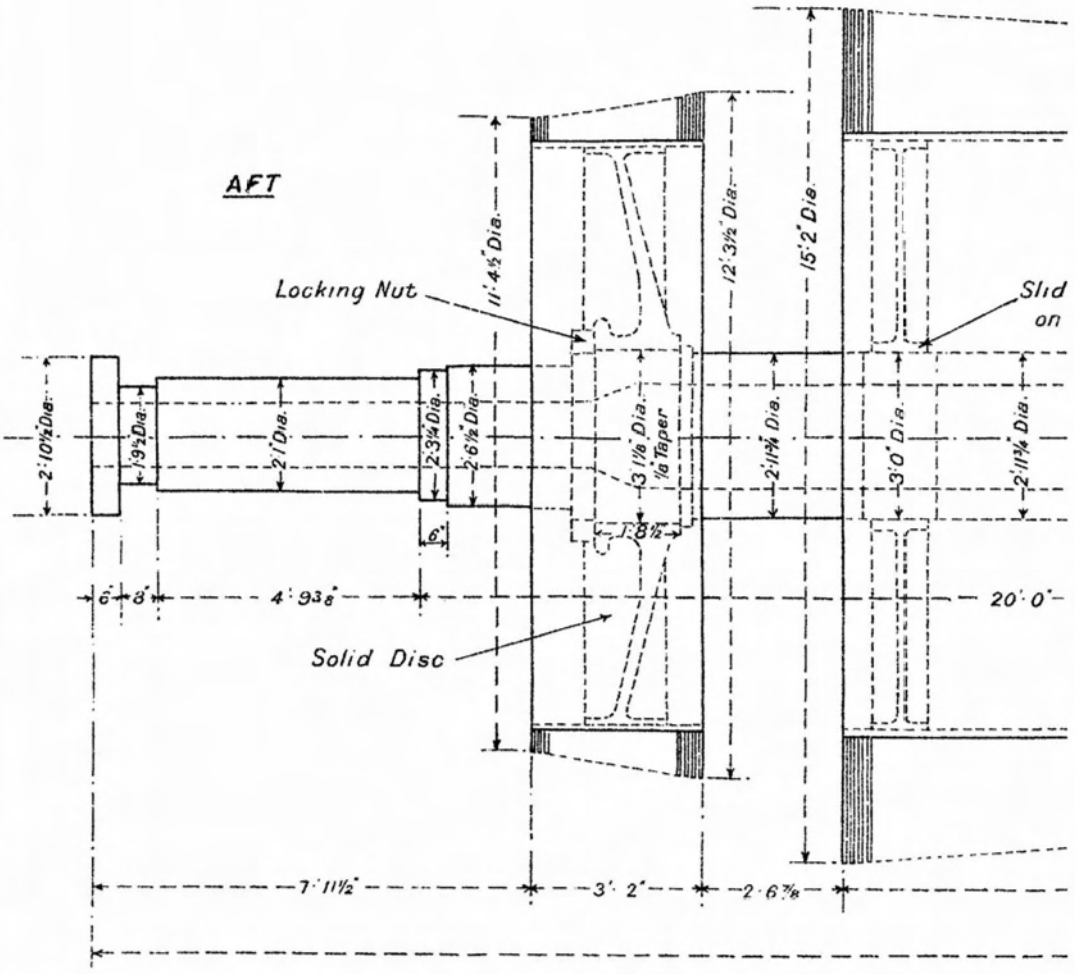
H. M. S.

L. P. & ASTERN

FIG

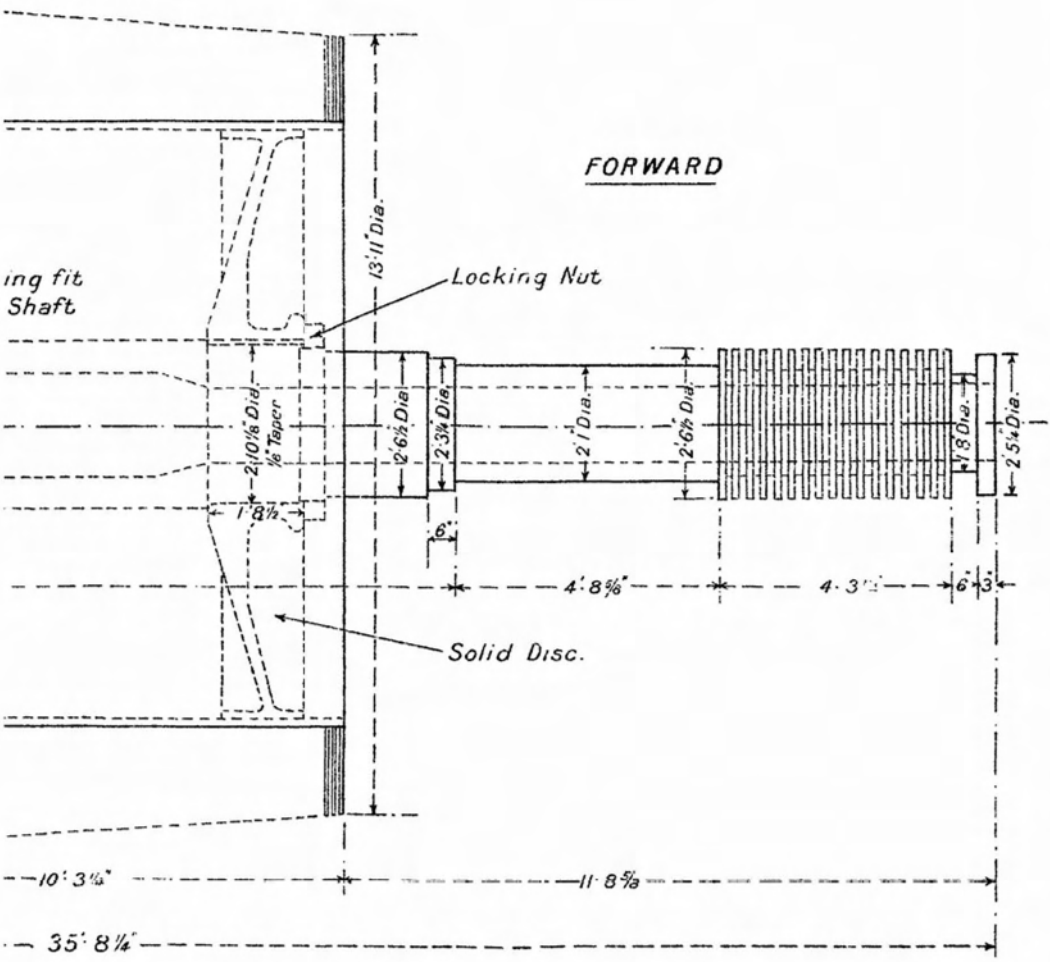


Estimated Total

7322. WT 12055/8265. 1800 5.36.

R E N O W N
TURBINE ROTOR.

