THE HOWELL TORPEDO: 14.2 INCHES, MARK I: GENERAL DESCRIPTION

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The Howell Torpedo.

U. S. NAVY,

14.2 INCHES, MARK I.

GENERAL DESCRIPTION.

PREPARED AT THE NAVAL TORPEDO STATION,

BY DIRECTION OF THE

BUREAU OF ORDNANCE.

NAVAL TORPEDO STATION PRINT.
1896.

This description of the Howell Torpedo, U. S. N., 14.2 inches, Mark I, prepared at the Naval Torpedo Station by order of the Bureau of Ordnance, is approved for use in the Navy.

W. T. Sampson,
Chief of Bureau.

Bureau of Ordnance,
September 1, 1896.

The Howell Torpedo.

U. S. NAVY, 14.2 INCHES, MARK I.

GENERAL DESCRIPTION.

Plates I and II.

The Howell Torpedo consists of a cylindrical middle-body, D, to which is attached an ogival head, A, and an ogival after-body, M, bearing the tail, S.

The principal dimensions of the model, U. S. Navy, 14.2 inch, Mark I, are:—

Extreme length	11 ft.		$1\frac{3}{4}$	in.
Greatest diameter			14.2	"
Weight of charge in war-head, 82 lbs. 12 oz. dry gun-cotton plus 20% water [approx.]	99 lbs.		4	oz.
Weight of dry gun-cotton primer	1	"	6	"
Displacement of torpedo immersed in sea-water, sp. gr. 1.026, at 62° F. [approx.]	528	"	4	"
Weight of torpedo with war-head filled and primed, ready for launching [approx.]	518	"	0	"
Reserve buoyancy of ditto in sea-water [approx.]	10	"	4	"
Weight of torpedo with exercise-head ballasted with fresh water, ready for launching [approx.]	518	"	0	"
Reserve buoyancy of ditto [approx.]	10	"	4	"

The head may be either the war-head, containing the explosive charge, for use in action, or the exercise-head, containing fresh water ballast and lead balance-weights, for use in exercise.

The middle-body contains the depth-register pocket, B; the calcium-phosphide pocket, C; and the fly-wheel, F, whose stored-up energy, when set in motion by a motor situated outside the tube from which the torpedo is launched and clutched to the fly-wheel shaft by the clutches, G, is transmitted to the propellers, Y Y, by gears, H H, gear-shafts, I I, and propeller-shafts, R R, and whose gyroscopic influence tends strongly to stiffen the torpedo, laterally, in its course.

The after-body contains the hydrostatic-piston, E, and horizontal-rudder pendulum, J, the action of each of which is transmitted, through the impulse-mechanism, L, to the horizontal-rudder, Z, by the horizontal-rudder tiller-rod, N; the vertical-rudder pendulum, K, whose action is transmitted, through the impulse-mechanism, L, to the vertical-rudder, X, by the vertical-rudder tiller-rod, P; the locking-mechanism, O; unlocking-rod, Q; and the propeller-shafts, R R.

The frame of the tail comprises the tail-cone, U; the side-blades, V V; and the top and bottom-blades, W W; and in the tail are the vertical-rudder, X; the horizontal-rudder, Z; the propellers, Y Y; and the speed-regulator, T.

The torpedo is launched by indirect gunpowder impulse from a tube above or below the water-line, with the fly-wheel revolving at a speed of ten thousand revolutions per minute, the clutch of the motor being disengaged from the intermediate-clutch, connecting it with the fly-wheel shaft at the moment before launching.

The shell of the torpedo is of hard-rolled brass, $\frac{1}{16}$ in.

in thickness, strengthened at various points by interior strengthening-rings and reinforced, at the junctions of the middle-body with the head and with the after-body, by stout joint-rings, brazed in. The fly-wheel is supported by a stout wheel-frame. The interior parts of the torpedo are of bronze, aluminum bronze and a few easily accessible parts of steel.

THE HEADS.

Plates III and IV.

There are two interchangeable heads supplied with each torpedo, the war-head and exercise-head, for use in war and in exercise, respectively. Their external appearance is the same.

The head is attached to the forward end of the middle-body by a bayonet-joint with four equidistant locks and is secured in place by a set-screw.

THE WAR-HEAD.

Plate IV.

The war-head, habitually attached to the torpedo in time of war, is stiffened and strengthened by the nose-ring, A, and by a joint-ring at its after end. The joint-ring is fitted with the studs of a bayonet-joint for attaching the head to the forward end of the middle-body, a set-screw passing through the joint-rings of the head and of the middle-body keeping it from unlocking, when shipped. The war-head is divided into two water-tight compartments, L and Q, by two bulkheads, P and R, which are secured by nuts against flat rubber washers, to screw-studs in bulkhead-rings brazed in the shell of the head. Reinforce-rings, one for each bulkhead, are shipped over the screw-studs and serve to take the thrust of the nuts and to stiffen the edges of the bulkheads. The after compart-

ment formed by these two bulkheads is a buoyancy chamber. In the forward compartment is compactly stowed the charge of wet gun-cotton, weighing approximately 99 lbs. 4 oz.

In the center of each bulkhead is a boss in which is tapped a screw-thread for the lifting-screw used in removing the bulkheads.

The primer-case, K, in which is inserted the dry gun-cotton primer when priming the torpedo, has at its forward end a flange, E, which seats on the nose-ring, A, and is brazed to it, thus forming a fixed part of the war-head. In the flange are two holes, one, F, a moisture-tap and the other, G, a vent hole, communicating with the interior of the head, closed ordinarily by screw-plugs. Should the charge lose moisture by evaporation, distilled or rain water may be poured through the moisture-tap to make up loss of weight.

The stowage weight of the war-head, that is, the weight of the shell and contained charge of wet gun-cotton only, is stamped on the after bulkhead of the war-head near the center of the bulkhead.

The after end of the primer-case is supported in the primer-case rest, N, a short socket soldered to the forward side of the bulkhead, P. In the primer-case is soldered the diaphragm, M, which constitutes the after end of the space in the primer-case actually filled with dry gun-cotton in priming.

The forward end of the primer-case is closed water-tight, after priming, by the primer-case cover, D, which is clamped tight against a flat rubber washer by the primer-case clamp-ring, B, screwed down on a boss on the primer-case flange. In the primer-case cover are two small holes, H H, closed by soluble plugs of soap, protected by patches of paper pasted over them, which dissolve at

the end of an unsuccessful war shot, admitting water to the dry primer and drowning it.

The primer-case cover, D, carries the exploder-pocket, I, brazed to its after side and forming part of it. The exploder-pocket is closed at its after end and open at its forward end for the reception of the exploder, J, which is held in place by a spring-latch, C, on the forward side of the primer-case cover.

The exploder is a closed copper tube, painted red, containing thirty-five grains, (approximately), of fulminate of mercury, primed with four grains of dry long staple gun-cotton, and capped at its forward end by a percussion cap.

The nose-ring, A, of the war-head is threaded internally for the reception of the war-nose.

THE WAR-NOSE.

Plate V.

The war-nose, screwed in the nose-ring of the war-head, consists of the mechanism for firing the exploder on impact of the torpedo with the target, and the safety-mechanism by which the firing-mechanism is rendered inactive until, after launching, the torpedo shall have traveled through the water a safe distance from the point of launching.

The construction of the war-nose is as follows: — in the forward end of the body, K, of the war-nose is screwed the cap, E, which is kept from unscrewing by the cap lock-screw, F, and which is bored out axially for the reception of the sleeve, G. The sleeve is capable of longitudinal motion within the cap but is prevented from turning by its guide-pin, I, which enters the guide-slot, J, in the cap. The sleeve is bored out axially for the reception of the firing-pin, H, which has longitudinal motion within the sleeve. The movement of the firing-

pin is limited in its travel aft by the head, C, which brings up against an interior shoulder in the sleeve, and the movement forward is restrained by the firing-spring, M, which encircles the after end of the firing-pin, the forward end of the spring bearing against an interior shoulder in the sleeve, and the after end against a collar, P, screwed on the after end of the firing-pin. The collar is kept from unscrewing by a lock-pin, and the head of the firing-pin is slotted for convenience in assembling.

A bent sear-spring, L, of steel, secured to the cap by two screws, catches over the collar on the after end of the firing-pin when the war-nose is cocked, as shown in the plate.

The safety-mechanism consists of the screw-fan, B, and the shearing-pin, D. The screw-fan, four-bladed, of steel, works on a screw-thread cut on a portion of the forward projecting end of the sleeve and can be run aft, to the safety position, until it bears on the cap, E, as shown in dotted lines in the plate, in which position it locks the sleeve, preventing it from being driven in to actuate the firing-pin; or it can be run forward, to the firing position, shown in full lines in the plate. The point, A, screwed in the forward end of the sleeve and kept from unscrewing by a lock-pin, prevents the screw-fan from running completely off the sleeve. The shoulder of a slot cut in the after side of the hub of the screw-fan brings up against a stud on the forward end of the cap, when the screw-fan is run aft, and prevents jamming on the thread.

To insure against explosion by an accidental blow, the screw-fan must always be kept, in store and while being handled, in its position of safety, with the screw-fan run aft on the end of the sleeve until stopped by the shoulder of the slot in the screw-fan bringing up against the stud on the cap.

The shearing-pin, D, of lead, passes through holes in the cap and in the sleeve and holds the latter in position against light forces tending to displace it when the screw-fan is in its firing position.

The action of the war-nose is as follows:—during the passage of the torpedo through the water, after launching, the screw-fan is revolved and run forward on the sleeve to its firing position. The extreme forward end of the sleeve is cut blank so that, when the screw-fan is in its firing position, it will have run clear of the screw-thread and will revolve freely, without opposing undue resistance in the water. On impact with the target, the sleeve is driven aft within the cap, shearing the shearing-pin and compressing the firing-spring between the after end of the sleeve and the collar on the after end of the firing-pin, until the after end of the sleeve trips the sear-spring and releases the firing-pin, which is then projected aft by the compressed firing-spring against the percussion cap of the exploder, firing it.

Holes, NN, in the body of the war-nose, admit water to the soluble plugs in the primer-case cover in the event of an unsuccessful shot.

The range necessary to run the screw-fan forward far enough to fire is from thirty to forty yards.

THE EXERCISE-HEAD.

Plate III.

The exercise-head, habitually attached to the torpedo in time of peace, is stiffened and strengthened by the nose-ring, A, and by a joint-ring at its after end. The joint-ring is fitted with the studs of a bayonet-joint for attaching the head to the middle-body, a set-screw passing through the joint-rings of the head and of the middle-body keeping it from unlocking, when shipped. The exercise-head is

divided into two water-tight compartments, L and P, by two bulkheads, M and R, which are secured by nuts against flat rubber washers to screw-studs in bulkhead-rings brazed in the shell of the head. Reinforce-rings, one for each bulkhead, are shipped over the screw-studs and serve to take the thrust of the nuts and to stiffen the edges of the bulkheads. The after compartment formed by these two bulkheads is a buoyancy chamber. The forward compartment is filled, for exercise, with fresh water which serves to ballast the torpedo to the same trim as that which would obtain were the war-head shipped in place. In the center of the after bulkhead is a boss in which is tapped a screw-thread for the lifting-screw used in removing the bulkhead.

A balance-weight, K, capable of longitudinal adjustment within the balance-weight tube, G, permits correction of slight errors in trim.

The balance-weight tube, extending through the entire length of the head, has at its forward end a flange, E, which butts against the inner face of the nose-ring, A, and is clamped in place by the following-ring, C, which screws on a thread cut on the forward end of the flange. After the following-ring is set up the flange of the balance-weight tube is soldered in place. The after end of the balance-weight tube is supported in the balance-weight tube-rest, N, a cylinder soldered to the after side of the bulkhead, M. A feather, H, is attached to the upper inner side of the balance-weight tube and extends throughout its length.

The balance-weight, K, is composed of a number of lead discs held between two followers, JJ. The discs and followers are slotted on their upper edges, the feather in the balance-weight tube entering the slots. The followers are cut, axially, with a screw-thread through which

threads the balance-weight rod, I, the ends of which are supported, free to revolve, by the sockets, F and Q. A slot in the forward end of the balance-weight rod permits turning the rod, with a screw driver, to move the balance-weight forward or aft, as required to correct the trim of the torpedo. The socket, Q, is soldered in the after end of the tube. The socket, F, is slipped in the forward end of the tube, after adjustment of the balance-weight, a score in the upper edge fitting the feather, H. The socket, F, has a flange which rests on the end of the balance-weight tube, with a flat rubber washer interposed, and the tube is closed water-tight by screwing down the clamp-ring, B, against the flange.

In filling the compartment, L, with water the bulkheads, M and R, are removed, being replaced after the compartment is full. Any small deficiency of water may be made up through the filling-holes, DD, which are ordinarily kept closed by screw-plugs.

The nose-ring, A, of the exercise-head is threaded internally for the reception of the exercise-nose.

THE EXERCISE-NOSE.

Plate V.

The exercise-nose, screwed in the nose-ring of the exercise-head, is similar in external form and equal in weight to the war-nose, with the view of making the conditions of trim of the torpedo and resistance to the water the same in an exercise run as in those that obtain in a war shot.

In the forward end of the body, **f**, is screwed the cap, **d**, which terminates in a spindle, **b**, threaded for a portion of its length and left blank at its forward end. The cap is kept from unscrewing by a cap lock-screw, **e**. On the spindle ships the screw-fan, **c**, four-bladed, of steel,

similar to the screw-fan of the war-nose. The point, a, screwed in the forward end of the spindle and kept from unscrewing by a lock-pin, prevents the screw-fan from running completely off the spindle. The shoulder of a slot cut in the after side of the hub of the screw-fan brings up against a stud on the forward end of the cap, when the screw-fan is run aft, and prevents jamming on the thread.

Before launching the torpedo the screw-fan is run aft. After launching, the screw-fan is revolved during the passage of the torpedo through the water and is run forward, revolving freely on the thread and on the blank of the spindle, when it has reached its forward position, without opposing undue resistance in the water. The possible effect of the screw-fan during a run is thus the same, in exercise, as in a war shot.

THE MIDDLE-BODY.

Plate VI.

The middle-body, D, cylindrical in shape, is stiffened and strengthened by two joint-rings, one at either end, two interior strengthening-rings, J J, soldered in, and the fly-wheel frame.

The forward joint-ring is fitted with a sleeve in which are the slots of a bayonet-joint for attaching the head, and the forward end of the middle-body is closed water-tight by a bulkhead, which is secured by nuts, against a flat rubber washer, to screw-studs in the joint-ring. A reinforce-ring is shipped over the screw-studs and serves to take the thrust of the nuts and to stiffen the edge of the bulkhead.

The after joint-ring is fitted with a sleeve over which ships the forward end of the after-body against a solid rubber gasket of circular cross-section let in the angle of the joint-ring. The after-body is held in place by eighteen steel joint-screws at its junction with the middle-body.

