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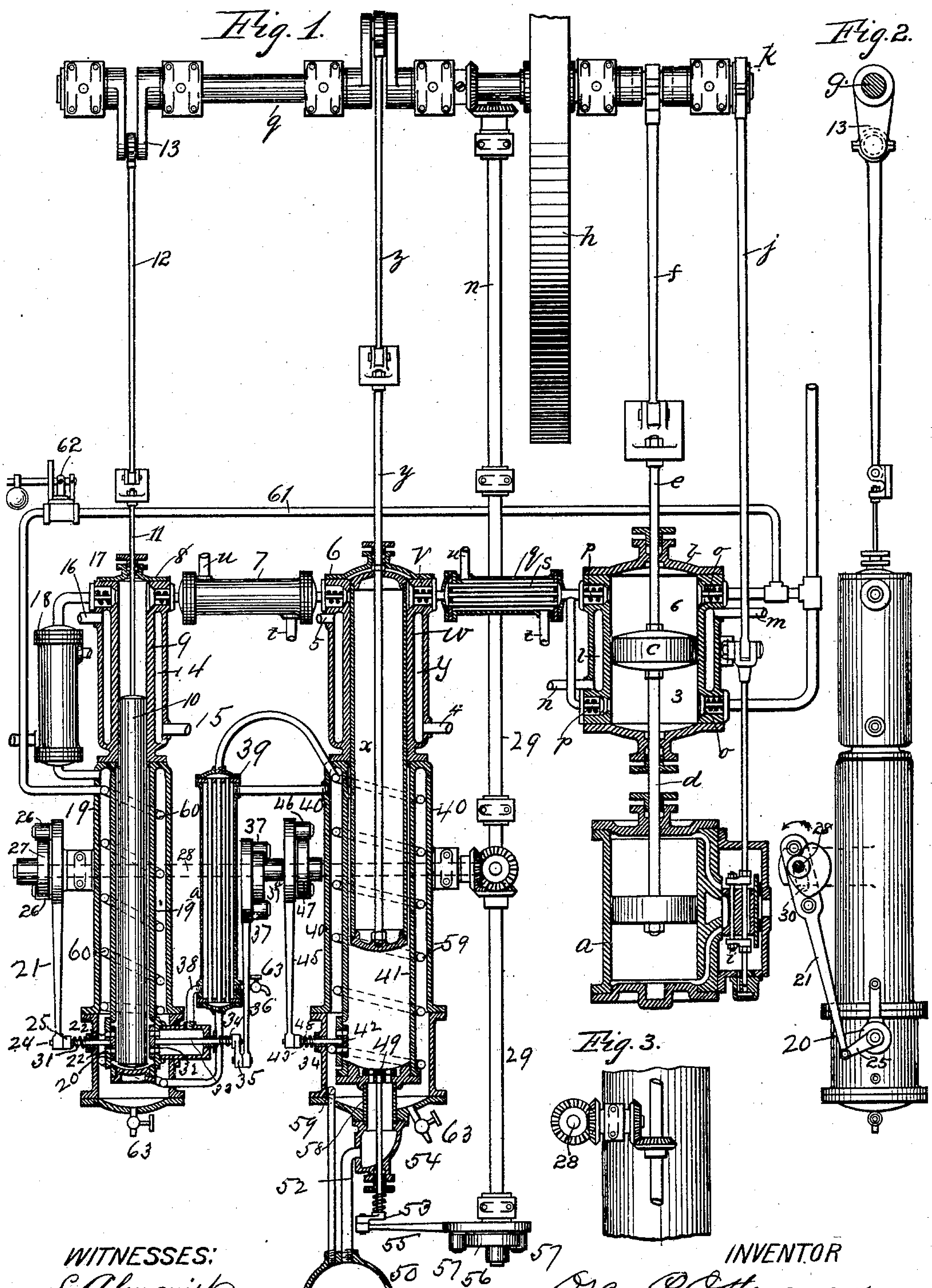
O. P. OSTERGREN.

APPARATUS FOR REFRIGERATION OF ATMOSPHERIC AIR.

(Application filed Oct. 20, 1900.)

(No Model.)



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APPARATUS FOR REFRIGERATION OF ATMOSPHERIC AIR.

SPECIFICATION forming part of Letters Patent No. 679,907, dated August 6, 1901.

Application filed October 20, 1900. Serial No. 33,681. (No model.)

To all whom it may concern:

Be it known that I, OSCAR P. OSTERGREN, a subject of the King of Sweden and Norway, and a resident of Bedford Park, borough of Bronx, city and State of New York, have invented certain new and useful Improvements in Apparatus for Refrigeration of Atmospheric Air, of which the following is a specification.

My invention consists of improvements in apparatus for refrigerating and possibly liquefying atmospheric air by means of compression, cooling, and expansion of the air, as hereinafter described, reference being made to the accompanying drawings, in which—

Figure 1 is mainly a vertical section of apparatus adapted for carrying out my invention, but some parts are shown in elevation. Fig. 2 represents a part of said apparatus in side elevation. Fig. 3 represents another part of said apparatus in side elevation.