.1.



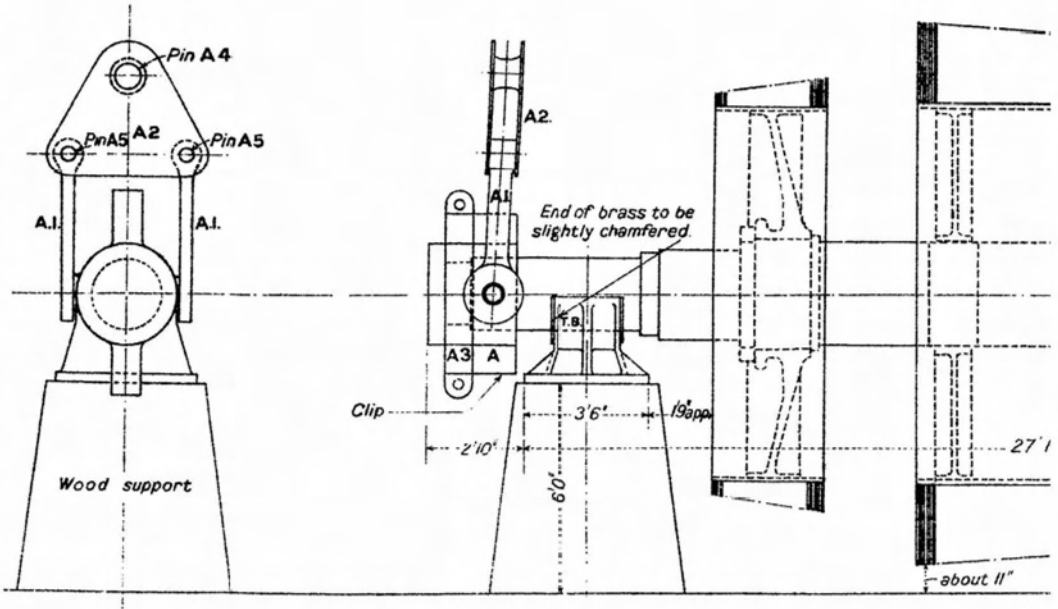
Weight 79 Tons.

H. M. S.

STARBOARD L. P. AND

GENERAL ARRANGEMENT OF ROTOR IN TEMPOR

FIG.

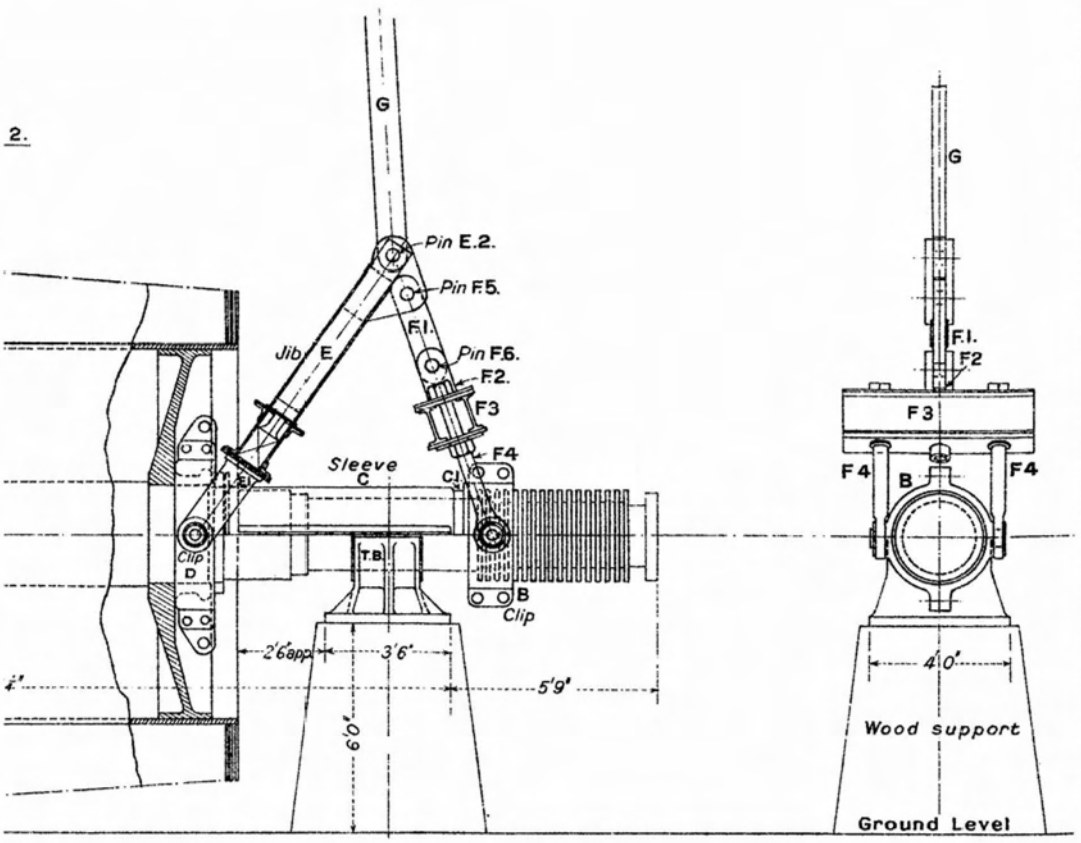


"RENOWN"

