No. 845,980. PATENTED MAR. 5, 1907.

R. SCHULZ.

STEAM TURBINE.

APPLICATION FILED FEB. 26, 1906.

6 SHEETS—SHEET 1.

Fig.1.

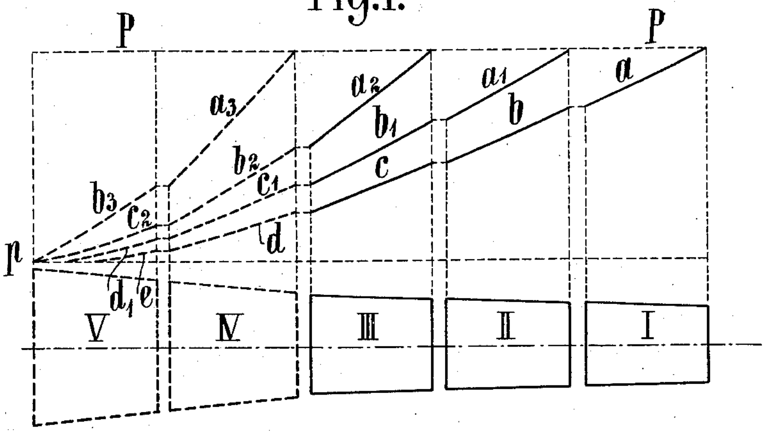


Fig.2.

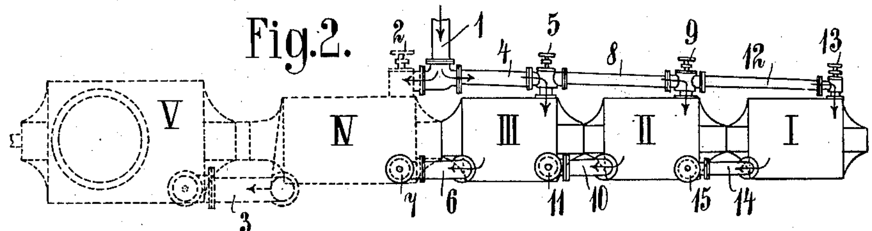


Fig.3.

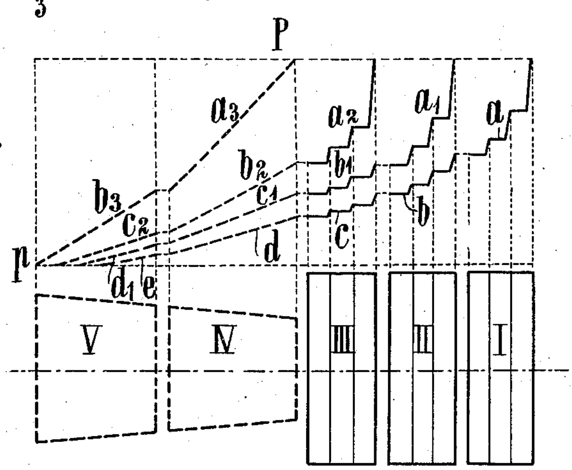
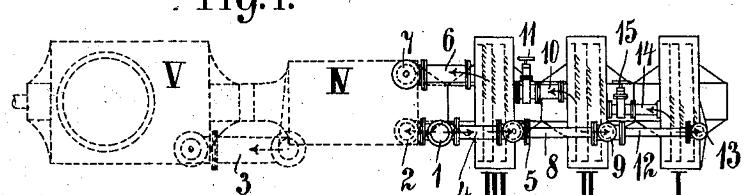


Fig.4.



Witnesses.

H. L. Amer.

B. Sommers

Inventor.

Richard Schulz.

by Henry Orth Jr. atty.

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6 SHEETS—SHEET 2.

Fig.5.

