



ENGRAVING COPPER CHART PLATES

INTRODUCTORY REMARKS

by Director A. P. NIBLACK

A summary of the replies of twelve of the States-Members to questions (a), (b) and (c) of the Bureau's Circular-Letter No. 49 of 1922, was given in the *Hydrographic Review* Vol. I, No. 2, as far as received up to the date of its publication. These three questions related to :

- a) The perfection of a satisfactory mechanical method for the execution of copper plate engraving.
- b) The effective repair of a cracked copper-plate, and.
- c) The permanent retention of copper inserted into a copper-plate where a hole may have become formed owing to excessive correction in one place.

Since then no further replies have been received except one from the HYDROGRAPHIC OFFICE of the U. S. NAVY DEPARTMENT on the subject (a): "THE MECHANICAL ENGRAVING OF CHART PLATES", which is published herewith. In this connection it is interesting to reproduce a summary of the replies to (a) as previously published concerning the practices of the various Hydrographic Offices as to the use of mechanical engraving of chart plates, which were as follows :—

GREECE, PORTUGAL AND SIAM : Except in rare cases, these countries do not use copper plates for chart printing.

CHILE : For engraving soundings, borders, shading of scales and land tints, a set of machines is used.

DENMARK : None.

FRANCE : Now perfecting a method of engraving of copper plates, up to Double Elephant size, from a tracing in black.

GREAT BRITAIN : For ruling, tinting and sand dotting, by means of the ordinary tinting machine.

ITALY : The engraving of plates, when not done by hand, is carried out either by galvanoplastic photogravure or by chemical photogravure.

JAPAN : (Before the Earthquake, September 1st. 1923). By machine for dotted lines, compass roses, border ruling, tinting and soundings.

NETHERLANDS : Mechanical means are used for tinting and only occasionally for engraving soundings.

SWEDEN : None.

U. S. OF AMERICA (COAST AND GEODETIC SURVEY) : By machines for soundings, bottom, and sub-dividing border scales ; by roulettes for edge of sand stipple, for bluffs, sand dunes, *etc.*, and for fathom curves ; by punches for marsh tufting, and marking buoys, by marker for railway ties ; ruling machines for marsh symbols and tinting ; by photographic process for transferring the work from the drawing (compilation sheet) to the copper plate similar to etching ; by electrolytic process for filling-in engraved work or making erasures rapidly on copper where corrections are to be made, and making electro type "altos" of the copper plates as soon as engraved.

U. S. OF AMERICA (HYDROGRAPHIC OFFICE) : The Hydrographic Office of the U. S. Navy Department actually engraves its copper plates for charts by mechanical engravers, or machines, which are subsequently described herewith in the article entitled "MECHANICAL ENGRAVING OF CHART PLATES".

In the Annual Report of the U. S. Hydrographic Office for 1924, the Hydrographer states :

The "pantograver" designed by Mr. T. P. LAMPE, embodying Mr. J. H. LARRABEE's compensating device, was manufactured at the NAVAL GUN FACTORY, WASHINGTON, D. C. It has been thoroughly tested and meets all requirements for which it was designed. This instrument is most effective and economical for engraving on copper from compilations.

The "letter engraving machine" designed by Mr. ROSS E. GRAY of the Hydrographic Office and manufactured at the Naval Gun Factory was installed during the year. This machine has met all requirements for which it was designed. This machine, while efficient in engraving lettering generally, is especially efficient and economical for engraving titles on charts.

The patent rights of the pantograver, letter engraving machine, and attachments were released for Government use by Mr. LARRABEE, Mr. GRAY and Mr. LAMPE. The Navy Department has applied for patents on these machines.

An improved model OURDAN sounding-engraving machine was manufactured at the Naval Gun Factory. This machine was invented by Mr. V. L. OURDAN about 25 years ago while he was employed as an engraver in the Hydrographic Office. This machine embodies many improvements over the original machine, among them being a device for cutting soundings on glass negatives and for operating the machine with one or with two operators. (See page 35, Vol. I, No. 2, *Hydrographic Review*).

Engraved copper plates have long been regarded as the principal means of chart printing, having the advantages of lending themselves to frequent correction, and at the same time of being a permanent and almost indestructible record of the results of field surveying work, which function they will continue to fulfil, even if printing from them directly is not

considered to be, in certain or in all cases, the most desirable method of chart production.

Unquestionably charts printed from copper plates are generally very distinct and durable on account of the possibility of using strong paper which will stand hard service ; but there is often considerable distortion ; it wears out the plate in time unless it is repeatedly steeled ; and the greatest drawback is that it is very slow compared with lithographic printing on dry paper. Incident to the wear of copper plates, it is usual to make an " alto " from a newly engraved plate to preserve it in case of wear to the original plate. As to the relative importance of the different forms of chart printing, there are, of course, many considerations more important than economy and rapidity, but, if we assume that the field surveying parties collect the raw materials and the Hydrographic Offices run the manufacturing or production department of the business, the funds are always limited, and the question of economy, rapidity and ease of making subsequent corrections to existing chart plates are legitimate objects of concern from a business standpoint. There is the further consideration as to distortion in the various methods of printing, and a further discussion as to chart production and chart distortion, therefore, may be of interest.

The following are the figures of the chart production for the U. S. Hydrographic Office for the year 1924 :

Number of engraved copper plates of navigational charts for current issue : 2,611.

Number of charts printed or pulled directly from same : 29,523.

Number of charts printed by lithography : 198,094.

Pilot and miscellaneous charts printed by lithography : 879,873.

It is interesting to analyse further the 198,094 charts printed by the lithographic process, 31,019 being corrected photo-reproductions, 17,450 being corrected transfers from copper plates, 100,125 being from existing zinc plates needing corrections, and 49,500 from zinc plates not needing corrections.

In explanation of this the following data, furnished by the Hydrographer of the U. S. Navy are interesting :

DISTORSION IN CHARTS CAUSED BY DIFFERENT METHODS EMPLOYED IN PRINTING

The Hydrographic Office uses three methods of obtaining printed charts for issue from copper base plates as follows :

a) Prints taken directly from the copper plates by plate printing. This method is only used where the plates are not suitable for transferring or photolithographing.

b) Prints by lithography obtained by transferring the design from a copper plate to zinc plate for lithographic printing. This method is used when the copper plate is not suitable for making photolithographs.

c) Prints by photolithography obtained by making a print of the design from a copper plate practically free of distortion, photographing and photo printing on zinc plates for lithographing. This method gives the least distortion of any of the above methods; the difference in dimensions between the copper plate and finished chart being negligible.

In order to compare the distortion encountered in printing by methods (a), (b) and (c), the measurements of the plates and resulting finished chart in centimeters are given for each process.

a) Printing from copper plate direct :—

	N.-S.	E.-W.
Copper Plate	68.834 cms.	96.6978 cms.
Plate printed print	67.63 cms.	96.06 cms.

b) Lithographic prints from copper plate transfers :

	N.-S.	E.-W.
Copper Plate	94.437 cms.	64.135 cms.
Transfer (Zinc plate).....	95.28 cms.	65.25 cms.
Lithograph print	95.28 cms.	65.25 cms.

c) Photolithographs from copper plate.

	N.-S.	E.-W.
Copper plate	97.688 cms.	64.719 cms.
Photolith. (Zinc plate)	97.73 cms.	64.71 cms.
Lithograph print	97.73 cms.	64.1 cms.

It may be of interest also to compare the above with data from the U. S. Coast and Geodetic Survey of a similar nature. It uses aluminium plates for lithographic work instead of zinc. It is more expensive, but is said to give better results. Plate No. I shows graphically the relative distortions of the paper through different methods of printing. The Copper plate used was that of U. S. C. and G. S. Harbour chart No. 348, Wood's Hole, Massachusetts, U. S. A., and was 51.55 cms. long by 33.63 cms. wide, and the average results are from (a) "Velox" print (photographic method), (b) Starch paper print for the transfer (non-photographic method), and (c) a print pulled direct from the copper plate.

