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SECOND EDITION.

DESCRIPTION

OF

THE BRIDGES-LEE

NEW PATENT

PHOTO-THEODOLITE,

With Instructions as to its manipulation in the field

AND

How to make Maps from the Photographs, with Specimen Photographs and Map.

L. CASELLA,

MAKER TO THE ADMIRALTY, ORDNANCE, &c.

147, HOLBORN BARS, LONDON, E.C.

[Entered at Stationers' Hall.]

1899.

No. 203

PREFACE TO SECOND EDITION.

SINCE the first edition of this descriptive pamphlet was written the Photo-Theodolite has met with a very gratifying reception by the Scientific, Engineering and Photographic Press in England and abroad, and instruments have been purchased by—

(1) Government of India, for Surveyor-General.

(2) Government of India, for Meteorological Department.

(3) Director United States Geological Survey.

(4) Mexican Government.

(5) Chilian Government.

(6) French Government (Colonel Laussedat).

(7) Professor of Surveying, McGill University, Canada.

Of the very numerous Press notices which have appeared from time to time special attention may be invited to—

(1) *Engineering* for 10th September, 1897, pages 312, 314, 315. (NOTE.—This article was afterwards copied almost *verbatim*, with the illustration, in *Engineering and Mining Journal of New York* for 2nd October, 1897, page 397, and later in *Scientific American Supplement* and the *Chili Times*.)

(2) The *Photographic Journal* for October, 1897.

(3) The *Journal of the Amateur Photographic Society of Madras* for October, 1897, page 45, in which the article was written and initialled by the Government Astronomer, Madras.

(4) *Invention*, 10th October, 1897.

(5) *Trade and Industry*, 30th November, 1897, pages 571, 572.

(6) *The Photogram*, February, 1898, pages 47 to 49.

(7) *Nature*, 14th April, 1898, pages 563, 564.

Attention may also be invited to—

Photography Annual for 1898, pages 431 to 435 and page 437.

Mr. Bennett Brough's text book on *Mine Surveying*, last edition, last chapter.

The present edition of this small pamphlet has been rendered more complete by the inclusion of a specimen set of photographs overlooking Trafalgar Square and a portion of the Ordnance Survey map of the area overlooked.

By reference to these photographs and the map anyone possessing a copy of the pamphlet can test for himself the practical working of Photogrammetric methods. He can either make the ground plan from the photographs, or use the photographs for testing the map, or *vice versâ*.

There have also been added to the present edition a set of condensed directions for plotting from the photographs by what is known as the method of intersections, and notes concerning the information which can be gathered from a single photograph.

It is hoped that all these numerous additions to this edition will be found of practical service, especially to beginners.

INTRODUCTION.

PHOTOGRAMMETRY (or Metrophotography as it is often called) may be defined as *that branch of technical applied science which is concerned with the determination of the forms and dimensions of objects from Photographic pictures of those objects.*

A photograph which is free from optical or mechanical distortion is in truth a perspective pure and simple, and all the laws and principles of perspective are applicable to the interpretation of photographs.

For the correct interpretation and use of perspectives for measuring purposes it is necessary not only that they should be true geometrically, but we must know or ascertain by some means a number of particulars concerning each perspective. Especially is it necessary to know—

(1) The position of the spot where the perspective was obtained (station).
(2) The picture plane.
(3) The orientation of the view
(4) The trace of the principal plane.
(5) The trace of the horizon plane.
(6) The principal point (intersection of (3) and (4).).
(7) The length of the distance line, which in the case of a photograph is the working focal length of the lens.

The Instrument which is described hereafter as the Bridges-Lee Photo-Theodolite has been specially designed to give true photographic perspectives, always in a vertical plane and at constant distance, and it is furnished with specially designed mechanism inside the camera for recording on the negative all or nearly all the information necessary for interpreting the picture.

The practical advantages which result from having necessary data for interpretation recorded on the face of the picture instead of in separate note-books are very great. Risks of error and confusion are very much reduced. Much time is saved both in the field and in office. Plotting operations are rendered more easy, certain, and accurate, and the pictures will be more valuable as permanent records for future reference.

The theory and the methods of photogrammetric measurement are not at all new. They were fully expounded more than forty years ago by Col. Laussedat, the present Directeur of the Conservatoire des Arts et Metiers, Paris. Also from time to time there have been many photographic surveys effected in many different countries over limited areas and with excellent results, but it has been reserved for the Canadian Surveyors under the guidance of Mr. E. Deville, the Surveyor-General, to demonstrate on a very large scale, and finally and conclusively that for hilly and mountainous districts the photographic method is superior to all others. It has been proved to be very much quicker and cheaper than any other known method and more convenient and at least as accurate.*

Some of the special advantages of the photographic method may be epitomized as follows :—

(1) It is often possible to obtain photographic pictures of places for surveying purposes which it would be quite impossible to survey by any more ordinary means, *e.g.*,—

(*a*) In many exposed mountainous regions where the weather is generally unsettled and uncertain with only occasional breaks; or when so much time is of necessity consumed in travelling to and returning from a surveying station that it is impossible to spend much time at the station.

(*b*) For military purposes in an enemy's country.

(*c*) When a traveller is compelled by circumstances to traverse unknown country at a rapid pace;

and speaking generally wherever and whenever it is possible to obtain occasional clear views from spots visited, but not possible to stay for any length of time at those spots or to revisit them. In all such cases the Photographic method is beyond all comparison the best because it is the *only possible effective method.*

(2) Photographs contain an amount of detailed information concerning the country photographed, which it is perfectly impossible to gather from notes of observations and sketches alone, so that in all cases they may be of great practical service; not only for checking observations made and noted in the field, but also for supplementing those observations and filling in details which had escaped notice.

(3) Frequently it happens that preliminary experimental surveys are required for irrigation purposes, or for ascertaining the best routes for roads or railways. In such cases it is often excessively difficult, if not impossible, to decide at the outset how much plotting will be necessary for the purposes immediately in view. If a series of observations taken and noted turn out to be insufficient, it may be necessary to revisit the stations for further observations; or if, to be on the safe side, a tolerably exhaustive detailed survey is made in the first instance, it may turn out afterwards that the whole

* Mr. Deville has shown that in Canada the cost of a photographic survey by methods heretofore in use is considerably less than one-third of the cost of a plane table survey.

of the labour will be wasted, so far as the particular purpose in view is concerned, because the ground surveyed may ultimately prove to be unsuitable. In either case there will be waste of valuable time, and in every case where a complete detailed survey has not been carried through in the first instance, it will always be necessary to make such a survey after a general plan of construction has been decided upon.

With Photographic surveys there need be little or no waste of time from such causes. A fairly complete series of photographs can be taken in the first instance in less time and at less cost than would be required for the most cursory preliminary survey, and these photographs will afterwards serve all purposes, not only for plotting preliminary surveys, but also for filling in details whenever and wherever a precise knowledge of detail is required.

(4) Not only can a photographic surveying party cover a much larger area during a working field season than an ordinary survey party with a plane table, but it is also possible in many cases to employ (for part of the field work at least) less expensive labour, *e.g.*, a person of ordinary intelligence after a little training might be entrusted in some cases with the task of setting up the instrument and exposing plates at prescribed stations without requiring of necessity the presence of a trained surveyor. All these are practical advantages, and not mere speculative creations of the imagination. They have been proved in practice by the evidence of immense areas surveyed and mapped with extraordinary rapidity, accuracy, and economy, and without doubt photogrammetry is now making rapid headway as a subject for study in technical schools and colleges; it is commencing to find a place in standard text books on surveying; and it is being applied practically over larger and larger areas, and in many parts of the world to such an extent as to warrant a belief that *within a few years it will be the most popular method* wherever it is applicable.

Hitherto there have been many difficulties in the way of rapid development. The chief and, perhaps, the most important of these is the powerful element of human inertia. Surveyors who have been trained to apply old methods with which they have become intimately familiar from long practice naturally find those old methods more easy for them individually than a method which they have not yet studied or applied. Most subjects appear difficult to people who have not seriously studied them with close application, and all subjects (even the most abstruse) come in time to appear easy to persons who have mastered them.

It is thus the common experience of mankind that in all professions it is extremely difficult to develop radical changes of procedure until such time as it has been quite conclusively proved that the old methods must give place to the new ones, and until a new school of young members is ready to work the new methods wherever required.

For Photogrammetry that time is arriving fast. There are now quite a number of well-trained photographic surveyors actually at work and many more will doubtless be ready soon, and their day of unchecked progress is coming rapidly if it has not already arrived.

For the rest, the elements of difficulty which affect the subject may be all ranged conveniently under two heads, which are:

(1) The difficulty of obtaining sufficiently good photographs suitable in all respects for mapping purposes.

(2) The difficulty of constructing maps from those photographs.

All difficulties under the first head, which are of a purely photographic character, are to be conquered by technical photographic training on the part of the persons who are concerned in producing the photographic pictures. It is not in all cases essential that the surveyor should be technically skilled in all the details of practical photography (though it is best that he should be), but it is essential that he should have the aid of a competent photographer who can be trusted not to spoil his pictures by careless and ignorant manipulation.

