Dec. 22, 1953 C. R. ANDERSON 2,663,166

METHOD OF AND APPARATUS FOR PUMPING LIQUEFIED GASES

Filed Aug. 22, 1949 2 Sheets-Sheet 1

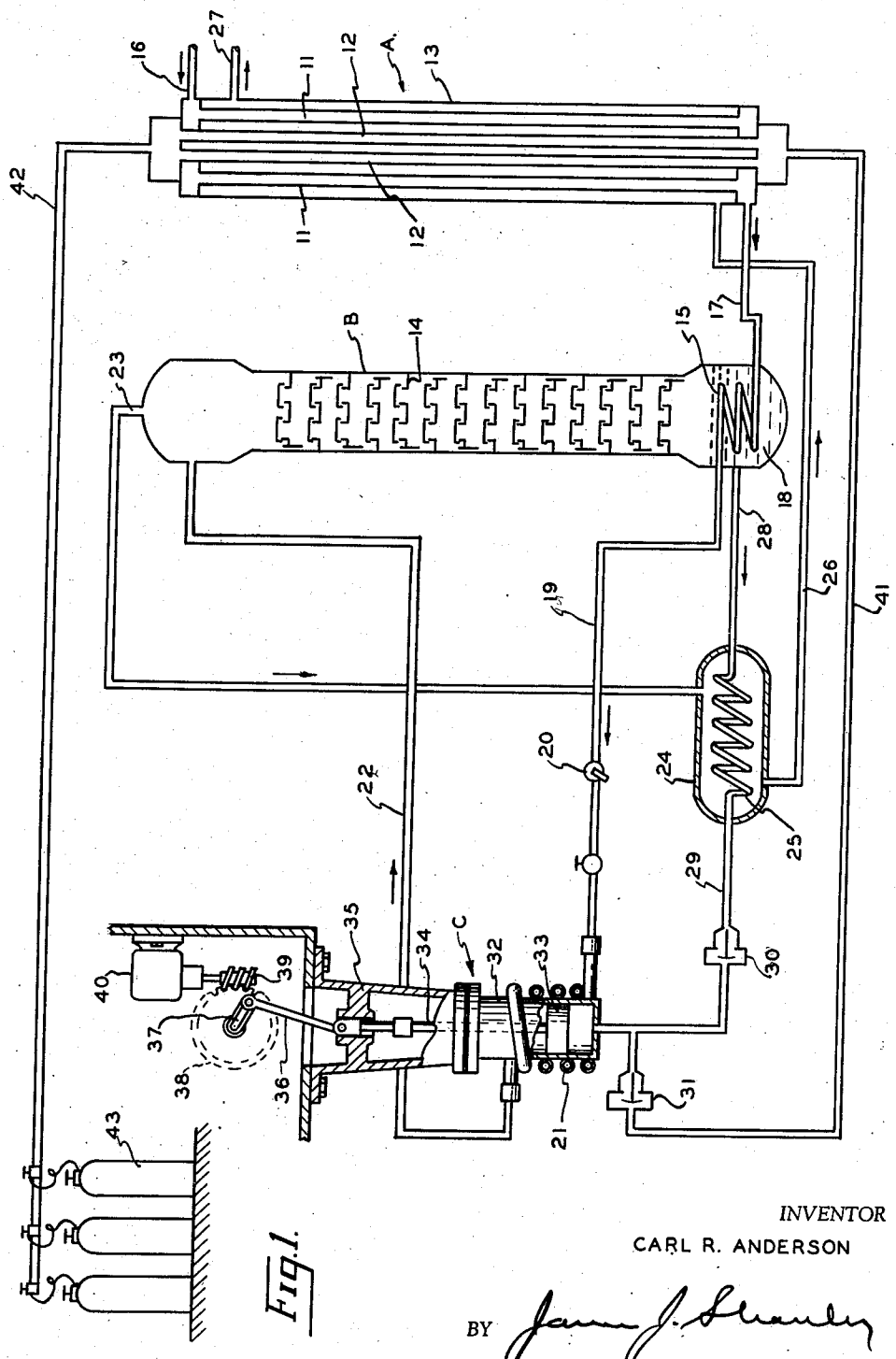


Fig. 1.

