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[54] METHOD AND APPARATUS FOR STORAGE ATMOSPHERE CONTROL

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[51] Int. Cl. E04h 7/22

[58] Field of Search ..... 98/1.5, 55; 99/235 S

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[57] ABSTRACT

A storage unit having a gas generator connected to a generally sealed storage structure for supplying a controlled atmosphere gas to the structure. The generator is controlled by initiating generator operation when the storage structure pressure declines to a predetermined differential with the ambient, and by terminating generator operation when pressure in the storage structure builds to a second predetermined differential above the value of the first. A set of pressure switches in communication with storage pressure detect the predetermined differentials and start and stop the generator through an interlocking switching circuit connecting the switches to a generator control. The interlocking switching circuit includes a timer which precludes the pressure switches from frequent starting and stopping of the generator.

8 Claims, 4 Drawing Figures

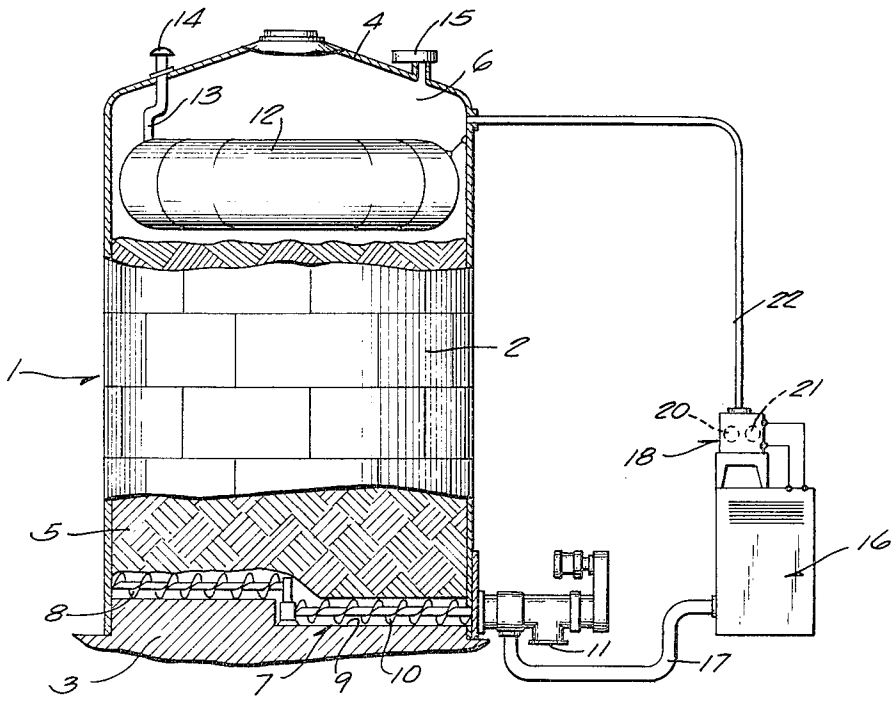


Fig. 1

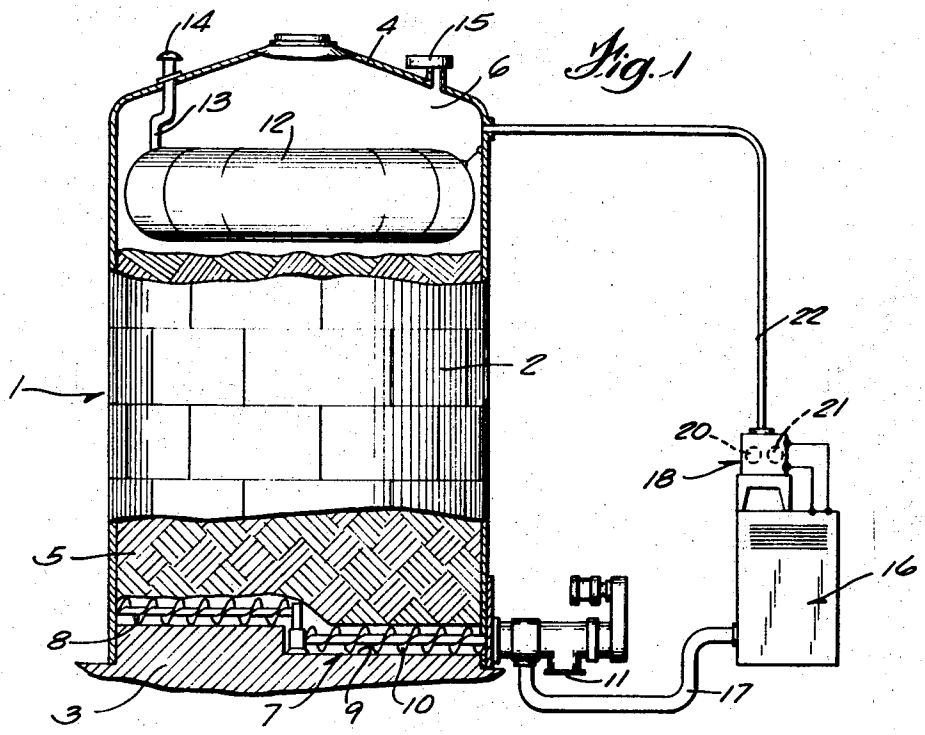


Fig. 2

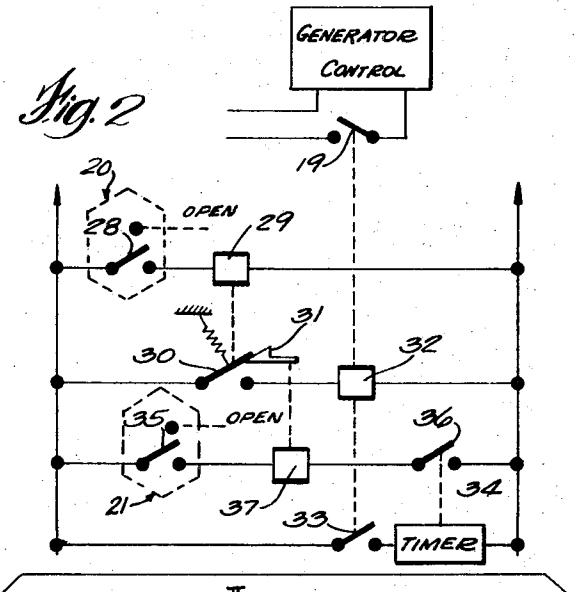


Fig. 3

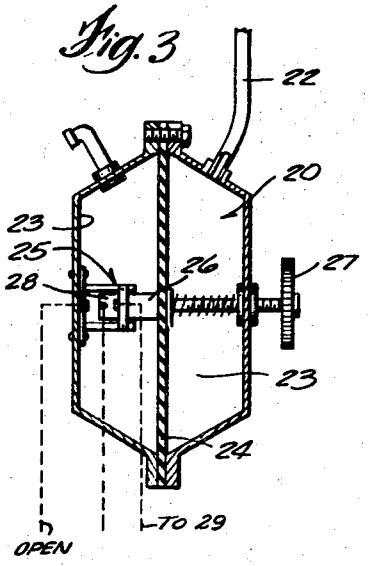
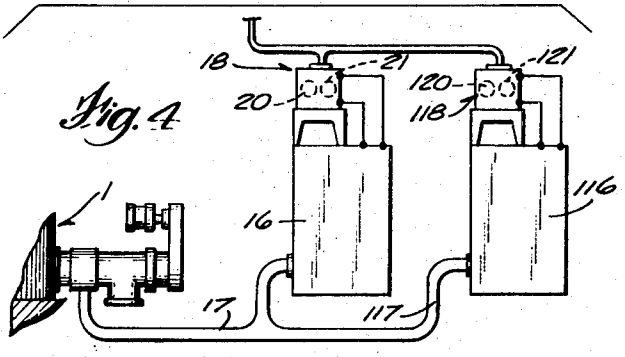


Fig. 4



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METHOD AND APPARATUS FOR STORAGE ATMOSPHERE CONTROL

BACKGROUND OF THE INVENTION

The invention relates to storage units and more particularly to an atmosphere control system for generally sealed storage structures.

