

July 7, 1942.

F. GOODWIN

2,289,188

DRY ICE STORAGE SYSTEM

Filed July 28, 1941

Fig. 1.

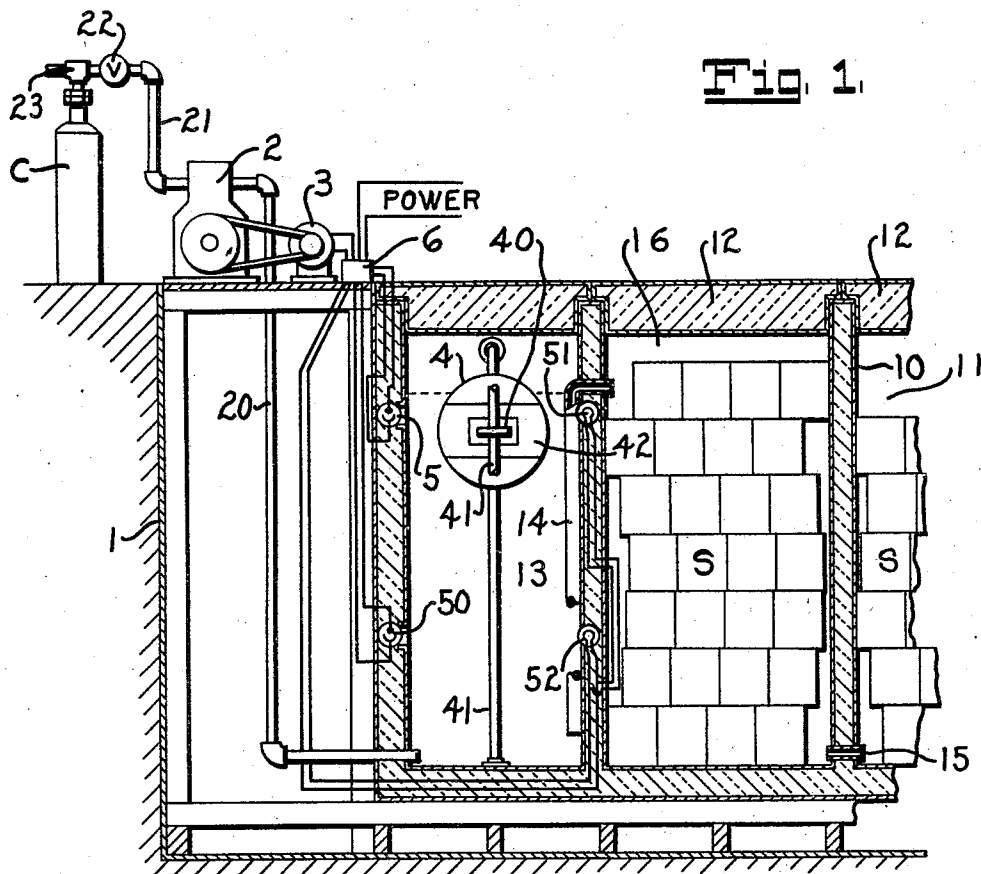


Fig. 2.

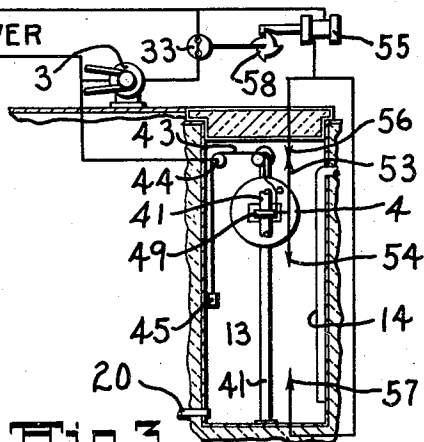
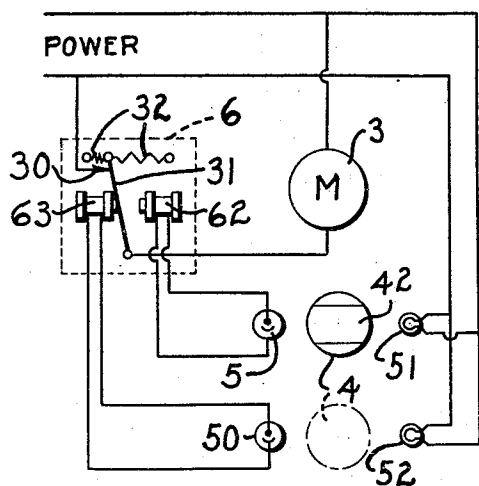


