United States Patent [19]

Fish

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[45] **Jan. 22, 1974**

[54] **INFLATABLE DAMS AND DAM UNITS**

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[21] Appl. No.: **266,554**

[52] **U.S. Cl.** **61/30**

[51] **Int. Cl.** **E02b 7/02**

[58] **Field of Search** 61/30, 31, 32, 33, 4, 5, 29, 61/1

[56] **References Cited**

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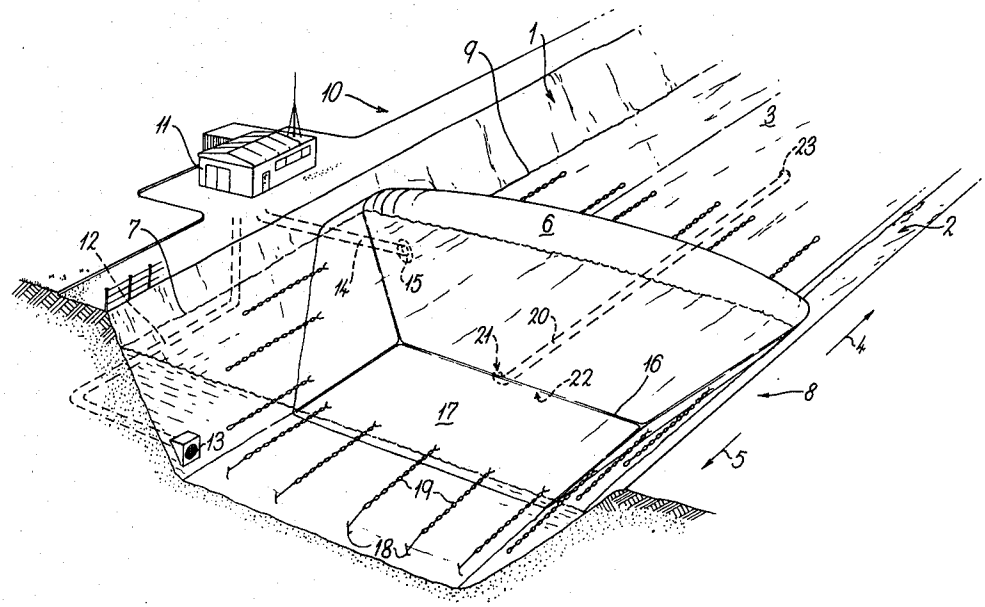
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Assistant Examiner—Philip C. Kannan
Attorney, Agent, or Firm—Gordon W. Daisley

[57] **ABSTRACT**

An inflatable dam unit with means to anchor it to the bed of a water course. These means are in two parts, one which primarily resists bodily movement of the unit downstream and the other which concentrates on resisting the tendency of the unit to roll. The invention also includes dams including such units when installed, and methods of damming water flow.

