K. BAUMANN.

STEAM TURBINE.

APPLICATION FILED JUNE 23, 1916.

1,302,282.

Patented Apr. 29, 1919.

7 SHEETS—SHEET 1.

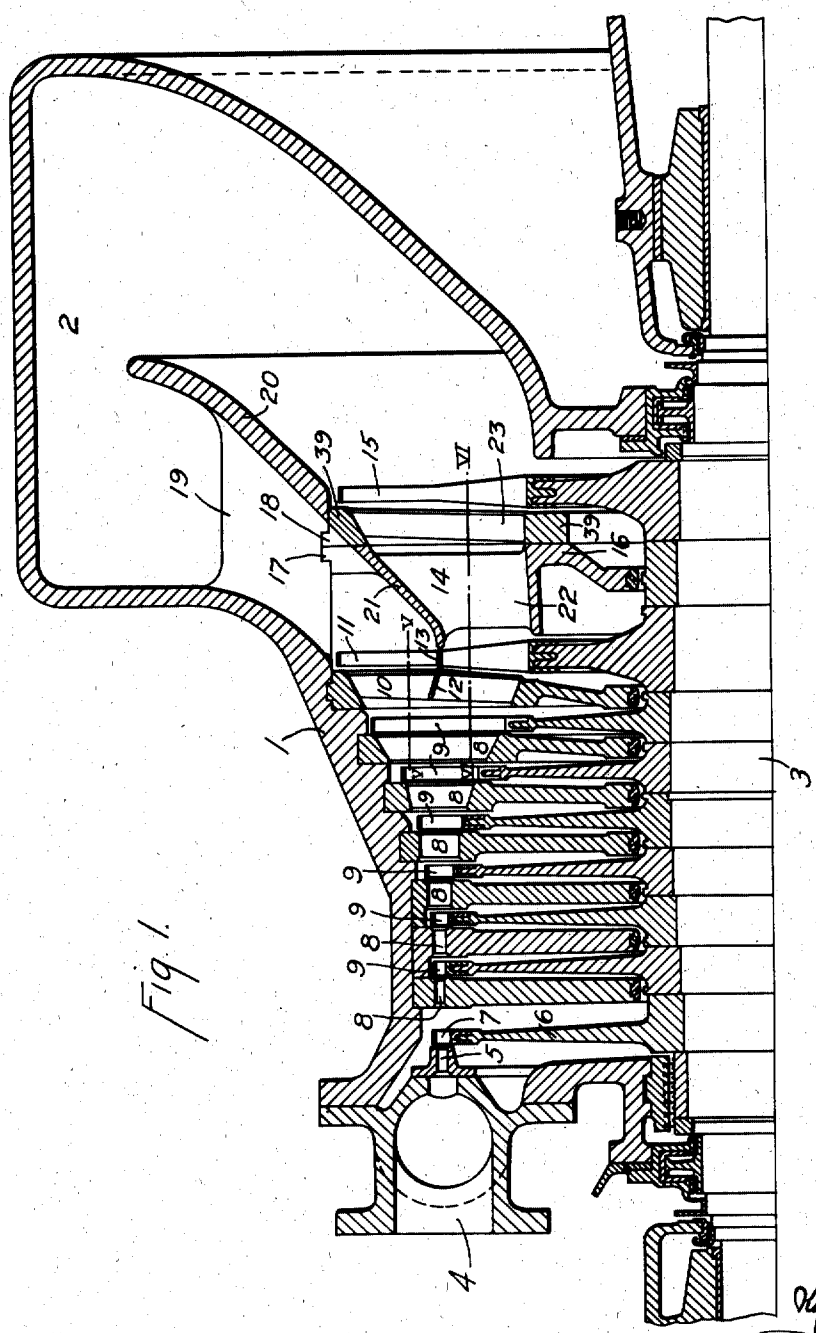


Fig. 1.

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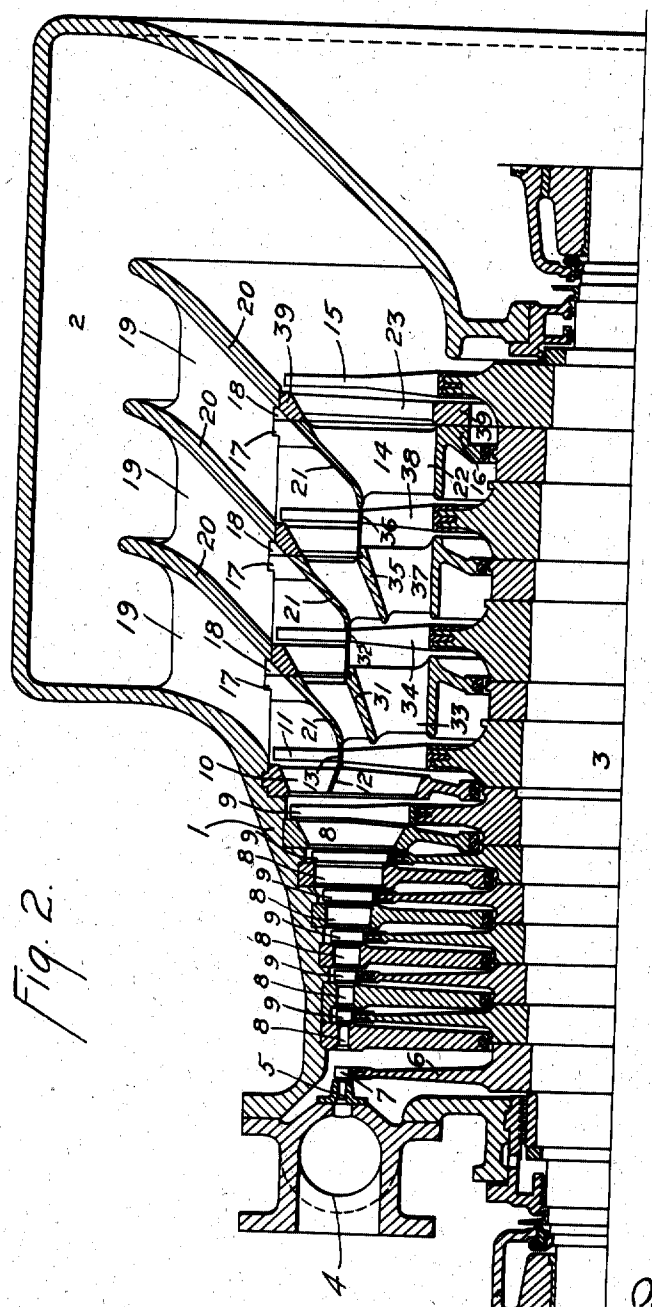


Fig. 2.