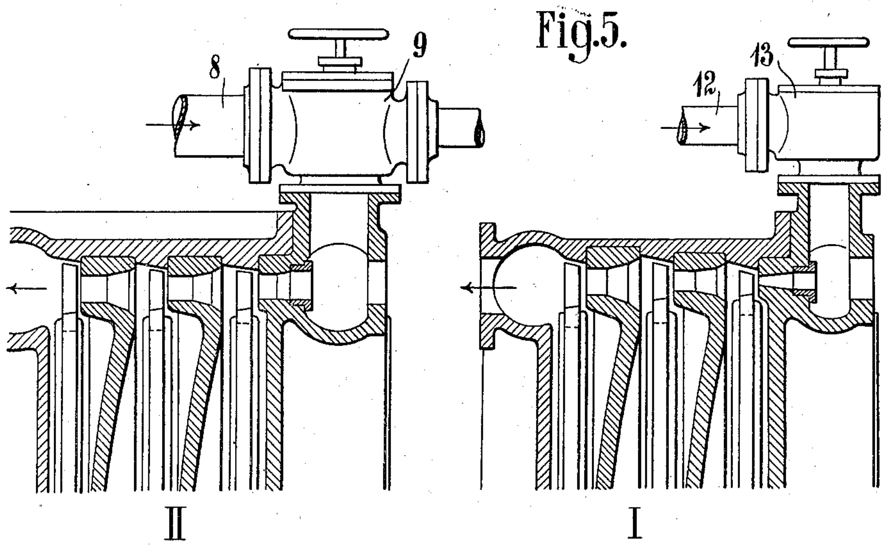
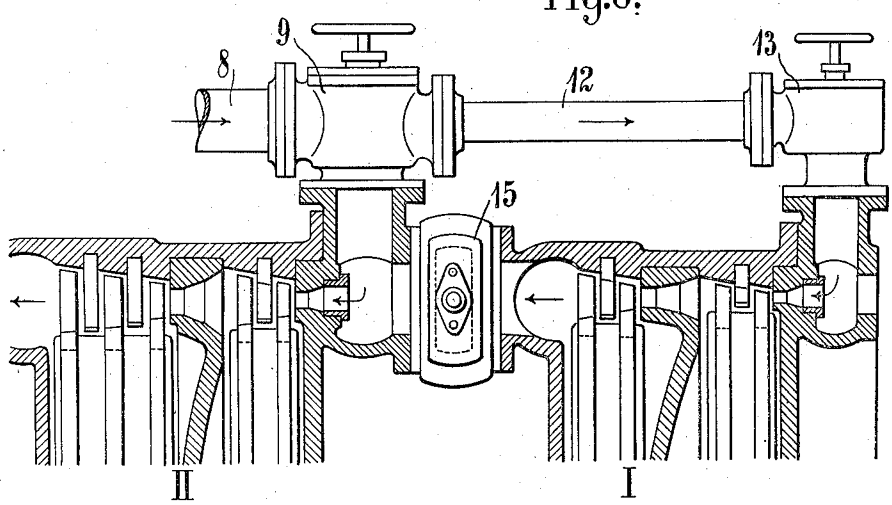


Fig.6.



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6 SHEETS—SHEET 3.

Fig. 7.

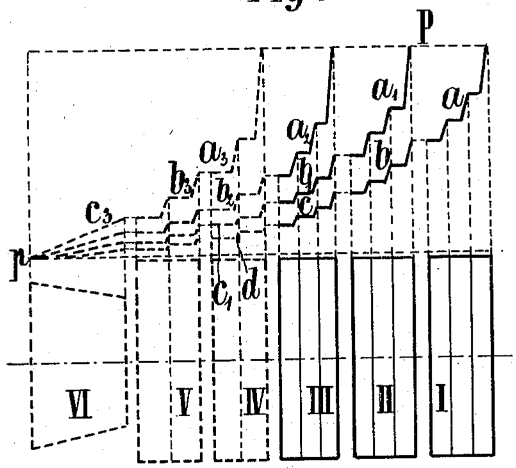


Fig. 8.

