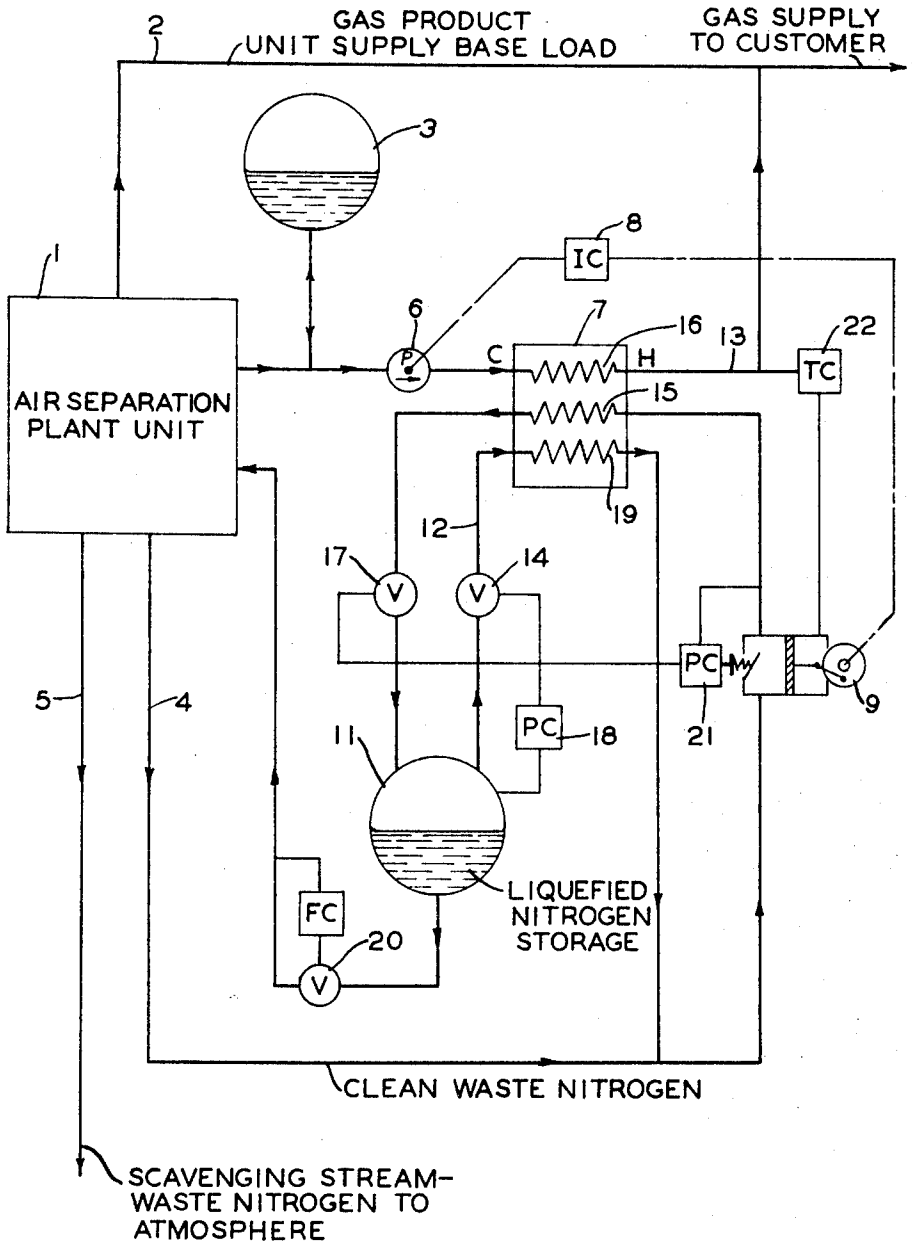
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VARIABLE DEMAND AIR RECTIFICATION PLANT WITH RECYCLE

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VARIABLE DEMAND AIR RECTIFICATION PLANT WITH RECYCLE

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This invention relates to the economic design of an air rectification process including the utilization of the refrigeration capacity of a stored liquid product of said process.

More specifically, this invention relates to an economic design of an air rectification process, saving a substantial part of the power consumption needed to supply the required refrigeration including storage of liquefied product of said process, in which the refrigeration capacity is recovered from the liquefied product as a result of heat exchange with recycled nitrogen. The stored liquefied product meets peak demands, which peak demands may exceed the steady supply capacity of the air rectification process.