The "Velox" transfer method (a) is based on a pull direct from the copper plate on specially prepared blotter-backed paper. This is photographed and transferred direct from the negative by printing on to an aluminium plate, and then by lithographic presses. The starch paper print (b), briefly stated, consists of coating India, or similar thin paper, with starch or other ingredients on which the pull is made from the copper

UNITED STATES COAST AND GEODETIC SURVEY.

COMPARISON OF PRINTS FOR DISTORTION.

(Comparaison des Distorsions dues à l'Impression)

(THE TOP LINE REPRESENTS THE SIZE OF THE COPPER PLATE OF THE
U.S.C. & G.S. HARBOUR CHART N° 348 OF WOODS HOLE, MASSACHUSETTS, U.S.A.)

LENGTH COMPARISONS.

Copperplate (51.55 cms.)

(a) "Velox" print

(b) Starch paper print for transfer

(c) Regular copperplate print

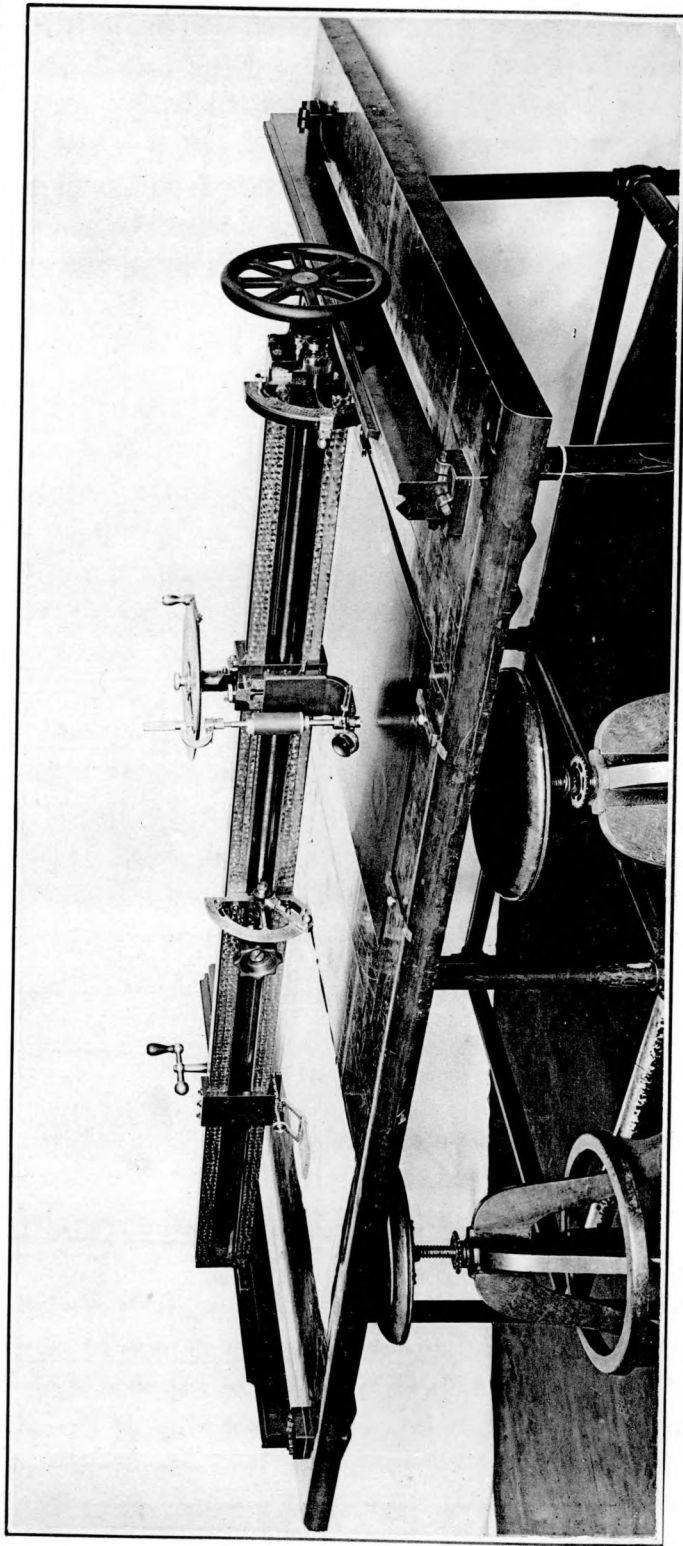
WIDTH COMPARISONS.

Copperplate (33.63 cms.)

(a) "Velox" print

(b) Starch paper print for transfer

(c) Regular copperplate print



SOUNDING ENGRAVING MACHINE

MACHINE A GRAVER LES SONDES

plate. If the offset process is to be used a reverse print is pulled from this print and the latter laid down on the aluminium plate for printing. If printing is to be made direct the transfer is made from the first print to the aluminium plate. The print from the copper plate (c) needs no explanation.

For charts of larger size than this No. 348, it is claimed by the U. S. Coast and Geodetic Survey that the shrinkages will be in direct proportion to the increase or decrease in dimensions, but at the same time it is generally recognised that there are irregularities in distortion which follow no rule.

THE MECHANICAL ENGRAVING OF CHART PLATES

With regard to the "pantograver" and other mechanical means of copper plate chart engraving, the results, as shown by recent issues of Hydrographic Office Charts, are quite satisfactory, and it has increased the output fully one third through time saved in engraving.

The following information has been kindly furnished by the U. S. Hydrographer on the subject.

The Hydrographic Office of the Navy Department of the U. S. of America uses several mechanical aids to the more economical and rapid production of engraved copper plate bases for nautical charts. The instruments, machines and devices in use have been invented and developed by the personnel of the Hydrographic Office, for which patents are held or are pending.

The mechanical engravers in use are as follows :

- I. — Sounding engraving machine (OURDAN, 1893).
- II. — Border subdividing device (GRAY, 1904).
- III. — Letter engraving machine (GRAY-LARRABEE, 1923).
- IV. — Pantograver (LARRABEE-LAMPE, 1923).

I. — SOUNDING ENGRAVING MACHINE (Plate II).

The sounding engraving machine, originally invented in 1893 to engrave soundings, required adjusting for each size of figures, but, since that date, the machine has been modified to engrave three sizes of figures without readjustment ; to engrave the lettering of the abbreviations of bottom characteristics directly under the soundings ; and also to be operated by one or by two persons depending upon the nature of the work in hand.

This machine not only engraves the figures and letters, but locates them in their proper positions direct from the drawing, without the medium of hand tracing or photo-transfer.

While this machine is used primarily and principally for engraving sounding figures on copper plates, it is also adapted for use on lithographic zinc plates, and a recent modification permits its advantageous use on glass photographic negatives.

The machine is mounted on a table large enough to accommodate both the drawing and the copper plate ; it is constructed with a stationing device on one side and the engraving carriage on the other. The stationing device is movable over the entire surface of the drawing and the machine is so arranged that the engraving point will automatically locate itself on the plate as the stationing point is moved from place to place on the drawing.

The characters are engraved by a weighted " dry point " either steel or diamond, which is controlled by a one bar pantograph. The master letters and figures are cut intaglio on a steel disc mounted on the engraving carriage. Each figure as it is needed is brought to the front center of the engraving carriage by rotating the disc. Tracing the master figure with the tracing point provided at the upper end of the stylus reproduces the figure at about one-tenth size on the plate.

An idea of the value of the Sounding Engraving Machine as a labor and time-saving device will be appreciated from the fact that the skilled hand engraver engraved only about 300 sounding figures per day while 2,000 figures per day is not an unusual accomplishment with the machine. (Fully described in Vol. I, No. 2, *Hydrographic Review*, page 35).

