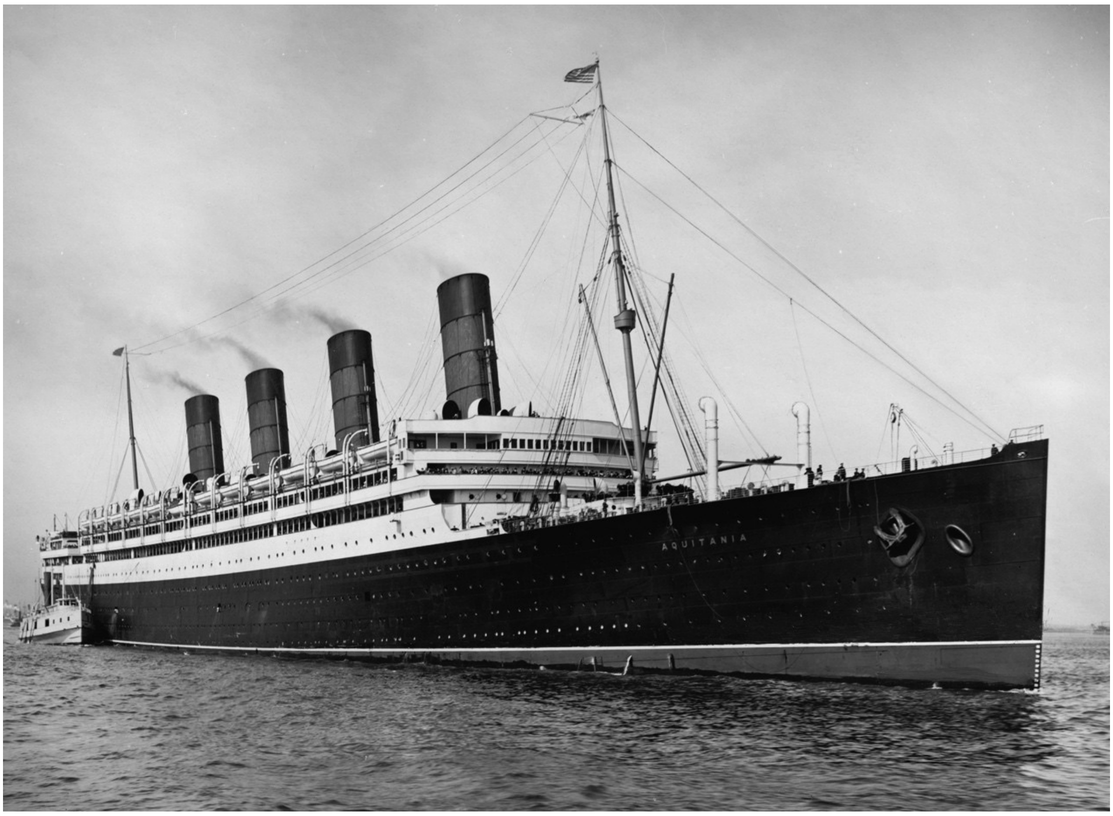

RMS Aquitania 1913

Owners: Cunard Line Ltd

Builders: John Brown, clydebank

Cold Starting

STARTING RMS AQUITANIA
(from cold)

Overview of machinery spaces

Boiler rooms

Aquitania is (or was) a quadruple screw Cunard liner fitted with 21 double-ended boilers, operating at 195lb/in2. These boilers are arranged six each in each of boiler rooms 1,2&3 (note that Cunard numbers forward to aft compared to White Star which numbers aft to forward), and 3 in No4 Boiler Room (the aftermost one).
The double-ended boilers are fired for transatlantic passages up to full speed and used for main propulsion, power generation, auxiliaries and many other services that require steam.
Each double-ended boiler has 4 furnaces served with coal from wing bunkers.
Combustion air for the boilers is provided by forced draught fans, as is usual for Cunard vessels.

Coal bunkers

Coal bunkers are provided either side of the stokehold furnaces in each boiler room to enable a ready supply of coal for the trimmers and firemen to stoke the boilers. These bunkers form the double side of the ship through all the boiler rooms in a similar way to the Mauretania (unlike Titanic which has transverse bunkers either side of the transverse watertight bulkheads).
Ash chutes are provided to discharge ash from the furnace bottoms overboard at regular intervals to keep the stokehold clear of ash whilst at sea. In port ash hoists are used to dispose of the ash to shore facilities.
The main steam pipes run the length of the boiler rooms to the bulkhead stops in the centre engineroom for distribution to the engines and auxiliaries.

Figure 1 Aquitania's stokehold prior to oil conversion

Propulsion engines

The propulsion system differs from the Mauretania's double (or compound) expansion as the turbines are arranged for triple expansion. The turbines are arranged in series to drive four shafts, there being one high-pressure (port turbine room), one intermediate-pressure (starboard turbine room) and two low-pressure turbines (centre turbine room). Astern turbines are fitted on all four shafts.

The ship has a very comprehensive redundant system for running the turbines together or in isolation, but we will explain the normal triple-expansion arrangement.

Steam from the two main steam pipes running the length of the boiler rooms enters the enginerooms via bulkhead stop valves, operated by Brown's engines and governors from the turbines. From the stop valves, the steam passes through a proprietary separator and via the manoeuvring valves into the ahead or astern hp turbine.

The exhaust from the hp turbine passes to the inlet of the ip turbine, which in turn exhausts to both the lp turbines.

Exhaust steam from the low-pressure turbines is directed to the vacuum condensers, situated in a further watertight compartment aft of the turbine room, where it is condensed into feed water and pumped back into the boilers.

Manoeuvring from ahead to astern is normally carried out using the lp ahead and astern turbines, with the hp and ip turbines used for working up to full speed.

The turbines may be isolated in case of breakdown, though this bypassing is only used in an emergency.

Regulating valves, driven by worm and quadrant gear via spindles operated from the starting and manoeuvring platform, admit steam to the engines as required by the telegraph orders.

Electrical power generation

Main generating sets

The vessel is fitted with four 400kW 225Vdc main turbo-generators driven by Parsons steam turbine prime movers at 1500rev/min. These sets are situated in a central station on H Deck, between Boiler Rooms 3 & 4. The main switchboard is situated at the fore end of the turbo-generator room.

Steam at a pressure of 150lb/in2 is fed to the turbines and exhaust steam is directed in port or at start up to the auxiliary condensers. At sea the exhaust steam is directed to the direct contact feed heaters to extract the remaining energy from the exhaust steam and deliver it to the feed heating system. This configuration gives a total installed power of 1.6MWdc, with three sets covering the full steaming load and one in stand-by.

Auxiliary/emergency generating set

Whilst the vessel is – unlike the previous ships – fitted with an emergency generator, this is only a 30kW diesel generator and is provided solely for emergency lighting, wireless telegraphy etc. It cannot run a FD Fan (50hp, or 37kW), so we still need to start using shore power. As it is not possible to cold start with the machine, it is open to conjecture why it is fitted. If all the boilers and main generator sets are out of action at sea (most unlikely with the amount of redundancy of the systems) it should have at minimum been able to power the emergency systems plus any one FD Fan, by fitting two such generators instead of one. In a Titanic situation it would at least allow the engineers to escape the doomed vessel!

