PERSPECTIVE ANALYSIS OF APPROACH LIGHT PATTERNS

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SUMMARY

This report describes the perspective studies of eight different approach lighting systems Twelve studies of each system were made showing how each pattern will appear to the pilot who is letting down on the proper approach path or on one of several erroneous paths Four of these studies assume unlimited visibility while the remaining eight assume that the approach lights are visible for approximately 1,000 feet only

The effect of cockpit cut-off is not shown on the perspective sketches Instead, cockpit cut-off templates are included for three types of transport airplanes These templates may be placed over the perspective drawings to show the cut-off effect

The slope line system furnishes more accurate information than any of the other systems Those systems with special devices to indicate attitude give good information on attitude and usually give a good indication of lateral position with respect to the approach axis The bars in the Calvert system give the best indication of attitude The single row systems, as well as some of those systems of two or more rows of point sources, may furnish ambiguous information None of the systems except the slope line system furnishes any reasonable indication of altitude

Use of studies such as these will not eliminate the need for field testing of approach light systems, but will furnish considerable preliminary information for engineers engaged in designing or installing them Further use may be made of them for preliminary instruction for pilots flying an approach light system for the first time

INTRODUCTION

There is considerable disagreement among pilots, engineers, and others as to how much information an approach light system should furnish in order that a pilot may land an airplane safely under poor visibility conditions Some contend that directional guidance alone is sufficient, while others believe that lateral position and attitude must be indicated also Still others believe that an indication of attitude is not necessary It is not the purpose of this report to enter into any such controversy, but to analyze each of several proposed approach light patterns in order to determine how much accurate information each pattern can furnish to the pilot

An approach light system should furnish accurate and unmistakable information even when only a short portion of the pattern is visible It should not require that the pilot supplement this information by reference to the ground or horizon If dependence must be placed on such outside reference, the approach lights become ineffective under conditions of poor visibility It also is undesirable to require the pilot to refer to his instruments after seeing the approach lights, since at a speed of 120 mph the lights will be in view only 17 seconds It also is difficult for the pilot, after seeing lights, to re-direct his attention to his instruments

Obviously, the approach light pattern will appear different when viewed from a different position or attitude It is this difference of appearance on which the pilot must depend to determine his position with respect to the approach path and his attitude It is essential that the appearance of the pattern be easily, quickly, and accurately interpreted by the pilot

USE OF PERSPECTIVE CO-ORDINATES

The development of a set of perspective co-ordinates by E S Calvert, Royal Aircraft Establishment, Farnsborough, Hants, England, makes it a relatively easy matter to project points from a horizontal plane on to a vertical plane, giving a true perspective view of the horizontal plane The perspective studies made on these co-ordinates are in exact proportion, provided they are held vertically and are viewed from a point 25 cms (approximately 10 in) directly opposite the left one of the two small circles shown on each perspective study

The cut-off diagrams (Figs 105 through 107) can be adjusted on the perspective studies by placing the lower vertices of the two triangles located at the top of the cut-off diagram directly on the two small circles The cut-off diagrams also are made on perspective

co-ordinates and can be used only on perspective sketches made to the same scale The cut-off diagrams are not complete, except for that portion which is important to the pilot in making a landing Since this report deals only superficially with cockpit visibility, and then only insofar as cut-off affects visibility of approach lights, the cut-off diagrams cover the area 30° left and right from the pilot in a forward and downward direction only

Table I indicates the pilot's lateral position with respect to the approach path, distance from threshold, altitude, and attitude for each assumed situation used in the perspective analysis. For the cases of assumed low visibility, the pilot is shown to be 3,000 feet from the threshold The height of the glide path is 180 feet at that point For cases of assumed unlimited visibility the pilot is 3,500 feet from the threshold in all situations The height of the glide path is 200 feet at this point The perspective sketches are purposely identified only by a situation code so that the reader can study each pattern with a minimum of foreknowledge and preconception The reader is thus presented with the same visual evidence as the pilot has at his disposal, and can make his own estimate of the attitude and position of the airplane before he refers to Table I

AXIAL SINGLE LINE APPROACH LIGHT SYSTEM

A plan view of the single line approach pattern is shown in Fig 1 The lights are shown on the extended centerline of the runway As in all patterns, the longitudinal spacing was taken as 100 feet The perspective sketches are included in Figs 2-13 incl The effect of an offset single row may be studied by covering one row of the double row system shown in Figs 14-26 incl From the single line pattern the pilot's only indication as to his altitude is a small variation in the visual angle subtended by successive pairs of lights Comparison of Figs 10 and 13 will show variation in visual angles for a difference in altitude of 100 feet Comparison of Figs 6 through 13 will show that the pilot can get no definite information as to attitude and lateral position with respect to the axis The perspective views of this pattern appear identical for the cases where the pilot is off the axis and where the attitude is not level but compensates visually with the displacement Fig 12 illustrates that it is entirely possible for a combination of the two errors to make the pattern appear as it would if the pilot were on course with a level attitude

DOUBLE ROW APPROACH LIGHT SYSTEM

During several months of 1948 the parallel row system, as shown in Fig 14, was used as an interim standard approach light system, while that and various other system were undergoing tests Perspective views of this pattern are given in Figs 15 to 26 incl On this pattern, as in most parallel row patterns, altitude is estimated by the apparent angle of convergence of the two rows of lights. Errors in attitude and in lateral position both give a perspective pattern of one row of light forming a more acute, and the other row a less acute angle with the path of flight Fig 25 shows a situation where the errors in attitude and lateral position appear to compensate one another and result in a perspective somewhat similar to that in Fig 23.

As previously stated, the offset single row may be studied by covering the right hand row of lights in Figs 15 to 26 incl

DOUBLE ROW APPROACH LIGHT SYSTEM WITH SATELLITES

A sketch of a double row approach light system with satellites is shown in Fig 27 This pattern is similar to the one previously described, except that a row of satellites has been added to each row ten feet farther out from the axis

A study of Figs 30, 32, 33, 34, 35, 37, and 38 will show that the addition of satellites facilitates determination of attitude Lateral position with respect to the approach path may be determined as long as the attitude is level When the attitude is not level the pattern does not indicate lateral position clearly

FUNNEL APPROACH LIGHT SYSTEM

Fig 40 is a plan view of the funnel approach light system Perspective studies of this pattern are included in Figs 41 through 52 The perspective patterns of this system are similar to those of the double row without satellites Because of the convergence of the rows of the funnel system, the perspective will show less acute angles between the p

of flight and each row than the double row placed parallel to the axis

THE SLOPE LINE APPROACH LIGHT SYSTEM

A sketch of a portion of the slope line system is shown in Fig 53 The individual fixtures are approximately 14 feet long and are designed to be seen as a bar of light The fixtures are mounted in pairs with a 100-foot longitudinal spacing Each fixture is set out from the axis a horizontal distance equal to the height of the approach path The two converging rows of lights then define two sloping planes which intersect at a 90° angle along the approach path The spacing between the bases of the first pair of fixtures is 360 feet, since the height of the glide path is 180 feet at that point If one row of lights is viewed from a point anywhere in the plane of that row, all of the lights in the row will appear to fall in the same straight line If the row of lights is viewed from a point above its plane, the lights will fall into echelon with the tops of the nearer bar of light falling on a line below the base of the succeeding light Conversely, if the row is viewed from a point below its plane, the top of the nearer bar of lights appears to fall on a line above the base of the succeeding light

The space surrounding the approach path is divided into four quadrants by the two intersecting planes of the two rows of lights There are nine characteristic patterns formed by these lights when viewed from various positions with respect to these co-ordinates Fig 53A illustrates nine miniature perspective views superimposed on the quadrants formed by the intersection of the planes of the two rows of lights This illustration is schematic and is not drawn to scale The dot located above the perspective sketch shows the location of the pilot with respect to the axes of the four quadrants

Figs 54 and 55 show the difference in the appearance of the patterns when seen from the approach path and from above the approach path under conditions of good visibility Figs 62 and 65 compare the appearance of the pattern when seen from the approach path and from below the approach path respectively Fig 58 shows the appearance of the pattern as seen by a pilot who is on the approach path, but whose airplane is banked 20° to the right Fig 60 illustrates the same situation, except that the pilot is 100 feet to the left of the axis. Figs 63 and 64 make it clear that errors in lateral position with respect to the axis, and in attitude, do not appear to compensate in perspective

PATH OF FLIGHT APPROACH LIGHT SYSTEM

The path of flight system shown in Fig. 66 has two parallel rows of lights with satellites, similar to the double row system of Fig 27, plus two additional rows, also with satellites, located on reverse curves of 10,000-foot radii At the approach portal the lights of the curved rows are approximately 300 feet from the axis. The chief function of the curved rows is to furnish a curved path which a pilot, who is off the axis, may follow in Theoretically, any row which is seen may be followed by the pilot As a secondary function, the curved rows furnish a wider approach portal, the width being in this case approximately 600 feet The satellites not only allow determination of attitude, but also furnish information to help the identification of the row

MULTI-LINE APPROACH LIGHT SYSTEM

Fig 79 is a diagram of the multi-line approach light system As in the path of flight system, the multi-line system furnishes a wider approach portal by addition of more rows of lights Altitude, lateral position with respect to the axis, and attitude are determined in the same way as in the double row system

Figs 80 and 81 compare the pattern for cases of "on course" and "too high" approaches. Figs 88 and 91 compare the pattern for cases of "on course" and "too low" approaches Fig 89 shows the pattern when the pilot is 100 feet to the left of the axis with the airplane banked 20° to the left Fig 90 shows the same situation, except that the airplane is 65 feet above the glide path This system may be misinterpreted under the same conditions as the double row system

CALVERT BAR APPROACH LIGHT SYSTEM

A plan view of the Calvert bar approach light system is illustrated in Fig 92 The system is essentially a single row on the cen-

ter line with horizontal bars added at right angles to the center line The light units on the center line are essentially point sources, while the units in the cross bars were considered to be approximately one foot high and two feet wide The spacing of the units within the bar was estimated

Comparison of Figs 93 with 94, and Figs 101 with 104 will indicate the variations in perspective for different altitudes Figs 97, 99, and 102 show perspective views for corresponding lateral positions and attitudes at higher altitudes This system furnishes the best indication of attitude

CONCLUSIONS

Any of the systems considered in this report furnish adequate directional guidance, provided attitude is level. Except in the case of the slope line lights, those patterns which include satellites or cross bars for horizontal reference furnish better directional guidance than those without a horizontal reference The slope line system furnishes the sharpest indication of direction

None of the systems furnishes an accurate indication of altitude, except the slope line Those patterns of two or more rows allow the pilot to make rough estimates of altitude based on apparent angle of convergence of the rows Likewise, in the Calvert system a rough estimate of altitude may be made when two of the cross bars are seen simultaneously The single row system will furnish no indication of altitude

The horizontal cross bar of the Calvert system furnishes the best indication of attitude Those systems having satellites also furnish good indications of attitude Other systems of two or more rows give a reasonable indication of attitude when seen from directly above the extended center line of the runway In the case of one or more rows of point source lights without satellites or cross bars, any lateral deviation from the approach axis produces a pattern distortion similar to that caused by an error in attitude Although there are no erroneous indications in the patterns of the slope line system, determination of attitude is difficult from any position other than a point near the approach path Any of the systems, not already having good indication of attitude, could be improved by adding horizontal cross bars

Only the slope line system will furnish accurate information as to lateral position with respect to the approach axis regardless of attitude Those systems having cross bars or satellites furnish good information as to lateral position, provided the attitude of the airplane is level. The remaining systems without satellites or cross bars can furnish ambiguous information because the effect of an error in lateral position may be cancelled by the effect of an error in attitude Except in the case of the slope line lights, those systems of two or more rows must resort to colors to differentiate between rows or groups of rows

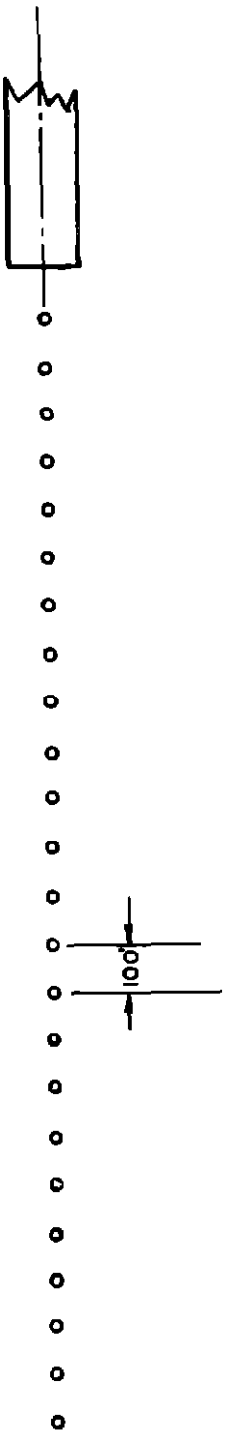


Fig. 1 Diagram of Single Line Approach Light System

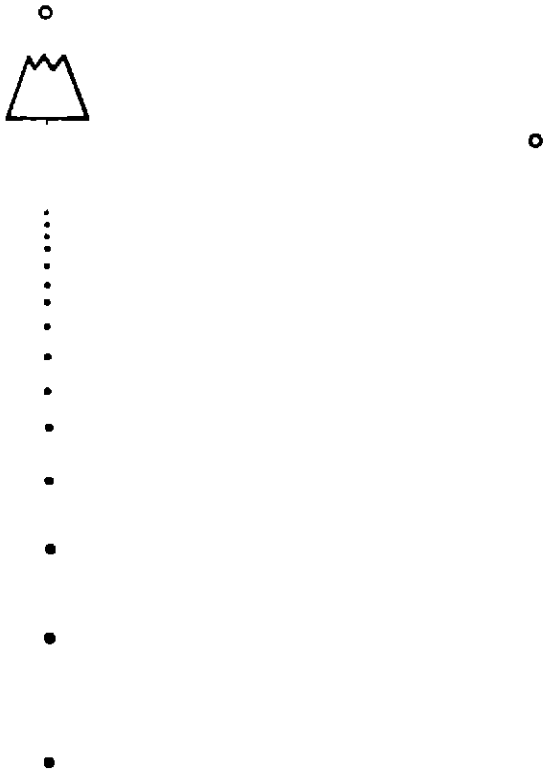


Fig. 2 Situation 1

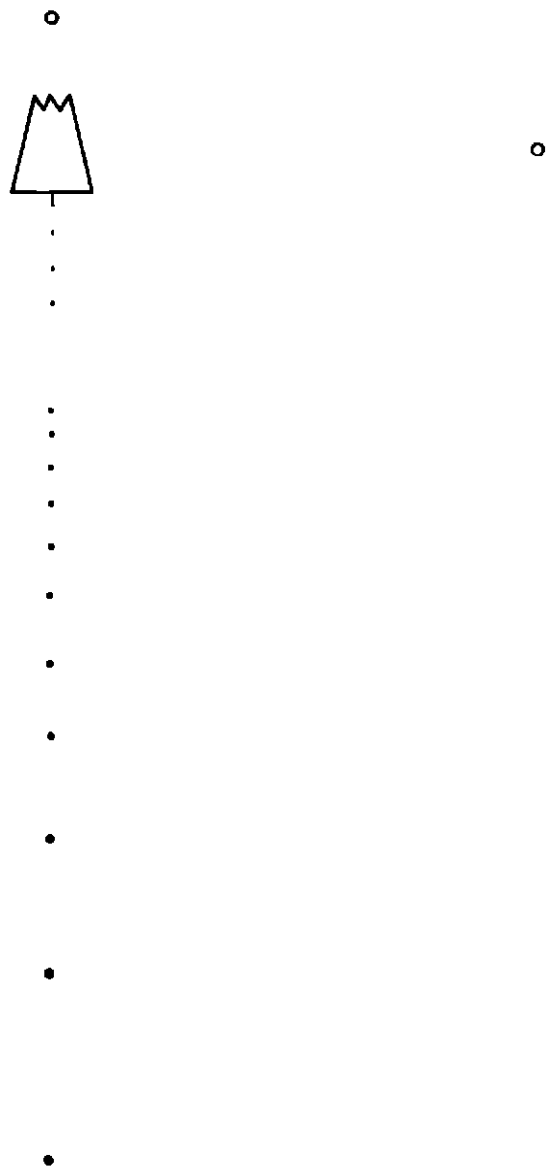


Fig. 3 Situation 2

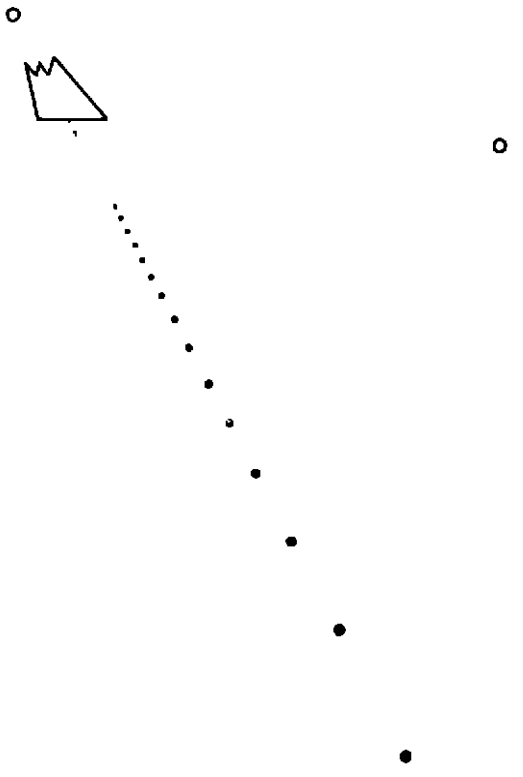
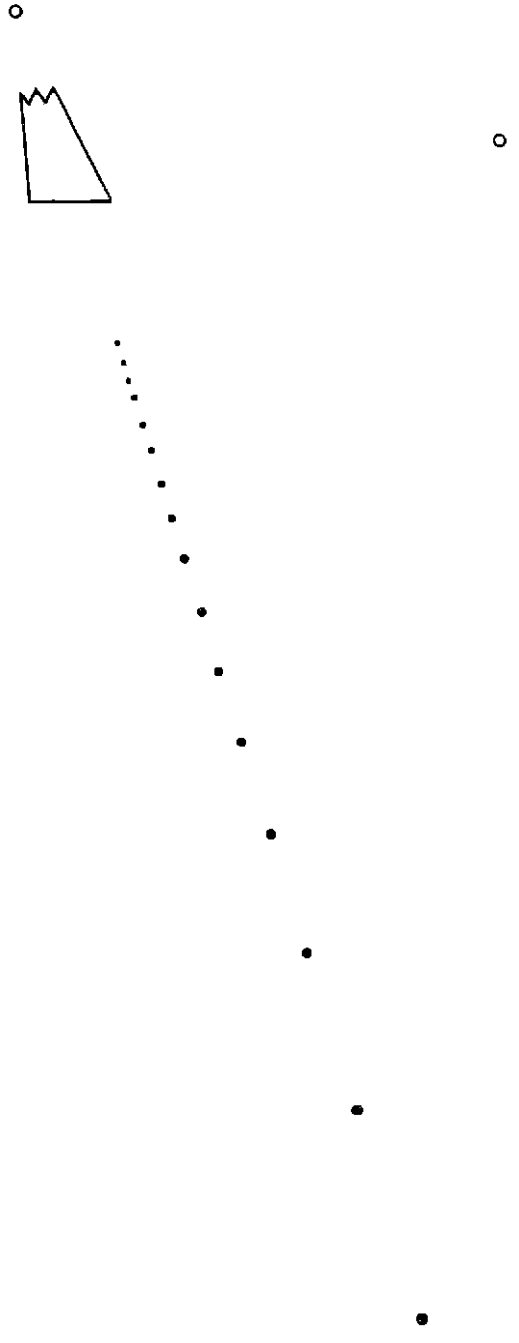


Fig. 4 Situation 3



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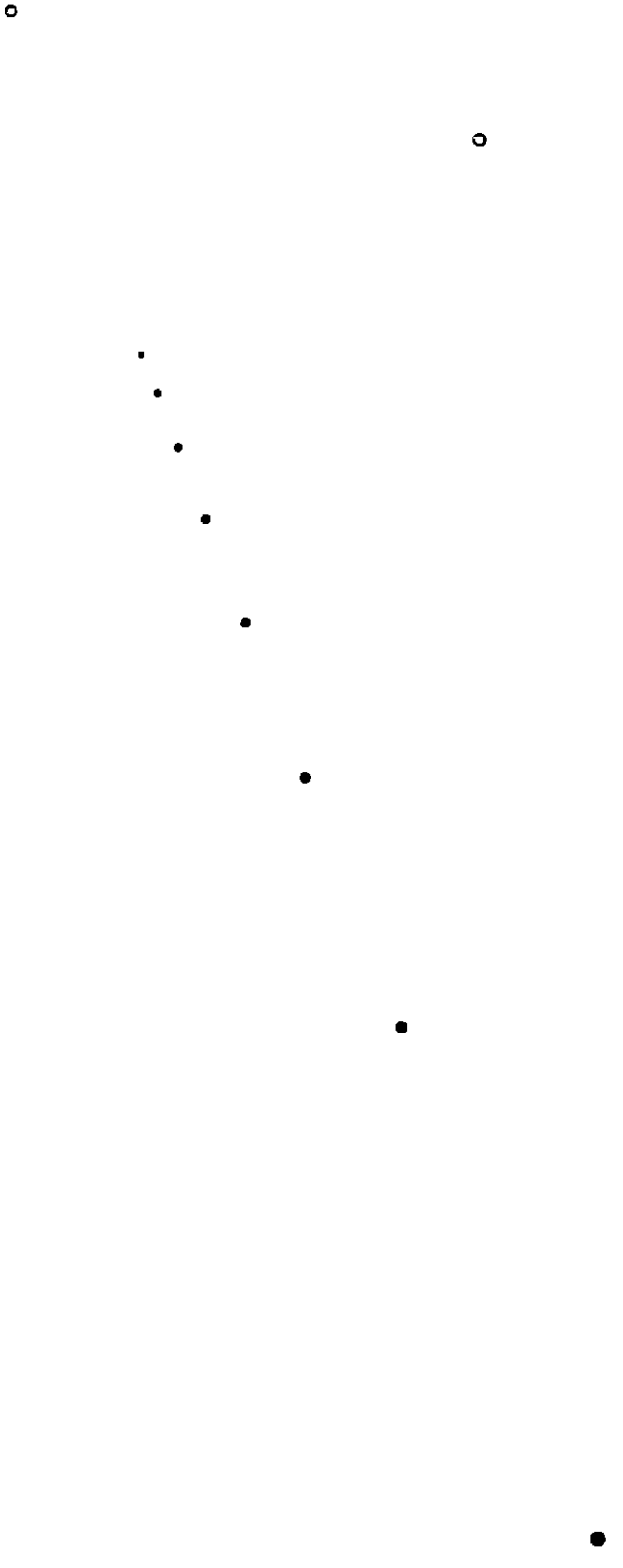

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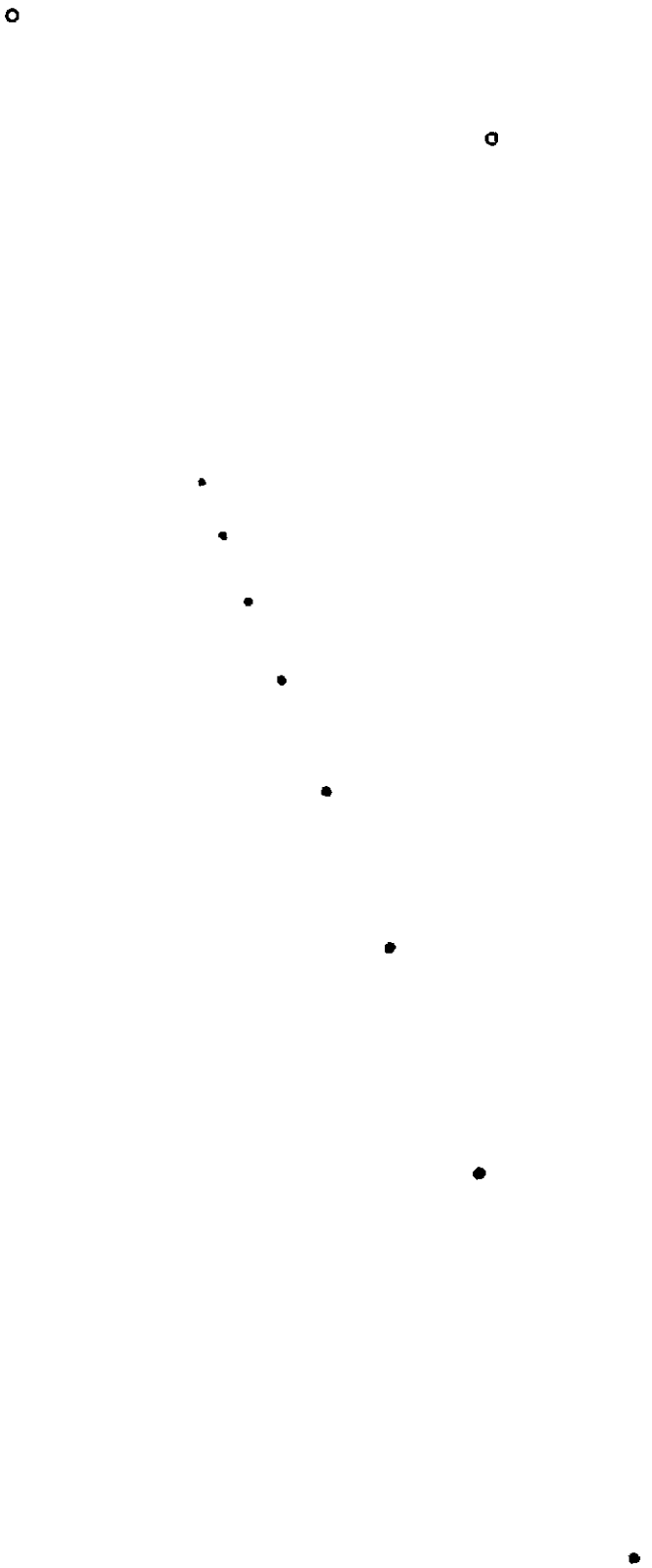

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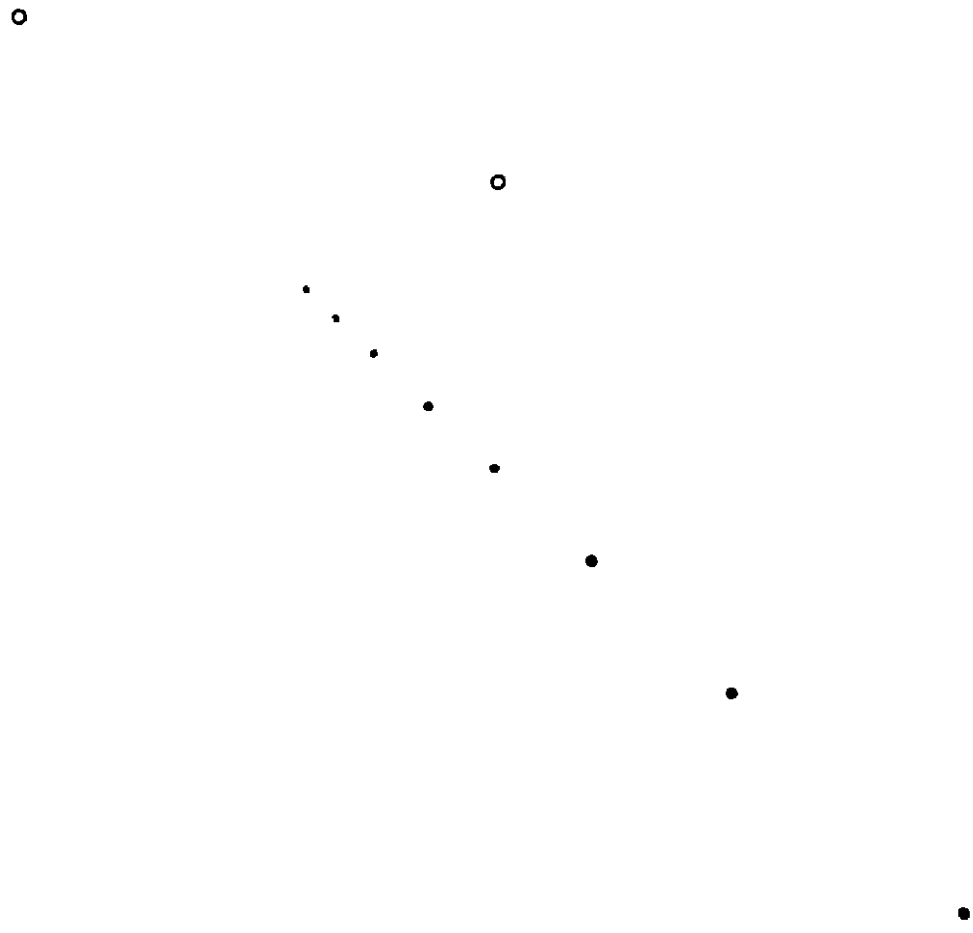