II. — BORDER SUBDIVIDING DEVICE. (Plate III, Fig. I).

A border subdividing device was invented by an engraver in the Hydrographic Office and has proven valuable and accurate in performing the otherwise tedious work of subdividing border scales on nautical chart plates. It consists of a straight edge *A* with an overlapping lip, to which is fastened in any desired position along its edge, by means of convenient clamp screws, a steel plate *B* which has on its upper surface a series of deeply engraved radial lines so arranged as to give subdivisions of sixty equal spaces. Along the edge of this plate *B* is moved a steel triangle *C* provided with an arm projecting over the plate *B* and carrying a sliding pointer *D* which engages in the spacing lines. By adjusting the pointer *D* to appropriate positions

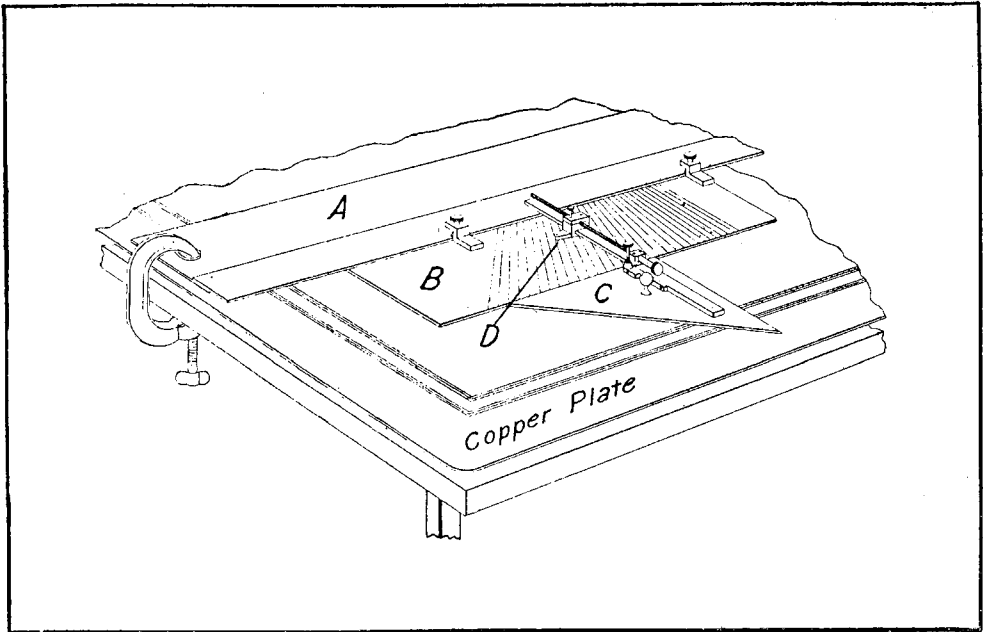


Fig. 1. — Border subdividing Device. — Dispositif pour diviser le cadre.
Copper plate. — Planche en cuivre.

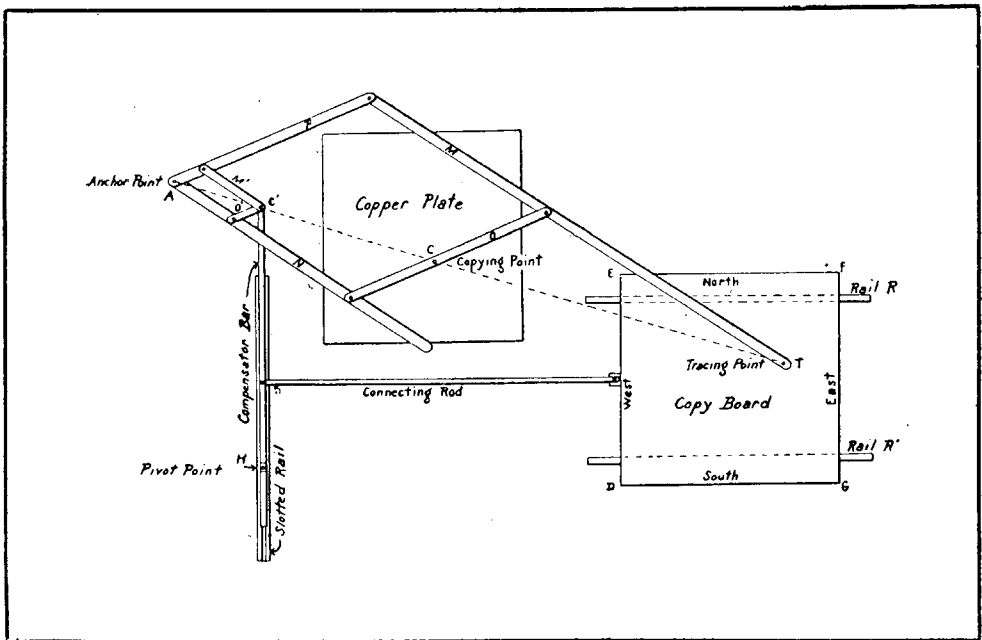
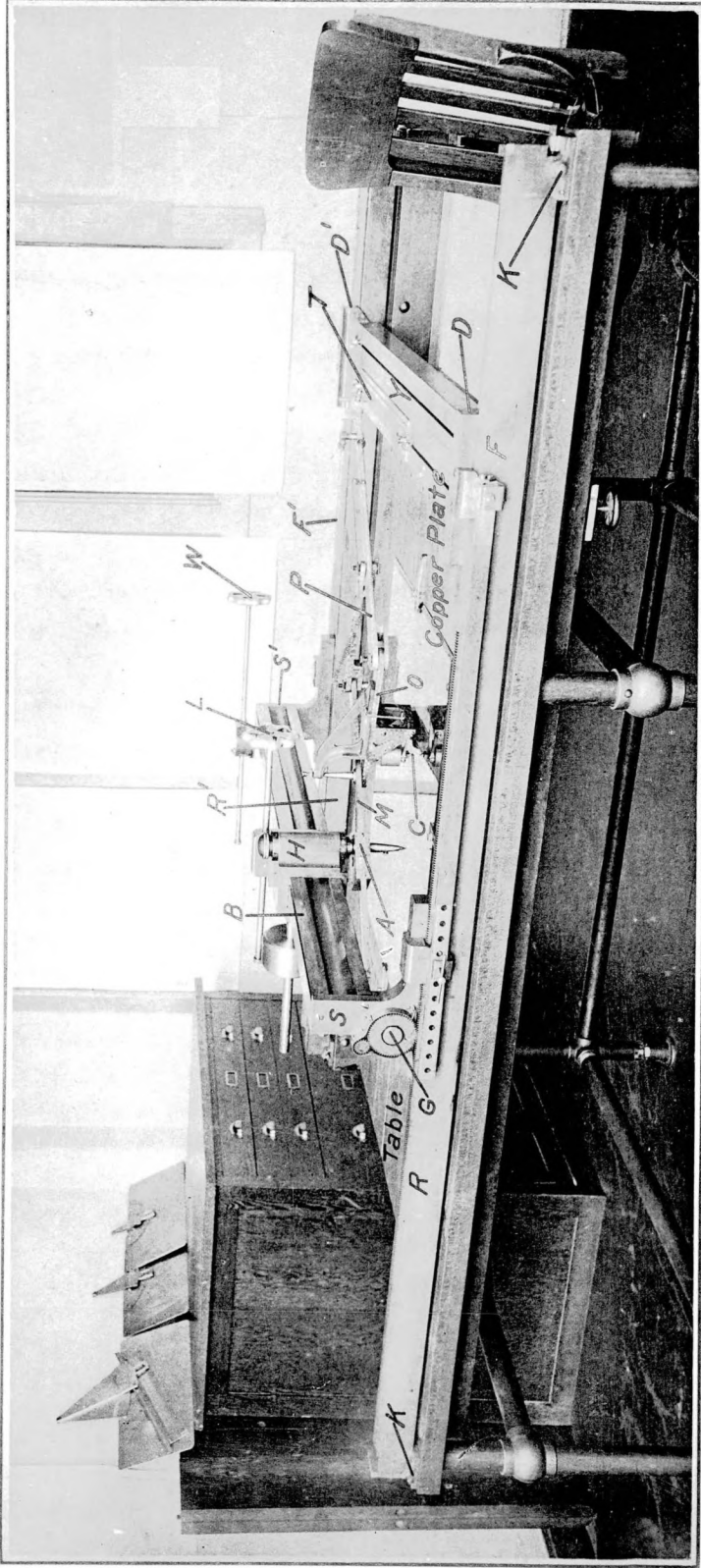


Fig. 2. — Diagram illustrating principle of compensating pantograph.
Schéma figurant le principe du pantographe compensateur

Anchor point, Point fixe. — Copper plate, Planche en cuivre. — Copying point, Pointe traçante.
Tracing point, Pointe directrice. — Copy board, Planche de l'épreuve. — Connecting rod, Bielle de liaison.
Pivot point, Pivot. — Compensator bar, Barre compensatrice. — Slotted rail, Rail à rainure.



