Jan. 5, 1971 G. H. HOOPER 3,552,129

HIGH PRESSURE RESISTANT COFFERDAM

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Fig. 1

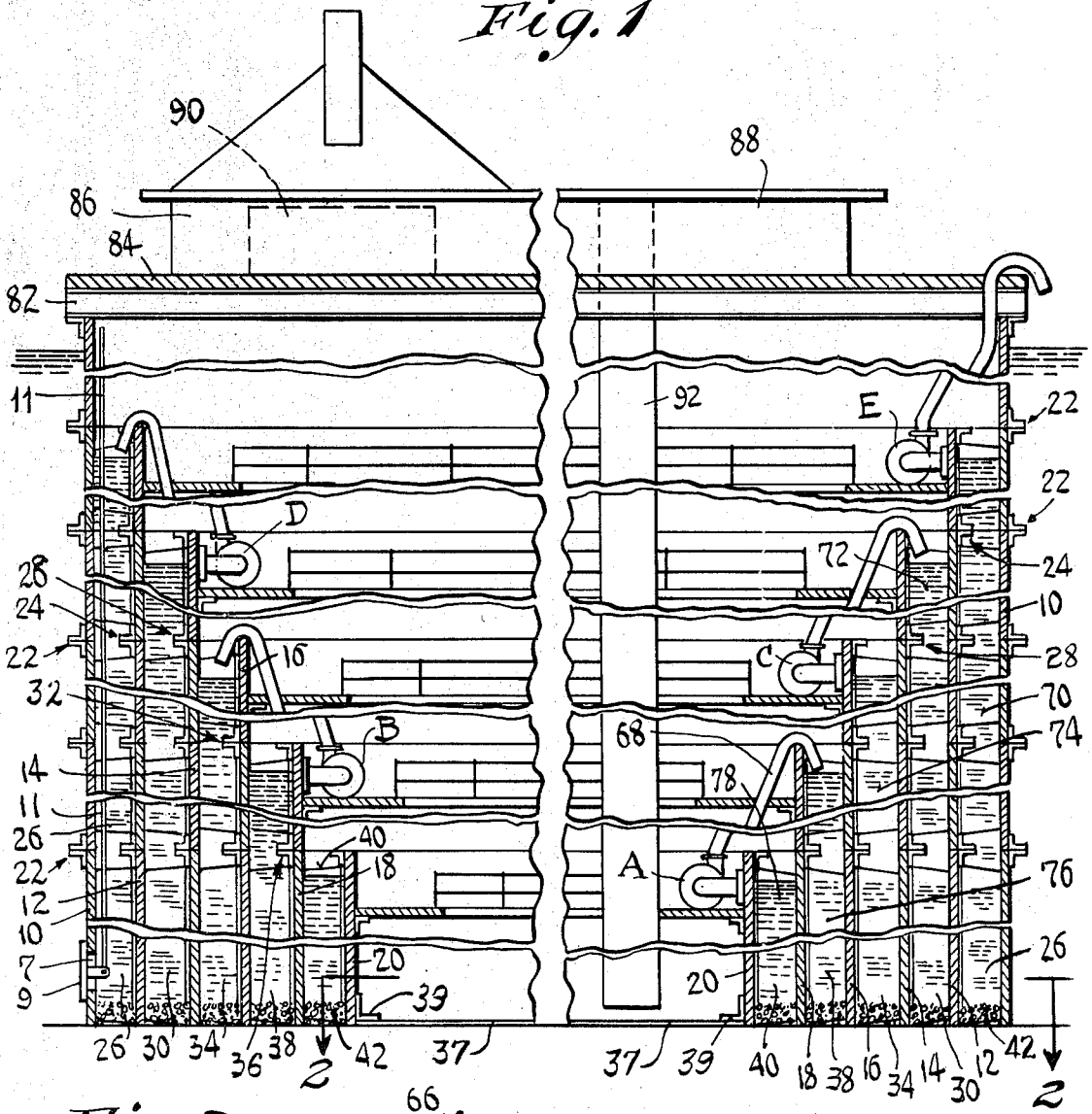
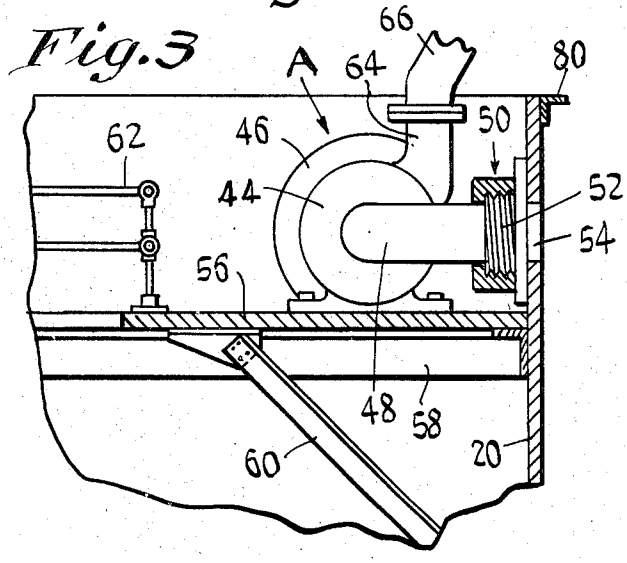