Storage structures, such as silos or grain bins, are often sealed to minimize contact between ambient are and the stored material, which may be subject to spoilage due to reactions with oxygen in the air. Although sealed, such structures still permit some oxygen to contact the stored material. This is due in large part to pressure differentials occuring across the structure walls, which cause ingress of ambient air through leaks, or which permit air infiltration when the structure is opened as for unloading operations.

Further, sealed structures often have breather systems which permit ingress or egress of gas in order to equalize pressure differentials. The breather system can be constructed to minimize air entry, as for example by the use of a breather bag which is open to the ambient and expands or contracts within the structure to equalize the pressure differentials. However, a relief valve is often employed on the storage structure to permit ingress or egress of gas to or from the structure when large differentials are experienced. In the operation of these relief valves, the atmosphere within a silo or bin can at times contain more oxygen than desired.

U.S. Pat. application, Ser. No. 836,063, filed on June 24, 1969, and copending with this application, discloses a gas generator system which provides atmosphere control for storage structures. The system of that patent application can be used to supply an inert gas atmosphere within a silo or the like, thus, purging the structure of undesirable oxygen which may have entered. A gas generator of this type has decreased longevity and is uneconomical to operate if run continuously, or if operated when the atmosphere in a silo or bin is already sufficiently purged of oxygen.

However, it would be inconvenient for an operator to manually start and stop the gas generator as the conditions required. Automatic control, on the other hand, risks being unreliable. For instance, if the control did not operate the generator at times when the pressure in the storage structure was well below that of the atmosphere, leakage of oxygen into the structure would increase and in more extreme cases, the relief valve could open to permit an inrush of ambient air. The problem is to automatically control an inert gas generator so that it will be operating at times when the gas is required in the storage structure.

Another instance in which generator operation is sometimes needed to bolster the pressure in a storage structure, is when the stored material is being unloaded. This is a particular problem with silos having cutter arm type unloaders which unload through open doors, and which in use with many materials, cut an air cavity at the bottom of the silo. Under these conditions a storage structure can draw in air during unloading, unless a gas generator is operating to assure positive pressure in the structure.

A similar problem results from sudden pressure drops in a storage structure. These are not predictable on a regular basis, as sudden temperature fluctuations within the storage structure can occur, and severe pressure differentials can result. For example, on a warm day with sunshine directly heating the storage structure roof and walls, the pressure within the structure will generally be positive with respect to the ambient as limited by the breather apparatus for the structure. If rain falls, or the sunlight is clouded, rapid cooling can be experienced in the structure, and the pressure will drop accordingly. In this situation, it is possible for the pressure within the silo to dip substantially below ambient pressure, so that air infiltration will occur, again, unless a gas generator is operating to support storage structure pressure.

SUMMARY OF THE INVENTION

The invention is directed to the solution of the above problems and has further advantages which will be apparent from the drawings and description.

The invention is a method and apparatus which provides reliable control for storage structure atmosphere, yet operates an atmosphere control system inexpensively and for longer life. A gas generator is connected to a storage structure and supplies atmosphere control gas on demand. The generator is operated only when pressure conditions in the storage structure relative to the ambient require a further supply of atmosphere control gas in the storage structure. To do this, the generator is operated when the pressure differential between the interior of the structure and the ambient is reduced to a predetermined gauge value, near zero, and is shut down when the pressure in the structure has built up to give a second more positive predetermined differential. In this way, the gas generator is operated only at times when pressure conditions risk air infiltration, and further, at all such times.

