CATECHISM
OF THE
MARINE STEAM ENGINE

BY

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CAPTAIN. R.N. F.R.G.S. F.S.A.

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MARINE STEAM ENGINE.

FOR THE USE OF

YOUNG NAVAL OFFICERS

AND OTHERS.

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CAPTAIN R.N., F.R.G.S., F.S.A.

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PREFACE.

SHOULD this small work, which occupied some of the Author's leisure hours during the *Clio's* passage out from England, prove useful to those for whom it is intended, a Second Edition, with Diagrams, is purposed.

H.M.S. "CLIO,"
PANAMA, CENTRAL AMERICA,
October, 1860.

CATECHISM,

ETC. ETC.

QUESTION 1. What is Force?

ANSWER. Whatever alters a body's state of rest or motion.

Q. 2. What two Kinds of Force require to be separately considered in Mechanics?

A. Statical and Dynamical.

Q. 3. Describe Statical Force?

A. Statical force is the consideration of stationary force, as weight, or pressure, and shows what pressure, through the intervention of levers, will balance some other weight, or what levers are required that two given different weights may balance each other.

Q. 4. What is a Lever?

A. A lever is any rigid inflexible body moving round a fixed centre, called its fulcrum; the effective leverage being the shortest distance from its fulcrum to the direction in which the force acts.

Q. 5. What is Dynamical Force?

A. Dynamical force is the consideration of force in motion, as horse power, and depends on the weight of the body and its velocity.

Q. 6. What is Horse Power?

A. The first engines made, superseded the use of horses in pumping water out of mines, &c.; and, for the convenience of calculating the useful work of an engine, which is the product of the resistance it can overcome multiplied into the space through which that resistance is moved, it was proposed to compare the work of an engine with what a certain number of strong horses could perform; and hence it was calculated that a strong horse could raise 33,000 lbs. one foot high per minute, since which time the measure of an engine has always been its horse power.

Q. 7. What is meant by Nominal Horse Power?

$$\frac{D^2 \times \cdot 7854 \times 7 \times \text{feet per minute}}{33000} = \text{Nominal H.P.}$$

or,

$$\frac{D^2 \times \text{Nominal vel.}}{6000} = \text{Nominal H.P.}$$

A. Nominal horse power is an understood arranged method for constructing engines so as to let the manufacturer and the party wishing to buy an engine have some idea of the power and expense. The pressure on each square inch of the piston is calculated for 7 lbs., and the speed per stroke and number of revolutions is also fixed. It is, therefore, evident that the horse power thus found is properly called nominal, and must fall very far short of the indicated horse power.

Q. 8. What is meant by the Indicated Horse Power?

$$\frac{D^2 \times \cdot 7854 \times \text{average pressure} \times \text{vel.}}{33000} = \text{Ind. H.P.}$$

A. The indicated horse power is the power exerted, before the friction is deducted, and is ascertained by means of an indicator attached to some part of the engine while at work, whereby the pressure of the steam acting on the surface of the piston is found.

Q. 9. How does the Resistance of a Body moving through the Water vary?

A. As the square of its velocity—that is, when the velocity varies, as 1, 2, 3, 4, &c., the resistance becomes 1, 4, 9, 16, &c.

Q. 10. How does the Force of Impact vary?

A. As the velocity squared.

Q. 11. How does Fuel to generate Power vary?

A. As the velocity squared, when referred to distance, because the space is constant; but as the velocity cubed, when referred to time, because both the pressure and the space vary.

Q. 12. How does Speed vary?

A. As the square root of the resistance.

Q. 13. What effect has Heat on a body?

A. The effect of raising its temperature or increasing its bulk.

Q. 14. Define the doctrine of Latent Heat, Sensible Heat, and Specific Heat?

A. Latent heat is that which converts a solid into a liquid, or a liquid into a gas. Sensible heat is that which raises the temperature. Specific heat is the relative quantity required by different bodies to raise their temperature one degree; that required by water being the standard of comparison.

Q. 15. On what does the Quantity of Heat which a body contains depend?

A. On its weight and hotness, or total heat, as expressed by its degree of heat, whether latent or sensible. In illustration.—The continued application of heat to water of 32° will eventually make it boil at 212°, so that the increase in the hotness is represented by 180°, which is the difference of those two arbitrary numbers. Further, if the water escaping, or rather the steam, be collected and afterwards employed in heating water, it will be found to have contained $5\frac{1}{2}$ times as much heat as was required in making the water boil; so that the heat which steam contains, in addition to that which is necessary to make water boil at 212°, is $5\frac{1}{2} \times 180° = 990°$, which, not being indicated by the thermometer, is called latent heat. Again, 2 lbs. of water at 212°, or 2 lbs. of steam, contain, it is obvious, more heat than 1 lb.;

because the hotness of each being the same, the weight of one is twice that of the other; it is also obvious that 1 lb. of steam at 212° contains more heat than 1 lb. of water at 212°, although the temperature and weight are the same in consequence of that additional heat called latent; and the quantity of heat which a body contains must be expressed by multiplying the weight of a body by its hotness.

Q. 16. Of what use is a knowledge of Latent Heat with reference to the steam engine?

A. For the purpose of explaining why the same quantity of fuel is required to generate steam irrespective of its pressure or temperature.

Q. 17. Why is a Steam Engine so called?

A. A steam engine is so called from steam being the principal agent, and heat the moving power, and may be used for almost any purpose where motion is required.

Q. 18. What is meant by Superheated Steam?

A. Superheated steam is steam with higher temperature than due to saturated steam of the same pressure.

Q. 19. Why is Common Steam sometimes called Saturated?

A. Because steam in its ordinary condition in the boiler has a greater or less amount of water amongst it in a finely divided state, whilst superheating, this same steam evaporates the water and leaves it drier.

Q. 20. Name the different Engines in general use?

A. Atmospheric or Newcomen's. Single-acting and double-acting. The latter are of two kinds, called low or high pressure, according as to whether they condense or not, and are the description of engines used for marine purposes. The double-acting condensing engine being most generally used in England, except on the rivers, where, as also in America, high pressure engines, which are non-condensing, are frequently introduced. The atmospheric and single-acting are used for pumping water out of mines, or other like purposes.

Q. 21. What Classes of Marine Steam Engines have we?

A. Two classes, viz., side lever and direct action.

Q. 22. Give a short description of them?

A. The side lever is a modification of the old sway-beam engine, and when steam was first used as a motive power on the water it was the only kind in vogue; but now they are seldom used, as they occupy too much space. Direct-acting engines produce a rotary motion of the crank by the piston without the aid of side beams or levers, and are so varied in their forms that scarcely two are alike.

Q. 23. What kind of Direct-acting Engines are most in use?

A. Gorgon, Fairbairn's, Maudslay's double cylinder, oscillating and trunk for propelling paddle steamers, and for those propelled by screw of every modification; the principal difference being that the same kind of engines for propelling screw vessels are placed with their cylinders horizontal, or inverted, the power being either applied direct to the screw shaft or by means of gearing, but generally the former.

Q. 24. Is there any difference in the internal arrangements of these and Side Lever Engines?

A. None.

Q. 25. What, then, is the difference beyond placing the Cylinders horizontal?

A. The difference lies in the way the power exerted is transmitted to the crank, and in the placing of the different parts. The prime object being to confine the space to the smallest limits.

