UNITIZATION OF MACHINERY

by

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The following article has formed the subject matter of a lecture to other Admiralty Technical Departments, with the object of indicating, to some extent, the detailed consideration necessary when designing machinery and equipment to obtain the best advantage from its arrangement in units.

It will only be possible here to give some typical examples of difficult points and the many angles from which each item must be viewed. It will be known by the initiated that it is possible to consider a given item for a long time and to make many modifications to the original conception, until it appears foolproof, and then a chance remark from a fresh mind brought to bear on the subject will show it to be full of holes.

Criticisms of arrangements are, of course, quite common ; many of them are well founded, as the proof of the pudding can never be obtained on the drawing board, but there are many not so well founded. An intelligent individual often fails to understand why a given service cannot perform certain functions, which functions would be quite safe in his hands, but, unfortunately, there are in any given ship a number of men whose standards of ability and intelligence call for foolproof equipment in the literal sense and these must be catered for. The average peacetime rating requires extended training to grasp the complexities of a modern warship and in wartime we must expect standards to fall considerably. It is safest to assume that steps to remedy action damage may be attempted, in the heat of the moment, by the men for whom the " foolproof " requirement is introduced. It is found to be a good policy therefore to analyse any arrangement by considering just what would happen if all the obviously wrong things were done, and then to see if the effects of such action can be reduced ; other factors, such as weight and space, must be balanced against the probabilities in any given case.

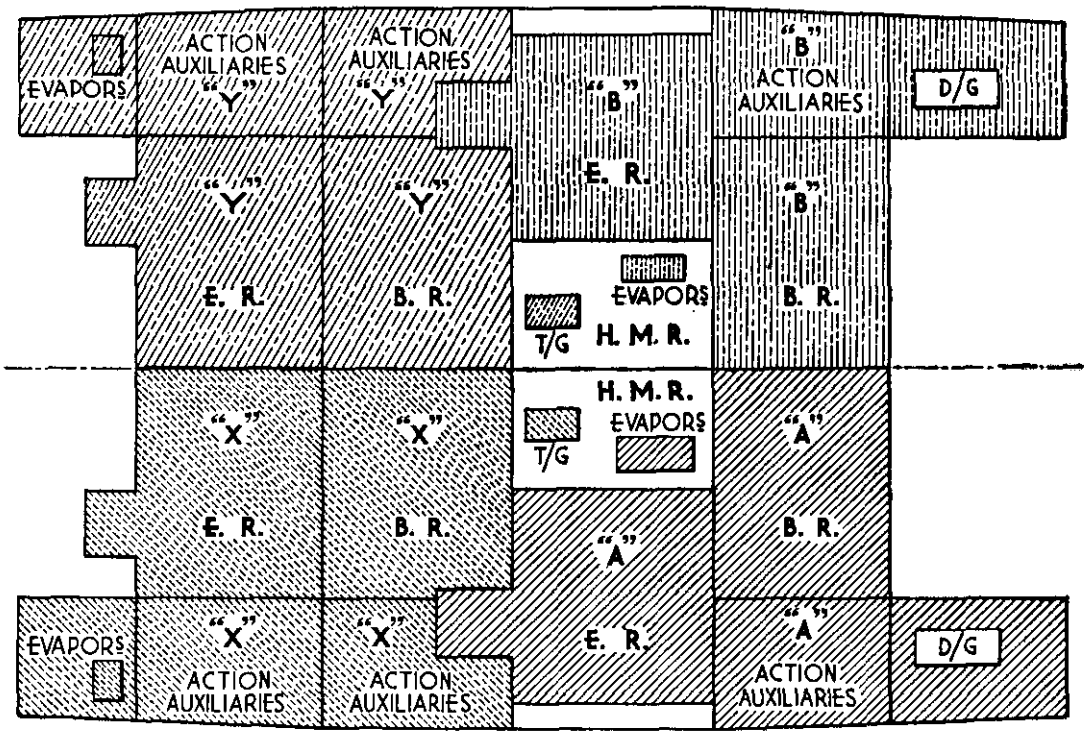
A common basis for criticism is the theory that the ship exists for the sole purpose of carrying around the machinery, a state of affairs that would simplify matters a good deal, but would not make for a very efficient fighting unit. The confliction of claims for every inch of space in a modern warship has grown steadily worse since the spacious days of the County Class cruiser and can only become still worse in the future, with the continual development of new types of fighting equipment.

