

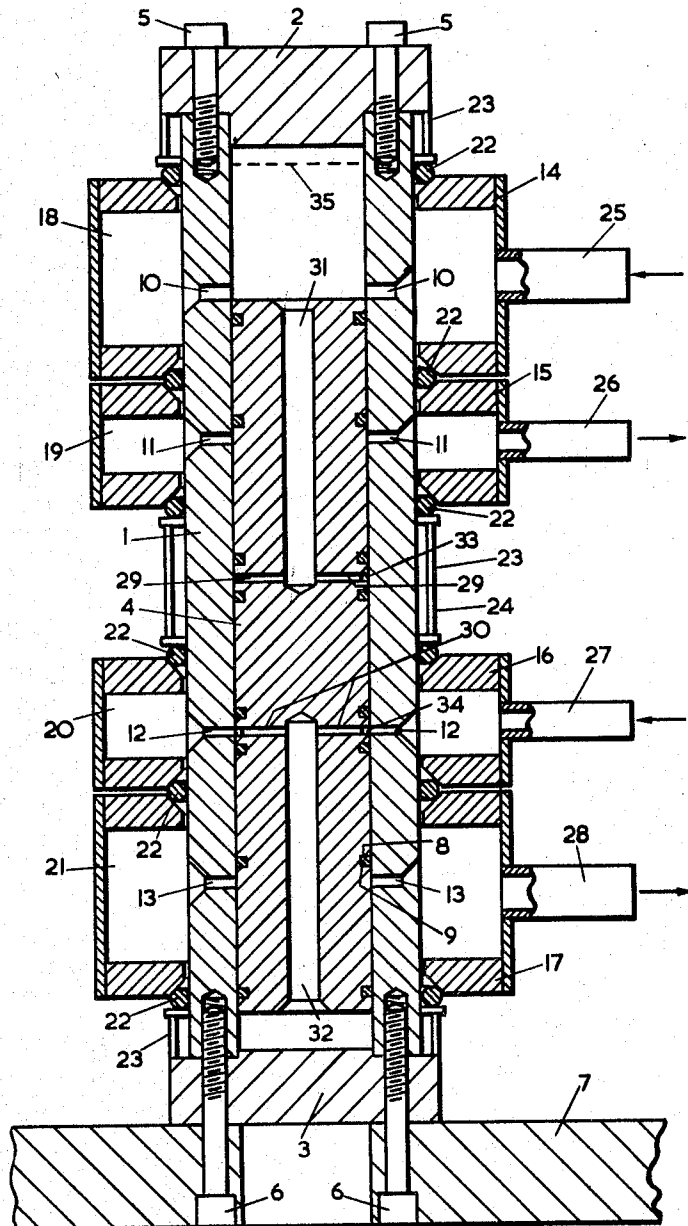
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COMBINED COMPRESSOR AND EXPANSION ENGINE

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COMBINED COMPRESSOR AND EXPANSION ENGINE

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1 Claim. (Cl. 230—54)

The present invention relates to apparatus for use in the reduction of temperature of gas.

It is known to expand a gas in a substantially adiabatic manner in an expansion engine comprising a piston and cylinder unit with resistance to relative movement between the piston and the cylinder applied during the expansion, in order to reduce the temperature of the gas. Application of resistance to relative movement between the piston and the cylinder causes the expanding gas to do work. Among the known ways of imposing resistance to relative movement between the piston and the cylinder caused by expansion of gas in the cylinder is the use of a form of so-called "brake" which converts the work of expansion into heat which is wasted. It is also known to connect the piston to a crank shaft to which is connected an electric current generator or a compressor.

The simple dissipation of heat from the work of expansion is undesirably wasteful and the machinery involved in prior proposals for making the expansion engine do useful work is usually undesirably complex.

It is an object of the present invention to obtain some useful work from an expansion engine which may be of mechanically simple construction and which may have a high order of reliability.