Guide-studs, E E, of steel, are secured, one on each side of the torpedo, with their after ends near the center of gravity of the torpedo and somewhat above it. They are soldered to the shell and bolted to interior strengthening-plates riveted and soldered to the shell and to the fly-wheel frame. The guide-studs support the torpedo in guide-slots in the launching-tube. The starboard guide-stud has a notch in which fits the stop-pin of the launching-tube when the torpedo is in the right position for the engagement of the motor-clutch.

The middle-body contains the depth-register pocket, B; the calcium-phosphide pocket, C; the fly-wheel, F, with its gears, L L, and gear-shafts, I I; and the clutches, G.

THE DEPTH-REGISTER AND POCKET.

Plates VII and VIII.

The depth-register pocket, B, is a brass tube supported transversely in the torpedo by flanges at each end soldered inside the shell. It is closed at the port end and open at the starboard end for the reception of the depth-register, through a hole in the shell of the torpedo, when that instrument is used for obtaining a curve of the depth maintained during the run.

When the depth-register is not used the depth-register pocket is closed water-tight by a cover held in against a solid rubber gasket of circular cross-section by a clamp-ring which screws in a thread cut in the flange of the pocket. The outer surface of the cover conforms to the curve of the shell, the correct placing of the cover being insured by the engagement of a locating-pin in the flange of the pocket with a slot in the rim of the cover.

The depth-register is employed in exercise runs to record the depth to which the torpedo descends below the surface of the water when launched and at which it travels

throughout its run. The principal features are shown in Plate VII., the details of the piston in Plate VIII.

The two supporting-stays, I, carry at the outer end a bronze cylinder, E′, terminating outside in a flange, K′, which seats on a solid rubber gasket of cylindrical cross-section, O, Plate VIII, against the shoulder of the flange, F′, of the depth-register pocket, B, and held in place by the clamp-ring, G′. On the inner end of the supporting-stays is mounted a music-box movement actuating a winding drum, F, which takes paper from an unwinding drum, G. At the extreme inner end is the counterpoise, H. The piston-rod, A, has two bearings, one at the inner end of the bronze cylinder at D, cast in one with it, the other at K. The outer end of the piston-rod carries the piston, H′.

The inner end of the piston-rod carries a pencil, L, which traces a depth-curve on the moving paper slip. A base-line is traced by a fixed pencil.

The piston moves its rod, A, against the tension of a spring, E, one end of which is secured to the rod and the other to the cylinder. Underneath the platform on which the drums are mounted is pivoted an arm, one end of which catches on a stop on the piston-rod and the other ends in a detent which checks the regulator of the music-box movement, thus preventing movement of the drums until the torpedo has gained a certain depth. The piston is permitted free movement in the cylinder by the flexible rubber diaphragm, D′. A ring, L′, holds the diaphragm in place by means of a friction-plate, N, and follower, I′. The diaphragm is secured to the piston by the cap, J, held in place by a washer and nut.

Encircling the stays and the piston-rod, is a middle spring-bearing of brass, the ends of which are locked previous to inserting the depth-register and unlocked before pushing it home. Four brass feathers are soldered to the

bottom and forward side of the cylinder to form an outer bearing for the depth-register. The depth-register is properly placed by the locating-pin in the after side of the depth-register pocket.

THE CALCIUM-PHOSPHIDE POCKET.

Plate VII.

The calcium-phosphide pocket, C, is a brass tube, closed at the lower end and open at the top, supported vertically in the torpedo by a flange at its upper end soldered inside the shell, around a hole through the shell of the torpedo. It is stiffened in position by a stay of sheet brass connecting its lower end to the depth-register pocket.

Prior to an exercise run of the torpedo a sealed can of calcium-phosphide is put in the pocket, holes having first been punched through each end of the can to admit water to its interior. The can is secured in the pocket by a flat strip of spring brass, slightly longer than the diameter of the pocket, sprung into nicks in opposite sides of the mouth of the pocket.

When the torpedo is immersed, the action of water on the chemical generates hydrogen-phosphide which burns at the surface of the water with dense white fumes, thus indicating the position of the torpedo. These fumes last about ten minutes, giving sufficient time to buoy the torpedo, in case it sinks, marking the spot for subsequent dragging.

In war service the calcium-phosphide pocket is left empty, its mouth being closed by a flat cork.

THE FLY-WHEEL.

Plate IX.

The fly-wheel, F, revolving in the longitudinal vertical plane of the torpedo, furnishes the motive power by

which the torpedo is propelled through the water. The stored-up energy of the fly-wheel when set in motion prior to launching, by a motor situated outside the tube from which the torpedo is launched and detachable at the moment before launching, is transmitted to the propellers by the fly-wheel gears, L L, the shaft-gears, H H, the gear-shafts, I I, and the propeller-shafts. The energy of the fly-wheel is also utilized, by power taken from the propeller-shafts, to operate the horizontal and vertical-rudders, the speed-regulator and the unlocking-mechanism.

The gyroscopic effect of the fly-wheel is such as to stiffen the torpedo laterally in its run, causing it to roll, rather than yield to any force tending to deflect it from its course, the roll of the torpedo being immediately corrected by the action of the vertical-rudder in response to the swing of the vertical-rudder pendulum. The fly-wheel, looked at from the starboard side, that on which the motor is situated, revolves from right to left, or against the sun. The standard fly-wheel speed for launching is ten thousand revolutions per minute, but the propeller speed is geared down by the fly-wheel gears and shaft-gears in the ratio of eight to ten of the fly-wheel speed.

The fly-wheel, F, of forged steel, weighs 131 lbs. It is secured by two keys and by two set-screws to the fly-wheel shaft, G, the ends of which are mounted in roller-bearings, J J, carried in the wheel-boxes, K K, within the bearings, N N, of the fly-wheel frame, O. The fly-wheel frame is rigidly constructed and is secured firmly in place by screws passing through the shell of the torpedo; it is soldered to the shell of the torpedo and the screws holding the frame are sweated in the shell, water-tight. Each roller-bearing of the fly-wheel shaft has eight cylindrical steel rolls, P, which are held in place in the wheel-boxes by the steel washers, Q. Ball-bearings, R R, composed

of steel balls let into grooves in the outer faces of the fly-wheel gears and the inner faces of the wheel-boxes, take the thrust of the fly-wheel, when the torpedo rolls, and prevent excessive friction.

The fly-wheel gears, L L, of steel, are bevel gears slipped over the ends of the fly-wheel shaft, one on either side, and keyed in place, thus being when assembled, practically in one with the fly-wheel and its shaft. With the fly-wheel gears engage the shaft-gears, H H, of bronze, which slip over the forward ends of the gear-shafts, I I, and are rigidly secured to them by set-screws.

The gear-shafts are carried in Babbitt metal bearings, S, one on either side, in the after part of the fly-wheel frame. The after ends of the gear-shafts are squared, and over them ship the couplings, M, of steel, which are secured to the gear-shafts by taper-pins. The couplings are cut axially throughout their length with a square hole and in the after ends of the couplings slip the squared forward ends of the propeller-shafts, when the after-body is shipped in place.

Two steel washers, T T, are slipped on each gear-shaft, one between the shaft-gear and a square shoulder on the shaft, and the other between a collar on the shaft and the coupling.

The fly-wheel is spun up, prior to launching, by a motor situated outside the launching-tube, on the starboard side of the tube, the motion of the motor being transmitted to the fly-wheel through the motor-clutch, the intermediate-clutches, U U′, and the fly-wheel clutch, V. The details of the clutches are given in the following section and illustrated in Plate X.

Oil is supplied to the bearings of the fly-wheel shaft and of the gear-shaft, and to the intermediate-clutch shaft stuffing-box by oil-pipes, which are filled from outside the

shell through oil-holes, and are kept closed by screw-plugs.

A light screen of sheet brass, not shown in the plate, secured by screws to the after side of the fly-wheel frame, shields the rubber diaphragm of the hydrostatic-piston from oil thrown off by the fly-wheel when in motion.

DETAILS OF THE CLUTCHES.

Plate X.

The motor-clutch is put in engagement with the outer intermediate-clutch, U′, and withdrawn from engagement with it, by the action of a cam operated by the firing-bar on the launching-tube, not shown in the plate. The firing-bar is so constructed that, in one motion of the firing-lever, the firing-bar successively shuts off steam from the motor, withdraws the motor-clutch from engagement with the intermediate-clutch, withdraws the stop-pin holding the torpedo in place in the tube, and fires the impulse-cartridge by which the torpedo is ejected from the tube. It is therefore impossible to discharge the torpedo without first withdrawing the clutch.

The intermediate-clutch is double, consisting of the outer intermediate-clutch, U′, and the inner intermediate-clutch, U, mounted on the ends of the intermediate-clutch shaft, R. The inner clutch is machined in one with the clutch-shaft and the outer clutch ships on a square on the outer end of the clutch-shaft, to which it is secured by a lock-screw. The intermediate-clutch shaft passes through the stuffing-box within the casing which forms a part of the fly-wheel frame. The stuffing-box is held in place by the follower, which screws in a thread cut in the casing, and the intermediate-clutch shaft is packed with braided cotton wicking, which prevents ingress of water to the interior of the torpedo. Channels admit oil to the packing around the shaft for lubricating

the shaft-bearing. The packing is set up by the gland, S, which screws left-handed in a thread cut in the casing.

The fly-wheel clutch ships on a square on the end of the fly-wheel shaft, to which it is secured by a lock-screw. The intermediate-clutch shaft is capable of longitudinal motion within the stuffing-box, as well as of a motion of revolution. When the motor-clutch is pressed into engagement with the outer intermediate-clutch, the clutch-shaft is forced inwards and the inner intermediate-clutch engages with the fly-wheel clutch. The backs of the clutch teeth are inclined, and the instant that the motor-clutch is withdrawn the fly-wheel clutch drives away the intermediate-clutch, freeing it from engagement, thus avoiding unnecessary friction and resistance.

The clutches, the intermediate-clutch shaft and the follower are of steel. The stuffing-box and gland are of bronze.

THE AFTER-BODY.

Plate XI.

The after-body, M, ogival in shape is stiffened and strengthened by the joint-ring, K, in its forward end, the middle joint-ring, N, the immersion-regulator frame, L, and the after bulkhead, B. The shell of the after-body is made in two parts permanently connected to the middle joint-ring, N, to which the abutting ends are secured by being brazed to it. The forward joint-ring is brazed inside the shell and ships over the sleeve of the after joint-ring of the middle-body to which it is secured by eighteen steel joint-screws against a solid rubber gasket of circular cross-section let in the angle of the joint-ring of the middle-body, thus making a water-tight joint.

From the bulkhead in the forward end of the middle-body to the after bulkhead, B, of the after-body, the

interior of the torpedo is one continuous water-tight compartment.

Two hand-holes, O O, closed by plates and gaskets permit of access to the interior of the shell just abaft the immersion-regulator for making adjustments; for filling the oil-pipe that supplies oil to the forward end of the impulse-rack; for filling the oil-cups of the outer eccentric-shaft bearings, forward propeller-shaft bearings and after end of the impulse-rack; and for oiling the center eccentric-shaft bearing, eccentric-straps and the forward ends of the eccentric-rods. A plate on the port side of the torpedo covers the hydrostatic-piston chamber, P. It admits water through two long openings masked by an interior screen which protects the rubber diaphragm. On the starboard side, in the frame carrying the immersion-regulator, is a hole for access to the adjusting-screw rod of the immersion-spring. This hole is closed by a leather washer and a screw-plug. On the top side of the after-body are oil-holes, one on each side, for supplying oil to the propeller-shaft bearings. These are kept closed by screw-plugs against leather washers. On each side of the rear end of the after-body are propeller-shaft sleeves dovetailed to the after bulkhead, secured by screws, and soldered to the shell. They are fitted with stuffing-boxes in the after ends through which pass the propeller-shafts. In the bulkhead, which is brazed in the after end of the shell, are also stuffing-boxes through which pass the horizontal and vertical-rudder tiller-rods and the unlocking-rod.

The after-body contains three bearings for each propeller-shaft: — one at the support-ring, Q, carrying the after portion of the impulse-mechanism; one at the middle joint-ring, N; and one forward of stuffing-box, S. in the propeller-shaft sleeve.

At the middle joint-ring is also a coupling for each propeller-shaft, similar to the couplings connecting the gear-shafts with the propeller-shafts, except that the taper-pin passes through both the coupling and the shaft.

IMMERSION-REGULATOR.

Plates XII, XIII, XIV and XV.

The immersion-regulator consists of the horizontal-rudder pendulum and angle-guide, the hydrostatic-piston, the immersion-spring, the impulse-racks (lower set) and the horizontal-rudder tiller-rod pallet.

The hydrostatic-piston governs the immersion of the torpedo during the run, and can be set for any desired depth within the limits of the immersion-spring.

The horizontal-rudder pendulum acts to maintain the axis of the torpedo in the horizontal plane.

The combined action of the horizontal-rudder pendulum and piston is transmitted to the horizontal-rudder angle-guide, thence to the pallet mounted in the horizontal-rudder tiller-rod. One end or the other of the pallet being lifted, every approach of the impulse-racks causes the tiller-rod to be moved, and consequently the rudder, to steer the torpedo to its "set depth" and to maintain it in the horizontal plane at that depth.

The immersion-regulator is mounted in its frame, a bronze casting secured by screws and soldered to the shell of the torpedo.

HORIZONTAL-RUDDER PENDULUM.

Plate XII.

The object of the horizontal-rudder pendulum is to cause a movement of the angle-guide in response to a deviation of the axis of the torpedo from the horizontal plane.

The pendulum is suspended from a bracket and knife-edge support, A. Its frame, B, is in the form of a letter, A, closed at the bottom. In the cross of the A, is a vertical slot which engages a pin. The pendulum-bob, J, is secured to the pendulum-frame by bolts bearing upon suspension-springs, the object of the springs being to relieve the strain on the supports in case of a sudden downward pull of the pendulum-bob. The bob is surrounded by the pendulum guide-frame, z, Plate XIII, secured by four screws to the immersion-regulator frame. On each side of the bob and pivoted to the guide-frame are two guide-rolls which decrease friction in case the torpedo, by rolling, throws the pendulum out of the vertical plane. The pendulum is limited in its swing by its guide-frame, against which strike checking-springs, C, fitted in the bob. These checking-springs can be adjusted to diminish or increase the resistance that they offer to the movement of the pendulum, thus varying the angle of inclination of the axis of the torpedo required to give the pendulum a given swing. This adjustment is made by pushing in the springs, and turning them to the right or left, thereby diminishing or increasing the compression of the springs.

The vertical slot in the cross of the pendulum-frame engages the horizontal-rudder pendulum-pin. This pin is rigidly secured to the horizontal-rudder pendulum-lever, D; and a movement of the pendulum turns the lever on its axis. The lever is crank-shaped, and dips under the impulse-movement frame. Its axis is a prolongation of the piston-rod, E. The piston-rod is free to turn in the piston, being held by adjustable nuts, A, Plate XIV, which form a collar, and is thereby free to take any rotary movement of the lever produced by a movement of the pendulum. The horizontal-rudder pendulum-pin is capable of adjustment by loosening a set-screw and sliding its shank up or down in the hole in the crank of the lever, thus raising or lowering the pin to a greater or less distance above the axis of the lever, and thereby giving to the lever itself a less or greater angular movement for the same swing of the pendulum.

