K. AHLQUIST.

METHOD OF AND APPARATUS FOR ALTERING THE CONDITION OF GASES.

APPLICATION FILED FEB. 17, 1906.

1,008,576. Patented Nov. 14, 1911.

Fig. 1.

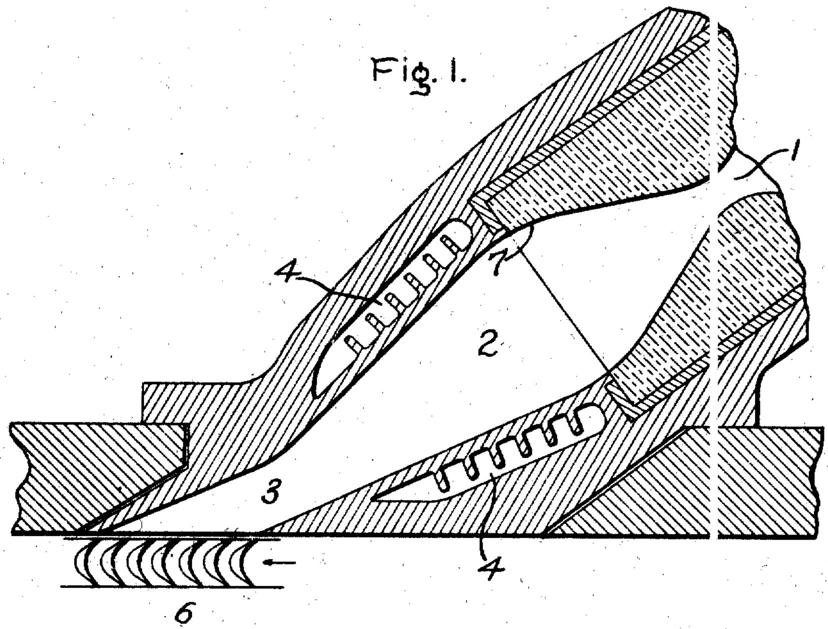
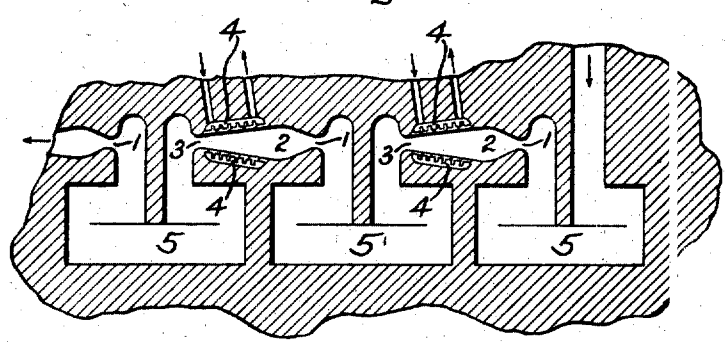


Fig. 2.



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UNITED STATES PATENT OFFICE.

KARL AHLQUIST, OF RUGBY, ENGLAND, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

METHOD OF AND APPARATUS FOR ALTERING THE CONDITION OF GASES.

1,008,576. Specification of Letters Patent. **Patented Nov. 14, 1911.**

Application filed February 17, 1906. Serial No. 301,601.

To all whom it may concern:

Be it known that I, KARL AHLQUIST, a subject of the King of Sweden, residing at 147 Clifton road, Rugby, England, have invented certain new and useful Improvements in Methods of and Apparatus for Altering the Condition of Gases, of which the following is a specification.

The invention relates to an improved method and apparatus for altering the condition of gases, such as are obtained by combustion of solid or liquid fuel, intended more particularly for use in connection with elastic fluid turbines. The invention is, however, not limited to turbines; it may also be used for the purpose of increasing the pressure of gases whether obtained as above indicated or otherwise.

My invention consists in causing the gas at a suitable pressure to expand so as to increase its kinetic energy by a desired amount and in utilizing more or less of this kinetic energy to produce recompression of the gas, the gas before and during compression being cooled in any suitable manner.

My invention further consists in an apparatus for carrying the method into effect.

In the accompanying drawing which serves to illustrate my invention, Figure 1 is a sectional elevation of a single nozzle for transforming the energy of a gas supplied to a rotary engine, and Fig. 2 is a sectional view of a number of such nozzles arranged to form a compressor.