Fig 8 Situation 7

Fig 9 Situation 8

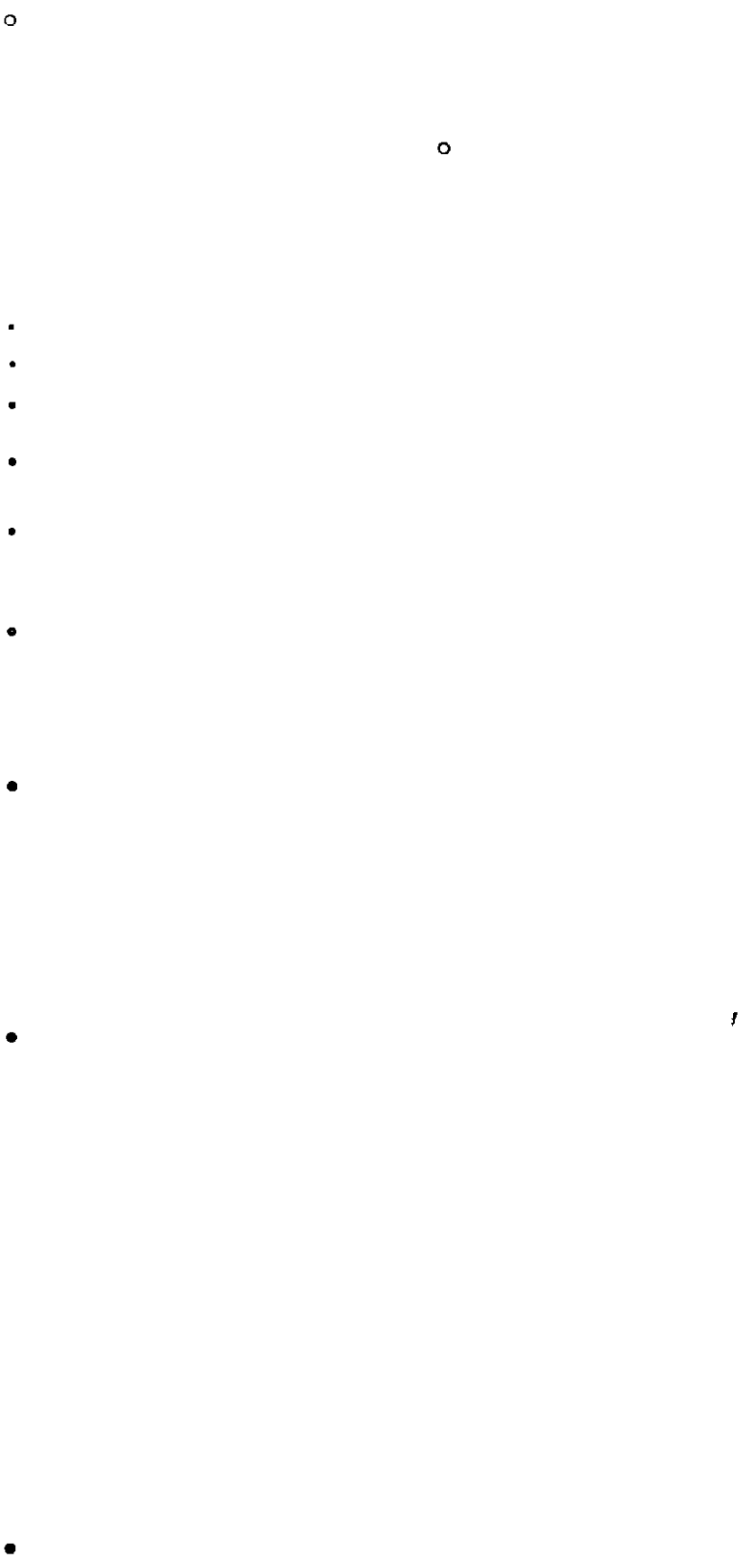


Fig 10 Situation 9

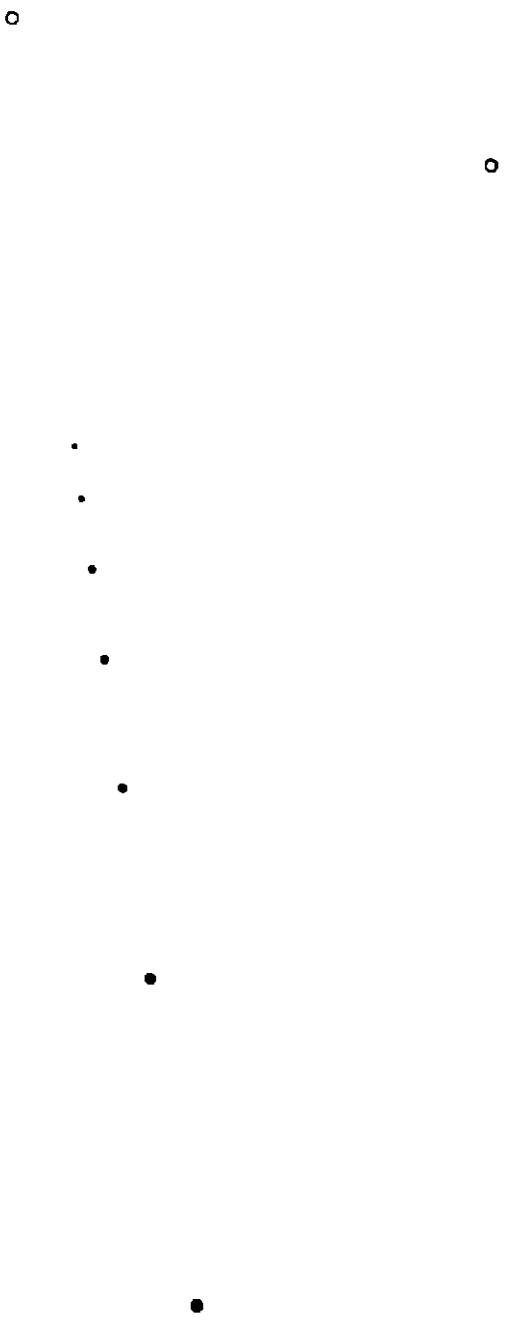


Fig 11 Situation 10

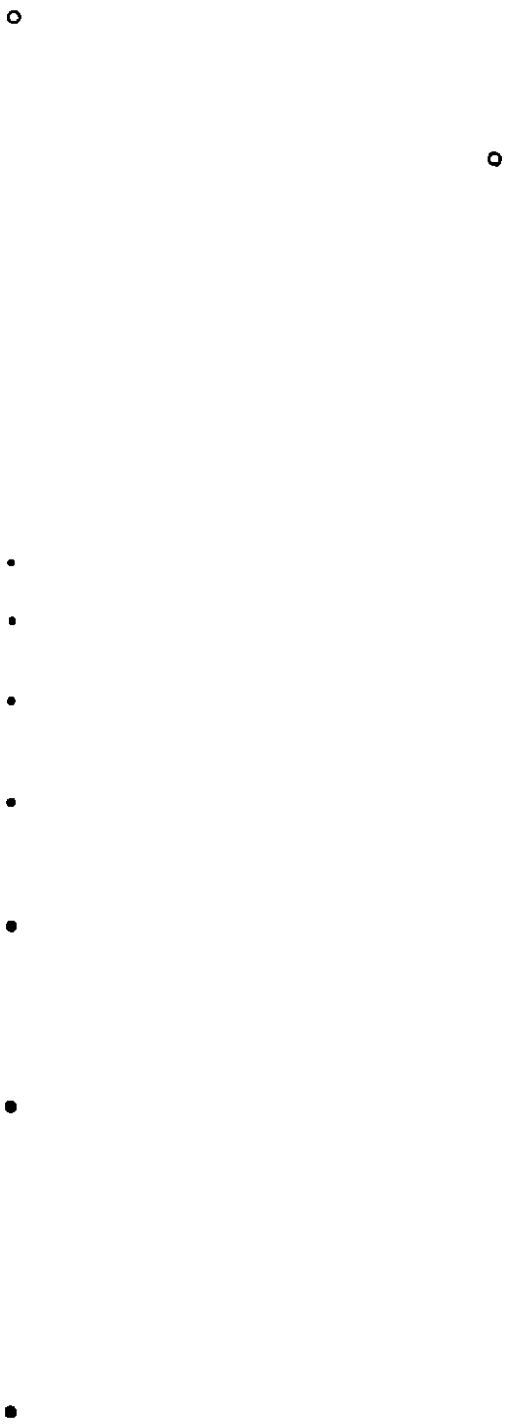


Fig 12 Situation 11

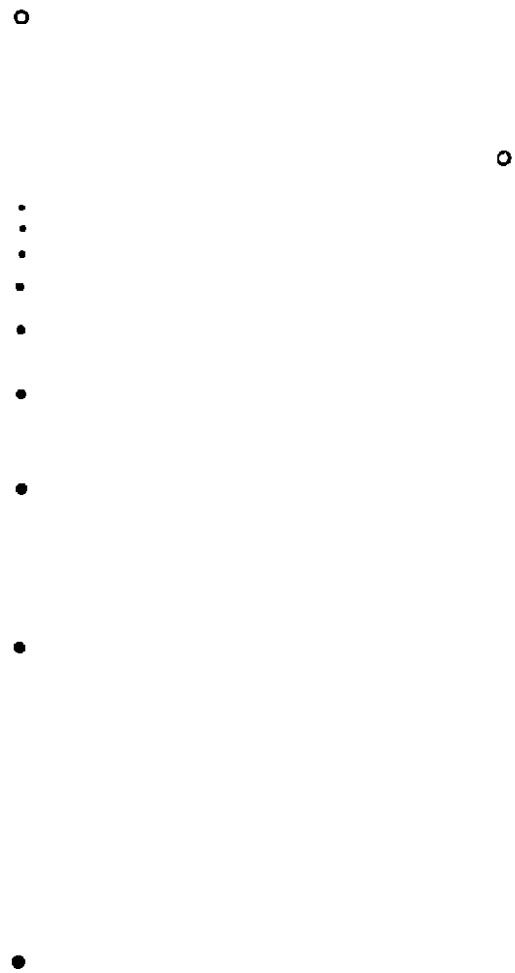


Fig 13 Situation 12

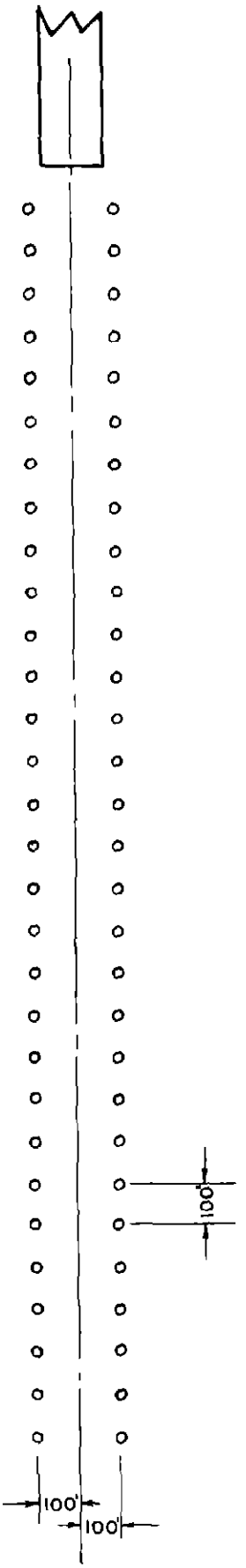


Fig 14 Diagram of Double Row Approach Light System

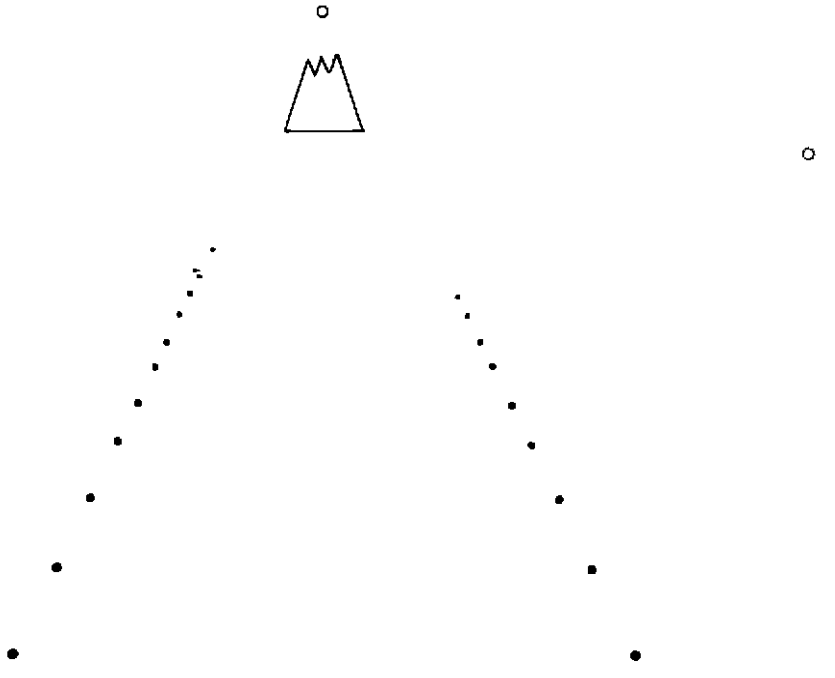
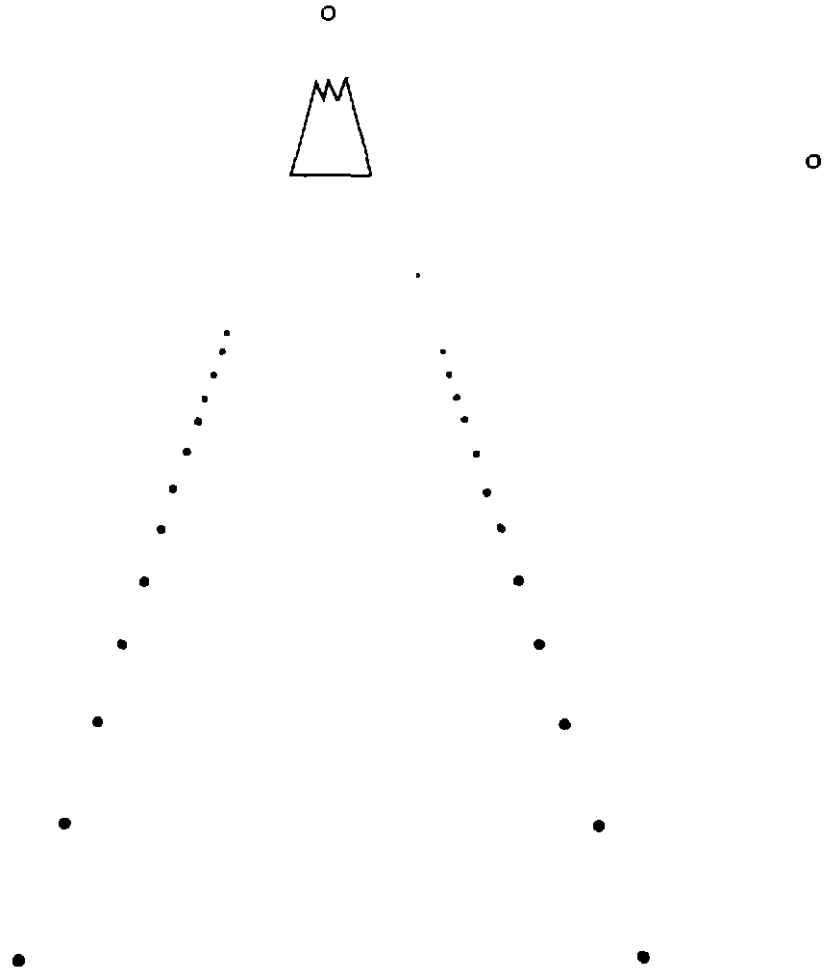


Fig 15 Situation 1



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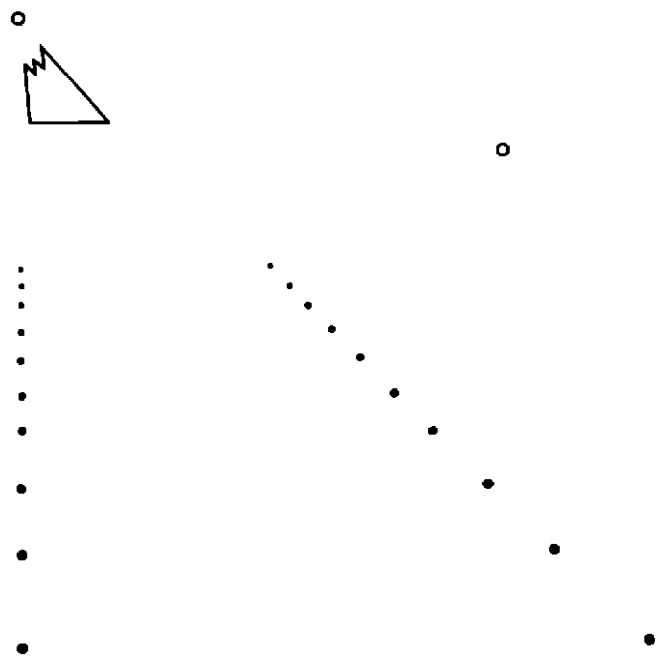

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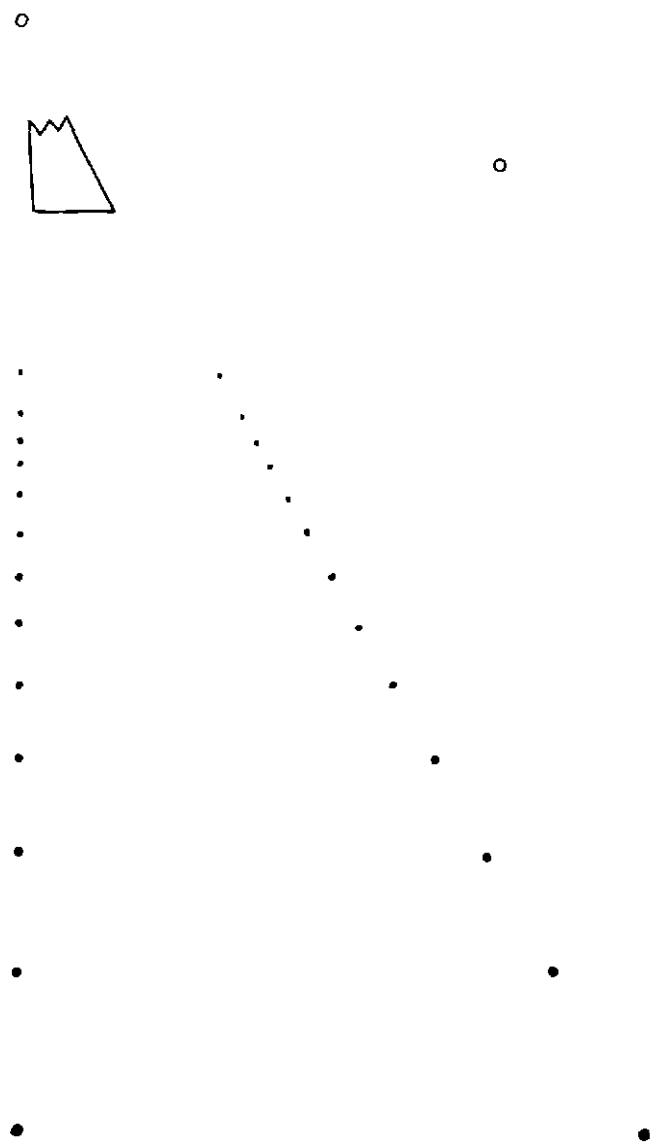
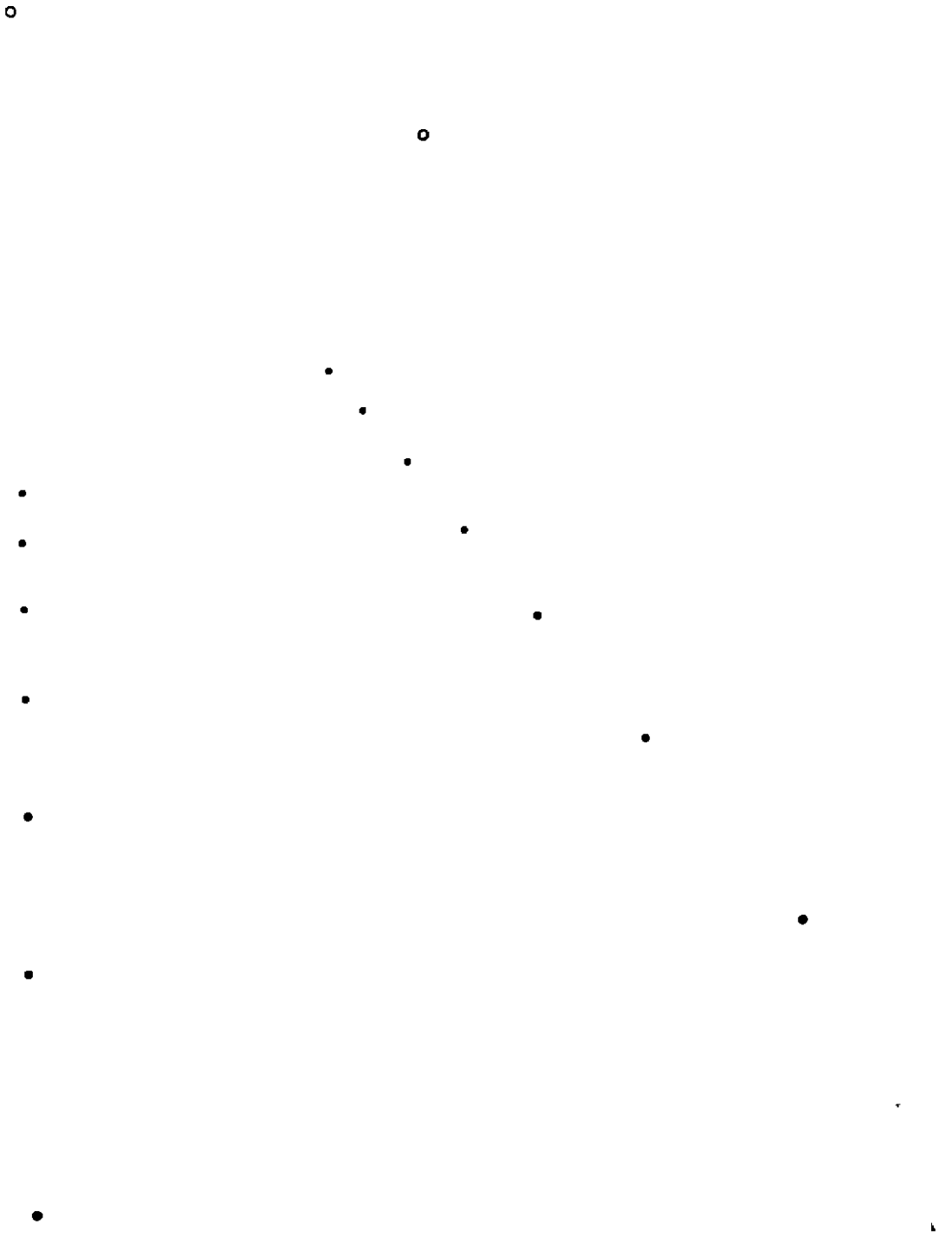


Fig 18 Situation 4

Fig 19 Situation 5



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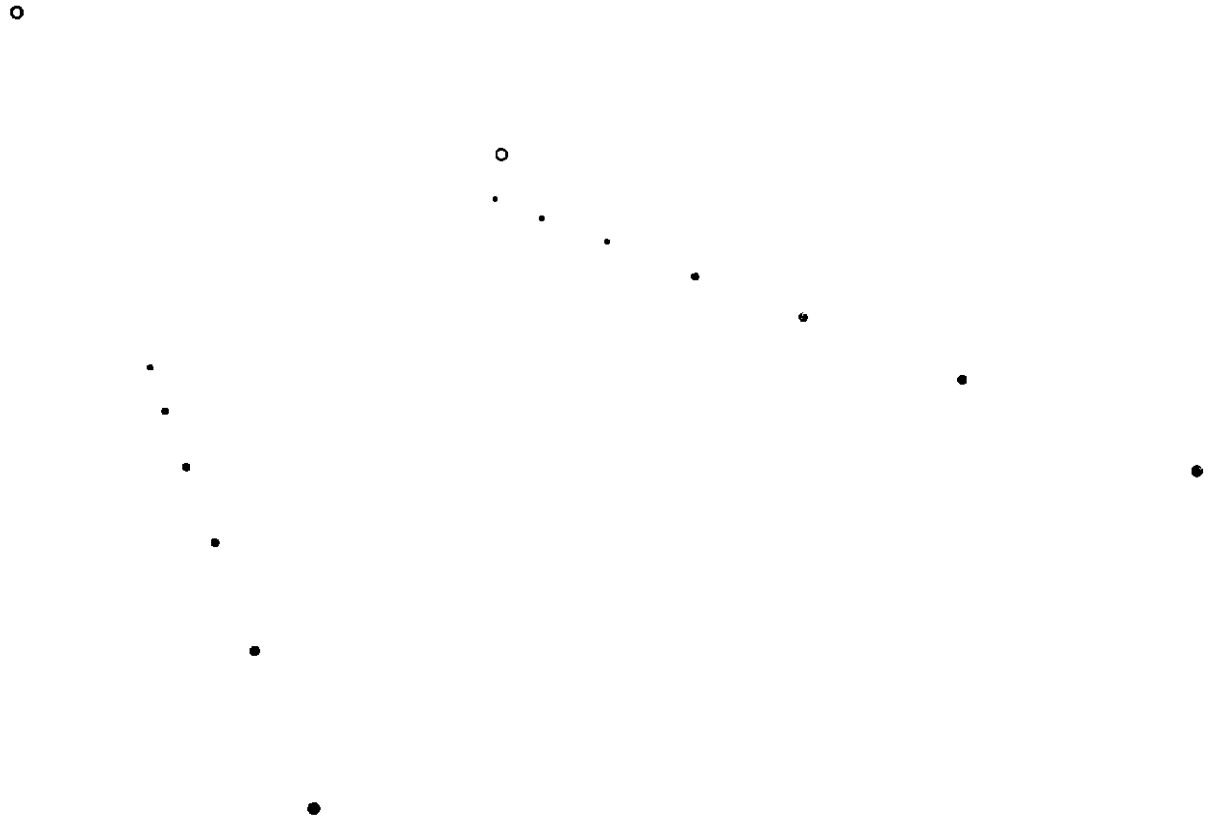

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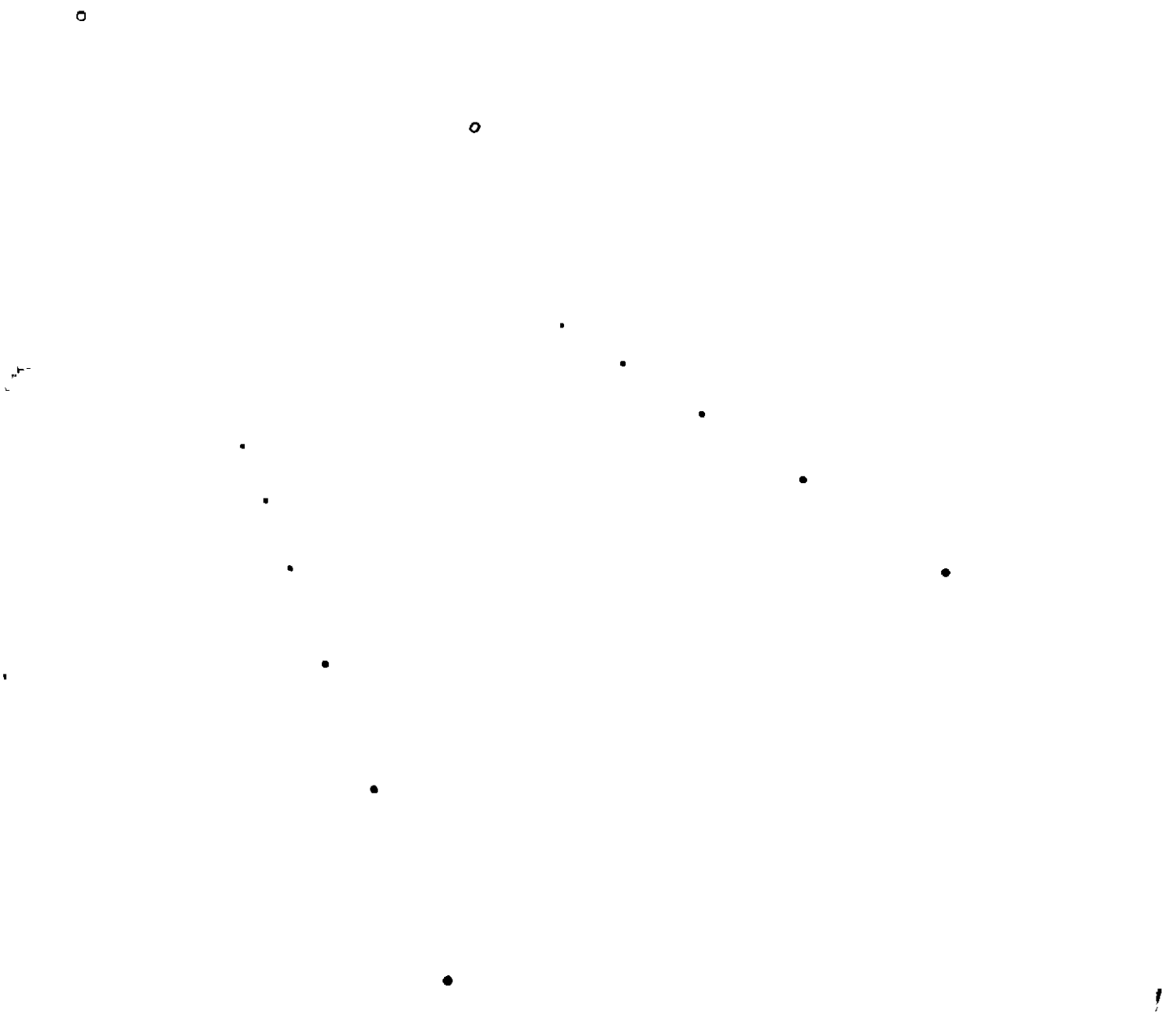

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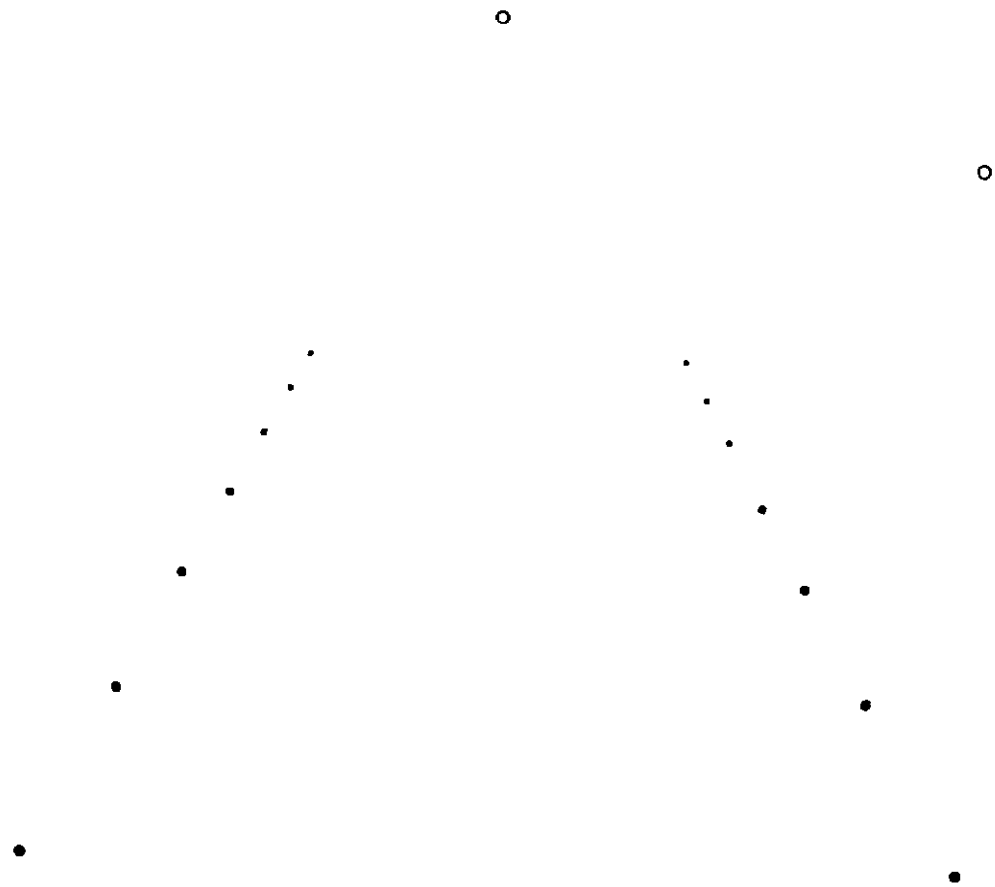