HORIZONTAL-RUDDER ANGLE-GUIDE AND PALLET.

Plates XIV and XV.

The piston-rod is connected to the angle-guide, G, Plate XIV, by a pin, B, which lies in the cam-slot, C, in the hub of the angle-guide; the axis of the angle-guide being the piston-rod. A swing of the pendulum produces a movement of the lever, which rotates the piston-rod and transmits motion to the angle-guide by the pin in the cam-slot.

This movement of the horizontal-rudder angle-guide which we have followed so far as relates to the horizontal-rudder pendulum, but which may also be caused by a movement of the hydrostatic-piston, controls the movement of the horizontal-rudder tiller-rod pallet in the following manner:—

The horizontal-rudder tiller-rod, N, Plate XV, slides in the guide below the impulse-racks. An offset in this rod between the guides, covered by a bar, s, forms a slot in which is mounted on a central axis the horizontal-rudder tiller-rod pallet, r. In a normal or central position, the pallet lies wholly within the slot, but if it is revolved to raise one or the other end, the raised end will engage in the teeth of the corresponding impulse-rack. A little forward of its axis the pallet has a pin which passes through the tiller-rod, and is permitted movement by a slot in this rod. The angle-guide engages this pin, and transmits the angular movement to the pallet, which is

then engaged by the impulse-racks, thus giving movement to the horizontal-rudder tiller-rod and consequently to the rudder. The movement of the tiller-rod will be great or small according as the pallet is tipped at a large or small angle. The angle-guide engages the pin of the pallet between two light flexible flat phosphor-bronze springs, V, Plate XIV, secured to the after end of the angle-guide, but having their forward ends free. In a normal position the forward ends of these springs rest on the end of the angle-guide but are free to move away from it under the slightest pressure. The pallet turns on its axis with almost inappreciable effort and when it is free the springs keep it always parallel to the angle-guide; but when it is engaged they are sufficiently flexible to permit the angle-guide to take any new position. If such new position be taken by the angle-guide during an engagement of the pallet with the impulse-rack, the spring will cause the pallet to take up this new position, the instant of its release. Whether or not the pallet is engaged, the angle-guide is equally free to take up any new position due to the influence, either of the horizontal-rudder pendulum, hydrostatic-piston, or both, thus obeying changing conditions of the torpedo; and this change of position is transmitted to the pallet; gradually, if free, — suddenly at the instant of its release, — if engaged.

THE HYDROSTATIC-PISTON.

Plate XIV.

As before stated, the piston-rod forms the axis of the horizontal-rudder pendulum-lever and rotates with it. It is supported at one end by the piston and at the other by the pendulum-lever bearing. The piston-rod passes through holes in the two arms of a hanging-frame, which

is secured by screws to the frame of the immersion-regulator.

The piston, H, receives a pressure of water due to the depth of the torpedo below the surface, modified to some extent by the pressure due to the wave of displacement.

The piston-frame, I, seats on a solid rubber gasket of circular cross-section in the piston-chamber, M, which is on the port side of the torpedo and slightly above the center. A rubber diaphragm, N, is held against the rim of the piston-frame by a following-ring, O, upon which screws a clamp-ring holding the whole in place. The piston is guided in its movements by the cross-bars of the piston-frame and clamp-ring. A metal washer, Q, and nut, P, secure the diaphragm to the piston and make it water-tight. A shoulder, R, on the outer end of the piston limits its outer throw, and stop-nuts, S, limit its inner throw, both taking against the clamp-ring.

A thin copper screen of hemi-spherical shape, is permanently placed over the piston on the inside to protect the rubber diaphragm from oil. It is cut away below to permit movement of the immersion-spring lever.

The piston-rod, E, is held in position by the cap, T, and adjusting-nuts, A. The cap screws upon the inner end of the piston; the adjusting-nuts form a collar and are held freely but without any appreciable lost motion between the cap and piston. A cap lock-nut, U, sets up against the cap after the latter is in place. The immersion-spring lever, **a**, Plate XIII, rests against the lock-nut.

The piston transmits movement to its rod in the direction of its axis. When the piston-rod moves in or out, its pin, B, moves in the cam-slot, C, in the hub of the angle-guide, thereby giving an angular motion to the angle-guide. A collar against the hanging-frame prevents the angle-guide from taking other than rotary movements.

The amount of this angular movement will vary with the throw of the piston and the angle formed in the cam-slot. Only the former is adjustable.

The piston-rod has a double function. It takes independently the angular movement of the lever due to the pendulum, and the longitudinal movement due to the piston and transmits them both as angular movements to the angle-guide; and these two movements are obeyed separately or simultaneously as they occur. When the pendulum is stationary any change of position that the angle-guide may take is due solely to a movement of the piston, thrusting in or drawing out its rod, and rotating the angle-guide through the pin in its cam-slot. When both pendulum and piston move, the movement of the angle-guide is the algebraic sum of their results.

In tracing the effect of the pendulum or piston movements on the horizontal-rudder it is convenient to notice that the angle-guide and rudder assume similar angles up or down, keeping sensibly parallel to each other.

THE IMMERSION-SPRING.

Plates XII and XIII.

The immersion-spring, **b**, is a tension spring whose function is to hold the piston out against the water pressure, until it is balanced by that pressure at "set depth." An eye, **c**, in the port end is pivoted to the lower end of the immersion-spring lever, **a**, which turns on a knife-edge, **d**, mounted on the piston-frame, I. The upper end of the lever is forked to embrace the piston-cap, and its ends bear against the cap lock-nut, U, Plate XIV, the tension of the spring holding the piston out. The tension of the spring is controlled by a regulator-screw, **e**, working in a regulator-nut, **f**. The regulator-screw is adjusted from the outside of the torpedo (starboard side). Turning the

screw to the right distends the spring and gives greater "set depth"; turning the screw to the left eases the spring and gives less "set depth". The guide-collar, **g**, engages in the guide, **h**, and prevents the spring from turning with the regulator-screw. The area of the piston is such that the pressure due to each foot of depth of immersion is two pounds, when the torpedo is running at normal speed though this is not the statical ratio. The adjustment of the spring may be made for any "set depth" by applying an equivalent pressure to the outer end of the piston. The spring is then adjusted to balance this pressure at the middle position of the piston.

THE IMPULSE-MECHANISM.

Plate XV.

The forward portion of this mechanism is carried in a hanging vertical frame secured to the frame of the immersion-regulator on the port side of the torpedo. There are three guides in this frame in which travel the impulse-racks, Plate XV, the horizontal-rudder tiller-rod, N, and the vertical-rudder tiller-rod, P.

The impulse-racks are moved in their guides by the eccentric-rods, **k**, whose eccentrics are mounted on an eccentric-shaft, **l**, which lies abaft the immersion-regulator and at right angles to the axis of the torpedo. It is supported by hanging-bearings from the ring, Q, Plate XI, and is driven by both propeller-shafts through worm-gearings. Each worm slides on a feather and its thrust is taken up by a stiff spiral-spring, **m**. By this arrangement the work in turning the eccentric-shaft is equalized. Should the thrust on one worm be greater than on the other, it will move forward against the spring and cause the spring to do extra work in tending to return the worm

to its original position, and thus lessen the work done by the worm on that particular side.

In assembling the torpedo, the springs should be of about the same tension and put on at such a distance as to make the initial pressure of the worm against the shaft-bearings as light as practicable, usually about one-half a pound.

The impulse-racks are caused to alternately approach and recede from each other, thus having reciprocal motion. The worm-wheels have thirty teeth each, which gear into the worms on the propeller-shafts. One revolution of the propellers gives one revolution to the worms, which turn the worm-wheels one tooth, and as thirty teeth are required to give the worm-wheels and therefore the eccentric-shaft a complete revolution, it is seen that it requires thirty revolutions of the propellers to give one revolution to the eccentric-shaft, which in turn gives one complete impulse to the racks.

Each impulse-rack has two sets of steps at its inner end, of which the lower set relates to the horizontal-rudder. There are five upper and six lower teeth. The lower teeth have a vertical clearance of ″.03, that is, the ends of the pallet can be raised to that extent without engaging the rack. At the end of the return movement, the ends of the pallet will swing clear of the upper teeth by ″.08, horizontally, thus permitting the pallet to take any new position as directed by the angle-guide.

The motion thus given to the horizontal-rudder is a series of impulses, which are in the same direction as long as the same rack is engaged, i. e., as long as the angle-guide is inclined the same way.

On the forward frame-cap is a flat return-spring to bring back the tiller-rod with the return movement of the racks. The pressure of water tending to diminish the rudder angle, aids the return-spring.

APPLICATION OF THE GYROSCOPE.

In the Howell Torpedo, the fly-wheel revolving upon its axis represents a gyroscope, for if this axis which is mounted horizontally is acted upon by a force in the horizontal plane and therefore tending to move the fly-wheel axis in the same plane about a vertical axis, the effect will be to move the fly-wheel axis about a third (or longitudinal) axis at right angles to the other two; and since the fly-wheel shaft, and with it the shell of the torpedo, is free to move in this new plane, it will do so, and will not move in the plane of application of the deflecting force.

For instance, a force in the horizontal plane, applied to the starboard bow of the torpedo would, were the fly-wheel at rest, deflect the torpedo to port, but since the fly-wheel revolves, the effect of such a deflecting force is to *roll* the torpedo to port. The same effect would be produced if the deflecting force were applied to the port quarter.

If such a deflecting force be applied to the port bow or starboard quarter, it will roll the torpedo to starboard.

If the torpedo has rolled due to a deflecting force, the axis of the fly-wheel becomes inclined at an angle with the horizon and would retain this new position if means were not employed to roll the torpedo back to its normal position. If the fly-wheel axis were allowed to remain inclined, the horizontal-rudder would have an element of lateral effect and give the torpedo lateral deviation; therefore a contrary deflecting force is applied, and the application of this force is the function of the vertical-rudder. If the torpedo is rolled to port by a force acting on the starboard bow (or port quarter), the vertical-rudder pendulum swings to port, ports the helm of the vertical-rudder

and thus applies a deflecting force to the starboard quarter and rolls the torpedo to starboard.

The connection of movements is easily remembered. Port deflection produces port roll which is corrected by port helm. Starboard deflection produces starboard roll which is corrected by starboard helm.

If instead of a deflecting force, a rolling effort be applied (like ballast) to bring the torpedo back to an even keel, thus tending to move the fly-wheel axis in the vertical plane, (or about a longitudinal axis) the effect will be a change in direction about a third or vertical axis, at right-angles to the other two, i. e., the torpedo will not roll but will be deflected.

Any tendency to deflect the torpedo rolls it; and any tendency to roll the torpedo deflects it.

THE VERTICAL-RUDDER.

The object of the vertical-rudder is to restore the torpedo to an even keel when rolled by a deflecting force. The vertical-rudder is controlled by the movement of the vertical-rudder pendulum.

THE VERTICAL-RUDDER PENDULUM, ANGLE-GUIDE AND PALLET.

Plates XII, XIII and XV.

The vertical-rudder pendulum is suspended in centers, p, in a frame secured by screws to the top of the impulse-movement frame, and swings in a plane at right-angles to the axis of the torpedo. On each side of the pendulum is an adjustable-screw, q, in an arm screwed to the frame of the immersion-regulator, thus limiting the swing of the pendulum. In the upper part of the pendulum is a pin which engages in a slot in the vertical arm of the angle-guide, r, the horizontal arm of which carries light flat springs, s, which grasp the pin of the vertical-rudder tiller-rod pallet, o; Plate XV. The vertical rudder tiller-rod, P, slides in the upper guide of the impulse-movement frame, and, with its pallet and return-spring, acts in the same manner as the horizontal-rudder tiller-rod. A movement of the vertical-rudder pendulum due to rolling of the torpedo, gives a motion to the vertical-rudder angle-guide and pallet. The lowered end of the pallet engages with one of the teeth on the upper side of the impulse-racks and transmits the impulse to the vertical-rudder through the vertical-rudder tiller-rod. The pin in the upper part of the pendulum may be raised or lowered thus diminishing or increasing the throw of the angle-guide, thereby giving a less or greater angular movement to the vertical-rudder pallet. The motion given to the vertical-rudder is a series of impulses, in the same manner as in the case of the horizontal-rudder, its action depending upon the number of teeth engaged by the pallet. On each side of the head of the pendulum is a light flexible spring which prevents motion of the pendulum within a roll of 1° 30′.

THE LOCKING-GEAR.

Plates XII and XIII.

The object of the locking-gear is to steady the pendulum on launching the torpedo and until it has run a short distance. It thus takes the firing shock and also avoids the down rudder effect which would otherwise be produced as the torpedo gathered speed.

It consists of the throwing-lever, u, locking-link, v, locking-lever, w, and an unlocking-rod, x, passing through a stuffing-box and connected to, and operated by the pitch-frame of the speed-regulator.

The speed of ejection from the launching-tube and that of the torpedo, after it is immersed, being so nearly equal in the Howell torpedo, it is, as a general rule, unnecessary to lock except for tubes at a considerable height above the water where the angle of entry is great, and the rudder is locked up to control the dive.

The forward end of the unlocking-rod passes through a guide in a projecting frame screwed to the frame of the immersion-regulator. The locking-lever, **W**, is mounted on a pivot passing through the fixed buffer, **Z**. On the forward top side of this lever is a toothed-rack, to which is clamped by a screw the hook, **i**, of right-angle shape, the transverse arm of which enters a hole in the side of the pendulum-bob, when the pendulum is locked.

The operation of unlocking is as follows:—when the torpedo is launched the pitch-frame moves the unlocking rod aft; the locking-lever revolves causing the hook to free the pendulum.

By means of the toothed-rack and hook, the position of the pendulum, when locked, can be regulated, this, in turn determining the position of the rudder.

Each tooth of this rack is equivalent to a tooth of the impulse-rack.

The rudder during the period of locking, may be up, horizontal, or slightly down. The zero or reference point of this adjustment is that position of the pendulum, which brings the horizontal-rudder tiller-rod pallet level, after the torpedo is adjusted for "set depth".

The time for which the pendulum is locked is regulated by adjusting the length of the locking-link, which is fitted with a turnbuckle for this purpose, and which controls the length of the pendulum-hook engaged in the pendulum-bob. There are eight marks on the hook, each one corresponding to three quarters of a second, equal to one

hundred revolutions of the propellers, equal to about ten yards run.

THE TAIL.

Plate XVI.

The tail of the torpedo comprises all that portion abaft the after-body; it carries the propellers, propeller-bearings, horizontal-rudder, tail-cone, tail-frame, horizontal and vertical-blades, vertical-rudder and speed-regulator.

The propellers, Y, are three-bladed, two in number and revolve towards each other.

The propeller-shafts have two bearings in the tail; one in the tail-frame abreast the tail-bolt, and the other abaft the propellers and secured to the horizontal-rudder frame; the ends of these after bearings are fashioned to limit the throw of the horizontal-rudder.