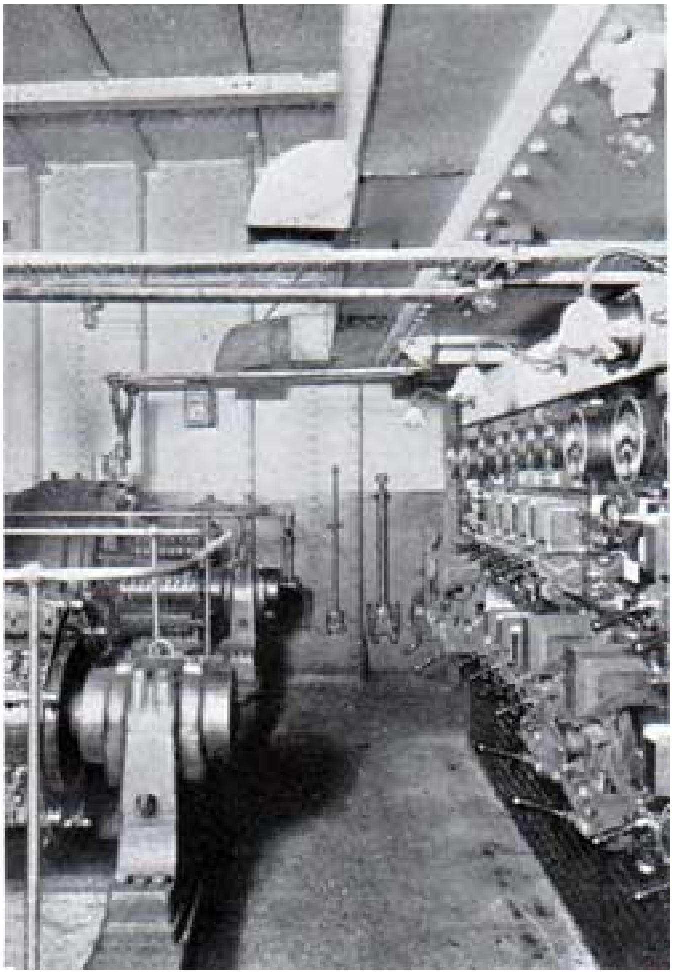

Figure 2 Generator room and switchboard

Firing up the boilers

The engineers start the required forced draught fans on the shore power supply. Assuming that for a main generator to run we need at least all the fires in one boiler room lit, one FD fan is started to supply the furnaces in one of the main boiler rooms. The firemen are set to work in this boiler room to lay fires in all required furnaces. Once lit, the boiler draft is adjusted by dampers and the fires start to heat the water in the fire-tube boilers. Water-tube boilers are much more efficient and faster starting than fire-tube, but hadn't been invented at this time. It would take around 12 hours to raise steam to manoeuvring pressure.

It's now 12 hours on, and we have around 190lb/in2 at the main stops to the main steam lines to the enginerooms. The main stop valves of the boilers are cracked open to the main steam pipe and the piping and valve drains opened to clear the lines of condensate, which can damage reciprocating and turbine machinery. The remaining boilers are banked until main power is available.

Starting the generators

Auxiliary seawater pumps and condensers

In order to start a turbo-generator, the exhaust steam from the engines is directed to an auxiliary condenser, of which there are two, one in each of the watertight wing engine rooms situated either side of the centre turbine room.
The seawater passing through this condenser condenses the exhaust steam into water, thereby dropping its pressure. Without this the engine would trip on high exhaust backpressure, as the exhaust steam has nowhere to go. In addition the condensers are supplied with an auxiliary air pump (or vacuum pump) to increase the vacuum in order to drop the exhaust steam pressure further.
The auxiliary seawater pumps are steam driven and situated in the same room as the auxiliary condensers.
With the drains open, steam is admitted to the pump, which circulates seawater through the auxiliary condenser to overboard. In the same way the auxiliary air pump is started in order to draw a vacuum. We are now ready to start a generator.

Starting the main generators

As we will soon be consuming steam, we will also need to be able to start a main feed pump to supply the boilers with feed water as required.
The generator bearings are forced lube type, so first we start a LO pump (again steam driven, as are nearly all the engineroom auxiliaries) in the usual way.
After warming through the generator steam lines and opening the engine exhaust to the auxiliary condenser, the first and subsequent generators are warmed through and run up to a speed of 1500rev/min.
On the main switchboard (of which there are two, joined by a bus-tie breaker), the breaker is closed for the generator in question and the shunt field regulator adjusted to give mains 225Vdc voltage. There is no need to synchronise dc machinery unlike alternating current machines. Once the generator has settled down on the board, the shore breaker is opened to avoid back-feeding the shore supply as the main generator loads up.
We can now put the other generators on the board as required. We are up and running and can connect other feeders via the main switchboard distribution.
As you can see, this is quite a long job compared to a modern diesel powered ship (though steamships still take some time). A blackout on a modern motorship can be restored within a few minutes.

Starting main engines

We now have power for firing all the boilers necessary for starting the main engines and getting the enginerooms ready for sea.
First we have to get the propulsion exhaust steam system arranged in a similar way to that of the generators but, in the case of the main engines, the auxiliary condenser is nowhere near big enough to handle the exhaust from the propulsion engines.
For this we need to draw a vacuum on the main condensers of which there are two, situated in a watertight condenser room aft of the low-pressure turbine room.

Main seawater pumps

As with the auxiliary condenser, we need seawater to condense the steam and drop its pressure to avoid exhaust backpressure on the engines. These are pretty huge and are driven by compound steam engines. There are two pumps per condenser (total of four) arranged adjacent to the condensers in the condenser room.
As with all steam engines, these are first warmed through with the drains open, then slowly started up until they are at full revs. Once the pumps are started, seawater passes through the condensers and discharges overboard – that's the large discharge that can be seen on any steamship up to the present day.

Main dual dry/wet-air pumps pumps

The air pumps (called vacuum pumps these days) evacuate air and water vapour from the condensers and draw a vacuum in so doing. This improves the exhaust flow from the engines and also extracts the maximum energy from the steam. They are situated aft of the main condensers and are of course steam driven. They are started in the usual way, and left to draw a vacuum on the condensers, usually around 28.5in with an atmospheric pressure of 30in. Water from the wet-air pumps is returned to the hotwell tank under the condensers, as is air from the dry-air pumps.

Main Generators

Now that the steam and feed system is up and running, we can extract the energy from the main generator exhaust by redirecting it from the auxiliary condenser to the contact/direct feed heaters, through which the condensate from the feed tank passes via the hotwell pumps (see later) to mix with the generator exhaust steam. This imparts heat to the feed water to avoid wasting the energy from the generator exhaust.