ASTERN TURBINE ROTOR

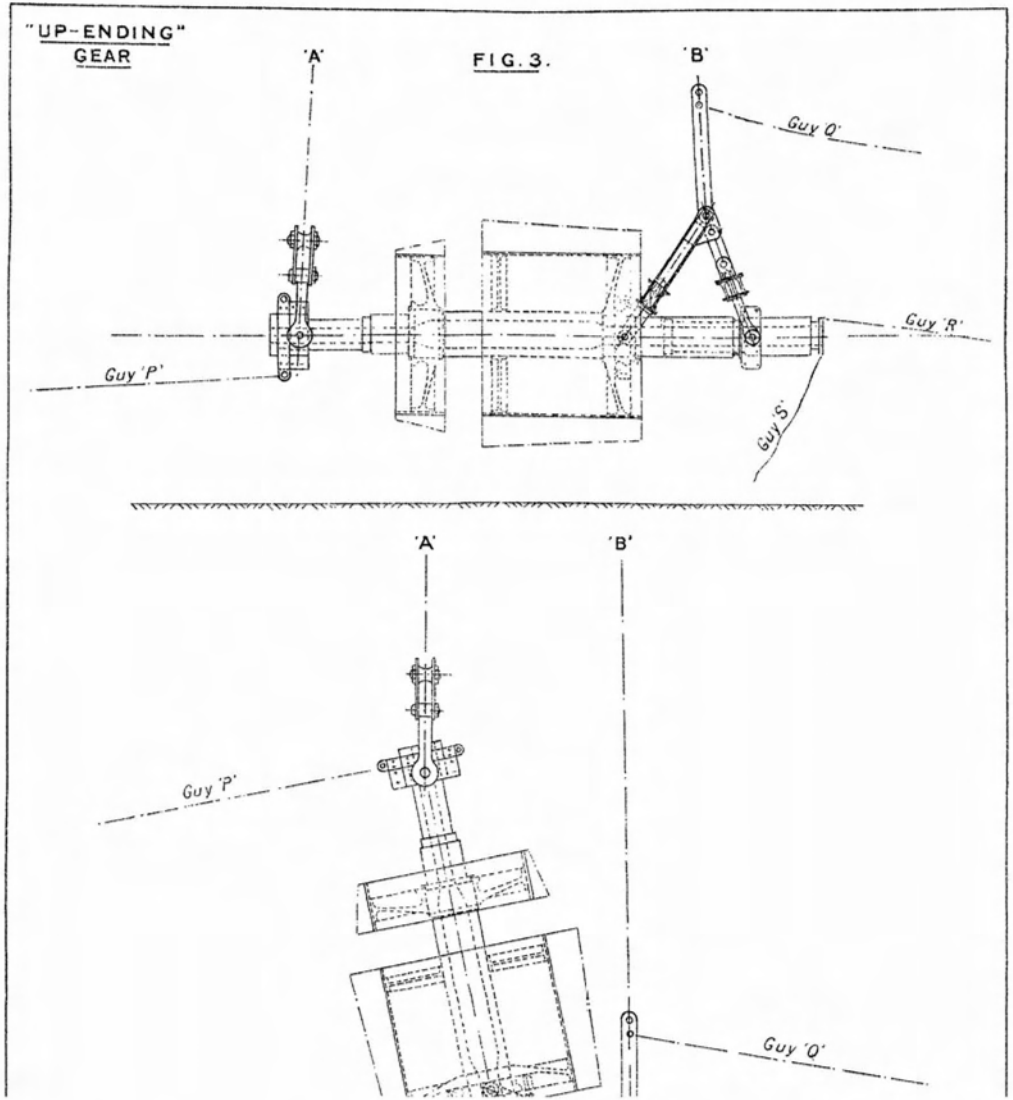
ARY BEARINGS WITH LIFTING GEAR FITTED.

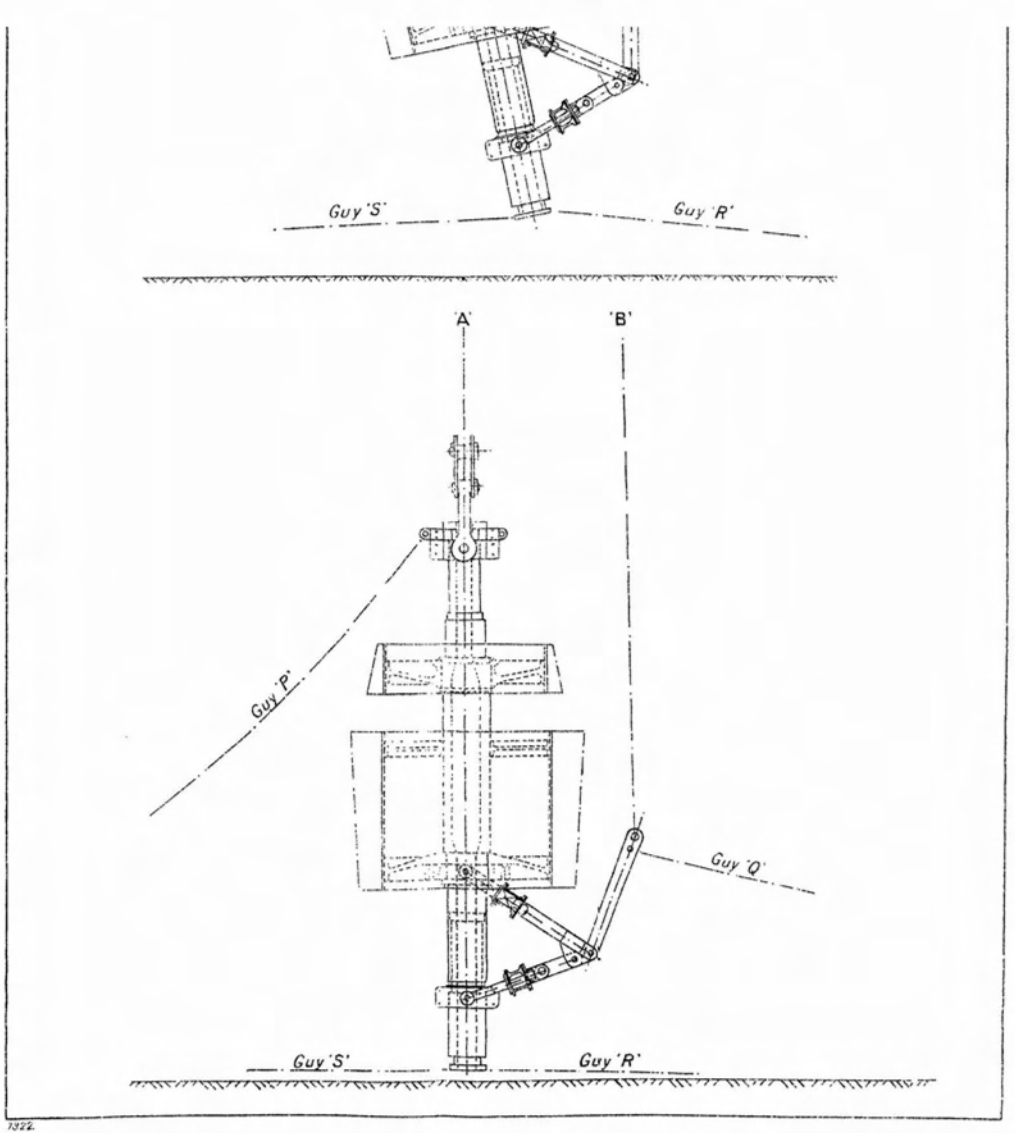
2.



"UP-ENDING" GEAR

FIG. 3.





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No. 2

REPAIRS TO LARGE L.P. TURBINE

Periodical examinations of the starboard L.P. rotor of *H.M.S. Renown* showed that the sliding boss at the after end was becoming progressively loose on the shaft. False bosses were fitted with a view to increasing the bearing surfaces but were not entirely effective, and in the course of time the movement at this point prejudiced the tightness of the coned and keyed connection at the forward end and accordingly it was decided to remove the shaft and effect a thorough repair.

