May 2, 1950 W. L. DE BAUFRE 2,506,350

PROCESS AND APPARATUS FOR VARIABLE LOW TEMPERATURE REFRIGERATION

Filed April 23, 1945

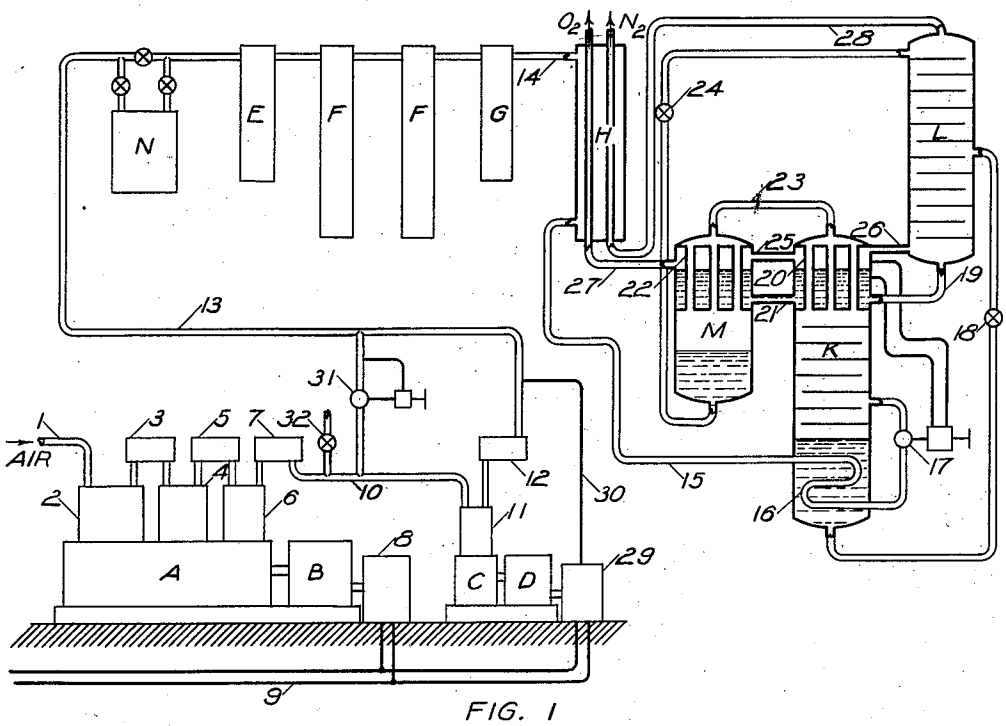


FIG. 1

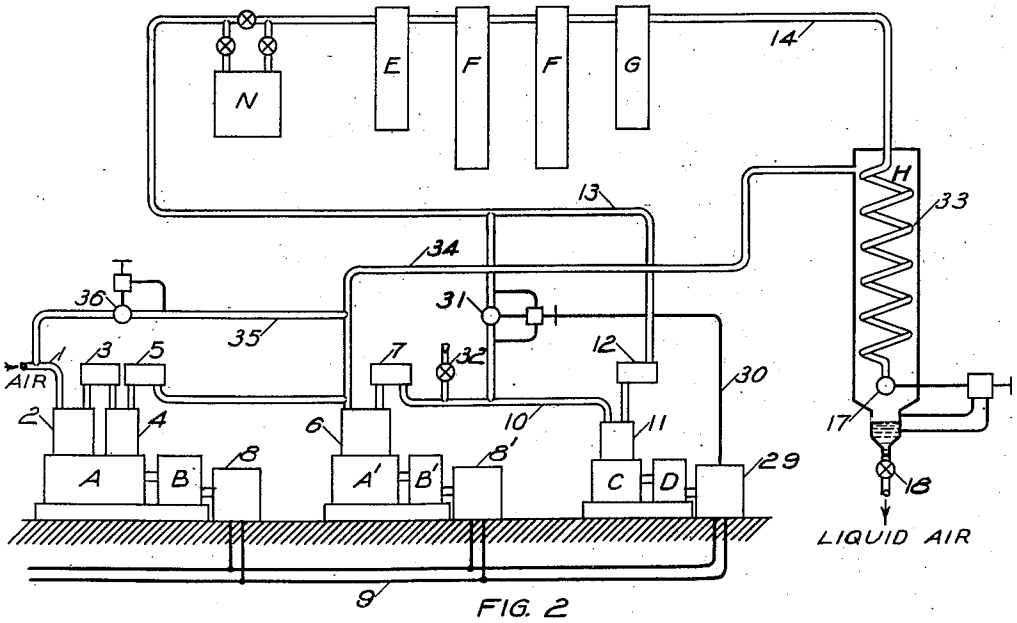


FIG. 2

INVENTOR

William Lane De Baufre

Patented May 2, 1950

2,506,350

UNITED STATES PATENT OFFICE

2,506,350

PROCESS AND APPARATUS FOR VARIABLE LOW TEMPERATURE REFRIGERATION

William Lane De Baufre, Lincoln, Nebr.

Application April 23, 1945, Serial No. 589,918

23 Claims. (Cl. 62—2)

1

This invention relates to liquefaction and rectification of atmospheric air and other gases where the atmospheric air or other gas is compressed to a maximum pressure which is varied in accordance with the refrigeration requirements of the process.

For example, when atmospheric air is rectified into oxygen and nitrogen products in relatively small plants, the refrigeration necessary for continuous operation below atmospheric temperature is usually obtained by compressing the atmospheric air to a high or to a moderately high pressure and then throttling the compressed air from its maximum pressure to a low pressure before subjecting the atmospheric air to rectification. The oxygen and nitrogen products of rectification are returned at low pressure in heat interchange with the compressed air. Refrigeration results from the fact that more heat is carried out of the apparatus by the returning products at low pressure than is carried into the apparatus in the compressed air at a high or a moderately high pressure.

When starting such an air rectification plant, it is desirable to furnish sufficient refrigeration to cool the apparatus to operating temperatures and quickly build up necessary reserves of liquefied gas. For this purpose, the atmospheric air is usually compressed to a maximum pressure of 3000 lbs. per sq. in. gage at starting the plant. But after normal operating conditions are attained, it is necessary to compress the atmospheric air to 600 to 1000 lbs. per sq. in. only in order to furnish sufficient refrigeration for continuous operation.

