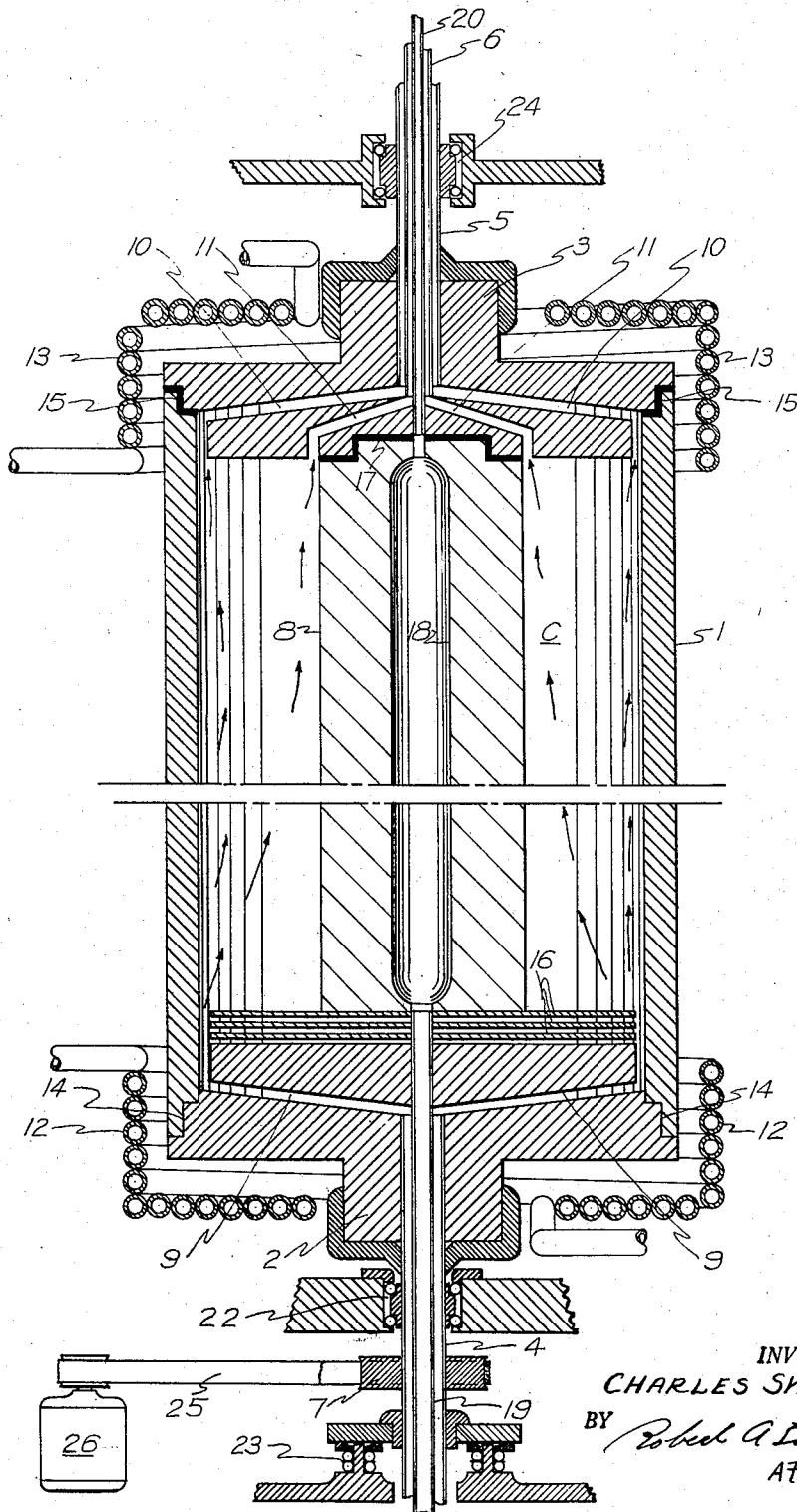


March 10, 1959

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CENTRIFUGAL SEPARATORS
Filed Sept. 12, 1944

2,876,949



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CENTRIFUGAL SEPARATORS

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Application September 12, 1944, Serial No. 553,746

8 Claims. (Cl. 233—11)

This invention relates to new and useful improvements in centrifugal separators, and more particularly to centrifugal separators of the continuous, flow-through type employed in the separation of gaseous or vaporous mixtures and isotopic mixtures.