Main engines

By this time the engineers (we assume we are not doing this on our own) will have engaged the electric turning gear motors on all four shafts, as well as starting the turbine forced lube oil pumps (steam driven). The engines are kept turning until required for use, whence the gear is withdrawn to avoid damage to it in the event of starting a turbine with it engaged. Gland steam is assumed to have been fitted (no mention in the Engineer & Shipbuilder reprint I have) and will be started up to extract leakage steam from the turbine shaft glands, and condense it back to the hotwell drains.
The turbines are kept warmed through ready for manoeuvring and working up to speed on passage, with manoeuvring steam admitted to the hp turbine with the drains full open and the exhaust open to the ip turbine. In series, the exhaust steam from ip turbine exhausts via two branches into the lp turbine sets. At first the main steam stop valves are cracked open until everything is warmed through, whence they can be fully opened.
Once the turbine drains are emitting steam, we can call the bridge and ask if the propellers are clear for a slow turn ahead and astern on all shafts. Once this is given, the hp turbine manoeuvring valve is set to the ahead position (which isolates the astern turbines) and the main steam regulating control valve cracked open at the starting platform at the forward end of the lp turbine room. Each engine turns ahead at low revs. After a few turns of the shafts ahead the

regulating valve is closed and the manoeuvring valve set to the astern position to feed steam to the astern turbines on each shaft. Again the regulating valve is cracked open and the astern hp turbine turns, with its exhaust to the ip astern turbine and the ip exhaust to the lp astern turbines. The shafts turn astern for a few revs at low speed.
We are about ready to go, and test the communications between the engineroom, boiler rooms and bridge so that we are ready for sea service. Around the same time an engineer is dispatched to the steering engine room to warm through the steering engines and test the rudder from midships to 30 degrees port, back to 30 degrees starboard then returning to midships.

Figure 3 Mauretania starting platform

The feed system

Steam from the condensers that has condensed into the hotwells under the condensers is returned to the boilers via two feed heaters using the sets of hotwell pumps located under the main condensers. These pumps deliver the condensate to the *surface feed heaters* located high in the engineroom above the lp turbines. These heaters are fed with exhaust steam from the auxiliaries (the pumps mentioned above, such as seawater, air pumps, lube oil pumps etc.) and this steam heats the feedwater passing through the shell and tube heating elements.
From the outlet of the surface heaters the feed water is passed to the second of the two feed heaters, which is a *direct/contact heater* where the water comes directly in contact with exhaust steam from the main generating sets. These heaters are also situated high in the engineroom above the lp turbines and act as a deaerator once the air vent at the top of the heater is opened up to the main condenser to extract undesirable gases (CO2 and O2), which can cause corrosion problems in the boilers. In this heater the generator exhaust steam condenses in contact with the boiler feed water stream from the hotwell pumps and is then extracted under gravity by the main feed pumps and sent to the boiler distribution mains as required. Aquitania did not have automatically operating feed control valves, so this was a manual operation. The height of the heater ensures that there is sufficient positive suction head for the main feed pumps that feed the boilers. All is now ready to go, with the stokers bending their backs to raise steam on all the boilers required for leaving port. Appropriate

recirculating piping is supplied to return feed water back to the hotwell depending on boiler load conditions.

Getting under way

In response to the bridge signals on the engineroom telegraphs, the ahead/astern turbine sets are manoeuvred accordingly as above and the ship departs her berth and heads for the open sea.

High-pressure and intermediate-pressure turbines

Once the ship is up to full ahead, and prior to full away, the steam is now passing from the boilers to the main steam lines, through the hp turbine, into the ip turbine, then the lp turbines and finally exhausting to the condensers, from where it is returned to the boilers as above in a closed feed cycle. Full power can now be worked up once full-away is rung on the telegraphs.

We're done, we've been down below on a coal-burner for over 12 hours, and it's time to go to bed.

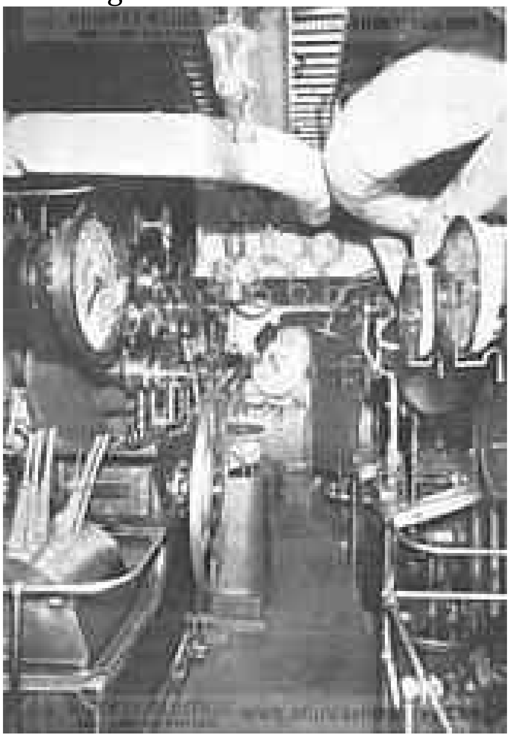

Figure 4 View between the lp turbines and starting platform of a transatlantic liner.

Coal-firing v oil-firing

Coal-firing was a dirty, messy, labour-intensive way to feed a furnace. As well as bunkering and firing the boilers, disposal of the ash was an additional burden on the stokehold staff. "Coaling ship" was an "all hands" task where everyone turned to in order to fill the coal bunkers via coaling ports in the side of the ship. Oil-burning on the other hand is far less labour-intensive, with the bunkering taking place via a hose from a bunker barge in to the same bunkers as the coal was previously.

A coal-fired ship needed some 250 stokehold staff to fire and tend the boilers, whereas ships like Aquitania when converted to oil-firing only needed some 60-odd stokers.

