TIDE GAUGES IN THE PORT OF LONDON

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During the year ending December, 1934, approximately 59,000,000 Net Registered Tons of shipping used the Port of London. Many of the ships in this total were deep drafted, proceeding to or from the Royal group of docks situated 40 miles from the sea traversing by night and by day a dredged channel on a rising or falling tide.

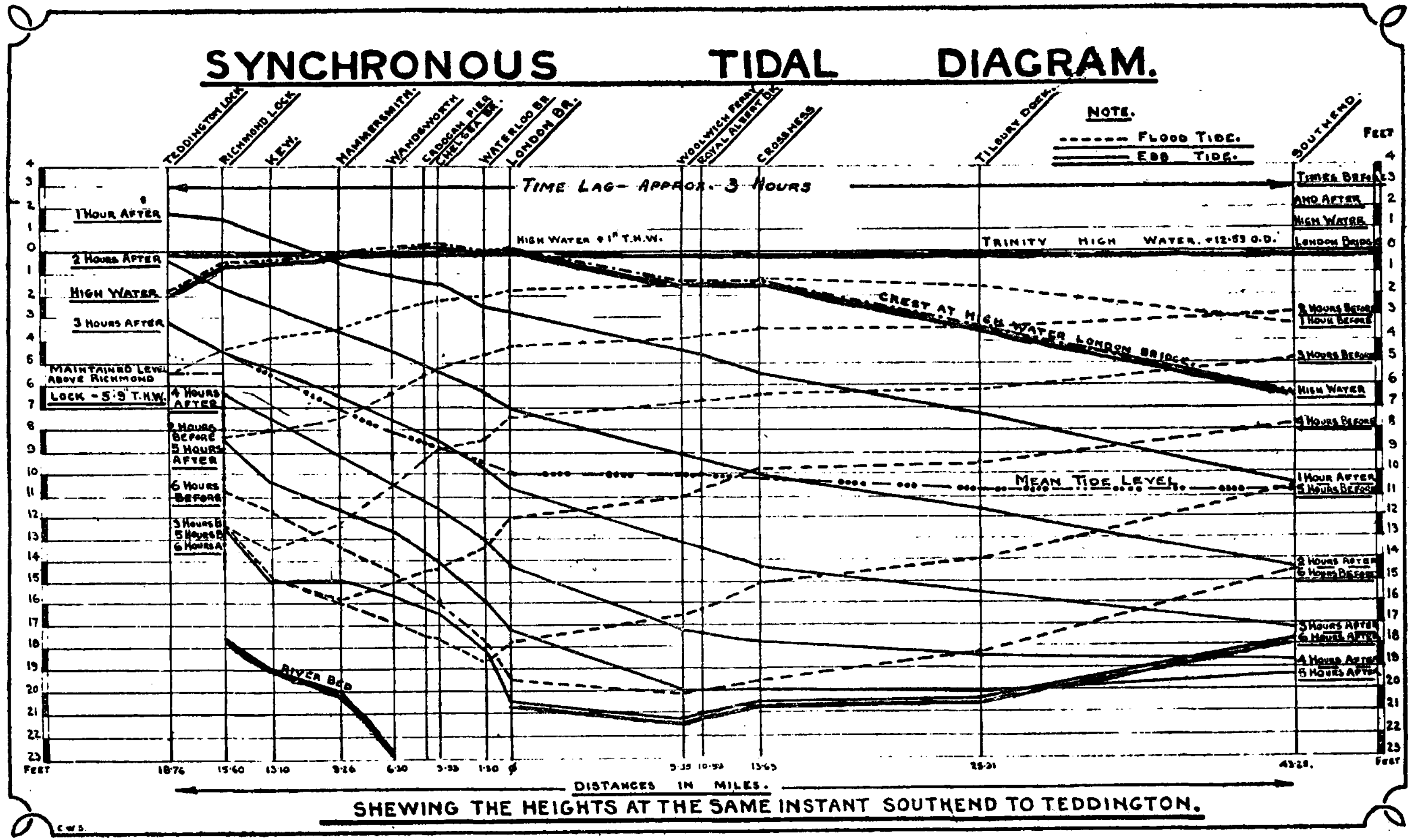
The tidal range in the water-way is considerable, varying from 15 ft. at Neaps to 22 ft. at Springs. The time lag of High Water is about one hour between King George V Dock and The Nore Light Vessel, which latter marks the seaward limit of the Port. This time lag and tidal range enable the deeper drafted vessels to navigate the estuarial channels, of which there are several, with a safe margin of draft provided the tidal conditions are studied. London, unlike Marseilles or Genoa, is prominently a tidal port and the navigator using London River requires to study the tidal factors.