The compressor furnished for compressing the atmospheric air therefore operates under a wide range of maximum compressed air pressure. If designed for most efficient operation at a compressed air pressure of 600 to 1000 lbs. per sq. in. normally, the compressor is unsuited for operation at 3000 lbs. per sq. in. at starting. If designed for satisfactory operation at a maximum compressed air pressure of 3000 lbs. per sq. in. at starting, the compressor has reduced efficiency during normal operation at 600 to 1000 lbs. per sq. in.

An object of the present invention is to secure the most efficient operation normally at a maximum compressed air pressure of 600 to 1000 lbs. per sq. in. and at the same time obtain satisfactory operation at a maximum compressed air pressure up to 3000 lbs. per sq. in.

A further object of the invention is to provide automatic control for changing from efficient

2

operation at the moderately high pressure to satisfactory operation at the high pressure.

A still further object of the invention is to provide automatic control for changing the maximum compressed air pressure in accordance with the refrigeration requirements of the apparatus.

These objects and such other advantages as are inherent in the invention, are realized by the method and apparatus shown in the accompanying drawing wherein Figure 1 shows the invention applied to the rectification of atmospheric air and Figure 2 shows the invention applied to the liquefaction only of atmospheric air.

In both cases, atmospheric air is compressed in a three-stage compressor to a moderately high pressure, say 600 to 1000 lbs. per sq. in. The three-stage compressor is designed for efficient operation at this maximum compressed air pressure with nearly equal compression ratios in the three stages and with intercoolers and after cooler to reduce the compressed air temperature nearly to atmospheric temperature after each stage of compression.