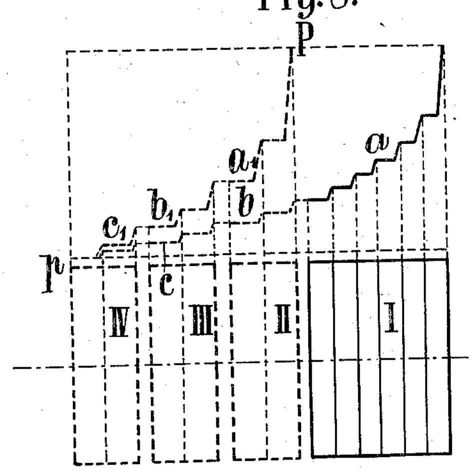
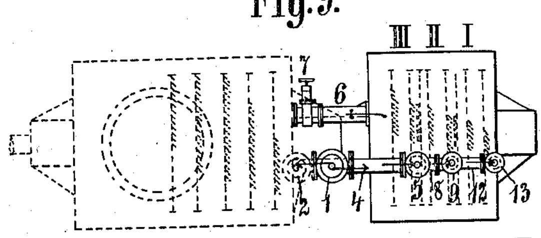


Fig. 9.



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H. L. Amer.

B. Sommers

Inventor.

Richard Schulz.

by Henry Orth Jr atty

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6 SHEETS—SHEET 4.

Fig.10.

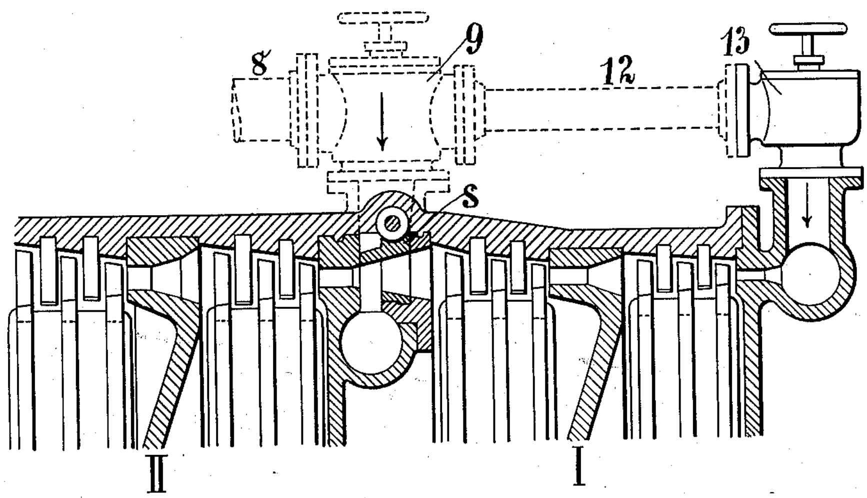


Fig.12.

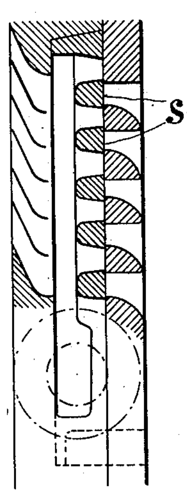
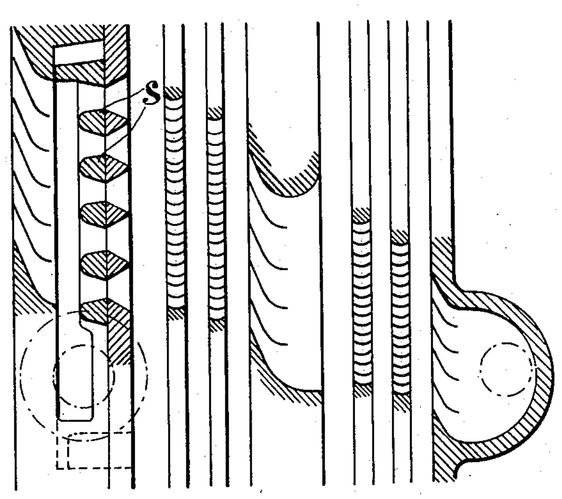


Fig.11.



Witnesses.

