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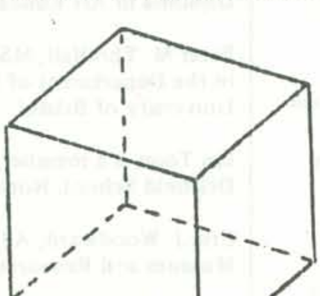
Operation Axoplan

Operation Axoplan is a research and development programme carried on by the Authors with the aim of finding and developing a simple, quick and economical method for making measured pictorial sketches of ordered three dimensional shapes. The method to be suitable for use in field and site studies and ordinary classrooms and within the ability of secondary school students to learn and use.

The pattern of Drawing Studies in schools is heavily influenced by the division of the work between the Departments of Art and Technology, the one preferring freedom and avoiding measurement, the other conforming to strict codes of practice and preferring to measure everything. This division soon becomes separation and isolation.

In their different ways the two Departments expect the drawings made by their students to stand on their own. The Art Drawing might have a different message for every viewer, for that is the nature of Art. The set of orthographic drawings made in the Technical Drawing Office has one and only one meaning for all because it is to be part of a legal document or of a plan for the management of vast numbers of men and of costly resources.

But by their separation the Departments of Art and Technology often leave neglected a great gap between them. This is in the area of Measured Pictorial Drawing made by radical, axometric or other projection. The *Projection Lines* through corresponding pairs of object and picture points all pass through a common 'eye' point in *Radial Projection.* The projection lines are all at right angles to the flat picture surface in *Right Axometric Projection.* The other kinds of projections will not be dealt with here. Such single projections are useful because each reveals the three-dimensional quality of the object. They can expedite the interpretation of sets of orthographic drawings.



CUBE

A single projection is ambiguous because an infinity of objects will match a single drawing picture. For example the picture above is an axometric picture of a cube but many shapes can fit the same drawing. However a single word 'cube' added to the drawing gives it a specific meaning.

Projected pictures which would be unsuitable for use in place of orthographic drawings nevertheless have a useful role to play in combination with a written text in books to inform those who are responsible for the sale, installation, commissioning, operation and maintenance of plant. In the Product Support Graphics Department of Rolls Royce Limited (Bristol Engines Division) all kinds of pictures are used, axometric and radial perspectives predominating.

Before axometric projection could be made convenient for domestic, field and site use it was necessary to release it from the limitations of the isometric grid. This was done in Operation Axoplan by the invention of the Axogrid and Scale, which, in addition has some other advantages.

Axometric projection takes care of the conversion of circles into ellipses but it was evidently desirable to provide an alternative way to draw certain ellipses and in addition to provide for the quick setting out of angles in the axo-picture. This led to the powerful elliptical protractor.

The Axogrid and scale and the elliptical protractor are the major contribution of Operation Axoplan to the simplification of Axometric Drawing but there are some secondary advantages. We have space here merely to state them: i. Simplicity ii. Speed iii. Compactness. Much of Secondary School work can be done on A5 sheets. iv. It is a simple matter to draw figures for solid geometry studies which can march at the side of plane geometry from the start. v. As the Axoplan Method assembles the pictures on tracings component pictures may be superposed vi. Economv vii. Mobility of the parts of a scene of fixed aspect viii. Suitability for numerical input ix. Self explanatory nature of the process x. Suitable for demonstration on overhead projector xi. Can be usefully applied by students with very slight knowledge of geometry or used with advantage by advanced students.

In considering how to present the development of Operation Axoplan the Authors decided that a brief but complete account of the method in widely readable form would enable many teachers to try it if they wish to do so.

Most students are familiar with the economy and convenience of 'squared paper' for making sketches.

