United States Patent

[11] 3,633,328

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[54] **PRESSURIZED STORAGE TANK**
8 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **52/224,** 52/169, 52/741
[51] **Int. Cl.** **E04c 3/26**
[50] **Field of Search** 52/224, 169, 741

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ABSTRACT: A prestressed concrete storage reservoir is provided for holding liquified gases. To increase the quantity of ambient gas stored in the reservoir and to permit a warmer than normal liquification temperature, the gas is stored under a substantial pressure. The structure is characterized by a prestressed sidewall system with the roof and floor systems tied together by a plurality of vertically prestressed columns, these combined systems being substantially independent of the sidewall whereby the combined systems may move substantially structurally free of the sidewall.

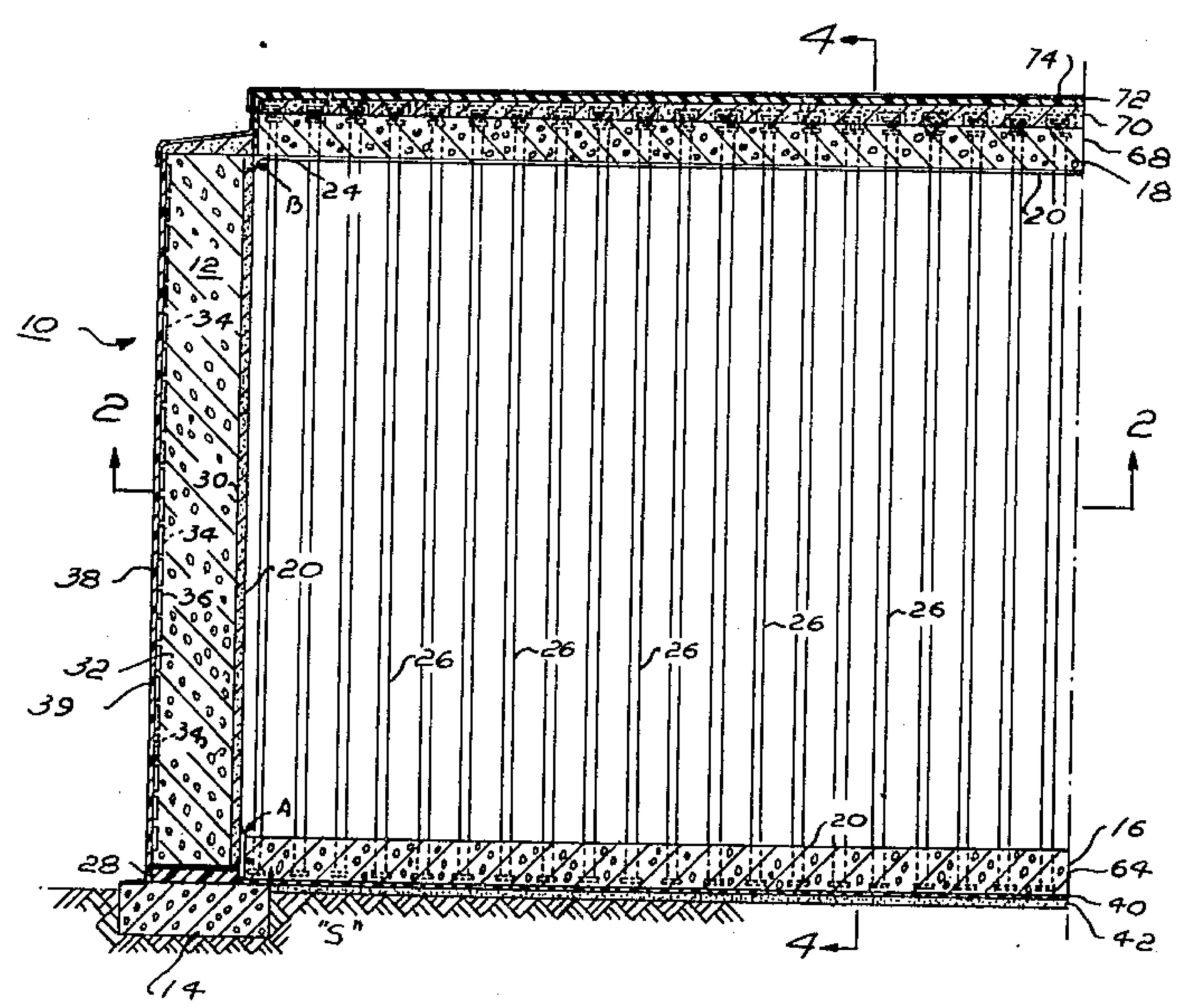

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FIG. 1

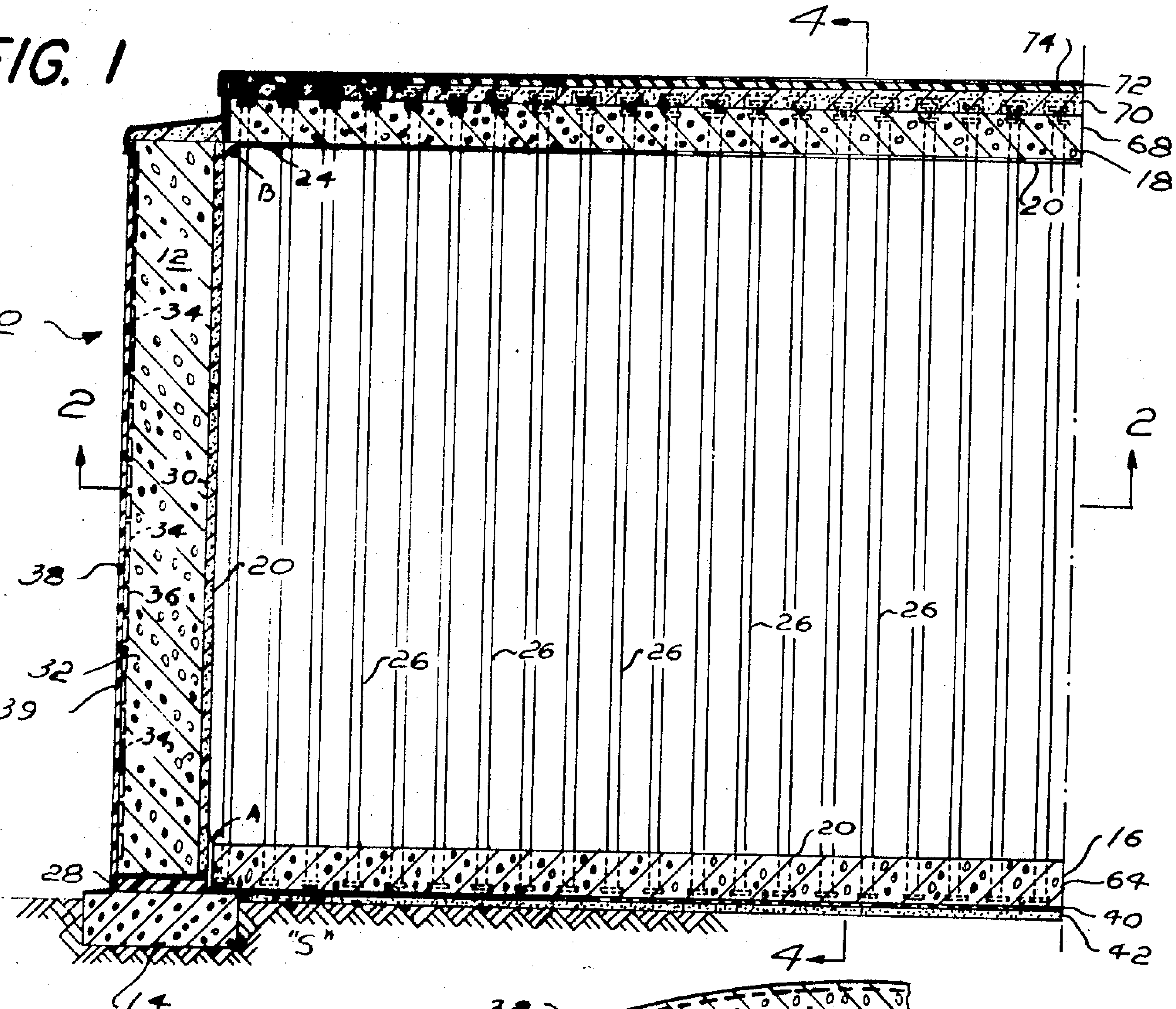

FIG. 2

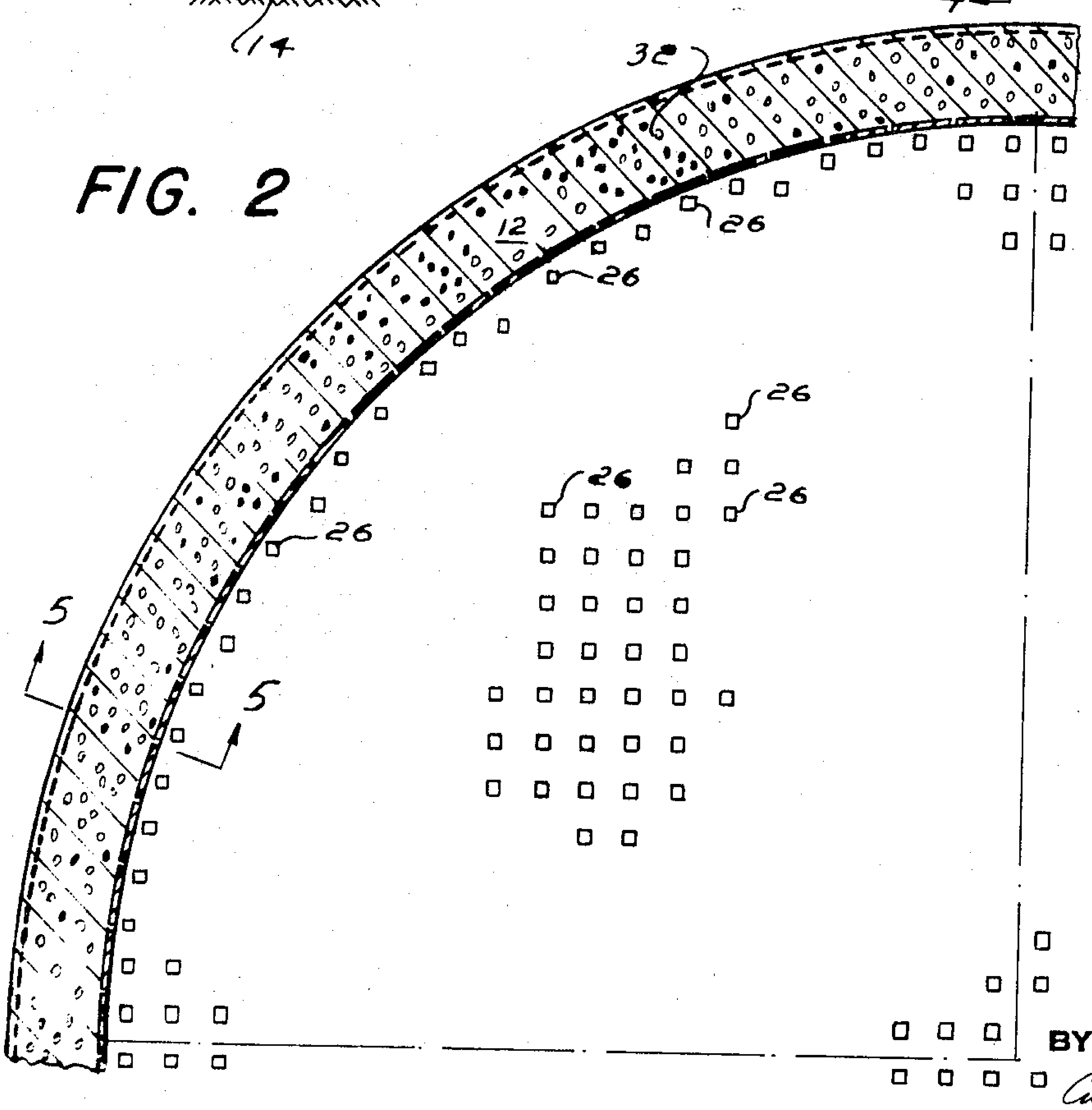

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FIG. 3

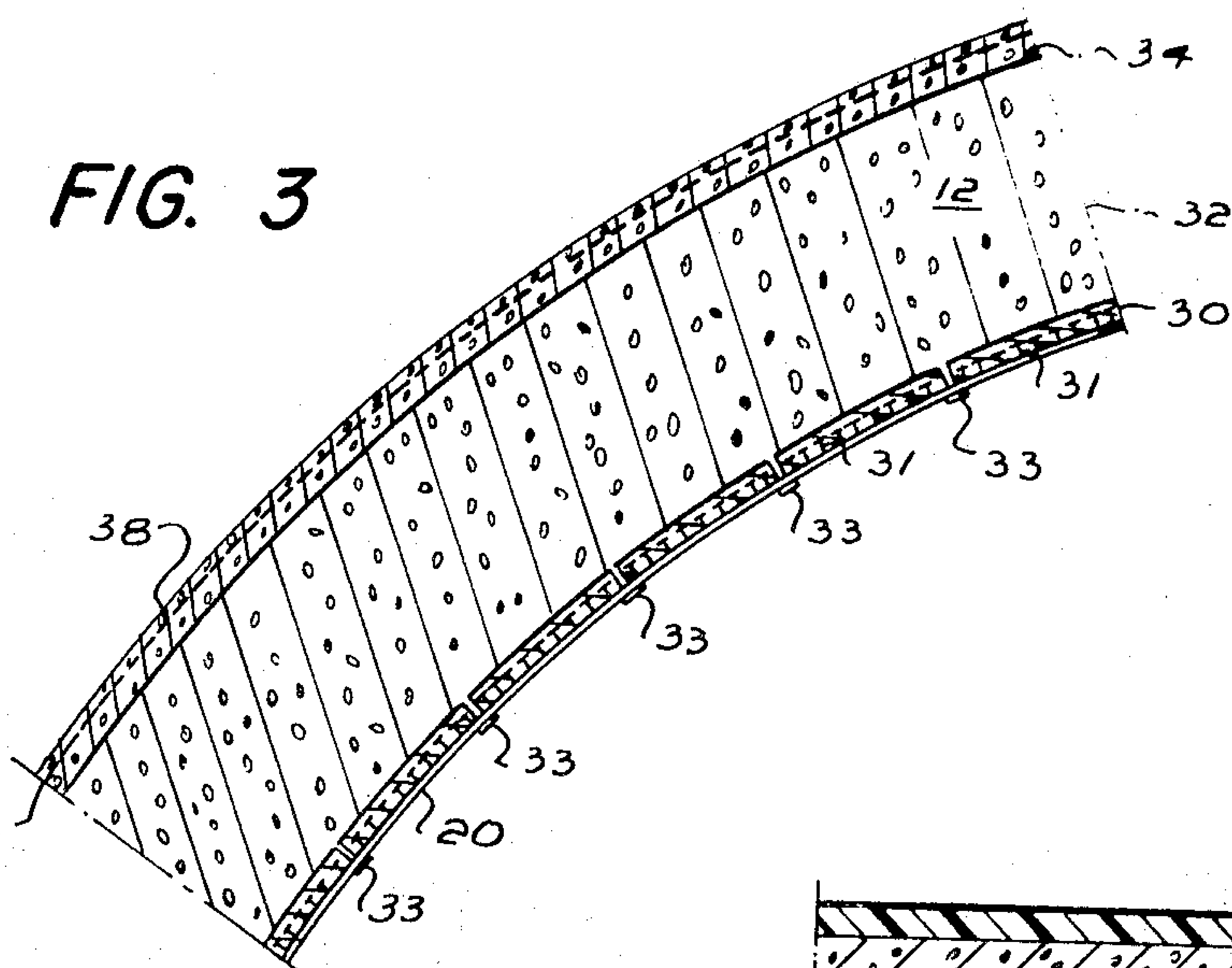
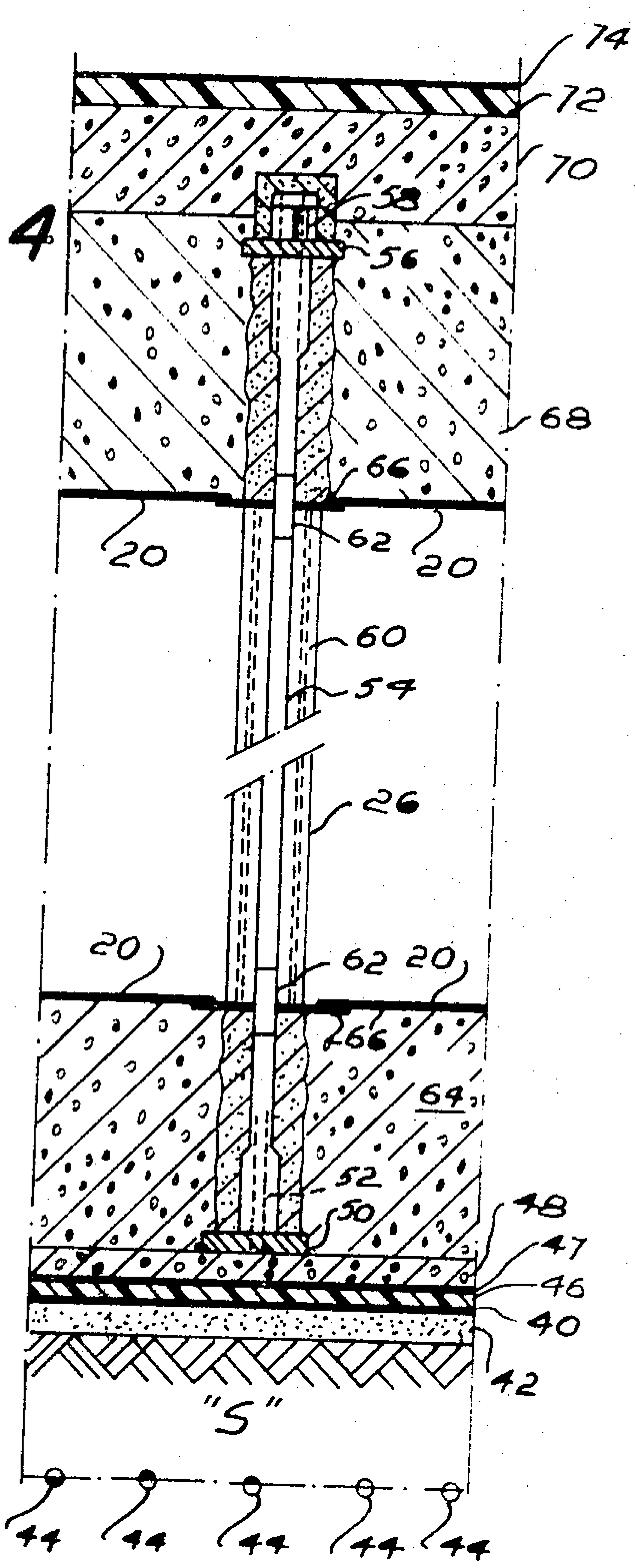