H. L. Amer.

B. Bommer

Inventor.

Richard Schulz.

by Henry Orth Jr. atty.

PATENTED MAR. 5, 1907.

R. SCHULZ.

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Fig. 13.

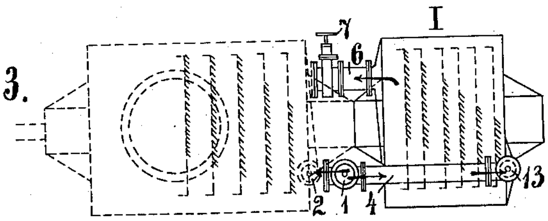


Fig. 14.

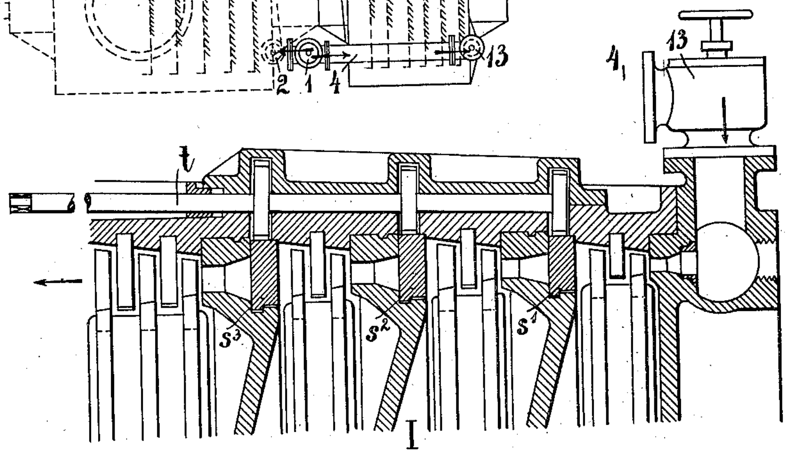


Fig. 15.

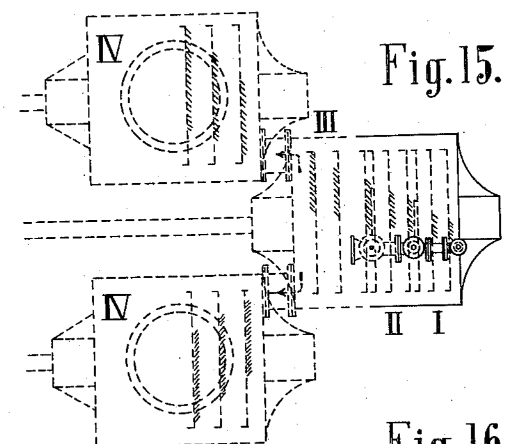
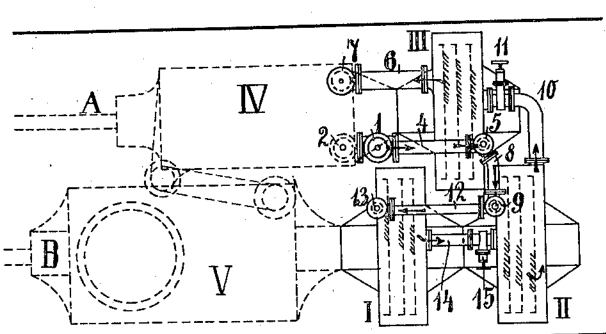


Fig. 16.



Witnesses.
H. L. Amer.
B. Sommers

Inventor.
Richard Schulz.
by Henry Orth Jr. atty.