5 Claims, 5 Drawing Figures



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SHEET 1 OF 4

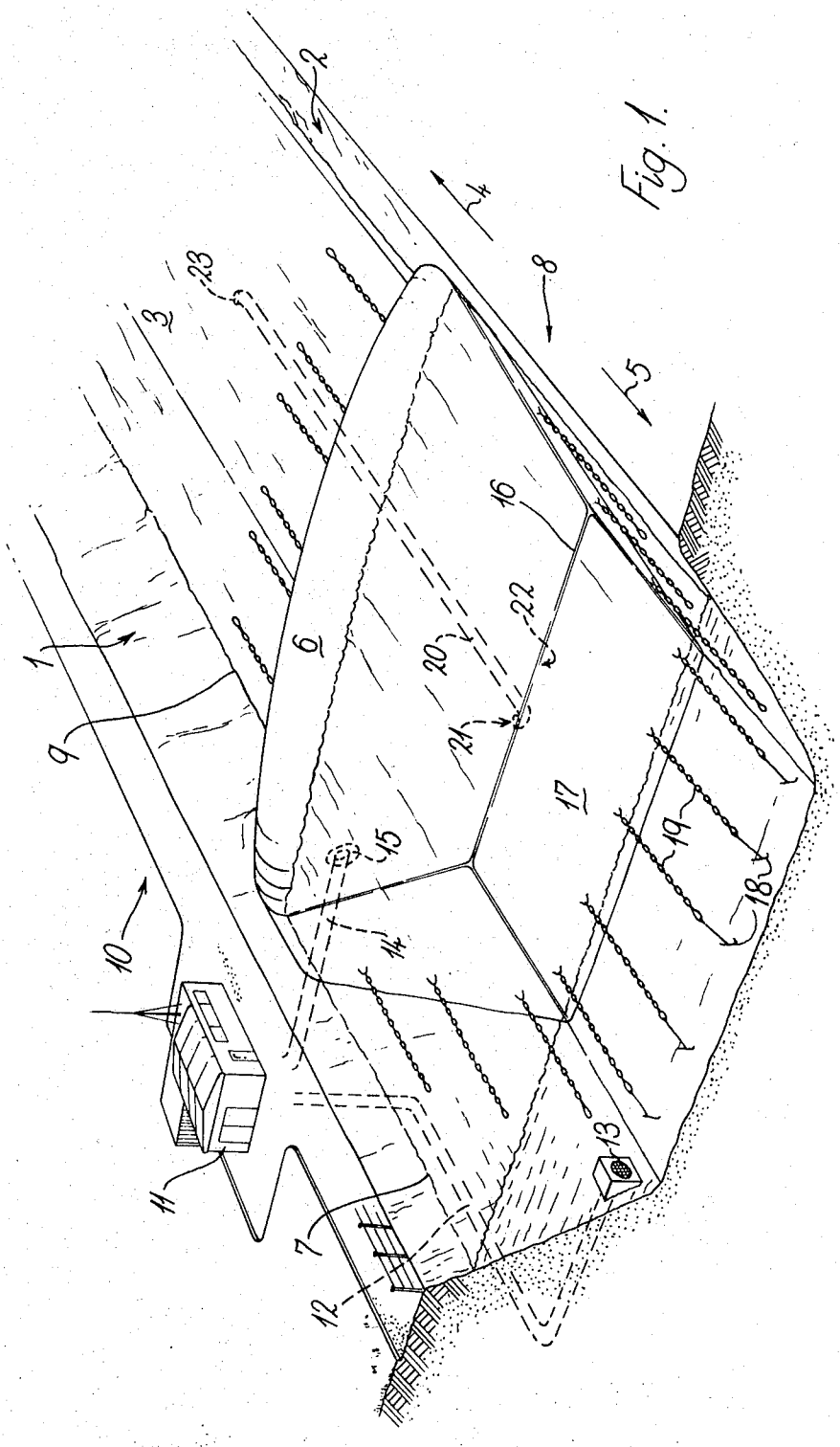


Fig. 1.

Fig. 3.

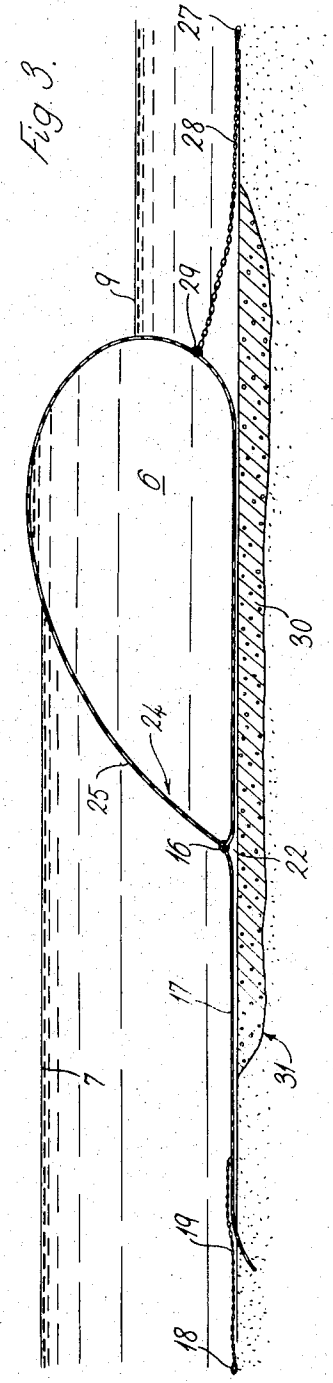
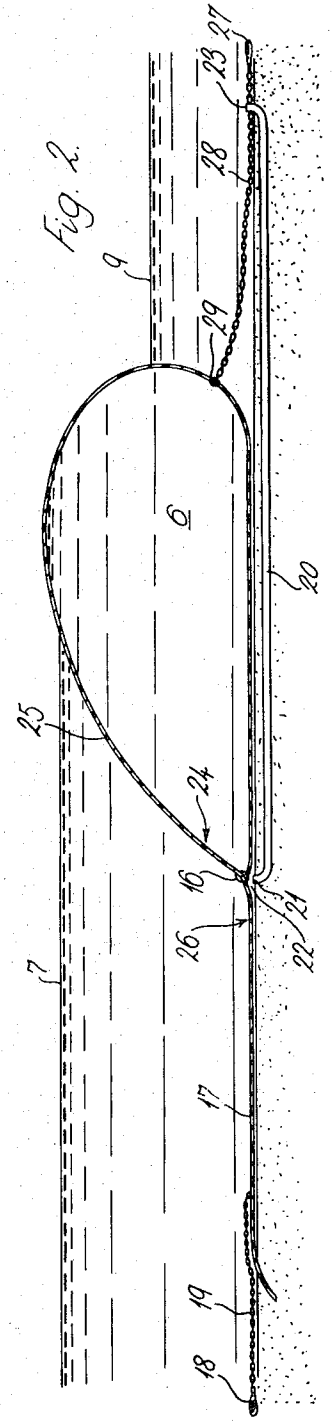