In centrifugal separators of the type named, gases introduced into the centrifuge are angularly accelerated and compressed with the result that they are heated, and gases leaving such a centrifuge from points other than the axis of rotation are decelerated and expanded with the result that they are cooled. In addition, gases moving within the centrifuge from one radial zone to another are heated or cooled due to compression or expansion as they move into stronger or weaker centrifugal fields, respectively. Such heating and cooling of the process gases produces temperature gradients, both axially and radially of the centrifugal separator, that have appreciable effects upon the separation obtainable in the centrifuge.

Thus a temperature gradient axially of a centrifuge, for example, caused by the heating of the incoming gases due to acceleration and compression thereof, and cooling of the outgoing gases by reason of the deceleration and expansion thereof, operates to produce thermal convection currents in the gases that deflect said gases from their normal paths of travel through the centrifuge, thereby deleteriously affecting the fractional separation of the gases in accordance with the centrifugal forces to which subjected in the centrifuge.

On the other hand, a temperature gradient existing radially of the centrifugal separator may be utilized to advantage. For example, the best separation of gaseous mixtures and isotopic mixtures into lighter and heavier fractions, by centrifugal forces, occurs in instances where the mean temperature radially of the centrifuge is at a minimum and, since the side wall of the centrifuge in most cases is relatively warm, a decreasing temperature gradient radially inward of the centrifuge, that is not greater than the adiabatic gradient, is advantageous in that it produces a relatively lower mean temperature radially of the centrifuge. The benefit derived from a temperature gradient radially of the centrifuge is confined to a gradient that is not greater than the adiabatic given by the following expression:

$$\frac{dT}{dr} = \frac{Mrw^2}{Cp}$$

wherein T is the absolute temperature, r is the radial coordinate in centimeters (variable), M is the mean molecular weight of the gaseous mixture expressed in grams per mole, w is the angular velocity of the rotor in radians per second, and Cp is the specific heat of the mixture, at constant pressure, in ergs per degree centigrade per mole.

The amount of cooling permissible, of course, is limited by the fact that the temperature of the process gas must not be allowed to fall below the dew-point at any point in the rotor. This dew-point will depend on the pressure,

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which varies radially of the centrifuge in a manner that can be calculated from the gas laws.

These phenomena consistently have been overlooked in the development of centrifugal separation, particularly the development of the separation of isotopic gaseous mixtures by centrifugal action, and prior to the present invention no provision has been made in such devices for balancing and compensating for increases or decreases in the temperature of the gases in the centrifuge, or for the neutralization of harmful, or the utilization of beneficial, temperature gradients produced thereby. The result of this is that the separation factor for such devices has been low, and such devices have not proven commercially practicable from an economic standpoint.

With the foregoing premises in mind, the principal object of the present invention is to provide a centrifugal separator for separating gaseous mixtures and isotopic mixtures wherein means are provided for controlling and regulating the temperature of the gases flowing through the centrifuge to thereby materially improve the separation that may be obtained.

Another object of the invention is to provide a centrifugal separator for gaseous mixtures as set forth, wherein means are provided for controlling and regulating the temperature gradients both longitudinally and radially of the centrifuge.

Another object of the invention is to provide a centrifugal separator of the stated character embodying means for balancing or compensating for increases or decreases in the temperature of the gases as the result of acceleration and compression or deceleration and expansion thereof, respectively.

A further object of the invention is to provide a centrifugal separator of the type described having means for neutralizing harmful, and utilizing beneficial, temperature gradients within the centrifuge.

More particularly it is an object of the present invention to provide a centrifugal separator embodying means for cooling the incoming gases that are heated due to acceleration and compression thereof, and means for heating the outgoing gases that are subject to deceleration and expansion thereby being cooled, together with suitable means for maintaining a relatively cool temperature at the core or central region of the centrifuge.

These and other objects of the invention, and the various features and details of the construction and operation thereof, are hereinafter fully set forth and described, and shown in the accompanying drawing, in which the figure is a sectional view taken vertically through a centrifugal separator embodying one suitable construction and arrangement of parts for achieving the stated objects of the present invention.