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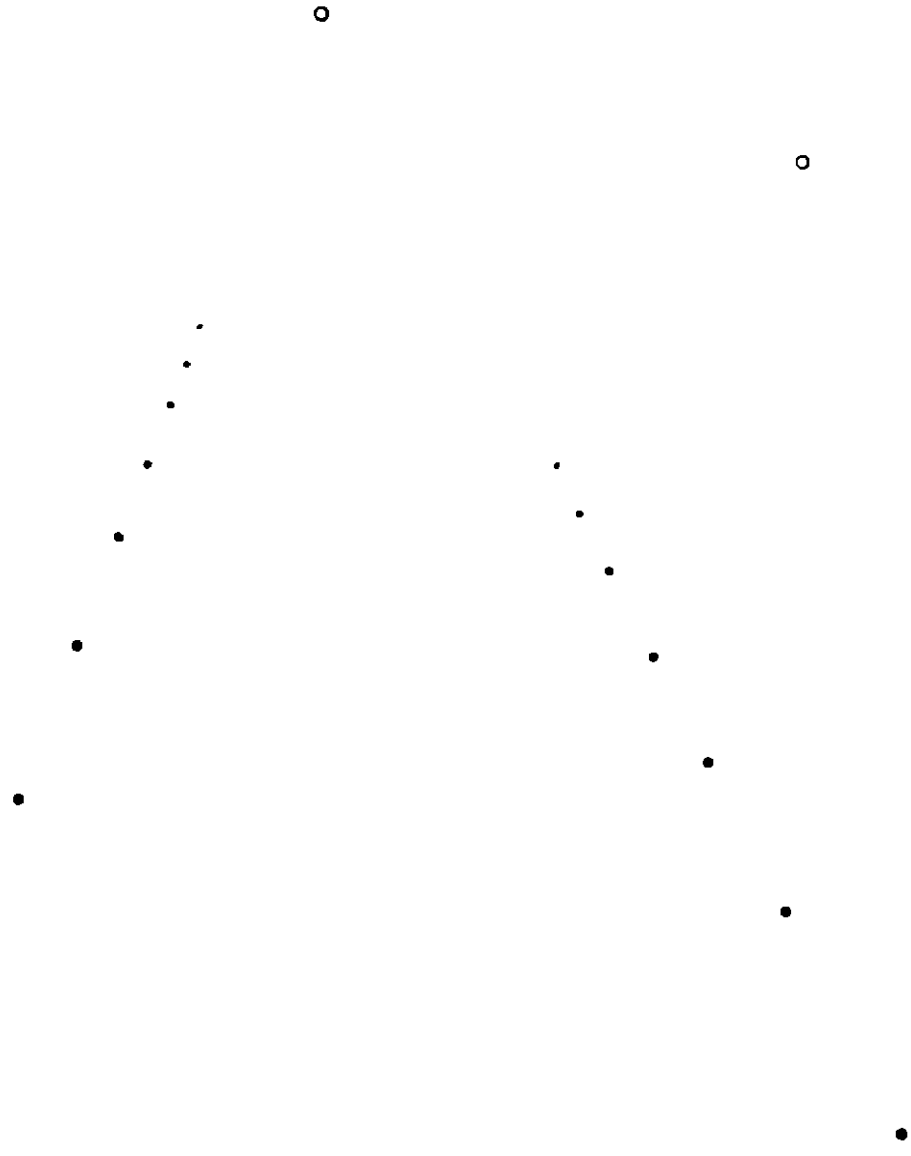

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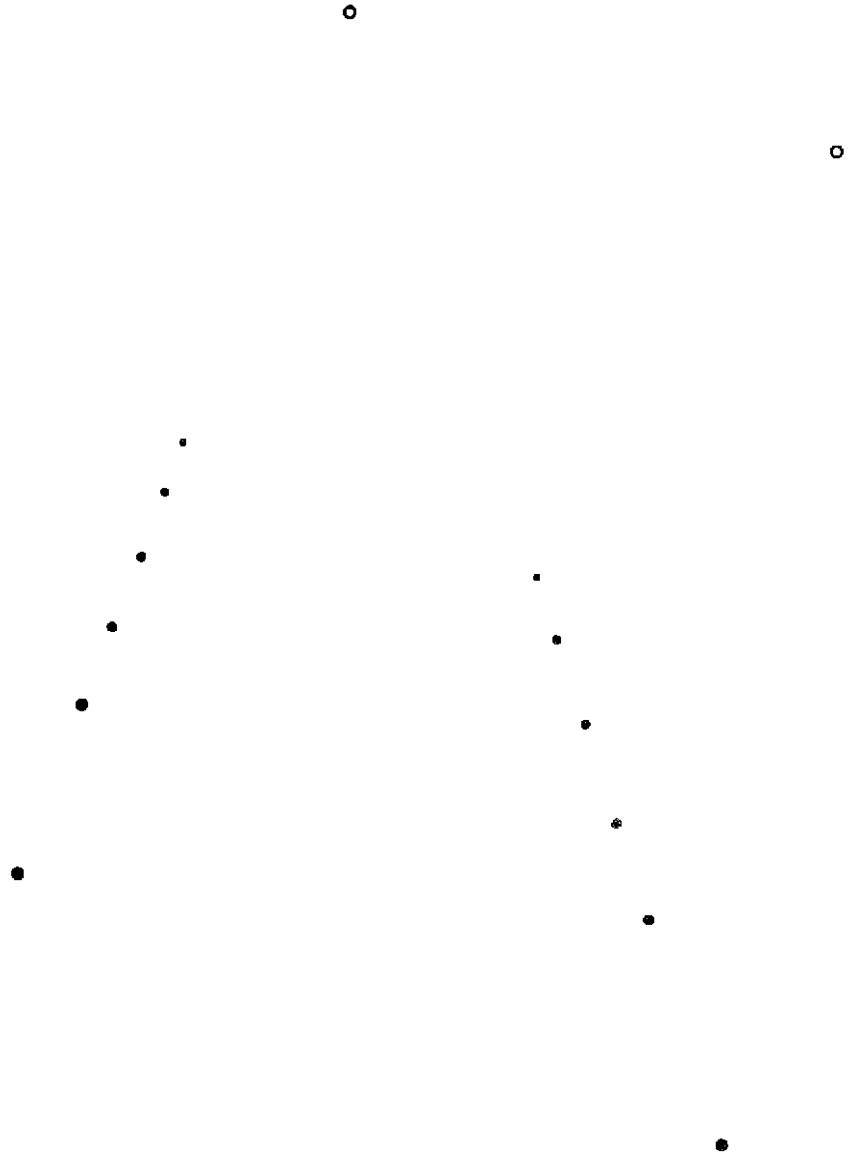

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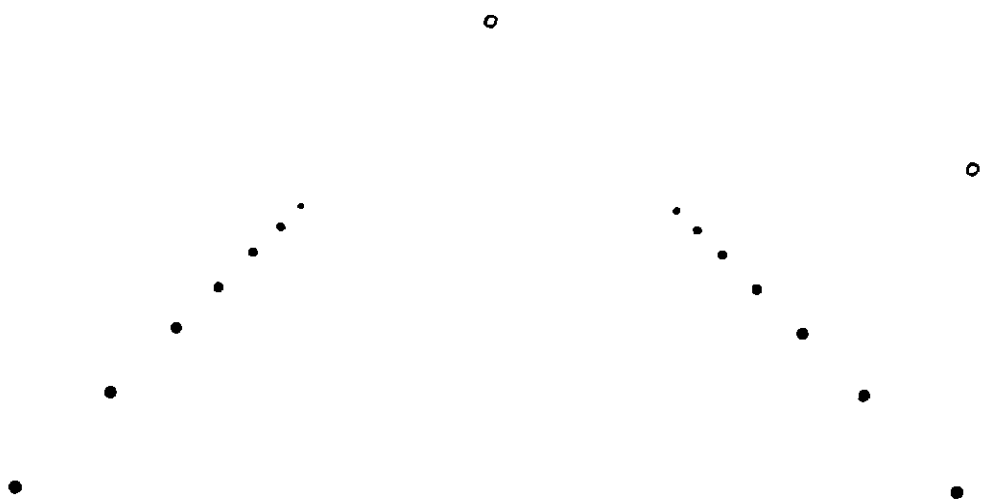

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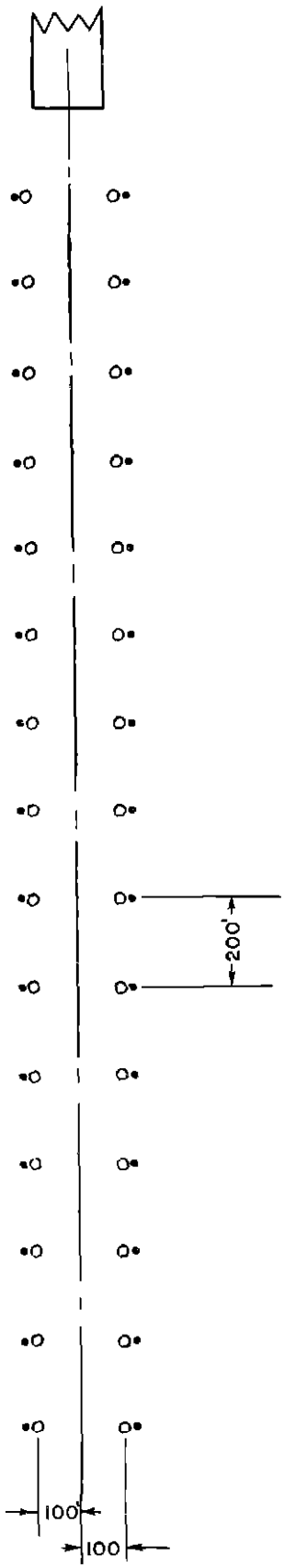


Fig 27 Diagram of Double Row Approach Light System with Satellites

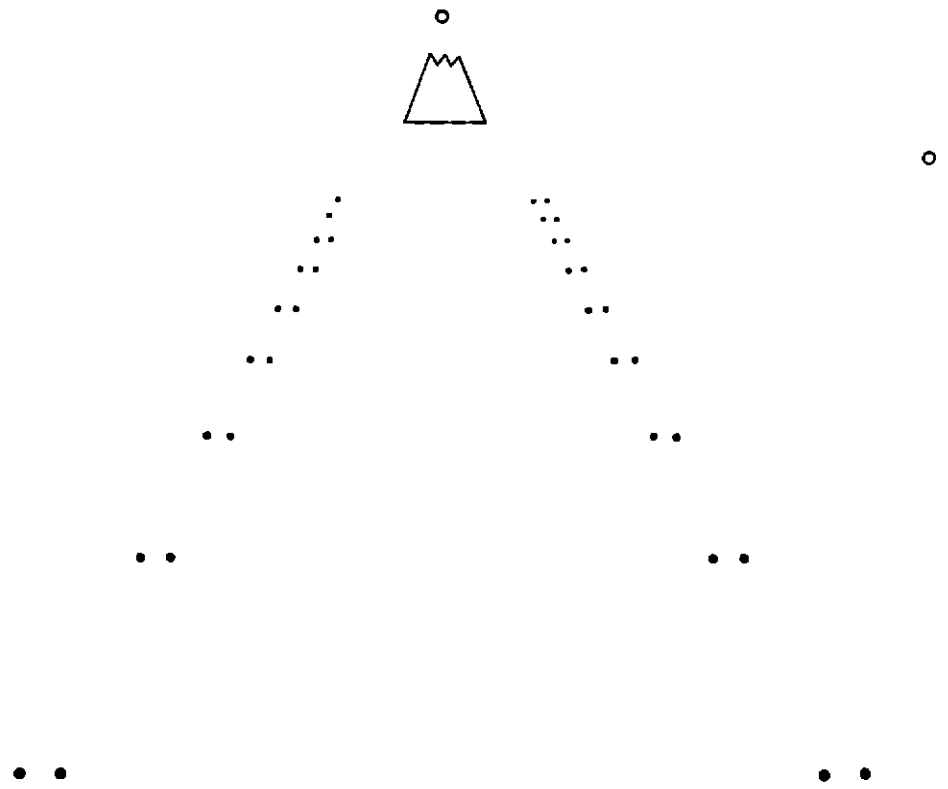


Fig. 28 Situation 1

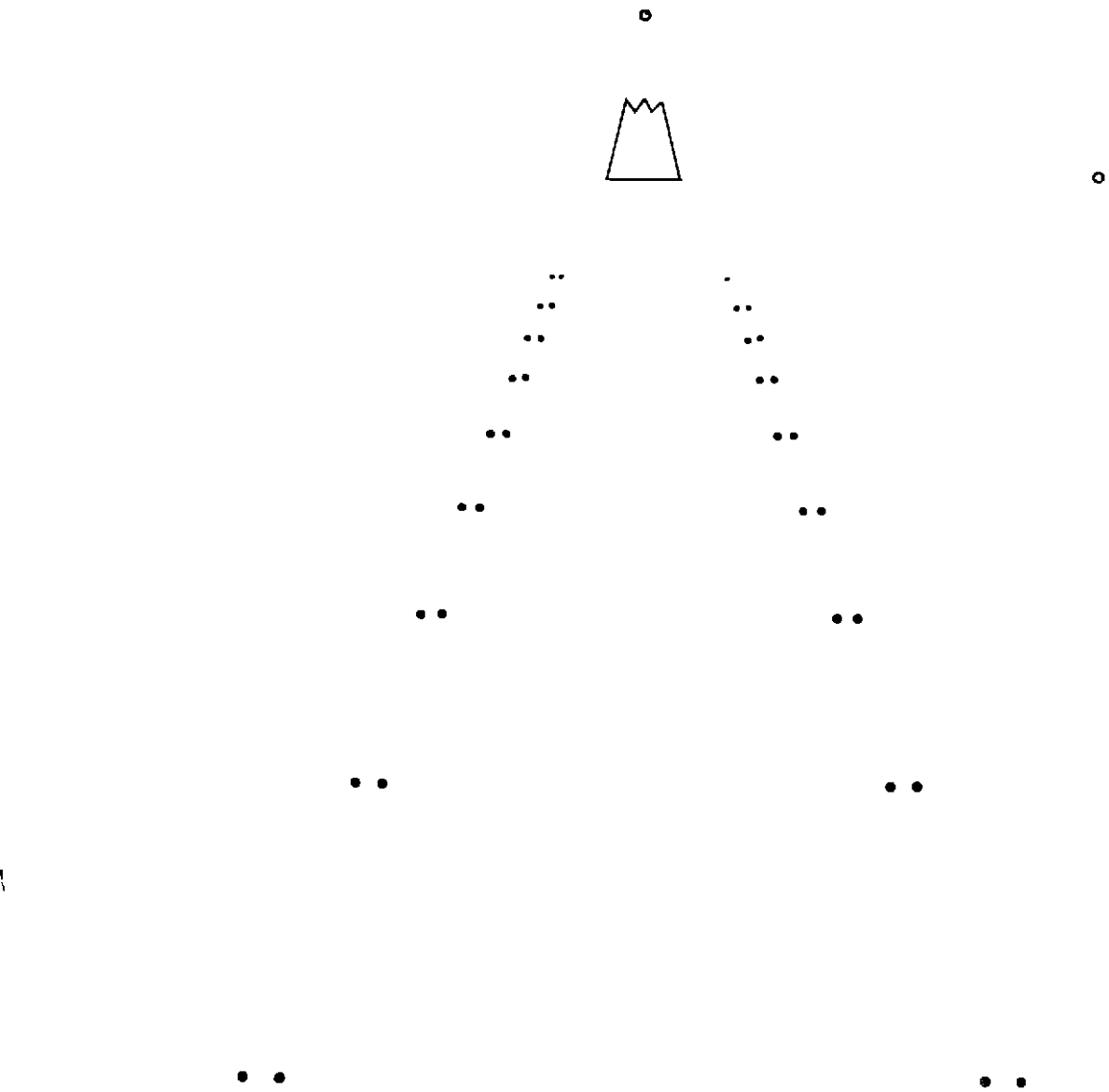
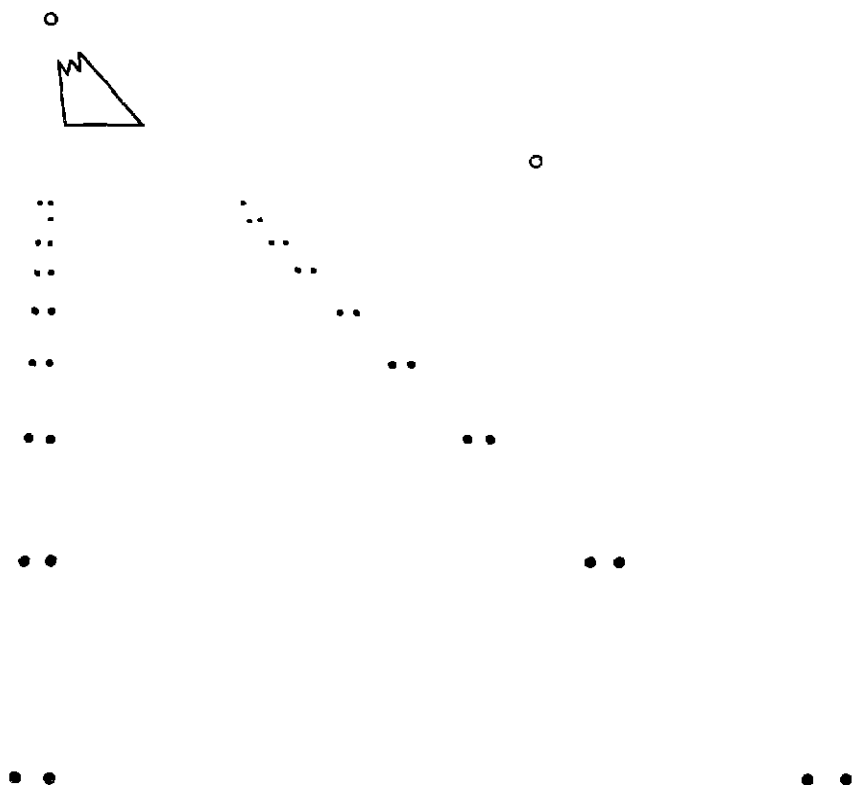


Fig. 29 Situation 2



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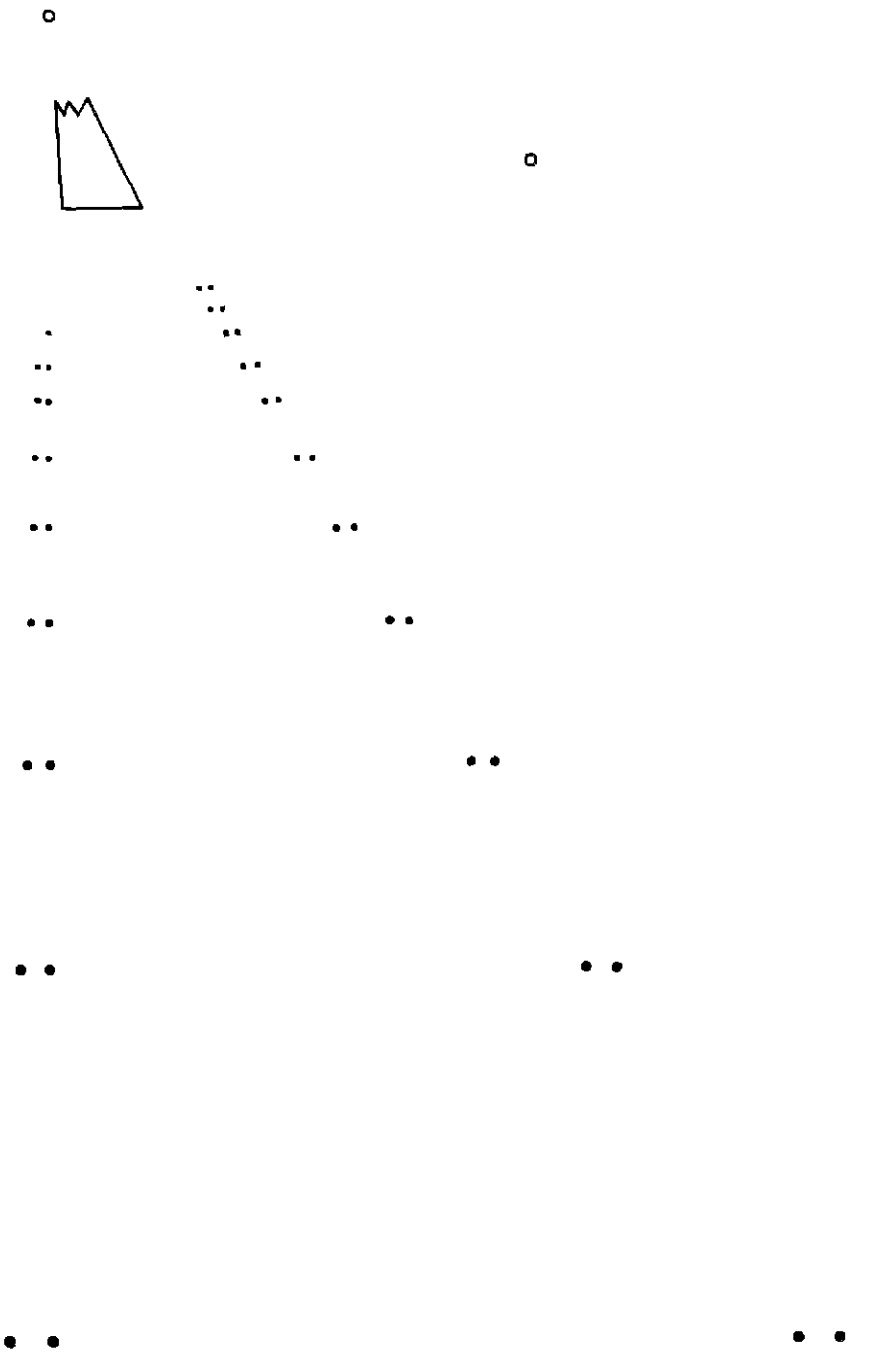

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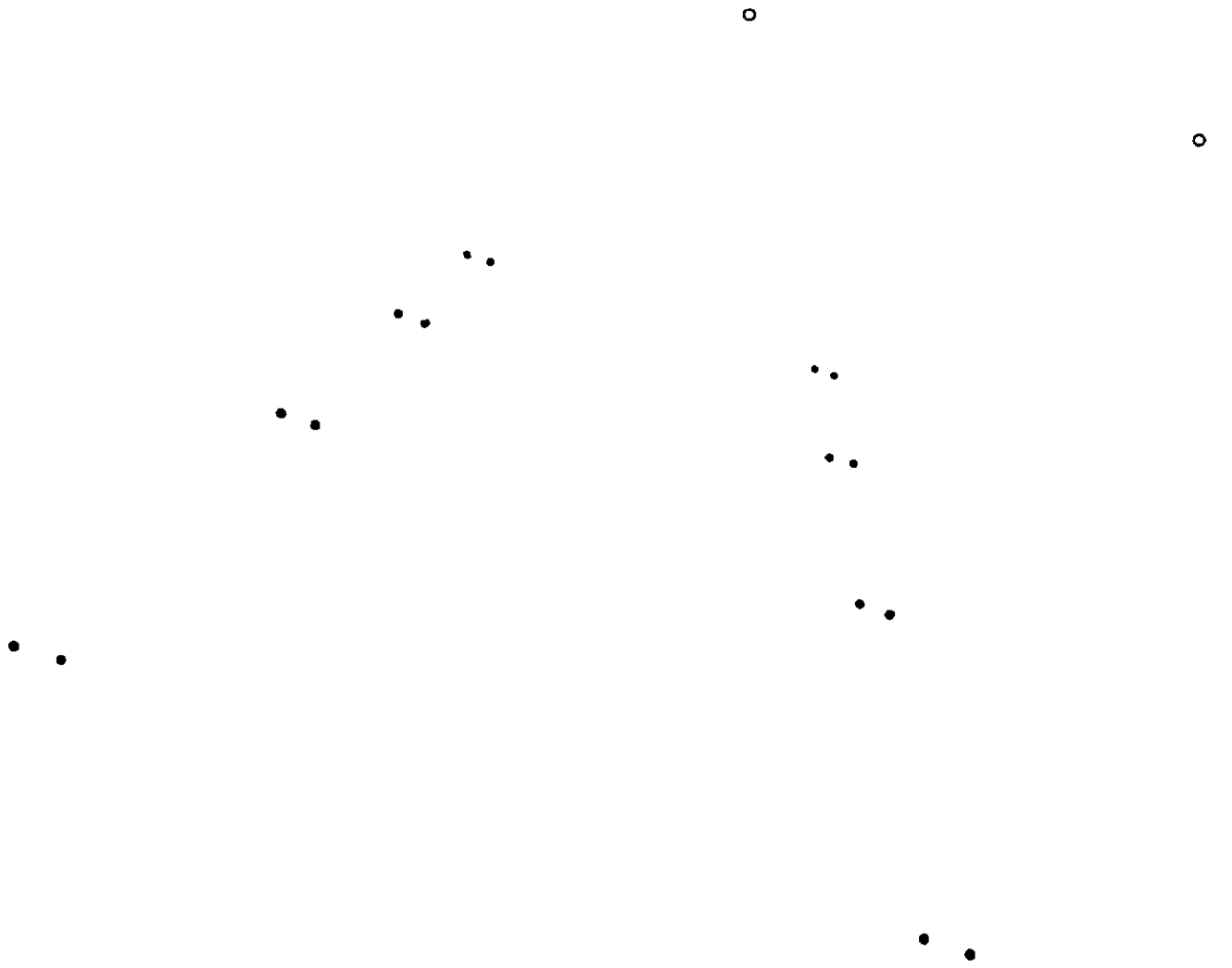


Fig 32 Situation 5

Fig 33 Situation 6

Fig 34 Situation 7

Fig. 35 Situation 8

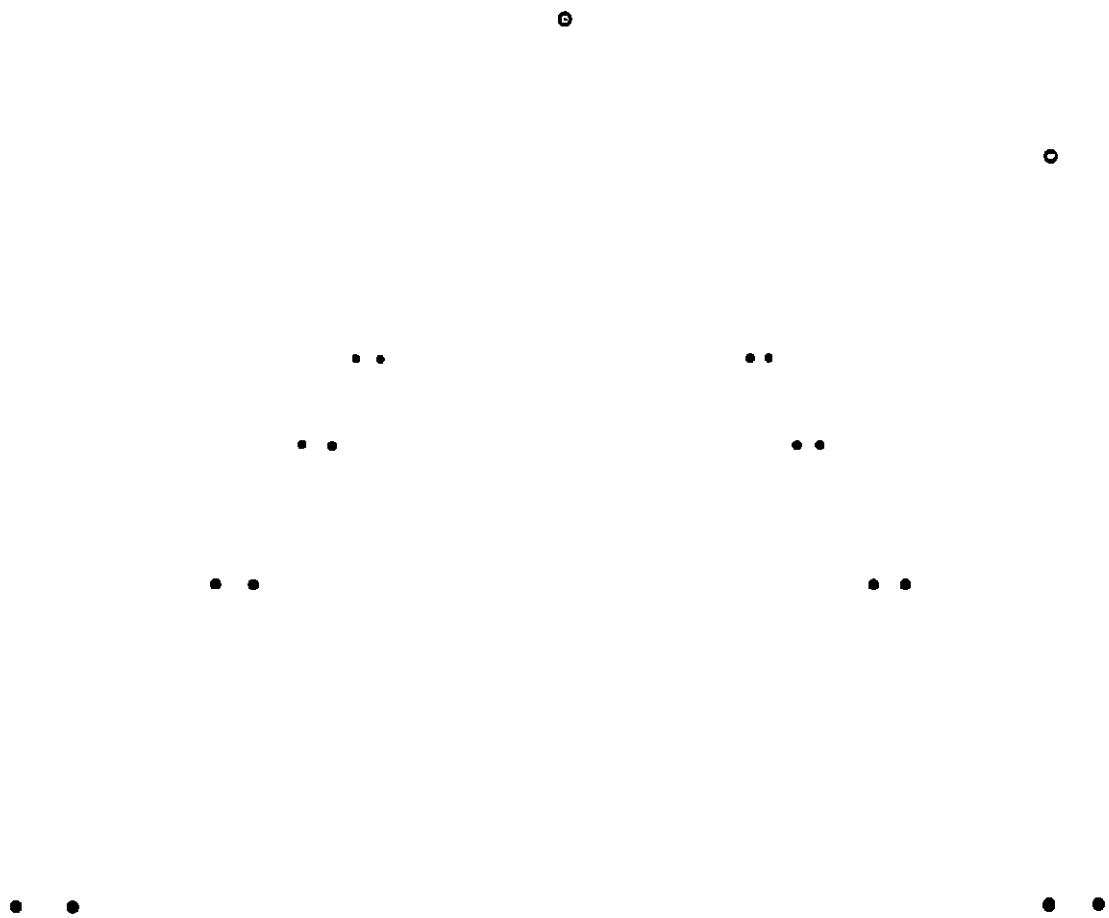
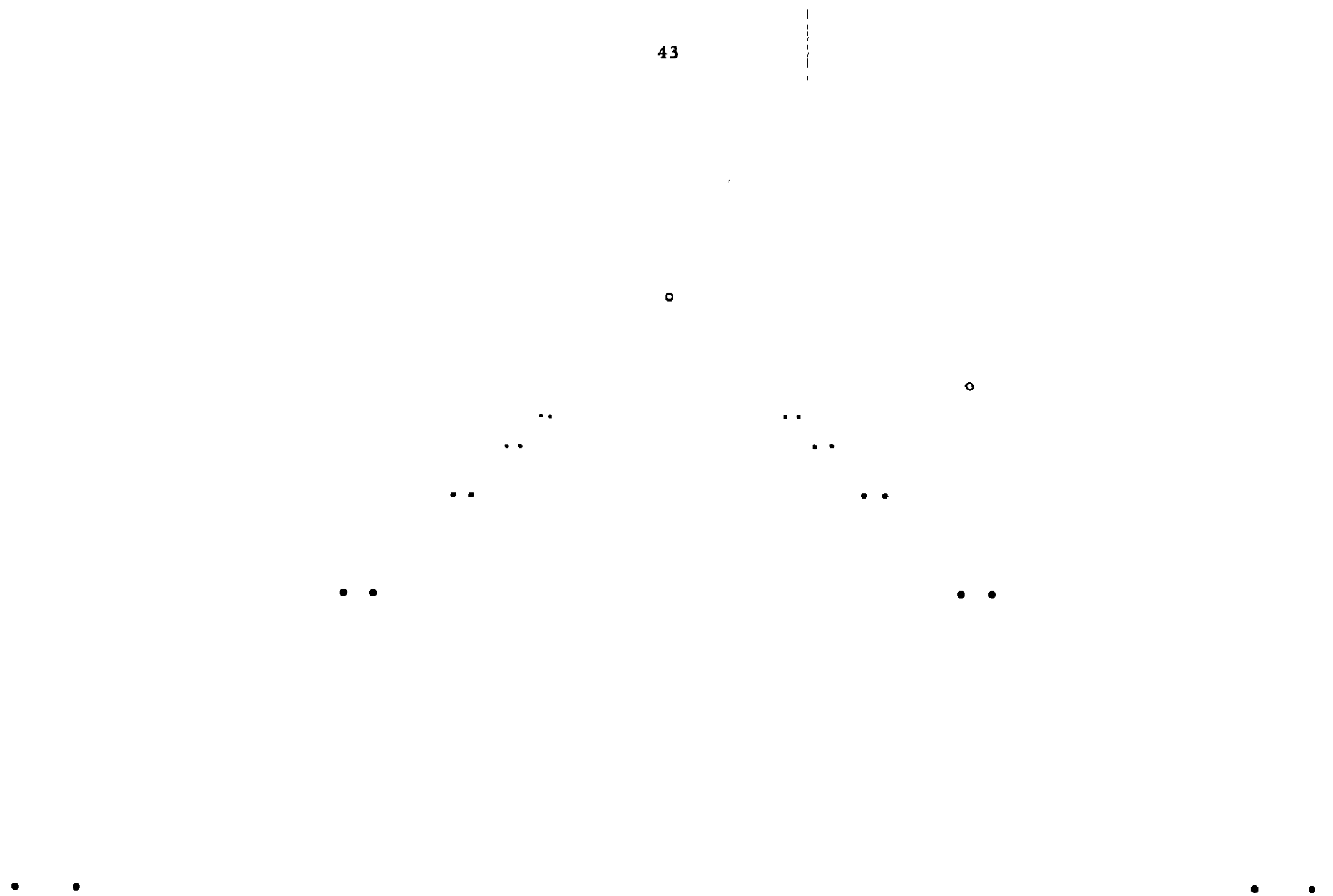