The surveyor (or whoever else is entrusted with the duty of exposing plates in the camera) must, however, have learnt by practical experience to judge correct exposure, and he must use sound judgment in selecting his stations and in orienting his instrument to obtain suitable views for after use. To simplify matters as far as possible, and to minimise risks of mistakes, he should as far as possible employ always the same standard instrument and lens, and work with the same aperture and the same brand of plates, which should be developed afterwards with the same standard developer. Experiments in the field where actual work is going on are to be deprecated, whenever they are not absolutely necessary, and it is well to limit variable conditions as much as possible.

Most persons who have tried their hands at Photographic surveying have found themselves in the position of being obliged to attend to a very large number of varying details and adjustments in the manipulation of their instruments when set up at a station, and they have been obliged to record multitudinous explanatory notes. Often from oversights or mistakes in adjusting the instrument or in recording notes the photographs obtained might turn out to be useless or nearly so for practical purposes, and sometimes the photographs themselves could not be identified after development.

The Instrument described hereafter has been designed to save trouble and to avoid as far as possible all sources of error from defective adjustments or wrong or omitted entries.

Clearness of atmosphere and brightness of illumination of the landscape are inevitable variable conditions and are best met by the use of colour screens and varied exposure only.

The principal plane may vary with each picture and the horizon plane with each station, but it is possible to fit the camera with cross hairs inside so that when the instrument is level the shadows of those hairs shall always mark the traces of those planes.

Similarly the orientation may vary with each view, but a compass can be so fitted inside the box that the orientation shall be automatically recorded.

Also it is possible to fit inside the camera a scale (the image of which can be impressed by contact printing on the negative) for determining immediately at any time the angular bearing of any visible point in the picture with reference to the principal plane. This scale will be found of great use, not only for the purpose just indicated, but also as affording a very ready and certain means for quickly ascertaining the working focal length of the lens or distance line or the equivalent distance line for enlargements.

Also to avoid possible after confusion among the pictures and for general convenience it has been thought best to record notes to indicate number of picture, station, altitude, magnetic variation, and other matters on the face of the picture rather than in note-books, and special provisions have been made to enable this to be done easily.

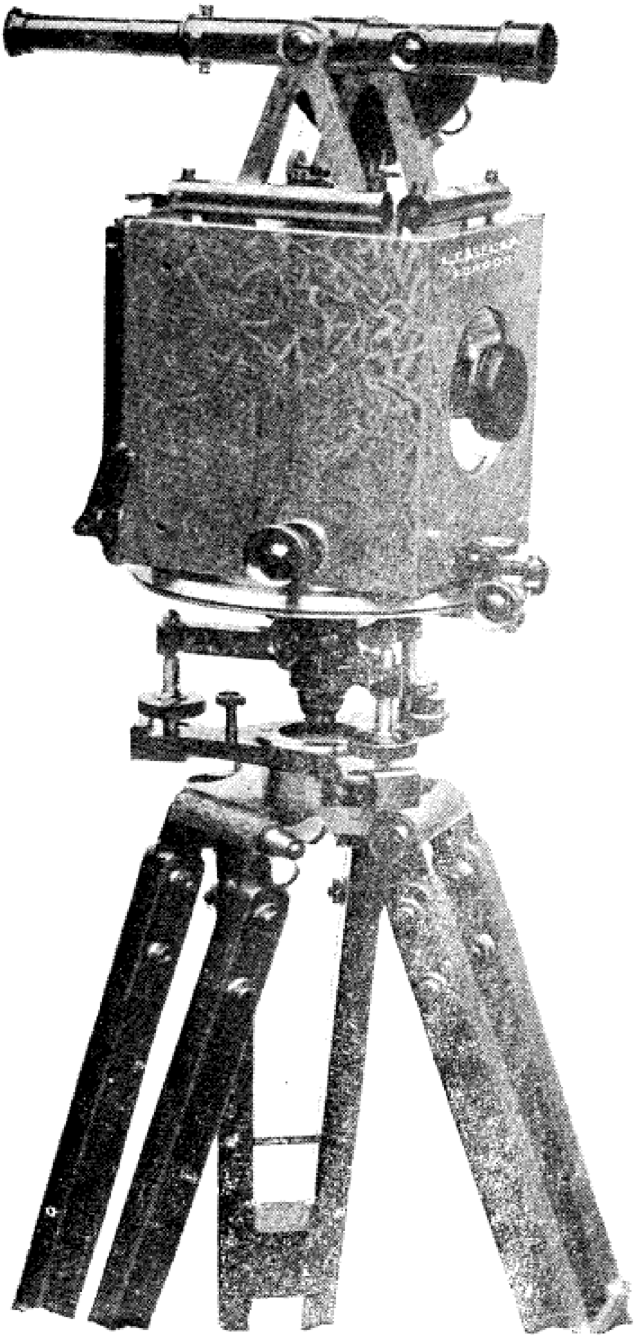
All these improvements are calculated to save time and trouble to the operator, and more especially to simplify after work.

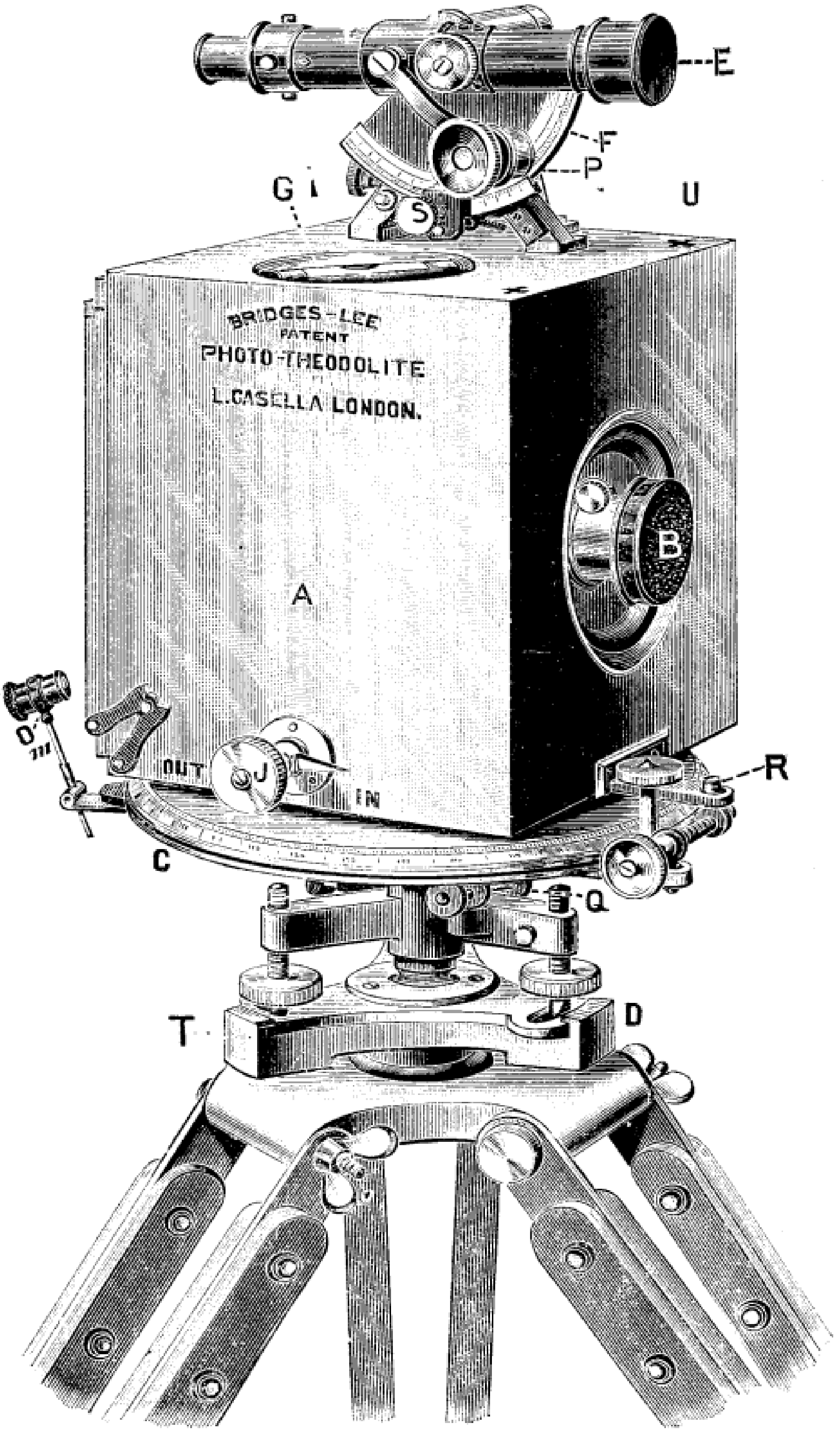
They serve also to a very large extent to eliminate risk of personal errors of observation or record, and it is hoped that they will be universally appreciated as they become more widely known, and that these improvements may play a not unimportant part in the task of popularising photogrammetry as a branch of applied science with a great future before it.

For the information of those persons who may not perhaps be familiar with the bibliography of the subject, and who may wish to study photogrammetry, it may be noted that by far the best and most complete treatise on the subject to date is a book, entitled "Photographic Surveying," by E. Deville, Surveyor-General of Dominion Lands, Canada (published, Ottawa, Government Printing Bureau, 1895).

