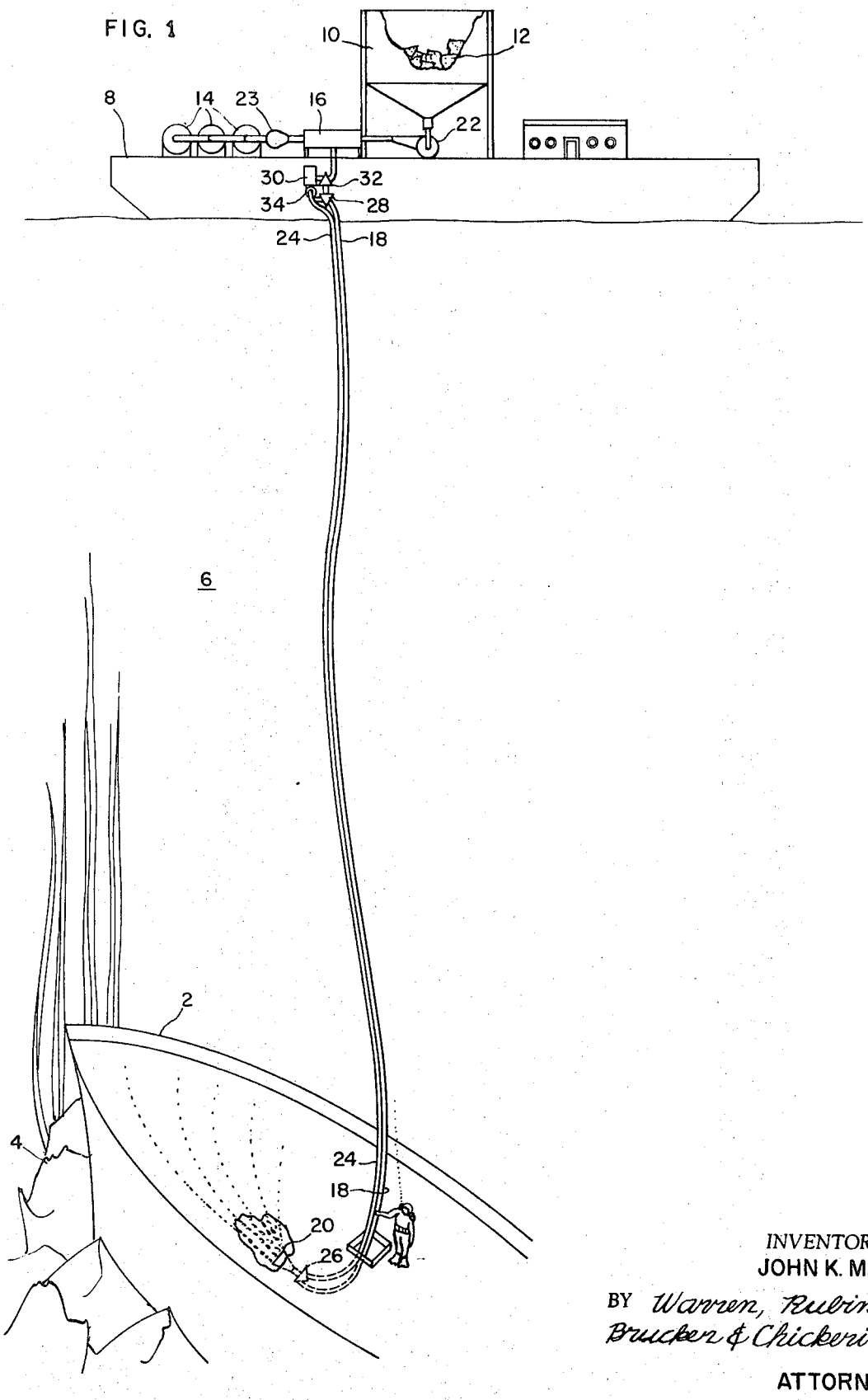
Sept. 29, 1970 J. K. MAX 3,531,233

METHOD FOR RAISING SUBMERGED OBJECTS

Filed April 17, 1968 3 Sheets-Sheet 1

FIG. 1



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METHOD FOR RAISING SUBMERGED OBJECTS