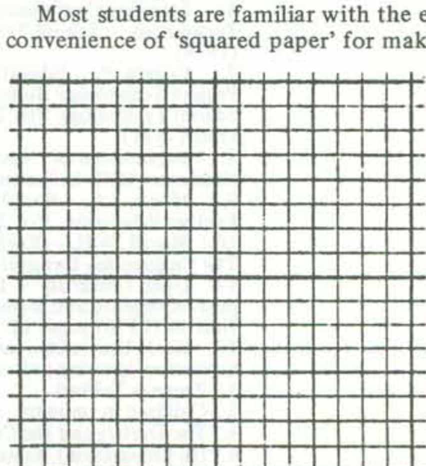
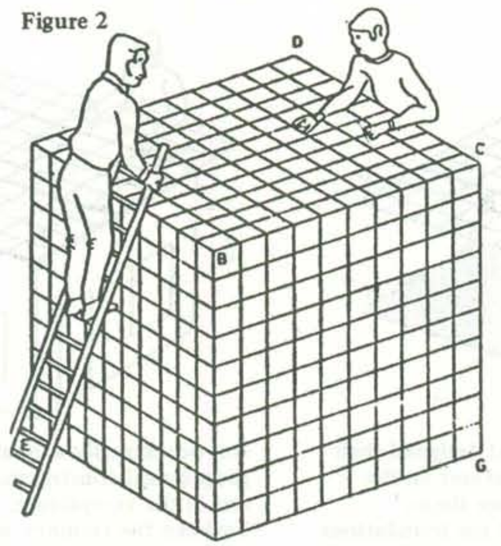


Figure 1

It provides direction by parallel and right angled lines, measurement by the spacing of the lines over the whole sheet and co-ordinate measurement of any points required. Is it possible to devise a similar kind of paper by which 3-D sketches could be made with equal freedom?

Figure 2



A real or imaginary stack of identical cubes placed edge to edge suggests a way to do it. But how can we look inside the stack? It would not help if we could look through it and see only the edges of the cubes as there would be so many lines that the picture would be utterly confusing.

If we had small wire models in our hands we could tilt and turn them to find that in some positions the wires were seen in ranks, one behind the other, forming a simple lattice.

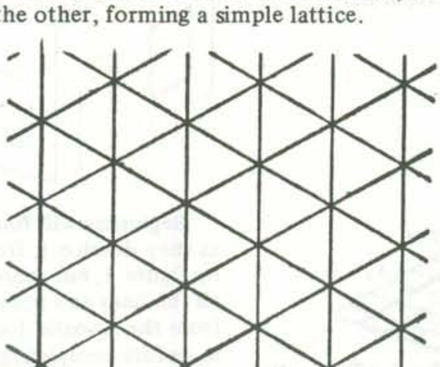


Figure 3

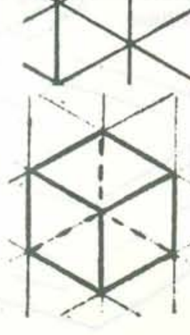


Figure 4

This occurs when the body diagonals of the cubes are at right angles to the picture surface. In this position the cubes are projected as hexagons and the picture of the stack is a lattice of equilateral triangles. It is known as *Isometric Projection* because the scales of measurement in the three directions of the lines are equal. The germ of the idea of isometric projection began about 200 years ago. Today isometric graph paper is widely available.

Isometric projection offers little variety of aspect. Some of the resulting pictures are poor and a few quite unsuitable. Some beginners are confused by having to deal with three dimensions at the same time but this difficulty may be relieved by the Axoplan Technique. The simplicity, economy and standard form of isometric projection will ensure its continued use even if it does not satisfy every purpose.

We may look inside an axometric picture of a stack of cubes if we slide part of it away. Provided we move the drawing in its own plane the movement may be parallel or rotational. By moving part *C* a face *a* is revealed which is identical with face *b* in the picture.

