

UNITED STATES PATENT OFFICE

2,645,128

APPARATUS FOR MEASURING WATER PRESSURES IN EARTH EMBANKMENTS

Harold N. Walker, Portland, and John L. Pulli,
Gladstone, Oreg.

Application February 9, 1951, Serial No. 210,269

3 Claims. (Cl. 73-432)

(Granted under Title 35, U. S. Code (1952),
sec. 266)

1

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without payment to us of any royalty thereon.

The present invention provides improved equipment which is adapted to measure pressures, for example pressures set up by water penetrating into porous environments such as earth fills, for an indication of the amount of porosity of such environment, and the water-permeability thereof. For example, as an illustration of the utility of the apparatus of the present invention, it may be employed to particular advantage in the measurement of pressures set up by water penetrating into an earth-fill dam or similar embankments, at various levels for the determination of conditions of porosity and water-permeability, and the existence of conditions related thereto which may be of potential danger unless rectified; and the invention will be described in connection with this particular utility, although it will be understood that the improved apparatus of the invention is not limited to such specific application, which, however, is illustrative of the general utility of the present improved device.

In the construction of earth dams, the materials to be used are selected carefully, the more impervious being placed in the upstream portion of the dam. Clay, with some sand, forms a desirable material. Too much sand results in too high permeability; too little sand may result in the formation of shrinkage cracks, or the lower internal friction within the clay may be such as to permit sliding. Material containing organic matter, humus, tree roots, etc., is not used. The more porous materials are placed in the downstream portion of the structure, and drainpipes sometimes are placed therein to assure drainage and a dry embankment. Materials are placed in earth dams either hydraulically or in layers which are tamped and rolled. Paving sometimes is used on the slopes of earth dams, particularly on the upstream slopes, to prevent erosion, to aid in preventing sliding, and sometimes, in the case of the upstream slope, to give greater imperviousness. Paving on a downstream slope must be well declined to prevent the accumulation of water within the embankment. Riprap, rubble, broken stone, cut-stone blocks, concrete slabs, etc., may be used as paving materials. If it is possible for water to accumulate behind paving on the upstream slope, and the reservoir is subjected to high waves or rapid changes in level, provision is made to permit the rapid escape of water from behind the paving to avoid the bursting pressure otherwise created.

2

A core wall frequently is used in an earth dam to prevent the passage of water through the embankment and as a barrier to the passage of burrowing animals. Materials used for core walls include, usually, clay puddle, concrete and steel. Clay puddle consists of a mixture of clay and sand with water. Such material is not so impervious as the others noted above, but it may serve the purpose and is less costly than any other material. Among materials for core walls, other than clay puddle, concrete is most frequently used. Not only are concrete and steel impervious, but they successfully prevent the passage of burrowing animals through the embankment.

From the above considerations, it will be apparent that it is an important consideration to know accurately the condition of permeability of the dam embankment at various points, for the obtaining of information as to conditions interiorly of the dam. The present invention provides improved equipment for obtaining requisite determinations of such internal conditions in the dam embankment, and the invention has for its principal object the provision of reliable and accurate instrumentalities for obtaining the pressure or level of water in the fills, which instrumentalities are characterized, in addition to their accuracy and reliability, by ruggedness in construction and which have a long life of operative accuracy and reliability. The improved equipment is intended to replace the apparatus customarily employed for this purpose, which apparatus, as customarily employed, use electrical strain gauges which are open to the foregoing objections of short life, unreliability, and excessive delicacy in construction; and the present equipment also is designed to replace conventionally employed diaphragm types of cells which are not sufficiently sensitive to indicate accurately pressure changes in the dam.

The present improved construction will be understood more clearly by reference to the accompanying drawings, in which:

Fig. 1 is a diagrammatic view of an earth-fill dam in which a plurality of units of the present invention are placed at selected strategic locations in the dam for measuring water pressures and levels therein;

Fig. 2 is an enlarged elevational view of one of the improved apparatus systems of this invention;

Fig. 3 is a longitudinal sectional elevation through the cell unit of Fig. 2, the view being on an enlarged scale, to show structural details, the

view being taken on the line III—III of Fig. 2; and

Fig. 4 is an enlarged fragmentary sectional elevation of the top electrical contact of the system shown in Fig. 2.

It will be seen from the accompanying drawings that the present invention comprises a plurality of units, each of which includes a bellows-type pressure cell which is buried in the earth fill, in a proper sand filter and saturated with water. A low voltage wire is soldered to a fixedly-mounted insulated contact screw and led through a copper tube which is secured to the cell, to the surface of the fill. In use, any water pressure at the cell expands the bellows and makes contact between a contact carried by the bellows and a fixed contact on the screw, which closes a circuit which includes a low voltage light and battery, which are connected in series. Gas pressure is introduced to the dry side of the cell through the copper tube. When the opposing pressures in the cell become equal, the contacts in the cell open and the light goes out. A gauge is provided, the reading of which at the instant when the light becomes extinguished indicates the pressure or water head at the cell. It is preferred to use a dehydrated inert gas for producing the balancing-pressure in the cell for eliminating, as much as possible, oxidation or corrosion of parts due to condensation of moisture from compressed air.