The generator is not operated solely in response to the pressure in the storage structure, but rather in response to the values of the differential between that pressure and the ambient pressure. In mathematical terms, this differential could be positive, zero, or negative, meaning respectively that the storage atmosphere is positive with respect to ambient, the same as ambient, or less than ambient.

The apparatus of the invention includes a generator starter control that provides this method of operation and has further advantages in that it is fully automatic and protects against unnecessarily frequent response to changes in the pressure differential. In the control, a set of pressure switches are in communication with the storage pressure and the ambient pressure. The switches operate in response to differentials between the two pressures, a first switch closing at a first predetermined value, near zero differential, and a second switch closing at a second, more positive, differential value. An interlocking circuit connects the pressure switches to the generator or more specifically, to the ignition or control system of the generator. The interlocking circuit serves to start the generator in response to closing of the first pressure switch, and to stop the generator in response to closing of the second pressure switch.

To restrict the system from hunting, or continually starting and stopping as the pressure differential changes, the interlocking circuit includes a timer which delays the response to closure of the second pressure switch until a preset time period has passed. The timer is activated by closure of the first pressure switch.

As another feature, the switches in the starter control circuit automatically resume their nonoperative status in preparation for another cycle of operation.

Thus, the method and apparatus of the invention provides reliable, convenient and inexpensive control of a gas generator for storage atmosphere control. The invention maintains the desired oxygen-depleted storage atmosphere control even when unusual pressure differentials occur or when the structure is open as for unloading. A feature of the invention is that if the generator is operative for unusual lengths of time, it is in effect signalling a failure of a breather apparatus in the storage structure, or is signalling the existence of unusual leaks permitting air infiltration. These and other additional features will be apparent from the following description.

The figures illustrate the best embodiment presently contemplated by the inventor.

In the drawings:

FIG. 1 is a side elevation with parts being in section;

FIG. 2 is a schematic diagram of the control shown in FIG. 1;

FIG. 3 is an enlarged cross-sectional view of a part of FIG. 1; and

FIG. 4 is a partial side elevation of a modified form of the invention.

DESCRIPTION

The drawings show a generally sealed storage structure **1** having a cylindrical sidewall **2** supported by a foundation **3**. The upper end of the cylindrical wall is enclosed by a roof **4**. A perishable material **5** such as grain, silage, shell corn, haylage, or the like is contained in structure **1**, leaving a headspace **6** between roof **4** and the material.

The illustrated storage structure **1** has a bottom unloader **7**, which is of a type often used in grain bins, for discharging material **5**. The unloader has an auger **8** that rotates over the foundation and moves the stored material to the central portion of a radially extending trough **9** formed in foundation **3**. In trough **9**, a discharge auger **10** operates to convey the material to the exterior of the storage structure through a normally closed discharge outlet **11**. Operation of unloader **7** does not permit appreciable air infiltration through nozzle **11**, since material discharging through the outlet serves to seal off trough **9** from ambient air under most conditions.

To equalize pressure differentials which occur between the storage structure and the ambient, a breather system may be provided for the storage structure. The illustrated system includes a flexible breather bag **12**, which is suspended from roof **4** in headspace **6** and has a neck **13** connecting to a vent **14** opening through the roof. Vent **14** provides communication between the ambient and the inside of bag **12**. Be expanding and contracting in response to pressure differentials between headspace **6** and the ambient, bag **12** will tend to equalize the differential.