The thrust of each propeller-shaft is taken by a ball-bearing of which the gland of the stuffing-box in the propeller-shaft sleeve, C, forms one side, and a thrust-washer on the shaft the other side. A thrust-collar behind the washer is secured to the shaft by a through-pin. A similar collar working against the tail-frame prevents any movement of the shaft in the opposite direction.

The horizontal-rudder, Z, is hung on its frame, its tiller being on its upper side. Both horizontal and vertical-rudder tiller-rods, from the impulse-movement frame to the tiller, are in four parts. The several parts are fitted with screw connections, which permit lengthening or shortening of the tiller-rod, just forward of the joints which are connected together by screws. The connections are located as follows:—one just abaft the impulse-movement frame, one forward of bulkhead, B, one just abaft bulkhead, B, and one at the tiller. The forward end of the section of the horizontal-rudder tiller-rod extending through the after-body of the torpedo is encircled

in a spring-box by a tension-spring which resists lengthening or shortening of the rod and serves to take up the sudden shock given to the horizontal-rudder when the torpedo enters the water.

The tail-cone, U, is secured to the after bulkhead, B, and is open to permit access to the speed-regulator and other adjustments. Casing-plates fit over these openings and give a smooth flow of water to the screws and rudders, but do not make the cone water-tight.

The tail-frame, A, is secured to the tail-cone by the tail-bolt, E. The tail-bolt is a prolongation in figure of the tail-cone, both being a continuation of the after section of the torpedo; after being screwed in place it is strongly secured to the horizontal-rudder frame, D. The horizontal-blades of the tail, V V, are secured to the tail-frame, A, to the propeller-shaft sleeve, C, and to the horizontal-rudder frame, D.

The vertical-blades, W W, (top and bottom) are secured to the tail-cone, the tail-bolt, and the horizontal-rudder frame.

The vertical-rudders, X X, are mounted in the vertical-blades and are so connected that the vertical-rudder tiller-rod, on the starboard side, moves both alike.

THE SPEED REGULATOR.

Plate XVI.

The object of the speed-regulator is to equalize the speed of the torpedo during its run by increasing the pitch of the propellers as the velocity of the fly-wheel decreases.

It consists of the following parts: — the gear-frame, F; the cam-gear, G; the revolving-cam, H; the intermediate-gear, I; the worm gear, J; the worm, R; the worm clutch, K; the water-tripper, L; the pitch-frame, M; the pitch-frame guides, O O; the pitch-forks, N N; the sliding-cams,

P P; the blade-levers, Q Q; and the variable-pitch propeller-blades, Y.

The gear-frame, F, is secured to the tail-cone. Mounted on the gear-frame is the cam-gear, G. Above the cam-gear and secured to it is the revolving-cam, H, a plate with a cam-groove in which slides a stud on the under side of the pitch-frame, M. The intermediate-gear, I, and the worm-gear, J, are also mounted on the gear-frame, F. A worm, R, on the propeller-shaft engages the worm-gear, J, whose pinion, S, engages the intermediate-gear, I, whose pinion engages the cam-gear, G.

Machined in one with the pitch-forks are their handles or side-rods which have longitudinal motion in their guides, O O, and through the tail-frame; they are pinned to the pitch-frame and practically form a part of it.

Sliding-cams, P P, of triangular section slide on feathers on the shafts forward of the propellers and revolve with them. Their forward ends are turned down to a cylindrical form with annular grooves which take the studs of the pitch-forks, N N. This construction permits the sliding-cams to revolve freely with the shafts and at the same time allows them to slide aft in obedience to the movements of the pitch-frame.

Thus a revolving movement of the worm, R, is transmitted to the cam, H, causing the pitch-frame to move aft which in turn move the sliding-cams aft.

The pitch-frame also moves the unlocking-rod which is attached to it.

Each propeller-blade, Y, turns in its hub, and its angle or pitch is determined by the position of the blade-lever, Q, to one end of which it is rigidly secured, while the forward end is fitted with a stud which moves in a slot in the corresponding face of the sliding-cam. Movement of the sliding-cam alters the pitch of the propeller.

Before running a torpedo the pitch-frame is set at its initial point—at or near the extreme forward throw of the revolving-cam.

A spring-guide in the groove of the revolving-cam serves to keep the stud of the pitch-frame in the right direction when resetting the pitch-frame at its initial point after a run.

The speed-regulator mechanism is not put in operation at the instant of launching but is delayed until the torpedo reaches the water. This is accomplished as follows:—

The worm, R, is free to revolve, but cannot slide, upon the shaft; the clutch, K, can slide upon the shaft and must revolve with it. On the port horizontal-blade of the tail is a support, L′; on which is mounted the water-tripper, L, one arm of which ends in a detent. In the position of the water-tripper before firing, this detent enters a hole in the worm and prevents the latter from revolving; at the same time another arm engages in an annular groove in the sliding-clutch, K, permitting it to revolve freely, but preventing it from moving on the shaft and engaging the worm. The water-tripper is kept in its normal position by a spring secured to the under side of, and projecting through a hole in, the horizontal-blade.

When the torpedo enters the water, the water-tripper is thrown back by the water pressure, overcoming the tension of its spring; the worm is released; the clutch is moved forward and engages the worm; the worm is revolved and the mechanism of the speed-regulator put in operation. The water-tripper when thrown back is held in place by the inclination of the after end of its spring.

The speed-regulator gearing is such that the cam-gear makes about one turn while the torpedo travels a range of

400 yds. the revolving-cam curve throwing in towards the center in estimated proportion to the decrease of revolutions. This decrease is more rapid towards the end of the run, since the stored-up energy in the fly-wheel decreases in proportion to the square of its angular velocity.

PITCH OF PROPELLERS.

The propeller-blades work between extreme pitches of 5″.22 and 9″.68, experiment having shown that this arrangement combined with the present fly-wheel and power developed produces the best results.

The variation in pitch is controlled by the form of groove in the sliding-cam and also by the travel of these cams. The travel is in turn controlled by the form and speed of the revolving-cam. Thus the character and rate of change of pitch is determined by the particular form of cams in use and the proportion of gearing, which will allow the initial pitch only, to be varied.

The slip is about 25%.

ACTION AND ADJUSTMENTS

OF

IMMERSION-REGULATOR AND HORIZONTAL-RUDDER.

The construction and adjustments of the torpedo are such that within small limits of departure of its axis from the horizontal plane, the hydrostatic-piston operates the horizontal-rudder without interference by the action of the pendulum; or at least the piston has the preponderating influence, depending on the angle of inclination of the torpedo.

For a large departure of the axis from the horizontal plane, whatever the depth, the pendulum preponderates.

When the path of the torpedo is such that it is *approaching* the plane of "set depth" from above, there must then be an instant when the *out* piston effect is equalled and cancelled by *forward* pendulum effect; the angle of inclination of the axis to the horizontal at this time is called the "free dive" angle, the rudder at such time being in the axis of the torpedo. This angle is generally 45′, having been determined by experiment as giving the best results.

Under similar conditions but when the torpedo is approaching "set depth" from below, the *in* piston effect being cancelled by *after* pendulum effect, no rudder action is produced, and the angle of inclination, 45′, is called the "free rise" angle.

The object of these two adjustments, is to allow the torpedo when it is near its plane of "set depth" to "gain sea to the front" instead of taking the longer path by making large angles with the horizontal.

On the other hand if the axis of the torpedo is inclined to any great extent from the horizontal, its high speed would soon cause it to come to the surface or to strike bottom. To prevent this the pendulum attains its maximum swing aft or forward when the inclination of the axis of the torpedo is about 1° 45′. These two angles are called the "full rise" and "full dive" angles respectively. They depend upon the "free rise" and "free dive" angles.

These four angles are determined by the adjustment of the checking-springs, C, Plate XIII. The method in the shop is as follows:—

The fly-wheel and all parts of the mechanism abaft it are assembled in a skeleton frame, so mounted that its axis can be inclined at known angles. The fly-wheel is then spun up to moderate speed, which gives movement to the impulse-racks. The piston is clamped in its central position as at "set depth" and the axis levelled; there should then be no rudder action.

The piston remaining at "set depth" the axis is inclined in both directions to note the action of the pendulum.

The clamp is removed, permitting the piston to come out as at above

"set depth" giving *down* rudder, and the axis is inclined at "free dive" angle. The forward checking-spring is then adjusted so that the *forward* swing of the pendulum cancels this effect and produces no rudder action.

The piston is then clamped at its full throw *in* as at below "set depth" giving *up* rudder, and the axis is inclined at the "free rise" angle. The after checking-spring is then adjusted until the *after* swing of the pendulum cancels this effect and produces no rudder action.

These adjustments, if necessary, can be made when the torpedo is assembled, either on shore or on board ship in port. Put the torpedo in the launching-tube, spin it up and withdraw it. Lay it on chocks so that it can be tilted at will. Adjust as above. A level with pointer and arc is supplied with the outfit.

If the torpedo shows a tendency to rise above "set depth", the "free dive" angle should be increased and the "free rise" angle diminished; and the reverse if there be a tendency to run below "set depth".

The unit of rudder action is that produced by the first tooth of the impulse-rack, no less result being possible; and the action of the rudder due to any position of the pallet, is the product of this unit by the number of teeth engaged.

The angle of the pallet corresponding to unit action is 2° 17′ 30″. This angle is sufficient for the pallet to engage the first tooth; if more than one tooth are engaged, this angle is multiplied by the number of teeth. The required movement of the hydrostatic-piston, the pendulum being stationary, to produce this unit rudder action, is ″.02.

The piston is usually adjusted for a total travel of ″.09, or ″.045 on each side of its central position which is sufficient to cause the pallet to engage the second tooth on each impulse-rack. The travel of the piston is controlled by the stop-nuts, S, Plate XIV.; and the throw of the angle-guide each way is equalized by the adjusting-nuts, A.

The required movement of the horizontal-rudder pendulum, the piston being stationary, to produce unit rudder action (angle-guide moved through 2° 17′ 30″) is 0° 12′ of arc; and as the pendulum has a maximum swing each way of 1°, it may cause the pallet to engage the fifth tooth. The maximum effect of the pendulum being to cause the pallet to engage the fifth tooth, and that of the piston being to cause it to engage the second tooth, if these two maxima are in opposite directions, the result will be three teeth of the pendulum effect. If they are in the same direction the result would be seven teeth were it not that the impulse-racks have but six teeth, the remaining one tooth of angle-guide movement being absorbed by its springs and inoperative for steering purposes.

Since a movement of 0° 12′ of arc of the horizontal-rudder pendulum produces unit rudder action, at "free dive" and "free rise" the pendulum will swing 24′.

The longitudinal movement of the horizontal-rudder tiller-rod for each tooth is ″.07, or a maximum of ″.42 for the six teeth.

The rudder angle for a movement of ″.07 of the tiller-rod, is about 3°, but is always diminished by the tiller-rod tension-spring.

The horizontal-rudder tiller-rod return-springs have an initial tension of one pound and a tension at full throw of the rod of six pounds.

NOTE.

The adjustment sheet (blue print) issued with each torpedo shows all the adjustments of the torpedo excepting the locking of the pendulum and if once made before the torpedoes are sent on board ship they should remain permanent for the cruise.

A copy of the Record of Running Trials for each torpedo is also issued for reference, under certain circumstances of practice.

PLATES.

Plate I.

GENERAL LONGITUDINAL SECTION.

A ..... .head.
B .....depth-register pocket.
C .....calcium-phosphide pocket.
D .....middle-body.
F .....fly-wheel.
H ..... shaft-gears.
I .....gear-shafts.
J .....horizontal-rudder pendulum.
K .....vertical-rudder pendulum.
L .....impulse-mechanism.
M .....after-body.
N .....horizontal-rudder tiller-rod.
P ..... vertical-rudder tiller-rod.
R .....propeller-shaft.
S.....tail.
U .....tail-cone.
W W....top and bottom blades.
X X.....vertical-rudder.
Y .....propeller.
Z.....horizontal-rudder.

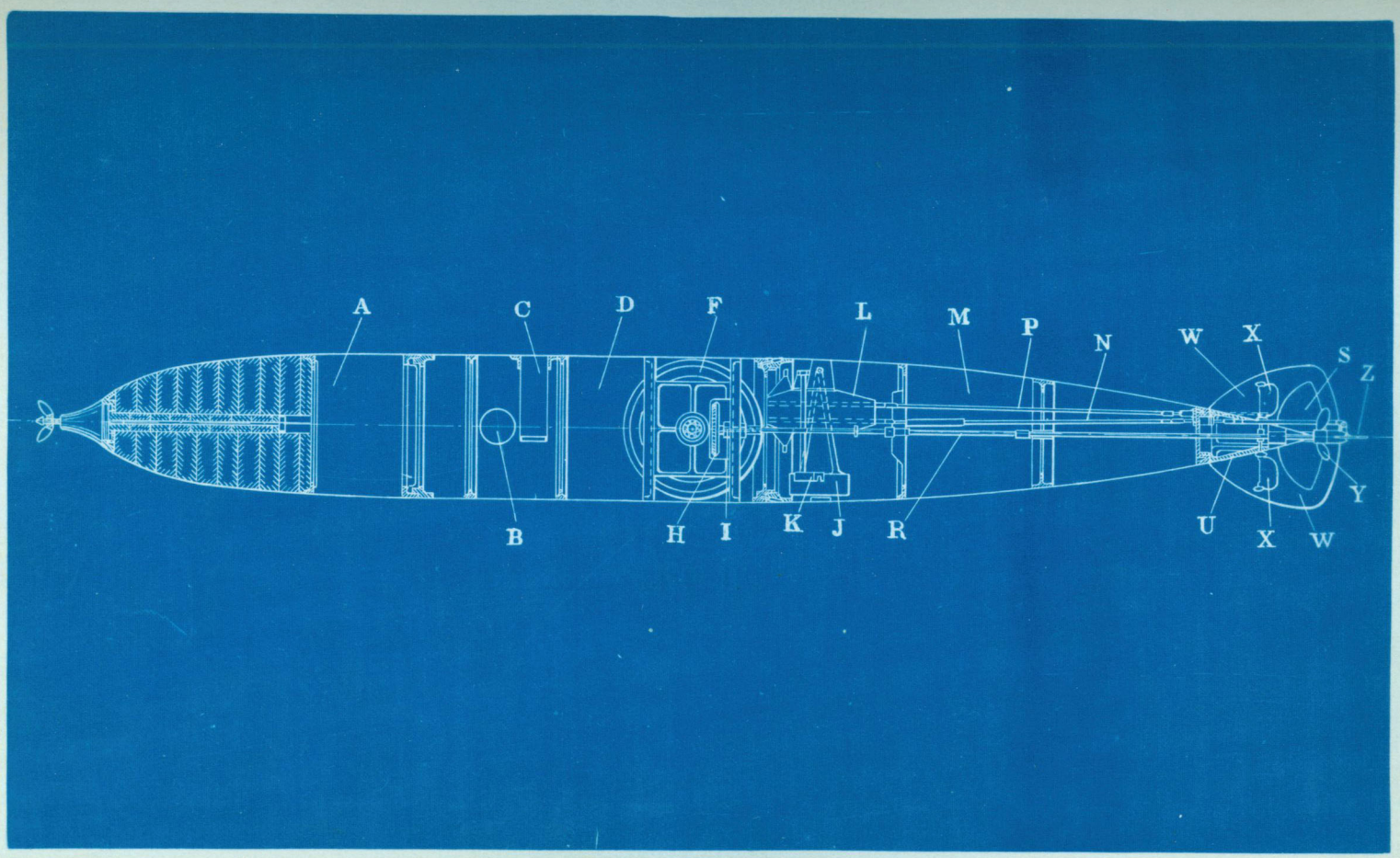

PLATE I.

