

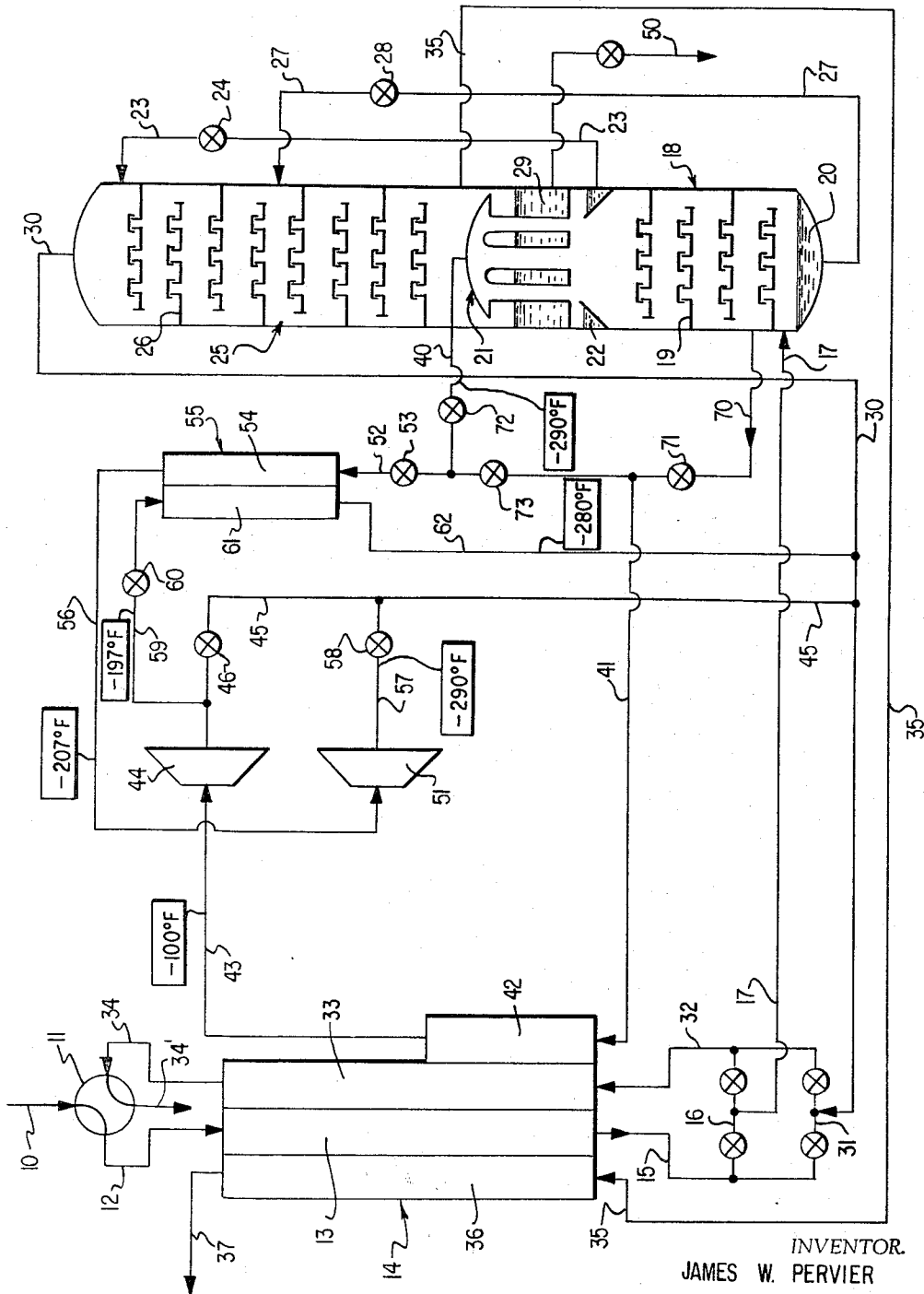
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REFRIGERATION SYSTEM FOR GAS LIQUEFACTION

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REFRIGERATION SYSTEM FOR GAS LIQUEFACTION

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This invention relates to refrigeration and more particularly to a refrigeration process employing a plurality of work expansion stages.