More particularly the drawing discloses one conventional type of centrifugal separator of the continuous, flow-through type that may be employed advantageously in the separation of gaseous vaporous mixtures and isotopic gaseous mixtures. As shown, such a centrifuge includes a centrifuge or separating chamber C enclosed by a rotor that may comprise a tubular wall member 1 having inlet and outlet caps 2 and 3, respectively, secured to opposite ends thereof. A tubular shaft 4 journaled in radial and vertical thrust bearings 22 and 23 is secured axially in the inlet end cap 2 of the rotor, and similarly secured in the outlet end cap 3, in alignment with said shaft 4, is a pair of concentrically spaced coaxially arranged tubular shafts 5 and 6, respectively. Shaft 5 is journaled for rotation in a bearing 24. The aligned tubular shafts 4 and 5 rotationally support the centrifuge rotor and these, together with the shaft 6, also constitute the inlet and outlets, respectively, to the chamber C. The rotor may be driven rotationally from any suitable

source of power, for example, by means of a pulley 7 secured upon the shaft 4 and belt 25 from an electric motor 26.

In order that the stream of gases flowing through the centrifuge chamber C may be directed through and confined to the relatively stronger fields of centrifugal force that exists outwardly from the rotational axis of the centrifuge, a cylindrical core or the like 8 may be positioned coaxially within the rotor intermediate the end caps 2 and 3. As shown, the construction of the inlet end cap 2 preferably is such that gases introduced through the inlet shaft 4 into the rotor, enter the chamber C adjacent the outer periphery thereof, and for this purpose there is provided in the inlet end cap 2 a plurality of radially extending passages 9 that have their inner end openings in communication with the inner end of the shaft 4 and their outer end openings arranged circumferentially of the centrifuge chamber C at the outer periphery thereof.

Gases entering the centrifuge chamber C and flowing upwardly therethrough are subjected to centrifugal forces that operate to separate the gaseous mixtures into relatively heavier and lighter fractions, the heavier gas fraction being produced adjacent the chamber wall 1 and the lighter fraction passing adjacent the surface of the central core member 8 as indicated by the arrows. In the illustrated embodiment of the invention, the heavier gas fraction produced adjacent the wall of the centrifuge is withdrawn therefrom through a series of radially extending passages 10 that are formed in the outlet end cap 3 and lead inwardly from the periphery of the centrifuge chamber substantially to the axis thereof where said passages communicate with the inner opening of the shaft 5 through which the heavier gas fraction passes to the exterior of the centrifuge.

On the other hand, the lighter gas fraction that is formed adjacent the core member 8 is withdrawn from the chamber C through a series of similar passages 11 that have their outer end openings arranged circumferentially of the rotational axis of the centrifuge and spaced outwardly therefrom a predetermined distance in accordance with the invention set forth in the application of Karl Cohen and Harold C. Urey Serial No. 575,532 filed January 31, 1945, now Patent Number 2,536,423. The inner end openings of the passages 11 communicate with the inner end of the tubular shaft 6 through which the lighter gas fraction is removed from the centrifuge. Preferably, the outlet shafts 5 and 6 are constructed and arranged in accordance with the invention set forth in the application of Karl Cohen and Harold C. Urey Serial No. 575,532 filed January 31, 1945, now Patent Number 2,536,423.

As previously stated, gases entering the centrifuge through shaft 4 and passages 9 are accelerated and compressed by the action of the centrifugal forces generated by rotation of the centrifuge, to an extent that said gases are heated, and gases leaving the centrifuge through passages 10 and 11, and shafts 5 and 6, are decelerated and expanded to an extent that they are cooled. Such heating and cooling of the gases entering and leaving the chamber normally creates a temperature gradient longitudinally of the centrifuge that causes thermal convection currents to be set up that disrupt and interfere with the normal gas flow and hence lessen the efficiency, or degree, of separation of the gaseous mixtures that otherwise would be obtained.

In accordance with the invention, therefore, means are provided for regulating and controlling the temperature of the incoming and outgoing gases at opposite ends of the centrifuge in order to balance or equalize such temperatures and thereby eliminate objectionable temperature gradients lengthwise of the centrifuge. This may be accomplished by providing at the inlet end of the centrifuge suitable means for cooling the entering gases that are heated by reason of the acceleration and compression thereof, and by providing at the outlet end of the cen-

trifuge suitable means for heating the outgoing gases that are cooled due to deceleration and expansion thereof.

In the illustrated embodiment of the invention, cooling of the inlet end cap, and consequently of the incoming gases, is effected by providing a coil 12 for circulating cooling fluid circumferentially adjacent and below the inlet end cap 2. A coil 13 for heating fluid is similarly arranged exteriorly of the outlet end cap 3 of the centrifuge. Cooling and heating fluids are circulated through the coils 12 and 13, respectively, and these circulated fluids are controlled and maintained at the proper temperature necessary to balance or otherwise control the temperature of the incoming and outgoing gases as desired, to eliminate harmful temperature gradients in the gases in a direction axially of the centrifuge.

