FEED SYSTEM FOR A FRIGATE

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BASIC REQUIREMENTS OF A FEED SYSTEM

The guiding principle of system design for an ' austerity ' single-shaft frigate is clearly to aim for the utmost simplicity consistent with the system fulfilling its functions. The basic functions of a feed system are :—

(*a*) To maintain a supply of feed water to the boiler at all times.

(*b*) To maintain the water in the condenser hot-well at a convenient working level by the automatic adjustment of the amount of water in circulation when manœuvring.

(*c*) To restore to the system the water lost by leaks or through drains which return to the feed tanks.

(*d*) To maintain the content of dissolved gases in the feed at an acceptably low level.

It is a further requirement, particularly in a remote control ship, that a failure of any pump shall not produce a catastrophic interruption of the above functions—that is, roughly, that ' water carnivals ', if they must happen, will happen slowly.

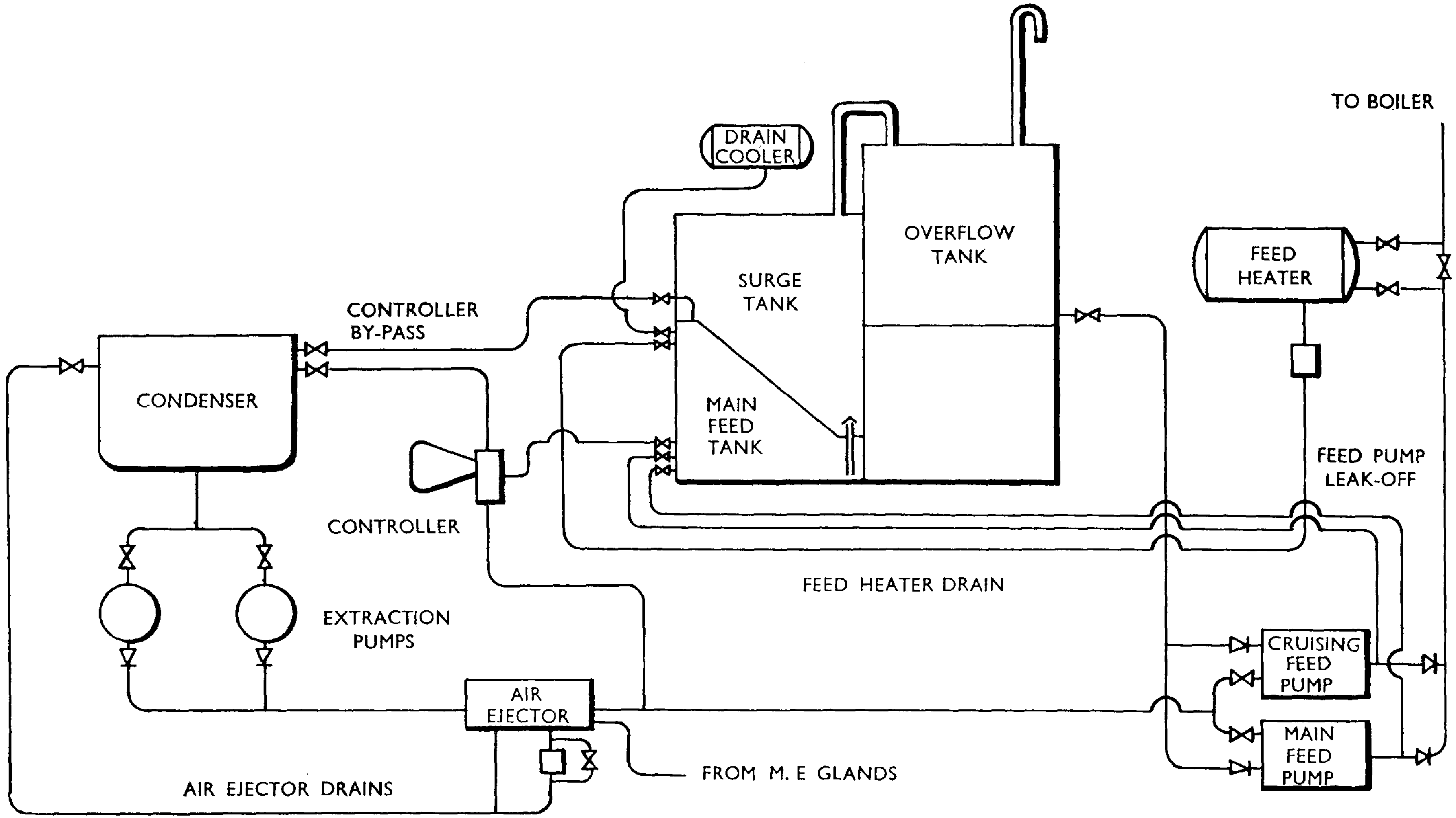
Maintenance of Feed Supply

The requirement to maintain a supply of feed to the boiler, even in the event of pump failure, dictates the fitting of two feed pumps. These pumps are arranged with automatic cut-in valves, so that the stand-by pump will start automatically should the discharge pressure of the running pump fail. Unfortunately, the need for economy of steam when cruising at low powers makes it necessary to fit a cruising (half-size) feed pump, which means that, when steaming at full power, the stand-by pump is only half-size. This is a definite limitation which would, of course, be overcome in a major, and less austere, warship by fitting a third full-size pump for the stand-by duty.

Referring to the Figure, it will be seen that the stand-by feed pump can take its suction from the overflow tank. It will normally stand by in this state with its suction valve to the extraction pump discharge closed. It will be seen later that the water in the overflow tank is normally static—that is, the tank is not a sink for drains which requires periodic pumping out. It is thus possible to arrange that there is always a good reserve of water in the overflow tank from which the stand-by pump can take a suction in emergency.

Water Level in the Condenser

A conventional closed feed controller is fitted, which maintains the working level in the condenser by supplementing from, or rejecting to, the main feed tank in the ordinary manner. The closed drains are returned to the main feed tank via the drain cooler, and the feed heater drain returns to the main feed



Feed System for a Frigate

tank direct. The closed feed controller is thus able to return this water to the system by its ordinary supplementing action. In this ship, as explained in the previous article, there is a surplus of closed exhaust for feed heating, and it is therefore possible to return the feed heater drain direct to the feed tank without loss of efficiency.

Referring again to the Figure, it will be seen that any loss of water from the system due to leaks will be made up automatically from the surge tank, the make-up water passing by gravity from the surge tank to the main tank through the stand pipe.