In both cases, an auxiliary compressor, or booster, is provided to further compress the atmospheric air to a maximum compressed air pressure exceeding 1000 lbs. per sq. in. and up to say 3000 lbs. per sq. in.

In Figure 1, the compressed air at its maximum pressure is supplied to a rectification unit for separating atmospheric air into oxygen and nitrogen products. In Figure 2, the compressed air at its maximum pressure is supplied to a liquefacton unit for liquefying a portion of the atmospheric air. In either case, the compressed air is throttled from its maximum pressure to a low pressure and liquefied gas accumulates in a vessel within the apparatus. The throttling is regulated manually or automatically to maintain the amount desired of accumulated liquid, so that the maximum compressed air pressure is varied in accordance with the refrigeration requirements of the apparatus.

The auxiliary compressor, or booster, is started when the maximum compressed air pressure exceeds 1000 lbs. per sq. in. and is stopped when the maximum compressed air pressure falls below 1000 lbs. per sq. in. This may be done manually or automatically as determined by the level of accumulated liquid. In the latter case, a range of pressure may be required to cause the automatic control device to function so that the auxiliary compressor will start when the maximum compressed air pressure rises above say 1000 lbs. per sq. in. but will not stop until the maximum compressed air pressure falls below say 900 lbs.

per sq. in. A by-pass valve may be provided for the auxiliary compressor so that the compressed air will not blow through the valves of the stopped compressor.

The operation of the process and apparatus illustrated in Figure 1 and in Figure 2 will be described separately as illustrative of the invention. It is to be understood that the invention is applicable to other gases and gaseous mixtures than atmospheric air and that certain features of the invention may be applied to other processes than rectification or liquefaction.

Referring to Figure 1, atmospheric air to be rectified into oxygen and nitrogen products enters the system through pipe 1, generally freed of carbon dioxide. In cylinders 2, 4 and 6 of compressor A, the air is compressed in three stages to a moderately high pressure of say 1000 lbs. per sq. in. gage. After each cylinder, the compressed air is cooled in intercoolers 3 and 5 and aftercooler 7 respectively. Three-stage compressor A is driven by electric motor B which is started and stopped by controller 8 connected to electrical supply mains 9.

The atmospheric air compressed to a moderately high pressure of say 1000 lbs. per sq. in. gage, flows through pipe 10 to auxiliary compressor C driven by electric motor D. The atmospheric air is further compressed to a high pressure of say 3000 lbs. per sq. in gage in cylinder 11 of auxiliary compressor C. The compressed air is cooled in aftercooler 12 from which the compressed air flows through pipe 13 to mechanical separator E for oil and water, thence to drying cylinders F and then to dust filter G.

The dry compressed air flows through pipe 14 to interchanger H where the compressed air is cooled by returning products of rectification. The cooled compressed air flows through pipe 15 to coil 16 immersed in liquid in the bottom of preliminary rectifier K. The further cooled compressed air is throttled through valve 17 into preliminary rectifier K.

Within preliminary rectifier K, the atmospheric air is rectified into nearly pure nitrogen vapor and oxygen-rich liquid. The latter accumulates in the bottom of preliminary rectifier K around coil 16 and flows through valve 18 into main rectifier L. In main rectifier L, the oxygen-rich liquid is rectified into nearly pure nitrogen vapor and nearly pure oxygen liquid. The oxygen liquid flows through pipe 19 into the space surrounding tubes 20 where the liquid is vaporized in condensing nearly pure nitrogen vapor within tubes 20. The remaining oxygen liquid flows through pipe 21 into the space surrounding tubes 22 in condenser M. The remaining nearly pure nitrogen vapor flows through pipe 23 into condenser M where the vapor is condensed within tubes 22.

