SOME RESULTS OF EXPERIMENTS IN CHART-PRINTING FROM COPPER-PLATES

Lecture delivered on 17 th April 1929 by
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Within the last few years there have been numerous changes and a great many improvements in the reproduction of nautical charts. Some of the larger hydrographic services have gradually been compelled to abandon copperplate printing in favour of lithography in order to cope successfully with the heavy demands of seafaring people. Still, most of the smaller services will probably find it more expedient, upon the whole, to continue to use the engraved copperplate. As I comprehend the matter, there will very likely be an increased use for copperplate printing in the near future. The new Norwegian engraving-machine substantially facilitates and cheapens the engraving of chart plates which up till now has been a slow and expensive process. Particularly at the smaller Hydrographic Offices where, as a rule, there is no need to publish large editions of charts in a hurry, the interest in copperplate printing will very likely be stimulated.

This being my opinion, I should like to direct attention for a few minutes to the results of some trials we have lately been making at the copperplate printing works of our Hydrographic Service. The aim we had in view was to simplify the copperplate printing as much as possible, and to try to eliminate the changes in dimensions of the chart-picture, which is not the least of the drawbacks connected with this kind of printing.

As is known, in copper-printing one generally uses a well-damped paper in order to get a clear and fine picture. Now this thorough moistening is followed by a considerable expansion of the paper. Our Swedish medium chartpaper (length 1032 mm. and width 698 mm.) increases on an average about 8 mm. in length and 16 mm. in width. The percentage of increase in the width, therefore, is three times as great as in the *length.* The fact is that the paper-fibres dilate much more in width than in length, and in manufacture, usually come to lie parallel with the cylinder, *i. e.* parallel with the longitudinal direction of the fibres.

By way of information I should perhaps mention that the chart-paper used at the Swedish Hydrographic Office consists chiefly of the chemical wood-pulp known as sulphite, with about 20 % of straw-pulp added and mixed in. The paper is soft sized and, by way of filling, sulphate of lime is intermingled in the ordinary manner.

The distortion of the chart-picture is also affected by another circumstance *viz.*, that the wet sheet is distended by the extortion of the printing-press. This enlargement amounts only to about 0.8 mm. in the length and 0.2 mm. in the width. When, however, the sheet with the newly-printed chart-picture has been put out to dry, it very nearly resumes its old dimensions.

After some days, during which the charts are stored in a room with a relative moisture of about 65 %, the reproduced picture on the chart will be found to differ about 9 and 16 mm. in length and width respectively from the corresponding measures on the copperplate. These alterations in the dimensions of the picture on the chart, directly caused by the moistening to which the chart-sheet has been subjected in printing, have been ascertained by means of repeated investigations to amount to about half a degree in *angular* measure.

This alteration in size does not, it is true, signify very much for *nautical* purposes; but it undoubtedly has other drawbacks which will assert themselves in several ways during the work of adjusting the chart and completing it

The drying of our charts after printing has, since 1925, been done in an electrical drying-machine of the same excellent type as that used by the Hydrographic Department in London. It is a very fine piece of machinery which may be seen in Fig. 1.

Another drawback associated with the wet method is that the printing-paper must be prepared a couple of days before the printing, which, of course, hampers the adaptation of the production to meet special requirements.

Besides, this work of moistening the paper is troublesome and takes much time, not to speak of a relatively high percentage of waste. The printing is also retarded, because the blankets used absorb so much water from the damp sheets that they have to be changed and dried from time to time.

The "wet" method has yet another disadvantage, namely, that the use of transfers in the colouring of lights is rendered difficult, or even impossible. Hence the production of charts takes still more time.

In order as far as possible to eliminate, or to diminish, all these disadvantages, experiments were commenced in November 1926 which aimed at *investigating* whether it was possible to use all but *dry* paper for printing.

The most obvious thing, of course, was merely to soften the printing-surface of the paper by means of a *rapid moistening*. After a series of experiments in that way, the following procedure was reached :— A sponge is slightly moistened in water after the colouring and drying of the copperplate has been almost completely finished. After that the wet sponge is rapidly passed over the sheet, which is then equally rapidly dried, with a linen cloth, in order to remove all water on the surface. The sheet is then laid immediately for printing on the plate, which rests on the printing-press table. It is of importance that the moistening should be carried out as *rapidly* as possible; the time requisite for this amounts to 30 to 45 seconds. Experience has clearly shown that the magnitude of the change in the paper is a direct function of the time in moistening.