Plate II.

GENERAL PLAN.

A .....head.
B ... ..depth-register pocket.
C .....calcium-phosphide pocket.
D .....middle-body.
F .....fly-wheel.
G .....clutches.
H H....shaft-gears.
I I..... gear-shafts.
J.....horizontal-rudder pendulum.
M.....after-body.
N .. .. horizontal-rudder tiller-rod.
O .....locking-mechanism.
P .....vertical-rudder tiller-rod.
Q .....unlocking-rod.
R R ....propeller-shafts.
S.....tail.
T.....speed-regulator.
V V ....side-blades.
Y Y ....propellers.
Z... ...horizontal-rudder.

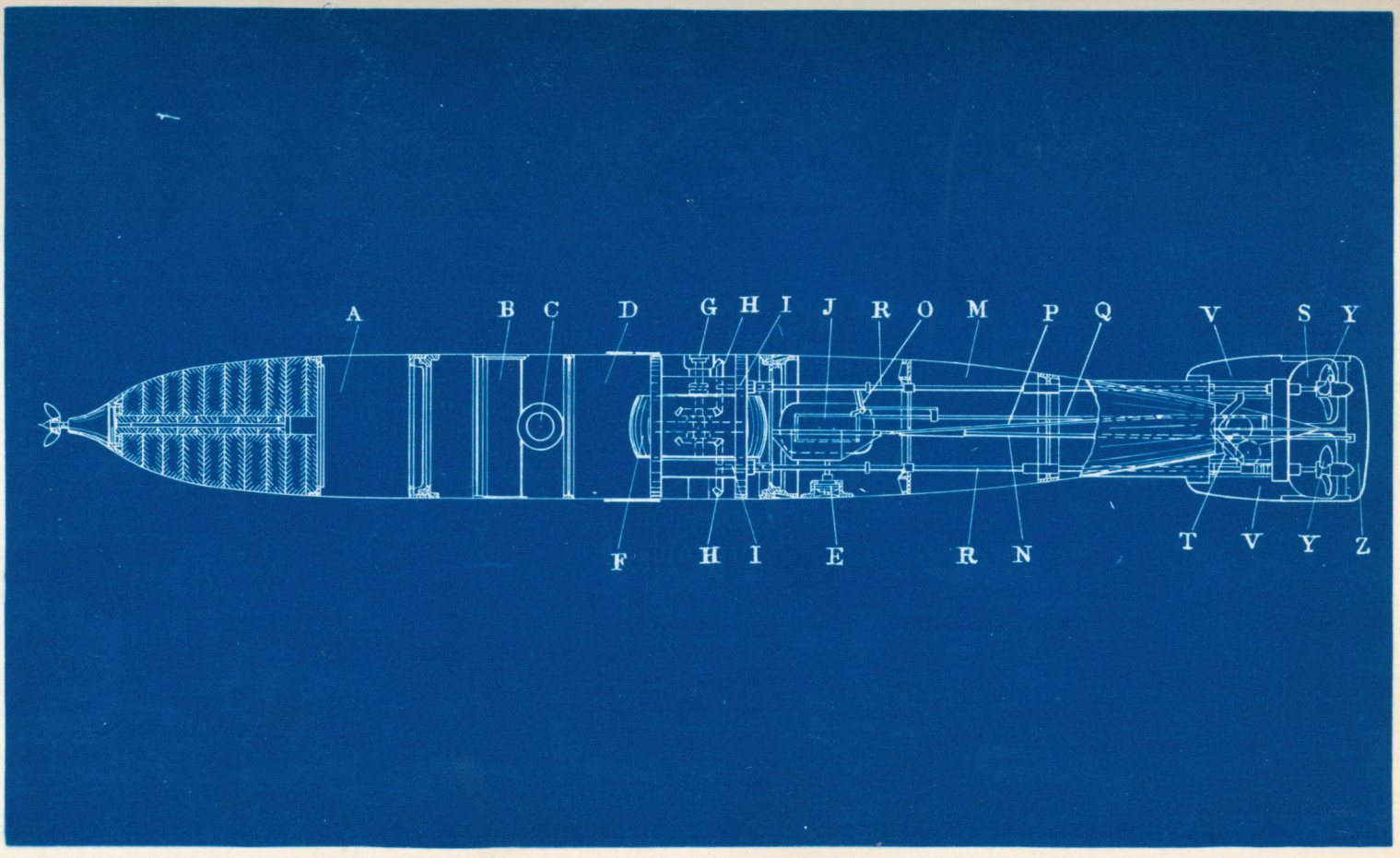

PLATE II.

Plate III.

EXERCISE-HEAD.

A.. ....nose-ring.
B.....clamp-ring.
C.....following-ring.
D D....filling-holes.
E.....flange.
F.....socket.
G.....balance-weight tube.
H .....feather.
I .....balance-weight rod.
J J .....followers.
K .....balance-weight.
L.....compartment.
M .....bulkhead.
N .....balance-weight tube-rest.
P .....buoyancy-chamber.
Q.....socket.
R.....bulkhead.

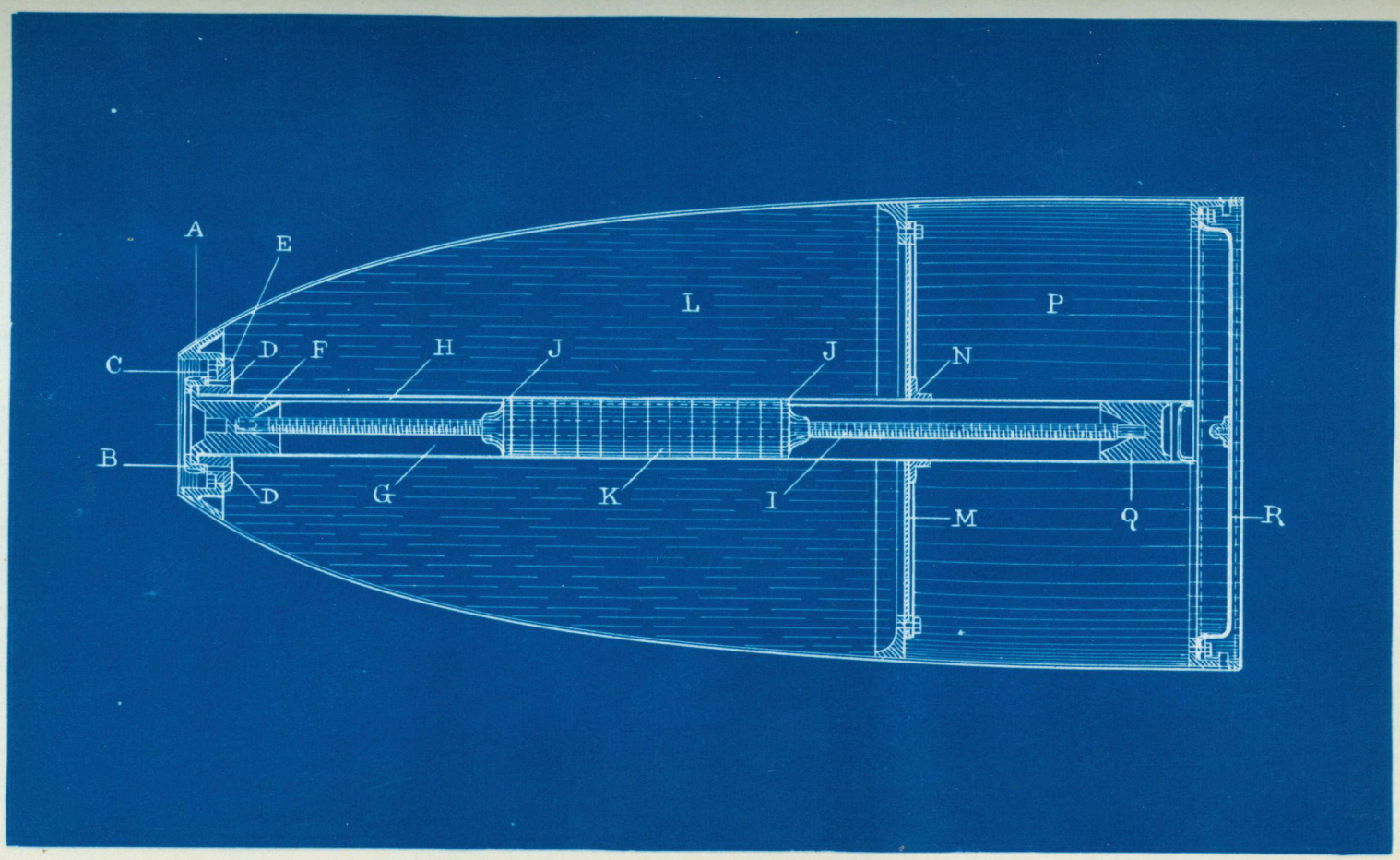

PLATE III.

Plate IV.

WAR-HEAD.

A.....nose-ring.
B.....primer-case clamp-ring.
C.....spring-latch.
D.....primer-case cover.
E.....primer-case flange.
F.....moisture-tap.
G.....vent-hole.
H H..soluble plugs.
I.....exploder-pocket.
J... .exploder.
K....primer-case.
L... compartment.
M....diaphragm.
N... primer-case rest.
P ...bulkhead.
Q ....buoyancy-chamber.
R ....bulkhead.

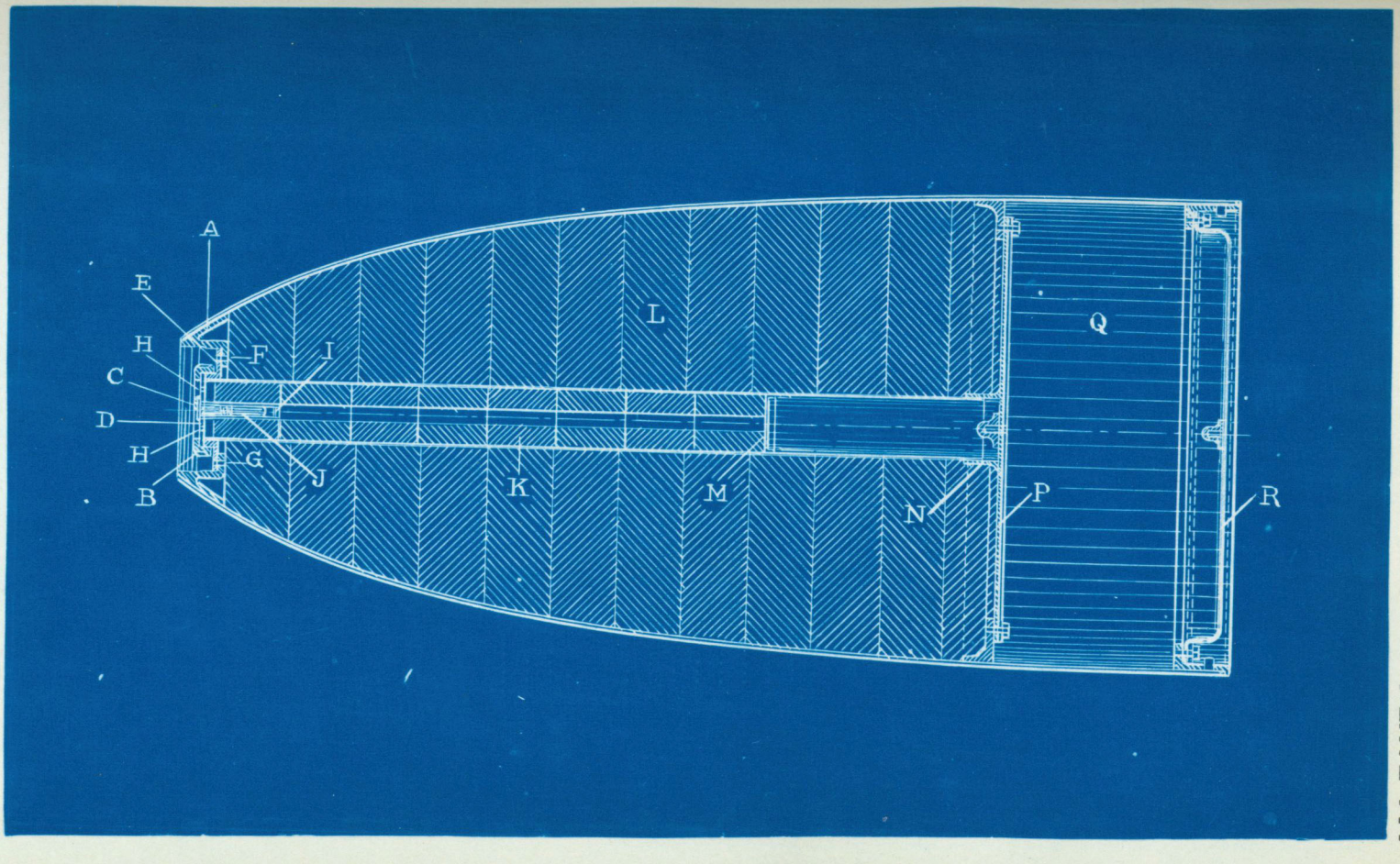

PLATE IV.

Plate V.

FIG. I. WAR-NOSE.

A .....point.
B .....screw-fan.
C .....head of firing-pin.
D .....shearing-pin.
E .....cap.
F .....cap lock-screw.
G .....sleeve.
H .....firing-pin.
I.....guide-pin.
J..... guide-slot.
K.....body.
L.....sear-spring.
M.....firing-spring.
N N....holes.
P .....collar.

FIG. 2. EXERCISE-NOSE.

a.....point.
b .....spindle.
c.....screw-fan.
d .....cap.
e .....cap lock-screw.
f.....body.