Fig. 3



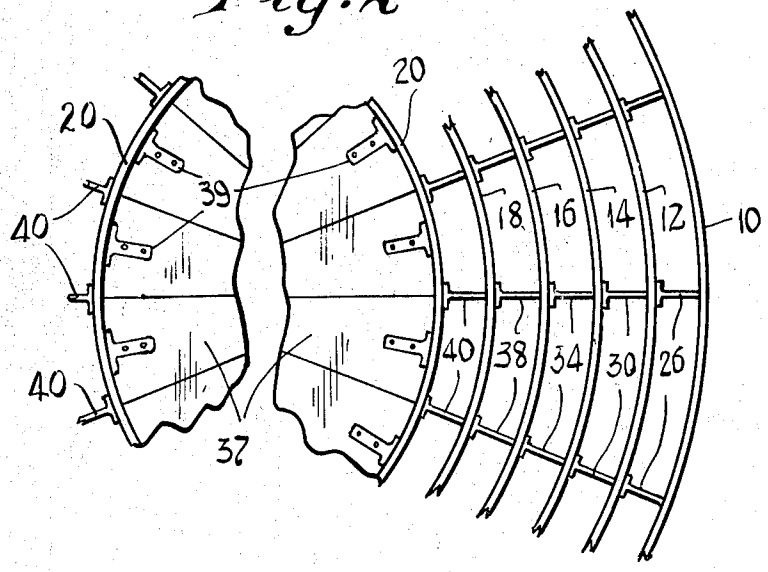
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Fig. 2



