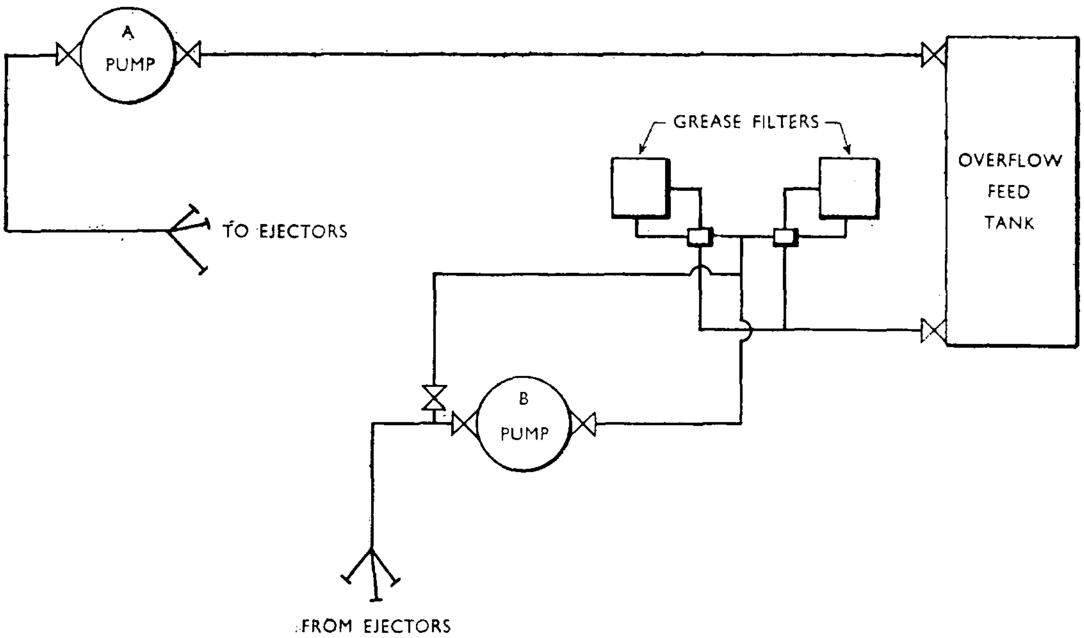

FIG. 1—DIAGRAMMATIC ARRANGEMENT OF TWO PUMP GLAND EVACUATION SYSTEM AS FITTED IN H.M.S. 'ARK ROYAL'

AUXILIARY GLAND EVACUATION SYSTEMS

BY

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The purpose of this article is to discuss the various forms of auxiliary gland evacuation systems fitted in H.M. ships and to provide the background to a recent decision to specify carbon glands in some applications for future back pressure auxiliary turbines.

Various Types

The introduction of the auxiliary gland evacuation system was a logical development of the main engine vapour suppression system first fitted in ships of the United States Navy at the beginning of the World War II, to improve the habitability of machinery spaces and to reduce excessive feed water losses. Various types of gland evacuation systems as described below have been fitted in H.M. ships.

Water Ejectors Operated by a Motor Driven Pump

The water ejectors take their supply from a small tank in a closed circuit, with the make-up surplus spilling into the overflow tank. This system is fitted in the cruisers *Sheffield*, *Newcastle*, *Newfoundland* and *Birmingham*, the carriers *Ark Royal*, *Eagle*, and the 1943 light fleet carriers have a second pump incorporated in the system to boost the return water from the ejectors, through grease filters, to the tank (FIG. 1). When water-operated ejectors were first