Q. 26. What are the advantages of Condensing and non-Condensing Engines?

A. Condensing engines are more economical in the consumption of fuel, but they take up much more space and cost more money. Non-condensing engines should only be used where fuel is cheap and readily obtained, and where it is important to save room and weight; hence they are used on railways and for short voyages; but for long voyages the condensing engines have a decided superiority.

Q. 27. Describe the Parallel Motion?

A. The parallel motion is a system of rods which admits of the piston moving in a straight line by having two fixed points, *i.e.*, causes, by moveable rods in connection with different parts of an engine, a strictly direct up and down action; and the form assumed by the various rods in motion to effect this being like a parallelogram, gives parallel motion for the term.

Q. 28. Give a short description of the Atmospheric Engine?

A. In this engine the cylinder was open to the atmosphere at the top. The steam did not exceed atmospheric pressure, viz., 14·70 lbs., and its use was to give a balance of forces; the weight of the rods, &c., was half that of the atmosphere, and the steam being admitted to the lower part of the cylinder, forced the piston up, not from its pressure—for the atmosphere acting on the other side established an equilibrium—but the weight of the rods overcame the pressure, and the piston descended with a like force; the weight of the rods acting against the atmosphere made the pressures alike. These engines condensed by injection in the cylinder.

Q. 29. What did James Watt's improvements consist in?

A. In adopting a separate chamber for the condensation of the steam after doing its duty in the cylinder, and in admitting the steam to the cylinder on the up and down stroke of the piston alternately.

Q. 30. Give a short description of the Single-acting Engine?

A. Single-acting engines were closed at both ends, and had a separate chamber for condensing. Still the weight of the rods was the motive power, and in these engines the steam was admitted into the upper part of cylinder, instead of the *lower*, as in the *atmospheric*, with a passage leading to the condenser at lower end of cylinder. The steam, after acting to force the piston down, is allowed a free access to the lower part, and then, an equilibrium being established, the weight of the rods carry the piston up, while, on descending, the steam below is passed into the condenser.

Q. 31. What is the great difference of principle in Double-acting Engines?

A. They admit steam both at the up and down stroke of the piston, by which means the counterbalancing weight of rods is done away with.

Q. 32. Describe Gorgon Engines?

A. Gorgon engines are direct-acting, and have the cylinder, air-pump, and condenser in a fore and aft line with the cylinder placed vertically below the paddle-shafts, the cross-head being connected to the crank by a short connecting-rod. A bar connecting the rocking-beam with a fixed point in the engine-room gives parallel motion. The air-pump is worked at the other extreme of rocking-beam, supported by a rocking standard. By this arrangement the engines occupy less of the ship's length. Rods are dispensed with, and the frame made much lighter; moreover, the effort which the engine exerts is sustained by its own frame in lieu of being distributed over three points, producing strain in contrary directions, as is the case with beam engines.

Q. 33. You have mentioned the advantages of these Engines; can you state if they possess any disadvantage?

A. There are many modifications of these engines, but they have the serious disadvantage of requiring a large diameter of paddle-wheel in proportion to the stroke, which causes considerable waste of fuel by slip, and renders the ship ill able to steam against head seas and strong gales.

Q. 34. Give a short description of Fairbairn's Engine?

A. Fairbairn's engines are very similar to the Gorgon engines, the chief peculiarity being in the parallel motion; and if you will conceive the rocking standard described in Gorgon engines as inverted, and the air-pump worked from a radius in an opposite direction, with the four main parts of the engine forming a square and occupying the least possible space, you can, doubtless, comprehend these engines.

Q. 35. Describe Maudslay's Double-cylinder Engines?

A. These engines have two cylinders for each, which, with the air-pump, stand in a fore and aft line upon the condenser, with one connecting-rod between them. They have a T-shaped cross-head, to lower end of which is attached the lower end of connecting-rod, the upper end being attached to the crank; and the shaft is placed vertically over the space that intervenes between the cylinders. The air-pump is worked by means of a beam, one end of which is connected to the T-shaped cross-head. By this arrangement less of the ship's length is required, and also a less height of paddle-shaft is obtained, with a greater length of connecting-rod. A cylindrical slide supplies both cylinders at the same instant.

Q. 36. Describe Oscillating Engines?

A. Oscillating engines *occupy* less space, and weigh less than any others, except trunk. They have the least diameter of paddle-wheel, and the fewest parts. The piston-rod is attached direct to the crank, the shaft being placed vertically over the cylinder, which is suspended on two hollow trunnions. The steam enters a belt on the cylinder through the trunnion nearest the ship's side, and escapes to the condenser by the opposite one. The air-pump is worked by a crank on the middle of the intermediate shaft, having a cross-head working in guides, and a connecting-rod. The slide-valve works on a lever, one end of which moves in a curved slot, whose form is such that, when this curved slot or sweep is motionless, and the cylinder oscillates, the slide maintains the same position on the cylinder, so that by the eccentric being connected to this slot or sweep, the slide receives motion, while the cylinder oscillates just as it would if the cylinder were at rest.

Q. 37. Describe Trunk Engines?

A. Trunk engines have no piston-rod. The connecting-rod comes direct from crank to piston, and vibrates in a hollow trunk, which is rigidly connected with the piston in the cylinder. The cylinders are horizontal, and connected direct to the screw-shaft. Now, as the crank revolves, the end of the connecting-rod must vibrate, which it is at liberty to do, though there is no piston-rod, because the size of the trunk admits of a vibratory motion within it. They are fitted with locomotive slides and double eccentrics, rendering the back and head turns always to be relied on. The air-pump is worked directly by the piston, the pump-rod passing through the cover of the cylinder. All the parts of the engine are as low as possible, so as to bring the machinery below the water-line.

Q. 38. What are the objections to Oscillating Engines?

A. The most substantial objection that is urged against oscillating engines, is their liability to wear oval in the trunnions and stuffing-box, whereby they become leaky.

Q. 39. Why are two Engines usually employed on board of Steamers instead of one?

A. Because, when one engine is broken down, $\frac{7}{10}$ths of the full speed can be obtained with the other. The resistance varies as the square of the velocity; a ship which encounters a certain resistance at 10 knots, encounters half that resistance at 7 knots. The square of 7 is half the square of 10.

Q. 40. How is an Equable Motion obtained where only one Engine is employed?

A. By reefing or removing those floats which are in the water when the crank is on the dead centre.

Q. 41. What kind of Engines have we for working the Screw Propeller?

A. We have every modification of engine, though they may be said to be of two kinds, viz., those that are arranged to work the screw-shaft direct, and those that do so by means of gearing. The latter plan has a longitudinal shaft above the cylinder connected to a large driving-wheel, which, acting on a smaller wheel connected with the screw-shaft, causes it to revolve; they are generally fitted with double eccentrics for the purpose of rapidly reversing the motion, which is most essential in ships propelled by the screw.

Q. 42. Give a concise description of Direct-acting Screw Engines?

A. The cylinders lie horizontally on opposite sides of the screw-shaft. The connecting-rods are attached to the same crank as gives motion to the shaft. There are usually four of these cylinders, two on each side of the shaft; but if two cylinders only, they do not work the same crank as gives motion to the shaft, for, if so, the engines would both be on their centres at the same time. The air-pumps are usually placed under the main shaft, and worked from it by means of eccentrics. The cylinders are placed as far as they can be conveniently from the shaft, so as to give length to the connecting-rod.