The feed pump leak-offs have also been led to the main feed tank, and are returned to the system via the controller. It is tempting to marry these leak-offs, but it appears possible that, if this were done, the discharge pressure of one pump might stop the other leaking off when the pumps were running in parallel while changing over. Fortunately, in the ship installation, these pipes are fairly short.

Deaeration

Much has been written on deaeration, and much of it is contradictory. Available evidence shows that boiler corrosion is associated with the presence of dissolved gases in the water, oxygen and carbon dioxide being among those which may be harmful. However, it is clear that concentrations of dissolved gas strong enough to be ruinous in some installations are harmless in others, and there is evidence that corrosion is only likely to be severe in those parts of the boiler where the water circulation is deficient. If this is so, then the logical solution of the boiler corrosion problem is to be found in careful design of the pressure parts to ensure the best possible circulation.

There is much uncertainty as to the source of the dissolved gases which may give rise to boiler corrosion. It is possible, and consistent with the available evidence, that dissociation of the water may occur at points in a highly forced boiler where the water circulation is faulty. And it is a reasonable theory that the unstable (nascent) oxygen atoms which would arise from dissociation are the main agents in corrosion. Oxygen atoms, which do not at once combine with the boiler steel as corrosion products, would pass over with the steam, subsequently coalescing into stable molecules, far less harmful from the corrosion aspect.

If this theory is correct, it follows that under conditions which favour use of a boiler compound of the corrosion inhibiting type, only limited advantage is likely to result from the removal of stable oxygen molecules from the feed by mechanical deaeration. The most effective cure would lie in the use of boiler compound, which can protect the steel against the action of the nascent oxygen atoms at source.

However, there can be no doubt that, until the mechanism of boiler corrosion is better understood, it is prudent to design the feed system to keep the content of dissolved gases in the feed water to a reasonably low level. The most that can be deduced from the best evidence at present available is that it is not possible to state a particular concentration of dissolved gases below which all will be well, and above which chaos will ensue. It follows that, at any rate in ships where the steam pressure allows the present corrosion inhibiting boiler compound to be used, it is sufficient to design a feed system which combines simplicity with a reasonable degree of deaeration, without necessarily going to the manifest complication of full-flow mechanical deaeration. At steam pressures above 650 lb/sq in, the present boiler compound is unstable, and a change has to be made to a compound of the oxygen neutralizing type. The extra complication necessary to reduce the oxygen content to the lowest level attainable is then much more justifiable.