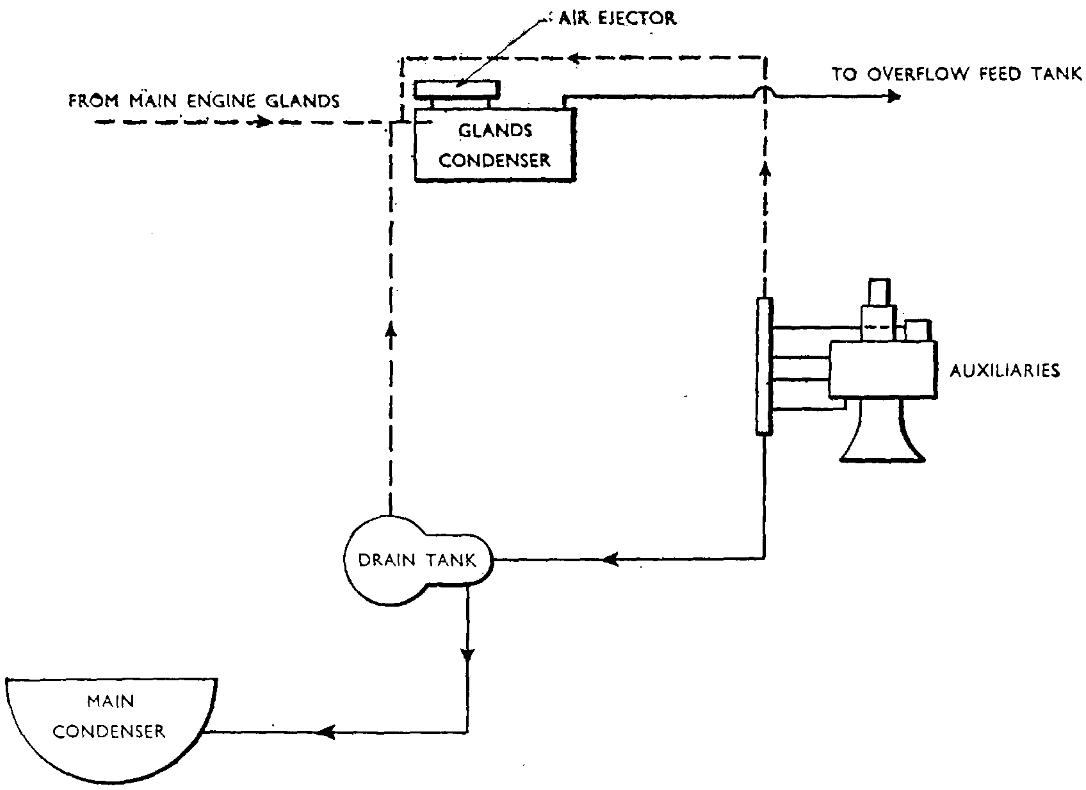


FIG. 2—DIAGRAMMATIC ARRANGEMENT OF GLAND EVACUATION SYSTEM AS FITTED IN 'WHITBY' AND 'BLACKWOOD' CLASS FRIGATES

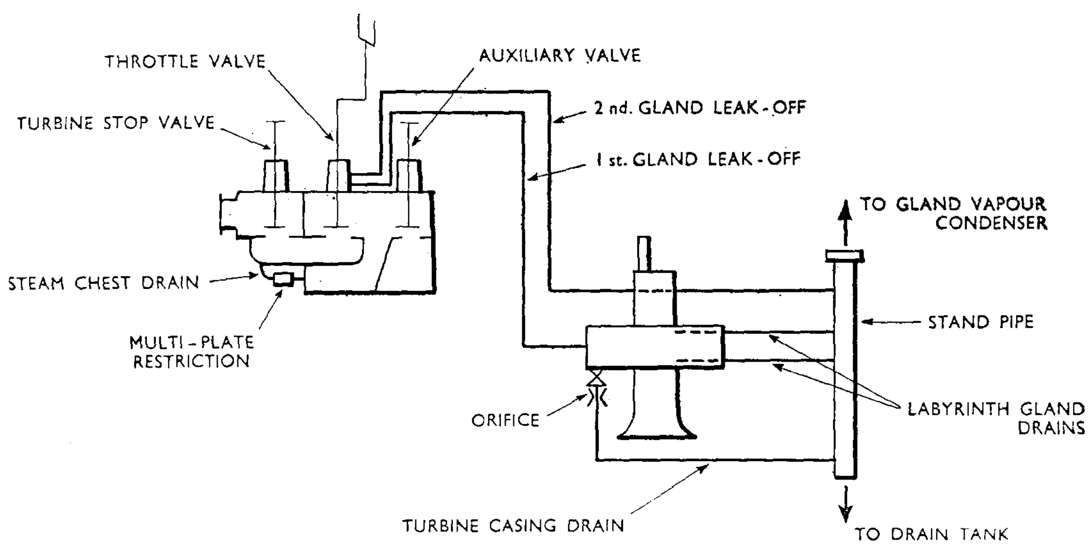


FIG. 3—DIAGRAMMATIC ARRANGEMENT OF DRAIN CONNECTIONS

introduced, they were frequently placed some distance from the auxiliary turbine concerned and were very critical with regard to discharge back pressure. Insufficient consideration was also given to the size of the discharge piping, particularly where a number of discharges were connected to a common pipe, with the result that the back pressure set up by the discharge lines was too great for the more remote units to operate satisfactorily. However, once these points are appreciated, the advantages of this system are that it is simple, fool-proof and self-contained, without risk of feed water contamination or aeration. As it is not affected by vapour and water pockets, it is less dependent on pipe layout than any other system and with water ejectors fitted on the turbine casing itself, as part of each machine, complete drainage of the gland pockets can be achieved at all times. The disadvantages are the additional weight and space of the pump and tank. If catering for twelve water ejectors, the pump size would be about 5 h.p. supplying 20,000 PPH at 50 lb/sq in with each ejector capable of dealing with some 120 PPH of vapour and water.

Ejectors Operated by Extraction Pump Discharge

This system is fitted in the carriers *Majestic* and *Bonaventure*. The advantages are the simplicity of system layout and the saving of the weight of a circulating pump and tank. The disadvantages are that the system is not self-contained and that the extraction pump discharge pressures are not specifically suited to the ejector needs. (Ideally the discharge pressure of an ejector should be less than 50 per cent of the minimum operating pressure). Great care has to be taken with the pipe layout, particularly if back pressures are high, with any ejectors distant from the extraction pump. For twelve ejectors some 20,000 PPH is lost from the closed feed system to the feed tank and this has to be made up continuously from the main feed tank, with consequent danger of aeration. The associated turbo generator extraction pumps also have to be of sufficient size to operate the water ejectors in harbour.