More extreme pressure differentials which may occur could require additional breather protection. Thus, the illustrated example has a relief valve **15** which is constructed in a well-known fashion. Valve **15** opens through roof **4** and may be set to exhaust or permit entry of gas at pressure differentials in the order of −1.5 inch to +3.5 inches of water. When the pressure within storage structure **1** is negative with respect to the ambient by such an amount, valve **15** permits air entry, thereby impairing atmosphere control in order to equalize the pressures. A gas, which is generally inert, or oxygen depleted, in the sense that it will not cause spoilage if used for atmosphere control in storage structure **1**, is provided in storage structure **1**. This gas is supplied by a gas generator **16** which is in communication with the storage structure interior via a gasline **17** extending through an appropriate opening in discharge outlet **11**. Generator **16** may be selected from a variety of types and is illustrated as being in general accordance with the carbonaceous fuel burning unit disclosed in copending U.S. Pat. application, Ser. No. 836,063, filed on June 24, 1969 and entitled All Weather Gas Generation Controlled Environment Storage. When operating, the generator will exhaust gaseous products of combustion into structure **1**, thus providing generally inert or minimum oxygen content atmosphere. The gas from generator **16** will flow through trough **9**, continue upwardly through the stored material and ultimately fill headspace **6**. When pressure builds in the structure beyond the threshold value of relief valve **15**, the valve opens to purge the storage atmosphere.

It should be noted that the gas purging could be accomplished by other gas flow arrangements. The illustrated structure contains free flowing material such as grain. In this structure, the illustrated auger unloader **7** is advantageously used and for that type of unloader, it is advantageous to connect gasline **17** to the tube of outlet **11**. This arrangement experiences no difficulty with air infiltration, since an insert gas pressure wall is generated between the structure interior and outlet **11**.

However, in structures used to store nonfree flowing materials such as silage, a rotating cutter arm type of unloader should be used. An unloader of this type is shown in the U.S. Pat. No. 2,635,770. Theses unloaders, in use with silage storing units, can permit more air infiltration through the unloader system during unloading. Thus, a different arrangement for the purge system is advantageously employed. This alternative arrangement would connect gasline **17** through the top of the storage structure and would have a gas discharge valve connected through the bottom of the structure. An example of such an arrangement is disclosed in copending patent application entitled STORAGE ATMOSPHERE CONTROL METHOD AND APPARATUS, filed on Aug. 15, 1969, with Ser. No. 850,455.

Gas generator **16** is started and stopped by a starter control unit **18** which operates a line switch **19** that connects the generator controls to a power source. Control unit **18** is thus electrically connected to generator **16** and has a set of micro switches **20** and **21** in communication with the internal pressure of the storage structure via monitor tubing **22**.

Micro switches **20** and **21** are of the type which operate in response to pressure differentials between the ambient and the monitored pressure. Mechanical, photoelectric and other types of switches may be used to accomplish this end. Such devices are well known and a mechanical switch will be described generally in connection with FIG. **3**. Each switch **20** and **21** has a pair of enclosed chambers **23** divided by a diaphragm **24**, a chamber **23** being exposed by monitor tubing **22** to storage structure pressure and the opposite chamber **23** being exposed to ambient pressure. Movement of diaphragm **24** in response to a pressure differential operates a single-pole, double-throw switch **25** having a sliding contact plate **26** attached to diaphragm **24**. In the arrangement here shown, only one contact of the switch is connected in the circuit depending on whether the microswitch gives an on or off signal. A spring-loaded, diaphragm adjusting dial **27** is attached to the diaphragm and may be screwed in or out to adjust the set point of the microswitch.

In accordance with the invention, microswitch assemblies **20** and **21** are set to close their contacts in a manner such that switch **20** starts the generator at a predetermined threshold, which is a least positive structure to ambient pressure differential, and such that switch **21** stops the generator when a second more positive predetermined threshold value is reached by operation of the generator. Thus, microswitch **20** will have its contacts closed for any differential which is at threshold or is more positive than its threshold.

Microswitches **20** and **21** are electrically connected into an interlocking circuit which is shown best in the schematic diagram of FIG. **3**. The figure illustrates component parts of a latching relay and a timer circuit into which pressure switches **20** and **21** are interlocked for control in accordance with the invention.

