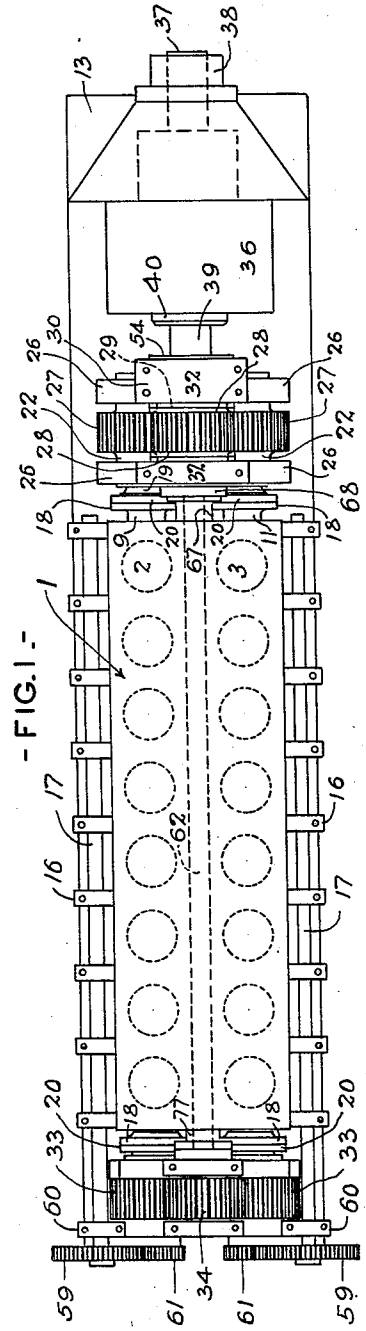
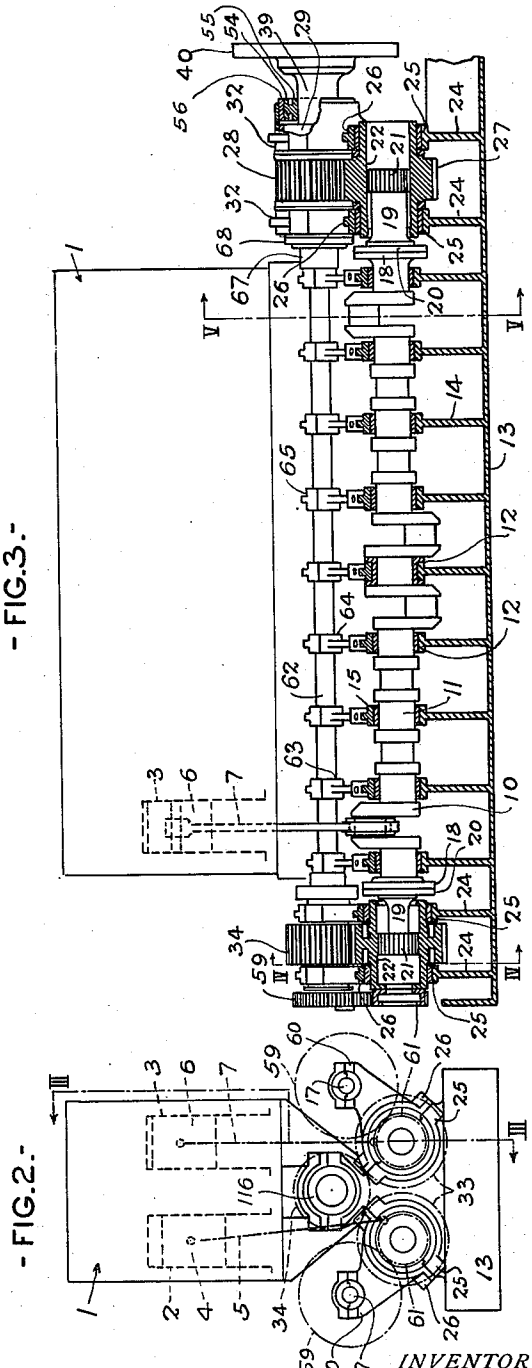
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TWIN BANK ENGINE

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- FIG. 1 -



- FIG. 3 -

- FIG. 2 -

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TWIN BANK ENGINE

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FIG. 5.