Referring more particularly to the drawings, an earth-fill dam is indicated at A, having an upstream zone B of limited water-permeability, a core C which is intended to be water-impervious, a core backing D, which also is intended to be water-impervious, and a downstream zone E, the water-permeability of which is not of great criticality. The upstream zone B may be composed of random gravel, the water-permeability of which may be decreased by a layer of paving G. The core C may be composed of dense clay, which is at least substantially water-impervious, the core backing D may be made of concrete, and the downstream zone E may be composed of random gravel and clay. These materials are to be regarded as being typically representative of an earth-fill dam construction, and not as being limiting, as the materials employed may be varied, and the construction of the dam itself forms no part of the invention which, however, embraces the locating of the improved testing units of the invention in strategic locations throughout the dam construction for determining the amount of water penetration, if any, in the various zones of the dam.

Each of the improved units of the present invention includes a pressure cell 8, which comprises a tubular section 10 which threadedly carries a forward section 12 and a rear reducing section 14, which tapers to a reduced internally threaded coupling end 16. The sections are secured firmly together by solder unions 17, between contiguous surfaces. The pressure cell assembly suitably is made of brass of sufficient thickness to withstand the pressures of the earth in which the cell assemblies are buried.

Threadedly mounted in the forward coupling section 12 is a suitable reticulated filter member 18, composed of bronze or other corrosion-resistant metal; and soldered to the forward end of the section 10 is a corrosion-resistant, corrugated metal bellows 20, secured in place by silver solder 22. By way of illustrative example only, it may be mentioned that the bellows 20 may have ten active corrugations, operating under

pressures up to approximately 315 lbs. total pressure (maximum), each corrugation having a stroke of about 0.00031 inch per square inch of corrugation and each corrugation having a length of about 0.065 inch. These values are illustrative only, as will be understood, and may be varied without departing from the spirit of the invention.

The bellows 20 carries on its inner end a platinum contact 24, which is adapted to engage a complementary contact 26, mounted on a brass contact screw 28 that is carried on an insulating backing 30 mounted in the inner end of the tubular section 10. This backing 30 is provided with a plurality of holes 32 for passing gas against the bellows 20 for counterbalancing expansion thereof, as will be pointed out more particularly hereinafter. The contact screw 28 has connected to it an insulated conducting wire 34 which passes through a pipe 36 to a connecting screw 38, which is insulated as shown at 40, from the side wall of a tubular contact section 42 that is connected to pipe 36 through a suitable T-connector 44, the contact section 42 being closed by insulation 46. A conductor 48 is connected to the screw 38 and leads to a signal light 48 which is energized by a six-volt battery 50 that is connected in series by lead 52 with the light 48 and contact 26 on the screw 28 in the pressure cell 8. The battery 50 is grounded to a pipe 54 through conductor lead 56, the pipe 54 being connected through coupling 58 and valve 60 to the stem of the T-connection 44, the valve 60 being mounted between pipe sections 62 and 64 for controlling flow of gas from a supply thereof through pipe 36 and into the pressure cell 8 for acting on the bellows 20 therein in opposition to the pressure exerted thereon by water entering into the pressure cell through filter 18.

This gas preferably is carbon dioxide which is inert to the parts of the equipment and protects the parts from oxidation and corrosion by forming an inert gaseous environment in the pressure cells 8. Other inert gas, such as nitrogen, for example, could be used for this purpose, but carbon dioxide is preferred because of its greater availability and lower cost. The source of gas preferably and conveniently is a cylinder or bottle of compressed gas indicated at 66, to which is connected a pipe section 68 which is connected through a control valve 70 to a pipe section 72, this latter being connected by an elbow connection 74 to a pipe section 76 that leads to a bleeder valve 78. A pipe section 80 interconnects the pipe section 76 and bleeder valve 78 to the pipe section 54 through a pressure gauge 82.

It will be understood that the system described above is identical for each pressure cell. When the equipment is installed in a dam or the like, as indicated in Fig. 1, as the construction of the dam proceeds, a pressure cell 8 is embedded therein at desired locations, each cell being embedded in a mass of sand 84, which serves as a filter for water seeping through the various portions of the dam structure.

Each of the tubes 36 is threaded into the end of its pressure cell 8 in the end 16 thereof. As the equipment is installed, all of the tubes 36 are brought together and extended up through the fill to the top of the dam, as is indicated on Fig. 1 and each tube is properly identified. The carbon dioxide bottle 66, pressure valve 70, bleeder valve 78, pressure gauge 82, the battery 50 and indicator light 48 are assembled as a portable test unit.