The control of temperature gradients radially of the centrifuge also is desirable in order that such gradient may be maintained at or below the adiabatic gradient, and at the same time provide a minimum mean temperature radially of the centrifuge. To this end, and in order that the centrifuge peripheral wall member 1 may be maintained at a relatively cool temperature, the said wall member 1, and the inlet cap 2, are secured together in thermal conductive relation or contact with each other, as indicated at 14, so that the wall member 1 is cooled by the coil 12 through conduction from the inlet cap 2. In order that the centrifuge wall member 1 may obtain the full benefit of the cooling action of the coil 12, through conduction from the end cap 2, the wall member 1 preferably is thermally insulated from the other or outlet end cap 3 that is heated by means of the coil 13. Insulation of the member 1 from thermal contact with the heated end cap 3 may be accomplished in any suitable manner such as, for example, by means of gaskets 15, or otherwise.

In order that the mean temperature transversely or radially of the centrifuge chamber C may be maintained within a range that will insure the greatest separation of the gaseous mixtures as aforesaid, and provide an increasing temperature gradient radially outward of the centrifuge to the relatively cool wall member 1 thereof, the core member 8 may be thermally insulated from both of the end caps 2 and 3, respectively, and in addition may be positively cooled, and its temperature controlled as dictated, to insure maximum separation of the gases flowing through the centrifuge.

The core member 8 may be insulated from the end caps 2 and 3 in any suitable manner. Thus, for example, insulation of the core 8 from the inlet end cap 2 may be accomplished by providing suitable baffles 16 intermediate the end cap 2 and core member 8, and the upper end of the said core member 8 may be insulated effectively from the outlet end cap 3 by means of suitable gaskets or the like 17 of heat insulating material, all in accordance with the construction and arrangement shown in the drawing.

In addition to maintaining the core 8 relatively cool by insulating the same from the centrifuge end caps 2 and 3, respectively, the core 8 may be independently and positively cooled to the desired temperature by passing axially therethrough a suitable volatile refrigerant or cooling fluid. To this end, the core 8 is provided with an axial bore or elongated chamber 18 therein of proper cross-sectional area, and refrigerant or cooling fluid is circulated through said chamber 18, in the same direction as the gas flow through the centrifuge, by means of comparatively small tubular shafts 19 and 20 secured coaxially and concentrically within the shafts 4 and 6, respectively, the inner ends of said shafts 19 and 20 communicating, respectively, with the opposite ends of the core chamber 18.

For example, the core chamber 18 may comprise the evaporator of a closed refrigerant system of the compression-condenser-evaporator type in which event the shaft 20 is connected to the suction side of a compressor (not

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shown) wherein the vapor withdrawn from chamber 18 is compressed, and then condensed and returned in liquid form to the chamber 18 through the shaft 19. The cooling liquid entering the chamber 18 is prevented from passing upwardly entirely through the chamber 18 by the centrifugal field generated by rotation of the centrifuge, and the cooling liquid is vaporized in the chamber 18 by the absorption of heat from the core 8, the resulting vapor being withdrawn from the chamber 18 through shaft 20 by the said compressor or pump, and recirculated. Retention of the cooling liquid in the core chamber 18 is aided by making the shaft 20 of slightly smaller diameter than the inlet shaft 19.

From the foregoing, it will be observed that the present invention provides a centrifugal separator for separating gaseous mixtures and isotopic gaseous mixtures wherein the temperature gradients both longitudinally and radially of the centrifuge may be controlled effectively to produce a maximum separation of the process gases flowing therethrough. The invention provides for the balancing or control of increases and decreases in temperature in various zones of the centrifuge chamber as the result of compression and expansion, respectively, of the process gases, and may be employed effectively both to neutralize harmful temperature gradients, and to utilize beneficial temperature gradients, within the centrifuge.

It will be obvious, of course, that means other than those herein disclosed may be employed as desired for heating and cooling the several portions of the centrifuge as well as for thermally insulating the certain portions or parts of the device from one another, and while a particular embodiment of the invention has been illustrated and described herein, it is not intended that the invention be limited to this disclosure, but that changes, modifications and substitutions may be made and incorporated therein within the scope of the claims.

I claim:

1. In a centrifuge for separating gaseous mixtures, a rotor comprising spaced inlet and outlet end caps having a tubular wall member therebetween and thermally contacting said inlet end cap, means supporting said rotor for rotation about its longitudinal axis, means operable to cool gases entering said rotor through said inlet end cap, means operable to heat gases leaving said rotor through said outlet end cap, and means thermally insulating said wall member from the outlet end cap whereby to effect maximum cooling of said wall member by conduction to said inlet end cap.