LETTER ENGRAVING MACHINE

MACHINE A GRAVER LA LETTRE

on the plate *B* the various scale lengths are readily subdivided as desired. A series of ten radially divided plates are provided in order to give the device the necessary scope.

III. — LETTER ENGRAVING MACHINE (Plate IV).

As the lettering of names, titles, and notes on nautical chart plates constitutes a large portion of the work of engraving such plates, it is evident that, in the development of mechanical means for chart engraving, the need of a suitable letter engraving machine was of outstanding importance.

Several letter engraving machines of various types adapted to the engraving of commercial work (card plates, invitations, announcements, and letter heads) are on the market and are used extensively by "Stationers and Engravers". These machines are of such design that their scope is limited to small plates, and in most cases the work must be cut through a ground and etched. They are, therefore, entirely unsuited for letter engraving on large size chart plates.

In inventing and developing a machine with which lettering on copper chart plates may be mechanically engraved the following principal requirements had to be met.

a) The machine to be capable of engraving or cutting, to a printing depth, outlines of letters on the surface of a copper plate.

b) The movements of the cutting tool to be so controlled that standard letter patterns of uniform gage and style may be employed, in the engraving of letters of the various standard gages.

c) The working parts of the machine which control the movements of the engraving tool in the engraving of letters to be so mounted and controlled that the engraving point may be readily brought to and accurately set on any portion of a large size copper chart plate, (plates as large as 36" × 52") and at the same time maintain the necessary relation between the engraving point and the standard letter patterns employed.

d) The letter patterns to be so constructed that words may be formed and engraved rapidly and the proper spacing between letters fixed automatically.

e) Provision to be made for so placing the letter patterns on the machine that lines of lettering may be quickly placed and engraved in any direction or angle on the plate which may be required.

An engraver in the Hydrographic Office, who had previously invented and developed a letter engraving machine for commercial work, undertook the design of a machine to meet the requirements for lettering on copper chart plates. As a result, the machine now being successfully

employed in the Hydrographic Office and described below, was originated and designed.

Referring to the accompanying photograph on which the several parts are designated by letters.

P is a pantograph of the reducing form as shown in Plate V (Fig. 3), Sketch I, of which *A* its the anchor point, *T* the tracing point, and *C* the cutting or engraving point. The arms of the pantograph *M* parallel to *M'* and *O* parallel to *O'* are joined with pivot joints at the points *d*, *e*, *f*, and *g*. With the points *A*, *C* and *T* on a straight line, for all movements of the tracing point *T*, the cutting point *C* will move in the same direction and through distances proportional to the movements of the tracing point in the ratio $\frac{AC}{AT}$. In order to change the value of the

ratio $\frac{AC}{AT}$ the anchor point *A* and the cutting point *C* may be moved on the bars *M* and *O* respectively. This pantograph is constructed with such proportions that when letter patterns with letters of a gage of 100 decimillimeters are placed under the tracing point *T* and traced, the relation $\frac{AC}{AT}$ can be varied so that the cutting point *C* will reproduce such letters on gages of from 6 decimillimeters to 20 decimillimeters, thus meeting the requirement (*b*). Bars *M* and *O* are provided with scales indicating the settings for the various gages.

In order to adapt this pantograph to the engraving of lettering on copper chart plates the following parts and mechanisms are provided, which, assembled together with the pantograph, constitute the letter engraving machine. (Plate IV).

On a fixed base of appropriate size are mounted two rails of equal length *R* and *R'*. These rails are parallel to each other and their ends rest in castings *K* fastened to the base. These castings are so designed as to support the rails at a sufficient distance above the base to allow a copper chart plate, placed on the base to pass under the rails. The castings *K* are also provided with adjusting screws bearing against the sides and ends of the rails by means of which the rails may be adjusted in position so that they are perfectly parallel and have their ends exactly opposite. The cross section of the rails *R* and *R'* is shown in Plate V, Figure 3, Sketch II.

Two carriages *S* and *S'* rest with roller bearings on the machined surfaces of the rails *R* and *R'*. These carriages are bolted to and support a horizontal bar *B* in a position perpendicular to the rails. The bar *B* has a cross section as shown in Sketch III. On the outer sides of the

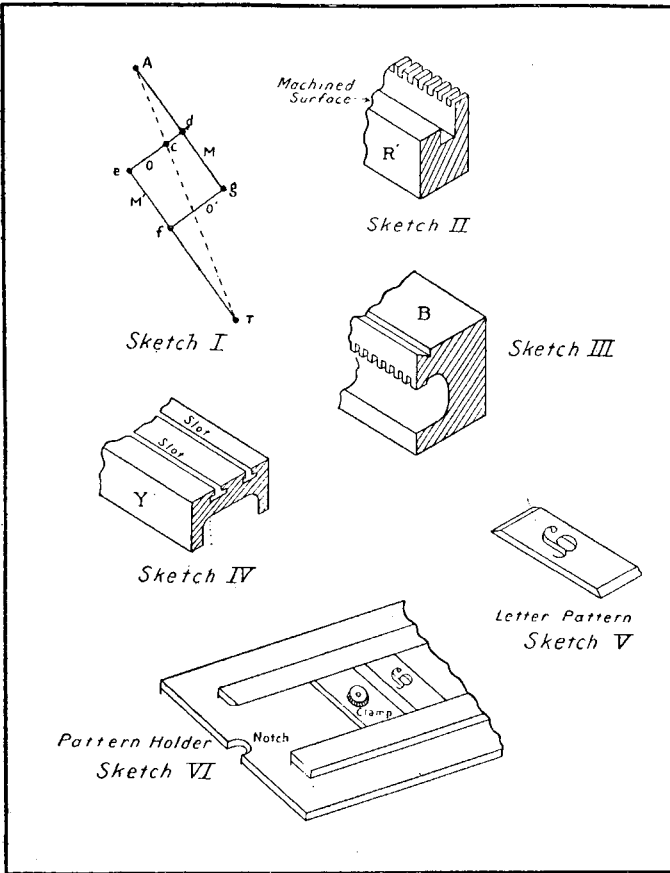


Fig. 3. — Sketch, Croquis. — Machined surface, Surface dressée. — Letter pattern, Patron de lettre. — Pattern holder, Porte-patron. — Notch, Encoche. — Clamp, Molette.