FIG. 4



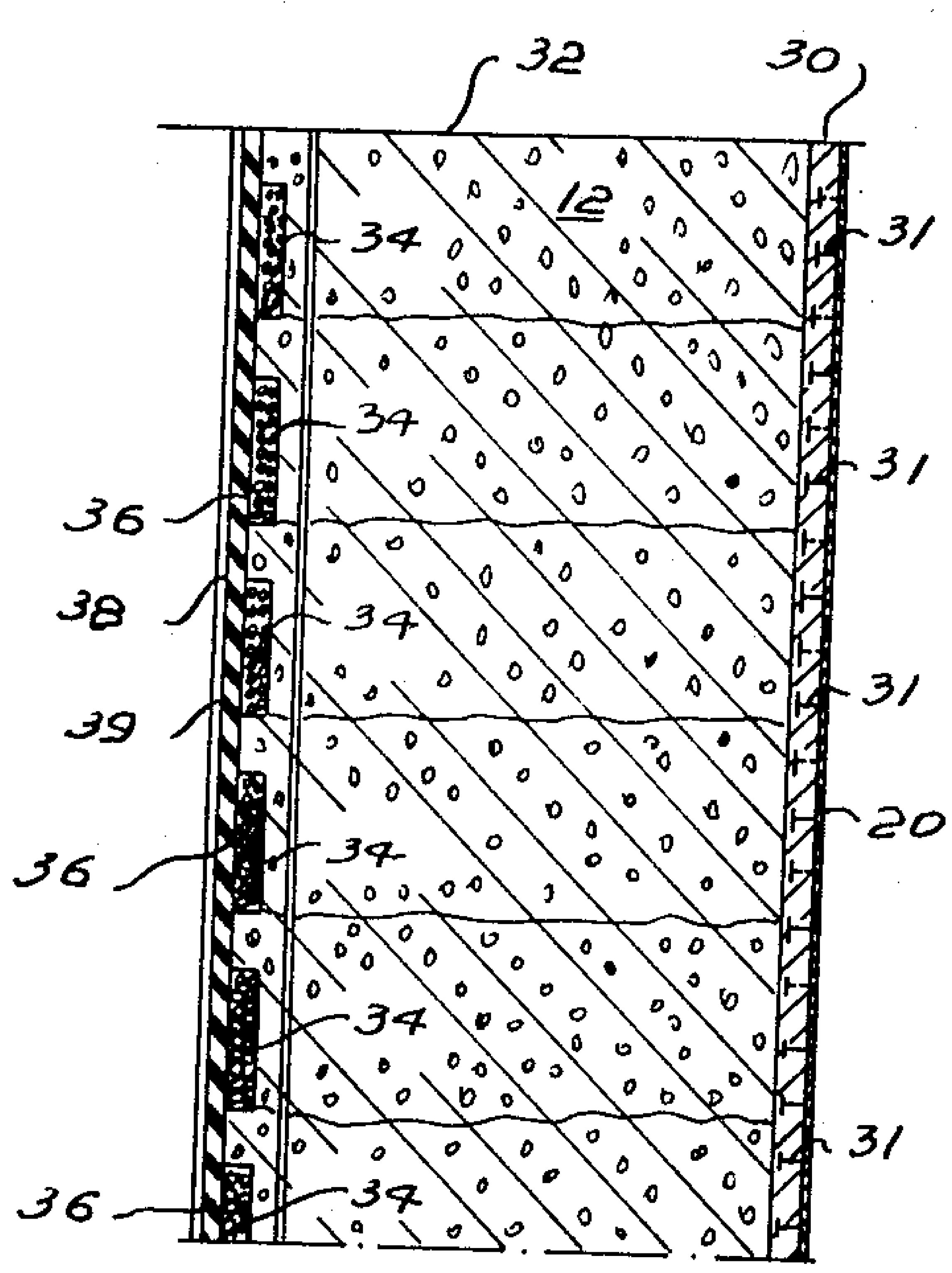


FIG. 5

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FIG. 6