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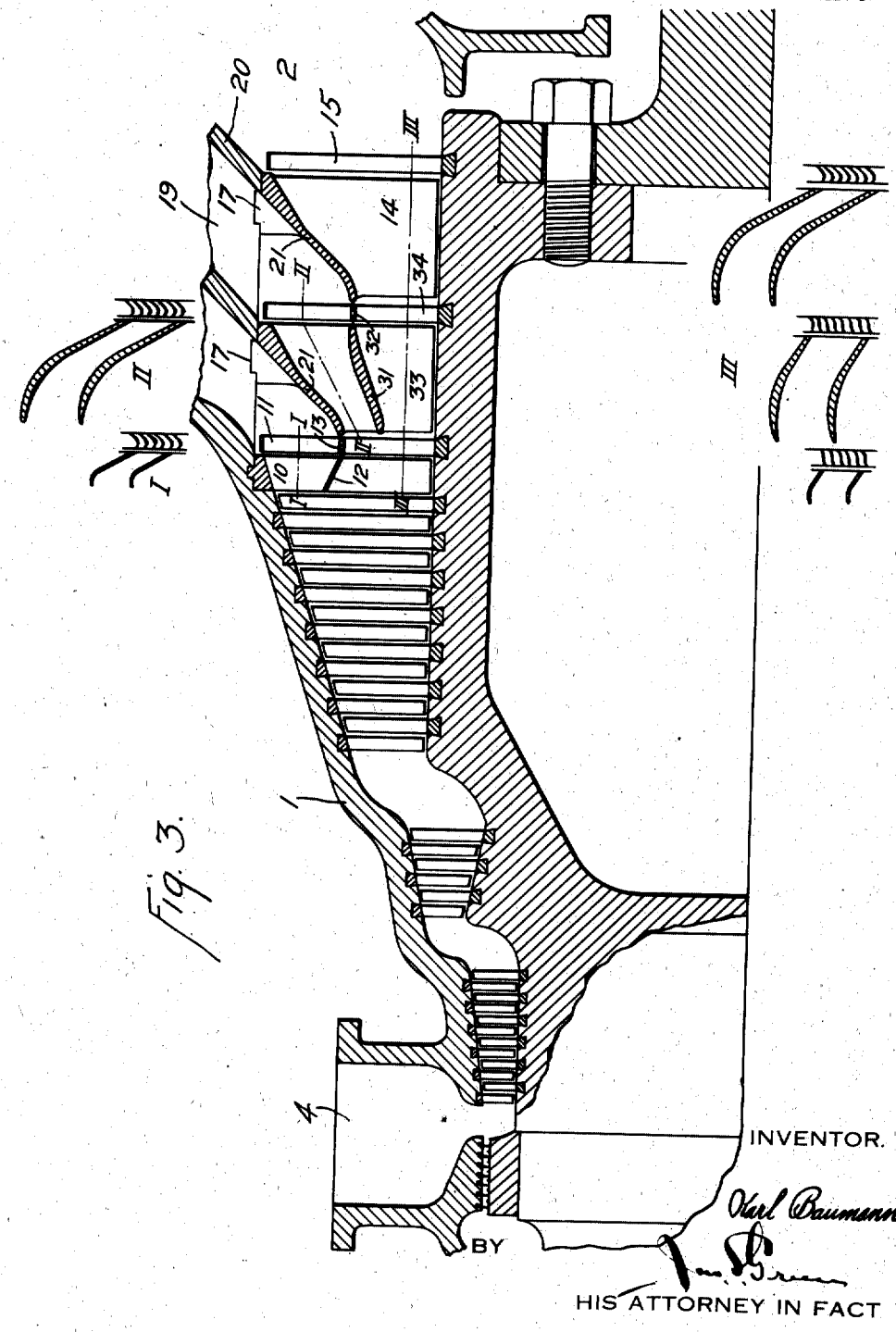


Fig. 3.

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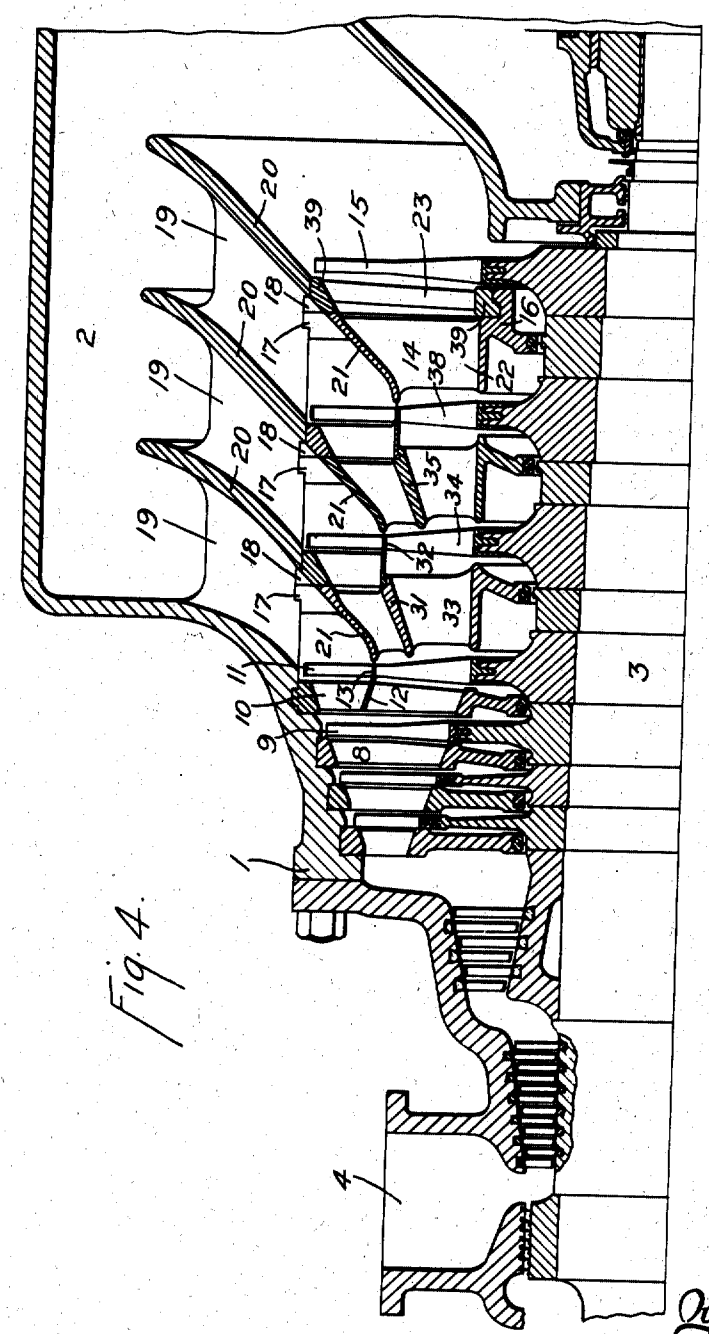


Fig. 4.