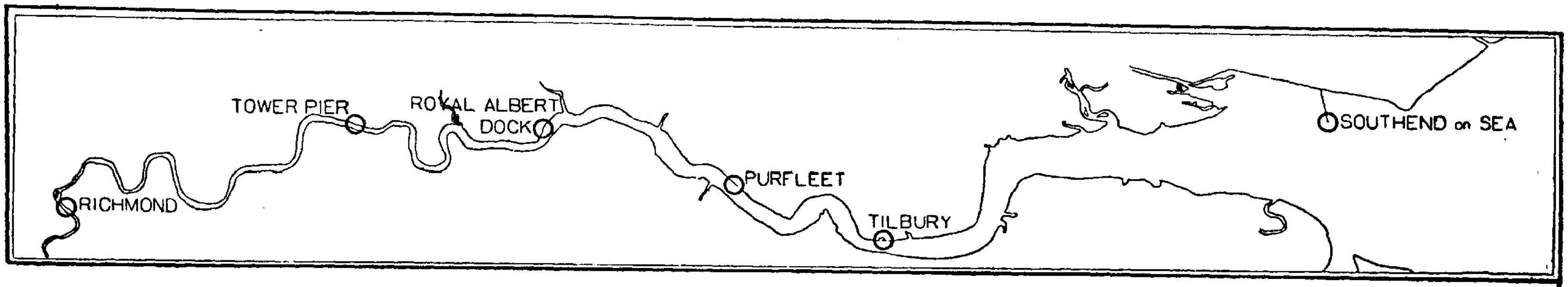
Tide gauges have existed for hydrographic purposes many years. For the pilotage of the deeper vessels special tide gauges have recently been installed. These several installations may be separated into four categories :–

1. Automatic gauges recording graphically the rise and fall of tide at suitable river stations, for hydrographic purposes.
2. Automatic gauges recording the artificially controlled river or dock levels, as at Richmond Lock and Royal Albert Dock.
3. Visual natural range gauges for pilotage night or day, the visibility of the figures being about 1/4 mile, shewing to the navigator the changing tide level continuously.
4. Monogrammic high visibility geared gauge for pilotage night or day — continuously recording.

The history of tidal recording in the Thames is disconnected but interesting.

Probably the earliest recorded attempt at tidal prediction refers to the Thames, found in the Codex Cottonianus Julius DVII, at the British Museum. This work contains calendar and other astronomical or geographical information, some of which are the production of John Wallingford, who died Abbot of St. Albans in 1213. At page 456 a table on one leaf shews the time of High Water at London Bridge, thus — "flod at london brigge".


SYNCHRONOUS TIDAL DIAGRAM.
NOTE.
FLOOD TIDE.
EBB TIDE.
TEDDINGTON LOCK
RICHMOND LOCK
KEW.
HAMMERSMITH.
WANDSWORTH
CADOGAN PIER
CHELSEA BR.
WATERLOO BR.
LONDON BR.
WOOLWICH FERRY
ROYAL ALBERT DK.
CROSSNESS
TILBURY DOCK.
SOUTHEND.
TIME LAG- APPROX. 3 HOURS
HIGH WATER +1" T.H.W.
TRINITY HIGH WATER. +12·53 O.D.
CREST AT HIGH WATER LONDON BRIDGE
MEAN TIDE LEVEL
RIVER BED
1 HOUR AFTER
2 HOURS AFTER
HIGH WATER
3 HOURS AFTER
MAINTAINED LEVEL ABOVE RICHMOND
LOCK - 5·9" T.H.W.
4 HOURS AFTER
2 HOURS BEFORE
5 HOURS AFTER
6 HOURS BEFORE
TIMES BEFORE AND AFTER HIGH WATER LONDON BRIDGE
1 HOUR BEFORE
3 HOURS BEFORE
4 HOURS BEFORE
1 HOUR AFTER
5 HOURS BEFORE
2 HOURS AFTER
6 HOURS BEFORE
3 HOURS AFTER
6 HOURS AFTER
4 HOURS AFTER
5 HOURS AFTER
FEET
18·76
15·60
13·10
9·26
6·30
3·33
1·50
ø
5·35
10·52
13·65
28·21
43·28.
DISTANCES IN MILES.
SHEWING THE HEIGHTS AT THE SAME INSTANT SOUTHEND TO TEDDINGTON.
C.W.S.



