(No Model.) 3 Sheets—Sheet 1.

A. H. ENGSTRÖM.

APPARATUS FOR REGENERATING EXHAUST STEAM.

No. 556,963. Patented Mar. 24, 1896.

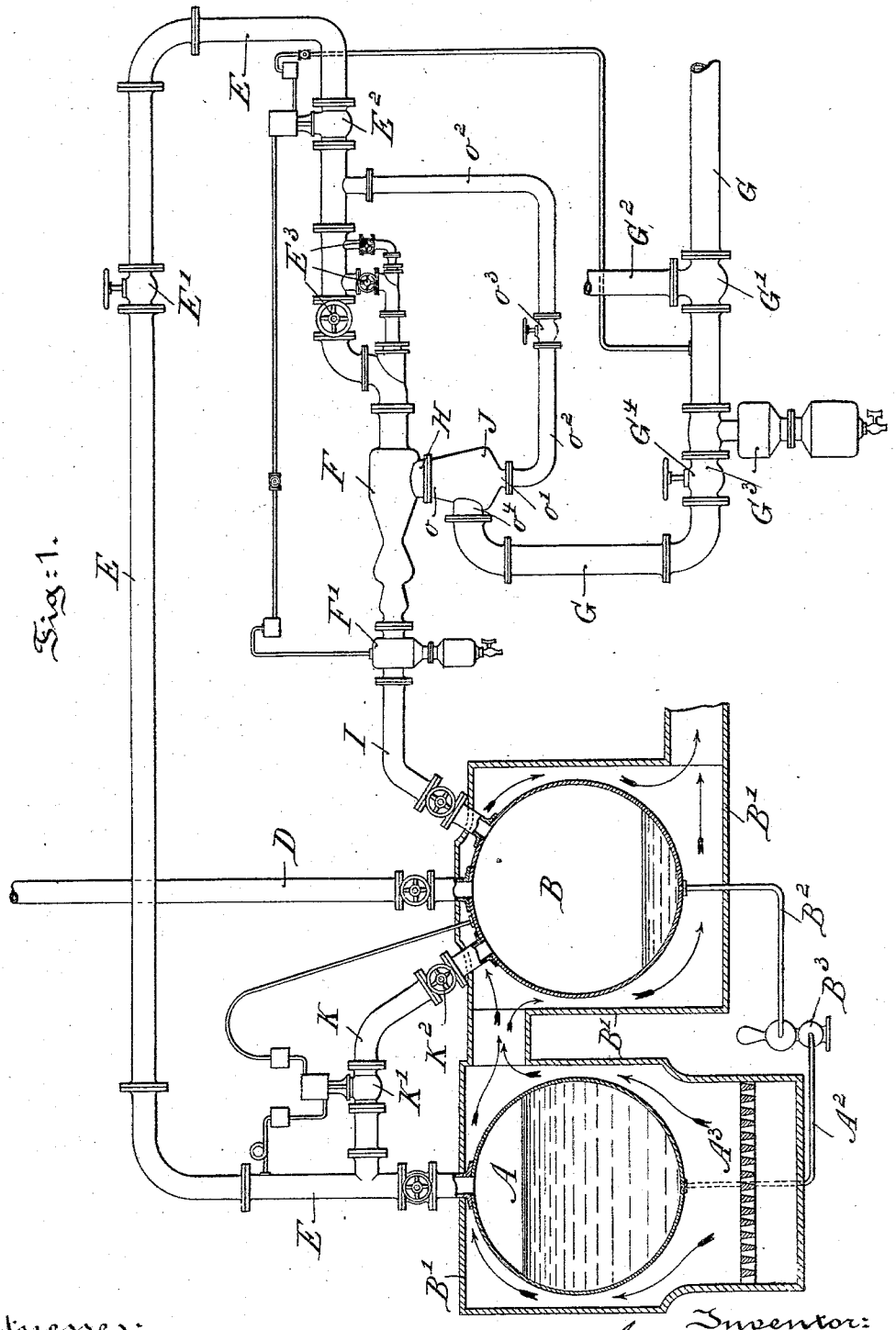

Fig: 1.

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(No Model.) 3 Sheets—Sheet 2.