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Fig. 13.

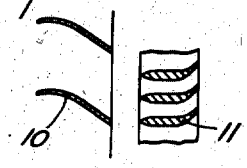


Fig. 15.

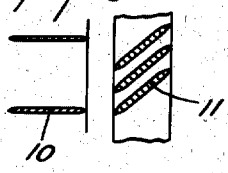
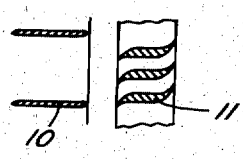


Fig. 14.



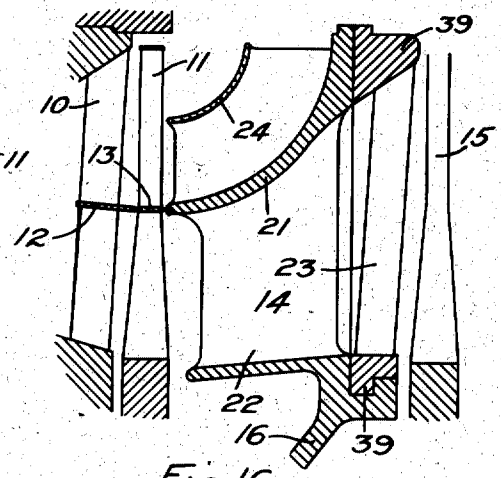
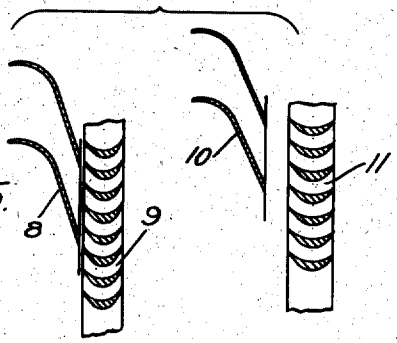
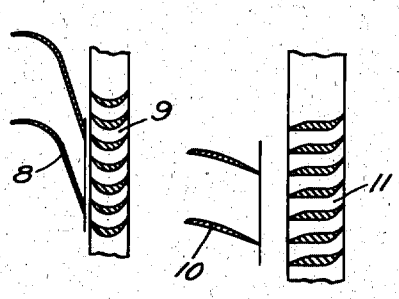


Fig. 16.





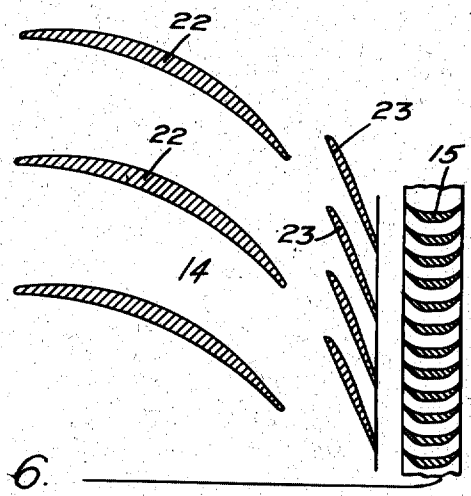


Fig. 6.

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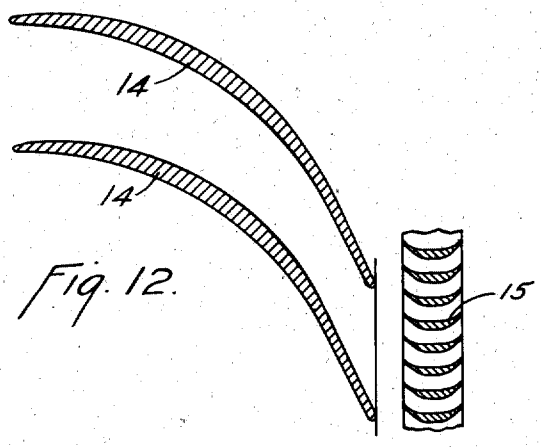


Fig. 12.

Fig. 9.

Fig. 10.

Fig. 8.

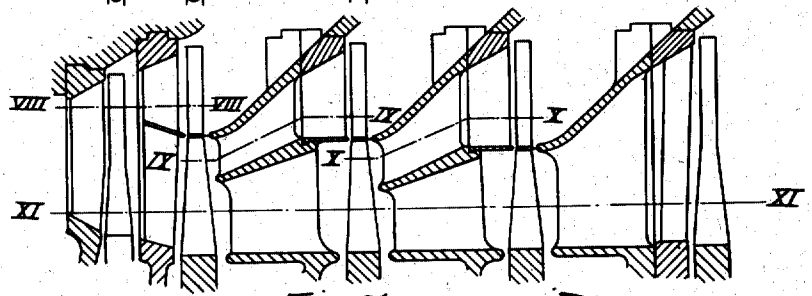


Fig. 7.

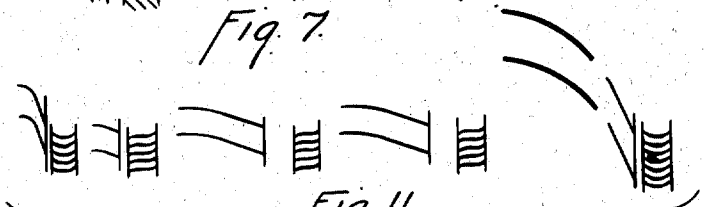


Fig. 11

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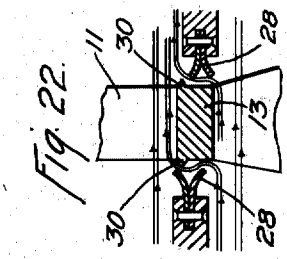


Fig. 22.

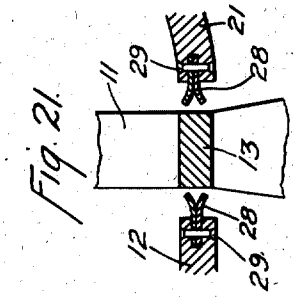


Fig. 21.