Figure 5 Disposing of ash from a furnace

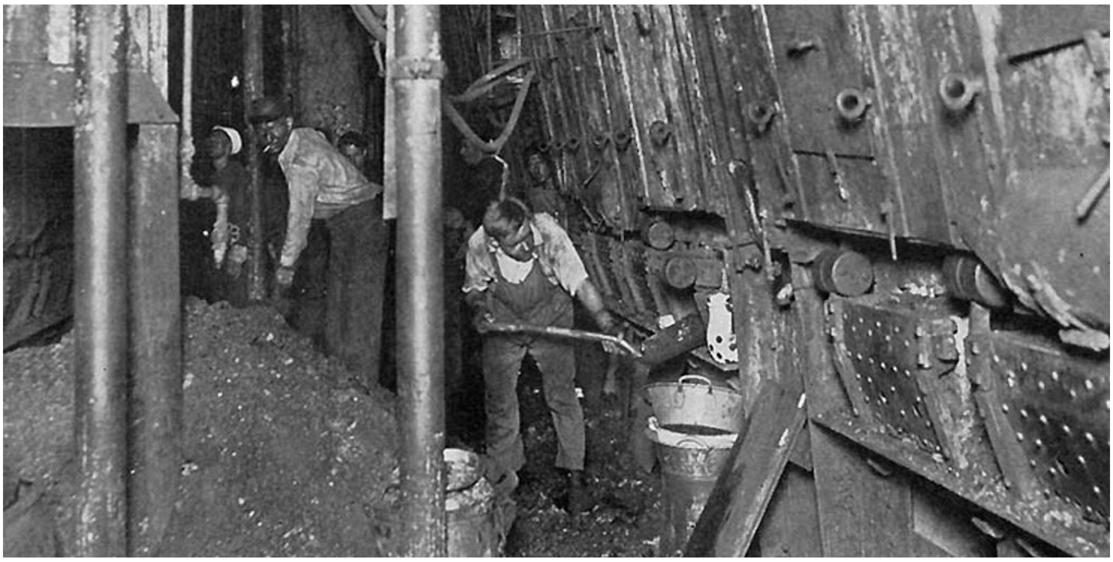

Figure 6 Filthy conditions in a coal-fired stokehold

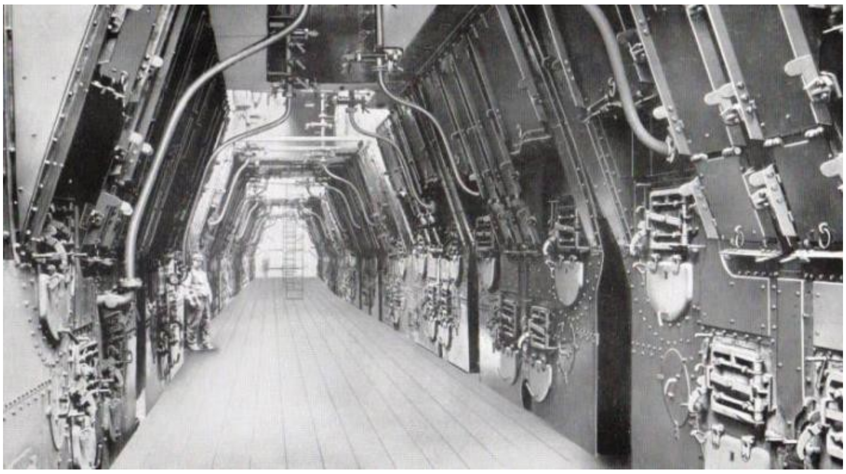
Figure 7 Typical stokehold after conversion

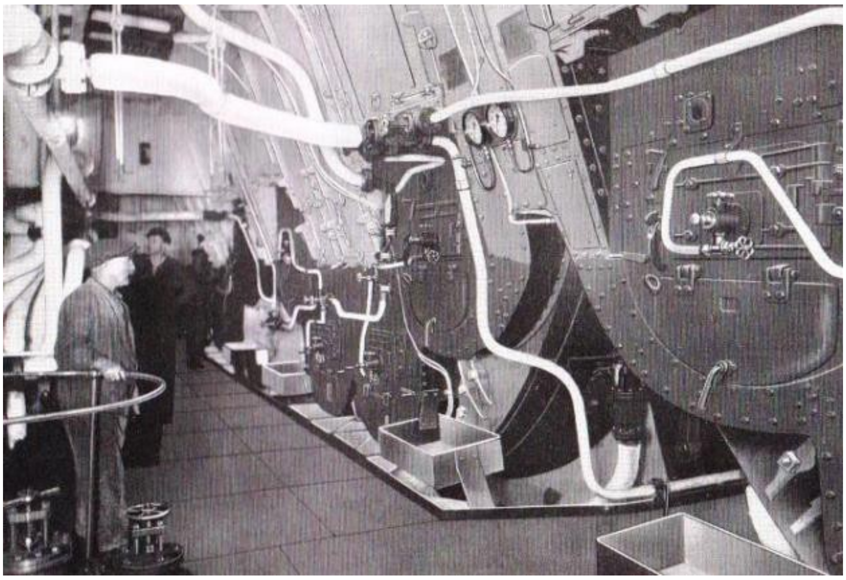
Figure 8 Mauretania boilers after conversion

From the pictures above, compared to the filthy conditions in a coal-fired ship, can be seen the huge improvement in working conditions once the stokehold had been converted to oil firing.
In addition, firing on oil was far more efficient, and the power output of Aquitania improved substantially after conversion, as did the overall Specific Fuel Consumption. As there was no requirement to discharge ash overboard, the ship was much cleaner and – even though the environment was not much considered in those days – oil firing opened up the world shipping fleets to better environmental conditions. The volume of smoke seen issuing from the funnels of these large passenger ships also reduced dramatically; an oil-fired boiler is designed to run cleanly, with no smoke other than a haze at the funnel tops, whereas it was difficult to avoid smoke – especially whilst manoeuvring – from over 20 boilers fired on coal. The coal fires are slow to react to changes in steam demand and draught requirements, whereas oil firing can react immediately.
One procedure that didn't really improve was the length of time taken to raise steam in fire-tube boilers, and it was some years before the next major trans-

Atlantic steamship was built using water-tube boilers. This was the Empress of Britain, which will be discussed in a further document on starting these large liners from cold.

Plates from the publication "Ocean Liners of the Past, Aquitania

(With notes to explain the various items of equipment fitted)