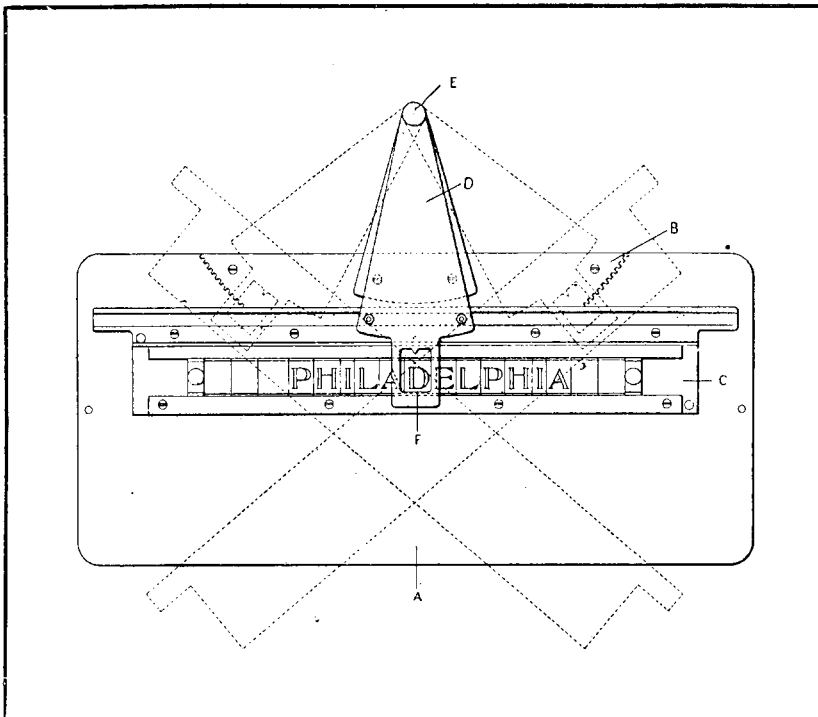


Fig. 4. — Curved lettering device. — Dispositif pour les lettres en courbe.

carriages S and S' are attached gear wheels G and G' (not visible in photograph) which are so placed as to engage in the gear teeth of the rails R and R' . These gear wheels are connected through a train of gears to the hand wheel W . When the hand wheel W is turned the horizontal bar B with its supporting carriages S and S' will travel either backward or forward on the rails R and R' .

A movable cross head H on the bar B carries on its face a vertical shaft which is free to revolve in ball bearings. On the lower end of this shaft is attached a block A which fits the pantograph arm M (Sketch I) and allows the arm M to pass through it, thus providing a support for the pantograph at its anchor point. The cross head H also carries a train of gears which connects the gear teeth on the bar B with the hand wheel L . When the hand wheel L is turned the cross head H moves to the right or to the left along the bar B .

From the above it is readily seen that the anchor point of the pantograph and hence the cutting point may be brought to any position on a copper plate placed on the base between the rails R and R' by simply operating the hand wheels W and L . An apron Y , (with cross section as shown in Plate V, Figure 3, Sketch IV), parallel to bar B and perpendicular to the rails R and R' , is supported by carriages D and D' bolted to its ends. These carriages rest with roller bearings on the machined surfaces of the rails R and R' . Connecting rods F and F' connect the carriages supporting the bar B with the carriages supporting the apron Y , and are so adjusted as to keep the apron Y parallel with the bar B . These connecting rods are so designed that the distance between bar B and apron Y may be varied. Letter patterns or pattern holders can be placed on the apron Y and clamped in position by means of clamps fitted in the slots of the apron. The dimensions and elevations of the various parts of the machine are so proportioned that when letter patterns are placed on the apron and traced with the tracing point of the pantograph the cutting point will engrave the letters on a copper plate resting on the base.

The engraving tool C (Plate V, Fig. 3, Sketch I) is suspended in a vertical position on horizontally spaced arms in the tool carriage which is movably mounted on the pantograph arm O . The tool is controlled (raised off the plate and lowered) by means of a cable which runs to a finger latch at the tracing point T . A special device provides for the employment of individual letter patterns cut on brass which can be distributed and kept in a type case. These letter patterns are in various styles of letters on a standard metric gage and have the letters so placed in relation to the sides of the patterns that when placed together in forming words the proper spaces between letters will be obtaining automa-

tically. The top and bottom sides of the letter patterns, Plate V, Figure 3, Sketch V, are bevelled to fit in a slot in the top of a pattern holder, Plate V, Figure 3, Sketch VI.

In operating the letter engraving machine the pattern holder, with the appropriate patterns held in place by clamps (Sketch VI) at each end of the row of patterns, is placed on the apron *Y* (photograph) and clamped to the apron by clamps which slide in the slots of the apron and fit into notches (Sketch VI) on the ends and sides of the pattern holder. The pattern holders are of such length that a line of several words may be set up at one time.

PROCEDURE IN OPERATING THE LETTER ENGRAVING MACHINE IN THE ENGRAVING OF THE LETTERING ON COPPER CHART PLATES

The work is first laid out on a chart plate on which the outlines have already been engraved. This is accomplished by coating the plate with a thin layer of shellac and drawing on the surface the position of either the beginning, the end, or the center of each line of lettering required, also the position of the bottom line of the letters. For convenience in setting up and placing the various lines of lettering, each line is numbered consecutively on the original (drawing or print) and its position on the plate is marked with the same number. The plate is then placed and securely fastened on the base of the machine in such a position that the top and bottom border lines of the plate are parallel to the apron *Y* and the bar *B*; bar *M* of the pantograph is moved through the block *A* and the engraving tool carriage is moved on the bar *O* to the appropriate settings for the gage of letters required. *

The appropriate letter patterns for a line of lettering are set up and clamped in the pattern holder; the pattern holder is placed and clamped on the apron *Y*; the tracing point is placed on the bottom line of the letters on the patterns; the cutting tool is then brought to the corresponding bottom line on the plate by means of the hand wheels, *W* and *L*; the pattern holder is then moved to the right or left until the cutting tool is in its correct position for engraving the first letter of the name or line of lettering to be engraved; the operator then traces the letters of the patterns lowering the engraving tool for each stroke of the letters and raising the tool between strokes.

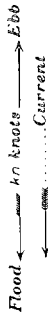
* *Note.* — In order to expedite the work all the lettering of one gage is engraved before changing the pantograph setting for another gage.

WEST INDIES
 BAHAMA ISLANDS
CROOKED ISLAND PASSAGE

From British surveys between 1829 and 1843
 with additions from other sources

SOUNDINGS IN FATHOMS
 HEIGHTS IN FEET

*Underlined figures in the water in brackets, thus (12)
 indicate the height of the adjacent island or rock
 above the plane of high water*



Co. coral. M. mud. S. sand. Sh. shells. rhy. rocky

Title engraved with Letter engraving Machine. The lettering to the right shows the nature of the engraving as it comes from the machine. The lettering to the left shows the machine engraving after completion by hand gravers.

Titre gravé avec la Machine à graver la lettre. Les lettres montrent la nature de la gravure telle qu'elle émane de la machine. Les lettres de gauche montrent la gravure une fois remplie à la main.

The strength of line of the engraved letters is controlled by placing various weights on the arms supporting the engraving tool ; after the machine work is completed the plate is taken from the machine and the burr or roughness caused by the engraving tool removed. The body strokes of the letters are then cut out by hand and the letters " trimmed " in the same manner as in hand engraved lettering (Plate VI). Hair line lettering requires no hand work.

The use of the Letter Engraving Machine in the Engraving of titles on chart plates has resulted in the remarkable saving of about 60 per cent in the cost of title engraving as well as the attainment of absolute uniformity in the lettering.

DEVICE FOR LETTERING ON CURVES

After the letter engraving machine was installed and in operation in the Hydrographic Office the desirability of adapting it to the engraving of lettering on curves became apparent. Several devices were suggested which required the use of special patterns. The device finally adopted was invented by the personnel, and employs the same patterns that are used for straight line lettering.