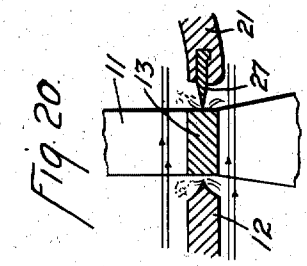


Fig. 20.

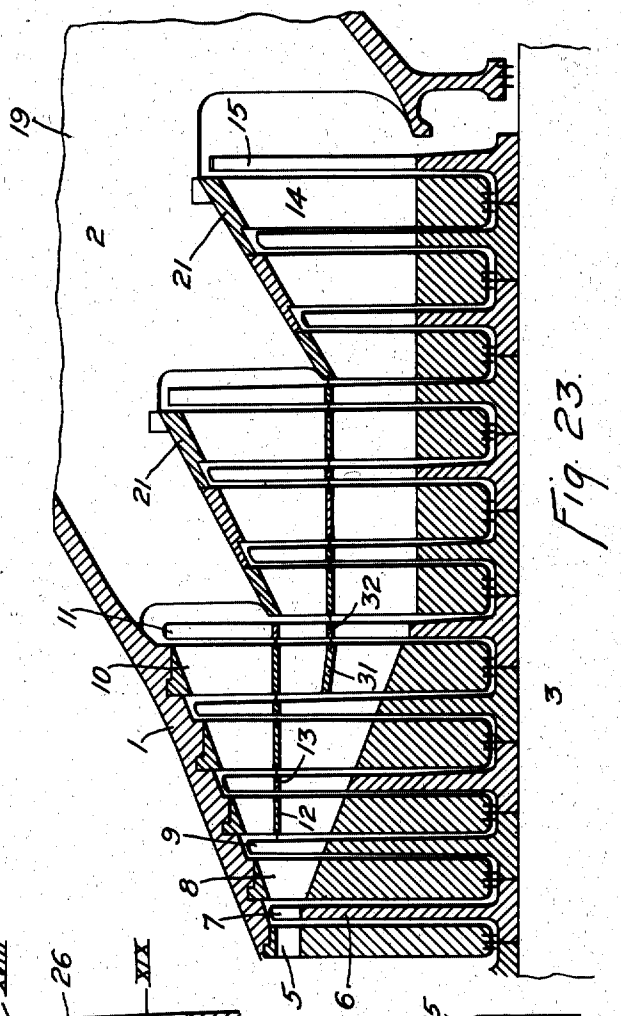


Fig. 23.

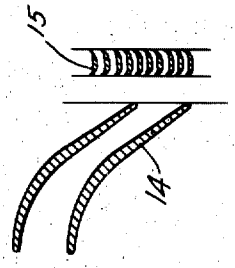


Fig. 18.

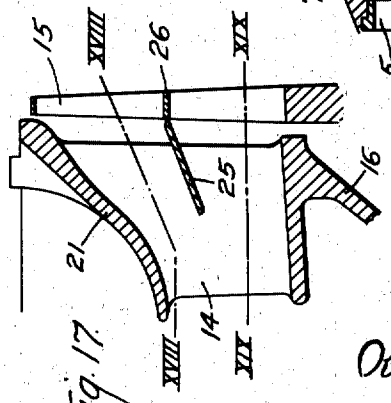


Fig. 17.

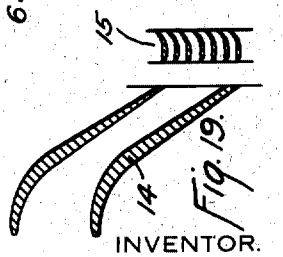


Fig. 19.

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UNITED STATES PATENT OFFICE.

KARL BAUMANN, OF URMSTON, ENGLAND, ASSIGNOR TO THE BRITISH WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY LIMITED, A COMPANY ORGANIZED UNDER THE LAWS OF GREAT BRITAIN.

STEAM-TURBINE.

1,302,282. Specification of Letters Patent. Patented Apr. 29, 1919.

Application filed June 23, 1916. Serial No. 105,409.

To all whom it may concern:

Be it known that I, KARL BAUMANN, a citizen of the Confederation of Switzerland, and a resident of Urmston, in the county of Lancaster, England, have invented a new and useful Improvement in Steam-Turbines, of which the following is a specification.

This invention relates to axial flow steam turbines of either the impulse or reaction type, or a combination of these types, and particularly to turbines adapted to work under a high vacuum.

The invention has for its object to provide an improved turbine of this kind in which certain constructional difficulties inherent in a turbine of this type are overcome in a novel and practical manner, and the output for a turbine of a given speed and efficiency is considerably increased.

As is well known, the maximum output which can be obtained in any given turbine is determined by the blade area through which the steam leaves the turbine proper. This blade area is limited by the practical difficulties which are encountered when blades above a certain length are used.

In some cases the outlet angle of the blades has been increased in order to obtain the necessary area for the steam to flow through. This arrangement, however, impairs the efficiency of the turbine.

The last stage or stages of the turbine have also been constructed as a double stage or stages, one-half only of the steam acting in each half of the double stage. In this arrangement the steam in the last stage or stages flows in opposite directions necessitating large and complicated passages for guiding one-half of the steam from the preceding stage to one-half of the divided last stage or stages, and for leading the exhaust steam to the condenser. With this construction the cost of the turbine is considerably increased and losses are caused by the formation of eddies in the steam during its flow through the guiding passages.

According to the present invention the turbine is so constructed that the steam flowing in substantially the same direction throughout a low pressure part passes from a plurality of rows of moving blades to the exhaust.

In carrying out the invention into practical effect one or more of the rows of both stationary and moving blades or of a row of moving blades in a low pressure stage or stages of the turbine, for example, the penultimate and ante-penultimate stages, is or are constructed in multiple tiers or rings, the individual tiers in a row of blades being separated from each other by circumferential dividing walls, so that the steam flowing through such row or rows of blades is segregated into two or more annular portions or belts, the steam flowing through the blades in an outer tier or tiers being expanded at a greater rate at each stage (comprising a row of guide blades or nozzles and its cooperating row of moving blades) than that at which the steam is expanded which flows through the blades or vanes of the adjacent inner tier or tiers of the same row or rows lying nearer the turbine shaft.

