United States Patent [19]

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[11] **3,925,036**

[45] **Dec. 9, 1975**

[54] **STAGE DESIGN**

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[22] Filed: **Mar. 23, 1951**

[21] Appl. No.: **217,116**

[52] **U.S. Cl.** **55/158;** 55/484; 233/18

[51] **Int. Cl.**[2] **B01D 13/00**

[58] **Field of Search** 230/121, 122, 123, 47; 183/2.2, 115; 55/158, 424; 233/18

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EXEMPLARY CLAIM

1. A method of cycling gases through a plurality of diffusion stages comprising the steps of admitting the diffused gases from a first diffusion stage into an axial compressor, simultaneously admitting the undiffused gases from a second diffusion stage into an intermediate pressure zone of said compressor corresponding in pressure to the pressure of said undiffused gases, and then admitting the resulting compressed mixture of diffused and undiffused gases into a third diffusion stage.

2 Claims, 3 Drawing Figures

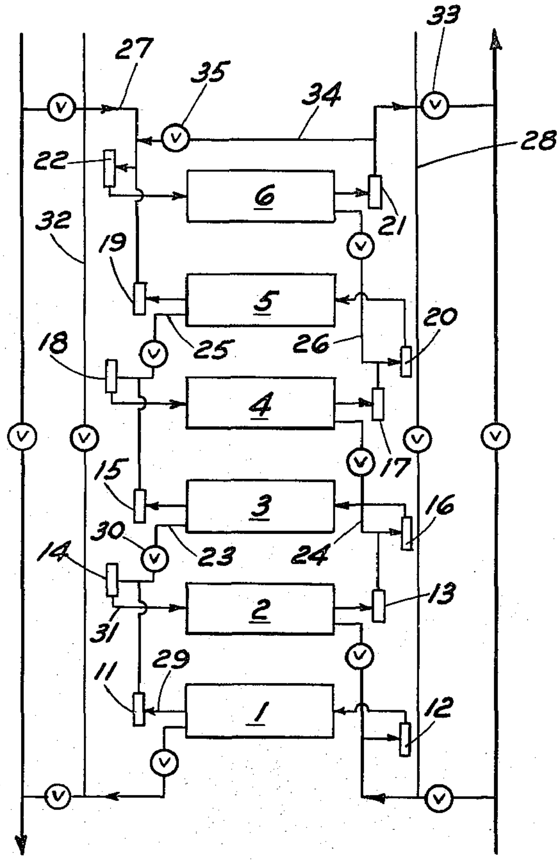

Fig. 1

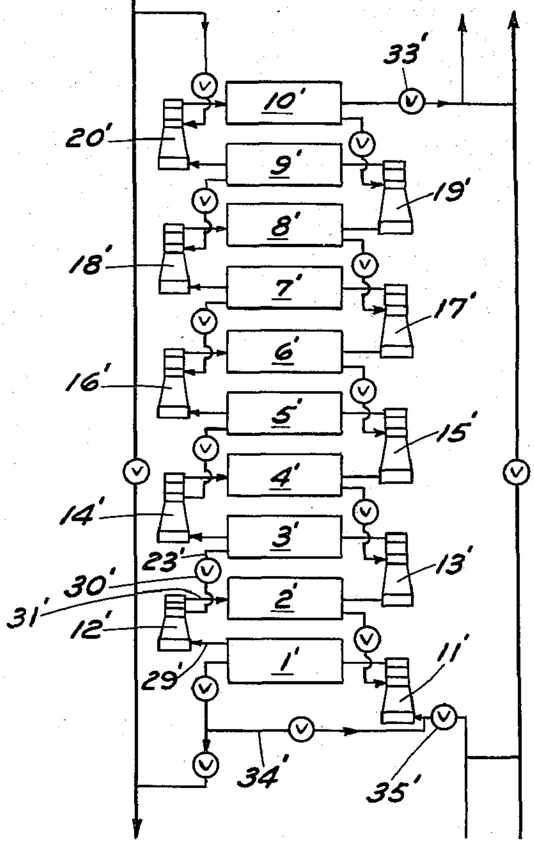

Fig. 2

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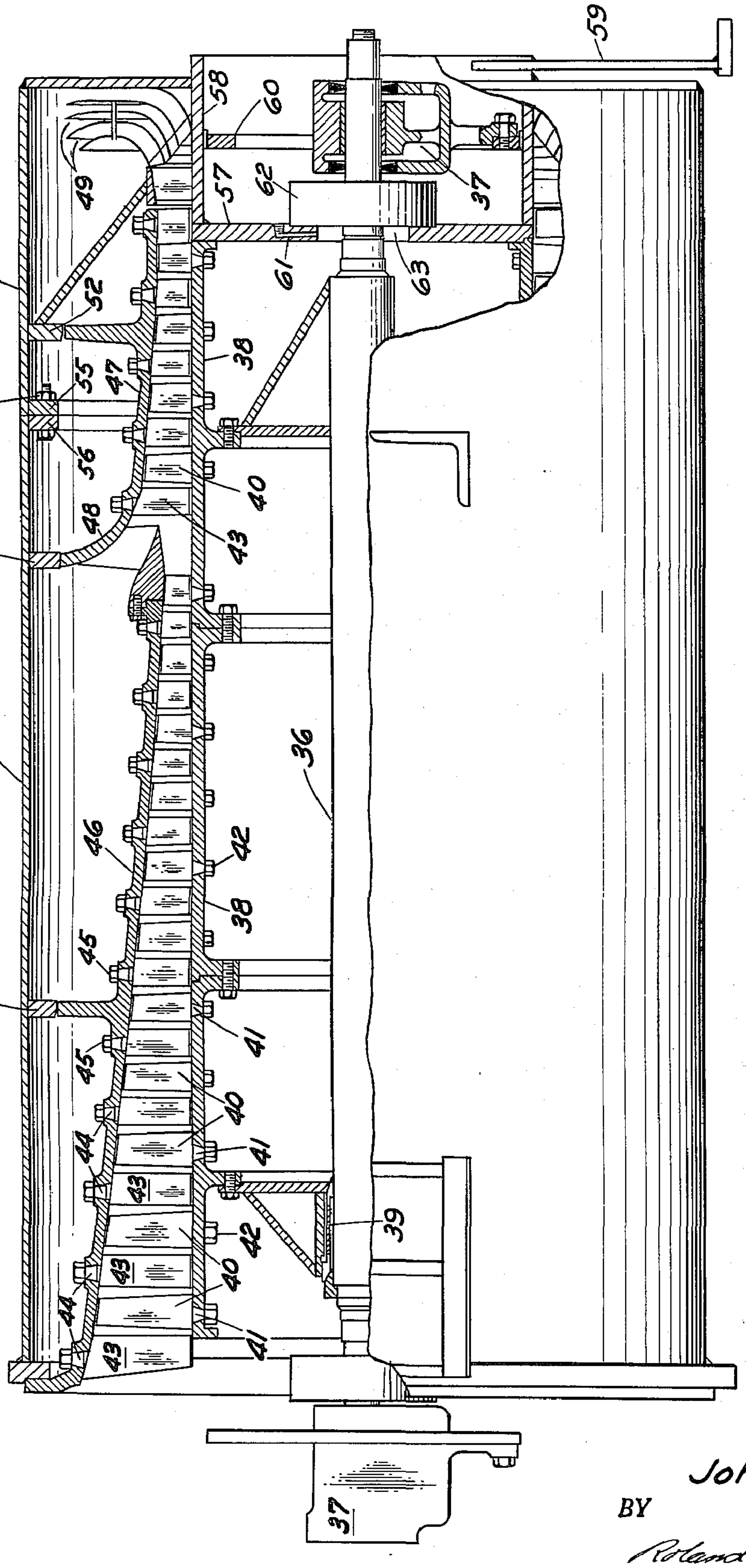

FIG. 3

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STAGE DESIGN

My invention relates to the separation of isotopes of elements and more particularly to an improved gaseous diffusion system for separating isotopes in the gaseous phase including a novel form of axial compressor for combining gases at different pressures during the cycling and recycling operations.