When the pressure differential reaches a least positive threshold value, microswitch assembly **20** closes and operates a normally open switch **28**, closing it and energizing a relay coil **29**. Switch **28**, shown in FIG. **2**, is comprised of the plate contact and one of the pole contacts of single throw, double-pole switch **25**, shown in FIG. **3**. Energized relay coil **29** closes a normally open contact **30**; contact **30** remains latched closed by operation of a latch **31**. Closure of switch **30** energizes another relay coil **32** that controls a pair of normally open contacts, one being contact **19** in the generator power circuit and another being contact **33** in the starter control circuit. Contacts **19** are closed by energizing relay coil **32** and serve to start generator **16**.

At the same time, switch **33** is closed by coil **32**, and a timer **34** is activated. Timer **34** may be any suitable device which operates to provide a control signal after a preset period. The purpose of the timer is to prevent short-cycle starting and stopping of the generator and for that purpose it should be set to provide a control signal after running a period in the range of a few minutes to 40 minutes.

In accordance with the invention, the second microswitch assembly **21** provides the stop signal for the system when a threshold pressure differential more positive than that for microswitch assembly **20** is reached. Thus, to prevent short cycling, timer **34** is interlocked with microswitch assembly **21** to delay the operation of the interlocking circuit, which would otherwise respond to closing of switch assembly **21**. To accomplish this, a pair of normally open switches is connected in

series, a first switch 35 operated by the action of pressure switch assembly 21, and a second switch 36 which is closed by timer 34 after the preset time period has run. Also connected in series with switches 35 and 36 is a relay coil 37 for the circuit of pressure switch assembly 21. Coil 27 controls latch 31 which serves to keep the generator operative by maintaining relay coil 32 energized. When both of switches 35 and 36 are closed, coil 37 is energized and it trips latch 31 to release switch 30 and, in turn, to stop generator 16 as well as timer 34.

Thus, if timer 34 has not run its cycle, microswitch assembly 21 can operate to close switch 35 but switch 30 will remain latched closed to maintain generator 16 operative. Then, after the timer runs out, the generator will be shut down. If microswitch assembly 21 closes switch 35 after timer 34 has closed switch 36, the generator will immediately shut down as coil 37 is energized to trip latch 31.

When the differentials between storage structure and ambient are caused to readjust due to operation of generator 16, the threshold value for microswitch 20 will again be reached, this time with the differential becoming more positive so that microswitch assembly 20 opens its respective switch 28, thereby being reset for another cycle. However, when this happens, switch 30 remains latched closed so that the generator continues operating until stopped by microswitch assembly 21.

Micro switch assembly 21 similarly reopens its switch 35 when the pressure differential becomes less positive beyond its threshold value, meaning when the structure pressure declines with respect to the ambient. Thus, both microswitch assemblies and the interlocking circuit are automatically reset for recycling.

METHOD OF OPERATION

The method of the invention is described in connection with the illustrated apparatus. Generally, generator 16 is operated to supply a minimum oxygen gas whenever the storage structure risks air infiltration, and the generator can be maintained inoperative at other times. The risk of air infiltration is directly sensed by measuring the pressure differential from storage atmosphere to ambient. In the illustrated example, this measurement is directly converted into control signals for generator 16 by microswitch assemblies 20 and 21 and the interlocking circuit.

Thus, in the practice of the invention, generator 16 is started when the pressure differential indicates that the risk of air infiltration warrants addition of inert gas in the storage structure. Correspondingly, the generator is shut down when the differential indicates that the risk has abated. A most preferred method would be to start the generator when the pressure differential has been reduced to slightly above zero gauge, such as at +0.02 inches of water. At this value the storage structure pressure is still positive with respect to the ambient and air infiltration is reliably prevented when for some reason the structure is opened, as when a bottom unloader of the cutter arm type is being operated. Although the invention is advantageous in use independently of the breather system of a storage structure, a further advantage of maintaining a positive differential is that a breather bag, where used, will be kept in a generally collapsed state, thus being prepared to contribute shock absorbing action at times of rapid cool down in the structure, which cool down may create pressure drops beyond the capacity of generator 16 to fully counter. As well, air leaks in the breather system and storage structure will be detectable by taking note of unusually constant operation of the generator, which is striving to maintain a positive pressure differential.