Most often it is proposed to store a product, for example, oxygen, of an air separation plant in gaseous form. In the usual air separation plant that supplies a customer by pipeline, the customer's steady gas demand is supplied directly from the producing unit, while high customer demand is supplied by high pressure gaseous storage. Liquid storage has not generally been used in this service, in spite of the lower capital investment in comparison to gaseous storage. This is due to the fact that considerable power is needed to make liquid by refrigerating the gas. This refrigeration has been lost when the liquid is vaporized and put into the pipeline for supply to the customer. It is therefore an object of this invention to make the cheaper liquid storage attractive by utilizing the refrigeration capacity of the liquefied product in an efficient and effective manner within the air separation plant.

It is further an object of this invention to provide an economic air separation process in which product gas flow surges demanded by the customer on the process are evened out.

It is further an object of this invention to effectively conserve the refrigeration effect captured within a liquefied product of an air rectification process for use within the process so as to provide for economic use of power.

These and other objects and advantages of this invention will become apparent in connection with the more detailed disclosure set forth hereinbelow.

The stored liquefied product may be oxygen, as shown in the drawing to be discussed hereinafter, or some other liquefied product of the process, such as nitrogen. Further description will be made in terms of product oxygen, although this invention is not limited to such stored product.

In general, liquid product, for example oxygen, produced by an air separation process, is pumped through a heat exchanger, where it is gasified. This pumping controls the operation of a variable capacity compressor. Nitrogen, for example clean waste nitrogen, emanating from an air separation process is compressed by the variable capacity compressor and condensed as a result of counter-current heat transfer with the gasifying oxygen. The nitrogen, just liquefied as a result of heat exchange with the vaporizing oxygen, is stored and fed at a steady rate to the air separation process to be used in any manner desired, for example as reflux to the low pressure column. Effectively, the gaseous nitrogen stream recovers the refrigeration capacity of the gasifying oxygen product before the product leaves the system. The disclosed process can be utilized most effectively where there is a large customer requirement for the product, be it nitrogen or oxygen or some other product, during periods of peak operation, as will be apparent from the more detailed description in connection with the drawing that follows.

The drawing shows schematically an air separation plant and an external process and equipment therefor. The drawing shows liquid oxygen storage; however, as stated earlier, other liquefied products, such as liquid nitrogen, could be utilized in the same manner as is described hereinafter.

The air separation plant unit **1** is steady state in its production of liquid and gaseous products; that is, for substantial periods of time it produces at a particular constant percent of capacity no matter what the customer's demands are. Of course, from time to time that percentage of capacity production may be altered. Said air separation plant unit **1** supplies oxygen gas product, at **2**, as a unit supply base load to the customer. The steady state air separation plant unit **1** also produces liquid oxygen which is stored at **3** to fulfill the surge requirements of the customer. Of course, liquid nitrogen may be stored at **3**, this description of the process shown in the drawing being written in terms of oxygen storage only for purposes of illustration.

Clean waste nitrogen gas emanates from the air separation plant unit at **4** in one pass of a multiple pass exchanger. The scavenging stream **5** usually exhausts to the atmosphere. Although the description is made with particular reference to the stream in pass **4** being "clean waste" nitrogen, other forms of nitrogen exhausted from the plant may be utilized. In the air separation plant **1** and external process of the drawing, the product liquid oxygen stored in the storage vessel **3** is vaporized in a heat exchanger **7** to satisfy surge gas demands of a customer, conserving the refrigeration value of the liquid oxygen by vaporizing said liquid oxygen against clean warm waste nitrogen gas **4** running countercurrently.

The clean waste nitrogen **4** when it leaves the air separation plant is at atmospheric pressure and is warm. A typical operating temperature of said clean waste nitrogen would be 86° F. The clean waste nitrogen gas **4**, after being compressed in the variable capacity gas compressor **9** is passed countercurrently to the vaporizing oxygen through pass **15** of heat exchanger apparatus **7**. The clean warm waste nitrogen gas transfers its heat in the heat exchanger to the cold liquid oxygen in the adjacent pass **16**, gasifying said liquid oxygen. The nitrogen gas is condensed as a result of the heat exchange with the cold liquid oxygen. The liquid oxygen is pumped to the heat exchanger **7** from the liquid storage vessel **3** by a pump **6** in response to the variable surge demands of the gas customer. The pump **6** may be linked through a motor drive interlock control **8** to the variable capacity nitrogen compressor **9**. (The nitrogen gas in line **4** is compressed by the compressor **9** when product oxygen is pumped by pump **6**, as a result of interlock control **8**.) The liquefied waste nitrogen is discharged from the heat exchanger **7** and passes through a throttle valve control **17**, at lower pressure, into a liquefied nitrogen storage vessel **11**. In passing through the throttle valve **17**, the liquid nitrogen undergoes a Joule-Thomson expansion in which some liquid is vaporized. This cold vapor, plus other cold vapor resulting from the effects on the liquid nitrogen of heat leak into the storage vessel **11**, is vented from the storage vessel through valve **14**, as determined by storage pressure control mechanism **18**, and passed countercurrently through pass **19** in heat exchange relationship in exchanger **7** to the warm waste nitrogen gas stream in pass **15**. Thus, a portion of the heat in said waste nitrogen gas stream in pass **15** is removed as a