According to the present invention there is provided a combined compressor and expansion engine having a compression cylinder and an expansion cylinder arranged in opposition to one another, a piston in each cylinder, the two pistons being connected together for movement in unison, and having valve means operated by the piston movement so that in a first piston position the compression cylinder communicates with a source of gas to be compressed and the expansion cylinder communicates with a source of gas to be expanded, and in a second piston position the compression cylinder communicates with a delivery line for compressed gas and the expansion cylinder communicates with a delivery line for expanded gas, and so that the ends of each cylinder lying outside the range of piston movement from the said first to said second positions constitute dead spaces in which gas is trapped when the pistons enter said dead spaces, and in which the volume of the dead spaces and the dimensions and mass of the pistons are chosen in accordance with the pressures of the gas sources and delivery lines so that the pistons resonate approximately between said first and second positions.

In a preferred form of the invention, there are no mechanical connections to the pistons, and the forces on the pistons are largely or wholly produced by gas pressure forces in the compression and expansion cylinders. The compression and expansion cylinders may be formed by a single tubular member closed at its ends, accommodating a single slidable cylindrical member the two ends of which constitute the two pistons, and having ports in its side wall co-operating with the pistons to provide the valve means.

The invention will now be described by way of example with reference to the drawing accompanying the provisional specification which shows an axial section of a unitary compressor and expansion engine in accordance with the present invention.

The unitary compressor and expansion engine shown in

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the drawing comprises a tubular member 1 closed at its ends by cylinder heads 2 and 3, and a cylindrical member 4 slidable within the tubular member 1.

The cylinder head 2 is secured to the tubular member 1 by bolts 5 extending through the head 2 and threadedly engaged in the tubular member 1. The cylinder head 3 is secured to the tubular member 1 by bolts 6 extending through a mounting platform 7 and the cylinder head 3 and threadedly engaged in the tubular member 1. The bolts 6 serve to secure the compressor and expansion engine to the mounting platform 7, the axis of the tubular member 1 being normal to the platform.

In the example shown in the drawing, the upper half of the tubular member 1 together with the cylinder head 2 constitute a compression cylinder and the lower half of the tubular member 1 together with the cylinder head 3 constitute an expansion cylinder.

The upper half of the slidable member 4 constitutes a piston for the compression cylinder and the lower half of the slidable member 4 constitutes a piston for the expansion cylinder.

In the arrangement shown in the drawing the slidable, cylindrical member 4 is provided with eight circumferential grooves 8 in each of which is located a piston ring 9 formed of carbon. It is to be understood, however, that the provision of piston rings and hence of grooves 8 may, in some cases, be omitted.

The tubular member 1 is provided with four sets of radially directed ports 10, 11, 12 and 13. The ports of each set are disposed in a common plane normal to the axis of the tubular member 1 and the sets are spaced axially of the tubular member 1. The sets of ports 10, 11, 12 and 13 constitute an inlet to the compression cylinder; an outlet from the compression cylinder; an inlet to the expansion cylinder and an outlet from the expansion cylinder respectively.

Located at the outside of the tubular member 1 are four housings 14, 15, 16 and 17 of annular form in section and co-axial with the tubular member 1. The housings 14, 15, 16 and 17 bound, together with portions of the outer surface of the tubular member 1, four plenum chambers 18, 19, 20 and 21 associated one with each of the four sets of ports 10, 11, 12 and 13 respectively. The housings 14, 15, 16 and 17 are sealed to the outer surface of the tubular member 1 in the present embodiment by means of six O-rings 22 formed of resilient material and biased into sealing engagement with a respective plenum chamber housing 14, 15, 16 or 17 and the outer surface of the tubular member 1 either by an adjacent plenum chamber housing or by a spacer member 23 or 24.

Conduits 25, 26, 27 and 28 lead from the plenum chamber housings 14, 15, 16 and 17 respectively.