Other values of the start threshold differential may be used. A zero gauge differential or −0.2 inches of water are other examples of threshold values which for many systems would provide adequate assurance of storage atmosphere integrity.

The threshold differential value for stopping the generator should be in a range such that the storage structure will be pressurized sufficiently to allow slight variations in pressure conditions without requiring assistance from the generator. A suggested range for a large storage structure would be between +0.04 inches to +0.25 inches of water. Experimentation with the specific system including the storage structure will suggest the proper values to those skilled in the art.

It should be noted that the operation of the invention with a breather bag will be different with different threshold values. A negative differential starting threshold will utilize the bag for equalizing the pressures and the generator will operate only when the bag fails to maintain a zero differential. As already noted, a positive starting threshold utilizes the breather bag in reserve.

Referring more particularly to the illustrated system, generator 16 is set for automatic operation by closing the start switch on starter control 18. Microswitch assemblies 20 and 21 are then ready to operate as before described. Initially, the pressure differential may be more positive than the threshold value for microswitch 21 in which case it holds switch 35 closed. However, switch 30 is at this time latched open, so that timer 34 permits switch 36 to remain open. When pressure drops in storage structure 1 relative to the ambient, the threshold value for microswitch assembly 21 is reached, and switch 35 is opened. A further pressure differential drop reaches the threshold valve for microswitch assembly 20, which closes switch 28 to also close and latch switch 30. As before explained, this starts generator 16 and also timer 34.

Generator 16 begins supplying inert gas to storage structure 1, thereby contributing to the pressure of the structure. When the differential becomes more positive, microswitch assembly 20 opens switch 28, but switch 30 remains latched closed and the generator continues operating. A further rise in differential to the threshold valve of microswitch assembly 21 serves to close switch 35. If timer 34 has run its preset period, switch 35 releases latched switch 30, and, as detailed previously, generator 16 is shut down. Otherwise, the generator will shut down when switch 36 is also closed.

MODIFICATIONS

It may be desirable to employ generators of higher capacity than usual if the atmosphere control is particularly important in a storage structure. In this situation, it may be that full capacity of such a large generator is not needed except for extreme pressure drops in the storage structure. For this reason, a battery of generators, each of which can be like the one illustrated, could be connected to the structure. The battery of generators would serve the purpose of a single, variable capacity generator, and in accordance with the method and apparatus of the invention, would be controlled to deliver gas when the pressure differential is sinking.

The practice of the invention with a battery of generators is illustrated by FIG. 4. In that figure a second inert gas generator 116 identical to generator 16 is connected via a gasline 117 to storage structure 1 in series with gasline 17. Generator 16 can operate as previously described and independently of generator 116. A starter control 118 for generator 116 provides for independent startup and shutdown of generator 116, the control 118 being identical in structure to control 18 and having a set of microswitch assemblies 120 and 121.

In accordance with the modified practice of the invention, microswitch assemblies 120 and 121, corresponding respectively to the functions of microswitch assemblies 20 and 21, start and stop generator 116 when the pressure differentials reach threshold values. Since the purpose of the battery of generators is to provide variable capacity as needed, switch 120 should function to start generator 116 at a threshold differential less positive than the threshold value for microswitch 20. Similarly, microswitch 121 should shut generator 116 down before the more positive threshold value of switch 21 is reached. Thus, generator 116 will be delivering extra gas to the structure when in a differential range which has lower thresholds than the range for control 18.

