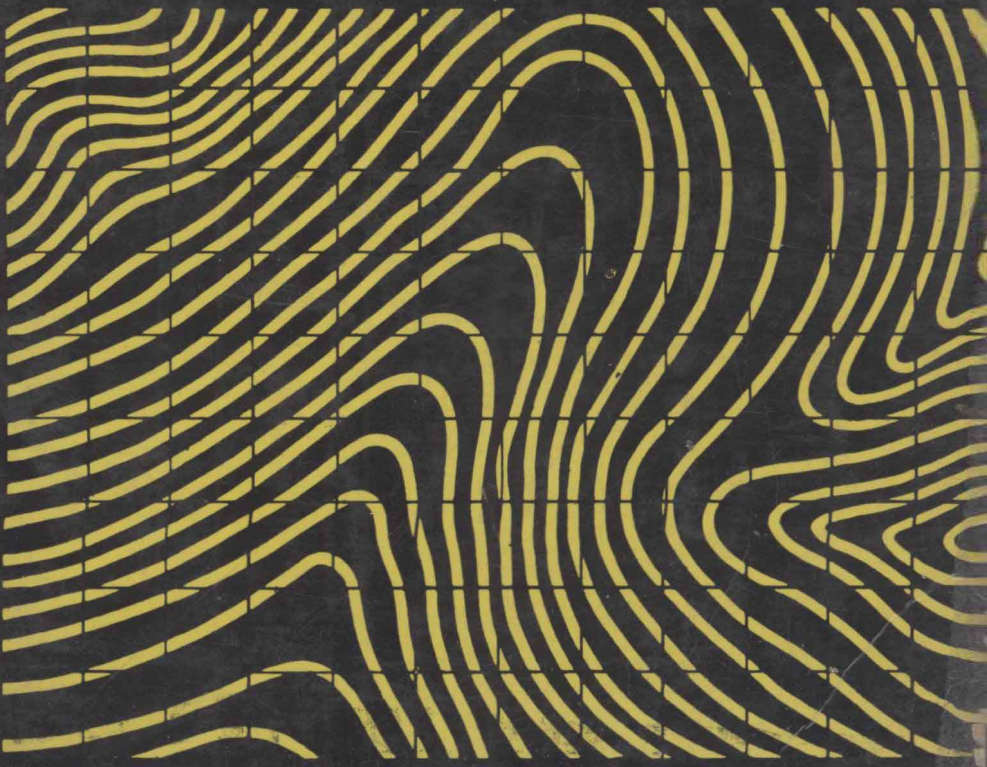
Plane and Geodetic Surveying For Engineers

by Late DAVID CLARK

PLANE SURVEYING

Vol 1



6th edition, revised by JEJackson

PLANE AND GEODETIC SURVEYING

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VOLUME ONE

PLANE SURVEYING

METRIC EDITION
(SI UNITS)

SIXTH EDITION REVISED BY
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With a chapter on Field Work for Aerial Surveys by
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PLANE AND GEODETIC SURVEYING

PREFACE TO THE FIRST EDITION

This textbook is designed to form a complete treatise on plane surveying with such parts of geodetic work as are of interest to the civil engineer. The author would emphasise at the outset that he does not claim that a knowledge of geodesy is a very essential part of the equipment of the engineer. The execution of surveys of such extent and character as to necessitate the general methods of geodetic surveying and levelling does, however, occasionally fall within his province. For this reason, a knowledge of its principles is required in the examinations of the Institution of Civil Engineers and of universities and colleges.

In a general text on surveying there is little room for originality, except in treatment. Although this work is intended to serve as a reference book for practising engineers and surveyors, the chief aim has been to cover ground suitable for a degree course, and, while it is hoped that the book will prove of value to those pursuing a college course, the needs of the self-taught student have been specially kept in view. In consequence, many explanatory notes and practical hints have been inserted, particularly with reference to the more common surveying operations. The latter are not meant to take the place of practice in the field, which, needless to say, is an essential part of a training in surveying, but are intended as a guide to the reader with limited opportunities for field practice, and are mainly suggested by the author's experience of the initial mistakes of young engineers in practice and of students undergoing field training in camp.

The subject-matter is presented in two volumes. The first covers in ten chapters the more common surveying operations of the engineer, and the second deals with astronomical and geodetic work and the methods employed in large surveys generally.