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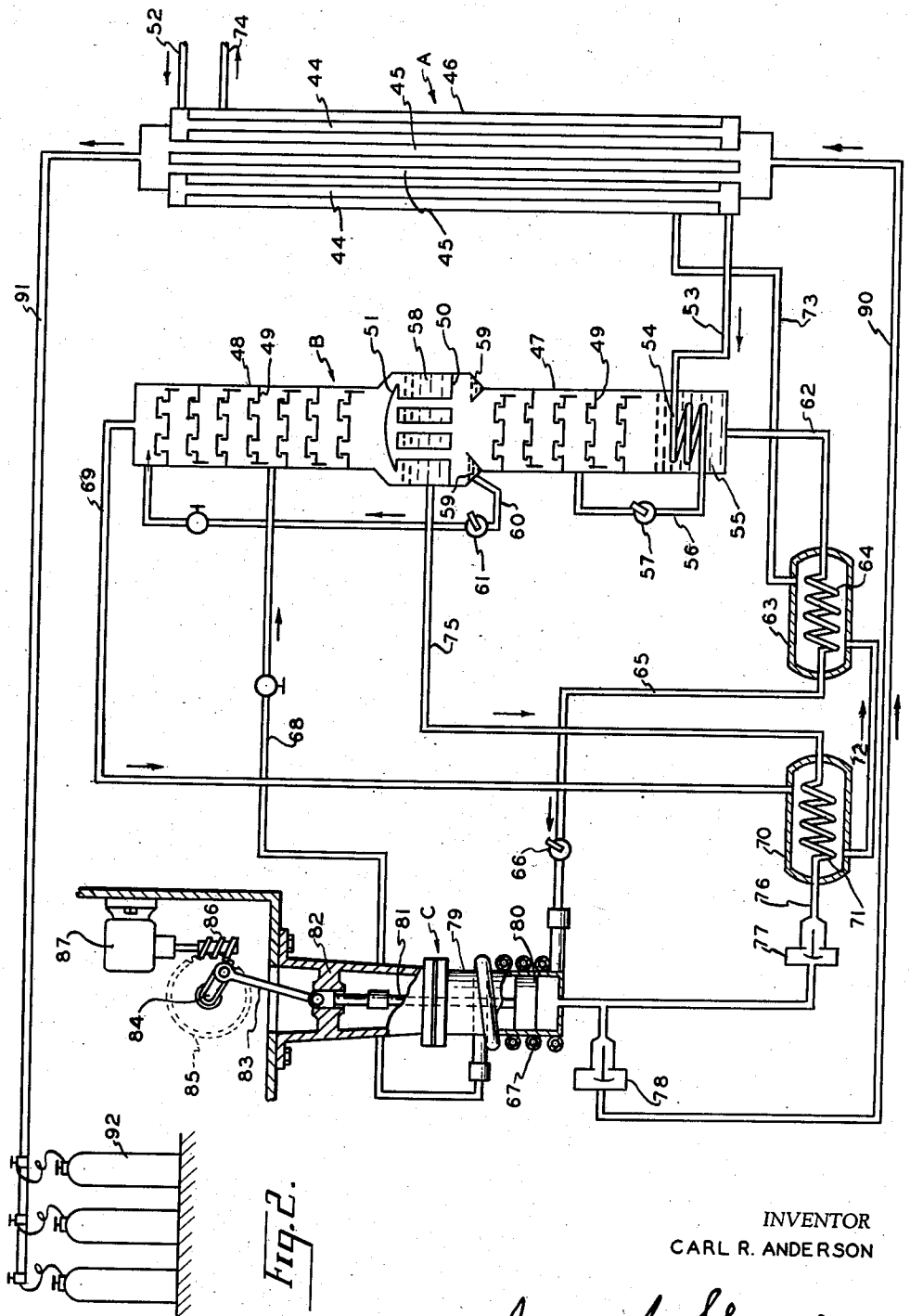


Fig. 2.

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METHOD OF AND APPARATUS FOR PUMPING LIQUEFIED GASES

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Application August 22, 1949, Serial No. 111,716

20 Claims. (Cl. 62—122)

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This invention relates to a method and apparatus for pumping liquefied gases from a gas separation operation.

This application is a continuation-in-part of my copending applications Serial No. 488,650, filed May 27, 1943, issuing as Patent No. 2,480,093 and Serial No. 605,407, filed July 16, 1945, issuing as Patent No. 2,480,094.

An important object of the invention is to provide a method and means for pumping a liquefied gas product from a fractionating operation utilizing colder fluids from the fractionating operation to prevent gas lock in the pumping step.

Another important object of the invention is to provide a method and means for pumping a stream of liquefied gas product of a fractionating operation utilizing a cold liquid from the fractionating operation to cool the pump.

A further important object of the invention is to provide a method and means for pumping liquefied oxygen directly from a pool of commercially pure oxygen in a fractionating tower to cylinders or pipe lines in which a cold gas is utilized to subcool the liquefied oxygen on the way to the pumping step and a relatively cold liquid from the fractionating operation is used to cool the pump.

A further important object of the invention is to provide a method and means for pumping natural gas in liquid phase from a fractionating system wherein it has been separated from its nitrogen content to cylinders or pipe lines in which it is transported under a high pressure, thereby avoiding the necessity for a gaseous compressing system.

While the invention is applicable to the handling of all liquefied gases (liquids having a boiling point so much below atmospheric temperature that heat leaking into insulated apparatus is likely to produce difficulties in pumping), it is found most useful in connection with the pumping of liquid oxygen because of the very low atmospheric pressure boiling point of this liquid. The invention will, therefore, be described in connection with the manipulation of oxygen, it being understood that such description is illustrative and not limiting.

If the oxygen product obtained in air fractionation were to be recovered as a gas at atmospheric temperature and pressure, it would merely be conducted in gaseous form to an interchanger, the pressure in the column being sufficient to discharge the gaseous product against frictional resistance and atmospheric pressure. It is, however, very desirable in many cases to conduct the oxygen product directly to the cylinder or pipe lines in which it is transported as a compressed gas, at pressures ranging up to 2500 or more pounds per square inch. Although it is common practice to bring the gaseous oxygen to substantially atmospheric temperature and pressure and to thereafter compress it, it is desirable to pump it as a liquid and to vaporize it while subjected to the raised pressure, prior to entering the pipe line or storage vessel.