The condensed nitrogen flows from condenser M through valve 24 to the top of main rectifier L. Part of the vaporized oxygen returns to main rectifier L through pipes 25 and 26. The remaining vaporized oxygen flows through pipe 27 to interchanger H where it returns in heat exchange with the compressed atmospheric air. Nitrogen vapor flows from the top of main rectifier L through pipe 28 to interchanger H where it also returns in heat exchange with the compressed atmospheric air.

Throttle valve 17 is automatically controlled by the liquid level surrounding tubes 20. During normal operation, this liquid level varies with the refrigeration requirements of the apparatus relative to the refrigeration furnished by throttling the atmospheric air from the maximum compressed air pressure. When the refrigeration supplied exceeds the refrigeration required, this liquid level rises, and vice versa. Consequently, control of throttle valve 17 by the liquid level surrounding tubes 20, automatically regulates the maximum compressed air pressure in accordance with the refrigeration requirements of the apparatus. This feature is claimed in U. S. Patent 2,154,668 issued April 18, 1939.

At starting, the maximum compressed air pressure is maintained at the highest permissible pressure of say 3000 lbs. per sq. in. gage in order to provide the maximum refrigeration for cooling the apparatus to operating temperatures and for building up necessary reserves of liquefied gases as quickly as possible. When this has been accomplished, throttle valve 17 is manually or automatically controlled to gradually reduce the maximum compressed air pressure below 3000 lbs. per sq. in. gage.

Eventually, the maximum compressed air pressure is reduced to the moderately high pressure of compression of main compressor A of say 1000 lbs. per sq. in. gage. When this occurs, auxiliary compressor C is stopped by operation of controller 29 which turns off the supply of electricity to electric motor D from mains 9. This is accomplished automatically through connection 30 from controller 29 to pipe 13 where the maximum compressed air pressure occurs. At the same time, by-pass valve 31 is automatically opened in order that the compressed air will not need to blow through the valves of auxiliary compressor C (a somewhat different means may be employed as described in connection with Figure 2).

Should the refrigeration requirements of the apparatus increase at any time, due say to withdrawal of some liquid oxygen from the rectifier, the decrease in the liquid level surrounding tubes 20 would automatically operate throttle valve 17 to cause the maximum compressed air pressure to increase beyond the moderately high pressure of say 1000 lbs. per sq. in. produced by main compressor A. This rise in the maximum compressed air pressure would automatically close by-pass valve 31 and would start auxiliary compressor C through controller 29 and electric motor D.

Auxiliary compressor C would thus be started and stopped with variation in the maximum compressed air pressure as determined by the refrigeration requirements of the apparatus. Whenever a high compressed air pressure were necessary, auxiliary compressor C would be started to boost the moderately high compressed air pressure produced by main compressor A, which would not be required to operate at such a high pressure as to have operating difficulties with valves, etc., nor need to be designed to withstand such high pressures. Whenever a moderately high compressed air pressure would be sufficient, auxiliary compressor C would be stopped with resultant maximum efficiency due to main compressor C being designed for most efficient operation under these conditions.

After operation for some days, frost accumulates within interchanger H and other parts of the apparatus. It becomes necessary to shut down to defrost interchanger H and the rectification apparatus by blowing warm dry air therethrough. It is desirable to do this at low pressure and with a smaller mass flow of air than would be supplied by main compressor A. By

operating controller 8 so as to shut down main compressor A, auxiliary compressor C may be kept in operation to supply a reduced quantity of low pressure air. This air may be drawn through valve 32 directly from the atmosphere and it may be warmed in defrosting heater N.

Referring to Figure 2, atmospheric air to be liquefied enters the system through pipe 1, generally freed of carbon dioxide. The atmospheric air is compressed in cylinders 2 and 4 of compressor A to say 200 lbs. per sq. in. gage. After each cylinder the compressed air is cooled in intercooler 3 and aftercooler 5 respectively. Compressor A is driven by electric motor B which is connected through controller 8 to electric supply mains 9.

The atmospheric air is further compressed in cylinder 6 of compressor A' to a moderately high pressure of say 1000 lbs. per sq. in. gage. The compressed air is cooled in aftercooler 7. Compressor A' is driven by electric motor B' which is connected through controller 8' to electric supply mains 9.

