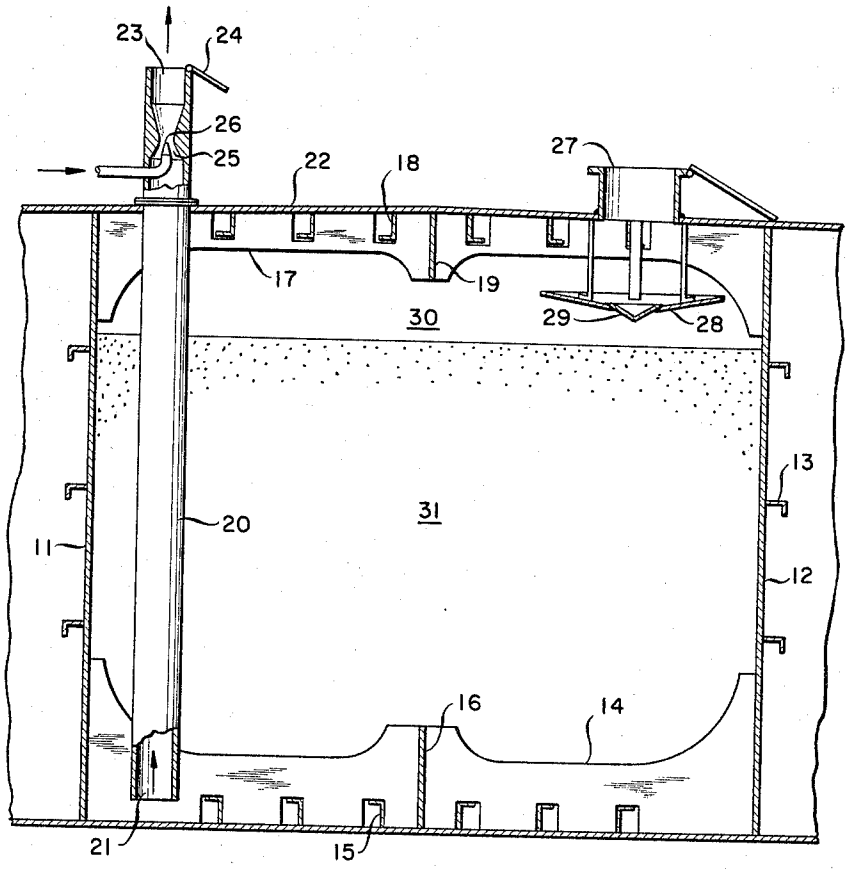
Oct. 18, 1966 E. B. AYERS ET AL 3,279,198

METHOD FOR REDUCING GAS CONCENTRATIONS IN CARGO TANKS

Filed Oct. 15, 1964



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United States Patent Office 3,279,198 Patented Oct. 18, 1966

3,279,198

METHOD FOR REDUCING GAS CONCENTRATIONS IN CARGO TANKS

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Filed Oct. 15, 1964, Ser. No. 404,192
1 Claim. (Cl. 62—45)

This invention relates to tank vessels and, more particularly, to a method for removing hydrocarbon vapors from the cargo tanks of a tanker. Essentially it is a safety measure to insure that cargo tanks (when empty) are in a non-explosive condition.

After discharge of cargo and stripping of tanks, it is normal practice for tankers in the clean products trade to wash cargo tanks and lines during the ballast voyage. This is done to avoid contamination when there is to be a change of product. The method of removing residual cargo from tanks and lines used in conjunction with this system of removing hydrocarbon vapors, is to flush the cargo lines back into the tanks with water. The resultant water and hydrocarbon mixture is then stripped out and transferred to a slop tank. A more usual method of removing product from cargo tanks and lines is to wash tanks with a machine equipped with rotating nozzles which direct jets of water at high pressure against the interior of the tanks. The slop is then stripped out through the cargo lines and discharged overboard.