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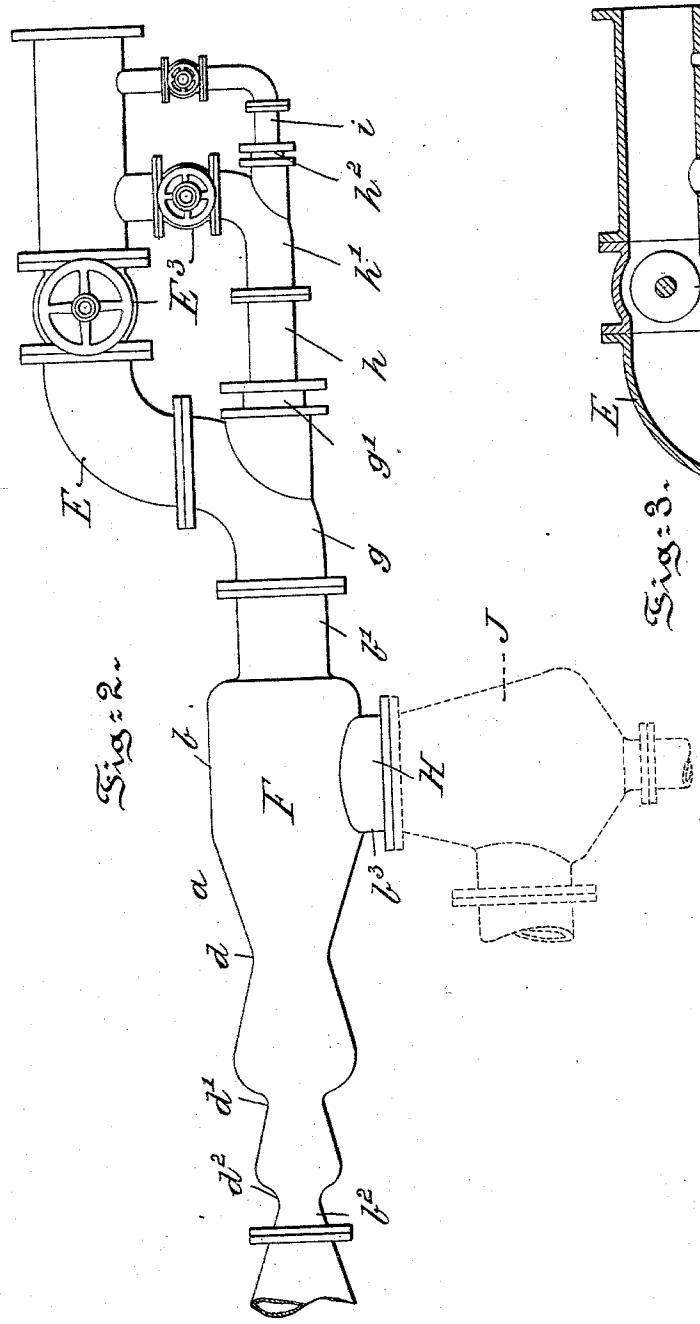

Fig. 2.

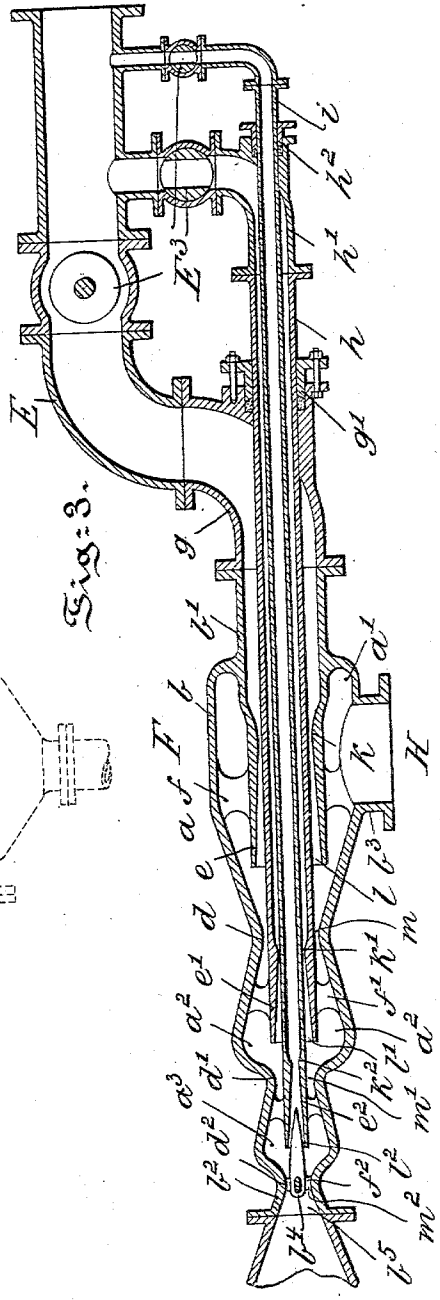

Fig. 3.