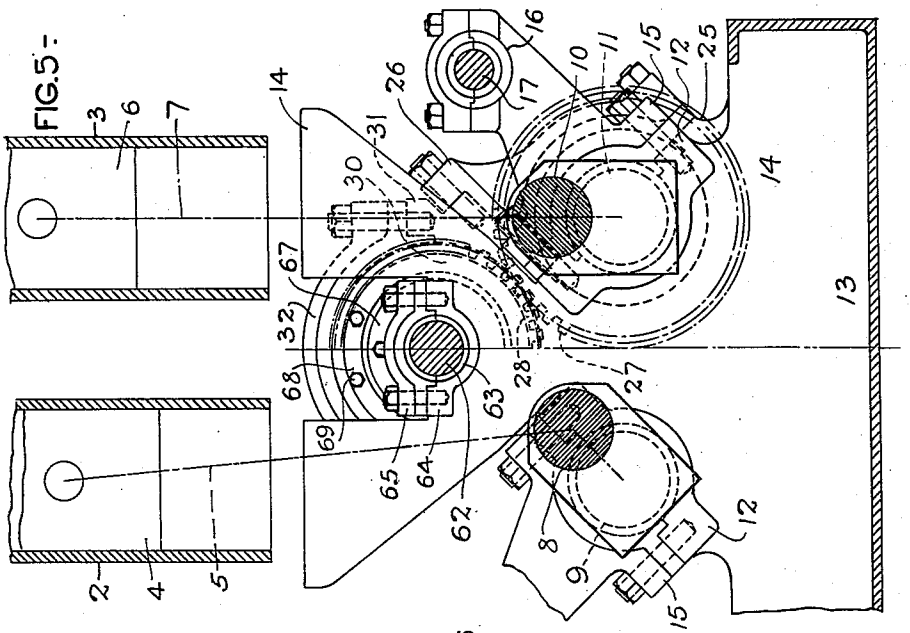
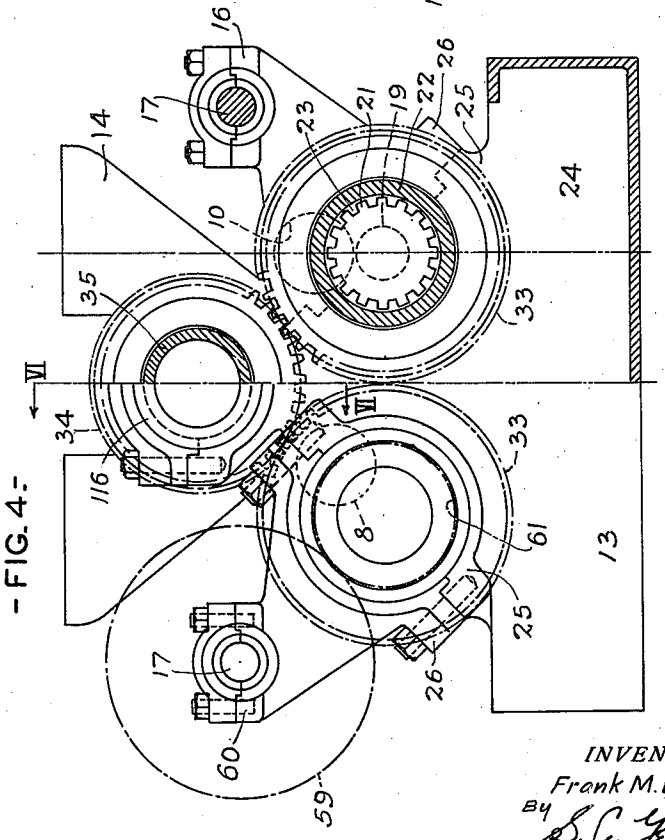


FIG. 4.



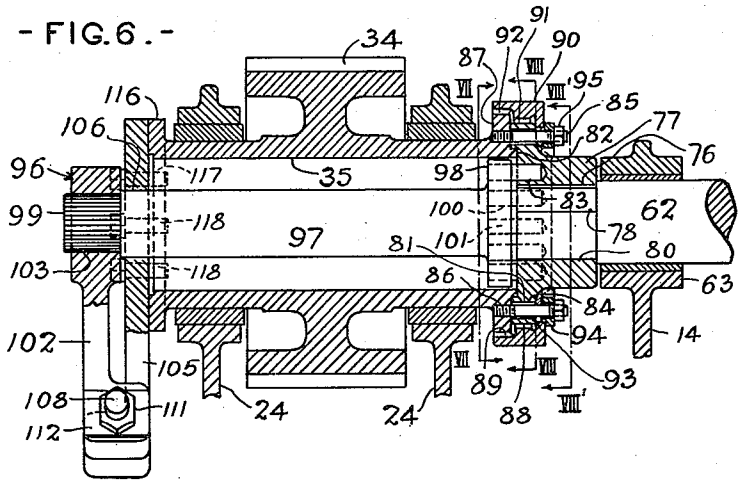
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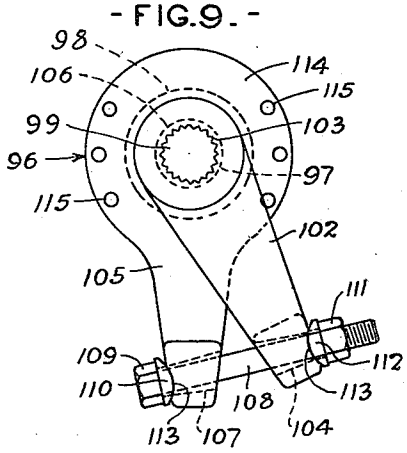
TWIN BANK ENGINE

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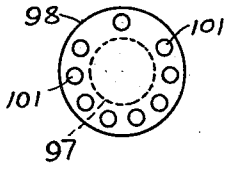
- FIG. 6 -



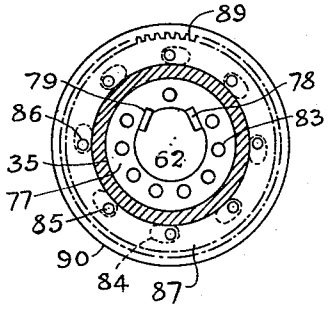
- FIG. 9 -



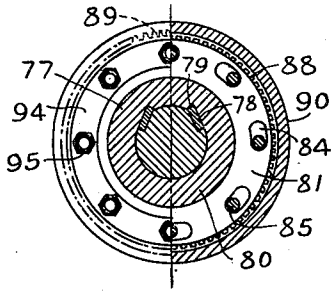
- FIG. 10 -



- FIG. 7 -



- FIG. 8 -



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Patented May 19, 1942 2,283,606

UNITED STATES PATENT OFFICE

2,283,606

TWIN BANK ENGINE

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Application April 10, 1941, Serial No. 387,885

12 Claims. (Cl. 123—52)

This invention relates to a twin bank engine.