Sketch of the river Thames.

AETAS LUNAE	*h*	*m*
1	3	48
2	4	36
3	5	24
...	...	...
...	...	...
30	3	0

In this table, column 1 gives the moon's age, columns 2 and 3 the time of high water corresponding to the age. It is evident from this table that the time of high water at London Bridge has advanced about one hour since the 13th century.

FLAMSTEED, the Astronomer Royal in 1683, friend of Isaac Newton, published a table giving times of high water at London Bridge, and so through the ages there have been tidal records of the Port of London. In 1800 Parliamentary powers were sought for the building of a dock adjoining the Pool of London when a statutory local tide level was fixed, named Trinity Standard. Observations were then made by a committee of the Trinity House under Captain HUDDART. This Committee appear to have chosen the new moon of the 20th August in that year with a meridian passage of 10 hrs. 20 mins. a. m. G.M.T. The range of this tide was measured and found to be 18 ft. 3 ins. below the level of the high water. This dimension was used for guidance in constructing the dock entrance, and a stone which commemorates and established this tidal reference exists near the Shadwell Dock at present.

Trinity Standard has come to be regarded as a horizontal tidal zero of approximately Spring Tide Level throughout the River. The statutory declaration, however, clearly intended it to be of local application only and it refers carefully to the adjustment necessary if applied to other parts of the River where the level and range would differ from the Pool of London.

Automatic gauges were apparently first tried at the Port of London in connection with further building operations for new docks. Old London Bridge, which acted as a dam to the Thames by reason of its many arches and piers, was removed in 1827 and the present one built. In order to obtain a continuous register of the changed behaviour of tide Mr. PALMER, the Engineer to the London Dock Company, established his automatic tide gauge there in 1831. Mr. BUNT, a few years later, produced a similar machine of his own design for the Port of Bristol.

In 1833 the Admiralty initiated what is now a world-wide practice by forecasting the tides of London, Sheerness, Portsmouth and Plymouth.

In 1892 the Thames Conservancy introduced a clockwork gauge to record the levels at Richmond Lock. This gauge made by LÉGÉ & Co. remained until 1923. When later the Port of London Authority was formed in 1909 greater attention was given to tide gauges due to the great water-way dredging scheme then contemplated. Approximately 55 million cubic yards of