Quite frequently it is desirable to provide a process for producing variable levels of refrigeration. For example, in the separation of gaseous mixture, the process may be operated to produce components of the gaseous mixture in gaseous phase and it may be desirable at times to produce components in liquid phase. The different refrigeration requirements for such performance have been difficult to achieve with efficiency by an internal refrigeration cycle which is preferred because of simplicity and low capital expense.

It is accordingly an object of the present invention to provide a novel refrigeration process.

Another object is to provide a refrigeration process of varying capacity which operates at relatively high efficiency.

Another object is to provide a refrigeration process having the foregoing characteristics which employs a plurality of expansion engines.

Still another object of the present invention is to provide a novel process for low temperature separation of gaseous mixtures which is capable of producing different components in different phases at different times.

Still another object is to provide a low pressure cycle for low temperature separation of gaseous mixtures designed to produce components of a gaseous mixture in gaseous phase and provided with a novel refrigeration process which makes it possible to produce at least a portion of at least one component in liquid phase without increasing the pressure of the gaseous mixture fed to the cycle and without requiring extraneous refrigeration producing means.

Other objects and features of the present invention will become apparent from the following detailed description considered in connection with the accompanying drawing which discloses one embodiment of the invention. It is to be expressly understood however that the drawing is designed for purposes of illustration only and not as a reference for the definition of the limits of the invention, reference for the latter purpose being had to the appended claims.

The single figure of the drawing discloses a novel refrigeration system embodied in a low temperature process for liquefaction and separation of gaseous mixtures.

With reference to the drawing, air under elevated pressure enters the cycle through conduit 10 and, after passing through switch valve 11, is conducted by conduit 12 for flow through passageway 13 of switching heat exchange device 14 in countercurrent heat interchange with relatively cold oxygen and nitrogen component gases as described below. The compressed air leaves the cold end of the heat exchange device 14 through conduit 15 and may be close to saturation temperature at the existing pressure. The cold air passes through valved manifold 16 and then by conduit 17 to the base of a high pressure fractionating column or section 18 providing a zone including liquid-vapor contact means such as fractionating plates 19 wherein the air undergoes preliminary separation producing liquid high boiling point fraction, crude oxygen, collecting in a pool 20, and gaseous low boiling

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point fraction, essentially pure nitrogen, which flows upwardly and is liquefied in a refluxing condenser 21. The liquefied nitrogen provides reflux for the high pressure column and also collects in pool 22 from which it is withdrawn by conduit 23 and, after pressure reduction in valve 24, is introduced as reflux into the top of a low pressure fractionating column or section 25. The low pressure column provides a fractionating zone including a series of liquid-vapor contact means such as fractionating plates 26 wherein occurs further separation of liquid high boiling point fraction withdrawn from the pool 20 and fed thereto by conduit 27 and pressure reducing valve 28, the liquid oxygen component collecting in a pool 29 surrounding the refluxing condenser 21 and gaseous high boiling point nitrogen being withdrawn from the dome of the low pressure column through conduit 30.

The conduit 30 leads to valved manifold 31 from which the cold nitrogen gas flows by conduit 32 through passageway 33 of the heat exchange device 14 in countercurrent heat interchange with the air feed as described above, the nitrogen gas leaving the warm end of the heat exchange device 14 through conduit 34 at about ambient temperature and, upon passing through the switching valve 11 is discharged from the process through conduit 34'. Gaseous oxygen component is withdrawn from the low pressure column from above the pool 29 through conduit 35 and conducted thereby for flow through passageway 36 of the heat exchange device 14 in countercurrent heat interchange with the incoming compressed air feed, the gaseous oxygen leaving the warmed end of the heat exchange device through conduit 37 at about ambient temperature. The switching valve 11 is operated periodically to alternate the flow of the air feed and the gaseous nitrogen component between the heat exchange passageways 13 and 33 and the manifolds 16 and 31 are provided with pressure responsive valves for directing the flow of air from conduits 15 or 32 to the conduit 17 and for directing the nitrogen flow from conduit 30 to conduits 15 or 32. A stream of high pressure nitrogen gas is withdrawn from the refluxing condenser 21 through conduit 40 and conducted by conduit 41 for flow through unbalancing passageway 42 of the heat exchange device 14. The high pressure nitrogen gas is warmed upon flowing through the unbalancing passageway to an optimum temperature for subsequent work expansion and is conducted by conduit 43 to the inlet of expansion engine 44. The effluent of the expansion engine 44 is conducted by conduit 45, provided with a control valve 46, and merged with the nitrogen gas in conduit 30 for flow therewith through the passageway 33 of the heat exchange device 14 to provide refrigeration for the air feed.