Fig. 3.

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2,289,188

DRY ICE STORAGE SYSTEM

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Application July 28, 1941, Serial No. 404,336

10 Claims. (Cl. 62—91.5)

It is necessary to store solid carbon dioxide, commonly called dry ice, for appreciable periods of time. During storage it sublimates, and it has been the practice to permit such sublimed CO₂ to escape to the atmosphere, since otherwise it would produce a very considerable pressure within the container, and it is not practicable to build such containers or storage receptacles sufficiently strongly to withstand the pressures which may develop.

This, of course, represents an economic loss, and systems have been devised for withdrawing such sublimed gas, and for compressing it into liquid form, since the liquid CO₂ has various commercial uses. The present invention is a system of the latter type, wherein the storage receptacle for the solid carbon dioxide is tight enough to prevent loss of gas, and the sublimed gas, which is heavier than air, and hence collects at the bottom of the receptacle, is periodically withdrawn therefrom and compressed, or otherwise usefully disposed of.

The principal object of the present invention is to provide a receptacle and system of the character indicated, wherein, as controlled by the level of the gas within the receptacle, withdrawal of sublimed gas is automatically initiated and discontinued, respectively.

It is also an object to provide a withdrawal device of the nature generally described above, and for use in such a storage receptacle or plant, which will operate primarily through the rise and fall of a float which is buoyant upon CO₂ gas, but not in air, and which therefore rises and falls with the rise and fall of the level of the heavy CO₂ gas at the bottom of the receptacle.

It is also an object to devise a control system for such an arrangement in which a compressor or equivalent withdrawing means is energized, or is capable of being energized, as a result of the slight forces generated by the rise and fall of such a float.

These and other objects will appear as the description of the invention progresses, and can be better ascertained from a study of the accompanying drawing, wherein the invention is shown in diagrammatic form in two possible embodiments, and of the appended claims.

Figure 1 is a diagram in the nature of a vertical section through such a storage receptacle, illustrating the control means and compressor.

Figure 2 is a simplified electrical diagram, illustrating the control principle incorporated in Figure 1.

Figure 3 is a simplified diagram, similar to Figure 1, showing a modified control system.

The receptacle for dry ice is designated generally by the numeral 1, and it may be subdivided internally by partitions 10 into a number of independent cells, 11, 13, and 16, each capable of containing a number of cakes of the solid dry ice S. A suitable cover 12 may be removably secured in place over each cell, and preferably these are not gas-tight, that is, they will permit escape of air from above the sublimed gas, as the level of the sublimed gas rises, and reentrance of air to replace the gas withdrawn.

The receptacle 1 as a whole, and the several parts thereof, may be suitably insulated, but since the details thereof form no part of this invention, are recognized as necessary, and can be supplied in known manner, they have not been shown in detail, and the insulation shown is merely intended as representative. As one means of accomplishing insulation of the contents the receptacle as a whole may be sunk within the ground, as shown.