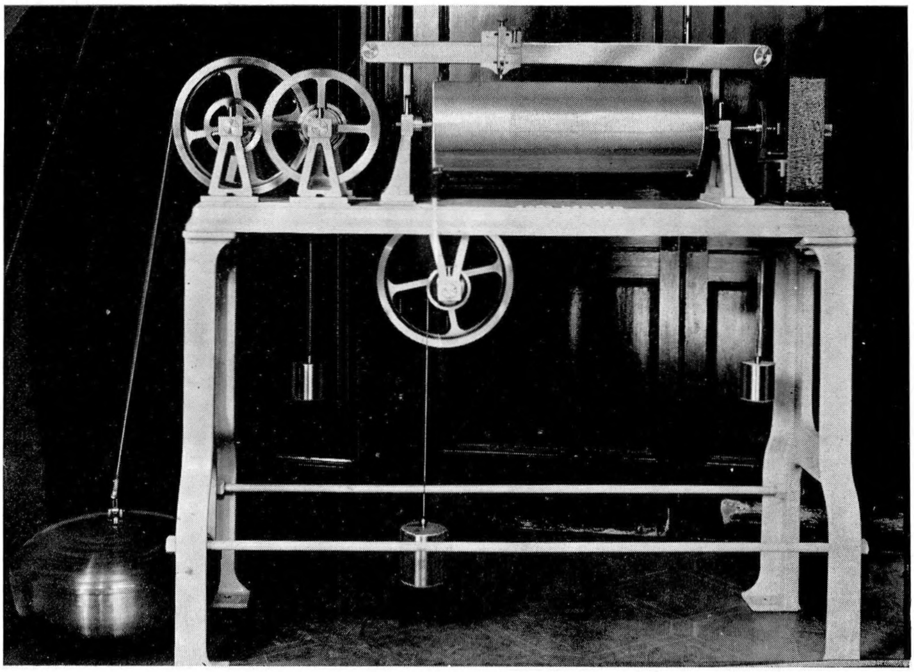


FIG. 1

Marégraphe automatique type CARY-PORTER
CARY-PORTER type of automatic tide gauge

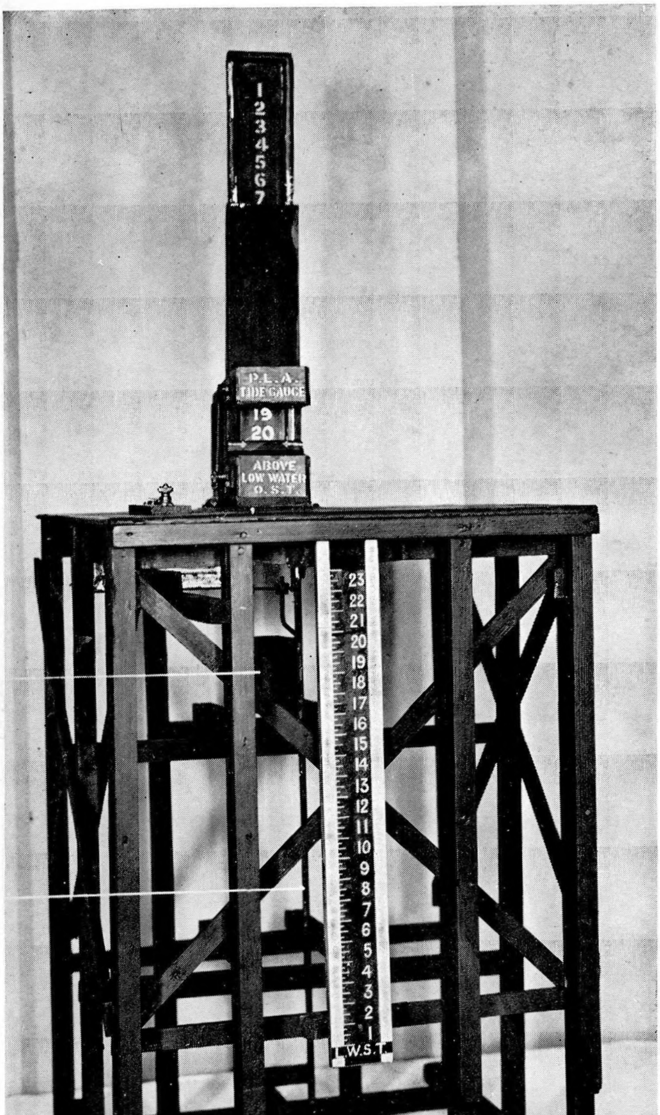


Fig. 3

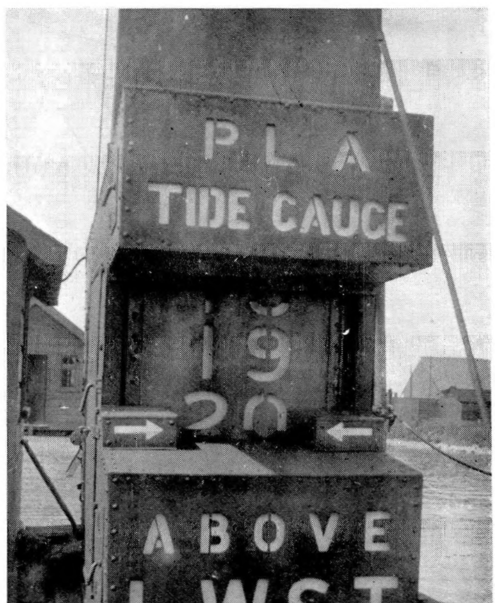


Fig. 3a

Pilot's gauge. — Marégraphe pour le pilotage.

material in situ have since been removed from the river bed. This approximates in quantity to the first cut through the Isthmus of Suez.

The year 1912 saw several automatic gauges installed for the surveying and extensive dredging programme of the new Port Authority.

