1.4 Basic survey methods

In order fully to understand the above techniques, an appreciation of the methods of obtaining the required information is necessary. By ignoring instruments and equipment, the techniques can be broken down into *four basic methods* of collecting information. Each method relies on the simple principle that if *two* points are established, a *third* point can be located in relation to them by various forms of measurement.

a) **Linear measurement** – measurement having only one dimension, i.e. length. Such a measurement in a straight line would give the shortest distance between any two points. When two linear measurements are multiplied together, square measure or area results (see Chapters 2 and 3).

b) **Angular measurement** – the measurement of the angle formed when two straight lines (or directions) meet (see Chapter 6). Although an angle possesses magnitude (i.e. size), it cannot be estimated as a length, breadth, or area; therefore special units are used, i.e. degrees and radians.

In order to discuss the methods in detail, it is necessary to state the following:

i) *The situation* In Fig. 1.3, the line AB represents a straight wall, while C is a point (say a vertical metal post) some distance way.

ii) *The requirement* To produce a two-dimensional plan, drawn to some suitable scale, showing the post in true relationship to the wall. (Note: Drawing out the measured information is known as *plotting the survey*.)

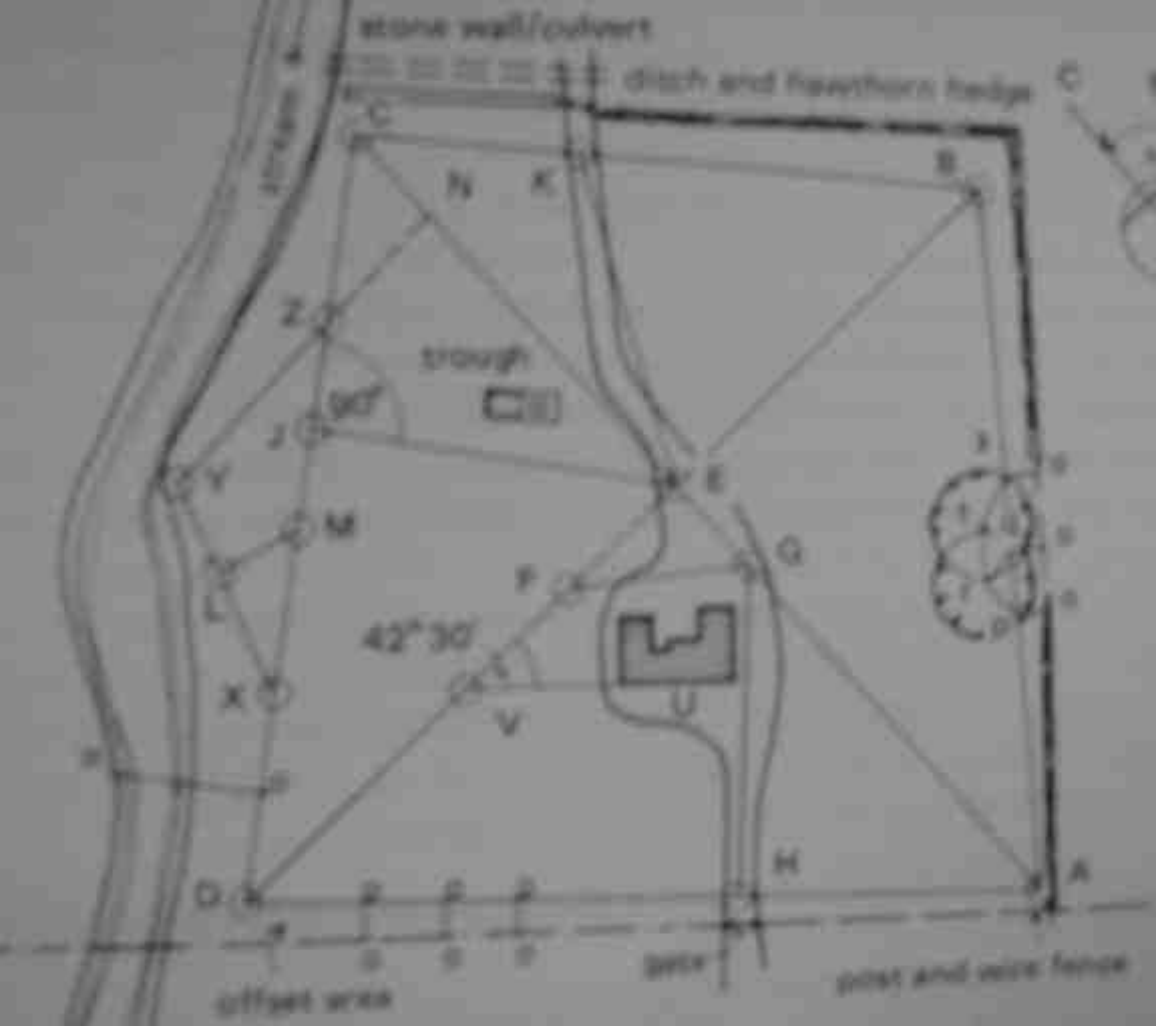
iii) *The problem* How can the post be located by measurement in relation to the wall in order that the requirement may be fulfilled?

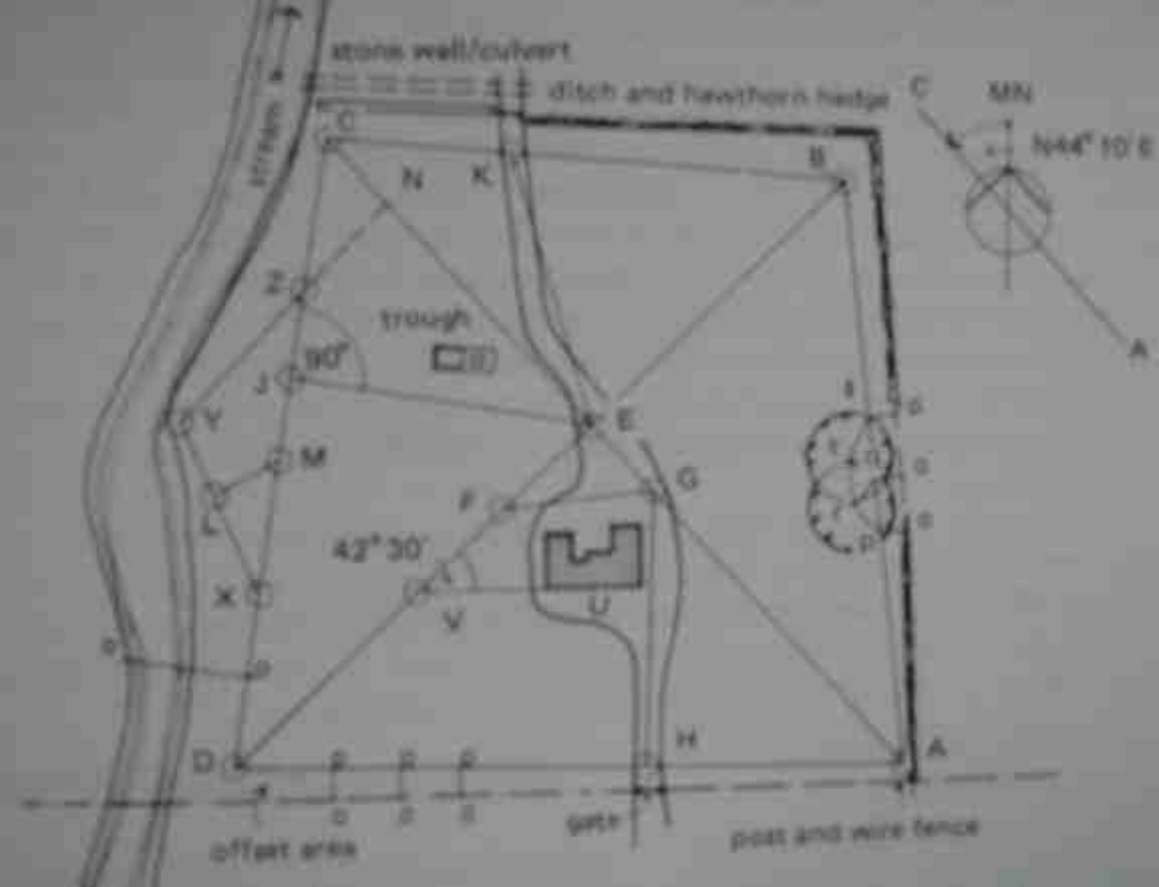
iii) *1:2500* is a highly detailed map providing accurate information to fairly large scale. A distinctive feature of the map is that each parcel land is identified by a number and has its area printed below (hectares and acres) which makes the map extremely useful for rati and valuation purposes as well as location plans for Local Author submissions.

iv) *1:1250* is the result of a double enlargement of the 1:2500 sheet whi renders it no more accurate than the smaller map. It is the largest sca of mapping published by the O.S., although in the 19th century an early 20th century 1:500 scale maps were produced and are still to b found in many offices. At 1:1250 scale all streets are named, as ar public and other buildings having a specific name. Remaining build ings are numbered.