Simultaneously with these experiments, trials were made with "packings" of different constructions. In the "wet" method of printing, the "packing"

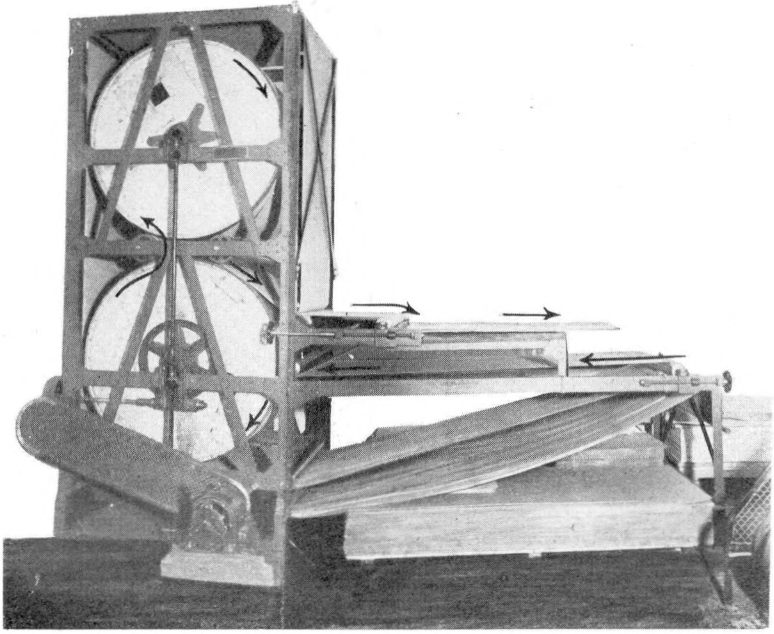

FIG. 1

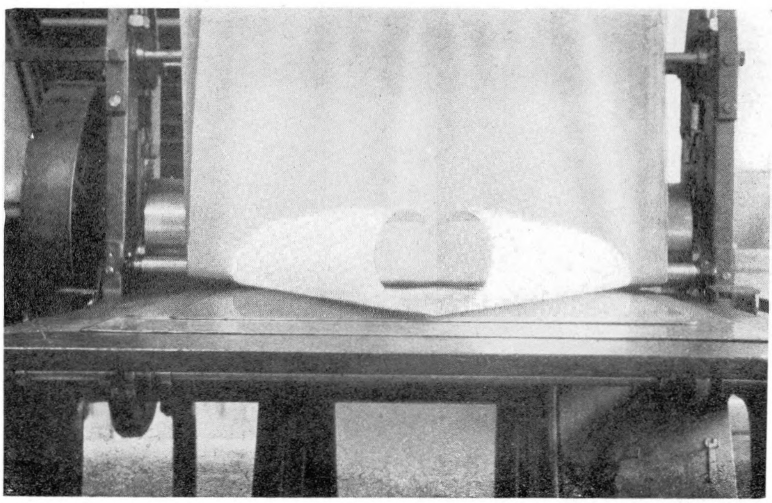

FIG. 2

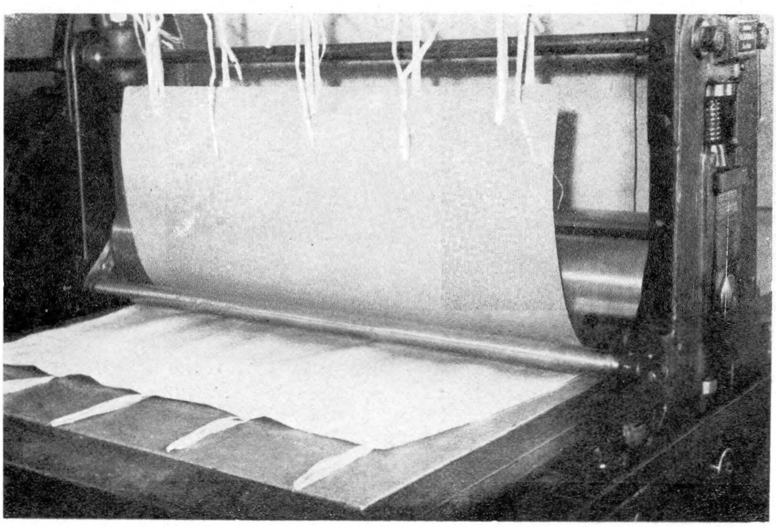

FIG. 3

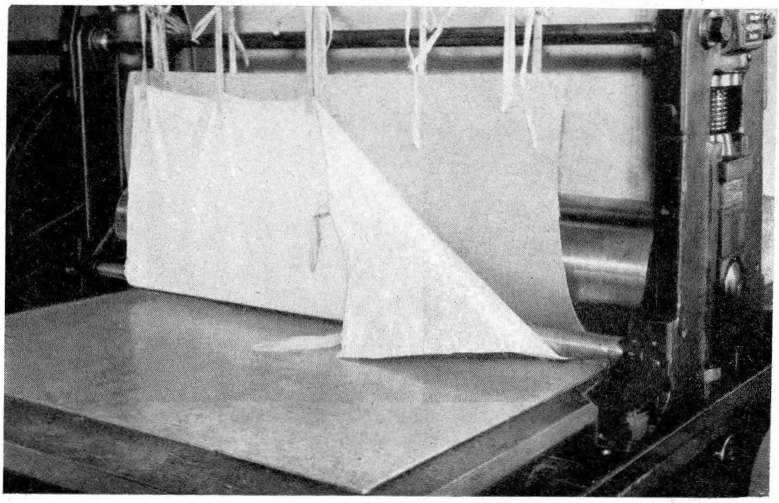

Fig. 4

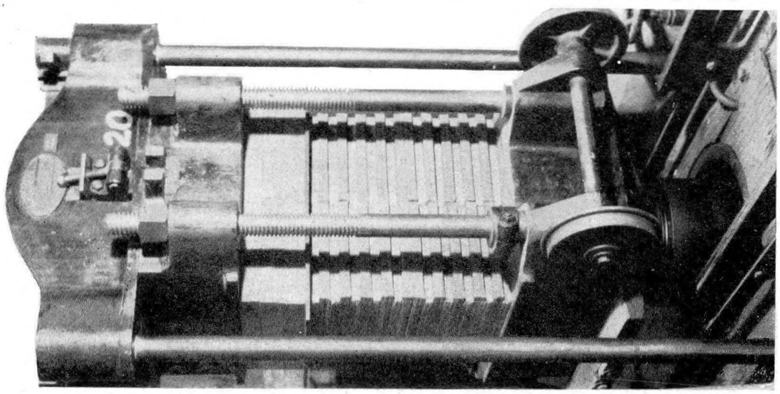

Fig. 12

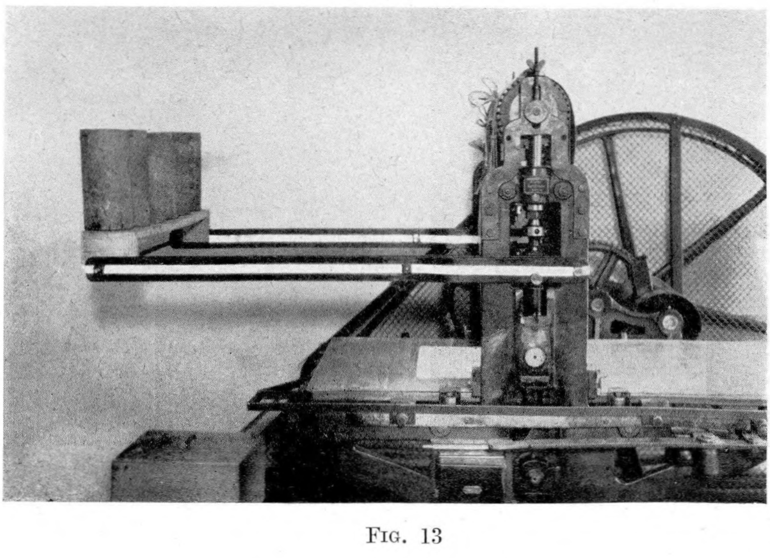

Fig. 13

has consisted of four printing blankets 4 mm. thick. This "packing" was highly elastic and suitable with the *wet* method, but did not answer the purpose of producing a perfectly good impression when the printing-surface of the paper was merely *moistened.* In consequence of this, to begin with, the number of blankets was reduced to two. But the result was not that which was intended, and consequently a rubber plate 2 mm. thick with a double layer of fabric was tried. The rubber plate was used both by itself and together with one or two blankets. As the rubber plate could not be adequately stretched, it became wrinkled during the process of printing, in consequence of which the printing paper was injured. Hence it became necessary to abandon the idea of using such an elastic plate. By using a hard "packing", instead of this elastic one, we gradually reached the type that has now been advantageously tested for two years. Thus "packing" consists of a bookbinder's pasteboard 2 mm. thick, placed between two printing blankets 4 mm. thick.