Steam Operated Ejectors

There is little to be gained by fitting individual steam operated ejectors instead of water ejectors, and the main penalties are the additional steam consumption, hot pipe lines and the need for a vapour condenser.

Condensate Cooled Condenser with Single Steam Ejector for Group of Auxiliaries

This arrangement was one of the first considered, and is fitted in the *Weapons*, *Darings* and A/S frigates (Fig. 2). In the latter, each auxiliary has a vertical stand-pipe to which the turbine casing, glands and spindle drains are connected (Fig. 3). The vapour is led off to the vapour condenser and thence to the overflow tank, with the water drains going to a float-operated drain tank and the main condenser. In all these ships, the vapour condenser and steam ejector are designed to cater for both main engine and auxiliary turbine glands but, unfortunately, in harbour, when lighting up and shutting down, there is no vacuum in the main condenser and no condensate flow through the gland condenser with the result that the system is out of action just when it is most required. Any system, which depends on vapour passing successfully through long winding lengths of small-bore piping and valves, is unlikely to be simple and fool-proof. In practice, vapour and water-logging is the result, even where considerable attention has been paid to the layout of the system and pipe runs. It is inevitable that the vacuum obtained at some of the more remote glands will be negligible and that one gland with either a bad air leak, or an excessive steam blow, will vitiate a number of glands.

Impellers Fitted to the Turbine Shaft

It is impractical to provide an impeller or air fan on the turbine shaft to achieve satisfactory evacuation ; sufficient pressure cannot be produced over the range of speeds at which auxiliaries operate to cause an inward flow of air at all times (to prevent steam coming out), or to provide an effective outflow to a condenser. It is of no use in the vital case of dealing with a stand-by auxiliary.