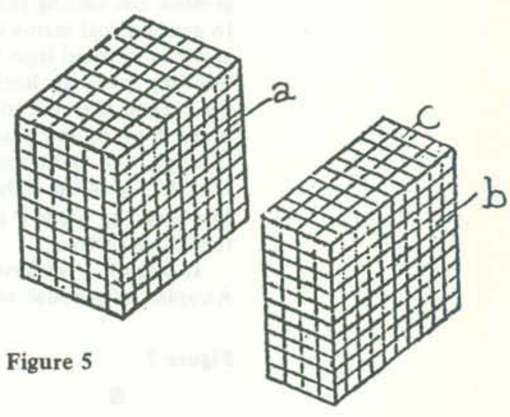


Figure 5

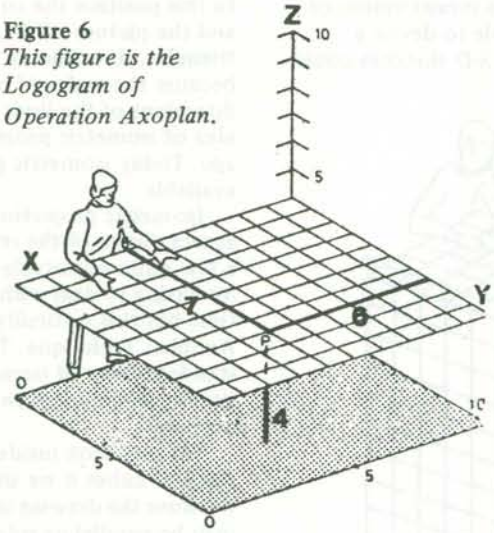
We may think of space being divided by equally spaced parallel planes, three sets of such planes at right angles dividing the space into stacked cubes. At elementary level it might be more convenient to think of a cubical stack of small cubes, say 10 x 10 x 10 as used in the previous figure.

The shape of such a stack is completely defined by the pattern of squares (projected as parallelograms) on the top and the scale of one edge at right angles to the top. We imagine that the top (named the Axogrid) is moved to any desired level (measured on the scale) when the position of any point may be marked by counting the squares in the picture.

This method of describing the position of a point was invented by a French mathematician in 1637. In accordance with international practice we label the three lengths which define the point x, y and z and name them co-ordinates. The point in the figure is (6,7,4). One point is not very interesting but instead of a point we could draw a plan of a

house on the grid, then raise the plan into three dimensions.

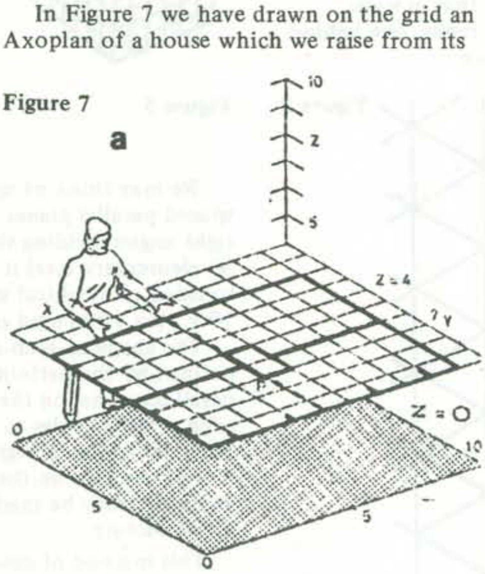
Figure 6
This figure is the Logogram of Operation Axoplan.



The earliest builders no doubt designed their buildings by marking the foundations on the ground and raising the walls above them.
In geometrical terms the plan of the foundations is where vertical lines through the parts of the building meet the horizontal ground plane.
We extend the idea to the projection of any point A on to any plane P by saying that a line through A at right angles to the plane P meets it at A′. A′ is the right projection of A on plane P.
In a plan the plane P is horizontal and the line AA′ therefore vertical.