It was impossible to carry this out on board, and after careful consideration of the whole problem, it was decided to lift the rotor out of the ship and draw the shaft from the ahead drum for transport to the factory. To re-secure the drum on the shaft, it was decided to reinforce the cone of the shaft by electric welding, bore out the boss of the forward wheel, fit new keys and finally shrink this wheel on to the shaft ; in the case of the after wheel to re-bush the bore to give the correct clearance on the shaft. (*See* Fig. 1.)

Particulars.—The weights and sizes of the items concerned are of interest :—

Top Half Casing—

Weight	70 tons
Length (maximum)	22 ft. 11⅜ in.
Breadth (maximum)	19 ft. 2 in.
Height (maximum)	9 ft. 11⅛ in.

Ahead Rotor Drum—

Weight	40 tons
Diameter of drum over blading ..	15 ft. 2 in.
Length overall	10 ft. 3¼ in.

Shaft and Astern Rotor—

Weight	39 tons
Length overall	35 ft. 8¼ in.

The problem of transport had first to be considered, and bearing in mind the size and weight of the rotor, the magnitude of the task can be imagined. Special lifting and " up-ending " gear had to be designed, the latter consisting of the tree trunnion clips A, B and D shown in Fig. 2. A sleeve C was also provided to fit between the forward wheel retaining nut and the nearest thrust collar in order to take the weight of the ahead drum when in the vertical position, should the threads of the retaining nut fail. (*See* Fig. 3.)

Removal and Parting of Rotor.—The ship's lifting gear was used to raise the upper half of the casing clear of the rotor and the casing supported on the supporting columns. The decks, and consequently the lifting gear, were then removed and the casing lifted out of the ship by means of a 240-ton cantilever crane using long wire pendants attached to two beams placed athwartships on the underside of the cover and bolted to it. The crane was also used to lift out the rotor, the following procedure being adopted: the rotor was lifted some 7 ft. or so using the lifting clips and guide columns provided for the purpose and rested on wooden blocks. The ship's lifting gear was then removed except for the inner clips round the shaft to which special gear, obtained for the purpose, was connected. The rotor was then lifted out of the ship, landed in temporary bearings ashore and the blading was covered with asbestos cloth and heavy canvas. (*See* Fig. 4.)

The special " up-ending " gear was now fitted and actually the operation of " up-ending " the rotor was completed in 20 minutes. (*See* Fig. 5.) After all redundant gear had been removed, the rotor was landed on a specially constructed wooden structure. (*See* Fig. 6.)

The lock nut on the shaft was split on both sides and removed. On taking the weight of the rotor shaft, it drew out of the fixed boss immediately, the two keys falling out as their securing screws had sheared.

Simplified " up-ending " gear was fitted, including clip " B " with plain links attached. (*See* Fig. 7.) The shaft with the astern rotor was returned to the horizontal, placed on a crocodile truck and transported to the factory.

The necessity of shrinking the rotor drum to the shaft after repairs involved experiments with gas rings being carried out next, to discover the best arrangement for uniform heating of the boss. On completion, the rotor drum was removed to the factory.

Repair Work in the Factory.—The procedure adopted was as follows :—

(*a*) To bore the fixed wheel boss accurately to a taper of ·030 in. on the whole length as compared to $\frac{1}{8}$ in. previously used.

(*b*) To manufacture a male gauge, machine and fit it accurately to the wheel boss, mark and cut keyways in it and fit the keys.

(*c*) To manufacture a female gauge, machine and fit it accurately to the male, mark and cut keyways from the male and fit the keys.

(*d*) To increase the internal diameter of the female gauge by ·015 in., the shrinkage allowance of the boss.

(*e*) To reinforce and machine the shaft cone to fit the female gauge, re-position the keyways from the gauge and fit the keys.

[*To face page* 12.

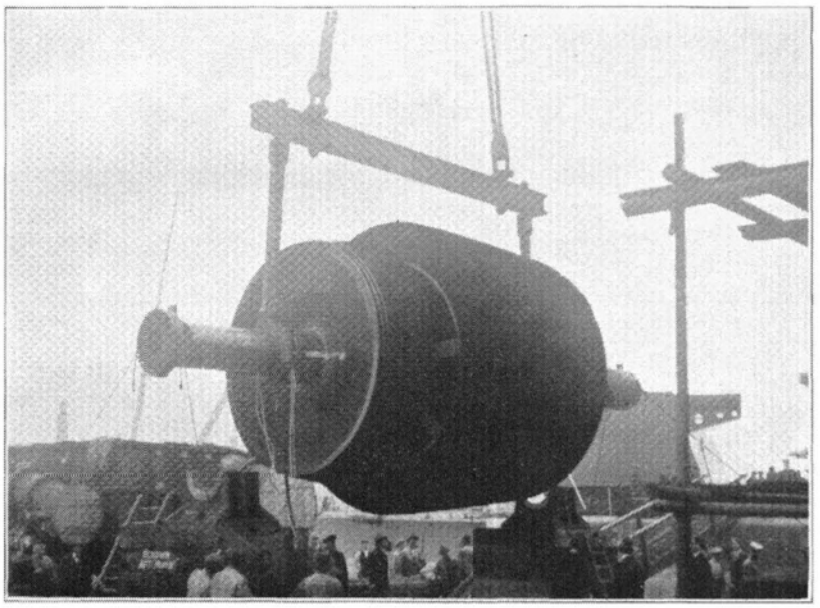


FIG. 4.

Starboard L.P. Rotor, lifted out of ship, being lowered into temporary bearings on shore.
View of aft end of Rotor, with special lifting gear.
Top half S.L.P. Turbine Casing landed on shore is in left-hand bottom corner.