One example of this modified form of the invention would be to operate second generator **116** in a pressure differential range which is entirely below the range of the first generator, meaning that the second generator operates when the pressure differential continues to dip after the first generator starts, but the second generator shuts down when the differential rises back to about the threshold for microswitch **20** of generator **16**. In this way generator **116** serves as an auxiliary to the first generator and operates only when the capacity of generator **16** has been taxed such that it cannot keep the differential from dropping or becoming too negative.

Thus, the invention provides a method, and an advantageous apparatus for the practice of the method, for controlling a storage atmosphere in a generally sealed storage structure. The embodiments described are examples of the invention. The scope of the invention is clearly defined in the following claims.

I claim:

1. A method of automatically controlling the storage atmosphere in a generally sealed storage structure, a plurality of gas generators being connected to the storage structure for delivering generally inert gas to the storage atmosphere; the method comprising;

sequentially initiating operation of the plurality of gas generators when the pressure in the storage atmosphere declines to a set of different thresholds being predetermined least positive differentials with respect to the ambient; and

terminating operation of the gas generators at least when the pressure in the storage atmosphere rises to a second predetermined differential more positive than any said least positive differential with respect to the ambient.

2. The method of claim **1**, wherein said different threshold values are in a declining succession, a first value being substantially at the differential upon which said storage structure would experience ambient air infiltration and the remaining values being successively less positive that said first value.

3. In a storage unit having a generally sealed storage structure enclosing a storage atmosphere and a gas generator for delivering a generally inert gas to said storage atmosphere; a generator starter control comprising:

a first pressure sensitive switch means in communication with the ambient and said storage atmosphere, for closing a set of contacts in response to a first pressure differential being a predetermined threshold pressure differential between said storage atmosphere and the ambient;

a second pressure sensitive switch means in communication with the ambient and said storage atmosphere, for closing a second set of contacts in response to a second pressure differential being a predetermined threshold pressure differential between said storage atmosphere and the ambient, said second pressure differential being more positive than said first pressure differential; and

interlock network means through which said first and second sets of contacts are connected in circuit, for providing a start signal to said generator in response to closure of said first set of contacts, and for continuing to operate said generator until providing a terminating signal to said generator in response to closure of said second set of contacts.

4. The structure of claim **3**, and including a timer means connected in said interlock means, for delaying said response to the closure of said second set of contacts until at least after a predetermined minimum timer period, the timer means being connected for activation by closure of said first set of contacts.

5. The structure of claim **3**, wherein said interlock network means comprises:

a latching switch connected to energize said generator, the latching switch being controlled by said first set of contacts, such that said latching switch is latched closed in response to closure of said first set of contacts, and the latching switch being further controlled by said second set of contacts such that said latching switch is opened in response to closure of said second set of contacts.

6. In a storage unit having a generally sealed storage structure enclosing a storage atmosphere, a storage atmosphere control apparatus comprising:

a gas generator means being a variable capacity generator in communication with said storage atmosphere, for delivering generally inert gas to said storage atmosphere in varied amounts; and

a sequential control connected to said gas generator means and having a pressure switch means in monitoring communication with said storage atmosphere and ambient pressure and connected to said gas generator means for successively increasing the output of inert gas in response to a successively declining pressure differential between said storage atmosphere and ambient.

7. The structure of claim **6**, wherein said gas generator means is comprised of a battery of inert gas generating members; and said pressure switch means is comprised of a plurality of independent pressure sensitive switch means for successively starting the gas generating members in accordance with a successively declining set of threshold pressure differentials between the storage atmosphere and ambient.

8. In a storage unit having a generally sealed storage structure enclosing a storage atmosphere, a storage atmosphere control apparatus comprising:

gas generator means for delivering inert gas to the storage structure;

pressure sensitive switch means in communication with the ambient and the storage atmosphere for initiating the operation of said gas generator means in response to a predetermined threshold pressure differential between the ambient and the storage atmosphere; and

interlock means having a presettable timer for maintaining said gas generator operative for a predetermined time in response to a signal from said pressure sensitive switch means.

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