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Fig. 2.


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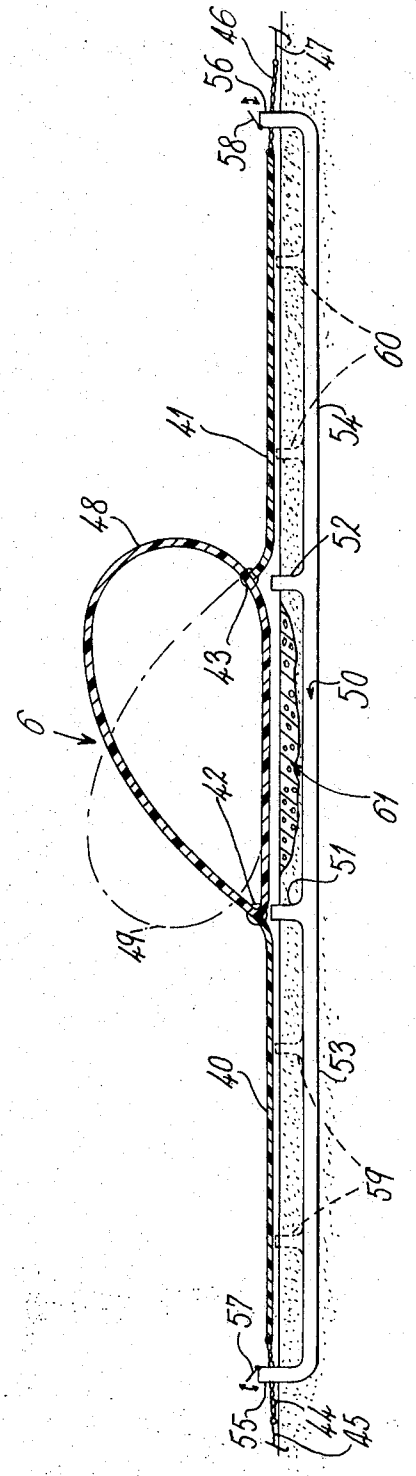


Fig. 4.