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(No Model.) 3 Sheets—Sheet 3.

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APPARATUS FOR REGENERATING EXHAUST STEAM.

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Fig. 4.

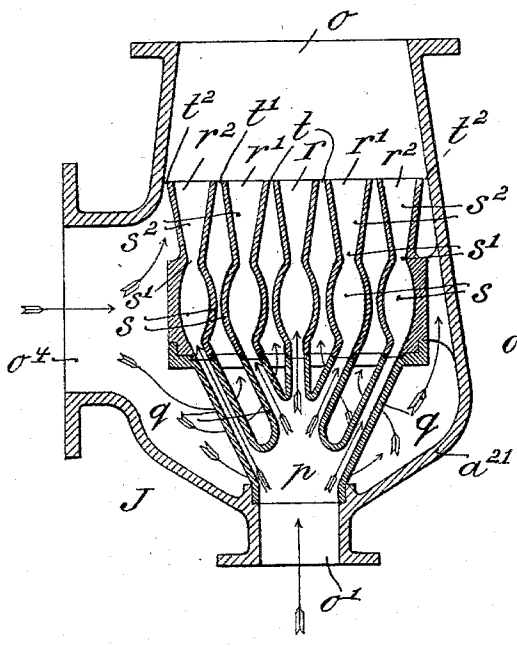


Fig. 5.

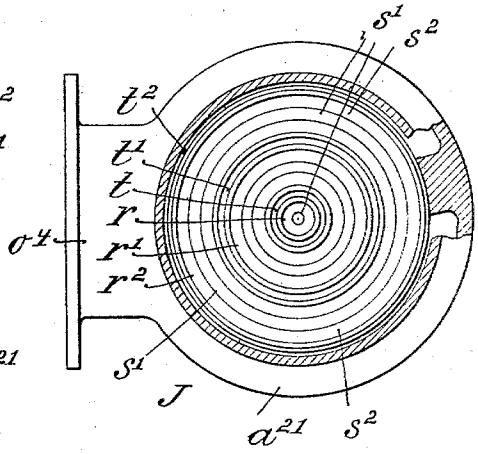


Fig. 7.

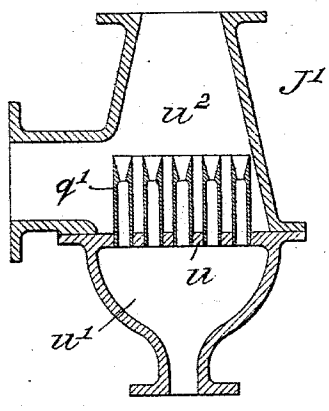


Fig. 6.

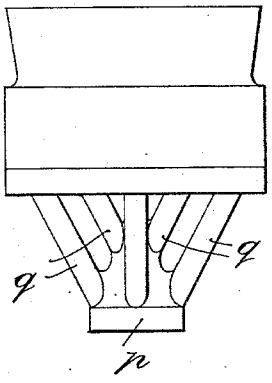
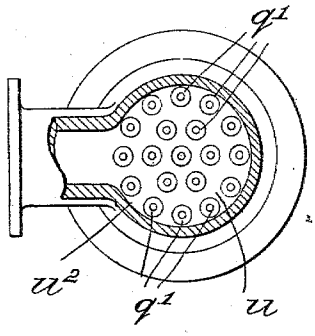


Fig. 8.



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UNITED STATES PATENT OFFICE.

AXEL H. ENGSTRÖM, OF PHILADELPHIA, PENNSYLVANIA, ASSIGNOR OF ONE-HALF TO GEORGE S. GANDY, OF SAME PLACE.

APPARATUS FOR REGENERATING EXHAUST-STEAM.