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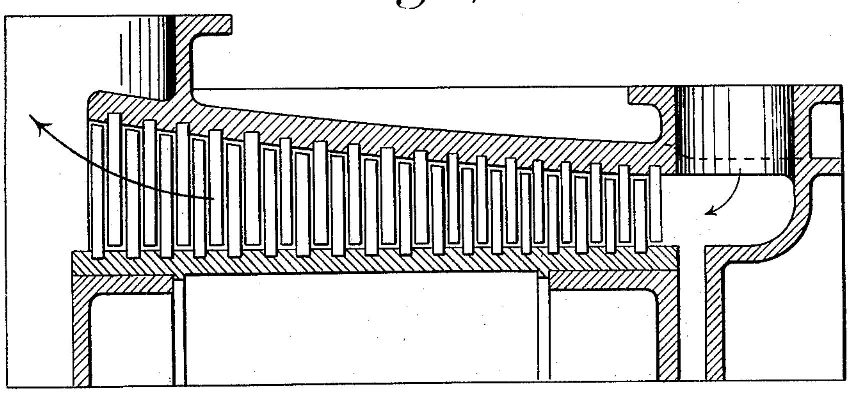
6 SHEETS—SHEET 6.

Fig. 17.



Witnesses

Jesse N. Lutton.

B. V. Sommers

Inventor

Richard Schulz

by Henry Orth Jr.

atty

UNITED STATES PATENT OFFICE.

RICHARD SCHULZ, OF BERLIN, GERMANY.

STEAM-TURBINE.

No. 845,980. Specification of Letters Patent. Patented March 5, 1907.

Application filed February 26, 1906. Serial No. 303,049.

To all whom it may concern:

Be it known that I, RICHARD SCHULZ, a subject of the King of Prussia, German Emperor, residing at Berlin, Germany, have invented certain new and useful Improvements in Steam-Turbines; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, and to letters or figures of reference marked thereon, which form a part of this specification.

This invention relates to steam-turbines, and more particularly to that class known as "compound steam-turbines," and has for its object to construct the turbines so that they will require a smaller number of running-wheels and less space for placing the turbines, that they will be easily regulable at various speeds and more especially be readily operated to develop power and be run economically at less than the designed maximum power, whether the turbines be of the tandem or cross compound type, as will be hereinafter more fully described and claimed.

According to Patent No. 725,880, the object of which is to regulate the speed and power with an economical use of the steam, the small overpressure or free-expansion-turbines in which all the blades are encountered by the steam are turned on in front of the steam-turbine for greatest power; and these smaller running wheels or groups of rings of blades are brought into action progressively the smaller the power is to be. The auxiliary or front turbines being free-expansion turbines in which the steam gradually expands in acting upon a large number of running wheels a large space for placing the turbines is necessary. These drawbacks are removed by the present invention.

Referring to the drawings, in which like parts are similarly designated, Figure 1 is a diagram illustrating two main tandem compound turbines IV and V, through which the steam gradually expands, with three auxiliary free-expansion turbines I, II, and III of the axial or parallel flow type capable of being connected in tandem in front of the main turbines. Fig. 2 is a plan view of the actual construction of such turbines with their steam connections. Fig. 3 is a view similar to Fig. 1, in which the three auxiliary turbines are constructed according to the present invention, so that the steam in passing through them will expand stepwise or in stages. Fig. 4 is a view similar to Fig. 2, but embodies the improvement shown in Fig. 3. Fig. 5 is a partial longitudinal section, partly in elevation, through turbines I and II, Fig. 4, each running wheel having a single set of blades. Fig. 6 is similar to Fig. 5, but where the remaining wheels have a plurality of sets of blades. Fig. 7 is a diagram showing two of the three turbines designed to give the maximum power as constructed, so that the steam will expand through them stepwise. Fig. 8 is similar to Fig. 7, in which the steam will expand stepwise through all of the turbines designed to give maximum power. Fig. 9 shows the turbine-wheels I, II, and III, Fig. 7, included in a single casing and IV, V, and VI in a single casing. Fig. 10 is a longitudinal section of turbines I and II contained in a single casing, and in which the communication between the separate wheel-compartments is controlled by circular grid slide-valves *s*. Fig. 11 is a horizontal section showing the valve *s* open. Fig. 12 is a horizontal section showing the valve *s* closed. Fig. 13 is a turbine constructed according to the diagram, Fig. 8. Fig. 14 shows all of the grid slide-valves for the turbines I, II, and III controlled by a single rod. Fig. 15 illustrates the turbines connected in tandem and on three different shafts. Fig. 16 illustrates the turbines distributed on two shafts in both tandem and cross compound arrangement. Fig. 17 is a section through one of the turbines IV or V.