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An advantage in pumping the oxygen in liquid phase lies in the avoidance of use of the aqueous lubricants required in compressing oxygen, these lubricants introducing water vapor which must be removed by chemical drying and adsorption to obtain dry oxygen in the transport cylinders or pipe line.

The step of pumping liquid oxygen has proven in practice to be one of great difficulty. The liquid is, in the nature of the case, at its boiling point at the existing pressure. From this, it follows that any reduction in pressure, such as is occasioned by fluid friction in the pump suction, or any increase in enthalpy due to leakage into the pump body or to frictional heat transmitted into the liquid, will cause the evolution of gas which locks the suction and puts the pump out of commission. A further cause of vapor lock is back leakage through the discharge valve, the high pressure leakage liquid partially flashing to the gaseous state.

I have solved this problem by two steps which are preferably used together but may be used individually. The first is to utilize a small portion of the cooling effect available in a colder fluid from the fractionating operation for cooling the stream of liquid oxygen, on its way to the pump, to a temperature below that corresponding to its boiling point at the pressure existing in the pump cylinder during the suction stroke. The second is to utilize a portion of the refrigerating value of a cold liquid from the fractionating operation in cooling the pump cylinder. In the attached drawings, the invention is illustrated schematically in two modifications, to wit:

Figure 1 illustrates a form in which oxygen in the liquid state is pumped from the pure oxygen pool of a single fractionating column and the stream is cooled below its boiling point at the pressure existing in the pump cylinder during the suction stroke by heat exchange against gaseous product nitrogen from the top of the column, and in which the pump cylinder is cooled

by heat exchange against the liquefied air feed stream.

Figure 2 illustrates a form in which oxygen is withdrawn in the liquid state from the pure oxygen pool in the base of the lower pressure section of a double fractionating column and is cooled below its boiling point at the pressure existing in the pump cylinder during the suction stroke by heat exchange against gaseous product nitrogen from the low pressure stage of the column, and in which the pump cylinder is cooled by heat interchange with expanded crude oxygen in its passage from the high pressure to the low pressure stage of the column.

The fractionating equipment illustrated is conventional, and any preferred form of either single or double fractionating column may be used.

Referring to the drawings, the system shown in Fig. 1 includes a heat interchanger A having two banks of tubes 11, 11 and 12, 12 within an outer shell 13 to provide three passageways therethrough in heat exchange relationship with one another. A single stage fractionating column B is provided with a plurality of bubbling plates 14 and a boiling coil 15 in the base thereof. Compressed air enters the interchanger A through feed pipe 16, passes through tubes 11, 11 and then through conduit 17 to the boiling coil 15 submerged in a pool of boiling oxygen 18 in the base of the column. The feed air is liquefied therein by giving up heat to the boiling liquid in the pool 18. The liquefied stream flows through conduit 19 and expansion valve 20 wherein it is expanded to the pressure existing in the fractionating column B. The expanded liquid air stream then flows to the coil 21 wrapped in heat exchange relationship around the cylinder of the pump C. In flowing through the coil 21, the liquid air stream prevents rise in temperature of the liquid in the pump to a point at which vapor would be evolved in the cylinder and tends to maintain the low temperature imparted to the liquid in a prior subcooling step to be described. From the coil 21, the air flows through conduit 22 to the top of the column. In place of the coil 21, a cooling jacket could be used for conducting the liquefied feed air stream in heat exchange with the pump cylinder.

Flowing downwardly through the column, the feed air is fractionated in the well-known manner into a pure liquid oxygen product collecting in the pool 18 at the base of the column and into an impure gaseous nitrogen leaving the top of the column through conduit 23. Conduit 23 conducts the nitrogen product from the top of the column to a passageway through a heat interchanger 24 which surrounds a coil therein. Conduit 26 conducts the nitrogen from this passageway to the shell of interchanger A from whence it is vented through conduit 27. In flowing through the passageway of interchanger 24, the gaseous nitrogen stream is in heat exchange relation with coil 25.

The pure oxygen collecting in the pool 18, by nature of the operation at its boiling point, is removed from the column in liquid form through conduit 28 and flows through coil 25 of heat interchanger 24. Coil 25, as previously described, is in heat exchange relation with the gaseous nitrogen flowing in the space surrounding it, and the liquid oxygen flowing through the coil 25 is cooled therein to a temperature sufficiently below its boiling point so that there will be substantially no flashing of the oxygen into vapor under the pressures encountered in the subsequent pumping operation. The subcooled stream of oxygen flows through conduit 29 to the oxygen pump C.

The oxygen pump indicated generally by the letter C may be any pump capable of handling liquids at high pressures but is here illustrated as a single acting plunger pump having a suction valve 30, a discharge valve 31, a cylinder 32, a plunger 33, a rod 34, a cross head 35, a connecting rod 36, a crank 37, a driven gear 38, a driving worm gear 39 and an actuating motor 40. The subcooled stream of oxygen flows through conduit 29 and suction valve 30 into the pump cylinder on the upstroke of the plunger 33. On the down stroke, the liquid passes through discharge valve 31 and conduit 41 to the interchanger 10 flowing through the tubes 12 in which the stream is brought to atmospheric temperature and gaseous condition. The gas is discharged at any desired pressure through conduit 42. If desired, the stream in conduit 41 could be directed to a storage vessel in the liquid condition but usually it will be passed through the interchanger 10 and delivered by conduit 42 to pressure cylinders 43 or other pressure vessels or to pipe lines in which it is transported under pressure.

