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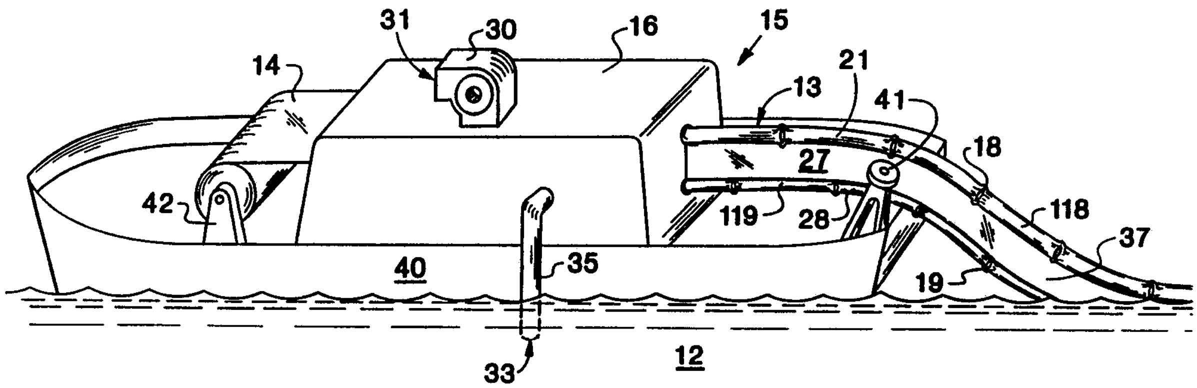

(57) Abstract

Leaking oil and other contaminants (10) floating on water (12) are contained by providing sheet material (14) at the site (15) of the contaminant for fabrication of a containment boom structure. Such containment boom structure (13) is continually fabricated from that sheet material at the site and upon the occurrence of the contaminant floating on water and is continually deployed into the water (12) against the spread of that contaminant on that water. By way of example, oceans and other bodies of water (12), as well as coastal environments (54), may thus be protected against the spread of leaking oil after accidents involving oil tankers (39) or offshore drilling operations, or against other floating contaminants (10).

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+ DESIGNATIONS OF "SU"

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Description

Floating Contaminant Containment Systems

Technical Field

The subject invention relates to systems for effectively impeding, if not in many cases preventing, the spread of leaking oil on seas and for containing other contaminants floating on water, and to systems for protecting coastal environments against such floating contaminants. It specifically addresses issues of speed of deployment, capacity and effectiveness of containment, and economy of manufacture and deployment.

Recent catastrophic contaminations from oil spills in Alaska, the Gulf of Mexico, and many other environmentally sensitive regions around the globe testify to the importance of such systems and the need to improve their effectiveness.

Background Art

Various systems, apparatus and devices for containing floating contaminants have been proposed over the years, including a number of varied designs for containment boom structures. Several of these systems have been put to use to contain actual spills, and most can deal adequately with small volumes of contaminant. However, well-publicized spill incidents of recent years have demonstrated that current containment technologies are not adequate to deal with the huge volumes of petroleum and other contaminants which can be released by a foundering supertanker or damaged drilling platform.

A clear shortcoming of existing containment systems is their inability to deploy sufficient lengths of floating containment boom around a leaking tanker or platform during the first few hours of a spill episode. While most industry experts concede that no containment technology is likely to be effective in heavy sea conditions or near rocky coastlines, the most damaging of recent spills have occurred in relatively calm conditions, and in locations where rapid deployment of containment booms would have greatly reduced the consequent environmental damage. Instead, vessels equipped for large-scale deployment of containment booms often took hours or days to reach the sites of spills, by which time the oil had spread over areas too large for the vessels' equipment to handle.

A number of measures have been taken or proposed to shorten these response times. Studies have been made into the feasibility of creating a chain of oil-spill response bases along the entire length of the U.S. coastline, each with one or more specially-designed cleanup vessels on call. Such vessels, which may typically carry about one kilometer of containment boom, recently began accompanying every outbound tanker during its passage through Prince William Sound in Alaska. But though they are regarded as the most effective spill fighting tool currently available, even if such a cleanup vessel were to accompany every tanker throughout its entire voyage, its containment capacity would be overwhelmed in the event of a major spill.

Rather than assigning a separate vessel to deploy containment booms, it is reasonable to question why large quantities of boom, along with a motorized launch to aid in deployment, cannot instead be carried by the tankers themselves, ready for immediate use. Certainly there is no shortage of potential storage space on the deck of a modern supertanker. In fact, most tankers and platforms do have lengths of fabricated containment boom stowed aboard. In practice, however, the amount of boom which may be deployed directly from a tanker is limited to a few hundred meters in most cases; this is enough to deal with tens or hundreds of barrels of floating oil, but not with major spills.

The basis of this limitation, apart from cost, is principally operational. In the early hours of a spill episode, it would typically be necessary to deploy the containment boom in a generally encircling or even multiply encircling pattern around the tanker. If an analysis is made of the operation of paying out a stored boom from the deck of a tanker while a separate motorized launch drags the initial end of the boom out and around a zone of floating oil, it is seen to be difficult if not impossible to deploy the boom so as to attain the desired encirclement. The physical laws which govern the movement of a flexible linear structure as it is towed through a viscous fluid tend at all times to force the containment boom into a more or less linear arrangement upon the water. Through skillful maneuvering of the launch, it is possible to coax a limited length of boom into an awkwardly polygonal pattern. But as the length of the boom increases, these maneuvers become more and more difficult since the entire length of the boom must be pulled out from the tanker before the launch begins to travel around the contaminant zone. In addition, the drag exerted on the launch by the boom under tow, and the tensile stresses experienced by the boom itself, rapidly become unmanageable. Sequential deployment of several separate lengths of boom does not offer much practical advantage since the boom segments must be brought together and joined end–to–end during deployment; such an undertaking requires highly trained personnel on the launch to perform difficult, time-consuming, and potentially hazardous tasks at sea.

These facts demonstrate that any practical system for deploying very long lengths of containment boom at sea must effect that deployment from a moving structure, e.g. a launch or another, independent vessel, rather than from the tanker itself. Thus, in determining the amount of containment boom available for deployment, it is the storage capacity of the launch or other vessel which is relevant, rather than that of the tanker. It is not surprising, therefore, that the problem of designing containment booms which are more compactly storable has received much attention in recent years.

A number of prior art containment systems utilize collapsible and/or inflatable boom structures, wrapping the compacted boom on a reel or stuffing it into a container for storage. Early versions of these systems borrowed technology from life raft designs, inflating the boom with cylinders of compressed gas or with combinations of gas producing chemicals, as seen for example in U.S. Patent 3 563 036, by Smith et al, issued February 16, 1971, for Inflatable Floating Booms, and in U.S. Patent 3 701 259, by Heartness, issued October 31, 1972, for an Oil Pollution Barrier. Later designs have used various other means of inflation or self-inflation of flotation tubes on collapsible containment booms; among these are the inclusion of coil springs in the collapsed flotation tube, as disclosed in U.S. Patent 4 295 755, by Meyers, issued October 20, 1981, for a Reel Mountable Boom Arrangement, or the inclusion of plastic foam formers in the collapsed flotation tube, as disclosed in U.S. Patent 4 652 173, by Kallestad, issued March 24, 1987 to Acme Containment Systems, for a Self-Inflating Oil Spill Boom. However, all of these methods greatly increase the stored volume and the cost of the containment boom structure.

The importance of achieving maximum storage compactness may be illustrated as follows. One kilometer of open-sea containment boom of typical dimensions may have a deployed volume on the order of 300 cubic meters. Certain commercial implementations of the above-mentioned self-inflating boom technologies offer compaction ratios (i.e. the ratio of deployed volume to collapsed volume) of approximately 20 to 1; one kilometer of boom would thus require 15 cubic meters for storage. Consequently, a vessel capable of carrying several kilometers of such boom, plus the support structures needed to store and deploy the boom, would obviously need to be of substantial size and expense. The cleanup vessels mentioned above are typically over 40 meters in length and cost over a million dollars for the basic vessel, plus another half million dollars or more for on-board equipment. A vessel of such size and expense would not reasonably be referred to as a "launch" or be considered an "accessory" of a tanker.