With the rows of blades provided with dividing walls as aforesaid, the steam leaving the outer portion of a row of moving blades will in some cases have been fully expanded and passes either direct to the exhaust or through one or more further rows of moving blades in which its remaining velocity energy is abstracted. The steam leaving the adjacent inner portion of the same row of blades will not have been fully expanded and may either be further expanded in a final row or rows of undivided or divided stationary and moving blades from the latter of which it flows to the exhaust, or may be further segregated into one or more portions in one or more succeeding rows of blading some only or all of which are provided with dividing walls, the outer portion or belt of steam leaving the moving blades of some or all of such succeeding row or rows passing direct to the exhaust, the inner portion of steam from the last divided row of blading passing to a final row or rows of blading in which it is fully expanded and thence to the exhaust. It will thus be seen that the steam in an outer tier or tiers is expanded at a greater rate than the steam passing through an inner tier or tiers of the same row or rows of blades.

The arrangement above described in which

the rows of blading are provided with circumferential dividing walls so as to form multiple tiers, enables the blading in each of the individual tiers of a row to be so designed as to obtain the best efficiency for the varying peripheral velocities obtaining in each tier. It is, in some cases, however, desirable to design the blading of an inner tier not with the object of attaining the maximum efficiency in that tier but with the object of securing the flow of a large amount of steam through such inner tier, at the same time maintaining the mechanical strength necessary to support the outer tier or tiers of moving blades. This can be done either by not expanding the steam far enough to obtain the best efficiency or by increasing the outlet angle of the blading or in both of these ways.

I have found that a very satisfactory way of accomplishing the above objects is to employ blading of the reaction type in one or more of the tiers and of the impulse type for the other tier or tiers of the same row or rows of blading. For example, for the intermediate rows of blading where considerable differences in the rate of expansion of the steam in the various tiers take place, I prefer to use blading of the reaction type for the inner tier or tiers and blading of the impulse type for the outer tiers. Blading of the reaction type may also be adopted for the inner tier or tiers and of the impulse type for the outer tier or tiers of the final row or rows of blades.

The use of dividing walls which separate the blading of a row into tiers is not restricted in its use to the intermediate row or rows of blading, where the pressure of the steam leaving the blades of the several tiers varies, but may also for structural reasons be advantageously employed in the final row or rows of blading where the pressure at which the steam leaving the blades is substantially uniform over the whole of the blade area in such final row or rows.

In some cases it may be desirable to design the blading in the inner tier or tiers of the intermediate rows to form guide passages only for the steam, the pressure and velocity of the steam being substantially the same at the entry and exit ends of a stage. In other cases the pressure of the steam may be reduced and its velocity correspondingly increased without, however, abstracting any of its energy while passing through the inner tier or tiers of blading. Thus the moving blades of an inner tier or tiers are sometimes so designed that the steam passage between them narrows from both edges, especially from the outlet edges toward the center. At other times the blades are so designed that the passage between them is of approximately constant width.

In other cases the blading is so designed that substantially no change in the direction of the flow of steam takes place during its passage through the stationary blades of the inner tiers, in which cases some or all of such blades may be omitted.

The invention may be carried into effect in a variety of ways, some of which will now be described with reference to the accompanying drawings, in which Figures 1 and 2 are conventional longitudinal sections of the upper half of turbines of the impulse type constructed in accordance with this invention. Fig. 3 is a part of a view similar to those of Figs. 1 and 2, showing the invention applied to a well known type of reaction turbine, and also illustrating sections of parts of the blading. Fig. 4 is a sectional view of a turbine in which the high pressure stages are of the reaction type, and in which the low pressure stages are of the well known disk construction, the blading being either of the reaction or of the impulse type. Fig. 5 is a sectional view on an enlarged scale of the blading on the line V—V of Fig. 1. Fig. 6 is a similar view of the blading on the line VI—VI of Fig. 1. Fig. 7 is a fragmentary reproduction of the last rows of the blading of the turbine illustrated in Fig. 2, Figs. 8, 9, 10 and 11 being sectional views respectively on the lines VIII—VIII, IX—IX, X—X, XI—XI, of Fig. 7. Fig. 12 is a sectional view also on an enlarged scale of an alternative form of blading which may be adopted in place of those shown in Figs. 9 and 10, or of the final row of stationary blades shown in Figs. 6 and 11. Figs. 13, 14 and 15 are fragmentary views showing in section alternative forms of blading which may be used in the inner tiers of blading in the turbines shown in Figs. 1 to 4. Fig. 16 is a detail constructional view hereinafter explained. Fig. 17 is a detail view of Figs. 18 and 19 sections on the lines XVIII—XVIII, XIX—XIX respectively of Fig. 17 hereinafter explained. Figs. 20, 21, 22 are enlarged detail views showing various forms of packing which may be employed between the stationary and moving blades. Fig. 23 is a fragmentary diagrammatic illustration of another form which a turbine, to which the present invention is applied, may take. Similar parts are indicated by the same reference numerals in the various figures of the drawings.

Referring now to Fig. 1, the turbine cylinder is indicated at 1 and the exhaust casing at 2. The turbine shaft is indicated at 3 and the steam inlet at 4. The inlet nozzles are shown at 5 and the first wheel at 6 provided with moving blades 7 as usual. Said nozzles and moving blades comprising the first stage are succeeded by further rows of stationary nozzles 8, 8 and moving blades 9,

9, forming subsequent stages in the usual way. The row of stationary blades 10 and coöperating moving blades 11 are each provided with a circumferential wall 12, 13 respectively, which divide the blades 10, 11 into inner and outer portions. This dividing wall may be formed by providing the blades with lugs or flanges at an intermediate point in their length. The outer portion of the blades 10, 11, forming the outer tier, namely that tier lying farthest from the turbine axis, is designed so as to expand the steam flowing through it at a greater rate than that at which the steam flowing through the inner tier of these blades, namely that tier lying nearer the turbine axis, is expanded. The stationary and moving blades 10, 11 are followed by a further row of stationary blades 14 and coöperating moving blades 15, the former being here shown as consisting of two portions, a main portion 22 and an outlet portion 23. As illustrated, the stationary blades 14 are supported in position in a diaphragm 16 which is held in position by means of lugs 17, 18 engaging with a web 19 extending between the turbine cylinder 1 and a guide wall 20 in the exhaust casing 2. The outer ends of the stationary guide blades 14 in the diaphragm 16 are provided with an inclosing wall or rim 21 which separates the steam passing through the stationary blades 14 from that leaving the outer portions of the moving blades 11.

