THE APPLICATION OF WORK STUDY TO THE COMPILATION OF A FAIR SHEET

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INTRODUCTION

In September 1958 Fleet Work Study Team No. 8 was formed, and appointed to work in the Surveying Service of the Royal Navy. The team consisted of three members — a General Service Lieutenant Commander of the Electrical specialization, a Chief Petty Officer, Surveying Recorder 1st Class, and the writer, then an Assistant Surveyor 1st Class.

The first task that the team was given was that of investigating the compilation of a fair chart, embracing all the stages from the field work to the submission into Office of the completed sheet. (For full directive see Appendix.) The object of the study was to reduce chartroom work; the present paper describes firstly how a Work Study is carried out, then the chartroom methods which were in use in 1958, and then the new method which was developed from them. Finally the advantages and disadvantages of the new method are discussed and the reasons explained as to why a method which gives a saving in chartroom work of over 50 % has yet to be fully adopted.

WORK STUDY

The following definitions are extracted from British Standard 3138 : 1959 (*).

Work Study : A generic term for those techniques, particularly Method Study and Work Measurement, which are used in the examination of human work in all its contexts, and which lead systematically to the investigation of all the factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement.

Method Study : The systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

(*) Later definitions follow the sense of this B.S. but are necessarily abbreviated.

The other main branch of Work Study, Work Measurement, by which the time is established in which a task may be carried out under certain specified conditions, was not used in this study.

The above definitions are necessarily lengthy in order to be all-embracing; a briefer definition of Work Study could be extracted from the above as " a systematic examination of all the factors which affect a situation, in order to improve it ".

Historically Work Study stems from the work of Frank Bunker GILBRETH and Frederick Winslow TAYLOR in the U.S.A. at the turn of the century. It arrived in Great Britain during the First World War and was originally applied to the repetitive motions of workers in the mass production industries. While doing this however it was found that the same questioning techniques could usefully be applied to the movements of men and materials on a much smaller scale — in the surveyor's sense of the word. In other words greater benefits were to be gained from a critical examination of the whole process of manufacture of a product than from the detailed analysis of the arm and finger movements of the operatives engaged in a single stage of the process.

From here it was but a small step to the realization that Work Study could be usefully applied not only to the mass production industries, not only to industry in general, but to any facet of human activity in which manual or clerical work is involved. Thus today Work Study has been, and is being, usefully employed in fields as diverse as hospitals, retail shops, agriculture, railways, office work, and the Armed Services, quite apart from the full range of industry.

THE CONDUCT OF A METHOD STUDY

Before describing the techniques employed it is as well to stress the human aspects of an inquiry into the way in which people work; an inquiry which will necessarily probe deeply and which will almost inevitably uncover facts hitherto unappreciated. The individual will fear that his livelihood may be threatened, that he may be made to work harder, or that the interest of his job will be removed; the manager will fear that his competence is being questioned or that his future freedom of action will be restricted. These very real fears must be faced, and answered frankly, as indeed they can be. Work Study can only function properly if it has the fullest cooperation and assistance from both management and managed. The first step then, once the directive for a study has been issued, is a full explanation and discussion with everyone likely to be involved.

The study proper begins by recording the method by which the task is at present carried out. The record is obtained by breaking the operation down into its constituent parts and classifying each part by one of the following symbols :

○ Operation In which the material or product is modified or changed
□ Inspection An inspection for quality or a check of quantity

⇒	Transport	The movement of the object being charted
▽	Storage	When the object charted is placed in a controlled storage
D	Delay	A delay in the sequence of events

The resulting diagram is known as a Process Chart — a Flow Process Chart if it uses all the above symbols, or an Outline Process Chart if it is restricted to the Operations and Inspections. The Flow Process Chart describes the method completely and is useful for showing the results of the study by comparing the old method with the new. The abbreviated Outline Process Chart is normally the one most useful at the next stage of the study, the Critical Examination.

There are a number of other charts, diagrams and recording techniques which might be used at this stage, but as all are additional rather than alternative to the Process Chart and as none were used in this study time will not be wasted in describing them here.