An object of the present invention is to provide a means for eliminating or avoiding the harmful torsional vibrations present in twin bank engines of prior construction.

A further object is to provide a twin bank engine having gears connecting its crank shafts at each end, and means, including a torque shaft, for preventing backlash of the gears.

A further object is to provide an improved tool for twisting a torque shaft.

Other and further objects of and advantages achieved by the present invention will be apparent from the following description of an approved embodiment thereof.

Referring to the drawings forming a part of this application, Figure 1 is a diagrammatic plan view of a twin bank engine including an electric generator, embodying the present invention; Fig. 2 is a diagrammatic end view of the engine as viewed from the left of Fig. 1, parts being indicated in dot and dash lines; Fig. 3 is a section on the line III—III of Fig. 2, parts being broken away or omitted and parts being shown in full; Fig. 4 is an enlarged view, being at the right, a section on the line IV—IV of Fig. 3, and at the left an end view as viewed from the left of Fig. 3, parts being indicated in dot and dash lines; Fig. 5 is an enlarged section on the line V—V of Fig. 3, parts being added, parts being broken away, and parts being omitted on the left side; Fig. 6 is an enlarged fragmental section on the line VI—VI of Fig. 4, parts being shown in full, and a torque shaft twisting tool, shown partly in section, applied to the torque shaft; Fig. 7 is a section on the line VII—VII of Fig. 6; Fig. 8 is a section at the right on the line VIII—VIII and at the left on the line VIII'—VIII' of Fig. 6; and Figs. 9 and 10 are respectively views of the left and right ends of the tool as viewed in Fig. 6.

The present invention has application to various types and sizes of twin bank engines but in order to maintain simplicity throughout the following description of a preferred embodiment of the invention, the description will be substantially confined to a sixteen cylinder twin bank four-cycle internal combustion engine, such an engine being indicated generally by the reference numeral 1 in the accompanying drawings. However, it will be understood that various features of the invention have application to two-cycle engines and engines having a greater or less number of cylinders.

The twin bank engine 1, includes a row or bank of eight cylinders 2 and a parallel row or bank of eight cylinders 3. Each of the cylinders 2 contains a piston 4 having a connecting rod 5 and each of the cylinders 3 contains a piston 6 having a connecting rod 7. The rods 5 are all connected to cranks 8 of a crank shaft 9 and the rods 7 are all connected to cranks 10 of a crank shaft 11, each of the crank shafts thereby having eight cranks.

The crank shafts are similar, and as to each crank shaft, the cranks are disposed at ninety degrees from the cranks just previously and subsequently receiving impulses from their respective pistons. Both banks of cylinders have the same firing order but opposite cylinders do not have the same events occurring at the same time.

In the instant engine the crank shafts are rotated or phased relative to each other forty-five degrees, as can best be seen in Fig. 5 wherein crank 8 leads the opposite crank 10 by forty-five degrees. This relative position of the crank shafts prevents two cylinders, one connected to each crank shaft, from firing simultaneously, and contrariwise causes alternate firing between the cylinders of the respective crank shafts at equally spaced intervals. The same result may be obtained in engines having a greater or lesser number of cylinders by suitably phasing the crank shafts, for instance, in a twelve cylinder twin bank engine one crank would lead its opposite crank by sixty degrees.

In the instant engine the crank shafts are supported in the usual manner by bearings 12 carried by the engine bed 13, the bearing 12 at the center of each crank shaft being a thrust bearing preventing longitudinal movement of the crank shaft. The bearings are made in two pieces, the lower halves being formed in vertical walls 14 of the bed and the upper halves or caps 15 being bolted to the lower halves. Each of the bearings includes a bushing as do all the bearings hereinafter referred to. The caps each support a two-piece cam shaft bearing 16 and a cam shaft 17 disposed therein, as is clearly shown in Fig. 5.

A bolting flange 18 is formed on each end of each crank shaft and a stub shaft 19 is secured to each of the bolting flanges 18 by means of a bolting flange 20 formed on the stub shaft. On the other or outer end of each stub shaft are formed splines 21. A hollow gear shaft 22, provided with internal splines 23, is connected to each stub shaft, the stub shafts extending into the hollow interior of the gear shafts 22 and the splines 21 engaging the splines 23, thereby adapting the crank shafts, with their respective gear shafts 22, to rotate together but permitting longi-

tudinal expansion movement of the crank shafts relative to their respective gear shafts. The bed 13 extends beneath the gear shafts 22 and provides two vertical walls 24 for supporting each of the gear shafts 22, each gear shaft 22 being mounted in two two-piece bearings, the lower half 25 of each being formed in the wall 24 and the upper half or cap 26 being secured to the lower half.

The gear shafts 22 at the forward end of the engine, which, as will hereinafter appear, is the generator end of the engine, are shown somewhat longer than, and their caps 26 (in view of limited available space) are of a somewhat different shape than, the gear shafts and their caps respectively at the opposite or rear end of the engine. Each gear shaft 22 at the engine forward end has formed thereon a gear 27, which gears are each in mesh with a single intermediate or idler gear 28, the gear 28 thereby tying together the crank shafts at the forward ends and preventing relative rotative movement between the crank shafts. Gear 28 is formed on a hollow gear shaft 29 which is supported in two-piece bearings 30, one at each end of the gear shaft 29. The lower halves 31 of the bearings 30 are formed in the walls 24, which walls extend upward between the stub shafts, as is best shown (in dotted lines) in Fig. 5, and caps 32 are secured to the lower halves 31 in the usual manner.