In cooling air through expansion the effect will be improved by heating the air during expansion in doing useful work, (just as the best effect in compressing air is obtained by cooling it during compression;) but as this can be done only partially, due to the limitation of the cylinder-surface, it is necessary for best results to expand in stages with intermediate heating, and as refrigeration is the ultimate purpose an especial advantage will result if such heat be taken out of the compressed air which in turn is being expanded, which is the essential feature of my invention and which in the present instance I seek to accomplish by the following apparatus.

a represents a steam-engine, which may be of any approved construction. *b* represents an air-compressor, whereof the piston *c* is connected to the rod *d* of the engine-piston, and piston C is connected by its rod *e* and connecting-rod *f* with a crank-shaft *g*, carrying a suitable balance-wheel *h* and suitably geared with the slide-valve *i* of said engine by a rod *j* and eccentric *k* for working said valve. The cylinder of the air-compressor has a jacket *l* for circulating water for cooling the air while being compressed, with an inlet-pipe *m* and outlet *n* for the water. Air for being compressed enters the compressing-cylinder through suction-valves *o*, and the compressed air escapes through eduction-valves *p* into a cooler *q*, where the air is further cooled by water circulating therein around the pipes *s*, through which the air passes, the water being supplied and discharged through suitable pipes *t u*. The power of this engine *a* is to be in excess of the power to be expended in compressing the air. From the cooler *q* the compressed air enters through inlet-valve *v* the compressing end *w* of a combined compressing and expanding cylinder of considerable length and containing a long plunger-piston *x*, which is connected by its rod *y* and the connecting-rod *z* with the crank-shaft *g* of the steam-engine. The compressing part *w* of said cylinder is of somewhat greater length than the length of the movement of the piston and fits the piston closely to enable further compression of the air and will, if necessary, in practice have suitable packing to hold the air and will have suitable means of lubricating the closely-fitting parts. This compressing part *w* of the combined cylinder is surrounded by a water-jacket having circulating-pipes 4 and 5 for further cooling the air while being compressed. The compressed air is ejected through eduction-valve 6 into another cooler 7 of like character as cooler *q* and passes on through inlet-valve 8 into the compressing end 9 of another long combined compressing and expanding cylinder, containing a long plunger-piston 10, which is connected by its rod 11 and connecting-rod 12 with a crank 13 of the crank-shaft *g*. These are of like character as the first combined compressing and expanding engine, but of smaller diameter and adapted for effecting higher compression. The part 9 of said cylinder is also jacketed at 14 for the circulating of cooling-water through pipes 15 and 16. The compressed air is ejected through eduction-valve 17 into another cooler 18 and therefrom into a jacket 19 of the expanding part of the second combined engine. From this jacket the compressed air is periodically admitted into the expanding part 19ª of said cylinder under piston 10, through the inlet-valve 20, to expand thereunder for being further cooled and to expend its energy on the piston for effecting part of the work of compressing the air, said valve being adapted to cut off the inlet, as is usual in working fluids expansively. Any form of valve and valve-operating mechanism may be employed; but in this example I have represented a rotatory disk having ports 22, which register with and are cut off from like ports 23 of the cylinder-port face, according as the valve is turned one way or the other, said valve having an axial stem 24, on which is a crank 25, to which a rod 21 is attached, which carries roller-tappets 26, between which a cam 27 works to operate the valve, said cam being carried on a shaft 28, which is geared with another shaft 29, that is geared with the crank-shaft *g*. The bar 21 has a slot 30, by which it rides on shaft 28 for its support. The contour of the cam 27 is calculated to open and close the valve at the proper times for admission and cut-off, as predetermined. A compression-spring 31 on the stem of the valve between the crank and the stuffing-box holds the valve on the valve-seat against the tendency of the compressed air to lift the valve. The exhaust-valve is another disk 32, having an axial stem 33 for operating it. The valve also has a compression-spring 34 on its stem to hold it on its seat. The ports are the same in this valve and its seat as in the other and like mechanism is employed for working it, as the crank 35, rod 36, roller-tappets 37 on said rod, and cam 37^a on shaft 28, said rod being slotted same as rod 21 for its support on shaft 28. The compressed air thus used and expanded in part 19^a of the cylinder is by such expansion cooled down below the air in the jacket and takes up heat therefrom during expansion for greater effect on the piston. When having thus expanded and accomplished its work in the cylinder, the expanded air is exhausted through pipe 38 into the counter-current apparatus 39 and through it into jacket 40 of part 41 of the first combined compressing and expanding cylinder, from which it is periodically admitted through valve 42 into said part 41 of the cylinder under piston x for being further expanded and for applying part of its energy to the crank-shaft. The valve 42 is of similar character as those employed in connection with expanding part 9 of the second combined compressing and expanding engine and has a crank 43 on its stem 44, to which a rod 45 is connected, said rod having roller-tappets 46, actuated by a cam 47 on the shaft 28, said rod also being yoked onto said shaft by a slot same as the others, and a compression-spring 48 on the stem of valve holds it to its seat. Although heat is absorbed by the air during expansion in this cylinder from the warmer air in jacket 40 to increase the effective energy under piston x, the temperature is nevertheless herein greatly reduced and possibly to the point of liquefaction of some of the air, and when the piston x is descending the contents are exhausted through valve 49 into a receiver 50, from which the liquid part, if any, may be drawn off through a cock 51 from time to time. From the valve 49 a pipe 58 conducts the escaping contents through the lower part of jacket 40 into another pipe 52, connecting with the receiver. The valve 49 is likewise a disk valve and has a crank 53 connected to its stem 54, and a rod 55 is connected to the crank and operated by a cam 56, working on roller-tappets 57, said cam being carried on the shaft 29, on which the rod 55 is yoked by a slot for its support. The air of the exhausting contents discharged into receiver 50 escapes through a coil 59 in jacket 40, thence through the counter-current device 39, and thence through another coil 60 in jacket 19, wherefrom it may be discharged into the atmosphere, but is preferably economized by being discharged into the suction side of the compressor through a pipe 61. The cold vapor is thus utilized in several stages of counter-current effects for gradual reduction of the air to be refrigerated. A relief-valve 62 in the pipe 61, with means for graduating its action, regulates the pressure of the escaping vapor as desired.