By the use of this cooling cycle, a properly designed and insulated pump may be caused to operate at full stroke capacity for extended periods and without any risk whatever of gas locking. The refrigerative value lost by the nitrogen in cooling the liquid oxygen is largely recovered in the evaporation of the oxygen in the interchanger. The heat absorbed by the liquefied feed air from the pump, which is due mainly to heat leakage from the atmospheric and packing friction, causes a small loss of refrigerating effect which may be compensated by a correspondingly slight increase in air feed pressure.

In the form of the invention shown in Figure 2, heat interchanger A is provided with two banks of tubes 44, 44 and 45, 45 within an outer shell 46 to provide three passageways therethrough in heat exchange relationship. The fractionating column, indicated generally by reference character B, consists of a high pressure section 47 and a low pressure section 48, each supplied with a stack of bubbling plates 49 separated by a partition 50 which includes the conventional downwardly draining condenser 51, the condensate from which drains into the high pressure section of the column 47. Compressed air enters the interchanger A through feed pipe 52, passes through tubes 44, 44 and then through conduit 53 to boiling coil 54 submerged in a pool of boiling crude oxygen 55 in the base of the high pressure section. The air flows from the coil 54 through conduit 56 and expansion valve 57 into the high pressure section of the column at a medial height. In this section of the column, the feed air is fractionated into a substantially pure gaseous nitrogen rising into the condenser 51 which is immersed in a pool of boiling pure oxygen 58 collecting in the base of the low pressure section of the column. As the upper section of the column is maintained at a materially lower pressure than the lower section, the condenser acts as a reboiler for the pure oxygen surrounding it. As a result, the nitrogen rich gas rising in the condenser is liquefied, part falling into the pool 59 and part falling onto the top plate of the lower section 47 where it acts as reflux for the lower section. Liquefied nitrogen from pool 59 is transferred through conduit 60 and expansion valve 61 to the top of the upper

section in which it acts as reflux. The crude oxygen product formed in the high pressure section of the column collects in the pool 55 in the base of the column.

As shown in this form of the invention, the crude oxygen collecting in the pool 55 may be utilized after expansion to cool the cylinder of the pump C before passing to the lower pressure section of the column. This is accomplished by withdrawing the crude oxygen through conduit 62 and passing it through interchanger 63, to be described hereinafter, and conduit 65 to expansion valve 66 and thence through the cooling coil 67 surrounding the oxygen pump C. From the cooling coil 67, which has the same purposes and functions as coil 21 in Fig. 1, the crude oxygen flows through conduit 68 into the low pressure section of the column at a medial height therein.

The high pressure nitrogen stream and the high pressure oxygen stream flowing into the low pressure section of the column are fractionated in the well-known manner to substantially pure oxygen and a slightly impure nitrogen product. The nitrogen product in gaseous form is withdrawn through conduit 69 at the top of the low pressure section of the column and is conducted to a passageway through the interchanger 70 surrounding a coil 71 therein where it passes in heat exchange relation with the coil 71. From the interchanger 70, the gaseous nitrogen flows through the shell of interchanger 63 wherein it cools the crude oxygen product on its way to the pump cooling coil. From the shell of the interchanger 63, the gaseous nitrogen flows through conduit 73 to the shell of the interchanger 10 where it gives up the remainder of its cold to the feed air, leaving the interchanger 10 through conduit 75. The pure oxygen product formed in the low pressure section of the column collects in the pool 56 at the lower end thereof and is removed in liquid form through conduit 75 and passes through the coil 71 in interchanger 70 wherein it is subcooled by heat interchange with the gaseous nitrogen stream flowing in the space surrounding the coil 71 in the interchanger 70. The liquid oxygen flowing through the coil 71 is thus cooled to a temperature sufficiently low so that there will be substantially no flashing of the oxygen into vapor during the subsequent pumping operation.

From the interchanger 70, the pure oxygen product flows through conduit 76 to the suction valve 77 of the liquid oxygen pump C wherein the stream is pumped to the desired pressure. The oxygen pump C may be any pump capable of handling a liquid at high pressure but is here illustrated as a single acting plunger pump having a suction valve 77, a discharge valve 78, a cylinder 79, a plunger 80, a rod 81, a crosshead 82, a connecting rod 83, a crank 84, a driven gear 85, a driving worm gear 86 and an actuating motor 87. The subcooled stream of oxygen flows through conduit 76 and suction valve 77 into the pump cylinder on the upstroke of the plunger 80. During its flow into and from the pump cylinder, the stream of liquid oxygen is prevented from rising in temperature to a point at which vapor would evolve under the conditions present, by the liquid flowing through the coil 67 surrounding the pump cylinder, as previously described with respect to coil 21. On the down stroke of the pump plunger, the liquid oxygen passes through the discharge valve 78 and flows through conduit 90 to the tubes 45, 45 of interchanger A in which the stream is brought to atmospheric temperature and gaseous condition and is discharged at any desired pressure through conduit 91. If desired, the stream in conduit 90 may be directed to a storage vessel or pipe line in liquid condition, but usually it will be passed through the interchanger and delivered by conduit 91 to the pressure cylinders 92 or other pressure vessels or to pipe lines in which it is transported under pressure in a gaseous state. Here again, the refrigerative value lost by the nitrogen in cooling the liquid oxygen is largely recovered in the evaporation of the oxygen in the interchanger A. The heat absorbed by the crude oxygen in cooling the pump cylinder, due mainly to packing friction and infiltration from the atmosphere, causes a small loss of refrigerating effect which may be compensated by corresponding adjustments in the air feed pressure.