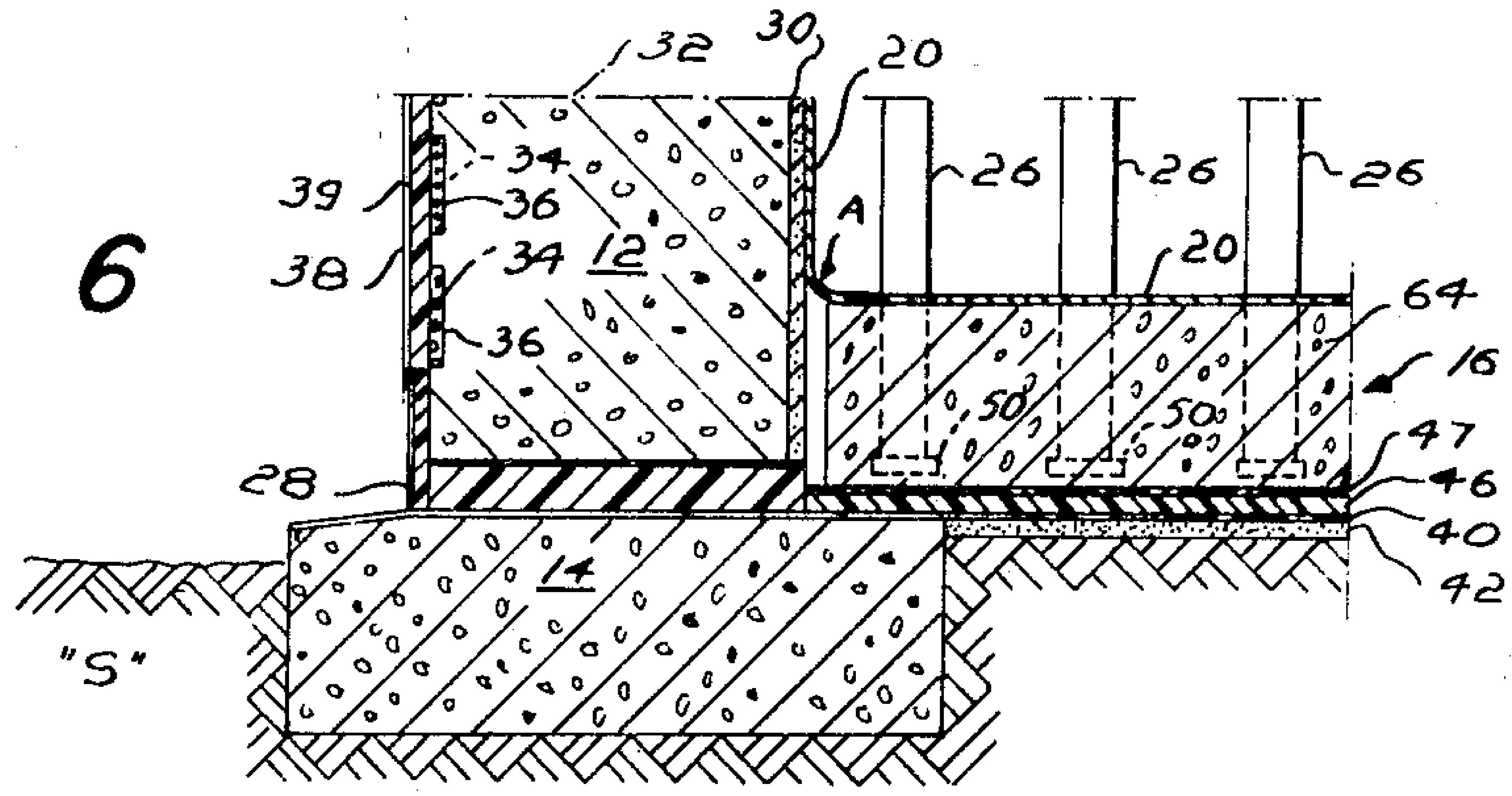


FIG. 7

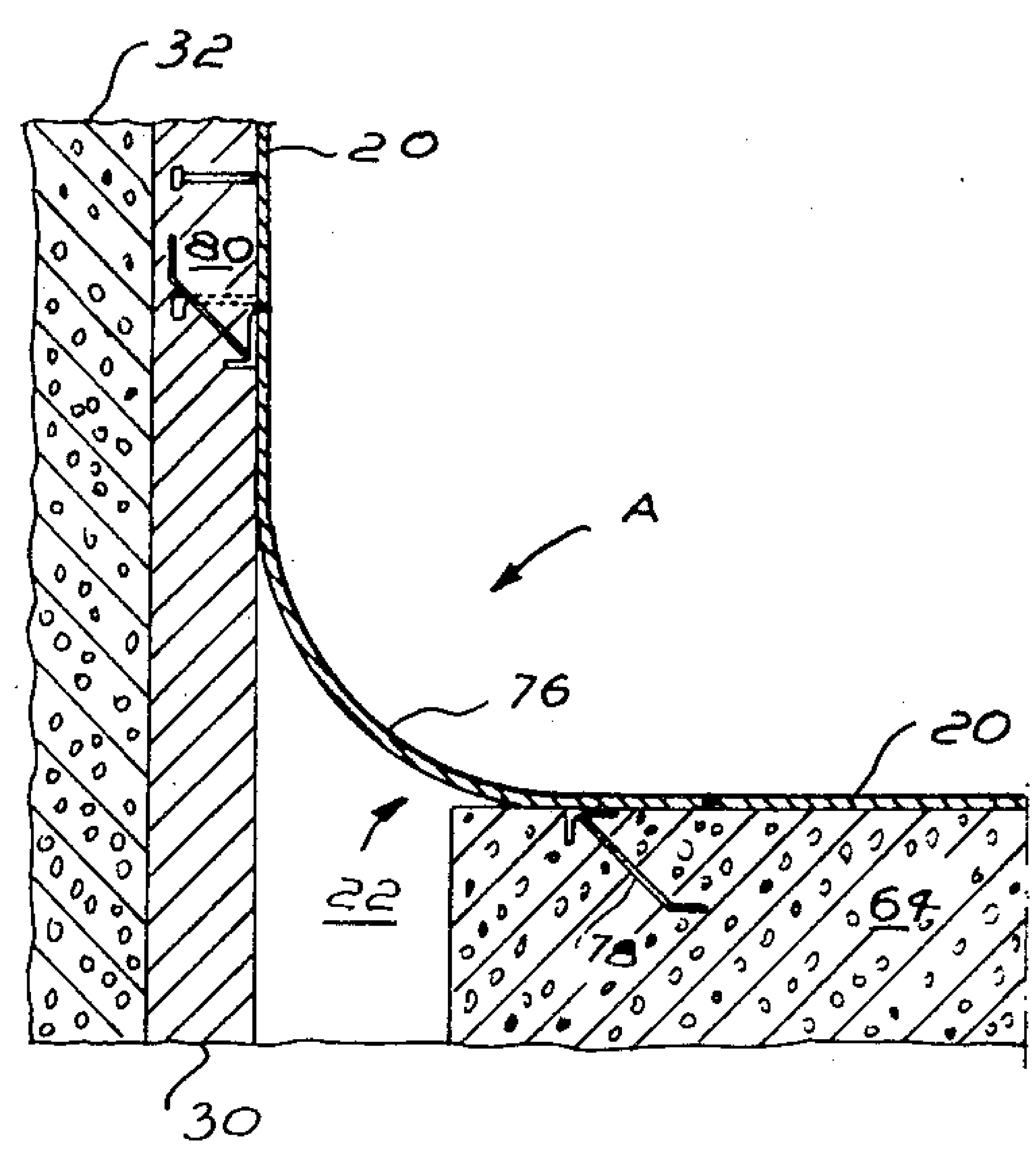
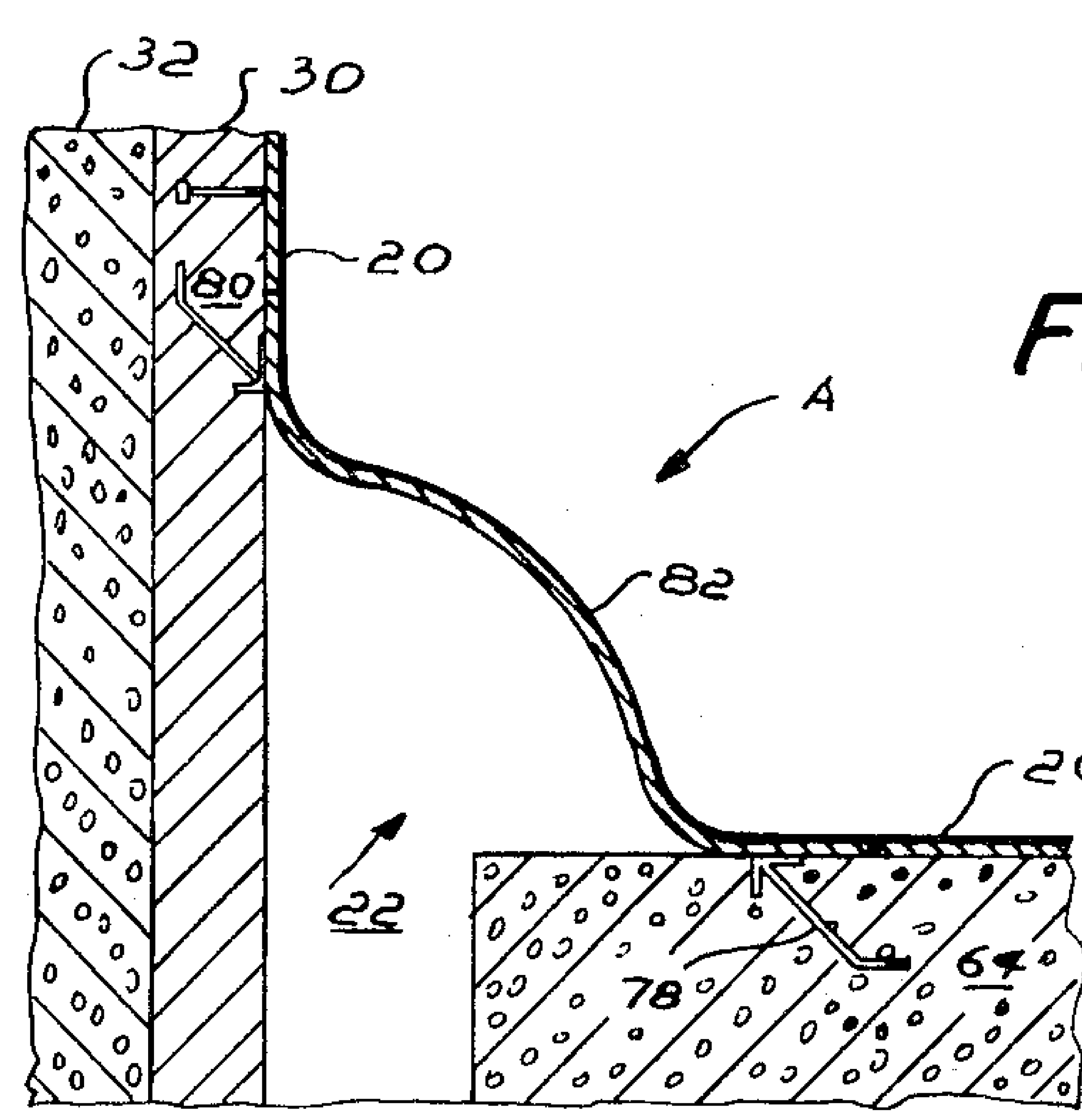