REQUIREMENTS

The requirements for unitization of machinery may be stated broadly as follows:

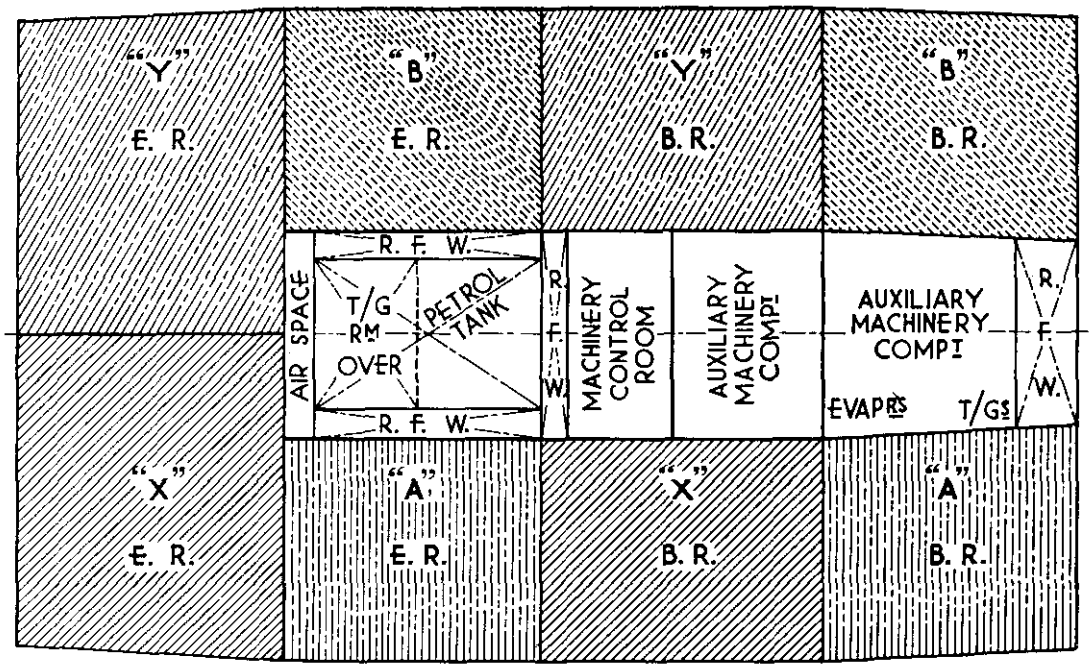
The machinery should be arranged to be capable of operation as a number of completely independent units, so that damage sustained in any one cannot prejudice the satisfactory operation of the remainder, *e.g.*, by loss of steam or contamination of feed water.

To meet this requirement absolutely, it is necessary that no part of any system pertaining to one unit shall be placed within the boundaries of another. As there are other requirements that have to be met in the production of a ship, it is a difficult problem. It implies close grouping of all compartments forming one unit, giving rise to many difficulties in an ordinary surface ship,



"VANGUARD" OR "K.G.V."

FIG. 1.



"IMPLACABLE"

FIG. 2.