Maps at this scale are used

- in part, as block plans or location plans when making applicatio for Planning and Building Regulation approval;
- by designers for initial layouts;
- by statutory undertakings to record the positions of power lines


stone wall/culvert
ditch and hawthorn hedge
trough
42° 30'
gate
post and wire fence
offset wire


stone wall/culvert
ditch and hawthorn hedge
MN
N44° 10' E
trough
90°
42° 30'
gate
post and wire fence
offset area

Chain lines : AB, BC, CD, DA, DB, and AC

2.1.2 Survey stations

A survey station is a point of importance at the beginning or end of a cha line, or at the junction of one line with another. It is usually marked by s insertion into the ground of a vertical ranging pole (see Section 2.3.4). On ha surfaces this point may be marked by a stud, while on normal ground where more permanent mark is required, a wooden peg (50 mm square) should driven in, which can be easily located at all times. It is not a bad idea to mak dimensioned sketch of the position of the pegs so that these may be relocate if a peg is lost or accidentally removed. For station points on hard grou which are not to be of a permanent nature, a stand should be used to suppo the rod vertically.

Stations should be placed as may be found convenient at the corner of area or at prominent points, so that the lines joining them are as close as possible the boundaries of the site in order to keep offset measurements short (se Section 2.1.7).

2.1.3 The base line

This is normally the longest of the chain lines forming the *pattern of triangles* should, if possible, be laid off on level ground through the centre of the si and encompass the whole length of the area. A compass bearing should b taken to fix its direction, which in turn will fix the direction of all other line and allow the position of north to be determined. All survey drawings requi a drawn north point.

Fig. 2.5 Typical chain-survey equipment

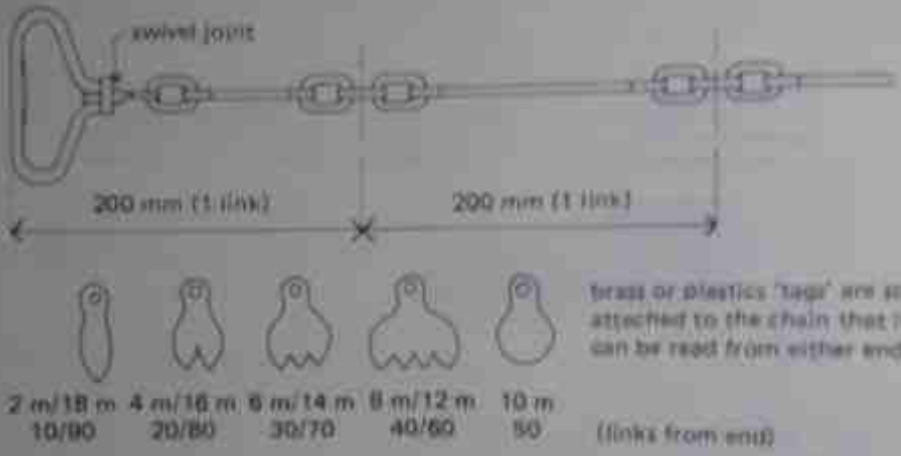
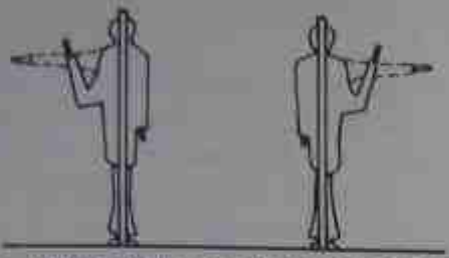


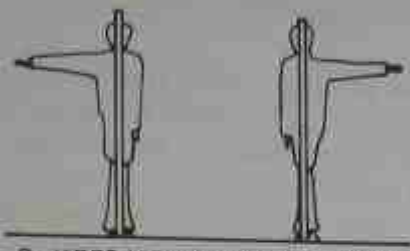
Fig. 2.4 Typical chain pattern. The tags shown are for a 20 m chain and may be of brass or plastics. Alternatively, a plastics tag may be attached at each whole metre position with a different colour used at each 5 m position. This is usual on chains longer than 20 m and still allows the chain to be read from either end.

2.3.6 Tapes

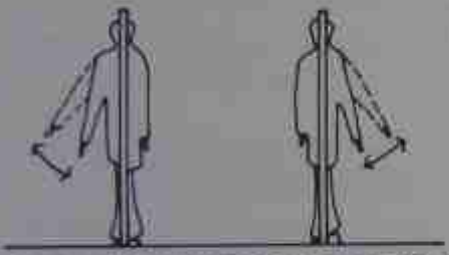
A tape is used for taking subsidiary measurements in the field. It is suitable for taking offsets, which are measurements taken from, and at right angles to, the chain line, or to fix adjacent points as on a boundary.



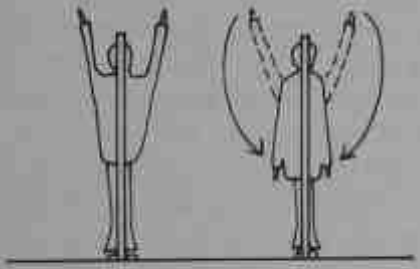
1. MOVE WELL OVER TO MY RIGHT (or LEFT) a rapid throwing-out type of movement with the hand.



2. KEEP MOVING TO MY RIGHT (or LEFT) arm held out horizontally and kept in position until move is completed.

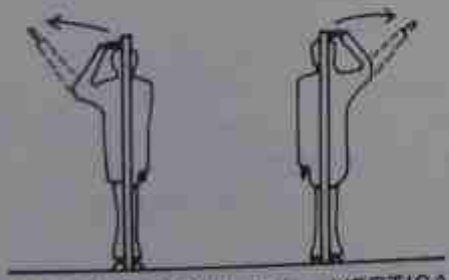


3. SMALL MOVEMENT TO MY RIGHT (or LEFT) slow sweeps of the arm to the side.

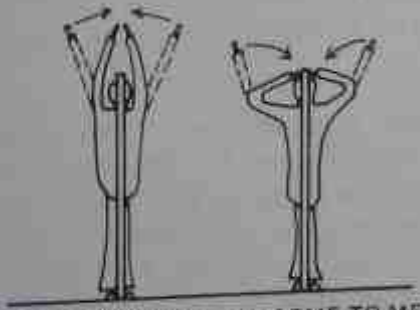


4. HOLD POLE STATIONARY

5. MARK! pole now on line.



6. MAKE POLE PLUMB (i.e. VERTICAL) tap top of head and straighten arm in the required direction. This will indicate that only the *top* of the pole is to be tilted.



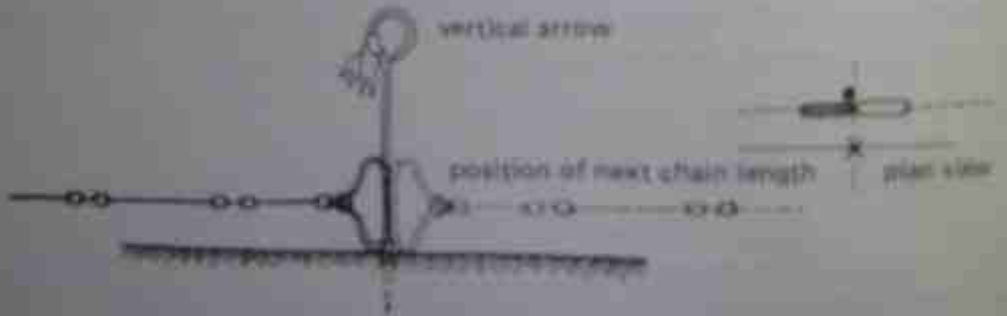
7. ALL FINISHED raise both arms and wave together then apart until signal seen.