CARBON VERSUS LABYRINTH GLANDS

The various gland evacuation systems briefly described here have shown that the best ' fit and forget ' arrangement is that of water-operated ejectors, supplied by their own pump as a self-contained system. However, on the basis of that excellent dictum 'what you don't fit won't break down ' it may well be asked whether an auxiliary gland evacuation system is required anyway and, for the answer, it is necessary to examine the problem from the aspect of labyrinth and carbon glands.

Carbon Glands

At the beginning of the war, all turbo auxiliaries were fitted with carbon glands and unplated carbon-steel turbine shafts. The maintenance was excessive because :—

(*a*) The shafts rapidly became pitted and scored

(*b*) The carbon segments required careful hand-fitting by experienced personnel

(*c*) Poor gland housing designs led to waterlogging and consequent electrolytic action between the carbons and the shaft, when the auxiliary was stand-by or stopped.

From 1943 onwards, shafts for auxiliaries were chromium-plated in way of carbon glands. The plating was not always satisfactory in the early days and tended to peel off but, since then, the technique of plating has been so well established that such defects have been eliminated. In 1943, an A.F.O. promulgated instructions for refitting carbon rings and it may well be that the publication of this order was as much responsible for the reduced wear as the introduction of chromium plating.

Fleet Opinion

In 1949 and again in 1953, enquiries were made of the Fleet and approximately 60 replies were received. The following extracts are typical of these reports :—

H.M.S. ' Glory '

From personal experience over the last fourteen months, and from the records, it is clear that auxiliary turbine carbon glands have given excellent service in *Glory* and that the glands on plated journals have given better service that those on unplated journals in the feed pumps. No pitting, roughening or exfoliation of the plating is evident. Many of the glands have not been touched for over four years.

It is my opinion that most of the damage to journals in way of carbon packing takes place when the turbines are idle. Under this condition water lies in the glands, forms into a weak carbonic acid by contact with the carbon, and sets up an electro-chemical corrosion cell, attack being concentrated at minute pinholes or discontinuities in the plating, leading to roughness, deep pitting and, in the limit, peeling of the plating due to corrosion of the steel beneath, by the cathodic carbon and chromium.

H.M.S. ' Vanguard'

(*a*) Carbon packing properly fitted to a plated journal will last about three years without special attention. Adequate drainage is required.

(*b*) The renewal of journal surfaces by metal spray and grinding is satisfactory.

(*c*) It is essential that the fitting of carbon packing is performed by skilled men. The truth of the rotating shaft journal must always be accurately checked ; any eccentricity will inevitably cause a great increase in wear.

H.M.S. ' Superb '

(*a*) Existing carbon gland assemblies require attention (e.g. examination) at two-yearly intervals to ensure that neither wear nor corrosion is excessive.

(*b*) If gland packs are correctly fitted and refitted, and adequate gland pocket drainage is ensured, the interval between examinations might well be extended to three years.

H.M.S. ' Scorpion '

There is no doubt that the chromium-plated carbon glands in *Scorpion* have required very little attention during the seven years since the ship was completed.

Analysis

The reaction to plated journals was favourable and although the reports concentrated on the refitting of the carbons, rather than the ability of the shafts to last without replating, it was clear that, even with carbon glands now in service, a three-year life is attainable if :—

(*a*) The carbons are correctly fitted in the first instance

(*b*) Adequate provision is made for draining the carbon gland pockets

(*c*) The shafts are plated in way of the carbons.

To meet these three requirements and ensure that future carbon glands can be of the ' fit and forget for three years ' variety, considerable advances have been made and carbon rings can now be supplied which require no hand fitting.