A different approach to inflatable boom design is disclosed in U.S. Patent 4 123 911, by Finigan et al, issued November 7, 1978 to The British Petroleum Company, for an Oil Control System. Finigan et al provide a relatively simple collapsible boom structure without internal springs or formers. This and other similar inflatable boom designs may achieve a compaction ratio on the order of 50 to 1. However, Finigan et al require machinery at both ends of their boom so that air may be pumped into one end of the preformed flotation tube while the other end is deployed from a reel. Such designs are subject to potential difficulties during deployment of very long lengths of boom, difficulties which may be visualized by considering the analogy of attempting to draw water through a tangled and kinked garden hose. From a topological perspective, it is practically impossible to unreel, unfold, or otherwise deploy an empty flattened continuous tube and simultaneously inflate that tube from the deploying side of the tube without breaching the continuity of the tube; inflation must be accomplished by pumping the inflating medium through the entire length of the tube from the initially deployed end.

An alternate way of dealing with this topological problem is to incorporate an air hose or hoses into the boom structure, such as disclosed in U.S. Patent 4 403 888, by Teasdale, issued September 13, 1983, for Oil Containment Booms. Teasdale's method of pumping air through the hoses to the initially deployed end of the boom eliminates the need for machinery at that end of the boom, but does not totally solve the problem of kinking and fouling of long booms during deployment. In addition, designs such as these which require an unobstructed path through the flotation tube are subject to total boom failure in the event of a rupture at any point along that tube.

Another method which has been suggested for containment is to manufacture containment booms on-site from foam plastics. Discussion of this approach may be seen in U.S. Patent 4 237 237, by Jarre et al, issued December 2, 1980, for Hydrophobic Polyurethane Foams, Their Manufacture and Use; from an article by K. Lanfermann et al, entitled **"Schaumstoffe zur Bekämpfung von Ölunfällen"** (subentitled "Foam Plastics for Control of an Accidental Oil Spill"), in Proc. of Int'l. Marine Science/ Ocean Engineering Conf. (1980), Hamburg, 9/24-25/80, Paper No. IMT 80-320, pp. 666-670; and from an article by K. Dietzel, entitled **"Öl-Barriere aus Superlastichem Polyurethanweichschaum"** (subentitled "Polyurethane Flexible Foam Boom Against Oil Pollution"), in Proc. of Int'l. Marine Science/ Ocean Engineering Conf. (1982), Hamburg, 9/29-30/82, Paper No. IMT 82-313, pp. 558-562. According to that literature, a polyurethane flexible foam boom can be manufactured by extrusion on and deployed from a floating vessel right at the site of the spill. A ratio of 60 to 1 between the volume of the deployed boom and the volume of the stored constituent chemicals is cited in the Dietzel article as a significant advantage over existing prefabricated oil booms. However, the foam boom systems described in these references are favored principally for their oil-absorbent properties, and do not readily lend themselves to the fabrication of conventional boom shapes, which incorporate wide dependent curtains below the flotation chambers to prevent oil from passing under the boom.

Indeed, the question of the size of the dependent curtain below an oil boom is an issue of some debate in judging the effectiveness of containment boom systems. The curtain must be sufficiently deep to span the thickness of the oil or other floating pollutant, and to prevent underflow of the pollutant due to localized wave-induced pitching of the boom. However, if a containment boom is secured at a fixed location, any currents which may exist in the body of water will cause floating oil to be carried along and to accumulate in front of the boom. This transport of oil is due to drag at the interface between the layer of oil and the water below it. At low current velocities, the thickness of the oil layer in front of the boom reaches an equilibrium value; containment is then possible provided the boom incorporates a dependent curtain at least as wide as the equilibrium thickness of the oil layer. At higher current velocities, however, the accumulation of oil occurs faster than the oil can spread back away from its accumulation front; oil droplets can also become entrapped in the flowing water at the boundary layer between the oil and the water, and the undersurface of the floating oil can experience unstable wave phenomena. In such currents, as a result of these failure mechanisms, effective containment is not possible regardless of the width of the dependent curtain.

Extensive research has been undertaken to determine the factors which affect this "zero containment current"; such research is discussed in **"The Cleanup of Oil Spills from Unprotected Waters"**, by J. Milgram, in Oceanus, Vol. 20, No. 4, Fall 1977, pp. 86-94; in **"Loss rates and operational limits for booms used as oil barriers"**, by T. Fannelop, in Applied Ocean Research, Vol. 5, No. 2, 1983, pp. 80-92; and in **"Barrier Failure by Critical Accumulation of Viscous Oil"**, by G. Delvigne, in Proc. of American Petroleum Institute 20th Anniv. Oil Spill Conference (1989), pp. 143-148. The results of this research indicate that oil may begin to escape a floating barrier, regardless of its draft, at currents below 0.25 meters/second (approximately one-half knot) of relative velocity between the boom and the underlying body of water. At relative velocities in excess of 0.5 meter/second (approximately one knot), these losses become so great that the boom's containment capacity is seriously compromised. Existing containment systems and strategies, insofar as they employ single barriers secured in more or less fixed positions, do not adequately account for these current-induced failure modes.

In addition, many existing containment boom designs are optimized to work in concert with skimmer ships and other systems for recovering the floating pollutant from the water. To fulfill this role, such containment booms are often of robust construction, capable of surviving days or weeks of deployment at sea, and even capable of being recovered and reused. Such design criteria have weighed against boom designs which are economically manufacturable, compactly storable, and rapidly deployable.

Disclosure of Invention

It is an object of the subject invention to provide methods and apparatus which will allow several kilometers of lightweight floating containment boom to be economically deployed within the first few hours following a oil or other contaminant spill. By acting as "first aid" during a pollution episode, embodiments of the subject invention overcome the speed, cost, and effectiveness limitations of existing containment technologies. When employed in conjunction with existing cleanup technologies, the invention will greatly enhance the oil industry's ability to prevent the ecological disasters which have too often accompanied the mishaps of ocean drilling and transport.

The invention resides in a method of containing a contaminant floating on water, comprising in combination the steps of providing sheet material at the site of that contaminant for fabrication of a containment boom structure, continually fabricating that containment boom structure from that sheet material at the site and upon the occurrence of the contaminant floating on water, and continually deploying the continually fabricated containment boom structure into the water against the spread of the contaminant on that water. The invention resides also in a containment boom structure made by such method.

In terms of apparatus for fabricating a containment boom structure, the invention resides in means for continually fabricating the containment boom structure from sheet material at the site of the contaminant, in combination with means for continually deploying that continually fabricated containment boom structure into the water at the site of the contaminant. A preferred embodiment of the invention resides in apparatus for fabricating a containment boom structure comprising in combination a launch capable of being carried by an oil tanker, means for storing sheet material on that launch prior to fabrication of a containment boom structure, and means on that launch for continually fabricating from that sheet material and for deploying from that launch the containment boom structure at the site of the contaminant.

Preferred Embodiments of the Invention

According to the invention, a contaminant 10 floating on water 12 is contained by continually fabricating a containment boom structure 13 from sheet material 14 upon occurrence and at the site 15 of that contaminant, such as shown in Figs. 2 and 3, and by continually deploying onto the water 12 that containment boom structure 13 as continually fabricated from sheet material 14 at the site 15 of that contaminant, such as shown in Fig. 4.

In particular, according to a preferred embodiment of the invention, the containment boom structure 13 is fabricated from sheet material 14 using machinery 16, and both that sheet material and that machinery are stored on a moveable structure prior to use. Such moveable structure may typically be a launch or similar watercraft, such as shown at 40 in Fig. 4. Upon the occurrence of a contaminant spill, such launch is deployed to or at the site 15 of the contaminant, and fabrication of the containment boom structure 13 is then initiated. The containment boom structure is thereupon continually fabricated on the launch 40 at the site of the contaminant and is continually deployed from that launch against the spread of the contaminant. Within the scope of the invention, a transportable structure may be provided for transporting the machinery 16 to the site 15 of, or to a location 54 potentially threatened by, the contaminant 10, and the containment boom structure 13 is continually fabricated from sheet material 14 with the machinery 16 and is continually deployed from the transportable structure as herein disclosed.

