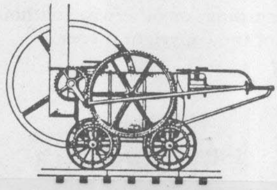
A HISTORY OF ENGINEERING DRAWING

BY

Peter Jeffrey Booker

Secretary, Institution of Engineering Designers



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A HISTORY OF ENGINEERING DRAWING

To Draughtsmen
past, present and future

'The charm which accompanies these studies will conquer the repugnance which men have in general for intense thought, and make them find pleasure in that exercise of their intellect which almost all regard as painful and irksome.'

Gaspard Monge, 1795

'These things are extremely plain and agreeable to persons of clear heads and of a genius turned to painting, let them be couched in terms ever so rude; but to men of low capacities and of minds not formed for these politer arts, though explained by the most eloquent pens, they would still be unpleasant.'

Leone Battista Alberti, 1435

List of Plates

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Preface

THE pencil has been called the most potent instrument in the world, for it gives most of man's thoughts and aspirations their first visible form.

Drawings are like windows through which we see things. The draughtsman, who is a maker of these windows, appreciates the effort put into them much more so than others, who only see *through* drawings, as it were, to the things themselves depicted and so take drawing for granted.

In its narrowest sense engineering drawing is a language used for communication. However, languages in general are not only useful for communication; they play an inherent part in our very thinking, for we tend to think in terms of the languages we know. Drawing is of this nature, and he who can draw can think of, and deal with, many things and problems which another man cannot. Between thinking and communication, in the form of geometry, drawing has another function; it allows us to predetermine the shapes we require and it is, therefore, a primary tool of design.

Engineering drawing is not, however, the same as engineering design; neither are the two inseparable as some persons suppose, for a medium of expression can generally be isolated from what is expressed through it.

This book is the direct result of numerous requests from draughtsmen, engineers and teachers for information about the historical development of the engineering drawing language. The complete field of graphics is so large that some limits had to be set and, to avoid wandering off into graphs, charts and general graphical constructions, I have taken as the main theme the representation of three-dimensional objects on a two-dimensional surface. Even so, the story is complex, becoming one of the evolution of ideas, very few of which can be attached absolutely to particular individuals. There are exceptions, of course, and the contributions of Descartes, Desargues, Monge and Farish in particular have been covered.

The material presented has been selected for its general interest and since the book may be used as a work of reference, it has been made as comprehensive as space permits. A number of quotations have been included from original works as being of some value or interest, especially as they are mainly from works not within easy access of most draughtsmen and engineers.

The numbers given in parentheses throughout the text refer to the bibliography at the end of the book.

In my investigations I have received co-operation and help from very many people–practising engineers, professors, and museum and library officials. I would especially like to mention the late George Noble of the Dominion Engineering Co. Ltd., Canada, who played a large part in the standardisation of drawings on the national and international levels, Dr W. Abbott for his encouragement, Mr W. E. Walters, through whom I had my first contact with the history of engineering drawing, Dr D. Pepys Whitely of the Pepysian Library, University of Cambridge, and Professor Wayne L. Shick of the University of Illinois.

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Engineering drawing has played and is playing a key role in our civilisation. With roots in art, science and mathematics, it has been both the servant and master of engineering, affecting and being affected by changing technology and organisation. There is probably much more to come; in the meantime I hope these pages have captured some of the past before it is forgotten and lost to the future.

Contents

Introducing Shadows and Projection

ACCORDING to a 19th-century encyclopedia, tradition said that 'drawing and sculpture took their rise together when the daughter of Dibutades drew the outline of the shadow of her lover upon a wall, which her father cut out and modelled into a statue'.

The interest of this statement lies not so much in the story itself as in the way that some 19th-century scholars used it to support a theory. By this time the perspective projection had been exhaustively examined and written about in profusion to the point when, to many, drawing and projection were so intimately bound up as to be considered synonymous. Since projection springs from geometrical ideas, and since the ancient Greeks were remarkable geometers, it seemed to these scholars reasonable to presume that perspective projection was known, understood and perhaps even used as early as the times of Pythagoras. So much did they expect this to be true that they grasped every odd piece of information, however vague, which seemed to support this thesis. The story of Dibutades, for instance, invoked the idea of tracing round the outline of a shadow, which was a 'projection' of his daughter's lover.