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FIG. 3

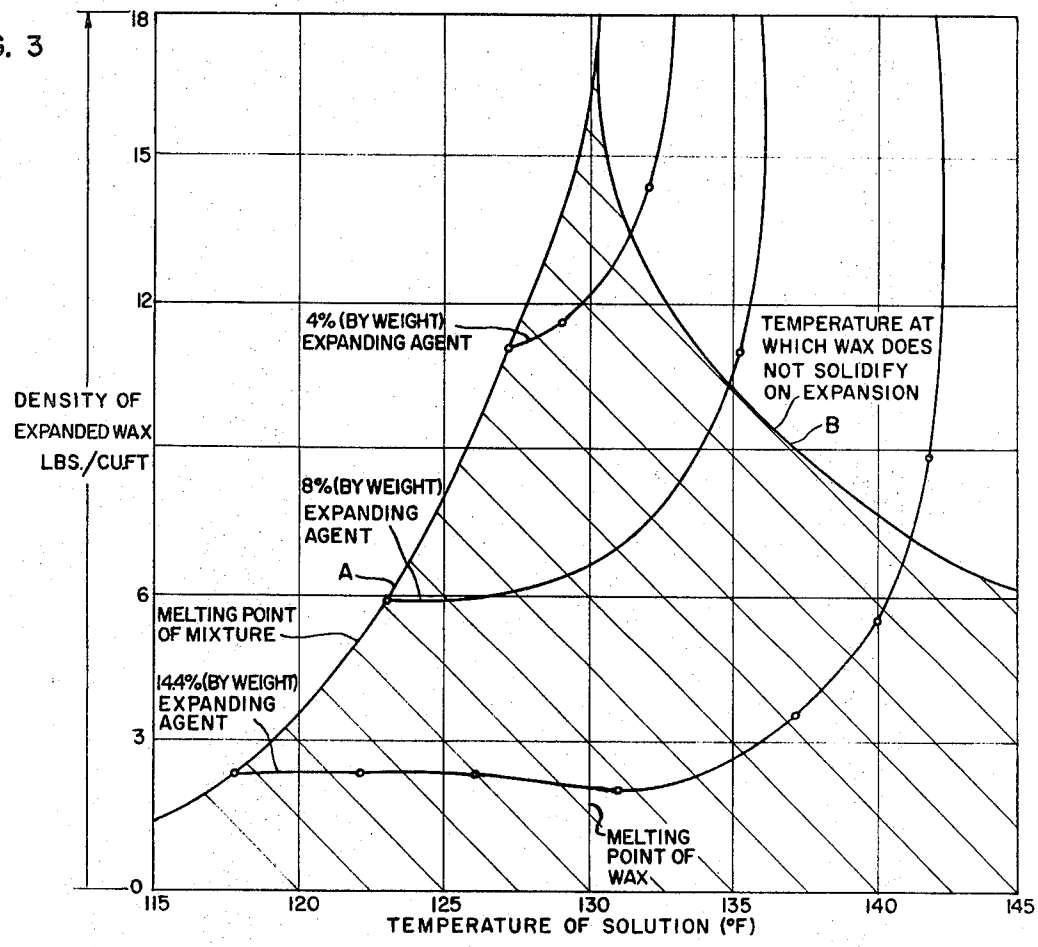
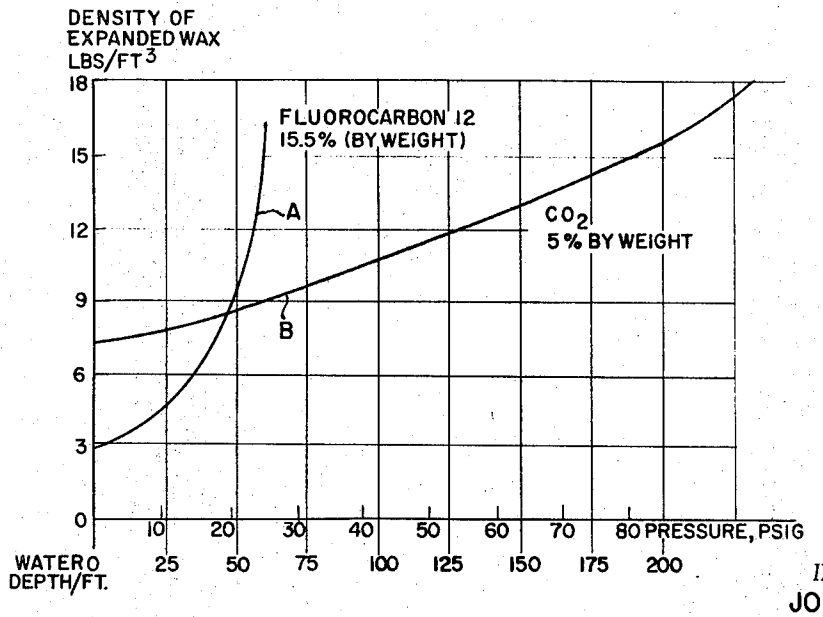