Heretofore, in the prior art, it has been the practice in separating the lighter isotopes of a gas from the heavier ones to selectively diffuse them through a permeable membrane. Where the isotopes of uranium, for example, are to be separated, the permeable membrane may take the form of a series of porous tubes or barriers through which the gaseous uranium, preferably in the form of UF_6, flows. In its passage through the tubes or barriers the lighter isotopes of the gas diffuse outwardly through the walls thereof at a faster rate than the heavier ones. A large number of tubes may be arranged in parallel and enclosed in a shell or casing to form a diffuser, which, together with the pumping and control equipment make up a stage. A plurality of these diffusion stages are arranged in groups to form cells. The cells are connected in series so that the ligher diffusion product provides the feed for the next stage in line, and the heavier product in each case is recycled back to the adjacent lower stage. In a similar manner, a group of cells may be cascaded, the lighter diffusion product for each cell providing the feed for the next cell in line, and the heavier product being recycled to the next lower cell. The lighter product is diffused up the cascade and is withdrawn at the top, whereas the heavier material, which constitutes the waste, travels down the cascade and is removed at the bottom. For the purpose of forwarding the diffused gases, and combining the diffused gases with undiffused gases of higher stages for further cycling, it has been the practice to employ at least two centrifugal compressors or pumps for each stage. Each centrifugal pump requires special shaft supports or bearings and special seals at the shafts to prevent ingress of humid atmospheric air into the system, and is, at the present level of industrial knowledge, very limited in the magnitude of the compression ratio with UF_6 gas. In addition, with present knowledge, each centrifugal pump or compressor is limited in overall efficiency of performance, and requires a separate motor for driving it. This results in larger power consumption and limits the efficiency of operation. Also, the cost of construction and maintenance of such units reflects the fact that each pump is an integral, complete unit of equipment with all necessary auxiliary components.

Applicant with a knowledge of these problems in the prior art has for an object of his invention the provision of a mechanical diffusion system employing axial compressors to replace the centrifugal compressors employed heretofore for cycling and recycling the gases through the system.

Applicant has as another object of his invention the provision of a mechanical diffusion system for the separation of isotopes wherein a single axial compressor is utilized in each stage for cycling and recycling the gases and to assume, with superior performance and greater efficiency, the functions of a plurality of centrifugal pumps.

Applicant has as a further object of his invention the provision of a mechanical diffusion system made up of a series of stages wherein a single axial compressor, driven by a single motor, is employed in each stage for cycling and recycling gases through the system, thereby eliminating the use of a plurality of electrical motors as well as of centrifugal compressors and thereby also attaining greater efficiencies of energy conversion, since a single larger motor can be utilized to provide more efficiency than a number of small motors.

Applicant has as a still further object of his invention the provision of a mechanical diffusion system employing in each stage a single multistage axial compressor for combining gases at different pressures and cycling and recycling them through the system.

Other objects and advantages of my invention will appear from the following specification and accompanying drawings, and the novel features will be particularly brought out in the annexed claims.

In the drawings,

FIG. 1 is a schematic of a cell of a diffusion system employing the conventional pumping arrangement of the prior art.

FIG. 2 is a schematic of a cell of my improved diffusion system incorporating the novel axial compressor therein.

FIG. 3 is an elevation, partly in section, of an axial compressor for use in a diffusion system, which unit was constructed in consequence to my invention and illustrates the utilization of my ideas.