J. BRIDGES-LEE.

6, King's Bench Walk, Temple,
London, E.C.

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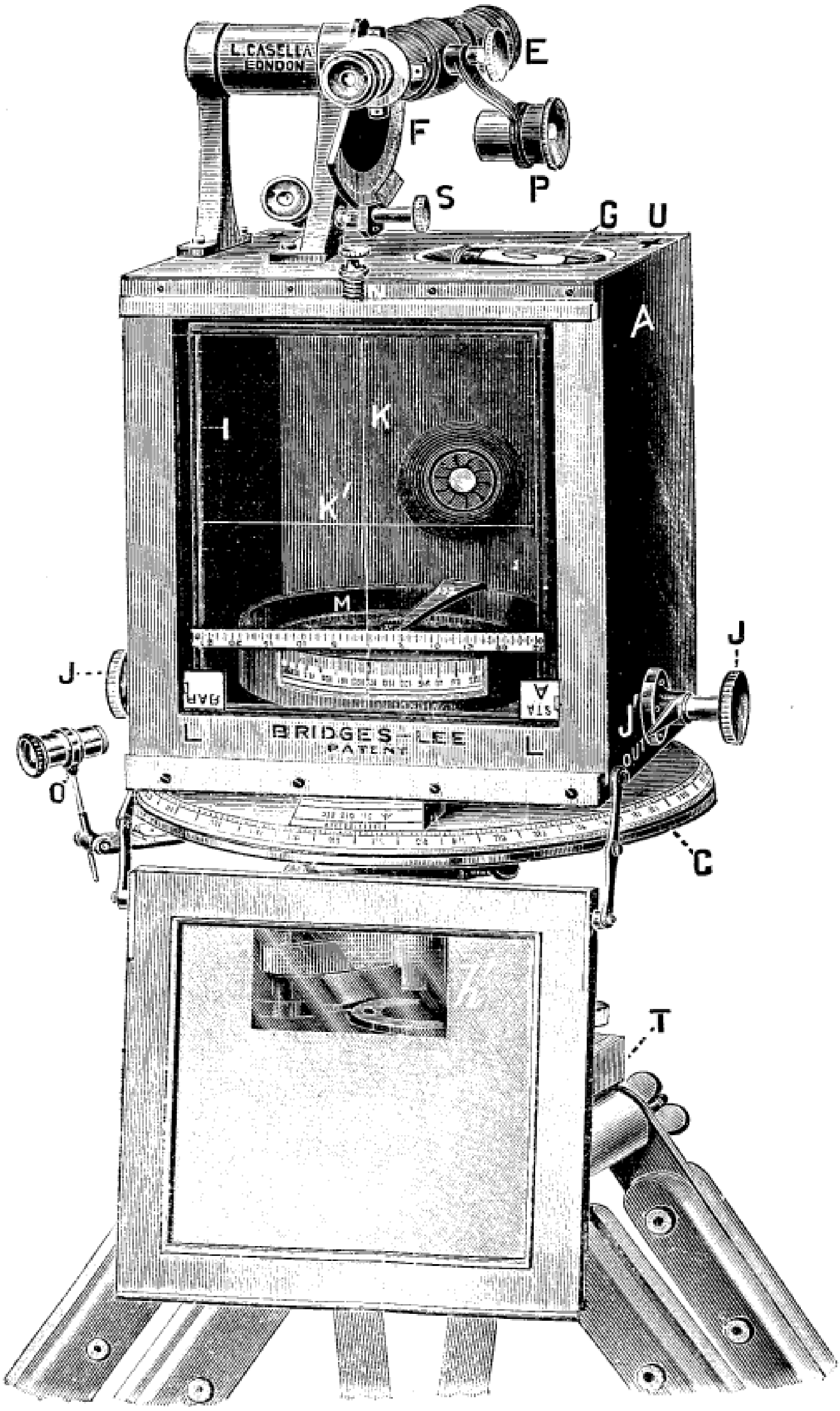
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DESCRIPTION

OF A

NEW PHOTO-THEODOLITE,

DESIGNED BY

J. BRIDGES-LEE, Esq., M.A., F.G.S., etc.

PATENTED IN ENGLAND AND ABROAD.

Made by LOUIS P. CASELLA, 147, Holborn Bars, London.

The Index Letters refer to the woodcuts.

A. Rectangular box of aluminium (cast metal).

B. Rectilinear photographic lens with iris diaphragm. This lens is accurately set in correct position with reference to the other parts of the Instrument, and it has no focussing adjustment.

For the purpose of fitting the Instrument to be used for ordinary photographic work at short distances, a second photographic lens working in a focussing sleeve with rack and pinion adjustment can be supplied at an extra cost.

C. Azimuthal circle divided to half degrees with vernier attached to back of the box to read to minutes.

D. Tribrach locking plates and levelling screws.

E. Telescope with cross webs in the body and usual adjustments. This telescope is free to rotate only in a vertical plane when the instrument is accurately levelled, and the line of collimation and the vertical web are in the median vertical plane of the instrument —the same plane which bisects the photographic lens and passes through the axis of revolution of the internal magnetic compass and the vertical hair in the camera.

F. Vertical limb divided to half degrees, moving with the telescope with fixed vernier to read to minutes.

G. Revolving tubular level let into a socket in the roof of the aluminium box. By the aid of this level the horizontality of the instrument can be adjusted in any position without disturbing the position of the camera.

G. G. A pair of fixed levels at right angles to serve as additional security for accurate levelling.

H. Falling back to camera with hinged joints. The ground glass (*h*) has in it a window of polished glass (*h*') through which the vertical index hair and compass scale can be read, with or without the aid of a microscope.

I. Rectangular frame of metal with strong back stays not shown in the drawing. This frame is rigidly attached to a bottom plate which supports the compass box, and is free to move only in an antero-posterior direction, with rigid guides fixed to the base of the box to control its motion.

The back surfaces of the frame are all in a true vertical plane when the instrument is accurately levelled, and that vertical plane is accurately perpendicular to the principal axis of the photographic lens.

This frame can be racked backwards and forwards by aid of a transverse pinion traversing the bottom of the box

JJ. and terminating in two milled heads (**JJ.**).

Pointers (*jj*), which revolve with the pinion, serve to indicate whether the internal structures are forward or back when the falling back of the camera has been let down and replaced by a double dark slide containing a photographically sensitive plate. The dimensions of the rectangular frame (**I.**) are such that it can pass completely inside the double dark slides used (when the shutters are open), and carry back the **K.K.**' hairs which it supports until they actually touch the plate.

There are also two small stops in the form of sliding bolts, which serve to prevent the frame from being carried back with too much force, or too far. These stops secure uniformity of focal distance. They do not appear in the woodcuts.

K. Vertical hair carried by the frame. This hair serves to mark on the photograph the median vertical plane of the instrument, and cuts the principal optic axis of the lens at right angles. This vertical hair serves also as an index by which to read the compass scale. It is in the same plane as the vertical web in the telescope, the optical axis of the telescope, the optical centre of the photographic lens, and the axis of revolution of the compass.

K.' Horizontal hair carried by the frame. This hair crosses the vertical hair at right angles at the point where both hairs intersect the optical axis of the photographic lens. It serves to mark the horizon of the instrument on the picture when a photograph is taken, the instrument having been first accurately levelled. The intersection of these hairs marks the principal point of the perspective.

The hairs are fixed to the frame by the aid of small wood pegs. The proper positions are ascertained and fixed by the maker. If broken at any time they can be easily replaced in a few minutes by anybody.

LL. Small tablets of thin transparent celluloid on which Magnetic error, Barometric pressure, station mark, or other particulars which it may be desirable to record photographically on the picture, can be noted by observer with quick drying ink. These are written upon in an ordinary way and then placed upside down in little pockets in the frame specially designed to hold them and print out as shadowgraphs on the negatives and prints.

M. Magnetic compass with vertical cylindrical transparent scale divided to half degrees 0° to 360°. The cylindrical transparent scale passes quite close in its revolution to the vertical index hair, but never touches it. The pivot of the compass is rigidly fixed to the base plate before referred to, so that the compass scale is always at exactly the same distance from the vertical hair. When the base plate carrying the frame and compass is racked forward in the box, a copper disc automatically rises and lifts the agate off its pivot, and presses the top of the agate cup against the support (*m*) so that the compass is firmly clamped, and can suffer no injury from friction at the pivot or otherwise. When the base plate is racked back so as to carry the frame and cross hairs, and part of the compass scale inside a double dark slide, and close to a photographically prepared plate, the agate cup is automatically lowered upon its pivot, and the magnetic compass adjusts itself to its natural position. This part of the internal mechanism is not visible in the woodcuts.

N. Catch to hold double dark slide in place. The back surface of the box is provided with a frame of aluminium to hold the double dark slides, and exclude light, and as a still further safeguard against the entry of extraneous light there are facings of velvet.

O. Microscope with universal joint movement to permit of its being used either for reading horizontal angles on the azimuthal circle, or for reading the compass bearings through the window in the ground-glass back.