SPECIFICATION forming part of Letters Patent No. 556,963, dated March 24, 1896.

Application filed November 26, 1895. Serial No. 570,189. (No model.)

To all whom it may concern:

Be it known that I, AXEL H. ENGSTRÖM, a subject of the King of Sweden and Norway, residing at the city of Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Improvements in a System for Regenerating and Increasing the Pressure of Exhaust or Low-Pressure Steam, of which the following is a specification.

My invention has relation to a system of revivifying or regenerating exhaust or low-pressure steam, and in such system it relates to the heating of exhaust or low-pressure steam to impart thereto the requisite heat units, compressing and expanding the heated exhaust or low-pressure steam, and finally combining or mixing with the exhaust or low-pressure steam live steam of high pressure, which live steam has preferably been first used in heating said exhaust or low-pressure steam and compressing the same.

My invention also relates to apparatus whereby the above system may be accomplished, and in such connection it relates particularly to the general construction and arrangement of such apparatus for said purposes.

The principal objects of my invention are, first, to provide a system whereby low-pressure or exhaust steam may be revivified or regenerated and increased in pressure for use in the engine or other steam apparatus, whereby the heat units of the exhaust or low-pressure steam are utilized without loss; second, to provide a system whereby exhaust or low-pressure steam is compressed and expanded, the exhaust-steam during compression absorbing the latent heat due to condensation, the exhaust being thereafter mixed with live or high-pressure steam to receive the assumed temperature and required pressure for reutilization; third, to provide a system for the utilization of exhaust or low-pressure steam by means of which the exhaust or low-pressure steam is first heated by live steam, the heated exhaust being then successively compressed and expanded by and finally mixed with live steam, and, fourth, to provide in such a system a regenerator or other suitable apparatus whereby the successive steps of the system may be accomplished.

My invention, stated in general terms, consists of a system for revivifying exhaust or low-pressure steam for reutilization.

My invention further consists of a regenerator for exhaust or low-pressure steam constructed and arranged in substantially the manner hereinafter described and claimed.

The nature and scope of my invention will be more fully understood from the following description, taken in connection with the accompanying drawings, forming part hereof, and illustrating an apparatus for carrying into effect the system of my invention, and in which—

Figure 1 is a view illustrating in diagram and in side elevation a system for the regeneration or revivifying of exhaust or low-pressure steam. Fig. 2 is a side elevation, enlarged, of the regenerator illustrated in Fig. 1, the position and connections of an auxiliary regenerator being indicated in dotted lines. Fig. 3 is a longitudinal central section of the regenerator illustrated in Fig. 2. Fig. 4 is a longitudinal central section, enlarged, of the auxiliary regenerator. Fig. 5 is a top or plan view, partly broken away, of Fig. 4, looking toward the discharge or outlet end of the auxiliary regenerator. Fig. 6 is a side elevation of the live-steam nozzle detached from the casing of the auxiliary regenerator, and Figs. 7 and 8 are respectively a longitudinal central sectional view and a partly-broken-away top view of a modified form of auxiliary regenerator.

Referring to Fig. 1 of the drawings, A represents a boiler or steam-generator of approximately high pressure—say of about one hundred and fifty pounds—and B represents a secondary boiler or steam-supply of approximately lower pressure—say about one hundred pounds. The fire-rooms of these two boilers are preferably connected by flues B′, through which the heated gases from the fire-box A′ of the boiler A pass to heat the boiler B, as indicated in diagram in Fig. 1. The engine or engines are to be run or the steam radiation or heating system is to be supplied

at the latter pressure, and are fed with steam directly from the boiler B through a pipe or pipes D.

From the boiler A is led a pipe E, conveying steam to one end of a regenerator F, the construction of which will be hereinafter more fully described.

The exhaust from the engines or other steam apparatus is conducted by a pipe G to an inlet H of the regenerator F. The exhaust-steam is first heated and compressed in the regenerator, then expanded and mixed with the live steam in said regenerator, and so on *ad seriatim* until it is discharged through a pipe I to the boiler B. The exhaust thus regenerated absorbs the requisite number of heat units in its heating by an admixture with the live steam, and by its successive contractions and expansions the exhaust-steam is increased both in temperature and in pressure until it enters the boiler B at one hundred pounds pressure or at such higher or lower pressure as required. The degree of pressure to which the exhaust-steam is raised will depend naturally upon, first, the number of heat units in and the initial pressure of the exhaust-steam; second, the pressure and amount of live steam introduced into the regenerator and mixed with the exhaust-steam, and, third, the latent heat given off by condensation under compression and combining with the exhaust-steam.