In Figure 7 we have drawn on the grid an Axoplan of a house which we raise from its

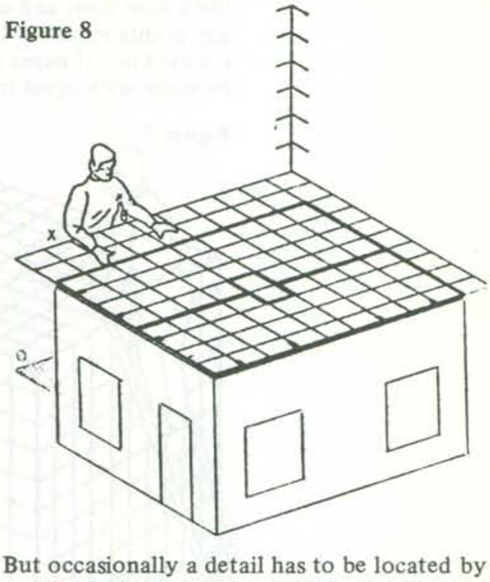
Figure 7



foundations in the picture. In Figure 8 the process has reached the eaves.

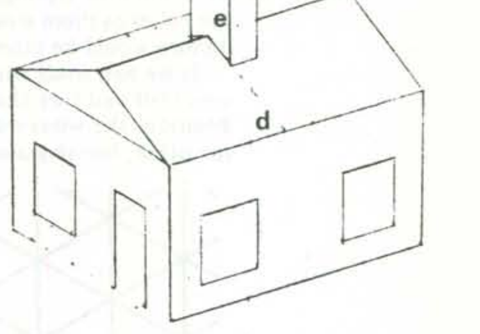
Notice that most of the lines of the completed picture can be drawn between points which are mapped from the Axogrid by a sketcher who has the design of the house in mind and some of the lines can be directly traced from the Axoplan.

Figure 8



But occasionally a detail has to be located by a geometrical construction which might be carried out in the axo-picture. For example the junction between the chimney stack and the roof is found by drawing the dotted line d to mark the limit of the vertical line e, (Figure 9).

Figure 9



Beginners will find it best to complete the sketch as they develop it from the Axoplan as is suggested by figure 8, but more experienced users will draw all the lines and points which can be traced directly from the Axogrid for the whole figure, or a part of it, before completing it by drawing the vertical and other lines.

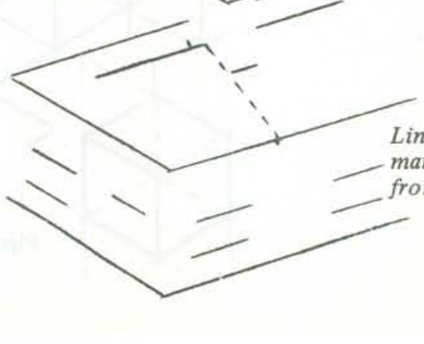


Figure 10

Lines and points marked directly from Axoplan

The Sliding Tracing
In fact it is not a very satisfactory arrangement to slide the Axogrid under the fixed tracing. It is easier and quicker to fix the Axogrid and scale and slide the tracing into position above it.

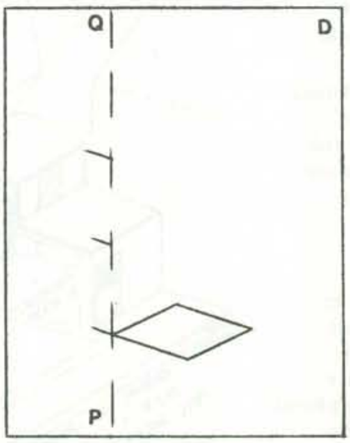


Figure 11

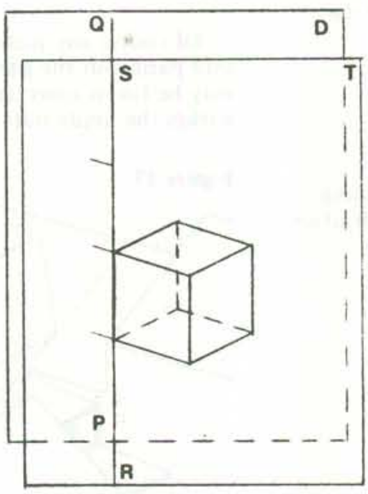


Figure 12

For simple applications it is sufficient to extend the scale line PQ on the drawing of the axoplan on sheet D. This line determines the direction of movement of the tracing. A location line RS is drawn on the tracing T. The tracing is placed with RS in register with PQ and is slid to the desired position where it is held while the desired detail is traced.

