No. 834,006. PATENTED OCT. 23, 1906.

H. L. DOHERTY.

PROCESS FOR CONVERTING HEAT INTO WORK.

APPLICATION FILED MAY 9, 1905. RENEWED APR. 3, 1906.

3 SHEETS—SHEET 1.

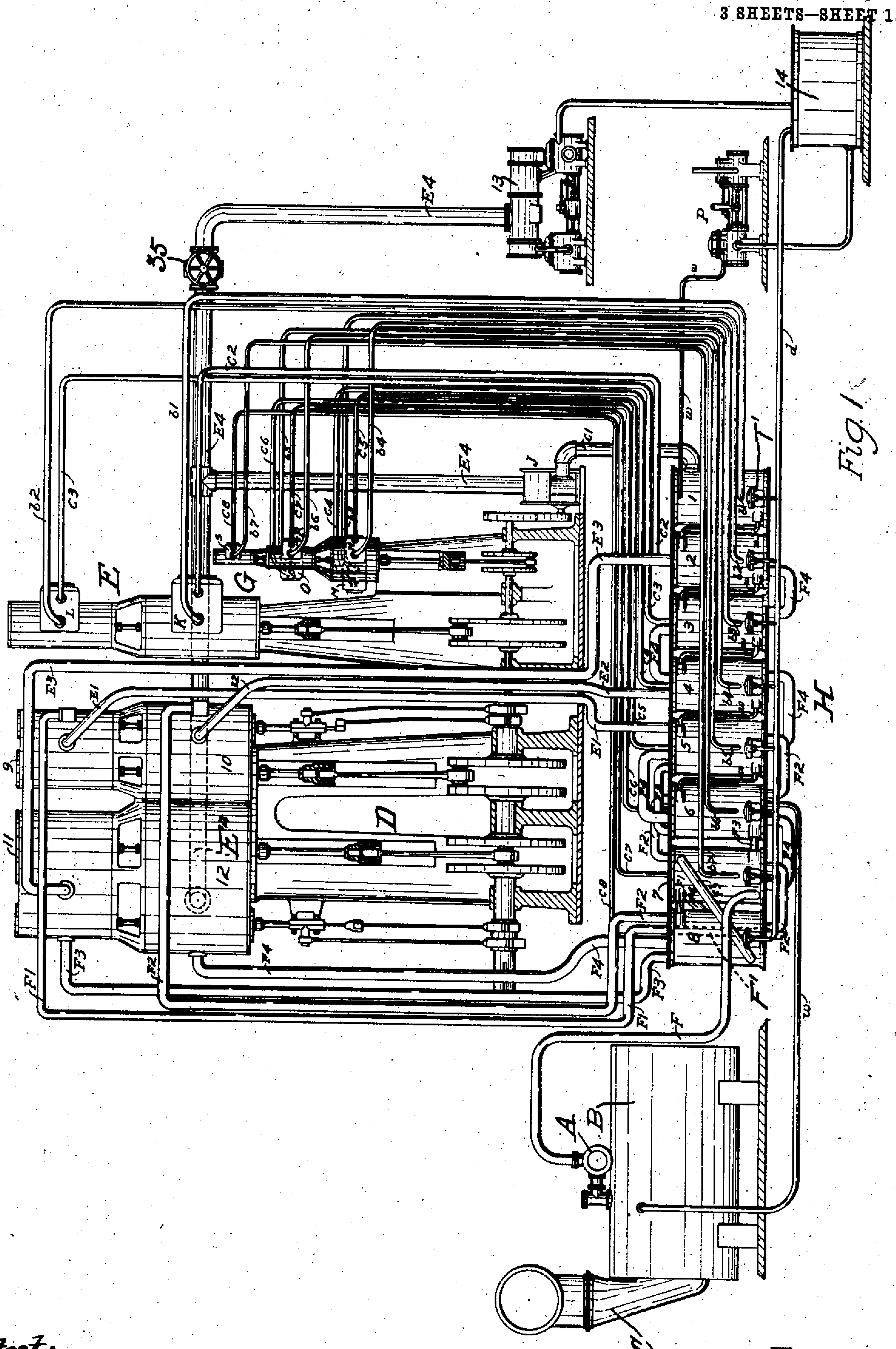

Fig. 1.