The next stage, Critical Examination, is without doubt the most important. It is the systematic questioning of the necessity of each of the operations and inspections on the chart, and when their necessity has been established, the questioning of the sequence and situation of the activities and the personnel who carry them out. In each case every conceivable alternative is considered in the endeavour to develop an " Ideal Method ". It must be stressed that Work Study merely poses the questions — the answers normally come from the organization being studied and the eventual solution is therefore a joint one in which all concerned have participated.

There are frequently reasons of finance or personality why the " Ideal Method " cannot be employed. The method proposed should however be as close as possible to the " ideal " while remaining both practical and acceptable to those principally affected.

When the proposed new method has been accepted by the Command or management the next stage of the study is to instal the new method, assist in training the staff and overcome any teething troubles. Finally the new method must be " maintained " by occasional checks, to ensure that retrograde practices do not creep back.

DESCRIPTION OF THE ORIGINAL METHOD

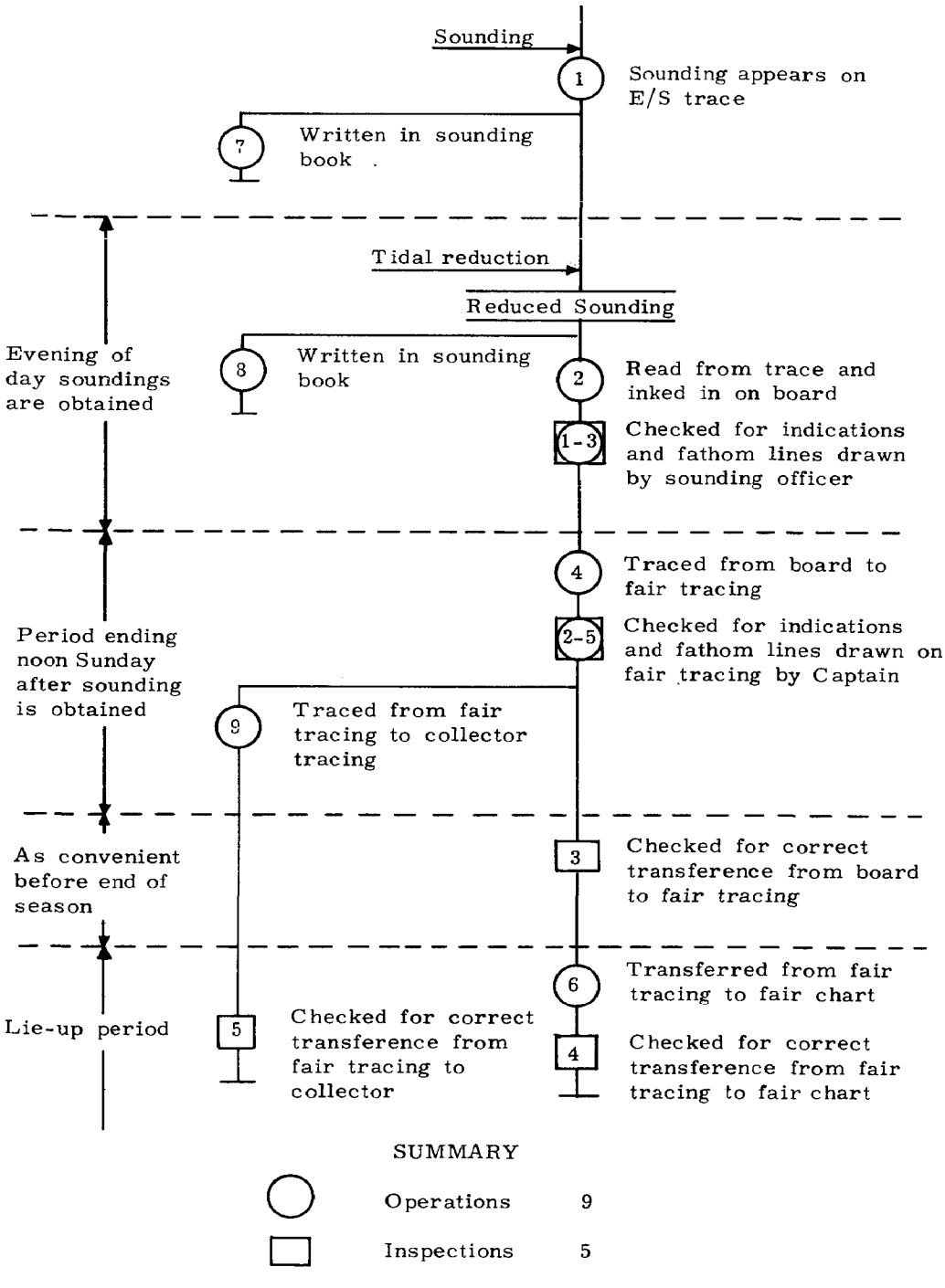
The method to be described was that used in H.M.S. *Scott* in October 1958, which was with small variations common throughout the Surveying Service at that time. With one important exception, which will be mentioned later, it was the method described in the *Admiralty Manual of Hydrographic Surveying* (1938), as modified on the introduction of dry scale trace readers. Such a period has elapsed however since the method was used that it is probably necessary to describe it in a fair amount of detail.