Today this view has been rejected and the history of perspective applied to pictures is considered as beginning in the Middle Ages. This may seem rather late in mankind's development, but as we shall see more clearly in the next chapter, fundamentally there is no natural, self-evident connection between drawing and projection. From any standpoint, psychological or historical, the concept of projection, especially in making pictures, is an advanced one.

The view held by some 19th-century geometers that the ancient Greeks were familiar with the concept of perspective was not, on the face of it, unreasonable, however. When the Dark Ages descended, nearly all of the ancient Greek writings in Europe disappeared. Fortunately, however, the works of Archimedes, Pythagoras, Euclid, Hero and many others had found their way into the Arabic centres of learning and, as the Arabic area of influence extended, so a knowledge of these early writings spread along the north coast of Africa, then across to Spain by way of the Moors, until they came to Italy.

Early in the 16th century a start was made upon translating these Arabic texts back into Latin, and gradually the Western world rediscovered the science and geometry of the ancient Greeks. This work was continued by scholars over the next 200 years and, by the 19th century, learned men had elucidated enough to be quite astonished by what they found the Greek philosophers had known.

Greek geometry in particular was extremely advanced; indeed one might say that nothing new was added until the time of Descartes. The ancient Greeks certainly had the ability and sufficient geometrical knowledge to develop perspective and if they did not, as seems to be the case, it was probably through a lack of motivation. Since the ancient Greeks' knowledge was found to be so vast and profound, and their ability sufficient to handle ideas more complex to them than perspective, it seemed unreasonable to suppose that this had been neglected. What gave particular substance to this 19th-century view was the stereographic projection. The beginnings of this are obscure, but the motivation, at least, probably lay in astronomy.

Astronomy was a major interest in the early civilisations for many reasons. One of the most important was that the spinning of the earth on its axis was, in effect, the clock denoting the time of day, while the movements of the stars in the heavens gave the calendar for planting seeds or moving animals to new pastures.

The ancient Greeks knew far more than might have been expected about astronomy. Thales of Asia Minor discovered the Solstices and Equinoxes; Anaximander, his friend, discovered that the moon's light was reflected and that the moon revolved about the earth once a month. The phases of the moon were thus explained about 600 B.C. Pythagoras (582–500 B.C.) taught that the earth was a globe which revolved round a central fire, and Aristarchus of Samos discovered the earth's obliquity to the plane of the ecliptic about 250 B.C. In short, by this time it was known that the earth was a globe, that it spun on its axis, that it moved round the sun, that its axis was tilted at $23\frac{1}{2}°$ to the plane of the earth's orbit, and that the moon revolved about the earth. These facts are not unimportant as we shall see in a later chapter.

Knowing this, the ancient astronomers looked beyond the sun and moon, to the planets and stars. Even in primitive times man had learnt to recognise certain constellations and the time naturally came when he found it necessary to map representations of the heavens. Crude drawings were good enough for some purposes, such as simple recognition, but for the science to advance more accurate star maps were required.

In the times we are considering, the heavens were generally supposed to be a number of glass spheres in one of which all the stars were fixed. After devising a method of measuring the positions of stars, the real problem of star map-making was how to represent the surface of a sphere on a flat surface, since this was the only reasonable medium for drawing upon and carrying around. Even if one did not subscribe to the idea of the stars being embedded in a glass sphere, the problem, reduced to the same thing.

Two basic methods were eventually devised; nobody knows exactly from where they came or when, but the ideas of projection have been credited to Apollonius of Perga, next to Archimedes the most illustrious of the ancient Greek geometers, about the year 250 B.C. The two systems became known later as the *orthographic* and *stereographic* projections of the sphere.

Man's earliest ideas of projection no doubt arose from his study of shadows. He soon came to recognise two kinds of projection. There were shadows cast by the sun's rays which were the same size as the object when thrown upon a surface parallel to the object; and there were shadows cast by a candle, effectively a point source of light with diverging rays, giving shadows larger than the objects illuminated. These two lighting systems represent the two fundamental types of projection–parallel and conical.