5

6

In operation each of the pressure cells 8 is connected in turn to the portable test unit above described. If water seepage has occurred to any of the pressure cells 8, when the test unit is connected thereto as has been described above, indicator light 48 will glow by virtue of the closing of the contacts 24 and 26 through expansion of the bellows 20 under action of the water pressure. The valve 60 is opened and bleeder valve 78 is closed. The control valve 70 for the gas bottle 66 is opened slowly, which allows gas from the bottle 66 to flow into the pipe 36 and thence into the pressure cell, in which it flows against the bellows 20 in opposition to the water pressure in the bellows. When this gas pressure in the pressure cell counter-balances the water pressure, contacts 24 and 26 separate and the light 48 goes out. The gauge 82 indicates the pressure in the cell at this time. A check can be made by closing valve 70 and slowly opening the valve 78 to bleed out the gas. As the balance point is reached, the light comes on again, and a gauge reading again gives the pressure in the cell. The contact points 24, 26 are adjusted in the cell before it is installed so that contact is first made at atmospheric pressure; then a slight pressure on either side will make or break the circuit.

As will be seen from Fig. 1, the cells 8 are distributed at strategic locations through the dam structure and at various levels, the installations being made as the construction of the dam proceeds. Thus, any seepage in any of the zones or parts of the structure can be detected and measured for determination of proper imperviousness of the various zones against water penetration. Similarly, pressure cells positioned beneath the dam in the foundation thereof will measure the seepage of water into the foundation, and the vertical lifting effect thereof on the dam structure. In the event of any excessive seepage or permeation of the dam structure by water, proper remedial steps therefor may be taken.

The gas employed for the counterbalancing pressure in the cells 8 preferably is carbon dioxide, as has been mentioned above. This carbon dioxide has been freed from entrained moisture as completely as possible and the inertness of the gas with reference to the mechanisms in the cells, coupled with its dehydration, assure that the cells will remain in operative condition for indefinitely long periods of time, so that accurate measurements of pressure conditions in the pressure cells may be made at any selected time interval.

It will be seen from the drawings that the apparatus of this invention includes in each instance a pair of cooperating systems, one of which is the pressure cell, conduit therefrom and the conductor leading through the conduit, the other system being a fully portable system which comprises the supply of compressed fluid (compressed gas), the signal light and source of current, and connecting means for connecting the fluid supply to the conduit from the pressure cell for introducing pressure in the cell in opposition to the liquid pressure therein, and control valves and pressure measuring gauge means for measuring amount of counterbalancing fluid pressure in the cell, the signal light and current source being adapted to be connected in a series circuit with the conductor from the pressure cell, unbalanced pressure conditions in the pressure cell activating the light, and equalizing gas pressure extinguishing the light when the pressure conditions in the

cell become equalized. The signal light and current supply are low-voltage elements, a six-volt light and six-volt current source being very suitable for the present purpose.

Having thus described our invention, what we claim as new and wish to secure by Letters Patent is:

1. In pressure-measuring apparatus for measuring pressures of water seeping into an earth-fill dam through the faces of the dam, a pressure cell including a tubular housing having a forward end and a rear end, a porous, corrosion-resisting filter means mounted in the forward end of the housing and defining a water-permeable closure for the forward end of the housing for preventing entry of water-borne silt into the housing while permitting passage of seeping water into the housing, means dividing the housing interiorly into two compartments, one of the said compartments being a forward compartment for receiving water passing through the filter, the other compartment being a gas-receiving compartment, a corrugated resilient bellows mounted in the housing and having an open end directed towards the liquid-receiving compartment and communicating therewith and also having a closed end extending into the gas-receiving compartment, corrosion-resisting sealing means enclosing the said bellows and peripherally sealing the bellows at its open end to the housing for preventing passage of liquid from the forward liquid-receiving compartment into the rear gas-receiving compartment while permitting expansion of the bellows into the said rear gas-receiving compartment under pressure of water within the bellows and against the closed end thereof, an electrical contact fixedly mounted on the closed end of the bellows exteriorly thereof, a second fixed contact mounted in the gas-receiving compartment for engagement with the contact on the bellows responsively to movement thereof in accordance with expansion of the bellows, insulating mounting means rigidly securing the said fixed contact in aligned position relative to the bellows contact, the said insulating mounting means having gas-admitting openings therethrough, means for admitting an inert, dehydrated gas into the gas-receiving compartment and against the closed end of the bellows for counterbalancing liquid pressure in the bellows for normally retaining the said contacts in open relation, electrical conducting means connected to the fixedly mounted contact, a source of current, means for completing an electrical circuit including the contacts in the housing and source of current whenever liquid pressure within the bellows exceeds opposing gas pressure acting against the bellows in opposition to the liquid pressure for closing the contact on the bellows and the said fixed contacts, signal means in the said electrical circuit actuable responsively to the closing of the said contacts, and soldered sealing means exterior of the housing and enclosing the said housing for preventing access of extraneous materials from the gas-receiving compartment.