The method of fabricating a containment boom structure from sheet material right at the site of the contamination when it occurs, and of performing this fabrication and deployment from a moveable structure such as a launch, as provided in a preferred embodiment of the subject invention, offers several significant advantages over the use of prefabricated containment booms. These advantages include: the ability to begin deploying extremely long continuous lengths of containment boom at the site of the contaminant within minutes following the onset of a spill; the ability to deploy these continuous lengths of containment boom out of storage volumes which are much smaller relative to the volume of the deployed boom than heretofore realized; the ability to maneuver the containment boom during deployment so that it forms single or multiple spiral or independent loops or arcs on the surface of the water, in whatever position or combination of positions are deemed most efficacious in containing the floating contaminant; and the ability to provide long lengths of containment boom at the site of the contaminant much more economically than heretofore realized. While some existing containment boom technologies have the ability theoretically to provide some of the above stated advantages, the subject invention is able to provide all of these advantages in combination. The need for a containment method which provides these benefits is evident in view of the oil industry's inability to deploy sufficiently large amounts of prefabricated containment boom in the critical hours immediately following recent oil spill incidents.

By way of quantitative example, a roll of sheet material 0.25 millimeters thick, 1 meter in diameter, wound on a 200 millimeter diameter core, can theoretically provide the material for a containment boom over 3 kilometers in length. This is a much longer length of continuous containment boom than is currently available for immediate deployment from oil tankers or platforms. Further, according to an embodiment of the invention, the volume of the containment boom structure 13 fabricated from the sheet material at the site 15 of the contaminant 10 is at least two orders of magnitude larger than the combined volume of that sheet material 14 and any machinery 16 employed in that fabrication. This ratio of deployed containment boom volume to "standby volume", i.e. the volume required to store the materials and machinery prior to use, is better than the 50:1 ratio which is quoted for certain commercially available collapsible boom structures, which ratio does not even include the volume of reels or other apparatus required to store and deploy said structures. It is also better than the 60:1 ratio given in the above mentioned Dietzel article relative to the volume of the polyurethane foam raw materials, which ratio does not even take into account the volume of the machinery required to mix, cure, and deploy the foam boom. For direct comparison, an analysis of the cross-sectional area of several proven containment booms shapes and the cross-sectional area of the thin sheet material from which they could be fabricated according to the subject invention shows that volume ratios in excess of 250:1 can be realized between the deployed volume of the boom and the stored volume of the sheet material only. The machinery required to continually fabricate the containment boom structure from the sheet material at the site of the contaminant, as will be described hereinafter, is not significantly more voluminous than the machinery required to store and deploy many prior art collapsible boom structures. Nor is it significantly more voluminous than the machinery required to mix, cure, and deploy the polyurethane foam boom as described in the Dietzel article, which machinery is described therein as occupying the volume of one 20-foot long ocean cargo container, with the raw materials for the production of 1 kilometer of boom being stored in a second such container.

An embodiment of the subject invention fabricates a containment boom structure from sheet material 14 at the site 15 of the contaminant 10 by providing machinery 16 including a forming shoulder assembly 20 such as shown in Figure 3. The sheet material 14 is passed through the forming shoulder assembly 20 to form the sheet material into a tubular structure 21, and the containment boom structure 13 is made or completed from such tubular structure. The forming shoulder assembly may be of the type shown at 20 in Fig. 3, or of any other type which performs the equivalent function of forming sheet material into a tubular structure. Piping 23 may be provided in conjunction with the forming shoulder assembly 20 for loading the tubular structure as disclosed hereinafter.

For rapid implementation of the invention, technology may be transferred from the material packaging field where sheet material formers have been used for a long time to form tubular structures that are made into bags to enclose granular or other solid materials or even liquids. By way of example, reference may be made to U.S. Patent 4 288 965, for Form-Fill-Seal Packaging Method and Apparatus, by Robert C. James, issued September 15, 1981 to Hayssen Manufacturing Company, and U.S. Patent 4 578 931, for Apparatus for Producing Pouch Packages, by Gijsbertus Roovers, issued April 1, 1986 to Robert Bosch GmbH. Both of these patents with their disclosures are herewith incorporated by reference herein for any and all sheet forming equipment, tube sealing means and methods, and for sheet and tube advancing means shown only symbolically at 22, and for pouch sealing or forming means shown only symbolically at 122 in Fig. 3.

According to a preferred embodiment of the subject invention, Fig. 2 diagrammatically shows a first sheet forming assembly at 25 and a second sheet forming assembly at 26. These sheet forming assemblies may comprise a pair of forming shoulder assemblies for forming the sheet material 14 into tubes at the site 15 of the contaminant. Each of these forming shoulder assemblies may be of the type shown at 20 in

Fig. 3, or as otherwise mentioned above. The sheet material 14 is passed through the sheet forming assemblies 25 and 26 to form the sheet material into a tubular structure 27 having a first tube 21 for flotation and a second tube 28 for ballast. Accordingly, the containment boom structure 13 is made or completed at the site of the contaminant from the tubular structure 27.

In particular, a pump or fan is symbolically shown at 30 in Fig. 2 and somewhat differently in Fig. 4 for loading air into the tube 21, such as by way of piping 23 associated with the forming shoulder assembly 20. The same piping 23 may be used to load the flotation tube with a gas other than air, or with foam plastic material if desired. However, the presently conceived most convenient method of providing flotation is to fill the tube 21 with air as it is being formed. Correspondingly, using methods such as described in the above mentioned U.S. Patents by James and by Roovers, heavier granular or other materials may be loaded into the second tube 28 as ballast. However, the presently conceived most convenient method of providing ballast is to pump water 33 from the body of water 12 into the tube 28 as it is being formed. This may be accomplished by using a pump as diagrammatically shown at 34 in Fig. 2, drawing water 33 from the body of water 12 through an immersed pipe 35, and pumping the water to the second sheet forming assembly, where it is loaded into the tube 28 though piping associated with the second forming shoulder assembly. There may be advantages to first forming and filling the flotation tube 21, then forming and filling the ballast tube 28, as shown in Fig. 2, but as conceived in this disclosure, these two form-and-fill operations may be performed in either order.

According to Figs. 2 and 3, the first sheet forming process at 20 or 25 leaves a web 36 in parallel to the flotation tube 21. According to Fig. 2, the similar second sheet forming process at 26 forms the ballast tube 28 from that web, leaving a resulting web 37 between the flotation tube 21 and the ballast tube 28. By adjusting the dimensions of the sheet formers and associated mechanisms, the width of that resulting web may be set to any desired fraction of the width of the original sheet material. When the containment boom structure 13 is deployed onto the water 12, the web 37 and attached ballast tube 28 form a dependent curtain which is suspended in the water below the flotation tube 21, thus serving to prevent or at least impede the floating contaminant 10 from passing under the flotation tube. The same or similar fabrication and deployment method may be used for containment boom designs which include little or no web between the flotation and ballast chambers, such as described in U.S. Patent 4 140 424, for a Barrier for Oil Spilt on Water, by Bretherick et al, issued February 20, 1979 to The British Petroleum Company. In the case of these webless containment boom designs or any other containment boom designs comprising combinations of flexible weblike and tubular elements, the method of continual fabrication from sheet material at the site of the contaminant, as disclosed pursuant to an embodiment of the subject invention, may be applied. That embodiment of the invention may also be used to fabricate boom structures which include folds and pockets to enhance the stability of the containment boom in the water, such as those disclosed in U.K. Patent 2 117 326, by Milligan, published 12 October 1983, for an Oil Containment Boom.

