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Summary.—The hull launching tank has been built in order that systematic measurements of impact pressures can be made on large model seaplane hulls to supplement full scale tests, and to cover conditions of impact which would be dangerous full scale. The object is to obtain generalised formulæ for the maximum local pressures, the total impact load and the simultaneous distribution of pressure on any hull form for any impact condition.

The report describes the hull launching tank and apparatus, the range of impact conditions possible for test, and the methods developed for measuring the parameters which affect the impact loads. Theoretical considerations, the results of tests and further developments, will be found in existing or in subsequent reports.

1. *Introduction.*—Systematic tests on the pressure distribution and loads on flying boat hull bottoms during impact with the water were required to extend the scope of tests already made. Such tests are now being made by launching large scale model hulls into a water tank. The general principles of this scheme have been described in an earlier report[1].

The general problem of pressure distribution covers the measurement of the simultaneous pressure distribution and total load over the hull bottom, and the maximum local pressure distribution[2]. Tests have been made full scale on the Southampton (R. & M. 1638), Singapore (R. & M. 1807) and Perth[5,6] flying boats, and model scale by dropping straight sided V-shapes into water over a range of speeds and attitudes (R. & M's. 2312 and 3393). A summary of the results of these tests is given in Ref. 9. The range of full scale tests is limited by the risk factor. Information has been gained on the value of the local maximum pressures, and an empirical formula, based on theory and measurement, has been developed (R. & M. 3393 and Refs. 2 and 9), covering all impacts within the range of the apparatus. This formula applies to simple V-shapes and to first impact only. Further tests are required to check this formula and to cover such factors as beam loading, inertia distribution, waves, assymetrical impacts, initial acceleration. In addition, tests under controlled conditions are required to give the simultaneous distribution of pressure over the hull bottom and total load for a range of impacts, particular attention being paid to nose down (fly on) and tail down (stalled) landings, and to the effect of waves.

The value of the hull launching tank lies in the control over the conditions of impact, covering those which would be dangerous full scale, and the use of true hull forms instead of simplified straight sided *V*-shapes.

2. *Range of Investigation.*—This report is confined to the description of the hull launching tank as finally constructed and the development of methods of measurement of parameters determining the peak pressure distribution. Methods of measurement of total impact and wave impacts will

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be considered in other reports. The results of tests and methods of analysis will be given in further reports, but reference is made to existing results in explaining the development of tank technique.

3. *Description of Hull Launching Tank Apparatus.*—The essential principles of the scheme are described in Ref. 1, written before the apparatus was built. A short description of the final scheme is therefore given with special attention to operation and measurement.

3.1. *Description of General Scheme.*—The essentials of the apparatus are (Figs. 1 and 2), a water tank, a hull attached to a launching carriage by a balanced beam and parallel motion mechanism, and a runway mounted over the tank. The runway comprises a horizontal centre portion with inclined portions at each end. At the top of the longer inclined portion a winch operates a steel cable attached to a small auxiliary trolley. By attaching this small trolley, the launching carriage may be hauled up to any position on the slope. Upon release the carriage runs down under gravity towards the tank attaining a maximum velocity at the bottom of the incline. On reaching the level track the hull is automatically released and swings down on to the water. A wing lift is represented by balance weights on the end of the beam. This weight can be varied to cover conditions from 'fly on' landings to fully stalled landings. A range of vertical velocity is obtained by varying the height through which the hull drops. The attitude of the hull is mechanically controlled until immediately prior to the impact, after which the hull is free in pitch and heave, but restrained in yaw and roll.

3.2. *Runway and Tank.*—The beginning of the runway is a ramp 120 ft long with a slope of 1 in 4 (Fig. 1) which allows a maximum speed of 36 ft/sec to be reached at impact. There is 70 ft of level track in which the hull is launched and a further 70 ft for stopping the carriage by hydraulically actuated brakes. There is also 20 ft beyond the end of the tank which is covered in by a working house for instrument adjustment and housing the carriage when not in use. Finally, in case the hydraulic brakes fail, there is a short 30 ft upward slope at the end of the runway with buffers at the top.

The tank is made of pressed steel sections and is 140 ft long, 11 ft wide, and 6 ft deep. The normal water level is 3 ft 6 in. At the working house end two top plates of the tank have been removed and a sloping wooden ramp leading down to the water surface has been fitted. This ramp picks up trunnions on the hull and raises the hull out of the water into the working house. In the house there are working platforms at each side.

3.3. *Carriage.*—The carriage is shown in Figs. 3 and 4. The mechanism consists of a beam ABC (Fig. 3) with the hull suspended from (C) and the balance weights at (A). The beam swings about an axis through (B). The hull is supported on trunnion bearings through its centre of gravity at (D). (E) is a fixed bearing braced from the trolley so that (BE) is vertical. The links (BC) and (DE) then form a parallel motion so that the link (CD) is vertical during the drop. A bolt in a housing parallel to (CD) on a crossbar between (CD) and a parallel beam (C'D') fits into a coxcomb on the hull decking (Fig. 5). The bolt is held vertical because of the parallel motion so that attitude is fixed during the drop. The bolt is pulled out of the coxcomb by a wire attached to a fixed part of the carriage, just before impact. The hull is then free in pitch during impact. To avoid damage check cables are fitted to prevent the hull from pitching too far.

The rate of pitching can be controlled by means of a simple friction plate clutch type damper, illustrated in Fig. 6. A wire attached at the bow and stern of the hull is wound round a drum (A). This drum is constrained in rotation by the pressure from the spring (B), which spring could be adjusted by the lock nut (C), thus varying the damping.

The mechanism for holding the hull at any desired height and releasing it is shown diagrammatically in Fig. 7. The figure shows half the mechanism. The other half is similar and works in step on the other side of the trolley. The weight of the hull and the out of balance load is taken on chains, both ends of which are attached to the beam, one above and one below the bearings.

The chain wheel is prevented from rotating by pawl (B) holding ratchet wheel (C) which is keyed to the chain wheel shaft. The release is caused by lever (D) operated by the actuating ramp which is situated at the beginning of the level portion of the track, thereby lifting pawl (B) from the ratchet wheel and allowing the hull to drop. The actuating ramp is sufficiently long to hold the lever back during the whole of the highest drop. The secondary pawl and ratchet system is to prevent the hull from dropping a second time after it has rebounded from the water. It is required because the main pawl and ratchet system must be held out so long as to allow for all heights of drop. The pawl (E) is held clear of the ratchet wheel (F) by the follower (G) on the end of which is a roller running on a cam track (H) keyed to the chain wheel shaft. The cam track contains a gap which allows the follower (G) to fall after the hull has been released and dropped to almost its lowest position. The pawl (E) then drops on to the smooth part of the wheel (F). When the model rebounds from the water the rotation of the chain wheel is reversed so that the ratchet wheel (F) is turned in an anti-clockwise direction and allows the pawl (E) to slip over it while the roller on the follower (G) comes back underneath the cam track. As soon as the hull starts to fall again the direction of rotation is reversed and the pawl engages in the ratchet wheel.

The trolley is brought to rest by caliper brakes, acting on the web of the rails. The operation is hydraulic, actuated from a second ramp, which is placed just beyond the end of the main actuating ramps for the dropping mechanism. This means that the brakes do not come on until after the hull has reached the bottom if its swing from the highest drop. There is a single hand brake of caliper design at one corner of the trolley.

3.4. *Auxiliary Trolley.*—The auxiliary trolley provides a platform from which an operator may release the carriage from any desired position on the slope. A drawing is given in Fig. 8. The auxiliary trolley, which has the winch cable permanently secured to it, also provides a link by which the main trolley may be hauled up the slope. Two slotted towing links (A) may be fastened into fork ends (B) on the carriage by pins (C), thus securing the trolleys together. The links are slotted so that when the desired position on the slope is reached and the carriage held on the slope by the hand operated brake, the trolley may be lowered and be linked by a bomb release (D). There is a hand turning gear (E) by which the auxiliary trolley may be taken along the horizontal part of the track away from the winch. The carriage may be pushed along the track in this way by inserting wedges (F) in the towing links. These make a rigid connection and keep the trolleys apart.

3.5. *Hull.*—The hull (Fig. 9) is constructed with a detachable planing bottom (Fig. 9a). Tests can thus be made on planing bottoms with any combinations of beam and V-angle (angle of deadrise). For the first tests a beam of 3 ft and a deadrise angle of 20 deg were used. The main dimensions of the hull are, length 22 ft, depth at the main step 3 ft, beam 3 ft. The hull can be balanced about its trunnions by sliding weights in the afterbody.

3.6. *Description of Operation.*—The sequence of operations (illustrated in Fig. 10 by a series of photographs) is as follows. The auxiliary trolley (A) is lowered from the position on the slope and wound along to the carriage by the hand turning gear. The trolley and carriage are linked together by the towing links and the wedges inserted (B). The trolleys are wound into the working house by the hand turning gear. The trunnions on the hull pick up on the ramp (C) and lift the hull clear of the end of the tank. The covers are removed from the hull and any adjustments required to instruments made (D). The covers are replaced and the attitude fixed by fitting the attitude control bolt into the coxcomb. Damping in pitch is then adjusted and the hull is lifted manually to the desired height for the next drop. Next the trolleys are pulled along the track and up the slope by the winch until the desired mark on the slope has been reached. The hand brake on the carriage is applied and the wedges removed from the towing links. The auxiliary trolley is let down on to the carriage till the bomb release closes. The hand brake is then released and if the bomb release has not closed properly, the weight of the carriage will be again taken on the main links. If the bomb release has closed properly the two towing links are uncoupled and the carriage is ready for release (E). The officer in charge of the tests gives the signal for release from the ground when the operator on the auxiliary trolley switches on any necessary instruments and actuates the bomb release. The carriage accelerates down the slope (F), flattens out on to the level (G to H), the release levers are tripped by the ramps on either side (J), and the hull drops on to the water (K). This action (J) automatically switches on all the instruments. The hull rebounds from the water before the end of the ramps and is held by the auxiliary pawls (L). At the end of the release ramps, the braking ramp (M) is reached and the brakes operate to bring the trolley to rest.

4. *Measurements Required.*—Determination of the peak pressure distribution requires a knowledge of the geometrical and kinematical parameters over the hull bottom.