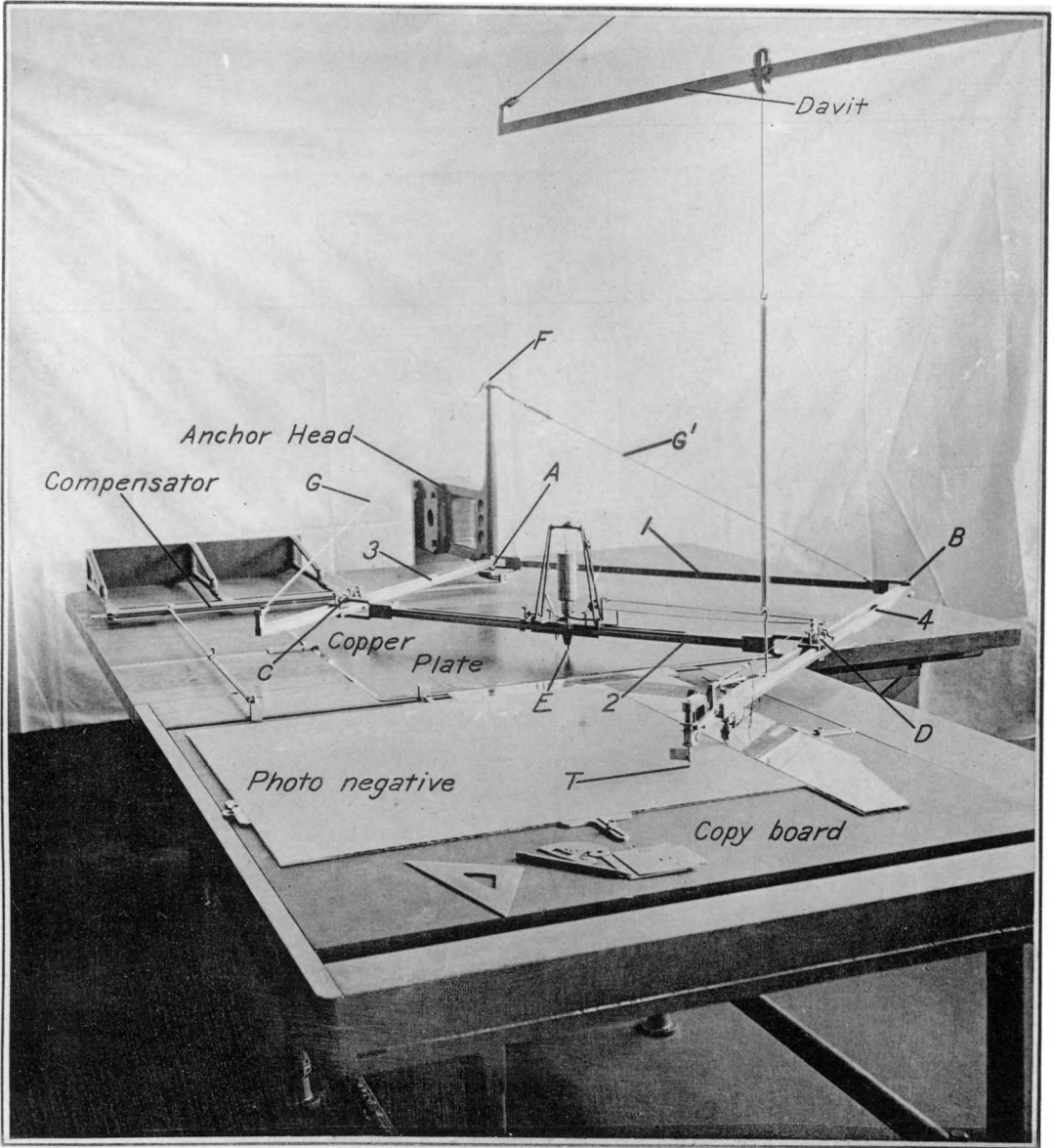
The device consists of a plate (Plate V, Fig. 4) on which is rigidly fastened a plate *B* which is a segment of a circle with gear teeth cut in the circular edge. On the back of a letter pattern holder of the same type as used for straight lettering is attached a plate with a straight edge having gear teeth to match and engage those of the plate *B*. This edge with gear teeth is located directly under and in line with the center line of the line of letters on the patterns. By placing the pattern holder, with letter patterns set up in words required, on the place *C* and engaging the gears of *B* and *C*, the pattern holder may be moved, keeping the gears engaged, so that the letter patterns will take successive positions along the arc of a circle. An arm *D* pivoted at *E*, the center of the circle of which plate *B* is a segment, serves to keep the pattern holder *C* in place and insures the keeping of the gears engaged. The entire device is clamped on the apron of the letter engraving machine and as each letter is traced for engraving, it is brought into proper position by moving the pattern holder *C* until the letter is directly under the opening *F* in the arm *D*. By providing several plates with segments *B* of different radii, lettering may be engraved on various curves.

IV. — “ PANTOGRAVER ” (Plate VII)

In investigating a means to rapidly reproduce mechanically on copper the design of a nautical chart from drawings of original surveys or from compilations of several larger scale charts, the pantograph suggested the most promising means. However, two major difficulties had to be surmounted, that of compensating for the unequal distortion in the drawing or copy and that of varying the strength of line. These two difficulties were solved and the designs of charts are now reproduced on copper by cutting the design through an etching ground with the “ pantografer ” and etching.

The “ Pantografer ” as a whole is an instrument consisting of three major parts, the table which is the base and support, four arms assembled upon a principle similar to that of a reducing pantograph, and the compensator which includes the copy board. Each part is dependent upon the others in order that the different units form a complete instrument. The table, with the exception of the wooden top, is of steel, rigid construction, but adjustable to a true horizontal plane. The copper plate to be engraved, and the copy board rest upon it. To the frame of the table there are fastened, in a rigid manner, anchor heads that support the engraving part of the instrument, the compensating device, and a davit that relieves the weight of the instrument on the copy board (Plate VII). The anchor head that supports the engraving part of the instrument is adjustable to a true vertical position for the part between *A* and *F*. The engraving part of the instrument is formed by the four arms or horizontal bars, (1), (2), (3), (4), and their fittings. They are connected by means of the vertical axes *A*, *B*, *C* and *D*, so as to form a movable parallelogram. The axis *A* forms at the same time the anchor point about which the engraving part of the instrument turns. The bars (1) and (2) are of equal length (40 inches) and bar (4) is equal to one and one quarter times that length (50 inches). The distance of the axis *B* from *A*, and *D* from *C* is invariable. The locations of axes *C* and *D* on bars (3) and (4) are adjustable. On bar (2) the engraving point *E* is adjustable. At the end of the bar (4) is the tracing point *T*. Scales are provided on the bars (2), (3) and (4) to provide for the setting of *E* and the axes *C* and *D*.

Different settings produce different ratios between movements of tracing point *T* and engraving point *E*; *BD* should be equal to *AC* and the anchor point or axis *A*, the engraving point *E* and the tracing point *T* should form a straight line for all ratios and the scales are so proportioned that direct settings can be made for any desired ratio between movement of tracing and engraving points.



PANTOGRAVER

- Anchor head
- Compensator
- Copper-plate
- Davit
- Photo negative
- Copy-board

PANTOGRAVEUR

- Point fixe
- Compensateur
- Planche en cuivre
- Potence
- Epreuve photographique négative
- Planche de l'épreuve

Bars (2), (3) and (4) are so designed that the weights upon them are always in the centre of their width. There are no offset axes from any of the bars such as are found on the usual drafting pantograph. This is an important feature as it eliminates torsion strains due to eccentric loads and thus minimizes the possibility of deflections in the bars. The axes *A*, *B*, *C*, *D* and *F*, are all ball bearing. *F* is the axis to which the guy wires *G* and *G'* are fastened. The other ends of *G* and *G'* are fastened at the ends of bars (1) and (3). The guys are adjustable so that the bars (1), (2), (3) and (4), can be adjusted to a true horizontal position. The engraving point *E* is a diamond ground to the desired shape and fastened to the bottom of a round steel shaft. The shaft is kept perpendicular by a sleeve which is part of the carriage that is adjustable on bar (2). Diamond point, shaft, sleeve and carriage are all designated at *E*. On the carriage, over the shaft are a series of weights. They are adjustable to the shaft to as to give additional pressure to the diamond. The pressure on the diamond determines the width of line to be engraved. The weights and the raising and lowering of the diamond point are controlled at the tracing point *T*.

The copy board is mounted on ball bearings resting on a steel bed-plate and is adjustable to a level position. The compensator (Plate III, Fig. 2) is designed on the principle described and has the auxiliary pantograph arms so proportioned and placed that the center of the joint *C'* has a movement of $\frac{1}{15}$ of that of the tracing point *T*. The amount of compensation is dependent upon the relative positions of the auxiliary pantograph, the pivot point, the connecting rod and the copy board. A maximum compensation of 1 part in 30 is provided for in this particular instrument. All parts of the compensating device are so supported as to allow sufficient clearance for moving and placing a copper plate on the table under them. This compensating device, being unique in principle, will be described in detail.