The Outline Process Chart is shown in Diagram A. It starts when the

DIAGRAM A

OUTLINE PROCESS CHART OF THE ORIGINAL METHOD OF RENDERING SOUNDING DATA

Observed in H.M.S. *SCOTT* 14.10.58



SUMMARY

Operations	9
Inspections	5

sounding first appears on the echo sounder trace and, being called out at regular intervals depending on the scale, was noted in the sounding or deck book. On completion of fieldwork the paper was dried and fed into a tracereading machine. On this the scale could be offset by the amount of the tidal reduction so that the reduced sounding could be read off directly. The reduced soundings were inked in on the sounding board, normally by the surveying officer who had done the sounding, and were simultaneously entered in the sounding book by a non-surveying officer. The trace-reader itself was normally operated by a Surveying Recorder. On completion of inking in the whole block of soundings was examined for indications of shoaling, which were drawn to the attention of the Captain, and fathom lines were drawn. The whole of this process was carried out on the evening of the day that the soundings were obtained.

The next stage was the transference of the soundings to the fair tracings. The fair tracings were made of tracing paper and were limited in size in order to reduce the effects of distortion. The corners of the tracings were formed by either the grid or geographical intersections. After the soundings had been traced it was usual for either the Captain or Senior Assistant to insert the fathom lines and to make a second check for indications of shoals.

The large number of tracings in an extensive survey — perhaps twenty to thirty — made it difficult to study the survey as a whole as it progressed, and it was normal to make in addition a collector tracing. This was a working document on tracing linen compiled from the fair tracings, and most ships' Surveying Orders included the requirement for it to be up to date by midday Sunday each week.

Once the survey had been completed a sparetime task was to check that the soundings had been correctly transferred from sounding board to fair tracing, after which the boards could be floated off.

The Fair Chart was almost invariably drawn during the annual lie-up period while the ship was being refitted. Each fair tracing was superimposed in turn over the prepared piece of linenbacked paper; the soundings being transferred by dotting through a piece of " ruddle ", or transfer paper, and drawing the sounding over the dot. Finally the fair tracing was checked against both fair chart and collector tracing, and the work was complete.

It will be seen that each sounding had been drawn four times and checked for correct transference three times.

DESCRIPTION OF THE SURVEYING MANUAL METHOD

This is perhaps a convenient moment to discuss the differences between the above method and that described in the *Admiralty Manual of Hydrographic Surveying* (1938 Edition). The Manual method involves one less drawing stage and therefore one less checking stage. The fair tracing is

laid over the fixes on the sounding board and the reduced soundings are inked directly on to the fair tracing. It is not certain why the method involving more work came into use but is felt that there were probably two reasons. Firstly, when the Surveying Service expanded immediately after the war the overall standard of draughtmanship was necessarily low. The introduction of an extra drawing stage gave an opportunity for uneven figure sizes and irregular slopes to be tidied up, and the appearance of the fair charts undoubtedly profited from it. Secondly, there is considerable practical inconvenience when using fair tracings six inches square and lines of soundings are eight or nine inches long. Some lines will fall on two, three, or even four tracings. One then has the choice of continually realigning tracings or of dealing with one tracing at a time and dodging from the middle of one line to the middle of the next, to the inconvenience of the reader-out. When the ship and three boats are working in the same area there is the further complication that each seems to require the same tracing at the same time.

