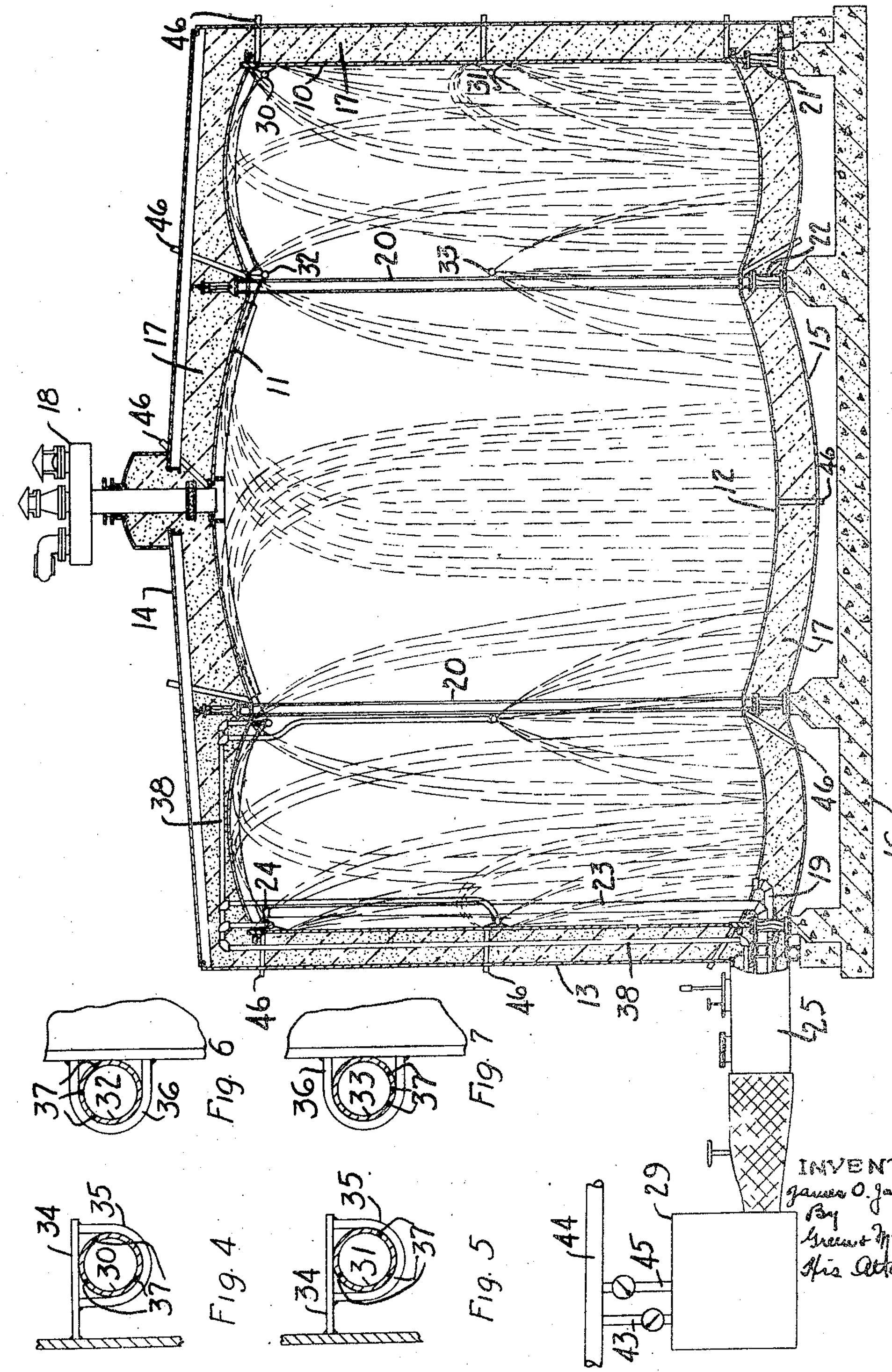
Aug. 30, 1949. J. O. JACKSON 2,480,472

METHOD AND MEANS OF PRECOOLING INSULATED TANKS FOR STORING COLD LIQUIDS

Filed Sept. 20, 1944 2 Sheets-Sheet 1



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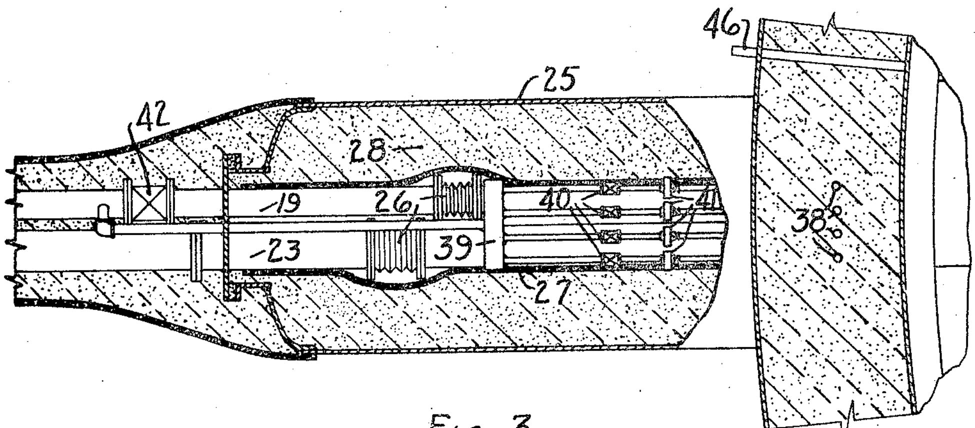

Fig. 3

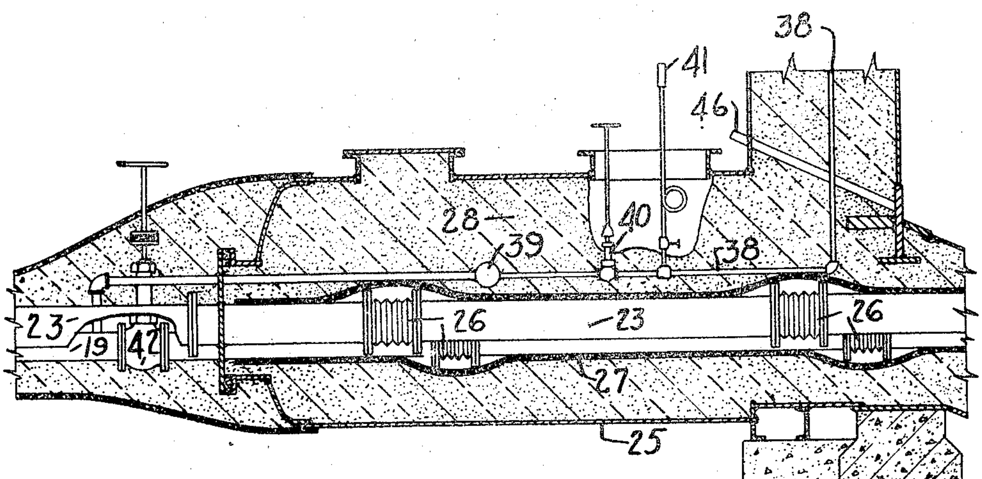

Fig. 2

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METHOD AND MEANS OF PRECOOLING INSULATED TANKS FOR STORING COLD LIQUIDS

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9 Claims. (Cl. 62—1)

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This invention relates to double walled insulated tanks used as reservoirs for storing above ground relatively great quantities of liquefied gas, such as liquefied natural gas, liquefied oxygen, liquefied propane, etc.

Several forms of double walled insulated tanks adapted to serve as reservoirs for storing such liquefied gases are disclosed in an application filed by me January 9, 1942, numbered 426,192 and since abandoned.

A serious problem encountered in placing in service tanks such as these (when the inner shell of such tank is fabricated from a metal such as ferrous metal) is that occasioned by thermal shocks and stresses due to uneven cooling when such shell is charged with these extremely cold liquefied gases. This is liable to rupture or crack some portion of such inner shell structure and thus render the entire tank useless.

The invention of this application relates particularly to a method and means for precooling the inner shell structure of such double walled insulated tanks or containers in order to condition them to receive and store liquefied gas without harmful thermal shock or stress.

This invention has as one of its objects the provision of an improved method of cooling down all parts of the inner shell structure of such double walled insulated tanks or containers from the prevailing ambient temperature to approximately that of the low temperature liquid to be stored therein.

Another object is the provision of means for carrying out the method of this invention.

A further object is to produce a double walled insulated storage tank or reservoir for liquefied gas, which in its make-up includes means whereby all interior parts of the inner shell structures thereof can be slowly and substantially uniformly cooled from the prevailing ambient temperature to approximately that of the liquefied gas to be stored therein.

These and other objects, I attain by the method and apparatus described in the specification and illustrated in the drawings accompanying and forming part of this application.