The gear shafts 22 at the rear end of the engine have formed thereon gears 33 which mesh with a single intermediate or idler gear 34 which is formed on a hollow gear shaft 35 (see Fig. 6), thereby tying the crank shafts together at the rear ends similarly to the tying together of the crank shafts at their forward ends as aforedescribed. Gear shaft 35 is supported in a manner substantially similar to the supporting of gear shaft 29 and no further description thereof is deemed necessary.

Referring to Fig. 1, it will be seen that the engine per se is employed to run an electric generator 36, which is shown diagrammatically and may be of any suitable type. Its drive shaft 37 is supported at its forward end in a bearing 38 carried by the engine bed and at its rear end is formed as a stub shaft 39 supportedly secured at its forward end in the armature hub 40, all according to usual practice. The rear end of the stub shaft 39 is disposed in the hollow interior of the gear shaft 29 and is connected thereto by a well-known type of torsionally flexible connection described in detail in the patent to Alben, No. 2,106,823, dated February 1, 1938. In the following description wherever flexibility of the generator drive is referred to, it will be understood that reference is to torsional flexibility.

The stub shaft 39 is supported in a self-aligning bushing 54, carried by the bed 13, for rotation therein. The bushing 54 consists of a member 55 engaging the stub shaft 39 and a member 56 engaging the bed, the member 55 having a convex face and the member 56 having a complementary concave face engaging the convex face, permitting tilting of the stub shaft 39 relative to the engine. The bushing 54 is supported by the bed by means of an extension of the adjacent bearing 30, both the lower half 31 and cap 32 being wide enough to encircle the bushing 54.

The type of flexible drive for the electric generator forms no part of the present invention and any of the well-known types of flexible drives may be employed, the type above referred to being merely by way of example only. As instances of other flexible drives, a flexible shaft may be secured at one end to the intermediate generator drive gear to be driven thereby and at its other end may be geared to the generator shaft for driving same, or the flexibility of the generator shaft may be relied upon. The manner of providing flexibility forming no part of the present invention, as aforesaid, a "flexible shaft" as employed in the claims is intended to include any suitable means providing torsional flexibility of the generator drive. In this latter instance the shaft would be connected at one end to the intermediate drive gear to be driven thereby, it would pass through the armature and would be connected at its far or opposite end to the armature for driving same.

The engine as thus far described, attains the first object of the invention, namely, the harmful torsional vibrations present in twin bank engines of prior construction have been prevented in the present engine. This has been accomplished by eliminating or avoiding harmful critical speeds from the normal operating range of speeds of the engine, say, as illustrative, from 250–750 R. P. M., as the aforesaid harmful torsional vibrations of prior engines were a consequence of operating the prior engine at one of its harmful critical speeds.

For the purpose of understanding the present manner of avoiding a harmful critical speed in the normal operating range of the engine, brief appropriate remarks regarding critical speeds are deemed necessary. If one end of the crank shaft of a single crank shaft engine of conventional design, with the generator armature or other equipment it is driving, is given a twist in a given direction while the other end is twisted in the other direction, and the two ends are then simultaneously released, the shaft will be set into torsional vibration. The vibration will be of the one-noded type or mode, one end of the system vibrating against the other with a nodal point, or point of zero vibration, somewhere in the length of shafting between the ends. This vibration has a fixed frequency, dependent upon the masses associated with the engine cranks and with the generator, and upon the elasticity in the length of shafting connecting these masses.

Again, if the above crank shaft, with attached generator, has both its ends twisted in a given direction and its center is twisted in the opposite direction and it is then released, it will vibrate in a manner called the 2-noded mode of vibration. This mode of vibration will have a frequency distinct from that of the 1-noded mode, also dependent upon the associated masses and shafting elasticity as in the 1-noded mode.

When the engine is operating, the individual cylinders exert a turning effort upon the crank shaft, and this turning effort is not uniform, but is very irregular.

The turning effort of the engine as a whole therefore consists of a uniform part, upon which is superimposed periodic irregularities, having a definite pattern during each revolution of the engine. The turning effort will have a number of peaks in each revolution of the engine, equal to the number of firing impulses of the cylinders in a revolution of the engine. For example, in a 6-cylinder 4-cycle engine there would be three principal peaks in each revolution. There may also exist impulses having a greater or lesser number of peaks per revolution. The number of such impulses or peaks in each revolution of the engine is called the order of the vibration.

Such impulses tend to wind up and unwind the crank shaft. When the frequency of the impulses imparted to the crank shaft by the cylinders is equal to the natural frequency of the shaft itself, a critical speed is said to exist, and under these conditions the winding and unwinding oscillations in the crank shaft tend to build up to a large amplitude and may be of sufficient magnitude to damage the shaft or cause other disturbances.

For example, an 8-cylinder 4-cycle engine crank shaft would receive four power impulses per revolution. In the 1-noded mode of vibration, assuming the crank shaft has a natural frequency of 2400 vibrations per minute, then a critical speed would exist at 600 revolutions per minute.

It is shown in the technical literature on the subject that critical speeds having a different order number than the above (four impulses per revolution), in particular those occurring at one-half and one-third the speed of the above, also exist and some of these may be dangerous.