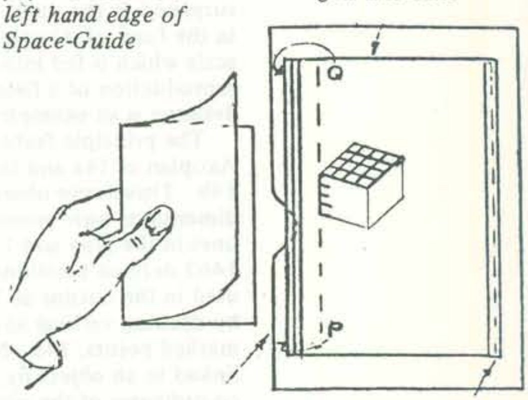
It is quite practicable to hold the tracing by hand while a simple detail is traced but it is quicker and more reliable in complicated work if some kind of mechanical guide is provided. One very simple and cheap way to do this is to use the edge of the sheet on which the Axogrid or the axoplan is drawn. For A5 sheets this is quite satisfactory for field work which can be done on the stiff back of a ring file to which the sheet is attached by adhesive tape so that it does not move when the tracing is pressed against it.

Only certain points and lines can be traced from the axogrid or axoplan. The picture has to be completed by connecting these lines and points,

Figure 13

Cut and fold tracing paper to slide on left hand edge of Space-Guide

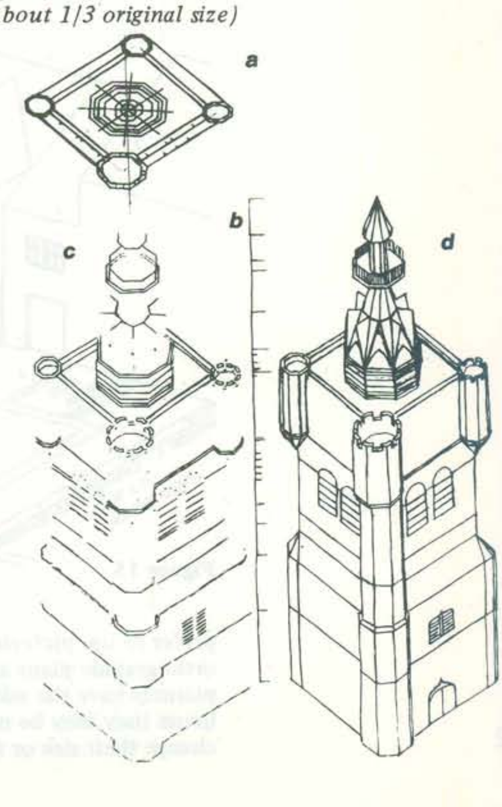
Space-Guide with grid and scale



Hard board with recess to allow folded tracing to be pressed against edge of Space-Guide

Fix Space-Guide to board by tape along right hand edge

Figure 14
(About 1/3 original size)



mainly by vertical lines. To guide the student a set of equally spaced parallel lines may be provided.

Often other than vertical lines are required. If they are short they can be drawn by 'eye'. Otherwise the tracing may be placed over a straight line to guide the hand.

For heavier use or greater precision a more durable but nevertheless simple and economical guide may be used.

Users of the Axoplan Technique are sometimes surprised at the small amount of 'information' in the form of Axoplan and levels marked on the scale which is fed into the picture. The miniature reproduction of a field sketch of the belfry at Bethune is an example.

The principle features are shown in the Axoplan at 14a and the levels on the scale at 14b. These were observed at a distance and the dimensions were guessed. There are 86 separate lines in the plan and 17 levels giving a total of 1462 defined positions. Only a few of these are used in the outline at 14c. The picture is completed by drawing vertical and other lines between the marked points, 14d. Notice that a picture may be linked to an object by the numerical values of the co-ordinates of the points which determine the shape of the object.