Referring to the drawings in detail, and particularly to FIG. 1, wherein a group of six succeeding diffusion stages including diffusers **1, 2, 3, 4, 5,** and **6,** serve to make up the conventional cell of the prior art. This is the smallest group of diffusion stages which was selected for operation as an independent unit in this particular cascade. Each diffusion stage of the cell comprises a diffuser, a pressure control valve, two centrifugal compressors, and inter-connecting lines. It is thus seen that the centrifugal compressors **11, 13, 15, 17, 19** and **21** receive the gases diffused through the barriers of diffusers **1, 2, 3, 4, 5** and **6,** respectively, and raise them to higher pressures so as to correspond to the pressures of undiffused gases carried from the higher diffusers by lines **23, 24, 25, 26, 27,** plus an additional line (not shown) in the adjacent higher cell (not shown), in order that they may becombined and fed into centrifugal compressors **14, 16, 18, 20** and **22,** plus an additional compressor (not shown) in the adjacent cell (not shown), for recycling through the system of diffusers. In this arrangement, gases which have diffused through the barriers of diffuser **1,** for instance, pass through line **29** to centrifugal compressor **11** where the pressure is raised to that corresponding to the undiffused gases from diffuser **3** which pass through line **23** and pressure valve **30,** of conventional form. This enables the output of diffused gases of diffuser **1** from pump **11** to be combined with the undiffused gases from diffuser **3,** higher in the cascade, as they pass out through line **23.** The combined gases then pass into centrifugal compressor **14** which raises their pressure still further prior to entrance through line **31** into intermediate diffuser **2.** It is, therefore, apparent that in this arrangement the undiffused gases from a higher stage are combined with the diffused gases from a lower stage, and the combination of gases then provides the feed for an intermediate stage. In this arrangement, two centrifugal compressors are used for each stage, and they are driven with separate motors. while the two compressors or pumps might be coupled together through a single shaft for operation from a single motor, it has been found that this is not feasible in the larger sizes without additional supports, bearings, seals, and auxiliary equipment, since "whipping" results on the shaft due to its extended unsupported length.

This invention contemplates replacing the two centrifugal pumps of each diffusion stage with a single multi-stage axial compressor which integrates the compression requirements of the stage. As shown in FIG. **2**, the axial compressor of each stage has a single outlet, and is provided with both a conventional gas inlet for the admission of diffused gas and an interstage inlet for the addmission of undiffused gas. The interstage inlet communicates with that point in the compressor which is at a gas pressure corresponding to the pressure on the downstream side of the stage control valve. The axial compressor thus incorporates the functions of the two centrifugal pumps referred to above, with the initial stages of the axial compressor pressuring diffused gas, and the remaining stages pressuring a mixture of diffused and undiffused gas.

In FIG. **2**, a new cell with ten stages is shown instead of the six stages employed in the conventional arrangement of FIG. **1**. The diffusers **1'**, **2'**, **3'**, **4'**, **5'**, **6'**, **7'**, **8'**, **9'** and **10'**, are associated with axial compressors **11'**, **12'**, **13'**, **14'**, **15'**, **16'**, **17'**, **18'**, **19'** and **20'**, respectively, in a manner indicated hereinafter. The output from diffuser **1'**, which has diffused through the barriers therein, passes through line **29'** into one end of axial compressor **12'** while the undiffused output from diffuser **3'** passes into an intermediate portion of compressor **12'** through line **23'** and control valve **30'**. The combined gases then leave the axial compressor at the other end through line **31'** to form the feed for diffused **2'**. Other stages of the cell are connected in a similar manner. With the use of the axial compressor considerably greater pumping efficiency may be obtained than with the centrifugal compressor, due to the factors previously mentioned, and also due to the fact that the axial compressor is inherently well adapted to large gas volumes and to a much wider range of compression ratios.

Referring again to FIGS. **1** and **2**, it will be apparent that certain changes in process piping have been incorporated in the arrangement of FIG. **2**. For example, the inverse recycle lines **28** and **32** of FIG. **1** have been eliminated. These lines in the conventional arrangement, when the cell is isolated from the remaining cascade, serve to link the two inlets with the two outlets of the cell in order to permit continuous cycling of the terminal process flows. The upper recycle line **34** of FIG. **1**, designed to provide an outlet for compressor **21** through the automatically controlled valve **35** when the gate valve **33** is closed, is obviated by the arrangement of FIG. **2**, wherein the diffused gas compressor, in the adjacent cell (not shown), is located on the downstream side of the gate valve **33'**, thus permitting closing of the gate valve **33'** without a harmful buildup of pressure. The line **34'**, shown in FIG. **2**, has been provided to recycle undiffused gas through the initial stages of the axial compressor **11'** in the event that the inlet valve **35'** is closed. Such a provision is necessary to prevent the trapping and consequent overheating of gas in the initial stages of the compressor. Various auxiliary systems, including sampling lines, evacuation lines, etc., which form no part of this invention, have been omitted for purposes of clarity.