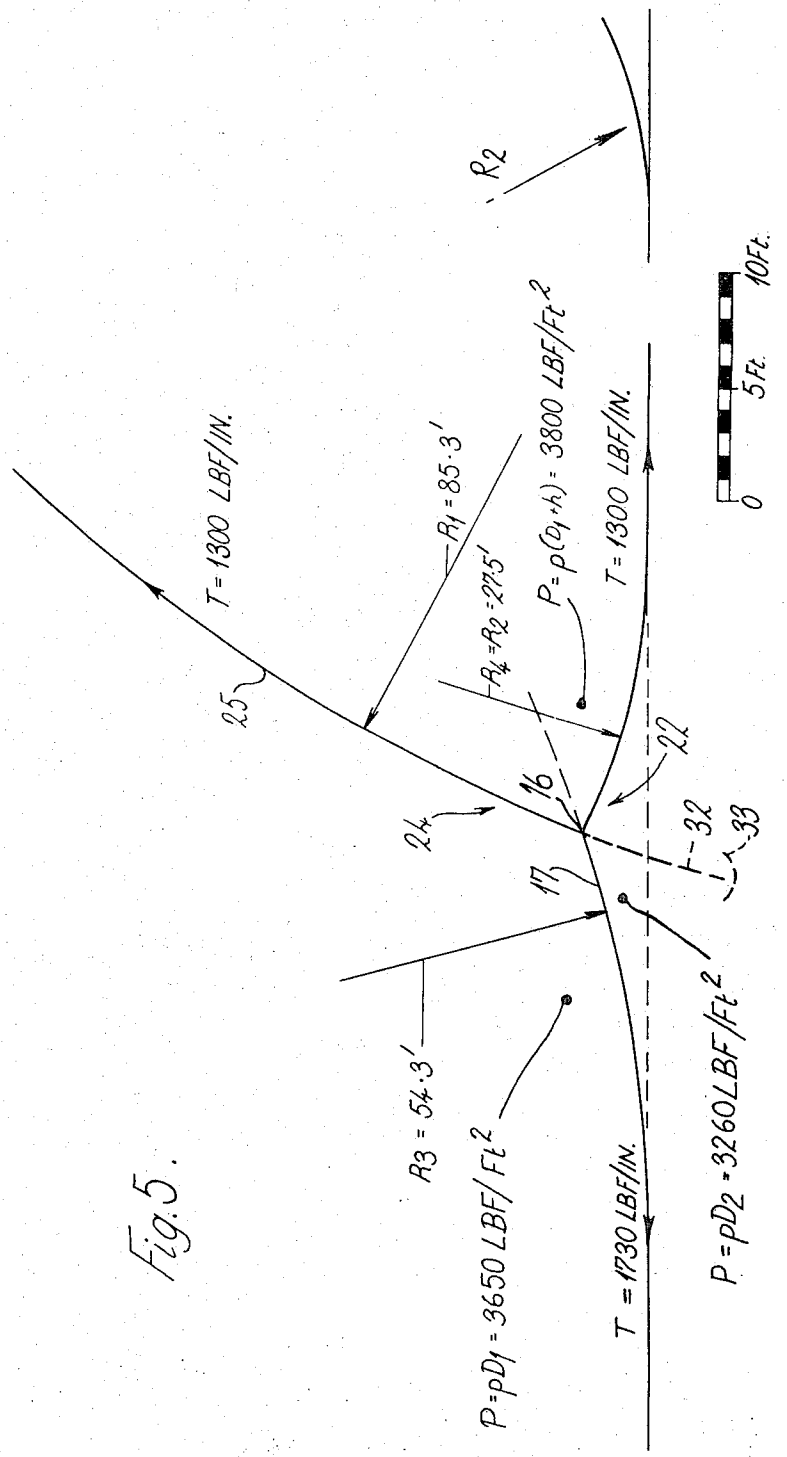

R2
T = 1300 LBF/IN.
R1 = 85.3'
R4 = R2 = 275'
P = p(D1+h) = 3800 LBF/Ft.2
T = 1300 LBF/IN.
0
5Ft.
10Ft.
25
24
16
22
17
32
33
R3 = 54.3'
P = pD1 = 3650 LBF/Ft2
T = 1730 LBF/IN.
P = pD2 = 3260 LBF/Ft2

Fig. 5.

INFLATABLE DAMS AND DAM UNITS

This invention relates to inflatable dam units and to inflatable dams including such units when installed. Dams are usually installed to separate an area where the level of water or other fluid is from another area which is dry or where the level of liquid is much lower. For convenience, such areas will be described in this specification as the upper pool and the lower pool. It will be understood therefore that these terms include not only pools and lakes but also, for instance, the reaches to either side of a dam installed across a river, canal or the like. In particular the invention may find use as a protection against exceptional tidal surges in tidal rivers; normally the dam will lie collapsed on the base of the river, but when a surge threatens the dam will be inflated, i.e., filled with fluid, to separate the "lower pool," i.e., the upstream reach of the river, from the "upper pool," i.e., the tidal reach.

