Appendix C to minutes of meeting of CCAP held in Chicago, October 4, 1943

PREPARATION OF TANK VESSELS* PRIOR TO ALTERATIONS OR REPAIRS

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1. Introduction

The prevention of personal injuries and damage to property has always been a serious problem in the alterations and repairs of tank vessels. The cleaning of the tanks and compartments of a tank vessel and the testing of the atmosphere within these tanks and compartments are technical problems regularly encountered when such vessels are used for transportation of crude petroleum and its products.

2. Toxic Effect of Petroleum Vapors

Vapors given off by crude petroleum, gasoline and other petroleum products cause anaesthetic effects when inhaled and, unless precautions are taken, such effects may be encountered by workers during the cleaning operations.

Exposure to petroleum vapors often results in irritation of the eyes and the development of a severe headache. When inhaled in comparatively small quantities these vapors produce merely a mild exhilaration. Upon inhaling the fumes in more concentrated form this condition rapidly develops into complete intoxication accompanied by a tendency on the part of the individual to sing, dance, or otherwise vigorously exert himself. As this stimulated activity wears off the victim's lips lose their natural color and become so stiff that proper enunciation is no longer possible. At this stage, further exposure causes unconsciousness and may result in death.

The toxic effect of gasoline vapors in various degrees of concentration is illustrated by data from the U.S.Bureau of Mines Technical Paper No. 272 as follows:

> Air containing .07 to .28% vapors by volume causes slight symptoms of dizziness when inhaled for 14 1/2 minutes.
>
> Air containing 1.13 to 2.22% vapors by volume represents the concentration which causes severe dizziness when inhaled for 3 minutes.
>
> Air containing 2.20 to 2.60% vapors by volume causes intoxication after 10 to 12 breaths.

3. Flammability of Petroleum Vapor-Air Mixtures

Petroleum vapors are highly flammable and considerable care is required to prevent the occurrence of fires or explosions. When mixed with the proper amounts of air (oxygen) these vapors form explosive mixtures, The explosive mixture range of gasoline in air, for example, is generally accepted to be from 1 to 6% by volume. The lower figure corresponds to the minimum amount and the higher figure to the maximum amount of gasoline vapor capable of producing a flammable mixture. The vapor concentration below which the mixture will not burn is called the "lower explosive limit" and the vapor concentration above which the mixture will not burn

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is called the "upper explosive limit." For some of the more volatile hydrocarbons, such as commercial propane, the upper explosive limit is 9.5%. The explosive range for natural gas is 4.8 to 13.5%. Although explosive limits have been established definitely for a number of hydrocarbons, it must be remembered that petroleum products seldom are handled as pure hydrocarbons. It is essential, therefore, to consider the lowest and the highest explosive limits of the hydrocarbons of any products or mixtures being handled.

The following table lists several of the more common combustibles with their lower and upper explosive limits:

Combustibles	Limits of Flammability	
	Lower	Upper
Methane	5.0	15.0*
Ethane	3.20	12.50**
Propane	2.40	9.50**
Butane	1.90	8.50**
Pentane	1.45	7.50**
Hexane	1.25	6.90***
Hydrogen	4.10	74.0**
Carbon Monoxide	12.50	74.2**
Natural Gas	4.80	13.50**
Illuminating Gas	5.30	31.00**

4. Other Gases Associated with Petroleum Products

Other gases associated with petroleum products also are toxic if breathed in sufficient quantity. Hydrogen sulfide, the most prominent of these gases, is contained in some crude oils and is present also in some unfinished refinery distillates as a result of reaction at high temperature and pressure. Hydrogen sulfide is harmful, and even fatal, in relatively small concentrations. It is especially hazardous because of its paralytic effect on the sense of smell, making detection by odor impossible. The U.S.Bureau of Mines has found that a concentration of 0.01% in air will produce irritation of the eyes and other physical disturbances upon exposure for two minutes, with increasingly harmful results upon continuous exposure. Exposure for two minutes in a concentration of 0.07% has resulted in death. Hydrogen sulfide** also is explosive in concentrations from 4.3 to 46.0% in air.

5. Oxygen Deficiency

The atmosphere within clean tanks which have been closed tightly for some time is frequently deficient in oxygen due to rusting of the metal of the tanks. Such tanks, therefore, should not be entered until they have been ventilated thoroughly. Normal air contains about 21% oxygen. Air which contains less than 16% will not safely sustain life.