The atmospheric air is still further compressed in cylinder 11 of compressor C driven by electric motor D. The atmospheric air is compressed to a high pressure of say 3000 lbs. per sq. in. gage. The compressed air is cooled in aftercooler 12, and then flows through mechanical separator E for removing condensed moisture, drying cylinders F for removing water vapor and dust filter G for removing particles of drying material carried over from drying cylinders F.

The dry compressed air flows through pipe 14 to coil 33 within interchanger H where the compressed air is cooled before it reaches throttle valve 17. After throttling, the air is partly liquefied. The liquefied part collects in the bottom of interchanger H from which the liquid air can be withdrawn through valve 18. The unliquefied part of the air returns over coil 33 in heat exchange with the compressed air flowing therethrough before throttling. The unliquefied part is warmed and returns through pipe 34 to the suction of compressor A'. Here the unliquefied part is commingled with atmospheric air from compressor A.

Compressor A is proportioned to supply an amount of atmospheric air equal to that liquefied and withdrawn through valve 18 or permitted to accumulate in the bottom of interchanger H. Within interchanger H, the pressure of the unliquefied air is equal to the discharge pressure of compressor A. Since returning unliquefied air at 200 lbs. per sq. in. gage has nearly the same total heat as it would have at atmospheric pressure and the same temperature, the refrigeration produced by throttling to 200 lbs. per sq. in. gage is nearly as large as throttling to atmospheric pressure. The expenditure of energy to compress the air is appreciably reduced, however, if only the part liquefied is compressed to 200 lbs. per sq. in. gage instead of the total amount cooled in interchanger H.

At starting and at other times when no liquefaction were occurring in interchanger H, there would be a tendency for a continued rise of pressure in the shell of interchanger H. This increase is prevented by means of pipe 35 and relief valve 36 which is arranged to return unliquefied air to the suction of compressor A whenever the suction pressure to compressor A' exceeds 200 lbs. per sq. in.

Throttle valve 17 is automatically controlled by the level of liquid air accumulated in the bottom of interchanger H. So long as this liquid level is low, throttle valve 17 is controlled to maintain a maximum compressed air pressure of say 3000 lbs. per sq. in. gage. This high compressed air pressure is maintained so long as liquid air is withdrawn through valve 18 as rapidly as it accumulates. But when the liquid level is permitted to rise, there is produced between the two tubes leading to the control mechanism of throttle valve 17, a differential pressure which operates this valve to reduce the maximum compressed air pressure below 3000 lbs. per sq. in. gage. When this maximum compressed air pressure falls to the moderately high pressure produced by compressor A', auxiliary compressor C adds no additional pressure. The moderately compressed air simply blows through the valves of auxiliary compressor C. The pressure differential between pipes 10 and 13 is therefore reduced substantially to zero. Valve 31 is arranged to open automatically when this occurs. The control mechanism of valve 31 is also connected to controller 29 by connection 30, which may be either a pressure connection or an electrical connection. Through this connection, controller 29 is caused to disconnect electric motor D from supply mains 9 so that auxiliary compressor C is stopped when the differential pressure between pipes 10 and 13 is reduced substantially to zero.

The control mechanism of valve 31 is also arranged to close valve 31 whenever the maximum compressed air pressure exceeds the moderately high pressure for which compressor A' is designed. Whenever this occurs, valve 31 closes and an impulse through connection 30 causes controller 29 to start electric motor D driving auxiliary compressor C. Auxiliary compressor C thus starts whenever the maximum compressed air pressure exceeds a predetermined moderately high pressure due say to withdrawal of liquid air through valve 18.

The unliquefied air returns through pipe 34 to inlet pipe of compressor A' and some of it may return to inlet pipe 1 of compressor A. The amount of atmospheric air drawn in through pipe 1 by compressor A is therefore equal to the portion liquefied in interchanger H.

