controlled so as to provide a maximum vibration amplitude of about 0.05 to 0.075 inch on the outer surface of the mold at locations generally opposite the locations of maximum vibration on the inner core surface. This amplitude is sufficient to give proper compaction of the concrete mixture under the vibration technique of this invention, since the vibration can be applied more

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uniformly over the entire surface of the inner core than is the case for the systems of the prior art. In general, the vibrating body or bodies should be maintained on the average not more than 1/32 inch away from the inner core surface, measured from dead center position of the vibrating body and thus in no event more than a maximum distance of 1/16 inch during vibration. The vibrations are passed into the concrete from all along substantially the entire length of the pipe section being molded. The vibration is performed without substantial deformation of the inside mold or core although controlled bending occurs and the preferred frequency of vibration is about 60 cycles per second, and the lower the vibration frequency, the higher is the vibration amplitude required at the interior surface of the molding zone, that is, at the core, to effect the desired compaction of the concrete. In prior art techniques, the vibration is less uniformly distributed along the length and around the periphery of the molding zone and thus a much greater amplitude must be obtained in order to insure that each part of the zone does get enough vibration strength to compact the concrete mixture sufficiently. In the vibration technique of this invention, about 20–30% of the vibrator power is not transmitted to the core but is lost in movement of vibrator assembly within the core. This movement perhaps accounts for the improvement in uniformity of vibration application. The vibration may be continued for further compaction of the concrete after pouring is finished. Pressure may be applied to the molding zone during this later step.

The concrete pipe sections made using the process of this invention will generally be about 2 to 20 feet long and from 18″ to 144″ in diameter although sizes outside these ranges may also be made. The "dry-mix" concrete formulas used in this invention generally contain about 1 pound of water to every 2.4 to 4.0 pounds of cement and about one pound of water to every 17 to 20 pounds of total solids. Preferably the water amounts to about one pound for every 2.4 to 4.0 pounds of cement or every 17 to 30 pounds of total solids. This is in contrast to "wet-mix" concrete formulas which use about 1 pound of water for each 1.7 to 3 pounds of cement or about 1 pound of water for each 10 to 18 pounds of total solids.

As mentioned, this invention employs a vibrating body or plurality of vibrating bodies closely adjacent to the inner surface of the molding zone functioning as the force-applying means, said body or bodies being so arranged as to contact the inner surface of the core at a plurality of locations spaced around the entire periphery of the core. In the preferred apparatus of this invention, the vibrations are transmitted through the medium of a plurality of fins which contact substantially the entire length of the core during the pouring of the concrete. This fin assembly is held snugly within the core preferably only at the top and bottom of the assembly. The fin assembly is adjacent the interior surface of the core but is not attached thereto, that is, it may be readily removed by detaching either the top or bottom holding member. The provision of fins unattached to the core assures a better distribution of the vibration amplitude through the length of the core and also around the periphery of the core than is the case in prior art devices where the vibrating body is held rigidly and fastened securely, for example, by welding to the interior surface of the core. Besides actual measurement of large variations in vibration amplitude, the unevenness of vibration distribution is evidenced in such devices by the metallic stress and fatigue which leads to frequent rupture and failure in the core. This invention avoids such stresses and fatigue and obviates this rupture and failure in the core, thereby providing decrease in down-time, decrease in required inventory of molds and decrease in overall cost of manufacturing the concrete pipe. As mentioned, the fin assembly preferably has a diameter which is 1/16 inch or less smaller than the interior of the core. Preferably the clearance between the fin assembly and the interior of the core is only large enough to permit insertion of the fin assembly into the core, but a "looser" arrangement may sometimes be desirable in the casting of thicker pipes to allow the fin assembly some freedom to rotate on its axis within the core during the vibration. A rotating fin moving in cyclic orbit thus may contact most of the interior surface of the core cylinder during the generally longer time periods required to cast a thicker pipe.

A preferred apparatus which may be employed in this invention is shown in the drawings which are to be considered illustrative and not limiting.

In the drawings:

FIGURE 1 is a cross-sectional view of the apparatus, with the vibrator housing partly cut away and with the apparatus in the condition suitable for pouring the concrete;

FIGURE 2 is a top elevational view of the apparatus of FIGURE 1, partly cut away; and

FIGURE 3 is a cross-sectional view of the top portion of the apparatus in the condition after pouring of the concrete.