The range of possible attitudes is + 10 deg to − 5 deg at the main step. The maximum attitude of 10 deg nose up corresponds to landings at or near stalling speed, the minimum of 5 deg nose down to a fly on landing at high speed. This latter case is really a crash landing but is considered because it was important to gain information on the maximum pressures near the nose. Normally a flying boat is unlikely to land at less than 0 deg attitude. The flight path varies from about 4 to 8 deg before the ‘ flatten out ’ but afterwards depends on the pilot, varying between 8 deg and 0 deg. The equivalent hull launching tank cases are obtained by giving the hull suitable combinations of horizontal and vertical velocity, the maximum range available being 0 to 35 ft/sec horizontally and 0 to 8 ft/sec vertically.

The speed during immersion is a function of the impact speed and direction and also the angular velocity developed. This angular velocity depends on the type of impact (nose or tail) and the inertia distribution. This inertia effect is stated to be slight in Ref. 1 and no attempt at scale representation of the inertia was made in the earlier experiments. The angular velocity is fully controlled by the damping device of Fig. 6. The hull is balanced statically about the axis of rotation, which is placed near the full scale C.G.

The landing case full scale is made with varying degrees of initial downwards acceleration due to the air lift being unequal to the weight of the aircraft. These cases are represented in the tank by drops with different out of balance loads, the variation of this out of balance being from 0 for a good landing to 20 per cent of the moving mass for a stalled landing. The moving mass on the tank equivalent to the full scale mass is made up of the masses of the hull, counter weights, and swinging mechanism.

The basic hull design for tests was a scale model of the Southampton, combinations of deadrise angles of 5 deg, 10 deg, 15 deg, 20 deg and 30 deg, and maximum beams of 3 ft, 3 ft 6 in. and 4 ft being available.

5. *Methods of Measurement.*—The methods of measurement were designed to determine the respective time variations of the parameters. They have therefore been modified from time to time in the light of experience to improve the accuracy of measurement. An analysis of the relative accuracies required is given in Appendix I.

5.1. *Maximum Pressure Recorder.*—Pressure-time records are made at various positions on the hull bottom. The positions for the first tests are shown in Fig. 11. The recorders have been described in detail in R. & Ms. 1638 and 2312, and other reports. The instrument is a deflector-meter and depends for its operation upon the deflection under water pressure of a small diaphragm carrying a central spindle. The movement of spindle is recorded in a D.V.L. type scratch recorder in which a diamond point scratches on a small flat slide of steel or glass which is driven at right angles to the line of motion of the spindle. Later D.V.L. models use a small cylindrical slide which is rotated so that the peripheral velocity is at right angles to the line of motion of the spindle. Timing marks are made at $\frac{1}{4}$ sec intervals by a second diamond operated by a solenoid actuated from an external timing clock. The slides are driven by flex-drive from two D.V.L. motors situated near the C.G. of the hull.

These recorders are of the flush fitting type with a stiffener ring to avoid distortion due to hull bottom distortion on impact. Drawings of a typical recorder mounting are shown in Fig. 12. Eleven of the diaphragms (Fig. 11) are of 1 in. diameter, three of 1·36 in. diameter but these were changed later for 1 in. diaphragms. These are made of German silver foil of 3, 4, or 5, thou' thickness according to the sensitivity required. A single large diaphragm of 5·0 in. diameter and 0·031 in. thickness is used at position 12 to show the effect of area on the recorded pressure. The one inch diaphragms were expected to be small enough to lie within the depth of the pressure wave front. These foil diaphragms differ from the machined type originally used (R. & Ms. 1638 and 2313), and were designed for greater sensitivity (Appendix I). Diaphragms had to give measurable deflections at 200 magnification for pressures of 0·5 lb/sq in. The diaphragm is shaped in a jig to fit the seating ring and then sweated on between that and a holding down ring (*see* Fig. 12) so that it is held in slight initial tension. The recording unit is calibrated in the laboratory against a mercury manometer.

5.2. *Horizontal Velocity Recorder.*—A Cambridge type chronograph was adapted to measure the horizontal velocity (Figs. 13, 14 and 15). Three solenoid-operated ink pens trace parallel lines on a moving tape. One solenoid is in circuit with a make-and-break contact on one of the carriage wheels, to record each revolution of the wheel (Fig. 15). A second solenoid is in circuit with a timing clock incorporated in the chronograph and its pen is displaced every $\frac{1}{4}$ sec. These traces give the horizontal velocity record. The third pen identified the time of the start and end of the drop, the controlling solenoid being actuated during the period of hull drop.

5.3. *Vertical Velocity Recorder.*—Two methods have been used to measure the vertical velocity. The first was by analysis of cine-film records of vertical drops from different heights without horizontal velocity. It was assumed that the same vertical velocity would always be obtained for the same height of drop and out of balance load whatever the horizontal velocity. However it became obvious as a result of analysis of the first systematic tests that this assumption was insufficiently accurate. Also it did not give the velocity after impact, and a second method was therefore used.

The principle of this second method depends on obtaining a time-record of the distance of the hull above the water in terms of the angular displacement of the rocking beam. The scheme is illustrated in Fig. 16. The angular displacement of the beam (B) with respect to the main carriage frame (F) is converted into a reduced linear movement which is recorded on a D.V.I. scratch recorder. A rod (R) is screwed at one end into a shaft (P) on which is mounted a cam (C). This cam actuates a rider (I) attached to the spindle (S) of the scratch recorder. The whole of this assembly is mounted on a fixed member (F) of the hull carriage frame. The other end of the rod (R) is allowed to slide in a block (L) which can swivel about a fixed point on the rocking beam. As the beam descends the hull drops, the block (B) moves in an arc causing an angular movement of the rod (R) which in turn actuates the cam and hence the scratch recorder. The record obtained can be translated on to a space time curve from which speed and acceleration may be obtained at any desired time. The recorded displacements are calibrated against the distance of the hull above a fixed datum level, with the carriage at rest on the runway. The cam is so shaped that no displacement is made until the hull is within 18 in. of the water surface when the total recorder movement is taken up during the actual impact. This gives the maximum sensitivity.

5.4. *Attitude Recorder.*—The attitude recorder works on the same principle as the vertical velocity recorder, but the angular movement of the hull is now measured relative to a fixed datum. It is shown in Fig. 17. The recorder unit is mounted rigidly on the hull decking (H) which rotates about the axis (X) which is fixed relative to (H). The fixed datum (D) is the crossbar which mounts the housing for the attitude control. This maintains a constant attitude during drops due to the parallel linkage mechanism of the hull suspension system.

6. *Operation and Synchronisation of Records.*—All records of pressure, velocity, and attitude, must be synchronised accurately (Appendix), and it must be possible to identify the beginning and end of all records accurately. Synchronisation is complicated by differences in slide speed between instruments and the short duration (one to two seconds) per drop. The maximum local impact pressure is built up in about one hundredth of a second, and pressure persists up to about a quarter of a second. The following technique was devised as the result of experience with the first set of systematic tests, but earlier variations from this are indicated.

The pressure and attitude D.V.L. recorders are all driven by flex-drives connected to two D.V.L. motors placed near the hull C.G. The vertical velocity recorder is driven by a separate motor because of its distance from the main motors. A motor wiring diagram is given in Fig. 18. The pressure recorders were driven so that flat slides would run through in 10 to 12 seconds and round slides in 25 to 30 seconds, and the vertical velocity and attitude slides in 4 to 5 seconds. The attitude recorder was geared up in the ratio 2 : 1 to attain this result. For the first two tests about a quarter of these speeds were used.

All these motors are started simultaneously by a master switch which is knocked on automatically as the release arm (A) is lifted by the actuating ramp. A sketch of the arrangement is given in Fig. 19. When the ramp is cleared, the release arm drops again and switches off the motors. Two switches are used, one (marked B in Fig. 19) for the large D.V.L. motors in the hull, and one (marked C) for the auxiliary motor to the vertical velocity recorder. Main switches are provided on a panel accessible to the auxiliary trolley for the motor armature and field circuits. The time of drop is marked on the chronograph tape by the knock-on switch making and breaking the third pen circuit simultaneously with the motor circuits. In earlier tests the motor had been started at the top of the incline before release but this method gave unnecessarily long records before peak pressures were obtained and necessitated slow slide speeds to obtain the complete record.

All timing is taken from the master clock on the chronograph, which gives $\frac{1}{4}$ sec timing intervals. The wiring circuit is shown in Fig. 20. The clock is switched on from the time of release of the carriage on the runway. It is switched on to the pressure attitude and vertical velocity records after the motors have been started to synchronise the records. This is done by means of a master knock-on switch mounted on the main carriage structure which is knocked on as the beam passes a fixed striker on the rocking beam. The time of knock-on can be adjusted as required by suitably setting the switch position on the rocker arm. The installation is illustrated in Fig. 21. The recorders are arranged in banks (circuit diagram Fig. 20), so arranged that two to three volts are available to each timing solenoid.

The operational sequence for the recorders is as follows. All slide changes, instrument adjustments, *etc.*, are made in the working house with all main switches off. The hull is lifted and rocked (D.V.L. motors off) before finally locking in position for dropping, these actions giving datum lines for the beginning of the vertical velocity and attitude records (*see* Figs. 16 and 17). The beginning of the pressure records is marked by lightly pressing each of the diaphragms by hand. The beginning of the timing is marked by running the timing clock, D.V.L. motors off, for about one second. At the top of the slope the main timing and field switches are put on, then the chronograph clock and tape and all pens switched on, before release of the hull. At the end of each run it is only necessary to switch off the chronograph and main timing and field switches. Vertical velocity and attitude slides are changed every two runs, and extra reference lines to the true datum made by driving the slides through at a series of fixed heights and attitudes to cover the range used during impact. These supplement the basic datum line and help the analysis of the records. Flat pressure slides are changed every four runs, round slides every twelve runs. On removal all slides are inspected for satisfactory operation of recorders.

7. *Discussion and Conclusions.*—The practicability of the tank is generally good but considerable maintenance is necessary. The main items requiring attention are the brakes, release and dropping mechanism, and release of the carriage at the start. Brakes require taking up approximately every ten runs and care is required in their adjustment to avoid fouling irregularities in the track without impairing braking power. The braking efficiency is good in dry weather but

insufficient in wet at maximum speeds. It is important to lubricate all moving parts to avoid gumming up and corrosion, which can result in brake failure. The release and dropping mechanism give little trouble but care in initial alignment of the tension chains is necessary to ensure a smooth vertical drop. Also the strain in the ratchet wheels is considerable and cracks in the body of the wheel have occurred. The auxiliary bounce pawl mechanism was successful but in high speed runs was not found necessary because the release arm came clear of the ramp before the hull had bounced to its maximum height so that the height pawls could engage in the main ratchet wheel. The attitude release gives the maximum trouble. The high accelerations imposed on the hull when the carriage levels out at the bottom of the ramp cause the hull to oscillate in pitch on the attitude pin. The hull rigidity about the attitude pin is inadequate to prevent this oscillation. As a result, when the attitude pin is pulled out the hull frequently possesses a fairly large angular velocity which would not be present full scale so the attitude as set is not obtained. Also, the rocking has occasionally made the pin jump out too early in the drop so that the attitude is not under control. Generally, therefore, although vertical and horizontal speeds can be controlled as required fairly accurately, the attitude control is not so reliable. The pitch damping device is effective in also reducing these unwanted oscillations, but the reduction is small unless a large amount of damping be used, which is not always desired.