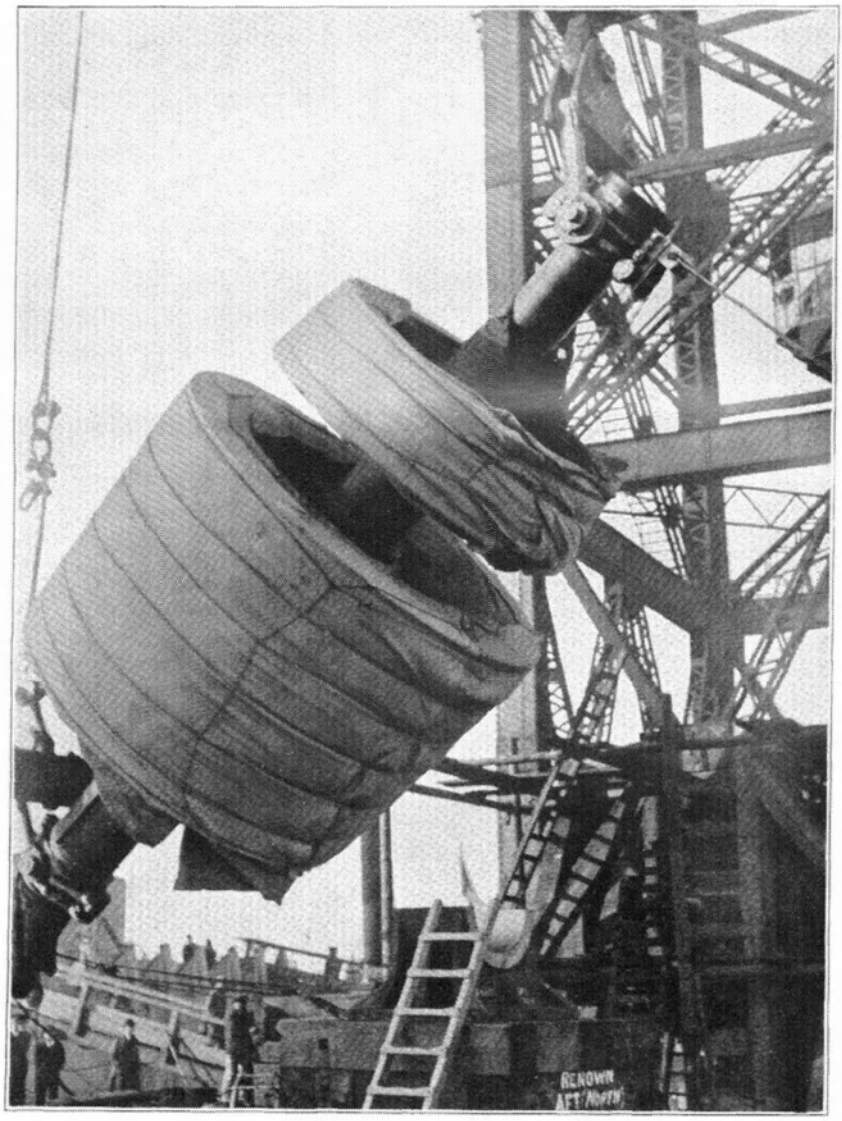


FIG. 5.

Complete Rotor during operation of upending, showing clip " A," aft end.

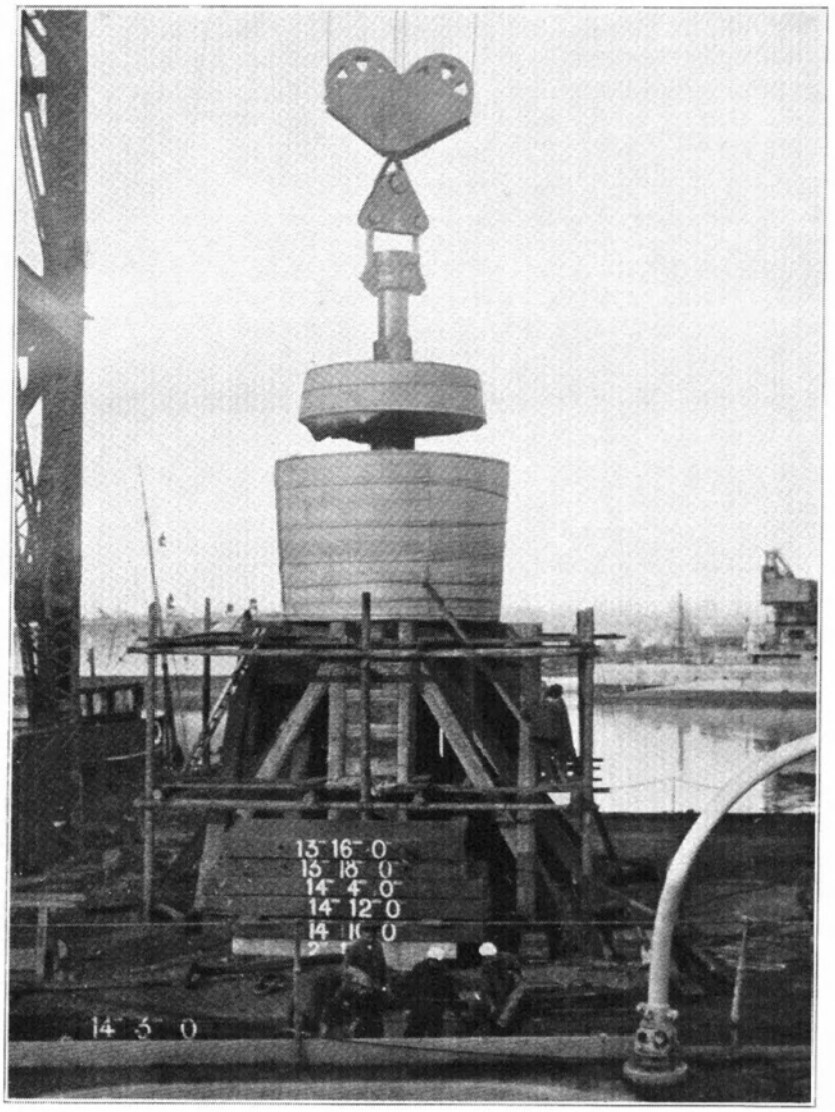


FIG. 6.

Ahead L.P. Rotor landed on wooden structures, and preparations being made for the withdrawal of the shaft.

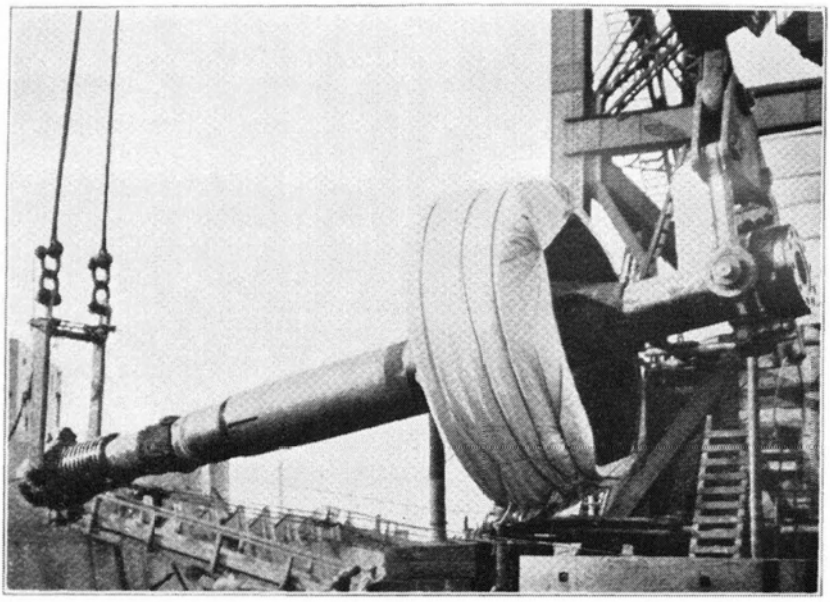


FIG. 7.