The mold is made up of inner core **11** and outer shell **13**. As can be seen, these elements are cylindrical and arranged concentrically to provide the annular space **15** of uniform thickness for reception of the cement mix. The bottom of the mold cavity is defined by the removable, shaped ring **18** which is of a configuration suitable to produce the desired end shape of the concrete pipe section. The top of the mold cavity **15** is defined by the shaped ring **20**, (FIGURE 3) which is placed atop the cavity after the cement is poured. The lower bell ring **18** may be held in place by the rotatable hooks **22** which extend under the ring and which are fastened to the lower end of shell **13** by means of the blocks **25** through which the hooks **22** pass and in which they may rotate to release the shell **13** from the ring **18**. The shell **13** also may be provided with the flanges **27** for strength and for ease of handling.

Inner mold member or core **11** is usually provided inwardly with the lower flange **30** and the upper flange **33**. They generally are welded rigidly to the interior surface of the core **11**, again for strengthening and handling purposes as well as to provide support. If desired, a means, for example, pipe legs **36**, may be provided to support the core **11** by means of the lower flange **30**. Lower bearing plate **39** rests on lower flange **30** but is not fastened thereto. Upper bearing plate **42** is held against upper flange **33**, but, again, is not fastened thereto. Between bearing plate **39** and bearing plate **42** is the vibration transmission assembly which comprises a plurality of vertical fins **44** which may be attached by the upper clamps **46** and the lower clamps **48** to each other and to the vibrator housing **50**. Journaled in the housing **50** is the vibrator which may comprise the eccentrically weighted shaft **52** which is rotated by drive shaft **55** which conveniently can be driven by electric motor **58** and directs the fins **44** in cyclic movement against the inner surface of core **11**. As shown, the vibrator **52** is arranged closer to the top than the bottom of the core **11**. In a preferred installation, where the pipe section to be formed is about 8 feet long, the distance between the top of the vibrator and the upper end of the core is about 21 inches. The vibrator used in any particular situation will generally be of such length and so arranged that its midpoint will be about 39 inches below the top of the core **11**.

As illustrated, the motor **58** rests on platform **60** which in turn rests on the fins **44**, but neither motor nor platform are essential to this apparatus, it being contemplated that the drive shaft **55** may be operated by a motor more remotely positioned, perhaps at a position sufficient to drive a number of vibrators, for example, by means of a shaft and flexible coupling. Such an arrangement would also enable the use of a variable speed motor in order to obtain different frequencies of vibration and thereby approach resonance frequencies of the various sizes and types of molds. The motor **58** should not be mounted at the bottom of the vibrator shaft as this will cause it to act as a pendulum.

To each fin **44** is preferably attached the contact surface or flattened bearing member **63** which aids in distributing the vibrations throughout the interior of the core **11**. As mentioned, the distance from the outer surface of a bearing **63**, i.e., the effective diameter across the vibrator fins, to the outer surface of its axially opposite bearing is no more than 1/16 inch, preferably no more than 1/32 inch, shorter than the inner diameter of the core **11**. As the vibrator is usually positioned coaxially within the core and shell, this means that the vibrating member, when resting, is spaced away from the inner surface of the core by a distance not in excess of about 1/32 inch, and during rotation its contact surfaces move against the inner core surface in a progression of bending forces.

For ease and accuracy in pouring the concrete the molding device may be provided with the removable distributor assembly shown in FIGURES 1 and 2. This distributor assembly comprises the central cone **66**, the guard ring **68** and the spacers **70**. As can be seen, the core is of such size that its base is congruent to the upper edge of core **11** and the guard ring **68** fits snugly against the outer shell **13**, perhaps resting on the upper flange **27**, as illustrated. It will be noted that the distributor assemblage also serves to keep the top of the core centered during pouring of the concrete.

The number of radial members of the apparatus, that is, the hooks **22** and blocks **25**, the fins **44** and the bearings **63** attached to the fins, and spacers **70** will be supplied to the apparatus in any number desired to fulfill their tasks and may be increased in number with an increase in the diameter of the apparatus. Also, where great mold lengths are employed, two or more vertically spaced-apart eccentric-type vibrators may be employed. In such a situation the top and bottom edges of a plurality of fin assemblies may be contiguous to each other. As shown in the drawing, in FIGURE 3, a tool, **72**, may be used to press down the upper ring **20** into the wet cement after the concrete is poured. The core **11** and shell **13**, especially the latter, may be split vertically for easier removal of the mold from the formed concrete pipe, if desired. Also, the cross-sectional configuration of the core and shell may be other than circular, e.g., square, when concrete pipe of other than cylindrical shape is to be cast.