Compressors A and A' may be a single compressor with all three cylinders mounted on the same bed plate but proportioned as described.

This invention has been described and illustrated as applied to apparatus where the refrigeration necessary for cooling to normal operating temperatures and for balancing heat leak into the apparatus is obtained by throttling a gas from a high compression pressure. Use of a main compressor and of a booster compressor is also applicable, and essentially for the same reasons, to apparatus where refrigeration is obtained by expansion of a compressed gas with performance of external work. In the latter case, the high pressure may be only 250 lbs. gage and the moderately high pressure may be only 125 lbs., as for the processes described in applications Serial No. 559,620 filed October 20, 1944 and Serial No. 586,798 filed April 5, 1945 and in Patent No. 2,503,939 issued April 11, 1950 on an application filed December 26, 1944. While most of the claims refer to processes in which refrigeration is obtained by throttling, some of the claims are worded broadly enough to include processes in which refrigeration is obtained by expansion with performance of external work. In all claims, the terms high pressure, moderately high pressure,

and moderate pressure are to be interpreted as relative to one another.

I claim:

1. Process of separating atmospheric air into oxygen and nitrogen products which includes compressing the atmospheric air to a moderately high pressure, further compressing the compressed air to a high pressure, cooling the compressed air at said high pressure to a low temperature, throttling the cooled air to a low pressure, rectifying the low pressure air, regulating the throttling in accordance with the refrigeration requirements of the process whereby the maximum pressure of the compressed air varies, and eliminating the further compression of the compressed air whenever the maximum compressed air pressure is reduced to said moderately high pressure.

2. Process of separating atmospheric air into oxygen and nitrogen products as in claim 1 wherein the further compression of the compressed air is reinstated whenever the maximum compressed air pressure is raised above said moderately high pressure.

3. Process of liquefying atmospheric air which includes compressing the atmospheric air to a moderately high pressure, further compressing the compressed air to a high pressure, cooling the compressed air at said high pressure to a low temperature, throttling the cooled air to a low pressure whereby a portion is liquefied, regulating the throttling in accordance with the refrigeration requirements of the process whereby the maximum compressed air pressure varies, and eliminating the further compression of the compressed air whenever the maximum compressed air pressure is reduced to said moderately high pressure.

4. Process of liquefying atmospheric air as in claim 3 wherein the further compression of the compressed air is reinstated whenever the maximum compressed air pressure is raised above said moderately high pressure.

5. Process of cooling a gas below atmospheric temperature which includes compressing the gas to a moderately high pressure, further compressing the compressed gas to a high pressure, throttling the highly compressed gas to a low pressure, regulating the throttling in accordance with the refrigeration requirements of the process whereby the maximum pressure of the compressed gas varies, eliminating the further compression to said high pressure whenever the maximum compressed gas pressure is reduced to said moderately high pressure and reinstating the further compression whenever the maximum compressed gas pressure exceeds said moderately high pressure.

6. Apparatus for separating atmospheric air into oxygen and nitrogen products which includes a main compressor for compressing the atmospheric air to a moderately high pressure, an auxiliary compressor for further compressing the compressed air to a high pressure, an interchanger for cooling the compressed air under said high pressure to a low temperature by oxygen and nitrogen products supplied to said interchanger, a throttle valve for reducing the pressure of the cooled air to a low pressure, a rectifier for separating the low pressure air into oxygen and nitrogen products, means for directing these products through the interchanger, means for operating said throttle valve in accordance with the refrigeration requirements of the apparatus whereby the maximum compressed air pressure varies, means for stopping the auxiliary compressor whenever the maximum compressed air pressure is reduced to said moderately high pressure, and means for starting the auxiliary compressor whenever the maximum compressed air pressure is raised above said moderately high pressure.