Table: *G. W. Jones, E. S. Harris and W. E. Miller - U.S.Bureau of Mines Technical Paper #544, 1933, page 26.
**H. F. Coward and Geo. W. Jones - U.S.Bureau of Mines Bulletin #279.
***G. W. Jones, E. S. Baker, R. E. Kennedy - U.S.Bureau of Mines Report on Investigations #337, February, 1937.

** H. F. Coward and Geo. W. Jones - U.S.Bureau of Mines Bulletin #279.

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6. Early Safety Measures

Prior to 1922 the cleaning of tanks and compartments of Standard Oil Company of New Jersey tankers was let by contract to outside concerns who supplied their own labor and supervisors for cleaning the tanks. In order to insure the detection of any explosive or toxic gases, analyses of the atmosphere in the tanks were made by chemists from a commercial testing laboratory.

Although this arrangement was reasonably satisfactory, a detailed study of the methods employed brought out the fact that too little attention was paid to cleaning and too much dependence put on the analyses of the atmosphere within the tanks. Most inspectors took samples of the atmosphere without entering the tanks and could not know, therefore, the condition of the bottoms and sides. Unless the tanks are known to be properly cleaned, there is no assurance that a gas-free atmosphere at time of inspection is a guarantee of safety during repair periods which may extend over several days. Numerous cases have been experienced where the atmosphere in tanks showing no signs of gas on one day, showed dangerous amounts twenty-four hours later, presumably because the tanks were not cleaned satisfactorily and vaporization of petroleum material took place after the analyses were made.

In this connection, it seems desirable to point out two fundamental principles which apparently were not universally recognized prior to 1922. The first is that a certificate of safety is worthless unless the inspector has entered the tank or compartment in question and has examined it carefully for deposits of oil and/or sediment which may generate vapor. Without such an examination the analysis of the atmosphere means nothing more than that the tank is safe for a man to enter at the time of testing. The practice of taking samples by means of a sampling tube or sampling bottle lowered from the deck seems entirely inadequate except for preliminary information.

The other fundamental principle is that the maximum permissible content of petroleum vapor is fixed by its effect on men inhaling the atmosphere rather than by the lower limit of the explosive range. The lower explosive limit of different hydrocarbons varies, but 1.0% is perhaps a representative figure. On the other hand, it is stated that petroleum vapors in concentrations of 0.3%* or more are intoxicating to some people on exposure for 30 minutes or longer, so that the actual danger limit is far below the explosive limit. It has been experienced that men are able to work in tanks for indefinite periods when a maximum of 0.2% of petroleum vapor calculated as pentane is enforced as a limit.

7. Cleaning Procedures

Because of the possibility of personal injuries and damage to property, the Standard Oil Company of New Jersey in January of 1922 instituted a standard plan for the preparation of tank vessels prior to alterations and repairs. A staff of men was employed for this purpose consisting of a supervisor, a chemist, several foremen, and a group of laborers. The cleaning method employed at the outset is referred to as the Manual Method. In this method hot water is applied with hand hose after a steaming operation. The recommended procedure today, however, is the Butterworth Method in which hot water is applied mechanically by means of special equipment. All the tank vessels owned by the Company are equipped to use the Butterworth Method, so that the Manual Method is used only on vessels when Butterworth machines are not available. Today the personnel employed for cleaning operations ha increased to one captain - who acts as supervisor, 3 certified chemists, 6 foremen, 5 pump men, 3 timekeepers, and a group of casual laborers who are experienced tank cleaners ranging in number from 50 to 75. The chemists employed in this work are

*G. W. Jones and W. P. Yant - U.S.Bureau of Mines Technical Paper #35.

graduates of recognized colleges and are recommended for certification by the American Bureau of Shipping only after they have worked at their profession in the oil industry for at least three years -- six months of which has actually been on cleaning of tank vessels used for the transportation of crude petroleum and its products.

It is impossible to specify arbitrarily that a tank of a given size shall be steamed or machine washed a certain number of hours, since the amount of steaming or washing required varies with the nature of the oil which was carried last, the atmospheric conditions, and other factors. The intensity and duration of each process rests therefore with the judgment of the supervisor and the chemist, and are governed by the conditions and circumstances which necessitate such cleaning.