Q. 43. Give a short description of Geared Engines?

A. The connecting-rod turns the crank, and with it the driving-wheel, which is geared, and acts upon the pinion on the screw-shaft; so, as the driving-wheel revolves one way, the pinion revolves the opposite, and thus rotation of the screw-shaft is produced.

Q. 44. Give a short description of Oscillating Horizontal Engines?

A. There are usually four cylinders, two pistons being coupled to each crank, the cylinders being allowed to oscillate about their steam and eduction-pipes. The piston-rods, which also serve as connecting-rods, turn the crank, and thus the motion is given. The air-pumps are worked as in direct-action, but in lieu of being placed vertically, are at an angle so as to be worked by one crank.

Q. 45. Describe the Engines as fitted on board H.M.S. *Clio?*

A. The engines as fitted to H.M.S. *Clio* are Horizontal Direct-acting, of 400 nominal horse power, by Ravenhill, Salkeld, & Co. They have two cylinders, contiguous to each other, in a fore and aft line on one side of the centre of the ship. Each engine has two piston-rods, one of which passes over the shaft, and the other under. These rods are attached to a short arm or elbow at each end of the cross-head, one of which stands up, and the other down, in order to meet the relative position of the end of each piston-rod. The ends of the cross-head work in guides. On the centre of the cross-head works one end of the connecting-rod; the other, of course, is attached to the crank. The air-pumps are double-acting, and are worked horizontally by the rods being attached to the ends of the lower arms on the cross-head, which are lengthened for this purpose. These engines differ mostly from others by having the condensers formed in the framing.

Diam. of Cylinders	64 in.
Stroke	3 feet.
Pitch of Screw	26 „
Length of Screw	3 „
Diameter of Screw...	16 „
Boilers (each boiler four furnaces)	4
Tubes in each...	1440
Tubes, in length	6 feet.
Diameter of Tubes...	$2\frac{1}{2}$ in.
Furnace, length	6 feet.
Furnace, breadth	2 ft. $10\frac{3}{4}$ in.
Pressure on Safety Valve	20 lbs.
Weight of Engines, Screw, Boilers (water included), and Screw Gear	286 tons.

Q. 46. What are Governors for?

A. Governors are for controlling the admission of steam through the throttle-valve as occasion requires. They are fitted to all land engines, and are sometimes fitted to screw steamers of light draught of water for the purpose of limiting the supply of steam to the cylinder when the vessel pitches. For as the propeller is at one extremity of the vessel, it will at times, by the pitching of the ship, be performing its revolutions in the air. The engines will then be relieved of their load, and if the supply of steam were not reduced, they would fly off at a great velocity, which would again be checked as the stern of the vessel became immersed, which would be detrimental to the machinery. The great difficulty in adapting the governors to steam-ships was in counteracting the action of gravity in such a manner as to leave the instrument sufficiently sensitive to the least variation in the speed of the engine. This is beautifully overcome in that highly ingenious and scientific invention, Silver's Marine Governor, which is extensively adopted in the merchant service, several hundred vessels being already fitted with it, where it works with the most complete success; and it is so sensitive, that if the engines only exceed their regulated speed over one-sixth of a revolution, this governor immediately checks it. All marine engines should have governors, as an additional means of insuring safety, by preventing the sudden and undue straining of the parts of the machine.

Q. 47. Would a Fine or a Coarse Pitch be best for such vessels? and would a two or three-bladed screw be found most advantageous?

A. A fine pitch would be best.—A three-bladed screw would be preferable, because there is always one blade in the water.

Q. 48. Describe the construction and use of the Indicator?

A. The indicator is an instrument temporarily applied to the cylinder of a steam engine, either at top or bottom, or both, for the purpose of ascertaining the various pressures of the steam corresponding to different positions of the piston, *i.e.*, the pressures of the steam with which different portions of the cylinder are filled; in fact, the indicator reveals the hidden imperfections of the engine. A small cylinder has a piston which fits steam-tight, but moves freely within it. The piston-rod is connected to the upper part of the instrument by a helical spring, so that the piston cannot move up without compressing, or down without extending it. Another small cylinder is attached to the side, round which is wrapped a slip of paper, on which rests a pencil, which is carried up and down as the pressure of steam differs from that of the atmosphere, and a horizontal motion, similar to that of the piston, but less in amount, is communicated to the cylinder by a string attached to any convenient part of the engine, by which it is pulled round one way, while the piston makes an up or down stroke, and rotates back when the string is released by the action of a watch-spring in the lower part of the cylinder during return stroke. A stop-cock is attached to the bottom for the purpose of admitting steam, so as to act upon the indicator piston; but previous to opening it the pencil is generally made to draw a straight line upon the paper, whilst both sides of the little piston are acted on by the atmosphere, after which, by opening the cock, the pencil will trace a curve for the most part above the atmospheric line on the up stroke, and on the return stroke of the piston another curve is traced entirely below the atmospheric line. The atmospheric line may be drawn either before or after the diagram is traced. When the indicator pencil rises, the steam pressure is increasing; when the indicator pencil falls, the steam pressure is decreasing; but in neither case is the little piston moving. When the pencil moves to the right, the piston is descending; when the pencil moves to the left, the piston is ascending.

Q. 49. How can the Indicator be tested?

A. The indicator is tested by stopping the engine, taking a diagram by pulling the string by hand, and observing the steam and vacuum gauges, from which comparison you perceive whether, and how much, the length or number of coils the spring should be increased.

Q. 50. What information is deduced from Indicator Diagrams?

A. 1. Ratio of indicated to nominal horse power, which represents the efficiency of the engines, and shows whether the power exerted is great or small in proportion to their size.

$$\frac{D^2 \times \cdot 7854 \times \text{Eff. Press.} \times \text{Vel.}}{33000} = \text{Ind. H. P.}$$

$$\frac{D^2}{12} \times \cdot 7854 \times \text{stroke} = \text{Cap. of Cylinder in Cubic Feet.}$$

2. The quantity of water evaporated and effectively employed per hour; or, more strictly speaking, the quantity of steam used in the cylinder in cubic feet per nominal horse power.

$$\frac{\text{Cap.} \times \text{Portion} \times \text{Revs.} \times 60}{\text{Rel. Vol.}} = \text{Cubic Feet of Water evaporated per hour.}$$

3. Ascertains the economy of the engines, showing what proportion the effect produced bears to the quantity of steam used; by which you learn how many horses' power is obtained out of each cubic foot of water evaporated per hour.

$$\frac{\text{Mean. Eff. Press.}}{\text{Press. at } \frac{9}{10} \text{ stroke}} \times 2\tfrac{1}{16} = \text{Eff. H. P. per Cubic Foot evaporated per hour.}$$

4. The amount of tube surface per nominal horse power, which shows whether the boiler power is great or small in proportion to the engines.

$$\frac{\text{Diam.}}{12} \times 3 \cdot 1416 \times \text{length (in feet)} = \text{Surface of each Tube in square feet.}$$

5. The amount of heating surface per cubic foot evaporated, shows the superiority of the boilers,

and that the quantity of steam produced is great or small in proportion to their size.

$$\frac{\text{Surface and No. of Tubes}}{\text{Nom. H. P.}} = \text{Surface per Nom. H.P.}$$

6. Ascertains if the steam flows freely into and out of the cylinder, by knowing the pressure in boiler and state of vacuum in condenser, and shows that with the pressure to which the boilers are loaded and the vacuum produced in the condenser, whether the power of the steam is fully, or imperfectly developed.