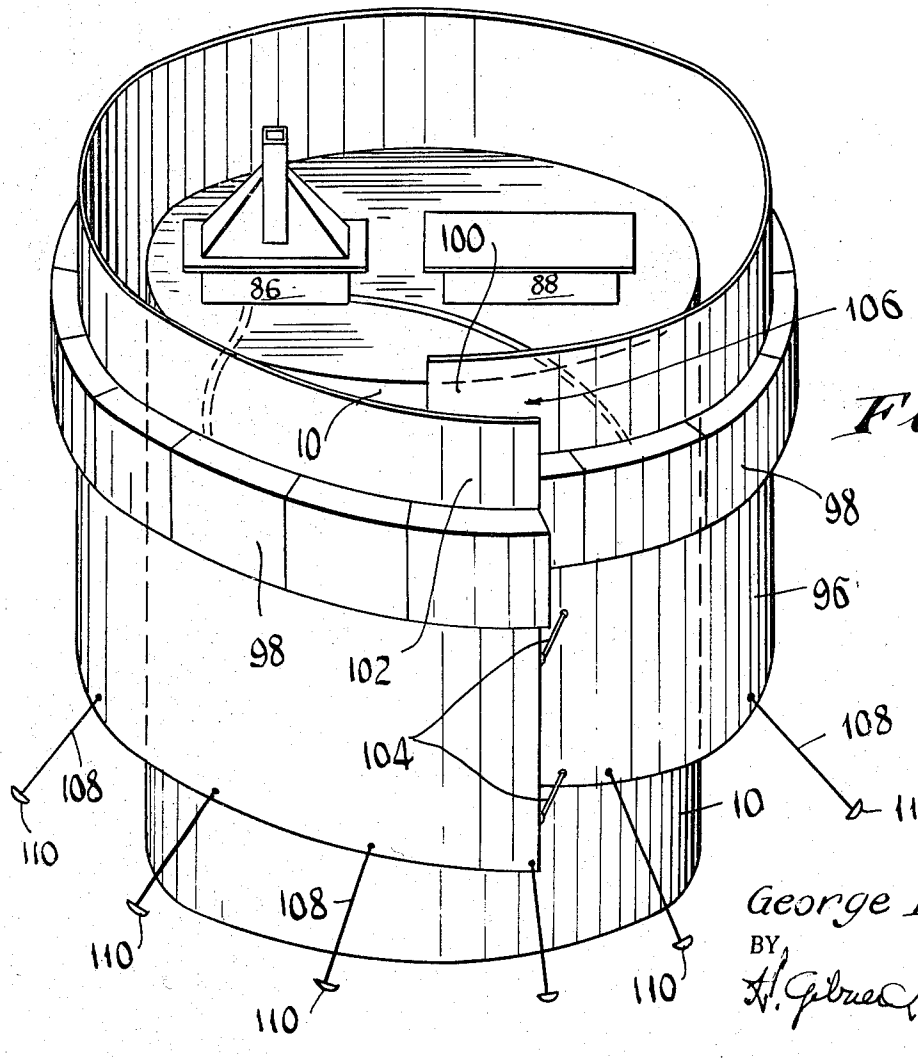


Fig. 4

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HIGH PRESSURE RESISTANT COFFERDAM

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ABSTRACT OF THE DISCLOSURE

A cofferdam of simple, generally circular configuration, adapted to withstand powerful external pressures at considerable depths. The cofferdam comprises concentric spaced cylindrical structures of graduated heights, being progressively less high at the inside. Seepage water in the spaces is continuously pumped out, and the weight of such water counteracts the powerful outside pressures at the intervals where the cylinders are not braced, thereby obviating the necessity for continuous massive bracing and structural elements at the lower portions of the dam.

PRIOR ART CITATIONS

U.S. Pat. No. 7,799, U.S. Pat. No. 154,935, U.S. Pat. No. 924,362, U.S. Pat. No. 946,841, and U.S. Pat. No. 2,596,788.

BACKGROUND

This invention relates to cofferdams and like structures. A practical cofferdam usable at great depths would have considerable advantage in carrying out mining, oil drilling and capping, salvaging and kindred operations. There is made possible a desirable mobility of personnel, not restricted by a pressurized environment, heavy gear such as diving suits, air lines, etc. and avoided problems which attend submarines provided with mechanical hands or hooks, including the stirring up of sediment from the water bottom, clouding of water and the like.

Heretofore, dam structures intended to hold back water from working or other areas were limited as to the working depth, since the powerful water pressures existing at greater depths required prohibitively massive and heavy structural elements to prevent the dam from collapsing. This constituted a distinct drawback, and virtually restricted the use of cofferdams to only those locations of a body of water which were relatively shallow, and devoid of high waves.