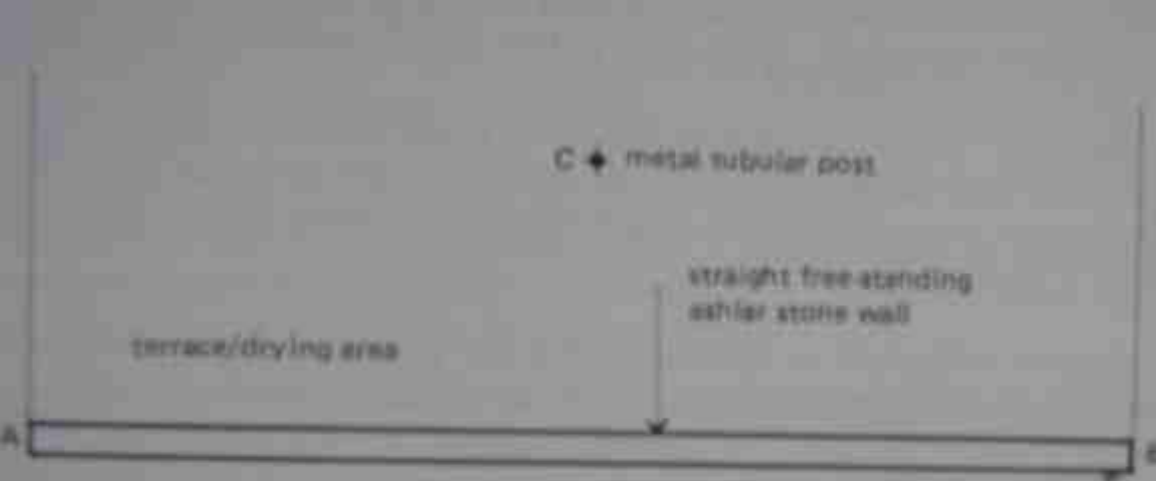
8. COME TO ME arms raised high and open, then bring palms on to head-hold.

9. GO AWAY FROM ME the opposite signal to 8. Start with the palms on the head then move arms into high open position. Repeat until movement

2.4.4 Laying-down the chain

The leader, equipped with his ten arrows, drags the chain until he is [illegible] up by a gradual pull and directed into line by the follower. Once alignment effected, an arrow is inserted which marks the measurement of one ch length. Care must be taken to ensure that arrows are inserted *vertically* at the side of the *vertical handle*, so that no error equal to the thickness of arrow or the thickness of the handle is introduced (see Fig. 2.6).





3 The situation: metal post in relation to straight stone wall

b) On hilly ground Very often, due to undulations of some size, the last station point cannot be seen from the first, yet intermediate poles must be positioned for lining in the chainmen. The difficulty may be resolved by tying two poles together, although this is not very accurate or satisfactory. Two other methods may be adopted, as follows.

i) In Fig. 2.8, A and B are the two stations seen in plan, with the hill between them (as shown by the section). Two assistants with poles take up positions, one on each side of the hill, at C_1 and D_1 and facing each other so that the observer at C_1 can see the pole at station A and the observer at D_1 can see the pole at station B. By successively directing each other into line, their positions will be altered until finally the finish at C and D exactly on the line AB and then the poles are inserted.

ii) In Fig. 2.9, A and B are again the two stations with the hill intervening so that A cannot be seen from B and vice versa. A trial line (known as a random line) is set out from A with poles erected at C_1, D_1, etc. and will end at B_1 (unless by the greatest of good fortune the line ends on B, when there would be no problem). There is therefore an error at the end of the line amounting to BB_1, which is measured. AC_1, AD_1 and AB_1 are also measured. By application of the principle of similar triangles, it is found that triangle ADD_1 is similar to triangle ABB_1

$$\therefore \frac{DD_1}{AD_1} = \frac{BB_1}{AB_1} \quad \text{or} \quad DD_1 = BB_1 \times \frac{AD_1}{AB_1}$$

Similarly the shift for any other pole is calculated.

(1) start

(2) C ranged in with D and B

(3) D ranged in with C and A

(4) C ranged in with D and B
The process is repeated until A, D, C and B are in line.

2.8 Ranging out over a hill – method 1

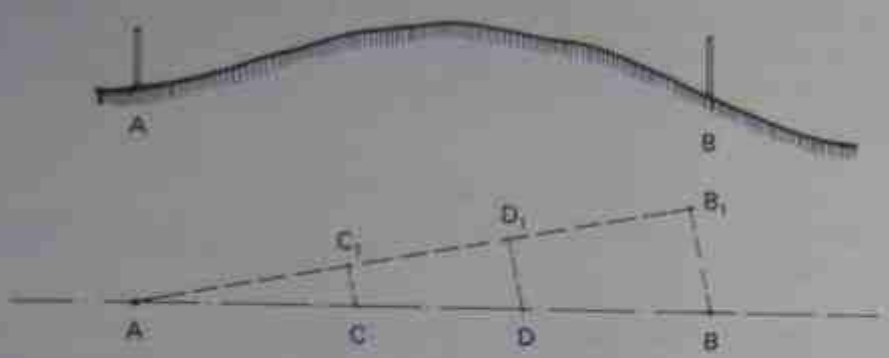


Fig. 2.9 Ranging out over a hill – method 2

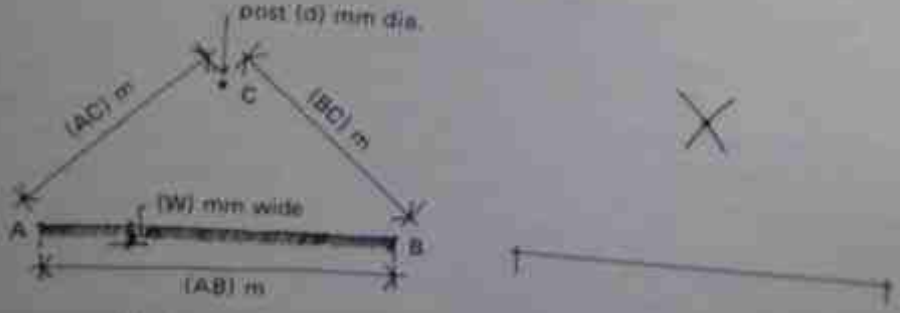
$$DD_1 = \frac{10 \text{ m} \times 300 \text{ m}}{400 \text{ m}} = 7{,}500 \text{ m}$$

1.4.1 Method 1 – intersecting arcs

i) *On site* Measure the horizontal distances AB, AC, and BC and note down the information on the sketch (Fig. 1.4(a)).

ii) *In the office* Draw line AB to scale. Using compasses, swing an arc from A with the radius set to the scale length of AC. Similarly, swing an arc from B with the radius set to the scale length of BC. The intersection of these arcs will locate point C (Fig. 1.4(b)).

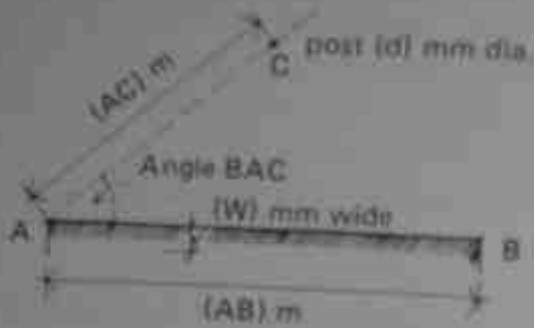
This method is the basis of *chain-survey technique* and may be used for land survey, building plans, etc. as will be discussed in Chapters 2, 3, and 7.



1.4.3 Method 3 – polar co-ordinates/radiation

i) *On site* Measure the horizontal angle BAC the length AB and the horizontal distance from point A to point C. Note down this information on the sketch (Fig. 1.6(a)).

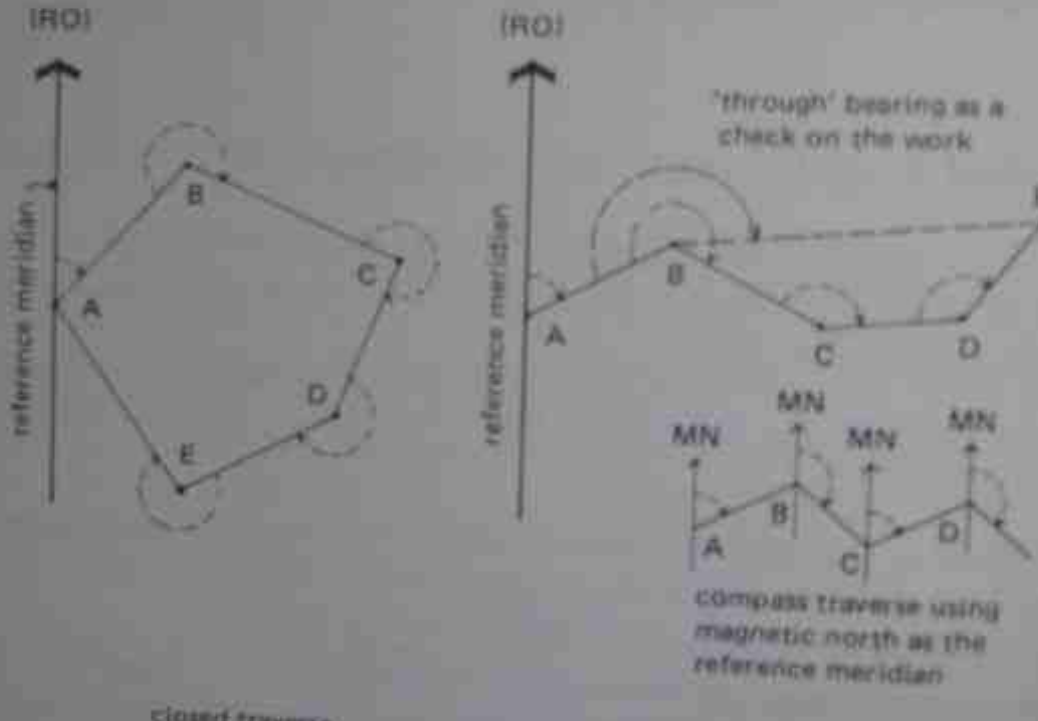
ii) *In the office* Draw line AB to scale. Use a protractor or an adjustable set square to set off the angle BAC. From A, scale off the distance measured to locate point C.