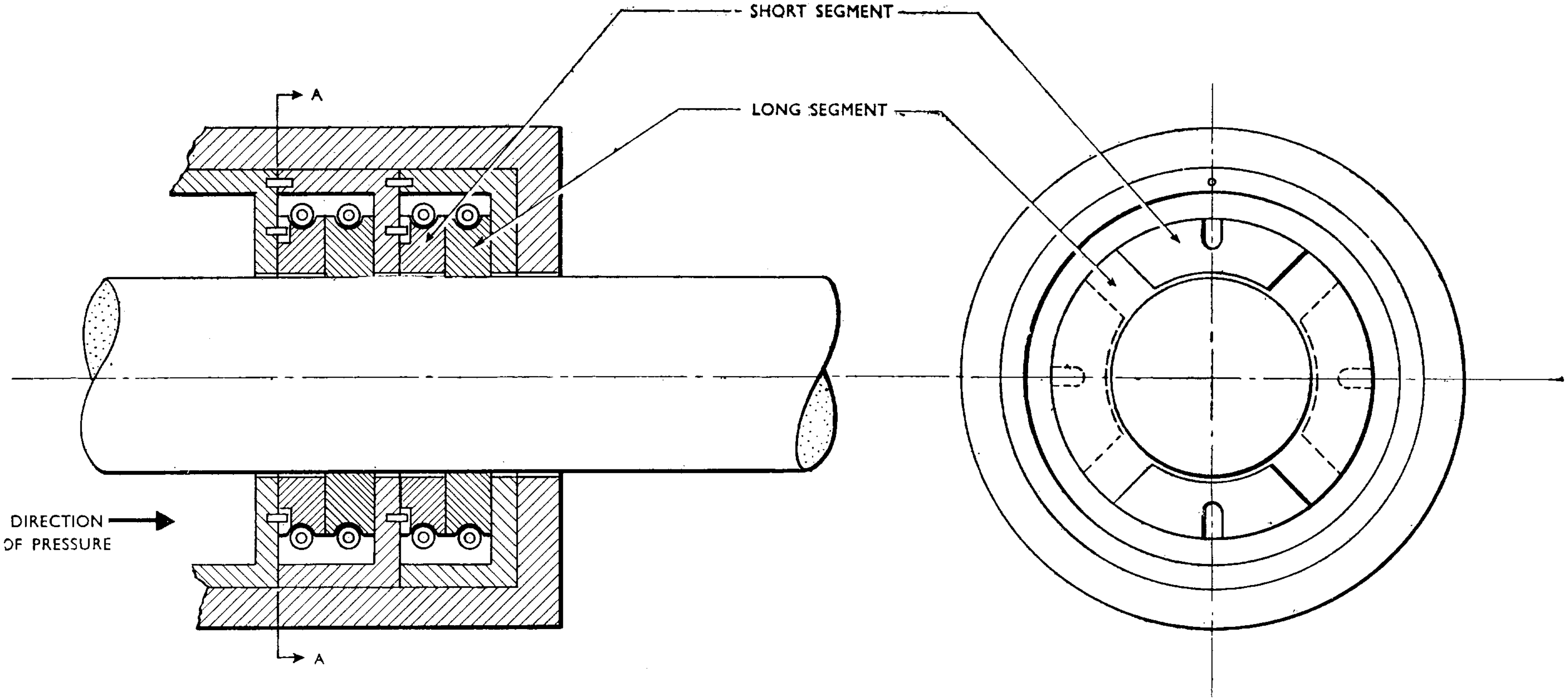
The unequal segment gland (FIG. 4) has been developed which :—

(*a*) Can adjust itself to variations in shaft diameter, which may be caused by changes of temperatures during operation.

(*b*) Can take up an appreciable amount of wear without leaving a clearance at the joints between the segments through which leakage could occur.

(*c*) Although made of rigid or non-deformable parts, can contract radially inwards upon a shaft without exerting an unduly high force when under pressure, thereby permitting very high shaft speeds.

Detailed evidence indicates that carbon glands and shafts deteriorate most under the hot stand-by condition and when lying idle if waterlogged. Manufacturers have therefore been instructed to pay particular attention to the design and materials of gland boxes, to obtain adequate drainage and reduce the chance of electrolytic action to a minimum. It is now specified that turbo auxiliaries of new design must be capable of rapid starting without preliminary warming through to eliminate waterlogging.