2. In a centrifuge for separating gaseous mixtures, a rotor comprising spaced gas inlet and outlet end caps having a tubular wall member therebetween and thermally contacting said inlet end cap, means supporting said rotor for rotation about its longitudinal axis, means operable to cool gases entering said rotor through said inlet end cap, means thermally insulating said wall member from the outlet end cap whereby to effect maximum cooling of said wall member by conduction to said inlet end cap, a core in said rotor disposed coaxially of the rotational axis thereof, and means insulating said core from the rotor end caps.

3. In a centrifuge for separating gaseous mixtures, a rotor comprising spaced gas inlet and outlet end caps having a tubular wall member therebetween and thermally contacting said inlet end cap, means supporting said rotor for rotation about its longitudinal axis, means operable to cool gases entering said rotor through said inlet end cap, means thermally insulating said wall member from the outlet end cap whereby to effect maximum cooling of said wall member by conduction to said inlet end cap, a core in said rotor disposed coaxially of the rotational axis thereof, means thermally insulating the core from the inlet end cap, and means for cooling said core.

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4. A centrifuge as claimed in claim 3 wherein the means insulating the core from the inlet end cap comprises a plurality of spaced baffle members disposed transversely of the rotational axis of the centrifuge intermediate said core and inlet end cap.

5. In a centrifuge for separating gaseous mixtures, a rotor comprising spaced gas inlet and outlet end caps having a tubular wall member therebetween and thermally contacting said inlet end cap, means supporting said rotor for rotation about its longitudinal axis, means operable to cool gases entering said rotor through said inlet end cap, means thermally insulating said wall member from the outlet end cap to effect maximum cooling of said wall member by conduction from said inlet end cap, a core in said rotor disposed coaxially of the rotational axis thereof, and means for circulating a cooling fluid through said core to cool the latter.

6. In a continuous flow-through centrifuge for separating gaseous mixtures, a rotor comprising spaced inlet and outlet end caps having a tubular wall member therebetween and thermally contacting said inlet end cap, aligned tubular shafts coaxially in said end caps and supporting said rotor for rotation about its longitudinal axis, said shafts constituting inlet and outlet passages to the rotor, means to cool gases entering said rotor through said inlet end cap, means to heat gases leaving said rotor through said outlet end cap, and means thermally insulating said wall member from the outlet end cap whereby to effect maximum cooling of the wall member by conduction to said inlet end cap.

7. In a continuous flow-through centrifuge for separating gaseous mixtures, a rotor comprising spaced inlet and outlet end caps having a tubular wall member therebetween and thermally contacting said inlet end cap, aligned tubular shafts secured coaxially in said end caps and supporting said rotor for rotation about its longitudinal axis, said shafts constituting inlet and outlet passages to the rotor, means to cool gases entering said rotor through said inlet end cap, means to heat gases leaving said rotor through said outlet end cap, means thermally insulating said wall member from the outlet end cap whereby to effect maximum cooling of the wall member by conduction from said inlet end cap, a core in said rotor disposed coaxially of the rotational axis thereof, and means thermally insulating said core from said inlet and outlet end caps.

8. In a continuous flow-through centrifuge for separating gaseous mixtures, a rotor comprising spaced inlet and outlet end caps having a tubular wall member therebetween and thermally contacting said inlet end cap, aligned tubular shafts secured coaxially in said end caps and supporting said rotor for rotation about its longitudinal axis, said shafts constituting inlet and outlet passages to the rotor, means to cool gases entering said rotor through said inlet end cap, means to heat gases leaving said rotor through said outlet end cap, means thermally insulating said wall member from the outlet end cap whereby to effect maximum cooling of the wall member by conduction to said inlet end cap, a core in said rotor disposed coaxially of the rotational axis thereof, means thermally insulating said core from said inlet and outlet end caps, and means for circulating a cooling fluid through said core to cool the latter.

References Cited in the file of this patent

UNITED STATES PATENTS

1,061,656	Black	May 13, 1913
1,571,943	Hall	Feb. 9, 1926
1,699,379	Sperry	Jan. 15, 1929
1,740,940	Brasington	Dec. 24, 1929
2,000,521	Jones	May 7, 1935
2,138,468	Ayres	Nov. 29, 1938
2,302,381	Scott	Nov. 17, 1942