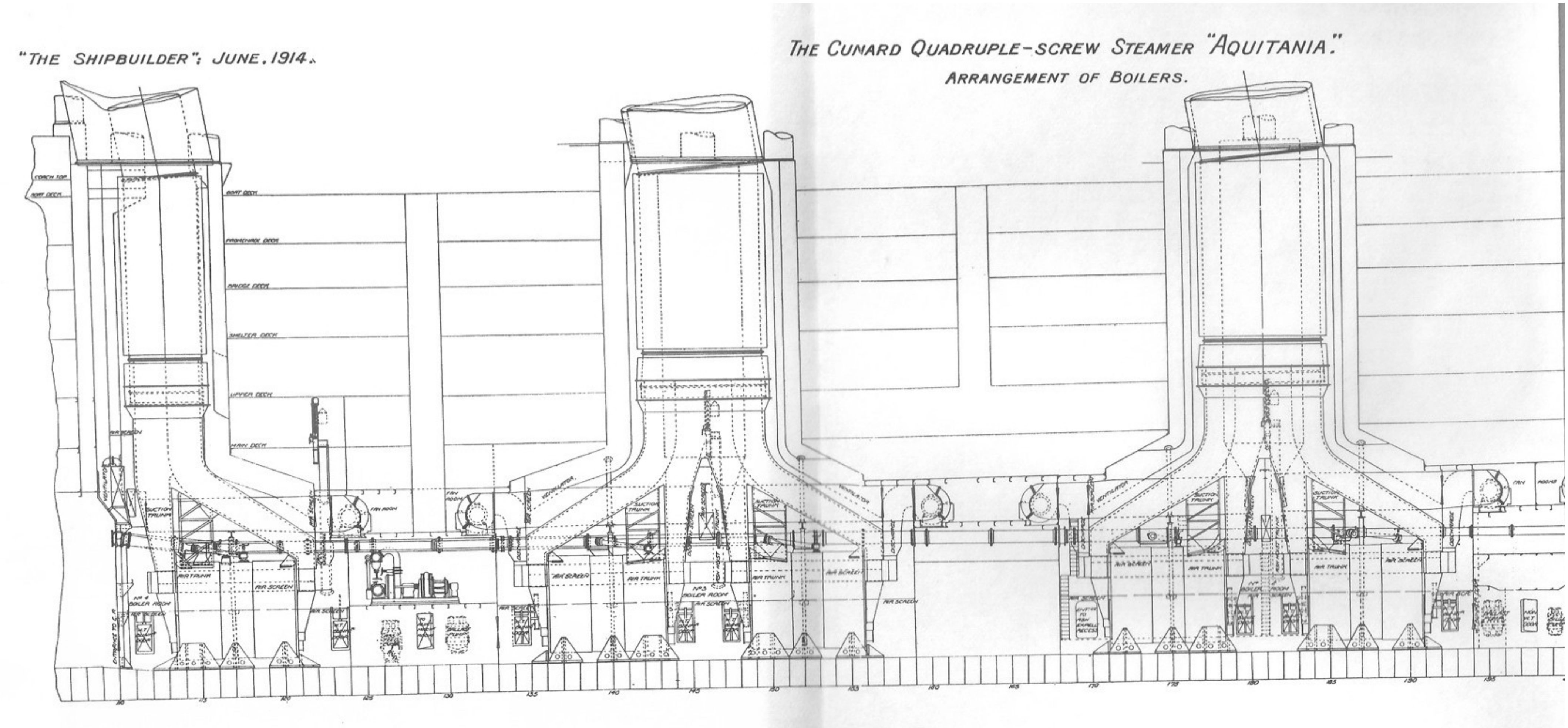

Figure 9 Elevation of boiler rooms up to the ER bulkhead

Profile of Boiler Rooms

On the view in Figure 9 can be seen the extent of boiler rooms 2,3 and 4, with a hint of Boiler Room 1 at the fore ends. The boilers are installed 6 to a room, 3 abreast.

Uptakes

The uptakes can clearly be seen, illustrating that all four funnels on this vessel served the boilers (unlike the Titanic, whose aft funnel was a ventilation shaft.

Turbo-Generator Flat

Between frames 124 and 133 are the 4 main generators and switchboard.

Main steam lines, FD Fans and escape ladders

On the profile view, note the main steam lines running the length of the ship above the boilers and the forced draft fans mounted on the deck above. Nos 1 & 2 boiler rooms feed one steam line, 3 & 4 the other. The line size changes towards the forward engineroom bulkhead as the steam volume increases with more boilers on line.
Also note the vertical ladders the same as the Titanic where the stokers can get out of the stokehold if the watertight doors are closed.

See Figure 15 for plans of the watertight subdivisions in the ship.

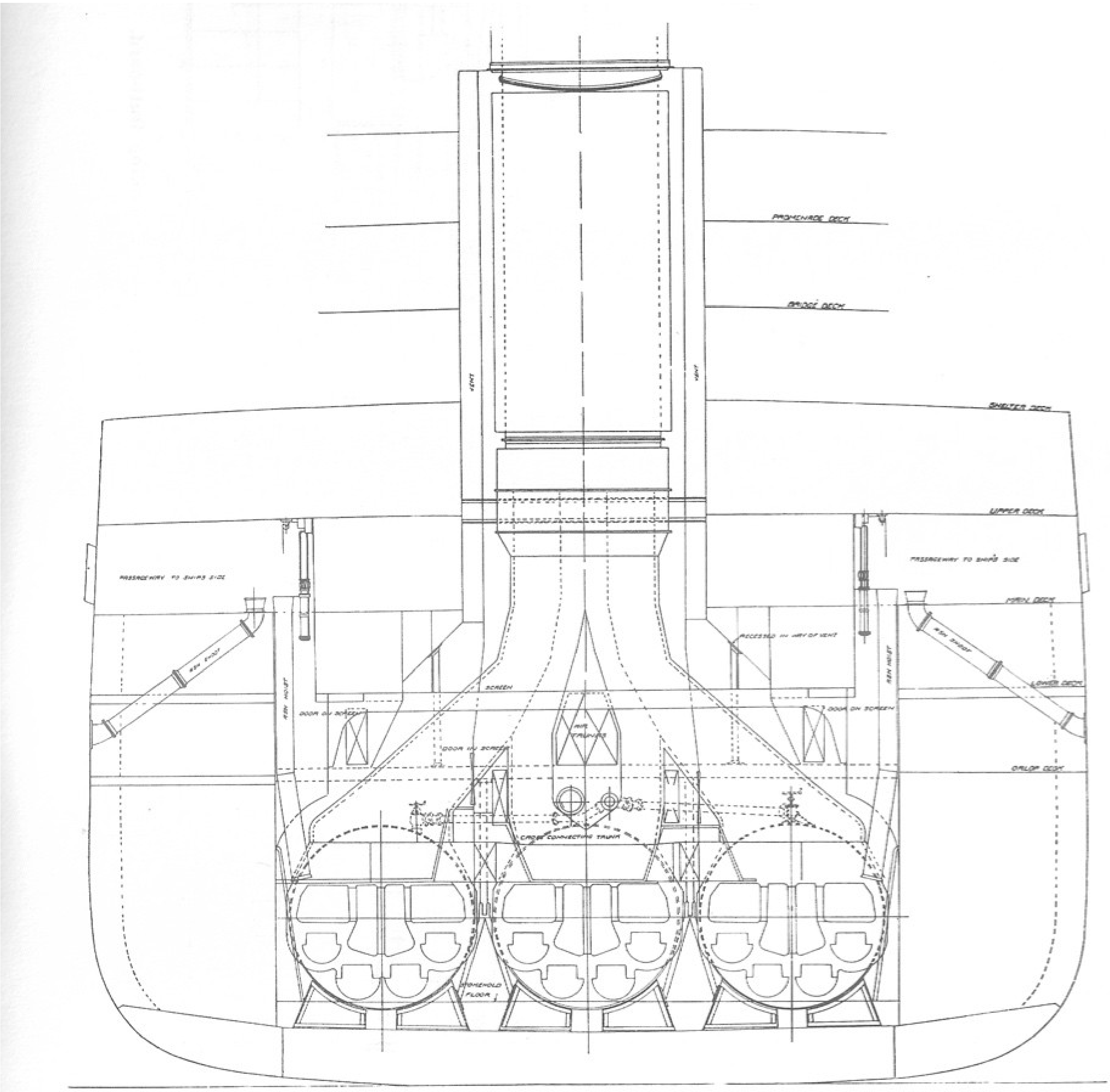

Figure 10 Section of boiler room at Fr.146

In this section can be seen the arrangement of the boilers athwartships in threes. Each double-ended boiler has 4 furnaces at each end, or 8 furnaces per boiler. Note the boiler seatings – not designed to hold the boilers in place if the ship takes a plunge to the bottom. The fine line just above the bottom of the boiler shell is the floor plating. This is fitted accurately into the stokehold to stop ash from dropping through and clogging the space below which, whilst it looks empty, is fairly full of piping. Ash from the furnaces is shovelled into holes covered by gratings, which are the ash chutes. The ash hoists take up ash, and a jet of water takes the ash over the side as shown in the pipes going outboard on the above drawing.
Also shown are the boiler main stops feeding the main steam lines running through the boiler rooms from forward to aft.