Fig 36 Situation 9

Fig 37 Situation 10

Fig 38 Situation 11



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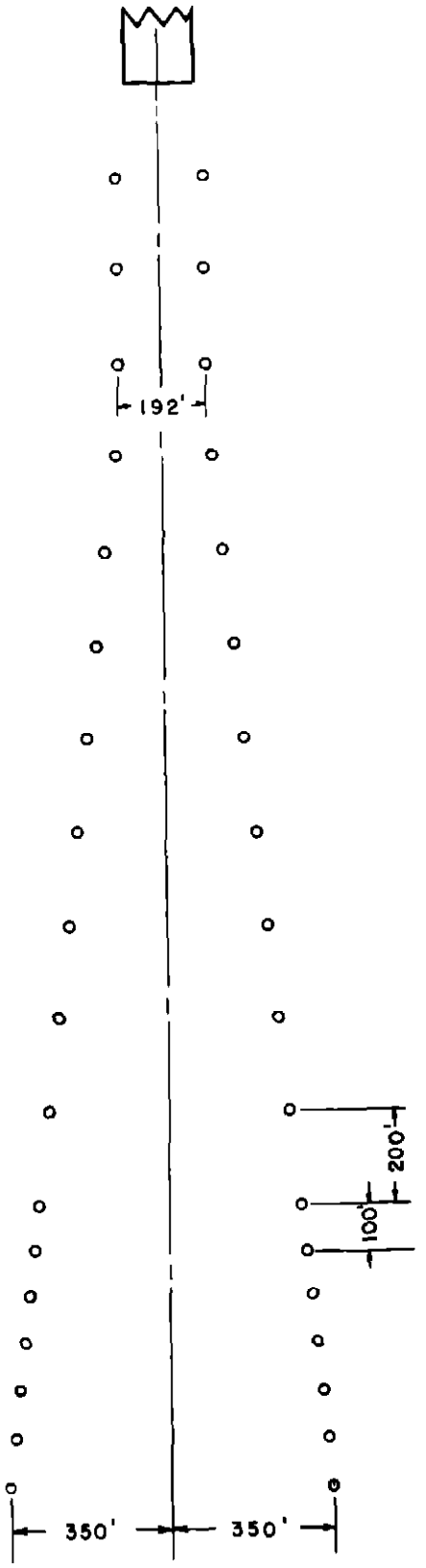


Fig. 40 Funnel Approach Light System

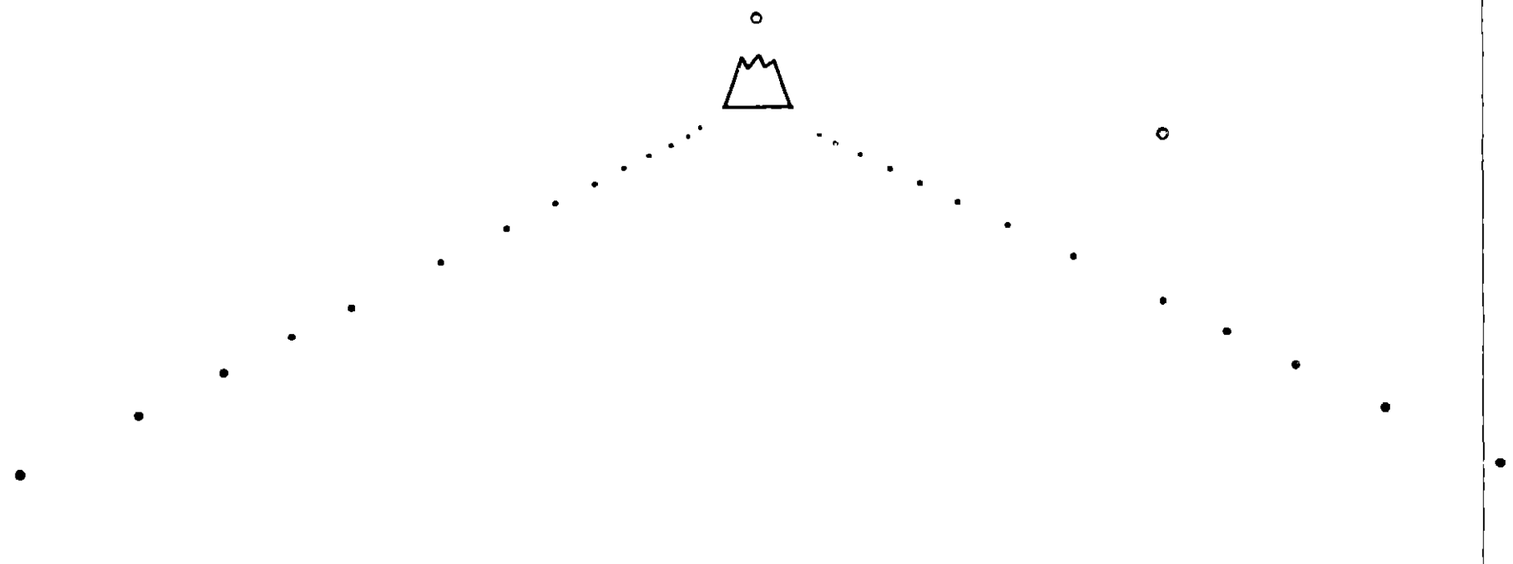
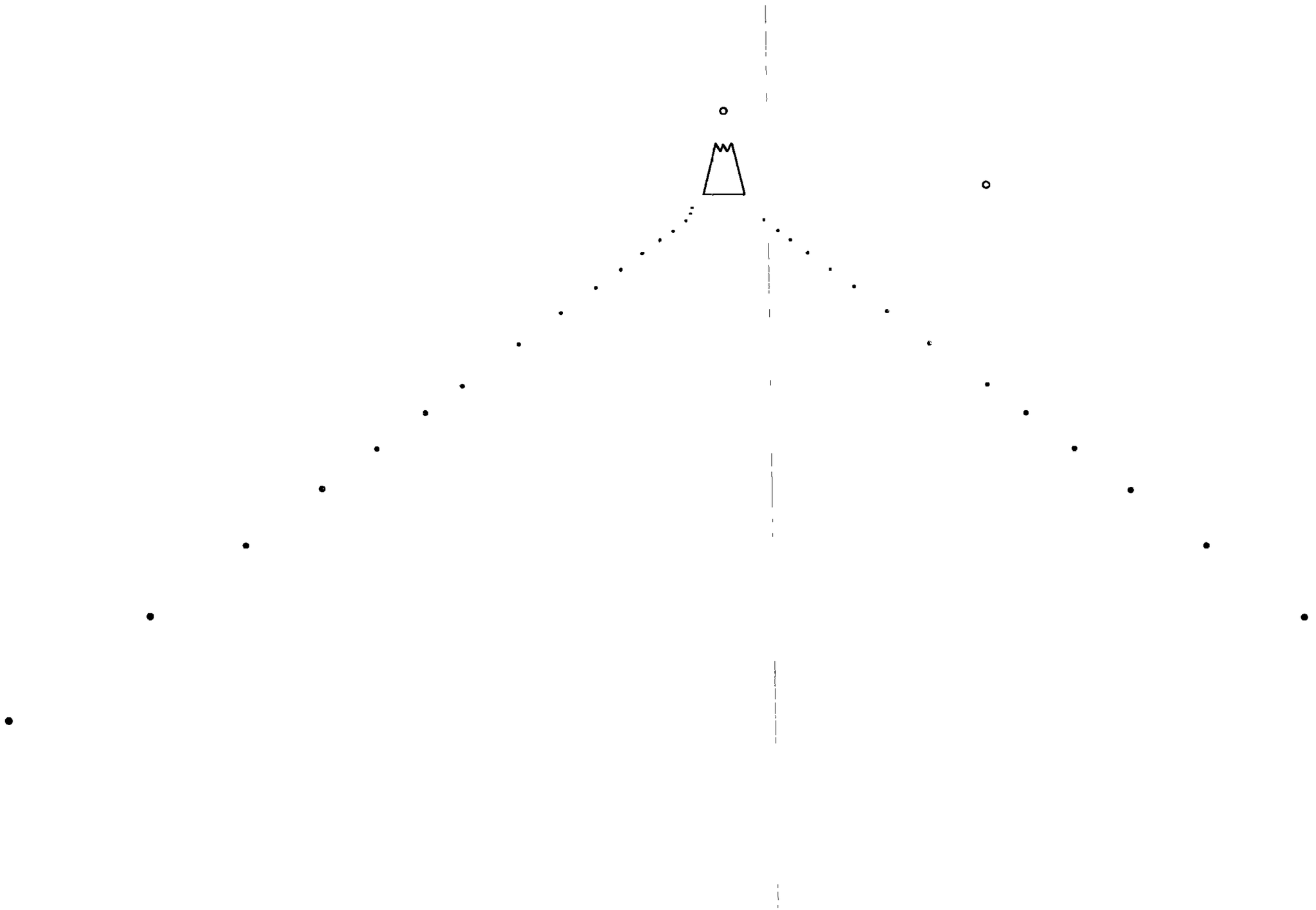


Fig. 41 Situation 1



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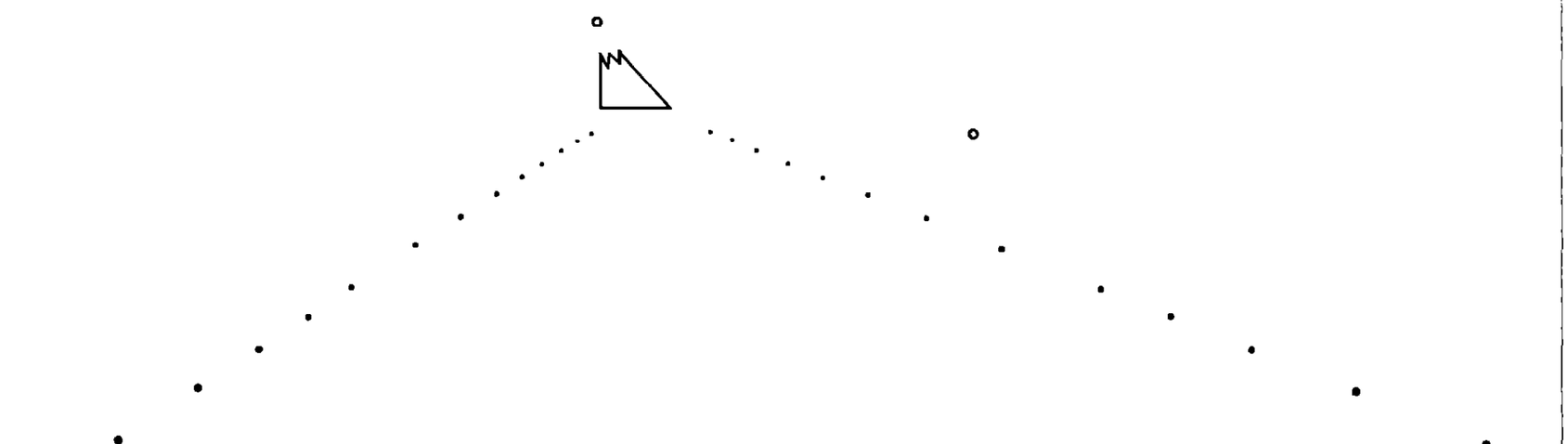

Fig. 43 Situation 3

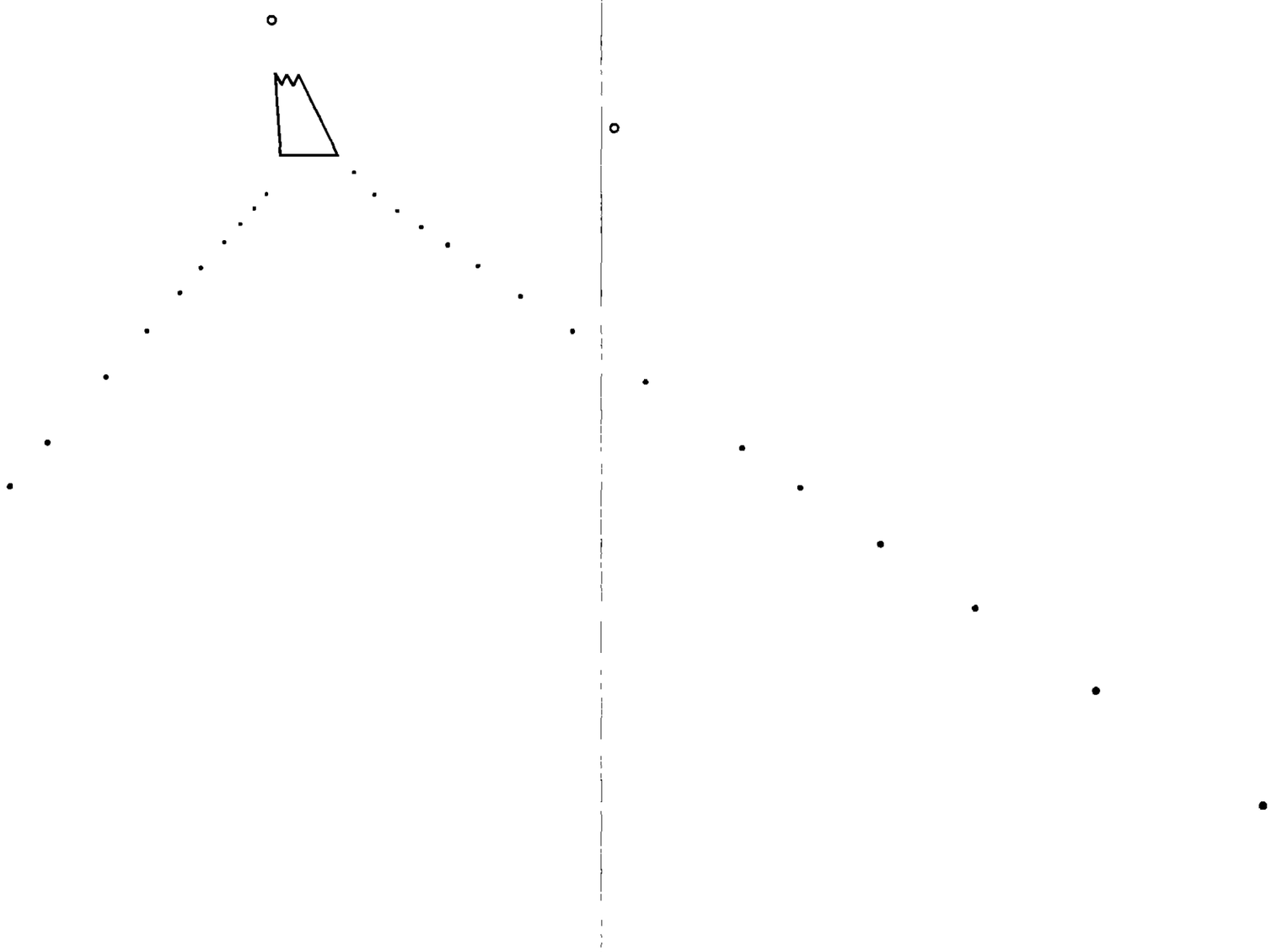

Fig 44 Situation 4

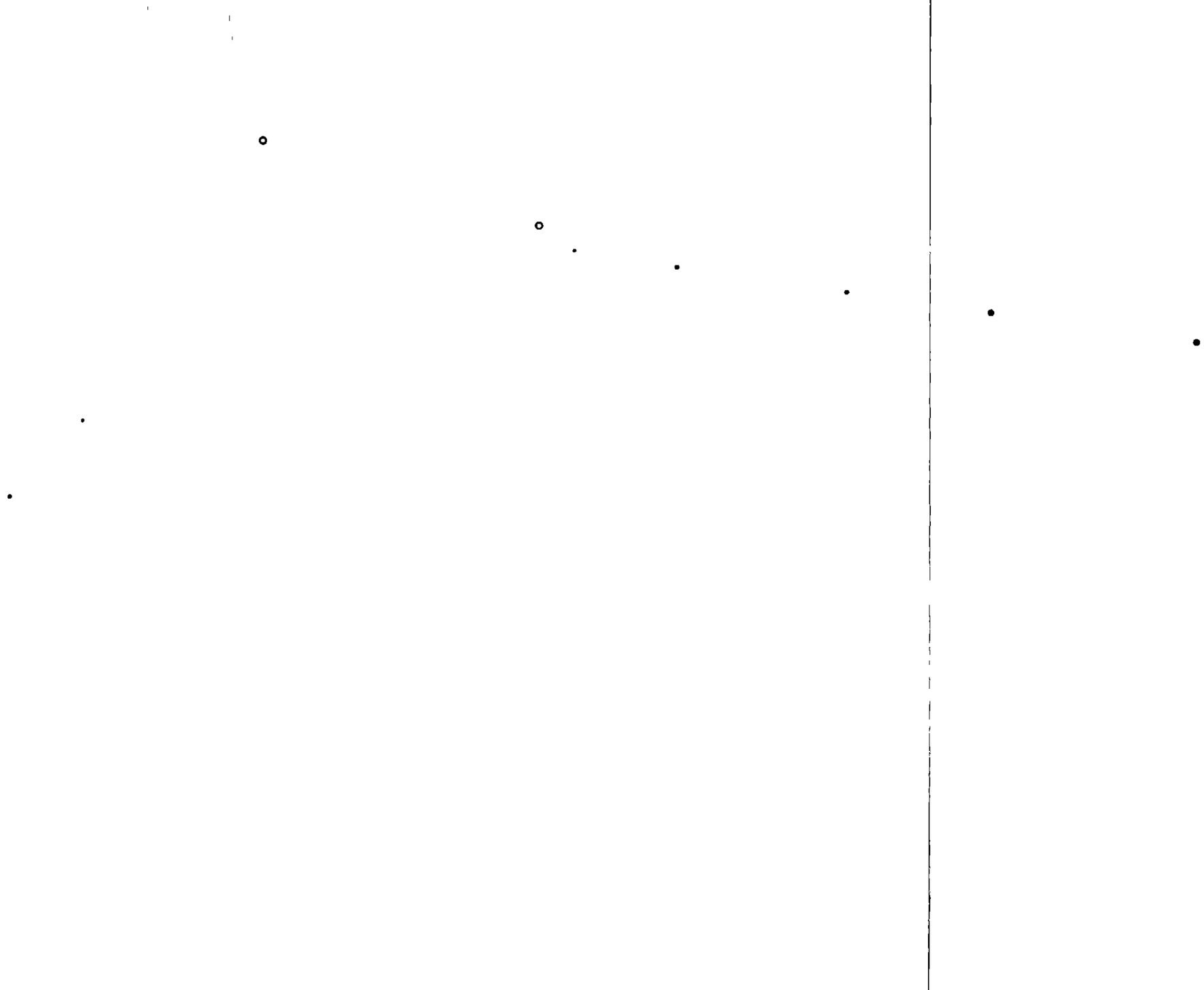

Fig 45 Situation 5

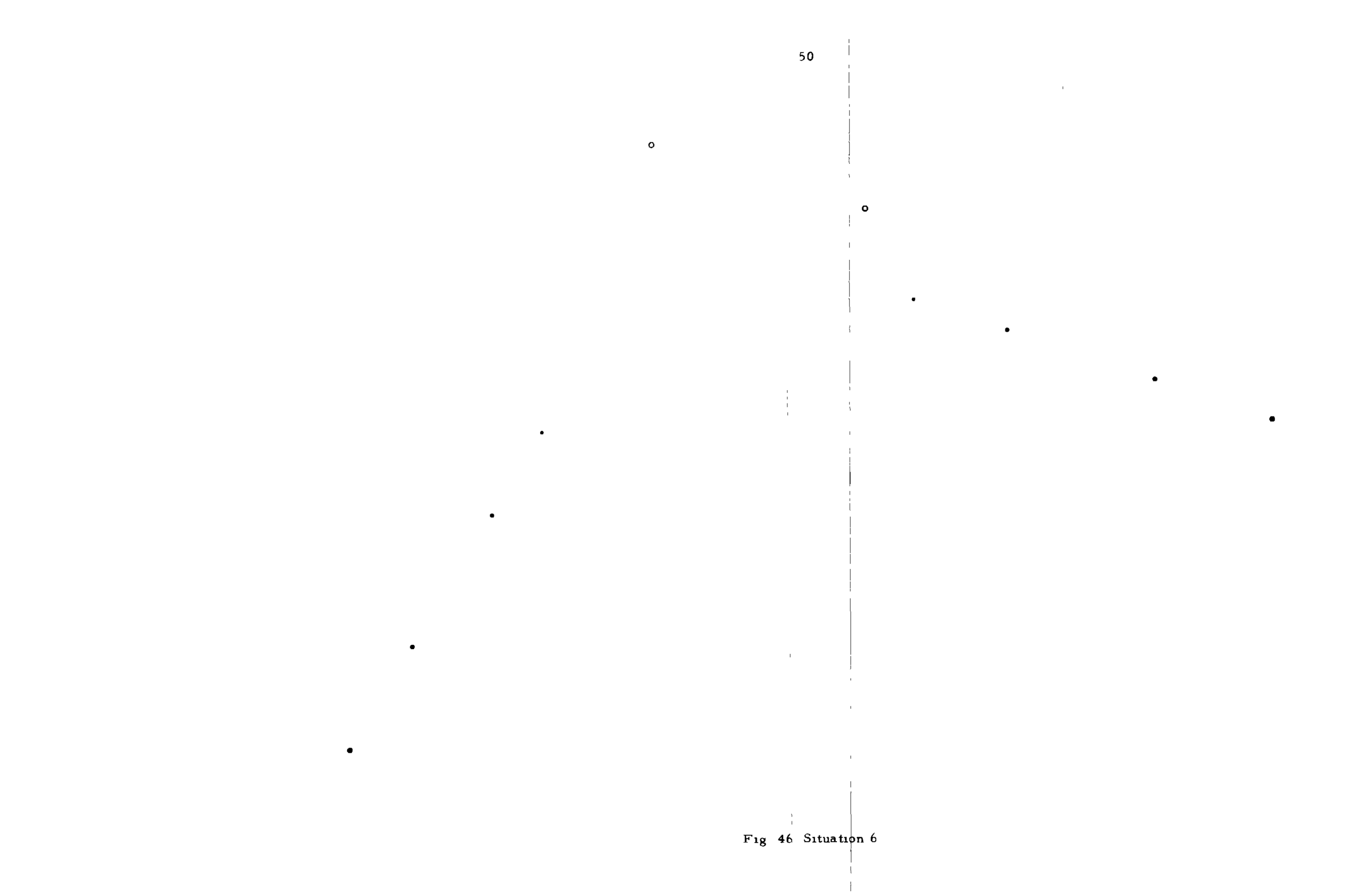

Fig 46 Situation 6

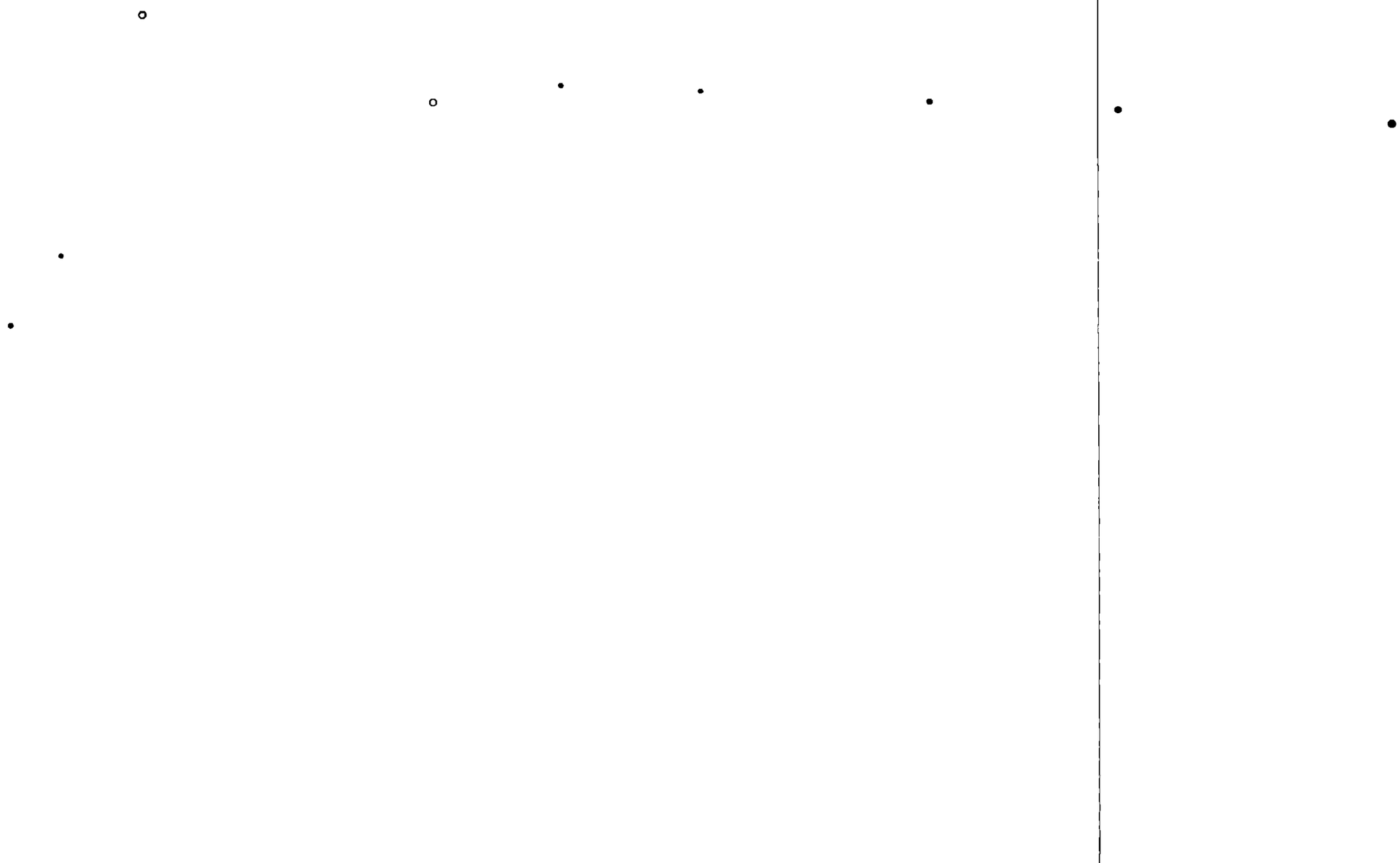

Fig 47 Situation 7

Fig. 48 Situation 8

Fig 49 Situation 9

Fig 50 Situation 10

Fig 51 Situation 11

Fig 52 Situation 12

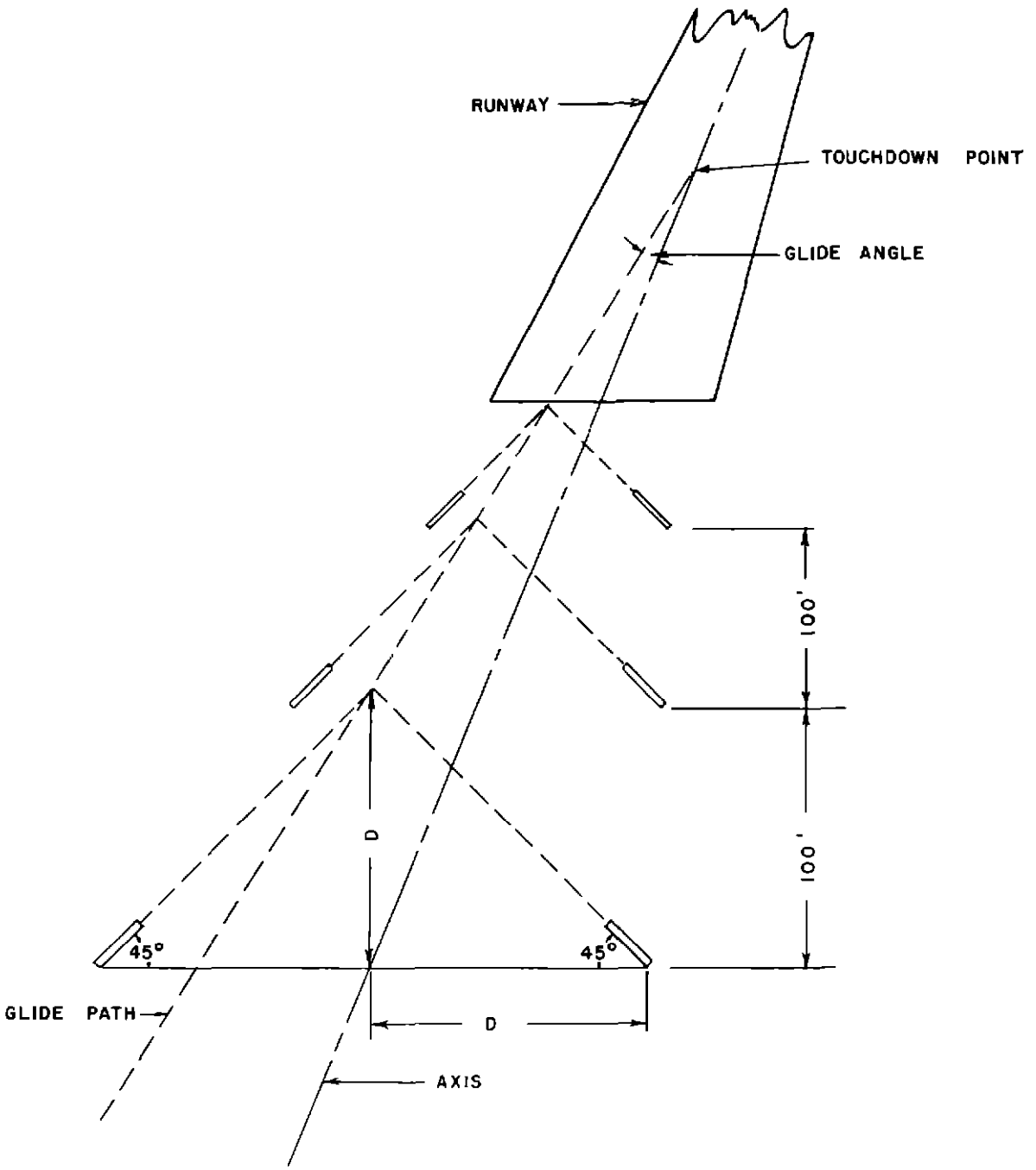

Fig 53 Diagram of Slope Line Approach Light System

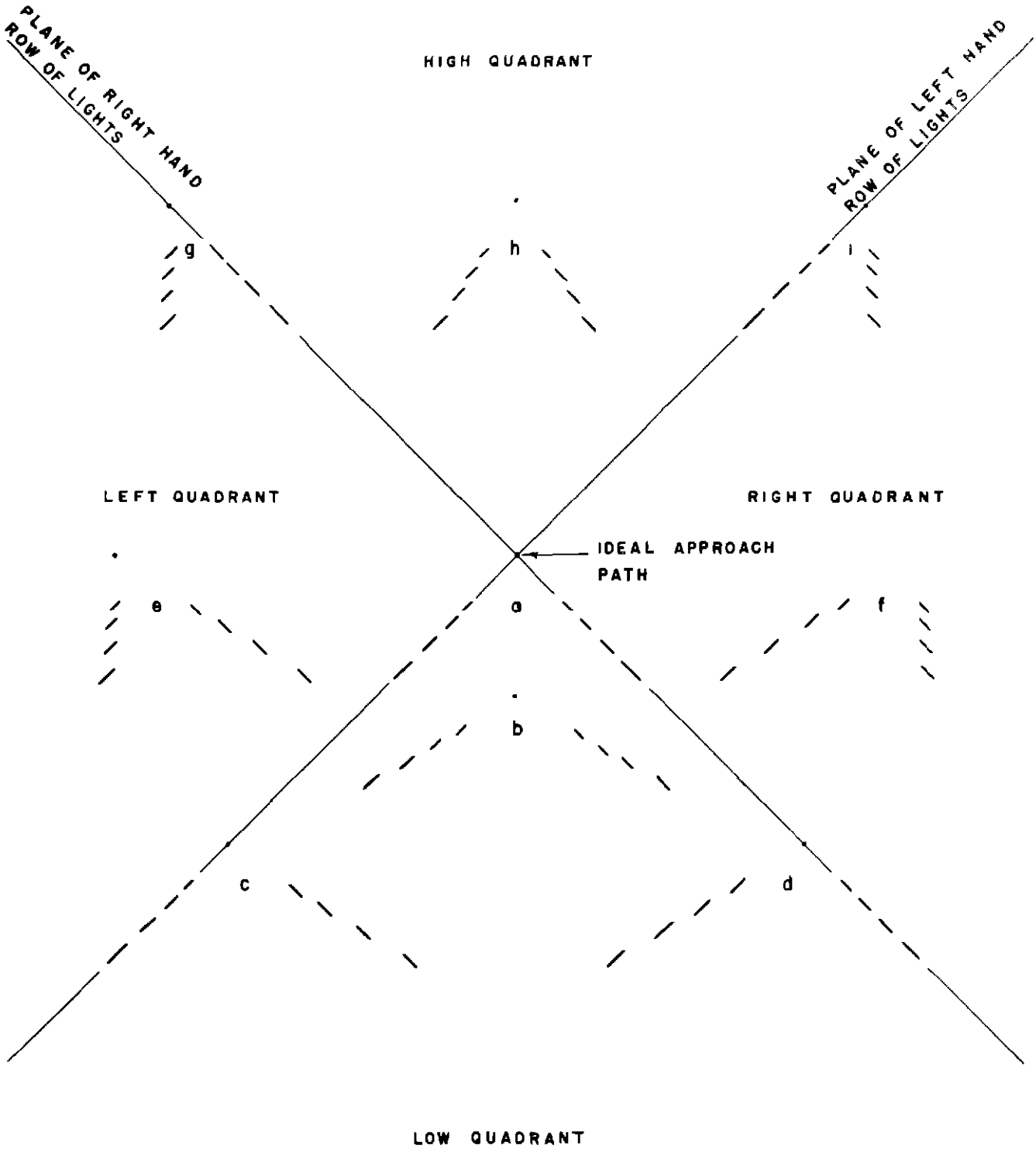

Fig 53A Nine Characteristic Perspective Views of the Slope Line Lights Superimposed on Co-ordinates Formed by Intersection of the Planes of the Two Rows with a Reference Plane Normal to the Approach Path