Application to Buildings
Extension to Cottage

Many people who are interested in the planning of houses and in the design of rooms and furniture

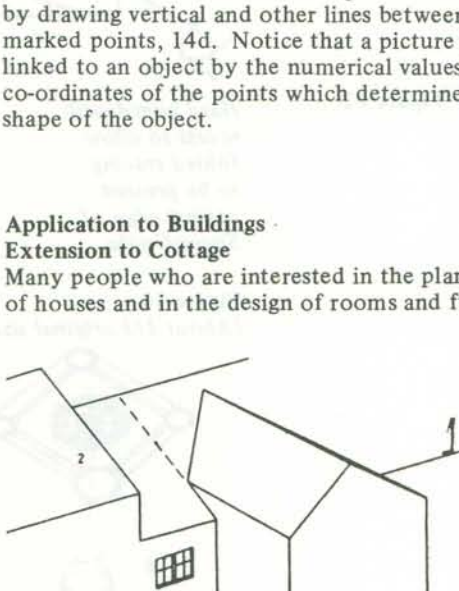


Figure 15

prefer to use pictorial sketches rather than sets of orthographic plans and elevations. Axometric pictures have the additional advantage that within limits they may be moved about without having to change their size or shape.

Any parallel or rotational movement of the tracing in the plane of the drawing may be permitted.

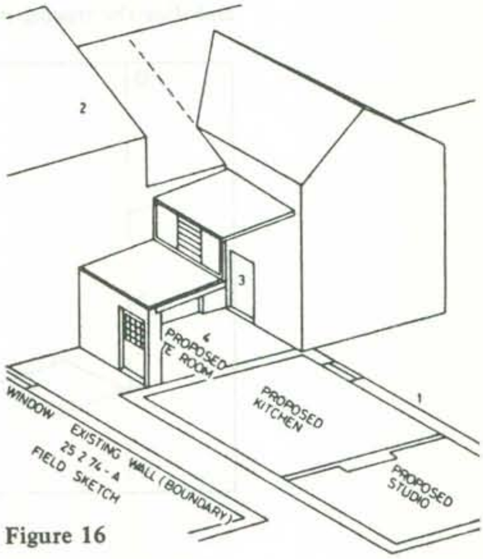
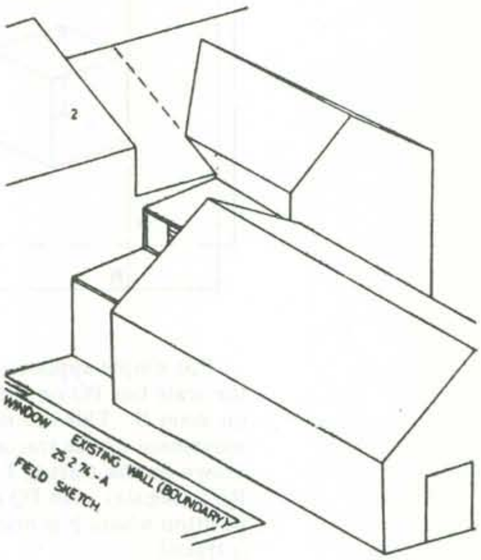


Figure 16

Of course any pictorial view may be separated into parts, but the parts of an axometric picture may be taken apart, re-arranged and re-assembled within the limits stated above.

Figure 17



The precision with which this may be done with axo-pictures is reassuring to users who are inexperienced in orthographic drawing. The three pictures here show an extension to a cottage. The connecting roof is set back to preserve neighbouring right of light.

Curves, Circles and Ellipses

In the past the drawing of curved shapes and especially of cricles which in most pictorial views are seen as ellipses has been a deterrent to people who would like to draw. Axoplan provides two solutions.

Firstly points may be positioned in the drawing by the method shown in Figure 6 or Figure 12 or by transferring points from rectangular graph paper to an Axogrid. Figure 18.