When only one side of the printing-paper is *moistened,* the paper tries to roll up from the plate, owing to the fact that only the printing-side of the paper is moistened and also to the fact that the expansion due to the moistening is different along and across the paper fibres on this surface (fig. 2) : for this reason the printing-press must be provided with some device to keep the sheet flat against the printing-plate during the process of printing. After a number of trials there have been fitted immediately above the printing-table on the press one narrow steel cylinder in front of the topmost printing cylinder and one behind it (fig. 3).

The outer blanket of the "packing" is stretched outside these small cylinders and, in the course of printing, thereby presses down the nearest edges of the somewhat rolled-up sheet against the printing plate (fig. 4) ; the back part of the sheet is held flat by hand.

The effect of the moistening on the chart-picture, in the experiments made, is shown by the following data (fig. 5).

Nr N°	Dimensions of engraved surface of the plate *Dimensions de la surface gravée de la plaque*		Dimensions of engraved surface of dried chart *Dimensions de la surface gravée de la carte séchée*		Difference *Difference*	
	Length – *Longueur*	Width – *Largeur*	Length – *Longueur*	Width – *Largeur*	Length – *Longueur*	Width – *Largeur*
65	1035,9 m.m.	690,9 m.m.	1034,2 m.m.	689,3 m.m.	1,7 m.m.	1,6 m.m.
6	1035,4 m.m.	690,4 m.m.	1033,7 m.m.	689,1 m.m.	1,7 m.m.	1,3 m.m.
24	950,9 m.m.	688,2 m.m.	949,4 m.m.	696,5 m.m.	1,5 m.m.	1,7 m.m.
132	1030,3 m.m.	696,3 m.m.	1028,6 m.m.	694,5 m.m.	1,7 m.m.	1,8 m.m.
78	729,5 m.m.	532,3 m.m.	728,1 m.m.	531,– m.m.	1,4 m.m.	1,3 m.m.
71	715,4 m.m.	514,7 m.m.	714,7 m.m.	513,5 m.m.	1,1 m.m.	1,2 m.m.

FIG. 5

Thus the experiments gave as a result a substantially smaller change in dimensions than that given by the use of the wet method. On the average that change has been found to amount to 0.17 % in the length and 0.26 % in the width, that is to say, one-*fifth* and one-*tenth* part respectively of that which was caused by the use of the wet method.

The experiments carried out down to the close of November 1926 led to the abandonment of the *wet method.* Up to that time water exclusively had been used for the moistening of the paper. In December 1926, the experiments were extended so as to comprise trials with a suitable moistening liquid At first a borax solution was used which, as being soft, might be expected to exert a favourable influence on the paper. It was found, however, that borax injured the sizing on the paper. Thus the result proved to be negative.

The experiments were continued however, with other liquids, which were regarded as likely to cause smaller changes in dimensions than water. In this connection, however, it was impossible to take into consideration intensely acid or alkaline substances, because they have an injurious effect on paper.

Substances which were more or less chemically indifferent were the only suitable ones. Trials were made with spirit, benzine and paraffin, and all turned out comparatively well. But spirit is too dear for the purpose, and benzine is too volatile to admit of regular moistening. Paraffin proved to be the most suitable. But all these substances have the drawback of being inflammable. It can surely not be impossible to find a suitable *organic* substance which lends itself to moistening purposes without being burdened with the disadvantages just mentioned.

Further experiments were directed towards producing a liquid of a suitable composition. During the year 1928 these experiments led to a result that must be characterised as good and which has not been excelled since. The liquid which has thus been found most suitable so far has the following composition (fig. 6) :—

COMPOSITION OF MOISTENING-LIQUID
COMPOSITION DU LIQUIDE À HUMECTER

8000	GRAM	WATER / *EAU*
250	»	COMMON SALT / *SEL COMMUN*
25-50	»	POTASH-ALUM / *ALUN DE POTASSE*
800-1000	»	GLYCOSE / *GLYCOSE*

Fig. 6

This liquid is produced in the following manner. The alum and the common salt are melted in half a litre of boiling water, after which glucose is added and the whole is stirred while the water is cooling. This solution is stirred into the water, after which the mixture is ready for use. The investigations that have so far been carried out have clearly shown that the use of this liquid offers the following advantages over ordinary water :—

1. The moistening of the sheet of paper is followed by a far smaller expansion.

2. Alum improves the properties of the paper. It strengthens the glaze by coagulating the size still more completely. The strengthening of the glaze makes the paper more resistant to the effect of atmospheric humidity. Moreover, it is easier to make corrections on the paper thus prepared.