Heat interchanger 63 through which product nitrogen passes on its way to the main interchanger A subcools the crude oxygen on its way from the high pressure stage to the low pressure stage. The use of such an interchanger is conventional, its purpose being to subcool the crude oxygen so as to reduce as far as possible the amount of flashing taking place when the crude oxygen is expanded. This interchanger 63 can be omitted from applicant's cycle without deleteriously affecting the pump cooling operation.

The cycles disclosed in the present application and in the applications of which the present application is a continuation-in-part can be utilized in handling any mixture of low boiling point gases where there is a tendency for vapor lock in the pump. An especially useful application of these cycles is in the treatment of natural gas to remove liquefied petroleum gas fractions such as ethane, propane, butane, etc., normally referred to as L. P. G. Even so-called dry natural gas, when subjected to a refrigeration cycle and fractionation, will produce appreciable quantities of L. P. G. Natural gas is also treated by refrigeration and fractionation to remove nitrogen. The nitrogen in natural gas is a diluent which raises the cost of transporting the gas in pipe lines. In either case, the natural gas is taken from the well for treatment, either at the formation pressure, when it is high enough or, if not, the gas is subjected to compreession. The gas under compression is cooled and expanded and the effluent subjected to fractionation to remove the nitrogen as overhead in one case and to remove the L. P. G. as bottom product in the other case.

The cycle of the present invention is readily adaptable to the foregoing treatment of natural gas. Natural gas under formation pressure or from compressors enters the system through 16, is cooled in heat interchanger A and passes, as has been described in the case of the air, through the remainder of the system. The bottom product corresponding to the pure oxygen is taken off in liquid form and its pressure raised to the desired storage or transportation pressure by pumping it in pump C in liquid phase. In the case where the bottoms are natural gas, with or without L. P. G. as constituents, the pressure on the liquid product is raised in pump C to above pipe line pressure which in some instances may be as high or higher than 1000 pounds per square inch. The liquid under this pressure passes from pump C through heat interchanger A, giving up its cold to the incoming natural gas and nitrogen and at the same time being vaporized.

Utilization of the present system for handling

natural gas results in great savings in compressor equipment where the pressure in the fractionating operation is appreciably below the pipe line pressure.

Where the recovery of L. P. G. from natural gas is to be effected utilizing the present invention, the cooling of the natural gas, under formation pressure or from compressors, results in the formation of a liquefied fraction containing the L. P. G. as components. In fractionator B, the L. P. G. are separated as final liquid product corresponding to the oxygen in the air fractionating system, and this liquid product is pumped to storage in the liquid phase in pump C. As in the treatment of air, fluids from the fractionator colder than the liquid product being pumped are used to prevent vapor lock of the pump.

I claim:

1. In combination with a fractionating apparatus for separating a mixture of low boiling point gases, a pump adapted to handle liquids, a conduit connecting the suction of the pump with a relatively warm liquid product collecting space in the apparatus, a heat interchanger interposed in the conduit, means for conducting a stream of a relatively cold fluid from the apparatus through the interchanger in heat exchange relation with the relatively warm liquid product for forming a subcooled liquid product flowing toward the pump, heat transfer means associated with the liquid-conveying end of the pump, means for passing a second relatively cold fluid in liquid form from the apparatus through the said heat transfer means, and means for conducting second relatively cold fluid from the heat transfer means to the apparatus.

2. In combination with an apparatus producing liquid oxygen product and a gaseous nitrogen-rich product, a liquid oxygen pump, means for bringing a stream of fluid from the liquid oxygen product from the apparatus into heat interchange relation with a fluid from the apparatus colder than the oxygen and thereby cooling the oxygen stream, means for conveying the cooled oxygen stream to the pump, means for producing heat interchange between the pump and a second relatively cold fluid in liquid form from the apparatus, and means for returning second relatively cold fluid from the heat interchange with the pump to the apparatus.

3. In combination with a fractionating column wherein a compressed and cooled mixture of low boiling gases is fractionated thereby producing a liquid higher boiling fraction as a product, a pump adapted to the pumping of liquids, a conduit connecting the pump with the liquid higher boiling fraction collecting space in the column, heat transfer means in heat transfer relation with the liquid-conveying end of the pump, means for passing a fluid colder than the liquid higher boiling fraction in liquid form from the column through the said heat transfer means, and means for returning last-named liquid from the heat transfer means to the column.