In the drawings:

Figure 1 is a sectional view in elevation of a double walled insulated tank for storing liquefied gas, equipped with means for conditioning or precooling the inner shell structure of such tank in accordance with the method of this invention.

Fig. 2 is an enlarged side sectional view of the tank "boot" with the parts enclosed thereby in elevation;

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Fig. 3 is a view such as Fig. 2 but is taken at 90° thereto looking down.

Figs. 4, 5, 6 and 7 are enlarged sectional views of coils comprised in the means for carrying out the precooling method of this invention.

The method of this invention can be utilized for the conditioning or precooling of any type of insulated tank or container designed to serve as a storage reservoir for low temperature liquids, such as liquefied natural gas, liquefied methane and its homologs, liquefied ethane, propane and butane, as well as other liquefied gases such as liquid oxygen, liquid nitrogen, etc.

For the purposes of this application, I have illustrated my method in connection with one form of storage tank or container disclosed in my said application 426,192. This, it is to be understood, is without any intent of limiting this invention to any particular form or type of storage tank or container, since both my method and the apparatus for carrying out such method can be used for conditioning or precooling any type of insulated tank or container for storing low temperature liquids. It is of particular value, however, when those portions of the tank or container, contacted by the stored liquid, are fabricated from metal that is subject to damage from thermal shock or stress, and when the size of the tank or container is great enough to make slow substantially uniform precooling necessary or worth while.

The method of this invention broadly comprises conveying precooling fluid into the interior of the inner shell of the tank or container, in so directing small jets of such fluid that substantially all interior parts of such inner shell structure are contacted thereby, and in periodically lowering the temperature of the precooling fluid in such an amount that the difference between the warmest part of the inner shell structure and the temperature of such precooling fluid is never so great that such precooling fluid will cause harmful thermal shock or stress in any part of such inner shell structure.

A storage tank such as disclosed in my said application 426,192 and illustrated in Fig. 1 of the drawings of this application has been built and is now in successful operation. Such tank was designed to store 160,000 cubic feet of liquefied natural gas under a maximum working pressure of about 5 pounds per square inch gauge. This quantity of liquefied gas upon evaporation produces 100 million cubic feet of gas.

Such tank is of welded construction and comprises inner and outer spaced cylindrical shells. The inner shell 10 is about 70 feet in diameter and 43 feet high. This shell is fabricated of low carbon steel having a nickel content of about 3.50% and a Charpy impact value of about 15 foot pounds at −260° F.

The plates forming the roof 11 and the bottom 12 of the inner shell can be said to be spherically dished; the bottom plates downwardly and the roof plates upwardly.

The outer shell 13 has a diameter of about 76 feet and a height of about 51 feet and is fabricated from ordinary tank (medium carbon) steel. This outer shell has a flattened cone roof 14 and the plates forming its bottom 15 can also be said to be spherically dished downwardly. The bottom of the outer shell parallels the bottom of the inner shell.

The tank is mounted on a concrete foundation 16 so constructed and arranged as to space the tank above the ground and permit circulation of air therebeneath.

A space of about three feet separates the inner and outer shells and this space is filled with finely divided dry insulating material 17. The container is equipped with automatic pressure and relief valves and rupture disks (numbered 18 as a group) to provide for safe operation.

A pipe 19 is provided for filling the tank with liquefied gas and discharging liquefied gas therefrom.

A circular row of equally spaced column-like members 20 located wholly within and extending from the bottom of the inner shell to the roof thereof assists in supporting the roof of such shell.

The inner shell and its contents are supported by two concentric circular rows of spaced wooden posts. The outer circular row of posts 21 is positioned directly below the cylindrical wall of the inner shell, while each post 22 of the inner circular row is placed directly below one of the roof supporting column-like members 20. These posts are so mounted that they are free to tilt radially with relation to the inner shell, as such shell expands and contracts due to temperature changes.

A vent pipe 23 extending upwardly through the inner shell bottom has its open upper end 24 located adjacent the roof of the inner shell. Vent pipe 23 and pipe 19 extend outwardly from the tank through a metal boot 25 which connects with the outer shell of the tank as shown in Figures 1, 2 and 3. These pipes parallel one another, are provided with expansion joints 26 and are encased in a jacket of sheet-like insulating material 27. The boot outside of such jacket is filled with finely divided insulating material 28. Pipes 19 and 23 connect with a liquefaction plant which is diagrammatically illustrated at 29.

When the construction of this storage tank was completed, it was cooled down with cold natural gas which was circulated through the inner shell thereof until such shell was believed to be cold enough to receive the cold liquefied natural gas to be stored.