In operation, it has been found that an amplitude of vibration of about 0.04 to 0.15 inch, measured at the bearing plates **39** and **42** will be adequate to give the necessary 0.05 to 0.075 inch amplitude at the points of greatest vibration on the outside of the pipe to be molded, that is, at points, for example, A and B of FIGURE 1, on the shell **13**, which are opposite the eccentric **52**, the portion of greatest vibration input.

The method of this invention may be performed in the apparatus illustrated as follows:

The shaped ring (**18**) 6 inches wide and 72 inches in outside diameter is set under a cement mixture hopper and a steel reinforcement cage about 98" high and 69" in average diameter is set in place resting on the ring **18**. The core **11** is a cylinder, 29¾" in radius and 101" long made of welded ¼" steel sheet. It has upper and lower flanges recessed about 3¼" from the top and bottom of the cylinder and extending about 4½" toward the axis of the cylinder. The vibrator, having six fins spaced at 60° angles to each other is held between the flanges by upper and lower bearing rings ⅜" thick. The core stands on four legs made of 1½" pipe. The fins are 92¾" long at their outer edges, each edge being welded to about the center of a ¼" by 1" steel bar which extends the length of the edge. The eccentric shaft (52) is 48¾" long and its lower edge is 31⅜" from the bottom of the core. The eccentric shaft has a center of gravity 1.75" from the axis and a weight of 8 pounds. The drive shaft **55** extends 6½" from the top of the eccentric shaft to a 15 H.P., 60-cycle A.C. electric motor **58** having a 20" diameter which rests on a 1" thick platform which rests on the fins. The eccentric shaft **52** is enclosed in a housing **50** made of ⅜" thick steel tubing 3" in outside diameter. The fins are rigidly connected to this housing at the top and bottom of the eccentric shaft by clamps made of 1" thick steel cylinders having horizontal flanges which penetrate about 2" into the fins. This core assembly is dropped by a hoist into the ring and reinforcement cage, fitting flush within the inside of the ring **18**.

An outer shell **13**, 72" in internal diameter, made of ⅜" steel sheet and 98" long, is provided at its bottom with four rotating ring holding devices **22** equally spaced around the periphery. Along the length of the outer shell are three horizontal flanges **27** which extend out about 3½". This outer shell **13** is then placed in position around the outer edge of ring **18**. The rotating hooks **22** are then engaged under the bottom of the outer shell **13**. The cone **66** has a base about 60" in diameter and a height of about 18". Guard ring **68**, about 72" in diameter and 8" high is attached to the base of the cone by means of 4 spacers **70** which, of course, are about 6" long, the thickness of the annular space **15** created by the core and shell.

A concrete mixture comprising about 1600 lbs. of sand, 1750 lbs. of coarse aggregate, 564 lbs. of Portland cement and 214 lbs. of water is prepared in a suitable concrete mixer as a charge of plastic material which is fed on to the cone **66** at which time the vibrator **52** is actuated. These vibrations are transmitted to the fins **44** which, through their bearing members **63**, distribute about 70 to 80% of the power of the motor **58** to the inner surface of the core **11**. The effect of the vibrations is to shake the cement from the cone into the annular space **15**. The pouring takes about 5 minutes and vibration is continued during the entire feeding operation until the annular space is filled and the concrete has reached a level of about 5" above the top of the core **11**, this additional depth of concrete being held within the guard ring **68**. Vibration continues for about 2 minutes, serving to compact the charge of plastic material or concrete around the reinforcing steel cage, until it is permissible to remove the cone and guard-ring assembly. The vibration is then stopped, and this assembly is removed, being replaced by ring **20**. Vibration is resumed for about 1 minute, the vibration amplitude at points A and B of the shell **13** being in the range of about 0.05 to 0.075 inch when concrete is in the annular space **15**. The tools **72** are used to apply additional pressure to the top of the ring **20**, during the later vibration, forcing the ring **20** into its final position. This ring is locked into position and the core is removed from inside the concrete by use of a hoist. The outer shell **13** and the concrete pipe are then picked up with the hoist and removed to the final or curing location where the shell **13** is then stripped from the outside of the pipe and returned to the pouring area where a complete unit may again be assembled. The finished pipe is allowed to stand for a period of about 3 hours at which time it is covered and steam cured for about 12 hours.