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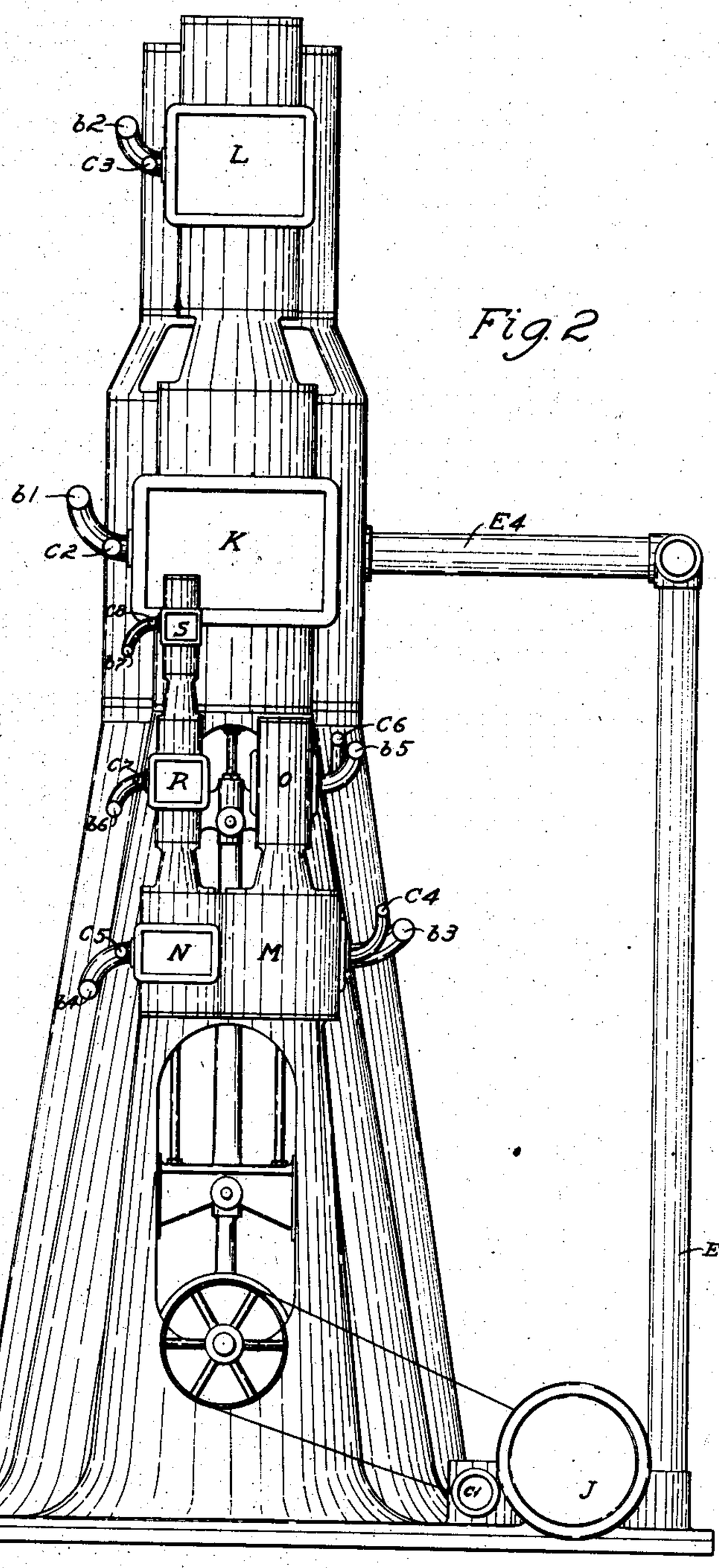

Fig 2

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3 SHEETS—SHEET 3.

