S. Z. DE FERRANTI.

COMBUSTION TURBINE.

APPLICATION FILED APR. 2, 1907.

999,976.

Patented Aug. 8, 1911.

4 SHEETS—SHEET 1.

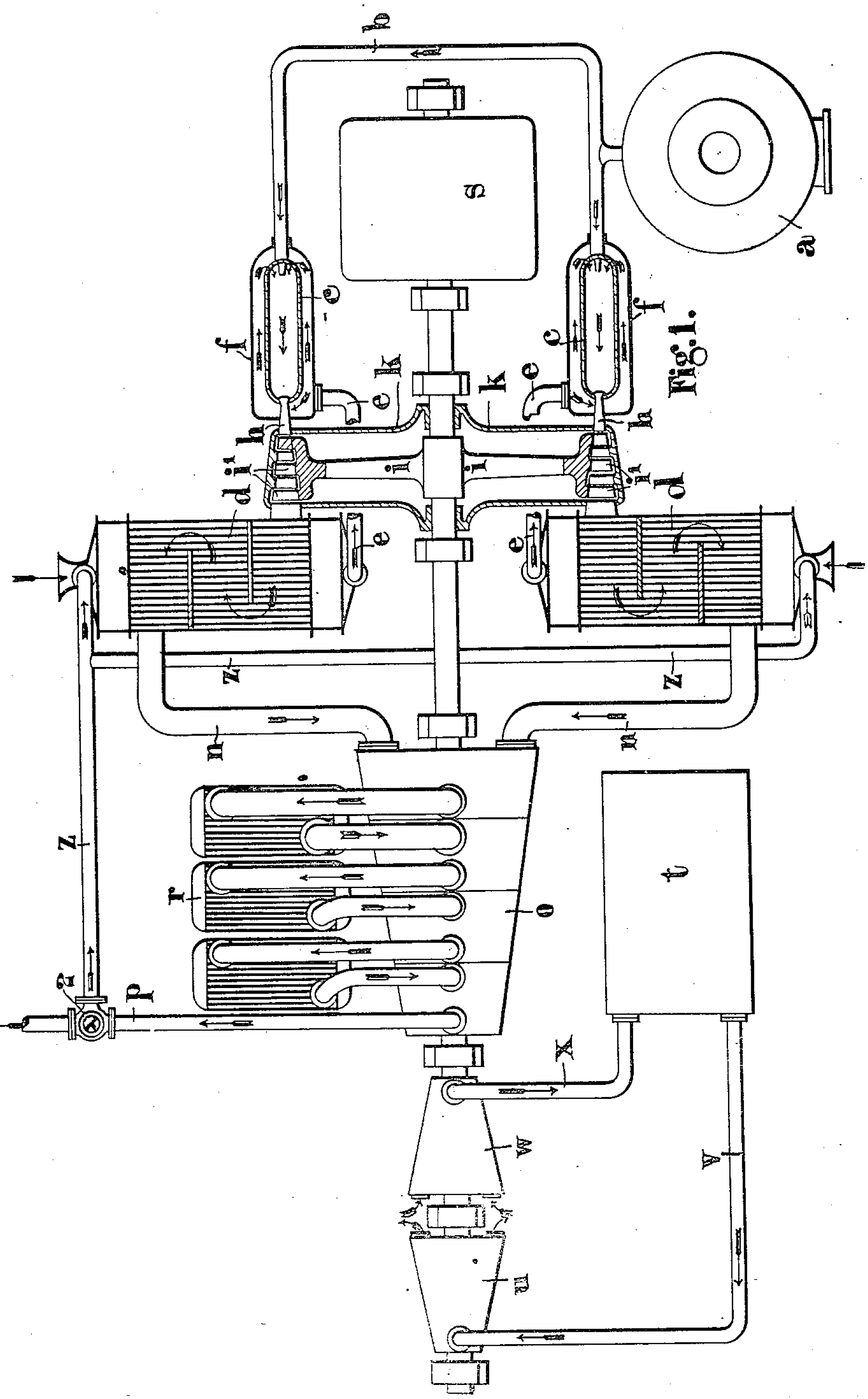

Fig. 1.