The Manual method had however been given an extensive trial in H.M.S. *Vidal,* the ship in which the writer served immediately prior to his

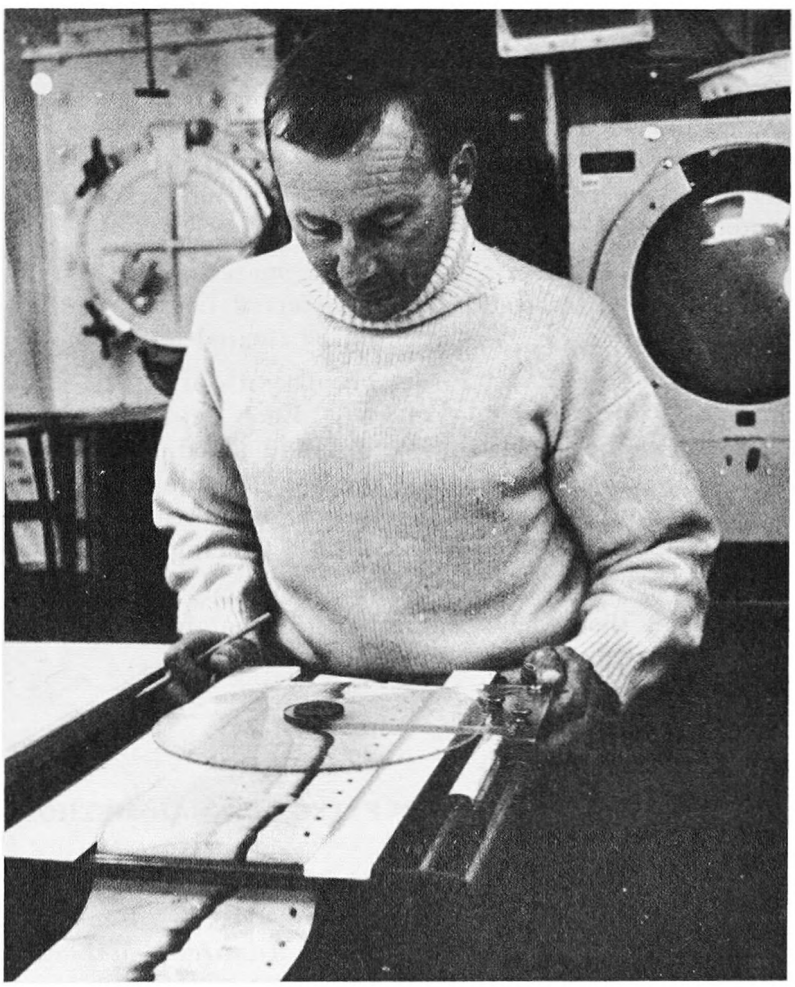


FIG. 1. — The redesigned trace-reader in use (By courtesy of Esso Newsline).

employment on Work Study duties. The saving of labour and the inconveniences described above were both fully realized, but in addition an unexpected bonus was discovered. This was that if each day's fixes, fix numbers, and tracks between, were inked in on the board with a different combination of colours for each day — a key being kept in a convenient corner of the board — it was possible to establish with ease the origin of any sounding on the tracing. Thus implausible looking soundings could be checked back to the original echo trace and errors in inking in corrected; a course which had been difficult in the more normal method since the pencil fix numbers were obscured by the soundings and since there was no means of telling to which boat's work or to which day a particular fix number referred.

The advantages of this easy reference were twofold; firstly of course a gain in accuracy, and secondly a reduction in unnecessary interlining and examination when attempting to substantiate spurious indications. The merits of this do not need to be underlined.

CRITICAL EXAMINATION OF THE ORIGINAL METHOD

Critical examination of the original method resulted in a number of points being raised which eventually led to the development of a new method in which two drawing stages — and their associated checks — were eliminated. Before giving an overall description of the new method it will be convenient to dispose of a number of points of detail that were investigated :

a) The soundings called at regular intervals and recorded in the sounding book had in the past been the soundings inked in on the board. When dry scale trace readers were introduced the soundings continued to be recorded as a precaution against the echo sounder trace fading before inking in. However potassium iodide paper, which was subsequently introduced, had proved to be permanent provided reasonable precautions were taken. It was therefore proposed by the Work Study Team, and accepted, that the sounding at the fix only should be recorded, this sounding having value in that it assists to locate errors in fix numbering. The advantage of eliminating the intermediate soundings was not so much the reduction of work for the Recorder as the greater freedom it gave in fixing. When soundings were called at regular 15 or 20 second intervals a fix was frequently missed because of a shower of spray or a heavy roll just before the sounding was called. When the soundings are not recorded a fix can be taken as soon as both anglers are ready.