FIG. 2



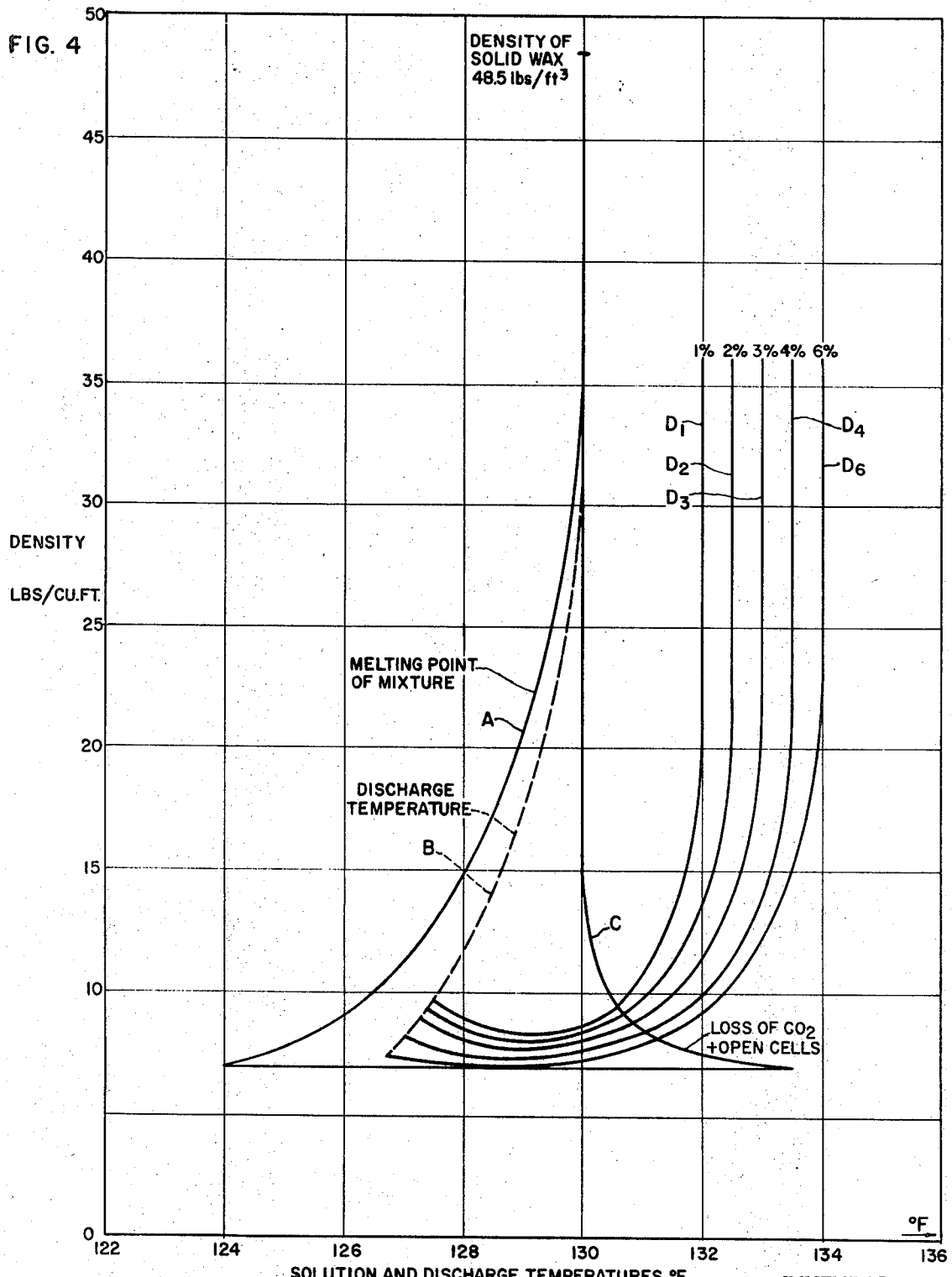
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METHOD FOR RAISING SUBMERGED OBJECTS

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FIG. 4



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METHOD FOR RAISING SUBMERGED OBJECTS

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U.S. Cl. 114—50 15 Claims

ABSTRACT OF THE DISCLOSURE

Wax and an expanding agent are selected so that their mixture either has a melting point below that of the wax alone, in which case the mixture is maintained at a temperature intermediate the melting point of the mixture and the wax alone; or so that the latent heat of vaporization of the expanding agent is sufficient upon its evaporation to reduce the temperature of the wax from the mixture temperature to below the melting point of the wax. The mixture is conducted to compartments of a submerged vessel and it is released, causing a substantially simultaneous evaporation of the blowing agent. The wax solidifies with great numbers of small cells which reduce its density and thereby impart buoyancy to the vessel.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to methods for raising submerged objects and more particularly to a method in which liquified wax is pumped into an interior portion of the object where it is expanded and solidified.

State of the prior art

The raising of a submerged object, particularly of a sunken vessel, to the surface of a body of water has long presented a difficult problem. The great weight as well as the inaccessibility of vessels has made it often virtually impossible to salvage them. A number of attempts have been made in the past to impart buoyancy to the vessel, float it and then tow it to a suitable repair place such as drydock.

One prior art approach provided that inflatable containers, such as rubber bags, are inserted into interior portions of the vessel while deflated. There air is forced into the containers, thereby displacing water from the vessel and imparting buoyancy thereto. In practice, this is difficult and it becomes virtually impossible to raise vessels of any appreciable size because the number and size of the containers becomes prohibitive. Moreover, due to motion of the sea, the containers rub against the vessel thereby abrading their surface, and sharp objects can puncture them and cause their deflation.

Attempts have been made to raise sunken vessels by pumping into them a large number of relatively small buoyant objects such as hollow glass or plastic balls, cork segments or closed-cell foam objects. The buoyant parts are pumped into the body of the vessel and are there released. This approach is expensive and requires complicated equipment since large numbers of such objects must be manipulated. Their relatively small size permits them to escape through openings in the vessel and can make it impossible to raise the vessel with a rupture in its hull.

More recently a method has been developed in which a mixture of polymerizable components is injected into the cavity of the vessel. This method not only requires a plurality of individual chemical components which must be pumped to the vessel independently to prevent their reaction in the lines, but also requires separate expanding agent and cleaning solvent streams. Expanding agents

may be preblended with one or more of the component streams, however, this requires that the material be handled in pressurized cylinders, further complicating the method. Thus, the handling equipment becomes exceedingly complicated and expensive to initially install as well as to maintain. The components are expensive and when considering the large displacement of ocean-going vessels, makes the salvage cost all but prohibitive. The actual injection of the chemicals must be controlled with respect to temperature as well as mixing ratio. The mixing itself must be performed in the immediate vicinity of the vessel under water since the mixture sets up almost instantaneously. The closed-cell foam is difficult to remove from the vessel once raised, because of its strength and its adhesion to walls of the vessel. None of the foam can be salvaged and later on reused. In addition, the components are toxic and present a health hazard during the application of the foam to the submerged vessel as well as during its removal.

