

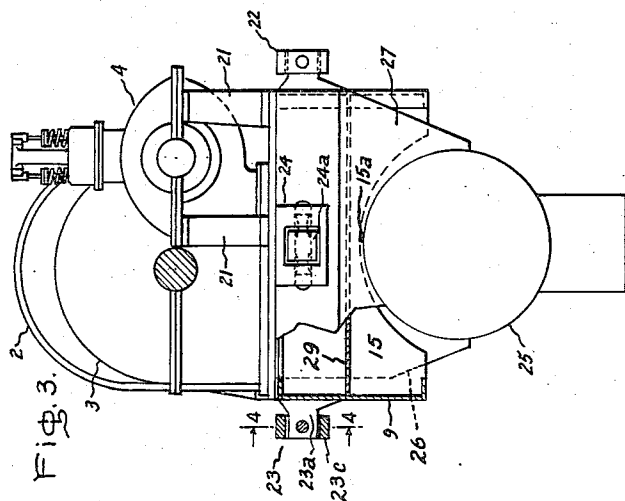
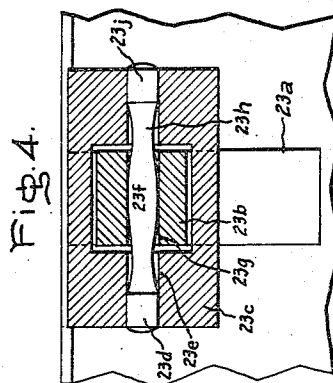
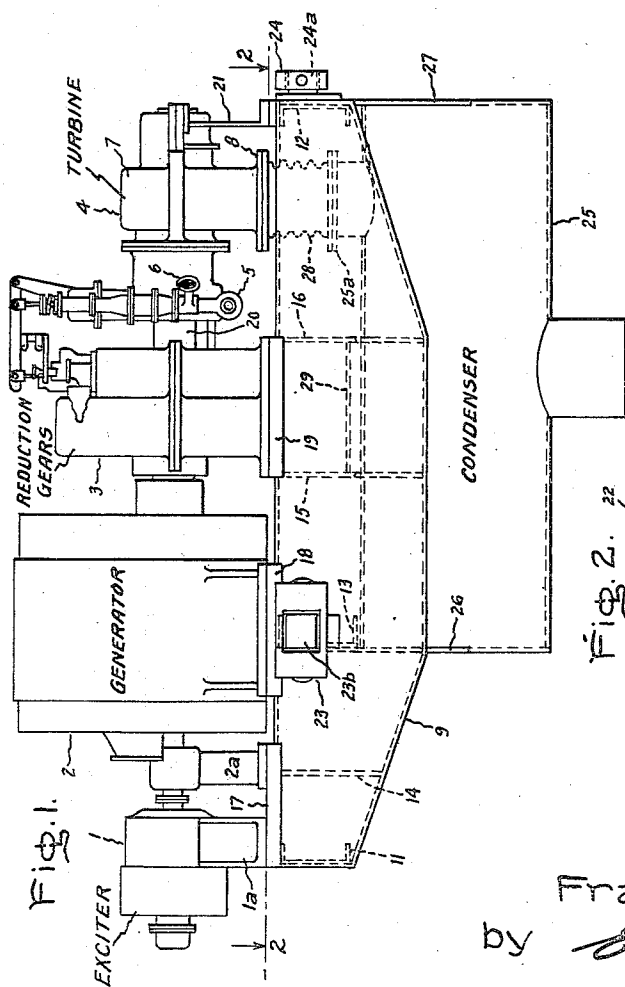
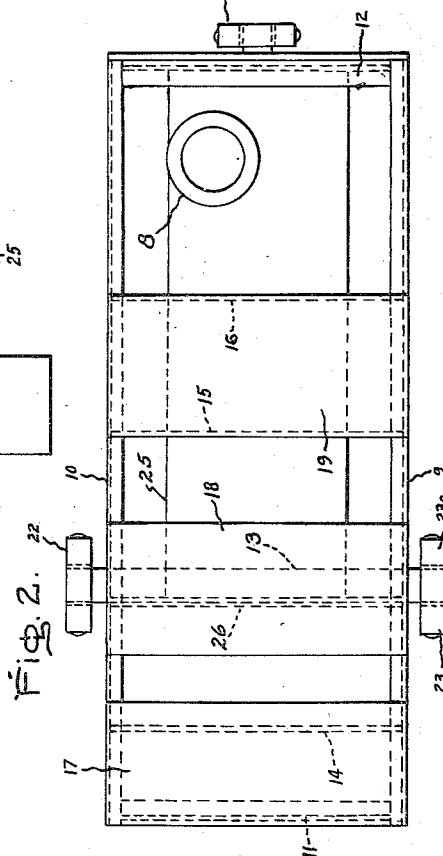
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FRAME STRUCTURE FOR TURBINE-GENERATOR PRIME MOVERS