Attest:

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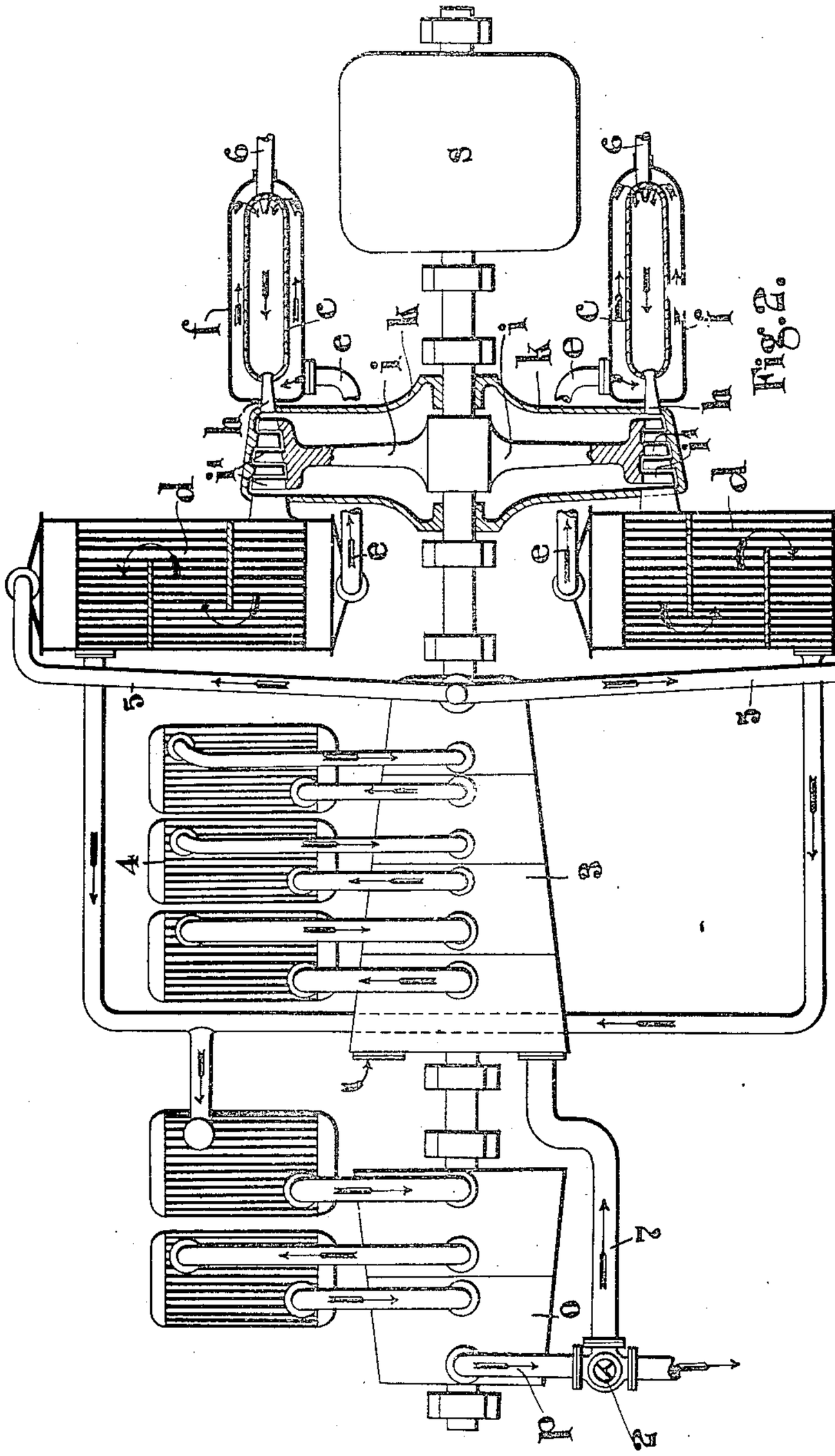

Fig. 2.