The diagrammatic view Fig. 1 illustrates the operation of the actual turbines and in which the main compound turbines IV and V (illustrated in dotted lines) are designed for the greatest development of power and in which expansion takes place through two groups from the initial steam-pressure P to the final steam-pressure p, as indicated by the lines $a^3\ b^3$. When it is desired to generate less power, one of the auxiliary turbines is connected to those IV and V. When the turbine III is included in the series, the steam expands in accordance with the line $a^2\ b^2\ c^2$. When two auxiliary turbines II and III are included in the series, the expansion through them approximates the line $a'\ b'\ c'\ d'$, and when the third is included the expansion follows the line *a b c d e*. In all of these cases the steam expands gradually from the initial pressure P to the final or exhaust pressure *p*. Calculation and experience have shown that in order to permit this gradual expansion from the initial to the final steam-pressure an unusually large number of sets of blades or turbine-wheels will be required, especially for war vessels, where the usual speed of the vessel is only about forty per cent. of the highest speed, as will be seen from the following example. A ship's turbine requires for full power and four hundred revolutions about sixty running wheels. Corresponding to the above assumption one hundred and sixty revolutions are then approximately necessary for the lowest power. The turbine must then as a whole have $\frac{400^2}{160^2}.60=375$ running wheels. The running wheels or sets of blades in such a large number must be so constructed that the wheels at the end where the steam enters will be extremely small, and what is of the greatest disadvantage the turbine set must be made very long, as will be seen from Fig. 2. The auxiliary turbines must be of smaller diameter, as indicated in the turbine bodies III II I, in order to provide the required areas for the passage of the steam through the blades. According to the foregoing formula, however, the number of the running wheels is calculated under the assumption that the peripheral speeds in the auxiliary and main turbines are equal under all circumstances, and therefore in actual practice in order to fulfil this condition the number of wheels or sets of blades must be still further increased. Furthermore, it will be observed that when working with a small load a number of sets of blades at the end of the main turbines not only do no work, but even offer a resistance, as will be seen from the lines *e*, *d'*, and c^2, so that the number two hundred and seventy-five for this reason also does not fully suffice.

Such conditions as above set forth cannot be fulfilled in the limited space available for the driving mechanism of war vessels or of locomotives, and the problem is also not solved where there are several driving-shafts, as in vessels. In locomotives it is not possible to make use in front of the main turbine of auxiliary free-expansion turbines in which all the blades are acted upon already, for the reason that at starting a comparatively great resistance has to be overcome, quite apart from the circumstance that such large turbines cannot be placed even on a larger number of shafts. These difficulties are overcome in the present invention by making the auxiliary turbines as impact-turbines, taking the steam in stages, so that the expansion of the steam takes place substantially only in the conducting means for the steam, here shown as the nozzles, while the wheels or sets of blades in each chamber operate under uniform steam-pressure with a corresponding reduction of the speed of the steam.

Fig. 3 shows diagrammatically a main turbine IV V in dotted lines and corresponding to Fig. 1, having three auxiliary action or impact turbines I II III inserted in front of it. Fig. 4 shows the practical execution on the same scale as Fig. 2. In each of the turbines I II III the steam is expanded in three stages, as shown by the lines a^2 *a'* *b'* and *a b c*, Fig. 3. From Fig. 4 it will be seen that the turbines I, II, and III are of considerably larger diameter than those shown in Fig. 2, but are much shorter, and the length of the steam-conduits is also diminished; but the arrangement of valves remains the same as in Fig. 2. In both Figs. 2 and 4 boiler-steam passes through pipe 1, valve 2, to turbine IV, thence through pipe 3 to turbine V, from which it is exhausted. All other valves are closed. The greatest power is thus developed. If less power is required, turbine III is placed in series with the main turbines IV and V, valve 2 is closed, and valves 5 and 7 are opened, the steam passing through the pipe 1, smaller pipe 4, valve 5, turbine III, pipe 6, valve 7, turbine IV, pipe 3, and turbine V. For still less power, another turbine II is included. Valve 5 is then closed and 9 and 11 are opened to include this turbine-wheel in the series. In like manner turbine I is included in the series, valves 13 and 15 being opened and valve 9 closed.