One cell of the receptacle, represented by the cell 13, is not filled with the solid carbon dioxide. Such an empty cell, instead of forming part of the receptacle 1, may be located distant therefrom, and be merely connected thereto. However, it is more convenient to form this cell 13 as an integral part of the receptacle 1. It is connected to an adjoining cell 16 by a pipe 14 piercing a partition wall near the top thereof, and preferably extending downward to a point adjacent the bottom of the cell 13. All cells of the receptacle are interconnected for flow of gas from one to the other, and preferably all cells except 13 and 16 are connected at their bottoms, as indicated by the connection at 15. The reason for locating such connections adjacent the bottom of the cells is in order never to produce intermixture of air and CO₂ gas. The air lies above the CO₂ gas, and escapes past the cover 12 as more CO₂ gas collects. All CO₂ gas collecting in any given cell is permitted to escape into other cells by means of the ports 15, and finally when the receptacle is nearly filled with CO₂ gas, this gas spills into the cell 13 by way of the connection 14.

A gas compressor is represented at 2, driven by an electric motor 3. The compressor 2 is intended to typify any suitable system for removing the CO₂ gas for use, for condensing it into liquid form, and for delivering the liquid into a suitable receptacle. The compressor thus is connected by the withdrawal pipe 20 to the cell 13, to

withdraw gas from a point adjacent the bottom of the cell, and the compressor is likewise connected to a discharge pipe 21, and past a cut-off valve 22, to a manifold 23, to which may be connected one or more cylinders C for receiving and containing liquid CO₂. The details of the compression system are diagrammatic and representative only, and any suitable means to this end may be employed, or indeed the withdrawn gas may be otherwise disposed of or conserved.

It is undesirable to permit the compressor 2 to operate continuously. Under some conditions this might withdraw CO₂ from the cell 13 at a rate slower than that at which the latter is filled, and some would be wasted. Since it is commercially desirable to retain the product, to the highest degree possible, in the solid form, and in their original shape, it becomes clear that excessive sublimation is to be avoided. It becomes necessary, therefore, to provide control means for the compressor, or for the motor 3 which drives the compressor, so that the compressor operates only when there is in cell 13 an accumulated supply of gaseous CO₂, and stops when the level of gaseous CO₂ in cell 13 has been lowered to a desired point.

It must be remembered that gaseous CO₂ is heavier than air. While it might be considered that these two gases, if both are present in the same space, will mingle by diffusion, and while this is true to a slight extent, particularly if there is any appreciable turbulence, nevertheless the two gases will remain separate, in the absence of turbulence, to a very appreciable degree, and for considerable periods. There will be a plane of separation between them in the nature of a rather indistinct boundary, one not so sharply defined as the boundary between oil and water, or air and water, but nevertheless a boundary, below which the atmosphere is principally CO₂ gas, and above which the atmosphere is principally air. It therefore becomes possible to provide a float, one which is buoyant upon the heavier CO₂ gas, but which is not buoyant in air, which float will remain in the zone of this boundary, and which will rise and fall as the boundary rises and falls.

Such a float is indicated at 4 within the cell 13. It may be considered as a balloon, filled with a gas sufficiently light to counteract its mass and to maintain its floating upon the surface of the CO₂ gas, yet not affording it so much buoyance as to cause it to rise in the air, but rather to remain at the bottom of the air within the cell. This float or balloon may be conveniently made of Cellophane, and might be filled with hydrogen gas or some other light gas, and it may be suitably counterweighted. The vertical guide clips 40, which are attached to the float 4, may constitute such a counterweight. Preferably the float is guided, as by the rods 41, for vertical movement in a given path within the cell or chamber 13.

Since this float remains always at the boundary between the air in the upper part of the cell and the gaseous carbon dioxide in the bottom thereof, it is possible to employ this float, first, as a means to indicate the level of CO₂ and therefore the amount of sublimation from the solid cakes S, and second, as an automatic control to initiate operation of the compressor to withdraw the excess CO₂ gas from cell 13, and to discontinue operation of the compressor automatically when sufficient gas has been withdrawn.