$$\frac{\text{Surface per Nom. H. P.}}{\text{Evap. per Nom. H. P.}} = \left\{ \begin{array}{l} \text{Square Feet of Surface per Cubic Foot of} \\ \text{Water evaporated per hour.} \end{array} \right.$$

7. Determines the capacity of the cylinder.

$$\frac{\text{Nom. H. P.}}{\text{Cap. of Cyl.}} = \text{Nom. H.P. per Cubic Foot of Cylinder.*}$$

Q. 51. Describe Marine Boilers?

A. Marine Boilers are of two descriptions, viz.: flue and tubular. The latter are the best, and their distinction lies in the manner in which the passages for the heated air between the fire-bridges and steam

* Nominal H. P. is used to determine the size of an engine; and if the method of calculating it was correct, the above information, all of which is referred to this standard, would be conclusive; but, since the mode of calculating Nominal H.P. is incorrect, it is necessary to determine the capacity of the cylinder, which is a correct measure; and, dividing Nom. H. P. by this we ascertain the number of H.P. at which each cubic foot of cylinder is rated.

funnel are constructed; they also occupy much less space with the same amount of heating surface. The fire-places are in front, divided in two parts (viz., the furnace and the ash-pit, one over the other) by the fire-bars, which slope downwards. The fuel is placed on the bars, supported by two cross-pieces fastened in the fire-places or furnaces—the underpart being the ash-pits—which have their separate doors, called fire-doors and dampers. These openings go back into the boiler say about five or six feet, where the ash-pit ceases, being closed by a barrier called the bridge, placed across to compel the air that enters the ash-pit to pass between the bars into the fire-place. The bridge goes partially across the upper part; the flame from the fire-place has to pass over this bridge. The uptake is where the heated airs of the different fires join before going up the funnel. In the flue boiler, the smoke or flame passes through a circuitous flue passage surrounded by water; in the tubular, through a series of tubes which are in like manner surrounded by water. The space in the boiler above the water is the steam chest. The cylindrical spiral boiler introduced and patented by Messrs. Randolph, Elder, & Co., engineers, of Glasgow, is a great and important improvement, both for economy and safety, as it enables steam of a high pressure to be employed without danger, and completely utilises the heat from the fuel, the waste heat in the uptake being under 500°. Its great superiority in all respects over the two just named cannot fail to lead to its general employment.

Q. 52. Name the Valves and Cocks usually fitted to Marine Boilers?

A. Safety valves, vacuum or reverse valves, valves in feed-cock, stop or communication valve, Kingston valves, steam gauge-cocks, blow-out cocks, feed-cocks for engine, feed-cocks for donkey, brine-cocks.

Q. 53. Name the Gear connected with Marine Boilers requiring the especial attention of the engineer?

A. Safety valves, stop valves, reverse valves, gauge cocks, glass water gauges, blow-out cocks or pipes, also pipes and cocks for getting rid of the brine, and feed pipes.

Q. 54. Describe a Safety Valve?

A. A safety valve is to open the communication between the boiler and the external air. When the internal pressure is more than the boiler can safely retain, the boiler would burst, but for the steam thus escaping from the safety valve.

Q. 55. Describe a Reverse Valve?

A. The reverse valve is the vacuum or internal safety valve, and is fitted to all boilers to prevent their collapsing, which they would do were an escape not fitted to allow the atmosphere to enter the boiler, when the pressure of the atmosphere is greater than that in the boiler, and which happens after the engines have done their work, and the fires have been drawn, and the water and steam are blown off.

Q. 56. Describe a Stop Valve?

A. The stop or communication valve is for admitting or shutting off the steam between the boiler and steam-pipe, and is most useful, as it enables the engineer to cut off the communication from any boiler at will. If there was no stop valve, the steam would pass freely from the boiler into the steam-pipe; but by having this valve, the steam, as fast as it is generated, is retained in the boiler, and, as the heat is confined to the boiler, the engine-room is kept cooler. If the steam-pipe was knocked away or pierced by shot, the steam, in lieu of rushing into the engine-room, would remain in the boiler.

Q. 57. Describe Gauge Cocks and Glass Water Gauges?

A. There are three gauge cocks to each boiler for ascertaining the height of the water, and the middle one is on the water level; so that, when opened, water should come from the lower, a mixture of steam and water from the middle, and steam from the upper; the glass water gauge serves to make the height of water visible to the eye.

Q. 58. What are Blow-out or Blow-off Cocks for?

A. Blow-out cocks are for filling the boilers, and for emptying them.

Q. 59. Where is the best place to fit the Reverse Valve, and why?

A. In front of the boiler in a casing, and fitted to open upwards; the upper side of valve to inside of boiler, and lower, to the atmosphere. Having them, as formerly, on top of boiler, rendered them more liable to be injured.

Q. 60. Have you any remarks to make on the Number of Boilers to be used when not going at Full Speed?

A. The usual practice is to use half the number of boilers and proceed at a proportionably less speed, in order to consume less fuel; the saving thus effected depending on the fact that consumption of fuel per hour varies as the cube of the speed, and per mile as the square of the speed.

Q. 61. Exemplify the above?

A. A vessel going 10 knots with 4 boilers would go 8 with 2; and if 2 boilers give a speed of 9 knots, 6 boilers would give a speed of 13 in smooth water and no wind.

Q. 62. Supposing the vessel meets with a strong head wind and tide, so as to compel her to use all her power, what would be her Rate then for the greatest Economy of Fuel?

A. Her rate of speed should be at least half as much again, as she would have gone in an opposite direction had no power been used; but in the event of the opposing tide being accompanied with a head wind, there can be no doubt that the greatest economy would be using full power.

$\frac{3}{2} \times$ rate of opposing tide = speed required.

Q. 63. Trace the Progress of the Steam through the Engines from its Generation in the Boiler?

A. Steam generated in the boiler passes through the stop or communication valve into the steam pipe, through the throttle and expansion valves into the slide casing, passing the slide valve, and by the action of the slide enters alternately into and out of each end of the cylinder, thence by the eduction-passage into the condenser, where it meets with a stream of water from the sea, by which the greater portion of it is condensed. The remainder expands and fills the condenser at a small pressure of about 2lbs., and by this force the water is driven out (if fitted with the single-acting air-pump) through the foot valve into the air-pump during the ascent of the bucket, and is raised up at the next stroke by the bucket dipping into it, and forced into the hot well through the delivery valve, whence it flows overboard by the waste water pipe, except a small portion which is drawn off by the feed pump and forced into the boiler.

Q. 64. The Boilers being empty, what steps must be taken to get up Steam so as to Start when required?

A. It is usual for the fires to be laid; therefore first run up the boiler by opening the blow-off cocks till the water has reached its level, then close them, and pump up the remainder by hand. Light the fires, attend to the funnel stays, open the stop and throttle valves, and all grease and drip-cocks attached to the cylinder and slide casing, in order that the engines may be gradually heated, shutting the grease and drip-cocks when steam escapes from them. Open the sea-cock and Kingston valve attached to donkey engine and injection pipes. Trim lubricators. Blow through by opening the blow-through valve, which will clear the condenser, affording a vacuum in it, and give the engines a complete turn by moving the slide valve by hand so as to bring both pistons to top of stroke.