At the end of such cooling down period, liquefied natural gas was very slowly run into the inner tank shell through the pipe 19 which serves both as inlet and outlet for the liquefied gas. After the bottom of the inner shell reached so low a temperature that some of the liquefied gas remained or collected at the bottom of the inner shell as a liquid, the flow of liquefied gas into the tank was gradually increased. When the liquefied gas had reached a depth of about one foot, the bottom of the inner shell ruptured and the liquefied gas which had been run into the tank was lost.

The ruptured bottom was repaired and the tank was then equipped with means for carrying out the method of this invention in order to insure that all parts of the inner shell structure cooled down slowly and uniformly to approximately the temperature of the liquefied gas to be stored, which is about −258° F.

The means for carrying out this method includes four coils 30–33 inclusive of ¾ inch copper pipe which were installed within the inner shell. Coil 30 extends circumferentially of the inner shell and is secured to the interior thereof just below its roof. Coil 31 is similarly placed around the interior of the inner shell about midway between its top and bottom. Coil 32 surrounds and is carried by the circular row of column-like members 20 adjacent the roof of the inner shell. Coil 33 surrounds and is supported by said column-like members 20 about midway between the roof and the bottom of the inner shell. Figures 4–7 inclusive are enlarged transverse sectional views of these coils and it will be seen from these views that coils 30 and 31 are secured to the inner face of the inner shell by bars 34 and U-shaped rods 35 and that coils 32 and 33 are secured to column-like members 20 by U-shaped rods 36 having their ends welded to certain of such column-like members.

Throughout the length of each coil, small holes (indicated by the numeral 37) of the order of .04 of an inch in diameter, are drilled. These holes are drilled at about one foot intervals and on a number of different axes, the choice depending on the portion of the coil within the inner shell and the portion of the shell structure the jets of precooling fluid issuing from such holes are designed to reach.

These holes are of such number and are so positioned as to cause the jets of precooling fluid issuing therefrom to contact all parts of the inner face of the inner shell and all parts of the shell structure such as supporting column-like members 20. Figs. 4 to 7 inclusive illustrate the approximate location and position of the jet openings or holes.

The coils are supplied with precooling fluid by means of copper pipe lines 38. Each of these pipe lines serves one coil and extends from such coil out through the roof of the inner shell and thence down through the insulation between the inner and outer shells to a common header 39 which is tapped off pipe 19; pipe 19 is the pipe by means of which liquefied gas is delivered to and withdrawn from the container.

Each pipe line 38, or that portion thereof within the boot, is equipped with a brass globe valve 40 and a low temperature pressure gauge 41 so that the volume or amount of precooling fluid delivered by each coil at any given time can be individually controlled. This arrangement is such that control of the coils is flexible and such that certain coils can be cut in or out in order to meet a situation wherein one portion of the inner shell structure cools more rapidly than other portions. In this way, it is possible to cut out any certain coil or coils to obtain the desired rate of cooling without undue or harmful temperature differences.

Pipe 19 runs from the liquefaction plant 29 through the boot and terminates within the inner shell near its bottom. A valve 42 between pipe

19 and header 39 enables liquid derived from the liquefaction plant, to be diverted from pipe 19 to header 39.

Vent 23, which extends through the boot, also connects with the liquefaction plant and serves to collect vapor or gas from the upper portion of the tank inner shell and conduct the same back to the liquefaction plant where it is either liquefied or discharged into the gas mains as gas.

The liquefaction plant receives raw natural gas through pipe 43 which extends from gas main 44 to the liquefaction plant. Vent gas and gas derived from the regasification of liquid derived from the container may be put into the gas mains through a pipe 45.

A number of thermocouples 46 which extend through openings in the outer shell, through the insulation 17 and contact the inner shell, are used to indicate or measure the temperature at various representative parts of the inner shell structure not only during the precooling period, but also during operation of the tank in service.

This cylindrical tank is designed to operate in conjunction with three spherical type storage tanks already in service storing liquefied natural gas for augmenting the city gas supply.

This natural gas has the following approximate analysis by volume:

	Per cent
Methane	85.15
Ethane	10.49
Propane	3.20
Butane	1.05
Pentane and higher	.11
Total	100.00

The liquid having the highest boiling point that can be obtained from this natural gas by proper adjustments of the liquefaction pressures and temperatures in the liquefaction plant is one having a boiling point at 2 pounds tank pressure of approximately −70° F. It was necessary, therefore, to slowly cool down this tank to about −30° F. before using this highest boiling point liquid in the precooling procedure. Since natural gas is continually vented from the three spherical tanks, it was decided to divide the precooling procedure into two stages, a first or gas stage and a second or liquid stage.