In the arrangement of the present volume it has been thought desirable, for convenience of reference, to group descriptions of the more commonly used instruments and their adjustments to form Chapter I. It is hoped that the detailed method of treating the subject of adjustments will afford a sound understanding of the geometrical principles in each case. In Chapters II to VI the subjects of Chain Surveying, Theodolite and Compass Traversing,

Ordinary Levelling, Plane Table Surveying, and Contouring are described as applied to cadastral and engineering surveys. Chapter VII deals with the office work of computing areas and volumes, the latter with particular reference to the measurement of earthwork quantities. The practice of setting out works is treated in Chapter VIII. The setting out of railways is the only branch of this subject meriting detailed description, and problems in connection with the setting out of simple, compound, reverse, and transition curves are treated. The principles and practice of Tacheometry are given in Chapter IX, and Hydrographical Surveying, including Marine Surveying and Stream Measurement, is dealt with in Chapter X. Owing to the number of texts available on mine surveying, no special reference has been made to that subject.

Sets of illustrative numerical examples and answers are given for practice. For permission to reproduce questions set by the Institution of Civil Engineers, the University of London, and the Royal Technical College, Glasgow, the author desires to express his thanks to the authorities concerned.

Lists of references have been inserted, after the appropriate chapters, on such subjects as readers might wish to pursue further. The author would gratefully acknowledge the assistance he has derived from these and other books and papers on Surveying.

D.C.

PREFACE TO THE SECOND EDITION

In the preparation of this edition it has been found desirable to enlarge the text and to re-write a considerable part of the book. The number of illustrations has also been increased. The eight years which have elapsed since the issue of the First Edition have witnessed extensive developments in the design and manufacture of surveying instruments, and an endeavour has been made to bring the book up to date in respect of these. For permission to reproduce questions set by the Institution of Civil Engineers, the University of London, the Royal Technical College, Glasgow, and Trinity College, Dublin, the author desires again to express his indebtedness. He would also express his thanks to Messrs. C. F. Casella and Co., Ltd., Cooke, Troughton and Simms, Ltd., George Russell and Co., Ltd., E. R. Watts and Son, Ltd., Henry Wild Surveying Instruments Supply Co. Ltd., and Carl Zeiss for placing at his disposal information regarding their recent instruments. He gratefully acknowledges his further indebtedness to Messrs. Cooke, Trough-

ton and Simms for permission to reproduce Figs. 71, 72, and 301, to Messrs. C. F. Casella and Co. and Henry Wild Co. for Fig. 69, and to Messrs. Carl Zeiss for Fig. 102.

D.C.

TRINITY COLLEGE,
DUBLIN, 1931.

PREFACE TO THE THIRD EDITION

In undertaking the revision of this book for a third edition, I have added certain matter, some of which, perhaps, is of greater interest and importance to engineers and surveyors working abroad or in the Colonies than it is to those whose work is confined to home practice. In Great Britain, the existence of the Ordnance Survey often simplifies the work of the private engineer or surveyor very considerably and makes it unnecessary for him to aim at the same degree of accuracy that is sometimes required abroad. Consequently, I have added a new chapter on linear measurements, in which work with the long steel band or tape, an article that is much more extensively used abroad than it is at home, is dealt with in considerable detail, and I have also made fairly considerable additions to the matter dealing with the theodolite traverse, for which purpose I have divided the original chapter on traversing into two, one dealing with the field work and the other with the office computations. Hitherto, most engineers and surveyors have regarded the limit of the standard of accuracy attainable by simple theodolite traversing as lying somewhere between 1/2000 and 1/5000, but, with the more extensive use of modern small theodolites with micrometer readings, such as the small Tavistock theodolite, and with reasonably careful taping with the long steel band, an accuracy of anywhere between 1/10,000 and 1/30,000 is now easily attainable in ordinary engineering and cadastral work. This makes it possible to substitute traversing for triangulation in cases where accuracy is necessary but where triangulation is difficult or unduly expensive.

In the chapters dealing with linear measurements and theodolite traversing I have used some of the results of the theory of errors, although a formal treatment of the theoretical aspects of this subject is reserved for Chapter IV of Vol. II. This is because it is of the utmost importance that the surveyor should have some idea of the different sources of error inherent in his work, the probable magnitude of these errors, and the manner in which they are propagated. Otherwise, it is not possible for him to do his

work in the most economical manner or to select the best methods. This applies particularly to traversing, and hence, and mainly for purposes of reference, I have thought it advisable to include with the description of certain operations some discussion of the resulting effect of those errors that are likely to affect them.