result of heat exchange with the cold gas in pass **19**, adding to the saving of the refrigeration capacity originally taken from the gasifying oxygen. More efficient and complete liquefying of the waste nitrogen gas and conserving of refrigeration and thus power is effected. The cold vented gas from storage container **11** is thus warmed in exchanger **7** and then combined in gaseous form with the clean warm waste nitrogen gas emanating in line **4** from the air separation plant unit **1**. The liquefied waste nitrogen storage vessel **11** discharges through a flow control valve **20** nitrogen liqued which is used in the air separation plant, for example, as reflux to the low pressure or so-called oxygen column.

The variable capacity compressor is linked to the gasified oxygen supply line **13** by a temperature capacity control **22**. This control adjusts the speed of the compressor **9**, so that adequate waste nitrogen is supplied to the exchanger **7** to vaporize all of the liquid oxygen in pass **16** of the exchanger. Pressure control **21** maintains the pass **15** of exchanger **7** at the proper pressure needed for the transfer of heat between the three exchanger fluids. This pressure controller maintains this pressure by control of throttling valve **17**, as above.

In a typical operation, the following process conditions will occur in the heat exchanger.

	Press. (p.s.i.a.)	Inlet Temp.,°F.	Disch. Temp.,°F.
Waste nitrogen gas	309	+86	−274
Oxygen	115	−287	0
Waste nitrogen flash recycle	25	−311	0

Warm end T=86° F.
Mass flow ratios: Waste nitrogen to flash recycle to liquid oxygen= 1.07 : 0.257 : 1.0 lb. waste nitrogen liquefied per lb. liquid oxygen=0.813.

The proposed process functions according to the product demanded by the customer. The refrigeration capacity of the liquid product is conserved by, in effect, transferring said refrigeration capacity to a waste nitrogen stream which is reintroduced back into the air separation plant. As a result of the liquefication of the clean waste nitrogen gas and then subsequent storage thereof, the refrigeration supply to the air separation process is evened out.

The process described above is external to the air separation plant unit **1** and is therefore independent of the particular cycle or process used in the air separation plant, since all that is required is that the air separation plant discharge some amount and form of nitrogen which discharge is standard. Therefore, the process described above can be used with all types of air separation processes or plants.

As stated previously, this invention is not limited to the storage of liquefied oxygen product and a clean waste nitrogen stream emanating from an air separation plant. As stated previously, oxygen product and clean waste nitrogen are used in this description only for purposes of illustration of the invention. It should be understood that other stored liquefied products than oxygen (such as nitrogen) and other streams emanating from an air separation plant than clean waste nitrogen (such as a scavenging stream of nitrogen which is then purified) can be utilized according to the invention described hereinbefore. Furthermore, this invention is not limited to any method, process or apparatus described hereinbefore, except as set forth in the following claims.

We claim:

1. A process for supply of gaseous oxygen from an air separation plant so as to meet varying demands comprising the steps of passing gaseous oxygen product at a substantially steady state from the plant to a source of demand, storing liquid oxygen product from said plant, vaporizing said liquid product in a vaporizer in response to demand, compressing waste nitrogen from said plant, cooling substantially all of said compressed waste nitrogen by heat exchange with said liquid oxygen product being vaporized, throttling said compressed and cooled waste nitrogen to liquefy it, controllably applying said liquefied waste nitrogen to said plant to provide refrigeration therefor, and passing vapors from said liquified nitrogen in heat exchange with the compressed nitrogen stream and then into mixture with the waste nitrogen before said waste nitrogen is compressed.

2. A process for supply of gas product from an air separation plant so as to meet varying demands, comprising the steps of passing a gas product stream at a substantially steady state from the plant to a source of demand, storing liquid products from said plant, vaporizing it in a vaporizer in response to the demand, compressing a nitrogen gas stream from said plant, cooling substantially all of said last-mentioned compressed gas by heat exchange with said liquid product being vaporized throttling said compressed and cooled nitrogen to liquefy it, controllably supplying said liquefied nitrogen stream to said plant to provide refrigeration therefor, passing said vaporized product on to the source of demand, and directing vapors emanating from said liquefied nitrogen in heat exchange with the nitrogen gas stream before said stream is compressed.

3. A process as set forth in claim **2**, the gaseous product stream and liquid products being oxygen.

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