Some extracts (figs. 7 and 8) from the diary which has been kept in the printing works ever since December 1926, and the following two graphs (figs. 9 and 10), will probably illustrate the experiments better than words :—

Chart nr 30 printed 7 August 1928
Carte n: 30 imprimée le 7 Août 1928

Printing surface of paper moistened with alum-water
Surface à imprimer du papier humectée avec de l'eau d'alun

Dimensions of engraved surface of the plate *Dimensions de la surface gravée de la plaque*		Dimensions of engraved surface of dried chart *Dimensions de la surface gravée de la carte séchée*		Difference *Différence*	
Length – *Longueur*	Width – *Largeur*	Length – *Longueur*	Width – *Largeur*	Length – *Longueur*	Width – *Largeur*
1028,55 m.m.	690,5 m.m.	1027,9 m.m.	690,3 m.m.	0,65 m.m.	0,2 m.m.
–„–	–„–	1027,9 m.m.	690,3 m.m.	0,65 m.m.	0,2 m.m.
–„–	–„–	1027,7 m.m.	690,3 m.m.	0,85 m.m.	0,2 m.m.
–„–	–„–	1027,9 m.m.	690,0 m.m.	0,65 m.m.	0,5 m.m.
–„–	–„–	1027,9 m.m.	690,1 m.m.	0,65 m.m.	0,4 m.m.

FIG. 7

Method of moistening paper *Méthode d'humectation du papier*	Chart-plate nr *Plaque n:*	Dimensions of engraved surface of the plate *Dimensions de la surface gravée de la plaque*		Dimensions of engraved surface of dried chart *Dimensions de la surface gravée de la carte séchée*		Difference *Différence*	
		Length – *Longueur*	Width – *Largeur*	Length – *Longueur*	Width – *Largeur*	Length – *Longueur*	Width – *Largeur*
Moistening all through *Mouillage complet*	53	1031,5 m.m.	695,9 m.m.	1022,5 m.m.	680,3 m.m.	9,0 m.m.	15,6 m.m.
Superficial moistening with water *Humectation à l'eau*	53	1031,5 m.m.	695,9 m.m.	1030,5 m.m.	694,75 m.m.	1,3 m.m.	1,15 m.m.
Superficial moistening with alum-water *Humectation à l'eau d'alun*	53	1031,5 m.m.	695,9 m.m.	1030,8 m.m.	695,3 m.m.	0,7 m.m.	0,6 m.m.

FIG. 8

The shrinkage of the chart-picture in the chart amounts, on an average, to 0.07 % in the length and to 0.04 % in the width.