In ancient Greek times the idea of longitude and latitude were known–they come from words meaning lengths and widths used originally upon small-scale maps, but derived in principle from the very methods used to measure a star's position–and by the projection of a sphere we really mean the projection of a grid of longitude and latitude lines lying on a sphere's surface. In Fig. 1 a simplified hemispherical grid–with circles of latitude at 30° intervals and circles of longitude at 45° intervals–is used to demonstrate parallel and conical projection. In (a) the hemisphere is positioned so that the sun's rays, in casting its shadow on a wall, give an orthographic projection of the sphere. The true form of this shadow or projection is shown in (b) by the full lines. The dotted lines are those of a more complete grid using circles of longitude and latitude at 15° intervals. The main disadvantage of this form of projection for mapping is that as one moves outwards from the centre the grid becomes more and more crowded and the shapes of constellations plotted upon it become badly distorted at the edges. The circles

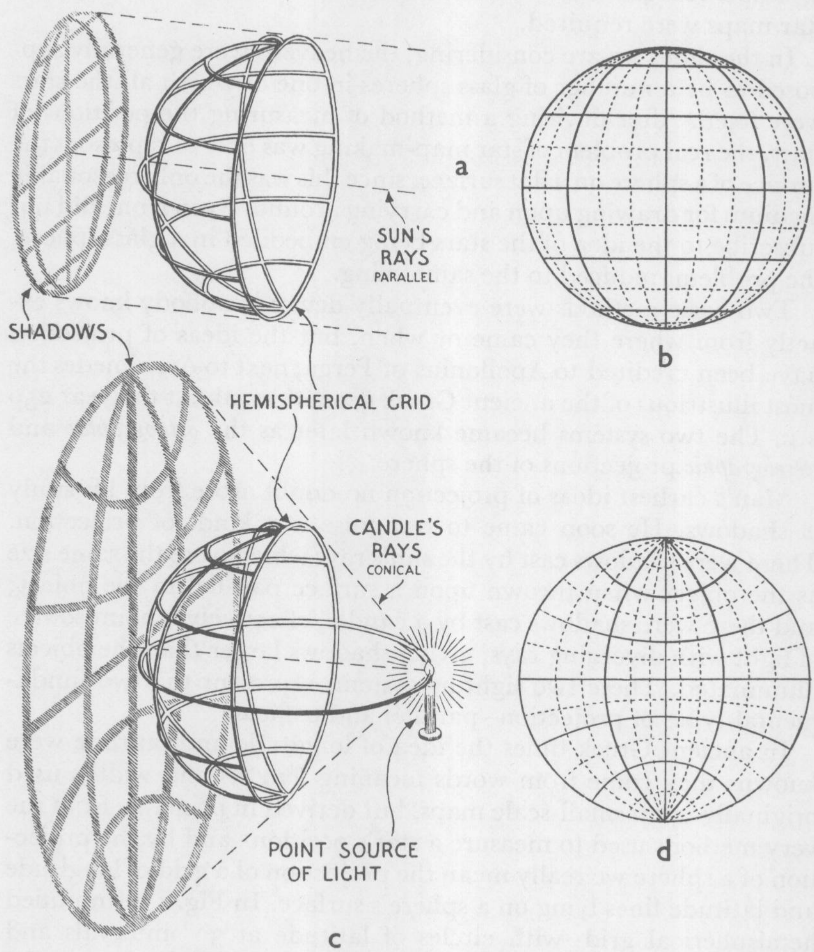

Fig. 1. (a) A hemispherical grid used to demonstrate the orthographic projection of a sphere by parallel light rays.

(b) An orthographic projection of a sphere. The full lines are those shown in (a); the dotted ones are additional lines of longitude and latitude.

(c) A hemispherical grid used to demonstrate the stereographic projection of a sphere by a system of conical rays emanating from a point source.

(d) A stereographic projection of a sphere to the same scale as that in (b). The full lines are those shown in (c); the dotted ones are additional lines of longitude and latitude.