Finally it is very important that the check cables provided should be of adequate strength to prevent the hull pitching to extreme attitudes either in the air or on the water. Very high forces in the bows can be obtained as a result of a nose down impact which will wreck the hull if sufficient to break the cables. Also high snatch loads can arise from the vicious pitching consequent upon nose down or tail down impacts in the absence of large damping.

The bomb release mechanism between the carriages was generally successful but showed a tendency to release prematurely. Care was therefore necessary to secure the carriage safely on the bomb hook before taking off the hand brake and auxiliary links.

The haulage mechanism gave no trouble except for electrical cut-outs on the winch under snatch loads.

The measuring instruments for vertical and horizontal velocity and attitude gave little mechanical trouble. Most of the snags arose in the D.V.L. scratch recorders and on the timing circuits. The attitude recorder gives consistent calibrations to within the accuracy of measurement, but stiffening was necessary on the centre top decking of the hull to prevent warping under load. The diaphragms of the pressure recorders, although extremely thin, gave consistent service unless overstretched when a 'pink' developed leading to variable zero and stiffness, or unless damaged by impact with floating debris in the tank. About half the diaphragms repeated their calibration to within one per cent, and the mean maximum error of the rest was five per cent. Approximately one in ten diaphragms gave greater errors and these were rejected. The diaphragms were recalibrated after every twenty runs.

Seventeen to twenty D.V.L. scratch recorders are used continuously during the tests and gave little trouble considering their severe treatment. The records were checked after every few drops. The common mechanical troubles included loss of diamond pressure due to varying thickness of slide, hollow backed flat slides, diamond wear, lost or irregular records due to girder failure, slide carriage shake (flat slides), or fouling of spindle from the diaphragm to the recorder, or finally loss, or reversal of, motion at time of impact due to fouling in the flex drive, broken connections and for and aft shake in the slide carriage (flat slides). One to three failures of these types occur each run on the average.

The worst sources of trouble were the electrical circuits which required continuous maintenance and test. Successive impacts led to loosened connections, broken insulated cable, and broken switches. It was found necessary to use a positive return system rather than earth return, because of 'shorts' produced by wet conditions. The instruments were continuously splashed and water leaked into the hull.

The timing records were generally good but the impact accelerations often made the timing marks indefinite at the time of impact unless high loads were used on the solenoids. The consistency of timing was such that synchronisation could be made to one five-hundredth of a second. The total time of impact is of the order of one tenth of a second.

8. *Further Developments.*—The technique of measurements with the hull launching tank will be modified so as to obtain the measurements of landings on to waves, of total impact loads, and the effect of area of diaphragm on peak pressures.

9. *Acknowledgments.*—Acknowledgments is due to members of the staff of the instrument shop, Messrs. Cook, Buxton and Balls for their co-operation in the design and maintenance of the methods of measurement, and to Mr. Balls for the design and manufacture of the diaphragm, vertical velocity and attitude measuring instruments.

APPENDIX I

Accuracy of Measurement Required

The parameters to be measured are the time variations of pressure, vertical velocity V_V, horizontal velocity V_H, attitude α, angular velocity $\dot{\alpha}$, and the geometry of the hull. The requisite accuracy will depend on that required for the final answer (which may be taken to be the greatest possible at the moment) and upon the relative weights of the different parameters in that answer. Assuming that the calculations are all to be based upon a basic relationship[9] of

$$K = \frac{V_n^2 \cot \phi}{p_{\max}}$$

where V_n = resultant velocity at first impact normal to keel,

ϕ = angle between water surface and hull sides at first impact for position considered,

K = constant,

the error in K is made up by

$$\frac{\Delta K}{K} = 2\frac{\Delta V_n}{V_n} + \frac{\Delta \cot \phi}{\cot \phi} + \frac{\Delta p_{\max}}{p_{\max}}$$

where ΔK, ΔV_n, $\Delta \cot \phi$ and $\Delta p_{\max}$ are the errors in measurement of the respective quantities.

The most important source of error is therefore likely to be V_n, if the fractional errors are of the same order. Both V_n and $\cot \phi$ involve the separate parameters of local keel attitude α, angular velocity $\dot{\alpha}$, vertical velocity V_V, horizontal velocity V_H, time, and the geometrical properties of the hull. The relative importance of these is required to determine the order of accuracy required.

The velocity V_n is given by

$$V_n = V_V \cos \alpha + V_H \sin \alpha - c\dot{\alpha}$$

where c is closely a constant given by the geometrical properties of the hull and the position of the diaphragm considered relative to the axis of rotation. Its maximum value is of the order of 0·1. Differentiating,

$$\Delta V_n = \Delta V_V \cos\alpha + (V_H \cos\alpha - V_V \sin\alpha)\,\Delta\alpha + \Delta V_H \sin\alpha - c\Delta\dot{\alpha}$$

where ΔV_n, ΔV_v, ΔV_H, $\Delta\alpha$, $\Delta\dot{\alpha}$, are the respective errors of measurement. The maximum value of α is 10 deg. so that approximately,

$$\Delta V_n = \Delta V_V + \left(V_H - \frac{V_V}{6}\right)\Delta\alpha + \frac{\Delta V_V}{6} - \frac{\Delta\dot{\alpha}}{10}.$$

V_V is about 5 ft/sec compared with V_H of 33 ft/sec so that again

$$\Delta V_n = \Delta V_V + V_H\,\Delta\alpha + \frac{\Delta V_H}{6} - \frac{\Delta\dot{\alpha}}{10}$$

The parameters for V_n requiring maximum accuracy of measurement are therefore first, α and second, V_V. Errors in V_H and $\dot{\alpha}$ are of a second order of importance. It is found in practice that the greatest source of error is in the timing, which in turn leads to large errors in α when $\dot{\alpha}$ is large and in V_V when $\dot{V}_V$ is large after first impact. It is therefore necessary to obtain very good time sensitivity and accurate time synchronisation, so that differences in time of the order of a five hundredth part of a second can be distinguished on pressure, attitude, and vertical velocity records. The estimated value of $\Delta V_n/V_n$ is ten to fifteen per cent when $\alpha = 10$ deg., $\dot{\alpha} = 60$ deg per second, $V_H = 30$ ft/sec and $V_V = 5$ ft/sec, an example of the worst combination of conditions found. It is five per cent under average conditions. Details for each set of measurements will be given in subsequent reports on results of tests.

The value of $\Delta\cot\phi/\cot\phi$, where $\cos\phi = \cos\theta\,.\,\cos\alpha$ and θ is the angle of deadrise, is given by

$$\frac{\Delta\cot\phi}{\cot\phi} = \left[\tan\alpha - \frac{\frac{\sin 2\alpha}{2}\cos^2\theta}{1 - \cos^2\alpha\cos^2\theta}\right]\Delta\alpha$$

It therefore depends on errors in α only, assuming θ known without error. When $\theta = 20$ deg and $\alpha = 10$ deg the value of the factor in brackets is 0·2. The error $\Delta\alpha$ must also be in radians so that the error in $\cot\phi$ is little affected by comparatively large errors in α deg. This term is therefore only a small source of error compared with V_n and in fact is not in error by more than one per cent. The required accuracy in α is controlled by the V_n term.

The value of $\Delta p_{max}/p_{max}$ is independent of the speed parameters, and depends entirely on the sensitivity of the diaphragm recording units, the accuracy of calibration, and the methods of measurements available. The percentage error will, or course, increase with decrease of measured pressure for the same absolute error of measurement. At 0·5 lb/sq in. the error is of the order of thirteen per cent, and at 3 to 5 lb/sq in. of the order of five per cent.

The total error in K will therefore be considerable if accurate measurements of α, V_V against time, and of maximum pressure are not available. As it is, at large rates of change of α or V_V with time, large errrors of the order of twenty-five per cent occur, and the error at average rates of change is ten per cent.

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No.	*Author*	*Title, etc.*
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2	H. M. Garner	Recent Full Scale and Model Research on Seaplanes. Lecture addressed to Lilienthal Gesellschaft 14 October, 1938.
3	E. T. Jones and W. H. Davies	Measurement of Water Pressure on the Hull of a Boat Seaplane R. & M. 1638. March, 1934.
4	E. T. Jones, G. Douglas, C. E. Stafford and R. K. Cushing	Measurement of Acceleration and Water Pressure on a Seaplane when Dropped into Water. R. & M. 1807. January, 1937.
5	J. L. Hutchinson	Measurements of Water Pressure on a Perth during Take-off and Alighting. A.R.C. 3611 and a. (*Unpublished.*)
6	W. Morris	Impact Pressures on the Hull of Perth Boat Seaplane when Dropped Vertically into Water. A.R.C. 3695. (*Unpublished.*)
7	E. T. Jones	Some Measurements of Pressure over a V-shape when Dropped into Water. R. & M. 2312. March, 1935.
8	E. T. Jones and R. W. Blundell.. ..	Force and Pressure Measurements on V-shapes on Impact with Water Compared with Theory and Seaplane Alighting Results. R. & M. 3393. 1939.
9	E. T. Jones	Proposal for Further Measurements on Flying Boat Hulls. A.R.C. 3691. (*Unpublished.*)

