"DENNY-BROWN" SHIP STABILISER.

PARTICULARS REQUIRED IN ORDER THAT CONSIDERATION MAY BE GIVEN TO THE INSTALLATION OF A STABILISER IN A SHIP.

1. Type of vessel and service on which engaged.

2. Length - B.P. or waterline.

3. Breadth.

4. Draught -
   (a) Maximum
   (b) Average on service.

5. Speed -
   (a) Maximum
   (b) Average on service.

(6) Displacement -
   (a) at draught 4 (a) above.
   (b) at draught 4 (b) above.

7. Metacentric height. The nearest approximation to the stability of the vessel in various conditions of service - which should be stated - should be given, as this has an important bearing on the design of the apparatus.

8. The period of roll. If any indication of this could be given it would be useful. Observations on previous vessels of the same type often provide data from which some information on this point could be made available.

THIS FOLDER CONTAINS THE FOLLOWING PRINTS.

DRG. NO.	DESCRIPTION
H.716	General Arrangement
H.793	Diagram of Hydraulic System
H.574	Key Wiring Diagram
H.816	Method of Operating Tail Flap

"DENNY-BROWN" SHIP STABILISER.

Patent Nos. 471220/1937 and 588965/1947.

GENERAL DESCRIPTION.

"Stabilisation" of a ship is achieved by imposing on the hull a rolling moment in the sense opposite and equal to that in which the ship is being rolled by wave motion.

Many elaborate installations have been fitted in ships solely in an attempt to overcome rolling. The Gyro Stabiliser and the Anti-Rolling Tank are well known, but owing to the large amount of space required, apart from their great weight and cost, these schemes have not attracted Shipbuilders or Owners. In any case their efficiency is doubtful and none has been fitted for years.

Fixed Bilge Keels are fitted to practically every ship afloat in order to reduce the amplitude and speed of roll, but these would require to be very large indeed to reduce the degree of rolling to a moderate figure. Moreover, the Bilge Keel is merely a damping device and is not active against the roll. If, however, the Bilge Keels, or sections of them, were angled relative to the slip stream in different directions on either side of the hull, the forward motion of the ship would cause these sections to act as rudders and apply a turning moment to the hull, clockwise or anti-clockwise, corresponding to their "angle of attack".

This is, in effect, the principle on which the design of the "Denny-Brown" Ship Stabiliser is based. Two fins, one on each side of the ship, project from the hull in the vicinity of the bilge.

When /

When extended, but not operating, the fins lie in the natural streamline so that they cause practically no reduction in the speed of the vessel and act as extra Bilge Keels.

Each fin is mounted on a shaft like a balanced rudder, with the rudder post horizontal, the axis of the shaft being arranged so that the fin is practically balanced and hence the torque required to produce angular movement of the fin is small. The fins are oscillated by their shafts and are so controlled that their angular movements are equal and opposite.

To visualise the operation of the apparatus consider the case of a ship being rolled to starboard by wave action. Before the roll can develop the fins are angled so that the starboard fin has a positive angle of attack (i.e. nose up) and the port fin has a negative angle of attack (i.e. nose down). The forward velocity of the ship causes the water to exert an upward force on the starboard fin and a downward force on the port fin. These forces constitute a couple acting on the hull tending to roll the ship to port, thus counteracting the roll to starboard imposed by the wave action.

It must be understood that it is of prime importance that the oscillation, that is the reversal of the "angle of attack" of the fins, should be effected rapidly. In the case of the "CHUSAN" the total period of double roll is about 20 seconds, and it is obvious that only a small part of this time may be allotted to the reversal of the fins at the end of a roll if the righting moment is to be effective over a sufficient period of time to produce the desired result. This reversal is therefore arranged to take place in approximately /

approximately 2 seconds during which time the fin moves through 40°. This partially explains the lack of success attending some of the other attempted methods of stabilising and may be contrasted with the 30 seconds usually required to move a rudder through 70°.

In order to keep the dimensions of the fins to a minimum, and to obtain maximum "lift" from a minimum angle of movement a special design of fin is employed. The fin is made in two parts, the main portion fixed to the finshaft and tilting about the finshaft centre, and the tail flap hinged to the trailing edge of the main fin and so arranged that its angular movement is always greater than that of the main fin and in the same direction - this is illustrated in Drawing No.

Hydraulic machinery is employed to tilt the fins and the movement is controlled, through relays, by small gyroscopes. These gyroscopes are so sensitive that as soon as the ship commences to roll the gyroscopes operate the fins to resist any movement from the vertical.

As the fins generally project beyond the Bilge Keel they are made retractable and can be withdrawn inside the hull line for docking or when not required. The fins are extended, housed and tilted by hydraulic machinery.

Complete control of the operation of the fins is vested in a control switch box situated on the bridge and the fins may be housed, extended and operated under gyroscopic control from this position.

DETAILS OF OPERATING GEAR.

See Drawing No. H716 - General Arrangement
" " H793 - Diagram of Hydraulic System.

Power for tilting the fins is supplied by two Size 24 Mark III VSG Variable Delivery Pumps each driven by a 50 H.P. Electric Motor, while a Size 6 Mark III VSG Variable Delivery Pump, driven by a 15 H.P. motor, supplies power for housing and extending the fins and also for operating the Tilting Gear Control Cylinder. This latter pump known as the "Servo Pump" is fitted with an automatic control which varies the pump delivery to meet requirements and maintains a constant supply of pressure fluid for this part of the system.

The Automatic Control is designed to supply two ranges of pressure, "High Pressure" for use when housing and extending the fins, and "Low Pressure" for operating the Tilting Gear Control Cylinder. The range of pressure is automatically altered when the Housing Control Valve (described hereunder) is operated.

The Automatic Control consists of a piston, opposed by a spring, operating the swashplate of the Servo Pump. The underside of the piston is connected directly to the delivery side of the pump and on the pressure rising above a predetermined amount the spring is compressed and the tilt on the pump swashplate reduced. On the upper limit of the pressure being reached the spring is fully compressed and the pump swashplate held at neutral position, no delivery is then obtained from the pump. Any fall in pressure in the system causes the spring to extend in proportion to the pressure drop and hence incline the swashplate of the pump. From this it will be seen that between the designed pressure at/

at maximum displacement and the stalling pressure the delivery **of the** pump is inversely proportional to the working pressure. The two ranges of pressure are obtained by connecting the top side of the Automatic Control Piston to either pressure fluid or exhaust. "Low Pressure" range is in operation when the top of the piston is connected to exhaust and the pressure fluid from the system operates on the whole bottom area of the piston. "High Pressure" is delivered when the top of the piston, as well as the bottom side, is connected to the pressure system, the effective area for compressing the Control Spring and operating the pump swashplate in this case is only that of the piston rod and thus high pressures are reached before the automatic control operates.

The preliminary stages of Tilting Gear Control are effected by the Gyroscopic Control Unit, described later, and the output end of this Unit acts on the Tilting Control Valve admitting pressure from the Servo VSG Pump to either end of the Control Cylinder. The consequent movement of the Control Cylinder is transmitted through links and levers to the swashplates of the main tilting VSG Pumps causing them to deliver fluid to one of each pair of the Tilting Cylinders while the fluid from the opposing Cylinders passes back to the suction side of the respective pump.

Each Fin is mechanically coupled to its respective Tilting Ram through links and levers and the gear is so arranged that when one Fin moves up the other Fin moves down.

The Tilting Control Valve is connected to the Gyroscopic Control Unit/

Unit through a hunting gear so that any movement of the Control Unit produces a proportional movement in the Control Cylinder and hence a proportional movement in the Fin Tilting Rams.

Each Fin Tilting Ram is connected by a hunting gear to its floating lever which controls the respective Main Tilting VSG Pump hence the Fins move to any angle predetermined by the movement of the Control Cylinder.

The whole operation follows exactly the action of an Electro-Hydraulic Steering Gear with the Gyroscopic Control Unit substituted for the helmsman and the Control Cylinder representing the Telemotor Receiver.

Provision is made for reducing the maximum angle of tilt of the Fins (20°aside of mid) to approximately 10°aside. This adjustment is made on the lever system transmitting the Control Cylinder movement to the Tilting Control Valve. Once the maximum working angle of tilt for the most effective working of the gear has been established by trial this setting should not be altered.

HOUSING GEAR. The Fins are each made in two pieces the main part being fixed to the Finshaft and the Tail hinged to the main part and tilting relatively to it. Both parts are withdrawn inside the Hull when the Fins are housed. The outboard end of the Finshaft is supported in a sliding crosshead running in guides secured to the ship's structure. The Finshaft passes through a sea gland and is bored out to form a cylinder in which is fitted a Piston carried on a Piston Rod anchored to the ship's structure for housing and extending/

extending the fins. Control of the housing and extending of the Fins is vested in small electric switches situated one on the Bridge for normal use and one in the Stabiliser Compartment for local control, if required, and a selection switch is fitted in the Stabiliser Compartment. The operation of the Housing and Extending Switch energises one of a pair of electro-magnetic solenoids and through the Housing Control Valve admits pressure fluid from the Servo VSG Pump to either side of the Housing Piston as required, the fluid proceeding from the valve through ports inside the Housing Piston Rod. To prevent the finshafts bumping, tappet operated cushioning valves are incorporated between the control valve and the housing piston which slow up the last 3" of movement, and, when the finshafts are fully extended or housed, tappet operated switches de-energise the solenoids and the housing control valve returns to mid position. The operation of the Housing Control Valve automatically throws the "Auto-Controlled" Servo VSG Pump on to "High Pressure" range when housing and extending the Fins and returns it to "Low Pressure" when at mid position.

TILTING GEAR: The Tilting Gear for each fin consists of two cast steel Cylinders attached to the fin box by an ample number of bolts. The rams are machined from forged steel and have the working surfaces highly finished. Each ram drives through a Rapson Slide arrangement, a lever securely keyed to the fin tilting shaft, this shaft is of hexagonal cross section and carries a sliding lever located in the finshaft inboard crosshead which moves along with the finshaft when the latter is housed or extended. Clutch jaws engage these/

these two levers when the finshaft is fully extended. The sliding lever is connected by links to the finshaft lever keyed to the finshaft.

The fixed and sliding levers cannot get out of step as both are located on one shaft, and the fins can therefore be housed or extended in any angular position. The Clutch Jaws are fitted to the fixed and sliding levers to eliminate stress in the tilting shaft when the fins are extended and operating.

Oil Replenishing Tank: An Oil Replenishing Tank is placed above the level of each Variable Delivery Pump and is fitted with a Cooling Coil supplied with water from the ship's mains.

Each tank is connected to its respective pump casing by two pipes, so arranged that the outlet of one pipe is considerably above the other (where the pipes are fitted to the bottom of the tank stand pipes are provided inside the tank). This arrangement, besides carrying a reserve of oil which is automatically drawn into the Pumps to make up for any leakage in the system, is utilised as a circulating system for cooling the oil. The centrifugal action of the rotating pump barrel, aided by the thermo-syphon action of the heated oil, causes the oil to flow continuously from the pump to the Tank from which it gravitates back, after being cooled, to the respective pump casing.

The Auto-Controlled Servo Pump for housing and extending the Fins and operating the control gear draws it oil supply directly from its tank and the return from this system is discharged back to the same tank.

Emergency/

Emergency Unit: A small hand operated variable delivery pump, supplied with oil from the servo tank, and driven by a 2 H.P. motor fed from the emergency circuit, is provided for housing or extending the fins if the main power supply should not be available.

AUTOMATIC CONTROL UNIT.

See Drawing No. H.574 - Wiring Diagram.

Gyro Unit: The Gyro Unit contains two Gyroscopes, one a vertical keeping Gyro measuring list and one mounted with its axis athwartships responding to the velocity of roll. These Gyros decide the amount of tilt and the actual time of tilting the Fins.

The Gyros are fed from the 3 phase 50 cycle supply obtained from the small rotary converter supplied. The vertical keeping Gyro acts as a pendulum and measures the actual angle of roll which is transmitted by linkages to two Magslip Transmitters - one for "Beam Sea" and one for "Following Sea" conditions, the Magslip in use being selected by the "Gyro Control Switch" in the Bridge Control Box.

The second Gyro is spring restrained and measures the angular velocity of the roll. As the ship rolls the Gyro precesses and operates a third Magslip Transmitter which is electrically connected to the "Following Sea" or "Beam Sea" Magslip Transmitters. The algebraic sum of the Gyro movements is transmitted to the A.R.L. Oil Unit which operates the Tilting Control Valve via a gear box and cam in accordance with the movements of the Gyros.

Bridge Control Box: A Control Switch Box containing three hand operated switches, three indicator lamps and a dimming switch is fitted/

fitted on the Bridge; these switches enable the installation to be started, stopped, the fins to be extended or housed, and the tilt of the fins to be automatically controlled by the gyroscopes. A hand operated switch is also fitted on the bridge enabling the ship to be either stabilised by hand or rolled in calm water if desired.

Stabiliser Compartment Signalling Panel: A panel is fitted in the Stabiliser Compartment containing a bell and two indicator lamps operated from the Bridge, one switch for signalling to the Bridge and two switches for housing and extending the fins locally as required.

OPERATING INSTRUCTIONS.

Normal Condition of Gear:

Fins housed but gear ready for immediate use.

Stabiliser Compartment.

Valves Open: Power Valves in Housing Valve Chest.

ByePass Valve on Size 6 VSG Pump.

Valves Shut: Emergency Unit Valves in Housing Valve Chest.

Housing Cylinder Valves in Housing Valve Chest.

Signalling Panel:

Lamps.

Stop Motors.	Start Motors.
Lit.	Out.

Fins.

Selection Switch	Local Switch	Bridge Signal Switch.
"Bridge"	"House"	"Off"

Bridge Control Panel:

Lamps.

Fins In.	Fins Out.	Motor Running.
Lit.	Out.	Out.

Fins Housing &   Stabiliser Compartment.   Gyro Control

To start Stabiliser and operate Fins.

Bridge.	Stabiliser Compartment
Operation: Turn Stabiliser Compartment Order Switch to "Start Motors."	**Result:** Bell Rings. "Stop Motors" lamp goes out and "Start" Motors lamp lights. **Operation:** Switch off Bell. Start Rotary Converter. Start Gyroscopes. Start Oil Unit Motor. Start Main Motors. Start Servo Motor. Shut ByePass Valve on Size 6 Pump. Open Housing Cylinder Valves in Housing Valve Chest.
Result: "Motors Running" lamp lights.	**Operation** Turn Bridge Signal Switch to "Motors Running".
Operation: Turn Fin Housing and Extending Switch to "Extend" **Result:** "Fins In" lamp goes out and approx. 2 minutes later "Fins Out" lamp lights	**Result:** Fins Extend. **Operation:** None.
Operation: Turn Gyro Control Switch to "Beam Sea" or "Following Sea" as required.	**Result:** Gear is controlled by Gyros to stabilise roll. **Operation:** None.

NOTE: If doubt is present as to whether "Beam Sea" or "Following Sea" setting should be used, try both in turn.

To stop Stabiliser and house Fins.

Bridge.	Stabiliser Compartment.
Operation: Turn Gyro Control Switch to "Off"	**Result:** Fins are disconnected from Automatic Control and return to mid position. **Operation:** None.
Operation: Turn Fin Housing & Extending Switch to "House" **Result:** "Fins Out" lamp goes out, approx. 1½ minutes later "Fins In" lamp lights.	**Result:** Fins house. **Operation:** None.
Operation: Turn Stabiliser Compartment Order Switch to "Stop Motors"	**Result:** Bell rings. "Start Motors" lamp goes out and "Stop Motors" lamp lights. **Operation:** Switch off Bell. Stop Oil Unit Motor. Stop Gyroscopes. Stop Rotary Converter. Stop Servo Motor. Open Byepass Valve on size 6 pump. Stop Main Motors. Close Housing Cylinder Valves in Housing Valve Chest.
Result: "Motors Running" lamp goes out.	**Operation:** Turn Bridge Signal Switch to "Off".

CHARGING INSTRUCTIONS.

Open all Screw-Down Valves in the system and all Air Valves, the latter being situated one on each Tilting Cylinder, one on each Finshaft Cover, two on each Housing Piston Rod End, two on the Tilting Control Cylinder, one on each Cushioning Valve, one in the Pressure Line from the Servo Pump and two plugs on each Variable Delivery Pump.

Fill oil into the Servo Pump Oil Tank by means of the Semi-Rotary Pump provided, and as the oil gravitates through the system keep the level in the tank well up. Close the various air valves when the oil issuing from them appears free of air.

Close the Power Stop Valves in the Housing Valve Chest and by means of the Emergency Pump apply enough pressure to expel air from the Housing Cylinders in the Finshafts, if possible extending and housing the Fins, opening the air valves at intervals.

Open air plug on delivery side of Servo Pump and bar coupling round in the indicated direction until pump is free of air. Close air plug and open Power Valves in Housing Valve Chest. Start pump and close byepass valve noting that the pump should cut off the pumping at a pressure of 400 lbs./sq. inch. If possible extend and house the Fins either by using the Local Control Switch or the Hand Lever on the Housing Control Valve. The maximum pressure allowed by the relief valve in the Housing Chest when extending is 500 lbs./sq. inch. The actual cut off pressure of the pump under these conditions and which is used when housing the Fins is 1100 lbs./sq. inch. Declutch the A.R.L.Gear and by rotating the coupling on the Cam/

Cam Gear Box move the Tilting Control Valve and Tilting Control Cylinder venting as necessary.

Next disconnect the pipes from the Tilting Cylinder Air Valves and fill oil into the Tilting Pump Tanks leaving the air valves open until all air ceases to issue from the valves.

By means of the Control Cylinder put a little stroke on the Tilting Pumps. Release the air plug on the discharge side and bar round in the indicated direction until free of air then tighten plug. Now put the opposite stroke on the pump and repeat the procedure using the other air plug.

Reconnect the pipes to the Cylinder Air Valves and put the Pump Control Levers to the neutral position. Start the Pumps and again using the Control Cylinder oscillate the Tilting Rams venting the Tilting Cylinders when on the pressure stroke.

Air in the pumps can be immediately recognised by its rapid rattling noise.

Clutch in the A.R.L.Control and in accordance with instructions set the gear to "Normal Conditions".

The gear is now ready for use but as there may still be some air in the system the various Air Valves should be opened occasionally while the gear is being tried out.

<u>Oil:</u> The oil used for charging must be a first class mineral oil, as used for forced lubrication in Turbine Bearings.

It is absolutely essential that the oil should be perfectly clean and that no water, grit or any foreign matter should be allowed to enter the systems. The Charging Pumps for the replenishing Tanks are/

are each fitted with a filter and if the oil is introduced to the system through any other opening, such as connections on the cylinders, it should be poured through a fine gauze strainer, and before opening such connections the surrounding surfaces should be wiped perfectly clean.

GENERAL NOTES ON STABILISER MAINTENANCE.

Lubrication: All inboard bearings are fitted with Tecalemit clip-on type nipples either connected direct to the bearing or through Spring Feed Lubricators. Only Tecalemit Solidified Oil should be used in these bearings.