Sources of Aeration

The problem of designing a feed system which will minimize aeration falls naturally into two parts. Firstly, possible sources of aeration must be identified and if practicable removed ; and secondly, provision must be made for the continuous extraction of any gases which do find their way into the system.

Possible sources of aeration are :—

(*a*) Dissociation of the feed water
(*b*) Valve glands under vacuum
(*c*) Gland evacuation system
(*d*) Open feed tanks.

Dissociation is only likely to occur within the boiler, usually as the result of bad circulation. Gases arising from such dissociation will pass over with the steam and will find their way into the feed system either in the main engine condensate, through the feed heater drain, or through the drain cooler. It is important that the method of deaeration provided shall remove these gases ' first time round ' before they are returned to the boiler with the incoming feed. As will be seen later, this is achieved in the present system by leading the feed heater and drain cooler drains to the top of the main feed tank, rather than, for example, returning the feed heater drain to the feed pump suction.

Valve Glands and Gland Evacuation

The glands of the extraction pump suction valves are fitted with lantern rings packed with water from the extraction pump discharge. Glandless diaphragm valves are used for all applications for which they are suitable.

The only gland evacuation system fitted in this ship is that for the main engines. Instead of fitting a separate gland condenser, use is being made of the air ejector second stage cooler, a small vacuum being kept in this cooler by means of a motor-driven fan fitted in the air escape pipe. Entrained air in the evacuated gland steam will be discharged by this fan, and deaeration of the second stage drain is aided by returning this through a trap to a point high up on the main condenser.

MAIN FEED TANK

It is clear that the water in an ordinary main feed tank is likely to contain considerable quantities of dissolved gases, absorbed from the atmosphere. In a conventional system the degree of aeration is reduced to some extent by the high temperature of the water and also by its limited ' residence ' time in the tank. Nevertheless, there is a considerable flow of supplementary feed from the tank to the condenser through the controller, carrying in air to the water in the condenser hot-well. This supplement, even when steaming at a steady power, arises from the need to restore to the system water which is led to the feed tank from the various drain discharges. Moreover, in a small ship, the aeration of the water in the tank will be aggravated by the small size of the tank and the rolling and pitching of the ship.

The position could be alleviated to some extent by arranging for the supplementary feed to enter high up in the condenser. Some measure of deaeration would then occur during the passage of the make-up water down the condenser. Such an arrangement would not, however, be very effective, since thorough deaeration demands good atomization of the water, to ensure that every droplet flashes to steam before reaching the lower part of the condenser and recondensing.

The Deaerating Spray

Good atomization of the aerated water, which is an essential of effective deaeration, can only be achieved in a properly designed spray nozzle. Such a nozzle is only fully effective if the flow through it is reasonably close to the design flow, a condition which could not be satisfied if the nozzle were placed at the end of a normal supplement pipe, which must be large enough to cope with the heavy demands which arise when manœuvring. This difficulty has been overcome in the present design by fitting the nozzle at the end of a separate pipe, run from the crown of the main feed tank and by-passing the controller. Referring to the Figure it will be seen that the flow through the controller by-pass depends only on the pressure difference between the condenser vacuum and the head of water over the main feed tank.

Operation of the System

Still referring to the Figure, it will be seen that the main feed tank is completely enclosed, and will always be full of water, provided the water in the surge tank is kept at a proper working level. Communication between the main feed tank and the surge tank is provided by a stand pipe, so arranged as to minimize flow by convection between the two tanks.

A study of the rate of diffusion of gases in water indicates that, with this arrangement, the water in the surge tank and stand pipe will effectively seal the water in the main feed tank from absorption of appreciable quantities of gas from the atmosphere.

Hot drains from the feed heater and drain cooler are led to a position high up on the main feed tank and the controller by-pass connection is taken from the highest point. This arrangement ensures that the water passing through the controller by-pass is always well above the saturation temperature of the condensate. The by-pass water will thus flash off in the condenser and good deaeration will result.

The controller by-pass is designed to pass a flow slightly greater than the feed heater and drain cooler drains and the feed pump leak-off under the full power condition. There will, therefore, always be a return flow to the feed tank through the overflow ports in the controller under steady steaming conditions. It will be seen, then, that there is a circulation of water under all conditions of steady steaming through the controller by-pass, condenser, extraction pump, air ejector jacket and back to the feed tank through the controller overflow ports. This by-pass circulation will :—

(*a*) Provide continuous and progressive deaeration of the water in the feed tank, and hence in the system as a whole.