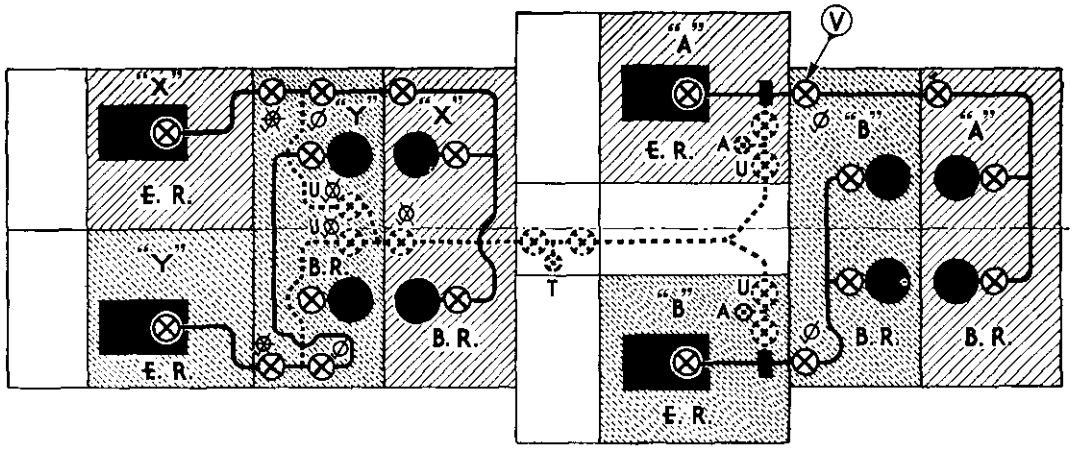


FIG. 3. "ARK ROYAL" & CLASS

Ø — EMERGENCY STOP VALVE QUICK CLOSING CONTROLLED FROM E.R. & MAIN DECK BY STEAM & MECHANICALLY CONTROLLED FROM ASSOCIATED E.R. & B.R.
— VALVES HYDRAULICALLY OPERATED FROM FAN FLAT ALSO LOCALLY CONTROLLED
— VALVES MECHANICALLY " FROM ASSOCIATED E.R^S & B.R^S
U — UNIT VALVES
A — AUXILIARIES
T — TERTIARY SUPPLY TO T/G^S

with an additional one in an aircraft carrier, in that there is the weight of an island superstructure to be balanced. Machinery provides a means of doing this to some extent.

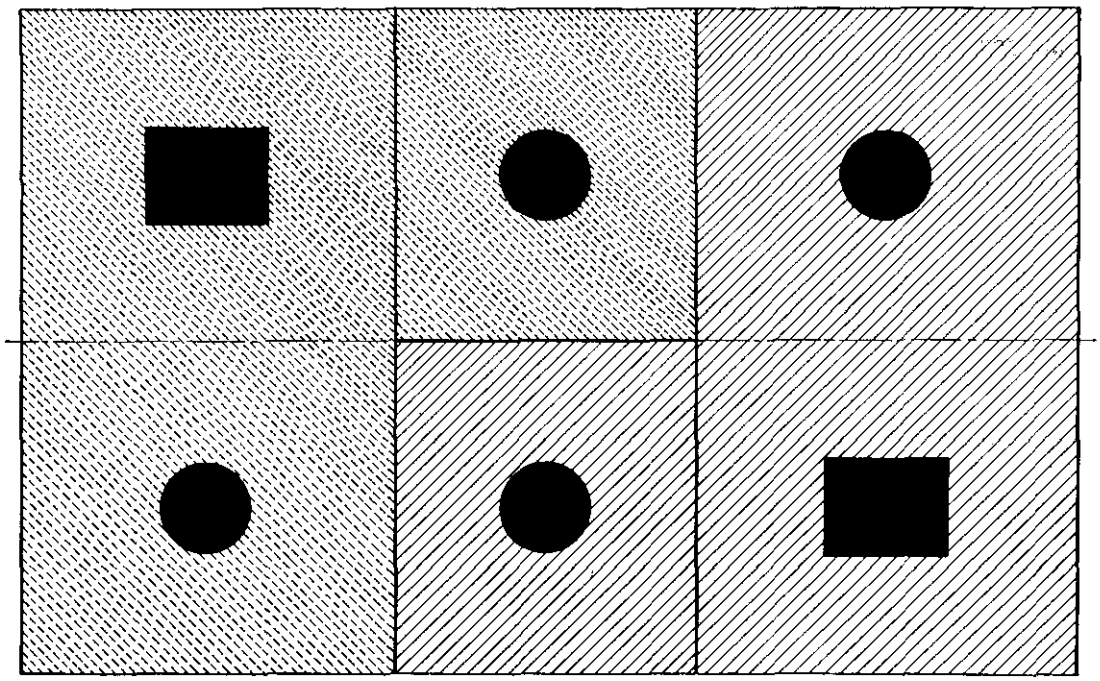
Faults in Existing Arrangements

In considering the accompanying diagrams, the main unitization faults, or departures from the ideal, some of which have arisen from necessity and some of which have become obvious from wartime experience, will be apparent from the run of the main steam systems. It follows broadly that similar faults will exist in the layouts of the pipelines for carrying the various other fluids with which we are concerned.