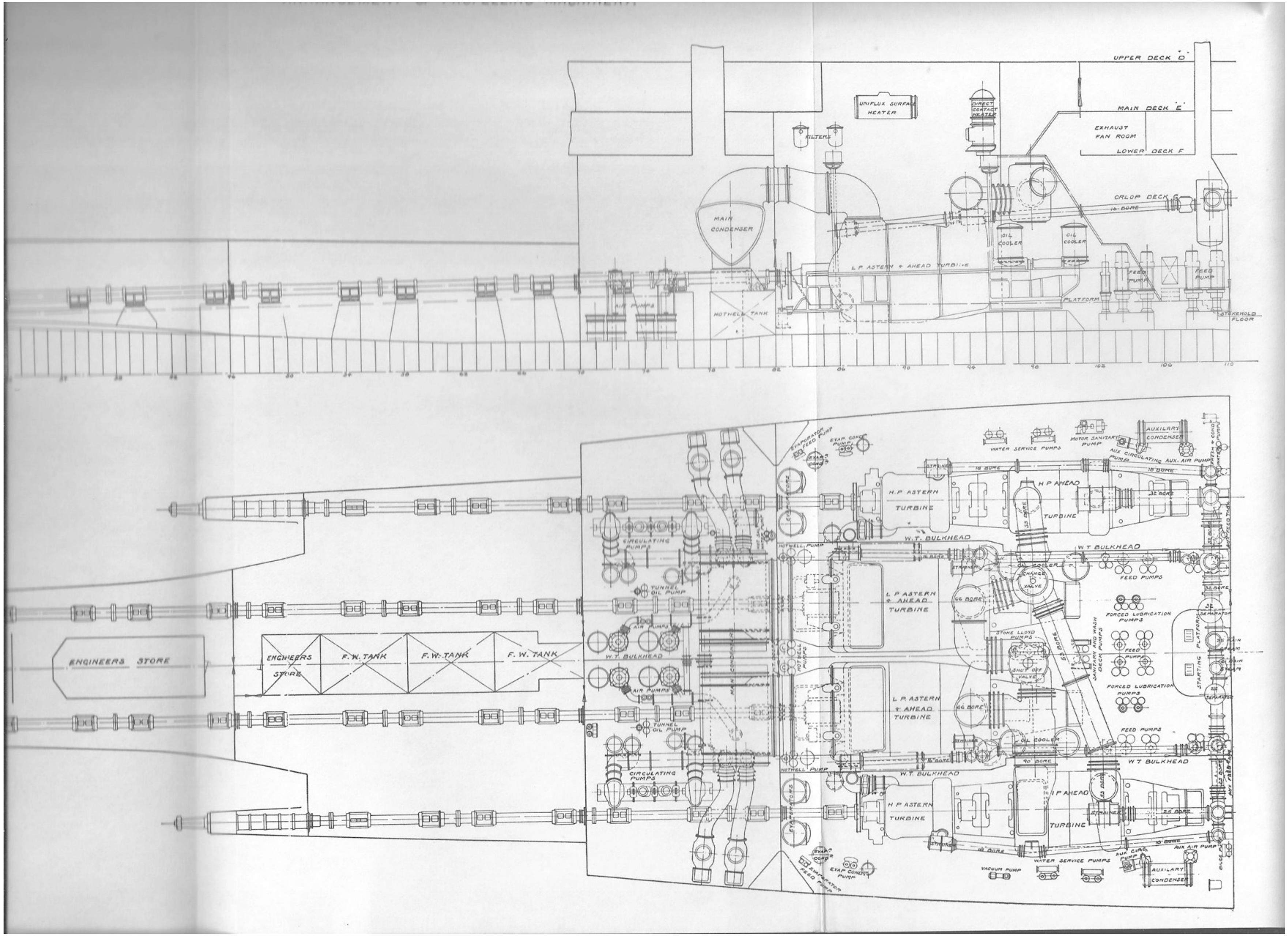

Figure 11 Plan and Elevation of machinery spaces

Plan and elevation of machinery rooms

The views in Figure 11 and Figure 12 show the forward engineroom bulkhead on which are the bulkhead stops for the two main steam lines exiting from No4 boiler room. The bulkhead stops are actuated by Brown's steam engines, as they are too large to manually operate. The engine overspeed governor can act on these valves and shut off the steam in the event of overspeed. Also shown are the direct steam lines to the wing turbines and the large steam separators.

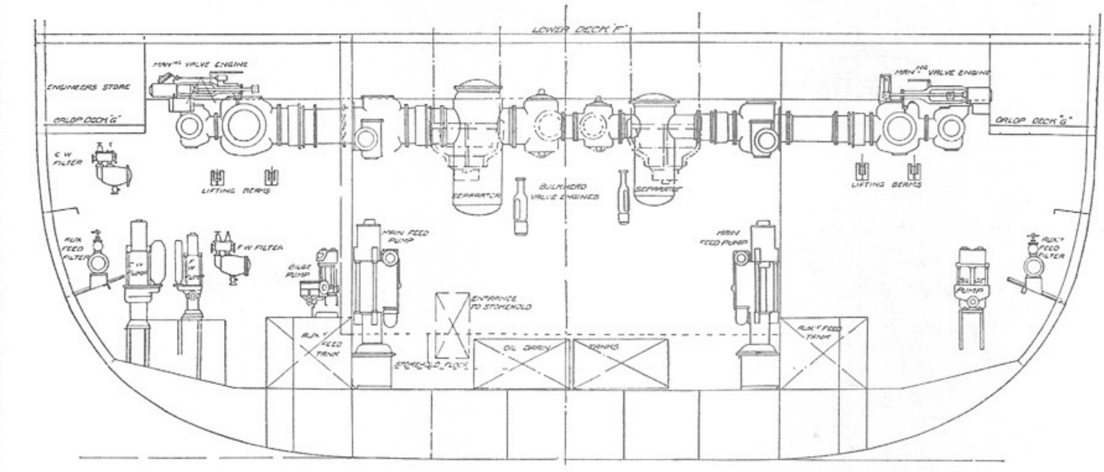

Figure 12 Section at Fr 10 looking forward

The four propulsion turbines are shown; the hp turbine in the port watertight compartment, the ip turbine in the starboard watertight compartment and the two lp turbines in the centre watertight compartment. The steam lines interconnecting the turbines in series are also shown.

Steam lines

The steam, after passing though a strainer to remove particles, is directed to the hp turbine via the pipe passing through the watertight longitudinal bulkhead. The ahead steam pipe of 32" bore is shown entering the turbine on the centreline, at Fr. 102. The hp astern steam line is shown outboard of the turbine passing aft to the hp astern turbine at Fr. 92.

The hp turbine exhaust is directed to the ip turbine inlet via the large changeover valve (used for isolation purposes) and the 53" pipe routed across the space to the ip turbine inlet at Fr. 102. Note that there is also a 25" steam line from the bulkhead stops direct to the ip turbine when the hp turbine is isolated.

The ip turbine exhaust is led via the 90" bore line to the 66" inlets on the two lp turbines.

After passing through the lp turbines, the steam exits to the condensers via the large rectangular exhaust ports shown on the top of the turbine casings at Fr.87.5.

When running astern on the hp and ip astern turbines, these units exhaust direct into the lp astern turbines on each side. In the astern case it seems from the drawings that the hp/ip and lp turbines are in compound arrangement and not triple-expansion. The hp and ip astern turbines are therefore controlled independently via the astern regulating valves for each set shown on the forward engineroom bulkhead.

The starting platform from where the engines are driven ahead and astern is located at the forward end of the lp engineroom, arranged on the centreline under the bulkhead stops. The starting wheels comprise a large outer wheel for the bulkhead stops, and a smaller inner wheel for the manoeuvring valves. The levers for controlling the turbine drains and sluice valves are close by.

See Figure 16 and Figure 17 for further sections through the turbine rooms.