The guide slippers on the Finshaft Crossheads are lubricated from a point on the end of the rod fixed to the Finshaft Crosshead and moving with the Finshaft when the Fins are housed or extended. These points should be supplied with grease, using the Grease Gun supplied with the gear. Only Tecalemit Solidified Oil or Heavy Cylinder Oil should be used for the lubrication of these bearings as grease tends to solidify in the pipes. The "No. 1 Junior Hand Compressor" Grease Gun should be used as smaller guns do not force the grease through the fairly long pipes employed.

The Finshaft bearings in the outboard and inboard sliding crossheads, the tilting shaft bearings and the Tail Flap Links are lubricated from Manzel Automatic Lubricators situated on the inboard Crossheads. The fin box sea gland bearings and the fin box tilting shaft brackets are lubricated from a similar Automatic Lubricator mounted on the tilting cylinder seating. These lubrication reservoirs should be kept full of heavy oil.

The/

The Tail Flap Bearings are lubricated through the Finshafts. The Servo Motor is geared down to operate a valve approximately every half-hour when the gear is running and admit oil under pressure to the finshafts for about one minute. This oil charges a small spring loaded accumulator in the fin and leaks through metering plugs to the hinge bearings. The oil used is taken from the Servo Oil Replenishing Tank.

THE FINS SHOULD BE EXTENDED AND HOUSED ONCE EVERY DAY TO PREVENT FORMATION OF RUST ETC. ON THE GUIDES.

Oil Replenishing Tanks: These should be kept fully charged, noting that when the Fins are extended the level of the oil in the Servo Tank will fall.

Stop Valve Glands: All stop valves are fitted with reversed seats so that the glands may be repacked when the valve is fully open. Screwed Stop Valve Glands are fitted with lock-nuts to ensure that they do not slacken off due to vibration; these lock-nuts must be slackened before adjusting the glands.

Air in Sytem: Particular attention shouldbe paid to keeping the system free from air and full use of the Air Cocks should be made.

Control Unit: If it is necessary to remove a Magslip Transmitter from its frame it must be lined up when replaced. To do this proceed as follows:-

(a) Replace transmitter roughly in alignment, leaving screws finger tight. Assemble connecting linkages.

(b) Align the Gyros and Transmitters not affected by the change by means of the "Lining Up" pins supplied in the baseplate of the Gyro Unit.

(c)/

(c) Rotate the Transmitter into alignment so that the "Lining-Up" pin easily enters the slot of the rotor hub and the lining up bush without distorting the connecting linkages. Tighten up the clamping screws.

(d) <u>Check Test</u>: Isolate the Gyros from the 50v 50c supply. Remove the "Lining up" pin from the replaced Transmitter. Start the Stabiliser leaving the fins in the "housed" position. Then for the following settings of the Gyro Control Switch in the Bridge Control Panel check that the movement of the Tilting Ram is within $\pm$ 3° of mid.

1. "Off"
2. "Beam Sea"
3. "Following Sea".

The damping of the velocity Gyro is such that on deflecting the Gyro to its stop, with the wheel stationary, it overshoots its zero position by about 1° or 2° before settling to the central position.

If incorrect adjust throttling screws in base of dashpot making setting of both screws the same. The dashpot should be filled with heavy "torpoyl".

A. R. L. CONTINUOUS CONTROL FOR SHIP STABILISATION.

The purpose of this control is to so position the control valve of the fin tilting gear that the angle of the fins will correspond moment to moment with the requirements for damping or opposing the rolling motion of the vessel. The control is called "continuous" because of this feature of smooth, as distinct from step-by-step or impulse, control of the fins.

The control is based upon the action of two gyroscopes, one of which measures the rolling velocity of the ship, the other the departure from the horizontal of the deck line of the ship. The outputs from these two gyroscopes are combined in any desired ratio in order to effect the best control. The signal or force available from the gyros is small and hence some form of amplification is necessary. This is achieved by means of a sensitive hydraulic unit developed by the Admiralty. In order to convey the movement of the gyros to the sensitive Oil Unit, a form of transmission is used which was also developed by the Admiralty. The control comprises, therefore, a Gyro Unit and a Control Unit linked together as shown diagrammatically in Fig. I. and referring to this it will be seen that the roll gyroscope has two electrical transmitters (Magslips) which are connected alternatively by a switch to another Magslip (Follow-Through type) operated by the velocity gyroscope. This system of transmission has the faculty of adding together the two motions algebraically the sum being passed on to the oil motor which copies the motion with sufficient increase in power to operate a cam, the rider upon which operates the control valve of the fin tilting gear. The selector switch, it will be seen, selects either of the two Magslips on the roll gyro, which are arranged to rotate in opposite directions as the roll gyro maintains its vertical while the ship is rolling.

The purpose of the cam and the addition of the motions of the two gyros, will now be explained. Referring to Fig. II, and dealing first with the cam. When working out a scheme of ship stabilisation it is obvious that some decision must be made as to what degree of motion of the ship will cause full stabilising torque to be applied. For example, if a ship is in a very rough sea and is being forced to roll 20 degrees in either direction, the control would normally be expected to oppose this motion and would be required to exert its full force for at least 90% of the available time, the remaining 10% being absorbed in the changeover of the fin from full tilt one side to full tilt the other. In the case, however, of a small roll - say 3 degrees - such vigorous action by the fins is not necessary since a small stabilising torque will bring the ship to the vertical position.

In tests with Naval vessels of the destroyer and sloop classes, a working value has been arrived at such that a tilt of the vessel of 3 degrees from the vertical position will give full fin angle, tending to erect the ship (this angle being derived from the right-hand Magslip operated from the roll gyro); again, a rolling velocity of 2 degrees/second (derived from the Follow-Through Magslip on the velocity gyro) would also give full fin angle. Smaller angles of roll and roll velocity produce proportionally less fin tilt. Any combination of these angular values will produce a net roll plus velocity signal as described above, to effect the movement of the final controlling cam. Thus a tilt of the vessel of 6 degrees to port, and a roll velocity of 4 degrees/second towards the midships position, will cancel each other out, the cam giving zero signal and the fins therefore being at the mid point. A roll velocity to port, however, of the same value and under the same condition of tilt would give a movement of the cam corresponding to four times the full fin signal, but the cam, once it moves past the full signal position, is circular and the signal therefore passed to the fins does not increase. This condition is represented by the fin movement plots indicated in Fig.II. The function of the cam, therefore, is to control the fins within the limits decided by the appropriate ratios of the gyro-magslip arrangement, and to absorb such excess movements as cannot be translated into fin movement instant by instant. Thus the movement of the hydraulic motor marked "O.U.B". on Fig I and the cam following it, is continuous, while for large roll conditions the fin movement is discontinuous. Should the ship movement, however, due to the sea, be well within the capacity of the stabiliser, the movement of the vessel away from the vertical results in a fin movement and as this movement causes a diminution of the rolling motion the fin will take up a position less than the full tilt just sufficient to balance the torque imposed by the sea.

The two types of control - 'Beam Sea' and 'Following Sea' - will now be dealt with. The names imply that the ship is being rolled by a sea approaching the vessel on the beam or forequarter in one case, and following up from a stern quarter in the second case. The characteristics of rolling of the vessel, as is well known, are different under these two conditions. With a strong beam sea the tendency is for the vessel to roll heavily in its own period, and under these conditions roll damping, rather than attempting to keep the vessel vertical, has been found to be the best form of control "Roll damping" may best be expressed as a control which opposes the velocity of roll at any moment. This implies that the tilt of the fin should change over at the extreme position of roll of the vessel, that is, when the rolling velocity is zero. If this were effected from the velocity gyro only, a lag would occur due to the inherent lag/

lag in operation of the fin tilting gear, so that part of the stabilising time would be lost.

Assuming that the rolling is roughly simple harmonic in character, the change over of the fins at the end of the roll can be made more precise by combining with the roll velocity an opposed roll vertical signal. The change over of the signal to the fins occurs at a time X1 before the true change over of the roll velocity of the vessel, and this gives the best roll damping for a given size of fin fitted to the vessel.

Under "Following Sea" conditions, however, there is a tendency for the vessel - in addition to rolling in its own period - to lie over on the contour of the waves in an irregular manner, and this can be partially compensated by effecting the control from the vertical keeping gyro. The signal for the change over of the fins is late in time by comparison with "Beam Sea" control, but it will be seen that the signal provides a fin movement giving a measure of both roll damping and of vertical keeping. The selection of either control is a matter for personal judgment of the Captain or Navigator.

The individual units of the control will now be described.

THE GYRO UNIT consists of a main casing in which are assembled the following items.

A Roll Velocity Gyro, which consists of a heavy gyro wheel mounted in a casing which is supported by bearings so that it can swing around its vertical axis, the axis of the gyro wheel itself being horizontal. The casing has attached to it spiral springs pulling in opposition, which centralise the movement of the gyro casing with relation to a fixed stop on the frame. On the opposite end of the horizontal axis of the casing to the attachment of the springs is a sector of a gear wheel which meshes with another wheel mounted on a vertical spindle. At the lower end this spindle passes into the Dashpot consisting of a housing in which are fixed two vanes. These co-operate with moving vanes on the spindle and form an oil damping chamber which serves to damp the movement of the velocity gyro. Screws for regulating the amount of damping are mounted in the side of the chamber. The upper part of the same spindle carries an arm to which is attached a Ball-pivoted link, the other end of the link being attached to an appropriate arm fixed to a Magslip Transmitter of the follow-through type.

A/

A Vertical Keeping Gyro is also mounted in the main case. The spin axis of this gyro is vertical and its casing is borne in bearings in a horizontal gimbal, the gimbal being supported by two pedestal bearings. The gyro casing is arranged to be bottom-heavy and so the gyro functions as a long-period pendulum. The period of conical precession is arranged to be approximately 6 minutes.

Attached to the gimbal are two ball-pivoted links similar to those used on the velocity gyro, and these are attached respectively to two Magslip Transmitters, one of which is used in the 'Beam Sea' Control and the other in the 'Following Sea' Control.

Located in the main case are two relays by which the connections to the Magslips are controlled from a selector switch operating on the bridge or other suitable position.

The Vertical Keeping Gyro has also fitted to it a means of automatic erection of the gyro. This consists of a contact-making means, consisting of mercury switches, which are fitted to the top plate of the gyro. Thus if the gyro remains truly vertical (or takes up the position of the apparent vertical) when a ship is turning, the pendulum or mercury switches will be inoperative. If, however, the gyro departs from the vertical, a contact will be made and either one of two small relays will be energised. These make the circuit to either of a pair of coils mounted on lugs on the gimbal. Passing through the centre of these coils is an iron armature, and when current flows in either coil a reaction will be exerted which tends to pull the coil towards the base of the control unit. The switches are arranged in such a way that the pull on the appropriate coil causes erection of the gyro. A rectifier is also mounted in the case for converting the alternating current available to D.C. for operating the gyro erecting relays and coils.

A bank of terminals is provided in the casing, to which all the local connections and the incoming cables are connected. The gyros operate on three-phase alternating current, 50 volts, 50 cycles, and the two Magslip Transmitters operated by the vertical keeping gyro are also fed from a single phase of this same supply. A single phase of the supply also feeds the erecting means, as mentioned above. The Follow-Through Magslip Transmitter on the velocity gyro has no supply direct from the mains, but derives its energisation from either of the two Magslip Transmitters.

Another item mounted in the case is a small resistance unit which is associated with the "Off" position of the control.

THE/

THE CONTROL UNIT. As indicated above, this comprises a sensitive hydraulic unit ('B' Type Oil Unit) which is arranged to drive through a gear box, the reduction of which is approximately 10: 1, a cam whose lift is approximately 1.3/8 ins. The cam follower operates, through linkage, the hydraulic control valve of the fin tilting gear.

The Oil Unit consists of several parts as follows. A driving motor coupled by a chain to a hydraulic pump, which is driven at approximately 600 revolutions per minute. The pump is of special construction having ball pistsons which co-operate with cam surfaces. A pressure controller in the unit is arranged to control the relative position of two cam surfaces, and by this means varies the volume of oil pumped per revolution of the main cylinder according to the demand at any moment. If the pressure rises, the pressure controller causes the cams to reduce the volume pumped. In effect, this arrangement gives approximately constant pressure output from the pump from zero to the maximum volume of which it is capable.

On the same axis as the pump, but mechanically separate from it, is a similar unit which serves as a motor. Between these two is a suitable valve and when the valve is moved, oil will flow in one direction causing the motor to rotate clockwise. Movement of the valve in the opposite direction will cause anti-clockwise rotation of the motor.

Above the pump and motor section is a casing in which are mounted the two Magslip units associated with the control, namely, a Resetting Transmitter and a Hunter. The Resetting Transmitter is similar to the Transmitters in the Gyro Unit. The Magslip Hunter has an arm approximately 1" in length, to which is secured, by means of a long strut, a pilot valve which is located in the lower hydraulic case. Movement of this valve by the Hunter causes oil to flow in small relay cylinders, which in turn control the movement of the valve operating between the pump and motor. In a position of rest the Transmitters in the Gyro Unit hold the Hunter in its central position, and the hydraulicmotor will remain stationary. Movement of either the Velocity Gyro or the Vertical Keeping Gyro will cause the Hunter to operate and initiate a movement of the hydraulic motor. The output shaft of this motor is coupled through the gear box to the output cam mentioned above, and it is also coupled by gearing to the rotor of the Resetting Transmitter. As the hydraulic motor turns, the Resetting Transmitter is therefore rotated in such a direction that the Hunter will approach its central position again, and when this is attained the oil motor will stop. The movement however, although described in stages, is continuous and oil motor smoothly follows up the controlling motion given to it by by the Gyro Unit. A detailed description of the parts, and maintenance of the hydraulic unit, are appended.

MAINTENANCE INSTRUCTIONS FOR GYRO CONTROL UNIT.

The maintenance required on this unit is very small and consists largely of a periodic check to find that no undue friction has arisen in any of the movements of the Gyros and Magslips.

GYROS:

The rotors of the two gyros are the same and run on grease-sealed bearings which should require no attention for five years or so. After this period the bearings should be replaced.

The gimbal bearings of the Vertical Keeping Gyro, and the vertical axis bearings of the Velocity Gyro, are required only to move through very small angles. They are lubricated with clock oil which should remain good for at least two years, and probably longer. When stiffness occurs the equipment must be dismantled and the bearings cleaned and re-lubricated.

MAGSLIPS:

The same remarks as for gimbal bearings apply to the Magslip bearings.

No other maintenance is required for these instruments.

CONNECTING LINKS BETWEEN GYROS AND MAGSLIPS:

The connection is made by means of ball jointed links, which are held in appropriate cups. The amount of wear expected on these joints is very small but an occasional check should be made that only the very smallest amount of shake is present to permit freedom of movement. A spot of clock oil say every six months on these joints should be sufficient to keep them free.

If for any reason the links or levers should be removed from the Magslips, care should be taken to clamp up the levers in the same position, and not to change the length of the connecting links.

When testing the freedom of operation of both Gyros and Magslips as assembled, the gyros should not be running and when disturbed from the vertical position the Vertical Keeping Gyro should restore under its own bottom-heavy weight to such a position that the gyro is within 1° to 2° of the position in which the lining-up peg can be inserted on the horizontal gimbal.

The Velocity Gyro should return under its spring control also to within a very small amount of the position for inserting the lining-up peg. If stiffness occurs it should be located by casting off the links from the gyros in turn until the point of stiffness is found.

The Velocity Gyro has geared to it a Dashpot. This is intended to prevent over-swing of the gyro when operating under rolling conditions. It can be tested by disturbing the gyro to the extent of say 10° or 20° and, on release, the spring control should carry the gyro back to centre and just overshoot once. If the damping is too great, there will be no appearance of overshoot; if the damping is too little, the gyro will oscillate more than once with decreasing amplitude. The adjustment of the Dashpot can be effected by taking off the covers for the regulating screws at the base, and, when increased damping is required, screwing in the adjusting screws (after loosening the locking nut) until the desired degree of damping is obtained. The regulating screws each control one-half of the damping power, and should be adjusted by the same amount.

After a considerable time the oil in the Dashpot may become too thick, or need replacement; the grade of oil to use is Heavy Torpoyl (Silvertown Lubricants Ltd.). The oil level is marked on the Dashpot cylinder.

ERECTION GEAR FOR VERTICAL KEEPING GYRO:

This consists of a pair of mercury switches mounted on the top of the gyro and connected to a pair of relays which make the circuit for the erection coils fixed to the horizontal gimbal. A metal type rectifier is used to supply this circuit with direct current from the 50 V. 50 cycles A.C. supply used for the gyros. The current through the erecting coils should be approximately 0.25 amp. An occasional check should be made that when the Vertical Keeping Gyro is lying over to the extent of say 2 degrees the appropriate relay contact should be made. The current through the coils of these relays should be approximately 13 mA per relay.

The relays for the control circuits of the Stabiliser are also located in the gyro unit. These are of normal type and require no special maintenance. The currents made and broken are not lage enough to cause sparking and hence the contacts do not require to be cleaned.