7. Apparatus for separating atmospheric air into oxygen and nitrogen products including a three-stage compressor for compressing the atmospheric air to a moderately high pressure, a fourth stage booster for further compressing the compressed air to a high pressure, a separation unit having an interchanger and a rectifier operating below atmospheric temperature, a throttle valve for varying the maximum compressed air pressure in accordance with the refrigeration requirements of the separation unit, and means for starting the booster whenever the maximum compressed air pressure rises above said moderately high pressure and for stopping the booster whenever the maximum compressed air pressure falls below said moderately high pressure.

8. Apparatus for separating a gaseous mixture below atmospheric temperature wherein refrigeration required to balance heat leak and other thermal losses is obtained by throttling the gaseous mixture from a high pressure, including a main compressor for compressing the gaseous mixture to a moderately high pressure, an auxiliary compressor for further compressing the compressed gaseous mixture to said high pressure and means for starting and stopping the auxiliary compressor independently of the main compressor whenever said high pressure rises above or falls to said moderately high pressure.

9. Apparatus for separating a gaseous mixture as in claim 8 including means for by-passing the auxiliary compressor whenever the auxiliary compressor is stopped.

10. Apparatus for separating a gaseous mixture below atmospheric temperature wherein refrigeration required to balance heat leak and other thermal losses is obtained by throttling the gaseous mixture from a high pressure, including a main compressor for compressing the gaseous mixture to a moderately high pressure, an auxiliary compressor for further compressing the compressed gaseous mixture to said high pressure, means for regulating said high pressure in order to balance heat leak and other thermal losses, and means for starting and stopping the auxiliary compressor automatically controlled by said high pressure.

11. Apparatus for liquefying atmospheric air wherein refrigeration for operating below atmospheric temperature is obtained by throttling the atmospheric air from a high compressed air pressure, including a main compressor for compressing the atmospheric air to a moderately high pressure, an auxiliary compressor for further compressing the compressed air to said high pressure, and means for starting or stopping the auxiliary compressor independently of the main compressor whenever the said high pressure varies above or below said moderately high pressure.

12. Apparatus for liquefying atmospheric air which includes a main compressor for compressing the atmospheric air to a moderately high pressure, an auxiliary compressor for further compressing the compressed air to a high pressure, an interchanger for cooling the compressed air under said high pressure to a low temperature, a throttle valve for reducing the pressure of the cooled air whereby a portion is liquefied, means for returning the unliquefied air through

the interchanger in heat exchange with the compressed air under said high pressure, means for operating said throttle valve in accordance with the refrigeration requirements of the apparatus whereby the maximum compressed air pressure varies, means for stopping the auxliary compressor whenever the maximum compressed air pressure is reduced to said moderately high pressure, and means for starting the auxiliary compressor whenever the maximum compressed air pressure is raised above said moderately high pressure.

13. Apparatus for liquefying a gas below atmospheric temperature including a main compressor for compressing the gas to a moderately high pressure, an auxiliary compressor for further compressing the gas to a high pressure, a throttle valve for reducing the pressure of the compressed gas and for regulating the maximum compressed gas pressure in accordance with the refrigeration requirements of the apparatus, means for stopping the auxiliary compressor whenever the maximum compressed gas pressure is reduced to said moderately high pressure and means for starting the auxiliary compressor whenever the maximum compressed gas pressure is raised above said moderately high pressure.

14. Apparatus for liquefying a gas as in claim 13 including a vessel for collecting liquefied gas, and automatic means for operating said throttle valve in accordance with the liquid level in said vessel.

15. Apparatus for liquefying a gas as in claim 13 wherein the means for starting and stopping the auxiliary compressor are automatically controlled by the maximum compressed gas pressure.

16. In apparatus operating below atmospheric temperature, means for supplying refrigeration required for continuous operation including a main compressor for compressing a gas to a moderately high pressure, an auxiliary compressor for further compressing the gas to a high pressure, and means for starting and stopping the auxiliary compressor in accordance with the refrigeration requirements of the apparatus while continuously operating the main compressor for compressing the gas to the said moderately high pressure.