P. Adjustable microscope for reading vertical angles.

Q. Clamp and tangent screw for azimuthal circle.

R. Clamp and tangent screw for camera.

S. Clamp and tangent screw for telescope.

T. Tripod with strong aluminium or other metal head and bronze clamping screws.

This tripod is fitted with transverse bars of bronze which serve as attachments for chains to safeguard the instrument. They also serve to give attachment to hooks attached to a net in which heavy stones can be placed, to give stability and steadiness to the instrument when in use.

These do not appear in the woodcuts. They are at a slightly lower level than the parts drawn.

U. The + + marks on the top of the box indicate the focal distance. A straight line joining the centres of those crosses is the working focal distance for ordinary temperatures.

Below the centre of the instrument in the axial line is a small hook which serves as an attachment for a small plumb bob.

The telescope has an erecting as well as inverting eyepiece.

There is an optical colour screen of optically worked green glass to fit inside the sunshade of the photographic lens. Yellow or orange glasses can also be supplied when desired.

Also attached to the frame which carries the hairs is a horizontal transparent scale of angular distances, photographically prepared by aid of the identical lens and instrument as it is used for surveying purposes.

By the aid of this scale the exact angular distances of any points in the picture right or left of the median vertical plane can be immediately read off with the aid of a parallel ruler.

This scale also facilitates the determination of compass errors, because if there are any points in a picture whose true bearings have been fixed with precision—trigonometrically or otherwise—it is only necessary to add or subtract the angular distances of those points (as read on the horizontal scale of angles) to or from the automatically recorded compass bearing of the median vertical plane, in order to ascertain the compass bearings of the points, and the difference between the compass bearings and the true bearings is the compass variation. This very simple operation can be performed in office at any time.

The instrument is supplied with six double dark slides of good construction to carry a dozen plates, size 5 × 4, either horizontally or vertically.

It fits easily and securely in a strong, well-made mahogany case, with lock and key, and catches.

The double dark slides, plumb bob, and optical screen, all fit in the same case, and for greater security and convenience of transport the mahogany case, with its contents, can be fitted with an outer leather case with straps at an extra cost.

In conclusion it may be noted that the instrument is a complete, symmetrical, well made theodolite, reading to minutes with sufficient vertical range for all ordinary terrestrial work. The camera is always in place, ready for immediate use whenever photographic record is required, and the camera can, when desired, be made immediately available for taking ordinary photographs of persons or things at short distances by lowering the back stops and racking back the internal mechanism quite out of the camera. If a small piece of velvet be then laid over the guide table and pinion, the inside of the camera resembles the inside of any ordinary camera, and the focussing adjustment of a subsidiary lens affords ready means for focussing objects at short distances. The compass is large and good, and the vertical scale with parallel line divisions admits of very close readings being made through the back window or by looking through the lens from in front.

It will thus be seen that anyone possessing this instrument is provided with: (1) A good theodolite, complete for terrestrial observations; (2) A complete photographic equipment for all ordinary photographic purposes; (3) A very good azimuth compass; and (4) By far the most perfect photogrammetric apparatus ever made up to this time.

It is confidently submitted that this is the most generally useful instrument which any explorer can take with him, and its cost and bulk and weight considerably less than a theodolite, photographic outfit, and azimuth compass of equal quality carried separately.

The fact that the internal mechanism acts to a large extent automatically serves to minimise risks of error from inaccurate observations or false entries, and every picture taken with the instrument when used as a photo-theodolite will carry on its face the following information, which can be used at any subsequent time for interpreting the photographs and for making maps.

(1). The median vertical plane (*i.e.*, trace of principal plane).

(2). The horizon of the instrument (*i.e.*, trace of a horizontal plane bisecting the lens).

(3). The principal point of the picture (at the intersection of the last mentioned lines).

(4). The magnetic bearing of the principal plane (note this must be correctly recorded if it is recorded at all because *(a)* If the observer were to omit accidently to rack back the frame and compass before exposure, the lines and figures would not be printed on the photograph; and *(b)* If he were to expose before the compass had come to rest, the compass scale and figures would not print out but would yield only an indistinct and almost invisible blur as the result of long exposure, such as is always given for photogrammetric purposes).

(5). A scale of horizontal angular distances right and left of the principal plane.

And the picture may be made to bear also on its face the following or other additional information which must be first written by the observer on strips of celluloid with Indian ink.

(6). Mark to denote the *station* where the instrument was placed when photograph taken.

(7). *Barometric pressure or computed altitude.*

(8). *Time, date, serial number* of photograph, magnetic error or other information which it may be desirable to have recorded on the photograph. All the above information is printed in what will ordinarily be the sky region of the picture, except of course the fine straight lines which mark the vertical and horizontal planes, and the pictures taken will form most valuable records which can be interpreted at any time afterwards with a minimum of assistance from note books, and with great accuracy.

One great advantage arising from recording as much necessary or useful information as possible on the faces of the photographs themselves, is that there cannot be any mistakes made afterwards as regards the particular facts recorded, and another great advantage is that whenever a photograph is enlarged for map making purposes, the lines and scales are enlarged at the same time and in the same proportion, and are always present in evidence for mapping or measuring purposes.

For the rest, the instrument is compact, strong, light in weight, and beautifully finished in every way, and of reasonable cost, having regard to its great efficiency and practical utility.

The instrument can at any time be made available for astronomical photographic observations, or for cloud photography, by the aid of an adjustable mirror or rectangular prism in front of the lens.

Price of the instrument, with one lens, six double dark slides, to carry twelve plates, various accessories, &c., in mahogany case, and with tripod stand complete £45 0 0

Lenses of any of the best known makers can be adapted to this instrument if required, at an extra cost.

INSTRUCTIONS

Relating to the use of the BRIDGES-LEE New Patent

PHOTO-THEODOLITE

IN THE FIELD.

A.—*Choice of Camera Stations.*

1. As a general rule select points which overlook the area to be surveyed.

2. When the area to be surveyed contains points whose positions have been previously determined with precision (trigonometrically or otherwise), it is frequently advisable to select those points as camera stations.

3. It is frequently convenient to select new stations by aid of observations made from other stations.

4. Stations should be selected at such distances apart, and in such directions with reference to each other and to the areas to be surveyed, as to yield good intersections for plotting purposes.

5. Special stations may be selected for special individual views in definite predetermined directions.

6. Before proceeding to occupy any station, due regard must be had to the time when it will probably be reached by the observer with reference to what will be the position of the sun (*a*) as regards the camera, and (*b*) as regards the particular areas to be photographed from that station.

7. Camera stations should be numerous, and the views from those stations should cover as much as possible of the ground to be surveyed. All the more important individual landmarks must be visible from two stations at least, and most of them and many minor points should be visible in photographs from three or more stations.

8. For the purpose of obtaining pictures from which contour lines can be most easily plotted, it is a good plan when practicable to establish a number of secondary camera stations at different altitudes on a hillside below a principal station. The differences of altitude of these secondary stations should be determined with care, as also their relative positions on a ground plan ; and when selecting positions for these secondary

stations, it is a good plan to select points of view as nearly as may be in the same vertical plane, which can be made a principal plane for one photograph at least taken at each point. Whenever an observer is ascending to or descending from a principal camera station on a hilltop, he should keep a sharp look out for suitable spots for secondary stations on the hillside.

B.—*Manipulation of the Photo-Theodolite at the Camera Stations.*

1. Set up the tripod with legs fairly wide apart and very firmly placed The tripod head should be approximately level.

2. By aid of the plumb-bob determine the exact position of the instrument, and mark the correct spot on the ground by aid of a peg.

3. Attach a strong net by hooks or cords to the metal cross-bars on the legs, and load this net with heavy stones or turf to secure great stability.

4. Then unscrew the metal protecting cover from the axis of the tripod head and screw on the tribrach Open the tribrach by pushing aside the locking plate to enable it to receive the terminal feet of the levelling screws.

5. Then take the instrument carefully out of its case and stand the feet in the recesses in the tribrach designed to receive them. Then close the locking plate and make certain that everything is secure.

6. Then take off the cap from the lens and open the iris diaphragm to full aperture, and rack back the internal structures as far as they will go (the stop bolts being pushed out).

7. Level the instrument. The best way to do this quickly is to turn the revolving level until the tube is approximately parallel to a line joining two of the levelling screws Then manipulate those two screws until the air-bubble rests approximately at the middle of its run. Then rotate the spirit-level through an angle of ninety degrees, and manipulate the third screw until the air-bubble rests at the middle of its run. Again rotate the level through ninety degrees, and if necessary again manipulate the first pair of screws, and so on until the bubble remains approximately in the middle of its run in all positions. After a little practice it will be found that the operation of levelling can be very rapidly effected in this way. At this stage of the operations approximate levelling is sufficient, and it is not necessary to lose time over efforts to secure an exactly level position until everything is ready for exposing a plate to take a picture.

8. Next adjust the microscope **O** in position to read the compass scale through the window. To do this correctly there are three main points to attend to: (*a*) the optic axis of the microscope should be approximately perpendicular to the window; (*b*) the index hair should bisect the field of view; (*c*) the focal distance should be conveniently adjusted so that the eye may be able at the same time to read the compass scale and to distinguish the vertical index hair.