The removal of substantially all of the liquid product from cargo tanks and lines, as well as eliminating a possible source of contamination of a subsequent product, removes a source of generation of more hydrocarbon vapors but does not remove the vapors remaining in the tank after discharge of cargo. The concentration of these vapors may be such as to create an explosive gas mixture within a tank. In recent years several explosions have occurred in tankers during tank washing operations.

This invention is directed to a method for degassing cargo tanks in a tanker. As used in this invention, a cargo tank is presumed to be degassed when the concentration of hazardous vapors within a tank is reduced below the explosive range. In the following evaluation, it is assumed that, as butane is one of the principal components of vapors associated with gasoline and similar low flash hydrocarbons, the explosive limits may be based on this gas. The lower explosive limit for butane is 1.69% butane by volume in air. Below this limit, a mixture is too lean to ignite. The upper explosive limit for butane is considered to be 6.5% butane by volume in air and above this limit the mixture is too rich to ignite. Further, it is assumed that if the butane concentration is reduced to one-half of the lower explosion limit, the tank has been degassed and that no danger of an explosion exists, one-half being used to insure a generous safety factor.

In order to provide a better understanding of this invention a complete operating cycle of tanker according to present practice will be reviewed. First it is assumed that a gas-free tank is being loaded with a normal automotive type of gasoline. The term "gas-free" is used in referring to a tank from which substantially all hydrocarbon vapor has been removed. The admission of the gasoline into the tank results in the immediate release of some gasoline vapor. The quantity of vapor released depends upon the surface area of the liquid in the tank, the temperature, the vapor pressure of the gasoline and the turbulence at the surface of the gasoline. It should be noted that pure gasoline vapor has a density of three to four times that of air and hence the rate of diffusion of the heavy gasoline vapor into the upper layer of air in the cargo tank is relatively slow. Under normal

loading conditions the vapor layer that has a concentration above the lower explosion limit may have a depth of three of five feet when the tank is about three-quarters full. During the balance of loading and topping-off some of the vapor expelled from the tank will be within the explosive range in the vicinity of the tank vent.

Of course, for products that are less volatile than gasoline, the depth and concentration of the vapor layer will be reduced.

The above data are based on the assumption that the cargo tank was substantially gas-free at the start of loading. If, in fact, there were hydrocarbon gases remaining within the tank, then these gases, augmented by the vaporization of the product being loaded, would be displaced from the tank, thereby adding to the volume of hazardous gases expelled from the tank.

After completion of loading, the ullage space above the product continues to be subject to diffusion and equalization of vapor pressures, with the gas concentration continuing to rise until equilibrium is reached. The following table indicates typical equilibrium levels of concentration reached for various products:

Motor gasoline, 30–40 times the lower explosive limit.

Military jet fuel, 3–6 times the lower explosive limit.

Kerosene turbine fuel, 0–0.3 times the lower explosive limit.

Kerosene, negligible.

Furnace oil, negligible.

From this data it will be noted that only in the case of military jet fuel is an explosion vapor likely to exist in the ullage space of a tank during the loaded voyage.

During the discharge of the product, the liquid level will fall and air will enter the tank. In the case of gasoline, as noted above, the space above the product normally is well above the explosive limit at the start of discharge, but as this small volume of vapor becomes diluted with air a layer of vapor at the interface will be produced which will fall to a level within the explosive range. The depth of this layer will increase as the discharge proceeds. Because of the relative lightness of the entering air in contrast to the gasoline vapors, the air tends to form a blanket above the gasoline vapor and thus, at the conclusion of discharge of the product, the upper one-third to one-half of the tank is likely to contain a vapor with a concentration below the lower explosive limit. Below this there will be a layer within the explosive range, and at the bottom a layer of vapor which is over-rich and well above the upper explosive limit. The thickness of the various layers can vary widely and will depend on the rate of discharge, the vapor pressure of the gasoline and the temperature.

Other products follow substantially the same pattern as for automotive gasoline but with products of lower volatility a larger portion of the tank will be below the lower explosive limit. In the case of kerosene and less volatile products, the vapor concentration throughout the empty tank is likely to be well below the lower explosive limit.