SUMMARY

The above drawbacks and limitations of prior dam structures are obviated by the present invention, and one object of the invention is to provide a novel and improved cofferdam which can be used at much greater water depth than was heretofore possible or feasible, and in water characterized by turbulence and high waves. This is accomplished by counteracting the powerful exterior water pressures due to the high column effect at great depths, by use of interior water pressures acting oppositely to the exterior and also created by high columns but which are progressively smaller, progressing from the exterior to the interior of the dam wall. Such wall comprises a composite structure having a plurality of elements, being preferably formed of a number of upright concentric spaced cylinders set on their ends with the inner cylinders progressively shorter or lower at their top portions. The spaces between the cylinders fill with seepage water which is continuously pumped through an overflow to maintain predetermined levels. The columns of seepage water in large part counteract the external pressures on unsupported or unbacked areas of the cylinders, whereby the cofferdam can be used at great depths without resorting to prohibitively heavy and massive structural forms.

Surrounding and spaced from the dam is a floating circular breakwater arranged to be anchored to the ocean or lake floor and to absorb the force of waves and turbulence, whereby the dam can be used in rough seas.

Other features and advantages of the invention reside in an improved cofferdam as above set forth, which is of comparatively simple and lightweight construction, which can provide relatively large work areas on the ocean floor, and which is safe, effective and reliable in operation.

Still other features and advantages will hereinafter appear.

In the drawings:

FIG. 1 is a vertical sectional view of a high pressure resistant cofferdam as provided by the invention.

FIG. 2 is a fragmentary horizontal section on line 2—2 of FIG. 1.

FIG. 3 is a fragmentary vertical sectional view of a portion of FIG. 1 but on a larger scale, showing details of one of the pumping units of the dam.

FIG. 4 is a perspective view of the cofferdam and a protective circular floating breakwater as provided by the invention.

Referring to FIGS. 1, 2 and 4, the present cofferdam is shown as being of generally circular configuration, comprising a number of concentric upright cylinders spaced one within another and setting at their bottom ends on the ocean, lake or sea floor. Although circular or cylindrical configurations are illustrated, it will be understood that the invention is not limited to perfect cylindrical shapes but instead can comprise other tubular configurations having a multiplicity of flat sides or sections instead.

In FIGS. 1 and 2 six cylindrical concentric structures are illustrated, being each less high as one progresses from the exterior to the interior of the cofferdam. The outermost and highest cylindrical section or wall is designated **10**, the next outer cylindrical wall is designated **12**, and so on, with the innermost and least high cylindrical wall being designated **20**.

The outermost wall **10**, in the illustrated embodiment of FIGS. 1 and 2, is seen to be fabricated of six individual parts disposed endwise with respect to each other, that is, one on top of another and joined at their abutting ends by suitable means such as pairs of circular flanges **22**. Suitable sealing means are provided at the flanges **22** to prevent appreciable leakage of sea water through the joints of the outer wall **10**. The lowermost wall section may have a flooding port **7** normally closed by a valve **9** controlled by a shaft **11**.

The next inner wall **12** is likewise made up of separate sections, shown as five in number, similarly set end-to-end and joined by pairs of circular flanges **24**. A spacing, which may be as small as six inches, is maintained between the walls **10** and **12**, by means of vertical ribs **26** which may be secured to the wall **12** as indicated in FIG. 2.

In a like manner the next inner wall **14** which is less high than the wall **12**, is made up of four sections disposed end-to-end and joined by circular flanges **28**. The wall **14** is maintained in spaced relation with the wall **12** by vertical ribs **30** similar to the ribs **26** and preferably secured to the less-high wall.

Similarly, the wall **16** is shown as comprising three separate parts disposed end-to-end or one above the other, said parts being joined by circular parts of flanges **32** and being spaced from the wall **14** by vertical ribs **34**. Following the same plan, the next to innermost wall **18** comprises two separate parts set end-to-end and joined by a pair of annular flanges **36**, said wall being spaced from the adjoining wall **16** by vertical ribs **38**. The innermost wall **20** is shown as comprising a single part, spaced from the adjoining wall **18** by vertical spacer ribs **40**.

A large, sectionalized floor plate **37** is disposed inside the inner wall **20**, being secured thereto by angle braces or fittings **39** and constituting a sturdy reinforcement of the inner wall, enabling the latter to withstand considerable external pressure.