Referring to the accompanying diagram : (Plate III, Fig. 2).

M, *N*, *O* and *P* are the arms of an ordinary pantograph as used for reducing drawings or diagrams.

T is the tracing point.

C is the copying point.

A is the anchor point.

Note. — For all settings of the pantograph the points *A*, *C* and *T* are on a straight line.

D, *E*, *F*, *G* is a copy board upon which the drawings or prints to be reproduced are fastened. The sides of the copy board are marked North, South, East and West for convenience in explanation. A copper plate or other medium upon which the reproduction

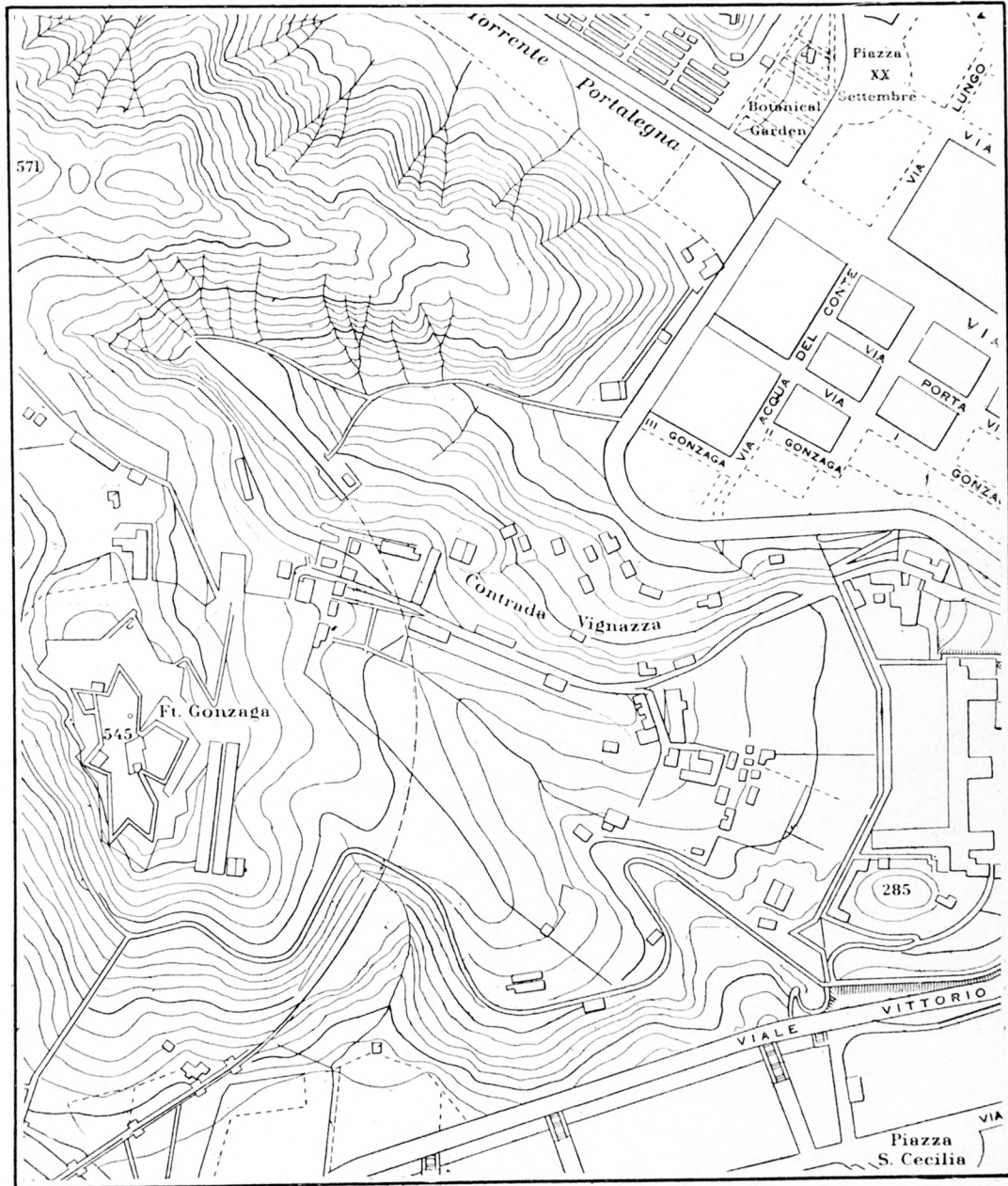
is to be pantographed is placed under the copying point C . It will be readily seen that for all movements of the tracing point T , the copying point C will move over the copper plate in the same direction and through distances proportional to the movements of the tracing point T in the ratio $\frac{AC}{AT}$.

Let us assume that there is placed on the copy board a print of a chart having its North-South dimension correct and its East-West dimension shortened by shrinkage, and that it is desired to reduce this chart onto the copper plate and at the same time restore the true proportion between North-South and East-West dimensions. The pantograph can be set so that the copying point C will reproduce all movements of the tracing point T in a North-South direction on a desired scale but distances in an East-West direction traced by the tracing point T will then be reproduced on a different scale and shorter in proportion to the shrinkage in the chart being traced.

If, however, when the tracing point T is moving in an East-West direction the copy board can be made to move progressively under the tracing point in the same direction and in an amount equal to the shrinkage in the chart, then the copying point C will reproduce East-West distances traversed by the tracing point in correct proportion to the true dimensions of the chart and the effect of shrinkage will be eliminated. The accomplishment of the required progressive movement of the copy board under the tracing point as the tracing point is moved in an East-West direction constitutes the invention.

The auxiliary parts necessary therefor and their functions are as follows :