GRAPH, SHOWING DIFFERENT DISTORSION OF CHART WHEN USING DIFFERENT MOISTENING METHODS

GRAPHIQUE REPRESENTANT LES DIFFERENSES DANS LA DEFORMATION DES CARTES SELON LES DIFFERENTS METHODES DE MOUILLAGE

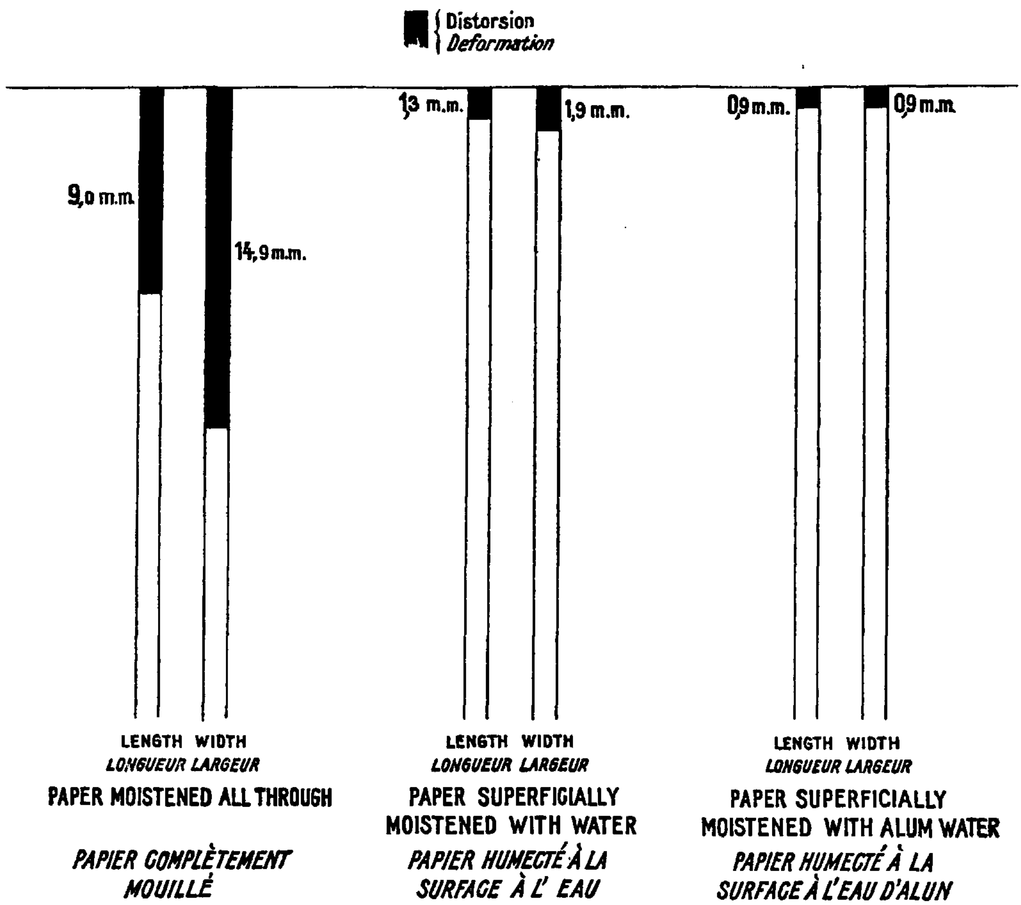

Fig. 9

GRAPH, SHOWING THE DISTORSION OF CHARTS AFTER PRINTING, FOR DIFFERENT MOISTENING METHODS

GRAPHIQUE REPRÉSENTANT LA DÉFORMATION DES CARTES IMPRINÉES, POUR LES DIFFÉRENTS MÉTHODES DE MOUILLAGE

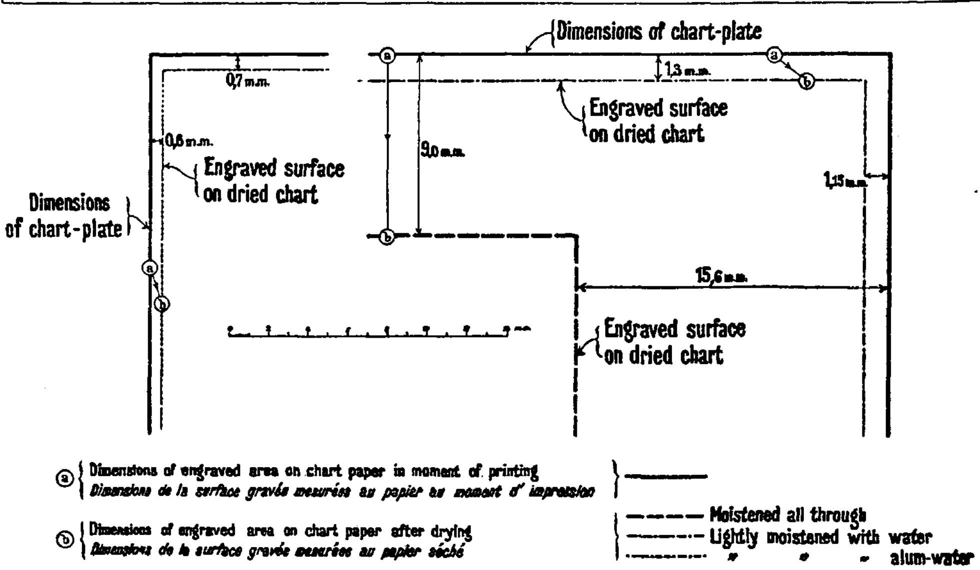

Fig. 10

The last two impressions of Chart 53 were taken on the same day and under conditions which were exactly similar in all respects.

An examination of the relation between longitudinal and latitudinal shrinkage yields the following results :—

Moistening all through *Mouillage complet*	Superficial moistening with water *Humectation à l'eau*	Superficial moistening with alum-water *Humectation à l'eau d'alun*	Superficial moistening with concentrated alum-water *Humectation à l'eau d'alun concentrée*
2,1 m.m	2,1 m.m.	1,4 m.m.	1,2 m.m.

FIG. 11

It is evident that the amount of water that is supplied to the paper is of great importance for the *absolute* measures. Nevertheless, the *relation* between longitudinal and latitudinal shrinkage is not affected by the amount of water. On the other hand, that relation is very highly affected by the addition of foreign substances. The same proportional chart-figure was obtained both on complete wetting and on moistening only one surface of the sheet with pure water; but the stronger the alum solution that was used, the smaller became the ratio between longitudinal and latitudinal shrinkage. The change in the dimensions of the chart-picture with the use of alum solution, measured by angular measure, amounts to only 1/75 of the change that is caused by the wet method.