By way of example, the innermost wall 20 may be ten feet high, and the spacer ribs 40 thereof may have a length of six inches whereby the walls 18 and 20 are spaced apart a distance of six inches. Each of the separate parts of the walls 10, 12, 14, 16, and 18 may also have a height of ten feet, and the spacer ribs 26, 30, 34, 38 and 40 may all be six inches in length, whereby each cylindrical wall is spaced from an adjoining wall by six inches. It will be understood, however, that other wall sizes and spacings may be utilized, depending on the particular conditions, working depth of the cofferdam, etc. The innermost wall 20, by way of example, may have a diameter of 100 feet, whereby the outermost wall 10 would have a diameter of approximately 105 feet, with a height of 60 feet.

If the total number of walls was ten, with the outermost wall slightly more than 100 feet high, and assuming that a cubic foot of water weighs 62.4 lbs., the inward crushing pressure at the bottom of the outer wall would be 6240 pounds per square foot. The water column pressure on the inside of the outer wall at the bottom would be 90 times 62.4 or 5616 pounds per square foot, making a net pressure differential of 624 pounds per square foot, exerted inward. Following the same type of calculation, the net pressure differential exerted inward on the innermost wall would be 624 pounds per square foot, this being easily withstood, as with the help of the sectionalized floor plate 37 shown in FIG. 2.

According to the invention, the strength of the structure at the locations of the ribs 26, 30, 34, 38 and 40 is sufficient to withstand the pressures of the water on the exterior of the dam. Such water pressures are least at the top areas, and greatest at the bottom areas of the dam, due to the well-known principle involving the weight of a column of liquid. Also, according to the invention, the weaker or unbacked, less supported areas or intervals of the cylinders located between the ribs are supported against outer pressures exerted inward by internal and only slightly lesser water pressure exerted outward, as effected by columns of water disposed between the cylindrical walls. This will be understood fully as the description proceeds.

In the operation of the dam, seepage water can flow into the spaces between the walls 10–20 at the bottoms thereof, and a control of the flow of such water is had by utilizing a fill which may be of sand, crushed stone, or other suitable heavier than water mixture. The fill is indicated in FIG. 1 by the numeral 42. An example of one suitable fill would be that formed of crushed stone coated with an underwater-setting adhesive which constitutes a binder whereby the agglomerate is of a somewhat porous nature. Such crushed stone agglomerate may be disposed on top of an initial sand fill, and in the operation of the cofferdam the amount of fill can be increased, or else the fill can be disturbed so as to provide a desired rate of seepage flow, this being determined by the capacity of pumping units, as will be hereinafter explained in greater detail.

In accordance with the invention, pumping units are provided to maintain predetermined water levels in the spaces between the walls 10–20, said units continuously pumping water through overflow or discharge passages and ultimately depositing the water outside of the outermost wall 10. Preferably the pumping units handle the water at stepped levels, starting at low locations adjacent the inner portions of the dam and proceeding progressively higher at outer portions, exhausting finally to the exterior of the dam at the highest and outermost wall 10. For example, a pumping group A will deliver water from the space between the inner walls 18 and 20 to the space between the walls 16 and 18. Another pumping group B will deliver water from the space between the walls 16, 18 to the space between the walls 14, 16. Still another pumping group C will deliver water from the space between the walls 14, 16 to the space between the walls 12, 14. Other pumping units D will deliver water from the space between the walls 12, 14 to the space between the outermost wall 10 and the wall 12, and finally still other pumping units E will deliver water from the space between the walls 10, 12 to the exterior of the wall 10. In each instance, utilizing the suggested dimensions given above it will be understood that the various pumping units will all operate to deliver water against a head of approximately 10 feet. That is, since the concentric spaced walls differ in height by 10 feet, the pumping units will be called on to pump the water from a given level to another level which is 10 feet higher.

An illustration of one type of pumping unit is given in FIG. 3. Here there is shown a centrifugal pump **44** which is driven by a motor **46**, the pump **44** having an inlet pipe **48** connected by a threaded coupling **50** with a suitable fitting **52** arranged to receive water through an opening **54** in the wall **14**.