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FRAME STRUCTURE FOR TURBINE-
GENERATOR PRIME MOVERS

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1

This invention relates to supporting frame structure for a prime mover such as a steam turbine generator, particularly to a frame structure for such a prime mover as used in marine vessels for auxiliary shipboard power where the ship's structure is subject to substantial deformations in operation and the frame structure of the prime mover is relied upon to maintain accurately the required alignment of the bearings.

As will be appreciated by those skilled in the art, the comparatively small turbine-generator units used for auxiliary power on marine vessels ordinarily comprise an electric generator, with its exciter, and a steam turbine arranged in substantially coaxial relation on a common supporting base or frame structure, or fastened to a portion of the ship's framework which is made sufficiently rigid as to maintain the required accurate alignment of the shafts of the respective components. In many such powerplants, the turbine is not directly connected to the generator but drives through a suitable speed reducing gear. For instance, the turbine speed may be on the order of from 10,000 to 25,000 R. P. M., while the generator runs at from 900 to 3600 R. P. M., and a single reduction gear, ordinarily of the helical type, is provided between turbine and generator. Because of the severe operating conditions under which such powerplants operate, maintaining proper alignment of the turbine, generator, and exciter rotors is always a substantial problem, particularly serious when a reduction gear is used since the noise level and life of the gears depend very largely on maintaining proper alignment.

Heretofore, it has been attempted to obtain the necessary accuracy of bearing alignment simply by making the supporting frame structure sufficiently large and massive as to provide the necessary rigidity. This practice has had certain undesirable consequences. The size and weight of the framework required have been a disadvantage since every pound added or cubic foot occupied reduces the payload which the ship may carry. Furthermore, if the prime mover frame or bed is connected at four or more points to the ship's structure, then any distortions in the ship's framework caused by severe stresses encountered in heavy seas is likely to be transmitted to the powerplant, with the resulting possibility that distortion of the frame and disalignment of the bearings will occur.

A further source of distortion of the prime mover frame has resulted from the increasing practice of supporting the steam turbine's con-

2

denser directly from the prime mover frame. The most usual practice has been to suspend the condenser below the frame. It is, of course, well known that a steam condenser changes its dimensions quite appreciably as the operating temperature changes. The most obvious and substantial change is that an elongated condenser will change in length. However, it has also been discovered that a long condenser will experience what is referred to hereinafter as "humping" distortion, resulting from the fact that there may be a very substantial temperature difference between the top and bottom of the condenser. Since the hotter fluid in the condenser is at the top while the cooler fluids sink to the bottom, the upper half of the condenser shell will tend to be at a substantially higher temperature than the lower half. The result is that the whole condenser shell tends to bulge or "hump" upwardly in the middle. Considerable difficulty has been experienced in providing suitable means for supporting the condenser from the prime mover frame in such a manner that these thermal distortions experienced by the condenser will not result in additional distorting forces being applied to the prime mover frame.

It is also to be noted that the steam turbine itself will change its length substantially so that special provision must be made in order that thermal changes in the dimensions of the turbine casing will not impose distorting forces on the framework.

Accordingly, the object of this invention is to provide a supporting frame for a powerplant of the type described so designed that it may be of minimum size and weight, yet has sufficient rigidity to maintain alignment of the powerplant components while requiring attachment to the ship's frame at only three points arranged so transmission of forces from the ship's frame to the powerplant frame will be minimized.

A further object is to provide a frame structure for a prime mover of the type described with special provision for suspending a condenser beneath the turbine-generator, the arrangement being such that not only does the condenser not transmit any distorting forces to the frame but on the contrary it enters into structural cooperation with the frame to greatly increase the rigidity thereof.

Other objects and advantages will be apparent from the following description taken in connection with the accompanying drawing, in which Fig. 1 is a side view in elevation of a steam turbine-generator prime mover having a base and

3

condenser arrangement arranged in accordance with the invention; Fig. 2 is a plan view of the base and condenser combination with the other powerplant components removed; Fig. 3 is an end view of the complete prime mover and frame structure, partly in section; and Fig. 4 is a sectional view on line 4—4 of Fig. 3 illustrating the special mounting trunnions for connecting the prime mover base to the ship's frame.