In order to obtain good and sharp impressions by this method, which I might venture to call the "half-dry method", it has been necessary to increase somewhat the pressure in the printing-press. In order to find out whether this increasing pressure might possibly bring about a gradual change in the dimensions of the copperplate, a number of trials have been made, that may perhaps be of interest.

The prime object of these tests was to measure the pressure, in kg/cm2, in the printing of charts by both the older (wet) method and by the new (half-dry) method. For this purpose there was used a hydraulic press (fig. 12) with an electrically-driven pump with highest practicable working-pressure of 87.0 tons. The copperplate used, a cold-rolled chart copperplate, had a surface of 2209 cm2 (470 × 470 × 2.3 mm.); and consequently the highest load could amount to 39.4 kg/cm2. As the plate was calculated to bear a pressure of 2400 kg/cm2 without the risk of any change in shape, there was thus a seventy-fold margin of security.

The copperplate was laid on a sheet of iron 20 mm. thick and under the upper printing-surface of the press there were fixed blankets and a sheet of pasteboard arranged in the usual way for the different methods of chart-printing. Colour was applied to the plate as usual, and both entirely wet and moistened chart-paper were used for the purpose of comparison between the different methods of printing. The printing was begun with a load of 4.8 kg/cm2 on the plate, and this load was gradually increased to 33.2 kg/cm2 for completely wet sheets and 37.4 kg/cm2 for moistened sheets. Clear chart impressions were obtained.

This test showed that under normal conditions there was no risk whatever of the deformation of the plates, as the highest pressure required is only one or two per cent of that which is needed for a permanent deformation of the copperplate.

The test also showed that the increase of pressure that was demanded in the use of the *half-dry method* in comparison with the *wet method* amounts to only about 10 %. In most cases an even smaller increase would seem to be adequate.

In order to check the values obtained in this test-printing, which was carried out at the note-printing press of the Bank of Sweden, further tests were made with the same copperplate on one of the presses of the Hydrographic Service (fig. 13). There seemed to be a possibility, in fact, that a momentarily greater pressure, involving danger for the condition of the plate, might appear at the very moment when the foremost edge of the plate comes under the cylinder.

In order to check the load, the tightening screws for the cylinder were thrown out of gear. Instead of them the press had been provided with two levers, the outer ends of which were loaded with weights. In addition to the load applied, the printing-plate was exposed to the weight of the printing cylinder with its cogwheel, levers and a number of other devices for the test.

A. *PRINTING WITH COMPLETELY WET PAPER.*

The printing was carried out with 4 blankets on the cylinder. The first trial was made with an extra load of 320.4 kg. The resultant impressions proved to be indistinct, and consequently the load was increased by five stages up to 414.8 kg., when quite good impressions were obtained. At that time the load corresponded to a pressure of 35.4 kg/cm2. At the note-printing press of the Bank of Sweden quite good impressions were obtained with *completely wetted paper* at a pressure of 33.2 kg/cm2 (fig. 14).

B. *PRINTING WITH MOISTENED PAPER.*

The printing was carried out against two blankets and a sheet of pasteboard — that is to say, with the use of the same packing as in ordinary printing. Eight impressions were taken with a gradual increase in the load. Quite good impressions were obtained when the load amounted to 433 kg., *i. e.* at a pressure of 37.1 kg/cm2. The corresponding figure at the note-printing press of the Bank of Sweden was 37.4 kg/cm2 (fig. 14).