Among other additions are a short description of road transition curves, following the discussion of transition curves on railways already included in the second edition, and a brief description of echo sounding, with special reference to its advantages and possibilities as applied to engineering problems. Road transition curves are becoming of increasing importance in the lay-out of modern roads, and echo sounding is a fairly recent development which is likely to replace the older methods of sounding in modern hydrographical surveying.

In conclusion, I should like to express my thanks to the following:— The Astronomer Royal, for providing me with data regarding the present values of the magnetic elements; The Director General, Ordnance Survey, for permission to include a short summary of the Ordnance Survey methods of detail survey, and Colonel G. Cheetham, D.S.O., M.C., R.E., Ordnance Survey, for looking over my draft on this subject and providing me with other information; Messrs. Carl Zeiss (London), Ltd., for lending the block of Fig. 74; Mr. A. D. Simms, of Messrs. Cooke, Troughton & Simms, for providing me with special information regarding instruments made by his firm; Messrs. E. R. Watts & Sons for providing details regarding the Connolly Standard Compass manufactured by them; Messrs. Henry Hughes & Son, Ltd., for lending the blocks used in printing Figs. 369 and 370 and for giving me information concerning echo sounding apparatus of their manufacture, and Dr. E. B. Worthington, of the Freshwater Biological Association, for allowing the use of a photograph, reproduced as Fig. 371, of an echo sounding record obtained during the course of an echo sounding survey of the English Lakes.

J. CLENDINNING

ANGMERING-ON-SEA,
SUSSEX.
21*st June* 1939.

PREFACE TO THE SIXTH EDITION (METRIC)

This sixth edition is a complete revision. It has been entirely reset thus providing the opportunity to discard obsolete material, re-write where necessary, or incorporate portions of the previous edition that seemed suitable, having regard to present-day requirements of the land surveyor and the civil engineer. The appendices that had been added to the fifth edition have disappeared, and new material is in its proper places in the chapters. This procedure may have resulted in a patchwork, and it is hoped that this structure will not be too obvious to the reader.

Measurements of angles and distances are now, as they always have been, the basic material of land-surveying, but the recent development of photogrammetry as a mapping tool has obliged authors of textbooks on surveying to consider including something on this rather special and highly mechanised technique. In practice, the camera is flown by aeronauts and the map is constructed by photogrammetrists, and it is unlikely that any of these practitioners is a trained land-surveyor. Neither is it desirable that one trained in land-surveying should occupy himself in piloting aircraft or operating plotting machines, even if he were able to do either of these jobs. The land-surveyor, as such, comes into the process mainly in the provision of ground control, the special requirements of which have been developed from the experiences of several decades of air-photographic mapping. Hence the appearance here of the additional Chapter XIII, written by Mr. Dalgleish, and intended to describe ground-control survey methods, rather than photogrammetric theory and techniques, which are more or less fully dealt with in many modern texts.

Referring in more detail to changes made in preparing this edition, mention may be made of the increased attention given to elementary geometrical optics, in consideration of modern developments of optical reading systems which make extensive use of reflecting prisms and the parallel-sided plate device. Some obsolete, or nearly obsolete, instrumental features are no longer included; it can be assumed that any modern telescope has internal focusing and zero additive constant for tachymetry. The accounts of the nature of propagation of errors, especially in traversing, seemed to need some re-writing. Mention is made of the use of mechanical computation, referring only to the simplest types of calculating machines. Plane-tabling occupies fewer pages: this method still

has its value, but it is no longer a primary method for continuous topographical mapping. Fewer pages are devoted to descriptions of tidal phenomena in Chapter XII.

Mr. J. Clendinning, who prepared some earlier editions of this volume, might have undertaken the present revision, but was prevented from doing so by ill health. As many readers will know, he died early in 1966. I am indebted to him for some notes and suggestions he gave me when he learned that I had agreed to make the sixth edition. I also wish to thank many others who have discussed the book with me, suggested the inclusion, or exclusion, of certain items, or provided information included in the new text. Particularly, I am grateful to Mr. D. F. Munsey M.A., Lecturer at the School of Military Science, Shrivenham, to my brother, Mr. F. S. Jackson M.A., who is a civil engineer, and to Mr. A. G. Dalgleish M.A. (now Deputy Director (Mapping) at the Directorate of Overseas Surveys) who also read through the whole of the original drafts. Mr. P. F. Dale assisted in the checking of answers to exercises.