A twin bank engine of conventional design as heretofore constructed consisted of two crank shafts connected together, and to a generator or other driven machinery, by gearing at one end of the engine. In considering critical speeds of the same order number of such an arrangement there are three modes of torsional vibration which are of importance:

Mode (a).—The after ends (ends opposite generator) of both shafts vibrate in the same direction with equal amplitudes, and the generator, considering the reversal of direction due to the gearing, vibrates in the same direction with a nodal point somewhere between.

Mode (b).—The after ends of the crank shafts vibrate in opposite directions, with a nodal point at the gear and zero amplitude of vibration at the generator.

Mode (c).—The after ends of the crank shafts vibrate in the same direction, and considering the reversal of direction, the generator gear vibrates in the same direction and the generator in the opposite direction, with nodal points between gear and generator, and in each crank shaft.

If the two shafts are so connected in phase angle by gearing or other means at one end only, so that the power impulses fall on one shaft alternately with those on the other, then the criticals of modes (*a*) or (*c*), having an order number equal to the number of power impulses per revolution of either shaft, for example, four per revolution in an 8-crank 4-cycle shaft, will cancel. The impulse imparted to the system by one of the shafts will then exactly cancel that imparted by the other. Such a phasing, however, would not cancel criticals of mode (*b*). In fact, it is the phasing which produces a maximum total vibration of mode (*b*).

If the shafts are connected by gearing at both ends then modes (*a*) and (*c*) are changed very little in frequency and can be cancelled as before by phasing the shafts so that the power impulses of the two shafts alternate. But now mode (*b*) can no longer exist since due to the gearing at each end of the shaft the crank shaft nodal points for vibration, in which the two shafts vibrate in opposite directions, are at these gears. Vibration of mode (*b*) having an order equal to the number of impulses per revolution per shaft is therefore eliminated and thus by the use of such gearing at each end of the shafting an object of the present invention is attained.

In the engine with gearing at both ends, other modes may exist. In particular, this system may vibrate so that the nodal points of the crank shafts are at the gears and the midpoints of the crank shafts vibrate in opposite directions. The frequency of this mode of vibration will exceed that of mode *b* and may in some instances be approximately double that of mode (*b*), providing a frequency having its critical speed above the highest operating speed of the engine, and therefore not dangerous.

In the twin bank engine so arranged with gearing at each end, a mode of vibration producing criticals of an order number double the number of firing impulses per shaft per revolution, i. e., order number eight in a 16-cylinder engine, also exists. These criticals, in general, will not be cancelled by the phase angles adopted to cancel certain of the criticals so far discussed. If with this arrangement a flexible coupling is placed between the gearings and the generator then this frequency can be so far lowered that the order number eight critical in a 16-cylinder engine is placed below the lowest operating speed. Thus the aforesaid object of the invention is further attained. The use of such a flexible coupling is not necessarily coupled with the use of gearing at each end of the shaft as a necessary feature of attaining this object of the invention, however.

It has been found that an engine constructed as aforedescribed to be free from harmful engine and generator critical speeds in the normal operating range of speeds of the engine, provides a great latitude insofar as auxiliary drives are concerned. That is to say, the various auxiliaries of the engine may be driven from the crank shafts and gears without consideration being given as to the effect of such drives on the torsional vibration problems of the engine. This is an added advantage of the present invention. Thus the pumps and other auxiliaries (not shown) may be driven by the idler gear **34** if desired, or from the gears **33**, or from the drives for the cam shafts **17**.

Each of the cam shafts **17**, at its rear end, is secured to a cam shaft gear **59**, the cam shafts adjacent the gears being supported in bearings **60** similar to the bearings **16**, the bearings **60** being supported on the rearmost caps **26** in a manner similar to the manner in which the caps **15** support the bearings **16**. Each of the cam shaft gears **59** meshes with a separate gear **61** secured to the rear end of the adjacent rear gear shaft **22**.

In an engine of the present type, wherein an idler gear is employed between crank shaft gears at the ends of the crank shafts, there is likely to be backlash between intermeshing gears, due to any of the usual causes. Such backlash, if allowed to occur, besides unduly wearing the gears, causes objectionable noise and sometimes results in fractures. Such backlash is prevented between the crank shaft gears and idler gears in the instant engine by means of a torque shaft **62**, connected at its forward end to the gear shaft **29** and at its rear end to the gear shaft **35**. The torque shaft is supported throughout its length by two-piece bearings **63**, the lower half **64** of each of which is formed integrally with a wall **14** and the upper half of which is formed by a cap **65** bolted to the lower half, the walls extending

upward between the crank shafts in order to support the torque shaft 62.

The gear shaft 29 is closed at its inner end by a block 68 to which is secured a hollow coupling 67, tap bolts 69 being employed for securing the block 68 to the gear shaft 29 and the coupling 67 to the block. The torque shaft 62 is secured in the hollow of this coupling.

The rear end of the torque shaft fits in an orifice 76 formed in a flanged coupling 77, and is held against rotation relative thereto by keys 78 and keyways 79. The couplings 77 consists of a tubular body 80, in which the orifice 76 is formed, and a flange 81. The rear wall 82 of the body 80 is provided with sockets 83 for a purpose presently to appear. The flange 81 is provided with the elongated orifices 84 through which studs 85 extend, the studs being threaded at their rear ends into threaded orifices 86 in a flange 87 formed integrally with the gear shaft 35 at the forward end thereof. The periphery of the flange 81 contains serrations 88 and the periphery of the flange 87 contains serrations 89. A retainer 90 is disposed around the peripheries of the flanges 81 and 87 and is provided with serrations 91 engaging the serrations 88 and serrations 92 engaging the serrations 89, connecting the coupling 77 to the gear shaft 35 against relative rotative movement. The retainer 90 has a flange 93 bearing against the forward face of the flange 81, and a shouldered washer 94 having orifices for mounting it on the studs, fits partly within and bears against this flange 93. Nuts 95 on the forward ends of the studs hold the washer 94, retainer 90, coupling 77 and gear shaft 35 together.