Figure 13 Starting platform showing manoeuvring wheels and drain valve levers

Turbine isolation

The various changeover valves and bypass lines show how the turbines can be arranged for maximum redundancy. However, operating on a wing shaft can only be carried out using the two shafts on that particular side of the ship. The large shut-off valve on the centreline isolates the hp and ip turbines from each other such that the hp and lp (P) run together, and/or the ip and lp (S) run together. The changeover valve isolates the ip turbine from the hp turbine, and allows the hp turbine to exhaust into the port lp turbine inlet.

Main manoeuvring valves

Arranged on the forward bulkhead can be seen the outlines of the various manoeuvring valves that direct steam into the turbine inlets.

Feedwater pumps and forced lube oil pumps

In the space between the starting platform and the forward end of the lp engines are arranged the main feedwater pumps. These pumps draw from the direct/contact feed heater mounted on the flat above the turbines, and is shown on the elevation at Fr.95.
The forced LO pumps are also shown in the same space, as are the large oil coolers further aft.

Auxiliary equipment

A set of evaporator machinery for producing fresh water is installed in each wing turbine room, as are various other water and service pumps.

The auxiliary condensers and associated seawater pumps and air pumps are arranged at the forward end of the wing turbines rooms. The Stone-Lloyd pumps are shown located under the shutoff valve in the centre of the lp turbine room, and are for operating the watertight doors.

Main condenser rooms

In the main condenser rooms are installed the main condensers, separated by a centreline watertight bulkhead. Mounted under the condensers are the hotwells for collecting the condensed steam, and the hotwell pumps, which pump the condensate into the feed system, are shown just forward on the centreline.
Also in the condenser rooms are the main seawater circulating pumps – 2 each side – and the dual air pumps for creating and maintaining vacuum on the condensers.

Shafting and propellers

In the watertight compartment aft of the condenser rooms and mounted within the double bottom are various water tanks. From the thrust bearings mounted at the aft end of the lp turbines (the engines which are coupled to the centre shafts) the two propulsion shafts are arranged in the shaft tunnels and exit the ship via the stern tubes. There are several intermediate bearings (Plummer Blocks) along the length of the shafting which are splash lubricated.

Figure 14 Shaft tunnel of a large liner

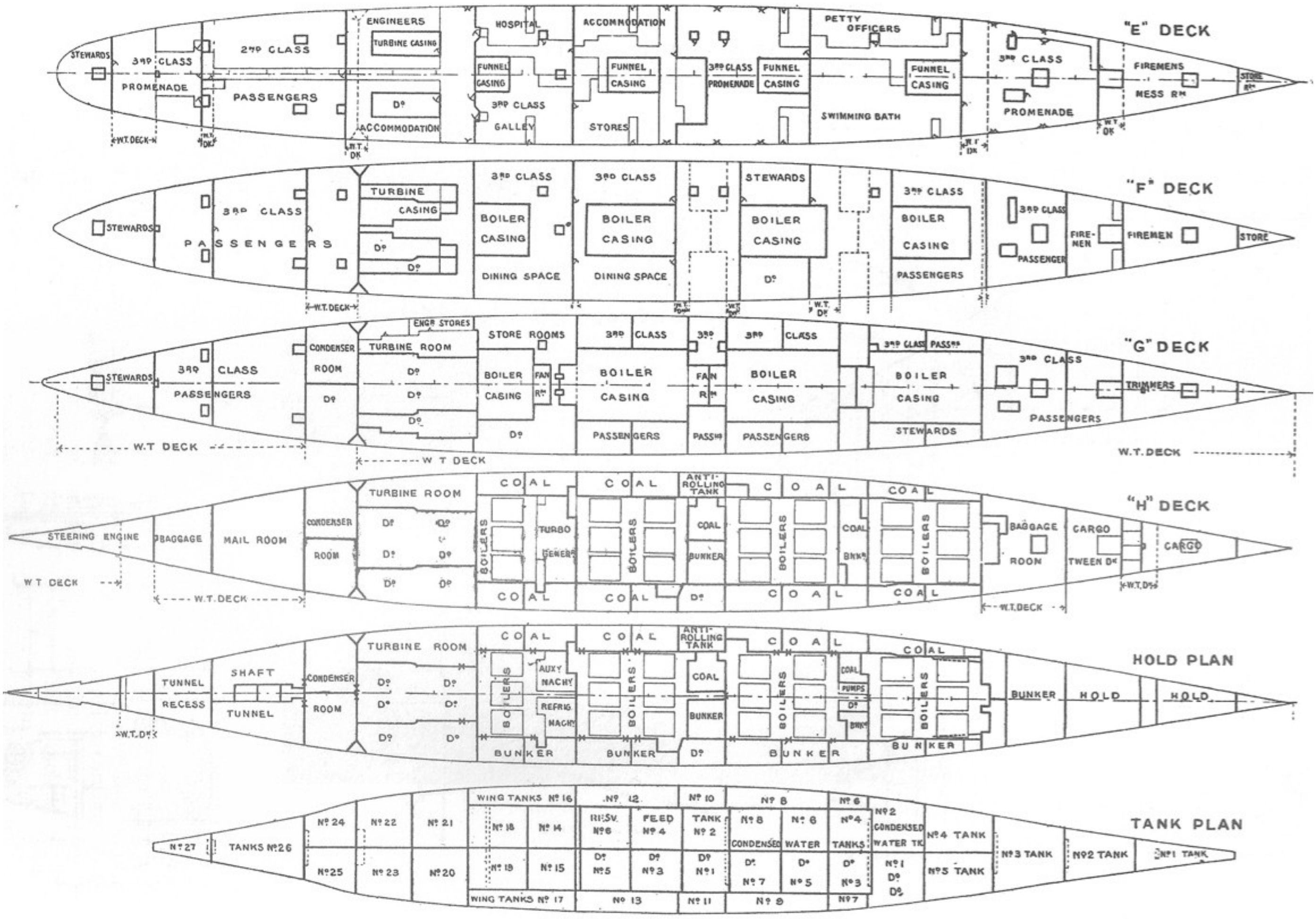

Figure 15 Plan of watertight subdivisions

On the plans above can be seen the subdivision of spaces within the ship. Unlike Titanic, the watertight bulkheads are not open at the top, but are connected to watertight decks.
The boiler rooms are subdivided by longitudinal (the watertight bunkers) and transverse bulkheads, which separate each set of 6 boilers from their neighbours.
Anti-rolling tanks are fitted outboard of Boiler Room 3, but it is not known whether these worked or not.

Coming next – a major departure from Scotch boilers and low steam pressures; the innovative Canadian Pacific liner Empress of Britain.