Fig 3

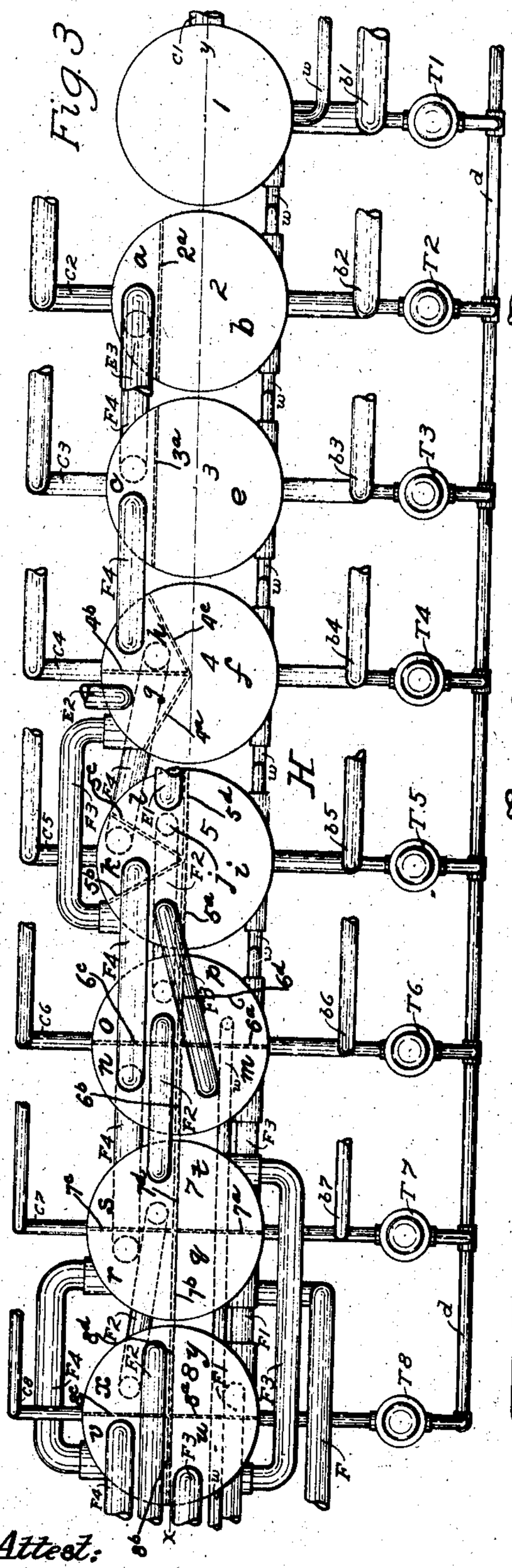
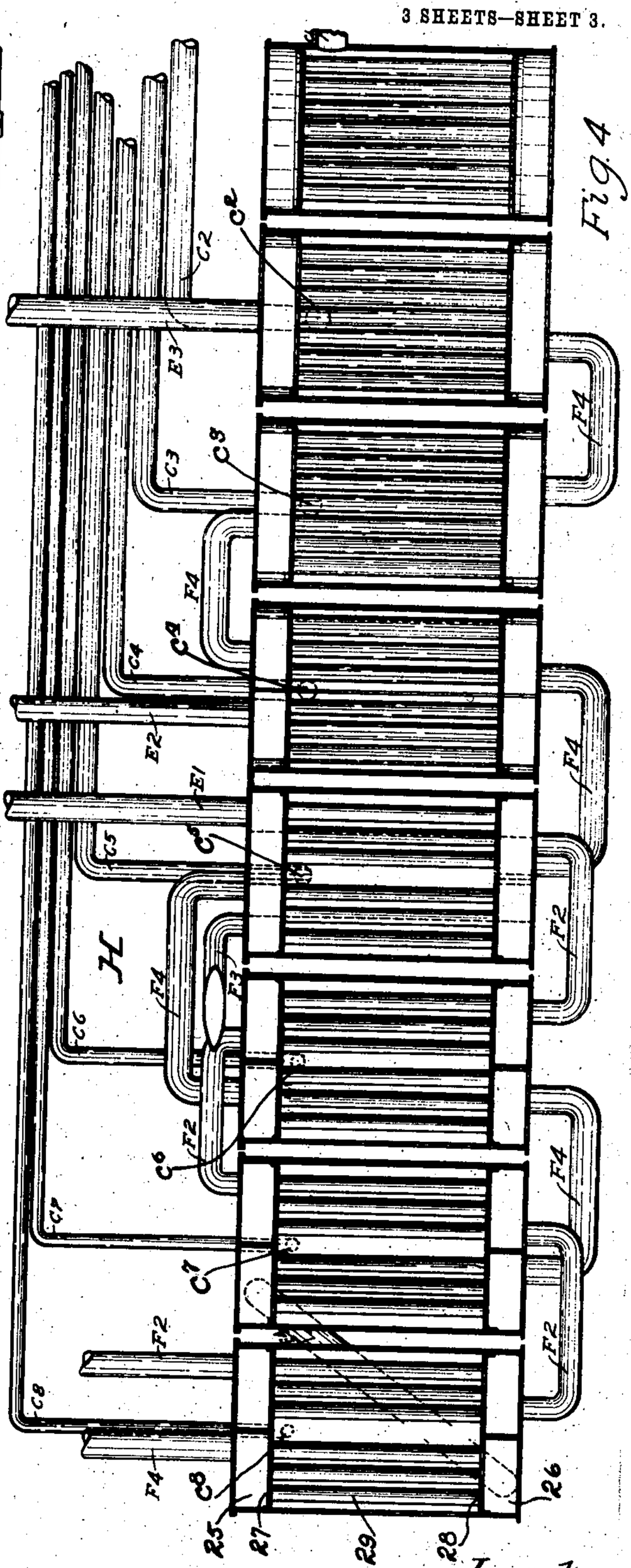