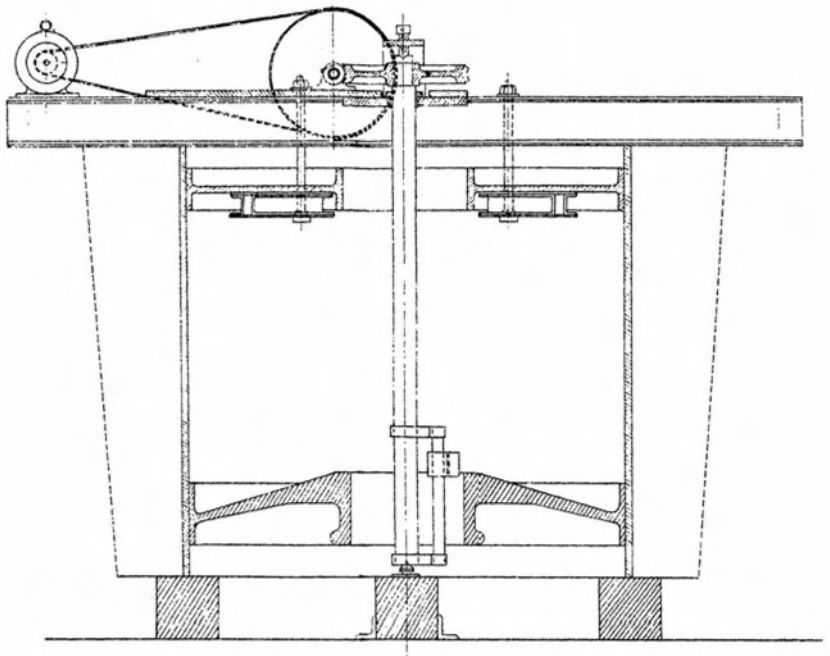
Shaft, after withdrawal, being turned horizontal, for transport to Factory.
Shaft, landed on bearings fitted on crocodile truck, ready for transport to Factory.

H. M. S. RENOWN

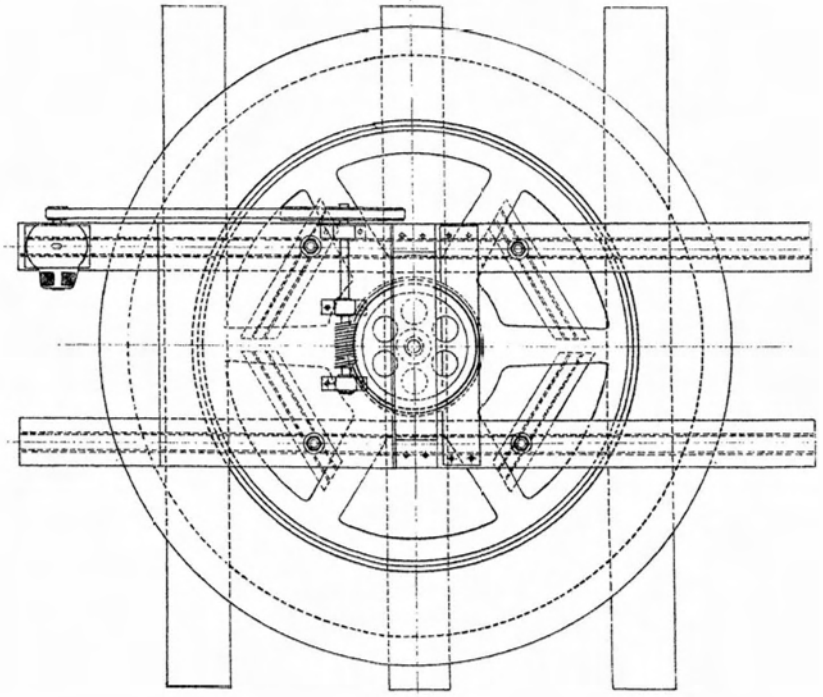
S.L.P. ROTOR

ARRANGEMENT OF BORING GEAR.

FIG. 8.



SECTIONAL ELEVATION



PLAN

(*a*) The ahead rotor drum was placed on end on 18-in. distance blocks on a rigid levelling slab. The boring bar was rigged through the wheel bosses and operated by a motor on top of the drum. (*See* Fig. 8.) A special attachment was made and fitted to the boring bar to enable accurate taper boring to be carried out. The boss was bored with a taper in diameter of ·030 in. over its whole length. The two keyways were then dressed up and given a taper in width of ·009 in. over the whole length, and two keys were made and fitted to within $1\frac{1}{2}$ in. of the lower end of the keyway. Their thickness was such as to allow a clearance of ·015 in. on the backs.

(*b*), (*c*), (*d*) The manufacture of the gauges was complicated by the fact that it was considered necessary to give the keyways in the wheel boss a taper in width of ·009 in. along their 20-in. length and to give the keys $1\frac{1}{2}$ in. draw. This allowance was made to take up the stretch of the keyway due to the shrinking process, and resulted in the following requirements :—

(1) Keys to fit in the keyways in the wheel boss with $1\frac{1}{2}$ in. draw.
(2) The male gauge to be an exact replica of the hole in the wheel boss, but with keys fitting the whole working length of the keyways in the gauge.
(3) The female gauge copied from the male, the keys fitting in it with $1\frac{1}{2}$ in. draw.
(4) Finally, the fitting of the female gauge to the rotor spindle with the keys fitting the whole length of the reinforced cone.

A male gauge of approximately $1\frac{1}{2}$ times the length of the wheel boss was machined to fit the boss accurately with the bottom of the gauge flush with the bottom of the boss. The additional length was allowed in case of errors in machining. The keyways were marked off and, after machining, hand fitted by the following method :—Two blocks 3 in. long were made to fit accurately the portions of the complete keyway at the extremities of the boss. The keyway in the gauge was then filed and scraped until these blocks were an accurate fit in their respective positions, flush with the ends of the keyway in the boss. The gauge was then removed and the full length of the keyway filed and scraped down to a straight edge, the longitudinal axis of the keyway being governed by the recesses positioned in it by the fitting of the blocks at each end. The key was then fitted in the gauge.

The second key was fitted in the same manner and the whole gauge lowered into the boss. The keys jammed when within $1\frac{1}{2}$ in. of the lower end of the boss thus proving the work.

The female gauge was then bored to fit the male gauge and the keys were fitted by the same method as above, using the male

gauge for marking off. The bore of the gauge was then increased by ·015 in. (*See* Fig. 9.)

(*e*) The reinforcing of the shaft cone was carried out by quasi-arc welding applied in strips $\frac{3}{8}$ in. wide and $\frac{1}{4}$ in. deep. To avoid distortion, the welding was carried out in positions alternately 180° and 90° apart.. The first strip was applied along the top of the spindle, after which the spindle was turned through 180° and a similar strip added. A turn back of 90° was now made, after which a second turn of 180° was made and a fourth strip applied. Subsequent strips were added to the four original strips, with the position concerned at an angle of 45° to the vertical, the rotor being turned after each application as above. This method avoided any serious local overheating of the shaft.