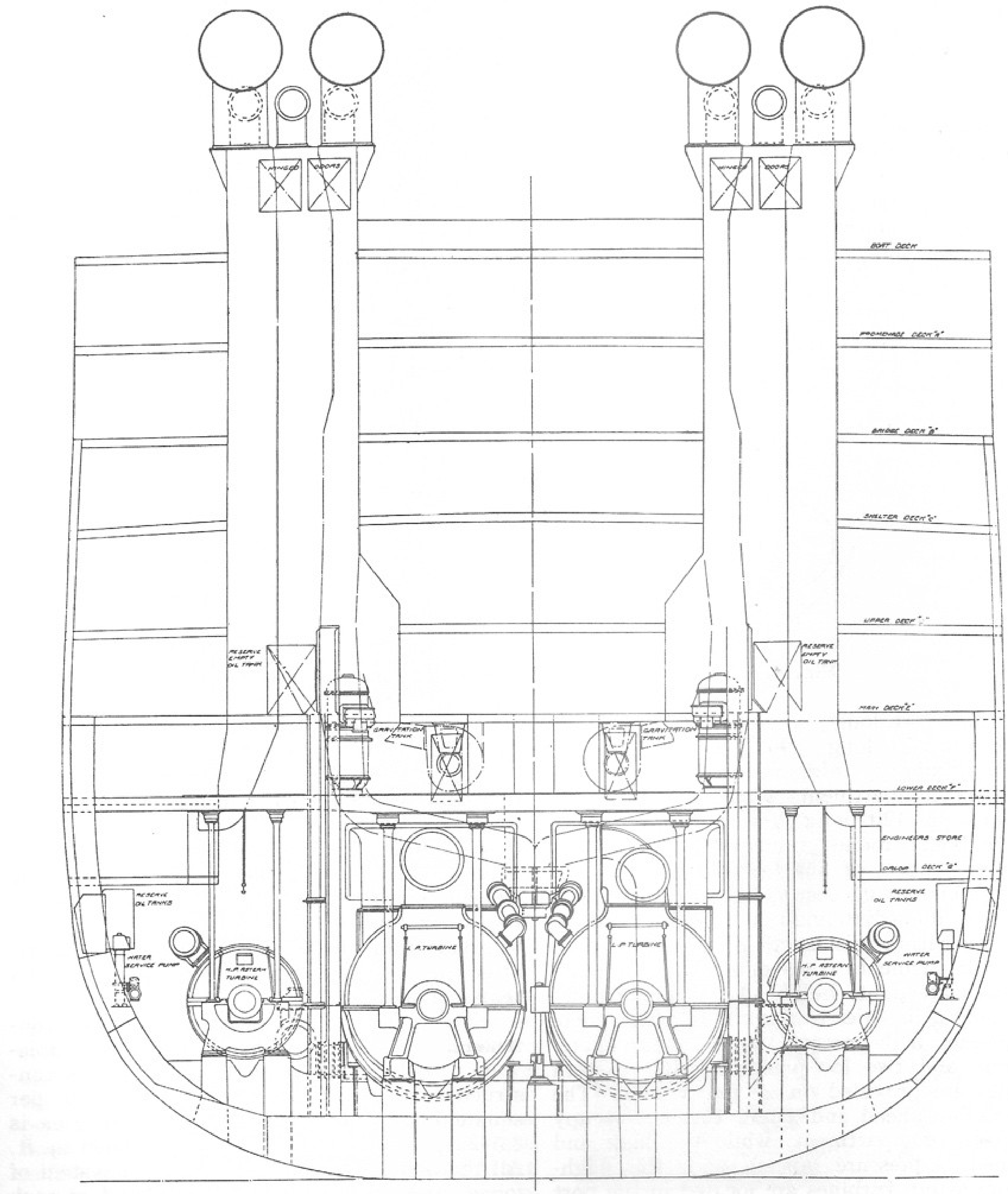

Figure 16 Section through Turbine Rooms at Fr.98, looking Aft

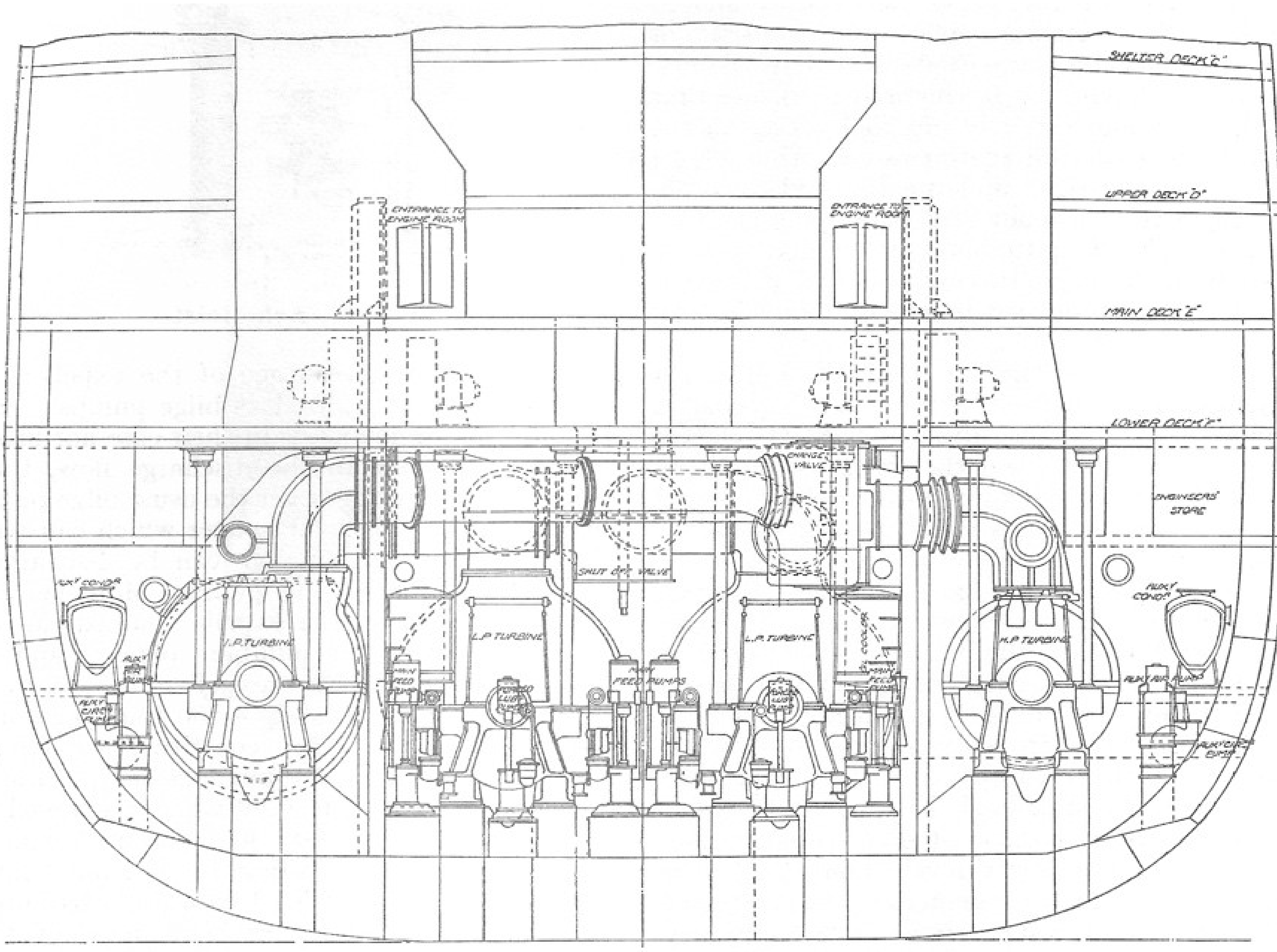

Figure 17 Section at Fr.109, looking Aft