It should be noted that in these diagrams, a circle represents a boiler and rectangle a set of turbines.

It will be seen that the layout in *Vanguard* and the " K.G.V." Class (Fig. 1) is superior to that of *Implacable* (Fig. 2), where the whole of the interconnecting piping between forward boiler rooms and engine rooms passes through the after boiler rooms and that for the after units passes through the forward engine rooms.

In the new *Ark Royal* Class (Fig. 3) the disposition of boiler rooms is objectionable from the same viewpoint, because " A " and " X " unit piping passes through " B " and " Y " boiler rooms respectively. This came about largely because of the undesirability of centre line or near centre line bulkheads and their possible effect on heel under conditions of damage. Such bulkheads, however, are inevitable in way of engine and gearing rooms in this type of arrangement.



PROJECTED BATTLESHIP
(ONE PAIR OF UNITS)
FIG. 4.

Combined Machinery Spaces

By far the most satisfactory arrangement to meet both the requirement for avoiding longitudinal bulkheads and that for completely independent units is the combined machinery space, of which we have an example in the Light Fleet Carriers, one compartment per unit, containing both engines and boilers.

A projected battleship, whose design was considered a few years ago, was to have the arrangement shown in Fig. 4. The design was started with both boilers in the same compartment as the engines, but the compartment required was too large to be acceptable, so one boiler was placed in its own compartment as shown. In this arrangement the essential pipe system requirements can obviously be met.

Space between Units

It is most desirable to have a space between units or pairs of units measured in a fore and aft direction, so as to avoid the possibility of one hit on the boundary between units putting more than one out of action. The overall dimensions of the damaged area resulting from such a hit will determine the required length of this space, but it is not always possible to meet the ideal requirements within hull dimensions determined by other factors.

Shafting

The requirements for units to be completely independent and for no part of one unit to be sited within the boundaries of another have never been met so far as shafting is concerned and it does not appear likely that they will ever be met, unless such a scheme as electric drive is adopted, doing away with the necessity for the existing long lengths of shafting. Shafts from the forward units are bound to pass through in the vicinity of the after unit or units, which is a forced departure from the ideal state of affairs. As such things as flexible

and self aligning bulkhead glands are now fitted, however, and anti-shock measures have been taken in the design of plummer blocks, it is believed that a unit could sustain a considerable amount of damage without necessarily affecting a shaft passing through it.

Harbour Conditions

For harbour conditions in wartime it is essential that each pair of units in a four shaft ship and each unit in a two shaft ship shall be able to supply the same services, *e.g.*, electric power and distilling plant, to mention two very important ones, and, so far as the machinery itself is concerned, such things as deaerators for the feed water and drain coolers to dispose of drains and surplus exhaust. If these requirements are met it becomes impossible to maintain the ship at a reasonable operational notice. In the new *Ark Royal* Class, each unit, as distinct from each pair of units, can supply all these services except for the deaerators, which are provided one for each pair of units. It has been suggested that a policy of selected units be adopted for essential services, but this is obviously impracticable, as the " selected " units would require their turns of maintenance just the same as the others. It is fully realised that it is only possible to scratch at the problem of maintenance unless it is possible to get rid of steam completely in the unit concerned and that a week in harbour with steam at short notice does not constitute an opportunity for a self refit.

CROSS CONNECTIONS, POLICY

The fewer cross connections there are fitted, the smaller is the chance of one being used incorrectly and so spreading contamination of feed water or causing loss of steam after damage. Cross connections are therefore kept to a minimum number.

All cross connecting after damage should be done in slow time and it should be regarded as an axiom that, when defects arise after damage in a particular system, that system should be replaced by another, pending investigation. The words " pending investigation " cannot be over emphasized, unless there is an overriding operational requirement, such as that for beaching the ship, when it matters little about the state of the engines provided they get there.