In order to obtain gas having the desired temperature for the first precooling stage, various amounts of the gas vented from the spherical tanks were mixed with city line gas. This gas mixture was first introduced at about 40° F. and at a rate of 25,000 cubic feet per hour. The temperature of the precooling gas was periodically lowered about 3° F. at a time by decreasing the amount of city line gas making up the precooling mixture, until the precooling gas eventually entered the precooling coils at about −70° F., the temperature of the highest boiling point liquid obtainable from the liquefaction plant.

Precooling gas was conveyed to the coils and forced in the form of jets through the small holes 37. These jets contacted substantially all parts of the interior of the inner shell structure.

The gas after absorbing heat from the inner shell structure was discharged back to the liquefaction plant through vent pipe 23.

The liquid used at the beginning of the second or liquid stage of precooling was a mixture consisting mainly of natural gasolines with an appreciable butane content and with very little of the other fractions. Only a very small amount of this liquid was produced but this was delivered to the coils and sprayed under pressure from the minute holes 37 in the coils to all parts of the interior surfaces of the inner shell structure.

It was found that when liquid instead of gas formed the precooling jets, the temperatures at the various parts of the inner shell structure became more nearly uniform, although temperature differences of as much as from 30–40° F. between different parts of the inner shell structure did exist. These temperature differences were probably caused by variations in the heat inflow in those portions of the inner shell structure containing the heavier metal sections and from those portions where the insulation thicknesses were greater and therefore the amount of stored heat larger.

The valves controlling the delivery of precooling liquid to the coils were regulated so that a temperature difference of no more than 50° F. existed at any given time between different parts of the inner shell structure. A temperature difference of 50° F. represents a stress of but approximately 10,000 pounds per square inch in the metal of the inner shell structure, so that such a temperature difference was considered safe. If one portion of the inner shell structure became too cold, the coil supplying cooling fluid to that portion was either adjusted or shut off until other portions of the inner shell structure were cooled to the temperature of such part.

After a stabilized condition was reached with the warmest liquid (the liquid having the highest boiling point) that could be produced in the liquefaction plant, adjustments in such plant were made so as to produce a liquid, the temperature (or boiling point) of which was not more than about 50° below the highest temperature of any portion of the inner tank shell structure. This liquid was then delivered to the coils and sprayed, by means of holes 37, onto all interior parts of the inner shell structure until another stabilized condition was reached.

This procedure was carried on or repeated until the liquid being introduced into the coils included all the fractions in this natural gas and was therefore at its lowest temperature or boiling point. By the time this condition was reached, a considerable quantity of liquid had accumulated in the bottom of the inner tank shell. This liquid, like the metal of the inner shell structure, was being continually cooled by the new liquid of lower boiling point which was being introduced into the coils. This was so because the new liquid which accumulated in the inner shell ran into and thus became part of the pool of liquid in the bottom of the inner tank shell and caused the newly introduced liquid of lower temperature to boil by the heat in the liquid forming the pool. This caused the liquid of the pool to become colder. In this way, the bottom of the inner shell was maintained at a very uniform temperature throughout.

After the precooling liquid had been reduced to its lowest temperature, it was also sprayed, by means of holes 37, onto all interior surfaces of the inner shell structure until a condition of equilibrium was approached where the heat coming in through the outer shell and the insulation, was just being absorbed by the boiling liquid within the inner shell.

When this condition was reached, liquefied natural gas was admitted to the tank through the liquid inlet pipe 19 as rapidly as it could be produced, until the tank was filled.

If the vent gas from the three spherical type tanks had not been available, refrigerated gas from the liquefaction plant could have been used in its place in the first or gas stage of precooling.

The temperature of the precooling liquid used in the second stage was lowered at intervals about 3° F., and, as in the first or gas stage, the maximum differential between the liquid entering the cooling coils and the warmest spot on the inner shell structure was held to a maximum of about 50° F. The temperature of the inner shell structure was lowered an average of about 8° F. every 24 hours. The entire precooling period consumed 40 days.