Fig 4



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UNITED STATES PATENT OFFICE.

HENRY L. DOHERTY, OF MADISON, WISCONSIN.

PROCESS FOR CONVERTING HEAT INTO WORK.

No. 834,006. Specification of Letters Patent. Patented Oct. 23, 1906.

Application filed May 9, 1905. Renewed April 3, 1906. Serial No. 309,664.

To all whom it may concern:

Be it known that I, HENRY L. DOHERTY, a citizen of the United States, and a resident of Madison, Dane county, Wisconsin, have invented certain new and useful Improvements in Processes for Converting Heat into Work, of which the following is a specification accompanied by drawings.

This invention relates to an improved process for converting heat into work which is adapted to heat engines of all kinds, more particularly to steam-engines, and has for its object to utilize the latent heat of vaporization of the expanded or partially-expanded steam by imparting said heat to the expanding medium doing work or to the feed-water, or to both.

Further objects of the invention will hereinafter appear; and to these ends the invention consists of a process for carrying out the above objects embodying the sequence of steps and method of operation, substantially as hereinafter fully described and claimed in this specification, and illustrated by means of the apparatus shown in the accompanying drawings, in which—

Figure 1 is a side elevation, partly in section, of a steam-engine adapted to illustrate this improved process. Fig. 2 is an end elevation of the same. Fig. 3 is a plan view of the superheaters used in this apparatus, and Fig. 4 is a sectional elevation of Fig. 3 on the line $x\,y$.

Referring to the drawings, B represents a suitable steam-boiler for supplying steam to the steam-engine, and A is a flue to which other boilers may be connected, if desired.

C represents the usual smoke-flue for the boiler.

D represents a suitable steam-engine for illustrating the process, in this instance a quadruple-expansion steam-engine being shown, in which the high-pressure cylinder is represented by the numeral 9, the first and second intermediate cylinders are represented by 10 and 11, and the low-pressure cylinder is represented by 12. Any suitable piston-rods, valve-gearing, and cranks and crank-shafts are provided. In this instance the engine D is shown driving series of compressors E and G.

H represents a series of eight superheaters, numbered from 1 to 8, inclusive, and suitably connected by appropriate piping with the engine and the series of compressors E and G, and 14 represents a tank to receive condensed steam from the superheaters H, and P is a suitable pump for pumping the condensed steam back through the superheaters and from thence back to boiler B.

13 is a condenser connected between the steam-engine and the condensed-steam tank 14.