b) The reduced soundings were entered in the sounding book so that the work could, if necessary, be subsequently replotted in Office. This was of doubtful value as a check however since an error of reading off the trace would not be detected. The only satisfactory check is the echo sounder trace which was not preserved. It was therefore proposed that all echo

traces should be preserved in Office for five years and that the reduced soundings should no longer be recorded.

c) The tracereading machines used were basic in design and somewhat rough and ready in construction having been made on board. Continual vigilance was necessary to ensure that they remained accurately set; while adjusting the scale for change of phase or tidal reduction was a fiddly, time-consuming process. Where such changes were frequent it was impossible to call soundings as rapidly as they could be inked in. Furthermore no aid was available in dividing up the space between fixes to give the intermediate soundings, and a controlled experiment showed that on a shelving bottom considerable errors could result from inaccurate interpolation.

The design and production of an improved machine took a great deal of time but eventually some 40 were produced in the Ordnance Workshops of the Royal Naval Barracks, Chatham. The machine is strongly constructed of brass and perspex with bearing surfaces of Tufnol. A knob connected by chain drive to rollers drives the paper in either direction, and the scale is so mounted that changes of reduction and phase may be made rapidly and positively. A device is attached which permits the space between adjacent fix marks to be divided into any required interval, up to nine. These machines have been in use for five years and are still proving satisfactory.

d) The task of selecting soundings from the trace, which in some circumstances requires experience and discrimination, was carried out by a Surveying Recorder, while the relatively routine task of inking them in was carried out by an officer. The Work Study recommendation was that these roles should be reversed, and the proposal was accepted. However experience showed that the Recorder Draughtsmen of that time had insufficient experience or speed, and the original procedure has been reverted to.

THE USE OF PERMATRACE

The new method to be described depends on the use of a stable transparent drawing medium, since the full benefit cannot be obtained if the tracings are limited in size. Astrafoil and Cobex had already been used to a limited extent but while excellent for plotting sheets they were less suitable for fair charts because of their liability to shatter and because of their difficult drawing characteristics. Fortunately — and fortuitously — the study was started soon after Permatrace was put on the market as a stable drawing plastic, and it soon became obvious that this was the most suitable material available at that time. However the Department has originals over 150 years old and before recommending a new medium it was necessary to ensure that a chart drawn on it would last as long.

There appears little doubt that the basic material — a sheet form of

Terylene — is sufficiently durable. Neither is there any doubt however that a moist rag and a little pressure will remove any ink that has been deposited on it — and of course in one respect this is one of its attractions. The manufacturers were known to be working on a more permanent ink, but in the meantime other alternatives were considered, of which the simplest was to coat the completed chart with a transparent lacquer. Trials were put in hand at the Central Dockyard Laboratory, H.M. Dockyard, Portsmouth, to test the ageing characteristics of different types of drawing ink and lacquer. The trials took a considerable time but the eventual report was that a combination of Winsor & Newton's ink and I.C.I. Cranco lacquer appeared to give the best result, and that there was a reasonable chance that such a chart would have a long life. On this basis the use of Permatrace was accepted by Hydrographer for a three year trial period.

DESCRIPTION OF THE NEW METHOD

The new method evolved by the team is shown in Process Chart form in Diagram B. It will be seen that the soundings are inked in on what are described as ship/boat tracings (*) and that a final tracing, or fair sheet, is compiled from these tracings. The speed with which this is done will depend on the nature of the survey and the wishes of the Charge Surveyor but there is no reason why the final tracing should not be sufficiently up to date on most surveys to serve the purpose of a collector tracing also. Furthermore the final tracing can if desired be rendered to Office within days of the last sounding being obtained. Both the ship/boat tracings and the final tracing are made of Permatrace; the former of .002″ thickness for economy and the latter of .005″ for durability.