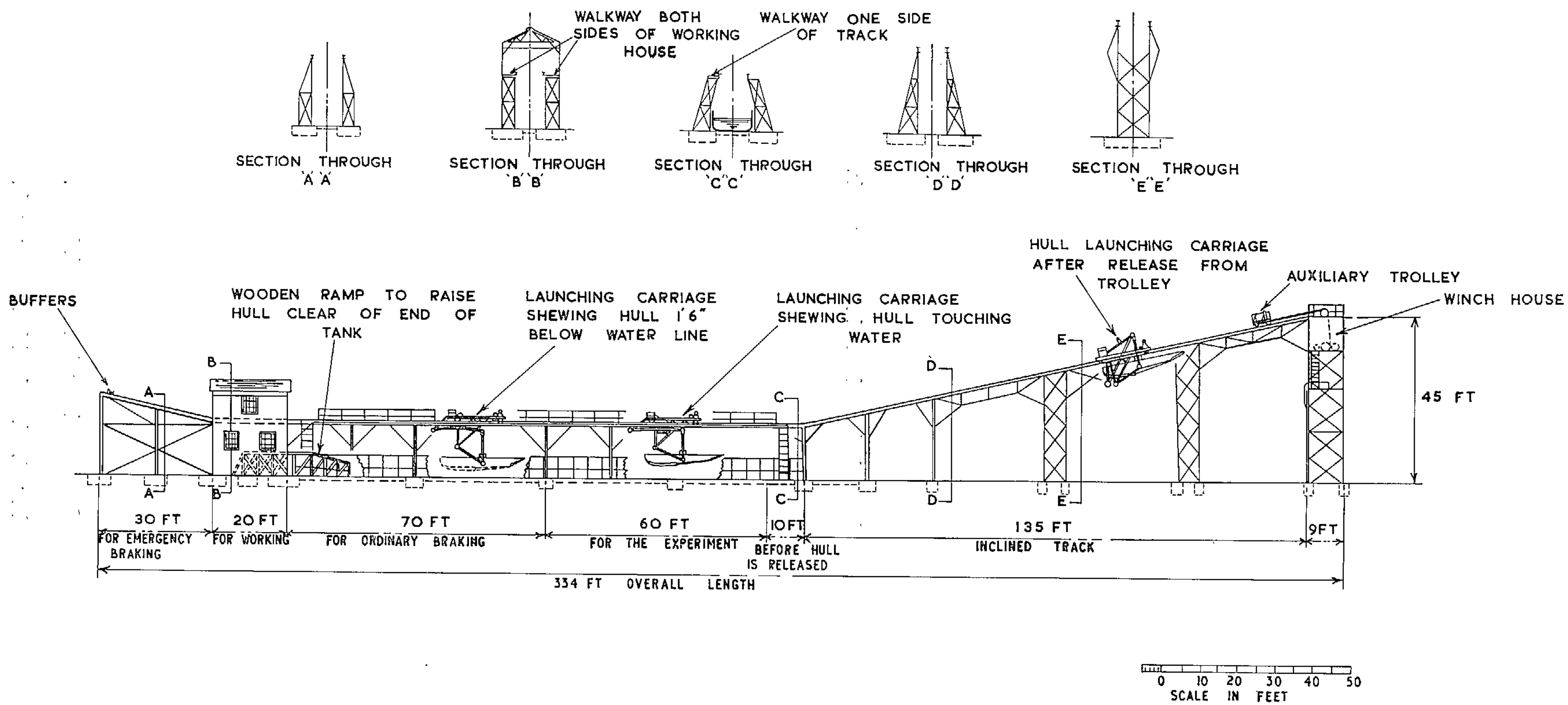
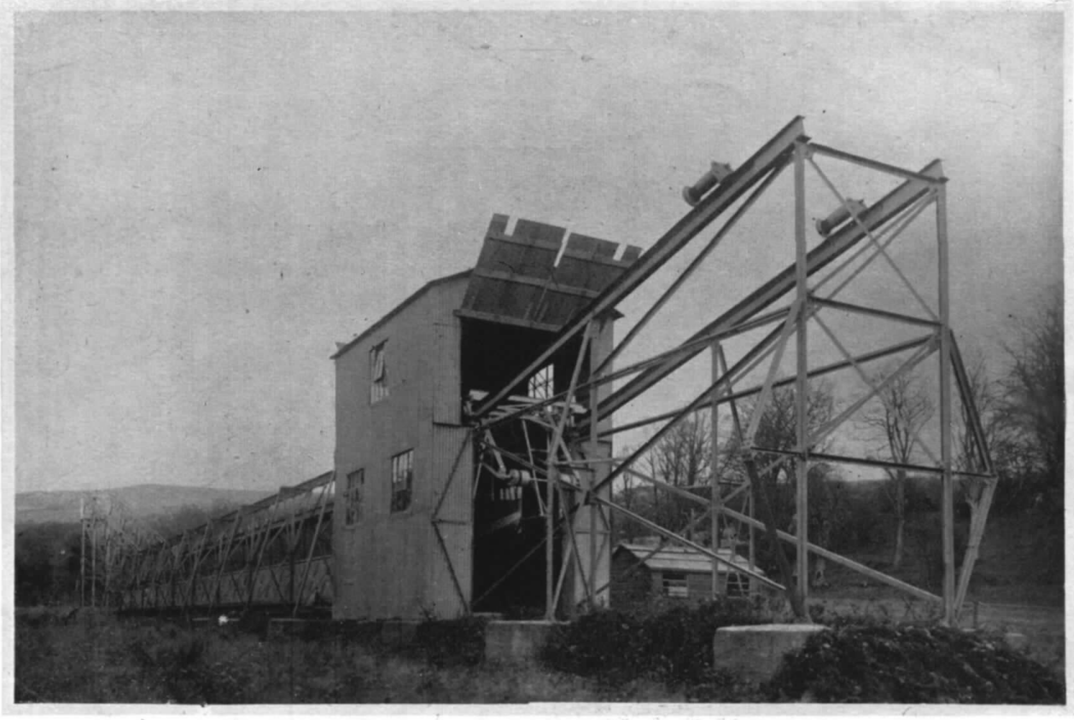
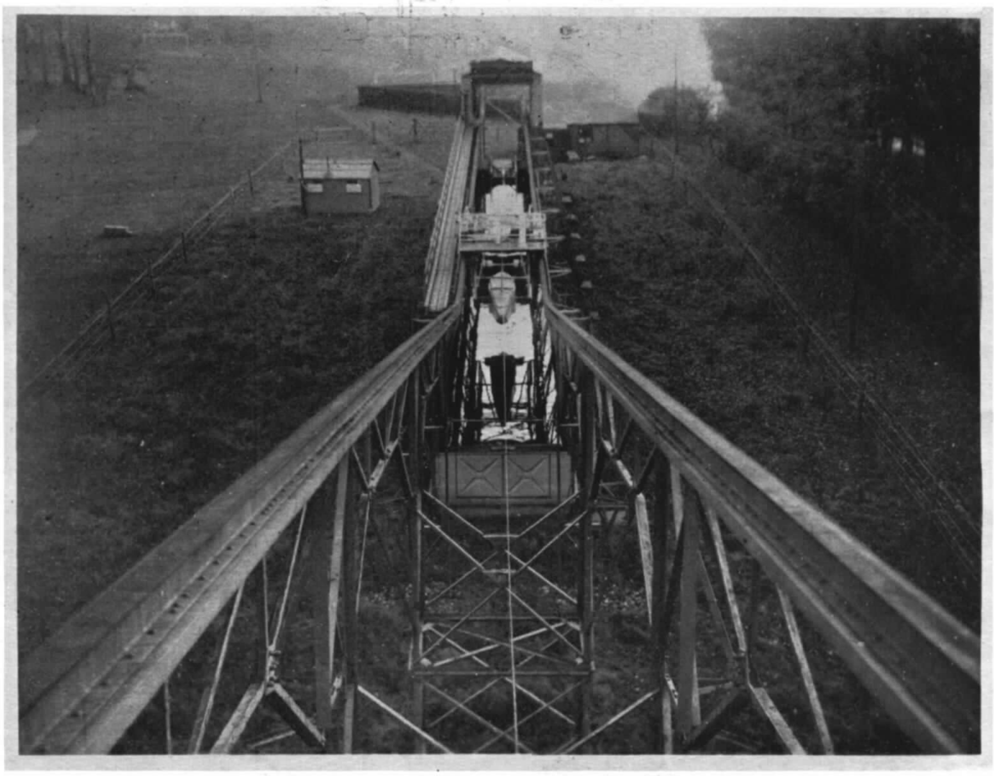


Fig. 1. General arrangement—hull launching tank.



General view of hull launching tank.



Looking down from winch house.

FIG. 2. The hull launching tank.