The apparatus so far referred to is one suitable form of apparatus for carrying out this process; but the invention is not limited to any particular form of engine and auxiliary devices, because obviously many different mechanisms will be found for carrying out the invention which may be applied in any connection and with any apparatus in which it is found useful.

In carrying out the process steam from the boiler B is preferably first superheated in a portion of the superheaters H and then led to the high-pressure cylinder 9, from which the exhaust-steam is led back to a portion of the superheaters and superheated, as will hereinafter appear, and this exhaust-steam is supplied to the first intermediate cylinder, and from thence the exhaust is again carried back to the superheaters and superheated and supplied to the second intermediate cylinder. From thence the steam is exhausted back to the superheaters, superheated, and is supplied to the low-pressure cylinder, and from thence the exhaust is carried to the compressor J and thence to the superheaters, so that the exhaust from the first three cylinders of the engine is carried to the superheaters and circulated therethrough and utilized expansively in doing work, while the steam from the low-pressure cylinder is compressed to a differential temperature and a portion of it is condensed in the superheaters, thereby imparting the latent heat of vaporization of the condensed portion to the working steam to superheat the same and also to preheat the feed-water, if desired.

A portion of the steam supplied to the superheater 1 from the compressor J is condensed in said superheater, and this condensed steam is led to the condenser-tank 14, while the uncondensed steam is led to the compressor K and thence back to superheater 2, where a portion of the compressed steam is condensed and the uncondensed portion led to another compressor L. This operation applies to each one of the superheaters—that is to say, compressed steam is supplied to each one of the superheaters and the condensed steam is led in each case back to the

condenser-tank 14, while the uncondensed steam is compressed in one of the compressors of the series E and G. The condensed steam is pumped by the pump P from the condenser-tank 14 back through a portion of the superheaters and from thence to the boiler B.

According to the cycle of operations outlined it will be seen that the working steam for the engine-cylinders and the condensed steam with more or less water is circulating through the superheaters, as is also the steam from the series of compressors E and G. According to this mode of operation the steam from the compressors which condenses is continually giving up its latent heat of vaporization to the working steam for the cylinders and to the condensed steam and water forming the feed-water for the boiler.

The superheaters H may be constructed in any suitable manner with separate compartments, and provision is made for circulating the condensed steam and water through one set of compartments while the steam is passing through another set. In this instance the superheaters are shown in the form of chambers having upper and lower compartments 25 and 26, formed by the tube-sheets 27 and 28, into which the tubes 29 are expanded in the usual manner, so that communication is afforded between the compartments 25 and 26 only through the tubes 29. The series of tubes 29 in each superheater are furthermore divided into groups by suitable partitions formed in the compartments 25 and 26.

Beginning with superheater 1, it will be seen that this superheater is not divided into compartments, because here the feed-water only is heated. Superheater 2 is divided into two groups of tubes by partition 2^a, as is superheater 3 by partition 3^a. Superheater 2 is provided with compartments *a* and *b*, and superheater 3 has compartments *c* and *e*. Superheater 4 is divided into three compartments *f*, *g*, and *h* by partitions 4^a, 4^b, and 4^c. Superheater 5 is divided into four compartments *i*, *j*, *k*, and *l* by partitions 5^a, 5^b, 5^c, and 5^d. Superheater 6 is divided into four compartments *m*, *n*, *o*, and *p* by partitions 6^a, 6^b, 6^c, and 6^d. Superheater 7 is divided into four compartments *q*, *r*, *s*, and *t* by partitions 7^a, 7^b, 7^c, and 7^d. Superheater 8 is divided into four compartments *u*, *v*, *x*, and *y* by partitions 8^a, 8^b, 8^c, and 8^d.

In order to illustrate the operation of the apparatus shown in the drawings, I will describe the course of the steam and water through the apparatus from beginning to end, and I will assume that the steam is taken from the boiler B at about two hundred and sixty-six pounds pressure and about 867.2° Fahrenheit absolute. In carrying out the operations of the apparatus I will also specify the approximate pressure and temperature at each stage of the operations.