The discussion of cross connections will refer mainly to the new *Ark Royal* Class, although it must be realized that in these days of rapid development, with ships taking a long time to build, nothing can ever be said to be completely up-to-date. The minimum number referred to must be sufficient to meet the following requirements :—

(*a*) Steaming at reduced speed after severe action damage
(*b*) Steaming out of units in peacetime for economy reasons
(*c*) Harbour steaming.

To meet these conditions, steam connections are provided between adjacent units and a fore and aft connection between pairs of units, including special arrangements for the turbo generators which will be discussed later. The main fore and aft connection should have a valve at each end, so that damage to it will not affect the normal working of the units. It should be run as high as possible under armour, *i.e.* above the engine and boiler rooms if possible, on the assumption that it is thus less liable to damage by underwater attack and also, that if it is damaged, by shell for example, there is a reasonable chance of the main steam leads below it remaining intact. For similar reasons, it is desirable to run it as near to the centre line of the ship as possible.

All valves that will link up units when open should have distinctive hand-wheels (the type generally fitted has a knob at the junction of each spoke with the rim) to make them identifiable in the dark as well as to prevent mistakes generally.

It is necessary to provide various means of transferring feed water between units, the most rapid in *Ark Royal* being the levelling pipe between all main feed tanks, which can be used to provide supplementary feed to any main condenser. The policy of later designs is to do away with this levelling pipe and the feed transfer pumps become the most rapid means of meeting the requirement.

Exhaust steam is cross connected in effect in the same way as main steam, although the actual pipe leads are more roundabout, to fit in with other requirements.

Fuel cross connections can be effected by opening the valves (normally locked shut) which divide the transfer pump suction ring main into four separate sections.

ITEMS OUTSIDE MAIN MACHINERY UNITS

Low Pressure air assumes great importance in *Ark Royal* because it provides the motive power for the Avgas pumps. The system is arranged, therefore, so that each Avgas pump room can be supplied from a separate L.P. air compressor or from the air ring main if desired.

The two catapults have three hydraulic pumps between them, supplied with steam from the forward pair of units. A cross connection between the port and starboard leads is provided approximately at the pumps and the leads from the boiler rooms are safeguarded at source by automatic valves which close if pressure in the pipes is lost for any reason.

Ship steam heating is unitized in *Ark Royal*, but the primary reason was to save weight, space and complication. Whatever the arrangement, it is necessary to return the steam heating drains to the unit from which the steam originated.

Turbo Generators

Each turbo generator is provided with three steam supplies, the primary from the associated unit boiler room, the secondary from the other boiler room in the same pair of units, and the tertiary from the fore and aft steam connection between the pairs of units. The secondary is intended to be under the hand of the watchkeeper, who should be able to change over quickly should the occasion arise ; immediate action, without investigation in this instance, being justified by the importance of maintaining electrical supplies.

This arrangement, referring to Fig. 5, means that under any conditions of steaming there will be two " dead ends " in the compartment requiring draining, and all three steam supplies originate in different units. It is necessary here to prevent damage in the turbo generator room causing salt water contamination of a unit and also the possibility of spreading contamination from an already damaged unit through a common drain system. This means that each of the three " dead end " trapped drains must have a separate lead back to the unit from which the steam originates, with a float operated automatic bulkhead shut off valve on each lead, to close in the event of flooding. Some idea of the complications arising from this policy can be obtained by considering the number of drains in the ship.

