Case.	Ratio of span.	Ratio of deflections.	Ratio of spindle diameter to preserve constant deflection.
1. Two outside bearings. Fig. 30a	1.86	6.5	1.6
2. One outside and one inside bearing. Fig. 30b	1.44	3	1.3
3. Two inside bearings. Fig. 30c	1	1	1

It will be noted that no allowance has been made for the buoyancy of the medium (water) in which the rotor revolves. The great importance of keeping the distance between bearings in a multi-stage turbine-pump as short as possible is abundantly clear from the foregoing, for with the more or less customary type, Case 1, Fig. 30a, with outside bearings at each end, it is seen we have a deflection of six and a half times that of a pump with two internal bearings. The direct result of this extra deflection is that the clearances between the outside of the eye of the impellers and the neck-ring must be increased to allow of the impellers revolving without touching, and this increased clearance necessarily means a correspondingly increased leakage and loss of efficiency.

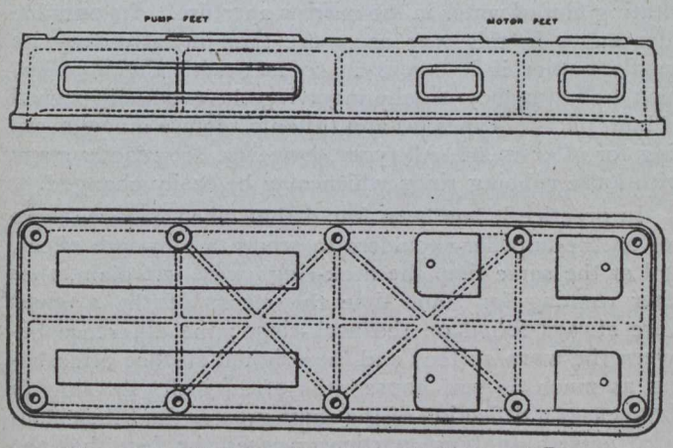

Fig. 33.—Bedplate for "Ring" Type of Pump

Further, as has been shown, the passage of a large volume of water through the running clearance means increased wear and a tendency to push the walls apart, and therefore force the impeller and shaft still farther out of the straight with consequent friction against the adjacent neck-ring surface. Dynamic out-of-balance may, and, very probably, will exist, even though considerable care has been taken in the workshop to overcome it; this factor is a very important consideration, and calls for a very stiff shaft to resist its possible occurrence, because, if the shaft and impellers are thrown out due to this, then further clearance at the neck-rings is necessary or abrasion will result. The question of the reactive effect of an impeller discharging unequally round its circumference is capable of so many variations that the only practical way to overcome this also, is a mechanical construction that will resist deflection, that is, a stiff shaft.

There is a further disturbing influence which is more active in smaller pumps, namely, the effect of the hand-packed and often ill-adjusted stuffing-box and gland; this detail is always standard for one end of the pump, and sometimes found at both suction and delivery ends. Apart from the cutting effect of such a packing on the shaft or its sleeve, it also, by reason of its compression in screwing up, tends to set the shaft out of the true centre, and so may intensify many other similar influences. The risk of outside bearings, separate or overhung, being slightly out of centre, must also not be forgotten. For very many reasons, therefore, it is extremely important that the distance between bearings be kept as short as possible, and to do this successfully, internal, specially designed, large diameter, grease-lubricated bearings are essential. Summarizing the effect of a long distance between bearings, we have:—

(a)—Increased deflection of rotor.
(b)—Increased neck-ring clearance.
(c)—Increased leakage from delivery to suction.
(d)—Increased wear thereby, and
(e)—Decreased efficiency.

Turning now to the dimensions of the rotor, the table shows the diameter of the shaft does not increase as fast as the length of span increases. However, a very serious increase in size (1.6 times) is entailed by the increase in span consequent upon changing from two internal bearings to two external bearings. Obviously increasing the diameter of the shaft will give the decreased deflection desired, but then it introduces a larger diameter of impeller boss and entrance eye, thus bringing about a corresponding drop in efficiency as well as more leakage owing to the larger leakage area consequent upon the increase in diameter of the boss and the neck-rings. It is clear, therefore, that securing the stiffness of a shaft by increasing its diameter is an inefficient method, for, besides the increased area for leakage through the neck-rings, we have much worse conditions of entrance in larger and more rapidly rotating eye and inlet edge of the impeller vanes.

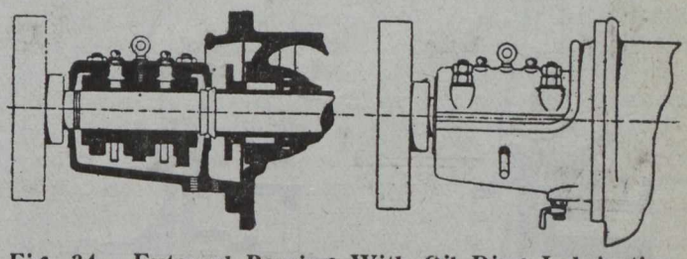

Fig. 34.—External Bearing With Oil Ring Lubrication

The desirable condition, therefore, from all points of view, is to use the smallest diameter of shaft with the shortest distance between the bearings.

Leakage Between Rotor and Stator

The leakage through the neck-rings may now be considered under different conditions and clearances. The material of these rings is the first important consideration. It is obvious that a material should be adopted in the first place of such a type that it will not tend to drag or tear if accidentally touched or rubbed by the running impeller. Material of a hard "short" nature like cast iron will meet this condition, and in practice the smallest clearance can be successfully run with such neck-rings; they are, however, subject to corrosion, particularly with acid waters, as are frequently met with in mines.

The impeller, for the reason of susceptibility to corrosion, together with considerations of the necessary strength to resist the centrifugal effects of high speeds, is usually made from phosphor-bronze; we therefore frequently get in practice phosphor-bronze impellers running in phosphor-bronze neck-rings, though it is obvious that dissimilar metals would be preferable. A phosphor-bronze impeller with a cast-iron neck-ring is a better combina-