It will be observed that the steam-pipes 1, 4, 8, and 12 decrease in diameter in the order named and that the pipes 14 10 6 3, connecting the adjacent exhaust and inlet ends of the turbines, increase in size in the order named.

The inlet-valves 2, 5, 9, and 13 may be slide-valves or valves of any other suitable construction and, if desired, may be controlled simultaneously. The cut-off valves 7, 11, and 15 may also be of any suitable construction. For example, they may be automatic back-pressure valves of any well-known form.

Fig. 5 shows a section of turbines I and II, each containing three turbine-wheels and in which the steam is expanded in three stages through three sets of nozzles. In Fig. 6 the turbines have but two wheels and two sets of inlet-nozzles each, so that the steam is expanded in two stages only in each turbine; but each wheel is provided with a plurality of sets of blades. In these figures the steam passes axially through the wheel. The wheel may be made so that the steam will pass through it radially. The impact of the steam is controlled by valves. It may be in the first stage only or in all of them, as the case may be.

The main compound turbine may also be

constructed either wholly or partially as impact or pressure turbines, as indicated in the diagram Figs. 7 and 8. In the first case two-thirds IV and V of the main turbines are constructed as impact-wheels and the latter third VI as an overpressure wheel or free-expansion turbine.

As shown in Fig. 9, in practical execution the insertible turbines I, II, and III may also be placed in a single casing, thus further shortening the length of the turbine. The valves 11 and 15 may then be preferably formed as sliding grid-valves.

Figs. 10, 11, and 12 show in vertical and horizontal section a portion of the auxiliary turbine where the steam passes from the first turbine I to the second turbine II through a sliding grid-valve *s*. (Shown open in Fig. 11 and closed in Fig. 12.) By so constructing the valves the steam passes from one wheel or set of blades to the next through the shortest possible distance, thereby preventing loss of pressure.

Fig. 13 illustrates a turbine in accordance with the diagram Fig. 8, a portion of which turbine (the auxiliary turbine-wheel I) is shown in section in Fig. 14. From the boiler steam-pipe 1 is a pipe 4, controlled by valve 13, and the passage of the steam from one set of blades to another is controlled by the sliding ring grid-valves s' s^2 s^3, operated from a single shaft *t*. These slide-valves operate to regulate the power and speed of the auxiliary turbines within wide limits for the same, or substantially the same, fall of steam-pressure, especially so when main turbines are constructed as pressure or impact wheels with means to control the impact. This also allows the main turbines being distributed over several shafts, as shown in Fig. 15, in such a way that by regulating the area of impact the power distributed over the second shafts is made approximately uniform. On the central shaft is mounted the high-pressure turbine III and on the lateral shafts the low-pressure turbines IV^a and IV^b, and in the casing of the high-pressure turbine III are the auxiliary turbines I and II. The turning on and off of these auxiliary turbines is done by means of two inlet-valves and sliding grid-valves, which allow of the passing over of the steam similarly to that shown in Fig. 11 and 12.

Even where the turbines are unsymmetrically arranged on several shafts by the use of impact-turbines with regulatable area of impact the uniform distribution of the power of the compound turbines is possible with the most varied speeds to the separate shafts.

In the unsymmetrical arrangement of Fig. 16 an even distribution of power is accomplished. On shaft A is the high-pressure turbine IV and the auxiliary turbine III, while on shaft B is the low-pressure turbine V and the auxiliary turbines I and II, so that when all are included in series steam will pass through turbines I, II, III, IV, and V in succession from one shaft to the other and then back again. Pipe connections and valves are the same as was described with reference to Fig. 4.