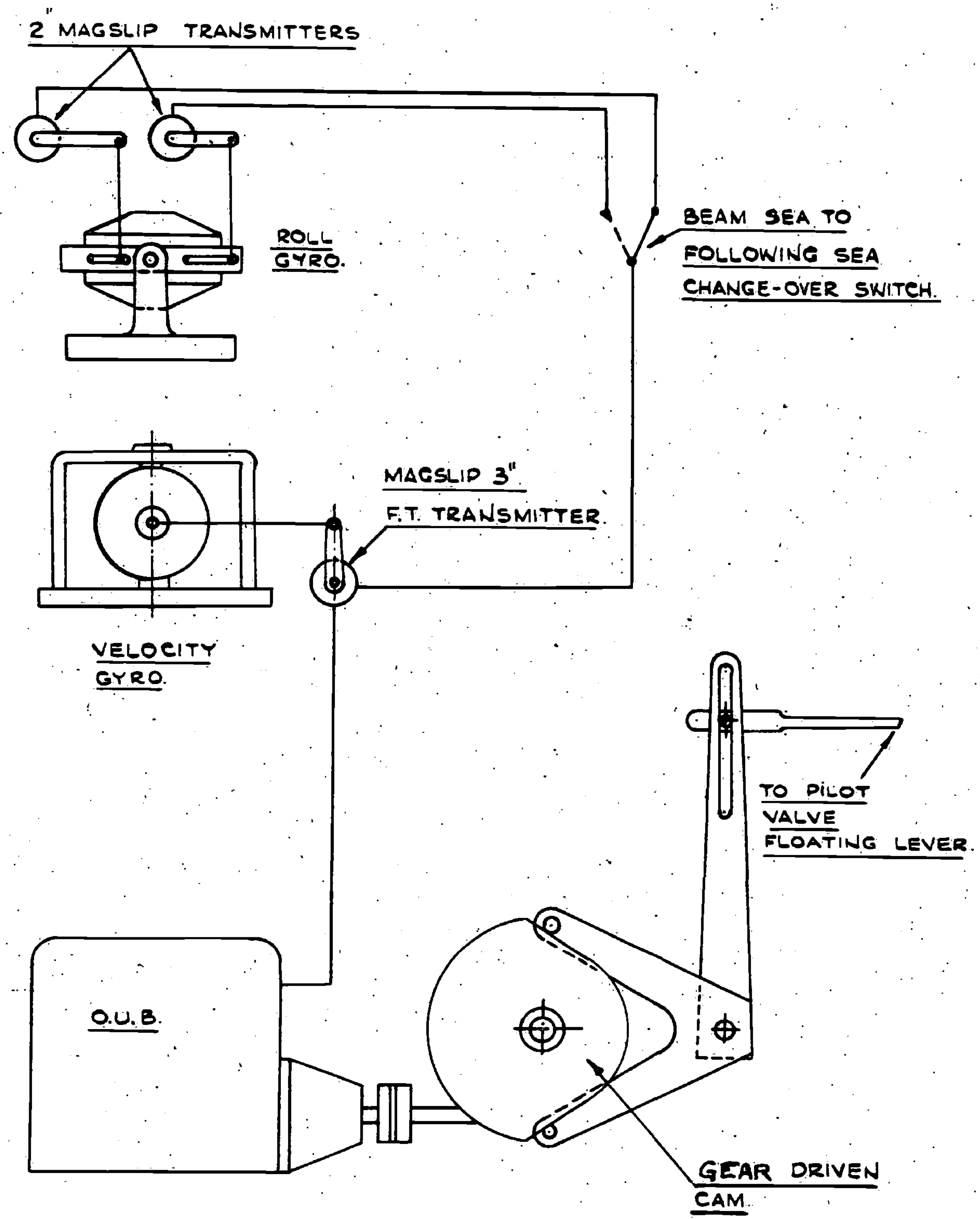
A diagram of the electrical connections of the Gyro Unit appears on the Key Wiring Diagram.

BROWN BROS. & CO. Ltd.
ENGINEERS
EDINBURGH

DRAWING No.

DATE 17.11.50

ISSUED BY [illegible]



STABILISER CONTROL.

FIG. 1.

Retd to DO 27/11/50

BROWN BROS. & CO. Ltd.
ENGINEERS
EDINBURGH

DRAWING No.

DATE 17-11-50

ISSUED BY [illegible]

R.M.S. "CHUSAN"
"DENNY-BROWN" SHIP STABILISER
STABILISER TRIALS

Principal Dimensions of Ship:-

Length 630 ft.
Beam 85 ft.
Draught 29 ft.
Designed Displacement - 26.000 tons.
G.M. 3'0".
Service Speed - 22 Knots.

Particulars of Stabiliser:-

2 - Fins.1 - fitted on each side of the ship, through bilge, immediately forward of Boiler Room.

Outreach from Hull 12'0"
Fore & Aft Width 6'6"
Area of 1 Fin 78 sq. ft.
The after 25% of the fin area takes the form of a Tail Flap which is angled relative to the Main Fin.
Max. Angle of Main Fin to Zero Position = 20° each side
Max. Angle of Tail Flap relative to Main Fin= 30° each side
Centre Line of Finshaft from leading edge = 2'2"
Centre Line of Tailstock from Trailing edge = 1'7½"
Max. Thickness of Fin (Streamlined Section) = 1'1"

Finshaft

Dia. of Finshaft 21½"
Bore of Housing Cylinder in Finshaft 10"

Tilting Cylinders & Rams (Rapson Slide Type)

Dia. of Rams 8½"
Normal Radius 31"
Max. Working Pressure - 1250 lbs. per sq. inch.
Max. Torque @ 20° & 1250 lbs. per sq. inch = 77 ft. tons per fin

Main Power Units (2 off)

Electric Motors 50 H.P. @ 465 R.P.M. on 220 volts D.C.
Pumps Size 24 "VSG" Variable Delivery Pumps.

Servo Unit.

Electric Motor 15 H.P. @ 400 R.P.M. on 220 volts D.C.
Pump Size 6 "VSG" Variable Delivery Pump.

Emergency/

Emergency Unit

Electric Motor 2 H.P. @ 1000 R.P.M. on 220 volts D.C.
Pump P. 0.6 Variable Delivery Pump.

Weight of Gear.

	T.	C.	Qrs.	Lbs.
Total weight of Gear, Spares & Oil in system	108-	15 -	0 -	0
Loss of Buoyancy	23-	0 -	0 -	0
Total	131-	15 -	0 -	0

DOCK TRIALS.

Previous to the Fins being fitted to the Stabiliser at Liverpool an endurance trial was held at Barrow, the operation of the fins being controlled by the Dock Trial Gear.

With the Tilting Gear moving hard-over to hard-over in approxim-ately 1.8 sec. with a 15 sec. period the Stabiliser was run continuously for 28½ hours. The performance of the gear was very satisfactory and running temperatures were low throughout the trial the final Pump temperatures being:-

Starboard Main Pump	116°F.
Port " "	122°F.
Servo. Pump	103°F.

SEA TRIALS.

Sea Trials of the Stabiliser were carried out on Saturday, 10th June, while the vessel was proceeding from Liverpool to the Clyde and also on Monday, 12th June in the Firth of Clyde.

Saturday 10th June, Ships Displacement 21.000 tons.

As the weather was not suitable for demonstrating the action of the installation stabilising the ship, there being no roll, the gyroscope leads were reversed and the stabiliser operated to impose a forced roll on the vessel. The ship's roll was measured by a gyroscopic roll recorder. The trials were completely successful, the gear running well within its power limits and neither mechanical nor electric faults developed. The roll imposed on the ship exceeded expectations and the final run, marked x, at 20 knots ± 20° Fin Angle, Forced Rolling, was stopped by Ships Authorities before the maximum angle of roll had built-up.

The result of the tests are shown in tabulated form hereunder/

Ships Speed.	Max. Fin Angle.	Time of Fin H.O. to H.O.	Main Motor Amps.	Period of Roll.	Max. Ships Roll.
15 K.	$\pm 12^{\circ}$	4 sec.	105	23.3 sec.	16°
15 K.	$\pm 16^{\circ}$	4 sec.	110	24 sec.	$23\frac{1}{2}^{\circ}$
15 K.	$\pm 20^{\circ}$	4 sec.		24 sec.	$27\frac{1}{4}^{\circ}$
15 K.	$\pm 20^{\circ}$	2 sec.		20 sec.	27°
15 K.	$\pm 20^{\circ}$	$2\frac{1}{2}$ sec.		20 sec.	$27\frac{1}{2}^{\circ}$
17 K.	$\pm 12^{\circ}$	2 sec.	100	23 sec.	$19\frac{1}{2}^{\circ}$
17 K.	$\pm 16^{\circ}$	2 sec.	130	23 sec.	$25\frac{1}{2}^{\circ}$
17 K.	$\pm 20^{\circ}$	2 sec.		23 sec.	30°
20 K.	$\pm 16^{\circ}$	2 sec.	130	21.7 sec.	30°
* 20 K.	$\pm 20^{\circ}$	2 sec.	160	19.4 sec.	35°

The ship's roll as registered by the gyro recorder is shown on the attached prints.

On the roll records a distinct difference can be seen between a forced roll which is allowed to decline naturally and a forced roll which is stabilised. The effect of changing over the control to "stabilise ship" was to bring the ship to the vertical in less than one roll.

Monday 12th June - Ships Displacement 22.500 tons.

On Monday, 12th June, two runs on the measured mile were taken with the stabiliser fins extended but not operating. When compared with the equivalent runs with the fins housed no reduction in the ship's speed could be observed.

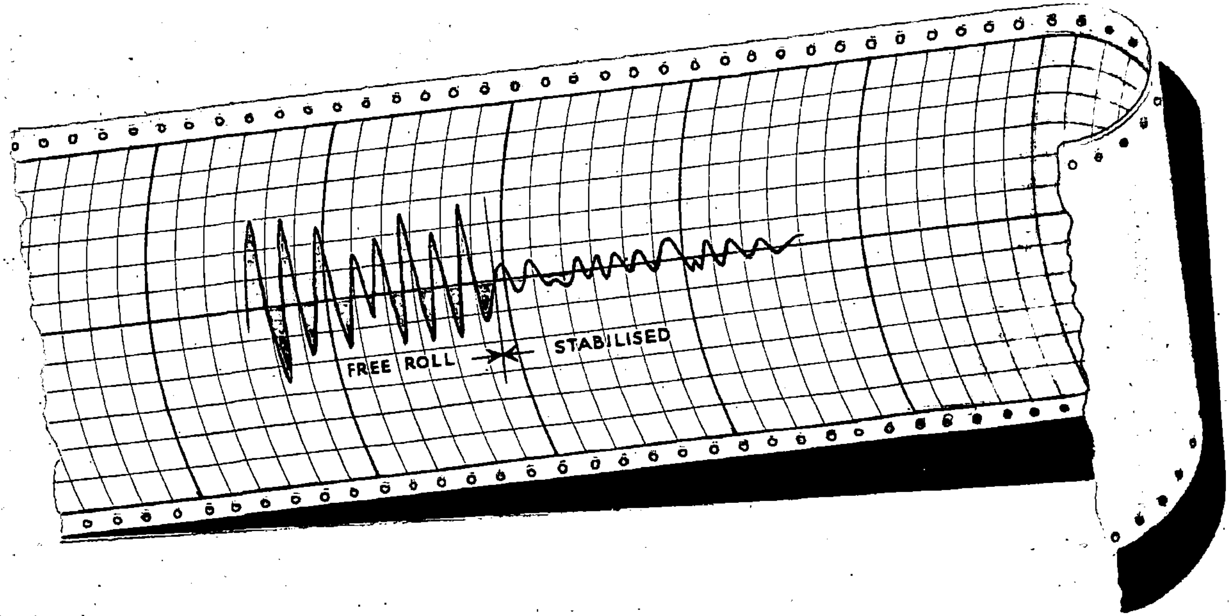
As the weather gave no opportunity for testing the gear as a stabiliser recourse had again to be made to force rolling the ship.

Owing to the short time allowed the demonstration was limited to two runs as detailed below. In the first run the fin angle was limited to $\pm 16^{\circ}$ at the request of the Ships Authorities. In the second run one fin was housed and the other left extended to demonstrate that, in the event of one fin being d maged or otherwise not/

not being operable, it is still possible to stabilise the ship although, naturally, not so effectively.

Ships Speed.	Max. Fin Angle.	Time of Fin H.O. to H.O.	Period of Roll.	Ship's Roll.	Remarks
20 K.	± 16°	2 sec.	19 sec.	28°	Both Fins extended and Gears in normal working condit: :ions.
20 K.	± 20°	2 sec.	19.7 sec.	21½°	One fin housed One fin only in operation

On Tuesday 13th June the ship left the Clyde for Southampton on endurance and consumption trials and the stabiliser was used to force roll the ship before guest and press representatives off the Isle of Wight, on Wednesday 14th June and again on the return run from Rotterdam to Southampton on Sunday 18th June.



THE DENNY-BROWN SHIP STABILISER

The DENNY-BROWN SHIP STABILISER

British Patent Nos. 471220/1937, 573954/1945, 578909/1946, and 588965/1947
French Patent 924236/47 Belgian Patent 463924/46
Applications pending in Holland, Sweden & U.S.A.

WILLIAM DENNY & BROTHERS LTD.
Leven Shipyard, Dumbarton

BROWN BROTHERS & CO. LTD.
Rosebank Iron Works, Edinburgh

First Reprint—April, 1948

The Denny-Brown Ship Stabiliser

FROM the earliest times ocean travel has been dreaded by many travellers because of the discomfort occasioned by the rolling of ships. In an attempt to overcome this, and over many years, various devices have been invented and tried. Practically every ship afloat is equipped with fixed bilge keels in order to reduce the amplitude of roll, but these would need to be very large indeed to reduce the degree of rolling to a moderate figure.

Many elaborate installations have been fitted in ships solely in an attempt to overcome rolling. The Gyro Stabiliser and the Anti-Rolling Tank are well known, but, owing to the large space occupied and the great weight and cost, these methods have not attracted Shipbuilders and Shipowners, and their installation has been on a very small scale and to very special ships. Even so, their efficacy is doubtful. It is, in fact, clear that to reduce rolling motion to negligible proportions active means of stabilisation must be introduced.

Successful stabilisation has been accomplished for the first time in the Electro-Hydraulic Denny-Brown Stabiliser.

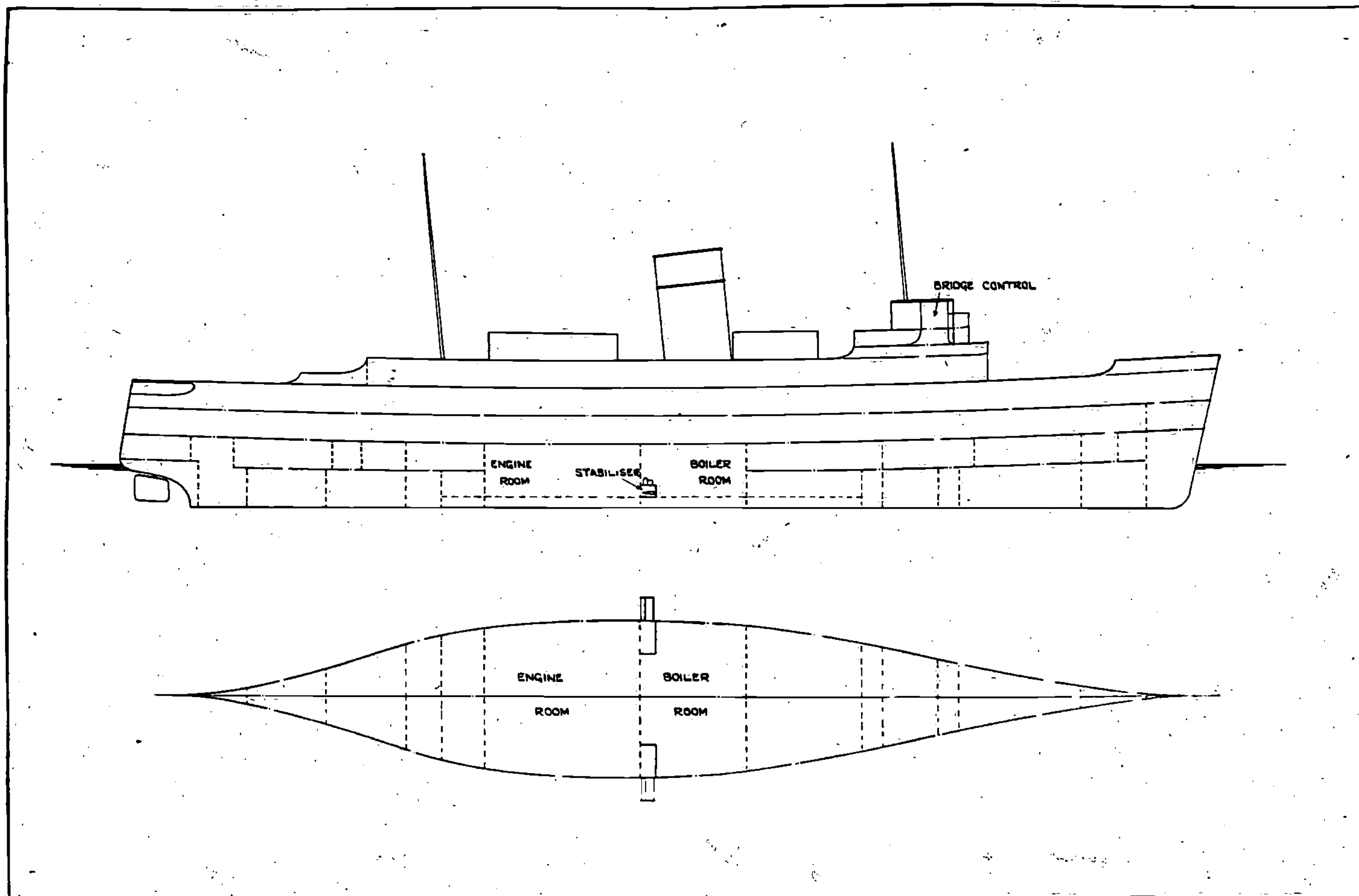
It can now be disclosed that during the war the Admiralty fitted Denny-Brown Stabilisers to a large number of vessels, in order to assist gunnery.

The gain in comfort to passengers and crew of a stabilised ship needs no emphasis. Competition from air transport accentuates the need to reduce the discomfort of sea travel as far as possible.

The Denny-Brown Stabiliser is comparatively cheap, and it is relatively small and light, perhaps *one-quarter* of the weight of a Stabiliser using Gyros to produce the same damping moment. It is also simple, the operation being easily understood by the ship's personnel. The power absorbed by the stabilising apparatus is small, and hence it is unnecessary to equip the ship with large additional electric generating power.

The Stabiliser does not attempt to eliminate the rolling of the ship utterly, but it reduces the rolling so greatly that the small movement remaining is not objectionable. (See Diagrams, page 14.)

The argument is sometimes advanced that a stabilised ship will be subjected to greater stresses than an unstabilised ship. The reverse is the case, for two reasons. In the first place racking stresses, which arise from

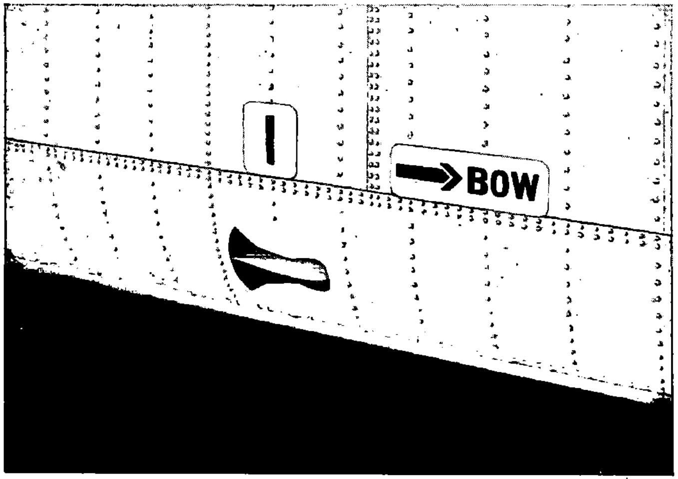

BRIDGE CONTROL
ENGINE ROOM
STABILISER
BOILER ROOM
ENGINE
BOILER
ROOM
ROOM

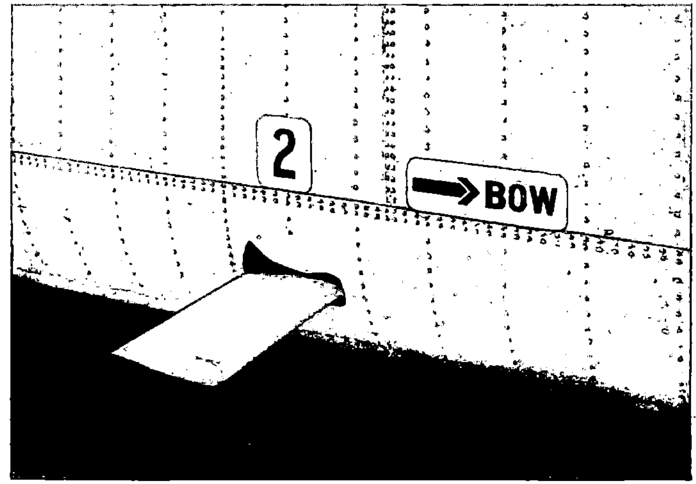
angular acceleration of the vessel in rolling, are often unpleasantly evident—especially in passenger vessels with tiers of erections—by reason of creaking noises, which are unavoidable even with the best of joiner work. These, obviously, will not be in evidence in a stabilised ship. In the second place, it is well known that in certain sea conditions the ship may roll against the sea, and it is in these conditions that the waves are noted as striking the ship. In this respect, also, the stabilised ship will be at an advantage. Reports are on record of stabilised ships being comparatively dry and able to maintain speed when other unstabilised vessels proceeding with them have had to reduce speed considerably. It is also on record that the use of the Stabiliser reduces yawing and helps to retain control, especially in following-sea conditions.