The torque shaft is twisted before it is secured to the gear shaft 35. That is to say the shaft in its twisted state forms part of the completed engine. It is energized by twisting it before it is placed in use so that it may perform its function when the engine is operating. It is with this meaning that such terms as "twist," "twisting" or "twisted" are employed hereinafter, and in the claims when used in connection with the torque shaft. The shaft exerts a force on the gear shafts 29 and 35 urging them to rotate in opposite directions, and holding the teeth of gears 28 and 34, in pressure engagement with the teeth of the crank shaft gears 27 and 33 respectively. This prevents any lost motion in the gears and eliminates the undesirable backlash condition which would be present if the torque shaft were not employed. Thus the second object of the present invention is attained.

Referring to Figs. 6, 9 and 10, a tool 96 is there shown for twisting the torque shaft 62. The tool consists of a shaft 97 having a head 98 at one end and a splined portion 99 at the other end. Orifices 100 are formed in the head and dowels 101 are disposed in the orifices and extend from the head in a direction opposite to the shaft 97. An arm 102 is secured to the splined end of the shaft by means of splines 103 formed in one end of the arm. The free end of the arm is enlarged, the enlarged portion extending in the direction of the head 98. A tapered orifice 104 is formed in the enlargement extending at right angles to the splines 103. Another arm 105 is rotatably mounted on the shaft 97, the arm at one end having an orifice 106 through which the shaft extends, the arm 105 being disposed between the arm 102 and the head 98, but adjacent the arm 102. The free end of the arm 105 is enlarged, the enlargement extending in a direction toward the arm 102 and overlapping the enlargement of the arm 102. A tapered orifice 107, oppositely directed to the orifice 104, is formed in the enlargement of arm 105 in alignment with the orifice 104. The arms are radial of the axis of the shaft 97 and spaced apart at their free ends, as is shown in Fig. 9.

A bolt 108 extends through the orifices 104 and 107. The bolt has a head 109 and a washer 110 at one end engaging the enlargement of arm 105 at one side thereof and a nut 111 and a washer 112 engaging the enlargement of the arm 102 at the opposite side thereof, the face of the washers adjacent the enlargements being convex and the adjacent faces of the enlargements having concave seats 113 therefor. The tapered orifices and the convex faces and concave seats permit the nut to be tightened up on the bolt, forcing the arms toward each other in a direction to decrease the space therebetween. The arm 105 further includes a bolting flange 114 surrounding the orifice 106, and orifices 115 are formed in the bolting flange for a purpose presently to appear.

The operation of the twisting tool is as follows: The torque shaft 62 having been assembled as aforedescribed with the nuts 95 removed and the washer 94 and retainer 90 retracted, the shaft coupling 77 is thereby free from the gear shaft 35 and free to rotate relative thereto due to the elongated orifices 84 by which the coupling is mounted on the studs 85. The tool is then applied in position for twisting the torque shaft 62, the shaft 97 being inserted in the hollow interior of the gear shaft 35 and the dowels 101 being inserted into the sockets 83 in the coupling 77. The dowels 101 and sockets 83 are so spaced that they register in only one position of the shaft 97. The nut 111 is, at this time, retracted, thereby allowing the arm 105 to be rotated relative to the arm 102 to its proper position. The bolting flange 114 of the arm 105 engages a bolting flange 116 formed on the rear end of the gear shaft 35 and when the arm 105 is in its proper position the orifices 115 are in alignment with threaded orifices 117 formed in the bolting flange 116. The orifices 115 and 117 are so spaced that they will register in only one position of the arm 105, thereby insuring proper relation of the arms 105 and 102 prior to twisting the shaft 62. Tap bolts 118 are then inserted into the orifices 115 and threaded into the orifices 117, firmly securing the arm 105 to the gear shaft 35.

To twist the shaft 62 it is then merely necessary to screw up the nut 111. As the nut is screwed up, the arm 102 rotates and moves toward arm 105, decreasing the space therebetween and twisting the shaft 62, the coupling 77 rotating relative to the gear shaft 35, this relative rotation being permitted by the elongated orifices 84. When the shaft 62 has been twisted a pedetermined extent, the retainer is then moved rearward into its retaining position, with the serrations 91 and 92 in engagement respectively with the serrations 88 and 89. The washer 94 is then placed on the studs 85 and the nuts 95 are screwed on the studs 85, completing the assemblage and preventing displacement of the retainer 90. The serrations prevent relative rotation between the coupling 77 and the gear shaft 35, thereby holding the twist in the torque shaft 62 and the teeth of the idler gears 28 and 34 against the teeth of their corresponding crank shaft gears, it being understood that the twisting

is in the direction that will cause the driving faces of the teeth of the crank shaft gears at the generator end of the engine to engage the corresponding faces of the adjacent idler gear teeth. The twisting is sufficient to prevent the aforesaid undesirable backlash but not of an amount to produce excessive pressure between the engaging teeth. After the twisting has been effected the tool is removed.

While there has been hereinbefore described an approved embodiment of this invention, it will be understood that many and various changes and modifications in form, arrangement of parts and details of construction thereof may be made without departing from the spirit of the invention and that all such changes and modifications as fall within the scope of the appended claims are contemplated as a part of this invention.