9. While the above-mentioned operations have been in progress the compass will almost certainly have come approximately to rest, and the azimuthal circle may now be oriented if desired by aid of the compass. To do this it is only necessary after releasing the circle by turning the clamping screw **Q** to rotate the circle (which of course carries the camera round with it) upon its axis until the magnetic compass reading corresponds with the reading on the azimuthal circle. In practice it is convenient (before proceeding to orient the circle) to bring the zero of the vernier to correspond exactly with one of the divisions on the circle. This can be done by aid of the tangent screw **R** (the camera being clamped.) The compass can also be read by looking through the photographic lens from the front of the camera. For this purpose the diaphragm aperture should be contracted (as small as possible), and a brightly illuminated sheet of white paper should be held at a short distance away from the glass back. When the orientation has been effected as above described, the azimuthal circle may be firmly clamped in position, and the accuracy of the orientation may be tested by releasing the camera clamp **R** and rotating the camera on its axis. The compass reading should in every position correspond with the reading on the azimuthal circle if the instrument is in accurate adjustment, and if the orientation has been correctly effected. If any important discrepancies appear, especially if these are found to be due to instrumental errors, it will be found best always to orient the azimuthal circle with the vernier zero opposite the same division of the scale.

It may be noted that the orientation of the azimuthal circle only becomes a matter of importance when it is intended to use the instrument as a Theodolite, and even then it is not always necessary, as for example when the observer only wishes to read off angular distances without reference to bearings.

With Photo-grammetric instruments of any of the old fashioned types, correct artificial orientation of the apparatus and accurate notes concerning the bearings were always essential: *but with this new form of Photo-theodolite the orientation of the principal plane of every picture taken is automatically recorded in the face of the picture, and the picture record will be exactly the same whether the azimuthal circle has been oriented or not.* In practice, therefore, the operations detailed under the last two headings (8 and 9) may be often altogether omitted, and time saved and risk of personal errors of observation and entry avoided.

10. Next (having rendered the azimuthal circle quite rigid by aid of its clamp **Q**, and having set the camera and telescope free) remove the cap from the telescope, substitute the erecting for the inverting eyepiece (if the observer finds this most convenient for his personal use), focus the eyepiece upon the crossed spider-webs in the body, and focus the object lens upon some distant object. Then having decided upon the general direction of the view of which a picture is desired direct the telescope towards some distant landmark, so that its image in the telescope shall be bisected by the vertical web. The image of that point in the camera will then be on the vertical hair **K**, and the principal plane of the picture to be taken will pass through that point and the camera station.

When camera stations or trigonometrical stations are visible through the telescope, it is nearly always advisable and convenient to take photographs with their principal planes passing through those points. On the other hand, it is frequently advisable to take other photographs in directions which comprise convenient areas of the ground to be surveyed without special reference to any previously determined points.

11. Next clamp the camera firmly to the azimuthal circle by the clamp **R**.

12. Next take small slips of celluloid, and write on them distinctly with Indian Ink:

(*a*) The total magnetic error.
(*b*) The station number, *e.g.* (S. 3).
(*c*) The altitude of the station if accurately known, *e.g.* (A. 5325), or, if not, the barometric pressure, *e.g.* (B. 20·1).
(*d*) The mark on which the telescope was directed, *e.g.* (Ps. 2).
(*e*) The serial number of the photograph, *e.g.* (N. 1).
(*f*) Time, *e.g* (T. 15 20) = 3.20 p. m.
(*g*) Date, e g. (D. 7/6/98).

Release and let down the falling back **H.**

Place the slips when the ink is dry in the slits in the frame provided for the purpose They should be inserted in the slits upside down, and with the writing on face nearest to the operator.

13. Next rack forward the internal structures by turning the milled heads **J J.** Close up the iris diaphragm as far as it admits of being contracted. Insert in its proper place in front of the lens an optical colour screen of green or orange glass, unless the atmosphere is so clear or the chief objects to be photographed are so near and distinct as to admit of the coloured glass being dispensed with. Cover the photographic

lens with its cap. Adjust in place a double dark slide charged with sensitive plates. Take care that this is securely held in place by the catch **N.** Then everything being secure, rigid, and light-tight, draw back the shutter of the dark slide as far as it will go. Then immediately rack back the internal structures by the milled heads **J J** until the frame has been carried against the surface of the sensitive plate as far as the stops will allow it to go.

NOTE.—While all these later operations are being performed it is well to shield the instrument, and more especially the double dark slide, from the sun and sky-light by a large thick umbrella ; and so soon as the dark slide is in place, it is a good plan to throw a piece of black velvet over the back of the instrument. A square velvet falling curtain attached to the top of the back of the box is convenient and answers well.

14. Now pay careful attention to the levelling, by manipulating the levelling screws and the revolving level by light touches only with the finger and thumb.

At this stage in the proceedings extreme accuracy should be aimed at, and especially should the air bubble rest exactly in the middle of its run when the axis of the tube is perpendicular to the principal plane of the instrument (*i.e.*, parallel to the front and back faces of the camera).

The pair of fixed levels at right angles will indicate when the instrument is accurately level, and they serve as a check on the revolving level.

15. Next, look again through the telescope, and if the vertical web does not now bisect the mark on which it was originally directed, bring it to its proper position by aid of the slow-motion (tangent) screw which operates the camera. Then, again test the levelling, and if that is right, everything is now ready for an exposure to be made.

16. Next remove the cap from in front of the lens, and give a full, but not excessive, exposure.

NOTE.—The cap over the lens should be as loose fitting as possible without danger of letting in light, or of falling or being blown off. The removal of a tight-fitting cap for exposure of a plate might possibly disturb the level of the instrument.

Concerning the exposure : it is assumed that the operator is a competent or even a skilled photographer, and if he is not he should endeavour to become thoroughly proficient in all that appertains to the art of producing sharp, clear negatives before he starts to use an instrument of this class for practical work in the field.

Further on will be found some special notes relating to the preparation of photographs for surveying purposes.

17. When the exposure is thought to be sufficient the cap should be replaced, and immediately afterwards the internal structures should be racked forward, the shutter of the slide shut, and the slide removed ; or, if another picture is to be taken

from the same station, the slide may be replaced with opposite face inwards, after the celluloid strips which record serial number and time, and direction of principal plane have been changed. The shutter may then be opened and the internal structures racked back. Then the camera is released and rotated on its axis until it points approximately in the right direction. It is again clamped and levelled, and brought to exactly the right position by slow motion adjustment as before described, and so on for any more pictures after the first. It is necessary, of course, to take care in every case to allow sufficient time for the compass to come to rest before exposure, but if the precaution is taken to set free the compass by racking it back before commencing to turn the camera on its axis, the compass will be very little disturbed, and the time occupied in coming to rest will be very short.

18. After as many photographs have been taken as are thought necessary at any particular station, the observer should throw a light protecting cloth over his instrument without disturbing it, and, note-book in hand, he should observe and note all facts which he thinks may be of interest for future reference; and after noting everything which seems to him to be worthy of note, so far as he can observe with the naked eye, he may then return to his instrument, and after releasing the camera and telescope, he can scan the horizon and examine more closely the visible outlook by aid of the telescope, and make supplementary notes in his note-book. At this time, also, he should search for other suitable camera stations, and if he is able at this time to fix upon suitable, or probably suitable, new stations, he may direct his camera towards the points selected and take supplementary photographs with their principal planes passing through those points. If he has still remaining some unexposed plates which he can afford to use up without risk of running short for other stations, he may now take duplicate photographs of portions of the area to be surveyed. As a general rule he should not waste time and plates by making a complete photographic tour of the horizon unless the camera station is well within the boundaries of the area to be surveyed, and unless clear well-defined views can be obtained in every direction. It is generally better to use the time and plates for obtaining duplicate or overlapping views in directions specially selected.

19. When the observer feels that there is nothing more to be done or noted at the particular station, he should at once prepare to dismount and pack up his instrument. This he should do carefully, as he values his instrument. The best way to do this is as follows:

First take care that the internal structures are racked forward as far as they will go, so that the compass cap may be firmly clamped against the top plate.

Then rotate the camera on its axis until the lens is over one of the levelling screws. Then tighten the clamp **R**.

Then slide the microscope **O** round the azimuthal circle **C** until it is opposite the front of the camera.

Then bring the telescope to an approximately horizontal position after first racking back the object glass, putting on its cap and substituting the short for the long eyepiece. Then clamp the telescope.

Then, all important structures being rigidly fixed in position by their respective clamps, the left hand may be laid on the top of the instrument to steady it while the locking plate of the tribrach is opened by lateral pressure of the thumb and finger of the right hand.

Then the instrument is gently lifted up by both hands and carefully placed in its wooden case face upwards.

The locking plate of the tribrach is then again closed and the tribrach unscrewed from the tripod head and the protecting metal cover is screwed on in its place.

The tribrach is then packed in its allotted space in the case. The plumb bob, erecting eyepiece, double dark slides, and other accessories should also be in their several allotted positions in the case, which may now be closed and locked and deposited in its outer leather case ready for transport to another station.

20. The tripod stand may then be unloaded, shut up, and the legs strapped together, and a protecting cover slipped over the head when everything is ready for a start—except that the observer should certainly not leave the spot before he has set up some kind of abiding mark at the place where the instrument has been standing, either in the shape of a staff or a pile of stones, or both, of sufficient dimensions to be visible afar off through a telescope like that by which the instrument is surmounted.