(a) "on-site" sketch

(b) office plotting

5 Polar co-ordinates



1.7 Types of traverse survey

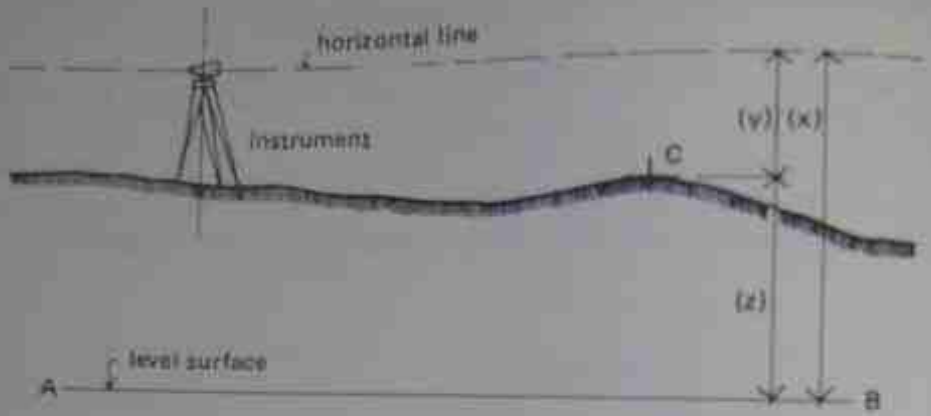
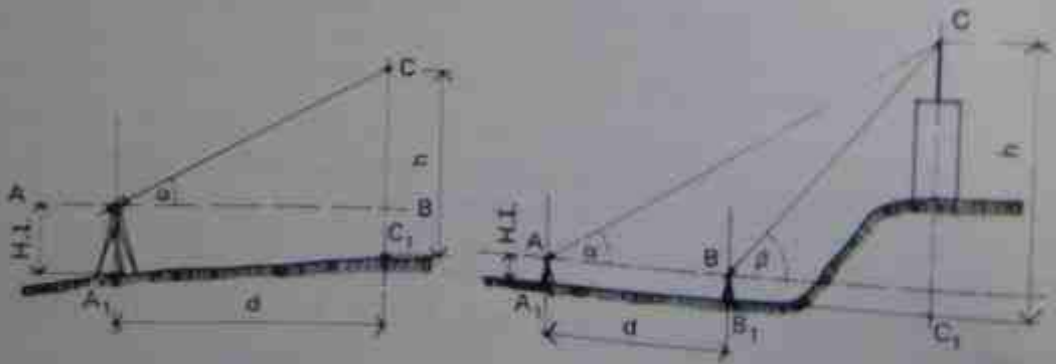


Fig. 1.9 Ordinary levelling. The difference in height (x) between the level su and the horizontal line can be calculated and the vertical distance (y) from horizontal line to point C can be measured. The height (z) of point C above AB is g by $(x - y) = z$.



(a) simple case

a) *The use of maps* will vary with the scale and the following text gives a b account of each of the four maps mentioned above, along with indication of some possible uses.

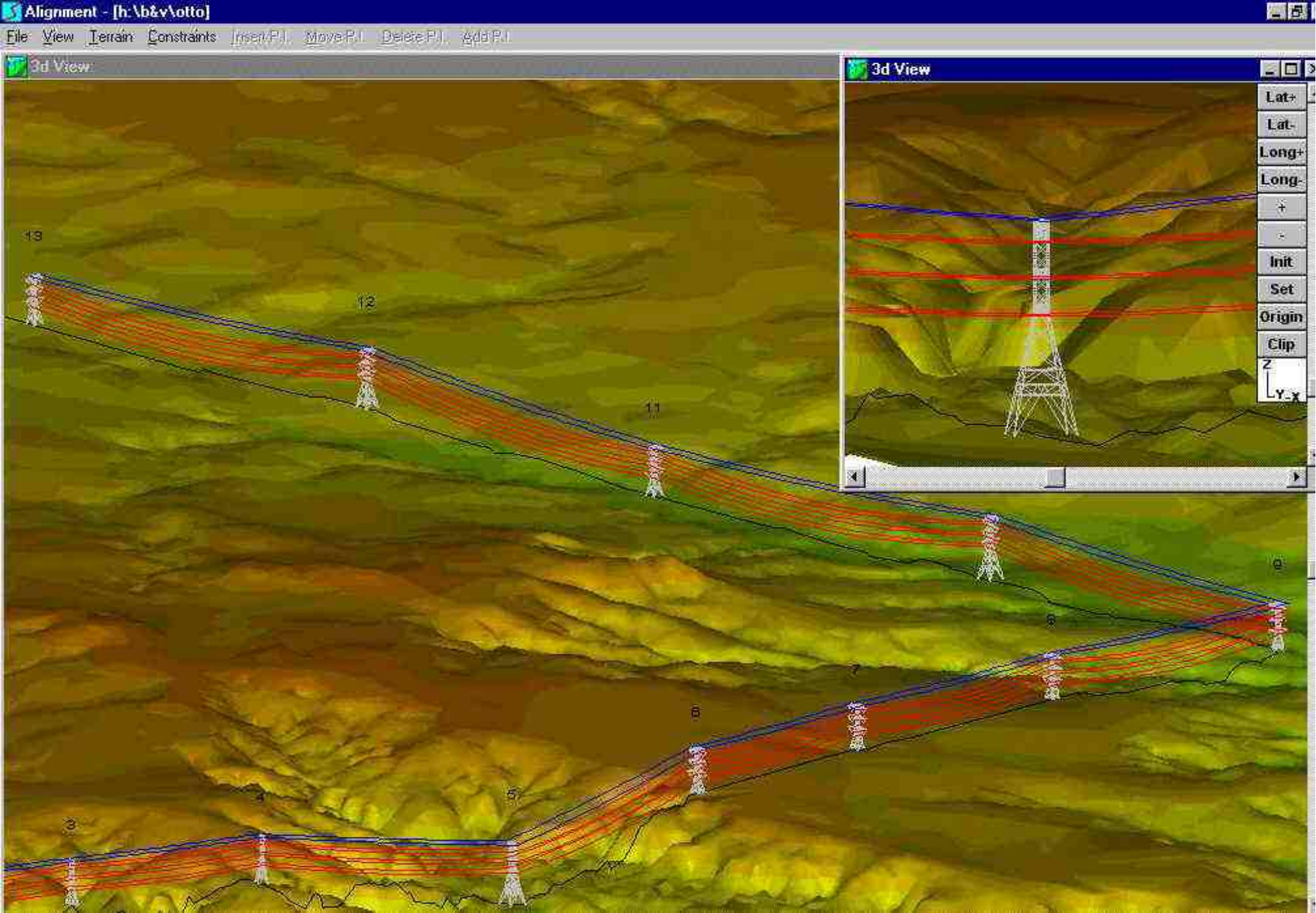
i) *1:25 000* is a relatively small scale map and the smallest scale at wh field boundaries are shown. Contour lines are drawn at 10m V.I. Section 5.12.1(c)) with altitudes shown as spot-levels at regular tervals along main roads.
Maps at this scale would be used

- when planning large-scale engineering works involving grade of roads, sewers and pipes;
- extensively when involved with the flow of rivers and strea (flooding abatement, irrigation, reservoirs);
- where the contour lines provide a means of solving problems intervisibility and clearance between points;
- to illustrate aspects of regional planning because the small s enables an 'overview' to be given.

iii) 1:10 000 is almost accurately drawn to scale although some r
widths are increased to accommodate road names. Conventions (sig
and symbols) are used to represent features in a semi-pictor
manner, e.g. orchard, quarry, cutting, embankment, etc. (see Fig. 3.
whilst individual parcels of land are shown, together with fences a
fields. Contour lines are drawn at 5m V.I., although this is increased
10m V.I. in mountainous areas.