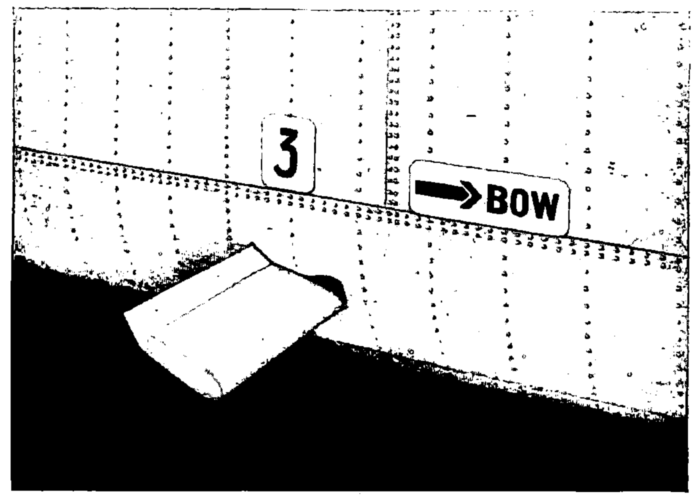
The stabilising system consists primarily of Fins (Hydrofoils) which project from the side of the ship. The best position is about the turn of the bilge and not too far forward or aft, so that the maximum distance conveniently possible may be obtained between Fins, thereby producing the maximum righting moment with a given area of Fin. (See Plate 1.) Even when stationary, the Fins act as efficient damping devices; they are, in fact, additional bilge keels. When stationary, they lie fore and aft as nearly as possible in the normal streamline flow past the ship's hull. If fitted near midships—the best and often the most convenient position—they may be arranged to lie horizontally. The Fins when not in use are housed in boxes within the ship's hull, the housing and extending of the Fins being controlled by the operation of an electric switch on the bridge.

When the ship is in motion and it is desired to stabilise, the Fins are rotated through a moderate angle synchronously and in opposite senses. If the starboard Fin is angled so that the leading edge is upwards, while the ship is moving ahead, the action of the water on the Fin produces two forces, one tending to impede the motion of the ship, and the other exerting an upward force on the Fin. A force tending to raise the starboard side of the vessel is therefore obtained. If the port Fin is simultaneously angled so that the leading edge is downwards, then the same causes produce a downward force on that Fin, tending to depress the port side. A righting moment is thus obtained varying with the total area of the Fins, the angle through which they are rotated and the speed of the vessel. To obtain the desired effect, i.e., the damping down of the ship's roll, it becomes only necessary to oscillate these Fins in such a way that their effort is continually exerted to produce the correct righting moment on the ship at the correct time.

The Fins are designed to oscillate round an axis so placed that the Fins are practically balanced, and hence the torque required to produce angular movement of the Fins is small.







No. 1—Fin retracted.

No. 2—Fin extended and not angled.

No. 3—Fin extended and fully angled "up."

It must be understood that it is of prime importance that the oscillation—that is, the reversal of aspect of the Fins—should be effected rapidly. In a vessel of moderate size, the total period of double roll may not exceed 10 seconds, and it is obvious that only a small part of this time may be allotted to the reversal of Fins at the end of each roll if the righting moment is to be effective over a sufficient period of time to produce the desired result. In practice reversal of attitude is arranged to take place in less than one second, during which time each Fin may have passed through an angle of 35° or 40°. This should be contrasted with the thirty seconds usually required to move a rudder through 70°.

Having made the necessary provision for rapid oscillation of the Fins, it is then only necessary to control them so as to provide the damping effort at the correct moment. This can be done simply by using the special properties inherent in a Gyroscope. The Gyroscope (or Gyroscopes) are quite small, absorbing a fraction of 1 h.p. It is not necessary to describe the control in detail. Suffice it to say that the movement of the Gyroscope is ultimately reflected in control by electric energy of the special gear which oscillates the Fins. This gear consists essentially of a Variable Delivery Pump, electrically driven, which provides the necessary fluid for operating the hydraulic ram (or rams) which oscillates the Fins.

It should be made clear that the Gyroscope only operates when the ship has angular velocity—that is, when it is rolling. So long as there is no angular velocity the Gyroscope remains in the central neutral position, and the Fins, therefore, remain in *their* neutral position.

So soon, however, as the ship commences to roll, the Gyroscope takes control, when the Fins take up their proper angles to resist movement from the vertical. At the end of a roll, when angular velocity ceases, the Fins return at once and automatically to the neutral position. Immediately thereafter the ship commences to roll back, when the Fins quickly assume the proper attitude to resist the return to the vertical. This sequence of operations continues so long as the ship continues to roll.

The Gyroscope is extremely sensitive, and can be arranged to bring the Fins into play even for very small angles of roll.

Plate 2 shows photographs of a large-scale model of a Fin in various positions.

THE CONTROL

The Stabiliser is controlled from the Bridge, the switch box being placed in any convenient position. The sequence of operation is as follows:—

1. The Captain, on deciding to put the Stabiliser into operation, presses a button, which sounds a gong near the gear and illuminates a panel reading "Start Stabiliser." The Engineer then starts the motor driving the pumps and starts the Gyroscope. So soon as full revolutions are reached, the Engineer presses a button, which illuminates a panel in the bridge box reading "Stabiliser Ready."

2. The Captain then closes a switch, which causes the Fins to protrude. About thirty seconds thereafter a panel in the box will light up, reading "Fins Out."

3. The Captain then closes a second switch. The Stabiliser comes under the control of the Gyroscope, begins to operate, and thereafter carries on automatically.

When it is desired to cease operating, the series of operations described in 2 and 3 above is reversed, when the Fins are retracted and the "Fins Out" panel goes dark. Finally, a "Stop Stabiliser" button is pressed. The gong sounds down below, the "Start Stabiliser" panel goes dark, and the "Stop Stabiliser" panel lights up. The Engineer then opens the switches to the motor and to the Gyroscope, when the "Stop Stabiliser" panel goes dark.

A special Testing Switch is fitted on the Bridge, enabling the Captain to control the movement of the Stabiliser Fins by hand. This switch, in a case separate from the remainder of the stabiliser control switches, only controls the Stabiliser when manually operated. The fins follow the motion of the switch and are not under gyro control. The fins return to zero position immediately the switch is released. By operating this control in synchronism with the natural rolling period of the ship, a roll may be built up in calm weather and then allowed to die down or be rapidly damped out by switching over to normal stabilised gyro control. A simple and convenient method of testing the Stabiliser is therefore always available.

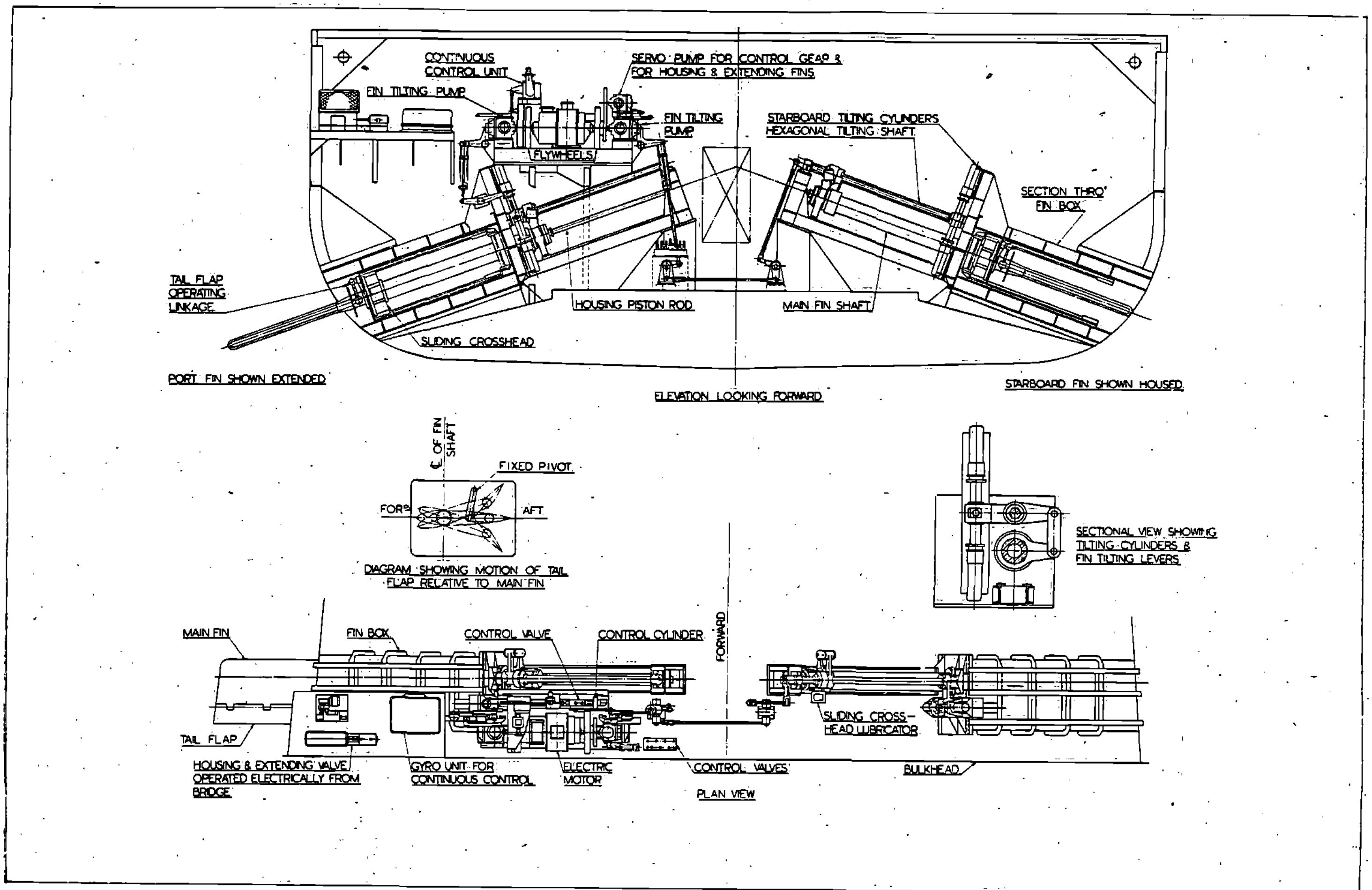
It is convenient at this point to discuss a fear sometimes expressed that, owing to maladjustment or damage to the gear, it may in service on some occasion operate so as to increase instead of to reduce rolling.

Experience of a large number of vessels has shown that there is no ground for such apprehension.

A remote possibility is that when in operation the Fins might jam, one fully up and the other fully down, and that all efforts to remedy this situation were ineffective. The result of such a misadventure would not be disastrous, but merely uncomfortable. If when the ship is proceeding at speed, the Fins are protruded and then rotated to the fully angled position *and held there*, all that happens is that a list of some 3° or 4° is produced. This test can be made at any time by use of the special Testing Switch provided.

On any assumption, it is impossible that the Stabiliser should endanger the ship. It is comprehensible that some nervousness should be felt either of a system where very large Gyroscopes dispose of immense stored energy, or of a system where masses of loose water are under more or less effective control. Both these features are absent from the Denny-Brown Stabiliser.

PLATE 3



CONTINUOUS CONTROL UNIT
SERVO PUMP FOR CONTROL GEAR & FOR HOUSING & EXTENDING FINS
FIN TILTING PUMP
FIN TILTING PUMP
FLYWHEELS
STARBOARD TILTING CYLINDERS HEXAGONAL TILTING SHAFT
SECTION THRO' FIN BOX
TAIL FLAP OPERATING LINKAGE
HOUSING PISTON ROD
MAIN FIN SHAFT
SLIDING CROSSHEAD
PORT FIN SHOWN EXTENDED
ELEVATION LOOKING FORWARD
STARBOARD FIN SHOWN HOUSED
℄ OF FIN SHAFT
FIXED PIVOT
FORD
AFT
DIAGRAM SHOWING MOTION OF TAIL FLAP RELATIVE TO MAIN FIN
SECTIONAL VIEW SHOWING TILTING CYLINDERS & FIN TILTING LEVERS
MAIN FIN
FIN BOX
CONTROL VALVE
CONTROL CYLINDER
FORWARD
SLIDING CROSS-HEAD LUBRICATOR
TAIL FLAP
HOUSING & EXTENDING VALVE OPERATED ELECTRICALLY FROM BRIDGE
GYRO UNIT FOR CONTINUOUS CONTROL
ELECTRIC MOTOR
CONTROL VALVES
BULKHEAD
PLAN VIEW

THE COST

The cost of the Stabiliser can be divided into two parts—technical and financial.

Technical.

This can be sub-divided into three sections:—

(*a*) Weight. (*b*) Space. (*c*) Power required.

(*a*) The weight of the installation can again be sub-divided into (i) weight and (ii) loss of buoyancy. The former comprises the weight of the Fins, Fin boxes, shafting and operating mechanism, while the latter arises from the fact that the recesses in which the Fins are housed are filled with water. This water can be regarded either as added weight or loss of buoyancy: from either angle the result is the same. It is the sum of (i) and (ii) that gives the total weight.

The weight is relatively small. For a passenger vessel of moderate dimensions and high speed it might amount to 30 tons, or say 1 per cent. of the average displacement. Corresponding figures for a 14-knot cargo and passenger liner might be 60 tons, or say .4 per cent.

It will be seen, therefore, that the weight of the installation is modest, and much smaller than that associated in the past with other types of Stabiliser of dubious efficacy.

(*b*) The space required is simply that necessary to accommodate the fin boxes, shafting and operating mechanism. In the passenger vessel mentioned in (*a*) above, each box is about 10 ft. 0 in. 'thwartships by 4 ft. 3 in. high by 4 ft. 9 in. fore and aft. From Plate 3 it will be seen that the top of the operating cylinder is about 6 ft. 6 in. above the bottom of the boxes. The controlling unit, comprising motor and pumps, can be conveniently accommodated above one of the boxes, while the few remaining items of control take up little space, and can be installed anywhere convenient adjacent to the main plant. The space above the other box may be utilised for any piece of auxiliary machinery that can conveniently be disposed in that position.

(*c*) The power required—as the weight—can also be sub-divided into two parts—(i) the power required to oscillate the Fins, and (ii) the power required, if any, to overcome the drag of the Fins.

The former is very small because the Fins are carefully balanced. It is provided by the main electric generators which furnish current to the electric motor driving the pump supplying the operating fluid under pressure.

The latter is provided by the main propelling engines of the ship, but it is not easy to be precise as to the amount required—if indeed any is required—because so many factors have to be taken into consideration.

In the first place it must be clearly understood that in no circumstances is it necessary to increase power to the extent required to overcome the whole drag. This follows from the important fact that less power is needed to drive an upright ship than a rolling ship.

In fact, if the drop in speed, due to the drag effect of operating fins, were the same as the natural drop in speed of the unstabilised ship when rolling, then no extra power at all would be required of the engine room.

A general statement is impossible, because the loss of speed in terms of rolling varies from one type of ship to another, and from one speed to another. As rough indications of what may be expected, it can be said that in the high speed passenger ship mentioned earlier the speed stabilised will not be less than that of the rolling ship, while in the cargo and passenger liner the reduction in speed might lie between one quarter and one half knot. It will be seen, therefore, that the power required from the main engines lies between nil and that necessary to retrieve a small reduction in speed.

Financial.

The period of experiment—indeed of rapid development—has been passed, and a basic design is now fundamentally established. The trend has been in the direction of simplification, in the reduction of the number of parts required, and in the ease with which the plant can be installed by the builder in the ship.

Each case must be considered on its merits. A slow ship will require larger Fins, and therefore a more costly outfit than will a faster ship. A very " stiff " ship will require a more powerful installation than will one with a more reasonable degree of stability.

As a guide, however, a Stabiliser in the fast passenger ship mentioned might increase the price of the ship by a little more than 2 per cent., while in the passenger and cargo liner the corresponding figure might be about 3 per cent.

THE RESULTS

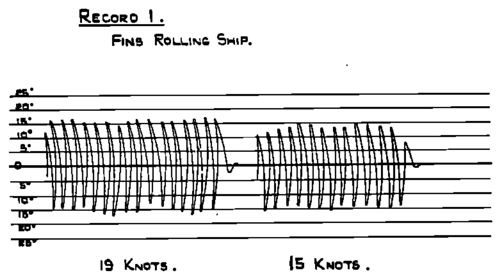
The performance of the Stabiliser at sea is the final evidence on which it should be judged. The Stabiliser has been freely adopted by the Admiralty, and acknowledgment is made here of the encouragement and help which they have given. Some unsatisfactory reports have been received from ships fitted with a now obsolete design, but these have usually been attributable to mechanical or electrical troubles. On the other hand, very satisfactory reports have been received from many ships, and it is fair to say that, where the gear has had an opportunity on all counts (installation, sea conditions and personnel) to prove its worth, it has given most valuable service. In many cases it has been operated continuously for days.

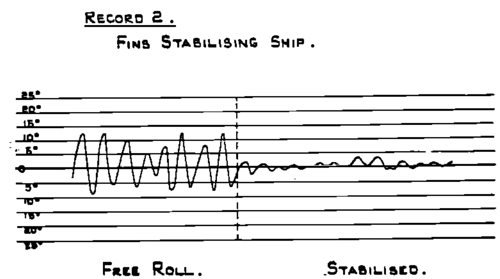
The records reproduced in Plate 4 are from results obtained at sea during the war and show the performance of the equipment under various conditions.