(*b*) Carry away to the condenser any entrained gas in the feed heater and drain cooler drains. This gas will be discharged to atmosphere by the main air ejector.

(*c*) Provide, in conjunction with the feed pump leak-off, a return of cooled water to the feed tank, to ensure that the feed tank does not boil.

(*d*) As power decreases, there is a corresponding reduction in the flow in the feed heater drain. Since the flow in the controller by-pass is sensibly constant, the reduction in the feed heater drain must be reflected by an increase in the flow back to tank through the controller. This provides a self-adjusting recirculation through the air-ejector jacket which will ensure adequate cooling of the air ejector under stand-by and low power conditions. The usual recirculation valve is therefore not required with this system.

Calculations indicate that the balance of hot and cold returns to the main feed tank will give a maximum working temperature of about 180 degrees F. at full power. At lower powers, the temperature of the water in the tank will fall, but at low powers, even with considerable under-cooling of the condensate, the temperature of the water in the controller by-pass will still be well in excess of the saturation temperature corresponding to the vacuum which, as was mentioned before, is an essential factor in good deaeration.

Manoeuvring

Under manœuvring conditions, the controller will operate in the normal way. Changes in the quantity of water in circuit will be accommodated by flow through the stand pipe between the main feed tank and the surge tank. The stand pipe and the connection to the controller are disposed at diagonally opposite corners of the main feed tank, so that, when supplementing, the deaerated water from the main tank will pass to the condenser, and will be replaced in the feed tank by aerated water from the surge tank. This aerated water will in due course be deaerated by passing through the controller by-pass. Make-up feed to replace water lost by leakage will be transferred from reserve to the surge tank.

'WATER CARNIVALS'

The possibility of the failure, or incorrect functioning, of any component of a closed feed system resulting in a sudden and often considerable involuntary transfer of feed water, usually to the bilge, is well known. Prompt action by the watchkeepers usually, but not always, serves to limit the trouble to manageable proportions. In a remote control ship, however, there is likely to be some delay in realizing that something is amiss, and diagnosis and remedial action may well take longer. It therefore seemed well worthwhile to examine the problem to see if it were possible to devise a system in which water carnivals were less likely, and in which, if they did occur, the ship would go on steaming without loss of feed water or other major ill effect.

The possible variants of the water carnival in a conventional closed feed system for a one-shaft unit are :—

(*a*) *Failure of Extraction Pump*
Feed pump trips. Stand-by feed pump is started on R.F.T. suction. Main condenser fills up. Water is lost to bilge through air ejector air escape pipe.

(*b*) *Failure of Main Feed Pump*
Stand-by feed pump is started on R.F.T. suction. Controller moves to overflow position. Main feed tank overflows.

(*c*) *Controller Stuck in Overflow Position*
Boiler water level falls. Stand-by feed pump is started on R.F.T. suction. Main feed tank overflows. Feed pump and/or extraction pump may trip.

(*d*) *Controller Stuck in Supplement Position*
Main condenser fills up. Water is lost to bilge through the air ejector escape pipe.

The objective must, therefore, be to design so that in any of the above circumstances the correct working level will be maintained in the boiler and condenser, and feed water will not be lost from the system as a whole.

Pump Auto Cut-in Arrangements

The first step is to fit each stand-by pump with an auto cut-in device so that, if the running pump fails, the stand-by pump will be started automatically with the minimum delay. This is readily arranged in the case of the feed pumps, where the pressure failure on the pump side of the running pump's non-return discharge valve provides a positive signal to operate the cut-in device on the stand-by pump. A similar arrangement may be fitted for the extraction pumps but a difficulty arises here from the considerable natural fluctuation in speed-governed extraction pump discharge pressure. The signal will be much less positive, and some care and practical experience will be needed in arriving at the optimum cut-in pressure.

An alternative cut-in arrangement is also under consideration for the extraction pumps. This would start the stand-by pump when the running pump stopped rotating, and would thus overcome the difficulty of an inadequate pressure signal.

As mentioned earlier, this design has, of necessity, half-capacity cruising pumps, and it is accepted that the machinery must be eased down to half-power should a running pump fail when steaming at high power.