From these few examples it will be seen that by the use of impact-wheels and by expanding the steam in stages in connection with means for controlling the impact the turbines may be distributed as desired on several shafts while maintaining an equal distribution of power, which is of great importance on war vesesls.

The turbines will require less area for mounting and less cubic space and they may all be placed on a single bed-plate, or the bed-plates may be placed very near together, thus assuring even running. The construction is also more compact as the bearings are placed closer together, which again enables a steady running of the engine. Finally, weight and cost are saved as compared with the free-expansion or reaction turbines with their high number of rings of blades. Under certain circumstances only a part of the rings of blades may also have full impact in one or other of the auxiliary turbines, either for the better utilization of the avaliable space or in order to better take up thrust and the like. In this case also by regulating the nozzles an economical working may be obtained. Such compound turbines can be used in locomotives, and the partial impact and expansion in stages will avoid the throttling of the steam, so that the steam will drive the turbine-wheels under its full pressure.

I claim—

1. In a multistage turbine the combination with the high-pressure stages, having wheels which are supplied with motive fluid partially around their circumference; of nozzles to supply motive fluid thereto in which the greater part of the energy is converted into velocity, a main turbine connected to the high-pressure stages, means to supply motive fluid to any one of the turbines and means to permit the decreasing of the number of high-pressure stages supplied with motive fluid to increase the power developed.

2. In a turbine, the combination with a plurality of shafts, of a main turbine on each shaft, high-pressure stages on each shaft having wheels which are supplied with motive fluid partially around their circumference, nozzles to supply motive fluid thereto in which the greater part of the energy is converted into velocity, means to supply motive fluid to any one of the stages and to the main turbines, whereby the supply to any of the stages may be stopped and said supply directed to any lower stage or main turbine to develop greater power and conversely.

3. In a turbine, the combination with main turbines of high-pressure stages con-

nected thereto, said stages having wheels which are supplied with motive fluid partially around their circumference, means to control and vary the area so supplied around the circumference, nozzles to supply motive fluid thereto in which energy of the motive fluid is converted into velocity, means to supply motive fluid to any one of the stages and main turbines, whereby the number of stages through which the motive fluid passes before entering the main turbines can be decreased at will to correspondingly increase the power, and conversely.

4. In a turbine, the combination with main turbines and means to discharge motive fluid around the entire periphery of the wheels of said turbines; of high-pressure stages connected to the main turbines having wheels that are supplied with motive fluid partially around their circumference, nozzles to supply motive fluid to the several stages in which part of the energy of the motive fluid is converted into velocity and means to supply motive fluid to the nozzle of any of the stages, whereby the number of stages through which said motive fluid passes before entering the main turbines can be decreased at will to correspondingly increase the power developed, and conversely.

5. In a turbine, the combination with a main turbine and means to discharge motive fluid around the entire periphery of the wheels of said turbines; of a number of high-pressure stages connected to the main turbine and having wheels that are supplied with motive fluid partially around their circumference, nozzles to supply motive fluid to the several stages in which energy of the fluid is converted into velocity, means to control and vary the area of impact of the motive fluid on the wheels of the stages and thereby control the expansion in the nozzles, and means to supply any one of the stages or the main turbine with motive fluid, whereby by decreasing the number of stages through which the steam passes the power will be correspondingly decreased, and conversely.

6. In a turbine, the combination with main turbines and means to discharge motive fluid around their entire periphery; of a number of high-pressure stages connected to the main turbines and having wheels that are supplied with motive fluid partially around their circumference, nozzles to supply motive fluid to the several stages in which energy of the motive fluid is converted into velocity, means to control the degree of energy converted into velocity and means to supply the main turbines and the stages with motive fluid in quantities decreasing from the lowest to the highest stage.

In testimony that I claim the foregoing as my invention I have signed my name in presence of two subscribing witnesses.

RICHARD SCHULZ.

Witnesses:

JOHANNES HEIN,

HENRY HASPER.