The pumping unit of FIG. 3 is shown as carried by a platform or catwalk **56** secured to the wall **20** by a suitable annular flange device **58** and braces **60**. The catwalk has an inner railing **62** for the protection of personnel. Thep ump **44** has a discharge port **64** connected with a discharge pipe **66** which extends upward inside of the wall **12** and has a gooseneck **68** whereby it discharges into the space between the walls **16, 18.**

It will be understood that a large number of such pump units may be disposed around the upper portion of the wall **14**. Similar pump units, progressively greater or fewer in number as required, will be carried by the upper portions of the walls **12, 14, 16** and **18.**

From the foregoing it will now be understood that the pressure due to the weight of the column of water in the space between the walls **10, 12** will be virtually the same as the pressure of an equally high column of water at the exterior of the outer wall **10.** Since the column of water within the wall **10** exerts pressures equally in all directions, it will exert outward pressures at the unsupported areas adjacent the bottom of the wall which will be commensurate with the pressures on opposite areas at the exterior of the bottom of the wall. The interior pressure of the column of water, indicated at **70** in FIG. 1, disposed within the outer wall **10** can be slightly less for the dynamic condition of the cofferdam, which involves the removal of seepage water from the column by the pumping system. Such seepage water will consist not only of water which seeps past the wall **10** from the exterior at the bottom edge thereof, but also the sum total of all the other seepage waters which are being pumped into the clumn **70** from the interiorly disposed water columns, labelled respectively **72, 74, 76** and **78.**

It will be understood that the seepage flow into the innermost column **78** will be less than the seepage flow into the next outer column **76,** this in turn being less than the seepage flow into the column **74** which likewise will be less than the seepage flow into the column **72.**

The continual pumping of all of the seepage flows out of the columns **70–78** provides a discharge which is always at least equal to the inflow of water past the bottom edges of the dam walls **10–20,** and in the event that the inflow tends to increase beyond the pumping capacity, additional fill is placed in whichever of the columns **70–78** seems to evidence too great a seepage inflow.

It will be understood that with the structure as above set forth, a continuous pumping is not necessary to supply the pressure differentials which prevent cave-in of unbacked wall areas, since for a static condition wherein the pumps are not operating the opposing water pressures at the bottoms of the cylindrical walls, and the forces transmitted through the ribs between the walls will be

such as to prevent structural failure, especially of the lowermost portions of the cofferdam. However, in consequence of continual removal of seepage water it will be understood that controlled inflow of water at the bottoms of the walls **10–20** can result in slightly lesser pressures from the exteriors, but the degree is thought to be not significant, as at present understood. A flow inward past the bottom of the outer wall **10** can result in slightly less external pressure at this point, but the amount of inflow is relatively small. However, the internal pressure due to the weight of the column of water **70** is appreciable, and enables the wall **10** at areas between the ribs **26** to withstand the pressures of considerable depths without requiring massive structural formations, braces, struts, etc. The same conditions apply for the next outer wall **12**, and also for the walls **14, 16, 18** and **20**, as will now be understood.

The use of the pumping system as set forth above obviates the necessity for perfectly tight fits and joints, and tight seals at the bottom of the cofferdam walls.

The upper edges of the circular walls **10–20** may be provided with annular flanges such as the flange **80** illustrated in FIG. 3. It will be understood that each of the circular walls has at the interior of its upper portion, a circular catwalk similar to that indicated at **56** in FIG. 3.

Across the top of the outer wall **10** there are provided girders **82**, on which there is supported a platform **84** constituting a cover for the interior of the wall **10**. Sheds **86** and **88** are provided on the platform **84**, for the purpose of respectively housing power equipment **90** for the pumping system, and for an elevator shaft **92** which extends downward to within the inner wall **20**.

Various changes can be made in the arrangement described above, without departing from the spirit of the invention, which embraces the utilization of graduated cylinders to take care of increased pressure at great depths, and columns of water between the cylinders to prevent collapse of areas thereof at locations between bracing struts.