The slidable member 4 is provided with two sets of radially directed bores 29 and 30 intersected by axially directed bores 31 and 32 respectively. The axially directed bore 31 or 32 extends from the set of radially directed bores 29 or 30 respectively to the nearer end of the slidable member 4.

Two circumferentially directed grooves 33 and 34 are formed in the cylindrical surface of the slidable member 4 so as to embrace the radially outer ends of the radially directed bores 29 and 30 respectively. These grooves allow communication between the cylinder ports and bores 29 and 30 even if the member 4 rotates within tubular member 1.

At a first piston position as shown, the compression cylinder communicates via ports 10 with a supply of gas to be compressed which enters the chamber 18 via the intake 25, and the expansion cylinder communicates via ports 12 and bores 30 and 32, with a supply of com-

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pressed gas to be expanded which enters chamber 20 via the intake 27. The compressed gas entering the expansion cylinder causes the member 4 to rise, cutting off the valve ports and compressing gas in the compression cylinder. At some stage when the member 4 is roughly central in the tubular member 1 the pressure of the gas expanding in the expansion cylinder becomes equal to that of the gas being compressed in the compression cylinder, but owing to the kinetic energy of the member 4 this continues to travel upwards until the second piston position is reached, indicated by the broken line 35. In this position the compression cylinder communicates via bores 31 and 29 and ports 11 with plenum chamber 19 and compressed gas delivery line 26, and the expansion cylinder communicates via ports 13 with chamber 21 and expanded gas delivery line 28. The release of gas from the expansion cylinder increases the downward force already acting on the member 4 which then returns to its first position.

It will be understood that the operation described must be considered dynamically as an oscillating system; if the system were restrained in such a way as to work under static forces only, the member 4 would quickly come to rest in a central position. The system may be regarded as a mass (that of member 4) oscillating between two springs constituted by the gas in the dead spaces of each cylinder, in which the movement is maintained by the excess of energy provided by the gas expanding in the expansion cylinder over the energy put into compressing the gas. In the design of this apparatus, dimensions must be chosen so that with the gas pressures to be used, the member 4 resonates from the stated first position to the second position, or with a slightly larger amplitude. Generally the piston will enter the dead spaces at the end of each stroke. Consequently, these spaces are not true dead spaces, and the term is to be understood as meaning the portions of the cylinder outside the first and second piston positions as defined with reference to the valve ports. The compression and expansion ratios refer to the ratio between such dead spaces and the maximum cylinder volume.

Particular dimensions of an apparatus suitable for expanding nitrogen from 100 p.s.i.g. to atmosphere at atmospheric temperature are as follows:

Bore 1".

Stroke 1".

Mass of piston 0.8 lb.

Expansion ratio of expansion cylinder 3.3.

Compression ratio of compression cylinder 5.3.

This apparatus was found to operate at a frequency of 36 cycles/sec., giving expansion throughput of 1.20 standard cubic ft. per minute.

In this type of apparatus the work obtained in compression is less than that theoretically available in expansion, due to unavoidable losses. In the above case, the throughput of the compressed gas is smaller than that of the expanded gas, although the maximum pressures in each cycle may be made the same. In this case therefore a refrigerating system would require an additional compressor working in parallel with the compression cylinder. An alternative arrangement would be to provide a compressor in series with the compression cylinder, and to lower the compression ratio of the compression cylinder so that the throughput could equal that of the expansion cylinder.

The design dimensions must be chosen for whatever pressures are to be used. If the dead spaces are made adjustable by means of a movable piston therein, this may form a convenient way of making an apparatus adjustable to different pressure conditions. No adjustment is necessary for pressure variations of less than about 5% from the design value.