The expanding parts 19^a and 41 of the combined compressing and expanding cylinders are made slightly larger than the pistons for clearance-spaces in the localities where the low temperatures might when the apparatus is at rest stick the parts together obstructively by freezing the moisture between them. In the compressing parts where the fit is close the heat generated by compression prevents such freezing.

Suitable drain-cocks, as 63, are connected with the counter-current device and the compressing and expanding cylinders for use when required.

Any greater number of the combined compressing and expanding engines than herein represented may be employed in the series as found best, and it is possible that the required refrigeration may be effected with one only of such engines, in combination with suitable power compressing and cooling apparatus ancillary thereto, and I do not limit myself to a plurality of such engines; but with a plurality arranged in series more economical results are obtained.

I am aware that it has been asserted that causing compressed air to expand while doing work in a cylinder with a piston, whereby the air was deprived of an amount of heat equivalent to the work performed and then causing the cold thus produced to be transferred to the compressed air passing to the expansion-engine, whereby it was assumed the temperature at the commencement and termination of the expansion would continue to sink until liquefaction ensued, has not proved susceptible of practical application so far as regards the attainment of such low temperatures as are required for liquefying air, because it was not possible to maintain an expansion-engine in proper action at temperatures below the critical temperature of air—namely, 140° centigrade—nor to protect the engine-cylinder in which the expansion of air was effected sufficiently against the absorption of heat from the outside to enable such low temperature to be attained. I have anticipated these contingencies as probable in an expansion-engine of the nature to be understood from the foregoing dictum—viz, an engine doing work independently and in which it was sought to effect such expansion—and I have therefore not only provided that the expansion-engine shall only be auxiliary to a prime mover which shall maintain action of the expansion-engine and continue the expansion of the air to a greater extent than when the continuance of the expansion is dependent on the energy of the air being expanded, but have provided for the expansion in two or more stages in other auxiliary expansion-engines, dividing the work so as to reach greater expansion in the final engine, even to the extent of not at all times contributing to the motive force, and thus affording greater efficiency of expansion and limitation of surface for absorption of heat from outside, the latter being due to the smaller capacity needed in the final expansion-cylinder, owing to the division of work. Since all known so-called "permanent gases" are kept up as gas on account of heat, and I have surely in my case a degenerating process that would work out all available heat in the atmospheric air, that is here at issue, we know that the molecules will come nearer together just in proportion as we reduce the heat in the gas. Nothing will stop the reduction of heat but the occurrence of liquefaction.

What I claim as my invention is—

1. In apparatus for refrigerating compressed air, the combination of air compressing and cooling apparatus, said compressing apparatus having power in excess of the power to be expended in compressing the air, a plurality of engines for utilizing the power of the compressed air and for expanding and cooling it, said engines arranged in series and being coupled with the compressing-engine, and means for regenerating the expanding air by heat absorbed from the compressed air prior to admission into the expanding-engines, the said expanding-engines together with the prime motor adapted to continue the operations of and the expansion in the terminal engine of the series however the expansive energy of the air therein may be reduced.

2. In apparatus for refrigerating compressed air, a combined air compressing, and expanding, power-utilizing and air-cooling engine, as auxiliary to the prime-motor engine, consisting of a two-part cylinder of continuous structure, and a like plunger-piston working in both parts, the compressing parts of the cylinder and piston being close fitting and having a jacket and means for the circulation of a cooling fluid around the parts subject to the heat of compression, and the expanding parts of the same being fitted with a clearance-space between the cylinder and plunger, and also having an air-regenerating jacket, and means whereby the compressed air enters the expanding part of the cylinder through said jacket, said compressing and expanding parts of the cylinder having suitable inlet and outlet ports and valves, and said engine adapted with the aid of the prime-motor engine to continue the expansion of the air however its expansive energy may be reduced.

Signed at New York city this 15th day of October, 1900.

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Witnesses:

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