Q. 65. What is Blowing out?

A. You blow out in order to remove the deposit that takes place in the boiler, and the brine thus expelled from the boiler is replaced by pure sea water from the feed-pumps, which are fitted to the boilers and worked by the engine. The brine is constantly passing from the boiler by the surface blow-off cocks. Brine pumps, as formerly fitted and worked by the engine, were not found to answer, and are now obsolete, or nearly so. The expulsion of the brine is, however, adjusted as before, viz., that the quantity they draw off, together with the quantity evaporated, shall equal the feed. Vessels fitted with brine-pumps have no occasion to blow out; but in order to prevent blow-out cocks setting fast, it is customary occasionally to do so.

Q. 66. Whereabouts is the Boiler Water Gauge placed, and how is it composed?

A. It is placed outside the boiler, and generally not far from the gauge cocks, and is composed of a vertical glass tube, about sixteen inches long; the ends of this tube fit into metal tubes, the lower one entering the water space, and the upper the steam space. Hence, the height of water in the tube is the same as that in the boiler. A stop-cock is fitted at the extremities to cut off communication with the boiler, and at the lower extreme there is another cock communicating with the stoke-hole to clear the gauge, when it becomes choked, by forcing steam through it. This gauge continues to indicate the height of the water when the pressure of the steam in the boiler is below atmospheric pressure, in which case the gauge-cocks fail.

Q. 67. What other means are there of ascertaining the Level of the Water?

A. The level of the water inside boiler may be ascertained by rapping on it from the outside.

Q. 68. Why is Blowing-through to be carefully attended to after the engine has done its work in cold climates?

A. Blowing through in cold climates is most essential, for if water was left in the condenser or air-pump, and was to freeze, it would necessarily retard the vessel when wishing to proceed.

Q. 69. Why is it necessary the different Pump-plungers should remain at the bottom of their cylinders?

A. The plungers should be at the bottom of their cylinders, so that no water should be beneath.

Q. 70. Why is it attended with danger to commence working the engines before the steam is well up?

A. Starting before the steam is well up is only attended with danger when on first starting you have to proceed through a difficult passage, or leaving a lee shore in bad weather; as, unless the expansive gear or throttle valve be attended to, the steam will fall in the boiler, and the engine will stop, perhaps at the very time it is wanted to exert its greatest power.

Q. 71. What is the Steam-gauge?

A. The steam-gauge is for ascertaining the pressure of steam within the boiler. It is composed of a bent hollow iron tube, one end communicating with the boiler, and the other open to the engine-room. This tube is partially filled with mercury, and when the pressure of steam in the boiler is the same as that of the atmosphere, the mercury will stand at the same level in both ends; but, as the pressure in the boiler increases or decreases over or under that of the atmosphere, the mercury will rise or fall in one leg, and *vice versa* in the other. Every rise of one inch in one leg is accompanied with the depression of one inch in the other; therefore, every rise of an inch shows a difference of level of two inches, and as two inches of mercury correspond to 1lb. pressure, it follows that every inch the mercury rises corresponds to an additional pound pressure of the steam. A thin rod floats in the mercury, having its upper end above the top of the tube, and is brought in contact with a scale of inches. The rod is pushed up by the force of the steam, and thus the number of pounds pressure becomes discernible.

Q. 72. What is the Vacuum Gauge?

A. An iron tube, open at the top and communicating with the condenser. Over this tube a glass tube, closed at the top, is placed, the lower part resting in a cup of mercury, and the lower part of the glass tube having a bulb. The mercury rises and falls between the iron and glass tubes, and denotes the state of condenser. When the scale attached to it stands at thirty inches, the vacuum in condenser is perfect, and for every two inches it falls it shows 1lb. pressure in condenser, the principle being that thirty inches of mercury, when in vacuo, correspond to 14·70 atmospheric pressure. A fixed scale is incorrect, on account of the area of the cup being larger than that of the glass tube, or should any of the mercury be spilt; therefore a sliding or floating scale is the most correct, and it is floated by a small piece of cork in the mercury, and shows by the elevation of the mercury in the tube the amount by which the pressure in condenser is less than that of the atmosphere.

Q. 73. What is the difference in principle between the Double-acting and Single-acting Air-pump?

A. The double-acting air-pump has no valves in the bucket, the bucket being solid, like a piston, and is worked to and fro by the rod passing through the cylinder cover, and attached to the piston in cylinder.

Q. 74. What description of vessels are fitted with Double-acting Air-pumps?

A. Generally vessels fitted with direct-action screw engines.

Q. 75. How is this description of pump fitted for Trunk Engines?

A. The air-pump fitted for trunk engines is horizontal, and worked direct by the piston.

Q. 76. What description of vessels are fitted with Single-acting Air-pumps?

A. Nearly, if not all, paddle steamers and all screw engines fitted with multiple gear.

Q. 77. What is Lap?

A. Lap is the excess of the slide face cover over the portway when the slide is at half stroke, and is a fixed expansion to the engine.

Q. 78. What is the object to be obtained by putting a certain amount of Lap on the Slide?

A. To procure a tolerable vacuum in condenser; for if the steam flowed into the cylinder during the whole stroke, and the velocity of the piston was considerable, it is evident a very imperfect condensation would take place, in consequence of the great quantity of steam to be condensed, and the little time to effect it. Hence it was found necessary to shut off the steam before the piston had completed its stroke.

Q. 79. What is Lead?

A. Lead is the space the port is open for steam when the piston is at the end of its stroke.

Q. 80. What is Cushioning?

A. Cushioning is closing the communication with condenser when the piston has completed about 9-10ths of its stroke, and is essential to prevent the momentum of piston before the fresh steam acts from damaging the cylinder covers.

Q. 81. What is Clearance?

A. Clearance forms the bed for the cushioning; it is the space between piston and extremity of cylinder at top and bottom stroke.

Q. 82. What is Slip?

A. Slip is the stern motion of the water caused by the propeller while forcing the ship ahead, and there can be no propulsion without slip; consequently it is the difference between the speed of the ship and that of the propeller, and is usually expressed per cent.

Revs. × 60 × Pitch = Speed of Propeller in feet per hour.
6082 × rate of steaming = Speed of Ship per hour.
The difference is the Slip.

Q. 83. What is its use?

A. To show the portion of power absorbed in driving the water astern, whereby the propeller is enabled to push the vessel ahead.

Q. 84. How do you obtain Slip per Cent.?

A. Multiply the slip thus found by 100, and divide the result by the speed of propeller, which will express the slip per cent., or cut off two right-hand figures of whole number in denominator of fraction producing slip, and divide as before; the result will express the slip per cent., or making a proportion, say, as the speed of propeller is to slip, so is 100 to slip per cent.

$$\frac{\text{Speed of Screw} - \text{Speed of Ship}}{\text{Speed of Screw}} = \text{Slip.}$$

$$\text{Speed of Screw} : \text{Slip} :: 100 : \text{Slip per cent.}$$

Q. 85. Have you any remarks to make as regards vessels propelled by Paddles?

A. Yes; in paddle-vessels you have to use the effective diameter of paddle to ascertain the circumferential velocity, and it is assumed that the centre of effect is at $\frac{1}{3}$rd the width of the float from outer edge; or, in other words, that the effective radius is $\frac{1}{3}$rd the width of the float less than that measured to the outer edge.

$$\frac{\text{Eff. Dia.} \times 3{\cdot}1416 \times \text{Rev.} \times 60}{6082} = \text{Circum. vel.}$$

$$\text{Circum. vel.} - \text{Speed} = \text{Slip.}$$

$$\text{As Circum. vel.} : \text{Slip} :: 100 : \text{Slip per cent.}$$

Q. 86. How do you ascertain the Circumferential Velocity?

A. The circumferential velocity is obtained by multiplying the effective diameter by 3·1416, by the revolutions per minute, and by 60 minutes, and dividing by 6082. The difference between this result, which is the distance she would have travelled in knots per hour, if its circumference had rolled upon a level path, and the speed of slip, represents the slip per hour; and, to facilitate comparison, is always expressed by the per centage that it bears to the speed of the paddle.