In principle, material heavier than water can be used in the ballast tube. Alternatively, lead or other ballast material may be crimped, riveted, or otherwise attached to the single web 36 of the tubular structure 21 produced by the first sheet forming assembly 25 as part of the continual fabrication process, and the resulting containment boom structure deployed directly into the water without the addition of a second ballast tube. Separately attached ballast material may also be used in conjunction with the water-filled ballast tube, or a heavy rope or cable may be inserted or laminated into the continually fabricated boom structure. However, using water from the body of water 12 in the ballast tube 28 is a useful expedient, since the storage and transportation of special ballast material may thus be avoided. Even if only water is used in the ballast tube, the inertial moment and drag of the ballast tube 28 against the vertical component of wave motion on the water 12 transmitted through the web 37 from the flotation tube 21 will tend to maintain the boom structure 13 in a fairly vertical orientation.

The type of continual on-site sheet-into-tube forming and filling process disclosed herein overcomes the previously discussed topological difficulties associated with filling continuous preformed tubes. It also offers a simple way of preventing boom failure caused by rupture of an unobstructed flotation tube, which was mentioned above in connection with the U.S. Patent by Finigan et al. The sheet forming equipment 25 and/or 26 may be provided with conventional pouch sealing means 122, such as disclosed in the above mentioned U.S. Patents by James and by Roovers, for producing in the tubular structure 27 or tubes 21 and 28 transverse seals 18 and/or 19 and elongate compartments 118 and/or 119. Accordingly, a tubular structure 21 is formed from the sheet material 14 in this or any other manner pursuant to the currently disclosed embodiment of the invention, and such tubular structure is continually subdivided into elongate compartments 118 and such elongate compartments are continually filled with gas for flotation, such as in Figs. 2, 3 and 4, during the continual fabricating of the containment boom structure 13. Such segmentation of the flotation and ballast chambers increases the durability of the boom structure by preventing a localized rupture from affecting the entire length of the containment boom.

Rather than forming the containment boom structure from flat sheet material at the site of the contaminant, it would also be possible to preform segments of flotation tube and/or ballast tube in the otherwise continuous sheet material using machinery in a factory on land, and to employ machinery at the site of the contaminant only to inflate or fill these tube segments as the continuous boom structure was deployed. However, though various geometries may be conceived for such preforming of the sheet material, and various apparatus may be employed for the on-site inflation or filling of the flotation and/or ballast chambers, all such geometries and apparatus would involve leaving one or more edges or corners of the flotation and/or ballast tube segments unsealed during the initial sheet forming process and would require their subsequent sealing after filling; or they would involve the insertion of piping into transverse holes in the tube segments and the subsequent sealing of those holes; or they would involve some similar type of technique which would still require on-site sealing of the flotation and/or ballast tubes after filling. Therefore the machinery required to realize such alternate boom fabrication methods is not significantly simpler, and may in fact be much more complex, than the machinery required to form, fill, and seal the entire containment boom structure from flat sheet material at the site of the contaminant. Thus a highly advantageous feature of the preferred embodiment of the subject invention is that the containment boom structure disclosed herein is fabricated from nothing more, or from almost nothing more, than simple flat sheet material, plus the air and water readily available at the site of the contaminant.

In practice, there are a number of different types of sheet material 14 which may be employed for the on-site fabrication of containment boom structures according to the subject invention. These may include polyethylene film, polypropylene film, polyester film, polyvinyl chloride film, and other plastic films, as well as certain types of papers treated so as to be water resistant, fabrics, and laminated combinations of paper, fabric, plastic film and/or metal foils.

A preferred embodiment of the subject invention provides a launch 40 capable of being carried by an oil tanker, installs fabrication machinery 16 on that launch for continually fabricating a containment boom structure, stores unformed sheet material on that launch prior to deployment, deploys that launch at the site 15 of the contaminant spill when it occurs, continually fabricates the containment boom structure 13 from that sheet material with that machinery, and continually deploys that containment boom structure from that launch against the spread of the contaminant. Such sheet material is stored on said launch in an unformed condition, typically on a roll, and is only formed into a tubular structure as part of the continual fabrication and deployment process which commences when a contaminant spill has occurred. A reel mechanism for storing and dispensing the sheet material on that launch is broadly shown at 42 in Fig. 4. Guide rollers and other equipment for assisting the deployment of the fabricated boom from the launch are broadly shown at 41.

A possible deployment scenario for the continually fabricated containment boom structure is shown in Fig. 1, in which the central structure 39 may represent a stationary structure such as an oil platform, or a temporarily stationary structure such as an oil tanker or other vessel, being located at the site 15 of the contaminant or even being the source of an oil slick or other contaminant 10 on the body of water 12. An initial length of boom as fabricated may be attached to an anchor point 116 which may be on the stationary structure 39. According to this possible deployment scenario, the launch 40 containing the sheet material 14 and the fabrication machinery 16 would proceed away from and encircle the stationary structure, all the while fabricating and deploying containment boom 13 to contain the floating contaminant 10. Because a substantial amount of boom material can be deployed by the launch as disclosed herein, it is possible to continue to encircle the source of the contaminant, laying down additional loops of containment boom such as shown at 113 in Fig. 1, so that any oil or other contaminant which succeeds in escaping over or under the initial loop of containment boom, such as shown at 110, will still be contained.

The fact that the containment boom structure is fabricated on and deployed from a moving structure, such as the aforementioned launch, at the site of the contaminant when it occurs is an important factor in the efficacy of the preferred embodiment of the subject invention such as shown in Figs. 1 through 5. Although it would be possible to mount the apparatus for storing the sheet material and fabricating the containment boom structure directly onto an oil tanker or platform, and to use a launch merely to tow the end of the containment boom away from the tanker or platform as the boom was fabricated, the physical forces at work on a floating containment boom as it is deployed in the water, as were previously discussed, make it practically impossible to achieve multiple encirclement of the floating contaminant unless the boom is deployed from a moving structure, such as in this case the launch.

Embodiments of the subject invention specify that sheet material and fabrication machinery be provided on a launch capable of being carried by an oil tanker, or that continual deployment of the fabricated containment boom be effected with such a launch, such as shown in Fig. 6. However, the expression "capable of being carried by an oil tanker" is herein employed to refer to the size of the launch 40 relative to ocean-going oil tankers and does not necessarily mean that the launch need actually be carried on an oil tanker. The launch 40 may be carried on an oil tanker, or may accompany the oil tanker under its own power during all or part of the tanker's voyage, or may be deployed from a platform, from another vessel or aircraft, or from nearby land. In each such case, the preferred embodiment of the subject invention deploys the continually fabricated containment boom structure from or with that launch at the site of the contaminant.

The above mentioned quantitative advantages offered by the method of on-site fabrication of containment boom structures from sheet material, specifically the ability to deploy several kilometers of containment boom within four to six hours immediately following a contaminant spill, lead to qualitative differences in the way in which such containment booms might be utilized in combatting an actual spill. By way of example, a boom deployment pattern which might be used in the event of a major oil spill is shown in Fig. 5. The initial end of the containment boom 13 has been anchored at point 116 on the oil tanker 39, and the launch 40 has deployed containment boom in a spiral pattern similar to that which was shown in Fig. 1. After deploying a second spiral loop 113, the launch reaches point 216, at which point the containment boom structure is attached to the previous loop 13, and the launch doubles back and deploys arc 213, which is then terminated by attaching the boom structure to the second loop at point 316, then deploying arc 313 to point 416, then arc 413, and so on as required. Substantial quantities of oil 10 have surfaced within the initial loops of containment boom and been carried by the current 43 so as to accumulate in front of and eventually flow under or over the containment booms; these successive zones of escaped oil are indicated by 110, 210, 310, and 410. However, each successive line of containment barrier serves to contain some of the oil and to delay the spread of that oil which it cannot stop. The launch 40 can continue to deploy additional arcs of containment boom as required until the available sheet material is exhausted. Additional quantities of sheet material can be delivered to the launch, and additional launches can be employed, if needed and available.