21. When several instruments and several observers are available it is convenient to occupy, and to take photographs from, several stations simultaneously over the same ground, and with the telescopes directed upon the same points at the same times.

In such cases the observers should endeavour to establish telephonic or heliographic communication, or they may maintain communication by means of a series of preconcerted flag signals.

22. When working with this instrument, the observer should of course take care that no iron or steel is anywhere near. Bunches of keys in the pockets might cause appreciable errors, and an observer moving about with iron in his pockets might unwittingly disturb the compass from its state of rest and fail to obtain an automatic record of the compass bearing; or if he

stood still during exposure, the bearing recorded might be wrong. It is true, as pointed out elsewhere, that compass errors can be easily detected and allowed for afterwards, but obviously artificial and unnecessary errors should not be introduced by mere carelessness.

23. Whenever it so happens that there is no well-defined point in a view whose exact position has been determined trigonometrically, it is always prudent to measure and record the exact angular distance between some well-defined point in the picture (the principal plane for choice), and one or more well-determined trigonometrical points which may be visible in any other direction.

C.—*Special Notes relating to the Preparation of Photographs for Surveying Purposes.*

1. A surveyor's photograph should be as sharp and clear and full of detail as it can possibly be made to be.

2. The working aperture of the diaphragm when exposure is given should be exceedingly small.

3. It is not expedient to use a deep orange optical screen on all occasions. Sometimes it happens that the prevailing conditions of light and atmosphere are such that perfectly bright clear pictures can be obtained without the use of any screen. More often the employment of a colour screen to stop the most refrangible rays of the spectrum is necessary, but in such cases a screen of bright, clear, optically worked green glass will often be more efficient than deep orange. The best plan is for the photographer to take with him several screens of different tints and to use the one which observation on the spot and his own past experience leads him to believe will work best at the particular time and place. A screen which necessitates an enormously increased exposure of half-an-hour or more is very inconvenient to use, and frequently the disadvantages which attend the use of a deep orange screen more than outbalance the advantages.

4. All the photographic operations should be conducted with a view to obtaining pictures which can be enlarged about three diameters, or more, if necessary, and yet yield sharp outlines. In this connection it is well to bear in mind that enlargement may, and often does, have the effect of giving increased sharpness to images of the more distant objects, so that a background which appears indistinct and as though obscured by haze in a small picture, may shew up fairly clear in the enlargement.

5. Thick coated glass plates should alone be used. Rapidity is not wanted, and rapid plates do not give such good results as slow fine-grain silver emulsion.

6. Do not be tempted to use celluloid instead of glass plates. The only possible advantages of celluloid plates are lightness of weight and unbreakability. The disadvantages for surveying purposes are serious. The flexibility of celluloid, and a liability to changes of form and dimensions under photographic manipulation, and changes of temperature, etc., may cause serious errors in the original perspectives which will affect the subsequent enlargements still more seriously. In practice, small coated glass plates very rarely break, and the number required for use by any one observer for any single day's work will never be so great that the difference of weight will be a matter of real importance.

7. Isochromatic plates should be used in preference to ordinary untinted plates. When deep orange screens are used, isochromatic plates are necessary. It is best and most convenient to the observer to keep to the same kind of plate for all his work. For most ordinary work isochromatic plates behind green colour screens will be found to answer well. The obscuring effects of atmospheric haze will be to a large extent overcome without introducing unnatural exaggerations of light and shade, or necessitating a very excessive exposure. The green glass should be homogeneous, clear, and highly transparent for all the middle regions of the spectrum from the yellow to the commencement of the blue, but quite opaque to the ends of the spectrum.

8. The photographer should aim at the production of negatives which will yield the best enlarged positives by direct projection without intermediate processes.

9. It is expedient to use an antihalation backing for the sensitive photographic plates, and to coat the edges as well as the backs of the plates.

10. When duplicate exposures are made equal care must be taken with the duplicates as with the originals, but it is generally prudent to vary the conditions as regards

(*a*) Exposure. For one plate the exposure should be what is estimated to be about right; for the other plate it should be considerably longer.

(*b*) Colour screen. This should be changed, or if the atmosphere appears to be very clear one plate may be exposed without a screen.

(*c*) Plates. It is a wise precaution to use plates from different boxes for duplicates.

Do not be tempted to change the working aperture of the diaphragm, and do not think of using a colour screen behind the lens.

It is a good plan to develop duplicates separately, and to different degrees of density.

To Use the Photographs for Plotting the Ground Plan.

1. Find and mark the position of the camera station on the plan.

For this purpose a station pointer or any of the ordinary well-known methods such as are described in standard works on surveying may be used.

NOTE.—It is possible to determine the position of the camera station from photographs taken at the station, or from cross views upon the station from other stations, but it is most prudent when possible to fix station points by accurate trigonometrical observations.

2. Having found and marked the station point on the plan, describe, by aid of a pair of compasses, a pencil circle with station point for centre and distance line (focal length of lens) for radius.

NOTE.—If the exact focal length is not already known it can be easily determined, as explained elsewhere, by means of the tangent scale and a table of natural tangents or by simple geometrical construction.

3. Next, by aid of a protractor, set off from the station the directions of the principal planes of the pictures which it is proposed to work with, and draw tangents to the pencil circle through the points where the direction lines meet the circumference.

These tangents to the distance circle will represent the intersections of the picture planes with the ground plan, and it is convenient at once to mark them with the serial numbers of the pictures to which they correspond.

It is essential to fix the positions of the stations and picture planes with care and exactness before any attempt is made to commence plotting.

4. For determining the directions of views from the station points, it is not generally safe to rely exclusively upon the compass readings.

The compass error for each station should be known or ascertained.

Whenever possible, the total compass error should be determined at the station itself by comparing the compass bearing of any point whose true bearing is accurately known with the true bearing, and the difference should be noted on one of the celluloid tablets in the instrument, so that it will appear on the face of every photograph taken at that station.

If, however, the photographs in hand do not bear this information on their faces, a search should be made to find in one or more of the photo views from the station one or more points whose true bearings are known or ascertainable.

The difference between the true and the apparent bearings as read on the picture will be the compass error.

The direction lines from the station should be set off by reference to true bearings.

5. The next practical step is to subject the photographs to a very careful scrutiny (preferably under a magnifying glass – a good and large reading glass will answer) and to mark and number the points which it is desired to plot.

A fine mapping pen and red ink may be used for this purpose. A fine dot should be made upon each selected point, and every dotted point should have its corresponding number in small but distinct figures. Each point should be marked with the same number in every picture upon which that point is visible.

Judgment and discrimination are necessary for selecting the most salient points, and every care should be taken to make sure that the points selected and similarly numbered in different pictures are really identical points. Whenever there is any real doubt about identity in the mind of the operator, it is best to postpone the marking of the doubtful point until the undoubted points have been all marked and plotted.

It is impossible to give full detailed instructions about the selection of points to be plotted, but any practical surveyor accustomed to ordinary surveying methods will, after a little practice with photographs, be able to select those points which will serve him best for mapping purposes after they are plotted, and aptitude in selecting and identifying points will be gained by practice.

The selection, identification, marking and numbering of points on the photographs may be done at any time.

6. The traces of the picture planes having been accurately marked on the plan and points marked and numbered on the photographs, there are various means available for plotting from the pictures. For example :—

(*a*) A good protractor may be laid upon the plan, with its centre at the station point and the zero on the distance line already drawn.

The bearings of the points marked in the photograph from that station with reference to the zero line can then be read directly by aid of a **T** square, and the tangent scale and their directions set off and numbered.

The protractor is then transferred to another station point and similarly adjusted with its zero on the distance line of a photograph from that station which embraces part of the same area. The corresponding directions are then set off and the intersections plotted.

This method of plotting by aid of a protractor is practically identical with the ordinary method of plotting from note-book entries of an ordinary prismatic compass, or Theodolite survey, and will be somewhat more rapid and less liable to accidental errors.

Plotting by a protractor is not, however, the most rapid method when working from photographs, and it is not the method most commonly employed.

The ordinary method used in Canada and elsewhere is to:

(*b*) Take straight, narrow strips of paper as long as the photographs are broad, or slightly longer. At the middle of each band rule a line perpendicular to the length. Lay one of these bands on one of the photographs, so that the ruled line may exactly cover the vertical line of the picture. Then on the lower edge of the band make dots at points equally distant from the middle line with the numbered dots previously marked on the picture

These dots on the band are then marked with the same numbers as the corresponding dots on the picture.

When a sufficient number of points have thus been marked and numbered on the paper band, the band is transferred from the photograph to the trace of the picture plane on the plan so that the line of dots may fall exactly on that line.

The same operations are performed with the other band and picture from another station. The bands, when adjusted in position, may be held in place by weights or pins.

Next insert needles (or drawing pins not pressed quite home will do) at the station points and over these slip loops at the end of fine silk threads or hairs of convenient length. The other ends of the threads or hairs are tied to elastic threads which terminate in paper weights. The paper weights are then moved in such manner as to keep the threads always stretched (*i.e.*, straight), and the threads from both stations are made to pass through dots on the respective bands similarly numbered. The intersection of the threads will then correspond with the position of that point on the plan.