Assume that steam is taken from the boiler B at the pressure and temperature specified and is led through pipe F to the lower portion of superheater 7 and supplied to compartment *q* and there superheated to about 905° absolute. It then passes from the top of superheater 7 to the top of superheater 8 into compartment *y* of said superheater, where it is heated to about 956.7° absolute and from thence is led by the pipe F′ to high-pressure cylinder 9, where the steam expands from about two hundred and sixty-six pounds absolute to about one hundred and twenty-one pounds absolute and is exhausted from said cylinder through exhaust-pipe E′ into section *l* of superheater 5, where its temperature is raised from about 805° absolute to about 855° absolute. The steam then passes from section *l* of superheater 5 by pipe F^2 to section *o* of superheater 6, where the temperature is raised to about 867.2° absolute. It then passes by pipe F^2 to section *s* of superheater 7, where the temperature is raised to about 905° absolute, and it then passes through pipe F^2 to section *x* of superheater 8 and from thence, still by pipe F^2, to the first intermediate cylinder 10, where the steam expands from about one hundred and twenty-one pounds absolute and about 956.7° absolute to sixty-one pounds absolute and about 755° absolute. The steam leaves the first intermediate cylinder 10 by exhaust-pipe E^2 and is led to compartment *g* in superheater 4, where its temperature is raised to about 805° absolute, thence passes by pipe F^3 to compartment *j* of superheater 5, thence by pipe F^3 to compartment *m* of superheater 6, thence by pipe F^3 to compartment *t* of superheater 7 and continues by pipe F^3 to compartment *u* of superheater 8, and from thence passes, still by pipe F^3, to the second intermediate cylinder 11, where the steam expands from about 61.1 pounds absolute and about 956.7° absolute to about eleven pounds absolute and about 658° absolute. The steam leaves the second intermediate cylinder 11 by pipe E^3 and passes to compartment *a* of superheater 2, where its temperature is raised to about 705.3° absolute. The steam passes through the superheaters by pipe F^4, and in compartment *c* of superheater 3 the temperature is raised to about 755° absolute. In each of compartments *h*, *k*, *n*, *r*, and *v* of superheaters 4, 5, 6, 7, and 8 the temperature is raised, as hereinbefore described, and finally leaves superheater 8 by pipe F^4 at about 956.7° absolute. The steam is led through pipe 4 to the low-pressure cylinder 12 at about eleven pounds absolute and the temperature specified about 956.7° absolute, where it is expanded and taken off at about

two pounds absolute and about 587.2° absolute through exhaust-pipe E^4. A portion of the steam may be condensed in condenser 13, connected to pipe E^4 and controlled by a suitable valve 35. The amount of steam taken to the condenser 13 depends upon the load on the engine and may be controlled as desired. The amount of steam led through the other branch of pipe E^4 to the compressor J depends upon the amount of steam required that can be compressed and condensed. In compressor J the steam is compressed to about eleven pounds absolute and about 658° and pumped through pipe C′ to superheater 1 to heat the feed-water which circulates through this superheater. In superheater 1 a portion of the compressed steam is condensed and gives up its latent heat of vaporization to heat the feed-water. The condensed steam is led off through a suitable trap T′ at the bottom of the superheater and is run into the tank 14, from which it may be pumped by pump P, together with the condensed steam from all of the eight traps T′ to T^8, inclusive, back to the superheaters, together with sufficient extra water necessary for the boiler-feed. The pipe *w* is shown connecting the pump P with superheater 1 and is also shown connecting all of the superheaters from 1 to 6 and leading from thence to the boiler B after the water has been heated to the corresponding temperatures already designated for each superheater, finally leaving superheater 6 at a temperature of about 867.2° absolute, thereby entering the boiler at the temperature of the steam in the boiler. It will be seen that the feed-water pipe *w* connects superheater 1 with compartment *b* of superheater 2, compartment *e* of superheater 3, compartment *f* of superheater 4, compartment *i* of superheater 5, and compartment *p* of superheater 6. From each one of the chambers in which pipes 29 are placed branch pipes lead to the traps T′ T^2, &c., which are all connected by the pipe *d*.