4. In combination with a fractionating column wherein a compressed and cooled mixture of low boiling gases is fractionated thereby producing a liquid higher boiling fraction as a product, a pump adapted to the pumping of liquids, a conduit connecting the suction of the pump with the liquid higher boiling fraction collecting space in the column, heat transfer means associated with the liquid conveying end of the pump, means for passing a stream of expanded liquefied feed mixture through the said heat transfer means, and means for conducting feed mixture from the heat transfer means to the column.

5. In combination with an air fractionating column in which compressed and cooled air is fractionated in two stages maintained respectively at a relatively high and a relatively low pressure, in which a product enriched in nitrogen and a product enriched in oxygen are produced in the high pressure stage and transferred to the low pressure stage and in which a cold nitrogen product and a liquid oxygen product having a temperature corresponding to its boiling point at the low pressure are produced in the low pressure stage, a pump adapted to the pumping of liquids, a conduit connecting the suction of the pump with the liquid oxygen collecting space in the low pressure stage of the column, heat transfer means in heat exchange relation with the liquid conveying end of the pump, means for passing expanded liquid product enriched in oxygen from the high pressure stage of the column through the said heat transfer means and, means for conducting liquid product enriched in oxygen from the heat transfer means into the low pressure stage of the column.

6. In combination with an air fractionating column in which compressed and cooled air is fractionated in two stages maintained respectively at a relatively high and a relatively low pressure, in which a product enriched in nitrogen and a product enriched in oxygen are produced in the high pressure stage and transferred to the low pressure stage and in which a gaseous nitrogen product and a liquid oxygen product having a temperature corresponding to its boiling point at the low pressure are produced in the low pressure stage, a pump adapted to the pumping of liquids, a conduit connecting the suction of the pump with the liquid oxygen collecting space in the low pressure stage of the column, a heat interchanger interposed in the conduit, means for directing a stream of fluid from the column colder than the liquid oxygen through the interchanger in heat exchange relation with the liquid oxygen flowing through the conduit toward the pump, heat transfer means associated with the liquid conveying end of the pump, means for passing expanded liquid product enriched in oxygen from the high pressure stage of the column through the said heat transfer means and means for conducting product enriched in oxygen from the heat transfer means into the low pressure stage of the column.

7. In combination with a fractionating column wherein a compressed and cooled mixture of low boiling gases is fractionated thereby producing a liquid higher boiling fraction and a gaseous lower boiling fraction as products, a pump adapted to the pumping of liquids, a conduit connecting the suction of the pump with the liquid higher boiling fraction collecting space in the column, a heat interchanger interposed in the conduit, means for directing a stream of relatively cold fluid from the column through the interchanger in heat exchange relation with the liquid higher boiling fraction flowing through the conduit toward the pump, heat transfer means associated with the liquid conveying end of the pump, means for passing a stream of expanded liquefied feed mixture through the said heat transfer means, and means for conducting expanded liquefied feed mixture from the heat transfer means to the column.

8. The method which comprises withdrawing a stream of higher boiling fraction from a frac-

tionating operation in which a mixture of low boiling gases is separated into a liquid higher boiling fraction product and a gaseous lower boiling fraction product, effecting a heat interchange between the stream of higher boiling fraction and a cold fluid stream from the fractionating operation which is colder than the stream of higher boiling fraction to reduce the temperature of the higher boiling fraction to a point below the boiling point of the higher boiling fraction at the minimum momentary pressure reached in an ensuing pumping step, pumping the cooled stream of higher boiling fraction in substantially liquid form, withdrawing a second fluid stream from the fractionating operation in liquid phase, expanding the second fluid stream to a pressure such that the expanded second fluid stream has a temperature below the boiling point of the liquid higher boiling fraction at the minimum momentary pressure reached in the pumping step, maintaining the liquid higher boiling fraction being pumped below its boiling point during the pumping step by effecting a heat interchange between the pump and a stream of expanded second fluid in liquid phase, and passing expanded second fluid from the heat interchange with the pump to the fractionating operation.

9. The method which comprises withdrawing a stream of liquid product at its boiling temperature from a collecting zone in a fractionating operation in which a mixture of low boiling gases is separated into a liquid product and a gaseous product, effecting a heat interchange between the stream of liquid product and a cold fluid stream from the fractionating operation which is colder than the stream of liquid product to reduce the temperature of the liquid product to a point below the boiling point of the liquid product at the minimum momentary pressure reached in an ensuing pumping step, pumping the cooled stream of liquid product in substantially liquid form, withdrawing a second fluid stream from the fractionating operation in liquid phase, expanding the second fluid stream to a pressure such that the expanded fluid stream has a temperature below the boiling point of the liquid product at the minimum momentary pressure reached in the pumping step, maintaining the liquid product being pumped below its boiling point during the pumping step by effecting a heat interchange between the pump and a stream of expanded second fluid in liquid phase, and passing expanded second fluid from the heat interchange with the pump to the fractionating operation.

10. In a method wherein a compressed and cooled mixture of low boiling gases is fractionated in an operation producing liquid and gaseous products, the steps comprising subjecting a relatively warm liquid product of the fractionation to heat exchange with a colder fluid from the fractionation to reduce the temperature of the liquid product to a point below the boiling point of the liquid product at the minimum momentary pressure reached in an ensuing pumping step and thereby forming a subcooled liquid product, pumping such subcooled liquid product to a desired higher pressure, withdrawing a second fluid stream from the operation in liquid phase, expanding the second fluid stream to a pressure such that the expanded fluid stream has a temperature below the boiling point of the liquid product at the minimum momentary pressure reached in the pumping step, maintaining the liquid product being pumped below its boiling point during the pumping step by subjecting the pump to heat exchange with a stream of expanded second fluid in liquid phase, passing expanded second fluid from the heat exchange with the pump to the operation, and converting the pumped liquid product at the higher pressure into a gas by heat exchange with the compressed mixture to be fractionated.