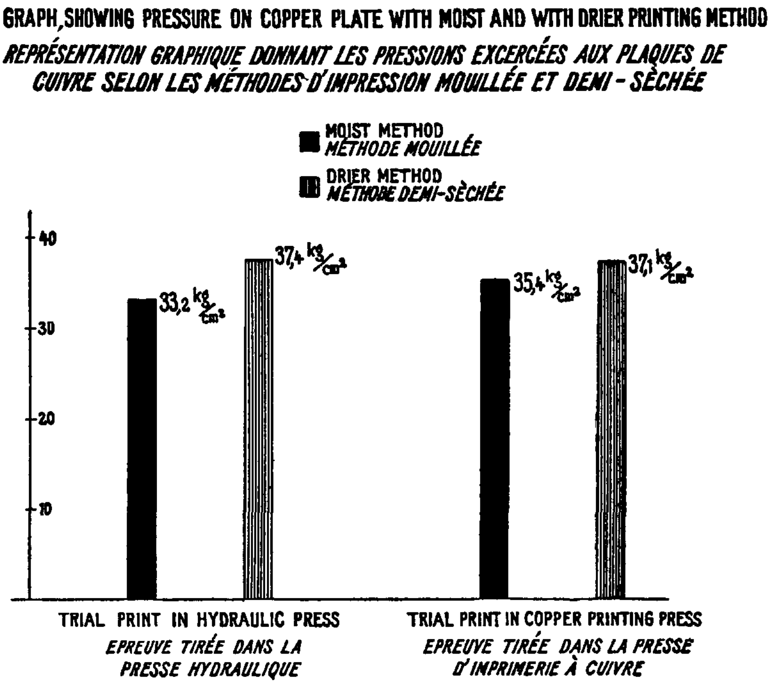

FIG. 14

In order to attain certitude as to the capacity of *galvanically* deposited copperplates to resist pressure without any change whatever in shape, comprehensive printing tests were also made at the BOLINDER's engineering workshops in Stockholm.

In these tests there was used a small hydraulic press, which was pumped by hand and which could produce a maximum pressure of 31.4 tons. In the test there was used a galvanic plate, specially made in the Hydrographic Office

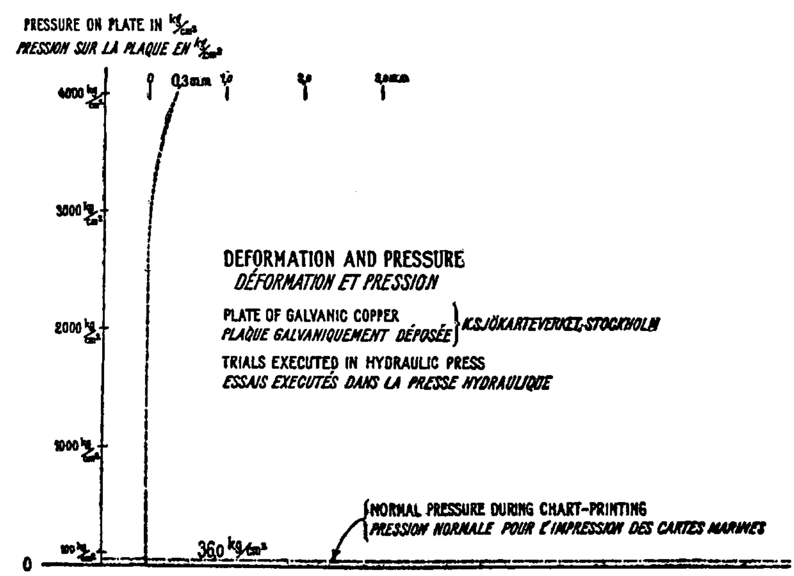

FIG. 15

for the purpose, with an area of 347 cm2. The water pressure could be brought up to a little over 100 kg/cm2. The load on the plate was gradually increased from 25 kg/cm2 to 90.8 kg/cm2, during which process control measurements were repeatedly made with micrometers as to length, breadth and thickness, but no measurable change of shape could be observed. Nor could any effect on the engraving be perceived. This pressure was nearly three times as great as that commonly employed in printing charts (fig. 15).

In order to investigate still further the conditions holding good with regard to deposited copper at *high pressures*, small pieces were inserted in the press. One piece was exposed to a pressure of 2780 kg/cm2, and here a minor deformation could be established. This pressure is nearly 80 times greater than that required for printing charts.

A still smaller piece of copper was inserted, so that the pressure could be brought up to 4040 kg/cm2. In this case the copperplate was crushed from 3.25 mm. to 2.90 mm., *i. e.* 0.35 mm., which means a diminution in thickness of 11 %. The strain was now 115 times greater than that which occurs in ordinary printing.

These tests show that galvanically-deposited copper can attain very high resistance values, and that no risk whatever of the destruction of the plates by deformation can really arise with this method of printing charts. Nor does a threefold rise of the pressure exercise any influence whatever on the engraving on the plate (fig. 15).

Quite recently experiments have been made with the use of *entirely dry paper* and moistening the *chart plate* itself instead of the paper. This has given a fine impression. The shrinkage after the drying of the chart has been measured and estimated at only 0.2 mm. in the length and just the same in the breadth. The difficulties involved in this method are, first, the correct adjustment of the sheet of paper and, second, an *even* moistening of the plate. If these difficulties can be overcome by some suitable device, it would seem possible that *this method might supply the best solution of the problem.*