The operation of the turbine, constructed as above described, is as follows:

The steam admitted through the inlet nozzles 5 flows through the moving blades 7 and then passes through the several stages 8, 9, 8, 9 and so on in succession in the usual way until it reaches the fixed guide blades 10 and moving blades 11 where the steam is divided into two portions by the circumferential walls 12, 13, the outer portion of steam, namely that flowing through the portions of these blades lying farthest from the turbine axis, being expanded to the pressure in the exhaust of the turbine, and passing from the outer portion of the moving blades 11 direct into the exhaust casing 2. The inner portion of steam, that flowing through the portions of the blades 10, 11 lying nearest the turbine axis, is only partially expanded and after leaving the inner portions of the moving blades 11 passes through the stationary guide blades 14 and moving blades 15 in which the steam is fully expanded, and after leaving the moving blades 15 also passes direct into the exhaust casing 2 of the turbine.

The steam leaving the inner portions of the stationary and moving blades 10 and 11 is thus at a higher pressure than the steam leaving the outer portions of said blades and it is necessary therefore that the clearance space between the circumferential guide walls 12 and 13 and between the circumferential guide wall 13 and the outer rim 21 of the diaphragm 16, should be as small as possible. This is best effected by means of a thrust block located as near as possible to the low pressure stages and by providing the edges of the circumferential wall 12 and of the rim 21 with gland strips, several forms of which are hereinafter described and shown in Figs. 20, 21 and 22 of the drawings.

It will be seen that with a turbine constructed and operating as above described, constituting what may be termed a "multiple exhaust turbine", the total area of the moving blades through which the steam leaves the turbine proper is that of the final row of moving blades 15 plus the area of the outer portion of the moving blades 11. In this way the desired increased leaving blade area necessary in order to secure an increased output is obtained without necessitating the employment of a final row of moving blades of inordinately great length or of a divided stage or stages through the blading of which the steam flows in opposite directions.

Alternatively, for the same output a smaller blade angle can be utilized for the leaving stages than with a turbine as heretofore constructed having but a single final row of blades of the same blade height, and thus a better efficiency for the leaving stages, and consequently for the whole turbine, can be obtained.

The energy extracted per unit weight of steam in the outer tiers of stationary blades 10 and moving blades 11 will be approximately equal to the energy extracted per unit weight of steam passing through the inner tiers of stationary blades 10 and moving blades 11 and the succeeding final row of stationary blades 14 and moving blades 15. In the construction illustrated, the steam flowing through the inner tiers of stationary blades 10 and moving blades 11 is expanded at a lower rate than is the steam flowing through the outer tiers of stationary blades 10 and moving blades 11, the remaining expansion of the steam flowing through the inner tiers of said blades taking place in the guide blades 14 and moving blades 15. The mean peripheral speed of the outer tier of moving blades 11 is considerably greater than the mean peripheral speed of the moving blades 15, consequently a greater amount of expansion can efficiently be utilized in said outer tier; in fact the expansion can be distributed in such a manner that the efficiency of said outer tier may be higher than that of the final stage 14, 15.

Figs. 5 and 6 are sections drawn to an enlarged scale showing one arrangement of blading which may be used in the final stages of the turbine illustrated in Fig. 1.

Referring to Fig. 5, the guide blades 8 and moving blades 9 as well as the outer tiers of the blades 10, 11, are of the usual impulse type. In Fig. 6 the stationary blades 8 and moving blades 9 are, of course, the same as the blades 8, 9 in Fig. 5, whereas the stationary blades 10 and moving blades 11 of the inner tiers of those blades are of a type specially designed with a view to passing a large quantity of steam through the available blade area, by which term is meant the total area of the complete ring of blades measured on a plane perpendicular to the shaft. The inner tiers of the blades 10, 11 are also designed for a relatively small expansion only of the steam flowing through them, and also with a view to providing the moving blades with the necessary mechanical strength. In order that a large quantity of steam may be passed through them the blade angles adopted for the blades of the inner tiers are considerably greater than the blade angles adopted for the outer tiers. The expansion in the inner tiers of this stage occurs mainly in the moving blades 11 in which the steam velocity is increased beyond that existing in the inner tier of the guide blades 10, as the space between the moving blades is reduced on account of the thickness which it is desirable to give to the inner portion of said blades to afford the necessary mechanical strength.

In order to obtain the maximum strength of the blades for a given steam velocity it is necessary to arrange that the expansion shall take place chiefly at the entrance of the passages between the moving blades 11, and that the velocity shall remain practically constant while the steam is passing through the remaining portions of the passages between the blades, the leaving angle being arranged as shown in Fig. 6 so that the width of the remaining portions of the passages between the blades is practically constant.

The final rows of guide blades 14 and moving blades 15 are, as shown in Fig. 6, of the usual type as regards the blade angles employed. It is, however, necessary to increase the width of the guide blades 14 and consequently the distance between the moving blades 11 and 15, in order to avoid the formation of eddies and obtain a satisfactory flow of the steam passing through said guide blades, as well as to provide the necessary space for the steam leaving the outer tier of moving blades 11. In the construction shown in Figs. 1 and 6, the guide blades 14 consist of two portions, namely main portions 22 which, in the construction shown, are cast in one piece with the diaphragm 16, and outlet portions 23, which are preferably formed separately and either cast or afterward inserted into a frame 39 forming part of the diaphragm 16. The stationary blades 14 need not, however, necessarily be constructed in two portions, as shown in Fig. 6, but may be formed as shown in section in Fig. 12, in one piece.

In some cases, in order to provide the necessary strength the moving blades 11 and the final row of moving blades 15 may be made to taper in width as shown in Fig. 1, or in thickness, or in both of these dimensions along the whole or a portion of their length, increasing in section toward the root of the blades. Advantageously these blades may be constructed as described in the specification of British Patent No. 14051 of October 4th, 1915.

Alternative designs for the inner tiers of stationary blades 10 and moving blades 11 shown in Fig. 6, which in certain cases may be adopted, are illustrated in Figs. 13, 14 and 15.

Fig. 13 shows a design in which the outlet angle of the guide blades 10 is smaller than in Fig. 6 and is such that having regard to the velocity of the moving blades 11, relative to that of the guide blades 10, the steam enters said moving blades in an approximately axial direction. In this design a relatively greater part of the expansion occurs in the guide blades 10 than in the corresponding guide blades 10 shown in Fig. 6. The inlet portions of the moving blades 11 are reduced to an edge as shown, so as to prevent eddies where the steam meets the edges of the blades. The expansion through the moving blades 11 takes place chiefly at the inlet portion of the blades, as is the case with the blades 11 shown in Fig. 6, practically no expansion taking place during the passage of the steam through the remaining portion of the moving blades 11 of Fig. 13, the leaving angle being arranged as shown so that the width of the remainder of the passage between the blades remains practically constant.

In the design shown in Fig. 14 no change in the direction of the steam takes place during its passage through the guide blades 10.