I have shown how the compressed steam is led to superheater 1 from compressor J and how a portion of the steam is condensed and returned to the tank 14. The remaining portion of the compressed steam not condensed in superheater 1 is led through pipe *b′* to compressor K of the series of compressors E, where it is compressed to about twenty-seven pounds absolute and about 705.3° absolute, and passes from thence through pipe c^2 to superheater 2. Pipe c^2 communicates with the chamber or space in which the superheater-pipes 29 are placed, so that the compressed steam circulates around and between the vertically-arranged superheater-pipes 29, and a portion of the steam is condensed, giving up its latent heat of vaporization and superheating the working steam which passes to the low-pressure cylinder and also heating the boiler feed-water in the superheater-pipes 29 to about 705.3° absolute. The condensed portion of the steam is led through trap T^2 and pipe *d* to tank 14.

It will be seen that from each of superheaters 3, 4, 5, 6, and 7 extend pipes b^3, b^4, b^5, b^6, and b^7, which are connected, respectively, with compressors M, N, O, R, and S. From each of the compressors L, M, N, O, R, and S pipes c^3, c^4, c^5, c^6, c^7, and c^8 lead to superheaters 3, 4, 5, 6, 7, and 8, respectively. By this arrangement of pipe connections, compressors, and superheaters it will be seen that the condensed compressed steam from each of the superheaters is led through pipe *d* to the tank 14, while the uncondensed compressed steam is led through a pipe to a compressor and from thence returned to the next adjacent superheater until the last superheater 8 is reached, in which all of the compressed steam should be condensed. If, however, a portion of the steam should remain uncondensed in the superheater 8, suitable provision should be provided for leading off said uncondensed steam. The compressed steam in each superheater circulates outside the pipes 29 and in and around said pipes and gives up its latent heat of vaporization to the working steam and to the boiler feed-water circulating inside the pipes.

As stated, the latent heat of vaporization of the compressed steam is utilized to superheat the steam for the low-pressure cylinder and to preheat the feed-water in superheater 2, and this is also true of superheater 3. The latent heat of the compressed steam is utilized in superheater 4 to superheat the working steam for the second intermediate cylinder and the low-pressure cylinder and to preheat the feed-water. In superheaters 5 and 6 the latent heat of vaporization of the compressed steam is utilized to superheat the working steam for the first and second intermediate cylinders and the low-pressure cylinder and to preheat the feed-water. In superheaters 7 and 8 the latent heat of vaporization of the compressed steam is utilized to superheat the working steam for all four cylinders of the engine.

In compressor L before the steam is led to superheater 3 it is compressed from about twenty-seven pounds absolute and about 705.3° to about sixty-one pounds and about 755°. In superheater 3 the working steam is superheated to about 755° absolute and the feed-water is preheated to about this same temperature. In compressor M before the steam is led to superheater 4 it is compressed from about sixty-one pounds and about 755° absolute to about one hundred and twenty-five pounds and about 805° absolute, while in superheater 4 the working steam is superheated to about 805° absolute. In compressor N before the steam enters superheater 5 it is compressed from about one hun-

dred and twenty-five pounds and 805° to about two hundred and thirty pounds and 855° absolute, and in this superheater the working steam is superheated to about 855° absolute and the water is preheated to about this temperature. In compressor O before the steam enters superheater 6 it is compressed from about two hundred and thirty pounds and about 855° to two hundred and seventy pounds and about 867.2° absolute, and in superheater 6 the working steam is superheated to about 867.2° absolute and the feed-water is preheated to about that temperature. The feed-water is taken off at this temperature and heated no higher, because its temperature corresponds with that of the steam in boiler B. In compressor R before the steam is led to superheater 7 it is compressed from about two hundred and seventy pounds and about 867.2° absolute to about four hundred pounds and about 905° absolute, and in superheater 7 the latent heat of vaporization is utilized in superheating the working steam only. In compressor S before the steam enters the last superheater 8 it is compressed from about four hundred pounds and about 905° to about six hundred and fifty pounds and about 956.7° absolute, and in the last superheater 8 the latent heat of vaporization is utilized in superheating the working steam only, since the feed-water is not passed through superheaters 7 and 8.