11. In the conduct of a multistage fractionating operation, the steps comprising, withdrawing a stream of the higher boiling fraction from the low pressure stage of the operation, bringing the stream into heat interchange against another colder fluid stream from the fractionating operation to reduce the temperature of the higher boiling fraction to a point below the boiling point of the higher boiling fraction at the minimum momentary pressure reached in an ensuing pumping step, pumping the cooled higher boiling fraction in substantially liquid form, withdrawing a second fluid stream from the fractionating operation in liquid phase, expanding the second fluid stream to a pressure such that the expanded fluid stream has a temperature below the boiling point of the higher boiling fraction at the minimum momentary pressure reached in the pumping step, maintaining the higher boiling fraction being pumped below its boiling point during the pumping step by effecting a heat interchange between the pump and a stream of expanded second fluid in liquid phase, and passing expanded second fluid from the heat interchange with the pump to the fractionating operation.

12. In a method wherein a compressed and cooled mixture of low boiling gases is fractionated in an operation producing liquid higher boiling fraction and gaseous lower boiling fraction as products, the steps comprising withdrawing a stream of the higher boiling fraction product from the fractionating operation, pumping the stream of higher boiling fraction product in substantially liquid form, expanding a stream of liquid feed mixture to be fractionated to a pressure such that the expanded feed mixture has a temperature below the boiling point of the liquid higher boiling fraction at the minimum momentary pressure reached in the pumping step, maintaining the liquid higher boiling fraction being pumped below its boiling point during the pumping step by effecting a heat interchange between the pump and a stream of expanded liquid feed mixture, and passing expanded feed mixture from the heat interchange with the pump to the operation.

13. In a method wherein a compressed and cooled mixture of low boiling gases is fractionated in an operation producing liquid higher boiling fraction and gaseous lower boiling fraction as products, the steps comprising withdrawing a stream of the higher boiling fraction product from the fractionating operation, subjecting the stream of higher boiling fraction to heat exchange with a colder fluid from the fractionating operation to reduce the temperature of the higher boiling fraction to a point below the boiling point of the higher boiling fraction at the minimum momentary pressure reached in an ensuing pumping step and thereby forming a subcooled liquid higher boiling fraction stream, pumping the subcooled liquid higher boiling fraction stream to a desired higher pressure, expanding a stream of liquid feed mixture to be fractionated to a pressure such that the expanded feed mix-

ture has a temperature below the boiling point of the liquid higher boiling fraction at the minimum momentary pressure reached in the pumping step, maintaining the liquid higher boiling fraction being pumped below its boiling point during the pumping step by effecting a heat interchange between the pump and a stream of expanded liquid feed mixture, and passing expanded liquid feed mixture from the heat interchange with the pump to the operation.

14. In a method for producing oxygen and conditioning it for delivery to a receiving means, in which compressed and cooled air is rectified in two stages maintained respectively at a relatively high and a relatively low pressure, in which a product enriched in nitrogen and a product enriched in oxygen are produced in the high pressure stage and transferred to the low pressure stage and in which a cold nitrogen product and a liquid oxygen product having a temperature corresponding to its boiling point at the low pressure are produced in the low pressure stage, the steps comprising withdrawing a stream of the liquid oxygen product from the low pressure stage of the column, pumping the oxygen stream in substantially liquid form, withdrawing a stream of liquid product enriched in oxygen from the high pressure stage, expanding the stream of liquid product enriched in oxygen to a pressure such that the expanded liquid product enriched in oxygen has a temperature below the boiling point of the liquid oxygen product at the minimum momentary pressure reached in the pumping step, maintaining the liquid oxygen product being pumped below its boiling point during the pumping step by passing a stream of expanded liquid product enriched in oxygen in heat interchange with the pump, and passing product enriched in oxygen from heat exchange with the pump into the low pressure stage.

15. In a method for producing oxygen and conditioning it for delivery to a receiving means, in which compressed and cooled air is fractionated in an operation including two stages maintained respectively at a relatively high and a relatively low pressure, in which a product enriched in nitrogen and a liquid product enriched in oxygen are produced in the high pressure stage and transferred to the low pressure stage and in which a cold nitrogen product and a liquid oxygen product having a temperature corresponding to its boiling point at the low pressure are produced in the low pressure stage, the steps comprising withdrawing a stream of the liquid oxygen product from the low pressure stage, effecting a heat interchange between the oxygen stream and another cold fluid stream from the fractionating operation which is colder than the oxygen stream to reduce the temperature of the oxygen stream to a point below the boiling point of the liquid oxygen product at the minimum momentary pressure reached in an ensuing pumping step, pumping the cooled oxygen stream in substantially liquid form, withdrawing a stream of liquid product enriched in oxygen from the high pressure stage, expanding the stream of liquid product enriched in oxygen to a pressure such that the expanded liquid product enriched in oxygen has a temperature below the boiling point of the liquid oxygen product at the minimum momentary pressure reached in the pumping step, maintaining the liquid oxygen product being pumped below its boiling point during the pumping step by effecting a heat interchange between the pump and a stream of expanded liquid product enriched in oxygen, and passing expanded liquid product enriched in oxygen from the heat interchange with the pump into the low pressure stage.