Most of the exercises given at the end of some of the Chapters are new: in almost all of them, quantities are expressed in the metric system of units. References to literature have been brought up to date, though no doubt they are incomplete, and many of the older references have been omitted.

J.E.J.

FITZWILLIAM COLLEGE,
CAMBRIDGE.
February 1971

CONTENTS

INTRODUCTION

Surveying is the art of making such measurements of the relative positions of points on the surface of the Earth that, on drawing them to scale, natural and artificial features may be exhibited in their correct horizontal or vertical relationships.

Less comprehensively, the term, 'surveying,' may be limited to operations directed to the representation of ground features in plan. Methods whereby relative altitudes are ascertained are distinguished as 'levelling,' the results being shown either as vertical sections or by conventional symbols on a plan.

Plane and Geodetic Surveying. A plan is a projection upon a horizontal surface, and in its construction all linear and angular quantities used must be horizontal dimensions. It is impossible to give a complete representation of distances following the undulations of the ground other than by a scale model. Now a horizontal surface is normal to the direction of gravity as indicated by a plumb line, but, on account of the form of the Earth, the directions of plumb lines suspended at different points in a survey are not strictly parallel, and the plane horizontal at one point does not precisely coincide with that through any other point. It is not the irregular shape of the Earth's physical surface that is referred to here, but the almost regular curvature of a level surface which is necessarily perpendicular to the vertical everywhere.

In surveys of small extent the effect of curvature is quite negligible, and it is justifiable to assume that a level surface of the Earth is a horizontal plane within the area covered. Surveying methods based on this supposition are comprised under the head of *Plane Surveying*. The assumption becomes invalid in the accurate survey of an area of such extent that it forms an appreciable part of the Earth's surface. Allowance must then be made for the effect of curvature, and the operations belong to *Geodetic Surveying*.

No definite limit can be assigned for the area up to which a survey may be treated as plane, since the degree of accuracy required forms the controlling factor. The sum of the interior angles of a geometrical figure laid out on the surface of the Earth differs from that of the corresponding plane figure only to the extent of one second for about every 200 square km (76 sq. miles) of area,

so that, unless extreme accuracy is required, plane surveying is applicable to areas of some thousands of square kilometres.

Plane Surveying. Plane surveying is of wide scope and utility, and its methods are employed in the vast majority of surveys undertaken for various purposes, such as engineering, architectural, legal, commercial, scientific, geographical, exploratory, military, and navigational. As applied to civil engineering, all surveying methods are utilised in the various surveys required for the location and construction of the different classes of works within the province of the engineer. These surveys may be rapid reconnaissances of an exploratory character undertaken to facilitate the selection of an approximate site for the work. They are followed by more detailed surveys of the selected region, in which a much greater degree of accuracy is sought, and from which the best location is ascertained. The obtaining of various data required in the design of the proposed works forms part of the preliminary operations, and may involve surveying methods of a specialised character. Previous to and during construction, the surveyor's duties also include the routine of setting out the lines and levels of the works and the measurement of areas and volumes.

Aerial Surveying. An engineer may have air-photographs of a site on which he has to design or set out works. It is important that he should understand their uses and limitations.

Though an air-photograph will probably show all the details the engineer requires, and indeed probably very much more, it must not be treated as a map because it is not possible to ensure that the axis of an air-camera is exactly vertical. The tilt may be several degrees in a so-called vertical photograph, so there may be appreciable differences of scale between opposite sides of a photograph. In any case, even if the camera axis is vertical, the relative positions of points at different heights will not be correctly shewn.

The most valuable property of an air-photograph is that angles round a point at or close to its centre may be regarded as correct, and in making maps from air-photographs this property is exploited. In other words, a near-vertical air-photograph may be regarded as a record of angles taken at its centre point or at any point very close to the centre.

If air-photographs from two different positions cover an area of common ground, and they are viewed by means of a suitable stereoscope, a three-dimensional picture is seen and can be of very great value, especially in the preliminary stages of design of a project.

The production of accurate maps from air photographs involves the use of techniques and equipment which will not normally be