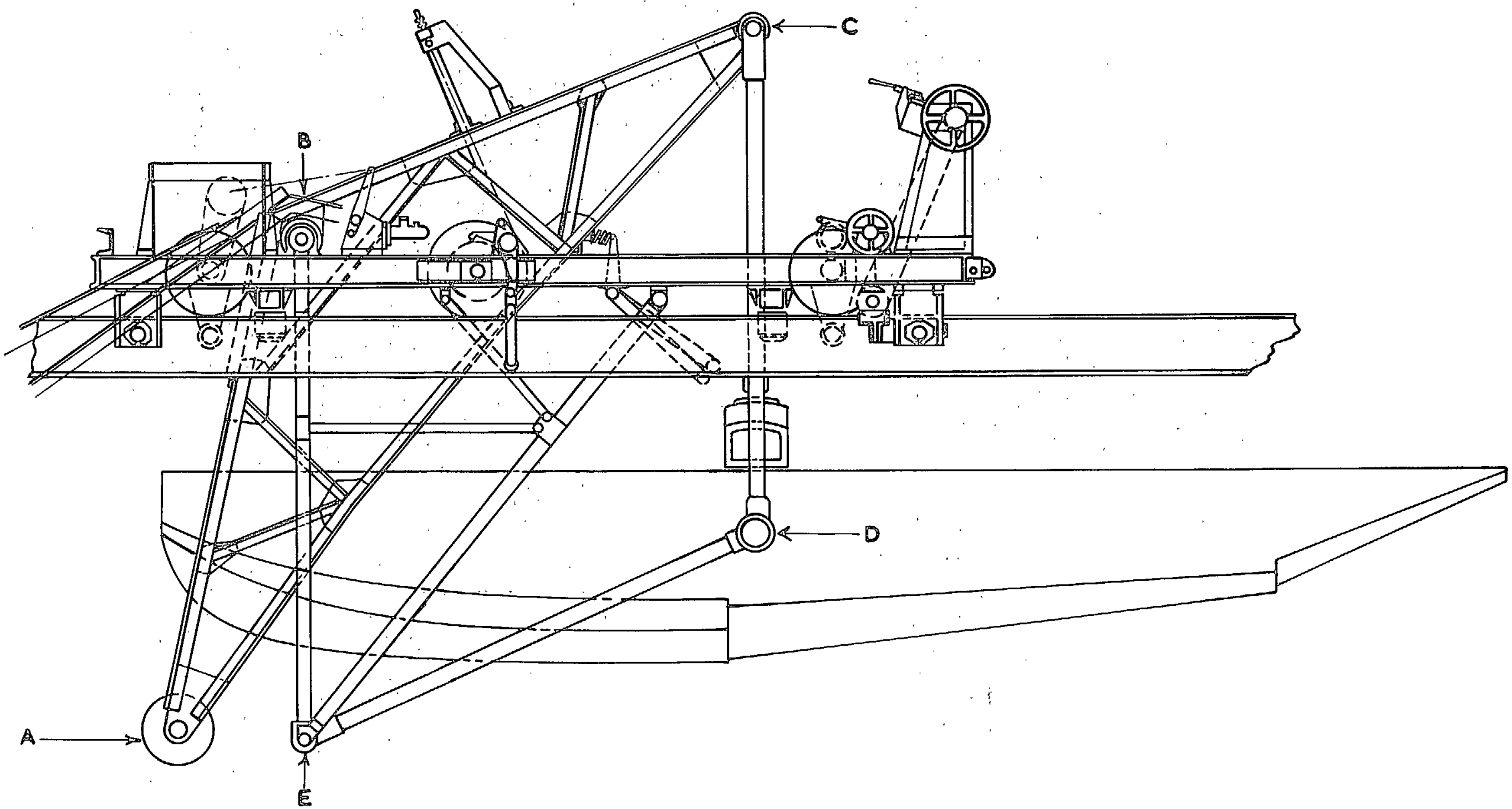
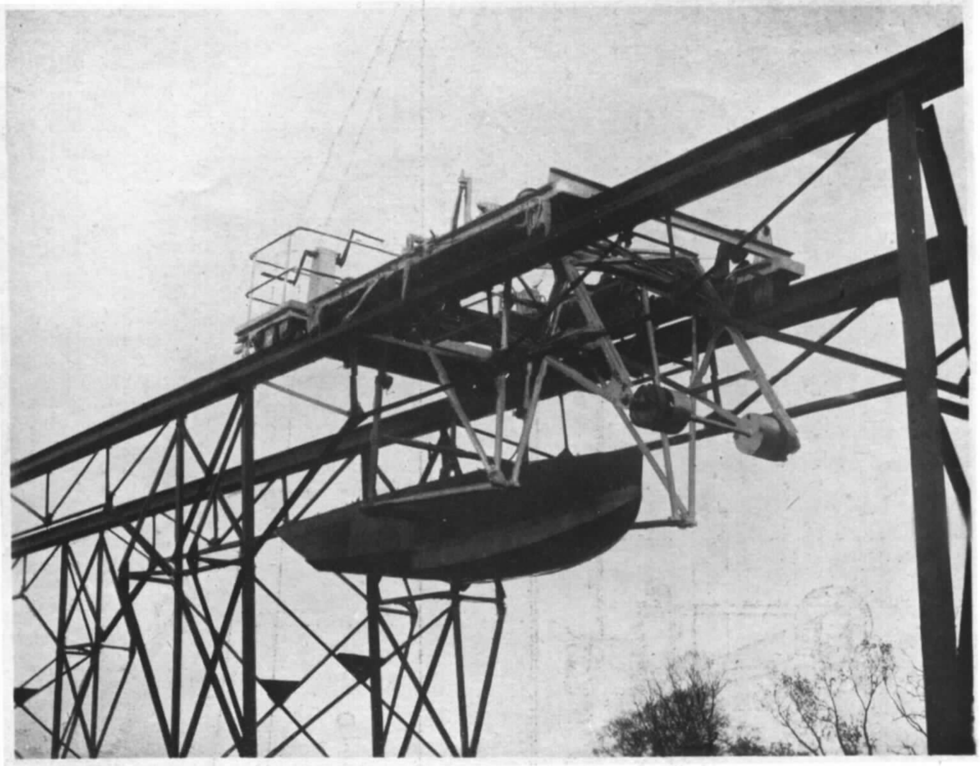
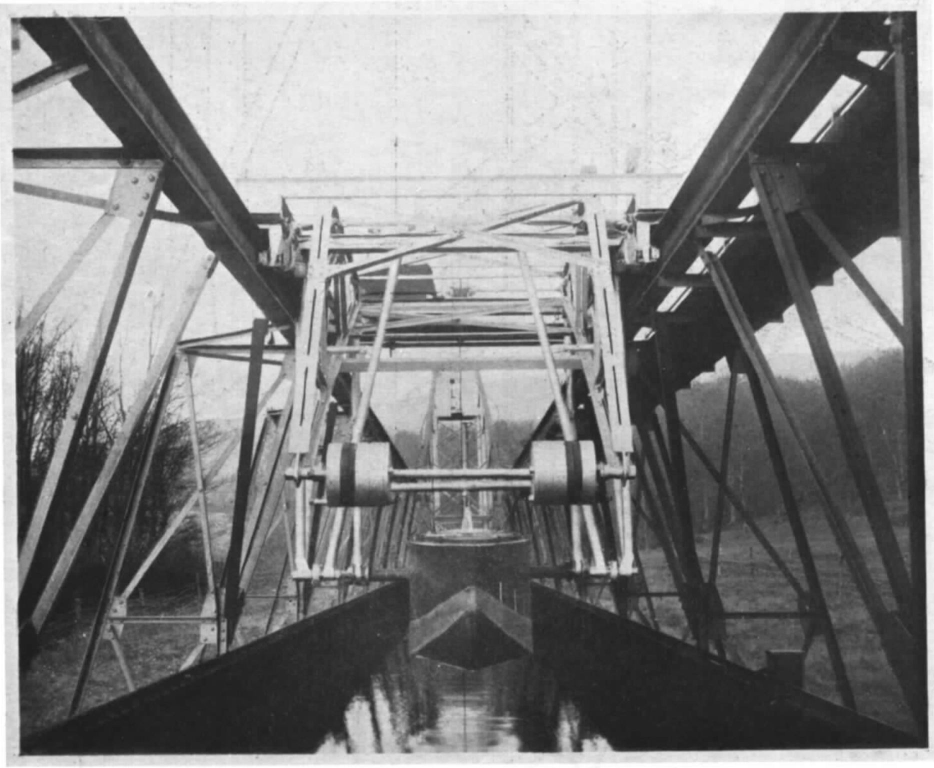


FIG. 3. Arrangement of carriage with hull.



Carriage attached to auxiliary trolley on slope.



Carriage with hull held clear of water.

FIG. 4

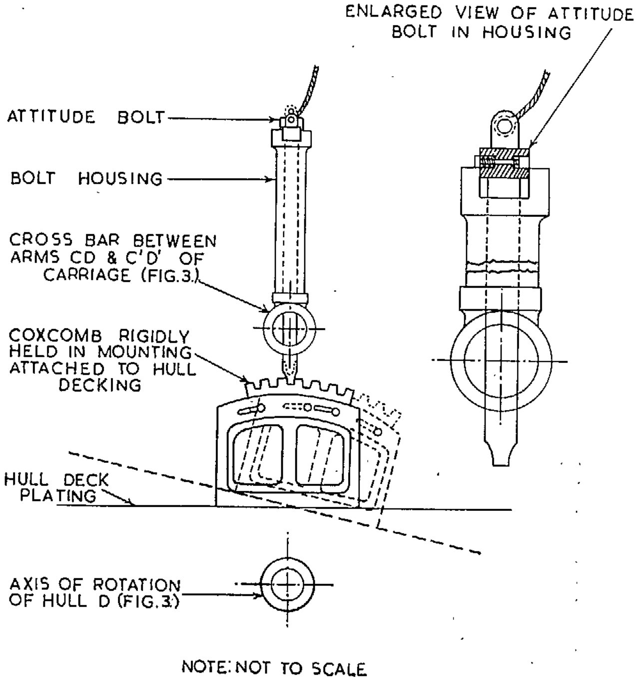


FIG. 5. Attitude adjustment and release mechanism.

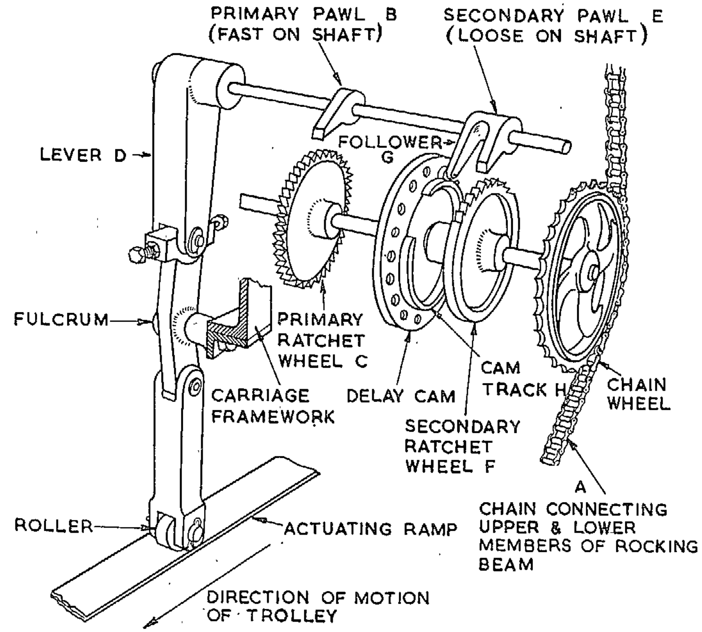


FIG. 7. Diagrammatic sketch showing mechanism for holding and releasing rocking beam incorporating delay action.
The mechanism is shown in a state of motion the follower being about to leave the cam track. Drawing not to scale.

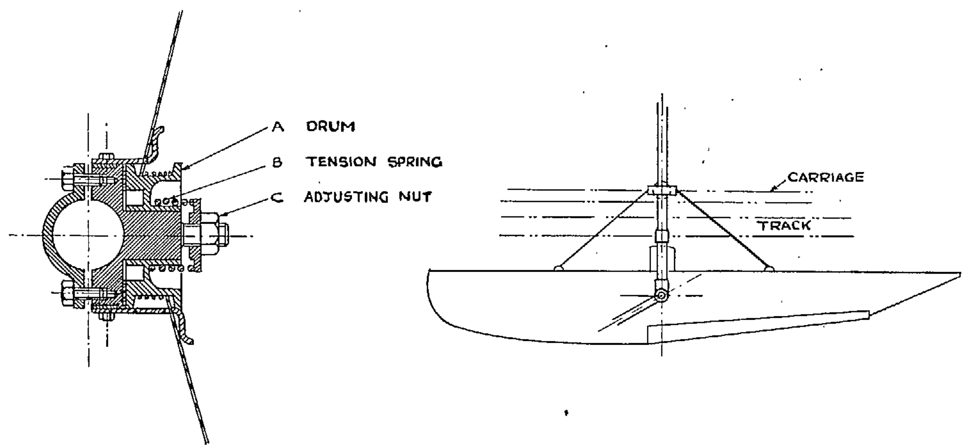


FIG. 6. General arrangement of damper in pitch.