Turbine-generator frames of the type described ordinarily comprise a pair of transversely spaced longitudinal beam members parallel to the axis of the turbine-generator. Such beams are comparatively easy to fabricate by welding plate and structural steel shapes to provide the requisite stiffness with respect to bending deformations. These longitudinal beam members are connected by a plurality of transverse beams and stiffener members, with suitable mounting plates secured to the top of the frame for supporting the exciter, generator, turbine, reduction gear, etc. While such a frame can be readily designed to provide good stiffness against bending deflections, it has been found extremely difficult to provide the necessary resistance to torsional deformation of the frame about a longitudinal axis parallel to the turbine-generator axis. Unfortunately, this particular type of deformation has a most serious effect on the alignment of the powerplant bearings, especially with respect to misalignment of the teeth in the reduction gear. The present invention is specifically intended to provide the necessary rigidity against such torsional deformations; and to this end the condenser mounted below the prime mover base structure is employed as a stressed member which enters into cooperative structural relation with the base, while at the same time the relation between condenser and base is such that the peculiar thermal distortions of the condenser do not impose any additional distorting forces on the base.

Referring now more particularly to Fig. 1, the turbine-generator comprises, from left to right, an exciter indicated generally at 1; a generator shown at 2, a reduction gear at 3, and a suitable steam turbine 4. The internal mechanical details of these components are not material to an understanding of the present invention and are therefore not disclosed more specifically. It may be noted, however, that high temperature steam is supplied to the turbine through a flanged inlet connection shown at 5 from which a manually operated shut-off valve 6 admits motive fluid to the valve chest, where suitable governing mechanism positions admission valves to control the operation of the turbine. Spent motive fluid passes from the exhaust casing 7 through a flanged outlet indicated at 8 to the condenser, in a manner described more particularly hereinafter.

The base proper comprises the main longitudinal beam members 9, 10. These have a plan shape as shown in Fig. 1 and a channel cross section as shown at 9 in Fig. 3, and are arranged in transversely spaced parallel relation as shown in Fig. 2. At the left-hand end, these main side beams are connected by an end cross beam 11, which may also be of a channel shaped section as indicated by the dotted lines in Fig. 1. A similar channel-shaped cross beam is provided at the right-hand end of the frame as shown at 12. Additional cross members for supporting the powerplant components and stiffening the base are provided in the form of an intermediate main cross beam 13 shown in dotted lines in Figs. 1

4

and 2, also a plurality of cross-brace plates shown at 14, 15, 16. The direct supporting members for the powerplant components are a plurality of base plates, as follows. The base plate 17 is welded to the side beams 9, 10, the end beam 11, and the cross-plate 14, and carries the generator pedestal 2a and the exciter pedestal 1a. The base plate 18 supports the main generator casing and is welded to the main cross beam 13 and the side beams 9, 10. Plate 19 is welded to the top edges of the cross-brace plates 15, 16 and to the side beams. It carries the reduction gear housing 3 from which the inlet end 20 of the turbine is supported. The exhaust end of the turbine casing is supported from the end cross-beam 12 by one or more vertical transversely arranged support plates 21. In the present instance, there are two of these plates as may be seen in Fig. 3. It is to be noted that these support plates 21 are sufficiently thin in cross section as to have appreciable flexibility in the longitudinal direction relative to the turbine axis. With this arrangement, the turbine casing portion 20 is fixed at the gear casing so that any change in length of the turbine casing due to changes in operating temperature results in flexing of the support plates 21. Thus the turbine casing is free to expand and contract without imposing bending stresses on the base structure. At the same time, the inlet end of the turbine is fixed in space relative to the base so that the problem of coupling the turbine shaft to the reduction gear is simplified.