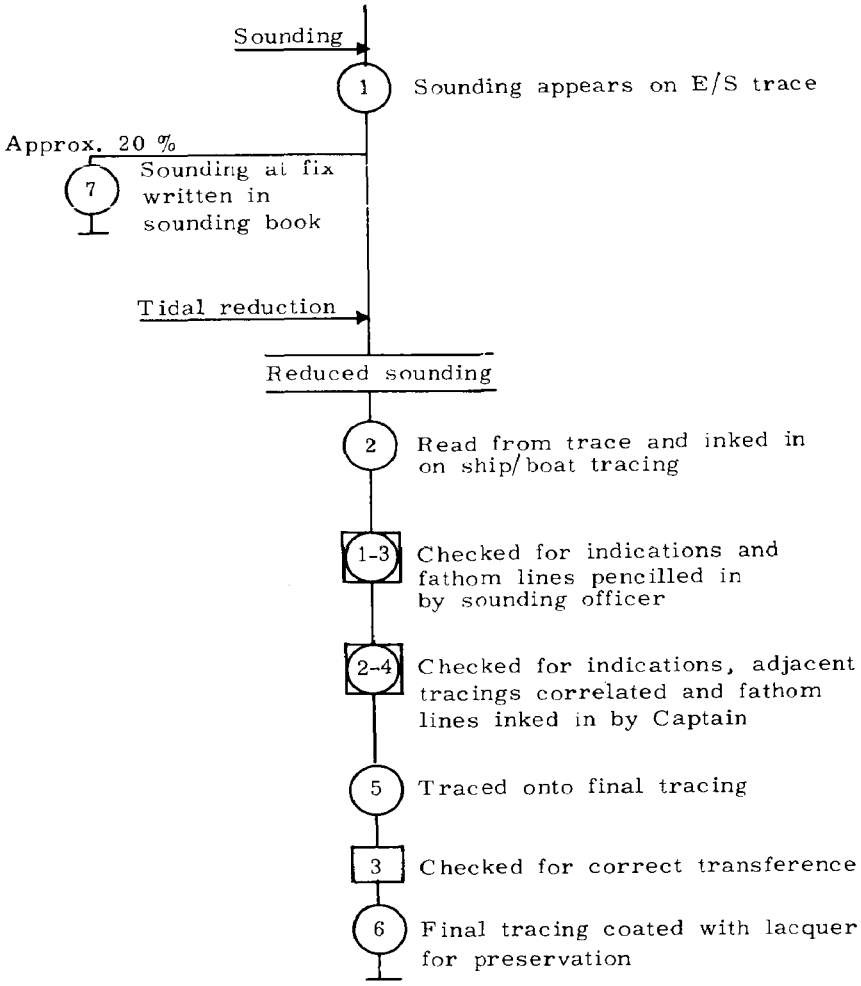
The crux of the method lies in the ship/boat tracings, of which the ship and boats each have a set that will cover the whole area in which the particular unit is required to work. Thus in the extreme case there might be four sets of tracings each covering the whole survey, but this would be exceptional. The important point is that, while inking in, no-one is delayed by waiting for someone else to finish with a tracing.

The tracings themselves may be irregular in size and shape, the sole criteria being convenience of stowage and use (convenience of use being taken to include the inclusion of a sufficient number of fitting points). Thus the probable direction of lines of soundings should be considered when the tracings are made, so that the necessity to change tracings while inking in a block of soundings may be avoided. Permatrace being a stable material, tracings as much as three or more feet square have been used, but it will be found that very large tracings are unwieldy to check and are better avoided.

(*) This term sounds unwieldy but is not so in practice since each tracing is described by the name of the unit and its number; thus " Ship No. 3 " or " Penguin No. 10 ".

DIAGRAM B

OUTLINE PROCESS CHART OF THE NEW METHOD OF RENDERING SOUNDING DATA



SUMMARY

○	Operations	7
□	Inspections	3

It is convenient if blocks of soundings which overlap are on different tracings as the two blocks may then be superimposed to ensure that they are in general agreement and that the most important soundings are selected from each. Where tracings overlap the recommended procedure is to superimpose the tracings and draw a line in coloured ink on the upper one delimiting the area within which that tracing is to be the master. If desired the soundings outside that area may be lightly crossed through. Any soundings on the lower tracing that fall within the limit line and are required to appear on the final chart, should then be traced on the upper tracing, for preference in a colour other than black. Finally the position of the tracings is reversed, the limit line traced through, and the procedure repeated.