SECTION AT A - A

FIG. 4—GLAND RINGS : SELF-COMPENSATING TYPE

The upper temperature for known grades of carbon is about 850 degrees F. but, in practice, the higher steam conditions now in use and foreseen for auxiliaries are not outside the limit of carbon glands, because the temperature at the gland is always appreciably less than that of the steam supply. For these high temperatures, the recommended material for the carbon gland box is heat-resisting stainless steel rather than the non-ferrous materials which have high coefficients of expansion.

The problem of carbon glands in the turbo auxiliaries of ships in reserve is being actively pursued and experiments carried out show that electrolytic action, and consequent deterioration, between the carbon and shaft can be prevented for long periods by thoroughly drying out the gland box and inserting waxed paper between the carbons and the shaft, so allowing the carbons to be left in place.

It will be appreciated that designs of turbo auxiliaries now coming into service still have labyrinth glands and it will be some time before units with the new type carbon glands can be proved under service conditions. We cannot tell yet how much their life can be extended beyond the three years already achieved with the earlier types of hand-fitted carbon glands.

Labyrinth Glands

In parallel with the drive for improved carbon glands, at the beginning of the war, considerable pressure was brought to bear on the principal suppliers of turbo auxiliaries to fit labyrinth glands. Both Messrs. Allen of Bedford, and Messrs. Weir of Glasgow, in 1941, carried out a thorough investigation and both reached the same conclusion that the introduction of labyrinth glands for small auxiliaries would not represent an improvement upon the carbon glands then in service. However, the Admiralty was firm in its belief that, with labyrinths, maintenance would be negligible and in ships built later than 1945, that is for *Daring* Class ships, *Whitby* and *Blackwood* Class A/S frigates, all turbo auxiliaries are fitted with labyrinth glands. Experience to date in manufacture, on shore trials, and at sea in *Daring* Class ships, has shown that labyrinths for small auxiliaries have the following serious disadvantages :—

(*a*) Expense involved in the manufacture and repair of the labyrinths, at the tolerances required, is considerable.

(*b*) Hand-fitting of bearings is necessary to ensure that the labyrinth clearances are correct and in *Darings* this has required considerable skilled maintenance effort.

(*c*) Labyrinths have no freedom to accommodate temporary lack of truth and, as the clearances have to be small, there is a serious risk of a rub leading to a bent shaft. Since labyrinths for auxiliaries were introduced, some dozen rotor shafts have been bent as a result of contact between the labyrinths and the shaft.

(*d*) Any increase from the small design clearances results in excessive steam leakage.

(*e*) The use of labyrinth glands always entails an elaborate drainage problem. The associated gland evacuation system is susceptible to vapour and waterlogging and may be rendered ineffective by (*d*) above.

(*f*) Stepped shafts cannot be plated satisfactorily because of the difficulty of plating in the corners.

Mechanical Seals

Mechanical seals are being fitted extensively to the pump ends of auxiliaries but, unfortunately, one has not yet been designed which is able to successfully withstand the very high rubbing speeds, steam temperatures and lack of lubrication associated with modern high-speed auxiliary turbines.

CONCLUSION

As the belief that the introduction of metallic labyrinths for small turbo auxiliaries would reduce maintenance to negligible proportions has not been borne out in practice, carbon glands have been specified, where applicable, in current specifications. Quite apart from avoiding all the disadvantages of labyrinths listed above, this change in policy means that auxiliary gland evacuation systems are no longer essential. There is no logical reason, on the basis of industrial experience, why, with modern carbon glands the leakage should not be so small that it can be ignored and, in consequence, all the multiplicity of small bore evacuation pipes and valves, which so clutter up turbo auxiliaries, can be thrown away.

This step is being taken with caution and in two new ship installations, while both will have carbon glands, one will have a gland evacuation system with water-operated ejectors and, in the other, provision will be made for water ejectors, but they will not be fitted unless found necessary as a result of service experience.

To sum up, it was right to experiment with labyrinths in the past but it is equally right now in the light of experience to reintroduce carbon glands for small turbo auxiliaries. There is, of course, no intention of changing the policy of having labyrinth glands for main engines and the larger self-condensing auxiliaries where the gland sizes and temperatures are such that the advantage is with labyrinths.