In the apparatus shown and described, no means are provided for ensuring that prior to starting the apparatus

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the bores 30 are in coplanar relationship with the ports 12. If, for example, the slidable member 4 has moved downwardly under gravity so as to rest on the cylinder head 3 the bores 30 will not be in coplanar relationship with the ports 12 so that pressure gas could not, if the slidable member 4 were a perfect sealing fit in the tubular member 1, be introduced into the expansion cylinder in order to start the expansion-compression cycle. In practice, however, it has been found that when pressure gas is admitted to the plenum chamber 20 there is sufficient leakage of gas from the ports 12 between the slidable member 4 and the tubular member 1 to the groove 34 and thence through the bores 30 and 32 to the expansion space that the pressure in the expansion space builds up so that the slidable member 4 moves upwardly to bring the bores 30 and ports 12 into coplanar relationship to establish free communication between the inlet plenum chamber 20 and the expansion space.

If it is not possible to rely on the member 4 falling sufficiently far by leakage of gas from the expansion cylinder, a vent may be provided communicating therewith to enable the member 4 to be positioned as required.

If however in any embodiment of the invention it is found that such a manner of starting normal operation of the apparatus is not satisfactory, means may be provided so that upon stopping the apparatus the slidable member 4 is retained in its position relative to the tubular member 1 as shown in the drawing, that is, with the bores 30 and ports 12 in coplanar relationship. Such means may take the form of a latch which is released manually or magnetically or mechanically or electro-mechanically when a required pressure has been built up in the expansion cylinder.

In the apparatus shown and described no lubrication is provided within the tubular member 1. Whilst it is not possible to lubricate the expansion cylinder end of the apparatus when the apparatus is being used for the production of very low temperatures it would be possible to lubricate the compression cylinder end of the apparatus. However, this would require the provision of a lubricant seal between the compression end and the expansion end and since apparatus according to the present invention may be so constructed as to operate without lubricant even at the compressor end, the necessity to provide a seal with concomitant problems in respect of wear in the seal is obviated.

It will be realised that the apparatus shown and described is mechanically simple and that mechanical valves are not used and hence the problems of sticking and blockage associated with mechanical valves operating at very low temperatures are not encountered.

Although not shown in the drawing or described, appropriate portions of the apparatus may be formed of materials having low heat conductivity and may be lagged to reduce the influx of heat to the gas being expanded, the expansion of which gas is desirably conducted as close to adiabatically as possible. For instance, the cylinder walls of the compression and expansion cylinders may be separated by a disc of a poorly conducting material such as Tufnol, and the pistons could be separated by a thin-walled tube of poorly conducting alloy such as stainless steel. This will cover the application of the apparatus to temperatures well below 0° C.

In the embodiment described the compression cylinder and the expansion cylinder have the same cross-sectional areas. However, embodiments of the invention may be constructed in which the areas of the two cylinders differ.

In apparatus in accordance with the invention the gas is compressed in the compression cylinder by the deceleration of a moving mass, the slidable member 4, so that any pressure of the compressed gas can be attained with cylinders of the same cross-sectional areas providing sufficient energy of acceleration can be supplied by the expanding gas. This is advantageous as the production of

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cylinders and of pistons having common cross-sectional areas is comparatively economical.

I claim:

A combined compressor and expansion engine for compressing gas from a first source into a compressed gas delivery line while expanding gas from a second source into an expanded gas delivery line, comprising a body member enclosing two cylindrical chambers constituting respectively a compression cylinder and an expansion cylinder arranged in opposition to one another, a piston in each cylinder, the two pistons being connected together for movement in unison, bores in the pistons, and ports in the cylinder walls which are covered and uncovered by the piston walls during piston movement in a preselected sequence so that in a first piston position communication is provided between the compression cylinder and the said first source and between the expansion cylinder and the said second source, and in a second piston position communication is provided between the

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compression cylinder and the said compressed gas delivery line and between the expansion cylinder and the said expanded gas delivery line, and so that the ends of each cylinder lying outside the range of piston movement from the said first to said second positions constitute dead spaces in which gas is trapped when the pistons enter said dead spaces, the volume of the dead spaces and the dimensions and mass of the pistons being chosen in accordance with the pressures of the gas sources and delivery lines so that the gas pressures in the compression and expansion cylinders cause the pistons to resonate approximately between said first and second positions.

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