The stages of drawing the final tracing, checking it, and coating it with lacquer are straightforward and need no explanation, except perhaps to mention that the neatest way of applying lacquer is with a large pad of cotton wool.

THE ADVANTAGES AND DISADVANTAGES OF THE NEW METHOD

The principal advantages of the new method are as follows :

a) A reduction in chartroom work since each sounding is now only drawn twice and checked once, as opposed to being drawn four times and checked three times in the original method. It is fair to claim that the reduction in drawing effort is greater than 50 % since one of the drawing stages eliminated is the laborious one of transferring to an opaque material.

b) Greater accuracy for the fair sheet since the number of tracing stages is reduced and since the transferring stage has been eliminated.

c) Increased accuracy when inking in through the use of the improved trace reader. A subsidiary gain in this respect is that soundings can be called out faster and it is rare for the inker-in to have to wait for the reader-out.

d) Greater facility in referring back to the original records. The ability to check unusual soundings gives both a gain in accuracy and a reduction in the amount of unnecessary interlining.

e) The ability to render a fair sheet to Office very soon after the survey is completed. This is of course highly desirable in itself, since it will be a better sheet for being drawn and checked while all the details are freshly in mind, and since it enables the information to be got to the mariner that much more quickly. In addition however, with the fair charts out of the way, the lie-up can be devoted to the proper supervision of the refit and the preparation of the triangulation data and other survey records, while still leaving time for the officers to take their leave.

The principal disadvantage is the doubt about the longevity of the final product; a doubt which will exist in respect of all plastic materials, and which will not be finally dispelled for another 150 years. As long as the

doubt remains it would be prudent to take a photocopy of all important original surveys and arrange that both copy and original be inspected at say 5-year intervals.

A lesser disadvantage is that no work on Permatrace can ever be as decorative as a well drawn chart on linen-backed paper, since the former medium cannot be given even colour tints to represent land and shallow water areas. Equally though the charts that we are accustomed to today are not as decorative as those of yesteryear, in which a cherub in the northwestern corner propelled a ship under full sail across those areas of the chart in which it had been difficult to obtain a full cover of soundings. Such is the price of progress.

THE REQUIREMENTS OF THE CARTOGRAPHER

When modifying the methods of preparing a fair chart one must consider not only economy of production but also the requirements of the cartographers who are going to use the chart. Of these perhaps the most important is suitability for photographic reproduction, since this is essential for economic cartographic compilation when a change of scale is involved. Even when working at the same scale it is the practice in the Hydrographic Department to use a photo copy for compilation in order to reduce the risk of damage to the original document.

Ideally the photocopy should reproduce exactly and completely those details which the cartographer requires and eliminate those for which he has no use, yet which appear on even the most austere fair chart. For example drying sand has long been represented by yellow dots and drying mud by brown cross-hatching, and these on the original give an excellent impression of the respective features. When reproduced in black on a photocopy however both symbols seriously handicap the cartographer by rendering the drying soundings indistinguishable. Similarly green trees and mangrove tend to obscure important detail on land when reproduced in black.

This is one of the unusual situations where the " ideal " solution can be realized. Experiment showed that if all unimportant detail of the type described was drawn in yellow or green — which, as it happens, are suitable colours for nearly all such detail — then it will not appear on the negative if it is photographed on to a panchromatic emulsion through a yellow filter. This leaves a full range of colours — red, blue, brown, violet and burnt sienna — with which the important detail can be differentiated on the original and which, when photographed in the manner described, will reproduce perfectly in black and white.

Unhappily however within the Hydrographic Department the geographic and domestic problems are such that copies cannot be made by this means with sufficient speed to be of use, and before the end of the trial period the practice had to be abandoned. In its place a different and more restricted range of colours has been adopted so that the dyeline process

may be used for reproduction. In passing it may be noted that the dyeline process is very much a second best. Unrepresentative colours such as green for streams must be used on the original, all fathom lines must be the same colour, the advantages of selective reproduction cannot be realized, and change of scale cannot be achieved. However it is rapid and it is cheap, and of course is well suited to a transparent original.