FIG. 7A



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PRESSURIZED STORAGE TANK

BACKGROUND OF THE INVENTION

The present invention relates to the storage of liquified gases under high pressure and more particularly to structures for containing the liquified gases as well as the method of constructing such structures.

Many gases, such as natural gas, oxygen, nitrogen and the like, are economically stored at temperatures far below the usual ambient temperatures so that they may be kept in liquified condition. When these gases are liquified they are in a cryogenic state and are known commonly as cryogenic liquids. Heretofore cryogenic liquids have been stored at about atmospheric pressure but at extremely low temperatures, such as about −260° F. for liquified natural gas. The proper atmospheric pressure storage temperature for different liquified gases varies, but they are well known to those skilled in the art.

In recent years there has been considerable activity to devise means and structures for storing liquified gases. Much of the activity has been concerned with the storage of natural gas. In many places there is a seasonal demand for natural gas for use as a heating fuel and, during the period of great demand, the supply and distribution system from the supply wells is obviously under a very heavy demand load. Also, during the nonheavy demand season the supply and distribution system is normally only partially used. In order to reduce the size of the gas transmission system it has been found feasible to stockpile liquified gases for use during the peak demand time, thus making greater use of the supply system.

Accordingly, there have been recent improvements in storage facilities for such gases. Storage structures which are useful for this purpose are shown and described in U.S. Pat. No. 3,092,933, issued June 11, 1963 and in U.S. Pat. No. 2,777,295, issued Jan. 15, 1957.

As shown in U.S. Pat. No. 3,092,933 prestressed concrete structures may advantageously be used for the storage of cryogenic liquids.

If liquified gas stored at a cryogenic temperature is also processed and stored under substantial pressure, the temperature at which liquification occurs is higher, thus reducing the amount of liquification required. To construct such a reservoir for storing liquified gas at such temperatures and pressure presents many problems. If the concept of using a conventional reinforced concrete reservoir having a thick floor, thick roof and thick walls were used, substantial bending and temperature moment problems would be encountered where the wall connects to the roof and to the floor. The sheer weight and massiveness of the elements needed and the floor contraction difficulties would be enough to make such a construction unfeasible from the viewpoint of economics.

Accordingly, it is an object of the present invention to provide a storage system including a prestressed reservoir with suitable means for resisting the pressure within the reservoir, as well as a method of constructing the same economically.