SUMMARY OF THE INVENTION

The present invention overcomes the shortcomings found in the prior art by providing means for imparting buoyancy into a submerged object such as a sunken vessel which employs low-cost equipment and inexpensive materials which are reusable. A minimum of supervision and skilled labor is required to apply the buoyant material, thereby further reducing the cost of salvaging sunken vessels.

Briefly, the present invention contemplates a method for floating submerged objects by first selecting a wax having the character of changing state from a liquid to a solid in a narrow temperature range and an expanding agent having a boiling point below the melting point of the wax and which, therefore, is a gas at the melting point of the wax and which is mixable therewith. The wax is heated to its liquid state and the expanding agent is introduced into the liquid wax and mixed therewith. The mixture which, hereinafter, shall mean a dispersion of the expanding agent in the molten wax or a solution of the two, is conveyed to an enclosure of the submerged object and released into it in such a manner that the agent and the wax separate, the agent expands the wax, and the wax solidifies in its expanded form.

In its presently preferred form, this invention contemplates the use of petroleum-based wax or paraffin and of carbon dioxide or halocarbon gases as the expanding agent. The use of carbon dioxide is preferred for lower cost and other reasons.

As is set forth in greater detail in subsequent portions of the specification, other wax materials as well as other expanding agents can, of course, be employed. The two should be selected, however, so that their mixture has a melting point which is below the melting point of the wax alone. In the alternative, the evaporation of the expanding agent upon release of the mixture into the enclosure of the object must reduce the temperature of the wax sufficiently so that it solidifies. Upon release of the mixture into the enclosure, the evaporating expanding agent expands the wax by forming a multiplicity of finely dispersed, small bubbles. The temperature reduction simultaneously solidifies the wax so that a substantially closed cell cellular body of wax is deposited in the interior of the vessel.

The expanded wax is of light weight and has a density which may be as low as about 2 pounds per cubic foot when the wax is expanded under atmospheric pressure. The density increases with increasing pressure at the releasing point of the mixture. The density is, of course ,also a function of the ratio between the wax and the expanding agent with which it is mixed. Thus, greater proportions of the expanding agent reduce the density of the

expanded wax, the greater percentages being preferably used at greater depth to offset the otherwise increased density of the expanded wax from the greater pressure head.

The wax-expanding agent mixture is easily handled and it can be mixed on the water surface and then pumped to the sunken vessel. Thus, complicated underwater mixing apparatus with all its dangers of malfunctioning or breakdowns have been eliminated. The apparatus itself is simple to constuct, has few components, and operates at the relatively low temperature of between about 100 and 200° F. The use of lower melting waxes reduces possible dangers from heat exposures to persons operating the equipment, particularly a diver working at the site of the sunken vessel. Thus, in contrast to heretofore practiced salvage methods, the present invention makes it possible to transport the mixture to the sunken vessel in a relatively simple insulated or heated hose.

Wax and carbon dioxide or halocarbon gases, in contrast to buoyant materials used in the prior art, can be obtained at low costs. If the material costs of obtaining a pound of buoyancy between the present invention and those practiced in the prior art, say the injection of a thermo-setting polyurethane foam are compared, it costs about 1.75 cents per pound of buoyancy to inject the urethane foam whereas the expanded wax costs less than .65 cent per pound of buoyancy. Thus, the most readily compared prior art method for imparting buoyancy to a sunken vessel is roughly about three times as expensive as the method provided by the present invention.

In addition to the raw material savings, the present invention permits the recovery of the wax after the vessel has been salvaged. The wax is washed down with hot water, recovered and can later on be reused for raising another sunken vessel to the surface. This, of course, further reduces the overall costs of salvaging vessels.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic representation of a salvage vessel adapted to inject a wax and expanding agent mixture into the body of a sunken vessel according to the present invention;

FIG. 2 is a diagram illustrating the effect of hydrostatic pressure on various expanding agents; and

FIG. 3 is a diagram illustrating operating conditions for a mixture of paraffin and fluorocarbon 12 (dichlorodifluoro methane) gas;

FIG. 4 is a diagram, similar to FIG. 3, illustrating operating conditions for a mixture of paraffin and carbon dioxide gas.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a submerged object such as a sunken vessel **2** rests on a floor **4** underlying a body of water **6** which is to be raised with the help of a floating salvage vessel **8** in accordance with the method provided by the present invention. The salvage vessel includes a heated tank **10** for melting solid wax cubes **12**, and one or more containers **14** for storing a suitable expanding agent as more fully described hereinafter. A mixer **16** proportionally mixes the molten wax with the expanding agent and conveys it to a hose **18** which extends downwardly and terminates in an expansion valve **20** projecting into an enclosure or cavity of the vessel. Suitable pumping means such as pump **22**, intermediate the heater and the mixer, and a pump **23**, intermediate the expanding agent storage container and the mixer, pressurize the wax and the expanding agent, respectively, as well as their mixture, and transport it toward and past the expansion valve.

It has been discovered that by dissolving under pressure certain low boiling liquids or gases with heated, liquified waxes and by discharging the mixture at a predetermined and controlled temperature into a flooded compartment of a sunken vessel, a lightweight, expanded, closed cell, solid wax product is instantly formed in situ within the compartment, thereby displacing the water therein and imparting buoyancy to raise the vessel.