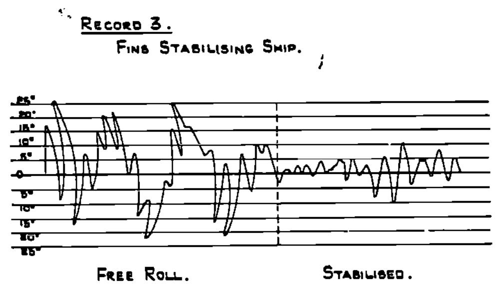
No. 1 is a record of forced rolling, i.e., the Stabiliser was hand operated, for test purposes as mentioned earlier in this booklet, so that it produced artificial rolling in calm water. Theory and experiment both show that a Stabiliser which can induce a certain degree of rolling in a calm sea will reduce natural regular rolling by about the same amount in a rough sea.

No. 2 is a record of stabilising in a fairly regular moderate beam sea, and, as can be seen, the rolling is eliminated for all practical purposes.

No. 3 is a record of stabilising in an irregular following sea described as "rough." Conditions were very bad, and even with the Stabiliser working there was an appreciable amount of rolling present; but when the Stabiliser was switched off the rolling was very heavy, and in fact the ship was almost out of control for a short time.







RECORD I. FINS ROLLING SHIP.

This record was obtained in smooth water by the use of hand control, through the special testing switch on the bridge.

RECORD 2. FINS STABILISING SHIP.

This record shows the effect of the stabiliser in conditions of fairly uniform rolling. A roll of 20° from out to out is substantially eliminated.

RECORD 3. FINS STABILISING SHIP.

In this case the very heavy and irregular rolling of the ship was produced by a confused following sea overtaking the ship on the quarter. Without the stabiliser the ship was difficult to control and in danger of broaching to. With the stabiliser working there was, as the diagram shows, a very material reduction in rolling movement and the ship was under control.

These records are for vessels around 300 ft. long and at speeds from 14 to 20 knots. It will be appreciated that the problem of stabilisation in this size of vessel is much more difficult than in heavier merchant ships, because, generally speaking, the larger the vessel the less the influence of the sea on it.

In the design of the Stabiliser each case must be treated individually in terms of the characteristics of the particular ship in question. Some of the gear, however, is common to all installations, and it will probably be found possible, as it is desirable, to work towards a certain degree of standardisation.

A usual standard for efficacy is to design the apparatus so that rolling may be reduced by about 20°. Thus, if when rolling freely the total arc of roll were 25°, then the use of the Stabiliser would reduce this to 5°. As pointed out earlier, no attempt is made, nor is it necessary, to work for absolute extinction of roll, as it is clear that a small residual roll of say 3° to each side of the vertical will not be deemed objectionable by the average passenger.

T.S.S. "FALAISE"

The following notes are of interest as giving the most recent results of a Denny-Brown Stabiliser ON SERVICE.

The "Falaise" is a Channel steamer, built for the Southern Railway Company, gross tonnage 3,710, speed 20.5 knots.

Reports received from the Masters of the s.s. "Falaise" regarding the working of the Stabiliser

Master A.B.C. 11/9/47

The Denny-Brown Stabiliser was brought into effective action this morning. Particulars are as follows:—Wind S. 3—4, Sea Smooth Long low swell from the westward, vessel rolling from 4° to 8°. 05.50 Stabiliser started and vessel immediately checked in her roll, bringing movement down to almost nothing, the moment of check could be observed. 06.50 ran out of swell and stopped Stabiliser. Small test but satisfactory.

Master A.B.C. 23/9/47

The Stabiliser apparatus was used at 06.11 a.m. until 07.05 a.m. Tuesday, 23rd. Vessel rolling up to 10° with a westerly swell; the Stabiliser was used and rolling reduced to practically nil.

Master D.E.F. 22/10/47

Wind S.W. 5, Sea 5, with a moderate long beam swell. Vessel rolling approx. 8°. Effect of Stabiliser immediately reduced the rolling to 2°.

Master D.E.F. 26/10/47

Wind East 7, Sea 6. With a moderate to heavy short steep swell. Vessel rolling approx. 12° and pitching considerably. Stabiliser used for a following sea and was at once effective by reducing the rolling to 4° maximum. The pitching also reduced. Its effect on the steering was at once noticed by the Quarter Master and greatly added to the steering power by maintaining the vessel on her course which otherwise was very difficult.

Master D.E.F. 26/10/47 **till** 27/10/47

Owing to stress of weather in harbour vessel put to sea, Wind E.N.E. 7.8, Sea 6.7, with a heavy steep average length swell, confused at times. Running before the wind and sea vessel pitched and rolled heavily at times. Steering was somewhat difficult. The Stabiliser when operated was immediately most effective, and almost completely steadied the vessel whilst proceeding at both half and slow speeds. With the Stabiliser in operation no difficulty was experienced in maintaining a reasonably good and steady course throughout the night under the influence of a gale, rough seas and heavy swell. Rolling and pitching and general motion of the vessel was very steady and comfortable.

Master D.E.F. 28/10/47

Wind East 6.7, Sea 6, with heavy average swell. Rolling almost ceased, pitching much reduced and vessel generally steadied immediately the Stabiliser was in action.

Master D.E.F. 2/11/47

Wind S.W. 5.6, Sea 4.5, moderate short swell weather. Vessel rolling easily but steadied soon as the Stabiliser was operated.

At times under the above weather conditions the vessel appeared to have a "cork-screw" motion which almost ceased when the Stabiliser was operated.

As a point of interest almost every time the Stabiliser was operated and unknown to most members of the crew, many of them remarked how they noticed at once the steadying effect it had on the vessel.

Especially interesting in the foregoing are the following points :—

1. The capacity of the Stabiliser to reduce the rolling to almost nothing.
2. That pitching was reduced.
3. That yawing was reduced, thereby improving steering.

It has sometimes been suggested that, while the D.B. Stabiliser is no doubt a most effective device when applied to small fast ships, it is not necessarily suited to larger vessels with a more moderate speed. This is quite incorrect. Actually the larger ship with its longer rolling period and its comparative freedom from buffeting in short or choppy seas is a better subject for stabilisation than is the smaller vessel.

T.S.S. "INNISFALLEN"

The "Innisfallen" is a Channel vessel built for the British and Irish Line and is in service between Cork and Fishguard. The particulars of the ship are—Gross Tonnage 3,700 ; Speed 19 knots.

The "Innisfallen" went on service in June 1948 and her normal service is one on which rough weather is frequently experienced.

The following reports have been received:

(1) **From the Superintendent Engineer,** 28/2/49

"I personally wish to say that from all reports, and from my own experience whilst travelling in the m.v. "Innisfallen," the Denny-Brown Stabiliser on our Cork/Fishguard Service is a great advantage to the travelling public, and is also a great help to us from the point of view of carrying livestock."

(2) **From the Master of the ship,** 6/12/48

"From records taken by me I have observed in a moderate Southerly Gale and rough beam sea a 12° roll reduced to 2°, and on other occasions a 5° to 6° eliminated.

On passage from Fishguard to Cork on Saturday, 6th November, in a S.E. Gale reported at Strumble Head to be in force 7 to 8 and high rough quarterly sea, what would have been an unpleasant passage was made without discomfort. Rolling was reduced from 12° and 14° to 2° and 3°, and yawing reduced to a minimum, which of course means good and easy steering.

Our latest and worst passage so far was on Wednesday 1st instant from Cork to Fishguard in a whole Southerly Gale and high rough beam sea. Due to there being no means of securing the First Class Smokeroom Chairs and Tables (they are not chained to the deck) I thought it unwise to stop the gyro control and carry out tests, but due to force of wind and sea the ship maintained a steady 4° port list and the Stabilisers gave a splendid performance under such conditions.

While they do, say, with a small roll 2 to 3°, reduce speed slightly, in my opinion they increase the speed in rough beam sea and heavier roll due to their efficiency in keeping the propellers in the water. They are trouble free and simple of operation taking only two minutes to put out or take in.

Another point I should perhaps mention is that horses are now successfully carried here when it would be most imprudent to ship them were it not for the Stabilisers."

(3) **From the Chief Engineer,** 24/2/49

"The ship came in to the Fishguard/Cork service on the 28th June, 1949, and until the present date the Stabiliser gear has functioned satisfactorily with a minimum of maintenance and has been free from mechanical defects."

T.S.S. "MAID OF ORLEANS"

Report received from the Master of the "Maid of Orleans" regarding the working of the Stabiliser—17/2/50.

I have to report that the Stabilisers have proved eminently satisfactory for the following reasons —

1. Vessel has been able to maintain scheduled times under weather conditions which would normally have necessitated a reduction in speed.
2. No course allowances have had to be made on account of weather.
3. Steering has been greatly improved both under bad weather conditions and in shallow water where steering is normally impaired.
4. The vessel's steadiness under bad weather conditions has materially added to the comfort of passengers and consequent popularity of Restaurant and Smoke Rooms.

T.S.S. "INVICTA"

Report received from the Master of the "Invicta" regarding the working of the Stabiliser—15/2/50.

During the last 10 days I have experienced a succession of westerly gales. The Stabiliser has been used during each passage and has reduced the ship's roll from sometimes 20° to 7°. (February 10th wind W.S.E. 8-9 a beam sea 7, swell 7).

Many of the passengers have remarked how steady the "Invicta" is during the crossing in heavy weather.

SHIPS FITTED WITH "DENNY-BROWN" STABILISER

British Admiralty

H.M. Battle Class Destroyers

2 Ships

H.M. DESTROYER "WOLFHOUND"

H.M. Hunt Class Destroyers

62 [redacted] Ships

H.M. Sloops

35 Ships

Royal Hellenic Navy

Hunt Type Destroyers

7 Ships

Royal Norwegian Navy

Hunt Type Destroyers

2 Ships

Merchant Ships

British Transport Commission

T.S.S. "Isle of Sark"

T.S.S. "Falaise"

T.S.S. "Maid of Orleans"

T.S.S. "Invicta"

T.S.S. "Falaise" (Repeat)

British & Irish Steam Packet Co. Ltd.

T.S.S. "Innisfallen"

P. & O. Steam Navigation Co. Ltd.

T.S.S. "Chusan"

Compagnie de Navigation Mixte

"Ville de Marseilles"

McCORQUODALE

STABILISING GEAR IN THE "CHUSAN"

DENNY-BROWN GEAR LARGEST STABILISER EVER FITTED

ONE OF THE most interesting features of the turbine steamship *Chusan*, the latest addition to the fleet of the Peninsular & Oriental Steam Navigation Co., Ltd., is that this 24,000-tons passenger liner is fitted with Denny-Brown stabilising equipment. Since the British Railways' cross-Channel passenger steamer *Invicta* conclusively demonstrated during her regular service the effectiveness of this stabilising equipment, a number of vessels, including other British Railways' ships, have been similarly equipped and rolling has been cut down to an appreciable extent. It is claimed that more than 100 installations are now in service and giving good results. More recently, arrangements were completed for the Denny-Brown stabiliser to be built under licence in the United States of America. Up to date the largest ship fitted with this equipment was of 3,600 tons displacement, but the installation of the Denny-Brown ship stabiliser in a vessel of 24,000 tons gross is proof, not only of the enterprise of the P. & O. Company in its efforts to offer greater comfort to passengers, but of the faith placed in the reliability of this equipment. It is believed that the stabilising equipment will reduce a roll of 14 deg. to one of 4 deg.

The stabiliser, manufactured by Brown Brothers & Co., Ltd., Edinburgh, consists of two rectangular fins—each 12 ft. by 6½ ft.—lying approximately in a horizontal plane, one on each side of the ship and projecting from the hull in the vicinity of the bilge. Each fin is mounted on a shaft arranged so that the fin is hydrodynamically balanced. When operating, the fins are tilted about their zero position and controlled so that their angular movements are equal and opposite. The forward velocity of the ship causes the water to exert an upward force on one fin and a downward force on the other, combining to damp down any roll imposed by wave action. The fins are retractable, and when not required can be withdrawn into recesses within the hull line. They are extended and housed by hydraulic machinery controlled from the bridge. When the machinery is operating to reduce the ship's roll, control is effected by two small gyroscopes, one measuring the angle and the other the velocity of the roll.

Fig. 1 shows the effect of a heavy sea on the port side tending to roll the ship to starboard. This causes the gyroscope, which is extremely sensitive, to operate the fins so that, before the roll can develop, the fins are angled until the starboard fin has a positive angle of attack—i.e., nose up—while the port fin has simultaneously a negative angle of attack—i.e., nose down. The forward velocity of the ship causes the water to exert an upward force on the starboard fin and a downward force on the port fin. These combined forces tend to roll the ship in the opposite direction to the roll caused by the wave action thus counteracting the force and considerably reducing the angle to which the vessel would otherwise have rolled. The Denny-Brown stabiliser is necessarily sturdy, reliable in operation and easy to operate. The sectional view, Fig. 2, illustrates the sequence of operation when the captain operates the "Start Motor" switch :—

This illuminates (A), the control panel on the bridge which registers on (B), the signal panel for the engineer to switch on (C)—the starters. This starts the motors for the servo unit (D) and (E), which is the main power unit, comprising variable delivery hydraulic pumps. The engineer then signals back to the bridge "Motors Running." By another switch on his panel, the captain then operates by remote control (F) the housing and extending control valve which admits oil from (D) to (G) which is the extending housing and cylinder ram. This pushes the fin (H) from its housed position in the finbox (J) to its working position as shown. When the fins are fully extended, the bridge is automatically signalled "Fins Out." The bridge then switches on (K), the gyro control unit which takes charge and, as the sea conditions cause the ship to roll, the gyro unit operates through electric and hydraulic relays, the tilting control valve (L) which is behind (D). The tilting control valve, through hydraulic and mechanical linkage, brings the pump in unit (E) into operation to deliver oil at high pressure to the tilting cylinders (M). These tilt the fin (H) *via* the tilting levers and shaft (N), the system being arranged to tilt the fins in opposite directions. When the fins are fully tilted, they automatically stop the oil delivery from the main pumps by means of the cut-off gear (P).

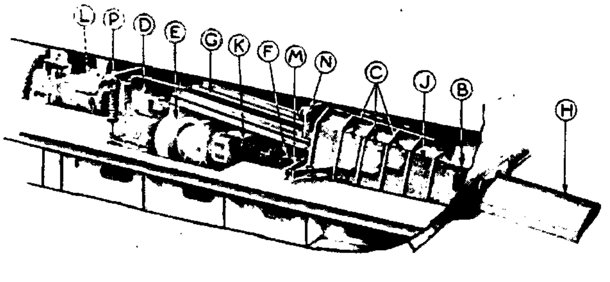


Fig. 2

The continued interest and increasing number of installations in vessels of all classes leaves little doubt as to the effectiveness of this ship stabilising equipment. Such an installation on so large a ship as the new *Chusan* must inevitably be the subject of special attention and its efficiency and reliability—if continued—will set a standard of comfort in sea travel which may well lead to the general adoption of ship stabilisers for all classes of passenger carrying vessels.

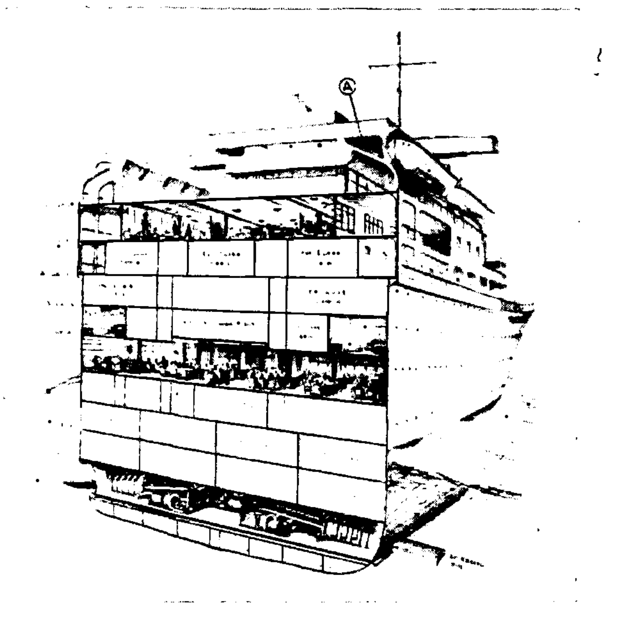


Fig. 1

Reprinted from THE TRIDENT, *August*, 1950.

The "Chusan's" Stabilisers

AN interesting technical feature of the *Chusan* is her Denny-Brown Stabilisers and particularly because she is the first large passenger liner to be fitted with them.

When the *Chusan* was on trials last June and approaching the Cumbraes, the passengers on board one of the Clyde Railway steamers, who were watching the new ship, must have had doubts as to whether they were seeing things, for the *Chusan* began to roll steadily about 34 degrees from side to side in a flat calm sea. There are those who were in the *Chusan* at the time who are prepared to say that the Railway Steamer altered course with the probable thought in the Captain's mind that something had gone wrong in the large ship and assistance would be required.

What was happening is quite simply explained; the leads to the gyros had been reversed and by doing this and operating manually the control switches, the ship was being made to roll by the action of the stabiliser fins. The purpose of the trials was to obtain technical information as to the hydraulic pressures in the tilting cylinders so that the torques in the fin shafts could be calculated.

The ship was rolled several times at various speeds from 14¾ knots to twenty knots and, when rolling, was allowed first to come out of the roll naturally, i.e. the roll gradually decreased, and then she was stabilised out of the roll. It was significant that when the stabilisers were brought into action to stop the roll, the roll ended immediately as the following rolling charts show:

(*a*) In this test the ship was rolling 35 degrees from side to side and the roll was allowed to decline naturally.

(*b*) In this test the ship was rolling 35 degrees from side to side and the roll was stopped by means of the Stabilisers.

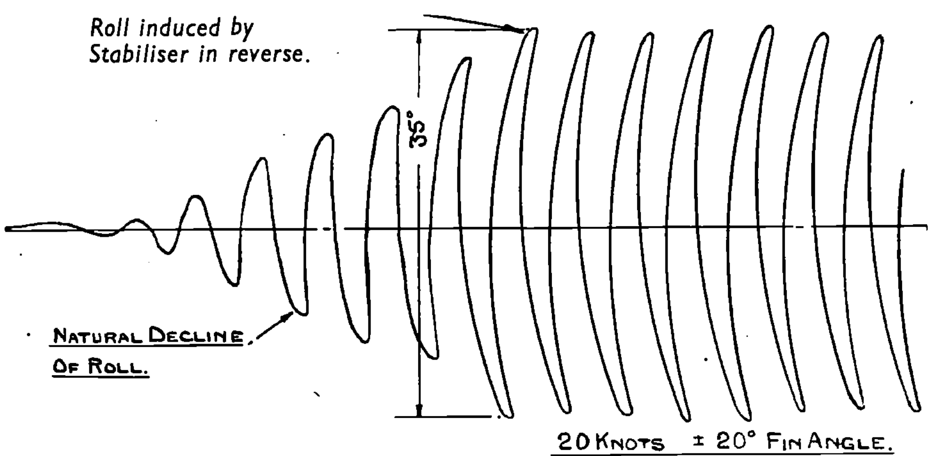
From the above records it will be apparent that the action of the stabilisers is immediately effective in stopping the roll even though it is artificially produced. In the same way, when the sea is causing the ship to roll, the stabilisers will have a steadying effect and will practically eliminate heavy rolling.