The objective of such an intensive boom deployment strategy would not be to bring the entire mass of floating contaminant to a "dead stop". As was discussed above, even light currents can cause floating oil to build up in front of containment booms and eventually to flow under them. Rather, the objective is to deploy as many nested loops and arcs of barrier as possible, to establish many thresholds of obstruction, so that the spread of the oil will be delayed at each successive line of boom and the oil will thus be confined to a significantly smaller area during the initial hours of a spill episode than would have been the case had it been allowed to be carried freely by the current and dispersed by wave action. Wherever the oil escapes the existing network of containment booms, another arc of boom would be laid by the deployment launch. In the presence of a current, the entire network of booms would tend to drift, with initially circular deployment patterns eventually distorting into elongated teardrop shapes originating at the leaking tanker or platform.

Such drift and distortion slowly reduce the containment capacity of the boom network, but this reduction can be continually counteracted by deploying additional lengths of boom.

What this containment strategy accomplishes is to "buy time" for heavier equipment such as oil skimming vessels to reach the site, deploy their heavy-duty containment booms, and begin their cleanup operations. Even though the lightweight boom structures which can be fabricated on-site from sheet material may not be sufficiently robust for use in an oil skimming operation, their intensive deployment during the first few hours of a spill may keep the contaminant sufficiently confined so as to contribute substantially to the speed and effectiveness of the skimming operation once it commences.

The mobility of the launch used to deploy the containment boom also allows a different strategy to be employed in the event that a contaminant spill occurs in the vicinity of a geographical area of particular environmental sensitivity, such as coastal wetlands or estuarial waters or other such area. In such a situation, it would be possible for the launch, after deploying, or instead of deploying, lengths of containment boom around the contaminant spill itself, to proceed in the direction of the sensitive area and to deploy one or more lines of containment boom around or in front of said area to provide it additional protection from contamination.

As an extension of this shoreline protection method, according to an alternative embodiment of the invention, sheet material 14 and machinery 16 for fabricating a containment boom structure from that sheet material are installed at a location immediately adjacent to the shore of a bay, harbor, estuary, wildlife refuge, or other shoreline feature before the occurrence of, or are deployed to that location upon the occurrence of, a potentially threatening contaminant spill. If such machinery and sheet material are to be installed in advance of a potential contaminant spill, they may be enclosed in fixed structures on land, or on a pier, or in a floating structure such as a barge positioned at or near the shore of the area to be protected. If such machinery and sheet material are to be deployed upon the occurrence of a contaminant spill, they may be transported to the shoreline location in structures similar to ocean cargo containers or any other appropriate transport containers by means of truck, helicopter, barge, or by any other available transport means, and may be placed upon prepared or unprepared sites on adjacent land, on piers, or on floating structures adjacent to the shore. Fixed or transportable structures which serve to house the sheet material and fabrication machinery pursuant to the subject embodiment are broadly shown at 52 in Fig. 6.

Once such machinery and sheet material are in place and upon the occurrence of a contaminant spill 10 such as from an oil tanker or oil platform or other structure shown at 39 in Fig. 6, continual fabrication of a containment boom structure is commenced. Because a generally linear boom structure deployment pattern is called for in such near-shore cases, rather than the generally encircling deployment patterns required for open-sea containment of floating contaminants discussed above, the launch 40 or a tugboat may in this method be used to pull the boom structure 13 away from the fabrication machinery 16 located at or in the shoreside structure 52 as such boom structure is being fabricated. Protection of areas such as the shoreline 51 or bay 54 against contamination is thus achieved through continual deployment by the launch 40 of the continually fabricated containment boom structure 13. In terms of apparatus, a first structure 52 mounts machinery 16 for continually fabricating the containment boom structure 13 at a shoreline 51, and continual deployment is effected by a moveable second structure 40 for pulling the continually fabricated containment boom structure away from the first structure 52.

A single shoreside boom manufacturing structure 52 and a single launch 40 for pulling the fabricated containment boom structure 13 away from that structure may be employed according to the subject method.

Alternatively, as further shown in Fig. 6, two boom manufacturing structures may be positioned at opposite points across a bay 54, for fabricating two boom structures 13 which are deployed by two launches 40 moving toward each other in opposite directions. The resulting pair of boom structures may be tied together where the launches meet in the middle of the bay to provide a long composite boom across the bay, or a space 57 may be left between the booms to provide increased protection or to facilitate skimming or pumping of floating contaminant.

For containment boom structures fabricated pursuant to such near-shore embodiments of the invention as shown in Fig. 6, the inclusion of reinforcing ropes or lines laminated within or attached to such boom structures and/or the inclusion of gravel or other ballast material heavier than water in their ballast tube 28 may be more feasible than would be the case with open-sea embodiments of the invention.

In this or any other manner within the scope of the invention, it is possible to protect a bay, harbor, estuary, beach, wildlife refuge, or other shoreline feature from contamination. Alternatively, an oil spill or other contamination occurring within a harbor, bay, river, or similarly confined body of water may be prevented from escaping into the ocean or other body of water by one or more containment booms continually manufactured at such location upon the occurrence of such contamination.

Also within the scope of the subject invention, it is anticipated that public agencies charged with the protection of the environment from contaminant spills, as well as owners and operators of tankers, oil platforms, and other facilities, and other parties under contract to these entities, will from time to time conduct exercises and maneuvers to train crews and test systems for the on-site manufacture and deployment of containment boom structures in the manner herein disclosed for the first time. In this respect, it is intended that the expression "contaminant" as herein employed be sufficiently broad to cover not only actual contaminants, but also contaminants supposed to exist for the purpose of practice exercises and maneuvers, and that the expression "upon occurrence" be sufficiently broad to cover occurrences supposed for the purposes of such exercises and maneuvers. Similarly, the expression "at the site of the contaminant" is intended to be sufficiently broad to cover not only the actual site of an oil spill or other contamination, but also the site of contamination supposed to exist for the purpose of exercises and maneuvers, as well as presently unaffected bays, inlets and other environmentally sensitive areas, such as the bay 54 in Fig. 6, which is endangered by a contaminant drifting toward it, or is supposed to be so endangered for the purpose of exercises.

The type of boom deployment strategies described here can only be undertaken if very substantial lengths of containment boom are available for immediate and continual deployment during the early hours of a spill episode. The method of on-site fabrication of containment boom structures from sheet material meets these requirements to a degree not heretofore attained.

Claims

1. A method of containing a contaminant floating on water, comprising in combination the steps of:

providing sheet material at the site of said contaminant for fabrication of a containment boom structure;

continually fabricating a containment boom structure from said sheet material at said site and upon the occurrence of said contaminant floating on water; and

continually deploying said continually fabricated containment boom structure into said water against the spread of said contaminant on said water.

2. A method as in claim 1, including the steps of:

providing machinery for continually fabricating said containment boom structure from said sheet material at said site; and

continually fabricating said containment boom structure with said machinery at said site.

3. A method as in claim 2, including the steps of:

providing a transportable structure for transporting said machinery to said site;

continually fabricating said containment boom structure from said sheet material with said machinery on said transportable structure at said site and upon the occurrence of said contaminant; and

continually deploying said containment boom structure from said transportable structure into said water against the spread of said contaminant.

4. A method as in claim 3, wherein:

said transportable structure is transported upon the occurrence of said contaminant floating on water to a stationary location which is potentially threatened by said contaminant;

said containment boom structure is continually fabricated from said sheet material with said machinery on said transportable structure at said location and upon the occurrence of said contaminant; and

said containment boom structure is continually deployed from said transportable structure into said water against the spread of said contaminant.

5. A method as in claim 2, including the steps of:

storing said machinery in a relatively stationary structure adjacent to a body of water for fabricating said containment boom structure;

continually fabricating said containment boom structure from said sheet material with said machinery on said relatively stationary structure upon the occurrence of said contaminant; and

continually deploying said containment boom structure from said relatively stationary structure into said body of water against the spread of said contaminant.

6. A method as in claim 2, including the steps of:

providing a launch capable of being carried by a oil tanker;

storing said machinery on said launch for fabricating said containment boom structure;

deploying said launch to said site; and

continually fabricating said containment boom structure from said sheet material with said machinery on said launch at the site and upon the occurrence of said contaminant, and continually deploying said containment boom structure from said launch into said water against the spread of said contaminant while said launch is advancing on said water at said site.