The exhaust-steam pipe G is provided with a relief-valve G′, preferably automatic, which is adapted when the amount of exhaust is too great to discharge a portion of the same into the open air through a pipe G^2. In the exhaust-pipe G is also located a separator G^3, of ordinary construction, adapted to separate and collect water of condensation and to render the exhaust sufficiently dry before it enters the regenerator. Immediately after the exhaust-steam passes the separator its amount is regulated by a combination check-valve G^4 of ordinary construction. The live-steam pipe E is also provided with a check or stop E′ and a regulator-valve E^2, preferably automatic in its action, and the entrance or entrances of the pipe E to the regenerator F is regulated by one or a series of check or stop valves E^3. As the regenerated exhaust passes from the regenerator F, the water of condensation is collected and separated by means of a separator F′. The two boilers A and B are connected by a steam-pipe K, provided with a regulating-valve K′, preferably automatic, and between the boiler B and regulator-valve K′ is located in the pipe K a check-valve K^2. By means of these two valves K′ and K^2 a uniform difference in pressure between the two boilers A and B is constantly maintained. From the water-chamber of each boiler A or B extends a water-pipe A′ or B′, terminating in the pump B^2, arranged so as to discharge the water of condensation in the boiler B to the boiler A.

Referring now to Figs. 2 and 3, the construction and arrangement of the regenerator F are as follows:

The exterior casing, *a*, is formed cylindrical at the end *b* for the reception of the pipe *b*′, into which the live steam from the pipe E enters, and this casing is tapered and bulbous in form toward the end b^2, at which point internally thereof the commingled live and exhaust steam are discharged. The casing *a* is also provided at b^3 with an inlet H, through which the exhaust-steam enters.

The internal walls of the casing *a* are provided with the annular shoulders *d*, *d*′ and d^2, which project abruptly downward. Within the casing *a* and terminating to the right of these shoulders *d*, *d*′ and d^2 is arranged a series of reducing and expanding nozzles or tubes *e*, *e*′ and e^2, arranged in concentric or nested form, the internal tube, e^2, of the same extending through the casing *a* to approximately the outlet end b^2 thereof, with the expanded mouth thereof terminating at a point below and to the right of the shoulder d^2. The middle tube, *e*′, extends from the inlet end *b*′ of the casing *a* to a point below and to the right of the shoulder *d*′, while the outer tube, *e*, is a continuation of the inlet *b*′ to a point below and to the right of the shoulder *d* of the casing *a*. The tubes *e*, *e*′ and e^2 are held in position respectively within the casing *a* by the ribs *f*, *f*′ and f^2. The casing *a* forms a series of reducing and expanding chambers for the reception of exhaust-steam.

Live steam is led directly to the tube *e* from the pipe E through the elbow *g* and inlet *b*′. This elbow *g* is provided with a stuffing-box *g*′, through which extends a pipe *h*, forming a continuation of the middle tube, *e*′. The pipe *h* is connected to a branch of the pipe E by means of an elbow *h*′. Through a stuffing-box h^2 of the elbow *h*′ extends a pipe *i*, forming a continuation of the internal tube, *e*. The tubes *e*, *e*′, and e^2 are each contracted, as at *k*, *k*′, and k^2, in their interior walls, and are then tapered outward to their discharge-openings *l*, *l*′, and l^2 on a line which if continued would strike against the shoulders *d*, *d*′, and d^2 of the casing *a*. The casing *a*, by reason of the annular shoulders *d*, *d*′, and d^2 and enlarged or bulbous walls of the tapered portion b^2, is divided into chambers *a*′, a^2, and a^3, in communication with each other by means of contracted openings *m*, *m*′, and m^2, the areas of which openings gradually diminish toward the outlet end b^2. These chambers and contracted openings correspond in number with those of the tubes *e*, *e*′, and e^2. The outlet b^2 is partially closed by the tapered reducing-piece b^4, the pointed end of which is extended into the outlet end of the interior tube, e^2.