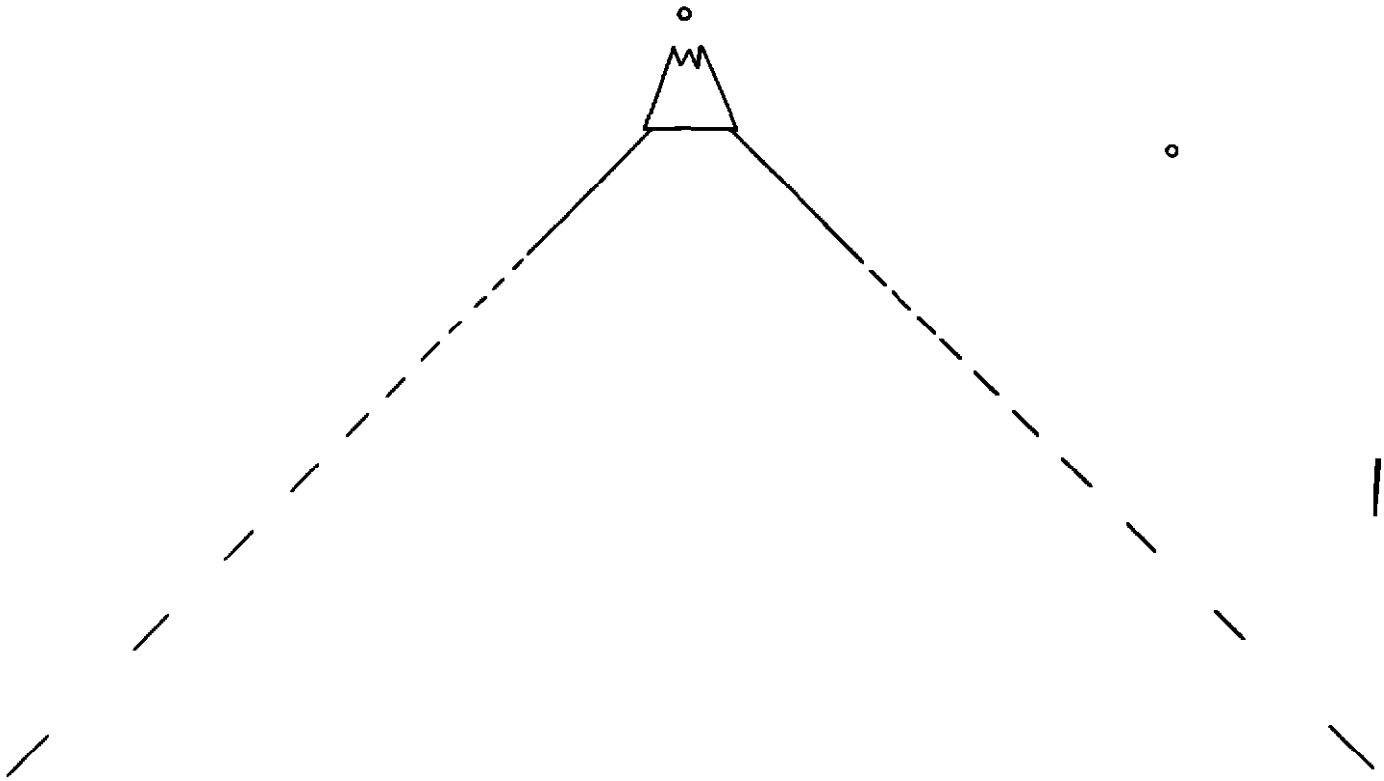

Fig. 54 Situation 1

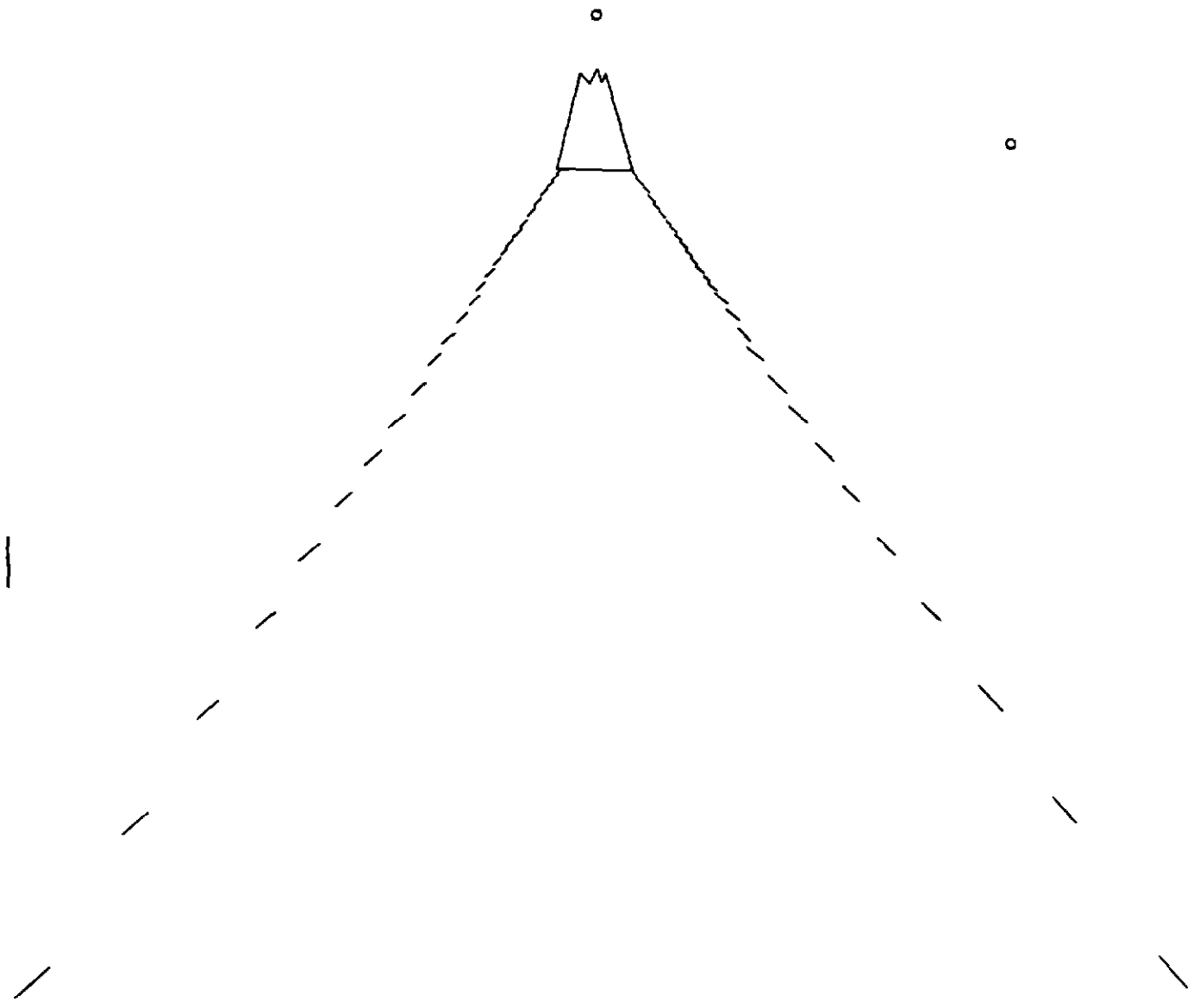

Fig. 55 Situation 2

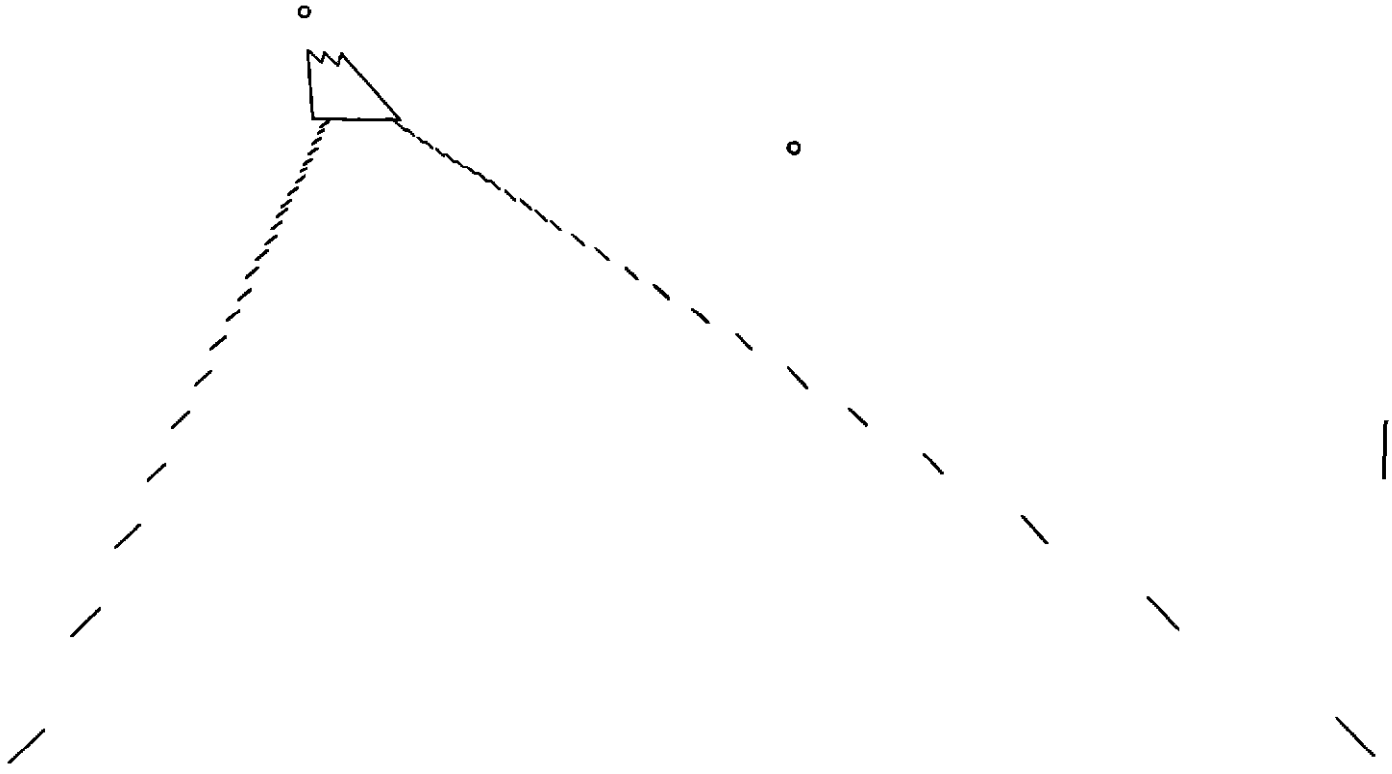

Fig 56 Situation 3

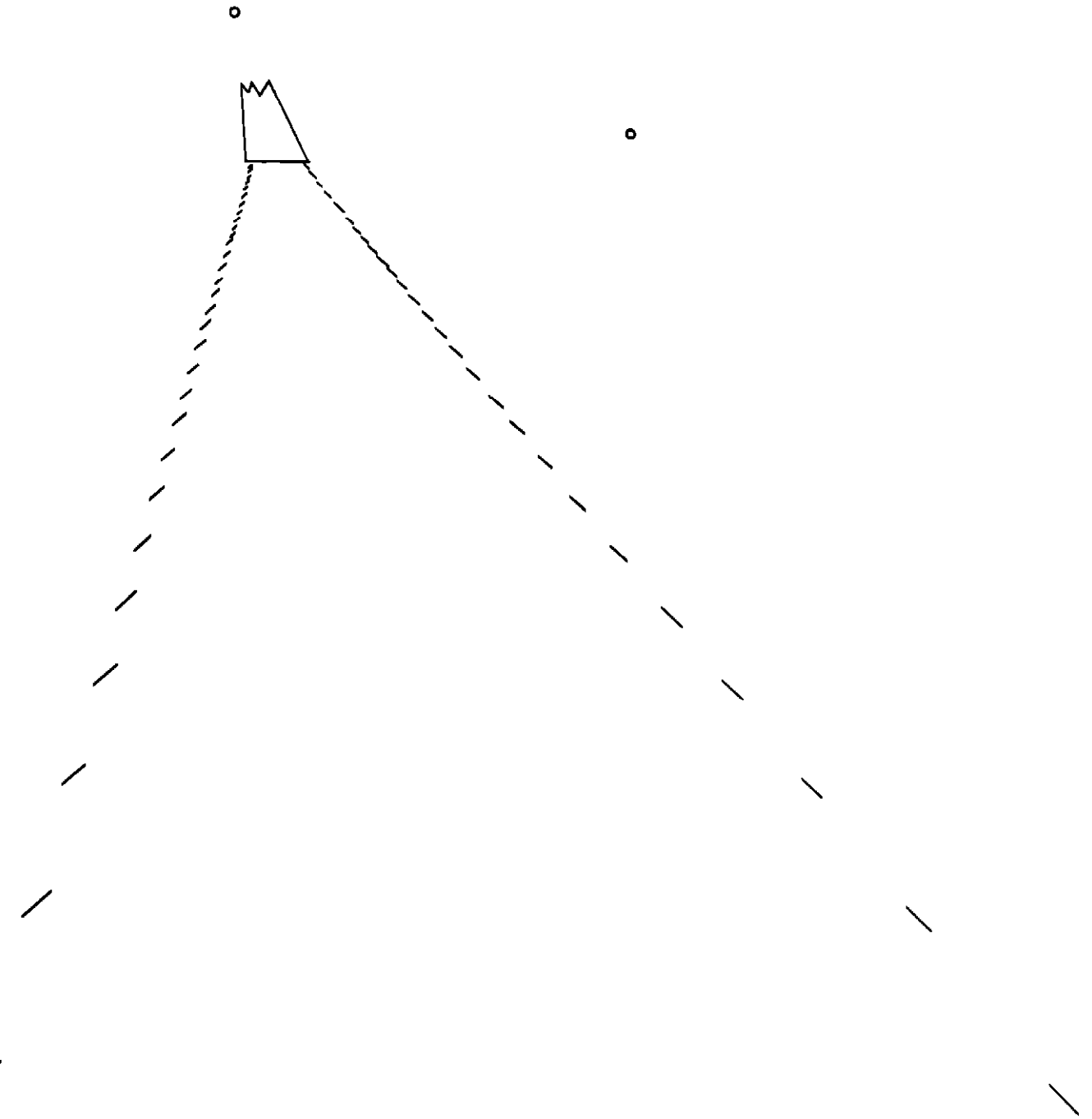

Fig. 57 Situation 4

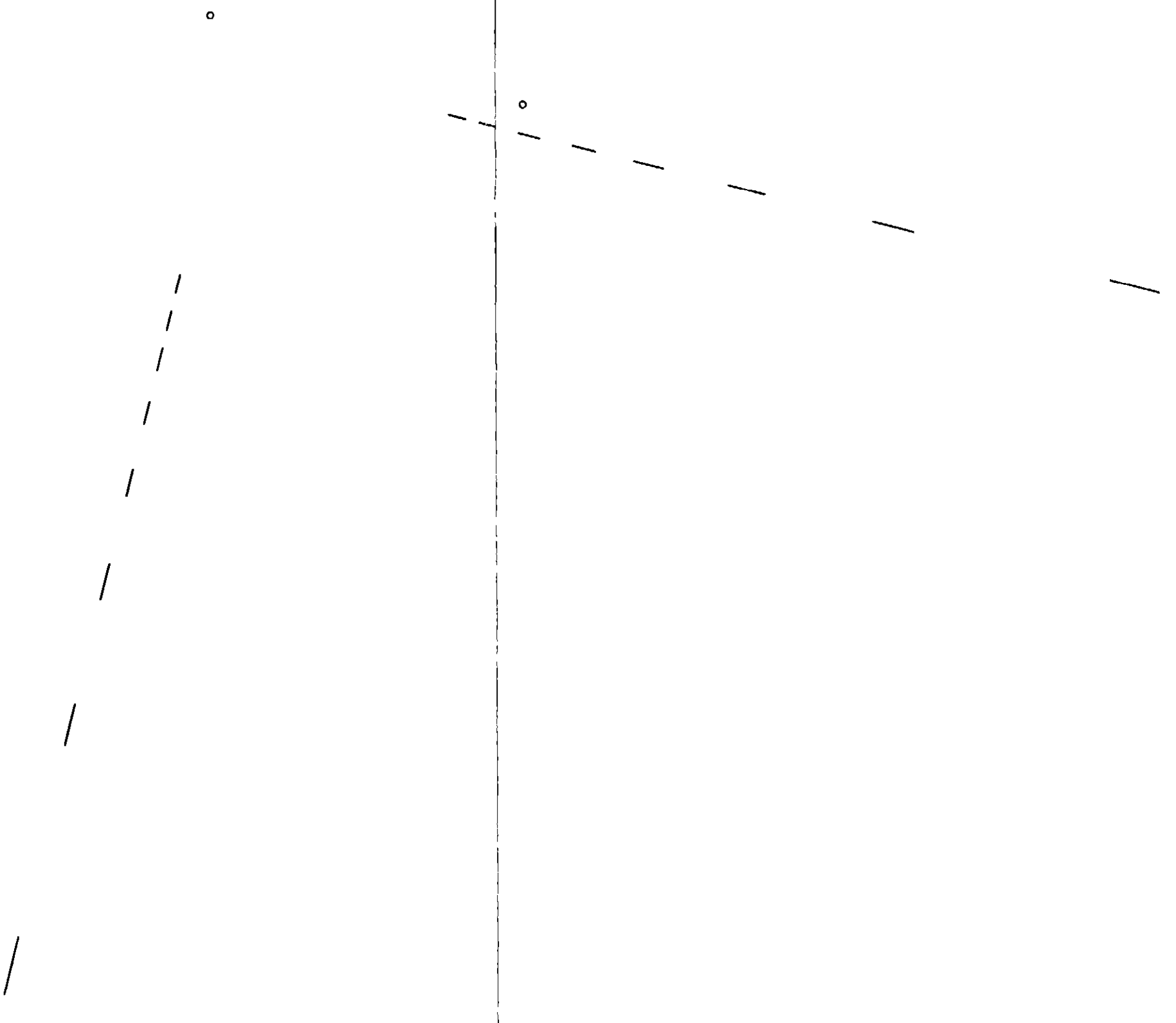

Fig 58 Situation 5

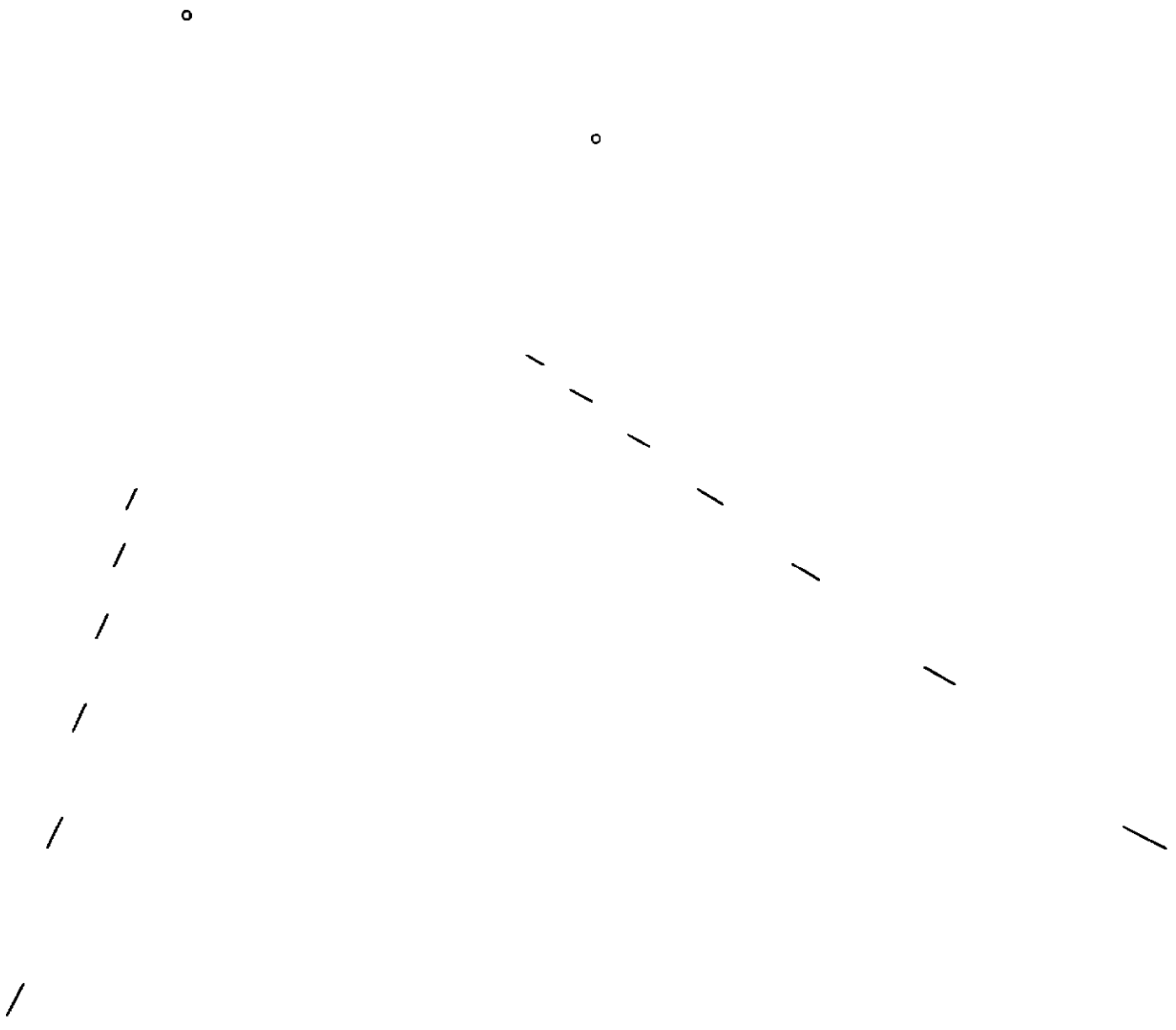

Fig 59 Situation 6

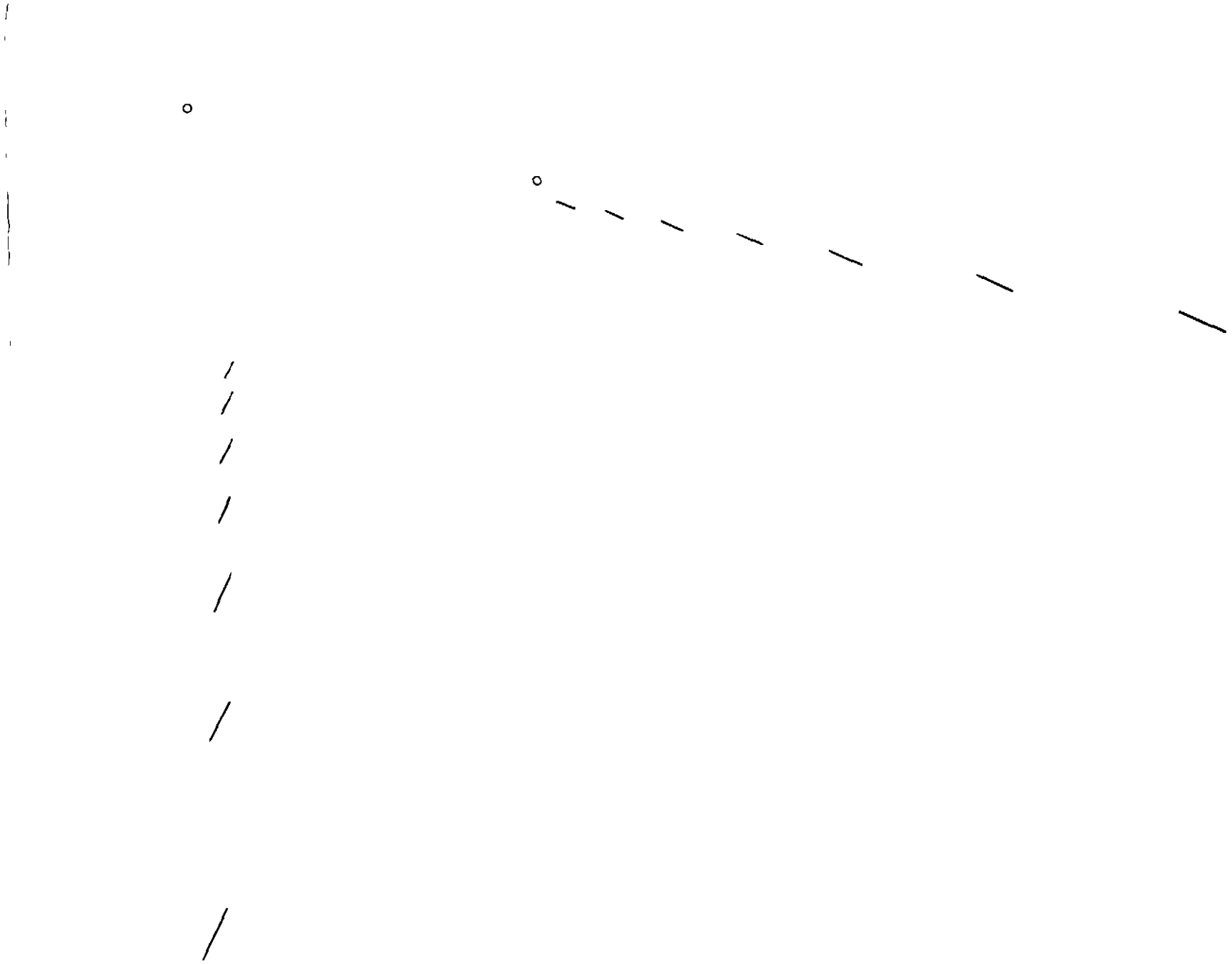

Fig 60 Situation 7

Fig. 61 Situation 8

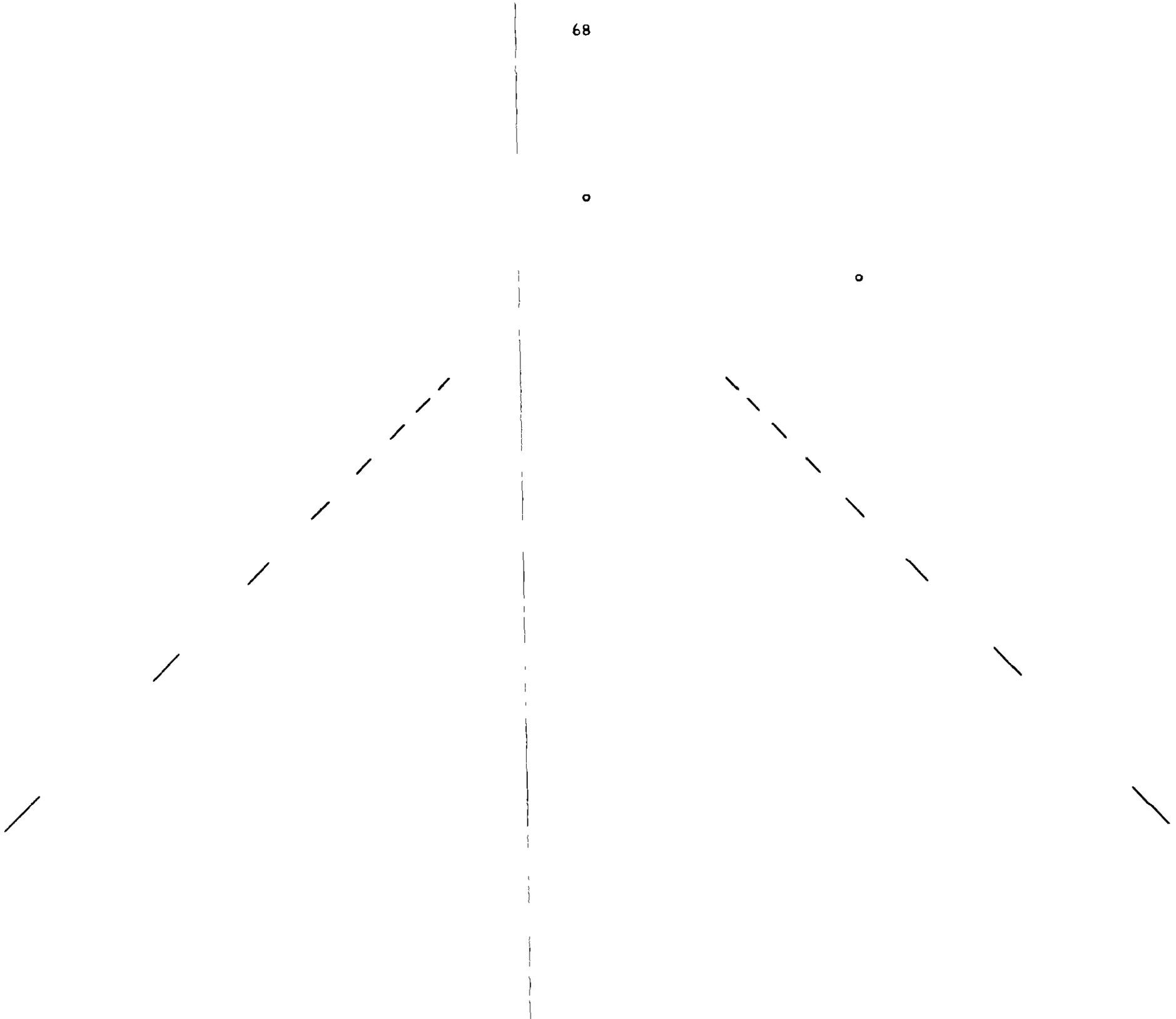

Fig 62 Situation 9

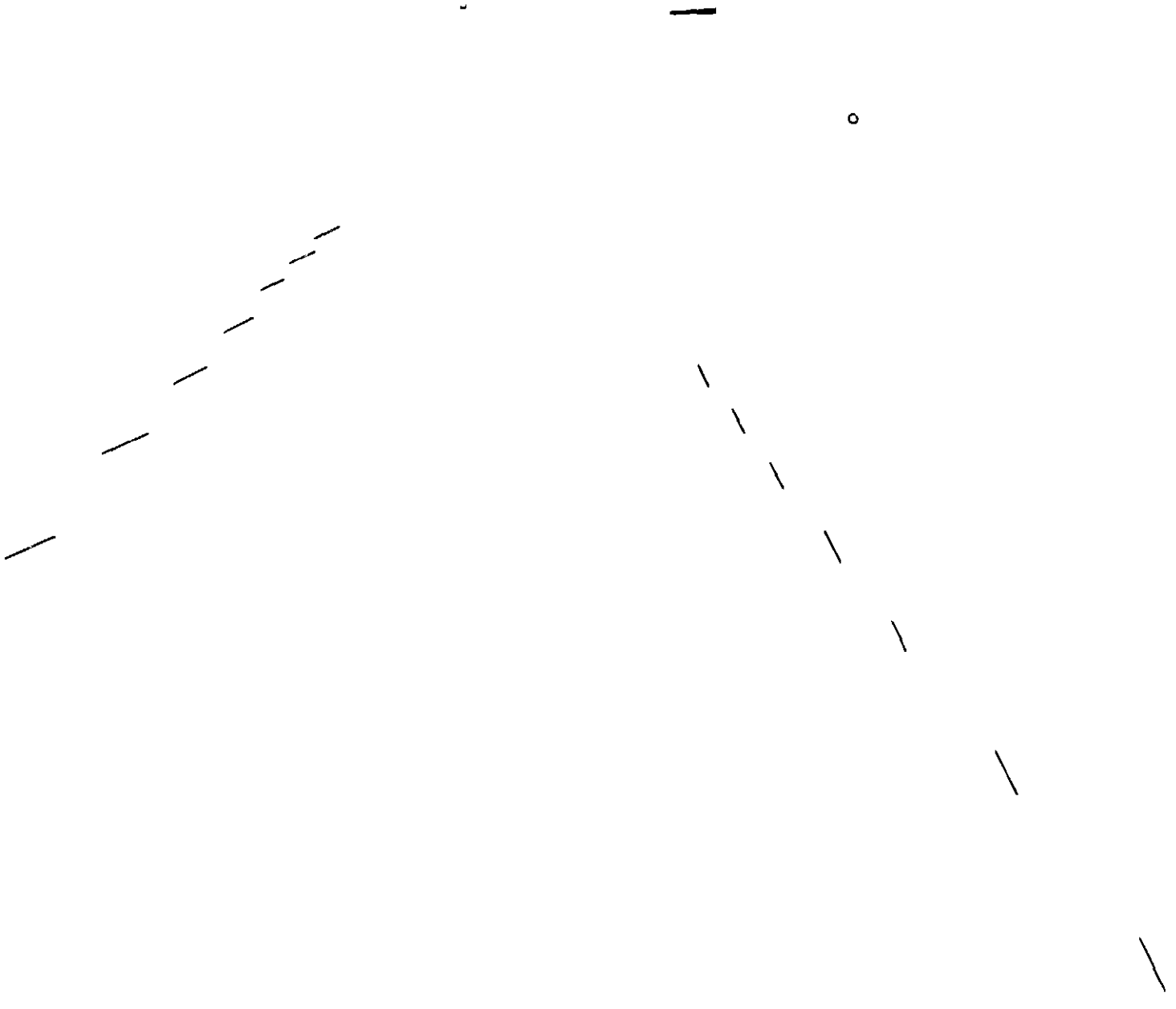

Fig. 63 Situation 10