To enable the cofferdam to be used in rough waters, a discontinuous circular floating breakwater **96** of flexible steel plate may be provided, extending around and spaced from the dam. The breakwater **96** can have one or more articulated flotation tanks **98** near its upper portion, and lapped end portions **100, 102** of the breakwater can be connected by hydraulic struts **104** to provide a channel **106** of variable width, through which a small vessel can pass.

The breakwater **96** can be positioned by cables **108** connected to anchors **110**. By pumping water into or out of the flotation tanks **98** the level of the breakwater can be varied. By making the breakwater **96** flexible or yieldable in its construction, especially above the water level, it can withstand the pounding of large waves more successfully than a similar structure made to be rigid.

I claim:

1. A cofferdam comprising, in combination:
(a) substantially circular and cylindrical, upright outer shell adapted to be set on end on the floor of a body of water,
(b) a plurality of consecutively lower, substantially circular and cylindrical, upright inner shells concentrically disposed within the first-mentioned shell and spaced therefrom and from each other,
(c) said plurality of shells being set on their ends on said water floor, the outer shell and the plurality of inner shells having graduated heights, the outer shell being the highest and the innermost shell being the lowest,
(d) spacers disposed between the shells to maintain the spacing therebetween,
(e) columns of water disposed between the shells, exerting inward and outward pressures thereon to prevent collapse of the shells, the column of water contained within the outer shell being higher than the column of water disposed within the shell next to the outer shell, and
(f) a pump means for disposing of seepage water which seeps in past the bottom of the shells.

2. A dam as in claim **1**, and further including:
(a) a central brace structure disposed within the innermost of said plurality of shells, reinforcing said innermost shell against pressures directed inward against the exterior thereof.

3. A cofferdam as in claim **1**, and further including:
(a) a cylindrical floating breakwater extending around and spaced from the outer shell, and
(b) anchorages secured to said breakwater, to position the same.

4. A cofferdam as in claim **3**, wherein:
(a) the breakwater is discontinuous and has spaced-apart end portions disposed broadside to each other and providing an access channel for small vessels.

5. A cofferdam comprising, in combination:
(a) a substantially circular and cylindrical, upright shell adapted to be set on end on the floor of a body of water.
(b) a plurality of consecutively lower, substantially circular and cylindrical, upright shells concentrically disposed within the first-mentioned shell and spaced therefrom and from each other,
(c) said plurality of shells being set on their ends on said water floor,
(d) spacers disposed between the shells to maintain the spacing therebetween, and
(e) columns of water disposed between the shells, exerting inward and outward pressures thereon to prevent collapse of the shells,
(f) a pump means for pumping seepage water from the spaces between the shells, consecutively from the lower level spaces to the higher level spaces and finally to the exterior of the first-mentioned shell.

6. A dam as in claim **5**, and further including:
(a) a seepage-retarding fill disposed at the bottoms of the spaces between the shells.

7. A dam as in claim **6**, wherein:
(a) the fill is a mixture including sand.

8. A dam as in claim **6**, wherein:
(a) the fill is a mixture including crushed stone with an underwater-setting synthetic binder-adhesive.

9. A dam as in claim **5**, wherein:
(a) each of the shells except the innermost one comprises a plurality of individual sections joined end-to-end.

10. A dam as in claim **5**, and further including:
(a) a cover means comprising a platform covering the uppermost end of the first-mentioned cylinder, and
(b) power means carried by the platform, for driving the pump means.

References Cited

UNITED STATES PATENTS

3,496,726	2/1970	Lutgendorf	61—41
7,799	11/1833	Easby.	
154,935	8/1874	Wenmaekers.	
924,362	6/1909	Leow.	
946,841	1/1910	Gilman.	
974,023	10/1910	Campbell	61—41
2,939,290	6/1960	Crake	61—344X
3,191,388	6/1965	Ludwig	61—814X

FOREIGN PATENTS

757,827	9/1956	Great Britain	61—41

PETER M. CAUN, Primary Examiner