The temperature of the mixture is preferably lower than the temperature at which the wax alone solidifies and higher than the solidification point of the wax-expanding agent mixture. A further requirement is that immediately after the expanding agent and the wax have separated the temperature of the wax is sufficiently low so that it solidifies while the expanding agent is dispersed within it.

In the alternative, the total heat required to evaporate the expanding agent must be sufficient to lower the temperature of the wax below its melting point. In this instance, the temperature of the mixture may be above the melting point of the wax alone.

The expanding agent must further be selected so that its vapor pressure in admixture with the wax in the desired ratio, that is the highest pressure at which it still evaporates at a given temperature, is above the pressure prevailing on the exterior of expansion valve **20**. As the mixture is released from the expansion valve, it is, of course, subjected to that pressure which equals the hydrostatic head plus the effective atmospheric pressure on the water surface.

A large variety of waxes have the above outlined desired properties. For purposes of this disclosure, wax may be defined as a meltable waxy solid which, on heating to its melting point, becomes a liquid having a viscosity no greater than about 500 centipoises at a temperature no higher than about 15 degrees above its melting point. Animal waxes, such as beeswax, vegetable waxes, such as carnauba, mineral waxes, such as paraffin and synthetic waxes, fall into this classification. All these waxes have the common characteristic that they change between their solid and liquid states in a narrow and sharply defined temperature range which in the main does not vary by more than between about ¼ to about 2° F. Although the waxes are strictly speaking not solid just below this narrow temperature range since they soften somewhat as their temperature approaches the melting point, their viscosity is, for practical purposes, equal to that of a solid and their transition to a very low viscosity fluid is rapid. Thus, by cooling wax to a temperature of just a few degrees below its melting point it can be solidified.

The expanding agent, which must be dispersable with or soluble in the liquid wax at the operating temperature and pressure of the mixture to prevent separation of the wax and the agent before they are released through the expansion valve and to assure a uniform distribution of the gas cells throughout the subsequently solidified wax, is chosen so that substantially all of it separates from the wax after the mixture has been released by the expansion valve. Otherwise, a portion of the expansion agent remains in the wax and is ineffective in forming the desired bubbles in the wax just prior to its solidification.

Although there are a large number of different expansion agents which can be employed in conjunction with the waxes, their choice is influenced by economic factors as well as by the hydrostatic head which overlies the expansion valve. FIG. 2 shows that an increasing hydrostatic pressure, that is an increasing water depth below which the sunken vessel **2** lies and from which it is to be floated, increases the density of the expanded wax. The curves of FIG. 2 demonstrate the feasibility of two preferred types of the possible expansion agents as a function of the hydrostatic pressure head and their concentration in the solution with the wax. Curve A is for fluorocarbon 12 and curve B for carbon dioxide, at the indicated ratio, in the wax-expanding agent mixture. Although the released, foamed wax originally has a lesser density at low hydrostatic heads where fluorocarbon is

used as an expanding agent, the diagram illustrates that as the hydrostatic pressure head is increased, the density increases becoming greater than that of wax expanded with carbon dioxide at a depth of about 45 feet. For this reason alone carbon dioxide is preferable over fluorocarbon 12. Carbon dioxide can be employed as an effective expanding agent at substantially greater hydrostatic pressures than fluorocarbon 12.

The versatility of the present invention, particularly its adaptability to utilize a large variety of waxes as well as different expanding agents is more clearly set forth in the following examples. In the examples all measurements were taken under atmospheric pressure conditions.

Example 1.—Molten paraffin, commercially available under the brand name "Scale Wax" from the Standard Oil Company of California, is thoroughly mixed with carbon dioxide in mixer **16** (FIG. 1). The temperature is controlled in the mixer, or shortly thereafter, to maintain it close to the melting point of the mixture without solidifying. As shown in Table 1, the melting point of the mixture is a function of the concentration of the carbon dioxide therein and decreases with increasing amounts thereof.

It is desirable to maximize the available temperature differential between the melting point of the wax and the wax-carbon dioxide mixture in order that practical operating temperature latitude may be obtained. This consideration sets practical limits to the ratio of carbon dioxide in the mixture. At the lower end of the scale, there is a limit at about ½ percent (by weight) of carbon dioxide in the mixture beyond which the density of the expanded wax becomes too great and the temperature differential between the melting point of the mixture and of the wax becomes so small that it is impractical to control it at a large scale operation in the field. At the upper limit, above about 6 percent of carbon dioxide (by weight) in the mixture, there is not only a waste of carbon dioxide when it is discharged under atmospheric pressure by the expansion valve but an increasingly large number of the cells in the solidified wax are broken open and absorb water, thereby substantially nullifying the desired buoyancy effect of the expanded wax. In addition, the discharged wax solidifies in granular form when the mixture includes more than about 6 percent of CO_2. If the compartment into which the gas is discharged has an opening the solidified granules can escape, thereby frustrating the attempt of imparting buoyancy to the vessel.