The exhaust-steam enters through the inlet b^3 into the chamber *a*′, within which the exterior tube, *a*, terminates. The exhaust-steam circulates in this chamber *a*′, and is heated by the live steam passing through the tube *e*. By reason of the contracted outlet *m* a vacuum is created through the live steam escaping

from the expanded tube e, and the exhaust-steam, after being heated, is forced through and is mixed at the outlet m with live steam issuing in expanded form from the tube or nozzle e. The mixed steam is then compressed in the bulbous chamber a^2. The steam thus treated passes through the chamber a^2, where it is further heated by contact with the tube e' and mixed at the contracted outlet m' of the chamber a^2 with live steam from the tube e'. The steam then escapes and is compressed in the chamber a^3, in which it is further heated by contact with the tube e^2, mixed with live steam at the outlet m^2, and finally compressed in the expanding-outlet b^3, from which it passes to the boiler B in required pressure and of required temperature.

In Figs. 4, 5, and 6 is shown a modified form of regenerator J, which may be substituted for the regenerator F, where but a low pressure is to be given to the exhaust-steam and which, however, by preference may be used in conjunction with the regenerator F for increasing the pressure given to the exhaust-steam. The position of the regenerator J, when used as an auxiliary to the regenerator F, is shown by full lines in Fig. 1 and by dotted lines in Fig. 2.

Briefly stated, the regenerator J is connected at its outlet end o with the exhaust-inlet H of the regenerator F. The inlet o' for live steam to the regenerator J is connected by a branch pipe o^2, provided with a valve o^3, with the pipe E, leading from the boiler A, and the exhaust-inlet o^4 is connected with the pipe G from the exhaust of the engine.

When the regenerator J is to be used alone, the inlet o' is connected directly to the live-steam pipe E, the outlet o is connected directly to the pipe I leading to the boiler B, and the inlet o^4 is connected to the exhaust-steam pipe G. In this form of regenerator the casing a^{21} is tapered from the inlet o' to the outlet o, and incloses a nozzle p branched into a series of pipes q, which flare outward from the nozzle p and terminate in a series of concentric annular channels r, r' and r^2. The interior walls of these channels are expanded, as at s, contracted, as at s', and flared outward, as at s^2, as fully illustrated in Fig. 4 of the drawings. In this form of regenerator the exhaust from the inlet o^3 enters the casing a^{21} and circulates around the pipes q, the direction of the exhaust being indicated by the curved arrows in Fig. 4. The exhaust is heated by contact with the pipes q, and is contracted at the points s corresponding to the points of expansion of the walls of the channels r, r' and r^2. The contracted and heated steam then passes into the gradually contracted annular chambers formed by the flaring walls s^2 of the channels r, r' and r^2, and as it escapes from the contracted outlets t, t', t^2 and t^3 mixes with the expanded live steam issuing from the expanded outlets to the channels r, r' and r^2, and is compressed in the outlet end of the casing a^{21}.

In the modified form of the auxiliary regenerator J illustrated in Figs. 7 and 8 the pipes q' are screwed or otherwise fastened in a plate or partition u, which separates the regenerator into two compartments, in one of which, u', the live steam enters and passing through the pipes q' is successively contracted and expanded before it reaches the chamber u^2. The exhaust-steam enters the chamber u^2 and circulates in the same around the pipes q', becoming heated thereby, and finally mixes with and is compressed by the expanding live steam as it is discharged from the expanded outlets of the said pipes. These pipes q' are arranged concentrically, as illustrated in Fig. 8 of the drawings.

It will be manifestly obvious from the foregoing description that I am not to be limited to the particular constructions and arrangements of parts of the apparatus of my invention for the carrying out of the same, and hence I do not wish to be understood as limiting myself herein to the precise arrangement of the apparatus, as hereinbefore described and illustrated; but,

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

1. A regenerator for revivifying or regenerating exhaust or low-pressure steam, consisting of two chambers into which respectively exhaust and live steam are conducted, the exhaust-chamber being heated by said live-steam chamber, and a series of contracted and expanded chambers in suitable communication with each other and with the live and exhaust chambers, wherein the exhaust is mixed with the live steam, and thereafter successively contracted and expanded, whereby the exhaust is increased both in temperature and pressure, substantially as and for the purposes described.