Notice that if the point source of light in (c) is moved to the right, the cone of rays becomes more acute; in the limiting position, when the point has reached 'infinity', the conditions of (a) result.

of latitude, being edgewise to the light rays, are projected into straight lines and all the longitude circles are projected into ellipses, except for the outer circle and the central meridian.

In Fig. 1 (c) the same hemisphere is used but this time with a point source of illumination, its position or pole being on the equatorial circle diametrically opposite to the point nearest the plane of projection. The light rays diverge from the point giving a larger shadow. The hemispherical grid is not, however, a plane figure and the various points on the circles are at different distances from the source of illumination, so that the projected shadow is not only different in size, but it is different in shape also. The true shape of this hemisphere's projection is shown in (d) reduced in scale to match (b). This is known as the stereographic projection of the sphere and the ancient Greeks noticed that it had peculiar properties – indeed, they proved these properties by geometrical reasoning. All the projections of the latitude and longitude lines are true arcs of circles and the whole projected grid is a system of orthogonal curves, that is curves which intersect each other at right angles.

At this point, it might be as well for us to make an interesting observation which will help to save much misunderstanding in our study of drawing. The original form of stereographic projection used what we may call a 'primary' geometry – a system of conical rays or projectors in space. The shadow on the wall mentioned above would be produced by this primary geometry. If we placed a camera at the pole point, instead of the candle, and took a photograph, the resulting picture would have been produced by this primary geometry. The candle and the camera do not have to know what shape, shadow or picture to produce; this results automatically from the system of projection.

However, the remarkable properties of the stereographic projection found by the Greeks gave what we may call a 'secondary' geometry – a method of drawing a stereographic grid without recourse to the idea of projection at all. One has only to work out the centres for the various arcs – and this can be accomplished by elementary geometrical constructions — and the whole grid can be drawn with a pair of compasses. This idea of primary and secondary geometries with respect to projections is worth remembering. Whilst the two are connected, in that one may be derived from the other, they are separate in that one can often make a 'picture' using a secondary form of geometry without having any knowledge whatsoever of the original primary geometry. These ideas are very useful in the study of axonometric and perspective projections. Unfortunately the difference between primary and secondary geometries is hardly ever pointed out in drawing-books and considerable mental confusion is caused because the outlines drawn are referred to as 'the projection' irrespective of the method used for drawing them.

How far stereographic projection was used at the time of its invention is difficult to say, but it seems to have been used in planispheres and analemmas. These appear in both ancient Greek and Arabic writings(16, 17)*, although their true nature is not always clear because both terms were used loosely, sometimes for an instrument based on projections, and sometimes as a synonym for projections. A planisphere in its simplest form consists of two parts; a flat sheet upon which is marked a projection of the stars in the heavens, and a second flat sheet with a circular (more often elliptical) hole in it, the edge of which represents the horizon at some particular location. The second sheet is mounted so that it can revolve on a centre over the star map; when turned to certain marked positions, that part of the map showing through the hole depicts the stars to be seen at certain hours and times of the year at that place. Instruments of this nature demanded a great deal of theoretical geometrical and astronomical knowledge and exhibit the remarkable progress made in the early civilisations.

Claudius Ptolemaeus, or Ptolemy (*c.* A.D. 90–168), was an Egyptian astronomer and geographer who was keen on mapping the known world. The world was known to be a sphere–indeed, Eratosthenes (*c.* 275–194 B.C.) had succeeded in calculating its size, his radius being within 500 miles of the true figure–and Ptolemy used stereographic projection for this purpose (amongst other projections). Although the earth's surface was on the outside of a sphere and the stars were, supposedly, on the inside of one, the general problem was the same–the representing of a spherical surface on a flat surface. In geographical map-making the original projectional basis of the stereographic projection is really forgotten; the lines are used merely as a convenient grid to work upon–that is, they may not only be drawn by a secondary kind of geometry, but they may be thought of in this way also.

Mapping has only a fringe connection with our subject, but astronomy, on the other hand, has a direct bearing, for the theories created to account for the apparent motions of the sun, moon and

***** **These figures, and other similar ones throughout the text, refer to the numbered authorities listed in the bibliography.**