It will be understood that the main side beams 9, 10 and the various transverse members are all suitably welded together so that the base proper forms a quite rigid integral structure. This integral base is supported from the ship's structure by a special three-point trunnion arrangement as follows. The location of these trunnion supports is best seen in the plan view of Fig. 2. A pair of transversely spaced trunnions are indicated at 22, 23. The third point of support is provided by a trunnion 24 associated with the end cross beam 12. The details of these supporting trunnions may be best seen by reference to Figs. 1, 3, and 4. In Fig. 3 it will be seen that the trunnion assembly consists of a heavy lug member 23a welded to the outer surface of the main side beam 9, and having an end portion 23b which is square in section as may be seen in Figs. 1, 4. As will be seen more clearly in Fig. 4, the lug end portion 23b is received in the central opening of a hollow rectangular mounting support 23c, which is carried on the ship's frame structure by any suitable means (not shown). Lug 23b is pivotally carried in the mounting support 23c by means of a specially shaped pintle 23d. This includes end portions fitting a transverse bore 23e as will be apparent from Fig. 4. The intermediate pintle portion 23f has a spherical curvature, the maximum diameter portion of which fits the transverse bore 23g in member 23b. It will also be apparent that the spherical intermediate portion 23f is connected by reduced diameter portions 23h to the pintle end portions 23j. With this pintle configuration, it will be apparent that the lug end portion 23b is free to move pivotally to a limited extent, either about the axis of the pintle 23d, or to tilt about an axis normal to the plane of Fig. 4, as permitted by the spherical intermediate portion 23f. With this arrangement, it will be obvious that any distortion of the mounting support 23c, due to "weaving" of the ship's frame,

will result in a certain degree of free angular adjustment of the supporting lugs 23a relative to the pintles, without any stresses being transmitted from the ship's structure to the prime mover base structure.

The mounting trunnions 22, 24 are, of course, similar in structure to the trunnion 23.

It will be apparent from the above that the side support trunnions 22, 23 may be displaced vertically, in opposite directions, without producing any torsional stresses on the base member, the only result being a slight rotational shifting of the end trunnion lug 24a.

The manner in which the condenser is incorporated into the prime mover frame structure is as follows. The condenser is shown generally at 25. In practicing the invention, the condenser used is of a type which is circular in cross section, as seen in Fig. 3, with an integral cylindrical outer shell of a thickness adequate to enable the condenser to perform the structural functions described hereinafter. It will also be observed that the condenser is of substantial axial length, roughly equal to the longitudinal distance between the side supporting trunnions 22, 23 and the end trunnion 24. While in an actual installation, this condenser would be provided with various auxiliary devices, such as an ejector or equivalent pump for removing air from the condenser, cooling water circulating pumps, and a hot-well or condensate pump, etc., these auxiliary devices have been omitted from the drawing since they are not material to an understanding of the present invention.

The condenser is suspended from the base proper in the following manner. At the respective ends of the condenser shell there are firmly secured transverse vertically extending support plates, each welded to the upper half of the circumference of the condenser shell, as may be seen in Fig. 3. The left-hand condenser support plate 26 extends upwardly as indicated by the dotted lines in Fig. 3, and is secured at its top edge only to the base, as by welding to the main intermediate cross beams 13. While this support plate 26 is comparatively thin so as to be flexible in an axial direction, its plan view, as shown in Fig. 3, is such that it is extremely rigid with respect to resistance to forces constituting a couple in the plane of the plate.

The other condenser end support plate 27 may be of thicker, stiffer cross section and is welded rigidly to the outer end surface of the main cross beam 12, with the result that the right-hand end of the condenser is supported in fixed relation relative to the base. The plan shape of the support plate 27 is likewise such that it furnishes very considerable resistance to any couple tending to rotate the end cross beam 12 relative to the condenser about a longitudinal axis. With this supporting arrangement, the condenser is fixed at the right-hand end but is free to expand to the left as its operating temperature changes, which expansion is accompanied by lateral flexing of the other end support plate 26. Thus changes in the over-all length of the condenser have no tendency to impose deforming forces on the base structure.

It will be apparent that, alternatively, the plate 26 might be rigidly fixed to the base, with the end plate 27 left free to flex with changes in the length of the condenser. The criterion is, of course, that the condenser must be rigidly secured to the base at one point in order to withstand shock loads in the fore and aft and sideways di-

rections, the support for the other end being free to flex in a longitudinal direction.

It is important to note that the cross-brace plates 15, 16 are not secured to but form a substantial clearance space, shown at 15a in Fig. 3, with the top of the condenser shell. When the condenser is subject to the "humping" type of distortion, the clearance space 15a will prevent any distorting effect on the base structure. Thus it will be seen that, by fixing the condenser at one end to the base, flexibly supporting it at the other end from the base, and having no intermediate points of contact between condenser and base, there is no tendency for deformations of the condenser to impose extraneous stresses on the base.