DETAILED DESCRIPTION

In the specification and the accompanying drawings, an embodiment of the present invention for the storage of pressurized liquified gases is shown. This embodiment is not to be construed as limiting the invention but rather it is for the purpose for informing those skilled in the art so that they may practice the invention in many embodiments and within the spirit and scope of the claims which are set forth hereinafter.

IN THE DRAWINGS

FIG. 1 is a partially fragmentary sectional side view of a cryogenic storage reservoir in accordance with the present invention;

FIG. 2 is a partially fragmentary quarter sectional plan view of the reservoir of FIG. 1 taken along lines 2—2;

FIG. 3 is an enlarged sectional plan view of a portion of the sidewall of the reservoir of FIG. 1;

FIG. 4 is an enlarged partly fragmentary sideview of a prestressed column taken along lines 4—4 of FIG. 1;

FIG. 5 is an enlarged sectional side view of the sidewall taken along lines 5—5 of FIG. 2;

FIG. 6 is a detailed sectional side view of the sidewall and footing construction of the reservoir shown in FIG. 1;

FIG. 7 is a sectional side view of the joint between the sidewall and the floor; and

FIG. 7*a* is a sectional side view of an alternate joint between the sidewall and the floor.

Referring to the drawings, and to FIGS. 1 and 2 in particular, a large cryogenic storage reservoir in the form of a tank 10 is shown. The illustrated tank 10 includes a cylindrical sidewall 12 which is set on a suitable footing or foundation 14. A floor system 16 is provided and it also rests on a peripheral portion of the foundation 14. A roof system 18 is positioned within the sidewall 12.

To insure the liquid and vapor tight integrity of the tank 10, a liner 20 is provided which extends along the inner surfaces of the sidewall 12, the upper surface of the floor system 16 and the under side of the roof system 18. At point A where the liner 20 passes from the floor to the sidewall, expansion joint 22 is provided; and a similar joint 24 is provided at point B where the liner 20 passes from the sidewall to the roof.

The liner 20 is advantageously made of nickel alloy steel since it is exposed to the liquified gas at cryogenic temperatures and must be resistant to brittle fracture. Approximately 8 percent nickel is usually satisfactory.

In order to support the roof system 18 substantially independent of the sidewall 12, a series of prestressed columns 26 are provided and act as internal ties to unify the wall and the floor systems.

A typical tank in accordance with the present invention when acting as a pressurized cryogenic storage structure advantageously may support an internal pressure of about 185 p.s.i. and a temperature of −175° F. as standard operating conditions. Such a tank would have to have substantial overall dimensions and would require an interior diameter of 200 feet and an interior height of about 80 feet to be of sufficient size to permit an economical construction. In order to resist the high internal pressure and low temperature, the sidewall 12 of such structure has an overall thickness of about 10 ½ feet and the supporting ring foundation 14, for a typical soil, a width of 18 feet and a height of about 6 ½ feet. The floor and the roof systems 16 and 18 each would have a thickness of approximately 5 to 6 feet.

It will be noted that the thickness of the roof and floor system is relatively thin when one considers the internal pressure and the diameters and height of the tank. This thin floor and roof construction is made possible by the use of the prestressed tie columns 26 spaced within the tank on centers of about 5 feet so that the floor and roof systems are tied together and are adapted to be moveable substantially independent of the sidewall.

METHOD OF CONSTRUCTION

In order to construct the illustrated tank 10, it is necessary that the soil "S," in which the foundation 14 will be set, be prepared properly and have sufficient strength to support the footing and the accompanying structure. The tank structure may be located where the soil is non-frost-susceptible. A frost-susceptible soil is one in which significant ice segregation will occur when the requisite moisture and freezing conditions exist.

After the soil has been properly prepared, the foundation 14 is set in place by well-known construction methods. The ring foundation 14 is preferably made discontinuous with joints about every 30 feet on the circumference where the tank is to have an inside diameter of about 200 feet. This discontinuous ring foundation advantageously minimizes the radial motion of the foundation during cooldown of the structure.

With the foundation **14** in place, the next step is to provide the sidewall **12**. The sidewall is preferably placed on an insulation and support pad **28** which may be made of any suitable material such as polyvinyl chloride foam. To facilitate construction of the sidewall, a unique stave system is used. The inner portion of the sidewall **12** is formed by using precast, pretensioned vertical staves **30** which are lined on their inner surface with the liner **20**. The vertical staves **30** are supported on the pad **28** and when erected serve as the interior form structure for the remainder of the sidewall **12**.

In the illustrated embodiment the staves **30** consist of pretensioned precast concrets about 6 inches thick with the pretensioning helping to control the vertical thermal stresses in the concrete developed at cryogenic temperatures. The liner **20** which is attached to each stave is about three-sixteenths of an inch thick and made of approximately 8 percent nickel alloy steel, and serves as an inner wall face reinforcement. Anchors **31** attached to the inner surface of the liner **20** are embedded in the stave concrete and assure an integral construction.

The liner portions on the staves **30** are joined together by plates **33** which are welded to adjoining staves.

The remainder of the sidewall **12** is comprised of the concrete core **32** in the outer surface of which are provided a series of recesses **34**. In the recesses **34** prestressing tendons **36** are placed when the sidewall is prestressed after erection. When the tendons **36** have been placed in the recesses **34** by well-known prestressing means and apparatus, the recesses are closed off and the tendons protected by grouting or by other suitable means, such as the injection of grease or the plastic coating of the tendons. A final finish to the sidewall **12** may be provided by use of protective cover **38** made of suitable material such as steel, or polyurethane and the like, under which is a layer of insulation **30**, such as urethane.

As a further precaution, a moisture barrier **41** may be provided in the outer portion of the sidewall **12**. This barrier is substantially coextensive with the sidewall **12** and maybe formed of carbon steel since it is placed in compression by the prestressing tendons, and, therefore, not subject to brittle fracture.

While the sidewall **12** is being erected, and before prestressing if desired, the floor system **16** may also be placed.

The floor system **16** consists of an insulated layer construction which has an outer vapor barrier **40** formed of a mild steel plate about three-sixteenths of an inch thick that is laid directly on a 6 inch layer of an oil-sand base **42**. The oil-sand base **42** is placed on non-frost-susceptible soil similar to that discussed previously in relationship to the foundation **14**. As a precaution to prevent any freezing of the sub-base, heating cables **44** are advantageously provided if the foundation soil is frost-susceptible.