In carrying my invention into effect according to the embodiment illustrated in Fig. 1, I provide a direct nozzle or nozzle portion which has a small inlet opening 1 and expands gradually therefrom into a practically cylindrical region 2 and a reversed nozzle or nozzle portion that gradually contracts from the region 2 toward the outlet 3. The contracting and practically cylindrical sections of the nozzle are arranged so that they can be cooled in any suitable manner. For example they may be formed with hollow walls containing passages 4 through which a suitable cooling fluid such as water may be circulated. The gas to be dealt with enters the throat 1 of the divergent portion of the direct nozzle and expands in this portion so as to reduce its pressure and increase its kinetic energy in a well understood manner. It is then cooled in the cylindrical portion 2 of the nozzle and during its passage through the convergent portion of the reversed nozzle. During the passage through the cylindrical portion 2 the volume of the gas diminishes due to the heat abstracted but the velocity of the particles is not interfered with. Owing to this cooling and consequent reduction in volume in the cylindrical and convergent portions of the nozzle less kinetic energy is required to compress the gas to a given pressure in said convergent portion of the nozzle than it would otherwise be necessary to expend. Consequently the pressure of the gas can be raised by a complete utilization of the kinetic energy, so that it issues from the throat 3 of the convergent part of the nozzle at a maximum pressure above its original pressure. Or it may be compressed in the convergent part of the nozzle to a given pressure less than said maximum pressure by a partial utilization of the kinetic energy and will then have more kinetic energy than it would have had by expansion to the same pressure in a simple divergent nozzle. In the first case, where the whole of the kinetic energy developed in the expanding and cylindrical portions of the nozzle is transformed back to pressure assuming frictionless motion, the apparatus acts as a compressor, and if a number of such nozzles are connected in series as shown in Fig. 2 with intervening reheating chambers 5 into which the gases from each nozzle enter and from which they pass into the succeeding nozzle a stage compressor will be formed by means of which the pressure of a gas may be raised by a desired amount. In the case, however, in which only a part of the kinetic energy of the gas is transformed back to pressure, the remaining energy of the gas may be used for producing motive power, for example, by driving a turbine wheel as illustrated in Fig. 1, the gas issuing from the nozzle on to the wheel 6.

In the operation of gas turbines the gas or fluid has usually to be delivered to the wheel at a high temperature which may be above that which the material of which the wheel is formed can withstand. According to the present invention the temperature of the gas or fluid may be lowered very materially without reducing the kinetic energy of the fluid. Indeed this kinetic energy may even be increased, if the friction in the cylindrical and converging parts of the nozzle is not so great as to absorb the gain in energy.

The main essential in the application of the invention to turbines is to cause the gas to expand in the divergent portion of the nozzle to a pressure below the pressure in the turbine. The expanding portion of the nozzle is provided with a lining 7 preferably of some refractory material. As much heat as is convenient is then abstracted and the gas allowed to compress to the desired pressure with further abstraction of heat in the convergent portion of the nozzle.

It will be obvious that the shape of the nozzle may be varied in different ways for producing the results above mentioned without departing from the spirit of the invention.

From the foregoing it will be seen that a direct nozzle is provided for converting pressure into velocity, and a second or reversed nozzle properly shaped which receives fluid at high velocity from the direct nozzle and converts the velocity into pressure. Between the direct and reversed nozzles is a means for cooling the fluid after it has passed through the direct nozzle. The entrance to the direct nozzle should be well rounded because the fluid expands while passing through it, as it also does in the expanding portion beyond. In some cases the nozzle should have the walls leading up to the throat—the point of greatest restriction—convergent. The shape of the nozzle is determined by the pressure differences on opposite sides of the throat. The direct nozzle shown in Fig. 1 is of the so-called de Laval type and the fluid enters with negligible velocity while the reversed nozzle in the present embodiment depends upon the fluid entering at a very high velocity. Thus it will be seen that there can be no direct comparison between the two.

In the arrangement described the fluid in passing through the portion 2 will have a relatively low pressure and high velocity, and from this point on the velocity will decrease but the pressure will increase. If the pressure range for the first or direct nozzle is greater than that corresponding to the maximum efficiency ratio of delivery to supply pressures then it should be first convergent and then divergent, as shown. If the pressure range through which the second or reversed nozzle is to work is greater than that corresponding to said maximum ratio, it should be first convergent and then divergent. For smaller ranges of pressure the form or shape of the nozzles can be suitably modified.