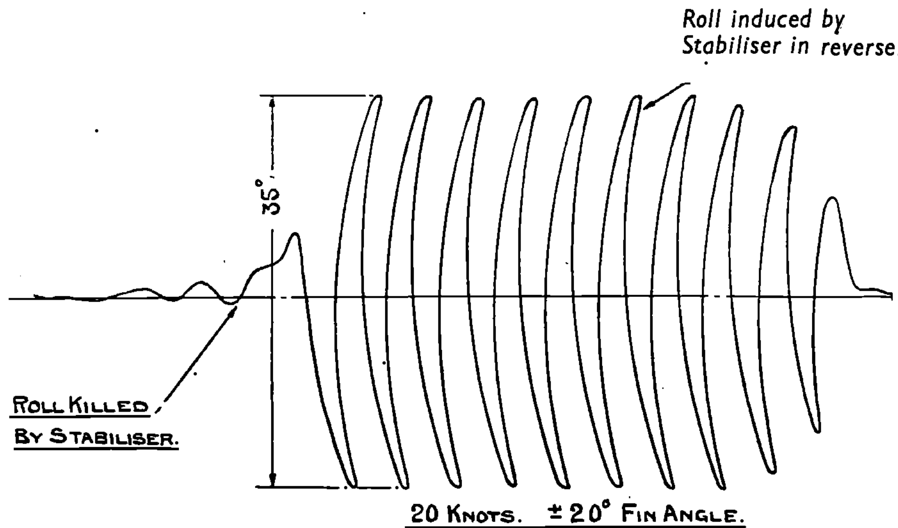
Mr. C. J. H. Goatley is the Chief Engineer of the "Chusan."

by "Navrig"

The *Chusan's* Stabilisers consist of two composite fins, one on each side of the ship. In action these fins project from the hull at about the position of the bilge keel and just forward of the boiler room. The fins are withdrawn into housings within the hull of the ship when not in use and are only extended if sea conditions cause the ship to roll.

Each fin measures 12 ft. by 6 ft. 6 ins., small by comparison with the effect. It is a composite structure consisting of a





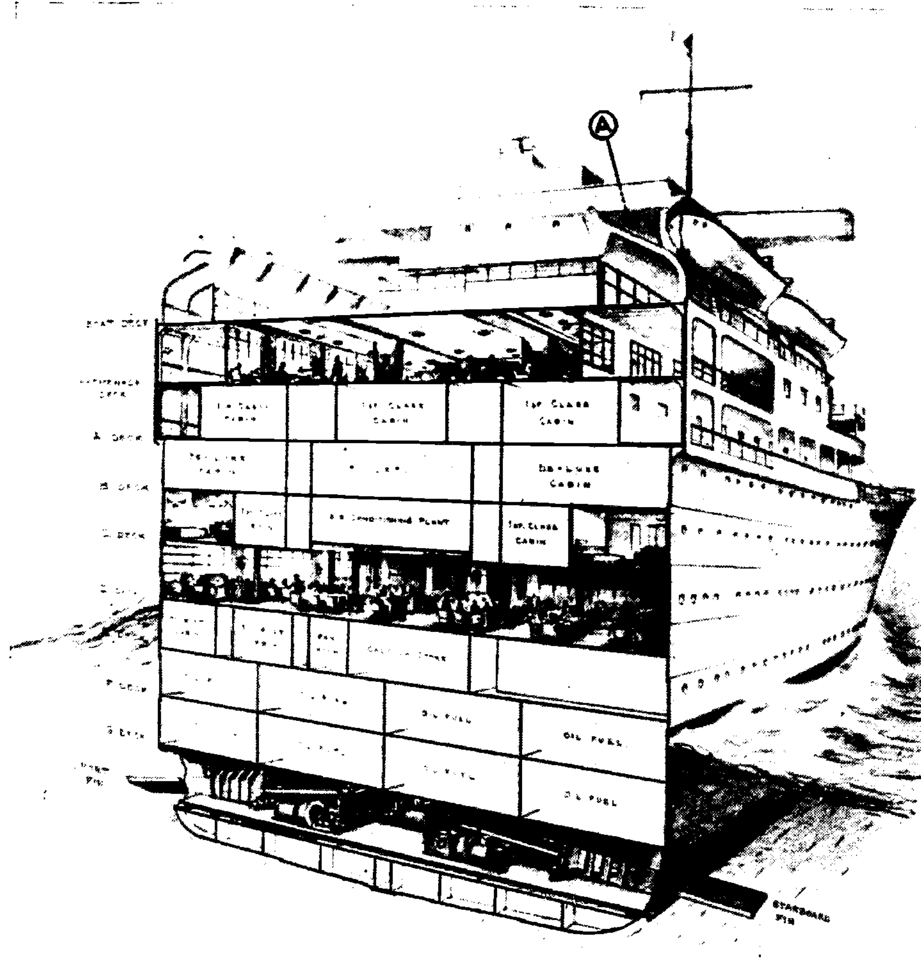
T.S.S. "Chusan" Stabiliser Trials, June 10th, 1950.

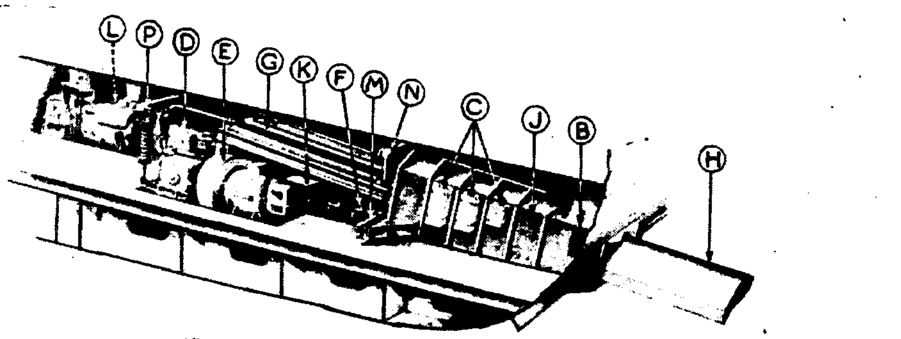
Above:

A. The ship was rolling 35° from side to side and the roll was allowed to decline naturally.

Right:

B. The roll was stopped by means of the Stabilisers.





When Stabilisers are required the Captain operates a switch " Start Motors " on : A, ORDER PANEL ON BRIDGE which registers on; B, SIGNAL PANEL. Engineer switches on ; C, STARTERS, to start motors for ; D, SERVO UNIT, and E, MAIN POWER UNIT, variable delivery hydraulic pumps. Engineer then signals back to Bridge " Motors Running." The Captain remotely operates, by another switch on his panel ; F, HOUSING AND EXTENDING CONTROL VALVE. This admits oil from D to G, EXTENDING AND HOUSING CYLINDER AND RAM, which pushes ; H, FIN, from its housed position in J, FINBOX, to working position as shown. When fins are extended fully, Bridge is automatically signalled " Fins out." The Bridge then switches on ; K, GYRO UNIT, which takes charge and as ship commences to roll due to sea conditions the Gyro Unit operates through electric and hydraulic relays ; L, TILTING CONTROL VALVE (behind D) which through hydraulic and mechanical linkage brings pump in Unit E into operation, delivering oil at high pressure to ; M, TILTING CYLINDERS. These tilt fin H via N, TILTING LEVERS AND SHAFT, the system being arranged to tilt fins in opposite directions. When fins are fully tilted they automatically stop the oil delivery from the main pumps by means of ; P, CUT-OFF GEAR. The sea pressure on the fins while the ship is moving through the water reduces and controls the roll of the ship. At the end of the reduced roll, the fins, controlled by the gyroscope, reverse and check the tendency of the ship to roll in the opposite direction.

main fin and tail fin. The tail fin has an angular movement in the same direction as the main fin but of greater magnitude. It has been proved that a fin of this design produces a lifting movement equal to that given by a plain fin of the hydroplane type twice the size.

The composite fin is mounted horizontally on a shaft in much the same way as a rudder is mounted vertically and the axis of the shaft is so arranged that the fins are practically balanced. Also they are so controlled that their angular movements are equal and opposite and the angle of each fin is reversed every time the ship alters the direction of her roll.

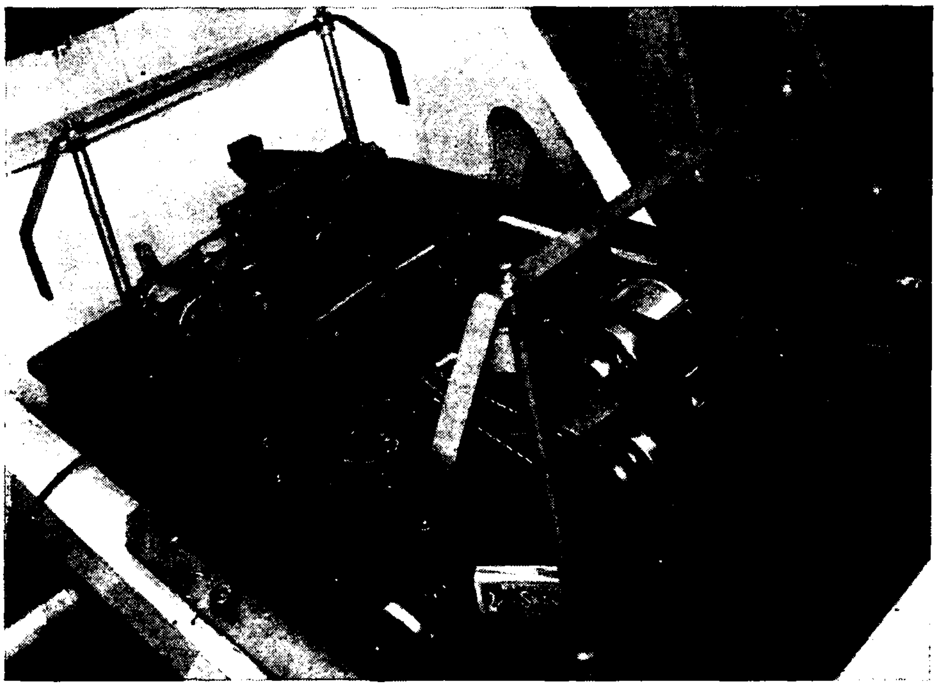
The fin movements are controlled by two gyroscopes ; one, a velocity gyro with its axis athwartships, responds to the speed of the roll and the other, a vertical gyro which measures the list of the ship. The gyros decide the actual time or roll position when the fins have to be tilted and also the amount of tilt to be applied to the fins.

The gyros are driven by alternating current from a small rotary converter and the vertical-keeping gyro acts as a pendulum measuring the angle of the roll and this measurement is communicated mechanically by means of two transmitters, one for " Beam Sea " and one for " Following Sea " conditions. The particular transmitter to be used can be selected by the gyro control switch on the bridge.

The velocity gyro, which measures the speed of the roll, is controlled by springs. As the ship rolls, this gyro operates a third transmitter which is electrically connected to either of the other two transmitters mentioned in the previous paragraph, and, as the ship approaches the limit of roll and the speed of the roll therefore decreases, operates the tilting mechanism which starts to reverse the direction of the fins one half second before the end of the roll. It will, therefore, be noted that, by the time the direction of roll is reversed, the angle of the fins has already been reversed to meet the new conditions.

Let us assume that the ship is running into weather rough enough to cause her to roll. The Officer on Watch presses a button that gives a signal to the Engineer Officer on Watch. This signal sounds a bell and illuminates the " Start Stabiliser " panel. The gyros and pumps are started and, as soon as they are up to the required speed, the Engineer presses a button which lights up a " Stabiliser Ready " panel on the Bridge. On receipt of this signal the fins are extended by means of a switch.

The whole operation takes about three minutes, at the end of which the fins are out in a horizontal position. They can now be brought under gyro control by means of a switch, after which the operation is entirely automatic.



GYRO CONTROL MECHANISM

The Vertical Gyro with its transmitter is on the left-hand side. On the right is the horizontal Gyro with its two transmitters for " Beam Sea " and " Following Sea " control. The mechanical connections between the horizontal Gyro and its transmitters can be clearly seen.

Now, consider the ship being rolled to starboard. Before the roll can develop, the fins are angled so that the starboard fin has a positive angle of attack, i.e. the forward side is pointing upwards and the port fin is angled in the opposite direction with the forward end pointing downwards. In this position the forward movement of the ship causes the water to exert an upward force on the starboard fin and a downward force on the port fin. These two forces acting on the hull of the ship tend to roll her to port and counteract the roll to starboard caused by the action of the sea.

When the gyros in the *Chusan* give the signal, the fins are moved through about forty degrees in one and a half seconds. The great advantage of this type of stabiliser is that the forward movement of the ship actually does the work and only sufficient power to angle the fins is necessary. The power for tilting each fin is hydraulic and is provided by a variable delivery pump driven by a fifty h.p. electric motor. Another automatically-controlled pump, driven by a fifteen h.p. electric motor, is needed for providing the pressure fluid used to amplify the signal from the gyro control and for extending and housing the fins.

The " Denny-Brown " scheme is not based on an entirely new idea. In 1898 a Mr. Wilson, a chemist of Stirling, took out a patent proposing to install in a ship oscillating fins placed on each side to damp out rolling and also at the bow and stern to damp out pitching. As far as is known, his patent was never applied to any vessel. Over the years many patents with the same general idea were taken out but the only application to a ship prior to the advent of the " Denny-Brown " installation was made in Japan to the designs of Dr. Motora.

Results obtained with this apparatus were far from perfect, due mainly to the limitations of the fin control mechanism, for the Japanese Engineers could not provide the means necessary to produce the rapid fin movement which was essential for success, particularly for any ship rolling with a short period. It was, however, apparent that progress had been made and the search for a perfect anti-rolling ship was pursued with greater enthusiasm than ever.

Between the two wars Messrs. Brown Bros. continued to search for the ideal and, as a result of close collaboration with the Shipbuilders, Messrs. Denny Bros. of Dumbarton, they produced the " Denny-Brown " Stabiliser. The first installation was fitted in the Channel steamer *Isle of Sark* in 1936. The installation had to be adapted to suit an old ship and could not be considered ideal; nevertheless the owners were more than satisfied with the performance, so much so that they decided to fit a stabiliser in their next new ship. Unfortunately the war intervened and, although the stabiliser was partially completed, it was not fitted because the ship had to go on war service as quickly as possible with no time to spare for fitting what was then considered to be a luxury.

Now the rolling of a ship can be a nuisance to the passenger but in a small warship, say a sloop or a destroyer, rolling can be a nightmare for the Gunnery Officer. It is no easy task, in any case, to hit the periscope or even the conning-tower of a submarine but when the guns are mounted on a platform that rolls as the sea dictates, then the chances of a direct hit are very chancy indeed.

The Admiralty was well aware of

Right :

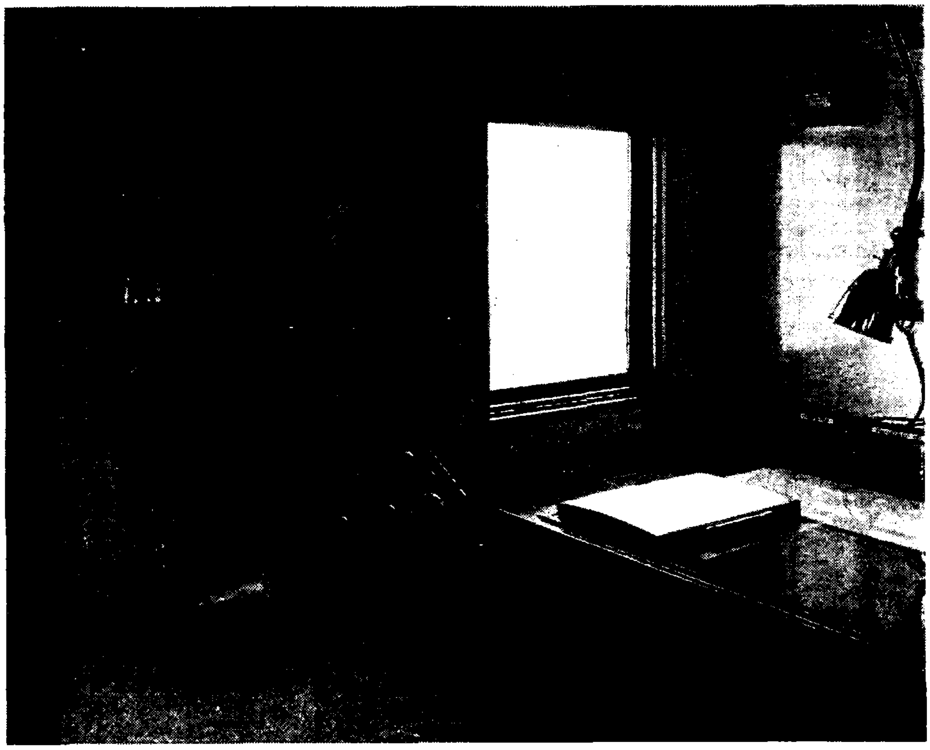
The " Chusan " in Dry Dock with the Starboard Stabiliser fin extended in the horizontal position.

Right :

Stabiliser Control on the Bridge. A detailed description of the method of operating the Stabiliser Fins is given earlier in this article.

Below :

Fitting the Stabiliser Fins in the "Chusan."



this fact and when it became known that the *Isle of Sark's* stabilising installation had been so successful, Messrs. Brown Bros. were commissioned to fit a stabiliser in the sloop *Bittern.* By 1939 extensive tests had satisfied the Admiralty that the idea was sound and during the war 109 ships, mostly sloops and destroyers, were so fitted. The performance of these installations was so good that the Gunnery Officer could always have his gun platform practically stable. Incidentally, it was the practice of sloop and destroyer Commanders to roll their ships artificially when entering the base port after a successful encounter with German submarines.

War, as is well known, accelerates progress in things mechanical and the stabiliser was no exception. By VE-Day the latest types gave evidence of the improvements which had been made, particularly in the fin design and control mechanism.

However, research into ship conditions and fin design continued to be carried out at the experimental tank at Denny's of Dumbarton. (For the technically-minded reader much information is contained in a Paper given before the Institution of Naval Architects in 1945 by Mr. Allan, late Chief of Denny's Experimental Tank.)

Previous to these experiments, the fin of the stabiliser had been designed in one piece much the same as the hydroplane of a submarine but, as the experiments proceeded, it became more and more apparent that seamen had something to learn from aircraft manufacturers and after many alterations the fin in its modern form was produced. It is really two fins and in appearance resembles an aeroplane wing, the smaller or after part hinged to the main fin increasing the lift in the same manner as the aeroplane landing flaps increase the lift at low speeds.