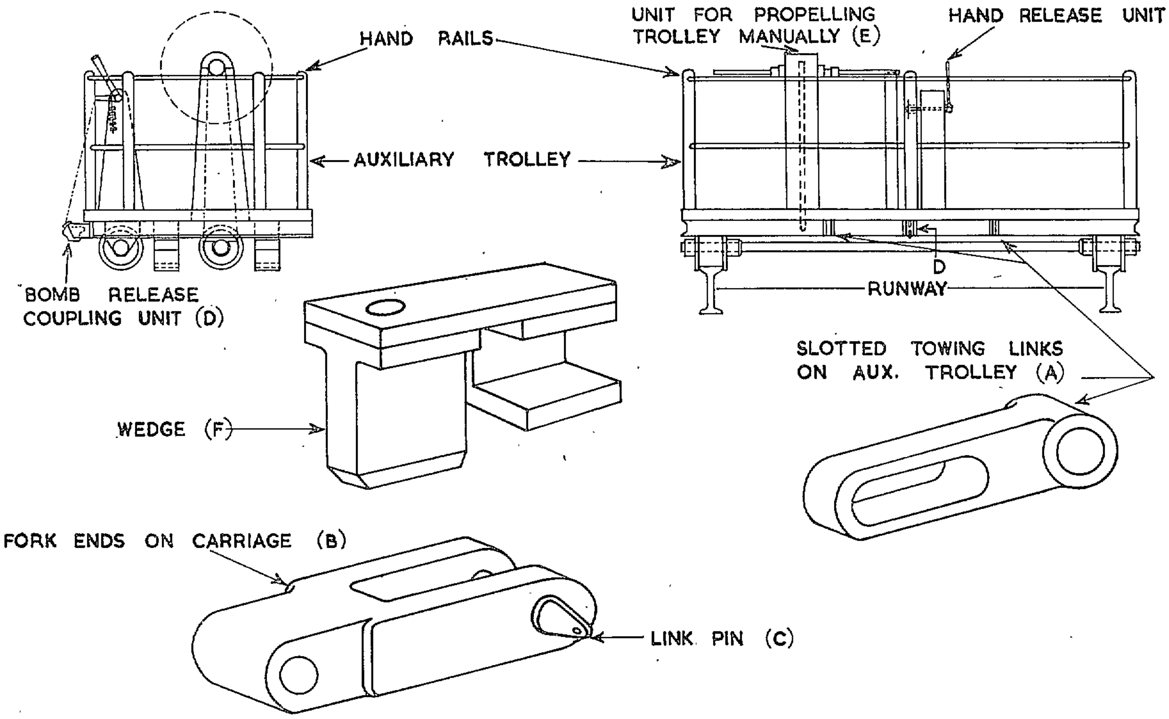


FIG. 8. Towing and safety links.

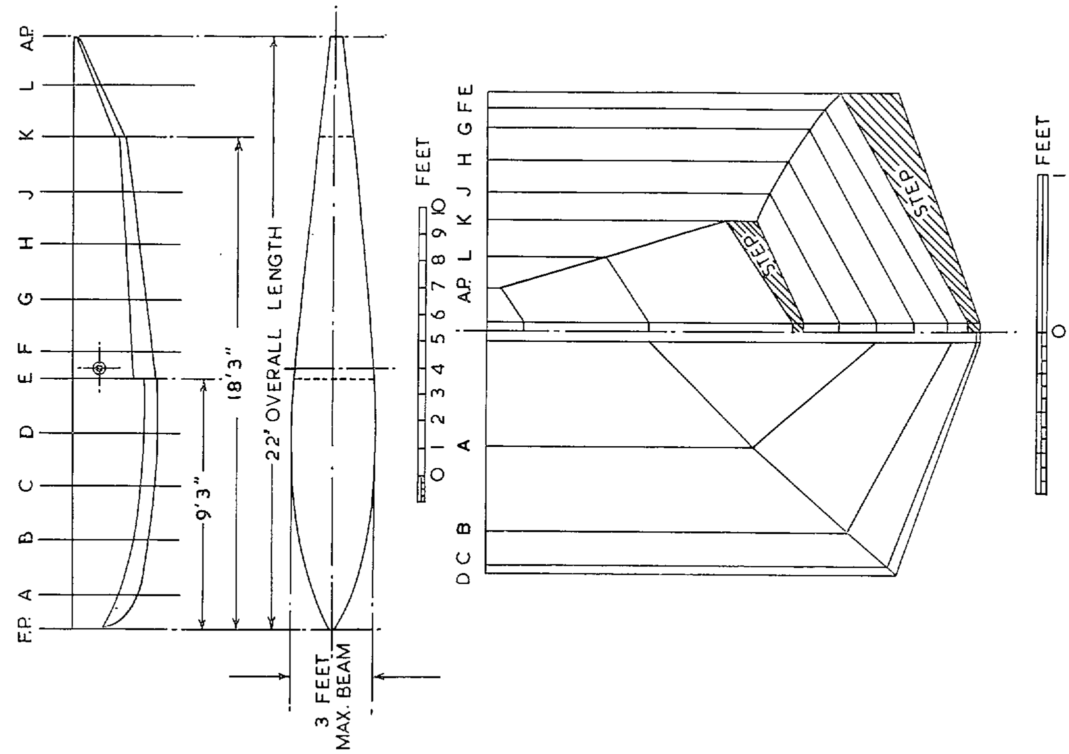


FIG. 9. Lines of basic hull without forebody planing bottom.

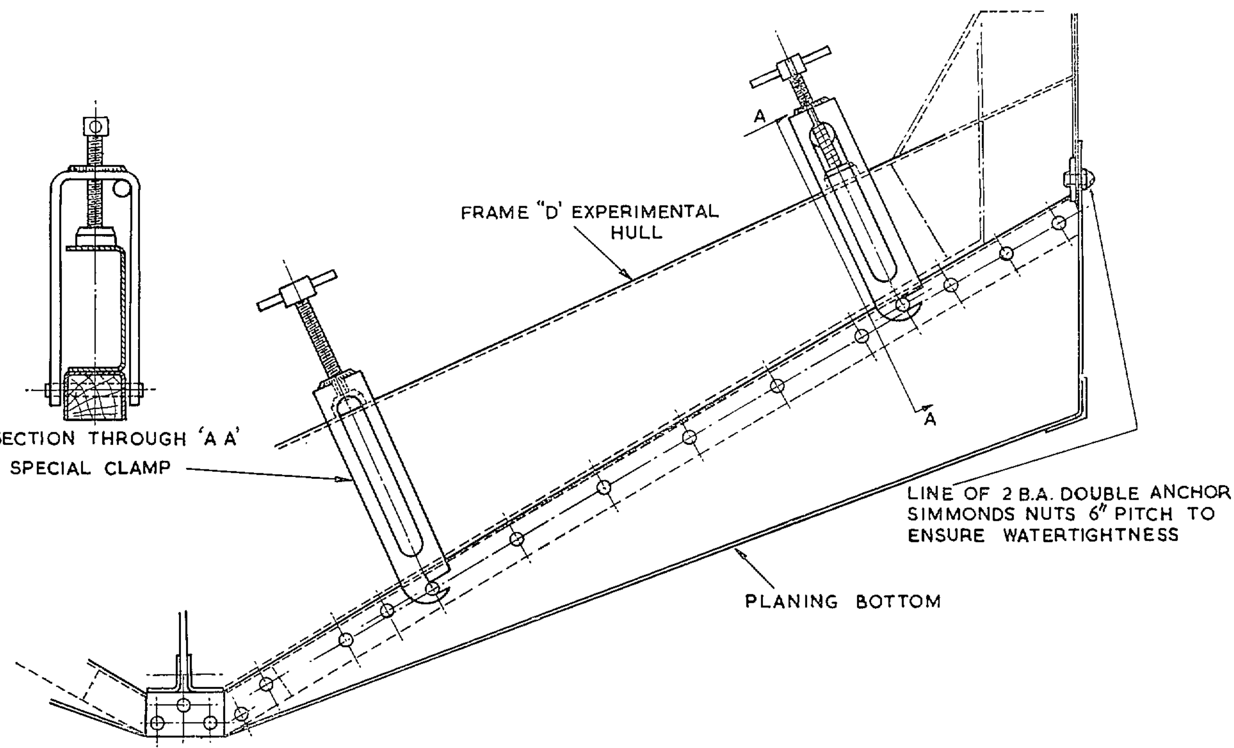


FIG. 9A. View on frame "D" showing typical method of attaching planing bottom.