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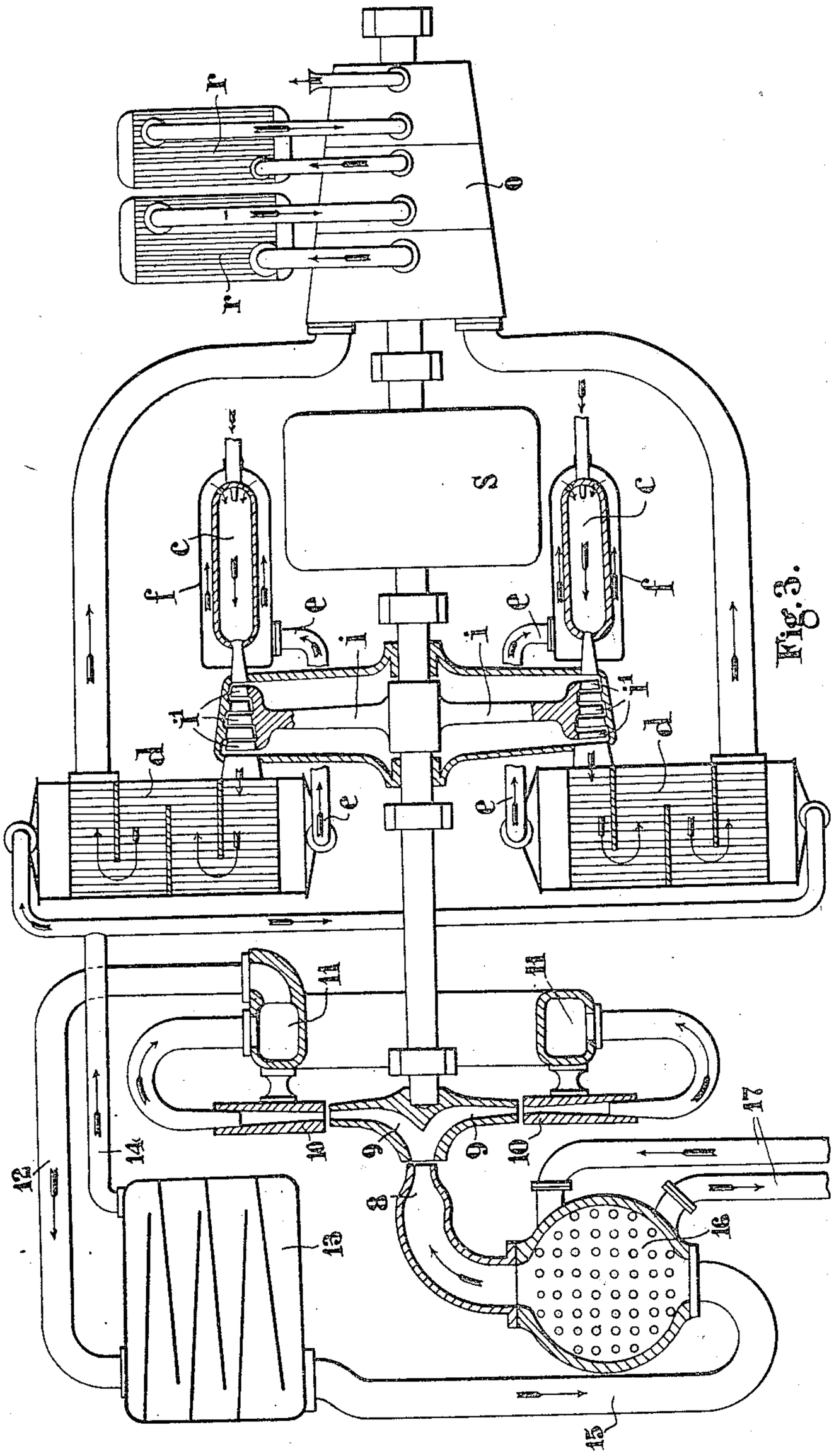

Fig. 3.

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4 SHEETS—SHEET 4.