The blades can, as shown, be flat and located in a plane parallel with the axis of the turbine, or they may be inclined in either direction with respect to the turbine axis. As no appreciable change in the direction of the steam takes place some or all of the blades 10 may be omitted. If these blades are omitted the velocity of the steam may be varied as desired either by decreasing or by increasing the radial height of the passage. If the inner tier of guide blades is omitted some means for directing the steam flowing from one row of moving blades to the next, to take the place of the inner circumferential wall of the guide passages, must be provided. This may take the form

of a cylinder extending between adjacent rows of moving blades and suitably supported in the proper position from the shaft or from the wheels.

The moving blades 11 shown in Fig. 14 are designed in such a manner that no expansion of the steam during its passage through them takes place and the direction of the steam leaving is the same as the direction of the steam entering the blades, no mechanical energy being abstracted from the steam during its passage through them, and consequently no appreciable change in its pressure occurs. The moving blades 11 are of an $\int$ shape, as shown, the central portion being straight and of uniform thickness, and the sides reduced to an edge, so that the steam passage between two adjacent blades is of practically constant width. This design enables blades of the necessary mechanical strength to be provided which do not change the velocity of the steam to any extent during its passage between them.

The guide blades shown in Fig. 15 are of the same type as those shown in Fig. 14. The moving blades 11 are flat and more or less inclined relative to the axis of the turbine, being reduced to a fine edge at both sides, especially at the outlet side, the center portion of the blades being preferably of substantially uniform thickness. A passage is thus formed between adjacent blades in which the pressure of the steam is reduced at the entrance of the blades and the velocity increased as it flows toward the middle portion of the passage the velocity being reconverted into pressure by the gradually increased width of the passage toward its outlet.

This design of moving blades lends itself particularly to the construction in which the inner tier of blades is made solid with the turbine disk or shaft, the outer tier of moving blades being secured to the rim of the disk or shaft by rivets or in any other suitable manner.

The various designs which the blading of the inner and outer tiers of a row and the final row may take, described above with reference to Figs. 5, 6, 12, 13, 14 and 15, have been given by way of example and as indicating some of the more advantageous designs which can be employed. The blading of the circumferentially divided tiers may sometimes be of the same character in two or more of the individual tiers of a row. The expansion however taking place at different rates in the several tiers of a row. The blades may in some cases also have the same inlet and outlet angles in the various tiers of a row. Frequently also it will be found advisable to provide an outer tier of a row with a greater number of blades than an inner tier of the same row.

Fig. 16 shows a modified form which the outer inclosing wall of the stationary blades may, with advantage, assume. The outer wall or rim 21 is here shaped so as to change the direction of the steam leaving the outer tier of the moving blades 11 from a substantially axial into a substantially radial direction during its passage to the exhaust casing. In order to prevent, as far as possible, the formation of eddies, due to the rapid change of direction of the steam, an additional guide 24 may be provided which will separate the steam flowing to the exhaust into two portions. More than one of such additional guides may of course be used if desired, and they need not necessarily be supported from the inclosing rim 21, as here illustrated, but may be attached to the turbine cylinder or exhaust casing. One or more similar guides to that shown at 24 in Fig. 16 may be provided for directing the steam leaving the last row of moving blades 15. The shape given to the inclosing rim 21 and curved guide 24 will obviously depend upon the direction in which it is desired the steam leaving the moving blades should flow toward the exhaust, as the change in the flow of the steam need not necessarily be from an axial into a radial direction.

Fig. 17 shows a further modified construction of the final guide blades 14 and moving blades 15, an additional circumferential dividing wall 25 being provided extending over a part or the whole width of the guide blades 14 and a corresponding dividing wall 26 separating the moving blades 15 into the inner and outer tiers. The stationary and moving blades of the outer tiers are again of the impulse type and those of the inner tiers are of the reaction type. The blades of the inner and outer tiers are respectively shown in section in Figs. 18 and 19, these figures being taken on the lines XVIII—XVIII, XIX—XIX of Fig. 17. This combined use of impulse and reaction blading in one and the same row is, in some cases, also adapted to obtain the best efficiency for the last stage of the turbine, as well as mechanical strength for the roots of the moving blades, blading of the reaction type being more suitable for the inner tier owing to the relatively higher steam velocities obtained in the passages between the moving blades which enables the roots of the moving blades to be made stronger. In other cases the same type of blading will be used for both inner and outer tiers but the outlet angles of the stationary blades in the inner and outer tiers may be different. I sometimes omit the stationary dividing wall 25 but retain the dividing wall 26 in order to separate the steam flowing through the inner and outer portions of the moving blades and prevent

eddies which may arise due to the great difference in steam velocities resulting from the great difference in the peripheral velocities between the inner and the outer tier.

Fig. 20 shows on an enlarged scale the type of packing shown in Fig. 1 as being used between the circumferential dividing walls of the stationary and moving blades 10, 11 and between the moving blades 11 and the inclosing wall 21 of the stationary blades 14. As shown in this figure the side of the circumferential wall 12 adjoining the circumferential wall 13 is sharpened to a knife edge so as to reduce the danger of heating in case rubbing takes place between the walls 12 and 13. The inclosing rim 21 is shown as being provided with a gland strip 27 of a well known type for a similar reason.

Fig. 21 shows an alternative form of packing strip 28 of a well known type which may be employed. The packing strips 28 are, however, in this case secured to the circumferential walls 12 and 21 by rivets 29 thus providing a very substantial mechanical design and one in which the replacement of the strips where necessary is much facilitated.

Fig. 22 shows a further arrangement in which the circumferential wall 13 is provided with projections 30 which are so located with respect to the packing strips 28 as to guide any leakage steam in substantially the same direction as the working steam passing through the turbine. The direction in which any leakage steam will be caused to flow with the arrangement shown in this figure is indicated diagrammatically by the stream lines.

Referring now to Fig. 2, this shows a construction which may be adopted in those cases where it is necessary to pass greater volumes of steam through the low pressure stages of the turbine than in the case of the turbine described with reference to Fig. 1. In other words, for similar steam conditions and efficiencies the output of the turbine can, with this construction, be considerably increased. In the turbine shown in Fig. 2 the steam flowing through the inner tiers of the circumferentially divided stationary and moving blades 10, 11 is further segregated by circumferential division walls 31, 32 in the succeeding stage comprising a row of fixed blades 33 and moving blades 34. The steam passing through the outer tier of the stationary and moving blades 33, 34 is expanded down to the pressure in the exhaust to which it directly flows on leaving the outer tier of moving blades 34. The steam expanding at a low rate during its passage through the inner tiers of the stationary and moving blades 33, 34 is again segregated into two portions by circumferential dividing walls 35, 36 in a further succeeding stage comprising stationary and moving blades indicated at 37, 38, respectively. The steam passing through the outer tier of the stationary and moving blades 37, 38 is expanded down to the pressure of the exhaust and on leaving the outer tier of moving blades 38 passes direct into the exhaust casing 2. The energy remaining in the steam after flowing through the inner tier of the stationary and moving blades 37, 38 in which it is expanded at a low rate is utilized in a final stage comprising stationary blades 14 and moving blades 15 in a manner already described with reference to Fig. 1.

It will be seen that in a turbine constructed as shown in Fig. 2 the total blade area through which the steam leaves the turbine proper is approximately increased by the blade areas of the outer tiers of the moving blades 34 and 38 as compared with the construction illustrated in Fig. 1.

One arrangement of blading which may be adopted in a turbine of the kind illustrated in Fig. 2 is shown for example in Figs. 7 to 11, inclusive. Fig. 7 it will be seen, is a reproduction of some of the low pressure stages of Fig. 2 and Figs. 8, 9, 10 and 11 are sections of the blading in Fig. 7 taken respectively on the lines VIII—VIII, IX—IX, X—X and XI—XI. The manner in which the turbine described and illustrated in Figs. 2, 7, 8, 9, 10 and 11 operates will be readily understood from what has been said in connection with Figs. 1, 5, 6 and 12, it being understood that in the turbine illustrated in Figs. 2, 7, 8, 9, 10 and 11 also various alternative designs and combinations of blading may be used as hereinbefore fully set forth.

One example of how the invention may be applied to a turbine in which the whole of the blading is of the reaction type is illustrated in Fig. 3, the construction and operation of which, taken in conjunction with the sectional views of the blading in the low pressure stages on the lines I—I, II—II and III—III and designated by these numerals respectively, will be easily comprehended without further detailed description.

Fig. 4 illustrates still another form of turbine constructed in accordance with this invention in which the high pressure stages are of the usual reaction type and the low pressure stages are of the well known disk construction, the blading being of either the impulse or reaction type or a combination of these types.

In the construction illustrated in Figs. 1, 2 and 4 the movng blades of the low pressure stages are shown as being attached to separate disks mounted on the shaft 3. In some cases it is preferable to attach some

or all of such moving blades directly to the shaft itself, the shaft in such cases being increased in diameter and provided with flanges or collars to which the moving blades are secured in any suitable way. In these figures also a single exhaust casing only is shown into which the steam leaving the several rows of moving blades passes. It is to be understood however that the steam leaving the various rows of moving blades may pass to separate exhaust casings and in some cases to separate condensers, if desired.

A still further constructional form which the invention may take is shown diagrammatically in Fig. 23. In the turbine diagrammatically indicated in this figure it will be seen that the segregated annular portions of steam each flow through a plurality of rows of fixed and moving blades before reaching the pressure of the exhaust and passing to the exhaust casing of the turbine. It will also be observed that in one row of stationary and moving blades the steam is segregated into three annular portions, the stationary and moving blades in question being constructed as a triple tier. The blading may be arranged in such a way that the ratio of the steam velocities and peripheral velocities obtaining in the various tiers is approximately constant, thus obtaining a uniform efficiency over the whole of the various rows of blades.

From the examples hereinabove described and illustrated it will be evident that the steam flowing through the working passages of a turbine constructed in accordance with this invention is divided into separate portions forming more or less complete and partially overlapping belts of steam, the outermost belt or belts while passing through the operative blading of the turbine being expanded at a greater rate than the inner belt or belts lying nearer the axis of the turbine. The steam in the outer belt or belts is led away separately to the exhaust immediately it has been expanded to the full extent, and its velocity energy abstracted therefrom.

Stated in other words, the belts of steam flowing through the turbine while in operation may be likened to a plurality of truncated hollow cones, the steam forming the smaller end of the second and any succeeding cones being derived from the steam of the preceding cone. At the base of each of such cones the steam will have been fully expanded and is conducted away to the exhaust. Thus the steam will be led away to the exhaust from a plurality of independent rows of moving blades.

As hereinabove set forth turbines of either the impulse or reaction type, or a combination of those types, may be constructed in accordance with this invention and although the invention is an improvement in turbines of the axial flow type it is to be understood that the high pressure or other sections of the turbine to which the invention is not applied may, if desired be of any other suitable type. The invention is especially applicable to exhaust turbines or mixed pressure turbines where the volume of steam passing into the condenser is relatively large, and may also be applied to turbines constructed as double flow turbines in which portions of the steam flow in opposite directions to the exhaust. In short, the invention may be applied to axial flow steam turbines of many of the various existing types adapted to operate at a high vacuum in which, as heretofore constructed, in order to obtain a large output, blades of inordinately great length would have to be used.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:

1. In an axial flow steam turbine, a stage or section provided with means for dividing the steam flowing therethrough into annular portions having different ratios of expansion.

2. In an axial flow steam turbine, a stage or section provided with blading structures so arranged as to segregate the steam into separate concentric annular portions having different expansion ratios.

3. In an axial flow steam turbine, a stage or section having blades constructed in multiple tiers and arranged so that the steam flowing through the different tiers will have different ratios of expansion.

4. In an axial flow steam turbine, a low pressure stage or section provided with blading means formed so as to segregate the steam flowing through said stage or section into separate portions having different expansion ratios.

5. In an axial flow steam turbine, a high pressure stage or section through which the steam flows in one annular body and a low pressure stage or section through which the steam flows in two or more annular bodies having different ratios of expansion.

6. In an axial flow steam turbine, a stage or section having blades constructed in multiple tiers formed so that the steam flowing through the outer tier has a greater ratio of expansion than the steam flowing through the inner tier.

7. In an axial flow steam turbine, a stage or section provided with means for segregating the steam flowing therethrough into separate portions having different ratios of expansion.

8. In an axial flow steam turbine, a stage

or section having superposed concentric rings or blades so formed that the blades farthest from the turbine axis have the greater outlet angles.

9. In an axial flow steam turbine, a partial peripheral admission high pressure stage and a full peripheral admission low pressure stage provided with means for segregating the steam flowing therethrough into portions having different ratios of expansion.

In witness whereof I have hereunto subscribed my name this second day of June, 1916.

KARL BAUMANN.

Witnesses:

A. E. LEIGH BEANE,

GEORGE SCOTT.