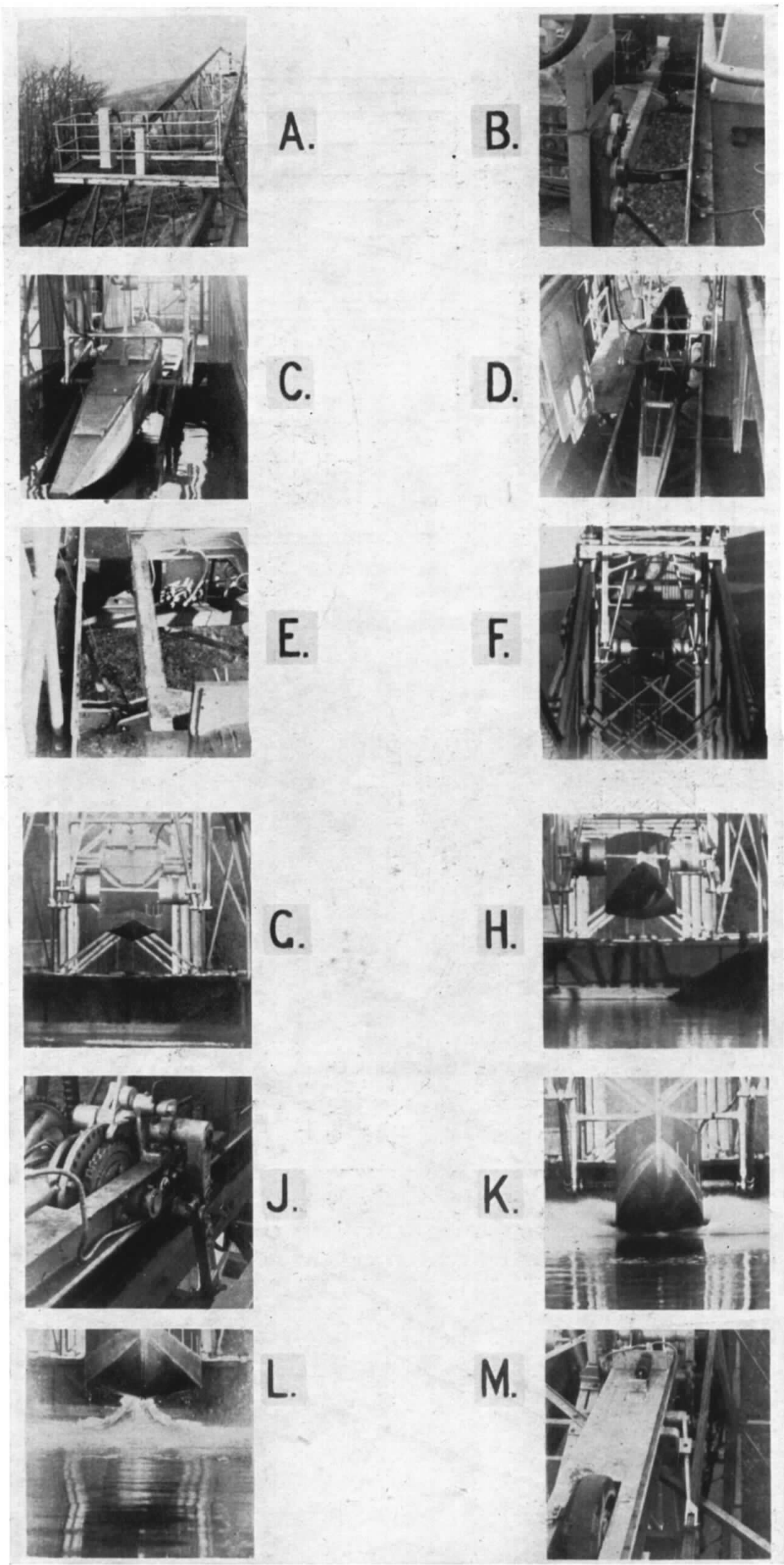
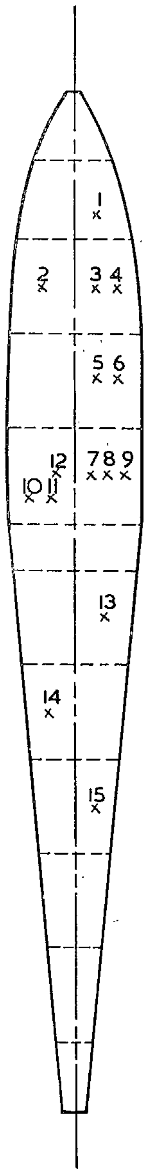


Fig. 10. Sequence of operations.



PARTICULARS OF DIAPHRAGMS			
POSITION NO	THICKNESS	DIAM.	θ°
1	0·003″	1·00″	32·7
2	0·003″	1·00″	24·2
3	0·003″	1·00″	24·2
4	0·003″	1·00″	24·2
5	0·005″	1·36″	20·0
6	0·005″	1·36″	20·0
7	0·004″	1·00″	20·0
8	0·004″	1·00″	20·0
9	0·005″	1·36″	20·0
10	0·004″	1·00″	20·0
11	0·004″	1·00″	20·0
12	0·031″	5·00″	20·0
13	0·003″	1·00″	29·3
14	0·003″	1·00″	28·75
15	0·003″	1·00″	27·9

θ = ANGLE OF DEADRISE OR "V" ANGLE

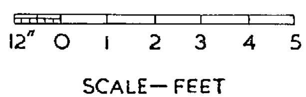


FIG. 11. Position and particulars of pressure recorders.

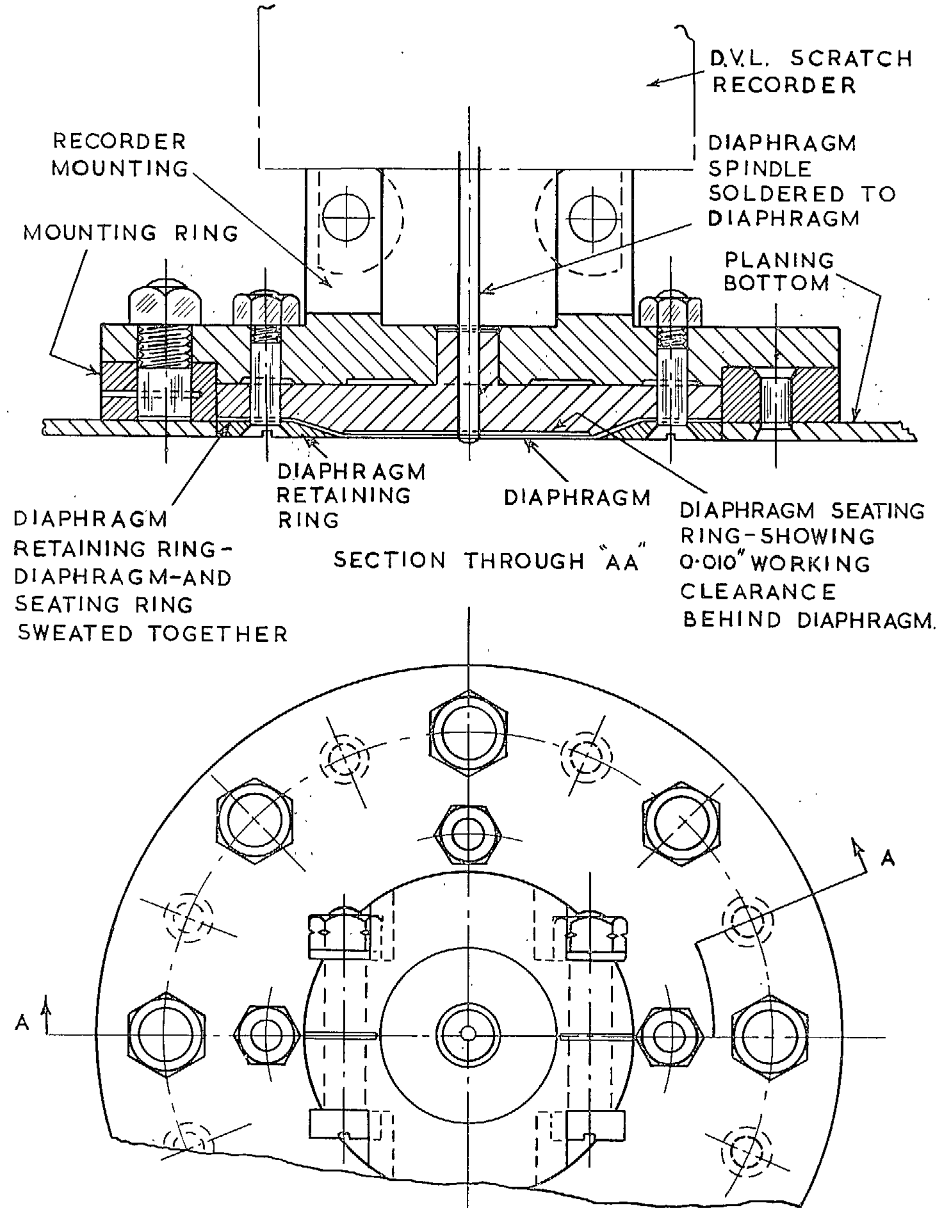


FIG. 12. Plan view—scratch recorder removed—pressure recorder.

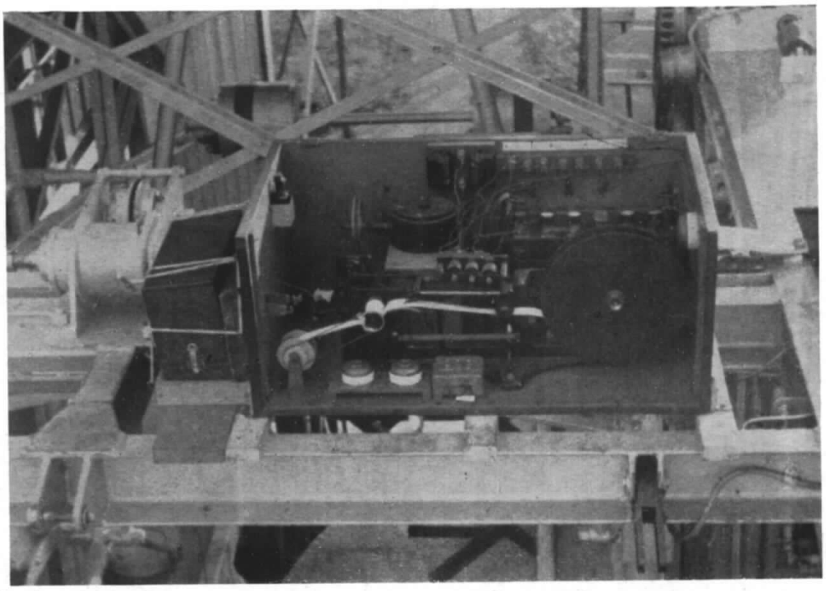


Fig. 13. Cambridge type chronograph.

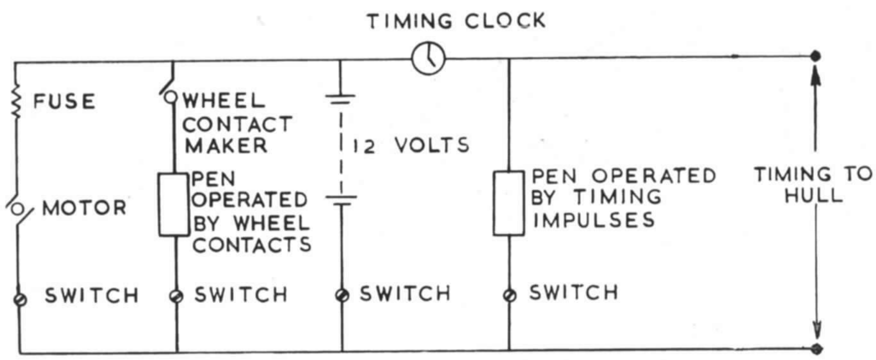


Fig. 14. Timing circuit.