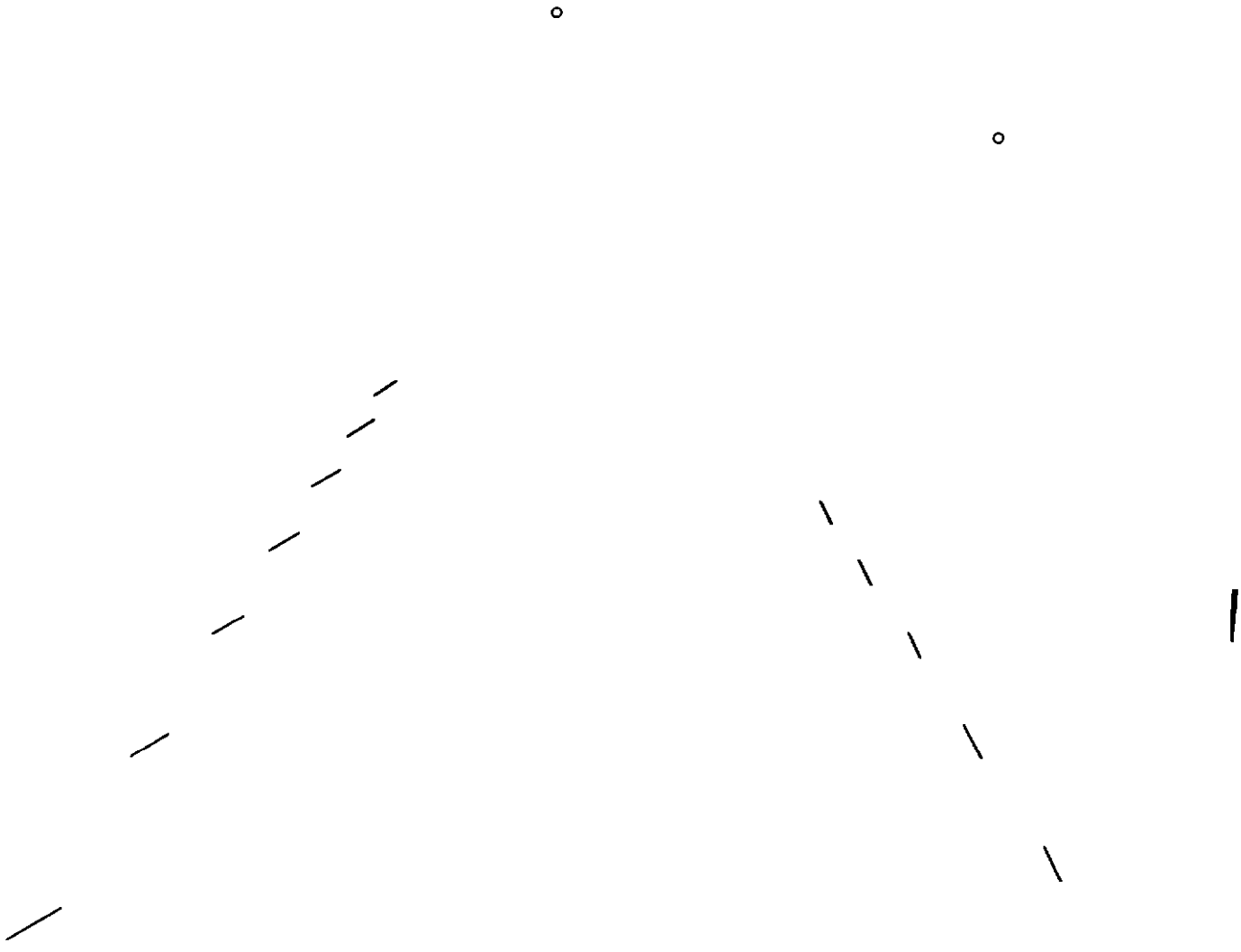

Fig 64 Situation 11

Fig 65 Situation 12

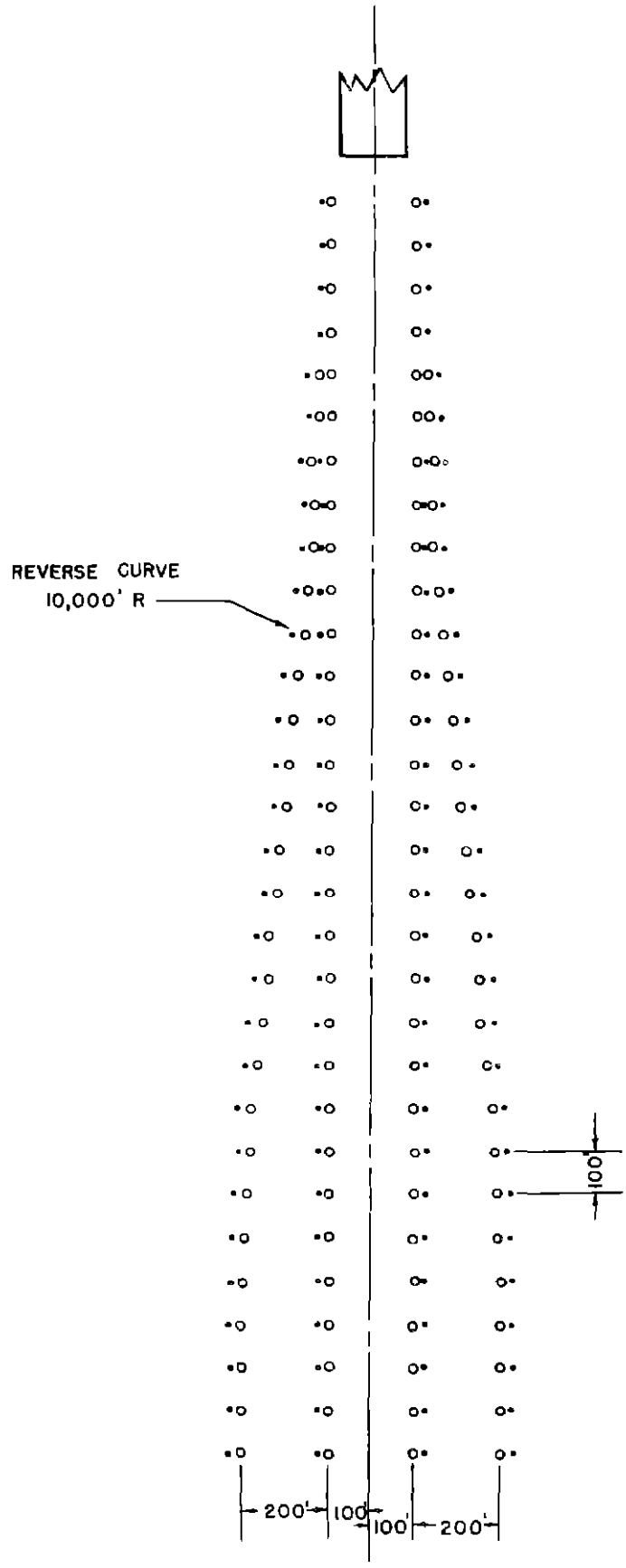

Fig 66 Diagram of Path of Flight Symmetrical Approach System

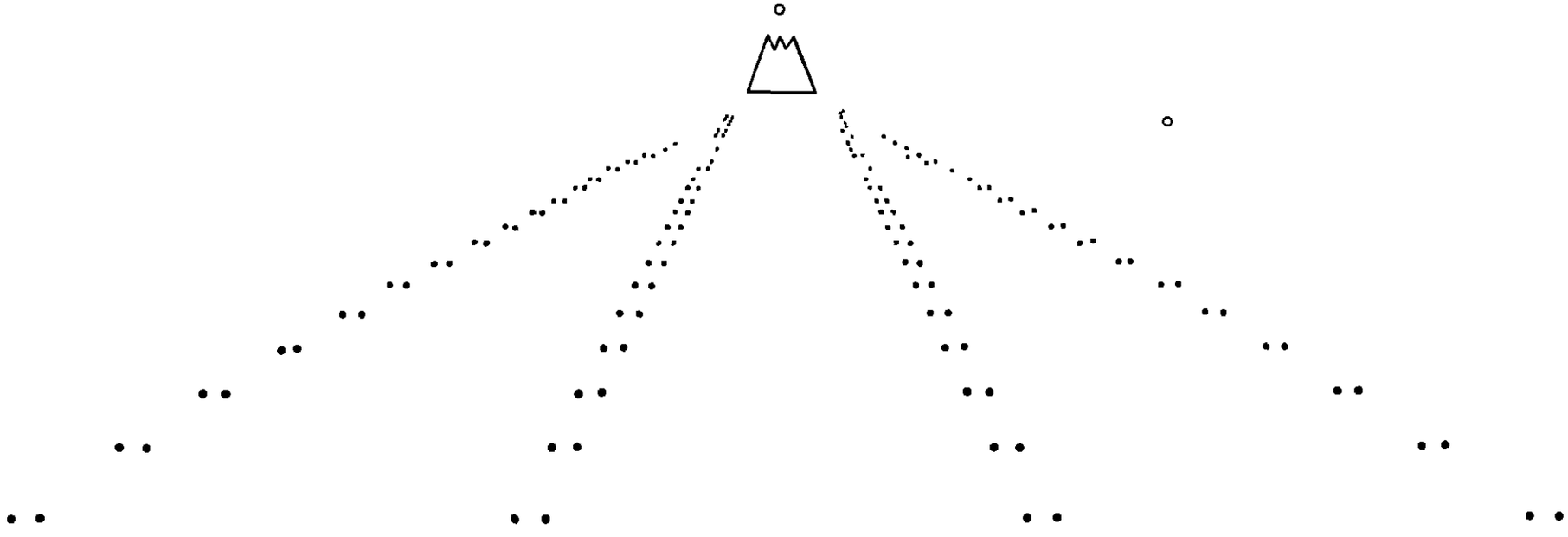

Fig 67 Situation 1

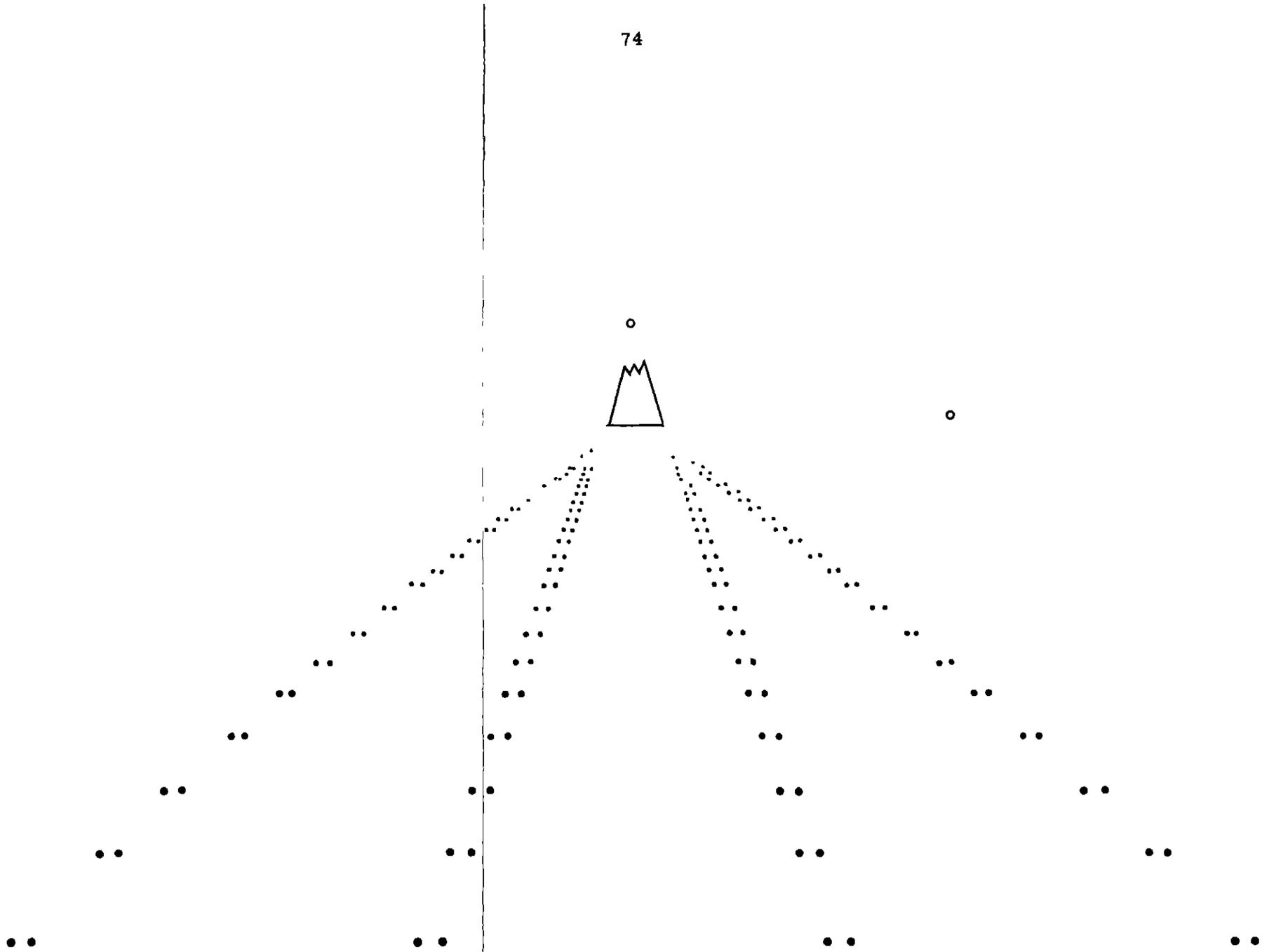

Fig 68 Situation 2

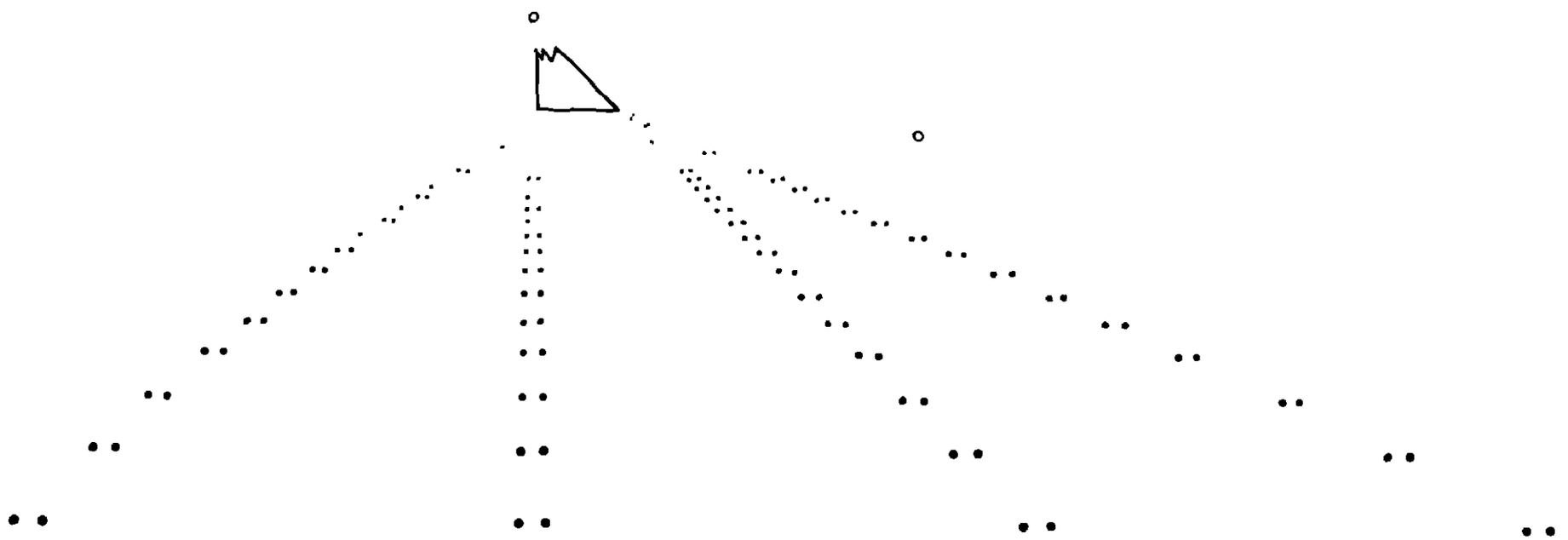

Fig 69 Situation 3

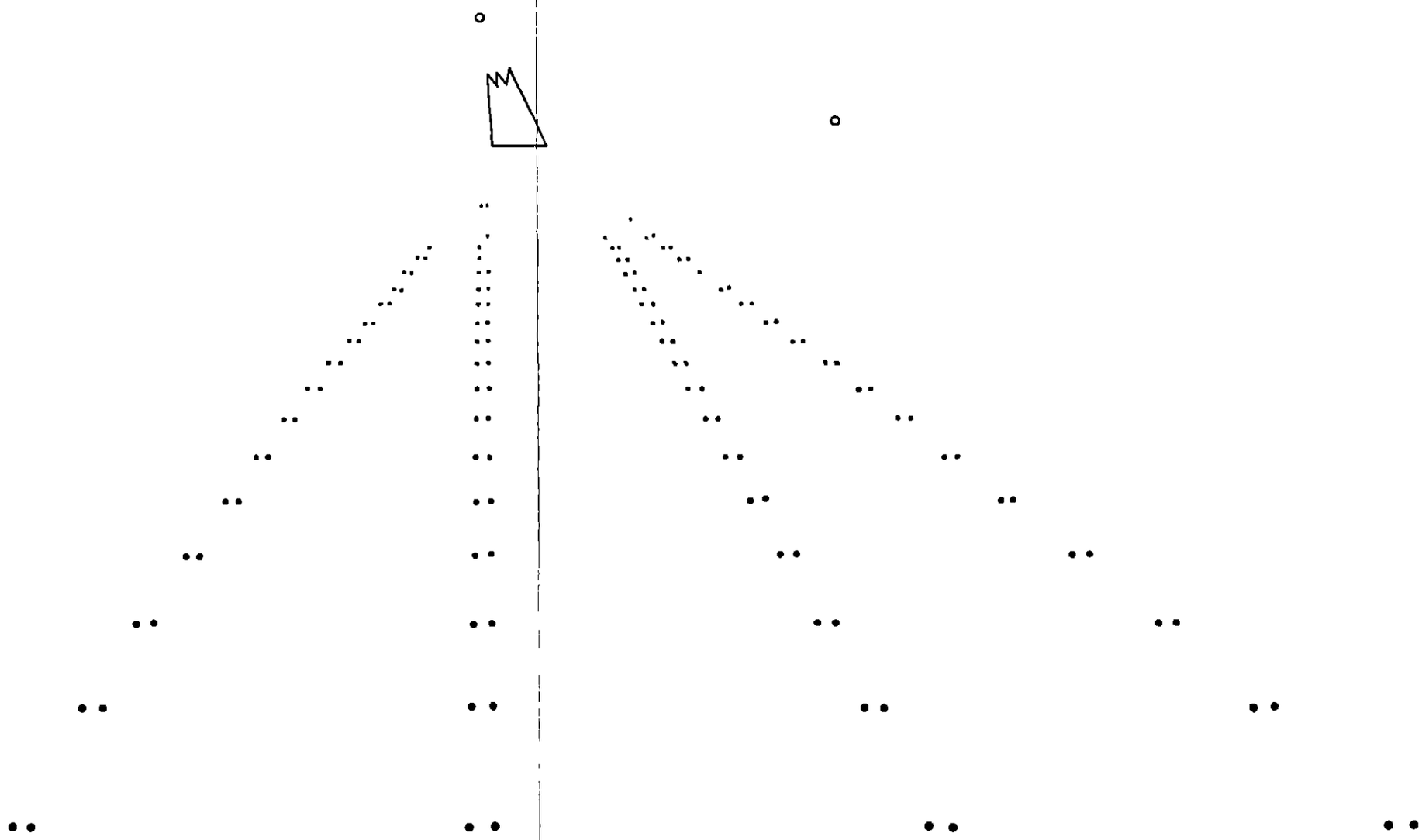

Fig 70 Situation 4

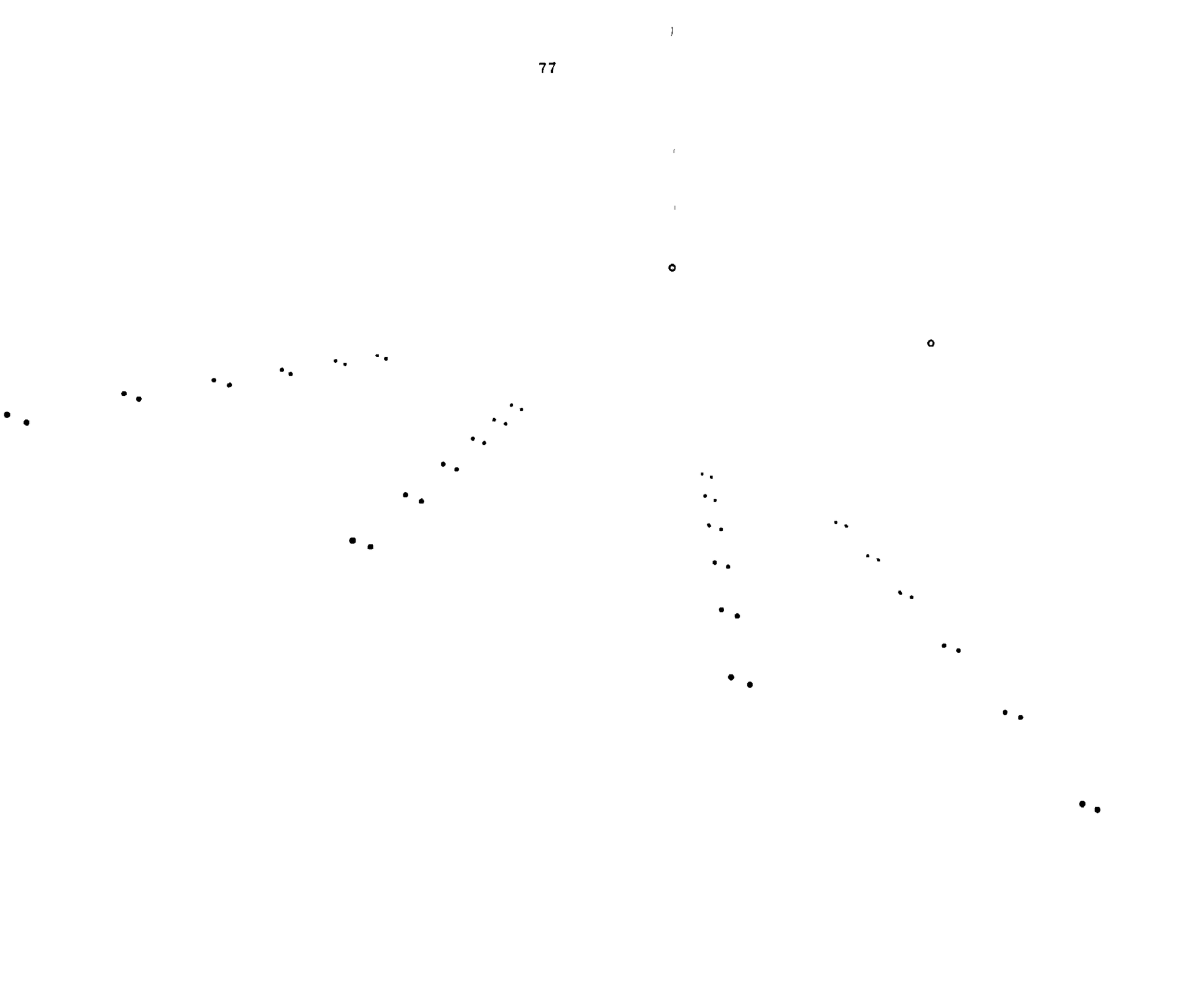

Fig. 71 Situation 5

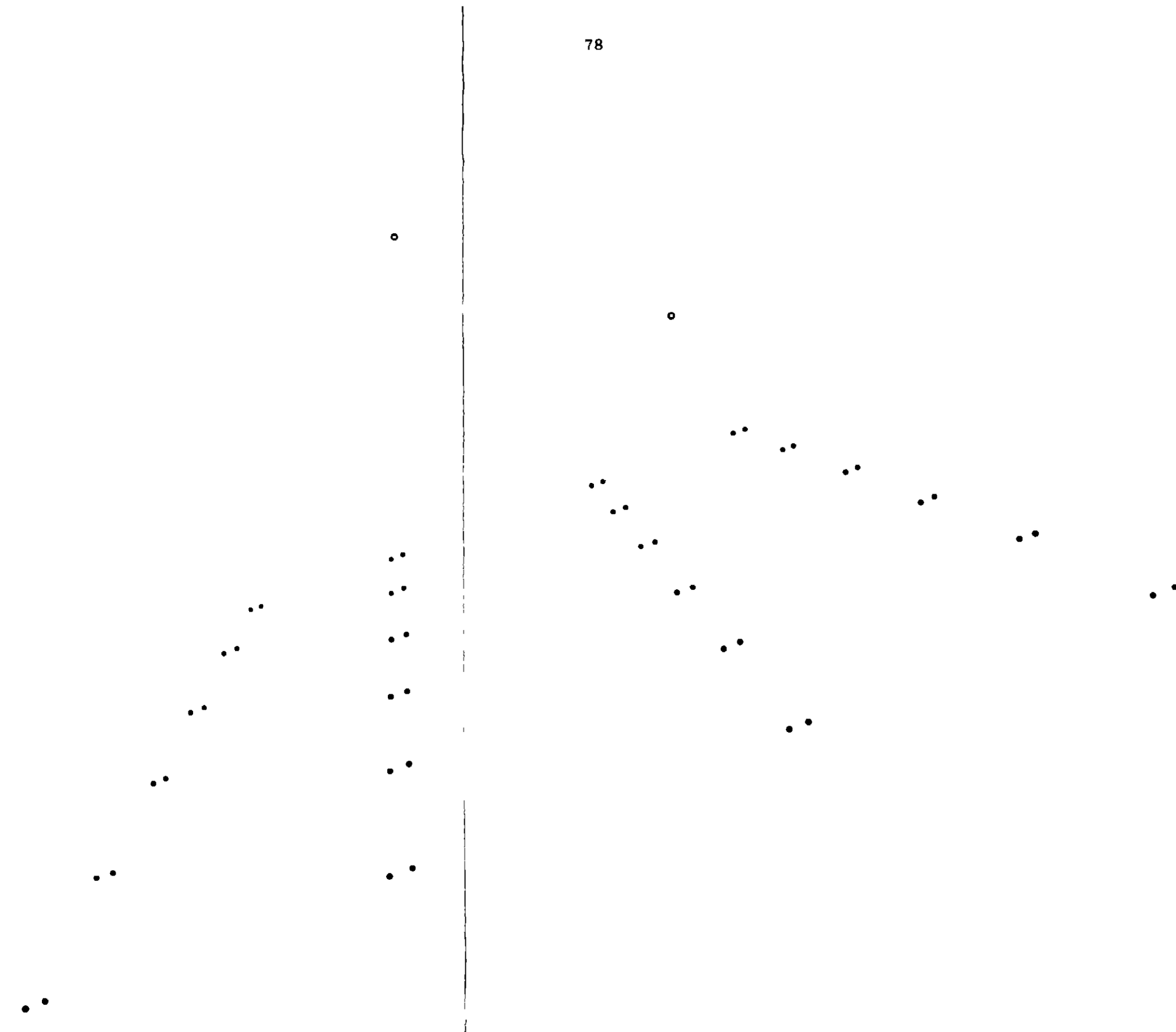

Fig 72 Situation 6

Fig 73 Situation 7

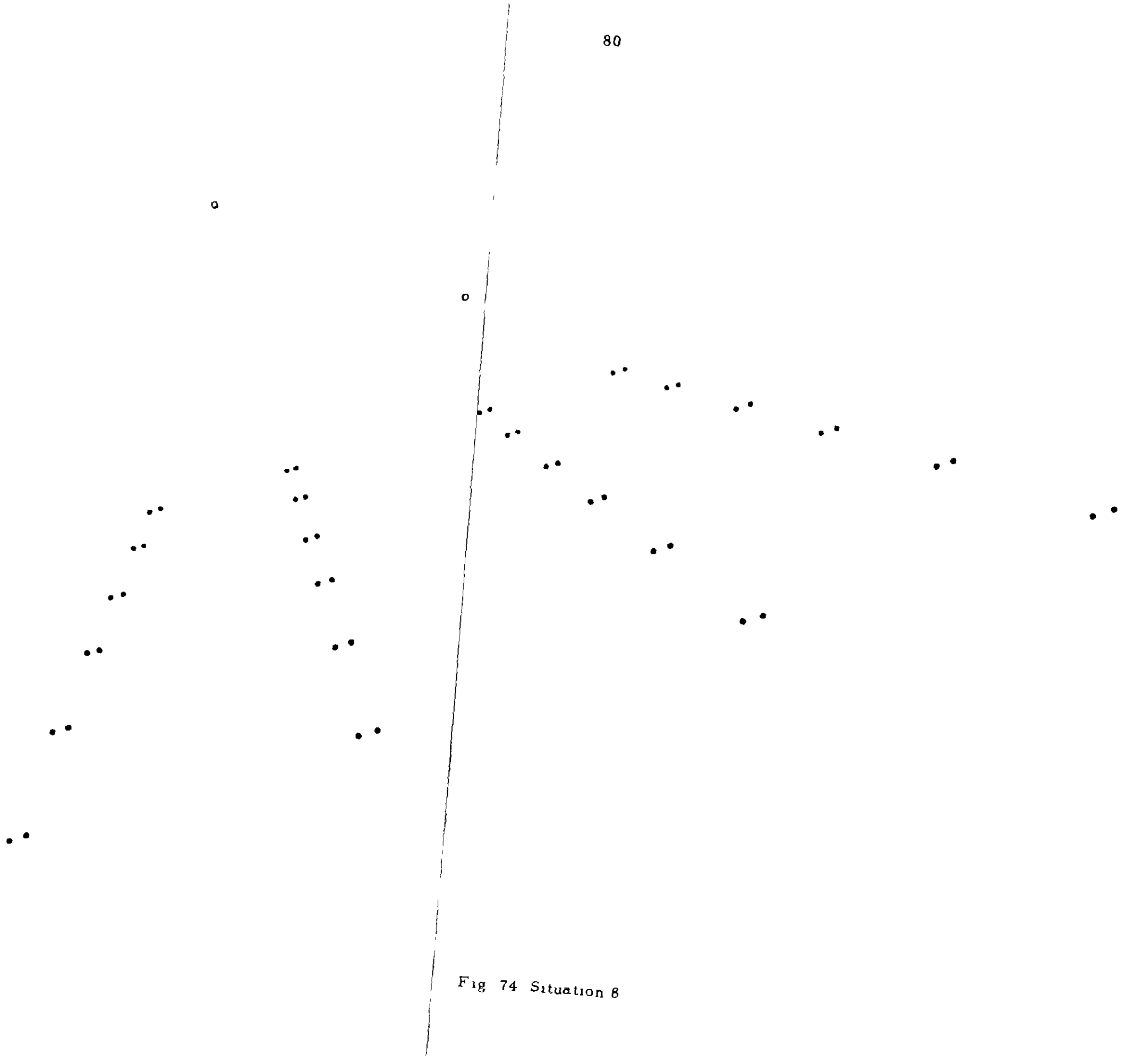