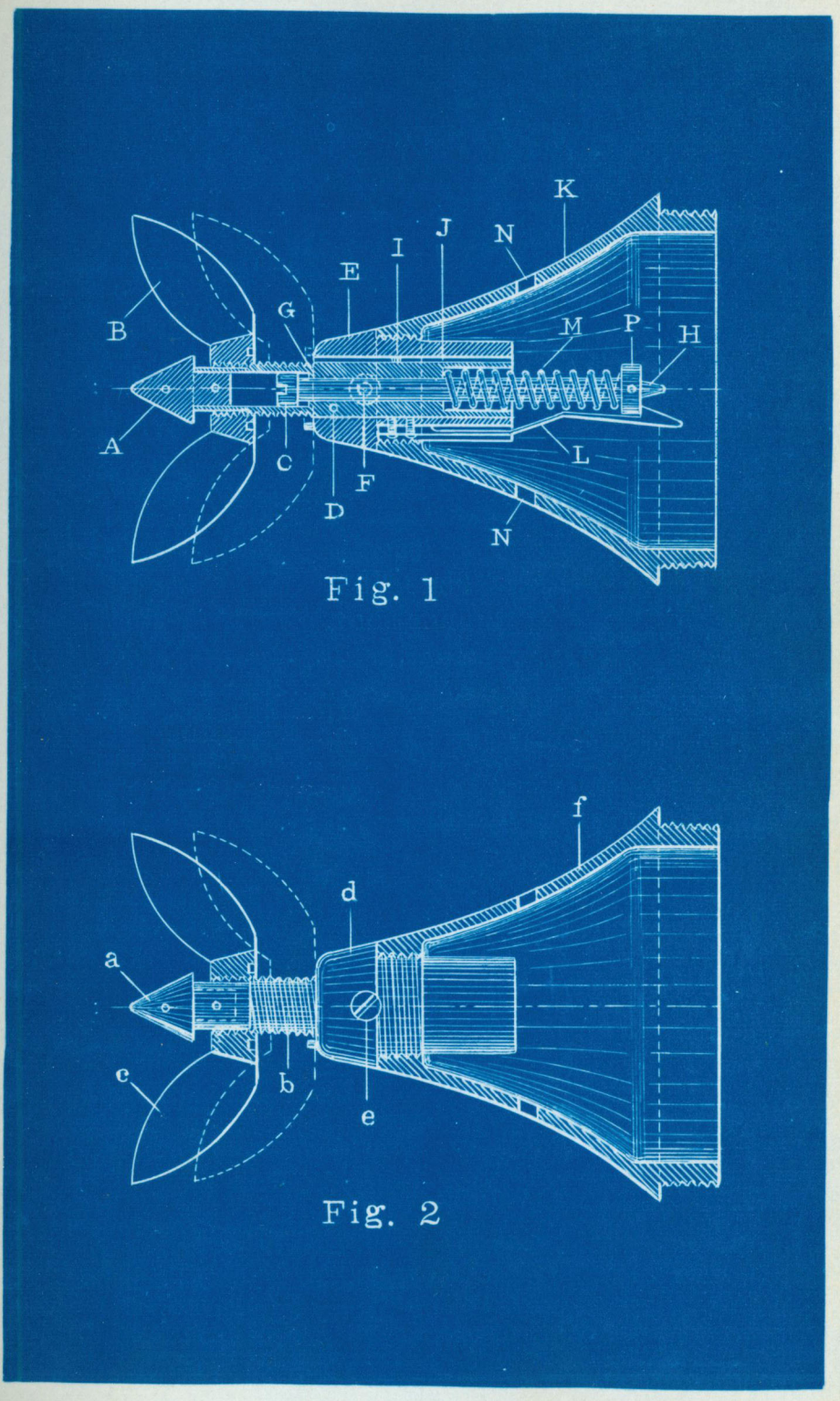

Fig. 1

Fig. 2

Plate VI.

MIDDLE-BODY.

Fig. 1. Elevation. Fig. 2. Plan.

B .....depth-register pocket.
C.....calcium-phosphide pocket.
D ..... middle-body.
E E.....guide-studs.
F.....fly-wheel.
G .....clutches.
H H....shaft-gears.
I I .....gear-shafts.
J J .....strengthening-ring.
L L ....fly-wheel gears.

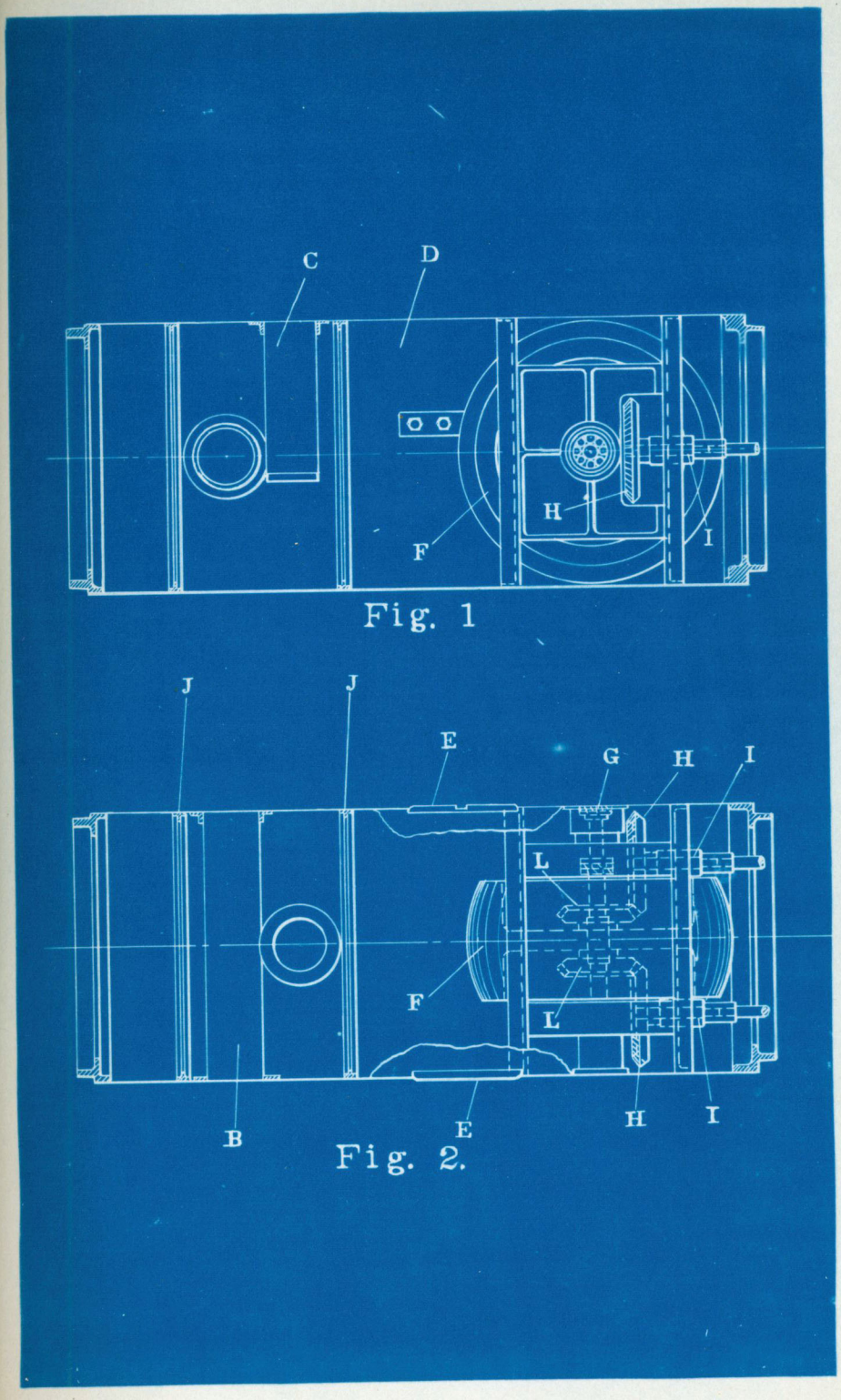

Plate VII.

FIG. 1. CALCIUM-PHOSPHIDE POCKET. FIG. 2. DEPTH-REGISTER AND POCKET.

A ....piston-rod.
B ....depth-register pocket.
C ....calcium-phosphide pocket.
D ....piston-rod guide, or bearing.
E ....spring.
F ....winding-drum.
G....unwinding-drum.
H....counterpoise.
I ....supporting-stays.
K....piston-rod guide, or bearing.
L....pencil.

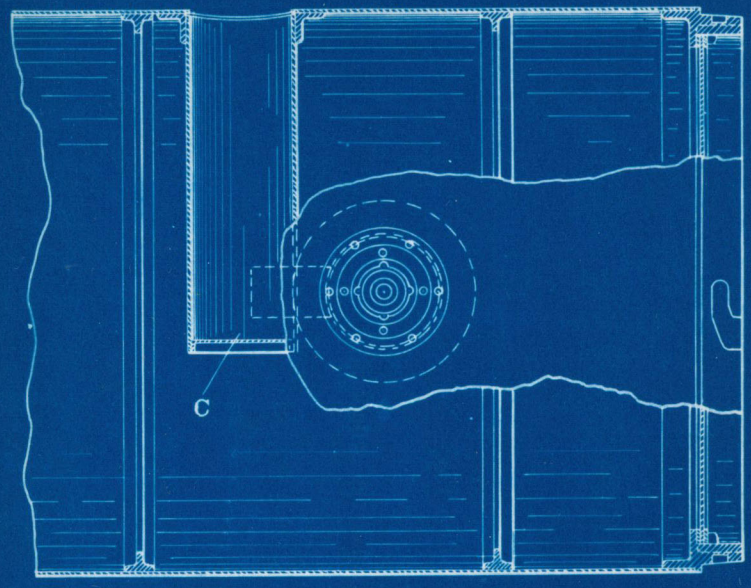

Fig. 1

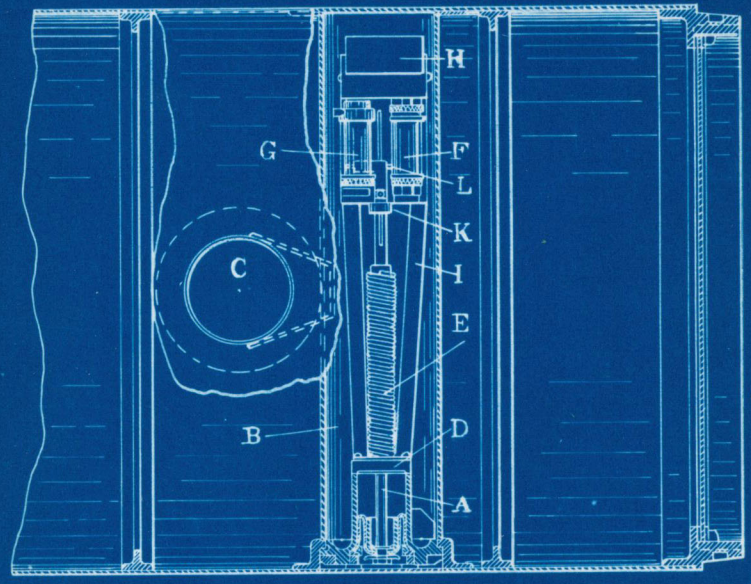

Fig. 2

Plate VIII.

DETAILS OF DEPTH-REGISTER PISTON.

A ....piston-rod.
B ....pocket.
D′....rubber diaphragm.
E′....cylinder.
F′....flange.
G′....clamp-ring.
H′....piston.
I′.....follower.
J .....cap.
K′....flange of cylinder.
L′....ring.
N ....friction-plate.
O ....rubber washer.

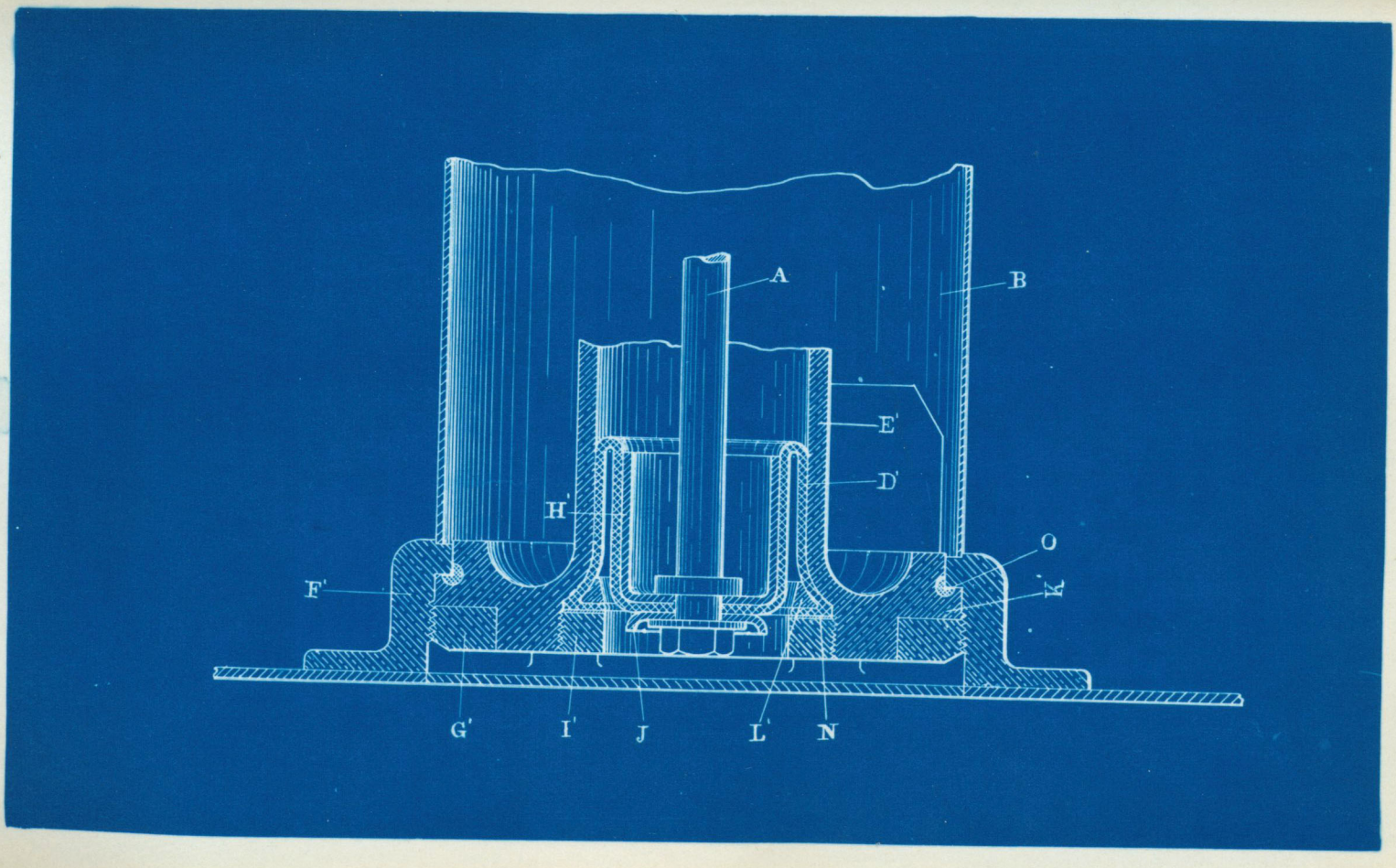

PLATE VIII.

Plate IX.

FLY-WHEEL.

Fig. 1. End view. Fig. 2. Section through fly-wheel.

F.....fly-wheel.
G.....fly-wheel shaft.
H.....shaft-gear.
I.....gear-shaft.
J J.....roller-bearings.
K K ....wheel-boxes.
L L.....fly-wheel gears.
M ..... coupling.
N N ....bearings.
O.....fly-wheel frame.
P P.....steel rolls.
Q.....steel washers.
R R.....ball-bearing.
S ... ...gear-shaft bearing.
T T.....steel washer.
U U'....intermediate-clutches.
V .....fly-wheel clutch.