17. In combination with apparatus for cooling a compressed gas below atmospheric temperature wherein refrigeration to cool the apparatus to normal operating temperatures an to balance heat leak into the apparatus varies with the compression pressure, a main compressor for compressing the gas, an auxiliary compressor for further compressing the gas, means for operating both compressors while cooling the apparatus, and means for operating the main compressor only when normal operating temperatures are reached.

18. In a process of cooling a compressed gas below atmospheric temperature wherein refrigeration to balance heat leak varies with the compression pressure, the steps of compressing the gas to a moderately high pressure, further compressing the gas to a high pressure, eliminating the said further compressing whenever the maximum compressed gas pressure is reduced to a predetermined value and resuming the said further compressing whenever the maximum compressed gas pressure is raised above a predetermined value.

19. The process of claim 18 in which eliminating and resuming the said further compressing is automatically controlled by the maximum compressed gas pressure.

20. In combination with appartus for cooling a compressed gas below atmospheric temperature wherein the compressed gas pressure is varied in accordance with refrigeration requirements, a main compressor for compressing the gas, a booster compresser for further compressing the gas, means for starting the booster compressor whenever the maximum compressed gas pressure exceeds a predetermined value and for stopping the booster compressor whenever the maximum compressed gas pressure falls below a predetermined value, and a by-pass for the booster compressor automatically controlled by the maximum compressed gas pressure.

21. Process of liquefying atmospheric air which includes compressing the atmospheric air to a moderate pressure, further compressing the compressed air to a moderately high pressure, still further compressing the compressed air to a high pressure, cooling the compressed air at said high pressure, throttling the cooled air to said moderate pressure whereby a portion is liquefied, subjecting the unliquefied portion to heat exchange with the compressed air, commingling part of the unliquefied portion with the air compressed to said moderate pressure, preventing a rise in said moderate pressure by discharging another part of the unliquefied portion and commingling it with the atmospheric air before compressing the latter whereby the amount of atmospheric air entering the system is reduced to the quantity liquefied, regulating the throttling in accordance with the refrigeration requirements of the process whereby the maximum compressed air pressure varies, eliminating the final compression to said high pressure whenever the maximum compressed air pressure is reduced to said moderately high pressure and reinstating the final compression to said high pressure whenever the maximum compressed air pressure is raised above said moderately high pressure.

22. Process of liquefying atmospheric air which includes compressing the atmospheric air to a moderate pressure, further compressing the compressed air to a moderately high pressure, cooling the compressed air at said high pressure, throttling the cooled air to said moderate pressure whereby a portion is liquefied, subjecting the unliquefied portion to heat exchange with the compressed air, commingling part of the unliquefied portion with the air compressed to said moderate pressure, preventing a rise in said moderate pressure by discharging another part of the unliquefied portion and commingling it with the atmospheric air before compressing the latter whereby the amount of atmospheric air entering the system is reduced to the quantity liquefied.

23. Apparatus for liquefying atmospheric air including a primary compressor for compressing atmospheric air, a main compressor for further compressing the compressed air to a moderately high pressure, an interchanger for cooling the compressed air, a throttle valve for reducing the pressure of the cooled compressed air whereby the air is partly liquefied, means for returning the unliquefied portion through said interchanger and thence to the main compressor whereby the unliquefied air is warmed by heat exchange with the compressed air in the interchanger and is recompressed by the main compressor, and means for discharging a portion of the unliquefied air to the primary compressor automatically controlled by the pressure of the returning unliquefied air

whereby the amount of atmospheric air entering the apparatus is reduced to the quantity liquefied.

WILLIAM LANE DE BAUFRE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,609,450	Van Nuys	Dec. 7, 1926
1,710,300	Dunkerley	Apr. 23, 1929
2,154,668	De Baufre	Apr. 18, 1939
2,360,468	Brown	Oct. 17, 1944

OTHER REFERENCES

Article, Economical Plant for Producing Oxygen by the Liquefaction Process, by Alan G. Wikoff, in Chemical and Metallurgical Engineering Feb. 4, 1924, pages 181 to 184 inclusive.