Obviously in the apparatus shown and described the compressed steam could be passed through the pipes 29 in the superheaters, while the working steam and the condensed steam and water could be passed through compartments formed outside of said pipes which would be the reverse of the construction shown and described, but would be its equivalent.

According to this invention it will be seen that the object in compressing the exhaust-vapor is to increase its temperature to the desired degree, and the pressure must be maintained at a point corresponding to the increased temperature of a saturated vapor. A part of the vapor will condense, giving up its latent heat of vaporization to the medium used, which in this particular instance is the working steam and feed-water, both being at a lower temperature, which is to be increased. As soon as the conditions are such that there is a transfer of heat from the compressed vapor to the working steam and feed-water, a portion of the compressed steam is condensed, and the pressure would drop and its temperature would have a corresponding drop if it was not maintained. This does not happen because the pressure is maintained by a new supply of the vapor coming over from the several compressors to take the place of the condensed portion in the superheaters.

This invention is designed to increase the efficiency of a steam-engine or any heat-engine in which condensible vapors are used as the working medium by utilizing the waste latent heat of vaporization of the exhaust-steam which otherwise would be wasted and would not contribute to doing work.

Obviously this invention may be carried out by any suitable apparatus, and the process may be embodied in widely-varying forms with different modes of operation without departing from the spirit of the invention. The stages of compression and expansion may be varied in any desired manner, and the number of expansions and number of compressions may be varied as desired without departing from the invention.

Without enumerating equivalents, I claim, and desire to obtain by Letters Patent, the following:

1. Heat-engine process consisting in expanding a condensible gas doing useful work and compressing a portion of the expanded gas to raise its temperature, and transferring its latent heat of vaporization to gas before expansion, whereby the waste latent heat of the expanded gas is partially restored to unexpanded portions of gas.

2. Heat-engine process consisting in expanding steam doing useful work and compressing a portion of the expanded steam to raise its temperature, and transferring its latent heat of vaporization to steam before expansion, whereby the waste latent heat of expanded steam is partially restored to unexpanded portions of steam.

3. Heat-engine process consisting in superheating and expanding a condensible gas doing useful work and compressing a portion of the expanded gas to raise its temperature, and transferring its latent heat of vaporization to gas before expansion, whereby the waste latent heat of vaporization of the expanded gas is partially restored to unexpanded portions of gas.

4. Heat-engine process consisting in expanding a condensible fluid doing useful work and superheating the expanding fluid and preheating the liquid from which the fluid is formed, by abstracting a portion of the working fluid at a low temperature, compressing it to the degree of superheat required, condensing a portion of the same and imparting its latent heat of vaporization to the working fluid and to the liquid.

5. Heat-engine process consisting in expanding a condensible fluid doing useful work and superheating the working fluid and preheating the liquid from which the working fluid is formed to the temperature corresponding to the pressure desired, by abstracting a portion of the working fluid at a low pressure and temperature and compressing the abstracted portion to a pressure corresponding to the temperature desired, condensing a portion of the compressed fluid and imparting its latent heat of vaporization to

heat the liquid and superheat the fluid formed from the liquid.

6. Heat-engine process consisting in expanding a condensible fluid doing useful work and superheating the working fluid and preheating the liquid from which said fluid is formed to a temperature corresponding to the desired pressure, by abstracting a portion of the working fluid at a low temperature and pressure, compressing the abstracted portion to the temperature of superheat desired in a plurality of stages, condensing a portion of the compressed fluid and imparting its latent heat of vaporization at each stage of compression to the working fluid to superheat said fluid and to preheat the liquid from which the fluid is formed.

7. Heat-engine process consisting in expanding a condensible gas doing useful work and compressing a portion of the gas abstracted at a low temperature and pressure to raise its temperature and transferring its latent heat of vaporization to partially or incompletely expanded gas, whereby the waste latent heat of the gas is partially restored to said partially or incompletely expanded portions.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

HENRY L. DOHERTY.

Witnesses:
A. L. O'BRIEN,
E. VAN ZANDT.