FIG. 4 diagrammatically illustrates a workable area between curves A and C within which the wax expanding operation can take place. In the diagram, curve A represents the melting point of the wax-expanding agent mixture and curve B the discharge temperature (at expansion valve **20**, FIG. 1) of the mixture. Curve C illustrates the upper temperature limit for the mixture being dicharged. If the mixture is discharged at higher temperatures, the wax fails to solidify and the expanding agent escapes from the non-solid wax instead of forming cells in a solid body of wax. Curves D_1, D_2, D_3, D_4 and D_6, respectively, show the operating characteristics for a paraffin-CO_2 mixture in which the ratio of CO_2 to paraffin is 1, 2, 3, 4, and 6 percent, respectively, by weight.

It will be observed that the temperature of the mixture increases upon being released by the expansion valve. This, it is believed, is due to the conversion of potential energy of the premixed solution into kinetic energy at discharge, which in turn converts into heat as the velocity of the emerging wax decreases.

At the indicated operating temperatures, approximately 124° F. to 130° F. and at the required discharge pressures for hydrostatic depths of salvage, see FIG. 2, carbon dioxide requires no evaporation heat since it can only exist as a gas. No refrigeration effect can, therefore, be achieved upon discharge of the mixture and it is not possible to obtain on a temperature decrease due to a heat loss from the evaporating expanding agent. The mixture must, therefore, be discharged at a temperature which is below the melting point of the wax, taking into account the temperature increase referred to in the preceding paragraph.

In operation, the temperature of the mixture must, therefore, fall within the area of the diagram of FIG. 4 line between curves A and C. It can also be observed that the density of the solidified, expanded wax decreases and the available temperature range within which the operation can take place increases with an increased CO_2 ratio in the mixture. Both are desirable. On the other hand, however, the aforementioned granulation of the expanded wax together with the cost and waste of CO_2 set upper limits to the CO_2 ratio in the mixture.

Table 1 shows the behavior of a paraffin-carbon dioxide solution at various concentrations of carbon dioxide.

TABLE 1

Wax: Paraffin
Melting point (M.P.) of wax 130° F.
Expanding agent: CO

	Weight Percent of Expanding Agent in Mixture			
	1/2	2	4.6	6
M. P. of mixture, ° F	129	126	124	123
Available temperature range, ° F.[1]	1	4	6	9
Density of solidified, expanded wax, lb./cu. ft.	22	9	7	7
Compressive strength of solidified, expanded wax, p.s.i.	4.4	-----	3.0	2.3

[1] Difference between melting point of wax and melting point of mixture.

It has been found that the optimal ratio of carbon dioxide to liquid wax is about 4.6 percent. At that level, a relatively large temperature differential, as seen in Table 1, is available which makes it convenient to practice the invention on a large scale without the danger of solidification of the mixture or of overheating the mixture beyond the melting point of the wax. The density of 7 pounds per cubic foot as well as the compressive strength of 3 p.s.i. is highly satisfactory for purposes of imparting buoyancy to a sunken vessel. At the same time, the enclosed cells in the finally solidified expanded wax are substantially closed and water absorption is minimized. Some water absorption of the expanded wax takes place to a limited extent after the wax has been solidified. It is a function of the density of the wax as well as of the hydrostatic pressure differential to which it is subjected. Since the expanded wax is at least initially in equilibrium, that is the internal cells of the wax are under a pressure equal to that of the exterior surrounding water, the pressure differential is minimal at the most.

It has been found that water absorption by the expanded wax takes place slowly. At a foam density of about 10 pounds per cubic foot and with hydrostatic pressure differential between the exterior and the interior of the expanded wax of 0.25 p.s.i. the absorption reduces the buoyancy of the foamed wax by about ¼ percent after approximately five days and by about 2 percent after approximately 15 days with a sample of 2 x 2 x 2 inches in size. As the surface-to-volume ratio of the sample decrease, the water absorption rate is reduced.

Example 2.—A mixture of liquid paraffin and fluorocarbon 12 (dichlorodifluoromethane) is formed as in Example 1 in the ratios shown in Table 2. Principally the same phenomena occurs as when paraffin is mixed with carbon dioxide except that a greater proportion of fluorocarbon 12 is necessary to achieve satisfactory results. At a mixing ratio of 5 percent (by weight) or less of fluorocarbon 12 in the paraffin, the temperature differential between the melting point of the mixture and the melting point of the wax becomes so small that operation under field conditions becomes difficult. On the other hand, a fluorocarbon 12 ratio in the mixture of more than about 20 percent results in solidified wax granules as well as in excessive numbers of open cells in the expanded, solidified wax and an economic waste of fluorocarbon 12. Optimal

results have been obtained with a paraffin-fluorocarbon 12 mixture which contains between about 14 to 15 percent (by weight) of fluorocarbon 12. The workable temperature range is sufficient for large scale, in field operations and the density as well as the compressive strength are satisfactory for most vessel-salvage operations.

From a practical standpoint, fluorocarbon 12 is less desirable to use as an expanding agent than carbon dioxide because of its greater cost and because of its inability to be used at large depths. See FIG. 2.

FIG. 3 diagrammatically illustrates the working area (shaded) for a paraffin-fluorocarbon 12 mixture and is similar to the diagram of FIG. 4. Curve A of FIG. 3 illustrates the melting point of the mixture while curve B illustrates the upper temperature limit for the mixture. Above that limit solidification of the released wax does not take place.