Q. 87. How can the accuracy of the Steam Gauge be tested?

A. By boring out the two legs with the same boring-bar, and by fixing a cock to draw off any water which may be lodged above the mercury's original level.

Q. 88. How can the accuracy of the Vacuum Gauge be tested?

A. By measuring the height of suspended column with a rule, and see whether it agrees with the scale, adding to or subtracting from the mercury in the trough as may be necessary.

Q. 89. What is the Refrigerator?

A. The refrigerator consists of a number of small tubes through which the feed passes on its way to the boiler, and round which the hot brine circulates on its way overboard, thereby absorbing a portion of the heat which would else have been wasted. It is, in fact, a "feed-water heater."

Q. 90. What is the Hydrometer?

A. The hydrometer is for testing the degree of saltness in the water, and shows the gravity of the water drawn from the boiler after the temperature is cooled down to 90°.

Q. 91. What is the Salinometer?

A. The salinometer combines the thermometer and hydrometer, and readily shows the saltness of the water by observing the indicator of the hydrometer at the instant the thermometer shows the temperature of 200°. It consists of a brass vessel with a pipe and a stop-cock communicating with the boiler. A. P. How's Patent Salinometers are the more generally approved.

Q. 92. How was the Water in the Boilers tested formerly?

A. In the earliest days, the saltness was tested by taste, and the gravity by seeing whether a potato would float or sink. This plan was succeeded by a thermometer observing the temperature at which it boiled under the pressure of the atmosphere, which ought not to exceed the boiling point of fresh water more than 3°.

Q. 93. What is the Expansion Valve for?

A. The use of the expansion valve is to cut off steam from the cylinder at various portions of the stroke, so as to economise fuel.

Q. 94. What are the advantages of using Steam Expansively?

A. Economy of fuel for the purpose of accomplishing long voyages, and to increase the power of the engines whenever the supply of steam is less than sufficient to fill the cylinder to full pressure, which will happen when a ship is being driven before the wind, or when the boilers have become defective.

Q. 95. What is the difference between Throttling the Steam, and using it Expansively?

A. When using the throttle, the steam flows into the cylinder in a continuous stream, and the work performed is every moment proportional to the quantity of steam used; but when using the expansion valve, the work performed after it closes is at no cost of steam whatever to the boiler.

Q. 96. The Slides of all Marine Screw Engines are fitted with the Link Motion. What are the advantages of the same?

A. The engineer cannot make a mistake in going ahead or astern, as he has only to turn the starting-wheel one way to go ahead, and the reverse to go astern: the engines can also be worked expansively by raising the link which shortens the travel of the valve, and in case of the expansion gear getting out of order, which is not uncommon, the engines may be worked expansively, almost as effectively as by an expansion valve.

Q. 97. If great inconvenience be experienced by Ashes, &c., escaping from the Funnel, how would you try and remedy it?

A. By partially closing the dampers.

Q. 98. What are the Dampers?

A. Dampers are generally circular discs or plates of iron, suitably shaped, for the purpose of controlling the draft up the funnel. Each boiler has its separate damper, and they are closed, opened, or partially so at the will of the engineer; they tend greatly to the economy of fuel.

Q. 99. What are the advantages and disadvantages of Long and Short Connecting-rods?

A. Long connecting-rods pass the top centre with greater facility, and impart to the piston a more uniform motion. There is less angular strain or shearing action upon the cross-head and adjacent surfaces. Short connecting-rods pass the bottom centre with more facility (a matter of no consequence), and impart a less uniform motion.

Q. 100. Why does fuel, required to generate power, when referred to distance, vary as the velocity squared?

A. Because the space is constant.

Q. 101. When does fuel, required to generate power (which is the product of pressure into space), vary as the velocity cubed?

A. When referred to time.

Q. 102. Why so?

A. Because both the pressure and the space vary.

Q. 103. Find the speed corresponding to a diminished consumption?

A. As the large consumption is to the small consumption, so is the large speed cubed to the small speed cubed. The cube root of result will give the speed—

$$C : c :: S^3 : s^3;$$

Cube root of result gives speed.

Q. 104. Find the Consumption of Fuel corresponding to an increased speed?

A. As the small speed cubed is to the large speed cubed, so is the former consumption to the present consumption.

$$s^3 : S^3 :: fc : pc.$$

Q. 105. How does the Consumption of Fuel during two or more voyages of known length, vary?

A. As the square of the velocity multiplied into the distance traversed.*

Q. 106. Are the Delivery Valve and Foot Valve actually necessary to the Operation of an Engine?

A. They are.

Q. 107. If a condensing engine were upwards of 30 ft. from the ground, could the air-pump be altogether dispensed with?

A. Yes; because there would be no pressure to force the water up so far.

Q. 108. Are the eccentrics of marine engines fixed on the shaft in the same manner as for land engines?

A. No; the latter are fixed, but in the former they

* When only Horse Power is given, the speed must be cubed.

can be shifted to different stops; and in order to give back motion, most of the marine engines are fitted with the link motion, when, of course, the eccentric is keyed fast on the shaft, so as to reverse the same.

Q. 109. Describe the Screw Propeller as used in the Navy?

A. A screw propeller as used in the navy is either two or three bladed, made of gun metal, placed obliquely on a shaft revolving by means of the engine.

Q. 110. How is an ordinary Screw-thread generated?

A. A screw is generated by wrapping a right-angled triangle round a cylinder, whose circumference is equal to the base of the triangle. The hypothenuse is equal to the thread, and the perpendicular equal to the pitch.

Q. 111. Describe the terms, Pitch, Length, Diameter, Angle, and Thread, with reference to the Screw Propeller?

A. Pitch is the distance the screw would advance in a solid during one revolution; length is the distance along the axis; diameter is the extreme distance from the end of one blade to the end of the other; angle is the angle formed with the axis by the thread and radius; thread is the outer edge of the blade.

Q. 112. When is the Screw Propeller said to have an Increasing Pitch?

A. When the angle of the screw is less on entering the water than on leaving it.

Q. 113. When is a Screw said to have a Coarse Pitch or Fine Pitch?

A. A coarse pitch has a greater angle than a fine; the blades stand at a greater angle with the shafting in a coarse than in a fine pitched screw; also, provided the length is the same in both cases, and the diameter is less than the pitch, it is a coarse, and *vice versa*.

Q. 114. Do Screw Propellers necessarily alter their Pitch if their Angles differ?

A. Screw propellers alter their pitch if their angles differ, but they do not alter the pitch if the diameter differs.

Q. 115. How do you calculate the pitch of a screw?

A. Multiply the diameter of the screw by 3·1416 and by the natural tangent of the angle of the screw; the result is the pitch required.

$$\text{Diam.} \times 3{\cdot}1416 \times \text{nat. tangent of angle} = \text{pitch}.$$

Q. 116. What is the Formula to find the Angle and the Area of a Screw Propeller?

A. 1. Sin. to angle of the screw $= \dfrac{\text{Pitch}}{\text{Circumf. of thread.}}$

2. The area may be obtained by dividing the height of blade (rad. of blade – rad. of boss) in parts, and calling the distance from each line to centre, – R;

calculating the circumference, corresponding to each by means of the formula

$$\sqrt{(2\,\pi\,R)^2 + Pitch^2}.$$

The average of these circumferences multiplied by height of blade will then give the area of the thread, and that again, reduced in the proportion of the length of the blade to the mechanical pitch, produces the area of the blade.