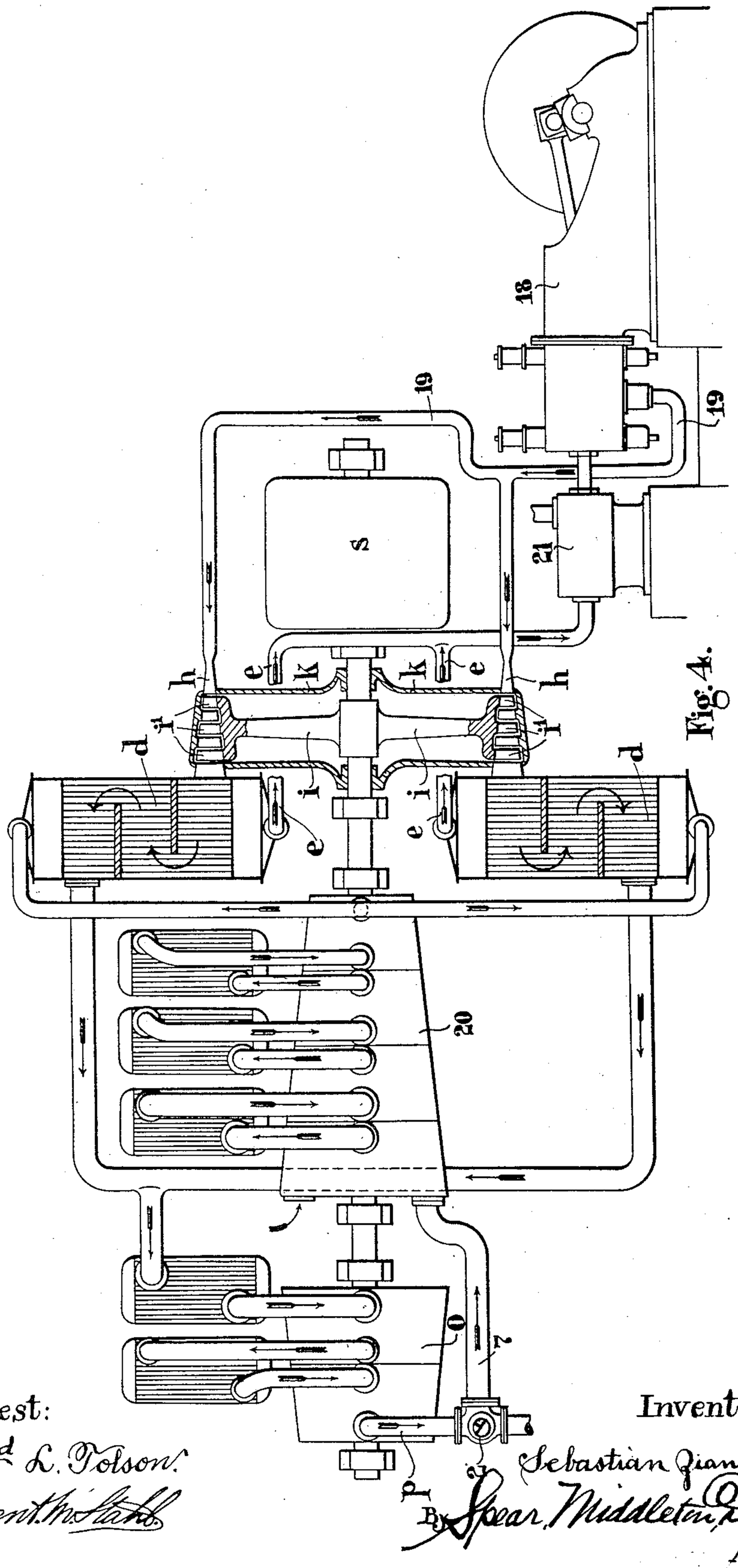

Fig. 4.

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UNITED STATES PATENT OFFICE.

SEBASTIAN ZIANI DE FERRANTI, OF GRINDLEFORD BRIDGE, NEAR SHEFFIELD, ENGLAND.

COMBUSTION-TURBINE.

999,976. Specification of Letters Patent. Patented Aug. 8, 1911.

Application filed April 2, 1907. Serial No. 366,000.

To all whom it may concern:

Be it known that I, SEBASTIAN ZIANI DE FERRANTI, a subject of the King of Great Britain and Ireland, and residing at Grindleford Bridge, Sheffield, in the county of York, England, and formerly of 31 Lyndhurst road, Hampstead, London N. W., have invented certain new and useful Improvements Relating to Combustion-Turbines and the Like, of which the following is a specification.

This invention relates to turbine motors of the type in which combustion is conducted in a combustion chamber or producer and the energy of the products utilized by means of expansion nozzles and one or more turbines working in conjunction with a rotary vacuum pump so as to permit of pressures less than that of the atmosphere to be utilized in the turbine cycle.

The main objects of my present invention are to enable a range of expansion below atmospheric pressure to be economically employed in working with such turbines and to secure a sufficient range of expansion even with low compression pressures above atmosphere by working below atmosphere to the required extent.