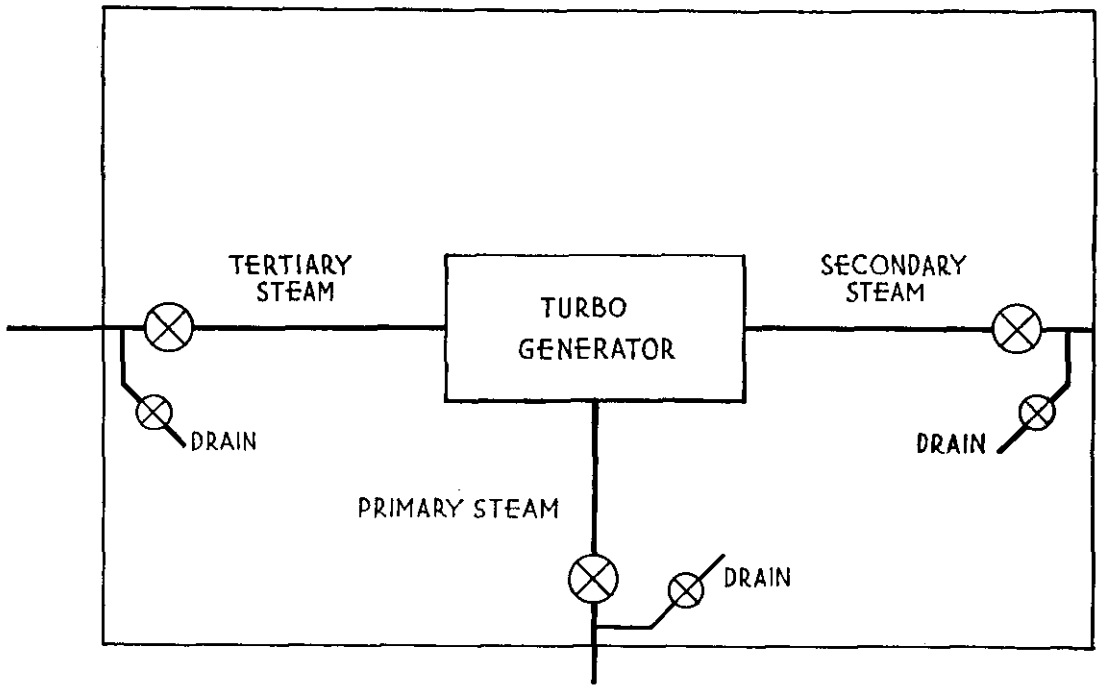


FIG. 5. TURBO GENERATOR IN "ARK ROYAL" ARRANGEMENT

Heating Steam for Aircraft Lubricating Oil

Some oils for this purpose require considerable heating in cold weather and *Ark Royal* is fitted to carry two grades of oil. This means that two connections are fitted at each point where oil is available for aircraft, with a lead to each stowage. Each oil lead requires its own steam heating pipe, with a drain leading back to the unit of origin of the steam. Actually, a single heating pipe has been lagged together with two oil pipes where possible and, to prevent the complication of the system exceeding the bounds of practicability, supply and drains are connected to one unit only.

Typical Main Steam Bulkhead Valve

An example of the consideration necessary for an important point in the system, including provision for the possibility of human error, is a main steam bulkhead valve. Each valve of this type must be considered individually so far as the details of operation are concerned and the valve " V " on Fig. 3 which is shown in more detail on Fig. 6, is chosen as an example.

The main valve can be closed in emergency by remote operation from the associated engine room and the main deck, and the primary position for hand operation is at the valve, in the boiler room.

Under emergency conditions, if a situation is considered where damage has caused flooding of " B " boiler room, it may not be possible to approach this valve, which is on the lead from " A " boiler room to " A " engine room. " B " unit is now out of action, with its boiler room flooded and it is fairly certain that the damage would have been accompanied by an escape of steam in that part of the ship in the vicinity of these machinery spaces. It is also fairly certain that both the emergency bulkhead valves at the after end of " B " boiler room will have been shut in the heat of the moment. This might or might not be