It is well known to make inflatable dam units from water-tight envelopes which normally lie collapsed on the bed of a river or other watercourse, but can be inflated with water to form a watertight barrier. Anchorage of the dam unit to the bed has proved difficult. Such anchorage must hold the collapsed unit down against the bed and must also resist the horizontal force that the flow of the undammed water will exert upon it. When the dam is raised, the anchorage must again hold the unit down and must resist linear horizontal movement due to the considerable horizontal force of the head of water created by the dam. The head of water may also tend to roll the raised dam along the bed of the pools, and the anchorage must resist this type of motion also. It is highly desirable that the anchorage should be provided by the natural bed of the pools, thus avoiding the need for laid foundations of concrete or the like, which are usually costly. The obvious key area of the natural base of the pools for foundations is the area closely adjacent to the collapsible envelope itself.

The present invention results from the realisation that it is important to locate the envelope vertically, relative to the pool base, by an anchorage bearing either directly upon the envelope or very close to it. The part of the anchorage that resists the linear horizontal movement can be much more distant. The invention is defined by the claims and will now be described, by way of example, with reference to the accompanying drawings in which:

FIG. 1 is a perspective view of a dam including an inflatable dam unit installed and in the inflated position;

FIG. 2 is a longitudinal section through the dam unit of FIG. 1;

FIG. 3 is a similar view of a modified dam unit;

FIG. 4 is a similar view of another modified dam unit, and

FIG. 5 is a schematic view illustrating the dimensions and forces to be expected of one proposed installation.

FIG. 1 shows a river watercourse with sloping river banks 1, 2, and a river bed 3. Arrow 4 indicates the direction towards the source of the river, and arrow 5 the direction towards the sea and the mouth of the river. The river is spanned by a dam unit comprising an elongated flexible, watertight envelope 6, according to this invention. The dam is raised, by inflating the envelope with water, to protect the upper reaches of the river from occasional tidal surges. When this happens, as is illustrated in FIGS. 1 to 3, filled envelope 6 becomes a barrier which spans the river from side to side and lies between the high water level 7 of the "upper pool" 8 that forms on the tidal side of the envelope and the low water level 9 that forms in the "lower pool" 10 on the source side. The envelope is inflated from its collapsed state by a pumping station 11 on the river bank 1 which draws water from upper pool 8 through a pipe 12 by way of a filter 13, and discharges it through a pipe 14 to an inlet 15 in envelope 6. Pipe 14 makes a sealed connection with inlet 15.

Envelope 6 is of one-piece construction, the envelope being closed by a single seal along the line of a horizontal three-way joint 16 running lengthwise of the envelope, i.e., transversely of the river. The third surface contributing to the three-way joint 16 is a tension member 17 comprising a sheet of watertight fabric. Anchors 18 of known marine type, for instance the U.K. Admiralty AC 14 type are attached to member 17 by chains 19 and engage with the bed of upper pool 8. Locating structures in the form of several parallel pipes 20, of which only one is shown as an example, are laid on the bed of the upper and lower pools so that their mouths 21 lie in the small triangular-section region 22 immediately under the three-way joint 16, and their opposite ends 23 lie on the bed of the lower pool 10. Because of the difference in height between water levels 7 and 9, the pressure at ends 23 will be less than that which would exist in region 22 if pipes 20 were not there.

This creates a comparative vacuum in region 22, thus creating a downwards force which tends to hold down the trailing edge 24 of the top surface 25 of the envelope 6. This helps to prevent envelope 6 from rolling in the direction of arrow 4, under the influence of the head of water in upper pool 8. It also tends to hold down the leading edge 26 of tension member 17, so enhancing the tendency for the head of water in upper pool 8 to flatten member 17 against the bed of the upper pool, thus excluding water and trapped gases and creating a vacuum joint. The friction created by this joint will offer the major part of the horizontal locating force by which tension member 17 resists horizontal movement of envelope 6 by the excess head of water in upper pool 8, provided the bed is not too slippery. With a firm bed anchors 18 need only offer an extra line of defence in use, but of course they are the only effective anchorage for the upper pool side of the structure when it is collapsed and they may be necessary to supplement the friction of the vacuum joint if the bed is slippery.