Maps at this scale would be used

- by the surveyor involved in estate management because individ
tenant holdings can readily be distinguished;
- for design of schemes for water supply;
- for geological surveys;
- by town planners and urban designers to illustrate initial p
posals.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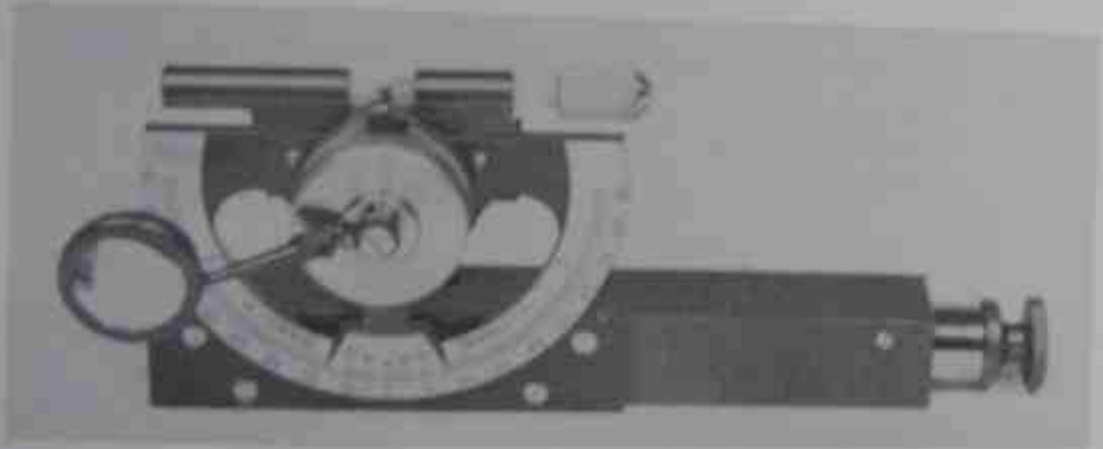
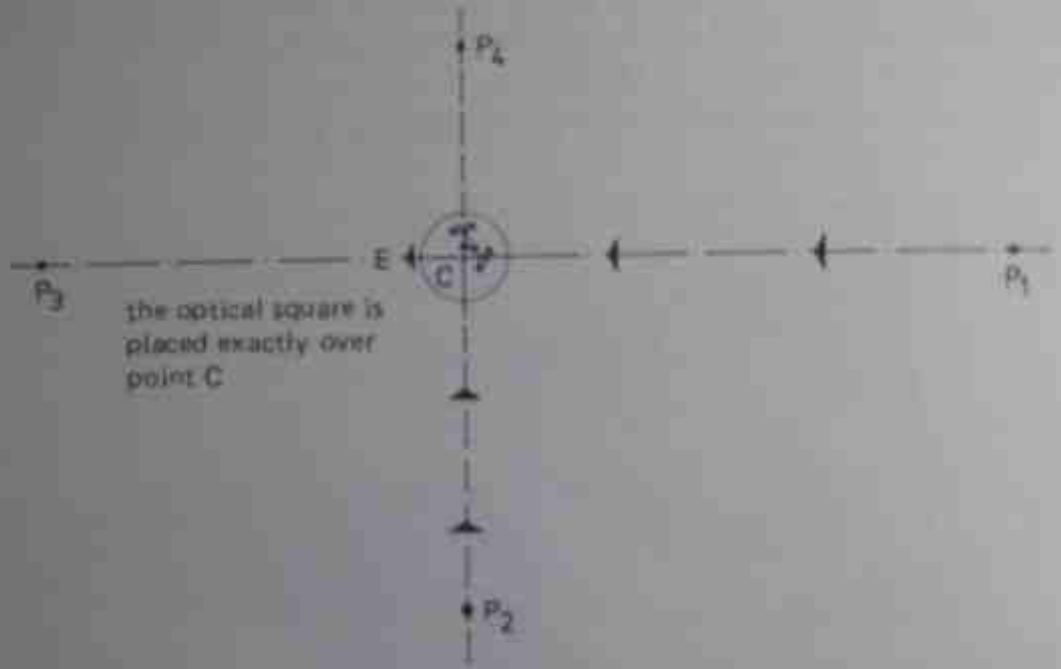


2.16 The Abney level



. 2.17 Setting off a right angle using an optical square

b) By prism The prism is held by the surveyor in his hand exactly over the point C, and the pole P_1 is sighted by direct vision over the prism. The rays of light forming the image of P_2 enter the prism from the side and are bent to the observer's eye. The assistant moves P_2 until the poles can be seen in vertical alignment, at which point the right angle has been set off.

c) By cross-staff Unlike the optical square or the prism, the right angle is set out by direct observation of all poles. The cross-staff is placed on a tripod with a special receiving head, and the slots are made vertical. By use of a plumb-line, the cross-staff can be placed over the exact spot C in the chain line (Fig. 2.17). Poles P_1 and P_3 are observed through the slots as a test that the staff is on the chain line. When the surveyor is satisfied that the cross-staff is in line, he then observes through the slots at 90° to the line and when he can see pole P_2 through the appropriate slot this signifies that P_2C is perpendicular to the chain line.

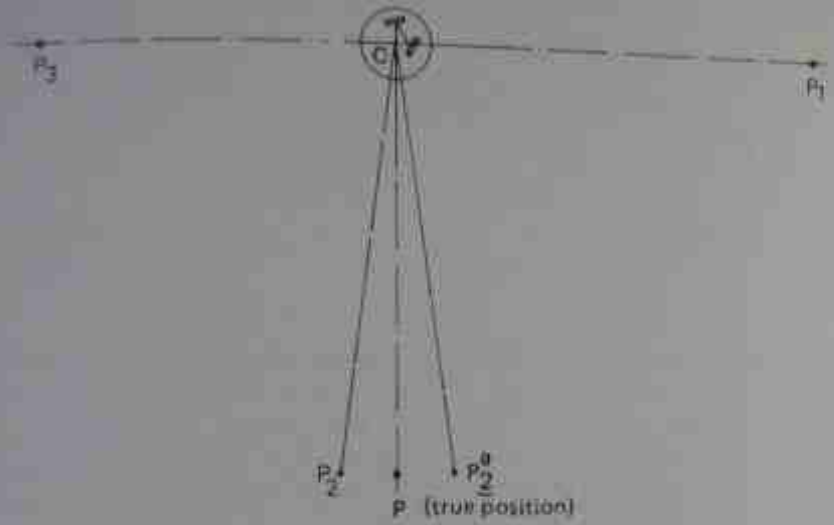


Fig. 2.18 Testing the optical square

2.6.2 Measuring slope angle

a) By clinometer To measure the ground slope of a line AB, the surveyor stands at point A holding the Watkin's clinometer to his eye. The assistant stands at B with a pole having a clear marking which is the same height above the ground level at B as that of the surveyor's eye level at A. This mark is observed through the instrument and, if it is *higher* than the surveyor's eye level at A, the instrument will be tilted upwards (elevated). Since the scale is

freely suspended, its position in relation to the horizontal will not alter and the angle of elevation will be read upon the scale from a fixed mark on the clinometer case (see Fig. 2.15).

Conversely, if the mark is *lower* than the surveyor's eye level at A, the instrument will be tilted downwards (depressed) and an angle of depression will be read from the scale.

Using the protractor type of clinometer, the surveyor observes the mark on the pole at B by sighting along the straight-edge while standing at point A. When the plumb-bob has taken up its position, the cord is fixed by the thumb and the angle is read off as in Fig. 2.15(b).

It must be appreciated that, for the above methods to be of use, the ground slope between A and B must be generally uniform, as illustrated in Fig. 2.