Another occasional requirement in compilation is the ability to " square up " the original in pencil. This is difficult to do on the face of the sheet after the lacquer has been applied. However Permatrace is available with a matt surface on both sides and if this form is used for the final tracing the squaring up may be carried out on the reverse side.

RESULTS OF THE TRIAL

At the end of the three year trial period reports were called for, both from sea and within the Office. From sea there was general agreement on the value of the reduction in drawing effort, tinged in some cases with nostalgic regret at the loss of the undoubted beauty of a well drawn fair chart on linen backed paper. Permatrace cannot be given a colour wash and a chart on it will never look as attractive as a similar chart on paper.

One unanimous request from sea was that the Officer in Charge of Survey should retain discretion to vary methods in detail to suit a particular survey. This is entirely acceptable since the basic method is a flexible one. Thus in the examination of a complex shoal it may well be found desirable to use one or more additional "Examination tracing" intermediate between ship/boat tracings and the final tracing. Alternatively one tracing stage may be eliminated on simple surveys of small extent where only one sounding unit is involved. Provided sufficient care has been taken when inking in, a title, border, graduation and lacquer may be applied to the sounding tracing which is then despatched to Office. This is the ultimate in economy of effort beyond which it would seem difficult to go — given that the requirement be a chart rather than a reel of tape or a box of punched cards.

Within the Office the picture was less clear, largely because the sheets that had been rendered rarely conformed completely with the instructions that had been issued, partly through an excess of initiative and partly through lack of the proper materials. Thus reports of detail rubbing off were traced back to the wrong brand of ink being used, and difficulty in squaring up to the use of single matt Permatrace. In one case an attempt had been made to apply colour wash, which frustrated the efforts of the photographer. There was however no doubt that in those cases where the final tracing had been drawn in accordance with the specification it fully measured up to the requirement. The ink remained firmly attached and the quality of the resulting photograph was excellent.

However, as has been said, it proved impossible to obtain the right type of photocopy within an acceptable period and this caused further

dissatisfaction with the method as a whole. Finally there were the objections of those who doubted the longevity of the tracing. No-one will ever be able to state beyond shadow of doubt that such a tracing will last for 150 years until 150 years have elapsed, and consequently such objections are difficult to refute.

The final decision was a compromise; that the new method *in toto*, using Permatrace final tracings, should be used for all routine re-surveys, and that a modification of this method, using a fair chart on linen backed paper, should be adopted for original surveys where the historical aspect is of greater importance. It is still however the intention to adopt plastic materials for all work as soon as a combination of material and ink which is entirely satisfactory is developed.

The reasons behind the decision have been discussed in some detail to explain why methods which have been proved to give a substantial saving in labour have yet to be fully implemented. Other organizations interested in adopting these methods might decide differently if for example they are less interested in long term durability, or if they are prepared to store a separate photocopy as an additional safeguard.

CONCLUSION AND ACKNOWLEDGEMENTS

It would be invidious to single out any of the many individuals who assisted the Work Study team during the course of the study. Suffice it to say that wholehearted support and cooperation were received throughout, both from the ships, the Hydrographic Department, and the various research and production organizations consulted. The study took a total of four months but because of the delays caused by Permatrace trials and the production of the trace readers it was a year and nine months after the directive was issued that the final report was submitted. The reduction in chartroom work claimed earlier has been realized in practice and has permitted full advantage to be taken of modern electronic aids. The study has therefore contributed to the significant increase in productivity achieved by the Surveying Service in recent years.

APPENDIX

STUDY DIRECTIVE No. 1 FLEET WORK STUDY TEAM No. 8 (H)

1. The Team is to study the compilation and rendering of surveying data with the object of reducing chartroom work.

2. **The Task of the Unit under Study**

Normal average production for Surveying Chartrooms of similar ships over the last ten years should be maintained as a minimum. Increases would be welcomed provided extra manhours are not entailed, and if not governed by bottlenecks elsewhere.

3. **Limits of Study**

a. General.

From the time data is obtained in surveying ship or boat until its ultimate despatch to the Hydrographic Office. The accuracy of the ultimate record is not to be less than is obtained by the present methods.

b. Financial and Material.

No expenditure (e.g. in new equipment, repositioning, increase of space, etc.) is to be recommended which will not pay for itself in terms of capitation costs of personnel released for other duties, or extra saleable production, etc., within a term of 18 months from installation of the new methods.