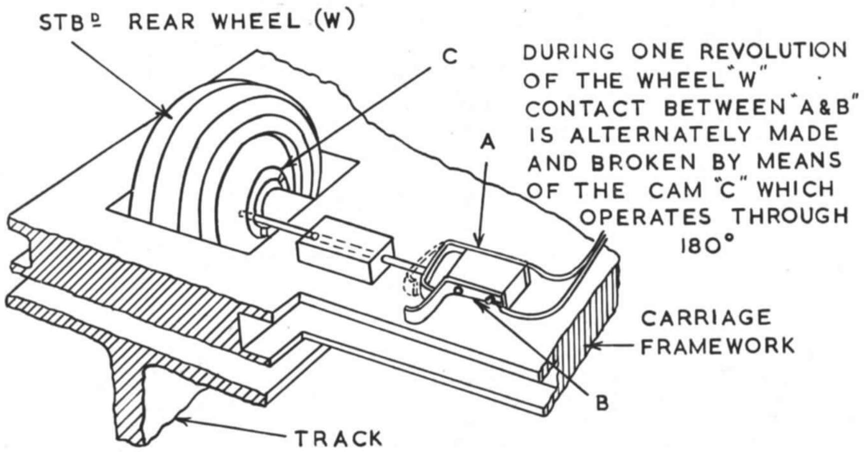


Fig. 15. Horizontal velocity recorder.

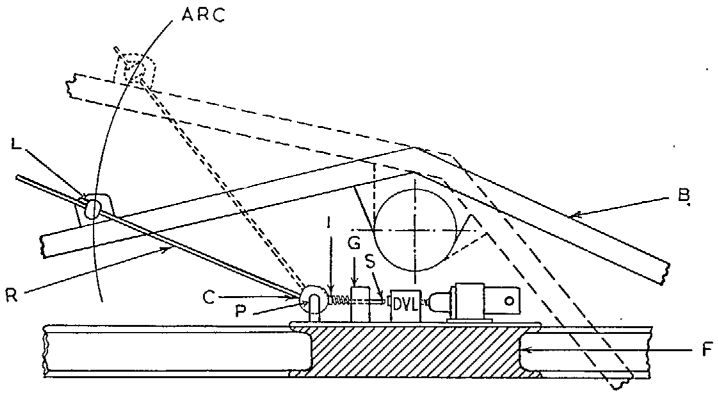


FIG. 16. Vertical velocity recorder.

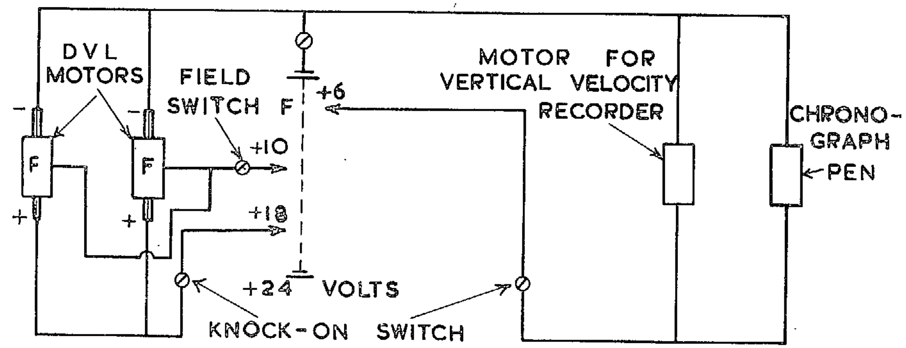


FIG. 18. Motor circuit diagram.

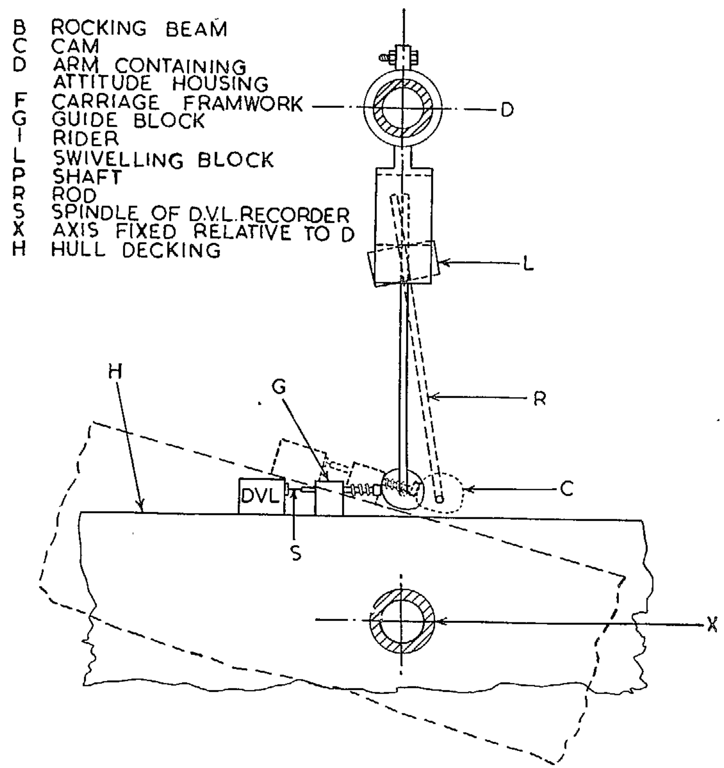


FIG. 17. Attitude recorder.

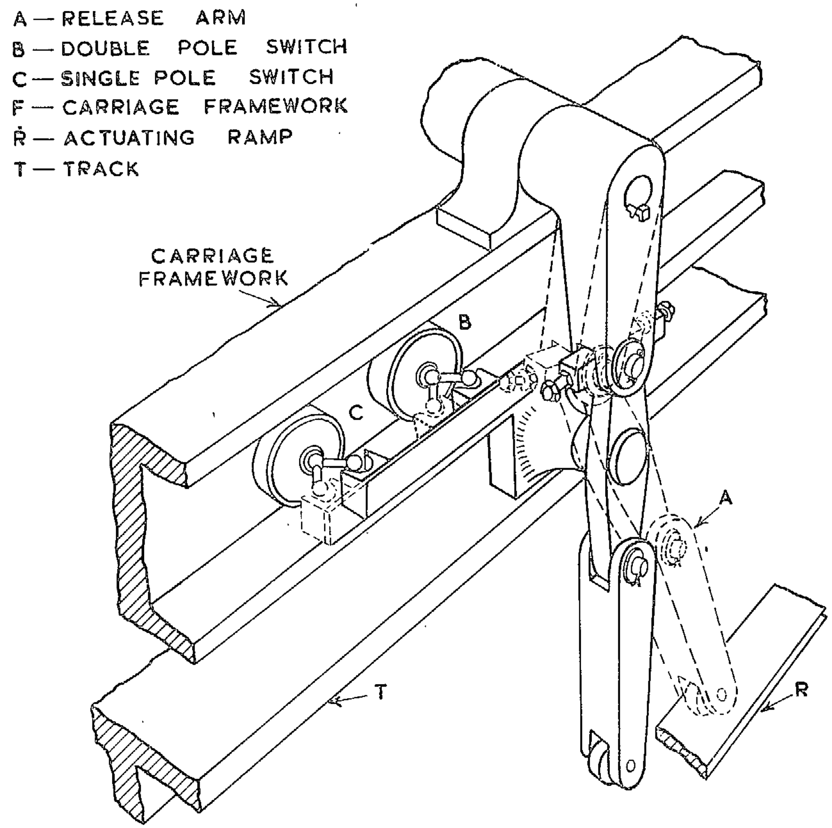


FIG. 19. Master knock-on switches for motors.

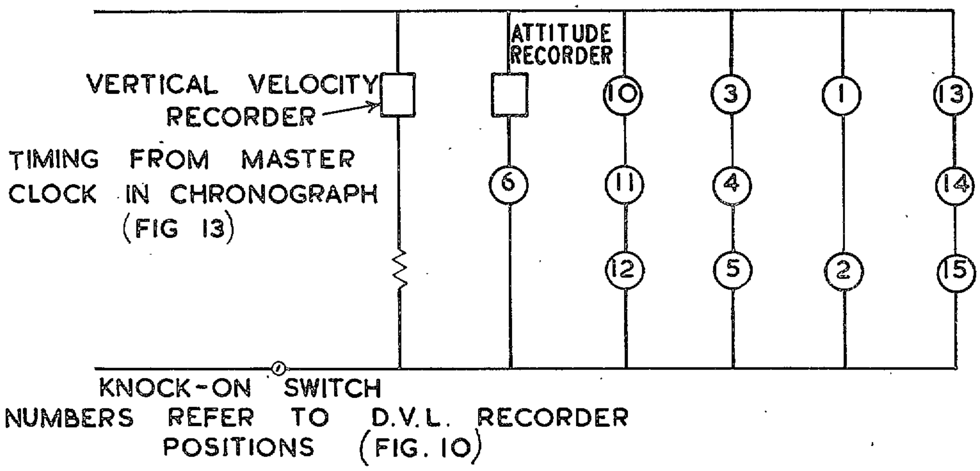


FIG. 20. Timing circuit to D.V.L. recorders.

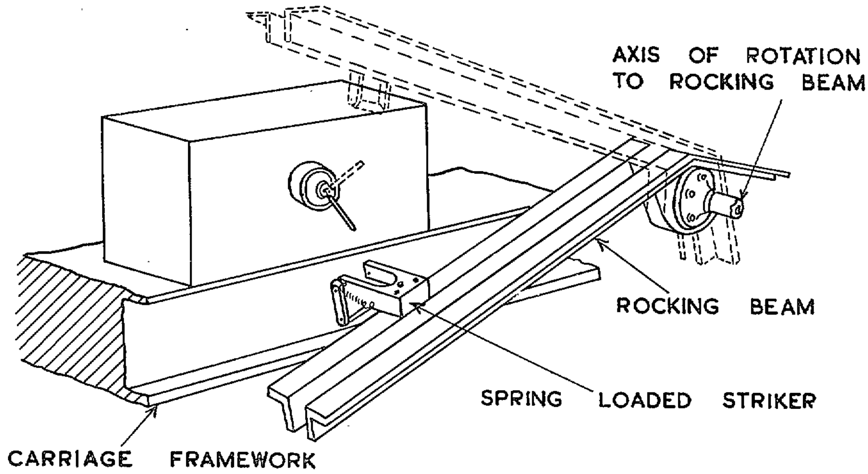


FIG. 21. Master timing knock-on switch.

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