After the discharge of cargo the tanker normally returns to a loading port, certain tanks being ballasted with sea water to provide adequate stability. Normally, during the ballast voyage, tanks are washed in anticipation of a change of cargo but, if there is to be no change of product, tanks may be shut down after discharge and left alone.

In this case the layering effect of the vapors, noted after discharge, will gradually dissipate and mixing will tend to bring about a uniform concentration of vapor in the tank.

The method of this invention is directed to the problem of degassing tanks that are empty and stripped of sub-

tantially all liquid hydrocarbons and is advantageously but not neccessarily practiced as soon as possible after discharge of cargo. Further, this invention seeks to reduce the time required to degas the tanks.

The degassing of tanks by the method of this invention is attained by providing the tank with a vent or standpipe that extends to the bottom of the tank and an inlet in the top of the tank. The standpipe is provided with a flow-inducing means to remove vapor from the tank. The inlet is provided with means for directing the air entering the tank into a horizontal layer, such as a horizontal baffle or slotted diffuser pipe. The horizontal air layer moves down the tank with a piston-like movement as additional vapor is removed. The combination of removing vapor from the bottom of the tnak and directing the entering air into a horizontal layer results in the degassing of the tank in a minimum time. Normally a volume of vapor equivalent to only one to one and one-half times the volume of the tank must be removed to degas the tank.

This invention will be further described with reference to the attached drawing showing a cross section of a typical center tank of a tanker with a degassing apparatus installed.

There is shown the longitudinal bulkheads **11** and **12** forming the sides of a tank. The longitudinal bulkheads are provided with longitudinal members **13** and a transverse bottom frame **14**. The bottom of the tank is also provided with longitudinal members **15** and a central keel **16**. The top of the tank is also provided with a transverse frame **17**, longitudinals **18** and center girder **19**. The cargo tank is equipped with a standpipe **20**, which terminates in an open end **21** near the bottom of the tank. Good results, using the method of this invention, have been achieved when the lower end of the standpipe terminated **12–18** inches above the bottom of the tank. The standpipe **20** passes through the deck **22** and terminates in an open end **23** above the deck. The upper end **23** of the standpipe is equipped with a hinged cover **24** which is opened only when the tank is being exhausted.

Positioned with the standpipe **22** at or above the deck level is an exhausting means for removing the vapor from the cargo tank. As illustrated in the attached drawing, the exhausting means may consist of a restricted passage **25** and a steam jet **26** pointed vertically upward. Thus by passing steam through the jet **26** a suction effect can be created and the vapor removed from the interior of the tank. Of course, other means of exhausting could be used as, for example, an axial fan driven by an electric motor or steam turbine.

Also positioned in the deck **22**, in the way of the tank, is an opening **27** for admitting air into the tank to replace the vapor that is removed therefrom. The opening **27** may be a Butterworth opening present in the top of a typical tank that is normally used to admit washing equipment into the tank. Positioned immediately below the opening **27** is a cone-shaped diffusing member **28**. The diffusing member may take various shapes, the cone-shaped member illustrated in the attached drawing having been found to be entirely satisfactory. The important features to be considered when designing the diffusing member **28** is that it should extend laterally beyond the edge of the opening in the deck **22** and should be mounted below the internal tank structure and relatively close to the opening **27**. The function of the diffusing member **28** is to eliminate the jet effect of the entering air, which could cause mixing of the air with the hydrocarbon vapors, and to cause the air entering the tank to be displaced in a horizontal layer so that it moves downward in substantially a piston-like movement. Because the air is lighter than the hydrocarbon vapor the horizontal layer of entering air moves from the top of the tank toward the bottom with a minimum of mixing between the entering air and the vapor present in the tank.

To operate the system of this invention, after discharge of cargo the vapor removal means, as for example the steam jet **26**, is placed in operation. This removes the vapor from the bottom of the cargo tank through the standpipe **20** and exhausts it to the atmosphere through the open end **23** of the standpipe, or an extension thereof. The steam-vapor mixture leaves the top of the end **23** at a velocity to carry it well above the deck level and has a hydrocarbon vapor concentration below the lower explosive limit.