Q. 117. Having boarded an enemy's steamer, and wishing to disable her without injuring the machinery, how could it be speedily and effectually accomplished?

A. Taking away the slide valves, as it is not customary to fit spare ones.

Q. 118. When you see Flame escaping from the Funnel, what is the cause in general?

A. The cause of flame is, that the gases have not had their due supply of air in the furnace; consequently they inflame upon meeting with it at the top of the funnel. A constant appearance would indicate a bad draft, and occasionally would indicate bad stoking.

Q. 119. What is meant when the Snifting Valve is said to be Drawing Air?

A. The snifting valve is said to be drawing air when it becomes gagged or choked from chips, or anything getting twisted in its orifice, so as to prevent its closing properly.

Q. 120. How is it generally obviated?

A. By throwing water over it.

Q. 121. How would you proceed to clear the Injection Orifice if it were choked up, as sometimes occurs, with sea-weed or ice?

A. I would close the snifting valve and waste water pipe, which is fitted with a shut-off valve, and force the steam through the injection orifice.

Q. 122. If the condenser of an engine were filled with water, how may the blowing through be expedited?

A. By throwing the vessel out of gear, and working her by hand slowly, the water would be gradually removed from the condenser.

Q. 123. What is the Throw of the Eccentric?

A. The throw of eccentric is the difference between the greatest and least distance measured from the shaft, and the eccentric is never fixed on the shaft unless required to give motion in one direction only, or the engine be fitted with the link motion.

Q. 124. How do you find the proper Length of the Eccentric Rod?

A. Place the slide in middle of its stroke; then let the throw of the eccentric be placed in a line with the eccentric, the throw being, as previously described, the distance between centre of eccentric and centre of shaft. With a pair of compasses place one point in centre of gab lever-pin, and with the other at any distance make a mark on rod; then turn the eccentric half round, so as to have the throw placed on opposite side in a line with the rod; do the same with the compasses, using the like opening when the centre of the gab should be the middle point between these two marks.

Q. 125. If the Gab Lever of an Engine be shortened, what alteration will take place in the Indicator Diagram?

A. If the gab be shortened, the travel of the slide will be increased, though the whole motion will occupy the same time. Steam will enter sooner, the upward motion increased longer; and, as the slide goes down, the steam opening is also increased, so that it will take longer to exhaust the steam. The vacuum line is also improved; consequently, if steam be wire-drawn at both ports, and the lead be too little, shortening the gab-lever will improve the diagram. Lengthening the gab gives a short steam line.

Q. 126. When is Steam said to be Wire-drawn?

A. Steam is said to be wire-drawn when the terminal pressure is rendered materially different by the action of the throttle from the initial. For example, if after starting I closed the throttle-valve, the engine would work very slowly by the leakage of valve, and the steam would then be wire-drawn.

Q. 127. What effect has lengthening or shortening the Slide-rod on the Indicator Diagram?

A. Lengthening the slide-rod gives a shorter steam line and longer exhaust. Shortening it gives a longer steam line and shorter exhaust.

Q. 128. What information does a Continuous Diagram give?

A. The rate at which the steam pressure increases or decreases.

Q. 129. In what cases would you consider it necessary to take an Indicator Diagram from top and bottom of the cylinder, and how would you, from these diagrams, get the work developed in the up and down strokes respectively?

A. In all cases where accuracy regarding the real effective pressure is required, the steam pressure on one side and vacuum on the other at up and down stroke would be given, and taken together will give a correct result.

Q. 130. Why does a Marine Engine work better in fine weather than foul?

A. The increased pressure of the atmosphere in fine weather holds down the safety-valve with more force, and produces a greater pressure on the piston, and also supplies more oxygen to the furnaces, which thereby give more steam.

Q. 131. How is it that a Safety-valve will remain open after the pressure of the steam is diminished by blowing off?

A. Because when open it presents a greater area for the action of the steam than when shut.

Q. 132. Why is it necessary to shut the Stop-valves before blowing out the boilers when the engines are done with?

A. In order to retain the steam belonging to each boiler, for the purpose of expelling its own water.

Q. 133. What would be the consequence of increasing the load on the Safety-valve to obtain more speed on an emergency, supposing the boilers strong enough to bear it.

A. Unless the weight on the relief-valve of the feed-pump was similarly increased, the boilers would be destroyed immediately after the increased speed was obtained, owing to no feed being able to enter.

Q. 134. In vessels propelled by paddle-wheels, what are the relative merits of the Common, the Cycloidal, and the Feathering?

A. The common has the advantage of simplicity, a matter of utmost importance; the cycloidal, whose simplicity of construction is almost equal to that of the common, is obviously superior to it, while the feathering has considerable advantages in deep immersion and in a sea-way; but in light immersion and smooth water its superiority is trifling.

Q. 135. How are the contents of a Condenser to be got rid of when blowing through, where there is no Snifting-valve?

A. The water is in this case blown through the foot valve (plunger valve when single-acting) and delivery valve of the air-pump into the hot well, and from thence forced overboard through the discharge pipe.

Q. 136. Why should not the Discharge Pipe be of the same diameter as the Injection, since all the water it delivers has passed through the Injection Pipe?

A. Because there is a continuous stream passing through the injection pipe; but the air-pump discharges all the water that has entered during an entire revolution in about one-sixth of the time.

Q. 137. What is meant by Link Motion?

A. An arranged mode for working the slides, by which means the travel or stroke of the valve may be varied at will and expansion given without a separate expansion valve being required.

Q. 138. What are Lubricators?

A. Metal oil cups for holding oil, and distributing the same to various parts of the engine.

Q. 139. What is meant by Banking up?

A. Pushing the fires back to the bridge of the furnace, and smothering them with small coal, closing the dampers, and checking all draft, so that the fires are kept in a state of slow combustion, but ready to burn up quickly, should steam be required at a short notice.

Q. 140. Have you any remarks to make on the use of Sails in a Steamer?

A. Yes; they form a most important aid, as they ease the engines very considerably, and thereby save fuel. They should be set upon every occasion of a fair wind, or, if confined to fore and aft sails, they are essentially useful when wind is three or four points on the bow; they admit of the steam being worked more or less expansively, and, of course, with a strong fair wind, the engines should be stopped *in toto*. Our large screw men-of-war are rigged and fitted so as at all times, except during calms, to be independent of steam power (if required).

Q. 141. What should be done to prevent an engine being broken down when water is in the cylinder?

A. The relief valves on both ends of the cylinder should immediately be opened in full, to allow the water to escape that way, instead of bursting the covers.

Q. 142. What is meant by Priming, and its cause?

A. When water from any cause becomes mixed with the steam, so that a mixture of steam and water escapes either through the safety-valve or through the steam-pipe from the boiler into the engine, it is called priming, and is caused by any sudden change of water, such as steaming from fresh into salt water, or *vice versa.* "Any foreign substance or mucilage in the water will cause it; also mud or vegetable matter." A small steam chest is also frequently the cause of priming.