(a) Butterworth Method

With the Butterworth Method, heated water is directed upon the interior surface of tanks by means of high pressure streams from two revolving nozzles. The nozzles are geared to turn simultaneously and slowly in all planes, horizontal to vertical, so that the water streams from the nozzles are directed eventually upon the entire interior surface of the tank.

As soon as the cargo is pumped out, steam is forced through the heater coils and steam smothering lines. If condensed steam comes through the heater coils clear, indications are that the lines are satisfactory. If steam fails to come through or if the condensate is oily, it is evident that the coil is ruptured, and that cleaning is necessary before a certificate can be issued for the compartment in which the questionable coil is located. Smothering lines are steamed for approximately ten minutes. Butterworth machines are next placed in the cargo tanks through special openings or through hatches if the vessel is not equipped with such special openings. Generally two machines are operated at the same time, one in each of two Main, Wing or Summer tanks. The hatch and ullage covers are closed but not dogged down. During the period of washing, which normally takes from 1 1/2 to 2 hours per tank, the ship is held at a slight list if necessary to speed the drainage of the tanks to the suction. The cargo pumps are operated slowly to withdraw from the tanks the refuse oil and hot water resulting from the washing operation. For most efficient cleaning operation, the water is heated to a temperature of approximately 175° F. The water is supplied at a pressure of approximately 175 pounds per square inch from the vessel's deck fire lines.

After the tanks have been washed sufficiently, the Butterworth machines are removed and the tanks ventilated by means of wind sails, Venturi tubes or air blowers lowered into the tanks through the hatch, or by steam gas suckers installed in the ship's deck discharge lines. When the atmosphere within the tanks has cooled sufficiently for men to enter, a sample of it is obtained by means of a sampling tube or sampling bottle lowered from the deck and analyzed for toxic or combustible gases. If the atmosphere is found to contain not more than 0.2% gas by volume, the supervisor in charge of cleaning enters the tanks to make a preliminary survey before men are sent into the tanks with hand hose to wash toward the suction any sediment or scale left in various parts of the tank. Sediment which is not pumped through the suction line is removed manually. A careful watch is maintained over the men doing the work.

(b) Manual Method

When Butterworth machines are not available, the approximate time required for steaming is estimated on the basis of previous cargoes. After the heater lines are blown, the hatch covers and ullage holes are closed but not dogged down. Steam at a line pressure of about 75 pounds is allowed to enter the tanks through the smothering lines for the period of time considered necessary to sufficiently soften and

loosen oil and sediment on the bulkheads, beams, etc., so as to permit removal with streams of hot water. Upon completion of the steaming, the hatch covers are thrown open and wind sails, air blowers or steam gas suckers are used as described above for purpose of expelling gases and steam. When the tanks have cooled sufficiently, a preliminary test of the atmosphere within is taken. If the gas content is more than 0.2% by volume, further ventilating or steaming and ventilating are required. If the gas content is 0.2% or less, men equipped with hand hose descend the ladders slowly, washing down the top, sides and beams as they go. The water used for washing is at an approximate temperature of 100° F. and at a pressure of about 50 pounds. A convenient means of supplying hot water for washing is provided by a "Y" connection which introduces steam into a nozzle on the fire line and provides a positive regulation of temperature. A careful watch is maintained from deck for the safety of the men below. When the top, sides and beams have been washed thoroughly, work is commenced on the bottom. Starting at the forward outboard corner of the tank the oil and sediment are washed toward the suction from which point they are removed to a barge or a slop tank ashore by means of the ship's pumps which are kept in operation throughout the entire washing period. Any material which is not removed through the suction line is removed manually.

(c) Final Inspection

After all tanks and compartments in question have been washed and cleaned in accordance with either of the above methods, the main pump room bilges are cleaned. Next, water is pumped through all ship's cargo lines and discharged into the slop line. After pumping for a predetermined period, the water is discharged on deck where it is examined by the chemist, the chief officer, and the supervisor in charge of tank cleaning. If the water is clear, the cargo lines are considered to be cleaned. Whenever possible, depending on the shifting of ballast, valves are left open to air out the cargo lines.

The tanks are then entered and inspected by a certified chemist; and, if found to be cleaned to his satisfaction and if the gas content is 0.2% or less, a Certificate is issued stating the tanks (reported individually) are either "Safe for Men and Fire" or "Safe for Men - Not Safe for Fire."