Thus the method and apparatus of this invention provides, within the annular molding core, a source of vibration, i.e., a vibrator or vibrating body which is closely adjacent the inner core surface so as to move in and out of contact with the interior core surface at a plurality of locations spaced around the inner periphery and extending along substantially the entire length of the mold, the vibrating body being disconnected from the inner core surface at all locations but being fitted sufficiently snugly when in the core so that about 70 to 80% of the vibration energy is transmitted to the core. The power and amplitude of vibration applied to the inner core surface is controlled so as to provide, on the outer surface of the mold, at locations generally opposite the locations of maximum vibration on the inner core surface, an amplitude within the range of about 0.05 to 0.075 inch. In general, the vibrating body or bodies are maintained on the average not more than ⅓₂ inch away from the inner core surface, measured from dead center position of the vibrating body, and thus in no event more than a maximum distance of ⅟₁₆ inch during vibration. The vibration intensity tends to be greatest at levels just opposite the eccentric and this eccentric weight itself usually extends along only a portion of the length of the core.

In the prior art, where the vibrating body is welded to the inner surface of the core, frequent rupture and failure of the core resulted. This invention avoids this problem, and also applies the vibration more uniformly over the entire surface of the inner core than is the case for systems in the prior art.

The mold may vary in both diameter and length depending upon the size of concrete pipe desired. Generally, the size range may vary from 18" to 144", preferably 24" to 72" diameter, and 2 to 20 feet in length and ³⁄₁₆" to ⅜" in thickness. A convenient length is eight feet. The number of vibrators employed will depend upon the type and size of the vibrator and the length of the mold. In the case of eccentric-type vibrators of the type shown only a single vibrator of adequate size is needed for mold lengths up to about 12 feet. For greater mold lengths, two or more vertically spaced-apart eccentric-type vibrators may be provided. In such a circumstance, the vibrators may employ one fin assembly or a plurality of vertically adjacent fin assemblies and the eccentrics will preferably be operated in phase with each other.

Longitudinal placement of the eccentric within the core is important. In the preferred apparatus it is located closer to the top than to the bottom of the core in order to obtain proper results. In a preferred installation, the distance between the top of the vibrator and the upper end of the core is 21 inches.

It will be understood that the annular molding zone or core may be of other than circular cross-sectional shape such as square or rectangular and the term annular is used herein in the above connection in a sense sufficiently broad to cover such other cross-sectional shapes. It will be understood that the invention is not considered to be limited in its broadest aspects to the specific examples of the method and apparatus in its application except as set forth in the following claims.

It is claimed:

1. An apparatus for casting hollow concrete members comprising an elongated hollow core and an elongated outer shell concentric with and spaced from said core to provide an annular space therebetween, and a vibrating means in physically separated adjacency to said core and including at least one vibrating body having circumferentially spaced contact surfaces movable against the core throughout substantially the entire length of the interior of said core, said vibrating body having a diameter no less than about ⅟₁₆ inch smaller than the interior diameter of the core.

2. The apparatus of claim **1** in which the bottom of the annular space is defined by a removable shaped ring of a configuration suitable to produce the desired end-shape of the member.

3. The apparatus of claim **2** in which rotating hooks attached to the shell support the removable shaped ring, said hooks being rotatable between ring-holding and ring-releasing positions.

4. The apparatus of claim **1** in which the vibrating body is a fin assembly comprising a plurality of fins.

5. The apparatus of claim **4** in which the core is provided internally with a first fixed flange above the fin assembly and a second fixed flange below the fin assembly to maintain the fin assembly in a longitudinal position.

6. The apparatus of claim 1 which includes a distributor assembly comprising a central cone having a base congruent to the upper edge of the core and a guard ring fitting snugly against the shell, said cone and guard ring being attached by a plurality of spacers.

7. An apparatus for casting hollow concrete members comprising an elongated hollow core and an elongated outer shell concentric with and spaced from said core to provide an annular space therebetween, said core being provided internally with a first fixed flange at the upper portion thereof and a second fixed flange at the lower portion thereof, said flanges serving to maintain in a longitudinal position therebetween a fin assembly comprising a plurality of fins in physically separated adjacency to substantially the entire length of the interior of said core, said fin assembly being a portion of a vibrator assembly, having a diameter no less than about 1/16 inch smaller than the interior diameter of the core, a first bearing plate interposed between the fin assembly and the first fixed flange, and a second bearing plate interposed between the fin assembly and the second fixed flange.