It will, of course, be understood that the turbine exhaust flange 8 is connected to the condenser inlet flange 25a by a flexible conduit such as the bellows shown in dotted lines at 28 in Fig. 1, or by any other equivalent suitable type of flexible expansion joint. The flexibility of this connection is, of course, important to insure that distortions of the condenser will impose no deforming forces on the turbine.

It will be observed that the base plate 19, the cross-brace plates 15, 16, enclose a space above the condenser which may be employed as the oil reservoir for the turbine, reduction gear, etc., simply by adding a flat horizontal plate shown in dotted lines at 29 in Fig. 1. Alternatively, a separately fabricated oil tank might be supported by suitable means in this space. Thus the oil reservoir is conveniently located relative to the turbine and gear, which are the components requiring most lubrication.

The manner in which the condenser enters into structural cooperation with the base may now be seen. As is well understood, a hollow cylindrical shell is the geometrical shape which has the maximum possible resistance, per unit weight of material employed, to torsional deformation about the axis of the cylinder. As noted above, the condenser is considerably elongated and extends substantially between the mounting trunnions, being connected to the base proper by the condenser support plates which are exceptionally rigid against torsional deformations about an axis normal to the plane of the support plates. Thus it will be apparent that, if the base should be held fixed at the side support trunnions 22, 23 and a twisting couple applied to the right-hand end of the base, this couple will be transmitted through the condenser support plates to the cylindrical condenser shell which will strongly tend to resist any such torsional deformation. Thus it is seen that the condenser shell cooperates as a structural member with the base to prevent torsional deformation thereof.

As will be apparent from the drawing, the cylindrical condenser shell has a diameter roughly equal to half the width of the base. It would, of course, be feasible to use cylindrical members somewhat smaller, or much larger, in diameter than that shown. The larger the diameter of the shell, the stiffer it will be in resisting torsional deformations. As a practical matter, in order to have a neat compact assembly, it is desirable that the diameter of the shell should not have a diameter greater than the width of the base. On the other hand, the diameter of the shell should not be less than about half the width of the base if the requisite stiffness against torsional deformation is to be obtained. It will be obvious that in some installations the deforming

forces may be sufficiently low that a somewhat smaller shell would be adequate to prevent twisting of the base. In general then, it may be said that for all practicable purposes the diameter of the cylindrical member should at least be on the order of half the width of the base, with the maximum practical value about equal to the width of the base.

Likewise it will be obvious that the depending transverse plate members must be spaced apart a sufficient distance longitudinally. Ordinarily, the three mounting trunnions will be located first, giving due consideration to the distribution of the weight of the machine components on the base, the location of the center of gravity of the whole assembly, and the effect of any gyroscopic loads on the mounting trunnions which may be encountered, etc. Having determined the location of the trunnions, the depending plate members are located in close proximity to the longitudinally spaced trunnions so that any twisting couple transmitted to the base through the trunnions will be directly transferred to the cylindrical shell.

The invention provides a compact steam turbine prime mover frame in which an elongated steam condenser occupies a minimum amount of space beneath the base and is so connected thereto that the condenser serves as an important stressed component of the complete frame structure, providing exceptional rigidity against torsional deformation of the base. With the aid of the invention, an integral turbine-generator frame is provided of such rigidity that it may be conveniently supported by three mounting trunnions from a ship's framework as described above, the trunnion supports being specially arranged to prevent the transmission of any deforming forces from the ship's structure to the prime mover. At the same time, the compact shape and minimum over-all dimensions of the turbine-generator with its integral base and condenser structure make it exceptionally easy to handle in installing and removing it from its foundation in a marine vessel.

While the invention has been described as applied to steam turbine-generator units for marine vessels, it is obviously adapted to other uses, for instance gas turbine powerplants supported from framework subject to distortions, such as the chassis of a locomotive or frame of an aircraft, in which cases the condenser might be replaced by a cylindrical fuel tank. It may also be used on land-based powerplants to simplify installation and to overcome difficulties which sometimes are caused by foundations settling.

While only one embodiment of the invention has been described in detail, it will be apparent to those skilled in the art that many changes may be made in the specific arrangement of the prime mover components on the base, and in the mechanical details of the base structure; and it is desired to cover by the appended claims all such changes and modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a frame for a machine of substantial axial length having bearings the alignment of which depends on the rigidity of the frame, the combination of a base comprising a pair of transversely spaced longitudinal side beams extending substantially the length of the machine, at least two longitudinally spaced cross members connecting the side beams, two parallel trans-

verse plate members depending from the cross members, at least one of the plate members being adapted to flex in a longitudinal direction so the distance between the depending end portions of the plates may change without imposing excessive stresses on the base, a hollow elongated substantially cylindrical shell disposed longitudinally beneath the base, and means securely fastening said depending plate end portions to axially spaced portions of said shell whereby forces tending to torsionally deform the base about a longitudinal axis are resisted by the shell while the shell is free to expand and contract longitudinally, there being no points of rigidly fixed connection between the shell and base intermediate said plates.