As the hydrocarbon vapor is removed, air from the surrounding atmosphere enters through the opening **27** to replace the removed vapor. The entering air is diffused into a horizontal layer across the upper portion of the tank by means of the diffuser or baffle **28**. As additional vapor is removed, the air in the upper part of the tank moves downward vertically as a piston, thus displacing the removed vapor without any appreciable mixing between the entering air and the vapor being removed.

As shown in the attached drawing, a layer **30** consisting of air, substantially immixed with hydrocarbon vapor, is maintained in the upper part of the cargo tank while the hydrocarbon vapor remains in a layer **31** in the lower part of the tank. Continued removal of vapor is followed by the lowering of the bottom of the horizontal layer of air, thus displacing the vapor.

From actual operations, it has been found that the vapor level within the tank can be lowered below the lower explosive level by withdrawing through the standpipe **20** approximately one to one and one-half times the volume of the cargo tank. Thus, it is seen that, except at the interface, substantially no mixing takes place between the entering air and the vapor being removed. Near the completion of the procedure, it has been found that the internal structural members retard the movement of vapor to the standpipe. Thus a little turbulence is desired at the tank bottom at this time.

To create the desired turbulence suitable means for flowing air to the tank bottom are provided. For example, the diffuser **28** may be provided with a removable center section **29**. The center section **29** can be removed, thereby directing a small but effective jet of incoming air to the tank bottom which creates the minor turbulence required.

In some cases, particularly where the tank bottom includes considerable internal structure, it may be necessary to use a collection system in combination with the standpipe **20**. The collection system included a plurality of intakes designed to permit the standpipe to remove vapor from all locations in the bottom of the tank. Often the internal tank structure will have sufficient openings in it to permit the use of a single open-ended standpipe **20**.

In contrast to the method of the present invention, it has been the practice in the past to blow or force air into a cargo tank. This causes a considerable amount of turbulence and mixing of the entering air with the vapors present within the tank. Thus, the process is one of dilution and a large volume of air must be introduced to lower the vapor concentration within the tank below the lower explosive limit. This is inefficient and delays the time when all cargo tanks will be degassed to the point where an explosive danger no longer exists. Furthermore, as dilution and mixing take place, the air-vapor mixture throughout practically the entire tank will assume a composition within the explosive range and will remain within this range for an extended period before the tank is degassed.

Therefore, important features of this invention include means for removing the vapors from the bottom of the cargo tank; a means for introducing air into the upper part of the cargo tank to replace the removed vapors; and a means for diffusing the entering air to cause it to form a substantially horizontal, non-turbulent layer that travels toward the bottom of the tank as a piston. Utilizing these three features, it is possible to substantially degas cargo tanks in a tanker with improved safety by exhausting air and hydrocarbon vapors to the extent

of only one to one and one-half times the volume of the cargo tank, thus reducing the time required.

Of course, when it is desired to gas-free the cargo tank, a considerably larger amount of air and vapor must be withdrawn, for example, at least several times the volume of the cargo tank. A gas-free tank is one in which vapors remaining in the tank are not only below the explosive concentration for the particular vapors but in addition low enough for humans to enter safely.

We claim as our invention:

A method for eliminating the vapor hazard in cargo tanks of tank vessels carrying liquid hydrocarbons, which method comprises:

(a) after removing substantially all of the liquid hydrocarbon from the tank, removing vapor from the tank from a location adjacent to the bottom thereof;

(b) admitting atmospheric air to the top of the tank

and distributing the air substantially as a horizontal, non-turbulent layer;

(c) causing the air in said horizontal layer to flow downward over substantially the full tank area and to act as a piston to displace the vapor without substantial mixing; and

(d) continuing to remove the vapor and replacing it with air until the hydrocarbon vapor remaining in the tank is below the explosive level.

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MEYER PERLIN, *Primary Examiner.*