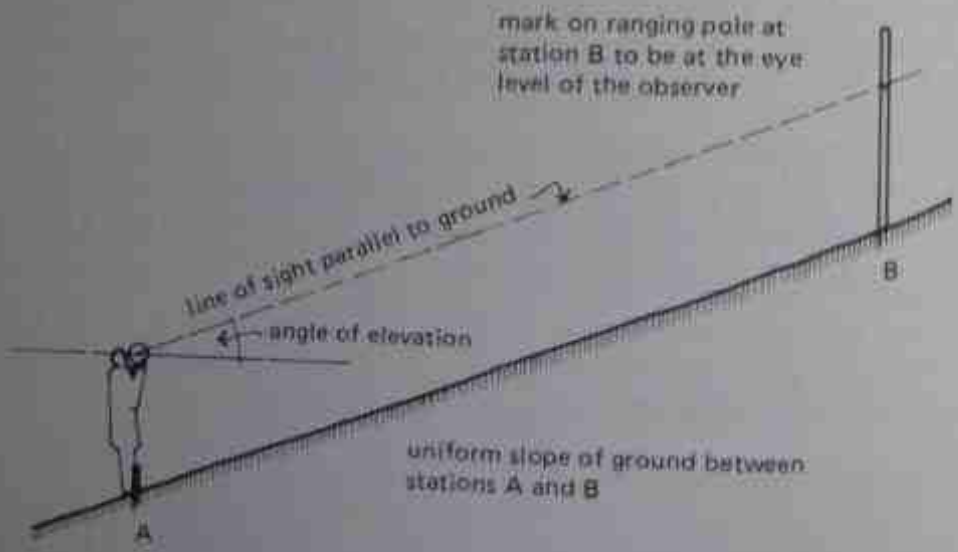


Fig. 2.19 Use of the clinometer

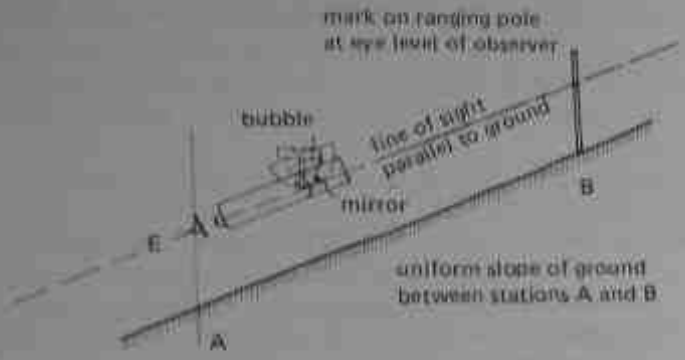


Fig. 2.20 Use of the Abney level

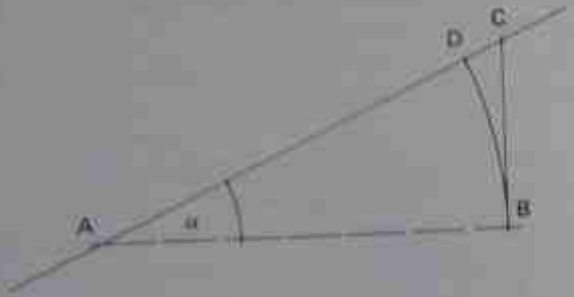


Fig. 2.21 Hypotenusal allowance

$$\frac{AC}{AB} = \sec \alpha \quad \text{or} \quad AC = AB \sec \alpha$$

Since AB is 100 links, the corresponding distance along the slope (AC) is

3.14 Chain angles

When surveying an area such as a wood, a pond, a standing crop, etc., it will be impossible to measure diagonals in order to divide the shape into triangles. It is, however, necessary to fix the angles of the perimeter in some way, and this can be done by the measurement of tie lines using a chain or tape. Angles fixed by measurement in this way, without recourse to angle-measuring equipment, are referred to as chain angles.

Figure 3.16 shows the outline of an area where the measurement of diagonals is impossible. Survey stations are chosen at A, B, C, and D. The angles at the stations are fixed by referral to lines, such as FE, or by external to lines such as GH, KL, and MN.

In order to obtain external tie lines, one or both of the sides adjacent to the angle must be extended. In Fig. 3.16, for example, DC is extended to L and a

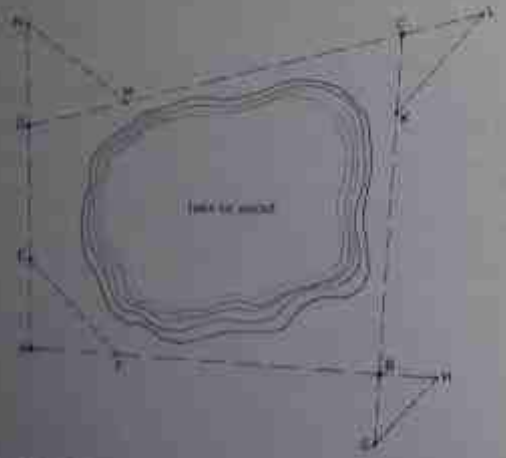


Fig. 3.16 Chain angles

There is no need to dwell at any great length on the subject of draughtsmanship. Numerous books are available on the subject, and even then there is only one way to become a competent draughtsman and that is by practice.

However, certain guide-lines can be given with regard to the plotting of a chain survey. Apart from the obvious skills of draughtsmanship, the person plotting the survey needs to have a thorough understanding of the principles on which the survey fieldwork was based and the reasons for which the information and drawings are required. It is better if the draughtsman has been involved in the fieldwork, although, with a good set of survey notes, any competent draughtsman should be able to plot the survey.

3.15.1 Equipment

This is basically as listed in Section 7.2, with the following additions and notes:

a) **Long steel straight-edge** to rule the long chain lines which form the triangulation pattern.

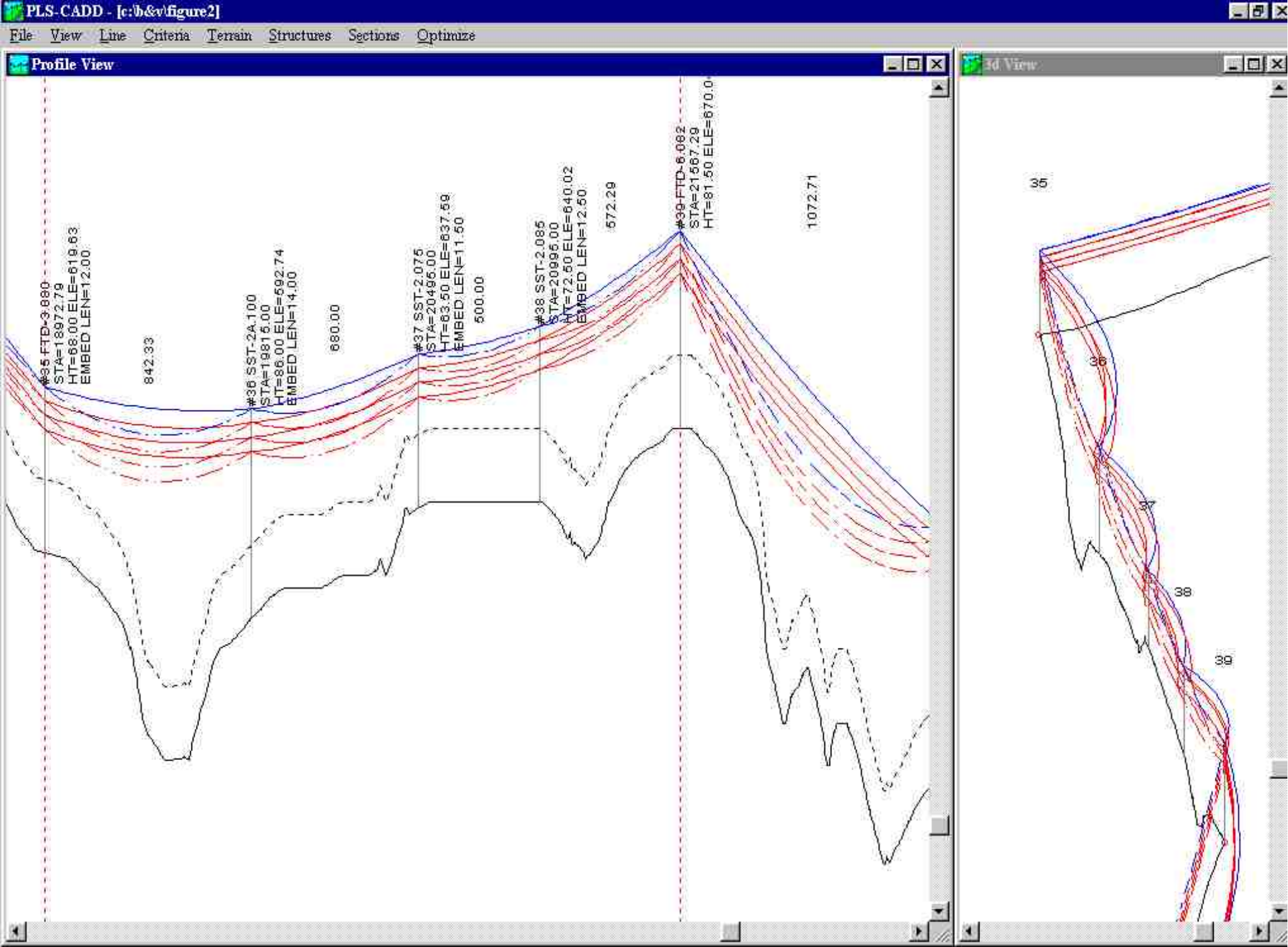
b) **Parallel rule** useful for transferring lines and points across the drawing paper.