8. The apparatus of claim 7 in which the vibrator assembly comprises an eccentric shaft attached to the fin assembly through a housing and a motor in driving connection with the said shaft.

9. The apparatus in claim 8 in which the motor is placed at the upper portion of the fin assembly.

10. An apparatus for casting concrete pipe comprising an elongated, hollow core and an elongated outer shell concentric with and spaced from said core to provide an annular space therebetween, a vibrating means in physically separated adjacency to the core and including a fin assembly comprising a plurality of fins having eccentrically rotatable surfaces contacting substantially the entire length of the interior of said core, said fin assembly having a diameter no less than about 1/16 inch smaller than the interior diameter of the core, and said fin assembly being held in place by a first bearing at the top of the assembly and a second bearing at the bottom of the assembly and being removable from the vibrator on detachment of one of said bearings.

11. The apparatus of claim 10 in which a flattened bearing member attached to each fin contacts the core.

12. An apparatus for casting hollow concrete members, comprising a hollow, tubular forming member for containing a plastic material to be shaped, a force-applying member disposed interiorly of the tubular member in physically separated adjacency thereto and having a plurality of movable portions in circumferentially spaced arrangement, each having a contact surface for directing controlled bending forces against the inner tubular surface of the hollow member throughout its lengthwise and circumferential extent in a cyclic action, and means associated with the force-applying member for driving the movable portions at a frequency and amplitude maintaining vibrating compaction on the contained plastic material imparted by bending movements of the inner surface of the tubular member in the cyclic action.

13. An apparatus for casting hollow concrete members, comprising a hollow, tubular forming member for containing a plastic material to be shaped, a force-applying member disposed interiorly of the tubular member in physically separated adjacency thereto and having a plurality of movable portions radially extending and in circumferentially spaced arrangement, each having a contact surface for directing controlled bending forces against the inner tubular surface of the hollow member throughout its lengthwise and circumferential extent in a cyclic action, and means associated with the force-applying member for driving the movable portions at a frequency and amplitude maintaining vibrating compaction on the contained plastic material impacted by bending movements of the inner surface of the tubular member in the cyclic action.

14. An apparatus for casting hollow concrete members, comprising a hollow, tubular forming member for containing a plastic material to be shaped, a force-applying member disposed interiorly of the tubular member in physically separated adjacency thereto and having a plurality of movable portions in circumferentially spaced arrangement, each having a contact surface for directing controlled bending forces against the inner tubular surface of the hollow member throughout its lengthwise and circumferential extent in a cyclic action, and means associated with the force-applying member for rotating the movable portions eccentrically at a frequency and amplitude maintaining vibrating compaction on the contained plastic material imparted by bending movements of the inner surface of the tubular member in the cyclic action.

15. An apparatus for casting hollow concrete members, comprising a hollow, tubular forming member for containing a plastic material to be shaped, a force-applying member disposed interiorly of the tubular member in physically separated adjacency thereto and having a plurality of movable portions in radial arrangement, each having a contact surface for directing controlled bending forces against the inner tubular surface of the hollow member throughout its lengthwise and circumferential extent in a cyclic action, and means associated with the force-applying member for rotating the radial portions eccentrically at a frequency and amplitude maintaining vibrating compaction on the contained plastic material imparted by bending movements of the inner surface of the tubular member in the cyclic action.

16. A system for casting hollow concrete members, comprising a hollow tubular molding structure for confining a concrete mixture in plastic condition in its interior and having sufficient elasticity to withstand vibration impacts without substantial deformation, means in physically separated adjacency to the tubular member and having a plurality of circumferentially spaced contacting surfaces for directing impact forces against the inner confining surface of the structure throughout its lengthwise and circumferential extent in a cyclic action producing bending movements in said surface, and means for initiating said forces from an independently-supported source at a frequency and amplitude maintaining vibrating compaction on the confined plastic material during the cyclic action.

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J. SPENCER OVERHOLSER, *Primary Examiner.*

ALEXANDER H. BRODMERKEL, WILLIAM J. STEPHENSON, *Examiners.*

R. B. MOFFITT, G. A. KAP, R. D. BALDWIN, *Assistant Examiners.*