The reinforced portion of the shaft cone was now machined with a ·030 in. taper to a diameter ·015 in. larger than the hole in the boss. The female gauge was then offered up and by filing and scraping the cone the gauge was accurately fitted to within $\frac{1}{4}$ in. of the shoulder on the spindle.

The keyways were transferred from female gauge to spindle cone by the use of blocks as before except that, as the keys did not extend for the full length of the cone, in this case " windows " had to be cut in the female gauge in the wake of the extremities of the keyways and the work carried out through them. (*See* Fig. 10.)

Actually when the final fitting took place, the keys jammed with the end of the gauge $2\frac{1}{4}$ in. from the collar on the shaft, thus allowing $2\frac{1}{4}$ in. draw instead of the $1\frac{1}{2}$ in. designed. This was considered acceptable as it would tend to increase the tightness of the keys still more, after shrinkage had taken place.

On completion of the work in the factory, the shaft and the ahead drum were transported separately to the dock side.

Reassembly and Replacement of Rotor.—The ahead drum was placed in its previous position on the wooden structure and the gas rings were fitted, the results of the previous experiments having indicated the best positions (*see* Fig. 11). These were started at their lowest capacity to heat the mass of the metal as uniformly as possible. The rise of temperature and the resulting expansion were checked by frequent surface pyrometer and trammel readings. Control was maintained by regulating the individual gas rings or by varying the number of jets in use in any ring, by means of plugs in the form of brass spills. The intention was to give the boss an expansion of ·050 in. on the diameter, which would mean an increase in the breadth of the keyway of about ·004 in. This would allow sufficient margin over the $2\frac{1}{4}$ in. draw of the keys to prevent jamming when lowering the rotor into place.

A perforated air line was fitted above the upper surface of the diaphragm to hasten the cooling of that part after assembly, the lower ring being kept alight to prevent premature contraction of

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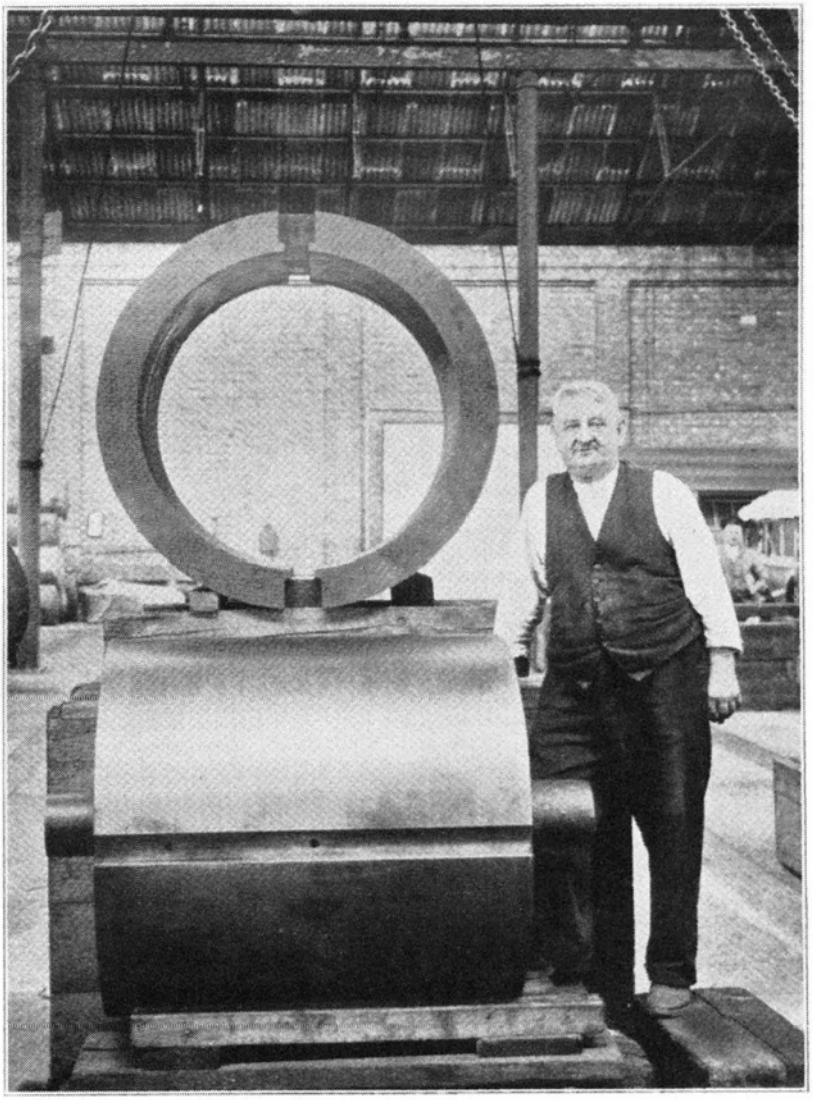


FIG. 9.
View of Male and Female Gauges.