2. In a frame for a machine of substantial length having longitudinally spaced bearings the alignment of which depends on the rigidity of the frame, the combination of a base comprising a pair of transversely spaced longitudinal side beams extending substantially the length of the machine, a plurality of longitudinally spaced cross members connecting the side beams, two parallel transverse plate members depending from two of said cross members and spaced longitudinally a substantial distance apart, at least one of said plate members being adapted to flex in a longitudinal direction so that the distance between the depending end portions of the plates may change without imposing excessive stresses on the longitudinal beams or cross members, said depending plate end portions being securely fastened to axially spaced portions of a longitudinally extending cylindrical member whereby forces tending to torsionally deform said base about a longitudinal axis are resisted by the cylindrical member while the latter is free to expand and contract longitudinally.

3. In a frame for a machine of substantial axial length having longitudinally spaced bearings the alignment of which depends on the rigidity of the frame, the combination of a base comprising a pair of transversely spaced longitudinal side beams extending substantially the length of the machine and adapted to withstand bending stresses without substantial deformation, at least two longitudinally spaced cross members connecting the side beams, an elongated cylindrical shell disposed below and with its axis parallel to the length of the base, the diameter of said shell being at least on the order of half the width of the base, two transverse plate members, one secured to each of said cross members, said plates having depending end portions firmly secured to axially spaced portions of said shell around substantially half the circumference thereof, at least one of said plate members being adapted to flex in a longitudinal direction in order that the shell can change length without imposing substantial bending stresses on the base, whereby any forces imposing a couple on the base tending to deform it torsionally about a longitudinal axis are resisted by the cylindrical shell.

4. In a frame for a prime mover of substantial axial length having longitudinally spaced bearings the alignment of which depends on the rigidity of the frame and adapted to be supported from other frame structure subject to substantial deformation in service, the combination of a base comprising a pair of transversely spaced longitudinal beams extending substantially the length of the machine, at least two longitudinally spaced cross members connecting the beams, two parallel transverse plate members depending from said

respective cross members, at least one of the plate members being adapted to flex so the distance between the depending end portions of the plates may change without imposing excessive deforming stresses on the base, said depending plate end portions being securely fastened to axially spaced portions of a hollow cylindrical shell around substantially half the circumference thereof whereby forces tending to torsionally deform the base about a longitudinal axis are resisted by the shell while the latter is free to expand and contract longitudinally, and means for supporting the base at three points including a pair of transversely spaced trunnions adjacent one of said plates and a third trunnion adjacent the other plate, each of said trunnions being adapted to effect a limited degree of free movement between the base and the supporting frame both about an axis which is parallel to the plane of the base and also parallel to the longitudinal axis of the prime mover and also about an axis normal to said first axis and parallel to the plane of the base, whereby deformations of the supporting frame structure during operation result only in limited relative movement in said trunnions without transmitting deforming forces from the supporting framework to the base.

5. In a frame for an elastic fluid turbine-generator of substantial axial length having longitudinally spaced bearings the alignment of which depends on the rigidity of the frame, the combination of a base comprising a pair of transversely spaced longitudinal beams extending substantially the length of the machine, at least two longitudinally spaced cross members connecting said beams, two transverse plate members depending from said respective cross members, one

of the plate members being located adjacent the exhaust casing of the turbine, and one of the plates being adapted to flex transversely so the distance between the depending end portions of the plates may change without imposing excessive deforming stresses on the base, a motive fluid condenser disposed below the base and having an elongated cylindrical shell with end portions adjacent said plate members, and means securing the end portions of the condenser shell to said depending plate end portions whereby forces tending to torsionally deform the base about a longitudinal axis are resisted by the condenser shell, the flexibility of said plate member permitting the condenser to expand and contract longitudinally without imposing deforming forces on the base, flexible conduit means connecting the exhaust casing of the turbine with the condenser, said flexible conduit constituting the only point of contact between said shell and base intermediate the supporting plate members whereby humping deformation of the condenser imposes no deforming stresses on the base.

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