Q. 143. What are the remedies?

A. Tallow is introduced into the boiler as a remedy, either by a tallow cup fitted to the boiler for the same purpose, or by a boiler syringe; but if the priming goes on while getting up steam, which is pretty safe to happen if the boilers be filled with fresh water, the dampers should be closed, and the ebullition checked by throwing some extra water on by the hand-pump. The stop-valves should be carefully closed to prevent water getting into the cylinder, and but partially opened on first starting.

Q. 144. What are the usual Indications of Priming; what is generally the cause; and how must it be removed?

A. The appearance of dirt in the glass water-gauge, after which a careful engineer will detect the noise caused by the water striking upon the bends of the steam-pipe, while being conveyed into the cylinder, where, when it arrives, a violent shock is produced while the water is being driven out through the escape valves. It can be allayed by partly closing the throttle valve, which diminishes the violence of ebullition; also by opening the fire-doors a little, which causes less steam to be generated. Blow out at earliest opportunity.

Q. 145. What is the nature of Combustion, and what are the Indications of Perfect Combustion?

A. Combustion is the chemical union of two gases that occupy a much smaller space when combined, and thereby give out a large quantity of latent heat, which becomes sensible. Coal consists principally of two substances, hydrogen (which is the bituminous portion), and carbon (which is the coke or cinder); when first thrown upon the fire, the hydrogen is distilled, robbing the fire of a certain quantity of heat; and when sufficiently heated, it inflames by uniting with an equivalent of oxygen, giving out a large quantity of latent heat and light. The two gases become condensed, and form the vapour of water; the carbon, when sufficiently heated, unites with an equivalent of oxygen when it inflames, and, like the hydrogen, gives out a large quantity of latent heat, and becomes condensed into carbonic acid gas, or choke damp, so that the perfect combustion of coal is the production of water and carbonic acid gas.

Q. 146. Why are Boilers and Engines using Steam of either high or low pressure made of the same thickness of metal?

A. Boiler plates are of that thickness which affords moderate durability without incurring excessive weight. Their strength is adapted to the pressure of steam they sustain by their flat sides being supported with stays. A cylindrical boiler which has no stays is made of the usual thickness of boiler-plate ($\frac{3}{8}$ths), and strength equal to steam of considerably more than 100lbs. pressure. Engines are made of such strength as experience has shown to be requisite, and the rule universally adopted is, to make a cylinder, whose diameter is 40in., 1in. thick, and proportionately thicker to those whose diameter is greater. The piston-rod is made $\frac{1}{10}$th the diameter of the cylinder, which renders all engines equally strong.

Q. 147. If the Grating over the Injection Valve becomes choked, how would you clean it?

A. Secure the slide and snifting valve, shut your discharge valve, and blow through.

Q. 148. What should be done to keep an Engine working after the cylinder cover had been broken by water or other cause?

A. Patch it up most expeditiously by bars of angle-iron held down by the cylinder bolts, securing the crack by a canvass plaster and red lead, interposing a piece of wood of suitable form.

Q. 149. How is the Screw Propeller connected to the Shaft?

A. A slot-way is cut in after end of propeller-shaft, which shaft extends from the engines, resting at short spaces on plummer-blocks, in a horizontal direction above the kelson, to a water-tight stuffing-box fitted in the stern port, through which it passes: on the foremost end of the screw propeller there is a cross called a T end, from its similarity to that letter, which, when the propeller is lowered, fits into the slot-way in the end of shaft. "It is on the principle of the screw driver to corresponding screw head; the propeller representing the screw driver, and the clutch on end of the shaft the screw driver."

Q. 150. Where is the Screw Propeller placed in Vessels of War?

A. In an aperture between the stern-post and rudder-post, sufficiently large to raise, lower, and permit the propeller to revolve freely.

Q. 151. Mention some advantages possessed by Vessels propelled by the Screw?

A. The screw, when at anchor and calm, turns the vessel round in the same place; but if required to turn short in a paddle vessel, say, at the moment before leaving the anchorage, she will require ropes, or, if wind (should the direction permit), sails. When not at anchor a screw-ship can, if properly handled, turn herself. For example, if the screw backs, the vessel will turn to starboard; and when she has gone half her length, if you reverse the engines and port the helm, the vessel will go ahead, but still turn on the same side; so, by repetition of this operation, and shifting the helm, you turn quite round. As regards keeping position or taking in tow, the screw propeller has every advantage, specially the having less lee-way. You can, also, by a judicious use of the braces with canvass, and an equally judicious control of the throttle valve, keep a screw-ship quite stationary. The sails, also brought to act against the screw propellers, allow them to enter crowded anchorages with ease.—N.B. A screw ship steers before moving; a paddle cannot steer without moving.

Q. 152. Define the difference between a Right and Left-handed Screw Propeller?

A. The difference consists in the position that the blade bears to the axis. In a right-handed screw, the right edge or corner of the blade is furthest off, but presses the water first; in a left it is just the reverse, and the eye can detect instantly by looking at the screw blade along the axis, as the relative position of the blades is the same whether viewed from forward or aft.

Q. 153. What Ships are generally supplied with Left-handed Screws?

A. Ships fitted with engines that impart their motion immediately direct to the crank. Penn's Trunk Engines use the left-handed screw, and the reason is, because, if they had a right, the trunks would have a tendency to wear all upon the lower side.

Q. 154. Which has the greatest angle on entering the water, a Fine or Coarse Pitch Screw, and why?

A. The coarse has the greatest angle formed by the inclination of the blade with the shaft or axis, and the reason is, that the nearer it approaches to a right angle with the axis, the finer the pitch and less the angle at which it strikes the water, which can be understood easily enough on inspection.

Q. 155. Is the Screw Propeller fixed in any way to the Shaft when lowered into its place?

A. In no way whatever; but the frame in which the propeller works rests on beds.

Q. 156. Why is it necessary to lock the Screw when under canvass, the Propeller being down?

A. Because, if not locked, the motion of the propeller would tend to turn the engines round.

Q. 157. Having the Pitch and Diameter, how do you ascertain the Angle of a Screw?

A. Thus, let Perpendicular represent Pitch, base the circumference, then $\frac{\text{Pitch}}{\text{Circum.}}$ = tangent of the angle.

Q. 158. If 400 tons of coal suffice for a voyage at 10 knots, at what rate must the vessel steam to make 300 tons last out the voyage?

$$400 : 300 :: 10^2 : x^2$$

$$x^2 = \frac{300 \times 10^2}{400} = 75$$

$$x = \sqrt{75} = 8 \cdot 6$$

Q. 159. If the speed of a vessel be 9′ with 350 horse power, what power will give her a speed of 11′?

A. Let x = speed required—

$$x : 350 :: 11^3 : 9^3$$

$$x = \frac{350 \times 1331}{729} = 639 \text{ H.P.}$$

Q. 160. If the speed when using three boilers be 7′, what speed would four boilers give?

A.

$$3 : 4 :: 7^3 : x^3$$

$$x^3 = \tfrac{4}{3} \times 343 = 457{\cdot}33$$

$$x = 7'{\cdot}7$$

Q. 161. If 150 tons of coal suffice for a voyage of 700′ at the rate of 9 knots, how many tons would be required for 1100′ at 7 knots?

A.

$$x = \text{number required.}$$

$$x : 150 :: 1100 \times 7^2 : 700 \times 9^2$$

$$x = 150 \times \frac{1100 \times 7^2}{700 \times 9^2}$$

$$x = 142\tfrac{1}{2}.$$