It will happen not unfrequently that the traces of the picture planes of corresponding views taken from two stations will cross each other so that a portion of one band will be covered by the other. If bands of tracing paper be used the covered portion of the lower band can be seen through the upper band, or if opaque paper be used the covered marks should be repeated in their proper relative position across the face of the top band. Any number of points may be plotted in this way.

The intersections of the threads should be marked as dots with a sharp pointed pencil, and the corresponding numbers also entered in pencil on the plan close to the plotted dots.

It is best not to ink in the plotted points and connecting lines until the accuracy of the original plotting has been tested by reference to photographs taken from one or more other stations or by some other available means.

This method of plotting by aid of paper bands and threads from the station points has been found in practice to be sufficiently accurate for all ordinary purposes, and it is very much more rapid than plotting by aid of a protractor. LASTLY (*c*) there is a method of plotting directly from the photographs themselves by aid of specially constructed plotting apparatus designed by the writer. This method is more simple and direct in practice and much more rapid than any other, and risks of error are less.

It is intended to publish a separate full detailed description of the special plotting apparatus and its use so soon as circumstances permit.

7. It is possible to plot from the small photographs without enlargement, but when any amount of serious work is intended it is best to use enlargements.

Good enlargements are very much easier to work with and yield more accurate results than small pictures, assuming always that there has been no appreciable distortion introduced by the operation of enlarging. Every possible care should be taken over the enlargement, and no actual plotting should be attempted from an enlarged picture until it has been examined and tested and found to be free from perceptible distortion.

It is not essential that all pictures used should be enlarged to the same extent, though in a general way it is best that they should be.

It is, however, quite essential to determine with accuracy the new distance line for each enlargement brought into use.

This can be obtained by multiplying the original distance line by the linear magnification of the enlarged picture, or it may be obtained (and in any case should be checked) by aid of the enlarged tangent scale as described elsewhere.

CONTOUR LINES.

1. The simplest and the best way to obtain contours is to take series of photographs with the photo-theodolite at different ascertained altitudes.

The horizon lines will mark planes of equal altitudes with the stations whose altitudes are known.

Intermediate levels can be sketched in and points can be fixed by observing their angular altitude and distance from the station.

The readiest way to determine angular altitudes is to lay a specially constructed transparent glass protractor in position over the picture, when altitudes can be read at a glance with approximate accuracy.

Another way is to use the specially designed plotting apparatus (elsewhere referred to) for direct reading of altitudes.

Information which can be gathered from the study of a Single Photograph.

1. The horizon line marks the intersection of a horizontal plane (which bisected the photographic lens when the picture was taken) with all points in the view through which it passes.

As a consequence, therefore, all points bisected by the horizon line may be considered to be at the same altitude when the distances of those points from the camera station are such that the curvature of the earth and atmospheric refraction may be treated as negligeable quantities.

For very distant points, usual corrections are required of exactly the same character as would be applied to horizontal readings of distant points by a theodolite or level.

The horizon line on the picture bisects the same points as would be bisected by the horizontal web of the telescope of a theodolite or level, clamped in a horizontal position and rotated on the vertical axis.

The horizontal line may therefore serve in a large number of cases for the direct plotting of a contour line on a map, and if a series of views at ascertained differences of altitude are taken over the same limited area, a number of contour lines can be directly plotted to correspond to those altitudes.

NOTE.--Horizontal lines ruled across a photograph parallel to the true horizon line do not mark equal levels or even equal angular altitudes or depressions. It is important not to fall into error about this.

2. All points bisected by the principal vertical line have the same azimuth as the optic axis of the lens when the picture was taken.

3. The top scale of the picture shows the magnetic bearing of the optic axis (and principal plane).

The bearing is here recorded just as it would be observed if any good azimuth compass were set up at the spot where the view was taken and the possible causes of error are the same, and the same precautions should be observed and corrections applied.

As a general rule, however, the danger of being misled by magnetic errors is immensely less with photographs than would be the risk of going wrong by relying upon magnetic observations observed and noted during an ordinary rapid survey.

The reason for this is that a photograph commonly contains some one or more points of reference whose true bearings may be known or can be easily determined by reference to one or more known points in some other photograph taken at the same station.

If several views have been taken from the same station point, it is ordinarily sufficient to determine the magnetic error from any one of the photographs, because the error will be a constant quantity for all, unless the photographer carelessly moved about with sufficient iron to affect the compass.

4. All points bisected by any straight line parallel to the principal vertical line will have the same azimuth.

5. The tangent scale, which stretches across the top of the photograph, below the compass scale, affords a ready means for determining the angular distances of points right and left of the principal plane.

If the straight edge of a parallel ruler be made to correspond with the principal vertical line, and the ruler be then opened out until the edge cuts any desired point visible in the photograph, the division on the tangent scale through which the edge passes will indicate the correct angular distance of the point right or left of the principal plane.

If the point lies to the right of the principal plane the angle indicated by the tangent scale should be added to the compass reading for the principal line to give the magnetic bearing of the point from the station.

If it lies to the left it should be subtracted. Also the horizontal angle between any two points visible in the picture can be read by aid of a parallel ruler and the tangent scale.

If the two points are on opposite sides of the principal line the sum of the scale readings is the horizontal angle.

If the points are on the same side the difference is the angle.

6. The distance line or working focal length of the lens used for taking a picture (or what is the same thing, the length of a perpendicular from the station point upon the picture plane) can be determined at any time either by simple geometrical construction or by multiplying the measured length of a portion of the tangent scale right or left of the 0° line by the cotangent of the angle indicated.

Or if no mathematical tables chance to be at hand the focal length can be found geometrically, as follows :—

Rule two lines at right angles to one another from any point on a large sheet of paper. Then set off upon one of these lines the exact length corresponding to say 20° or 25° of the scale measured from 0°. Then by aid of a protractor set off an angle of (90—20) or (90—25) and prolong the bounding line until it meets the other perpendicular. The distance thus cut off on the second perpendicular is the focal length.

7. If the camera station is at considerable angular altitude any level surface visible in the picture not too distant can be roughly and rapidly plotted by aid of a perspectometer and corresponding squares ruled on the plan. (Note.—This method of plotting direct from a single photograph is only approximately reliable when a lens of very large angle has been used, and even then is not so accurate as the more ordinary method of plotting

by intersections from two photographs from well chosen stations.)

The reason for this is that the angles of vertical intersection obtainable from a single photograph are in nearly all cases too acute for precision. It may, however, be usefully employed in many cases for obtaining a rapid rough outline sketch of the ground plan of near objects in the foreground.

8. Finally.—All the rules and principles of perspective are applicable to the interpretation of each individual photograph. The forms, dimensions, and distances of natural objects whose images are all depicted in true mathematical perspective on the face of a single photograph may vary to an almost infinite extent, and regular geometrical forms must of necessity be comparatively scarce, except where the objects photographed include the works of man, such as roads, buildings, canals, etc. When the images of such regular objects appear in a photograph it is generally an easy matter to ascertain the outlines of those objects in plan and elevation from photographs taken with the photo-theodolite. The direction of level roads and canals, the frontage of houses, etc., can be ascertained from any single photograph in which they are clearly visible, and many kinds of useful information for assisting or checking work as it proceeds can be obtained by applying the rules and geometrical constructions of perspective, but for most working purposes it will be found simplest and best to plot by reference to points whose positions are fixed with precision by good intersections obtained from cross views on those points. Generally it is easier to obtain good intersections for plotting a ground plan than to obtain good intersections for elevations. When the position of a spot has been determined on a ground plan the elevation can be determined from the observed angular altitude and the measured distance on the plan. One photograph suffices for the determination, but it is expedient to check the result by reference to other photographs from other points of view. For most practical detailed work it is best to use enlargements from the original pictures. For one thing an enlarged picture presents a much more natural appearance to the eye than the short focus picture, and this is a consideration of great practical importance to the topographer engaged in mapping. Also the precision is greater in proportion to the magnification—assuming that the lens used for enlargement does not introduce distortion.

Enlargement by magic lantern projection has many practical advantages, not the least of which is economy in working expense.

Students who aim at a high standard of proficiency in the art and science of photogrammetry are recommended to study Mr. Deville's book on "Photographic Surveying," and standard treatises on descriptive geometry and perspective.

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(The list is far from complete, but sufficiently indicates the class of instruments, and L. Casella will be happy to reply to any enquiries as to any kind not mentioned.

ENGINEERING AND SURVEYING. Transit Theodolites and Theodolites —Tacheometers—Dumpy and other Levels—Pocket Altazimuths—Azimuth Compasses—Repeating Circles—Tide Gauges—Current Meters—Mountain Barometers—Hypsometers—Aneroids (Field's and others)—Circumferentors—Miners' Dials—Levelling Staves—Chains—Pentagraphs—Planimeters—Station Pointers—Protractors—Computing Scales—Plotting Scales—Drawing Instruments—Parallel Rulers—Architects and Engineers' Curves—Steam and Pressure Gauges—Richards' and other Indicators—Gun and Torpedo Directors.