Various means of accomplishing such auto-

matic operation of the compressor may be employed. In Figures 1 and 2 I have shown such a control actuated by means of photo-electric cells. An upper cell 5 may be normally illuminated by a lamp 51, and a lower cell 50 may be illuminated and energized by a lamp 52. The path of the balloon or float 4 is arranged to interrupt each of these beams, and the particular one which is interrupted depends upon the vertical position of the float, and therefore the level of the gaseous CO₂ within the cell 13. This effect may be advanced, and the action made more decisive, by banding the equator of the float 4 with a dark-colored band, as indicated at 42.

As may be observed best in Figure 2, the cells 5 and 50 are connected by suitable circuit means to a control device, which in Figure 1 is represented at 6. Within this control device is provided a switch in the circuit to the motor 3, consisting, for example, of the fixed contact point 30 and the movable arm 31. Light centering springs 32 tend to retain the switch arm 31 in neutral position except as they are overcome and the arm is pulled into contact with the switch point 30 by a relay 63 in circuit with the cell 50, or is pulled to a switch-open position by the relay 62 in circuit with the cell 5.

It will now be clear that the cell 16 will collect gas flowing from all the other cells 11, and the gas within the cell 16 will overflow into the cell 13. As the CO₂ gas collects in the bottom of the cell 13 the boundary of separation between the CO₂ gas and the air rises, and with it rises the float 4, until the float interrupts the light beam between the source 51 and the cell 5. This de-energizes the relay 62, but since the cell 50 is still energized its relay 63 pulls the switch arm 31 into contact with the switch point 30, and energizes the motor 3. Energization of the motor initiates operation of the compressor, which withdraws gas by way of the pipe 20, to be replaced by inflowing air entering at the top of cell 13, and discharges the CO₂ gas in condensed liquid form by way of the pipe 22 into a suitable receptacle, indicated at C. The level of the CO₂ gas drops, and the float 4 drops with it, but even though the beam from the light source 51 to the cell 5 is reestablished the switch arm 31 remains in contact with the terminal 30. The relay 63 may indeed be a self-holding relay to this end if need be; the showing of Figure 2 is purely representative, and such amplifiers or relays as may be found necessary would be employed. When the float 4 drops to a level to interrupt the beam from the source 52 to the cell 50 the relay 63 is immediately deenergized, and the switch arm 31 is positively pulled away from the fixed terminal 30, breaking the motor circuit. Operation of the compressor thereupon ceases, and is not resumed until, through the gradual process of collection of the gas in the bottom of the cells 11 and 16, and its overflow into cell 13, enough has collected to warrant its withdrawal, which occurs when the float 4 again interrupts the beam between the source 51 and the cell 5.

In the alternative arrangement shown diagrammatically in Figure 3 the float itself is provided with contacts 53 and 54, which are in the circuit of a relay 55. Current is supplied to the contact 53 or 54 through the guide ferrules 49 from a conducting counterweight cord 43, extending over guide pulleys 44 and supporting a counterweight 45. Upon contact of the terminals 53 or 54 with one or the other of the fixed terminals 56 or 57 at top and bottom of the cell

13, respectively, the relay 55 is energized, and a step-by-step mechanism 58 is advanced one step. This mechanism is operatively connected to a switch 33 in the circuit of the motor 3, so that alternate energizations of the relay 55 will initiate operation of the motor, and will deenergize the motor, respectively. The arrangement shown and described is not intended to be practicable, but merely to represent a principle, and any suitable device as designed for the purpose intended may be substituted for that described.

What I claim as my invention is:

1. A storage plant for solid carbon dioxide comprising a suitable receptacle, a compressor connected thereto to withdraw CO₂ gas, a float within said receptacle buoyant upon CO₂ gas but not in air, and hence movable vertically as the level of CO₂ gas rises or falls, and means operatively connected to the compressor, and arranged for automatic actuation when the float reaches a selected upper level to initiate operation of the compressor for withdrawal of CO₂ gas.