Anchors 27, carried on cables 28 attached to envelope 6 at joints 29, lie on the lower pool side of the envelope. They are without significant effect when the envelope is filled, but when it is collapsed and empty they offer the main resistance to the structure being swept downstream by the river.

FIG. 3 shows a modified construction in which a surface layer 30 of the river bed is of filter construction, typically comprising particles of sand, shingle, pebble etc., rising in size as one proceeds through the layer from its bottom surface to its top surface. In such a case the structure of the layer itself becomes the locating structure in place of the pipes 20 already described. The porosity of such a layer may offer communication,

similar to that provided by pipes **20**, between space **22** and the lower pool **10**. The extension **31** of layer **30** under tension member **17** enhances the grip of that member upon the bed of upper pool **8**.

FIG. **5** shows typical tensions and dimensions that may be expected if a collapsible dam according to this invention is set up as an emergency tidal surge barrier in the lower reaches of the river Thames. D_1 represents the depth of water in the upstream pool, D_2 the corresponding depth for the downstream pool, p the density of the water of the river, T various tensions and R_1, R_3 and R_4 the radii of curvature of top surface **25**, tension member **17** and the lower skin of the envelope all close to joint **16**, where indicated by the arrows. Reference h represents the "filling head" within the envelope, i.e., the height which water would reach in an open-ended standpipe mounted at the crest of the envelope. Reference R_2 represents the radius of curvature of the lower skin of the envelope as it leaves the bed of the river at the downstream side of the dam. For such an application, it is considered that a suitable material might be a heavy-woven nylon cloth with a nominal tensile strength of 6,000 lbf/in width in the warp direction, weighing about 75 ozs. per sq. yd. It has also been suggested that this cloth could be sprayed with a rubber coating to a depth of 0.020 inch.

The filter layer construction shown in FIG. **3** might of course be laid for the purpose, or could indeed exist naturally on certain beds. The invention also includes constructions in which the vacuum phenomena illustrated with reference to FIGS. **1** to **3** do not exist, but the method by which the envelope **6** is anchored to the base of upper pool **8** still involves an anchorage in which the principal horizontal and vertical restraints are divided. For instance, tension member **17** could simply comprise cables such as **19**, or could be in the form of a pervious net. In such case anchors **18** would alone provide the resistance to horizontal movement by the head of water in upper pool **8**. Vertical restraint could be provided directly beneath joint **16** by cables **32** and anchors **33**, as indicated diagrammatically by dotted lines in FIG. **5**. It is also possible that the envelope could be filled by gases, e.g. air, rather than liquids, or by a mixture of gas and liquid or even by solid particles capable of flow-like movement.

The dam could easily be made reversible, i.e., capable of holding a head of water in the opposite direction. With certain types of quite firm river bed this could be done by simply attaching an anchor, similar to **33**, at **29**, to resist vertical separation of joint **29** from the bed of the river.

FIG. **4** shows another reversible dam, more suitable if the bed of the pools is more slippery. Here two sheets **40** and **41**, both similar to member **17** already described, are attached to envelope **6** along two three-way joints **42** and **43**. Sheet **40** carries chains **44** with anchors **45** at their ends, and sheet **41** similarly carries chains **46** and anchors **47**. Sheet **40** and its attached securing devices lie on the pool bed to one side of envelope **6**, and sheet **41** and its similar devices lie to the other side. Full lines **48** and broken lines **49** illustrate the shape that envelope **6** takes up if the natural flow through the pools is from left to right, and from right to left, respectively. A pipe **50** is laid on the bed of the pools beneath the dam unit, and has central openings **51, 52** located underneath joints **42, 43** and leading by way of limbs **53** and **54** to end openings **55** and **56**. Opening **55** carries a one-way flap valve **57** and opening **56** a similar valve **58**. When the natural flow is from left to right and envelope **6** takes up outline **48**, valve **57** closes and valve **58** opens. This puts opening **51**, which lies in the region directly beneath joint **42**, in communication with the comparatively low pressure of the waterhead in the right-hand (lower) pool. This ensures firm downward pressure upon the dam unit along joint **42**. A similar effect is obtained when the natural flow is from right to left and when envelope **6** has taken up outline **49** by causing valve **58** to shut and valve **57** to open.