METEOROLOGICAL. Barometers (Standard, Photographically Recording, King's Recording, Aneroids, Fortin's, Kew pattern, Long-range)—Thermometers (Standard, Max., Min., Earth, Sun, Radiation, Photographically Recording, Pocket)—Hygrometers (Dry and Wet, Daniell's, Regnault's, Dines')—Anemometers (Dines', Robinson's, Beckley's, Embossing)—Helio-Pyrometer—Rain Gauges (Ordinary, Engineering, Recording)—Actinometers—Sunshine Recorders—Cathetometers.

NAUTICAL. For Ships and Yachts—Sextants—Marine Barometers—Aneroids — Compasses — Artificial Horizons — Quadrants — Logs — Deep-sea Thermometers - Sounders—Hydrometers —Telescopes—Chronometers— Binoculars.

ELECTRICAL AND PHYSICAL APPARATUS. Galvanometers—Electrometers—Resistance Coils—Keys—Batteries — Mechanical and Mercurial High Vacuum Pumps, &c., &c.

MAGNETIC. Magnetographs—Magnetometers—Dip Circles—Fox's Circles —Goolden-Casella Dipping Needle Instrument, &c., &c.

ASTRONOMICAL. Telescopes — Equatorials—Transit Circles — Chronographs—Sun Dials—Spectroscopes.

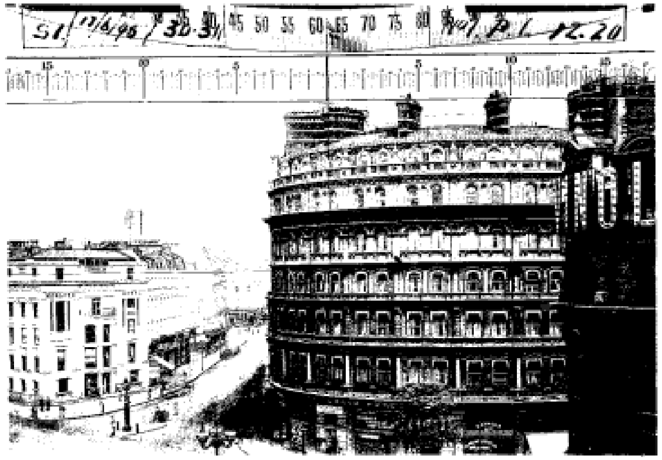
CHEMICAL AND PHOTOGRAPHIC APPARATUS. Cameras—Lenses —Tents—Chemicals—Assay Balances—Blow-pipe Apparatus.

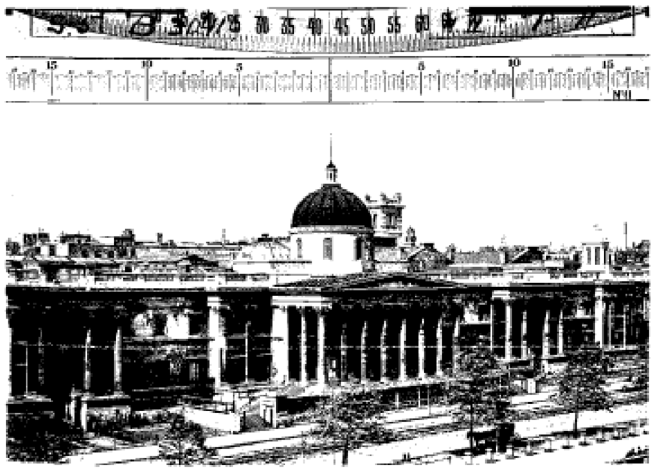
MEDICAL. Clinical Thermometers—Air Meters—Spirometers—Microscopes and accessories.

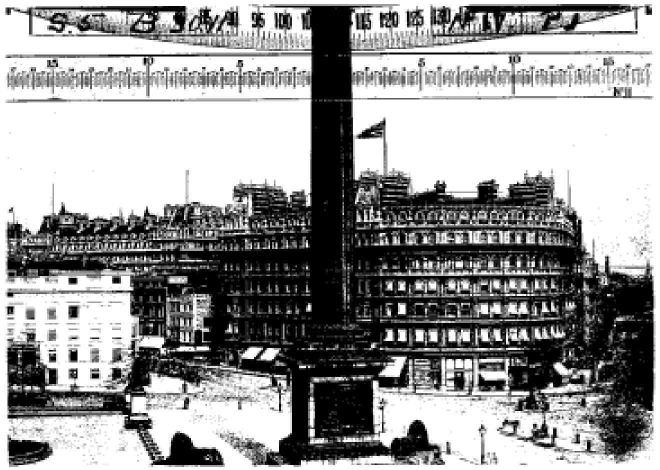
BRIDGES-LEE PHOTO-THEODOLITE.

A SERIES OF VIEWS FROM TWO STATIONS OVERLOOKING TRAFALGAR SQUARE, LONDON.

The Upper Row of Views taken from a point on the top of Drummond's Bank. The Lower Row of Views taken from a point on the top of the Union Club.
From this Series of Views it is possible to construct a Map of the greater part of Trafalgar Square, which will be found to correspond almost exactly at all points with the published Map of the Ordnance Survey







L. CASELLA,

Surveying Meteorological and Electrical Instrument Maker to the Admiralty, Ordnance, Board of Trade and other Government Departments,

Various Observatories, the Royal Meteorological and Royal Geographical Societies, and the Governments of India and the Colonies. America, Spain, Portugal, Russia, &c., &c.

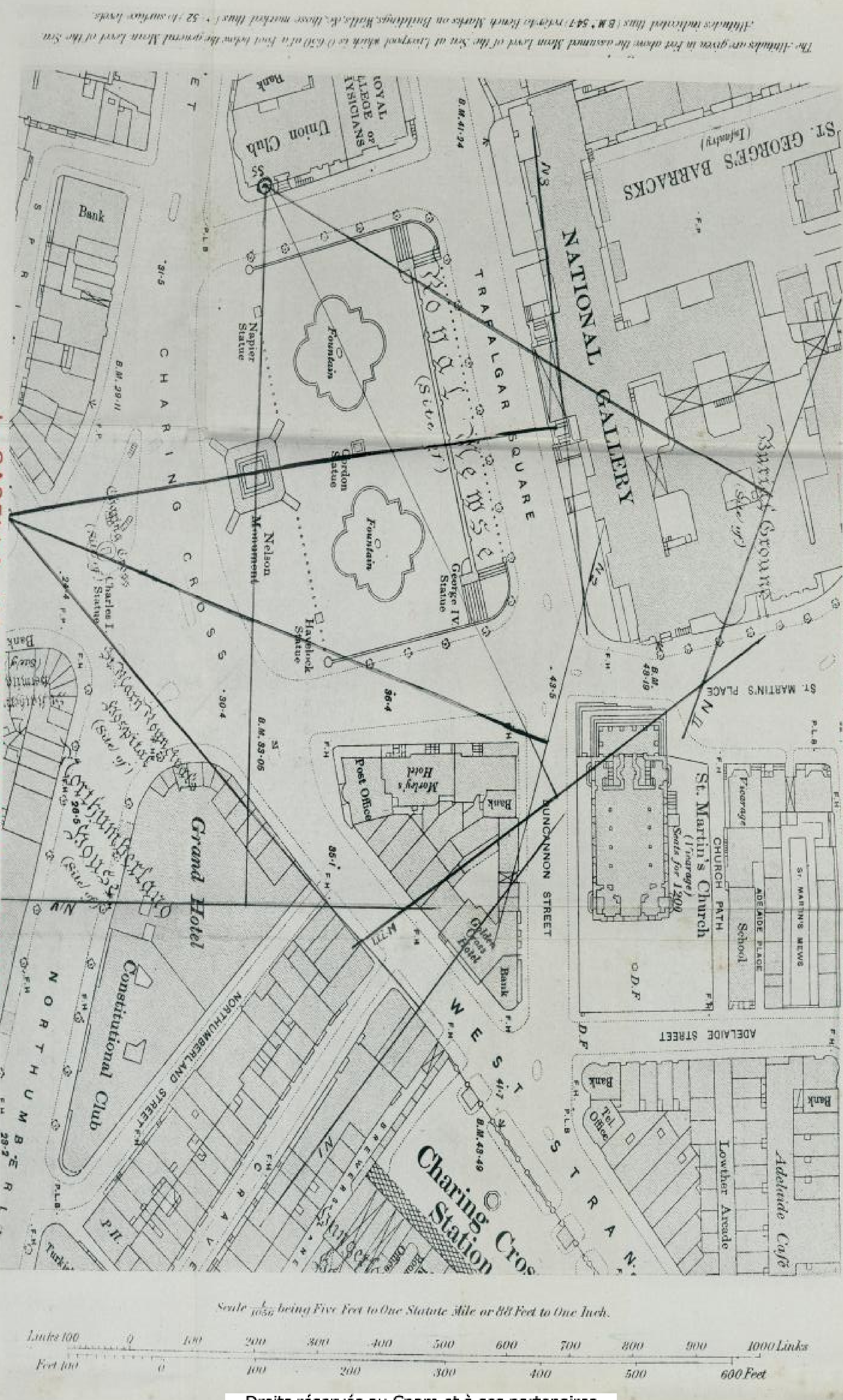
147, HOLBORN BARS, LONDON, E.C.

1898.

ERRATA IN MAP.

1. The measuring scale has been reduced 1 % in process of reproduction.

2. The location of S 5 is about 12 scale feet too far north.



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