With the vapor barrier plate **40** in position, insulation **46** consisting of urethane foam or foam glass is next positioned. On top of the insulation **46** a layer of plywood **47** is placed. The plywood **47** serves to act as a protection for the insulation and a slab of concrete **48** about 6 inches thick is placed on the plywood and the slab serves as a working platform.

Base plates **50** are set on the working slab **48** and these base plates act to support the internal tie columns **26**.

The tie columns **26** consist of a post-tensioned tendon **56** which is anchored to the baseplate **50**, a gastight conduit **54** for a tendon **52**, a top plate **56**, tensioning means **58** and a reinforced concrete casing **60** surrounding the conduit **54**. The conduit **54** is advantageously made of low-cost carbon steel except for the portions **62** which are adjacent to the liner **20**. The intermediate portions **62** are made preferably from nickel alloy pipe, with approximately an 8 percent nickel content.

With the columns in place, the floor slab **64** may then be placed and the liner **20** placed thereon. If desired, the slab **64** may be placed first leaving space therein for the tie columns **26**.

The liner **20** is joined to the intermediate portions **62** of the conduit **54** by means of splice plates **66** which are welded to the column portions **62** and to the liner **20**.

With the columns in place, the roof system **18** is next constructed. The illustrated roof system **18** consists of a roof slab of reinforced concrete **68** placed on the liner **20**, if desired a lightweight concrete cover slab **70**, a layer of insulation **72** of formed urethane or the like and a roofing coating **74**.

As shown in FIGS. **7** and **7*a*** in particular, an expansion joint **22** is provided at point A between the liner portion **20** overlying the floor and that which is integrally formed with the sidewall **12** and particularly as part of the precast staves **30**. In FIG. 7, a concave expansion joint plate **76** is anchored to the floor system **16** and to the sidewall **12** by anchorages **78** and **80**, respectively. During the cool down of the interior of the tank, the plate **76** is free to deflect as the wall **12** is moved inwardly and the tie columns **26** shorten, thus lowering the roof slab with respect to the wall. During pressurization and operation the tank walls **12** move outwardly and the slab upwardly, thus the plate **76** is free to deflect with these movements.

In FIG. **7*a*** an alternative form or embodiment of the expansion joint **22** is shown. In this embodiment, the plate **82** joining the liner **20** overlying the floor and liner **20** integrally formed is of a convex configuration. The convex plate **82** is anchored by anchorages **78** and **80** in a manner similar to that for holding the concave plate **76** in place. However, the convex arrangement of FIG. **7*a*** has greater strength since a load placed against the plate **82** will have reaction point not only at the anchorages **78** and **80**, but also against the liner **20**.

While the liner **20** has been shown in the illustrated embodiment as indirect contact with the concrete wall staves, floor and roof, it may be desirable to place a layer of insulation between the liner and the concrete in some instances.

What is claimed is:

1. A structure for storing liquified gases maintained at cryogenic temperatures and high pressures comprising a floor, a sidewalls, a roof and tension members connecting the roof and floor together, said sidewall and tension members being made of prestressed reinforced concrete; the floor, roof and tension members connected together to form an integral assembly, said assembly moveable substantially independent of the sidewall.

2. A structure as defined in claim **1** and further including sealing means between the roof and sidewall and the floor and sidewall whereby the tank remains substantially liquidtight under high pressure.

3. A structure as defined in claim **1** wherein the tension members connected to the floor and roof are prestressed concrete columns comprised of prestressing tendons of high-strength steel encased in concrete, said tendons anchored to the floor and roof and tensioned so that the concrete in the columns is in a state of compression when the interior of the structure is not under high pressure.

4. A structure as defined in claim **1** and further including a liner within the structure comprised of a material resistant to brittle fracture.

5. A structure as defined in claim **1** and further including an expansion joint having a convex shape between the sidewall and the floor system.

6. A structure for storing liquified gases maintained at cryogenic temperatures and high pressures comprising a floor system, a sidewall, a roof system and tension members connecting the roof and floor system together, said sidewall including a concrete core having an inner surface with an attached liner of steel resistant to brittle fracture and an outer surface having a plurality of recesses adapted to receive tendons for prestressing said wall and an insulation system thereon, said floor system including a outer vapor and moisture barrier, an insulation layer and a concrete slab, said roof system including a concrete slab, an insulation layer and an outer coating, said tension members comprising high-tensile-strength tendons encased in concrete, said tendons connected to said floor slabs and tensioned to place the encasing concrete in compression, a liner of material resistant to brittle fracture on the inner surfaces of said floor and roof systems and connected to the liner on said sidewall by expansion joints the floor and roof systems connected by said tension members forming an integral assembly substantially independent of the sidewall.

7. A method for constructing a tank for holding liquified gases at cryogenic temperatures and high pressure, and including a foundation, a sidewall, a floor, a roof and tie columns between the floor and roof, comprising the steps of

1. preparing and placing a foundation in the peripheral area of the tank;
2. erecting a prestressed concrete sidewall on said foundation, said wall having a steel liner on the inner surface thereof and being an integral part of the sidewall;
3. placing a floor within the sidewall, said floor having a steel liner therewith and said liner adapted to be joined to the liner on the staves of the sidewall;
4. erecting a plurality of tie columns having post-tensioned tendons therein, said tendons being anchored to the floor and positioned within the boundary formed by the sidewall; and
5. placing a roof, said roof having a steel liner therewith and said liner adapted to be joined to the liner on the staves of the sidewall, said roof joined to the columns;

whereby the assembly of the floor roof and post-tensioned tie columns are adapted to act substantially independent of the sidewall.

8. A method as defined in claim 7 wherein the step of erecting a prestressed concrete sidewall includes erecting precast pretensioned vertical staves having a steel liner on the inner surface thereof said staves being an integral part of the sidewall and acting as the inner form for placing the remainder of the wall before prestressing the composite wall.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,633,328 Dated January 11, 1972

Inventor(s) John J. Closner and Morris Schupack and Eugene Marlowe

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

Column 4, line 38, change "sidewalls" to --sidewall--; and

Column 4, line 75, after "said" insert --roof and--.

Signed and sealed this 25th day of July 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

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