The low temperature process described above incorporates the novel refrigeration cycle of the present invention which makes it possible to withdraw from the process component product in liquid phase; for example, liquid oxygen withdrawn from the pool 29 through valved conduit 50. The novel refrigeration cycle includes an expansion engine 51 fed with high pressure fluid previously warmed by heat interchange with effluent of the expansion engine 44. As shown, the conduit 40 feeds a branch conduit 52 having a control valve 53 leading to passageway 54 of heat exchange device 55 and the passageway 54 is connected by conduit 56 to the inlet of the expansion engine 51, effluent of the latter expansion engine being connected by conduit 57 having a control valve 58 to the conduit 45. The low pressure side of the expansion engine 44 is connected by conduit 59, provided with a control valve 60, for flow through passageway 61 of the heat exchange device 55 in countercurrent heat interchange with the high pressure nitrogen gas flowing through the passageway 54, the other end of the passageway 61

being connected by conduit 62 to the conduit 30. The feature of utilizing effluent of a first expansion engine to warm the feed of a second expansion engine makes it possible to obtain optimum refrigeration upon work expansion of a given mass of high pressure fluid and the first or both of the expansion engines may be operated to provide different levels of refrigeration without material adjustment of process parameters.

As an example of an operating cycle, a quantity of nitrogen gas corresponding to about 10% of the air feed is withdrawn from the refluxing condenser 21 under a pressure of about 75 p.s.i.a. and a temperature of about -290° F. and flowed through the unbalancing passageway 42 wherein the high pressure nitrogen gas is warmed to about -100° F. The thus warmed nitrogen gas is expanded in the expansion engine 44 to about 20 p.s.i.a. and thereby cooled to about -197° F. with valve 46 closed and valve 60 open, the effluent of the expansion engine 44 flows through the passageway 61 in countercurrent heat interchange with high pressure nitrogen gas in the passageway 54 of a mass equal to about 10% of the air feed. The effluent leaves the passageway 61 at about -280° F. and is merged by way of conduit 62 with the low pressure nitrogen gas in conduit 30, while the high pressure nitrogen gas leaves the passageway 54 at about -207° F. and at that temperature is expanded in the expansion engine 51 to about 20 p.s.i.a. and cooled to about -290° F. The effluent from the latter expansion engine is passed through conduit 57 and open control valve 58 to conduit 45 and merged with the low pressure nitrogen gas in conduit 30. Of course, if it is not desired to withdraw liquid product from the cycle, additional refrigeration would not be required and the expansion engine 51 would not be operated. In such case, effluent from the expansion engine 44 would flow past open valve 46 and through conduit 45 to the conduit 30 and the valves 53 and 60 would be closed. The path of flow of effluent of the expansion engine 44 could include the passageway 61 whether the expansion engine 51 is or is not operating. The refrigeration produced by the expansion engine 44 is greater than the refrigeration produced by the expansion engine 51 for fluids of the same mass and pressure due to the pre-expansion temperatures. However, the total refrigeration obtained from the expansion engines 44 and 51 when the effluent of one is used to warm the feed to the other is substantially greater than if the expansion engines were operated in series or fed in parallel with high pressure fluid warmed to a uniform intermediate temperature. In the environment of a low temperature separation process, the present invention makes it possible to provide a given quantity of refrigeration by making available more reflux for the separation, as compared to prior refrigeration systems employing parallel connected expansion engines. A portion or all of the high pressure fluid fed to the expansion engines 44 and 51 may be derived from the high pressure column other than the refluxing condenser. For example, high pressure gas may be withdrawn from the high pressure column above the feed point by a conduit 70 having a control valve 71 and merged with the conduit 41 and control valves 72 and 73 may be provided in conduits 40 and 41, respectively.