It will be observed in FIG. **4** that end openings **55, 56** of pipe **50** must lie clear of the ends of sheets **40** and **41**, in order of course to be exposed fully to the pressures existing in their respective "pools" and to be able to transmit those pressures to central openings **51** or **52**. It may in practice be very important, even if the bed of the pools is porous to some degree, to ensure by some such means that a specially low pressure is created in the region immediately underneath joints **42, 43**. Without such measures, the pressure in this region may suffer because it is close to bed region **61**, where the main weight of the envelope bears upon the pool bed when in use, tending to expel fluid into neighbouring regions and thus to cause any vacuum in those regions to decay.

It may be noted that the drainage structure comprising pipe **50**, with its various openings, affects pressures in another way also. If the watercourse bed were porous but no such structure were present, then a head of upwardly acting hydraulic pressure within the bed would diminish from a maximum, at the upstream end of the upstream sheet (**40** or **41**), reaching a minimum only at the downstream side of the envelope where the pressure of the lower pool is first encountered. Thus some upward hydraulic head exists under the inflated envelope itself, which is undesirable. By equating the pressure under the upper three-way joint with that in the lower pool, this slight head under the envelope is avoided — the entire length of bed under the envelope is at minimum head. This effect is extended by providing further outlets like **59, 60** in limbs **53, 54** under sheets **40, 41**; the adhesion of these sheets to the bed is thus improved, and this augments the forces of anchors **45, 47** to hold the envelope against linear movement by the stream. It should also be noted that this steepens the gradient of the drop in hydraulic head in the bed between its maximum at the end of sheet **40** or **41** and its minimum which it reaches at the nearest outlet **59** or **60**.

As an alternative to the pipe **50** shown in FIG. **4**, the pool bed could be given a structure having a surface layer similar to **30** (FIG. **3**) which extends to both sides of the envelope, stopping short of the extremity of the sheets **40, 41** on each side. Then whichever way the dam unit is facing, the entire area of the surface layer will be covered. The layer must therefore be connected to a vacuum source whereby the required low pressure may be set up in the layer to exert the necessary downward force upon joint **16** whichever way the dam is facing. The vacuum member within the surface layer should be placed to maximise the desirable effects just described with relation to FIG. **4**.

I claim:

1. An inflatable dam unit comprising an envelope capable of being inflated by fluid to take up an elongated

shape, a tension member joined to the outer wall of the envelope at least at close intervals along a line extending substantially its whole length and operable to exert a locating force upon the envelope, and means adjacent the join between the tension member and the envelope operable to create a region of low pressure close to the join and thereby exert a locating force in a second direction upon the region of the join.

2. An inflatable dam unit according to claim 1 in which the means adjacent the join between the tension member and the envelope comprises a porous layer of particulate material beneath and extending both upstream and downstream of the envelope.

3. An inflatable dam unit comprising an envelope capable of being inflated by fluid to take up an elongated shape, a water-tight tension member having a water-tight join to the outer wall of the envelope at least at close intervals along a line extending along substantially its whole length and operable to exert a locating force in a first direction upon the envelope, and a locating structure adjacent the join between the tension member and the envelope operable to create a pressure differential across the tension member in the region of the join and thereby exert a locating force in a second direction upon the region of the join, the locating structure including a drainage member adapted to create a region of low pressure close to the join.

4. An inflatable dam unit according to claim 3 in which the first and second directions lie substantially at right angles to each other.

5. A dam comprising an upstream and a communicating downstream pool and a dam unit according to claim 3, in which the envelope lies between the pools with its length transverse to the natural flow of fluid between them, in which the locating structure exerts a downward force upon the region of the join to locate it to the bed of the upstream pool, and the tension member is held to the same bed further upstream and exerts a substantially horizontal pull on the envelope in a direction opposite to that of the natural flow between the pools.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,786,638 Dated January 22, 1974

Inventor(s) Daniel Cecil Edward Fish

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

Cover page, item "[76]" should read --[75]--; after item [76], insert --[73] Assignee; National Research Development Corporation, London, England.--; after item [21], insert --[30] Foreign Application Priority Data June 29, 1971 Great Britain 30495/71--.

Signed and sealed this 9th day of July 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,786,638 Dated January 22, 1974

Inventor(s) Daniel Cecil Edward Fish

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

Column 1, line 6, after "is" insert --high--.

Signed and sealed this 3rd day of September 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents