This invention relates to improvements in steam power plants.

In installing steam power plants including a steam turbine and condenser therefor, considerable difficulty has been experienced in providing a suitable operating connection between the exhaust side of the turbine casing and the inlet side of the condenser casing, such as will freely provide for differences in expanding and contracting action between the turbine and condenser casings without giving rise to additional stresses on the latter over those imposed incident to operation of the plant, which will eliminate the necessity for provision of abnormally large supporting or anchoring foundations for the turbine and condenser casings, and which will not occupy any appreciable space. Various types of connections between the turbine and condenser casings have been proposed, but they represent but a compromise between the ideal connection, that is, these connections constructed heretofore have certain of the advantages or desirable characteristics of the ideal connection, but are lacking in the remainder of such characteristics.

One of the methods employed heretofore for the purpose of providing for expanding and contracting action of the turbine and condenser casings has been to mount or seat the turbine on a suitable foundation and to arrange the condenser below the turbine and to anchor or secure the condenser casing to a second lower foundation, suitable flexible couplings or expansion joints being interposed between the respective adjacent turbine exhaust and condenser inlet connections to allow for expanding and contracting action between the two casings in a direction axially of said connections as well as in a direction transversely thereof; such connections necessitating allowance of an appreciable space between the turbine and condenser connections. In this construction, the turbine foundation is subjected to the full downward force on the turbine casing due to the exterior atmospheric pressure, this force amounting to as much as 40 tons for a 10,000 kilowatt unit and being of such magnitude as to result in considerable strain on the foundation and undesirable distortion of the turbine casing. Furthermore, when the plant is running condensing, the foundation and anchorage for the condenser is subjected to an upward force of considerable magnitude due to the action of the exterior atmospheric pressure against the vacuum condition within the condenser casing. These conditions referred to necessitate the provision of larger and more expensive foundations and anchorage for the turbine and condenser. To provide against this undesirable condition it has been proposed to make rigid connection between the turbine and condenser casings in large installations so that the entire condenser is suspended from the turbine casing and is free to expand and contract with respect thereto, springs in some instances, however, being interposed and placed in compression between the lower foundation and the condenser casing to partly support the latter while permitting of free expanding and contracting action of the same. While this expedient has the advantage that the downward force exerted on the turbine casing when the plant is operating condensing acts directly against and is opposed and neutralized more or less by the upward force acting on the condenser casing due to the vacuum condition therein, it has the serious disadvantage that undesirable vibrations are transmitted to the various inlet and outlet pipes connected to the condenser casing and which are usually disposed or laid in a horizontal plane, these vibrations in some cases being sufficient to eventually cause rupture of the pipe joints, particularly where the pipes are joined to the condenser casing. This construction, furthermore, gives rise to a second and more serious difficulty when a turbine with more than one exhaust connection is connected to a single condenser, since the rigid connections allow for no unequal lateral expanding and contracting action between the turbine and condenser casings. Where such action is appreciable, such as in large installations, employment of this construction is prohibitive on account of dangerous distortion of the
turbine casing and connections which would occur. In such cases recourse must be had to the expansion joints referred to and the disadvantages thereof tolerated.

One of the objects of the present invention, therefore, is to provide an improved steam power plant embodying all the advantages of those constructed heretofore, referring particularly to the connections between the turbine and condenser casings, while eliminating the various undesirable characteristics referred to.

Another object is to provide an improved steam power plant comprising a turbine and condenser, wherein the turbine and condenser casings are so disposed and connected as to relieve the same and the supporting foundation of the great forces to which the same have been subjected heretofore, while at the same time permitting of free and independent expanding and contracting action of the turbine and condenser casings and permitting of arrangement of the casings in close proximity with respect to each other.

Other objects and advantages will hereinafter appear.

For the purpose of illustrating the invention, one embodiment thereof is shown in the drawings, wherein

Figure 1 is a side elevational view illustrating a steam power plant embodying the structural arrangement used heretofore;

Fig. 2 is an enlarged detail sectional view, the section being taken on the line 2-2 in Fig. 1;

Fig. 3 is a view similar to Fig. 1, illustrating a steam power plant constructed in accordance with the present improvements;

Fig. 4 is an enlarged detail sectional view, the section being taken on the line 4-4 in Fig. 3;

Fig. 5 is an enlarged detail sectional view, the section being taken on the line 5-5 in Fig. 3;

Fig. 6 is a view similar to Fig. 4, showing a detail modification; and

Fig. 7 is a view similar to Fig. 4 showing a second detail modification.

Referring more particularly to Fig. 1, showing a steam power plant embodying the structural arrangement used heretofore, the turbine 10 is seated or mounted on the upper horizontal supporting foundation 11 through suitable lugs or legs 12 and 13 with which the turbine casing is provided, the turbine being rigidly secured to the foundation by retaining bolts 14 passing through lug 13 into the foundation. The retaining bolts 15 for the other end of the turbine casing pass through openings in lug 12 elongated, as shown in Fig. 2, in the direction of the power shaft 16 leading to the generator (not shown), such construction permitting of free expanding and contracting action of the turbine casing from the fixed lug 13 while, at the same time, holding both ends of the casing down upon the foundation. The condenser 17 is disposed below the turbine and rests upon the lower foundation 18 and is securely fixed or anchored to the latter by means of bolts or other elements 19 passing through lugs or legs 20 which might be formed integrally with the condenser casing. Suitable flexible couplings or expansion joints 21 of well-known construction are interposed between the exhaust side of the turbine and the inlet side of the condenser, as shown, and provide an operating connection therebetween, permitting freely of vertical expanding and contracting action of the turbine and condenser casings. It is to be noted that the expansion joints 21 occupy an appreciable space, and necessitate vertical spacing of the turbine and condenser a corresponding amount. In this construction, the upper supporting foundation 11 is subjected to the full downward force acting on the turbine and which is measured by the difference between the exterior atmospheric pressure and the vacuum condition within the turbine casing, this force, as mentioned above, amounting to as much as 40 tons in a 10,000 kilowatt installation. The lower foundation 18 and the anchorage holding the condenser thereupon are subjected to an upward force of similar magnitude, and which is measured by the difference between the exterior atmospheric pressure and the vacuum condition within the condenser. The expansion joints 21 provide for the expanding and contracting action of the turbine and condenser casings in the direction of flow of the steam, as well as in a direction transversely thereof, but act in no way to relieve the supporting foundations 11 and 18 and their associated parts of the forces referred to above, and which are incident to condensing operation of the plant.

Referring now to Fig. 3, showing a steam power plant embodying the present improvements, certain of the parts are designated by primed reference characters similar to the reference characters designating corresponding parts in Fig. 1. The turbine casing is provided with rigid flanged exhaust connections 22 and 23 complementary respectively to the rigid flanged inlet connections 24 and 25 with which the condenser casing is provided. The turbine and condenser connections 23 and 25 are secured rigidly together by means of bolts 26 passing through their flanges, suitable packing being interposed between the flanges to provide a fluid-tight connection. The turbine and condenser connections 22 and 24, on the other hand, are disposed for firm seating engagement against each other and for free sliding movement with respect to each other in a direction transversely of themselves, or in other words, transversely of the steam flow, suitable thrust bearing means being interposed between the
respective flanges 27 and 28 with which these connections are provided. Suitable packing means is also interposed between these flanges to provide a fluid-tight connection while permitting of such sliding movement.

A preferred construction of the thrust bearing means referred to comprises a plurality of thrust units spaced circumferentially about connections 22 and 24, one of such units being shown in Fig. 4 and including steel balls or other suitable bearing elements 29 engaging and having rolling contact with a steel insert or bearing plate 30 in the under face of flange 27 and the head 31 of an adjustable stud 32 threaded, as shown, through the lower flange 28 and provided with the lock nut 33. The bearing elements or balls 29 are held in position between insert 30 and the head 31 by a suitable race comprising an annular outer ring 34 and a central disk 35 mounted on the upper reduced end 36 of a pin 37 extending upwardly and loosely through stud 32, the lower end of the pin having threaded engagement, as shown, with the lower end of the stud and being locked in position by any suitable means such as the nut 38. Such construction permits the balls or bearing elements 29 to roll freely on the bearing or thrust faces provided by insert 30 and the head 31 upon sliding or shifting movement laterally of connections 22 and 24 with respect to each other, at which time the pin 37 will flex or bend a corresponding amount from about the point 39.

Suitable packing means, such as a hollow rubber ring 40, filled with liquid under pressure, is interposed between connections 22 and 24 to provide a fluid seal therebetween, a plate or band 41 being arranged as shown and secured to connection 24 by studs 42 to hold the packing in place and to provide a suitable seat for the latter and against which the same is firmly pressed by the action of the greater exterior atmospheric pressure.

The thrust bearing units just described are of sufficient number to take the full thrust between connections 22 and 24 without subjecting each of the bearing elements or balls 29 to any great stress.

Springs or other suitable yieldable means 43 and 44 are interposed between the lower foundation 18' and the condenser, as shown, to partially support the latter. For the purpose of ascertaining as to the details of a suitable construction for such yieldable means, reference might be made to Patent No. 1,573,792 of February 23, 1926, to Allerton.

Studs 45, as shown in Fig. 5, are provided with heads 46 and extend upwardly and loosely through the flange 28 of the condenser connection 24 and are threaded into the flange 27 of the turbine exhaust connection 22 for the purpose hereinafter explained, these studs being spaced circumferentially about connections 22 and 24 and alternating with the thrust units. The play allowed between flange 28 and each stud is sufficient to permit of any relative lateral movement which might occur between connections 22 and 24.

In installing the turbine and condenser, the latter is partly filled with the cooling liquid therefor, and is jacked up through springs 43 and 44 until the faces or flanges of connections 22 and 24 seat evenly and firmly against each other and the bearing elements 29 engage the inserts 30, the adjusting studs 32 of the various thrust bearing units being adjusted so that each of the units takes up an equal amount of the thrust and the packing ring 40 is partially compressed, as shown in Fig. 4, to insure sealing action of the latter. The connections 22 and 24 are then rigidly secured together by means of bolts 26 passing through the flanges with which these connections are provided. It will therefore be seen that the springs 43 and 44 are compressed initially by such an amount as to cause application to the condenser structure of a supporting force sufficient to support the latter when it is only partly filled with the cooling liquid therefor. The reason for this practice is to allow for the vertical expanding action of the condenser casing subsequent to starting of the plant, which action causes such further compression of springs 43 and 44 as to appreciably increase the supporting force which they provide. When the plant is operating condensing, this increased supporting force from the springs is added to the large upward force on the condenser due to the greater exterior atmospheric pressure and the expansion of the proposed practice being to so arrange and proportion the parts that the sum of these two upward forces acting on the condenser neutralizes more or less the downward force acting on the turbine. If the springs 43 and 44 were placed under such initial compression as to support the entire condenser structure when the casing thereof is filled to capacity with cooling liquid, further compression of the springs, upon vertical expanding action of the condenser when the plant is started up to operate condensing, might give rise to an additional upward force of such magnitude as to tend to or actually lift the turbine from its supporting foundation 11', or at least subject the retaining bolts 14' and 15' to undesirable stresses. Following this step in the installation, stud bolts 45 are each adjusted so that the heads 46 thereof are spaced a slight amount from the lower face of flange 28, such amount being in the neighborhood of one sixty-fourth of an inch, more or less, depending on particular conditions. Cooling liquid is then added to the condenser until the same is filled to its normal operating capacity, during which operation the entire condenser structure will drop a very slight amount with a pivotal movement about the
rigid connection 23–25 as a center until the flange 28 seats upon the heads 46 of studs 45, at which time the bearing elements 29 will be out of contacting relation with inserts 30 by an amount equal to the play previously allowed between flange 28 and the stud heads. The packing ring 40, at this time, will also expand a corresponding amount and thus maintain its sealing relation with respect to connections 22 and 24.

The operation as is follows: Assuming that the plant is about to be started, the turbine and condenser casings being at substantially room temperature and the condenser being filled with cooling liquid to its full operating capacity, the condition of the parts will be such that the right half of the condenser will be partly suspended from the supporting rigid connection 23–25 and partly supported by the partially-compressed springs 44, the left half of the condenser being supported by the combined action of the partially-compressed springs 43 and the stud heads 46 upon which flange 28 is at this time seating. When the plant is started for condensing operation; the large supporting force then occurring and which is due to the greater exterior atmospheric pressure to which the condenser is then subjected, together with the greater upward force now occurring due to further compression of springs 43 and 44 upon vertical expanding action of the turbine, is sufficient to lift the left half of the condenser upwardly from the supporting stud heads 46 and to cause firm engagement of the bearing elements 29 with inserts 30 with a strong thrust action, such action opposing and neutralizing more or less the downward force to which the exhaust end of the turbine is now subjected due to atmospheric pressure. As the turbine and condenser heat up, a certain amount of expanding action of each will take place in a horizontal direction, or in a direction lateral of the connections 22–24 and 23–25, such expanding action taking place from the fixed lugs or legs 13. Any unequal expansion in this direction between the turbine and condenser will be allowed for by lateral sliding movement of connections 22 and 24 a corresponding amount with respect to each other, at which time the bearing elements 29 will roll upon the plates 30 and heads 31.

From the foregoing it will be seen that an improved power plant has been provided wherein the structural arrangement and cooperative action of the various parts is such as to freely allow for independent expanding and contracting action of the turbine and condenser casings in a vertical as well as in a horizontal direction, while at the same time providing for direct and rigid vertical contact between the turbine and condenser connections such that the downward force acting on the turbine is opposed and neutralized more or less by the upward force acting on the condenser when the plant is running condensing and, further, is such that it is possible to place the turbine and condenser in closer proximity to each other than has been possible heretofore.

It will be seen, furthermore, that by the provision of the supporting studs 45, which supplement the supporting effect of springs 43 and 44 and come into supporting action when the plant is shut down, it is possible to limit the initial compression of the springs and the corresponding initial upward supporting action thereof, thereby relieving the turbine foundation and associated parts of undue stress during condensing operation of the plant.

The arrangement shown in Fig. 4 might be used in installations where the adjusting studs 32 and their associated lock nuts 33 are accessible from the outside during erection of the turbine and condenser. Where such accessibility of these parts is precluded in any case due to the nature of the foundations or other parts of the installation, the adjusting studs are arranged inside of the connection 22–24, as shown in Fig. 6, in which case the packing ring 40 is placed on the outside of the thrust bearing units and seats against a suitable shoulder 47 with which the condenser connection 24' is provided. The thrust bearing unit shown in Fig. 6 is identical in construction to that shown in Fig. 4.

The connection 24' is provided with suitable recesses 48 receiving the thrust bearing units so that the same offer no appreciable resistance to the flow of steam, a protecting apron or plate 49 being inserted in the manner shown into connection 24' to cover recesses 48 and protect the thrust bearing units against direct contact with the exhaust steam. The apron 49 may be held in place by means of studs 50 threaded into the upper exhaust connection 22' of the turbine.

In lieu of the ball bearing thrust unit shown in Figs. 4 and 6, the arrangement shown in Fig. 7 might be adopted, wherein white metal is inserted between the flanges 27' and 28' and oil or grease supplied to the bearing faces through a suitable connection 52. In inserting this metal, uniformity of contact between flanges 27' and 28' is insured by first bolting together the connections 23 and 25 and then pouring or otherwise introducing white metal between the flanges in such manner as to form a bearing ring 53 which rests firmly against the shoulder 54. A relatively thin annular ring 55 of harder material is then inserted between the flanges and pressed against the adjacent edge of ring 53. White metal is then introduced again to form a second bearing ring 56, the right edge of which is made to press firmly against the adjacent edge of the intermediate ring 55. A suitable band 57
is secured by studs 58 to flange 28° to hold the bearing assemblage in place. The intermediate ring 55 of harder material is appreciably thinner than the white metal bearing rings 53 and 56, as shown, and acts as a gauge to insure such spacing of the latter as to provide lubricating passages for the oil or grease. The packing ring 40 is disposed as shown, and seats against the shoulder 59 with the greater exterior atmospheric pressure.

While but one embodiment of the invention has been shown and described, it will be understood that various changes in the size, shape and arrangement of the parts might be adopted without departing from the spirit of the invention or the scope of the claims.

The invention claimed is:

1. In a steam power plant, a steam turbine having a casing supported for expanding and contracting action in a given direction and provided with exhaust connections extending substantially transversely of said given direction, and a condenser associated with said turbine and having a casing disposed for expanding and contracting action in said given direction and provided with inlet connections complementary respectively to said exhaust connections, certain of said supplementary connections seating firmly against each other to effect direct opposing action between the forces to which said casings are subject incident to condensing operation of said plant and cooperating with each other to permit freely of relative movement between said certain connections in said given direction while providing for a fluid-seal therebetween.

2. In a steam power plant, a supporting foundation, a steam turbine having a casing seated on said foundation for expanding and contracting action in a substantially horizontal plane and provided with a pair of downwardly-directed exhaust connections, a condenser arranged below said turbine and having a casing disposed for such action in a substantially a horizontal plane and provided with upwardly-directed inlet connections complementary respectively to said exhaust connections, bearing elements interposed between and engaging certain of said complementary connections with a rolling action such as to permit freely of relative movement of the latter in said direction while providing a rigid thrust connection between the same, the other of said condenser-inlet connections seating firmly against and being rigidly secured to its associated turbine-exhaust connection and providing therewith a fluid-tight operating connection between said casings, the other of said condenser-inlet connections seating firmly against its associated turbine-exhaust connection and being freely movable with respect thereto in such plane while providing with the same a second operating connection between said casings, means interposed between said last-mentioned connections and cooperating therewith to render said second operating connection fluid-tight, and means providing for application to said condenser casing of a substantially vertically-directed supporting force and being operable to exert such force while permitting of expanding and contracting action of said condenser casing in a vertical plane.

3. In a steam power plant, a supporting foundation, a steam turbine having a casing seated on said foundation for expanding and contracting action in a substantially horizontal plane and provided with downwardly-directed exhaust connections, a condenser arranged below said turbine and having a casing disposed for such action in substantially a horizontal plane and for free vertical movement upwardly under the influence of the greater exterior atmospheric pressure to which said condenser casing is subjected incident to condensing operation of said plant, said condenser casing being provided with upwardly-directed inlet connections complementary respectively to said turbine-exhaust connections, certain of said turbine-exhaust connections engaging directly certain of said condenser inlet connections and providing for the latter a rigid seat operating to hold said condenser casing against such upward vertical movement, said turbine and condenser connections cooperating to permit of free relative movement of the same laterally with respect to each other while providing for a fluid-tight operating connection between said casings, and means providing for application to said condenser casing of a substantially vertically-and-upwardly-directed force and being operable to exert such force while permitting of free vertical expanding and contracting action of said condenser casing from said turbine and condenser connections.

4. In a steam power plant, a steam turbine having a casing supported for expanding and contracting action in a given direction and provided with exhaust connections extending substantially transversely of said direction, a condenser associated with said turbine and having a casing disposed for such action in substantially a horizontal plane and provided with a pair of upwardly-directed inlet connections complementary respectively to said exhaust connections, bearing elements interposed between and engaging certain of said complementary connections with a rolling action such as to permit freely of relative movement of the latter in said direction while providing a rigid thrust connection between the same, means interposed between said last-mentioned connections and cooperating therewith to provide a fluid-tight operating connection between said casings.

5. In a steam power plant, a steam turbine having a casing supported for expanding and contracting action in a given direction and provided with a plurality of exhaust connections, a condenser associated with said turbine and having a casing disposed for such action in said direction and provided with
inlet connections complementary respectively to said turbine exhaust connections; and means providing for such action of said casings independently of each other and including thrust bearing means interposed between certain of said complementary connections and means providing a fluid seal therebetween.

6. In a steam power plant, a steam turbine having a casing supported for expanding and contracting action in a given direction and provided with a plurality of exhaust connections, a condenser associated with said turbine and having a casing disposed for such action in said direction and provided with inlet connections complementary respectively to said turbine exhaust connections, one of said turbine-exhaust connections being rigidly secured to its associated condenser-inlet connection, and thrust bearing means interposed between the other of said turbine-exhaust and condenser-inlet connections and being operable to permit freely of such action of said casings independently of each other.

7. In a steam power plant, a supporting foundation, a steam turbine including a casing seated on said foundation and having one end rigidly affixed thereto and its other end freely movable with respect to the fixed end consequent upon contracting and expanding action of said casing between said ends thereof, said casing being provided at substantially said ends thereof with exhaust connections, a condenser associated with said turbine and having a casing provided with inlet connections complementary respectively to said turbine exhaust connections, the complementary turbine exhaust and condenser-inlet connections adjacent the fixed end of the turbine casing being rigidly secured together, and thrust bearing means interposed between the other of said turbine-exhaust and condenser-inlet connections.

8. In a steam power plant, a steam turbine having a casing provided with rigid exhaust connections, a condenser associated with said turbine and having a casing provided with rigid inlet connections complementary respectively to said turbine exhaust connections, one of said condenser-inlet connections being rigidly secured to its associated turbine-exhaust connection, the other of said condenser-inlet connections being disposed for direct seating against the other of said turbine exhaust connections and for sliding movement with respect thereto in a direction substantially transversely of said last-mentioned condenser and turbine connections.

9. In a steam power plant, a substantially horizontal supporting foundation, a steam turbine including a casing seated on said foundation for horizontal expanding and contracting action and provided with a downwardly-directed exhaust connection, a condenser arranged below said turbine and including a casing provided with an upwardly-directed inlet connection complementary to said turbine-exhaust connection and disposed for firm seating engagement thereof and for relative lateral movement with respect thereto, and supporting means for said condenser.

10. In a steam power plant, a substantially horizontal supporting foundation, a steam turbine including a casing seated on said foundation for horizontal expanding and contracting action and provided with a downwardly-directed exhaust connection, a condenser arranged below said turbine and including a casing provided with an upwardly-directed inlet connection complementary to said turbine-exhaust connection and disposed for firm seating engagement therewith and for relative lateral movement with respect thereto, means operable during operating and non-operating conditions of said plant to provide for application to said condenser of a supporting force and being operable during operating condition of said plant to permit of vertical expanding and contracting action of said condenser from the engaging turbine exhaust and condenser-inlet connections, and means operable during non-operating condition of said plant to supplement the supporting action of said first-mentioned supporting means.

11. In a steam power plant, a steam turbine including a casing provided with an exhaust connection, a condenser including a casing provided with an inlet connection complementary to said turbine-exhaust connection and disposed for relative lateral movement with respect thereto, and thrust bearing means interposed between the respective adjacent faces of said connections and comprising a plurality of units circumferentially spaced about the latter and adjustable in a direction normal to said faces thereof.

12. In a steam power plant, a steam turbine including a casing provided with an exhaust connection, a condenser including a casing provided with an inlet connection complementary to said turbine-exhaust connection and disposed for relative lateral movement with respect thereto, and thrust bearing means interposed between the respective adjacent faces of said connections and comprising a plurality of units circumferentially spaced about the latter; each of said units comprising a stud screw-threaded in one of said connections for adjustment in a direction normal to the face thereof and provided with a head disposed intermediate said faces, and a bearing element interposed between and having rolling contact with said head and one of said faces.

13. In a steam power plant, a steam turbine including a casing provided with an ex-
haust connection, a condenser including a casing provided with an inlet connection complementary to said turbine-exhaust connection and disposed for relative lateral movement with respect thereto, one of said connections being provided with a laterally-extending flange disposed opposite to and spaced from the adjacent face of the other of said connections, and thrust bearing means interposed between said connections and comprising a stud screw-threaded in said flange for adjustment in a direction perpendicularly thereof and provided with a bearing head disposed intermediate said flange and said face, and a bearing element arranged intermediate said head and said face and having rolling contact therewith.

14. In a steam power plant, upper and lower horizontally-disposed supporting foundations, a steam turbine including a casing seated on the upper foundation for horizontal expanding and contracting action and provided with a pair of downwardly-directed exhaust connections, a condenser arranged between said foundations and including a casing provided with a pair of upwardly-directed inlet connections complementary respectively to said turbine-exhaust connections, one of said turbine-exhaust connections being rigidly secured to its associated condenser-inlet connection, spring means interposed and compressed between the lower foundation and said condenser to provide an upwardly-directed supporting force against the latter of such magnitude as to partially support the same during non-operating condition of said plant, thrust bearing means interposed between the other of said turbine-exhaust and condenser-inlet connections, fluid-sealing means interposed between said last-mentioned connections, and means disposed for cohesion with the adjacent edge portions of said last-mentioned connections and being operable during non-operating condition of said plant to provide a supporting suspension connection for said condenser casing from said turbine casing supplementing the supporting action of said spring means by such amount as to provide with the latter full support for said condenser.

In testimony whereof I have hereunto subscribed my name this 27th day of January, A. D. 1928.

OTTO FREY.