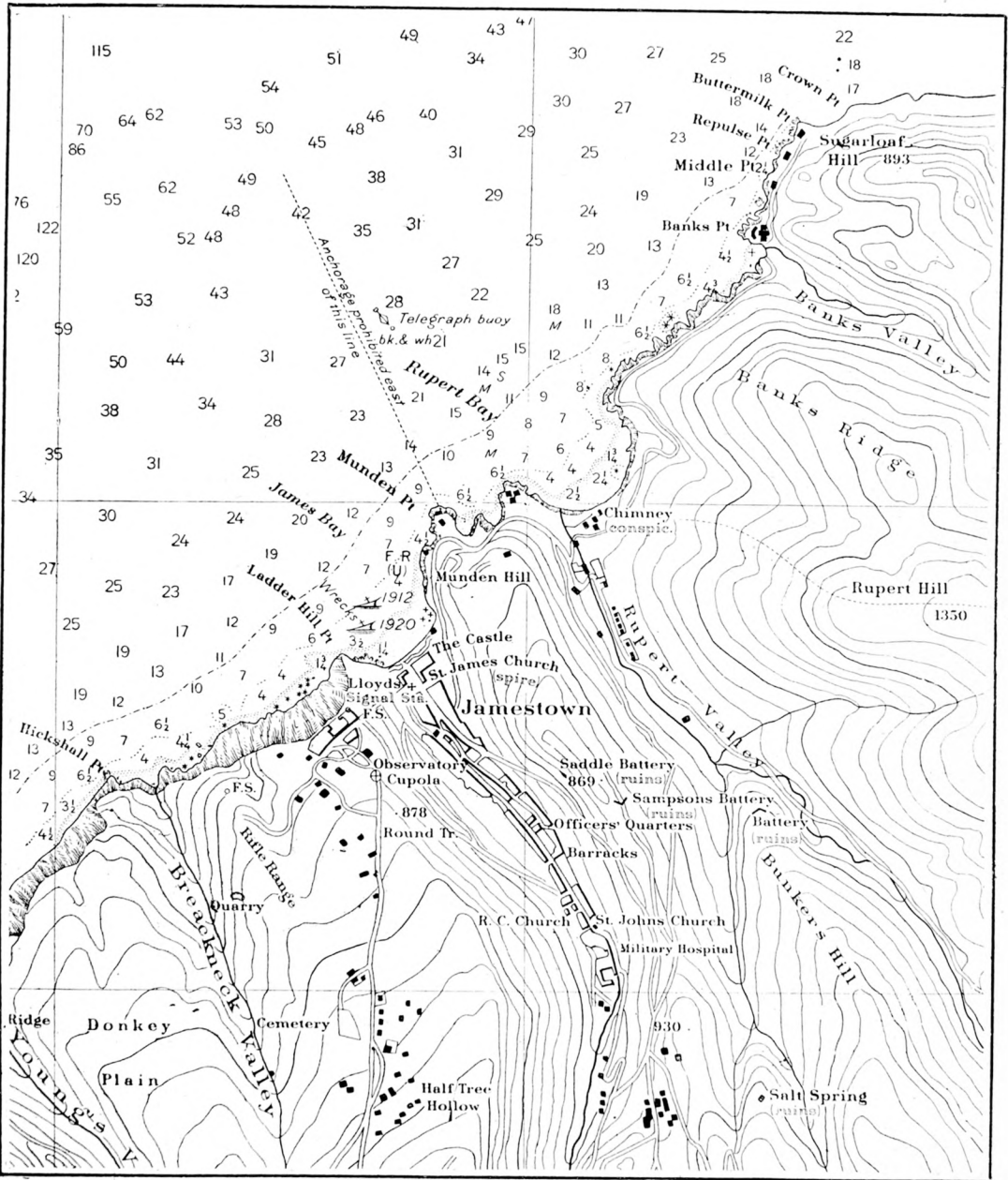
Two rails R and R' are placed under the copy board in an East-West direction, and the copy board is mounted on these rails with ball and roller bearings, thus allowing a free movement of the copy board in an East-West direction but no movement in a North-South direction. Two auxiliary pantograph arms, M' parallel to M , and O' parallel to O , are inserted near the anchor point. These auxiliary arms intersect at a pin joint C' which is on the line AT and at such distance from A that $\frac{AC'}{AT} = \frac{1}{15}$. With this arrangement, it is readily seen that for all movements of the tracing point T , the center of the joint C' will move in the same direction as and through distances proportional to the movements of the tracing point T in the ratio $\frac{1}{15}$. A bar with compensation graduations is attached at the joint C' . A pivot point H is attached to this compensating bar and is adjustable to any position along the bar. The



PLATES VIII and IX

PORTIONS OF U. S. HYDROGRAPHIC OFFICE CHARTS MECHANICALLY ENGRAVED.

Outlines, Contours, Roads, and buildings were engraved with « Pantograver ». Soundings were engraved with Sounding Engraving Machine. Lettering was engraved with Letter Engraving machine.



ANCHES VIII et IX.

PARTIES DE CARTES DE L'HYDROGRAPHIC OFFICE DES ÉTATS-UNIS
GRAVÉES A LA MACHINE.

Les contours, les lignes de niveau, les routes et les édifices ont été gravés avec le « Panto-graveur ». Les sondages ont été gravés avec la machine à graver les sondes. Les lettres ont été gravées avec la machine à graver la lettre.

pivot H rests in a slotted rail so placed that the slot is at right angles to the rails under the copy board (R and R'). A connecting rod extending in an East-West direction connects the center of the West side of the copy board with the compensating bar.

With the above described auxiliary parts in place the following results take place :

When the tracing point T is moved in a North-South direction the center of the joint C' moves in a North-South direction and the pivot H , regardless of its location on the compensating bar, slides in the slotted rail in a North-South direction and there is no East-West movement of the connecting rod. Hence, the copy board remains stationary. When the tracing point T moves in an East-West direction the center of the joint C' moves in an East-West direction and the compensating bar pivots about point H . With the pivot point H north or south of the connecting rod, the East-West movement is communicated to the connecting rod and thence to the copy board. This movement of the copy board is proportional to the East-West movement of the tracing point T and in a ratio depending upon the distance of the pivot point H from the connecting rod. When the pivot point H is South of the connecting rod the copy board and tracing point will move in the same direction thus compensating for shrinkage, and when the pivot point H is North of the connecting rod the copy board and tracing point will move in opposite directions thus compensating for expansion. When the pivot point H is in line with the connecting rod the copy board will remain stationary for all movements of the tracing point. This is the position of pivot point for use when no distortion is to be compensated.

In operating the "Pantograver" with compensating device the amount of shrinkage or expansion to be compensated for must be determined and the pivot point H set accordingly. Settings of the pivot point H necessary to produce various percentages of compensation may be computed and graduated on the compensator bar.

In the engraving of a chart on copper by means of the "Pantograver" the procedure is as follows :

The scale and limits of the chart having been determined, lay down a computed projection on the copper plate and point-in lightly the meridians and parallels. Photograph the original data sheets (drawings, survey sheets, maps or charts) to a scale from two to three times greater than the scale determined for the engraving. These data sheets should have projection lines corresponding to those laid down on the plate. Either reversed photo-prints or the negatives themselves can be used on the "Pantograver" (As the engraving must be backwards the data to be

traced must also be backwards). After pointing in the projection on the plate an etching ground is flowed on to the surface of the plate. The plate is then placed on the table of the "Pantograver" under the engraving point and with its meridians and parallels parallel to the sides of the copy board. The settings of the bars and tool carriage of the "Pantograver" are determined by carefully measuring corresponding vertical and horizontal distances between projection lines both on the data print or negative and on the copper plate and determining the ratios between them. If the ratios for vertical and horizontal distances are equal, no compensation is necessary and the ratio is used as the setting for the bars and tool carriage. If the vertical and horizontal ratios differ, then the vertical ratio is used for setting bars and tool carriage and the compensator bar setting to compensate for the difference determined. Having set the instrument for the required reduction and compensation the data print or negative is placed on the copy board and both copper plate and data print adjusted in position so that when the tracing point is placed at any projection point on the data print the engraving point will be at the corresponding point on the copper plate. The work is now ready to be traced. The operator carefully traces the design on the data print, raising, lowering and adjusting pressure on the engraving tool by means of the levers near the tracing point. The design is thus cut through the etching ground into the plate. The plate is then etched and cleaned off and the work engraved is ready for printing.

The "Pantograver" has also been employed in the engraving of chart outlines directly on lithographic zinc plates. In this process the zinc plate is coated with gum and then placed on the "Pantograver" and engraved in the same manner as described for copper plates except that the weight on the diamond cutting point is reduced just sufficient to cut through the gum and expose the raw surface of the zinc. After the design has been thus engraved the zinc plate is treated with asphaltum, dried, washed out and again gummed. It is then ready for printing in a lithographic press. This process may be applied either to direct or offset lithographic printing, the only difference being in the reversing of the design.

The chart features which have been successfully engraved with the "Pantograver" are outlines, including shore lines, rivers, roads, buildings, piers, docks, railroads, canals, and boundary lines, contours, and form contours, symbols for buoys, beacons, lighthouses, wrecks, kelp, current arrows, and anchorages (Plate VIII). In the engraving of various symbols brass templates are employed. These templates are of thin sheet brass with the outlines of the symbols cut through the brass in

various sizes so that an appropriate size may be selected for the work in hand. In using the template it is placed on the copy board and the proper symbol brought to correct position over the copy from which chart design is being traced. The tracing point is then inserted in the template and the symbol design traced. This method ensures absolute uniformity of symbols.

The installation and use in the Hydrographic Office of the three major engraving devices, "Pantograver", Sounding Engraving Machine, and Letter Engraving Machine, together with improved methods employed in the photolithographic reproduction of nautical charts based on engraved copper plates, have resulted in greatly increased efficiency in chart production both in the quantity and quality of the product. Expensive copper plate engravings are no longer worn by constant printing. Features which must be periodically changed, such as compass roses, variation curves, light sectors, range lines, and track lines are not engraved on the copper plates but are supplied in the photo-lithographic process, thereby obviating the expense and damage to engraved plates.