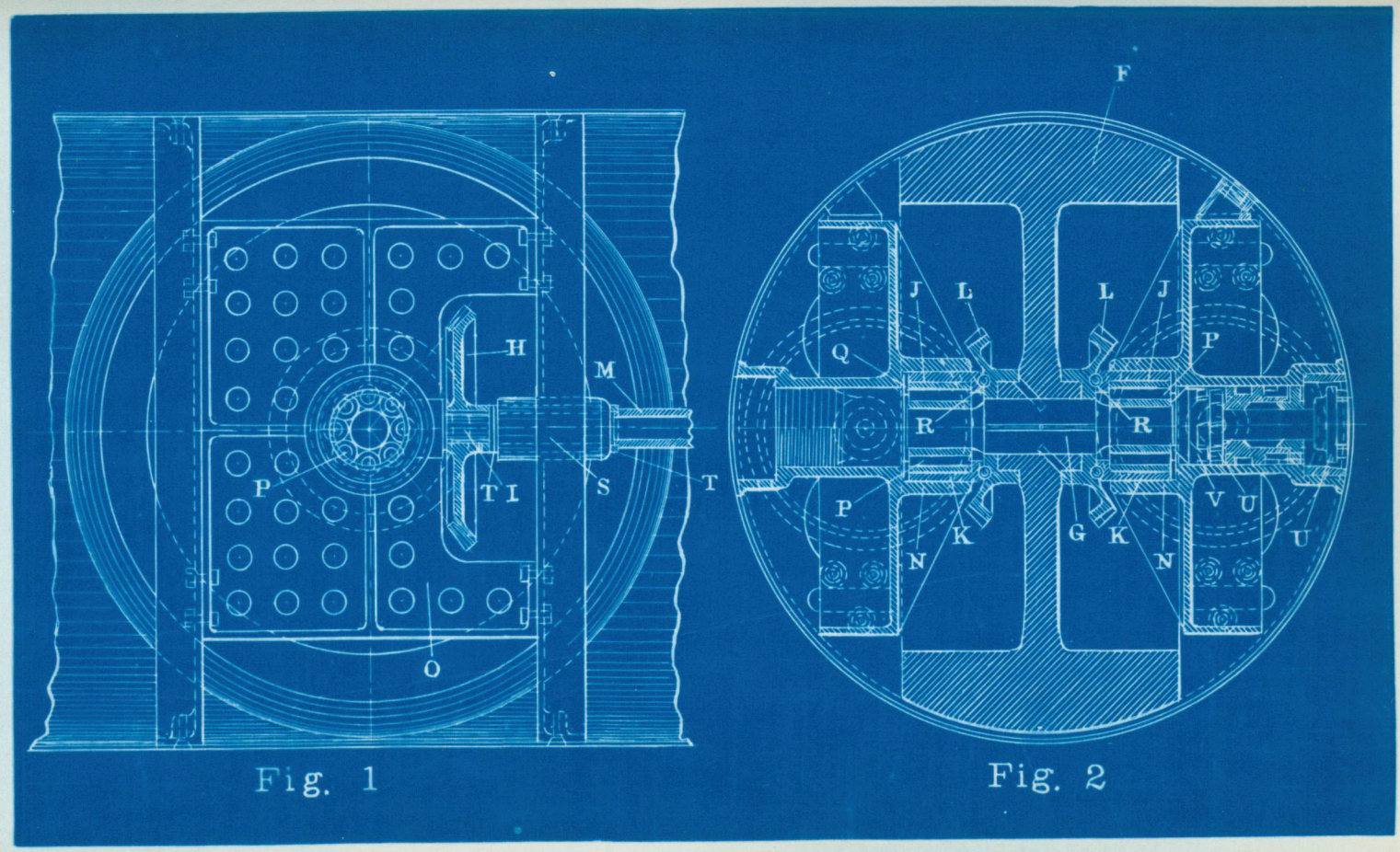

Fig. 1

Fig. 2

PLATE IX.

Plate X.

FIG. 1. END VIEW OF OUTER INTERMEDIATE-CLUTCH. FIG. 2. LONGITUDINAL SECTION THROUGH CLUTCHES.

R ....intermediate-clutch shaft.
S.....gland.
U ....inner intermediate-clutch.
U'....outer intermediate-clutch.
V ....fly-wheel clutch.

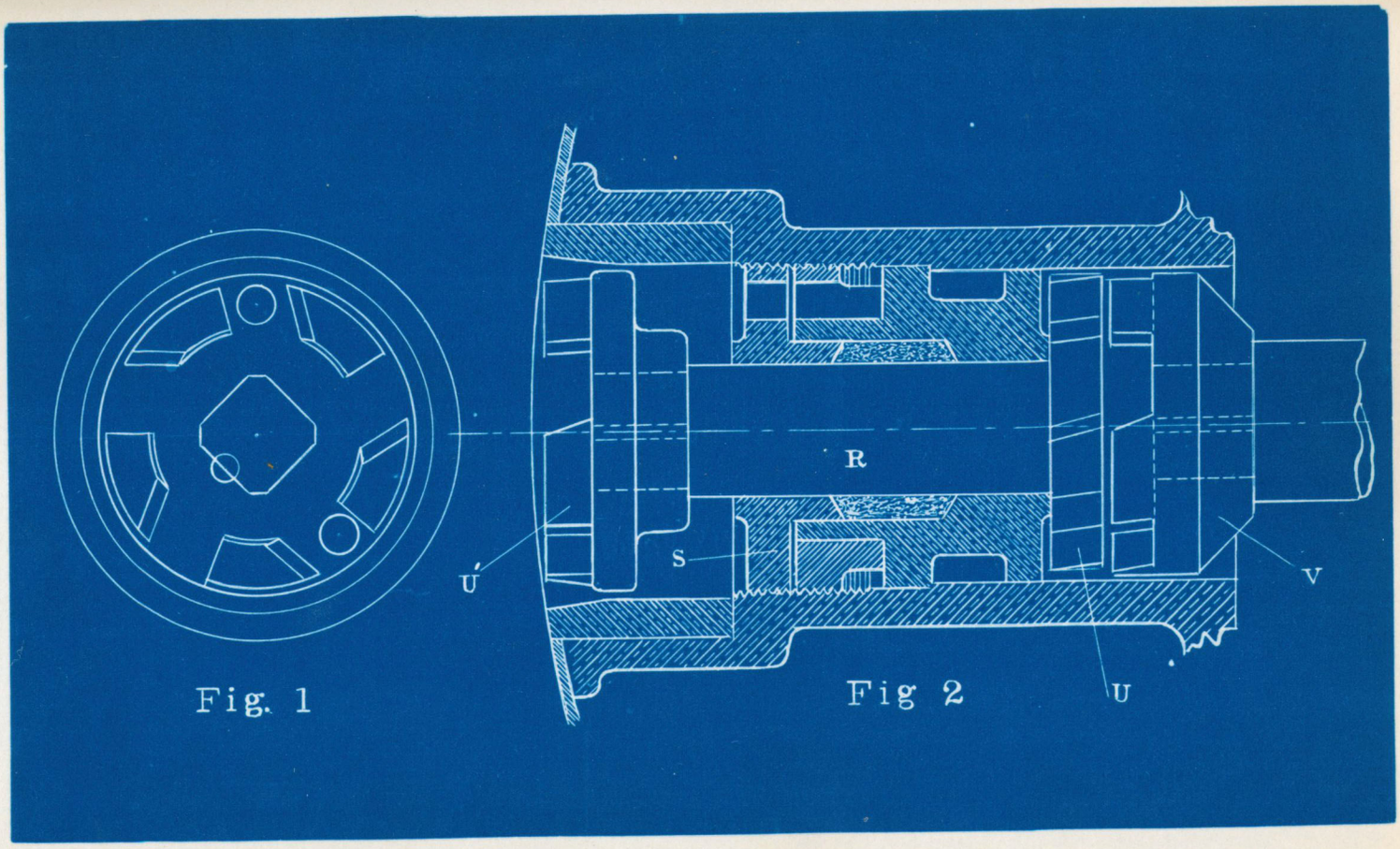

Fig. 1

Fig 2

PLATE X.

Plate XI.

AFTER-BODY.

Plan.

B .....after-bulkhead.
K.....forward joint-ring.
L.....immersion-regulator frame.
M .....after-body.
N.....middle joint-ring.
O O....hand-holes.
P .....hydrostatic-piston chamber.
Q ..... support-ring.
S .....stuffing-box.

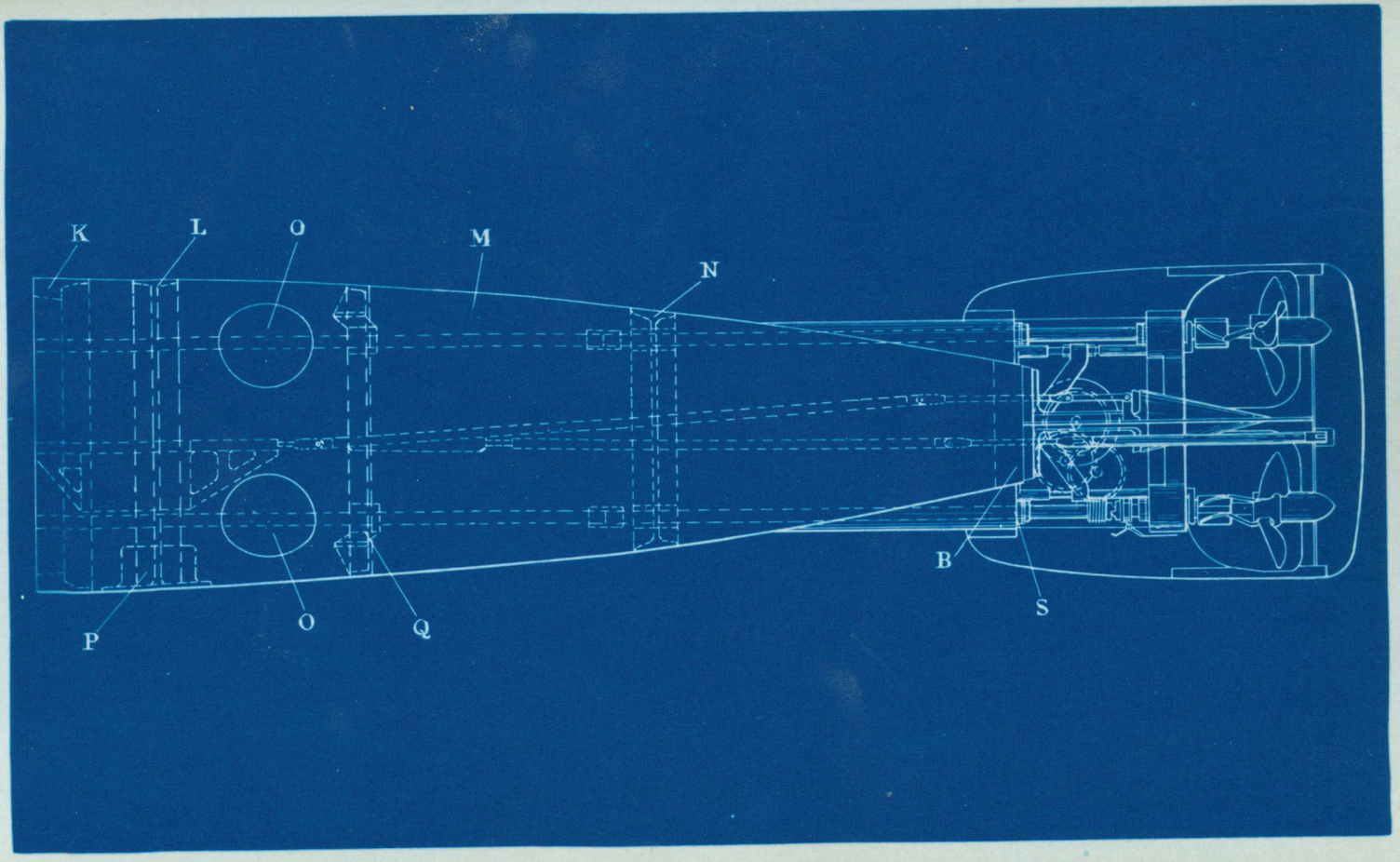

PLATE XI.

Plate XII.

FIG. 1. IMMERSION-REGULATOR; CROSS SECTION.

D ....horizontal-rudder pendulum-lever.
E ....piston-rod.
I.....piston-frame.
J ....pendulum-bob.
K ...vertical-rudder pendulum.
M....piston-chamber.
a ....immersion-spring lever.
b ....immersion-spring.
c ....eye.
d ....knife-edge.
e ....regulator-screw.
f.....regulator-nut.
g ....guide-collar.
h ....guide.
q ....adjustable-screw.
r.....vertical-rudder angle-guide.
s.....angle-guide springs.

FIG. 2. HORIZONTAL-RUDDER PENDULUM; ELEVATION. LOCKING-GEAR.

A....pendulum-support.
B....pendulum-frame.
D....horizontal-rudder pendulum-lever.
F....pendulum-pin.
p ....suspension for vertical-rudder pendulum.
u ....throwing-lever.
v ....locking-link.
w....locking-lever.
x ....unlocking-rod.

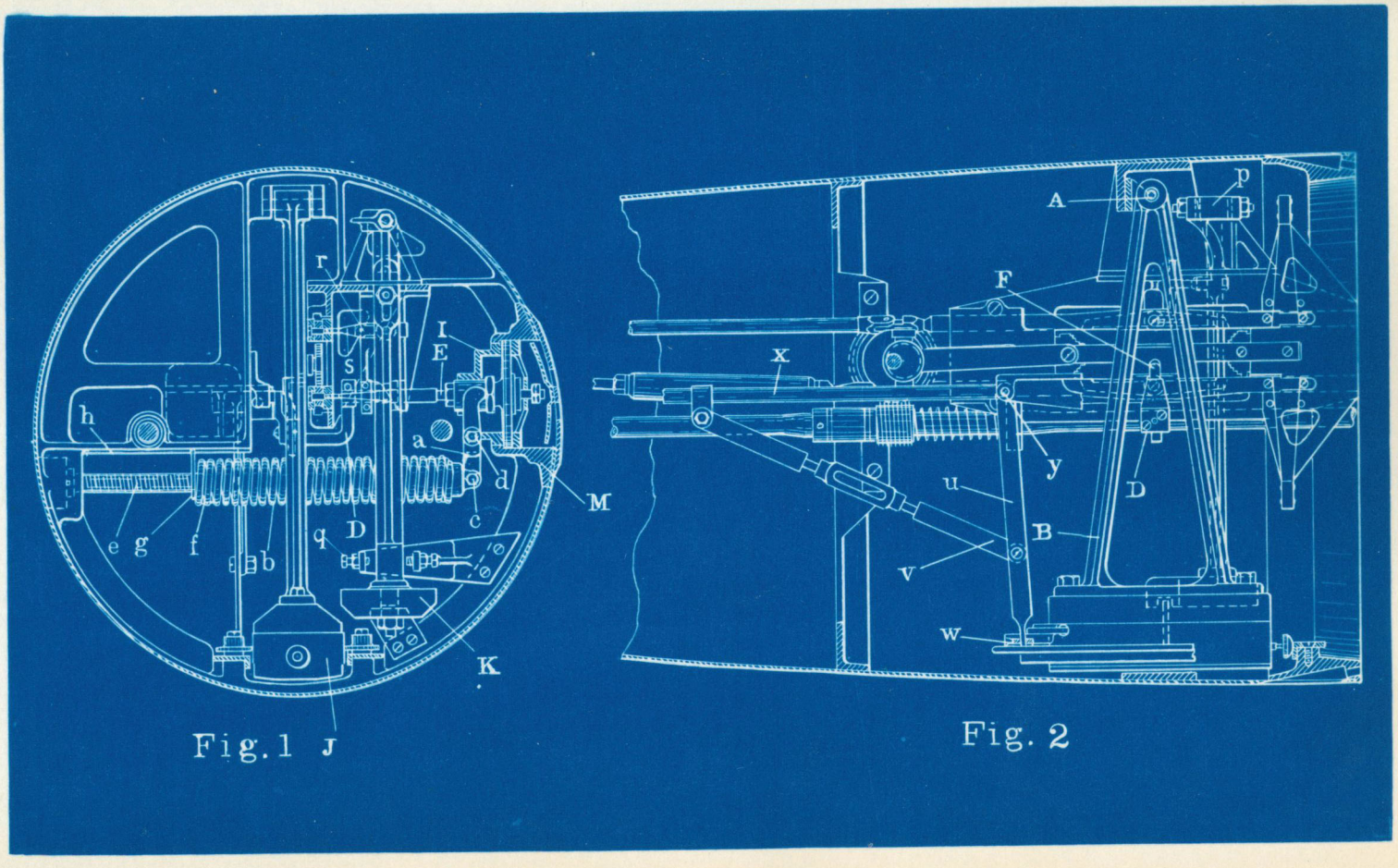

Fig. 1

Fig. 2

PLATE XII.