Fig 74 Situation 8

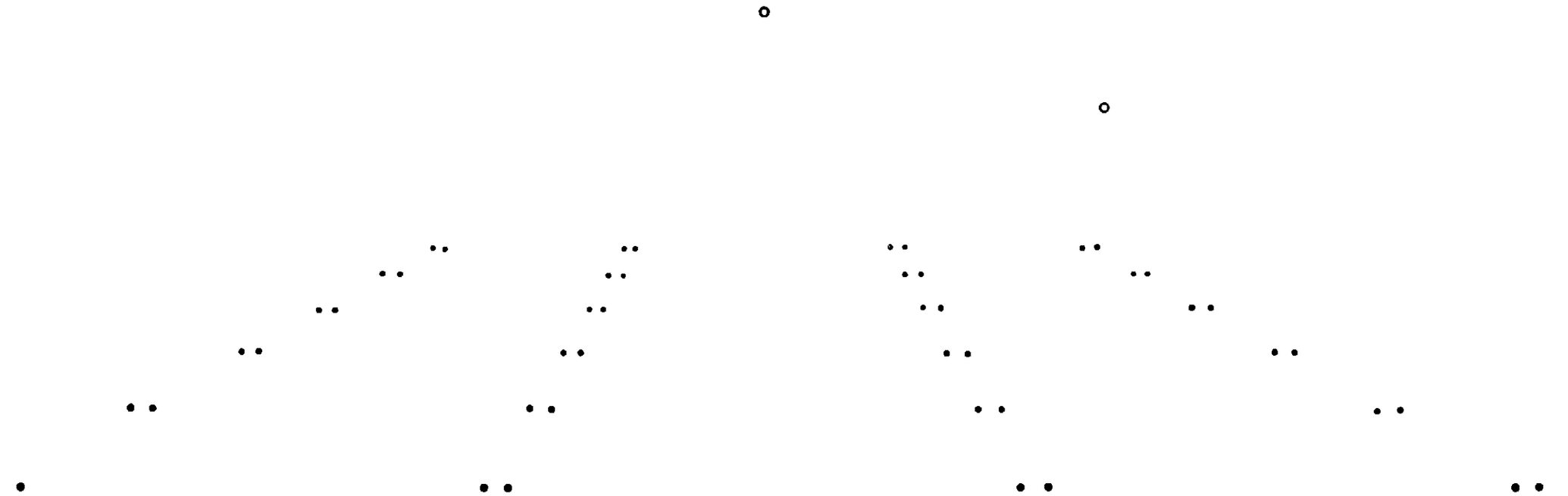

Fig 75 Situation 9

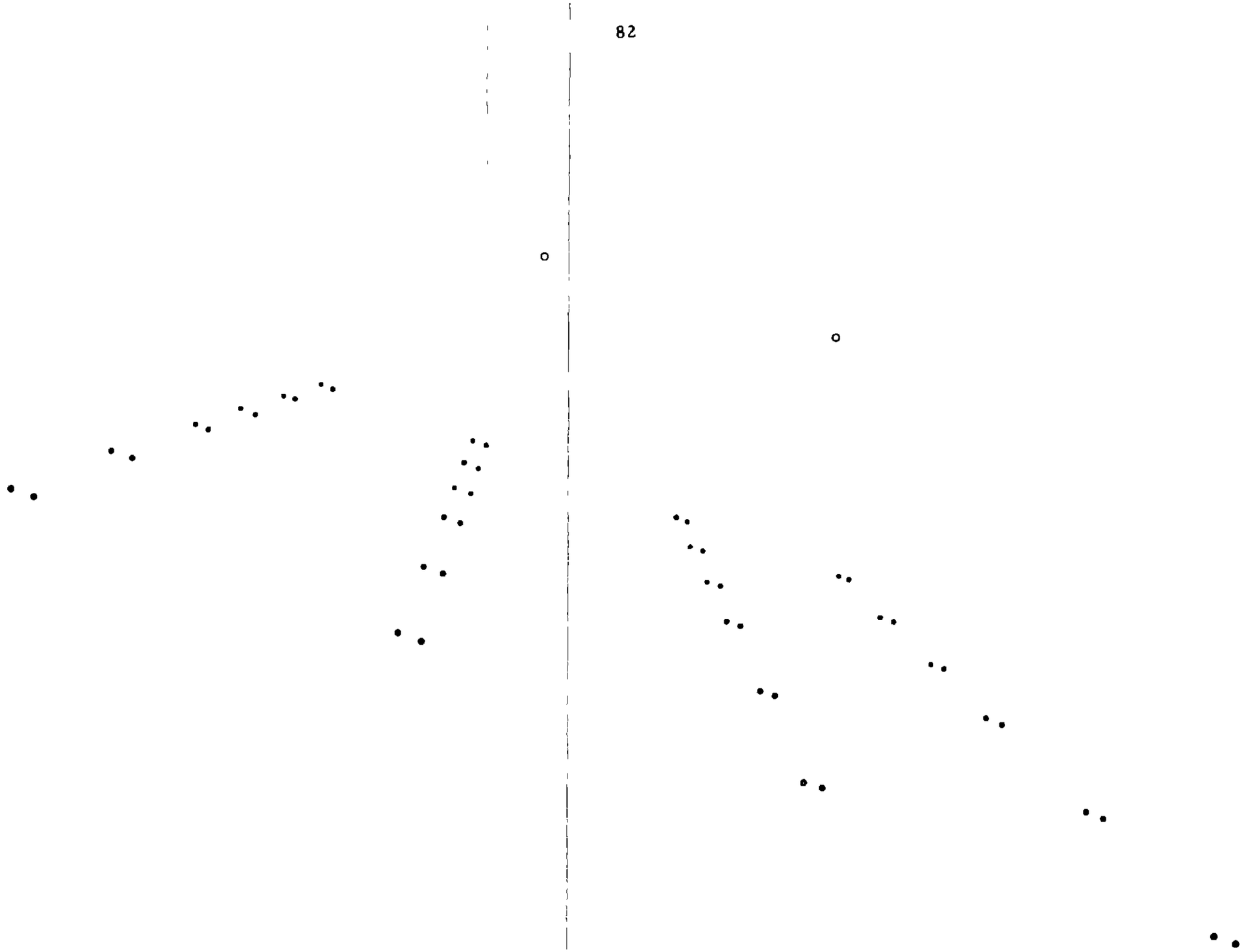

Fig. 76 Situation 10

Fig 77 Situation 11

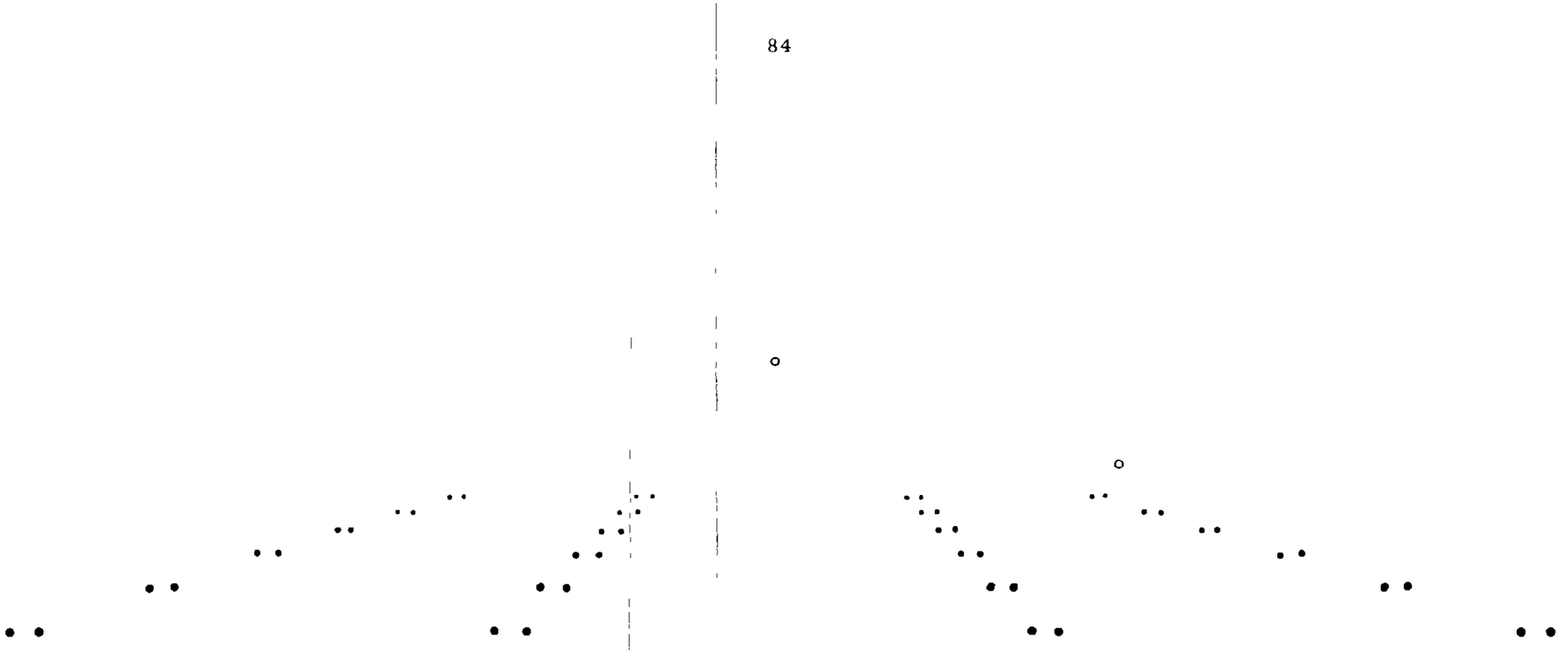

Fig 78 Situation 12

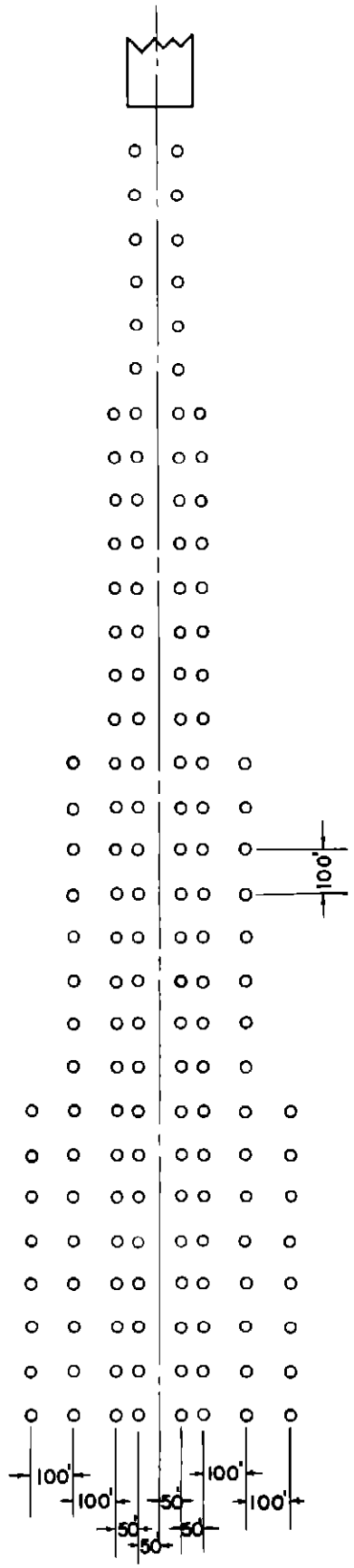

Fig 79 Diagram of Multi-Line Approach Light System

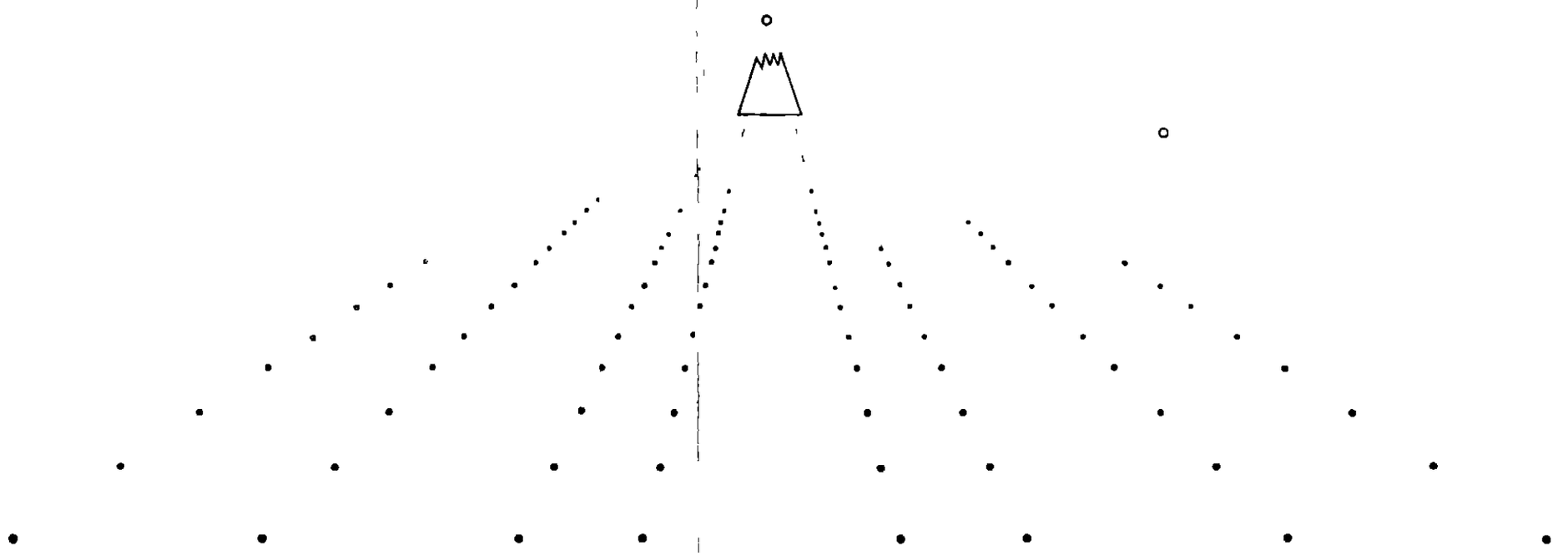

Fig 80 Situation 1

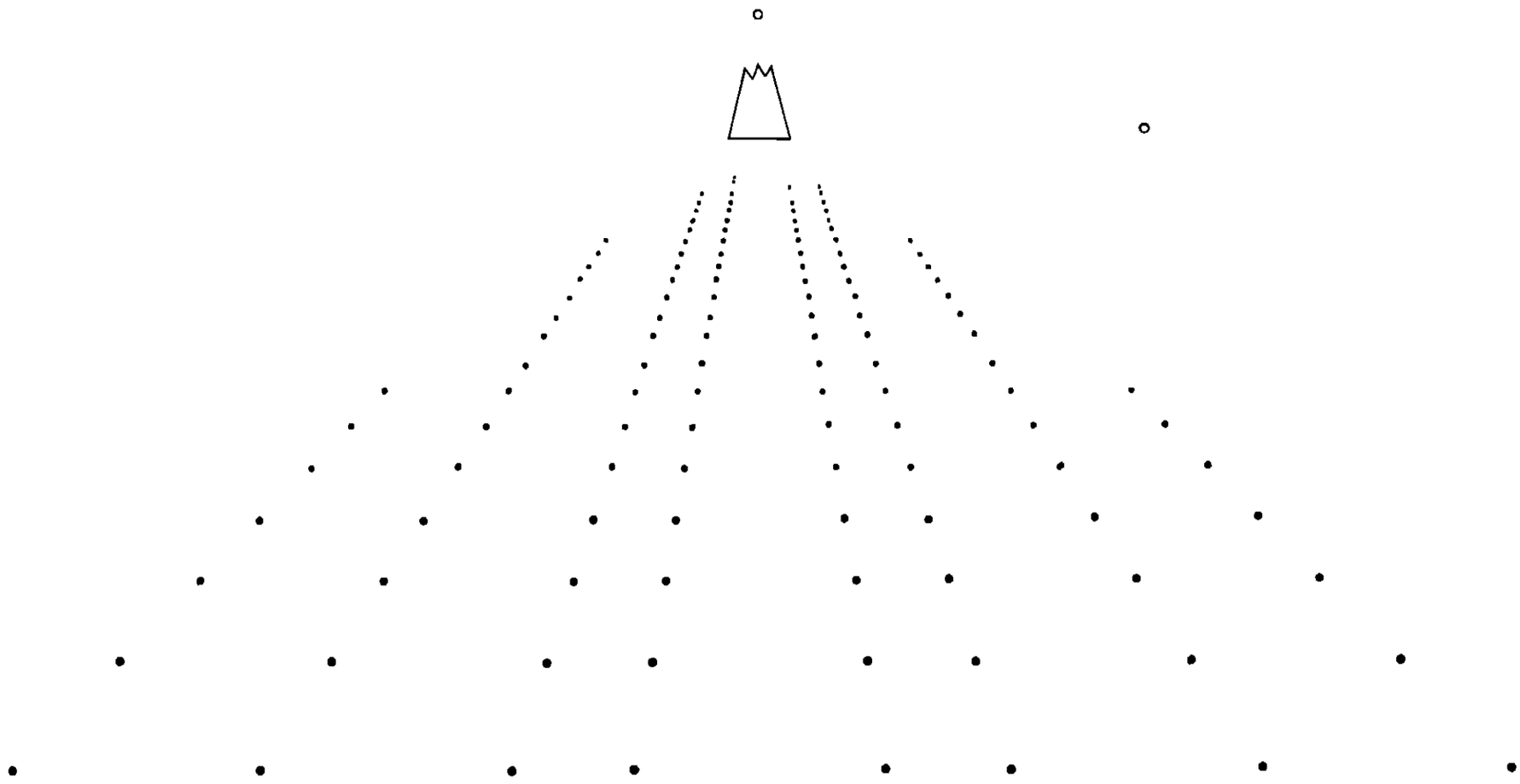

Fig 81 Situation 2

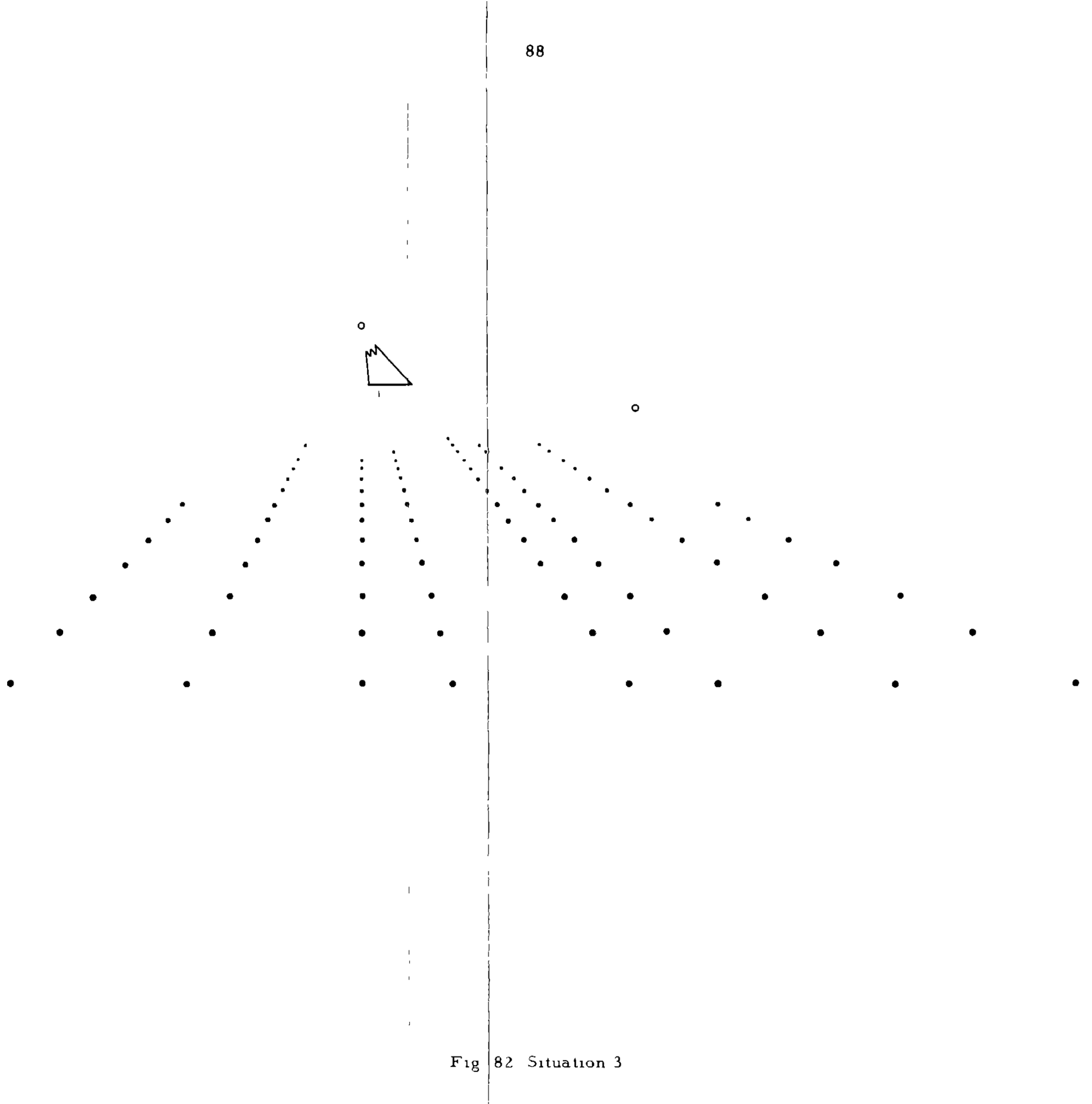

Fig 82 Situation 3

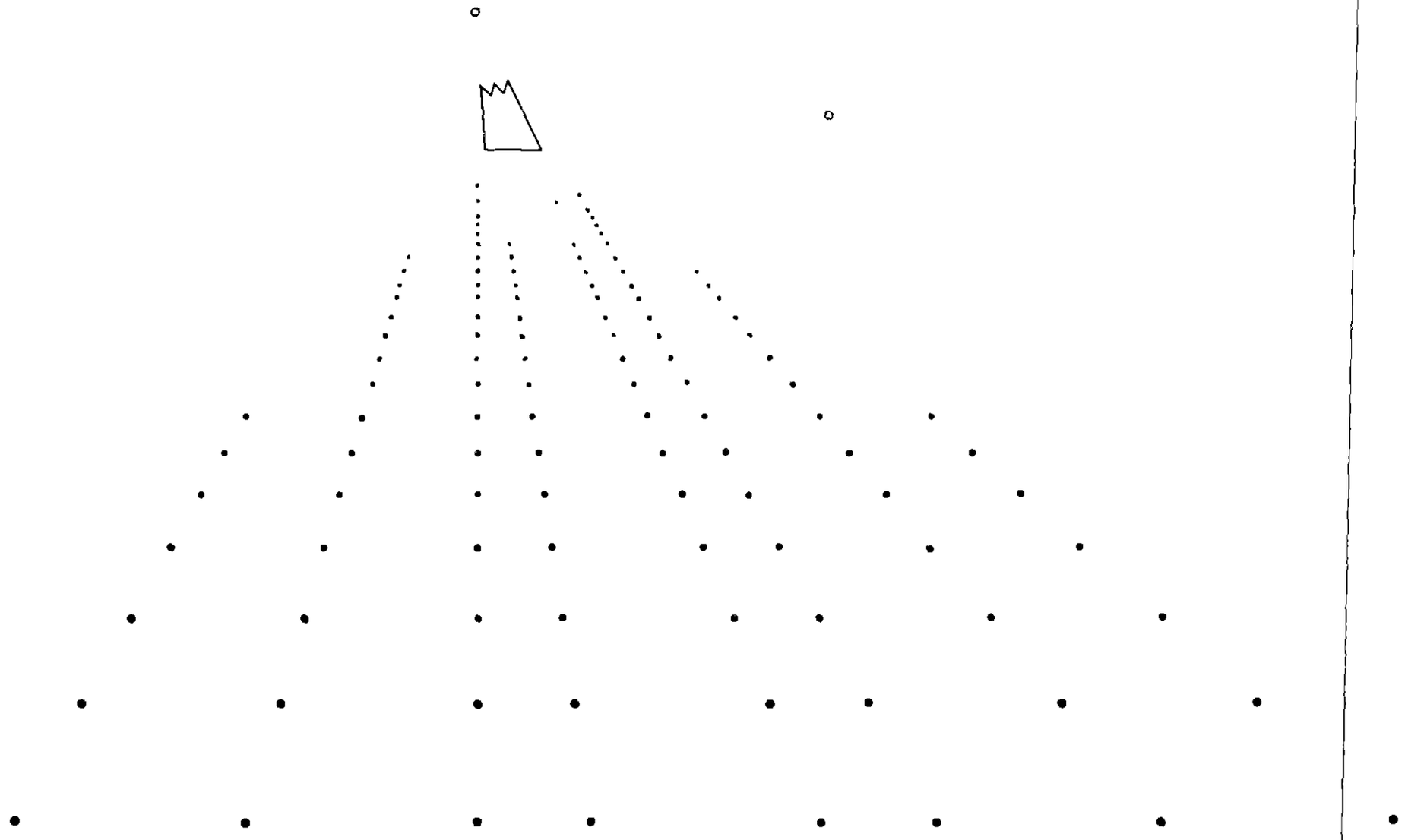

Fig 83 Situation 4