It will be observed that a greater temperature range for the mixture is available when compared with a paraffin-CO_2 mixture. This results from the fact that, in contrast to CO_2, fluorocarbon 12 absorbs heat when the mixture is released through expansion valve **20** (FIG. 1) and evaporates. The heat absorption in turn reduces the temperature of the released wax so that satisfactory solidification of the wax takes place even if the mixture has a temperature above the melting point of the wax.

Table 2 shows the behavior of a paraffin-fluorocarbon 12 mixture at various concentrations of fluorocarbon 12 in the mixture.

TABLE 2

Wax: Paraffin
Melting point (M.P.) of wax 130° F.
Expanding agent: Fluorocarbon 12 (CCl_2F_2)

	Weight percent of expanding agent in mixture				
	5	10	15	20	25
M.P. of mixture, ° F	126	122	117	115	113
Available temp. range, ° F	4	8	13	15	17
Density of solidified expanded wax, lb./cu.ft	8	4	2.8	2.1	2.1
Compressive strength of solidified, expanded wax, p.s.i.	1.3	0.8	0.6	0.4	

Example 3.—Liquid paraffin is mixed with fluorocarbon 22 (difluoromonochloromethane) as in Example 1. The expanded, solidified wax has characteristics similar to that of a paraffin-fluorocarbon 12 mixture. With fluorocarbon 22, however, the expanded wax is of a somewhat lesser density and has a somewhat reduced compressive strength. Wax granulation and an excessive number of open cells occur at fluorocarbon 22 ratios (by weight) in the mixture of above between about 15 to 20 percent. Operating difficulties, particularly the narrow temperature range between the melting point of the mixture and of the wax occur at fluorocarbon 22 ratios of less than about 2 percent. The preferred optimal range from the standpoint of both operating temperature range and density, compressive strength, a closed-cell structure and economic considerations is in the range between about 9 and 10 percent, best results having been achieved with a mixture containing 9.7 percent fluorocarbon 22.

Table 3 shows the behavior of a paraffin-fluorocarbon 22 mixture at various concentrations of Freon 22 in the mixture.

TABLE 3

Wax: Paraffin
Melting point (M.P.) of wax 130° F.
Expanding agent: Freon 22

	Weight percent of expanding agent in mixture			
	5	10	15	20
M.P. of mixture, ° F	123	121	119	115
Available temp. range, ° F	7	9	11	15
Density of solidified, expanded wax, lb./cu.ft	5.0	3.7	3.0	2.5
Compressive strength of solidified, expanded wax	0.8	0.6	0.5	0.4

Example 4.—Methane is blended with liquid paraffin as in Example 1 and then discharged through expansion valve **20** to form the expanded wax. Table 4 below shows the results achieved with various ratios of methane in the mixture.

TABLE 4

Wax: Paraffin
Melting Point (M.P.) of wax 130° F.
Expanding agent: Methane (CH_4)

	Equilibrium vapor pressure of methane-paraffin mixture p.s.i. at the M.P. of the mixture			
	100	300	600	800
M.P. of mixture, ° F	128	127	125.5	125.5
Available temperature range	2	3	4.5	4.5
Density of solidified expanded wax, p.c.f.	12.5	8.5	7.5	7.1

Propane was also evaluated as an expanding agent and found to exhibit characteristics similar to methane, but had lower vapor pressures at equivalent weight percent mixtures.

Example 5.—Sulfur hexafluoride is mixed with liquid paraffin as in Example 1 and then discharged through expansion valve **20** to form the expanded wax. Table 5 below shows the results achieved with various ratios of sulfur hexafluoride in the mixture.

It is most notable that the temperature differential between the melting point of the mixture and of the wax is substantially smaller than in the case of the fluorocarbon propellants or carbon dioxide. In addition, the density of the expanded wax is larger than in the preceding examples and the compressive strength of the foamed wax is reduced. Although sulfur hexafluoride has good expansion characteristics under large hydrostatic pressures, the relatively small temperature differential and its high cost make it less desirable for use in large scale field operations. For the same reasons as those given in the preceding examples, the acceptable range of sulfur hexafluoride in the mixture is between about 1 and about 6 percent (by weight) of the mixture, optimal results having been obtained with a mixture having a sulfur hexafluoride ratio of between about 3 and about 4 percent. At ratios over about 6 percent excessive granulation and cell opening takes place.

TABLE 5

Wax: Paraffin
Melting Point (M.P.) of wax 130° F.
Expanding agent: SF_6 (sulfur hexachloride)

	Weight percent of expanding agent in mixture				
	1	2	3	5	7
M.P. of mixture, ° F	128	127	126	125	124
Available temp. range, ° F	2	3	4	5	6
Density of solidified, expanded wax, lb./cu. ft	15	11.8	10	8	7.5
Compressive strength of solidified, expanded was, p.s.i.	4.6	3.3	2.5	1.5	

Example 6.—Microcrystalline wax, which is similar to paraffin, but which may be distinguished by the fineness of its crystals, and fluorocarbon 12 are mixed as in Example 1. The melting points of the wax and the mixture is about 168° and 165° F., respectively, at 5 percent by weight of fluorocarbon 12 thus substantially above that of paraffin wax and its mixtures. This makes the wax less desirable because a greater amount of heat exchange between the cold water surounding hose **18** leading from mixer **16** to the expansion valve **20** takes place and a greater amount of insulation or heating is required. Its compressive strength, however, is substantially greater than that of paraffin. If beeswax is substituted for the microcrystalline wax results similar to those stated above.