2. In pressure-measuring apparatus for measuring water pressures originating from water seeping into earthen embankments, a pressure cell including a tubular corrosion-resisting housing having a forward end and a rear end, a tubular sleeve threadedly mounted on the forward end of the housing, a porous, corrosion-resisting filter mounted in the forward sleeve and being a forwardly projecting closure for the sleeve and housing a second tubular sleeve threadedly mounted

7

on the rear end of the housing and projecting rearwardly thereof, the said forward sleeve defining with the housing a liquid receiving chamber, a corrugated, resilient bellows member mounted in the housing and having an open end communicating with the forward liquid-receiving chamber, the said rearwardly projecting sleeve defining a rear gas-receiving chamber, the said bellows member having a closed end projecting into the said rear gas-receiving chamber, a solder seal enclosing the bellows member adjacent to its open end and joining the bellows member to the housing, the said solder seal being impervious to passage of liquid and gas therethrough and confining liquid and gas to the respective chambers, an electrical contact mounted on the closed end of the bellows member on the exterior surface thereof, a fixed electrical contact mounted in the rear gas-receiving chamber adjacent to the contact on the bellows for engagement therewith responsively to expansion of the bellows responsively to liquid pressure in the bellows causing expansion of the bellows from a retracted position with the said contacts separated, to an expanded position with the contacts closed, insulating mounting means in the rear gas-receiving chamber, means for introducing an inert, dehydrated gas into the gas-receiving chamber in counter-balancing relation with respect to liquid pressure in the forward chamber acting on the bellows to expand the said bellows, the said insulating mounting means having gas passages therethrough, corrosion resisting solder sealing means enclosing the housing and uniting the housing to both the forward and rear chambers in leakproof relation relative to the housing, and current conducting means connected to the contacts for completing an electrical circuit including the pressure cell, a source of electric current, and a signalling device actuatable responsively to closing the contacts when liquid pressure in the forward chamber exceeds counterbalancing gas pressure in the gas-receiving chamber, the porous filter closing the forward end of the liquid-receiving chamber preventing admission of water-borne silt into the liquid-receiving chamber and bellows.

3. In pressure-measuring apparatus for measuring water pressures originating from water seeping into earth fill dams, a pressure cell including a tubular housing having a forward end and a rear end, a porous, corrosion-resisting filter mounted on the forward end of the housing and projecting therefrom for excluding water-borne silt from the housing while permitting passage of water into the housing, means dividing the housing into two compartments, one being a forward compartment, the other being a rear compartment, the forward compartment being a compartment for receiving water passing through the

8

filter, the said filter defining a closure for the forward compartment, the rear compartment being a gas-receiving compartment, a hollow, pressure-expandable contact carrying member mounted in the housing, the said member elongating under pressure of liquid entering the said member in excess of gas pressure in the rear compartment, corrosion-resisting sealing means enclosing the said member and joining the said member in liquid-tight relation to the interior of the housing, the said member being retractable to original position responsively to gas pressure in the rear compartment exceeding water pressure against the said member, an electrical contact mounted on the said member, a second contact fixedly mounted in the rear compartment and engageable by the said contact mounted on the said member responsively to elongation of the said member under water pressure in excess of the gas pressure in the rear compartment, insulating mounting means rigidly spacing the said second contact from the tubular housing and in continuous alignment with the contact on the pressure-elongating member, the insulating mounting means having gas passages therethrough for enabling gas introduced into the rear chamber of the housing to reach the said pressure-elongating member for acting on the said member in a direction counter to water pressure in the said member, means for introducing an inert dehydrated gas under a known constant pressure into the rear chamber for counterbalancing water pressure behind the said member, and electrical circuit means actuated by the said contacts including a source of current, signalling means, and electrical lead means interconnecting the said contacts, source of current and signalling means, the said signalling means being arranged to be actuated responsively to closing the contacts in the cell responsively to water pressure in the cell exceeding the known counterbalancing gas pressure in the cell to cause the said contacts to close.

HAROLD N. WALKER.
JOHN L. PULLI.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
419,924	Catz	Jan. 21, 1890
1,692,513	Newell	Nov. 20, 1928
2,284,707	Wilson	June 2, 1942
2,360,886	Osterberg	Oct. 24, 1944
2,542,905	Cromer et al.	Feb. 20, 1951
2,567,519	Livingston	Sept. 11, 1951

OTHER REFERENCES

Catalog #48 of the American Instrument Co. (copyright 1948), page 192.