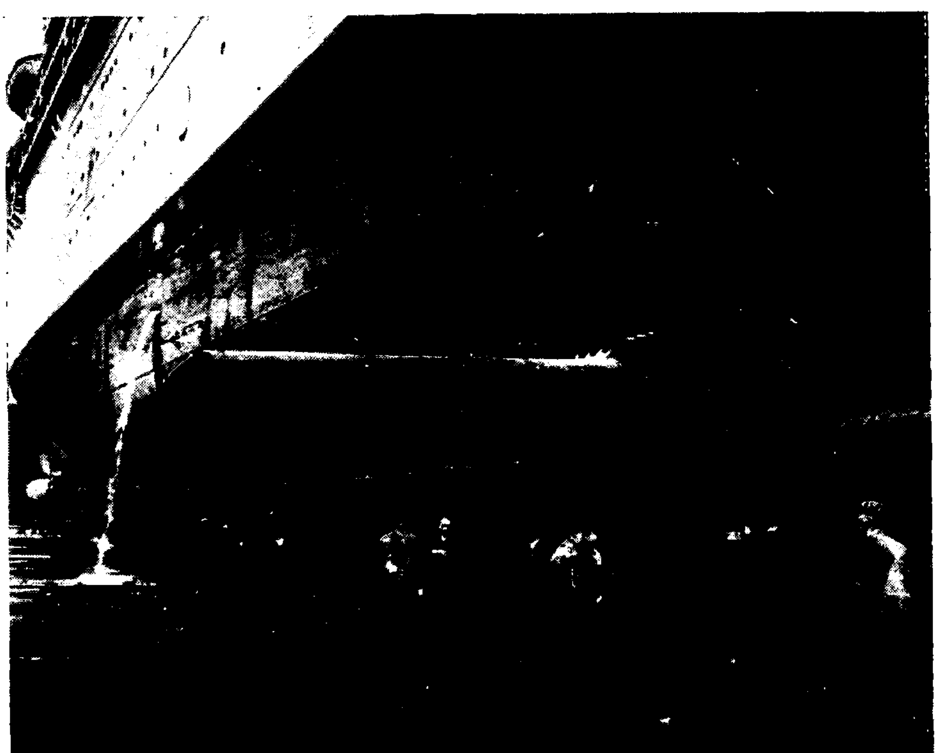
As we said at the beginning of this article, the 24,000 ton *Chusan* is the first large passenger liner to be fitted with these stabilisers so that their performance will be watched with great interest. Their installation is undoubtedly a contribution to the advancement of British Shipbuilding.

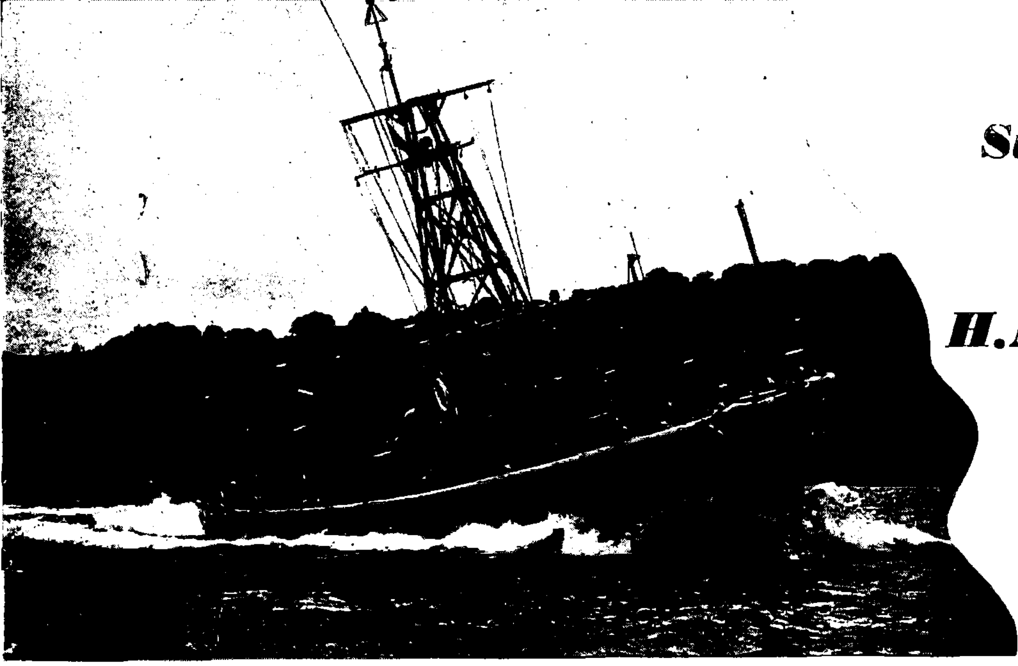
The *Chusan's* Stabilisers were Designed, Constructed and Installed by

BROWN BROTHERS & COMPANY LIMITED, ROSEBANK IRONWORKS, EDINBURGH.

Naval Architects—

WILLIAM DENNY & BROTHERS LIMITED, DUMBARTON.





Stabiliser Trials on H.M.S. REEDHAM.

DENNY - BROWN.

A RECENT contract carried out by Saunders-Roe (Anglesey) Limited has been the fitting of H.M.S. *Reedham* with Denny-Brown/Saunders-Roe retractable Stabilisers of Mark I design. This craft which is an Admiralty Minesweeper of all wood construction has a waterline length of 100 ft., a maximum beam of 21 ft. 3 in., and a displacement of approximately 165 tons.

The activated fins of the stabiliser unit have an outreach of 3 ft., a chord length of 1 ft. 6 in., an area of 4·5 sq. ft., and are angled at 32° to the horizontal in the athwartships direction.

To prove the effectiveness of the installation, forced rolling trials were carried out in calm weather followed by stabilising trials under rough weather conditions with the following results:

Forced Rolling Trials

These trials were carried out on a calm day, with a slight sea, over a measured mile course in the Menai Straits. At four engine settings of 550, 700, 850 and 990 r.p.m. speeds were measured with the fins retracted within the hull, after which the runs were repeated at the same engine settings with the stabiliser fins extended, but not operating. A further series of runs was made with the fins operating, during which measurements were made of the total amplitude of the forced roll induced on the vessel—usually referred to as the out-to-out roll amplitude.

Results

It was shown by these trials that a speed loss of only 0·06 knots was sustained when operating with the fins extended (but static) as compared with operation with the fins retracted into the hull.

At the various engine settings, the following roll amplitudes were measured:

Mean Engine r.p.m.	*Mean Forced Roll Amplitude*
550	18½°
700	23½°
850	27½°
990 (full speed of vessel)	29¾°

Conclusions

The results show that the drag induced by the stabiliser fins is extremely small and may be considered as having negligible effect on the top speed of the boat.

The roll amplitudes measured at the four engine settings are a noteworthy demonstration of the effectiveness of the stabilising equipment, since they indicate the degree of roll which would have been damped out had the boat been proceeding in heavy seas with the gyroscope performing normally and actuating the fins to produce a damping effect.

Stabilising Trials

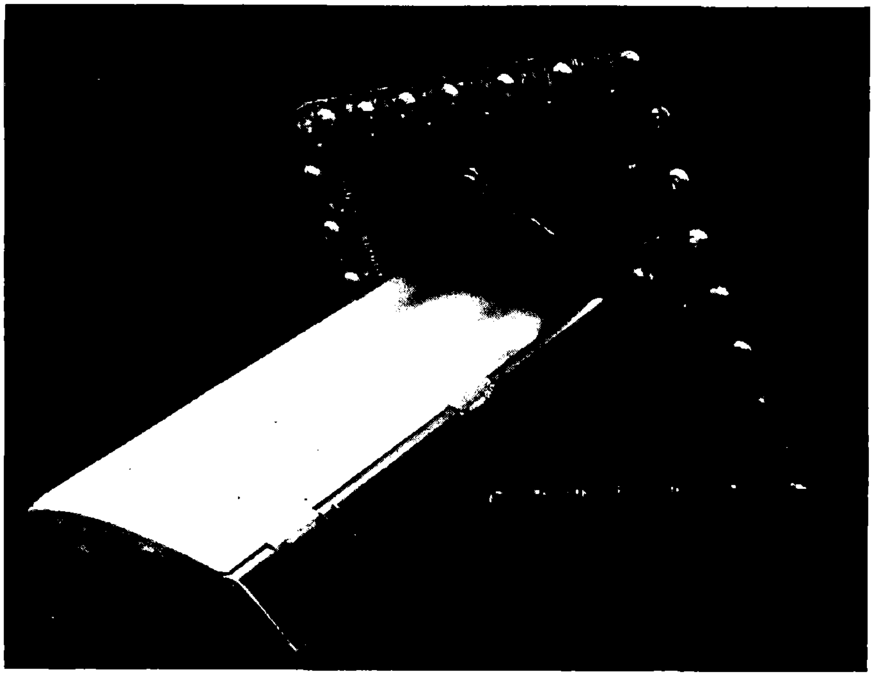
These trials were carried out in Llandudno Bay when the wind force was between 6 and 7, with the sea rough and confused.

For half of the trials, a straight course was steered with the sea running approximately 30° abaft the beam. The second half of the programme was performed over the reciprocal course.

Method of Procedure

During the trials, the procedure was to allow the vessel underway to roll freely for approximately 10 minutes with the fins housed and then to extend the fins for about two minutes to assess their effect as bilge keels. Fin stabilising was then started and continued for a 15-minute period followed by a two-minute period with the fins non-operative and acting as bilge keels. On retraction of the fins, a further 10 minutes' running was performed with the fins retracted. Trials were performed at engine speeds of 700 and 1,000 r.p.m., automatic recording equipment being used to measure the roll of the boat and the corresponding operating angle of the fins.

It was felt that this technique would make possible



Stabiliser fin extended; masking plate is removed to show strain gauging.

the most accurate assessment of the performance of the equipment, by comparing the results achieved during the stabilised run with the performance of the boat rolling freely, both immediately before and immediately following the run.

Results

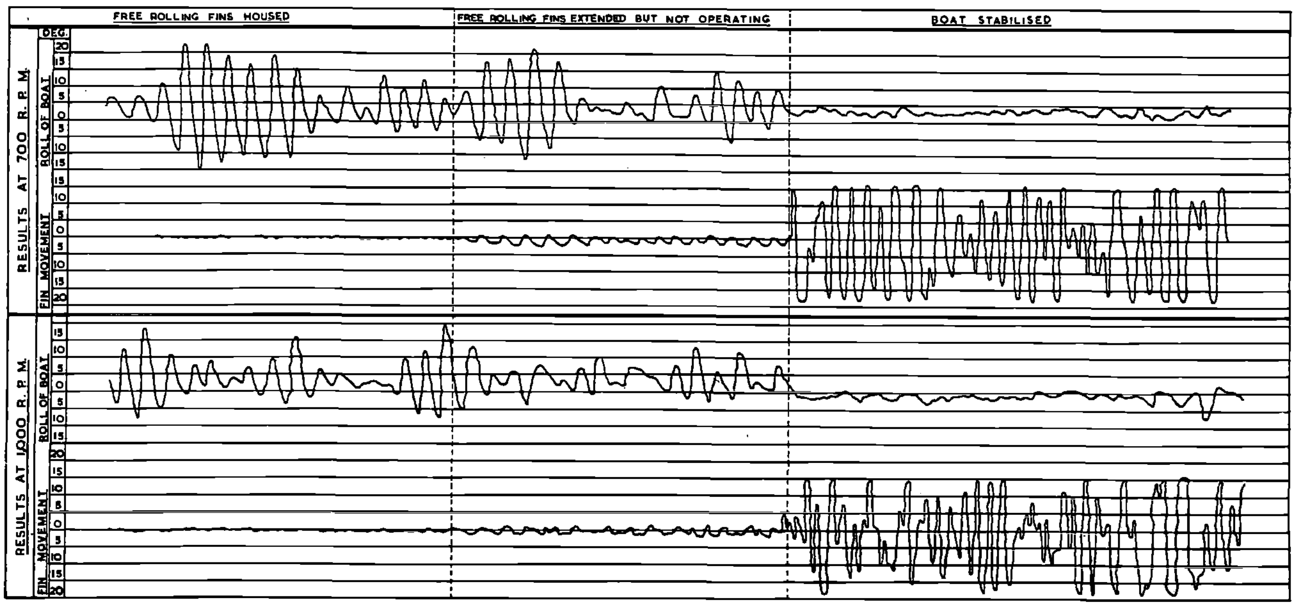
The trials were conclusive in demonstrating the effectiveness of the stabilisation. With the equipment in operation it was possible at all times to move freely to any part of the boat and for the crew to perform effectively. On the other hand, with the boat unstabilised, any movement of personnel was extremely hazardous, and it would have been impossible under such difficult conditions for a crew to have operated effectively had the boat been performing its normal service duties.

During the unstabilised trials, roll amplitudes of up to 37° were recorded, but with the stabilisers operating a peak roll amplitude of 10° was sustained only very occasionally. Generally speaking, the boat proceeded during stabilised running at a roll amplitude of 2°–3°. The records shown below were obtained at 700 and 1,000 r.p.m.:—

Conclusions

Extreme wind and sea conditions during the trials subjected the equipment to a most searching test, and it can be stated confidently that the results show the outstanding advantages obtainable on small craft which have been stabilised adequately.

The primary impression of naval observers present during the trials was of the enormous improvement in efficiency of the crew with the stabilisers in operation as compared with their effectiveness when the vessel was free to roll. In addition during the trials programme the advantage gained by having fully retractable fins was very apparent, especially when the vessel was being docked or moored.



PARTICULARS OF PIPES			
REF.	MATERIAL	BORE	OUTSIDE DIA.
A	STEEL	2·75"	3·5"
B	"	1·5"	2"
C	"	1·25"	1·75"
D	COPPER	2·5"	2·732"
E	"	1·25"	1·41"
F	"	·5"	·687"
G	"	·375"	·5"
SIZE 24 PUMP CIRC. PIPES	"	2"	2·208"
SIZE 6 PUMP CIRC. PIPES	"	1·25"	1·41"
OIL FILLING PIPES.	"	·5"	·687"
AIR RELEASE PIPES	"	·375"	·5"
PRESS. GAUGE PIPES	"	·25"	·375"

S.S. "CHUSAN."

"DENNY-BROWN" SHIP STABILISER
DIAGRAM OF HYDRAULIC SYSTEM.

D	ALTERATIONS & OR ADDITIONS.	BY	DATE
C	ALTERATIONS & OR ADDITIONS.	BY	DATE
B	ALTERATIONS & OR ADDITIONS.	BY	DATE
A	ALTERATIONS & OR ADDITIONS.	BY	DATE

DRAWN BY		18·11·48
TRACED BY		2·12·48
CHECKED BY		12·12·48
DRAWER NO		E 64

NOT TO SCALE.

DRG. NO. H793.

IARGE NO:- H2714.

MESSRS VICKERS-ARMSTRONGS LTD. T.S.S. "CHUSAN."

"DENNY-BROWN" SHIP STABILISER.
KEY WIRING DIAGRAM.

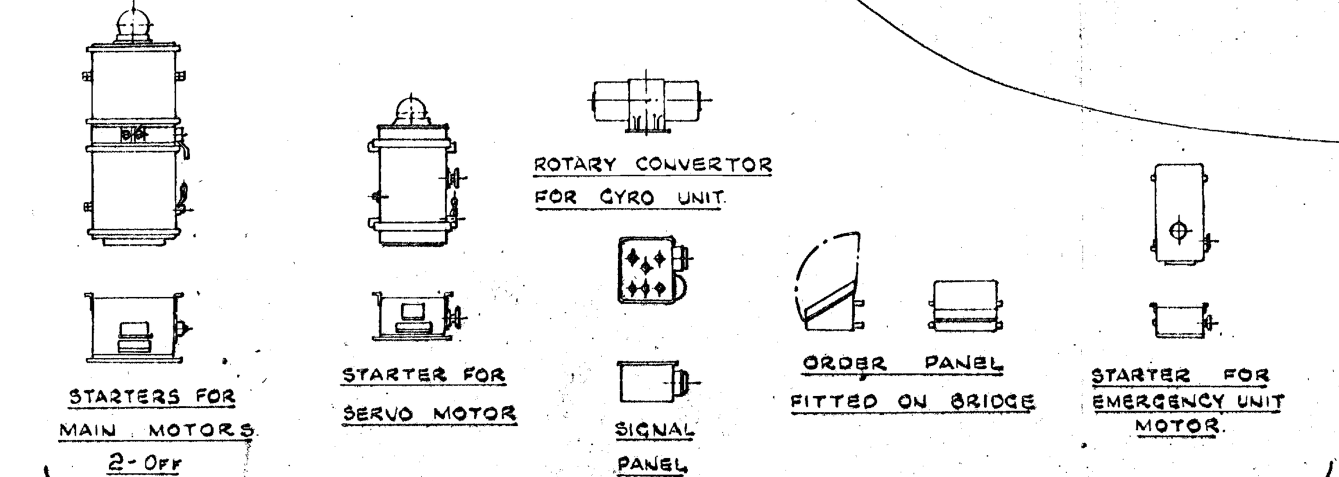
A	ALTERATIONS &/OR ADDITIONS.
	STARTER FOR EMERGENCY PUMPING UNIT MOTOR ADDED.
BY	DATE 18-11-49

DRAWN BY	G.W.O.	15-8-49
TRACED BY	R.M.H.	23-8-49
CHECKED BY		26-8-49
DRAWER NO		E64

DRG. NO. H574.

ARGE NO. H 2714.

ELEVATION LOOKING FORWARD.



THESE TO BE PLACED IN ANY CONVENIENT POSITION.

PLAN

ARROWS INDICATE DIRECTION OF MOTION WHEN STABILISING A ROLL TO PORT.

WORKING ANGLE OF FINS	MAIN FIN	20°
	TAIL FLAP TO MAIN FIN	30°
OUTREACH OF FINS		12'-0"
FORE & AFT WIDTH OF FINS		6'-6"
AREA OF ONE FIN		78 SQ. FT.
APPROX. TIME TO EXTEND FINS		125 SECS.
APPROX. TIME TO HOUSE FINS		80 SECS.
DIA. OF TILTING CYLINDER RAMS		8.5"
MAX. TORQUE OF TILTING CYLINDERS (AT 20°)		77 FT. TONS
HYDRAULIC PRESSURE EQUIVALENT TO MAX. TORQUE		1250 LBS/□"
WORKING STROKE OF TILTING CYLINDER RAMS (20°)		22.598"
STOP STROKE OF TILTING CYLINDER RAMS (21½°)		24.5"
"V.S.G." VARIABLE DELIVERY PUMPS	SERVO PUMP (1-OFF)	SIZE 6 MARK III
	TILTING PUMPS (2-OFF)	SIZE 24 MARK III
ELECTRIC MOTORS CONTINUOUS RUNNING NON-REVERSING	SERVO MOTOR	15 B.H.P. 220 VOLTS 400 R.P.M.
	MAIN MOTORS	50 B.H.P. 220 VOLTS 465 R.P.M.