7. A method as in claims 2, 3, 4, 5 or 6 wherein:

said machinery is provided with a forming shoulder assembly for forming said sheet material into a tubular structure; and

said sheet material is passed through said forming shoulder assembly at the site of said contaminant to form said sheet material into said tubular structure; and

said containment boom structure is completed at the site of said contaminant from said tubular structure.

8. A method as in claims 2, 3, 4, 5 or 6, wherein:

said machinery is provided with a pair of forming shoulder assemblies for forming said sheet material into tubes; and

said sheet material is passed through said forming shoulder assemblies at the site of said contaminant to form said sheet material into a tubular structure having a first tube for flotation and a second tube for ballast; and

said containment boom structure is completed at the site of said contaminant from said tubular structure.

9. A method as in claims 2, 3, 4, 5, 6, 7 or 8, wherein:

the volume of said containment boom structure continually fabricated from said sheet material with said machinery at the site and upon the occurrence of said contaminant is at least two orders of magnitude larger than the combined volume of said sheet material and machinery.

10. A method as in claims 1, 2, 3, 4, 5, 6, 7 or 8, wherein:

said containment boom structure is loaded with ballast and with gas for flotation in the course of said continual fabricating.

11. A method as in claims 1, 2, 3, 4, 5, 6, 7, 8 or 9, including the steps of:

forming a tubular structure from said sheet material;

continually subdividing said tubular structure into elongate compartments and continually filling said elongate compartments with gas for flotation during said continual fabricating of the containment boom structure.

12. Apparatus for fabricating a containment boom structure for containing a contaminant floating on water, comprising in combination:

means for continually fabricating said containment boom structure from sheet material at the site of said contaminant; and

means for continually deploying said continually fabricated containment boom structure into said water at the site of said contaminant.

13. Apparatus as in claim 12, including:

a first structure at a shoreline for mounting said means for continually fabricating said containment boom structure at said shoreline;

said means for continually deploying said continually fabricated containment boom structure including a moveable second structure for pulling said continually fabricated containment boom structure away from said first structure.

14. Apparatus as in claim 12, including:

a transportable structure;

said means for continually fabricating said containment boom structure at the site of said contaminant and said means for continually deploying said continually fabricated containment boom structure being on said transportable structure.

15. Apparatus as in claim 12, including:

a launch capable of being carried by an oil tanker;

said means for continually fabricating said containment boom structure at the site of said contaminant and said means for continually deploying said continually fabricated containment boom structure being on said launch.

16. Apparatus as in claims 12, 13, 14 or 15, wherein said means for continually fabricating said containment boom structure include:

a forming shoulder assembly;

means for forming said sheet material into a tubular structure by passing said sheet material through said forming shoulder assembly at the site of said contaminant; and

means for completing said containment boom structure at the site of said contaminant from said tubular structure.

17. Apparatus as in claims 12, 13, 14 or 15, wherein said means for continually fabricating said containment boom structure include:

a pair of forming shoulder assemblies;

means for forming said sheet material into a tubular structure having a first tube for flotation and a second tube for ballast by passing said sheet material through said forming shoulder assemblies at the site of said contaminant ; and

means for completing said containment boom structure at the site of said contaminant from said tubular structure.

18. Apparatus as in claims 12, 13, 14, 15, 16 or 17, wherein:

said means for fabricating said containment boom structure include means for loading said containment boom structure with ballast and with gas for flotation in the course of said continual fabricating.

19. Apparatus as in claims 12, 13, 14, 15, 16, 17 or 18, wherein:

the volume of said containment boom structure continually fabricated from said sheet material at the site of said contaminant is at least two orders of magnitude larger than the combined volume of said sheet material and said means for continually fabricating said containment boom structure.

20. A containment boom structure on a body of water at the site of a contaminant, made by a method comprising in combination the steps of:

continually fabricating said containment boom structure from sheet material at the site of said contaminant; and

continually deploying onto said water said containment boom structure as continually fabricated from said sheet material at the site of said contaminant.