Plate XIII.

FIG. 1. IMMERSION-REGULATOR; CROSS SECTION. FIG. 2. IMMERSION-REGULATOR; PLAN.

C C ..checking-springs.
E ....piston-rod.
G ....horizontal-rudder angle-guide.
H ....piston.
I. ...piston-frame.
M....piston-chamber.
W....locking-lever.
X ....unlocking-rod.
a.....immersion-spring lever.
b.....immersion-spring.
c ....eye.
d.....knife-edge.
e.....regulator-screw.
f.....regulator-nut.
g.....guide-collar.
h ....guide.
i.....pendulum-hook.
q.....adjustable-screw.
r ....vertical-rudder angle-guide.
s ....angle-guide springs.
z .....guide-frame.

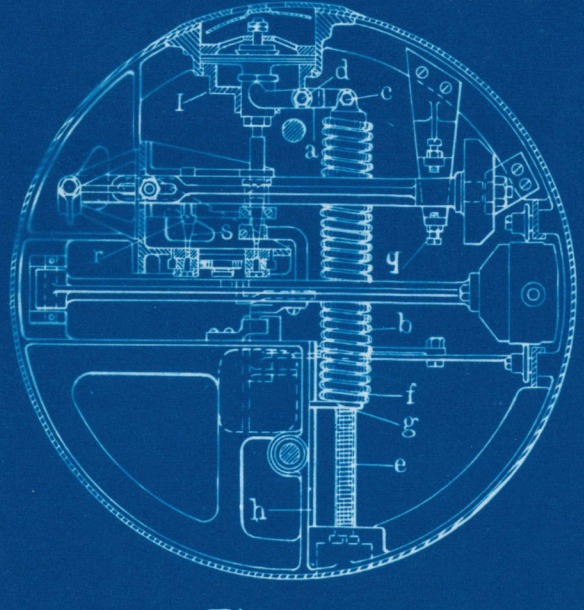

Fig. 1

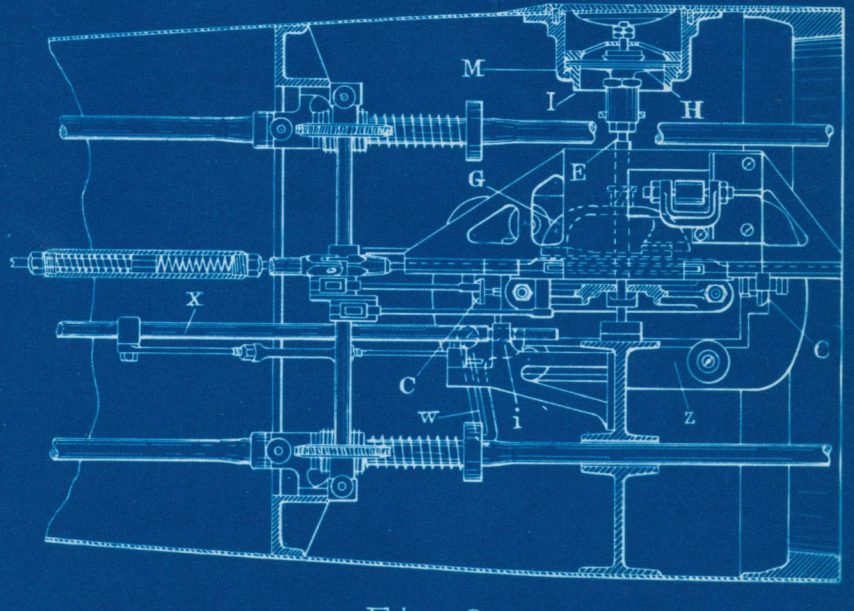

Fig. 2

PLATE XIII.

Plate XIV.

HYDROSTATIC-PISTON.

Fig. 1. Sectional Plan. Fig. 2. End view.

A ....adjusting-nuts.
B ....piston-rod pin.
C ....cam-slot.
E ....piston-rod.
G ....angle-guide.
H ....piston.
I ....piston-frame.
M....piston-chamber.
N ....diaphragm.
O ....following-ring.
P ... nut.
Q ....washer.
R ....shoulder.
S.....stop-nuts.
T ....piston-cap.
U ....cap lock-nut.
V ....angle-guide springs.

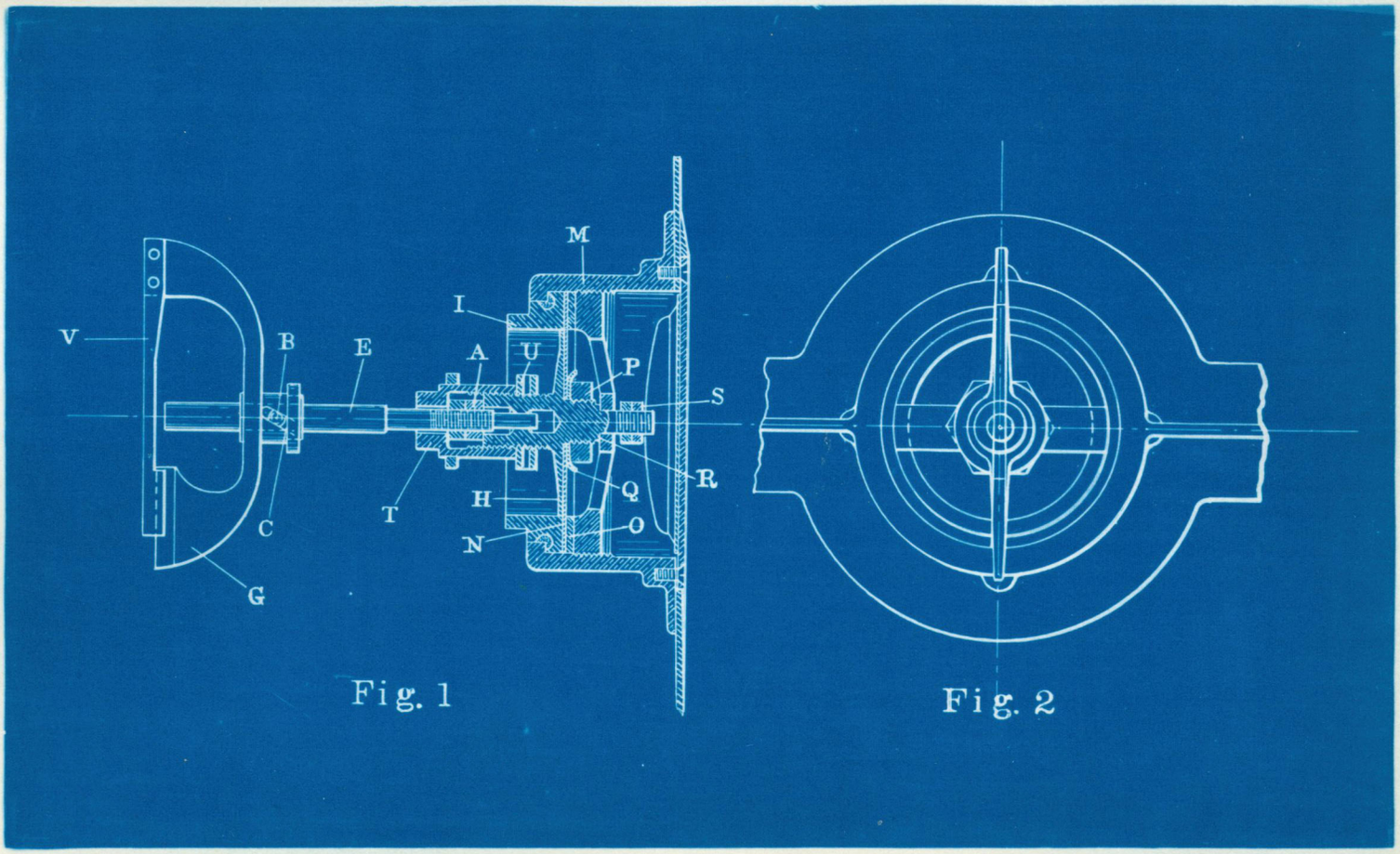

Fig. 1

Fig. 2

PLATE XIV.

Plate XV.

IMPULSE-MECHANISM.

Fig. 1. End view. Fig. 2. Plan. Fig. 3. Impulse-Racks and Pallets.

N .....horizontal-rudder tiller-rod.
P .....vertical-rudder tiller-rod.
k k .....eccentric-rods.
l.....eccentric shaft.
m m ....impulse-movement springs.
n .....offset bar.
o .....vertical-rudder tiller-rod pallet.
r .....horizontal-rudder tiller-rod pallet.
s .....offset bar.

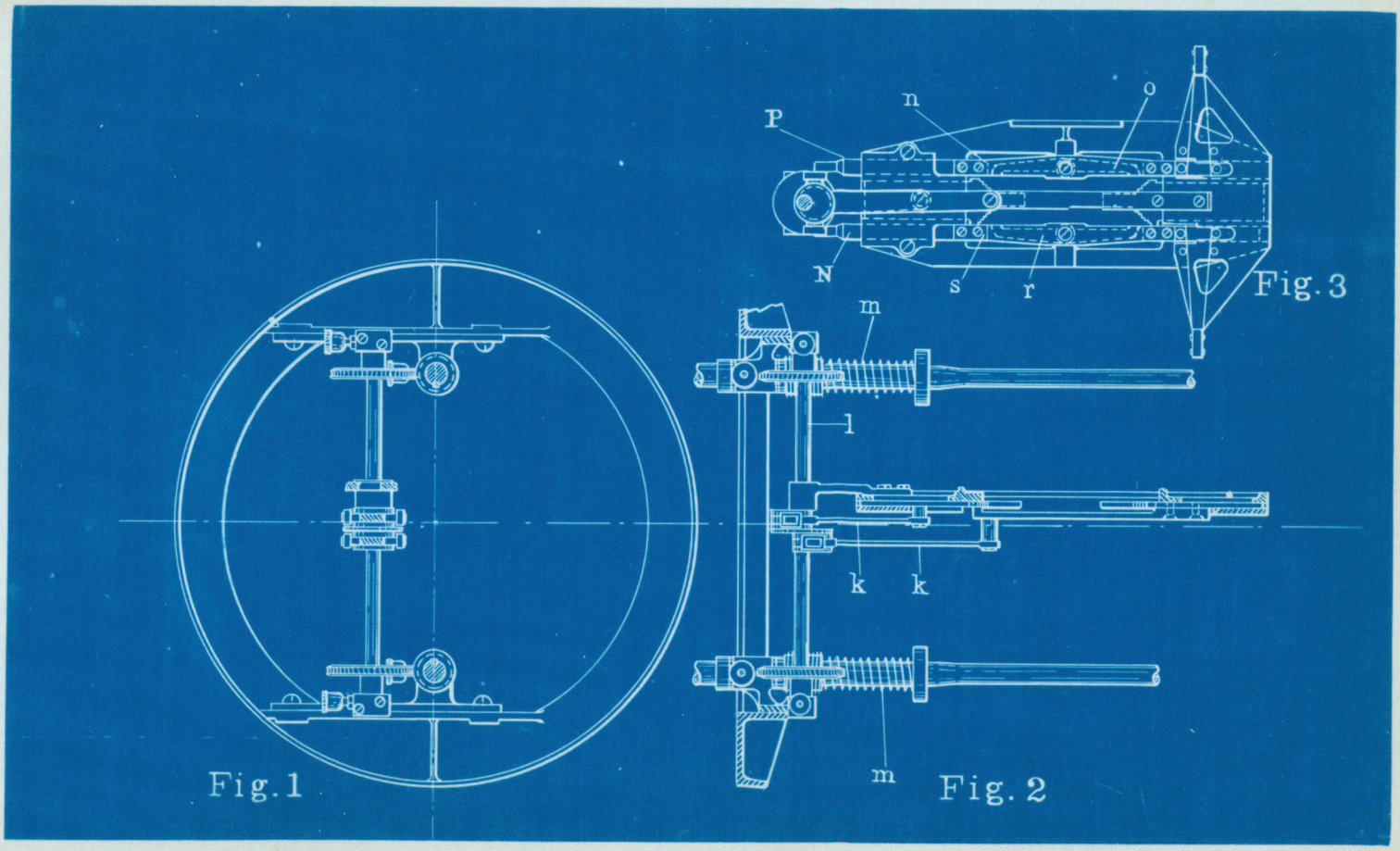

Fig. 3

Fig. 1

Fig. 2

PLATE XV.

Plate XVI.

TAIL.

Fig. 1. Vertical section. Fig. 2. Plan.

A.....tail.
B.....after-bulkhead.
C .....propeller-shaft sleeve.
D.....horizontal-rudder frame.
E .....tail-bolt.
F .....gear-frame.
G.....cam-gear.
H.....revolving-cam.
I..... ..intermediate-gear.
J .....worm-gear.
K.....worm-clutch.
L .....water-tripper.
L′ .....water-tripper support.
M .....pitch-frame.
N N.....pitch-forks.
O O .....pitch-frame guides.
P P .....sliding-cams.
Q Q... .blade-levers.
R... ...worm.
S .....pinion.
U .....tail-cone.
V V.....horizontal-blades.
W W ....top and bottom-blades.
X X... ..vertical-rudders.
Y Y .....propellers.
Z.....horizontal-rudder.