Before proceeding to describe the automatic gauges erected by the Port Authority from 1912 onwards, a description will be given of the first automatic gauge invented by Henry R. PALMER in 1831/33, when engineer to the dock under construction. The details were obtained from his paper read before the Royal Society of London by J. W. LUBBOCK (Phil. Trans. Volume 121 1835). Its mechanism consisted of a float resting upon the water in a well protected against tide undulations by wire gauze. The method of suspension was by chain passing twice around a light cast-iron vessel, and provided with a counter weight. The chain of this counter-weight was of such a length that both ends were always resting on the ground. A light horizontal shaft with bevel wheels was geared to an upright shaft which acted on the pencil rack. The pencil moved backwards and forwards, making its impression on graduated paper held on a drum rotated by a clock. The cylinder carrying the graduated paper had on its axis a large toothed wheel which received its rotation from the clock shaft. To control the revolutions a cam wheel, having six teeth, then raised a hammer striking an impression once in every hour so that the spaces passed through were measured as they occurred obviating any error due to expansion or contraction of materials. Illustrations of this automatic gauge of 1831-33 are shewn on figure 1.

Mr. T. G. BUNT's tide gauge erected at Bristol on the tidal River Avon in 1837 followed similar principles, viz:

An eight day clock, turning a vertical cylinder revolving once in 24 hours.

A float rising and falling with the tide operating a pencil to scribe the tidal curve through special gearing.

The history of artificial estuarial development shews that as dredging proceeds in a narrow tidal river or as embankments are erected to confine the water to narrower limits, tidal changes occur. By dredging the River Tyne a deepening of 10 ft. was effected in about 50 years, thus the tide levels were changed considerably.

Likewise in the Port of London above Gravesend the range of tide has altered materially due to widening and deepening the Channel over a period of 25 years. Embanking has also affected the tides by causing them to rise higher in certain parts of the waterway. We have therefore tidal complexity to consider.

Automatic tide gauges are essential to trace long period and short period effects. Mere recording of high and low water would not assist in tracing quarter-diurnal effects, for instance. These quarter-diurnals are very important in tidal research.

During the ten years preceding 1932 we found it necessary to frequently adjust our previous figures to obtain accurate tidal prediction. Harmonic Analysis has been employed for computing the times of High Water at London Bridge from the earliest use of tidal forecasts, but the analysis primarily depends on a correct register of observations.

Recently the standard place for predictions was changed from London Bridge to the entrance of the Port. It is now at Southend — where a tolerably free tidal wave exists.

At London Bridge the tidal wave in the form of a semi-diurnal rise and fall comes under the influence of several factors of a natural and artificial character.

1. When the Thames discharge reaches 10,000 million gallons per diem, the surface of tide at London Bridge may be raised 8 ins. by this fresh water layer.
2. When it reaches 15,000 million gallons the downstream flow retards the incoming tide wave, producing a false Low Water reading.
3. When the fluvial river is very low and the river bed dry the reverse conditions may arise to those mentioned in 2.

In order to obtain normality Southend-on-Sea was therefore adopted as the nexus of the tidal chain of predictions. Thus the Port of London tide tables have been revised to conform to the changed conditions.

Throughout the tideway occasional perturbations occur in a marked degree. These are invariably due to severe meteorological disturbances sometimes operating off the North-West coasts of the British Isles. The Straits of Dover appear to function as a sympathetic barrier to these tidal disturbances and the Thames Estuary being in close proximity registers these local reactions.

Figure 2 is an example of these perturbations.

On 19th October, 1935, an intense depression travelled from the Atlantic and on that date was centred over the North of Scotland (Fig. 2). The disturbance of the tidal levels in the lower part of the North Sea was such that the tide wave in the Port of London lost for a period its normal character with the effects seen on the curves.

The Automatic Tide Gauge at Southend was made by CARY PORTER and established in 1912, It is of the horizontal drum type, the float operating the pen, the clock revolving the recording drum one complete revolution in 24 hours. The gearing reduces the tidal movement to a record of half an inch to one foot vertical, and one inch to the hour horizontal, the scope being equal to a tidal range of 29 ft.