2. A regenerator for revivifying or regenerating exhaust or low-pressure steam provided with successive contracting and expanding chambers, and inlets to said chambers for both live and exhaust steam, all arranged so that said exhaust is first mixed with the live steam at the contracting-chambers, and compressed and condensed by said live steam in said expanding-chambers, said exhaust thereby absorbing the latent heat resulting from said condensation and thus increased in temperature and pressure, substantially as and for the purposes described.

3. In a system of revivifying or regenerating exhaust-steam, a boiler of predetermined pressure, an engine or set of engines operated under less pressure than that of said boiler, a regenerator connected with the exhaust from said engine or engines and with the boiler, said regenerator consisting of two chambers into which respectively exhaust from the engines and live steam from the boiler are conducted, the exhaust-chamber being heated by said live-steam chamber, and a series of contracting and expanding cham-

bers, in suitable communication with each other and with the live and exhaust chambers, wherein the exhaust is mixed with the live steam and successively contracted and expanded and thereafter conducted under increased heat and pressure to the engine or set of engines or to a point of further utilization of said revivified exhaust-steam, substantially as and for the purposes described.

4. A regenerator for increasing the temperature and pressure of exhaust-steam, consisting of a casing provided with one or more inlets for live steam, each inlet being provided with one or more expanded outlets within the casing, an inlet for exhaust-steam, a succession of gradually-contracted chambers within the casing adapted to receive the exhaust and to successively contract, expand and mix said exhaust with the live steam issuing from the expanded outlets within the casing, substantially as and for the purposes described.

5. In a system of revivifying or regenerating exhaust-steam for reutilization in engines, a boiler of predetermined pressure, a regenerator connected with said boiler and with the exhaust from said engines, said regenerator adapted to successively contract and expand said exhaust-steam and to mix the same with steam from said boiler and a connection between the regenerator and said engines, whereby the exhaust after passing through said regenerator and thereby increased in temperature and pressure, is conducted back for use in said engines, substantially as and for the purposes described.

6. A regenerator for revivifying or regenerating exhaust-steam consisting of an expanding nozzle or nozzles connected with a source of live or high-pressure steam, a chamber into which the nozzle or nozzles discharge, an inlet in said chamber for exhaust-steam, the interior of which is arranged so that exhaust-steam is caused to circulate around the live-steam nozzle and to be then compressed and expanded while being mixed with the live steam dischaging into said chamber having an outlet for the revivified exhaust-steam of less area than that of the live and exhaust steam inlet, substantially as and for the purposes described.

7. In a system of revivifying or regenerating exhaust-steam, an auxiliary regenerator consisting of a shell or casing having an inlet for exhaust-steam, a series of concentric contracting and expanding tubes or chambers connected with a source of live or high-pressure steam discharging within the shell or casing, the interior of which is constructed so that exhaust-steam is caused to circulate around and between the live-steam tubes or chambers and to be successively heated, compressed and expanded between the same and then mixed with the live steam, substantially as and for the purposes described.

8. In a system of revivifying or regenerating exhaust-steam, a regenerator, comprising a casing divided into a series of reducing and expanding chambers, an inlet for exhaust-steam into said casing, a series of expanding-tubes extending into said casing, nested together and of varying diameters and lengths, each of said expanding-tubes being connected by branch pipes with a main live or high-pressure steam pipe, substantially as and for the purposes described.

9. In a system of revivifying or regenerating exhaust-steam, a primary boiler containing high-pressure steam, a pipe leading therefrom, a regenerator provided with a series of expanding-nozzles connected with said live-steam pipe, said regenerator being divided into a series of reducing and expanding chambers, a pipe connecting said chambers with the exhaust from an engine or set of engines, a pipe leading from the regenerator to a secondary boiler or other source of steam-supply of lower pressure than that of the primary boiler, a pipe conveying steam from the secondary boiler to the engine or set of engines and adapted to actuate the same, and a pipe connecting the primary and secondary boilers together and provided with a regulator-valve adapted to maintain a constant and uniform difference in pressure between said boilers, substantially as and for the purposes described.

In testimony whereof I have hereunto set my signature in the presence of two subscribing witnesses.

AXEL H. ENGSTRÖM.

Witnesses:
J. WALTER DOUGLASS,
THOMAS M. SMITH.