Fuel used may be obtained from any convenient source such for example as coke ovens or blast furnaces or gas producers and is preferably taken direct, *i. e.*, without previous cooling.

In cases where my invention involves both a rotary pressure and a rotary vacuum pump, at least one of these pumps must be of the isothermal type but not necessarily both.

Referring now to the accompanying drawings which form part of this specification, Figure 1 shows a turbine plant with its range of expansion entirely below atmospheric pressure and taking gas from a suction producer; Fig. 2 shows a modification in which the range of expansion is partly above and partly below atmospheric pressure, Fig. 3 being a similar plant but with a liquid compressor pump substituted for the rotary turbine pump of Fig. 2, while Fig. 4 shows a turbine system adapted to work with the exhaust from an internal combustion engine.

I wish it to be understood that the drawings are to a large extent of a diagrammatic nature and should not be taken as working drawings.

Where desirable the same reference symbols are used to denote corresponding parts in the different figures.

In carrying my invention into effect according to one construction as applied in an apparatus working with atmospheric pressure as the maximum pressure of the cycle, (see Fig. 1) I employ a suction gas producer, *a*, of any suitable type, the hot gases from which pass by way of the pipe, *b*, to the interior of a combustion chamber, *c*, where they burn in air sucked in through the regenerator, *d*, pipe, *e*, and combustion chamber jacket, *f*. (In this and the following figures where parts of the apparatus are arranged in duplicate sets, one such set only will be referred to in order to simplify the description). I attach on the end of this combustion chamber an expanding nozzle, *h*, of suitable construction in which the products of combustion and any added inert fluid (such, for example, as an excess of air drawn in through the pipe, *e*,) are expanded down to the pressure ruling in the turbine casing, the fluid at the same time gaining velocity and being lowered in temperature to a degree allowing of its safe utilization in the turbine, *i*; on account of the high velocity acquired in the nozzle during this operation, I prefer to employ the type of turbine in which the velocity of the impinging jet is abstracted stage-wise in a succession of rings of blades, *i'*. The casing, *k*, of this turbine, is connected to the regenerator, *d*; which is in turn connected by way of the pipe, *n*, to a multi-stage rotary vacuum pump, *o*, having intermediate coolers, *r*, thus rendering the compression on the whole substantially isothermal. The vacuum pump, *o*, sucks the gases from the turbine casing through the regenerator, *d*, discharging them to atmosphere through the pipe, *p*, and is conveniently mounted direct on the turbine shaft. In the figure, the combustion chambers and regenerators are shown in duplicate, the one vacuum pump serving for both; but it will be obvious that this is merely a matter of design, and any departure may be made from the precise arrangements shown in Fig. 1 or in the figures to be hereinafter described so long as the essential elements of the invention are included.

Any suitable work may be done by the turbine and this I have indicated conventionally in Fig. 1 by a machine, *s*, which may, for instance, be a dynamo coupled direct to the turbine.

In order to start the power generator, I provide a store, *t*, of air under pressure which can be utilized for starting purposes by driving, say, the turbine *u*, connected to the store of air by the pipe, *v*; the vacuum pump, *o*, driven by the turbine, *u*, is thus caused to evacuate the main turbine casing and so draw in air through the producer. The starting air supply may be compressed by an additional rotary air compressor, *w*, driven by the main turbine, the air so compressed passing to the store through the pipe, *x*.

I provide for the addition of a quantity of inert fluid, which may be products of combustion or air, into the combustion chamber, so that the temperature of the gases after expansion in the nozzles may be sufficiently reduced.

When products of combustion are used as the added inert fluid, I may lead these to the regenerator by a branch pipe, *z*, from the vacuum pump discharge to atmosphere and arrange a suitable valve, 2, which may be of the three-way type for their control and adjustment.

For the gas producer above indicated I may substitute any other source of fuel for the combustion chamber.

In carrying my invention into effect according to a modified form (see Fig. 2) I employ a rotary isothermal compressor, 3, having intermediate coolers, 4, and I connect this compressor by way of the pipe, 5, to the regenerator, *d*, through which air is thus forced to the combustion chamber, *c*, by way of its jacket, *f*, the flow through the jacket preferably being counter to that through the combustion chamber as indicated by the arrows. Assuming that oil fuel is to be used, it is preferably introduced under pressure into the combustion chamber through the nozzle, 6. The nozzle, *h*, of this combustion chamber, is adapted for a very great range of expansion as in accordance with my invention, the casing, *k*, of the turbine is exhausted to any desired degree, say conveniently to three or four pounds absolute. To effect this, a rotary isothermal vacuum pump, *o*, as before, sucks from the turbine casing through the regenerator, *d*, and delivers the exhaust elastic fluid to the atmosphere through the pipe, *p*.