A typical form of axial compressor which may be used in the above system is shown in FIG. **3**, wherein shaft **36**, journalled in special cell bearings **37**, **37** serves to mount a rotor **38** through key **39**. The rotor **38** may be made up of a series of sections which are bolted together. The rotor **38** carries a series of spaced air foil blades **40** of progressively shorter length. These blades **40** may also be set in off-set relation longitudinally of the rotor. They carry tapered shanks **41** which seat in tapered holes in the rotor and have screw threaded ends for the reception of nuts **42** to retain them in place. The blades **40** may be of the usual configuration and are positioned between alternate rows of stationary blades **43** of similar configuration and have progressively shorter length. These stationary blades also have tapered shanks **44** with nuts **45** for mounting them on the outer housing **46** through which they pass. The housing **46** tapers inwardly from left to right and at an intermediate portion of the compressor merges with a similar housing **47** which is flared out to provide an intake **48**. At this point the fan blades **40** carried by the rotor **38** again become longer but progressively decrease in length as the opposite end or outlet is approached. These latter moving blades co-act with spaced stationary blades **43**, as heretofore indicated in connection with housing **46**. This latter housing with its flared portion **48** cooperates with an opening (not shown) to provide an intermediate intake for receiving the undiffused gases from a higher diffuser and blending them with the diffused gases of a lower diffuser passing through housing **46**. Finally, when the two sets of gases are blended and further compressed they reach the outlet **49** where they pass out to enter the feed of a diffuser in the cascade which is positioned intermediate of the above diffusers. For the purpose of enclosing and supporting the units an outer casing **50** is provided. This casing includes a series of supporting rings **51**, **51** welded to its inner surface at spaced intervals for engaging projections on the inner housings **46**, **47**. Casing **50** may be joined to an end cover **53** by flanges **55**, **56** through bolts **54**. A ring support **52**, carried by the cover **53** also serves to support housing **47** and to provide a partition. Inlet openings for the two intake positions and an outlet for the compressor in the cover **53** and casing **50** have been omitted for purposes of simplicity. This is also true of the supports and other miscellaneous structure of conventional type.

The rotor **38** abuts against a seal mounting plate or back plate **57** welded to the end of a cylindrical casing **58** which is supported by a leg or bracket **59**. Disposed within casing **58** and welded to an intermediate portion thereof is a supporting ring **60** which serves to support bearing **37**. The seal mounting plate has a passage **61** therein for the flow of gas to the interior of the compressor. It is also recessed to receive a shaft seal **62** carried by the shaft **36** for preventing the passage of gas through opening **63** in plate **57**, except via passage **61**.

Having thus described my invention, I claim:

1. A method of cycling gases through a plurality of diffusion stages comprising the steps of admitting the diffused gases from a first diffusion stage into an axial compressor, simultaneously admitting the undiffused gases from a second diffusion stage into an intermediate pressure zone of said compressor corresponding in pressure to the pressure of said undiffused gases, and then admitting the resulting compressed mixture of diffused and undiffused gases into a third diffusion stage.

2. An improved method of cycling gases through a plurality of diffusion stages in cascade relationship, which comprises admitting the diffused gases from a first diffusion stage into the initial compressor stage of a multi-stage axial compressor, admitting the undiffused gases from a diffusion stage at least two diffusion stages upstream from said first diffusion stage at least two diffusion stages upstream from said first diffusion stage into an intermediate stage of said axial compressor which is at a gas pressure corresponding to the pressure of said undiffused gas and admitting the resulting compressed mixture of diffused and undiffused gases from the exit cmpressor stage of said axial compressor into a diffusion stage intermediate the diffusion stages from which said gases were withdrawn.

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