The automatic gauges at Tilbury, 17 miles, and at Tower of London Pier, 43 miles respectively landward of Southend are of the same design. The clocks which are lever type receive special attention owing to vibrations which are inevitable from vessels manœuvring in the vicinity. At Galleons Reach, situated 33 miles landward from Southend, an automatic electrical recorder established 1912 is fitted to shew by remote control the variations of water level in the Tidal Basin with reference to the river levels. These diagrams are visible to the control engineer in the pumping station. Its arrangements consist, for the river levels, of a wooden trunk 3 ft. × 3 ft. situated on the upper end of Galleons Jetty, a float having a diameter of 18 ins. is connected with a counter-weight by a copper wire passing over a grooved wheel, geared to a transmitter installed on the top and centre of the

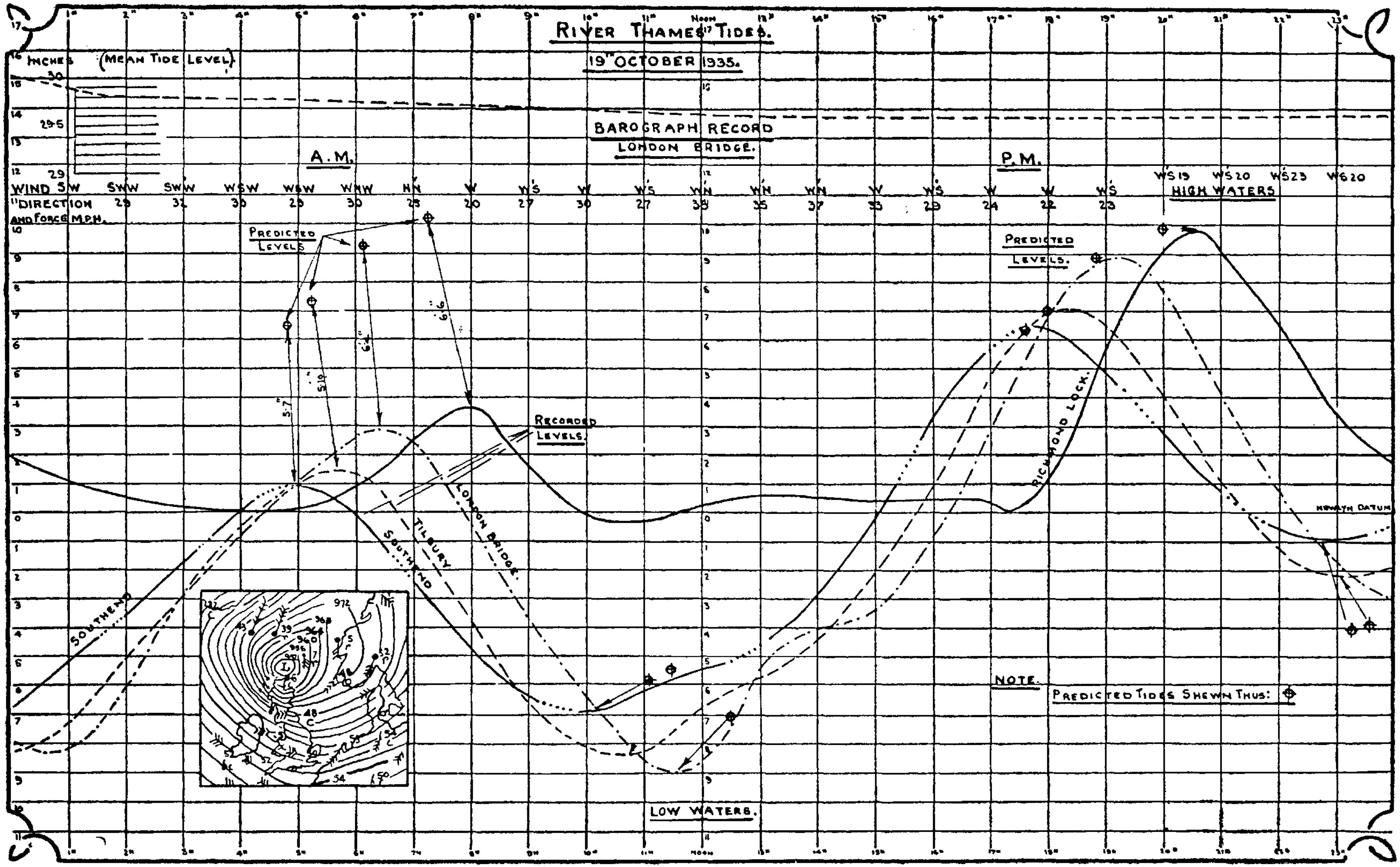

River Thames Tides.
19th October 1935.
Barograph Record
London Bridge.
Inches (Mean Tide Level)
A.M.
P.M.
Wind Direction and Force M.P.H.
Predicted Levels
Recorded Levels.
Southend
Tilbury
London Bridge.
Richmond Lock.
High Waters
Low Waters.
Newlyn Datum
Note. Predicted Tides Shewn Thus:

Fig. 2

trunk. A unique feature of this trunk is the method of keeping it free from mud. The bottom consists of a flat iron plate pierced with holes, and moving over the plate but in close contact is a steel wiper. To this wiper is attached a steel rod which runs to jetty level. The top end of the rod is squared to receive a key and a few turns of this causes the wiper to move over the plate, forcing the mud through the holes in the bottom and preventing general settlement.

A movement of 2 ins. in the tide causes an electrical impulse to be transmitted along wires to the pumping station where the main instrument registers this rise or fall on the chart. Fixed to this instrument are two sets of induction coils, one for the rising tide, in which case the current causing the pen to move vertically to a scale of 2 ins. and vice versa for the falling tide.

A plate is fixed in the river trunk at a level of 5 ft. below T.H.W. Tidal contact with this plate causes a bell to ring in the pumping station, enabling the engineer in charge to check the accuracy of the gauge and to adjust as necessary.

For dock levels a similar transmitter, sets of receiving coils, float and counter-weight are used. The greatest fluctuation in dock level is 2 ft. 6. ins. compared with the maximum river range of 30 ft. The distance of the transmitter from the pumping station in the case of the river levels is some 600ft. and in the dock level the distance is nearly half a mile.

Both the river and dock levels are recorded on the same tidal sheet which is fitted on a drum which revolves once in 24 hours and the record is changed daily. The drum is of the vertical type and consequently the pens move vertically.

The voltage used to operate this gauge is 20 volts and is supplied by a battery of 14 Léclanché cells.

From 1912, the date of installation of this gauge, to the present time, a chain passing over a sprocket wheel was used to link the float and counterweight to the transmitter, both in the case of the river levels and dock levels.

Considerable trouble was experienced by the stretching of the chain but this chain has now been replaced by a flexible copper wire which is wound round a grooved wheel.

For determining the non-harmonic constants we have recently examined the tidal slope at several points of the River from synchronous readings of the automatic gauges. From this diagram the position of maximun range of tide is clearly demonstrated as existing at Woolwich.

Moreover, it will be observed that the face of the Tidal Thames is more frequently a changing sinuous surface than a direct slope. (Fig. 3).

Pilots' gauges.

The delicate clockwork mechanism of the automatic gauge does not lend itself to long distance signalling of large figures to shew the rise and fall by day or night, which are essential for pilotage.

In several ports the rise and fall at important points in a long tidal river are shewn by distant signals, such as in the River Hughli.

In the Port of London we established in 1924 a pilots' day and night gauge which consists of 12 inch figures on a frame passing through an illuminated box. The frame is on vertical rods secured to a barrel-shaped float. The gauge is erected on an existing quay. It has been found desirable to build a protection around the float to reduce the vibration caused by the waves from passing ships.

This gauge was so successful that it has been repeated at Tilbury Pierhead eight miles downstream where ocean liners pass up and down the river under varying conditions of weather night and day. The Tilbury gauge is also within visual range of the Passenger Landing Stage where liners arrive and depart.

These 12 inch figure gauges for pilotage can be seen by the naked eye from mid-river under normal conditions of visibility.

Demonstrations have recently been made of a high visibility day and night gauge operating figures three feet in dimension. These figures are shewn on a screen by a method similar to electrical advertisement signs. It may therefore be called a monogram tide gauge. The tidal movement is transmitted by a float to a rotary drum suitably geared. A series of selecting keys which light the group lamps are engaged by the drum in its rotation. On the screen there are for the Thames range, 46 electric light lamps fitted with prismatic reflectors. The controller drum is constructed so that the selective switches cannot poise between any two display positions so that when the figures are changing from, say, 15 ft. to 16 ft. there is no illumination.

In sunshine this sign can be seen as far as at night, which is approximately one statute mile in clear weather.

The electrical character of the mechanism does not however confer the boon of cheapness upon the monogrammic type of gauge.