TURBO-DRIVEN FANS FOR BOILER ROOMS.

Turbo-driven auxiliaries have not at present made a great advance in the direction of displacing reciprocating auxiliaries in warships, although a few have been fitted in special cases for dynamos, fans, circulating, feed and bilge pumps. Also in the special cases of the vessels fitted with Weir's closed feed system the extractor pumps for removing the water from the condensers are turbo-driven. That they have not come into more general use is due to the fact that the present day high speed, forced lubrication reciprocating engine is a machine of proved reliability, and also at present has a smaller steam consumption than the direct-coupled turbine, its advantage in this respect being even more marked when a considerable portion of the working has to be carried out at reduced powers. It might be claimed that the steam consumption of turbo-auxiliaries does not increase with running wear and tear as in the case of a reciprocating engine, but this claim should not be pressed too far.

With respect to fans, turbo-driven units offer a number of advantages; they afford a neater and more compact arrangement and may be smaller than corresponding reciprocating sets for a similar output; they give a steady flow of air as they are not subject to slight velocity changes per revolution; they may be bolted close up to the deck, and thus, if arranged vertically with the fan uppermost, effect a considerable saving in trunking, which gives as a principal advantage much greater space in the boiler room, although the position of the fan with this arrangement leads, in small vessels, to a local congestion owing to the necessity of having to provide the requisite supports. This consideration has, however, to a great extent, influenced the adoption of such units in special cases where space is of paramount importance as in the "K" Class Submarines and a number of special T.B.D.'s. Two types have been principally fitted :—

(1) The Yarrow-Terry fan driven by a steam turbine of the Sturtevant type, and

(2) Those constructed by the British Thomson Houston Co., in this case the turbine being of the single-wheel impulse type and fitted with three rows of rotating blades. In a few cases some B.T.H. turbines have been arranged with the shaft horizontal and fitted to carry two fans, one each side of the turbine. This arrangement leads to a great saving of space, simplifying fan interference difficulties and incidentally permitting of a larger single turbine being fitted and a better relation of blade and steam speed consequently being obtained.

Geared Fans.

Before considering the question of the application of gearing to fans, it is necessary to comprehend a few of the salient details that govern fan design. A fan is usually specified to deliver a stated quantity of air against a definite pressure, this pressure being that required in the boiler room mainly to impel this desired quantity of air for combustion and products of combustion through the furnace, boiler tubes and uptake, &c.

The velocity of air supply to the inlet eye of the fan will be governed by the difference of pressure between the atmosphere and the reduced pressure created at the suction side of the fan The resistances of the supply trunks will affect this question, and it is modern practice to reduce these resistances to a minimum, for with a given design of fan running at designed revolutions and delivering the stated quantity of air, the total increase of pressure through the fan is constant, and therefore if restrictions in the intake shaft entail a reduction of pressure in the suction side at the fan eye, there will be a corresponding decrease in the boiler room pressure, or, in other words, the conditions will not admit of the required quantity of air being passed through the boilers.

The friction losses suffered by the air in its passage through the fan and shock losses at entry, if any, vary approximately as the square of the velocity of the air; hence the advisability of keeping the air speed as low as possible at these positions is immediately apparent. The external diameter of the fan depends on the speed of rotation and the pressure rise required; the higher the speed the less the diameter for a given pressure. It is usually arranged with reciprocating fans to keep the velocity of the incoming air at the fan eye in the neighbourhood of 40 ft. per second with a speed of rotation not exceeding 450 revolutions per minute, increasing to 50 f.s. in the case of T.B.D.'s with engines running at 600 revolutions. These figures would correspond in well-designed air trunks to a pressure in the fan eye of from $\frac{3}{4}$-in. to 1-in. water gauge respectively below the atmosphere. In the case of a direct coupled steam turbine-driven fan, in order to obtain an efficient turbine, the speed of rotation must be kept fairly high, *i.e.*, not less than, say, 1,000 revolutions per minute. This reduces the fan diameter necessary for a given pressure and a compromise has to be made between an effectual vane length and the air velocity at entrance. For high-speed turbo fans a velocity of 70–80 f.s. at the fan eye is worked to in order to keep the size of the inlet down. The trunks and entrances to the fan eye in such designs therefore require careful consideration, as 70 f.s. represents a theoretical loss of air pressure approaching $1\frac{1}{4}$ ins. From a practical point of view, in addition to the preceding considerations, the fan should also be kept small to minimise centrifugal stresses, thus necessitating with these units much shorter vanes than with the slower running type. This consideration is not without its effect on the discharge side which it is advisable to point out. In an ordinary fan the air is discharged with a large component velocity in the tangential direction, the air being collected in and discharged for best efficiency and to avoid interference with other fans and fittings from a volute casting, if space permits. Owing to the short length of vanes in a turbo fan it is not possible to change the velocity of the air so easily as in fans with longer blades, and the discharge is almost entirely in a radial direction. Such fans are therefore not usually fitted with a casing but given a free radial discharge. It is, however, necessary to arrange some small section of casing or deflectors if two fans are fitted side by side, to avoid interference one with the other and consequent loss of efficiency.