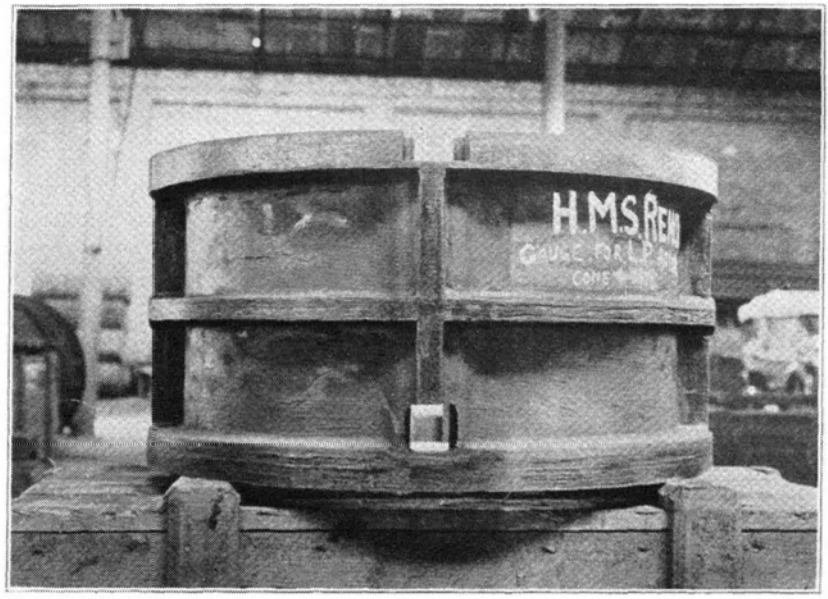
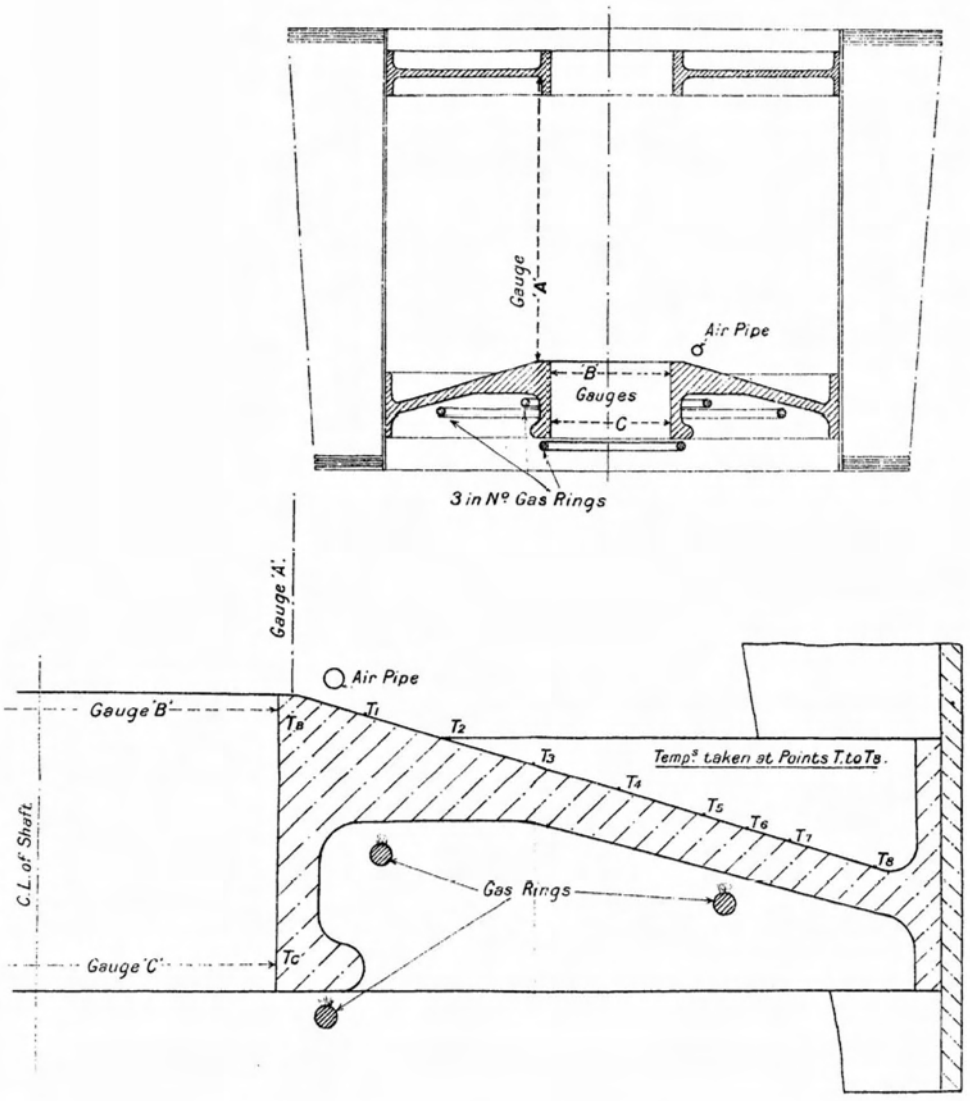


FIG. 10.
Female Gauge—Side view, showing " windows."

SHRINKING OF S.L.P. ROTOR DRUM ON SPINDLE.

FIG. II.



the lower end of the boss, with its relatively small mass, causing the upper end to draw away from the shoulder on the spindle. Meanwhile the rotor shaft was " up-ended " and the lifting gear at the lower end removed.

When the necessary temperature had been obtained the rotor spindle was plumbed above the boss of the upper wheel and twisted for approximate alignment of keys. It was found that, in spite of guying and slow rate of descent, the spindle tended to describe a zig-zag path and to rotate over a wide arc as well. However, the extensive use of wedges and pinch bars with carefully tended guys effectively counteracted this. The lower end of the spindle on entering the fixed boss naturally cut off the main exhaust aperture from the burners below, with the result that the inert gases soon extinguished all rings. However, by removing draught screens, some sort of combustion was maintained in the two most important inner rings.

As soon as the shoulder on the spindle was home on the boss of the wheel the lowering was stopped and the cooling air turned on full bore. The lower gas ring was moderated to maintain an expansion of ·020 in. at this end and a constant watch was kept on the contact between shoulder and boss to ensure that no drawing away took place during cooling. When comparative surface pyrometer readings showed that a positive shrink had occurred at the upper end of the boss, the lower gas ring was extinguished and rapid contraction of the lower end ensued.

The rotor spindle nut, remaining clips of the " up-ending " gear and the false bosses in the sliding wheel were now fitted. The shrink fit was tested by slackening back the rotor spindle nut and inserting a strip of liner brass between it and the boss to act as a feeler. The weight was then taken by the crane and the whole unit lifted 2 in. for 5 minutes. No relative movement took place between the rotor boss and spindle nut, the feeler remaining free the whole time, thus proving the satisfactory nature of the shrink in that it took the whole weight of the ahead drum.

The assembled rotor was returned to the horizontal, landed in the temporary bearings and the nut was hardened up. The ahead drum and spindle were tested for truth by rotating slowly in the temporary bearings by means of a parbuckle strop and the crane purchase, dial micrometers being used at each end of the ahead and astern drums and at the main bearing journals. No error of more than ·010 in. was recorded.

The rotor was then lifted inboard, using the same gear as before and landed on the wooden blocks. The ship's clips, with special connections for the crane purchases, were fitted and the rotor lowered into its working position. As the weather was now changing from fair to bad with rain and rising wind, the casing was lowered with all speed on to the supporting columns to give as much protection as possible.

After taking the final blade clearances, the crane purchases were connected to the top casing and the weight was taken to allow of removal of the supporting columns and final lowering into position. Owing to the unbalanced proportions of the casing when supported at the ends, the lowering movement was slower due to the necessary manipulation of an additional purchase, attached to the heavier side to prevent the casing jamming on the guide columns, and to avoid fouling of the blades.

The final closing up was carried out under bad weather conditions with heavy rain.

The reassembly of the various fittings followed in the normal course and satisfactory sea trials were carried out on completion.

The time taken in the various stages of the work was as follows :—

Commencement of work on board	.. 27th July, 1931
Rotor and shaft lifted out of ship	.. 16th Oct., 1931
Work in factory completed ..	.. 14th Dec., 1931
Rotor and casing replaced in ship	.. 7th Jan., 1932
Sea trials	.. June, 1932

That the repairs were effective has been borne out by the subsequent satisfactory performance of the vessel on service.