PIPE SIZES

REF.	BORE	OUTSIZE DIA.	MATERIAL	LOCATION
A	2.75"	3.5"	STEEL	TILTING CYLRS. TO TILTG. PUMPS
B	1.5"	2"	"	SERVO PRESSURE & RETURN
C	1.25"	1.75"	"	HOUSING & EXTENDING
D	2.5"	2.732"	COPPER	SERVO PUMP SUCTION
E	2"	2.208"	"	SIZE 24 PUMP CIRCULATING
F	1.25"	1.41"	"	SIZE 6 PUMP CIRCULATING
	& EMERGENCY UNIT OIL TANK TO SERVO UNIT OIL TANK			
G	.5"	.687"	COPPER	AUTO CONTROL, OIL FILLING
				& EMERGENCY UNIT.
H	.375"	.5"	"	LUBRICATION & AIR RELEASE
J	.25"	.375"	"	PRESSURE GAUGES.

RGE NO. H 2714.

D ALTERATIONS & OR ADDITIONS	C ALTERATIONS & OR ADDITIONS	B ALTERATIONS & OR ADDITIONS	A ALTERATIONS & OR ADDITIONS
			HOUSING & EXTENDING CUSHIONING VALVES ADDED
BY DATE	BY DATE	BY DATE	BY B.W.G. DATE 10-1-50

S.S. "CHUSAN".

"DENNY-BROWN" SHIP STABILISER. GENERAL ARRANGEMENT.

DRAWN BY	B.W.G.	12-10-49
TRACED BY	I.D.G. & M.Y.C.	15-11-49
CHECKED BY	M.	16-11-49
DRAWER No.		EG4

SCALE:- 3/8" = 1 FOOT.

DRG. No. H.716

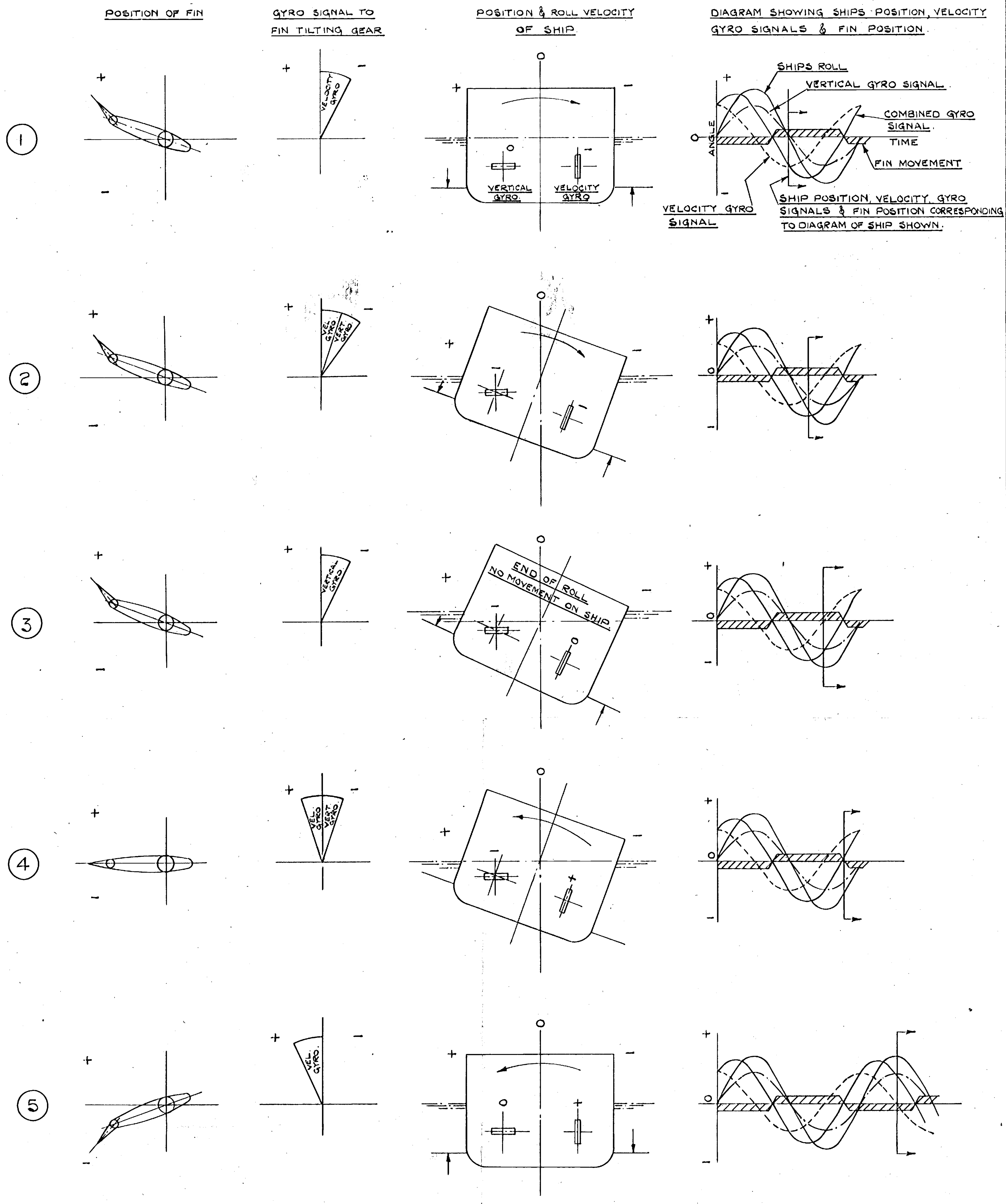
A.	ALTERATIONS & / OR ADDITIONS.
BY	DATE

METHOD OF OPERATING TAIL FLAP

DRAWN BY	B.W.O.	9-12-49
TRACED BY	I.O.O.	20-1-50
CHECKED BY	B.W.O.	10-2-50
DRAWER Nº		E.62

SCALE:- 3" = 1 FOOT

DRG. Nº H.816.



"DENNY - BROWN" SHIP STABILISER
DIAGRAM SHOWING OPERATION OF CONTINUOUS CONTROL GEAR
"FOLLOWING SEA" SETTING.

CASE	SHIP POSITION	GYRO SIGNALS			FIN.
		VERTICAL	VELOCITY	COMBINED	
1	VERTICAL: ROLLING TO −	O	−	−	RESISTING ROLL TO −
2	ANGLED TO −: ROLLING TO −	−	−	−	" " " −
3	" " −: END OF ROLL NO ROLL VELOCITY	−	O	−	" " " −
4	" " −: ROLLING TO +	−	+	O	AT MID.
5	VERTICAL : " " +	O	+	+	RESISTING ROLL TO +

Retd. to D.O. 27/11/50

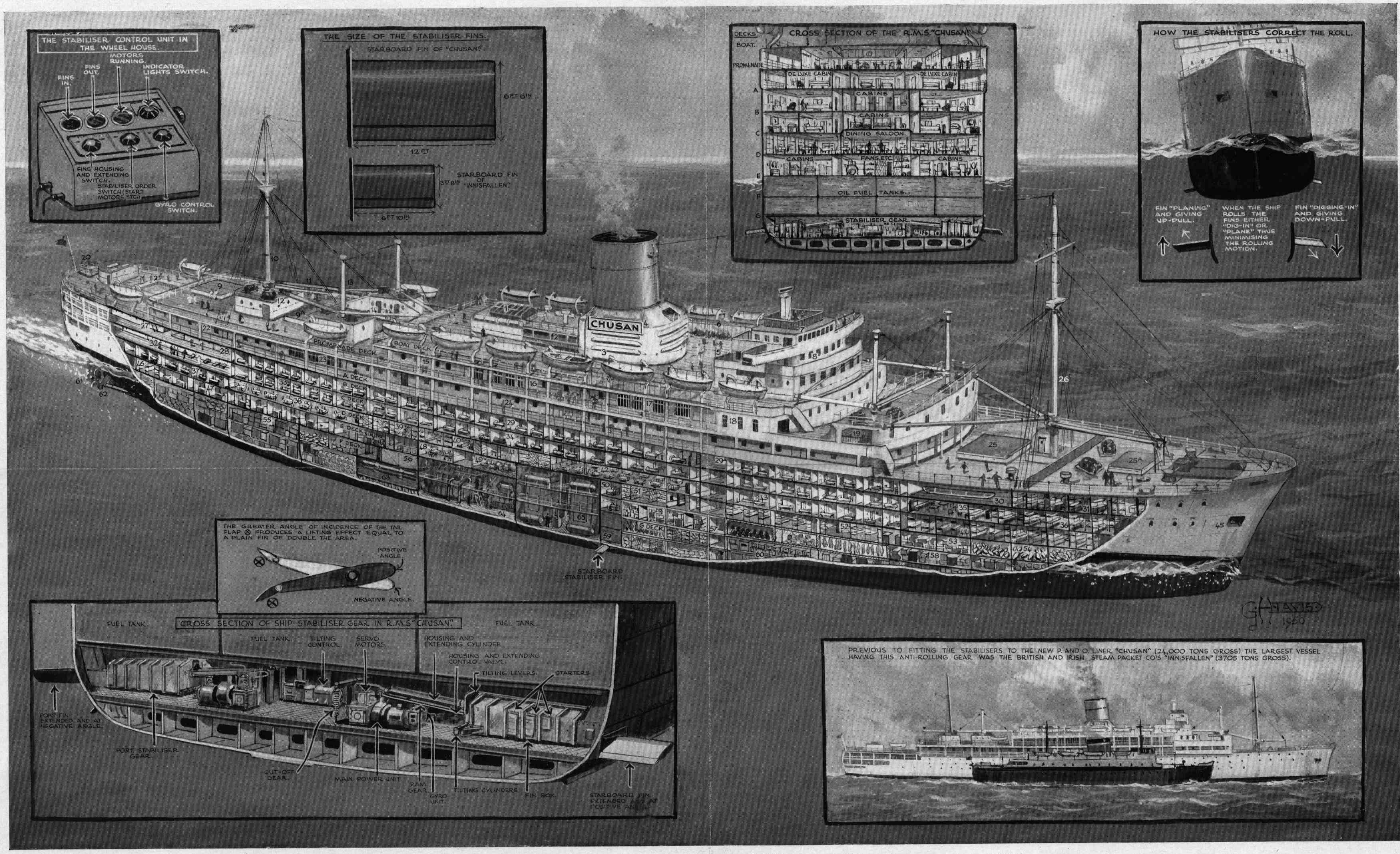
BROWN BROS. & CO. Ltd.
ENGINEERS
EDINBURGH
DRAWING No.
DATE 17-11-50.
ISSUED BY AW.

S.S. 'CHUSAN'
STABILISER TRIALS
12 JUNE 1950.
DISPLACEMENT 22,500 TONS.
FIN MOVEMENT.
SHIP MOVEMENT
STABILISED ROLL.
NATURAL DECLINE OF ROLL
20 KNOTS ± 20° FIN ANGLE.
PORT FIN RETRACTED, STARBOARD FIN EXTENDED. FIN 2 SEC. H.O. TO H.O.
TIME
10 SEC.
20 KNOTS ± 16° FIN ANGLE.
BOTH FINS OPERATING. FINS 2 SEC. H.O. TO H.O.
20° 15° 10° 5° 0° 5° 10° 15° 20°
SHIP'S ROLL.
S.S. 'CHUSAN'
STABILISER TRIALS
10 JUNE 1950.
DISPLACEMENT 21,000 TONS.
STABILISER STOPPED BY ORDER FROM BRIDGE
35°
NATURAL DECLINE OF ROLL
FIN MOVEMENT
SHIP MOVEMENT
STABILISED ROLL
STABILISE
"FOLLOWING SEA" CONTROL
"BEAM SEA" CONTROL
HAND CONTROL
20 KNOTS ± 20° FIN ANGLE
BEAM SEA CONTROL FINS 2 SEC. H.O. TO H.O.
TIME
10 SEC.
20 KNOTS ± 16° FIN ANGLE
FINS 2 SEC. H.O. TO H.O.
20° 15° 10° 5° 0° 5° 10° 15° 20°
SHIP'S ROLL.
S.S. 'CHUSAN'
STABILISER TRIALS.
10 JUNE 1950.
DISPLACEMENT 21,000 TONS.
FIN MOVEMENT
SHIP MOVEMENT
NATURAL DECLINE OF ROLL.
STABILISED ROLL.
STABILISED ROLL.
NATURAL DECLINE OF ROLL
TIME
10 SEC.
17 KNOTS ± 20° FIN ANGLE
FINS 2 SEC. H.O. TO H.O.
17 KNOTS ± 16° FIN ANGLE
FINS 2 SEC. H.O. TO H.O.
17 KNOTS ± 12° FIN ANGLE
FINS 2 SEC. H.O. TO H.O.
20° 15° 10° 5° 0° 5° 10° 15° 20°
SHIP'S ROLL.
FIN MOVEMENT
SHIP MOVEMENT
NATURAL DECLINE OF ROLL
15 KNOTS ± 20° FIN ANGLE
FINS 2½ SEC. H.O. TO H.O.
15 KNOTS ± 20° FIN ANGLE
FINS 2 SEC. H.O. TO H.O.
NATURAL DECLINE OF ROLL.
15 KNOTS ± 20° FIN ANGLE
FINS 4 SEC. H.O. TO H.O.
GYRO CONTROLLED SENSITIVITY ADJUSTED LATER.
HAND CONTROLLED.
FIN MOVEMENT.
STABILISED ROLL
SHIP MOVEMENT.
15 KNOTS ± 16° FIN ANGLE
FINS 4 SEC. H.O. TO H.O.
GYRO CONTROLLED, SENSITIVITY ADJUSTED LATER.
HAND CONTROLLED.
15 KNOTS ± 12° FIN ANGLE
FINS 4 SEC. H.O. TO H.O.
COMMENCEMENT OF RECORD.
SHIP'S ROLL.
S.S. 'CHUSAN'
STABILISER TRIALS
10 JUNE 1950.
DISPLACEMENT 21,000 TONS.
NOTE:- PENS ARE STATIONARY, PAPER MOVES IN THIS DIRECTION.

Reprinted from "THE ILLUSTRATED LONDON NEWS," *June 17, 1950.*

STABILISING A LUXURY LINER: R.M.S. *CHUSAN* (24,000 TONS GROSS), 1950's LARGEST NEW PASSENGER SHIP AND THE BIGGEST YET TO BE FITTED WITH STABILISING GEAR—HER LAYOUT AND EQUIPMENT.

Designed and Constructed by: BROWN BROTHERS & COMPANY LTD., ROSEBANK IRONWORKS, EDINBURGH. *Naval Architects:* WILLIAM DENNY & BROTHERS LTD., DUMBARTON.



July 1 is the date arranged for the maiden voyage of the R.M.S. *Chusan* (24,000 tons gross), the largest passenger liner completed anywhere in the world in 1950. The ship, which has been designed by the P. & O. Company for their Europe-Far East service, has been built at the Barrow-in-Furness yard of Vickers-Armstrongs, Ltd. She was ordered in May, 1946, the keel was laid in February, 1947, and she was launched on June 28, 1949. She will have taken two years and four months to complete and the estimated cost is £3,250,000. A singularly beautiful ship, she has a white hull, two masts and a single buff funnel. Ventilation units are enclosed within the deck-houses, and her name is installed in neon lighting on the port and starboard sides of the base of the funnel. Of 24,000 gross tonnage, she is 672 ft. in overall length, her engines develop 42,500 s.h.p., and she has a speed of 22 knots in service conditions. The accommodation is for 475 first-class passengers, 551 tourist-class and 572 crew, with a general cargo space of 415,000 cubic feet. The accommodation (for both passengers and crew) has been planned to modern concepts for coolness and airiness during tropical travel, but still to maintain the amenities and requirements for comfort in the more temperate and changeable climate of the Western Hemisphere. Fine public rooms and games facilities are a feature.

[*Continued opposite.*

KEY TO FIGURES

BOAT DECK

1. Engine-room hatch.
2. Dome over dance space.
3. Vents grouped round funnel.
4. Name (lit up at night).
5. Games deck.
6. Glass screens (P. and S.).
7. Wheelhouse and Bridge.
8. Officers' quarters.

PROMENADE DECK

9 and 9a. Cargo hatches.
10. Mainmast.
11. Derricks.
12. Tourist-class lift machinery, etc.
13. Derrick posts.
14. First-class swimming pool.
15. Verandah café.
16. Dance space.
17. First-class Lounge.
18. First-class Library and Writing Room.
19. Children's Nursery and Playground.

"A" DECK

20. After steering position.
21. Tourist-class Pool.
22. Tourist-class Lounge.
23. Gallery.
24. First-class cabins.
25 and 25a. Cargo hatches.
26. Foremast.

"B" DECK

27. Smoking-room.
28. Tourist-class dance space.
29. First-class cabins.
29a. First-class entrances and lifts.
30. Crew's deck.
31. Crew's quarters.

"C" DECK

32. Tourist-class children's playroom, etc.
33. Engineers' cabins.
34. First-class cabins.
35. Crew's recreation room.
36. Crew's quarters.

"D" DECK

37. Tourist-class cabins.
38. Tourist-class dining-saloon.
39. Tourist-class scullery, vegetable room, etc.
40. Chef's workroom.
41. Cold larder, silver room, etc.
42. First-class dining-saloon.
43. Passenger cabins.
44. European stewards' accommodation.
45. Starboard anchor.

"E" DECK

46. Asian firemen.
47. Tourist-class cabins.
48. Europeans' mess.
49. Generator room.
50. Fans, etc.
51. Bulk store.
52. Goanese crew's quarters.
53. Special cargo.
54. Mails.

"F" DECK

55. Cargo holds.
56. Fresh-water tanks.
57. Refrigerated stores.
58. Cargo holds.

"G" DECK

59. Fuel tanks.
60. Stores and cargo.

MACHINERY, ETC.

61. Rudder.
62. Starboard propeller.
63. Starboard shaft tunnel.
64. Starboard engine-room.
65. Boiler-room (starboard).

Continued.]
She has in addition two remarkable mechanical features. Like her sister-ship *Himalaya*, which entered into service in 1949, she has a new system of water distillation and is, in consequence, entirely self-supporting for all fresh-water services, although drinking water is carried in the usual way. She is also the largest ship to be fitted with the "Denny-Brown" Ship Stabiliser, an ingenious device which can cut down a 20-degree roll to one of 6 degrees. This device, which was amply tested in the war, when it was fitted to many vessels by the Admiralty to aid gunnery, has been tested also to the benefit of travellers in the cross-Channel boat *Falaise* and the Irish packet-boat *Innisfallen*. A diagrammatic drawing of the latter appeared in our issue of July 31, 1948. *Innisfallen*, previously the largest ship so stabilised, has a gross tonnage of 3,705, whereas *Chusan* is 24,000 tons gross; and this bold venture by the P. & O. designers will be watched with the greatest interest and may have a far-reaching effect on future luxury travel by sea.

DRAWN BY OUR SPECIAL ARTIST, G. H. DAVIS, S.M.A., WITH THE CO-OPERATION OF THE P. & O. COMPANY AND MESSRS. BROWN BROS. AND CO., LTD.