If products of combustion are used for the inert fluid a branch, 7, may be led from the pipe, *p*, to the inlet of the compressor, 3, and said products are thus forced through the regenerator to the combustion chamber.

Owing to my employing pressures considerably under atmospheric in the turbine casing, the friction of the surrounding fluid on the wheel is very much reduced; moreover I am able to utilize very great ranges of expansion.

In applying my present invention according to another modification, I substitute for the isothermal rotary compressor, 3, of Fig. 2, a compressor in which a suitable liquid is used as the medium of compression. Both in this case and the preceding, the air is cooled during the course of its compression to such a degree that it may usefully absorb heat from the exhaust gases while passing through the regenerator. Thus referring to Fig. 3 where one form of such a compressor is shown, water from the nozzle 8, enters the center of the thrower, 9, mounted on the main turbine shaft, this thrower having a suitable number of hollow arms passing over a ring of open ended tubes, 10, communicating with the annular chamber, 11; the effect of the rapid rotation of the thrower is to shoot plugs of water down the tubes, 10, at a high velocity, the air to be compressed being entrained between these plugs. From the chamber, 11, a connection, 12, passes to the separating chamber, 13, the compressed air then passing through the pipe, 14, to the regenerator as in previous modifications described above while the compressing water is led through the pipe, 15, to the cooler, 16, through which water is circulated by way of the pipes, 17, and after being thus cooled passes through the nozzle, 8, and repeats the cycle. The isothermal vacuum pump, *o*, is connected to the turbine casing as before by way of the regenerator, *d*. Other forms of such compressors using liquid as the medium of compression are described in my patent specifications, Nos. 832783 and 832784.

A further part of my invention consists in employing the exhaust of an ordinary reciprocating internal combustion motor in a turbine system of the above described character so as to utilize the range of expansion between the discharge pressure of the engine and a pressure considerably below atmospheric, thus increasing the efficiency of utilization of the fuel. Such a system is shown in Fig. 4, where the internal combustion motor, 18, is indicated as connected to the turbine nozzle, *h*, by way of the exhaust pipe, 19. The energy thus recovered may be employed to drive an electric generator as indicated in the figure, or it may be employed to perform the whole or a portion of the negative work of the internal combustion engine. According to one arrangement of this, fluid for the reciprocating engine may be isothermally compressed in the compressor, 20, and regenerated from the exhaust leaving the turbine. Where the turbine cannot supply the whole of the

energy required for compression in an engine using compressed fluid, I prefer to finish the compression by a piston compressor, 21, preferably driven from the engine.

In connection with the hereinbefore described vacuum turbine plants, I wish particularly to emphasize the feature of isothermal compression, since I consider this essential to the success of any such installation. Moreover, so far as I know, the best way of obtaining the advantages resulting from such isothermal compression is by working it in conjunction with a regenerator. By "isothermal compression" I mean the substantially isothermal compression produced by a multistage compressor with intermediate cooling.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:—

1. In combination, a turbine having blades and a casing; a stage rotary vacuum pump with intermediate coolers; a connection between said casing and the inlet of said pump with a regenerator disposed in said connection; a combustion chamber in which fuel is burned in air to form working fluid, said chamber having a connection to said regenerator; an expansion nozzle issuing from said chamber and directing said fluid on to said blades together with a connection between the outlet of said pump and said regenerator.

2. In combination, a turbine having blades and a casing; a stage rotary vacuum pump with intermediate coolers; a connection between said casing and the inlet of said pump with a regenerator disposed in said connection; a combustion chamber in which fuel is burned in air to form working fluid, said chamber having a connection to said regenerator; an expansion nozzle issuing from said chamber and directing said fluid on to said blades together with means for discharging exhaust from said pump at will into the atmosphere or into said regenerator.

In testimony whereof, I affix my signature in presence of two witnesses.

SEBASTIAN ZIANI DE FERRANTI.

Witnesses:
HENRY H. GRUNING,
BERTRAM H. MATTHEWS.