Surge and Overflow Tanks

If now the running feed pump fails, the stand-by pump will cut in, taking its suction from the overflow tank (see Figure). The immediate effect is that the controller will move to the overflow position and water will be discharged by the extraction pump to the main feed tank and thence to the surge tank.

Referring to the Figure, it will be seen that the surge tank is closed, and fitted with an overflow pipe leading to the overflow tank. Providing the water is at the correct working level in both tanks before the feed pump fails, it is a simple matter to arrange the tank sizes so that the flow of water from the surge tank to the overflow tank will be sufficient to keep an adequate head over the stand-by feed pump suction. Under these conditions the ship will steam on open feed for as long as necessary, with the extraction pump discharging through the controller to the main feed tank. The main feed and surge tanks will be full, and water will pass over continually to the overflow tank and thence to the stand-by feed pump suction.

The only really hot water in the main feed tank is in its upper portion. The water passing over to the overflow tank will be roughly at the temperature of the condensate, and there should, therefore, be no risk of the stand-by feed pump tripping due to boiling at its suction. Of course, action will be necessary as soon as convenient to restore the system to normal, as under the open feed condition there is no stand-by feed pump and considerable aeration of the feed.

Sticking of the Controller

The arrangements so far described should be sufficient to ensure that the system will continue to fulfil its function if a feed pump and/or an extraction pump fails. Some protection will also be given, at least for a time, should the controller stick in the overflow position. The effect in this case will be that the surge tank will fill up and the main condenser will empty. It may be necessary to change over to the stand-by feed pump, to prevent overflowing the overflow tank, but it is more probable that the running feed pump will trip due to insufficient suction head, in which case the change-over will be automatic.

If its governor is in good order, the extraction pump should ' snore ' satisfactorily with an empty condenser well.

If the controller is stuck wide open to overflow, the running feed pump will undoubtedly trip, and the system will revert satisfactorily to open feed. With the overflow ports partly open, the feed pump may not trip, but the boiler will be short of feed and the watchkeeper will start the stand-by feed pump. The feed flow will then be partly normal and partly through the feed tanks. In any case the inclusion of the feed tanks in the system will allow a sufficient reserve of water for manœuvring. Sticking of the controller in the overflow position, that is, with the piston valve at the top of its travel, is more likely to be due to a stuck main valve than to a stuck float. In such a case the trouble will be apparent at once, since the combined pressure gauge which measures the servo pressure will show full vacuum. This gauge is repeated in the machinery control room.

Should the controller stick in the lower, or supplement, position the situation is more serious. If the sticking should be due to the main valve, the combined pressure gauge will again show up the trouble, in this case by showing a pressure equal to the extraction pump discharge. If, however, the cause of the sticking lies in the float lever gear or is due to a punctured float, the combined gauge will not indicate that anything is amiss. There is, therefore, a grave risk of flooding the main condenser. To give timely warning of such an occurrence, a high level alarm is fitted in the machinery control room, which will indicate when the water level in the condenser reaches the top of the gauge glass.

Hand operation of the controller does not lend itself to remote control, since a visual indication of the position of the piston valve would be required in addition to manipulation of the hand wheel and a direct reading of the level in the condenser. It has, therefore, seemed better to be content with adequate instrumentation in the control room, consisting of the combined pressure gauge and the high level alarm, and to rely on local hand operation of the controller should the need arise.

Loss of Water through the Air Ejector

Should the main condenser flood, feed water would be lost to bilge through the air ejector. It seems, however, that this is the least of the troubles arising from a flooded condenser and that the complication of piping the air escape back to, say, the overflow tank is not worthwhile. The air ejector is not very effective as a water pump, and is unlikely to discharge more than about one ton in ten minutes. Since the high level alarm will have given notice of the rise of water in the condenser before it even reaches the level of the air ejector suction, it is evident that loss of water through the air ejector is a secondary hazard which does not justify fitting any additional piping.

CONCLUSION

This feed system is an attempt to cover the basic requirements in the simplest possible manner, at the same time providing a degree of automatic protection against the effects of pump failure and adequate warning in the event of the controller behaving erratically. It will be seen from the Figure that the number of valves has been reduced to a minimum, and that only two of these, the feed pump suction from extraction pump discharge valves, need to be remotely operated from the machinery control room. Other remote controls consist only of start, stop and reset-on-auto controls for the feed and extraction pumps, and the gauges in the control room are limited to pump discharge pressures, the controller gauge and feed tank contents gauges. It is hoped that with this simple equipment the ship can be steamed with confidence.