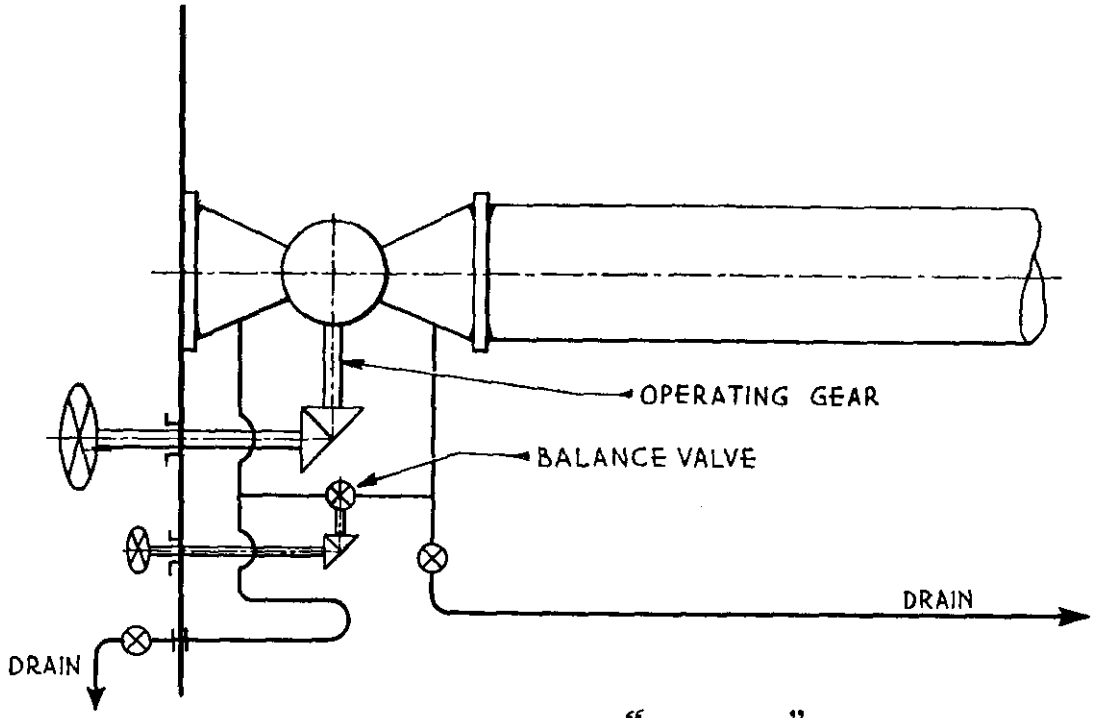


FIG. 6. BULKHEAD VALVE Ⓥ IN "ARK ROYAL" ARRANGEMENT

necessary in the case of the valve to " B " engine room and would be of little consequence in any case, but the closing of the valve " V " would have stopped the engines of " A " unit, perhaps quite unnecessarily. It now becomes necessary to re-open this valve, following the careful investigation referred to earlier. The main valve is therefore geared through to the engine room and, as it is necessary to operate the balance valve first, this is also geared through to the engine room.

The drainage arrangements for this valve also require careful consideration. There is a drain on each side of the valve in accordance with the usual practice and, except for lighting up conditions, these drains will be closed as a normal condition. For all normal use therefore, they could both well be led to the feed heater in the boiler room. If used when de-unitised, however, *e.g.*, after action damage, one will be necessary to keep a " dead end " drained, and so each must be led back to the unit from whieh the steam would originate under such conditions. This is done by the arrangement in Fig. 6, an ample bend being provided in the pipe to the engine room bulkhead to take care of any possible distortion. It is not possible to forecast which of the other units will be supplying steam to " A " engine room under such circumstances and so the drain joins up with the condensate in that engine room, for which disposal arrangements will have to be made to suit the situation.

No two of these bulkhead valves are likely to have to compete with exactly the same set of conditions, and it will be seen that the amount of work involved in settling even these details of such a steam system is considerable.

Personnel

Rigid unitisation, coupled with the time required to move around in a ship such as *Ark Royal*, has somewhat changed the conception of control of machinery. It is now necessary to rely much more on the officers and ratings

in charge of the various machinery compartments. The Commander (E) and Senior Engineer can be kept informed of what is going on, but can hardly hope to take any rapid action. The repeat instruments and gauges in D.C.H.Q.2 and the controlling engine room and the various broadcasting systems provided should do a lot to help. Advice and remote guidance should be possible, but the battle might well be over before these officers reached the affected spot in *Ark Royal.*

A further point affecting personnel is the 1950 system of compartment identification. This system, while an excellent means of identifying one of many compartments in a large ship, is likely to confuse a junior E.R. rating, who must be trained to be " Unit conscious ".

To avoid such confusion it has been decided to retain the unit identification lettering on all compartments concerned, in addition to the markings required by the 1950 system. It is considered that a newly joined Stoker in say, H.M.S. *Eagle*, will be more likely to associate " A " boiler room and " A " gearing room by the letter " A " than by the 1950 system markings of these compartments, 10LZ0 and 10NZ2 respectively.