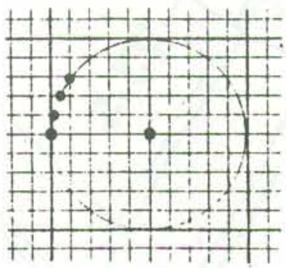


Figure 18a

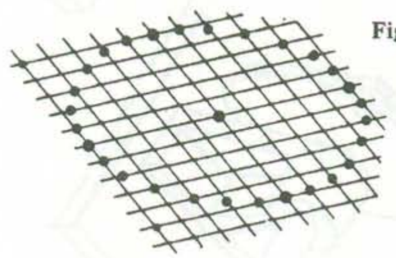


Figure 18b

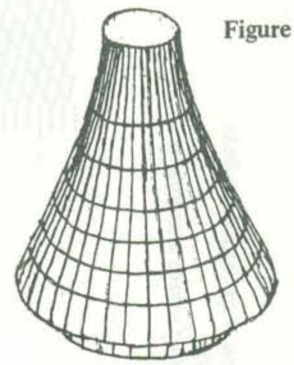


Figure 21

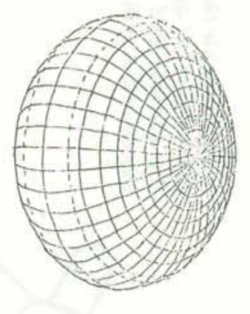


Figure 22

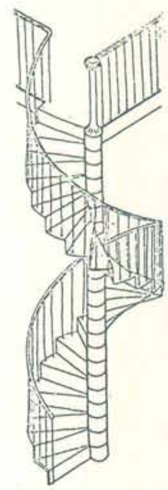


Figure 23

Secondly by taking advantage of the fact that products made on the Potter's Wheel or Engineering Lathe and similar tools have sets of circles which are in parallel planes, which leads to minor axis in Axometric Projection, it is ecomically practicable to have sets of ellipses drawn to guide the tracing of ellipses selected from the set. Figure 19 (See Back Cover).

Just as circles may be divided into angles in a circular protractor so the set of ellipses may be marked off to represent equal angles in an elliptical protractor. Figure 20 (See Back Cover). With the aid of this very powerful device surfaces of revolution spirals and other figures may be represented more vividly. Figure 21 shows a vase, Figure 22 an ellpsoid and Figure 23 a spiral staircase.

The set of ellipses may also be used for the construction of a grid representing an axometric picture of a square chequerboard. Figure 24 (See Back Cover), and a single set of ellipses may be used to create Axogrids of chequerboards seen at different angles.

One of the chequerboards may be combined with the set of ellipses from which it originated. Figure 25 (See Back Cover). This is convenient for experienced users but likely to be confusing for beginners.

We have assembled on the back cover four Axogrids so that readers who wish to try the Axoplan Method may do so at once as suggested in Figure 13. In order to do this in the necessarily limited space at our disposal we have left detailed explanations for another time.