The invention claimed and desired to be secured by Letters Patent is:

1. A sixteen-cylinder four-cycle twin bank internal combustion engine comprising two banks of power cylinders; pistons in said cylinders; connecting rods secured to said pistons; a crank shaft connected to the connecting rods of one of said banks, receiving four power impulses per revolution therefrom; a crank shaft connected to the connecting rods of the other of said banks, receiving four power impulses per revolution therefrom; gears tying together said crank shafts at one end thereof; means driven from said end of said crank shafts, said crank shafts having a harmful mode of vibration in which the other ends of said crank shafts tend to vibrate in opposite directions, with a nodal point thereof at each crank shaft gear and zero amplitude of vibration at said means, in the normal operating range of speeds of said engine; and gears tying together said crank shafts at the other end thereof, said tying together of said crank shafts at both ends thereof changing said mode of vibration to a mode of vibration in which the mid points of said crank shafts vibrate in opposite directions, through nodal points thereof at each of said crank shaft gears at an increased frequency not more than double that of said first mentioned mode, whereby said last mentioned vibration occurs at a speed above said normal operating range of speeds of said engine.

2. A twin bank internal combustion engine comprising two banks of power cylinders; pistons in said cylinders; connecting rods secured to said pistons; a crank shaft connected to the connecting rods of one of said banks, receiving power impulses therefrom; a crank shaft connected to the connecting rods of the other of said banks, receiving power impulses therefrom; gears tying together said crank shafts at one end thereof; an electric generator; a drive shaft connected at one end to said generator and at the other end to said gears for driving said generator; and gears tying together said crank shafts at the other end thereof, said tying together of said crank shafts at both ends thereof effecting avoidance of certain harmful critical speeds in the normal operating range of speeds of said engine.

3. A twin bank internal combustion engine comprising two banks of power cylinders; pistons in said cylinders; connecting rods secured to said pistons; a crank shaft connected to the connecting rods of one of said banks, receiving power impulses therefrom; a crank shaft connected to the connecting rods of the other of said banks, receiving power impulses therefrom; gears tying together said crank shafts at one end thereof; an electric generator; a torsionally flexible drive shaft connected at one end to said generator and at the other end to said gears for driving said generator; and gears tying together said crank shafts at the other end thereof, said tying together of said crank shafts at both ends thereof and said flexibility of said generator drive shaft effecting avoidance of certain harmful critical speeds in the normal operating range of speeds of said engine.

4. A twin bank internal combustion engine comprising two banks of power cylinders; pistons in said cylinders; connecting rods secured to said pistons; a crank shaft connected to the connecting rods of one of said banks, receiving power impulses therefrom; a crank shaft connected to the connecting rods of the other of said banks, receiving power impulses therefrom; gears tying together said crank shafts at one end thereof; an electric generator; a torsionally flexible drive shaft connected at one end to said generator and at the other end to said gears for driving said generator; and gears tying together said crank shafts at the other end thereof, said tying together of said crank shafts at both ends thereof and said flexibility of said generator drive shaft effecting avoidance of certain harmful critical speeds in the normal operating range of speeds of said engine, said crank shafts being phased a predetermined degree effecting, in cooperation with said tying together of said crank shafts at one end thereof, avoidance of certain other harmful critical speeds in said normal operating range of speeds of said engine.

5. A sixteen-cylinder four-cycle twin bank internal combustion engine comprising two banks of power cylinders; pistons in said cylinders; connecting rods secured to said pistons; a crank shaft connected to the connecting rods of one of said banks, receiving four power impulses per revolution therefrom; a crank shaft connected to the connecting rods of the other of said banks, receiving four power impulses per revolution therefrom; gears tying together said crank shafts at one end thereof; an electric generator; a torsionally flexible drive shaft connected at one end to said generator and at the other end to said gears for driving said generator; and gears tying together said crank shafts at the other end thereof, said tying together of said crank shafts at both ends thereof and said flexibility of said generator drive shaft effecting avoidance of certain harmful critical speeds in the normal operating range of speeds of said engine, said crank shafts being phased forty-five degrees effecting, in cooperation with said tying together of said crank shafts at one end thereof, avoidance of certain other harmful critical speeds in said normal operating range of speeds of said engine.

6. In a twin bank internal combustion engine having two parallel crank shafts geared together at one end and a generator driven from one of said gears, in which engine and generator there are four modes of vibration effecting harmful critical speeds in the normal operating range of speeds of said engine, said modes being first, vibration in the same direction of the ends of the crank shafts remote from said generator with equal amplitudes and of the generator in the same direction with a nodal point somewhere between, second, vibration of said remote ends in the same direction, of said generator gear in the same direction and of said generator in the opposite direction with a nodal point between said gen-

erator gear and generator and in each crank shaft, third, vibration of said remote ends in opposite directions with a nodal point of each crank shaft at the gear thereon and zero amplitude of vibration at said generator, said first three modes effecting critical speeds of an order number equal to the power impulses imparted to each crank shaft by its pistons per revolution, and fourth, vibration effecting a critical speed of an order number double that of the order number of the critical speeds produced by said first three modes of vibration, the method of eliminating said harmful critical speeds from the normal operating range of speeds of said engine, which consists in phasing said crank shafts a predetermined degree effecting, in cooperation with said tying together of said crank shafts, avoidance of said first and second modes of vibration, said phasing causing vibration-producing impulses emanating from one of said crank shafts to exactly cancel those emanating from the other of said crank shafts for said first and second modes of vibration, tying together said other ends of said crank shafts by gears, said tying together of said crank shafts at both ends thereof raising the frequency of said third mode of vibration and correspondingly raising its critical speed above said normal operating rang of speeds of said engine, said frequency being raised by changing said third mode of vibration through nodal points at one end only of said crank shafts to vibration through nodal points at both ends of said crank shafts, and further introducing an element of torsional flexibility into the drive from said generator gear to the armature of said generator, said flexibility lowering the frequency of said fourth mode of vibration and correspondingly lowering its critical speed below the normal operating range of speeds of said engine.