16. The method of transferring the liquefied product obtained in the treatment of natural gas to reduce its nitrogen content, in which treatment a compressed and cooled nitrogen-containing natural gas is expanded and the effluent of the expansion step subjected to a fractionating operation to produce a liquefied natural gas fraction and a gaseous nitrogen fraction, comprising withdrawing a stream of the liquefied natural gas fraction from the fractionating operation, pumping the stream of liquefied natural gas fraction in substantially liquid form, and maintaining the liquefied natural gas fraction being pumped below its boiling point during the pumping step by passing a relatively cold fluid stream from the fractionating operation in heat interchange with the pump, the relatively cold fluid stream being at a temperature below the boiling point of the liquefied natural gas fraction at the minimum momentary pressure reached in the pumping step.

17. The method of transferring the liquefied product obtained in the treatment of natural gas to reduce its nitrogen content, in which treatment a compressed and cooled nitrogen-containing natural gas is expanded and the effluent of the expansion step subjected to a fractionating operation to produce a liquefied natural gas fraction and a gaseous nitrogen fraction, comprising withdrawing a stream of liquefied natural gas fraction from the fractionating operation, effecting a heat interchange between the liquefied natural gas fraction stream and another cold fluid stream from the fractionating operation which is colder than the liquefied natural gas fraction stream to reduce the temperature of the liquefied natural gas fraction stream to a point below the boiling point of the liquefied natural gas fraction at the minimum momentary pressure reached in an ensuing pumping step, pumping the cooled liquefied natural gas fraction stream in substantially liquid form, maintaining the liquefied natural gas fraction being pumped below its boiling point during the pumping step by effecting a heat interchange between the pump and a relatively cold fluid stream from the fractionating operation, the relatively cold fluid stream being at a temperature below the boiling point of the liquefied natural gas fraction at the minimum momentary pressure reached in the pumping step, and passing relatively cold fluid from the heat interchange with the pump to the fractionating operation.

18. The method of transferring the liquefied product obtained in the treatment of natural gas to reduce its nitrogen content, in which treatment a compressed and cooled nitrogen-containing natural gas is expanded and the effluent of the expansion step subjected to a fractionating operation to produce a liquefied natural gas fraction and a gaseous nitrogen fraction, comprising withdrawing a stream of liquefied natural gas fraction from the fractionating operation, effecting a heat interchange between the liquefied natural gas fraction stream and another cold fluid stream from the fractionating operation which is colder than the liquefied natural gas fraction stream to reduce the temperature of the liquefied natural gas fraction to a point below the boiling point of the liquefied natural gas fraction at the minimum momentary pressure

reached in an ensuing pumping step, pumping the cooled liquefied natural gas fraction stream in substantially liquid form, maintaining the liquefied natural gas fraction being pumped below its boiling point during the pumping step by effecting a heat interchange between the pump and a relatively cold fluid stream from the fractionating operation in liquid phase, the relatively cold fluid stream being at a temperature below the boiling point of the liquefied natural gas fraction at the minimum momentary pressure reached in the pumping step, and passing relatively cold fluid from the heat interchange with the pump to the fractionating operation.

19. In a method wherein a compressed and cooled mixture of low boiling gases is fractionated thereby producing a liquid product and a gaseous product, the steps comprising withdrawing a stream of the liquid product at its boiling temperature from a collecting zone in the fractionating operating, pumping the stream of liquid product in substantially liquid form, withdrawing a second fluid stream from the fractionating operation in liquid phase, expanding the second fluid stream to a pressure such that the expanded second fluid stream has a temperature below the boiling point of the liquid product at the minimum momentary pressure reached in the pumping step, maintaining the liquid product being pumped below its boiling point during the pumping step by effecting a heat exchange between the pump and a stream of expanded second fluid in liquid phase, and passing expanded second fluid from the heat exchange with the pump to the fractionating operation.

20. In a method wherein a compressed and cooled mixture of low boiling gases is fractionated thereby producing a liquid product and a gaseous product, the steps comprising withdrawing a stream of the liquid product at its boiling temperature from a collecting zone in the fractionating operation, subjecting the stream of higher boiling fraction to heat exchange with a stream of the gaseous product to reduce the temperature of the liquid product to a point below the boiling point of the liquid product at the minimum momentary pressure reached in an ensuing pumping step and thereby forming a subcooled liquid product stream, pumping the subcooled liquid product stream to a desired higher pressure, expanding a stream of liquid feed mixture to be fractionated to a pressure such that the expanded feed mixture has a temperature below the boiling point of the liquid product at the minimum momentary pressure reached in the pumping step, maintaining the liquid product being pumped below its boiling point during the pumping step by effecting a heat interchange between the pump and a stream of expanded liquid feed mixture, and passing expanded feed mixture from the heat interchange with the pump to the fractionating operation.

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