It will be appreciated from the foregoing considerations that there are some analogous features between the direct-drive turbo-fan and the direct-drive turbine actuating a propeller shaft, and the adoption of gearing permits a greater efficiency of turbine and fan or propeller respectively, being separately aimed for. In the case of the turbo-fan, the turbine itself is, however, the most important considerations when all aspects of the question are taken into account.

One vessel in H.M. Service, the T.B.D. "Tourmaline," has been fitted with geared fans, and it is the intention to give a detailed description of this fan and compare it in its salient details with a similarly powered direct-driven fan.

In its main features the description will apply in general to the direct-drive fan, the various modifications being obvious and not requiring special indication.

The turbine is of the single wheel type, carrying three rows of rotating blades. The steam is led on to the blades by convergent divergent nozzles, and is re-directed between the successive rows of rotating blades by stationery guide blades, which are fixed to a mild steel segmental carrier. The turbine rotates at 6,000 revs. per minute, the mean peripheral blade speed being 367 f.s. on a mean diameter of 14 ins. In the direct drive the corresponding figure is about 123 f.s. These figures indicate a more ideal ratio between blade and steam speed (which is over 2,000 f.s.) in the former case under full power conditions.

The blades increase from $\frac{3}{4}$ in. in the first row to $1\frac{3}{4}$ ins. in the third row, and are secured to the wheel by dovetailed roots as in the B.C. turbines.

Steam is supplied through three sets of nozzles, one of which is always open if the master steam is opened, the other two groups being controlled by separate control-valves.

An emergency governor of the unbalanced eccentric ring type is fitted to trip and completely shut off the steam supply immediately a certain predetermined speed is attained. It is usual with this type of fan to allow a substantial margin between the full designed speed and the cut-out speed, as experience has shown that if one fan in a boiler-room trips, then, owing to the loss of pressure immediately obtaining, the other fans speed up and are also liable to trip. The limiting speed can only normally be reached in the event of a failure of the fan itself.

The gland is of the usual carbon packing type. The turbine spindle is of nickel steel, and is in one piece with the pinion which forms its lower extension. Single helical gear only is used, the axial thrust on the pinion acting in the opposite direction to the weight of and tending to balance the turbine spindle, etc. The gear-wheel has a cast steel centre and a forged steel rim shrunk on and pinned to the centre; on the rim 403 teeth are cut to mesh with 81 on the pinion, the ratio of the gearing being thus about 5 : 1, and the revolutions of the fan approximately 1,200 at full speed.

The lower part of the gear-case forms an oil well, and the oil is supplied to the bearings by means of a small gear-wheel pump worked off the end of the gear-wheel shaft. Special nozzles are connected to the discharge system from this pump for lubricating the teeth of the helical gearing. A small ventilator is fitted to the gear-case. The oil return from the bearings to the oil well is led by external pipes to the oil pump, these external pipes being fitted with fins to assist in the radiation from them, and therefore acting as oil coolers.

The bearings are plain, white-metal lined, and special spherical backed footstep bearings are provided for taking the weight or unbalanced thrust of the fan spindle. In the geared fan the axial thrust on the turbine spindle practically balances the weight at an intermediate power, a collar bearing taking the residual thrust at other powers.

The fan is mounted on a conical piston-shaped centre. The diameter of the inlet eye is 45 ins., the fan being guaranteed to deliver 45,000 cu. ft. of air per minute against a 6-in. water-gauge pressure. This gives an air velocity at the eye of about 70 f.s. The external diameter of the fan tapers from 4 ft. 2 ins. to 4 ft. 8 ins. the mean diameter being 4 ft. 5 ins.

These fan sizes correspond with the direct-drive double fans previously referred to, which run at 1,070 revs. per minute. The gain with the turbo-geared fan is, therefore, entirely in the direction of increase in turbine efficiency, the space and weight consideration having an important effect on the general question. In a T.B.D. that was cancelled subsequent to the Armistice, it was proposed to fit turbo-geared fans, in which the fan and turbine axis are inclined to the horizontal. With this arrangement the trunking would be simple and contain no sharp bends, while at the same time the fans would be fitted in the wings of the boiler room, thus simplifying the question of support.

High-speed Reciprocating Fan.

It is not out of place in connection with this article to mention that a new type of reciprocating fan engine is fitted in the T.B.D. "Veteran." The normal reciprocating fan in this class of vessel is of the single cylinder type, 7 ins. diameter and 5½ ins. stroke, or approximately equivalent figures, and guaranteed to deliver 35,000–40,000 cu. ft. of air per minute against 6 ins. pressure at

600 r.p.m. In "Veteran" this type is replaced by a twin-cylinder fan engine with cylinders 4½ ins. diameter and 3½ ins. stroke, the engine running at 1,000 revs. per minute. The fan is 51 ins. diameter, with a 36½-in. eye, compared with typical figures of 75 ins. and 54 ins. in the single-cylinder fan. The velocity at the eye is therefore considerable, exceeding 80 f.s. Other vessels would have been similarly fitted but for post-armistice cancellations, and in view of the satisfactory running of these units in "Veteran," extension of this fitting may arise in future construction.