c) **Protractor (360°)** for plotting horizontal bearings. The author's is a large, 10 inch (254 mm), brass circle which formerly belonged to his grandfather and the larger the protractor the more accurate the plotting. The majority of survey points read from the instrument (Theodolite etc.) will be outside the extent of all but the largest protractors and substantial errors can be produced by extrapolating the inaccuracies of a small-diameter protractor over a long distance. When using a 'modern' plastics protractor care must be taken to ensure that, because of its light weight, it does not move about when in use.

d) **French curves** useful when plotting highway boundaries, kerbs, and contours.

e) **Railway curves** for plotting roads and railways.

f) **Offset scales** used to facilitate the plotting of offsets. The scales are 50 mm long, being divided in exactly the same way as the long scale with which they are used. The long scale is laid down on the drawing, parallel to the chain line, and the offset scale is placed at right angles (see Fig. 3.17). The offset scale is then moved along the chain line to the various chainages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3d View
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HT=68.00 ELE=619.63
EMBED LEN=12.00
842.33
#36 SST-2A.100
STA=19815.00
HT=86.00 ELE=592.74
EMBED LEN=14.00
680.00
#37 SST-2.075
STA=20496.00
HT=63.50 ELE=637.59
EMBED LEN=11.50
500.00
#38 SST-2.085
STA=20996.00
HT=72.50 ELE=640.02
EMBED LEN=12.50
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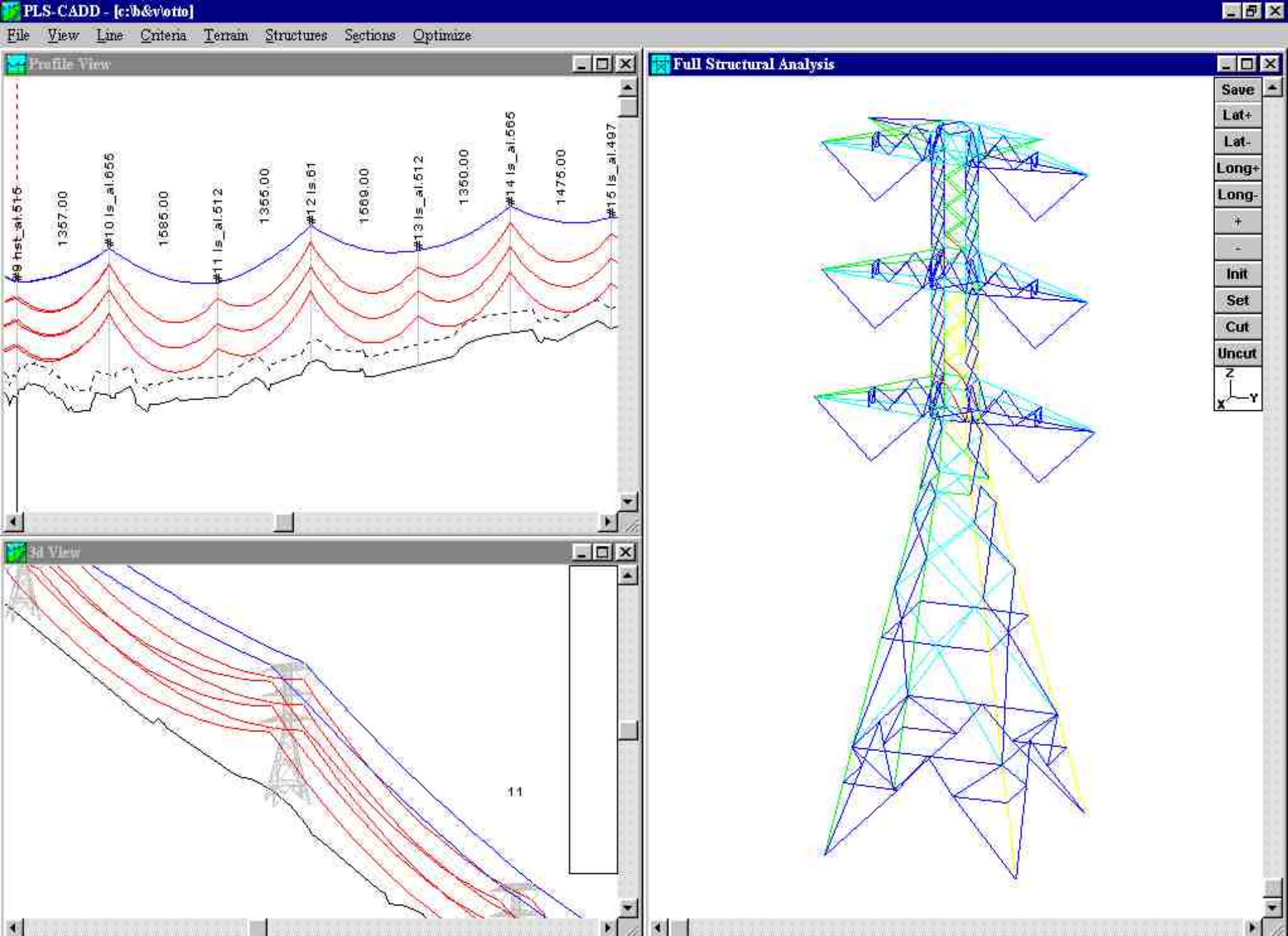
PLS-CADD - [c:\b&v\otto]
File View Line Criteria Terrain Structures Sections Optimize
Profile View
#9 tst_al.515
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#10 ls_al.655
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#11 ls_al.512
1355.00
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#13 ls_al.512
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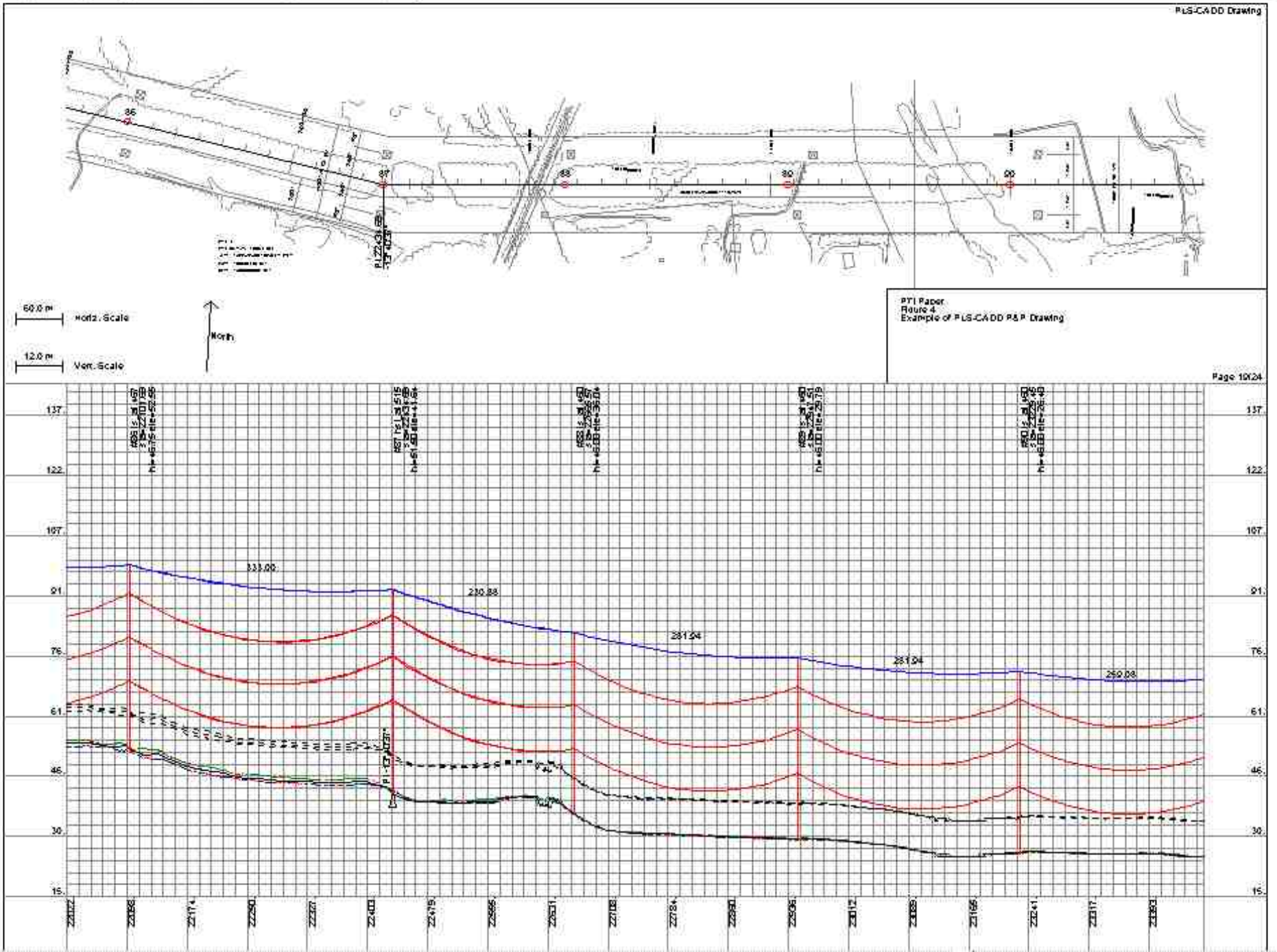
#14 ls_al.565
1475.00
#15 ls_al.497
3d View
11
Full Structural Analysis
Save
Lat+
Lat-
Long+
Long-
+
-
Init
Set
Cut
Uncut
Z
X
Y