7. A twin bank engine comprising two banks of cylinders, each having a separate crank shaft, one of said crank shafts being phased relative to the other of said crank shafts a number of degrees predetermined to cause power impulses to fall at regular intervals alternately on said crank shafts; a set of gears at each end of said crank shafts, each set including a gear secured to each end of said crank shafts adjacent thereto and an intermediate gear intermeshing with said adjacent crank shaft gears, one of said intermediate gears being an electric generator drive gear; an electric generator; and a torsionally flexible drive shaft for said generator, connected at one end thereto and at its other end to said intermediate drive gear.

8. The combination of a train of intermeshing gears having two spaced gears and an intermediate gear; another train of intermeshing gears having two spaced gears and an intermediate gear, said trains being oppositely disposed and spaced from each other; a shafting connecting a spaced gear of one of said trains with an opposed spaced gear of the other of said trains for rotation therewith; another shafting connecting the other of said spaced gears for rotation therewith; an intermediate shafting including a torque shaft, said intermediate shafting being connected at one of its ends to one of said intermediate gears, the other of its ends and the other of said intermediate gears being detachably connected together, said connections providing rotation of said intermediate shafting with said intermediate gears; and a torque shaft twisting appliance having a part detachably connected to said intermediate shafting at its detachably connected end, another part detachably connected to said detachable intermediate gear, said parts coacting to twist said torque shaft when rotated in opposite directions, and means operable to rotate said parts in said opposite directions for twisting said torque shaft, said twist being maintained in said torque shaft when said intermediate shafting is attached to said detachable intermediate gear, said twisted shaft producing forces tending to rotate said intermediate gears in opposite directions and said spaced gears cooperating to resist said forces, thereby preventing harmful backlash of the gears of the respective trains.

9. The method of avoiding harmful critical speeds in the normal operating range of speeds of a twin bank internal combustion engine driving an electric generator which consists in phasing the crank shafts a predetermined degree and tying the crank shafts together at one end thereof by gears, thereby avoiding harmful critical speeds of certain modes of vibration, tying the crank shafts together at their other ends by gears, thereby avoiding a harmful critical speed of another mode of vibration, said harmful critical speeds being of an order number equal to the number of power impulses imparted to each engine crank shaft per revolution, and torsionally flexibly connecting the generator armature to one of said gears for driving said armature, thereby avoiding a harmful critical speed of an order number substantially double said first mentioned order number.

10. A twin bank internal combustion engine comprising two banks of power cylinders; pistons in said cylinders; connecting rods secured to said pistons; a single crank shaft having its cranks connected to all the connecting rods of one of said banks for receiving power impulses therefrom; a single crank shaft having its cranks connected to all the connecting rods of the other of said banks for receiving power impulses therefrom; a set of gears tying together said crank shafts at one end thereof; equipment driven from said end of said crank shafts; a torsionally flexible drive shaft connected at one end to said equipment and at the other end to said set of gears for driving said equipment; and another set of gears tying together said crank shafts at the other end thereof, all of said cranks being disposed between said sets of gears, said tying together of said crank shafts at both ends thereof and said flexibility of said equipment drive shaft effecting avoidance of certain harmful critical speeds in the normal operating range of speeds of said engine.

11. A twin bank engine comprising two banks of power cylinders; pistons in said cylinders; connecting rods secured to said pistons; a power transmitting crank shaft having cranks connected one to each connecting rod of one of said banks; another power transmitting crank shaft having cranks connected one to each connecting rod of the other of said banks; a train of gears at each end of said crank shafts, each train including a gear mounted on and secured to each of said crank shafts; and a twisted shaft, said trains further including each an intermediate gear, one of said intermediate gears being mounted upon and secured to said twisted shaft at one end thereof and the other intermediate gear being mounted upon and secured to said twisted shaft at the other end thereof, said twisted shaft exerting forces on said intermediate gears tending to rotate them in opposite directions, and said crank shaft gears cooperating

to resist said forces, whereby the teeth of said intermediate gears are held in pressure engagement with the teeth of their respective engaged crank shaft gears, thereby preventing harmful backlash of the gears of the respective trains.

12. A twin bank internal combustion engine comprising two banks of power cylinders; pistons in said cylinders; connecting rods secured to said pistons; a single crank shaft having its cranks connected to all the connecting rods of one of said banks for receiving power impulses therefrom; a single crank shaft having its cranks connected to all the connecting rods of the other of said banks for receiving power impulses therefrom; a set of gears tying together said crank shafts at one end thereof; driven equipment; a drive for said equipment connected at one end to said equipment and at the other end to said set of gears including a torsionally flexible coupling device and a shaft connected thereto; and another set of gears tying together said crank shafts at the other end thereof, all of said cranks being disposed between said sets of gears, said tying together of said crank shafts at both ends thereof and said flexibility of said device effecting avoidance of certain harmful critical speeds in the normal operating range of speeds of said engine.

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