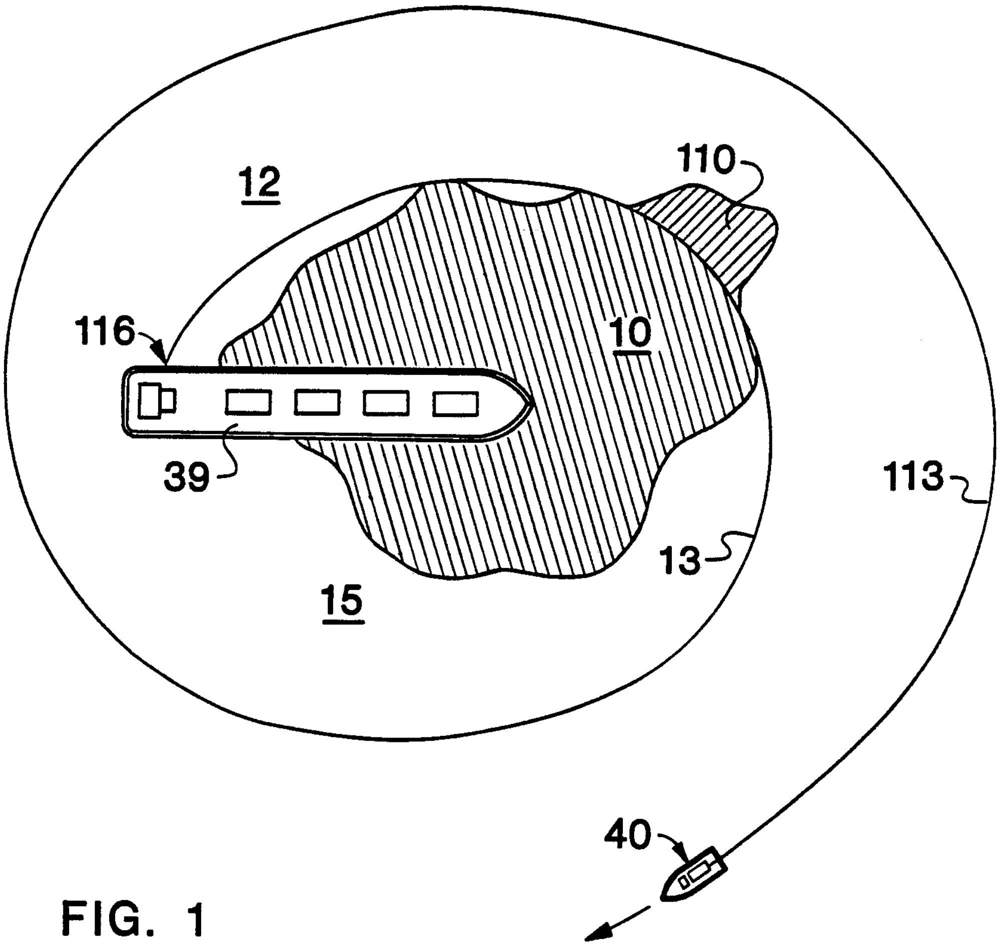


FIG. 1

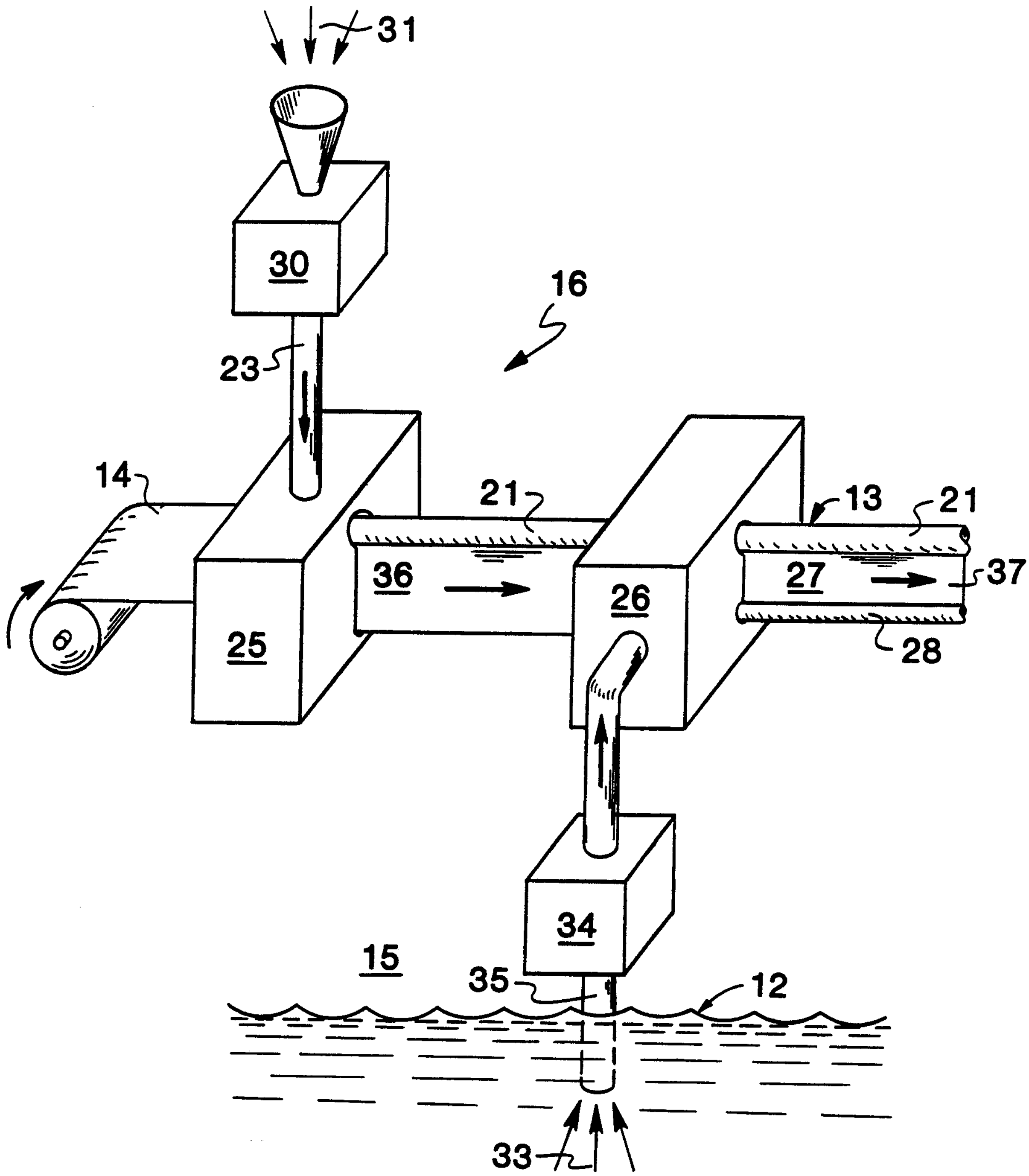


FIG. 2

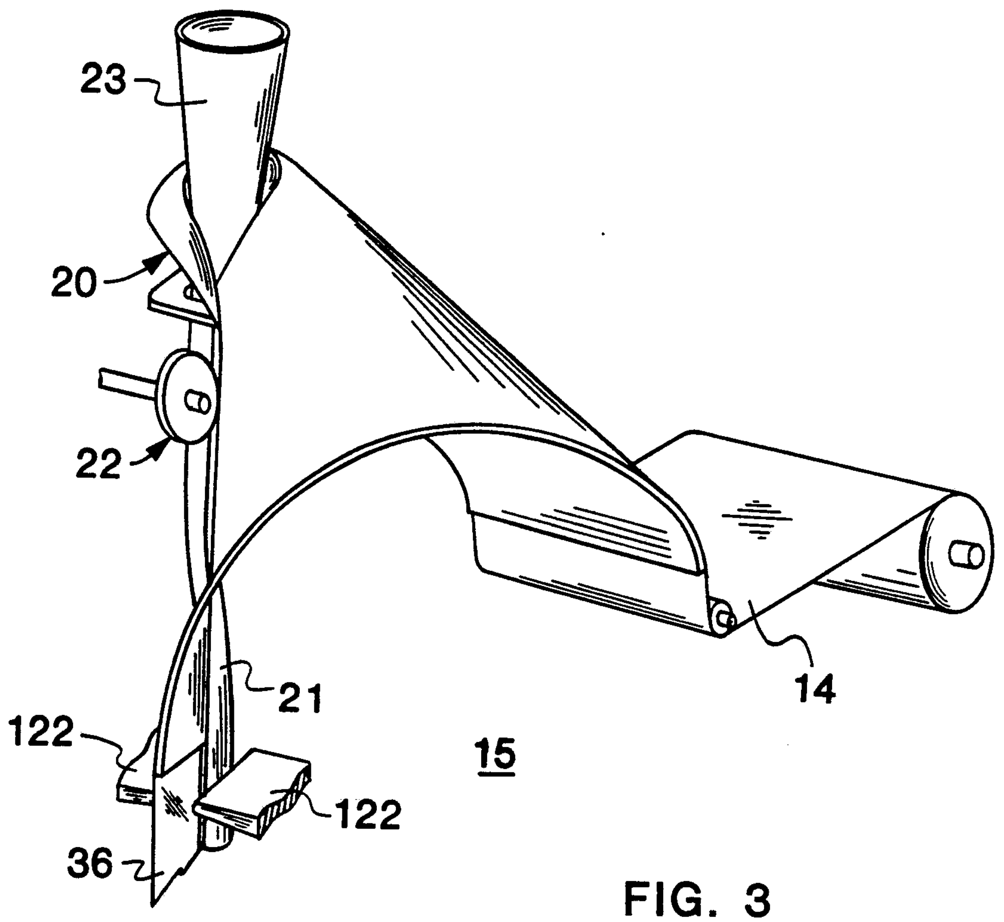


FIG. 3

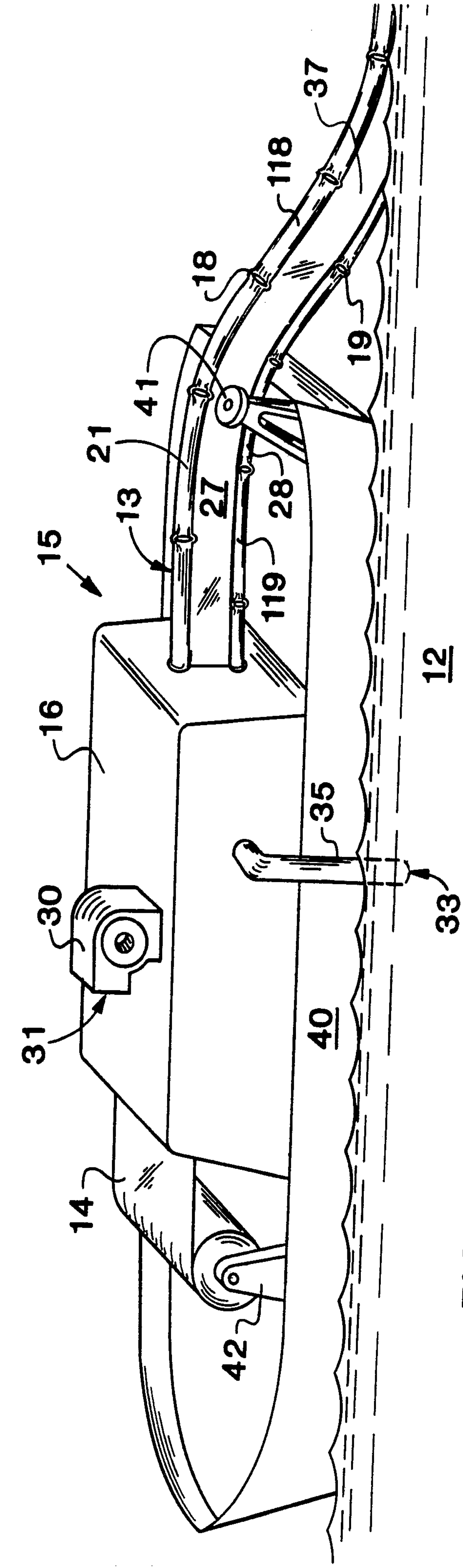
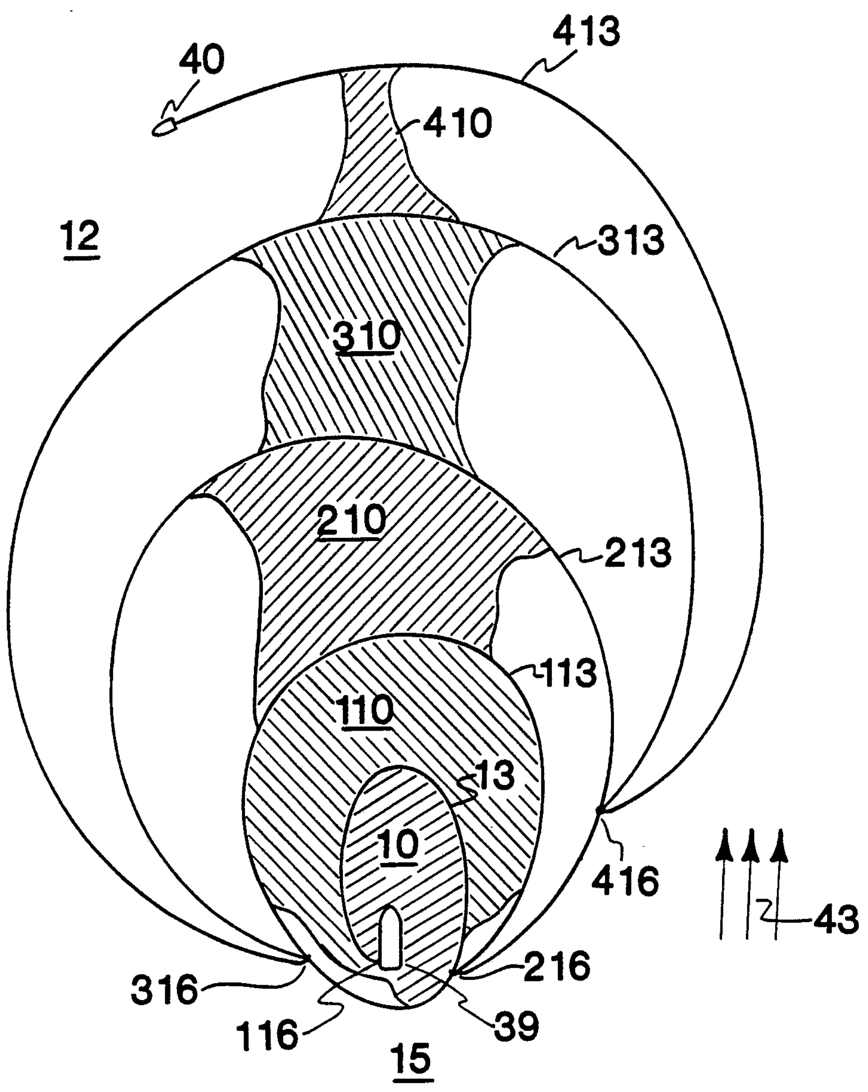


FIG. 4

FIG. 5


413
40
410
12
313
310
210
213
113
110
13
10
416
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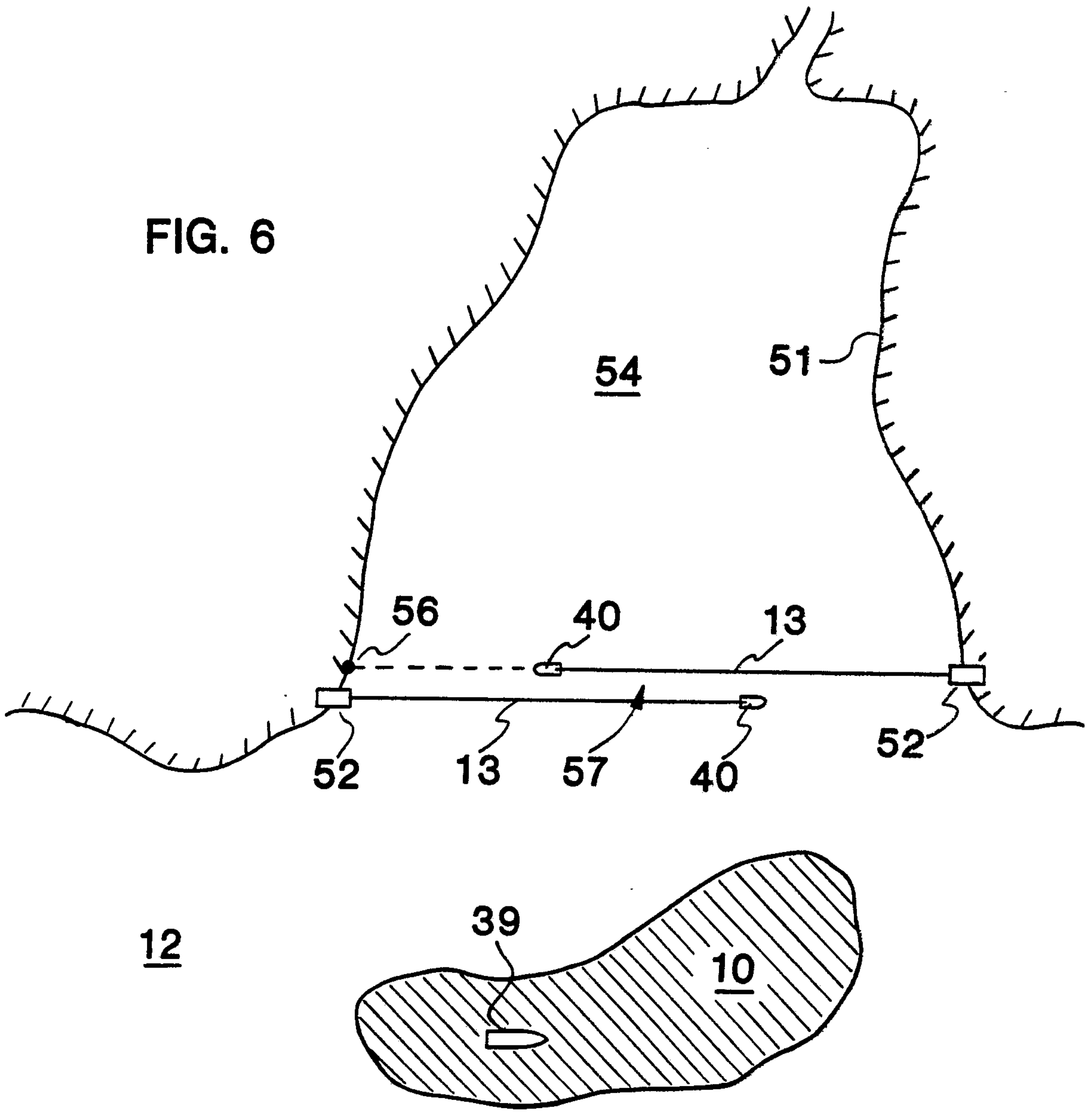
116
39
15

FIG. 6



INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/06958

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): E02B 15/06

U.S. CL.: 405/63,64,65,66,67,68,69,70,71,72

II FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	405/66.68

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A, 3,539,013 (SMITH) 10 November 1970, See Figure 4.	1-8,12-17, and 20
Y	US, A, 3,731,491 (MARKEL ET AL.) 08 May 1973, See column 1, lines 57-65.	1-6,12-15 and 20
X	US, A, 3,807,617 (TANKSLEY) 30 April 1974, See Abstract.	1-6,12-15 and 20
X	DE, A, 2,910,975 (DIETZEL) 09 October 1980, See Abstract.	1-8,12-17 and 20

* Special categories of cited documents: [15]
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
25 FEBRUARY 1991	21 MAR 1991
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	ARLEN L. OLSEN

Form PCT/ISA/210 (second sheet) (May 1986)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☒ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers , because they relate to subject matter [1] not required to be searched by this Authority, namely:

2. ☐ Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [1], specifically:

3. ☒ Claim numbers 9-11, 18, 19, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.