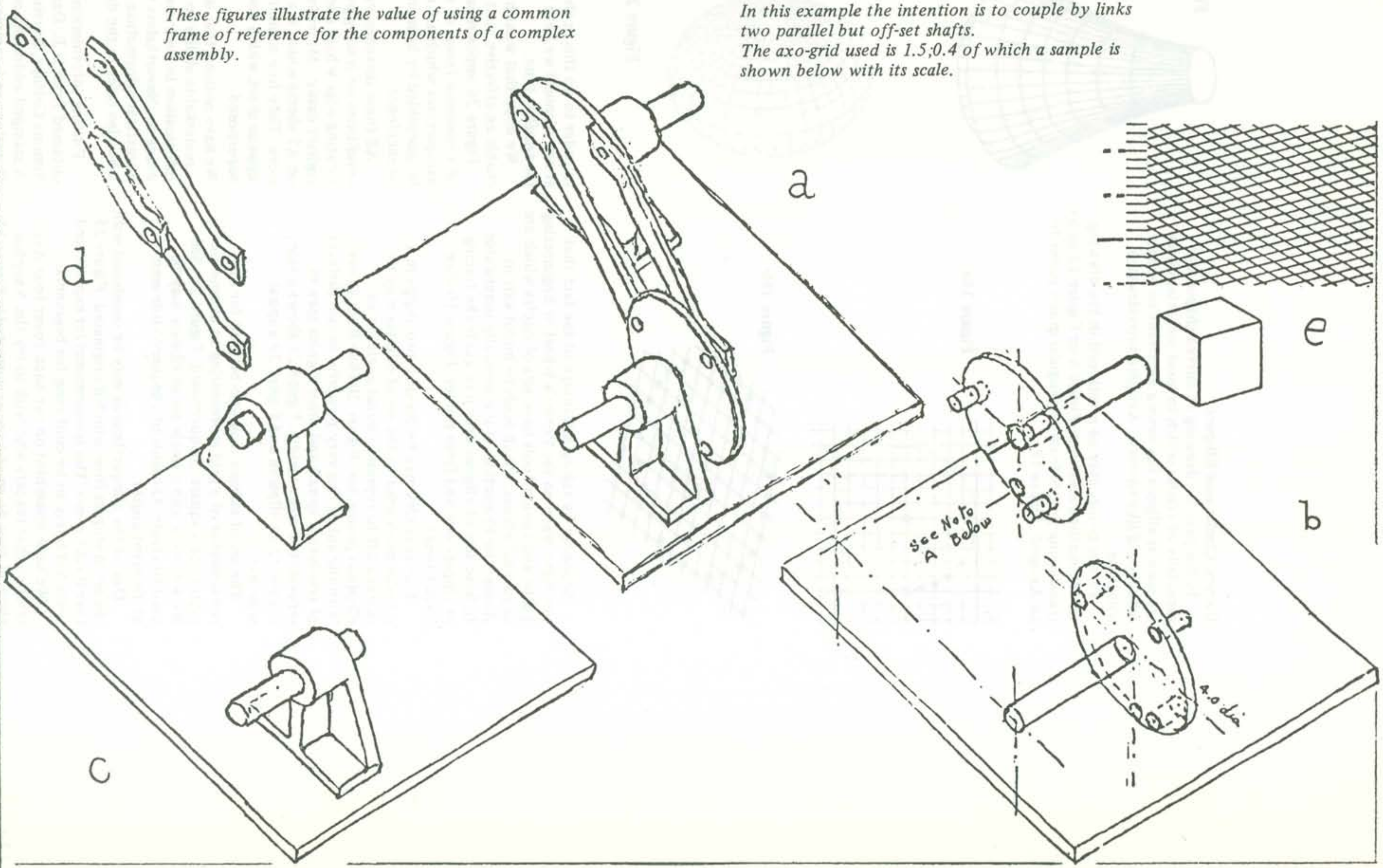
We hope that what has already been given will enable an effective start to be made.

Figure 26 opposite is an example of the use of a common frame of reference for a set of axo-pictures which are drawn separately but can be assembled by bringing the common axes into co-incidence.

All these sketches were done under field conditions on tracing paper with a standardised locating edge which allows them to be placed in register easily. Moreover the originals were made on A5 sheets which is a convenient size for field work. They lose something at being printed on one opaque sheet which does not allow them to be superposed.

We have noticed that some students develop a remarkable ability to carry this spatial information in their memories and delight in doing so. Nevertheless they should record the numerical information for the benefit of others who also refer to the drawings.

Further information about Axoplan may be obtained from H.E. Dance, M.Eng., C.Eng., Simons Cottage, Burrington, Avon, BS18 7AA. A stamped addressed envelope should be enclosed. Questions and comments are invited.



These figures illustrate the value of using a common frame of reference for the components of a complex assembly.

In this example the intention is to couple by links two parallel but off-set shafts. The axo-grid used is 1.5;0.4 of which a sample is shown below with its scale.