9. Repairs Remote from Cargo Tanks

Whenever a vessel must be dry docked for a survey on account of a seriously damaged bottom or for repairs confined solely to work on the rudder, propeller, tailshaft or other parts remote from the cargo compartments, such tanks may be smothered with steam and sealed prior to the vessel's arrival in the shipyard. In case it is found necessary to do any work in and/or around any of the tanks, the tanks in question are cleaned by either the Butterworth Method or the Manual Method and certified as heretofore described.

10. Cleaning Cargo Tanks at Sea

Whenever vessels after discharging at one port are ordered to proceed to a shipyard at some other port, it may be necessary to clean the tanks and compartments enroute. The same procedures outlined under Section 7 are followed except, of course, no certified chemist is present. However, each vessel is provided with a Combustible Gas Indicator by means of which it can be determined if it is safe for members of the crew to enter the cargo tanks to remove sediment and complete the cleaning. Upon arrival at the shipyard, the services of a certified chemist are obtained for a complete inspection. If the chemist is satisfied with the condition of the tanks and the analysis of the atmosphere within the tanks indicates absence of gas, a Certificate is requested. If further cleaning is necessary this is done to the satisfaction of the chemist and a Certificate is obtained before repairs are started.

Whenever it is necessary to carry out emergency repairs (requiring the use of spark producing tools) in a cargo tank while at sea, the tank in question and all adjacent tanks are cleaned, and the atmosphere within tested with a combustible gas indicator in accordance with the approved practice. If the gas content is 0.2% or less, the necessary repairs may be carried out.

11. Chemists Certificate

As a convenience for reporting the condition of tanks of a vessel, a ruled form of certificate with blank spaces resembling a conventional diagram of the horizontal cross section of a ship is provided. This certificate, affirming that the atmosphere in the tanks in which repairs are to be made, and adjacent tanks, are safe for the conduct of the work, must be signed by the inspecting chemist and given to the master or officer in charge before the ship is delivered to the contractor or person charged with making repairs.

In order that no possible misunderstanding can occur, the condition of tanks is indicated only by the notations "Safe for Men and Fire", "Safe for Men - Not Safe for Fire", and "Not Safe".

The notation "Safe for Men and Fire" implies that the tanks so designated as well as the adjacent tanks and compartments have been thoroughly cleaned of residues and deposits on frames and on the bottom which, when disturbed, might produce vapor; and that the gas content of the atmosphere within the tanks is not more than .2% by volume calculated as pentane. Welding, riveting and similar work requiring fire are permitted in tanks so designated.

The notation "Safe for Men - Not Safe for Fire" implies that tanks so designated but not the adjacent tanks have been thoroughly cleaned of residues and deposits on frames and on the bottom which, when disturbed, might produce vapor; and that the gas content of the atmosphere within the tanks is not more than .2% by volume calculated as pentane. Only work not requiring the use of fire or spark producing tools is permitted in such tanks.

The notation "Not Safe" is used when oil or dangerous amounts of residues or deposits are present, when leakage from adjacent tanks is possible, or when the gas content of the atmosphere is greater than .2%. Under such conditions, men are permitted to enter the tanks when an emergency exists but only when equipped with life-lines and fresh air hose masks, and only when a constant watch is maintained on deck for their safety.

The original and one copy of the chemist's Certificate are retained aboard ship and an entry of their receipt made in the Ship's Log Book. Upon completion of repairs a statement is made by the master or officer in charge on the original Certificate to this effect - and the Certificate then is forwarded to the New York Office.

12. Combustible Gas Indicator

Various types of indicators have been used in the past for the detection of petroleum vapors to insure that the atmosphere is non-toxic and to guard against fires and explosions. All have employed basic principles, such as diffusion, volume change on combustion, or heat of combustion. Of these, the last type seems most suitable for the petroleum industry because of the wide variety of gases which are likely to be encountered.

In the beginning, the Standard Oil Company of New Jersey employed a portable indicator based on the volume contraction on combustion principle, designed

especially for this type of work. It required careful handling and its operation involved a fair amount of skill and training but it served a useful purpose until the urgent need for such equipment brought about the adaptation and perfection of the heat of combustion principles in the form of a portable indicator. At present, several of these instruments are on the market and are used almost exclusively for this type of work.

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