PPSHEET - [c:\h&v\figure4] - [Plan & Prof View]

File View Line Terrain Constraints Structures Settings

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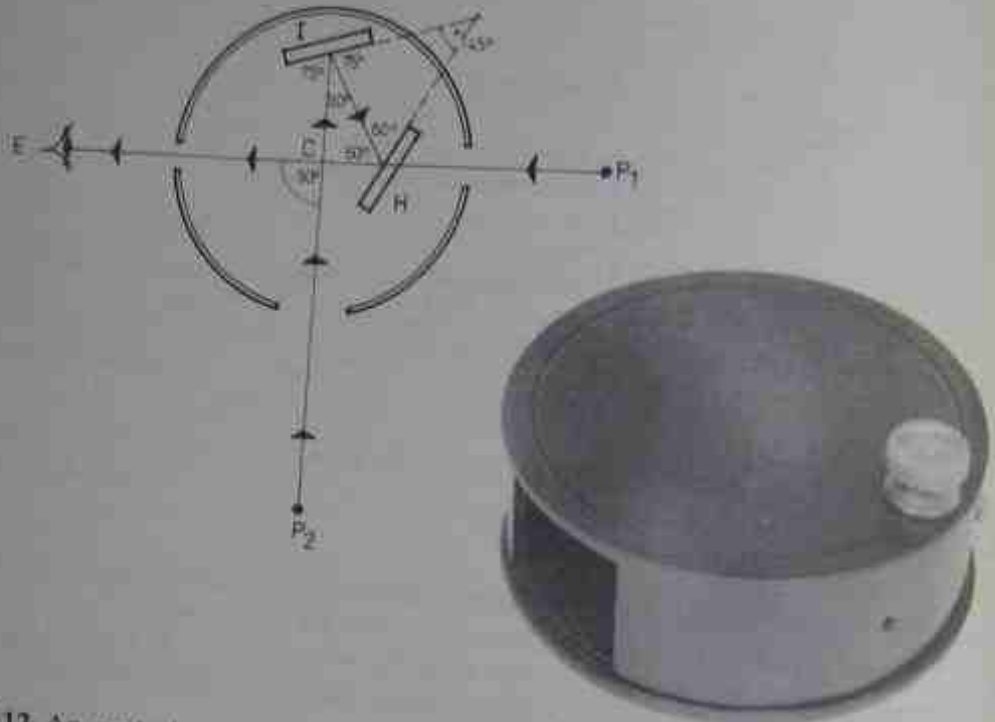
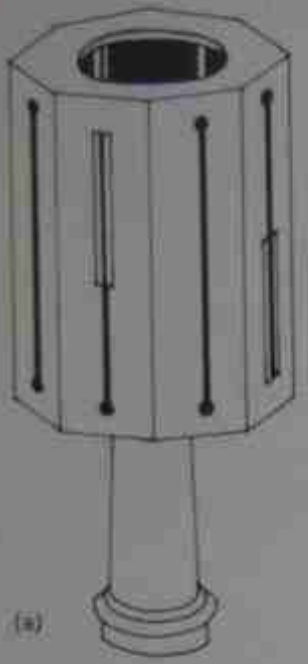
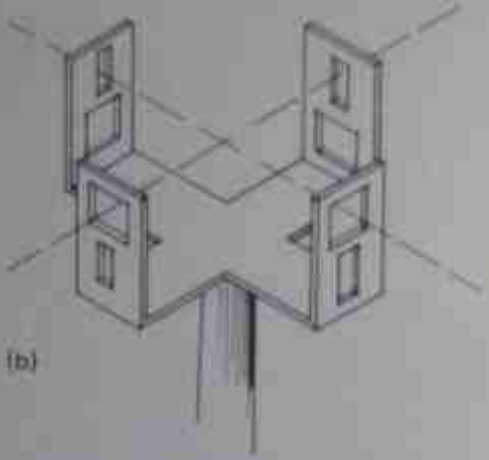


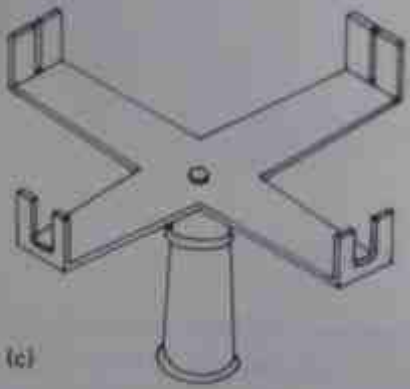
Fig. 2.12 An optical square



(a)

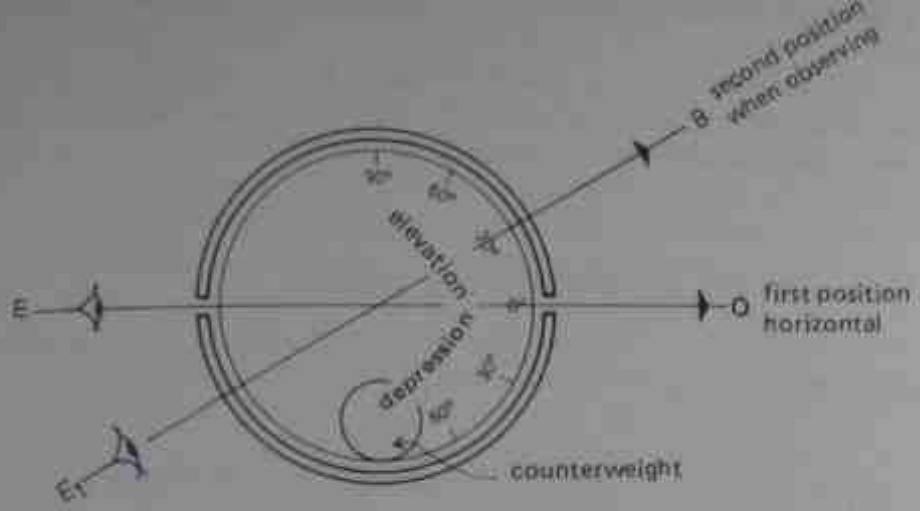


(b)

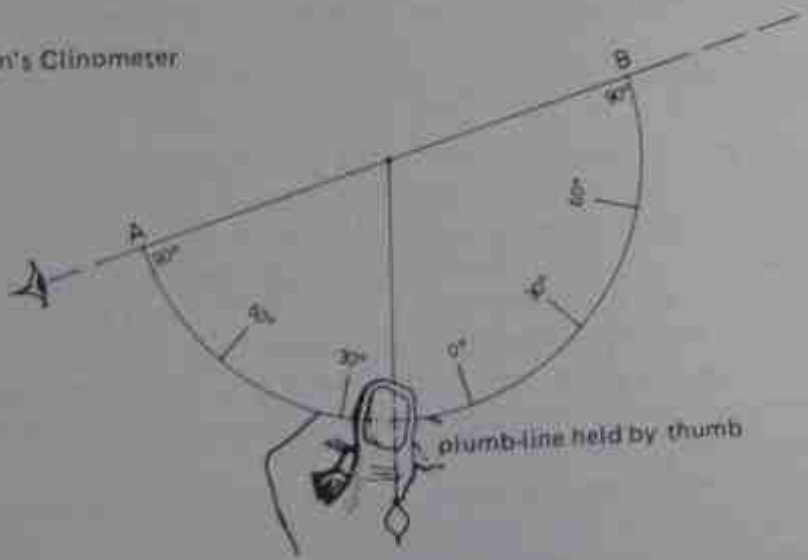


(c)

Fig. 2.14 Types of cross-staff. The one shown at (a) will also set out 45° angles.



(a) Watkin's Clinometer



(b) 'Protractor-type' Clinometer