Although the novel refrigeration system provided by the present invention is disclosed in combination with a low temperature separation process, it will be appreciated the system may be employed in other environments in which cooled high pressure fluid is work expanded in two zones with the high pressure fluid expanded in a first zone being prewarmed upon heat interchange with a process stream to be refrigerated and with the high pressure fluid expanded in the second zone being prewarmed upon heat interchange with effluent from the first expansion zone. Moreover, although the invention has been described in connection with a low temperature process for separation of air, it has utility with low temperature processes for separating other gaseous mixtures. Ref-

erence therefore will be had to the appended claims for a definition of the limits of the invention.

What is claimed is:

1. Process for producing refrigeration comprising the steps of
 - passing a first stream of compressed cold gas at a first relatively high pressure in heat interchange with a first relatively warm fluid to warm the first stream of compressed gas to a relatively high temperature, expanding the warm first stream of compressed gas at the relatively high temperature and under the first relatively high pressure with production of external work to produce first effluent under a first relatively low pressure,
 - passing a second stream of compressed cold gas at substantially the first relatively high pressure in countercurrent heat exchange with first effluent to cool the first effluent and to warm the second stream of compressed gas to a temperature lower than the relatively high temperature of the warm first stream of compressed gas,
 - expanding the warm second stream of compressed gas with production of external work to produce second effluent at a temperature lower than the temperature of the first effluent and under a pressure corresponding to the first relatively low pressure of the first effluent,
 - the first effluent being cooled to a temperature approaching the temperature of the second effluent by the heat interchange with the second stream of compressed gas,
 - and passing the cooled first effluent and the second effluent to a common utilization zone.
2. Process for producing refrigeration as defined in claim 1 in which the first stream of compressed gas and the second stream of compressed gas are derived from a common source of compressed gas.
3. Process for producing refrigeration as defined in claim 1 in which the common utilization zone comprises a heat exchange zone wherein the cooled first effluent and the second effluent are passed in heat interchange with a fluid to be cooled.
4. Process for producing refrigeration as defined in claim 3 in which
 - the first stream of compressed gas and the second stream of compressed gas are derived from the fluid to be cooled following heat interchange with the cooled first effluent and the second effluent.
5. Process for separating gaseous mixtures in a low pressure operation including preliminary separation in a high pressure fractionating zone and further separation in a low pressure fractionating zone which comprises the steps of
 - passing compressed gaseous mixture through a heat exchange zone of the operation in heat interchange with a least cold fluid withdrawn from the low pressure fractionating zone to cool the compressed gaseous mixture,
 - withdrawing cool gaseous mixture from the heat exchange zone,
 - feeding cold gaseous mixture withdrawn from the heat exchange zone to the high pressure fractionating zone,
 - deriving a first stream of cold fluid under a first pressure from cold gaseous mixture withdrawn from the heat exchange zone,
 - passing the first stream of cold fluid in heat interchange with the gaseous mixture in the heat exchange zone to warm the first stream,
 - expanding the warm first stream under the first pressure with production of external work to provide a first effluent,
 - deriving a second stream of cold fluid at substantially the first pressure from cold gaseous mixture withdrawn from the heat exchange zone,

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passing first effluent in countercurrent heat exchange with the second stream of cold fluid to warm the second stream of fluid and cool the first effluent, expanding the warm second stream of fluid with production of external work to provide a second effluent at a pressure corresponding to the pressure of the first effluent and at a temperature lower than the temperature of the first effluent, and passing cool first effluent and second effluent to a common zone of the operation.

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