During normal operation of this cylindrical storage tank, heat continually flows from the atmosphere through the outer shell, through the insulation and into the inner shell. This heat causes evaporation of enough stored liquefied natural gas to maintain the normal storage temperature of about −258° F. The vent or evaporated gas is either recycled for liquefaction or is passed into the distribution lines after being elevated to the temperature of the gas in such lines. This is done by passing the gas through a heat exchanger countercurrent to steam. Although this tank has been in operation for some months, heat contained in the insulation continues to be removed very slowly and it will take about one year until a more or less constant temperature gradient is established between the inner and outer shells of the tank.

The precooling apparatus and the thermocouples form a permanent part of this cylindrical storage container so that precooling operations can be carried on at a future date, if necessary. The thermocouples are also useful, since they will indicate settling or other failures in the insulation.

In accordance with the provisions of the patent statutes, I have explained the principle and operation of my invention and there illustrated and described a typical commercial embodiment of the same. I desire, however, to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than herein illustrated and described.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In a method of precooling the inner metal shell of an insulated tank in order to condition the same to receive liquefied gas for storage, the steps which comprise conveying precooling fluid to the interior of such shell, directing jets of such precooling fluid into contact with substantially all interior parts of such shell structure, and periodically lowering the boiling point of the precooling fluid so conveyed, until the temperature of such inner shell structure approximates the desired storage temperature.

2. In a method of precooling the inner metal shell of an insulated tank in order to condition the same to receive liquefied gas for storage, the steps which comprise conveying precooling liquid to the interior of such shell, directing jets of such liquid into contact with substantially all interior parts thereof, gradually lowering the boiling point of the precooling liquid until the temperature of such inner shell structure closely approximates the desired storage temperature, and during such precooling procedure, varying the volume of precooling liquid delivered by certain of such jets as temperature differences appear in different parts of such shell structure.

3. In a method of precooling the inner metal

shell of an insulated tank in order to condition the same to receive liquefied natural gas for storage, the steps which comprise conveying precooling liquid to the interior of such shell, directing jets of such liquid into contact with substantially all interior parts thereof, periodically lowering the boiling point of such precooling liquid until the temperature of such inner shell structure closely approximates the desired storage temperature, and in maintaining a relatively low pressure within such shell by continuously removing gas from such shell.

4. In a method of precooling the inner metal shell of an insulated tank in order to condition the same to receive liquefied natural gas for storage, the steps which comprise directing into contact with substantially all interior parts of such shell, jets of gaseous precooling fluid having a temperature so near the prevailing ambient temperature that such jets will not cause harmful thermal shock or stress, gradually lowering the temperature of the gaseous precooling fluid until its temperature is within about 50° of the highest boiling point precooling liquid available, directing into contact with all such interior parts of such shell, jets of pre-cooling liquid, and periodically lowering the boiling point of the precooling liquid until its boiling point closely approximates the desired storage temperature.

5. In a method of precooling the inner ferrous metal shell of an insulated tank structure in order to condition the same to receive, without harmful thermal shock or stress, liquefied natural gas for storage, the steps which comprise directing jets of gaseous fluid into contact with substantially all interior parts of such shell, periodically lowering the temperature of such gaseous fluid until the temperature of such inner shell is within about 50 Fahrenheit degrees of the temperature of the highest boiling point liquid available for precooling, spraying substantially all interior parts of such inner shell with available precooling liquid having the highest boiling point, and periodically lowering the boiling point of such liquid until the temperature of such inner shell approximates the desired storage temperature.

6. In a method of precooling the inner metal shell structure of an insulated tank in order to condition the same to receive liquefied gas for storage, the steps which comprise directing into contact with substantially all interior parts of such shell, jets of liquid having a boiling point below but so near the temperature of such interior parts as not to cause harmful thermal shock or stress thereto, and periodically lowering the boiling point of the precooling liquid supplied to such jets until such boiling point closely approximates the desired storage temperature.

7. In a method of precooling the inner metal shell of an insulated tank in order to condition the same to receive liquefied gas for storage, the steps which include directing into contact with substantially all interior parts of such shell, jets of liquid having a boiling point below but so near the temperature of such interior parts as not to cause harmful thermal shock or stress thereto and continuing with the liquid of such boiling point until a stabilized condition is reached, producing a liquid having a lower boiling point than such last liquid and discharging jets of such liquid against all such interior parts until another stabilized condition is reached and in repeating such procedure until the temperature of such inner shell approximates the desired storage temperature.

8. A method as set forth in claim 6, in which the precooling liquid is produced in the same plant that liquefies the gas to be stored.

9. A method as set forth in claim 6, in which the precooling liquid is produced from the gas to be stored in the plant that liquefies such gas.

JAMES O. JACKSON.

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