Example 7.—A mixture of Fischer-Tropsch wax and fluorocarbon 12 is prepared as in Example 1 and discharged through the expansion valve. Fischer-Tropsch wax has substantially the same density when expanded with 5 percent fluorocarbon 12 as does microcrystalline

wax. The operating temperature, however, is substantially above that of both microcrystalline wax and paraffin.

Example 8.—Carnauba wax, which is a vegetable wax, is mixed with 5 percent fluorocarbon 12 as in Example 1 and discharged through expansion valve **20**. The characteristics of this wax, its mixture and its expansion are similar to that of Fischer-Tropsch wax except that it has a lower density.

Referring now to FIG. 1, the wax-expanding agent mixture must be maintained at the proper temperature, that is above the melting point of the solution and preferably below the melting point of the wax, while it is being transported to expansion valve **20** in hose **18**. Hose **18** must, therefore, be insulated and if the length of the hose demands, it has to be heated to offset heat losses and prevent temperature reduction of the mixture which might cause the solidification of the latter. If the hose is of the heated type, the operation can be performed intermittently. For example, where various compartments (not shown) of the vessel are to be filled with expanded wax the operation is discontinued while a diver relocates the end of the hose provided with the expansion valve from one to another compartment.

As an alternative to the heated hose and to still permit intermittent operation, a circulating system may be provided by the use of a second hose **24** placed parallel to or concentric with hose **18** and connected with expansion valve **20** by a three-way valve **26**. The upper end of hose **24** is connected with mixer **16** via a three-way valve **28** and an auxiliary heater **30** which additionally communicates with the first hose **18** through another three-way valve **32**. The valves are preferably arranged so that during operation, that is while the mixture is discharged through the expansion valve **20**, the mixture is transported to the expansion valve through both hoses **18** and **24**. When the operation is to be interrupted, the three-way valves are operated so that a hydraulic circuit is closed which leads from the uppermost valve **32** through hose **18**, valve **26** up hose **24**, through heater **30** and back to valve **32**. A pump **34** is included in the circuit so that the mixture is continuously circulated through the heater and its temperature in the hoses is maintained above the melting point of the mixture. To commence the discharge of the mixture through the expansion valve, the operating means are again actuated to return the valves to their original position.

After the vessel has been floated and secured against sinking, the wax is removed from the interior of the vessel by washing it down with hot or boiling water. Particularly if paraffin is used as the wax, which has a melting point of substantially less than the temperature of hot or boiling water, the operation is performed, quickly, easily and with little expense. The molten wax is then separated from the wash water and can be reused in another salvage operation.

I claim:

1. The method of raising a submerged vessel under a hydrostatic head having a flooded compartment by the discharge into the compartment for displacement of water therefrom of a heated pressurized liquid wax and gas mixture, the steps comprising,

heating a wax to liquid form,

admixing gas under pressure with said heated liquid wax to provide a heated pressurized mixture,

selecting said wax and gas and the concentration of said gas to provide a melting point for said mixture lower than the melting point of said wax and a vapor pressure in said mixture greater than said hydrostatic head,

conducting said heated mixture to and discharging said mixture into said compartment,

and controlling the temperature of said mixture at discharge to a temperature greater than said mixture melting point and less than the sum of said wax melting point and a temperature increment provided by the heat of vaporization of said gas, thereby controlling the temperature of the wax product discharged into said compartment to less than the melting point of said wax.

2. The method defined in claim **1** wherein said gas is selected from the group consisting of carbon dioxide, fluorocarbon, hydrocarbon, and sulfurhexafluoride.

3. The method defined in claim **2** wherein the weight content of said gas is between about ½% and about 20% of the weight of said wax.

4. The method defined in claim **2** wherein the temperature of said mixture at discharge is less than the melting point of said wax.

5. The method defined in claim **1** wherein said wax is paraffin and said gas is CO_2 and the temperature of said mixture at discharge is less than the melting point of said wax.

6. The method defined in claim **5** wherein the weight content of said CO_2 is between ½% and 6% of the weight of said wax.

7. The method defined in claim **1** wherein said gas comprises a fluorocarbon.

8. The method defined in claim **7** wherein said wax is paraffin and said gas is dichlorodifluoromethane.

9. The method as defined in claim **8** wherein said weight content of said gas is between about 5% and about 20% of the weight of said wax.

10. The method defined in claim **7** wherein said wax is paraffin and said gas is difluoromonochloromethane.

11. The method as defined in claim **10** wherein said weight content of said gas is between about 5% and about 20% of the weight of said wax.

12. The method as defined in claim **1** wherein said gas comprises a hydrocarbon gas.

13. The method defined in claim **1** within the steps of heating said wax and admixing said gas therewith are performed at a station remote from said vessel, and returning at least a portion of said mixture from adjacent its point of discharge at said vessel to said station for reheating and recirculating.

14. The method as defined in claim **1** supporting the raised vessel, and washing out said compartment with water heated to above the melting point of said wax to remove said wax product.

15. The method as defined in claim **13** and separating the wax product removed from said water to recover said wax.

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264—45, 50

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,531,233 Dated September 29, 1970

Inventor(s) John K. Max

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 20, change "CO" to --CO_2--.

Column 8, line 55, change "was" to --wax--.

Column 8, line 65, change "surounding" to --surrounding--.

Signed and sealed this 14th day of September 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents

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