2. A storage plant for solid carbon dioxide comprising a suitable receptacle, a compressor connected thereto to withdraw CO₂ gas, a float within said receptacle buoyant upon CO₂ gas but not in air, and hence movable vertically as the level of CO₂ gas rises or falls, and means operatively connected to the compressor, and arranged for automatic actuation when the float reaches a selected upper level to initiate operation of the compressor for withdrawal of CO₂ gas, and also arranged for automatic actuation when the float reaches a selected lower level to discontinue operation of the compressor.

3. A storage plant for solid carbon dioxide comprising a suitable receptacle, a compressor connected thereto to withdraw CO₂ gas, a float within said receptacle buoyant upon CO₂ gas but not in air, and hence movable vertically as the level of CO₂ gas rises or falls, means operatively connected to the compressor, and arranged for automatic actuation when the float reaches a selected upper level to initiate operation of the compressor for withdrawal of CO₂ gas, and further means operatively connected to the compressor, and arranged for automatic actuation when the float reaches a selected lower level to discontinue operation of the compressor.

4. A storage plant for solid carbon dioxide comprising a suitable receptacle, a compressor connected thereto to withdraw CO₂ gas, a float within said receptacle buoyant upon CO₂ gas but not in air, and hence movable vertically as the level of CO₂ gas rises or falls, means operatively connected to the compressor to initiate operation thereof for withdrawal of CO₂ gas, and further means operatively connected to the compressor, and arranged for automatic actuation when the float reaches a selected lower level to discontinue operation of the compressor.

5. A storage plant for solid carbon dioxide comprising a suitable receptacle, a compressor connected to the receptacle to withdraw CO₂ gas, actuating means to initiate and to terminate operation of the compressor, and control means for said actuating means including a float buoyant upon CO₂ gas but not in air, movable vertically within said receptacle as the level of

CO₂ gas therein rises or falls, and means energizable automatically at selected upper and lower limits of the float's movement to appropriately govern said actuating means, and thereby to maintain the CO₂ gas level between such limits.

6. Means to effect the withdrawal of sublimed CO₂ gas from a storage receptacle for solid carbon dioxide, comprising a compressor or the like connected to such receptacle for withdrawal therefrom, a float within the receptacle which is buoyant upon CO₂ gas but not in air, and hence is movable vertically as the level of CO₂ gas rises and falls, and means operatively connected to the compressor, and arranged for automatic actuation when the float reaches a selected upper and a selected lower limit, to automatically initiate and discontinue operation, respectively, of said compressor.

7. Means to effect the withdrawal of sublimed CO₂ gas from a storage receptacle for solid carbon dioxide, comprising a compressor or the like connected to such receptacle for withdrawal therefrom, a float within the receptacle which is buoyant upon CO₂ gas but not in air, and hence is movable vertically as the level of CO₂ gas rises and falls, two circuit means, one at a selected upper limit of movement of the float and the other at a selected lower limit of its movement, both operatively connected to the compressor, said circuit means being respectively energizable by the float as it reaches such limits, and being arranged, the upper one to automatically initiate operation of the compressor and the lower one to automatically discontinue such operation.

8. The combination of claim 7, wherein each of the circuit means includes a photo-sensitive cell and a light source to illuminate the same, and means guiding the float to interrupt the light beam of the respective cells at the corresponding limits of its vertical movement, and means controlled by the respective cells to energize or to deenergize the compressor.

9. The combination of claim 7, including a vertical guide for the float, and wherein each of the circuit means includes a contact disposed respectively at the upper and lower limits of the float's movement, a common contact carried by the float, and included in each of said circuit means, and compressor control means energizable upon contact of the common contact with the upper contact to energize the compressor, and upon contact of the common contact with the lower contact to deenergize the compressor.

10. The combination of claim 7, including a vertical guide for the float, and wherein each of the circuit means includes a contact disposed respectively at the upper and lower limits of the float's movement, a common contact carried by the float, and included in each of said circuit means, a counterweight and supporting cord connected to the float, said cord constituting the electric lead to said common contact, and compressor control means energizable upon contact of the common contact with the upper contact to energize the compressor, and upon contact of the common contact with the lower contact to deenergize the compressor.

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