Where the reversed nozzle is first convergent and then divergent, a certain amount of compression will take place in the divergent portion as well as in the convergent portion. Cooling may therefore be desirable while the fluid is passing through the divergent portion. In other words, it may be desirable to continue the cooling passage up to beyond the point 3. The cooling of the motive fluid may be accomplished in any desired manner and at any suitable point in its passage through the intermediate chamber or portion 2 and the second nozzle. The cooling may take place partly in the intermediate chamber and partly in the second nozzle, or wholly in the chamber or wholly in the nozzle. The intermediate portion 2 may be made in a variety of ways to adapt it to the conditions of service. It may have a portion which has a certain definite length with cylindrical walls forming a non-expanding passage, or it may have walls suitably shaped to form an expanding or to form a divergent passage.

The action of the nozzle may be rendered clearer by consideration of a case in which in the initial stage air is taken at atmospheric temperature and pressure. This air is heated and introduced into the first nozzle, and there the pressure or a certain portion of it is converted into velocity and later this velocity is reconverted into pressure and at the same time the air or gas is cooled. This cooling somewhat reduces the volume of the gas while the pressure is raised somewhat above the initial. The loss in heat accounts for the energy expended in producing the increased pressure of the gas.

In accordance with the provisions of the patent statutes, I have described the principle of operation of my invention, together with the apparatus which I now consider to represent the best means for carrying it out, but I desire to have it understood that the apparatus shown is only illustrative, and that the invention can be carried out by other means.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. The method which consists in taking a supply of relatively hot gas under pressure at low velocity, increasing the velocity and kinetic energy of the gas by expansion under suitable conditions, then cooling the gas, and utilizing the energy so obtained to compress the gas to a desired pressure by discharging it at the high velocity due to the previous expansion and cooling under such conditions that more or less of its energy of velocity is converted into pressure, substantially as described.

2. The method for compressing gas by the utilization of its own heat energy which consists in allowing it to expand and thus develop velocity and kinetic energy and utilizing its kinetic energy thus developed to perform the work of compressing it through the direct conversion of velocity into pressure, reducing the amount of work necessary

for effecting compression of the gas by abstraction of heat from it so that its kinetic energy may suffice to bring it to a pressure higher than its initial pressure.

3. A nozzle comprising divergent and convergent portions in the former of which gas is expanded without substantial decrease of energy and in the latter of which it is recompressed, with means for cooling the gas after it passes through the first portion of the nozzle.

4. In combination, a nozzle arranged to receive an elastic fluid and convert pressure of the fluid into velocity as it flows through it, a second nozzle receiving fluid from the first for converting velocity into pressure as it flows through it, and a means for cooling the fluid after it flows into the first-mentioned nozzle.

5. A staged compressor comprising a number of nozzles arranged in series, each of which converts the pressure of the fluid into velocity and reconverts it into pressure and comprises means for reducing the volume of the fluid by abstraction of heat, with chambers situated between and communicating with the preceding and succeeding nozzles.

6. A staged compressor comprising a number of nozzles arranged in series, which first convert the pressure of the fluid into velocity and reconvert it into pressure, means for cooling the fluid at some portion of its passage through the nozzles, and chambers situated between and communicating with the preceding and succeeding nozzles.

7. In a compressor using heat as a motive power, the combination of a means which receives the heated fluid and expands it, a device receiving the motive fluid in its expanded condition and reconverting it into pressure, and a cooling means which abstracts heat from the fluid subsequent to the expansion thereof.

8. In combination, a direct nozzle arranged to receive an elastic fluid under pressure at low velocity and convert its pressure into velocity as the fluid flows through said nozzle, a reversed nozzle which receives the fluid at high velocity from the direct nozzle and converts its energy of velocity into pressure as the fluid flows through said reversed nozzle, and means for cooling the fluid during its flow from the direct nozzle into the reversed nozzle and in said reversed nozzle.

In witness whereof I have hereunto set my hand this second day of February, 1906.

KARL AHLQUIST.

Witnesses:
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C. G. SEELEY.