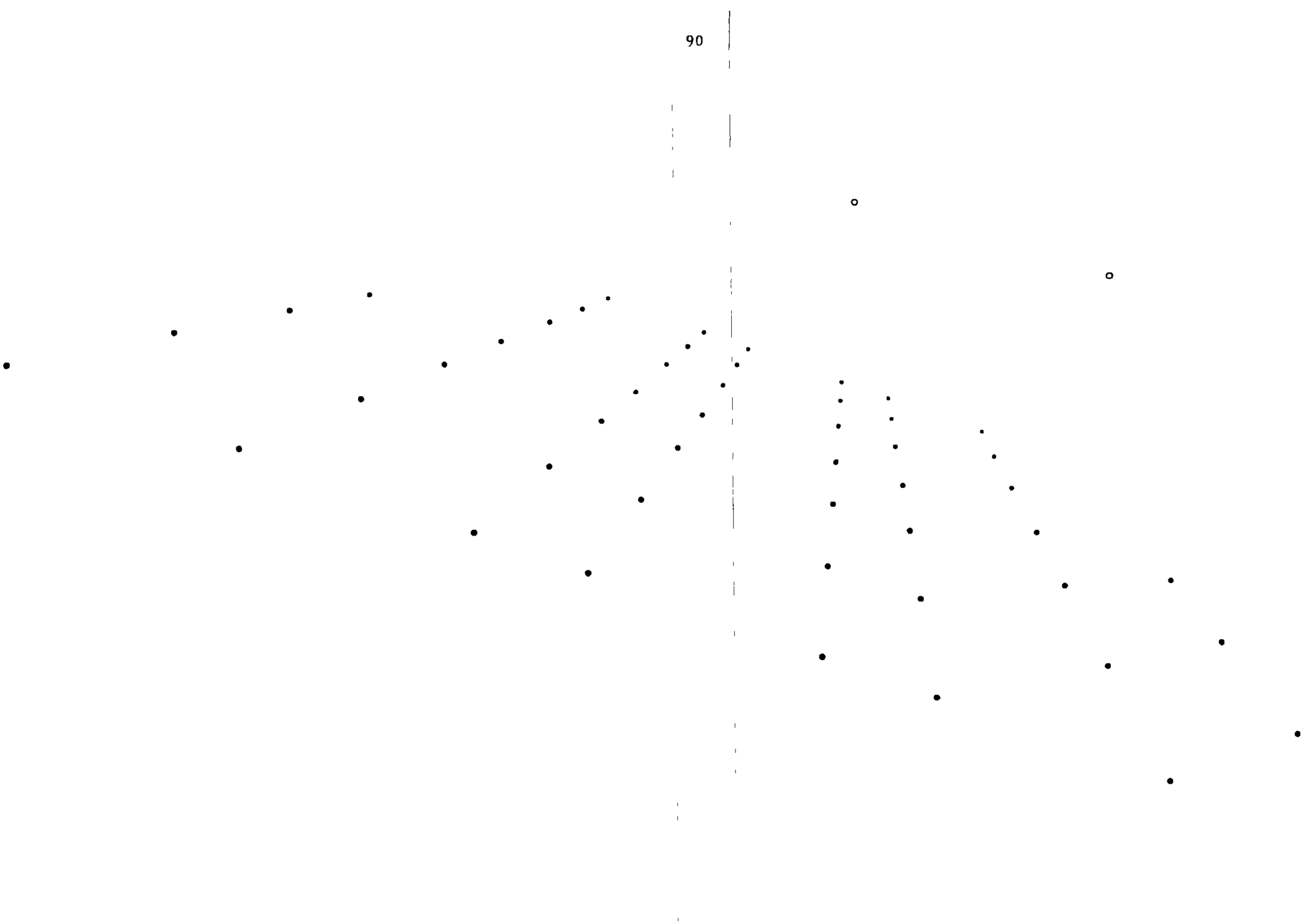

Fig 84 Situation 5

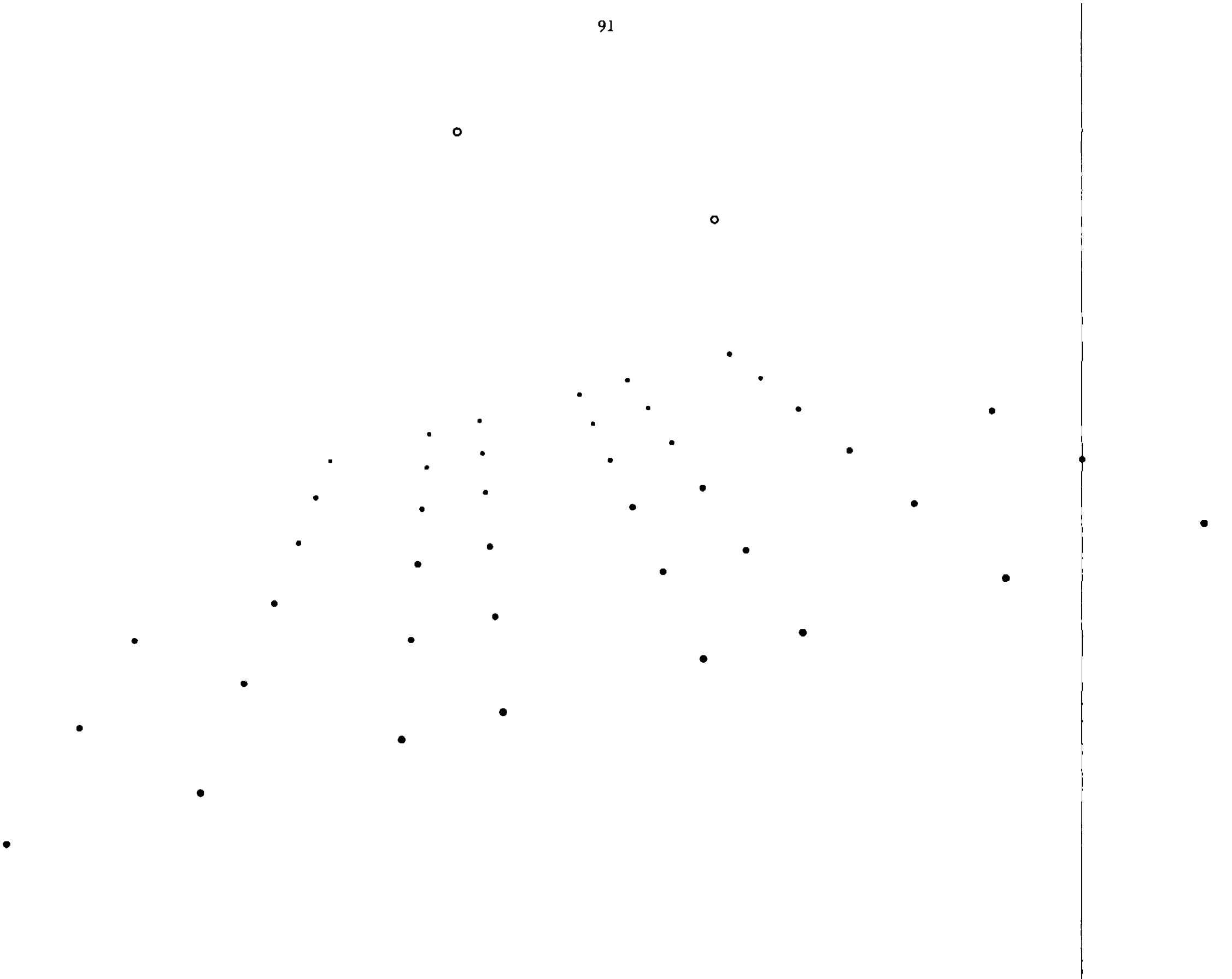

Fig 85 Situation 6

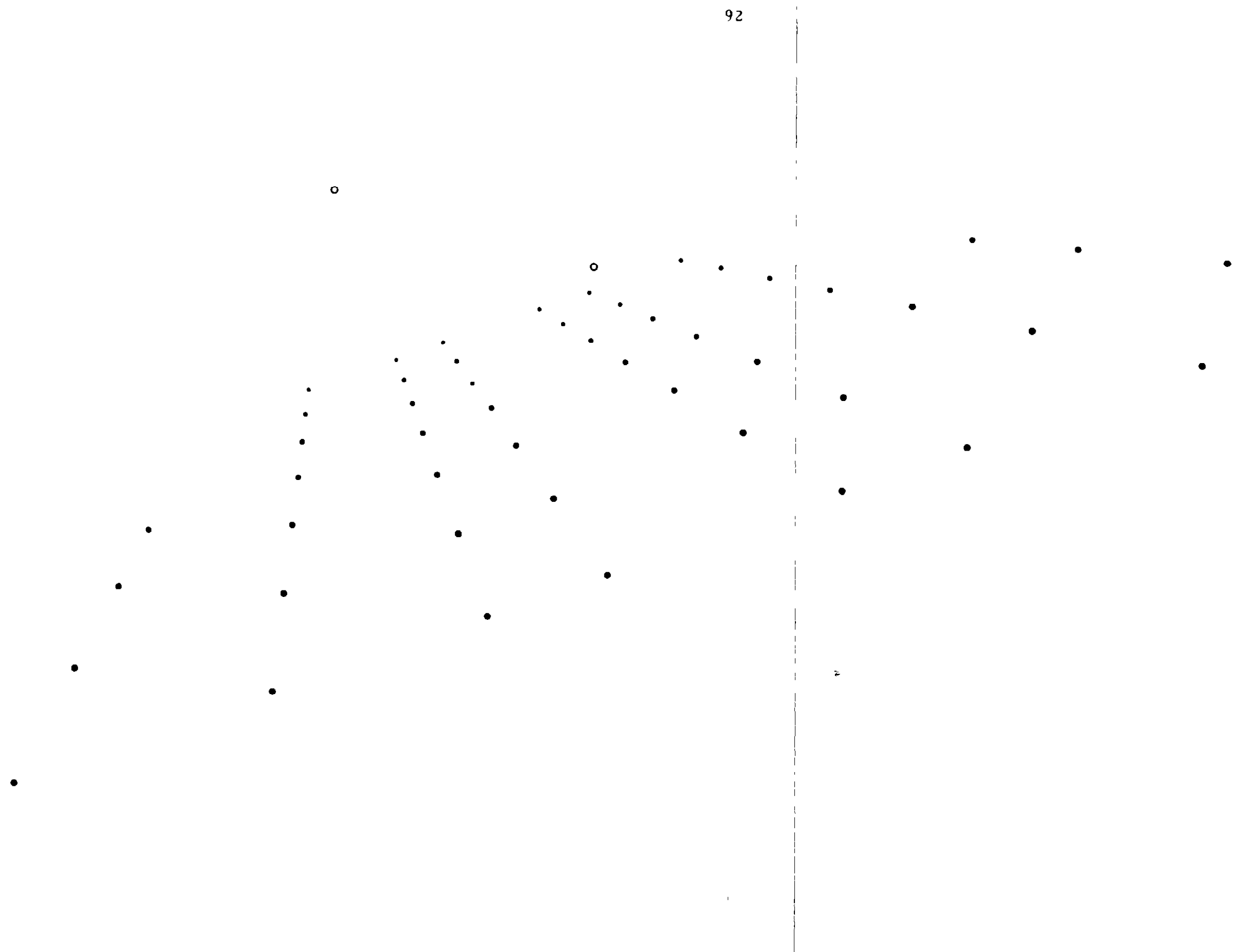

Fig 86 Situation 7

Fig 87 Situation 8

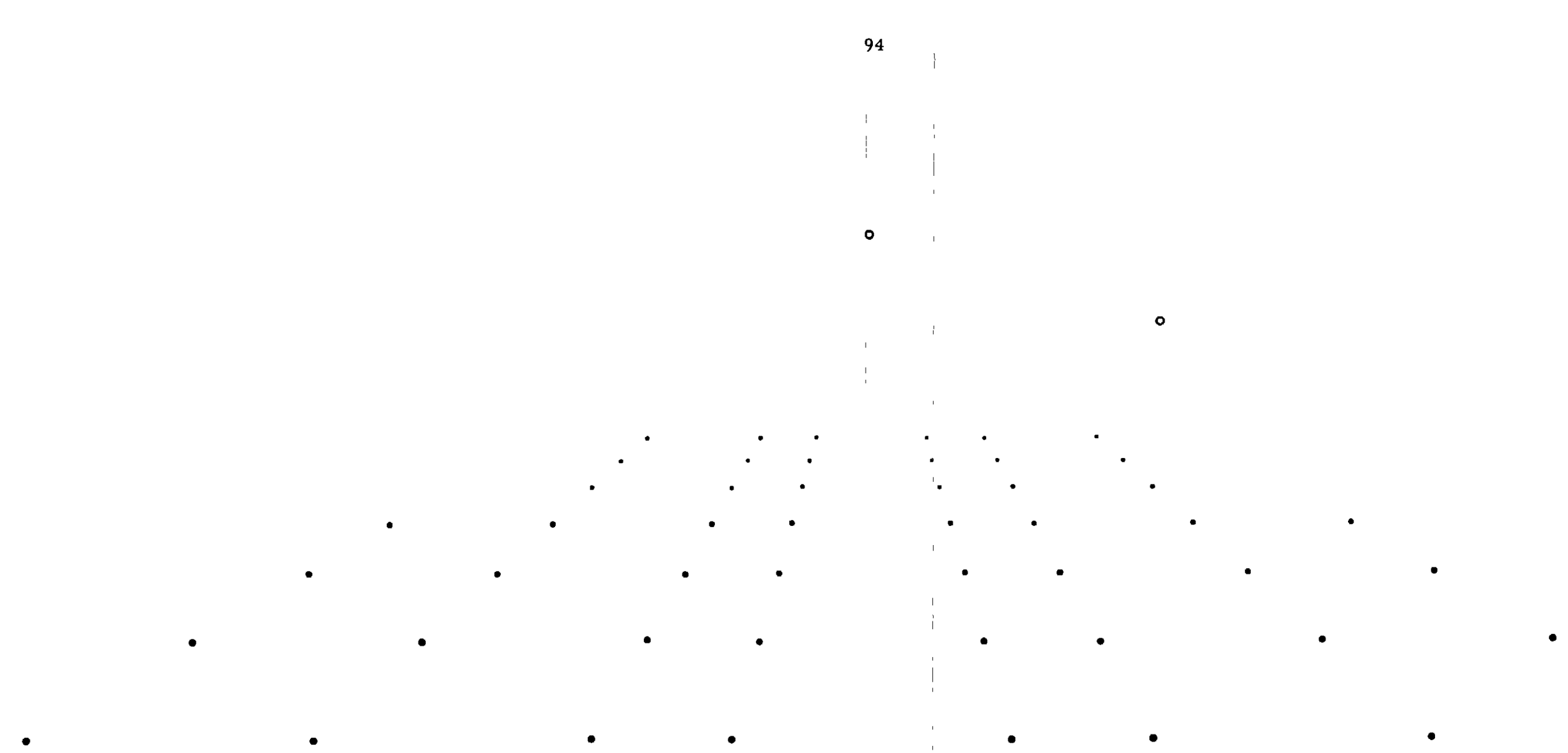

Fig. 88 Situation 9

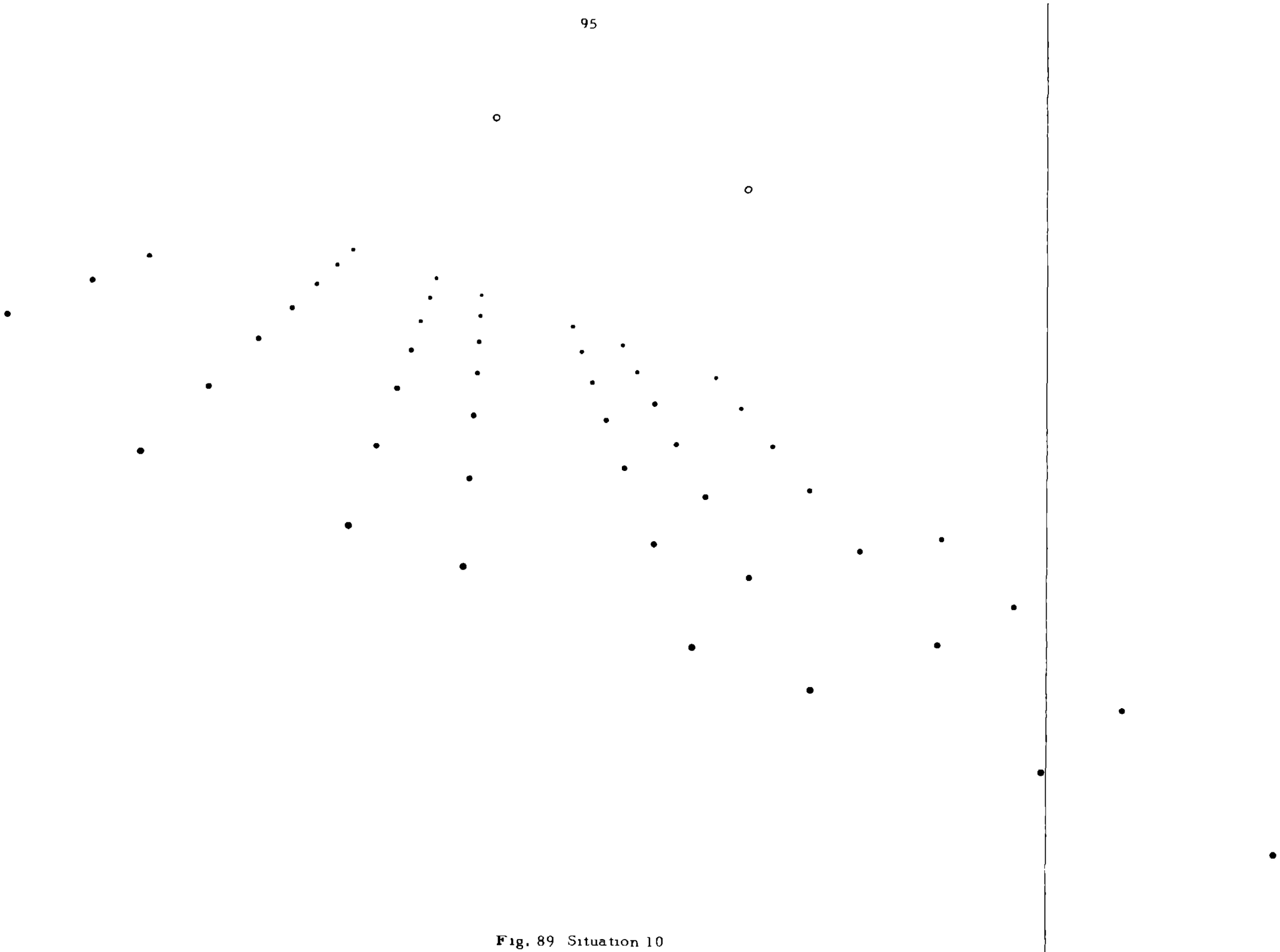

Fig. 89 Situation 10

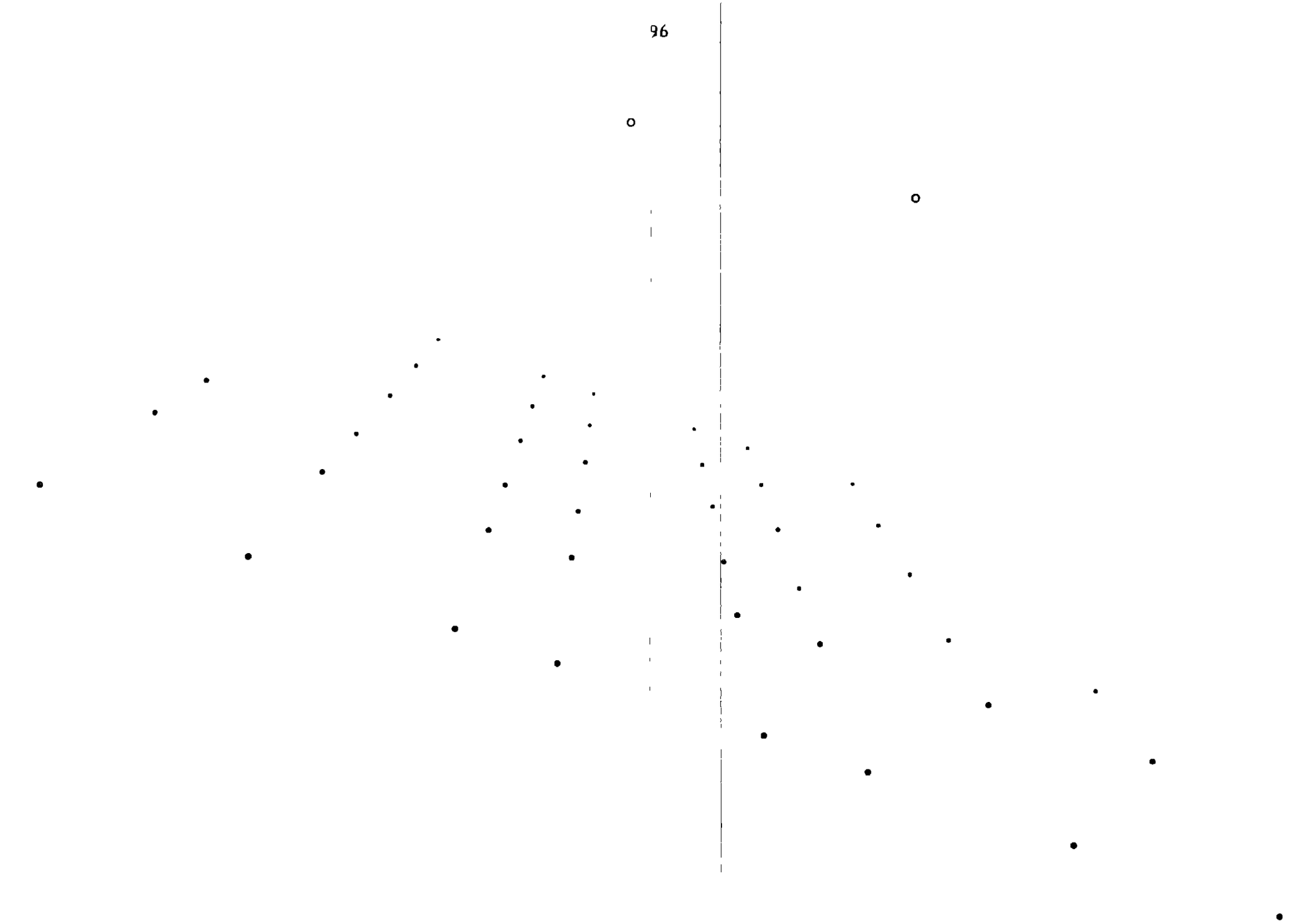

Fig 90 Situation 11

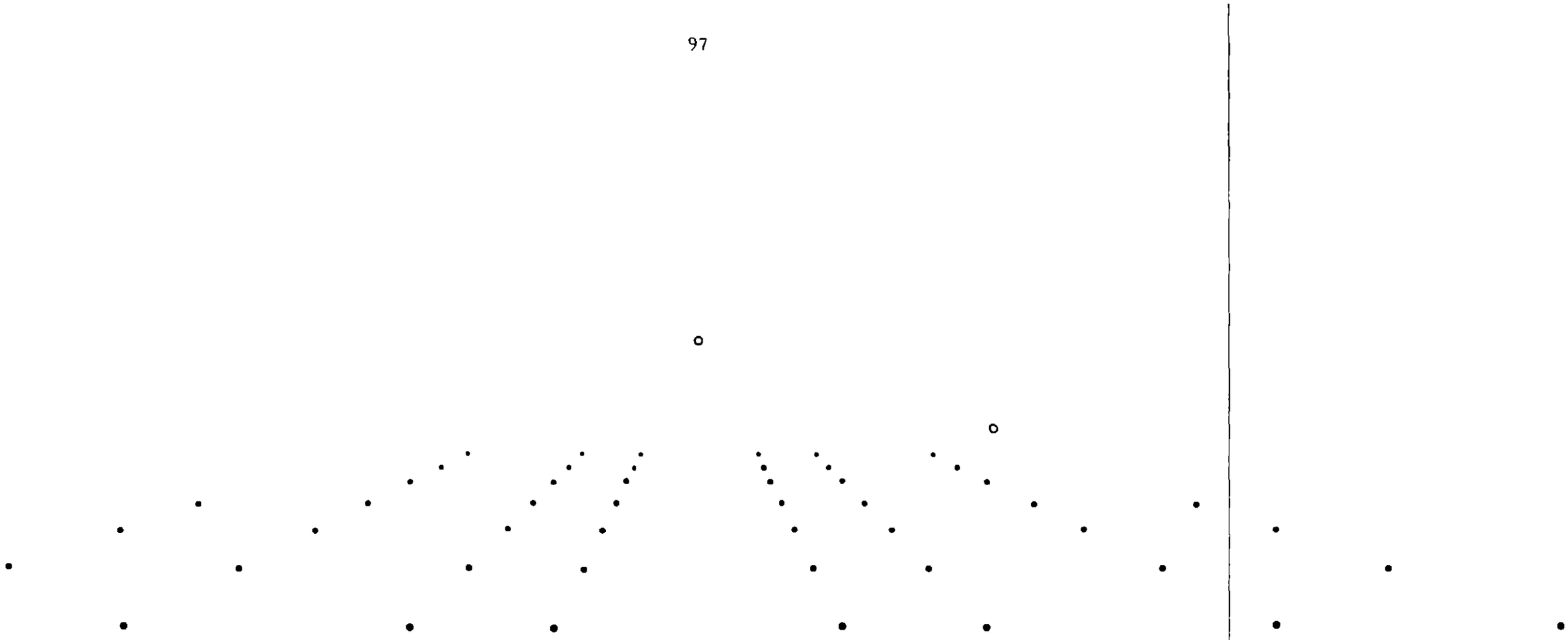

Fig 91 Situation 12

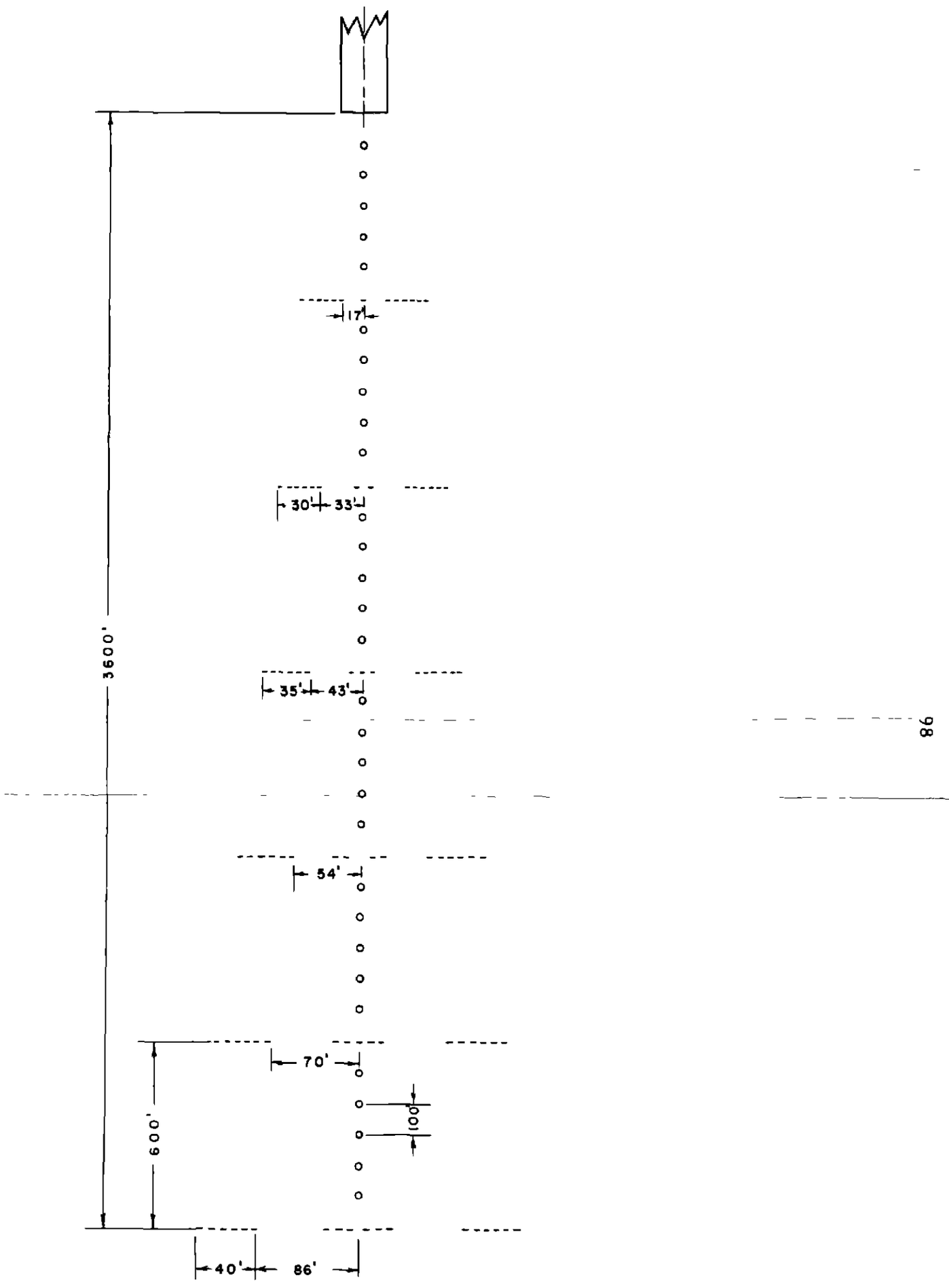

Fig 92 Diagram of the Calvert Bar Approach Light System

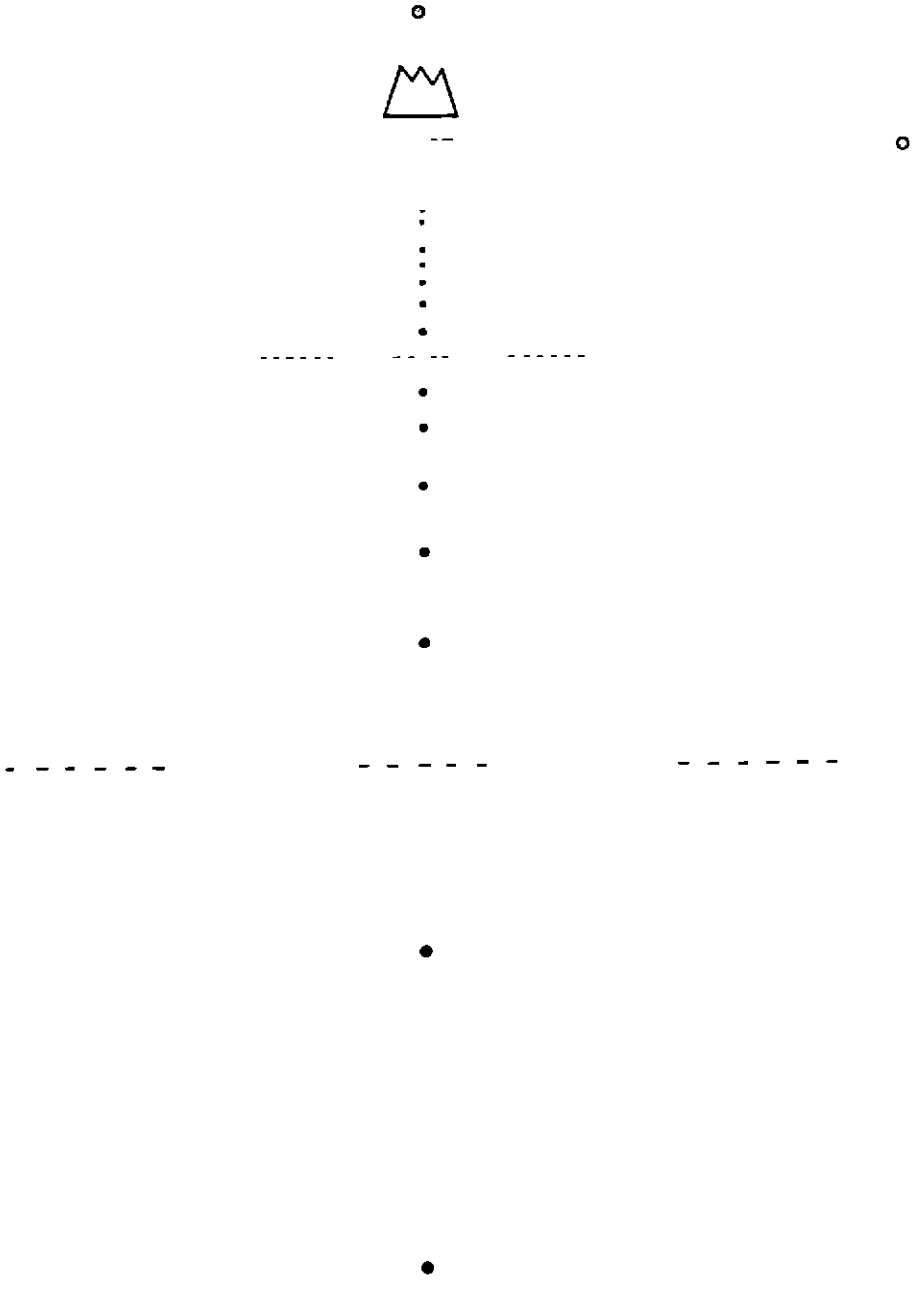

Fig 93 Situation 1

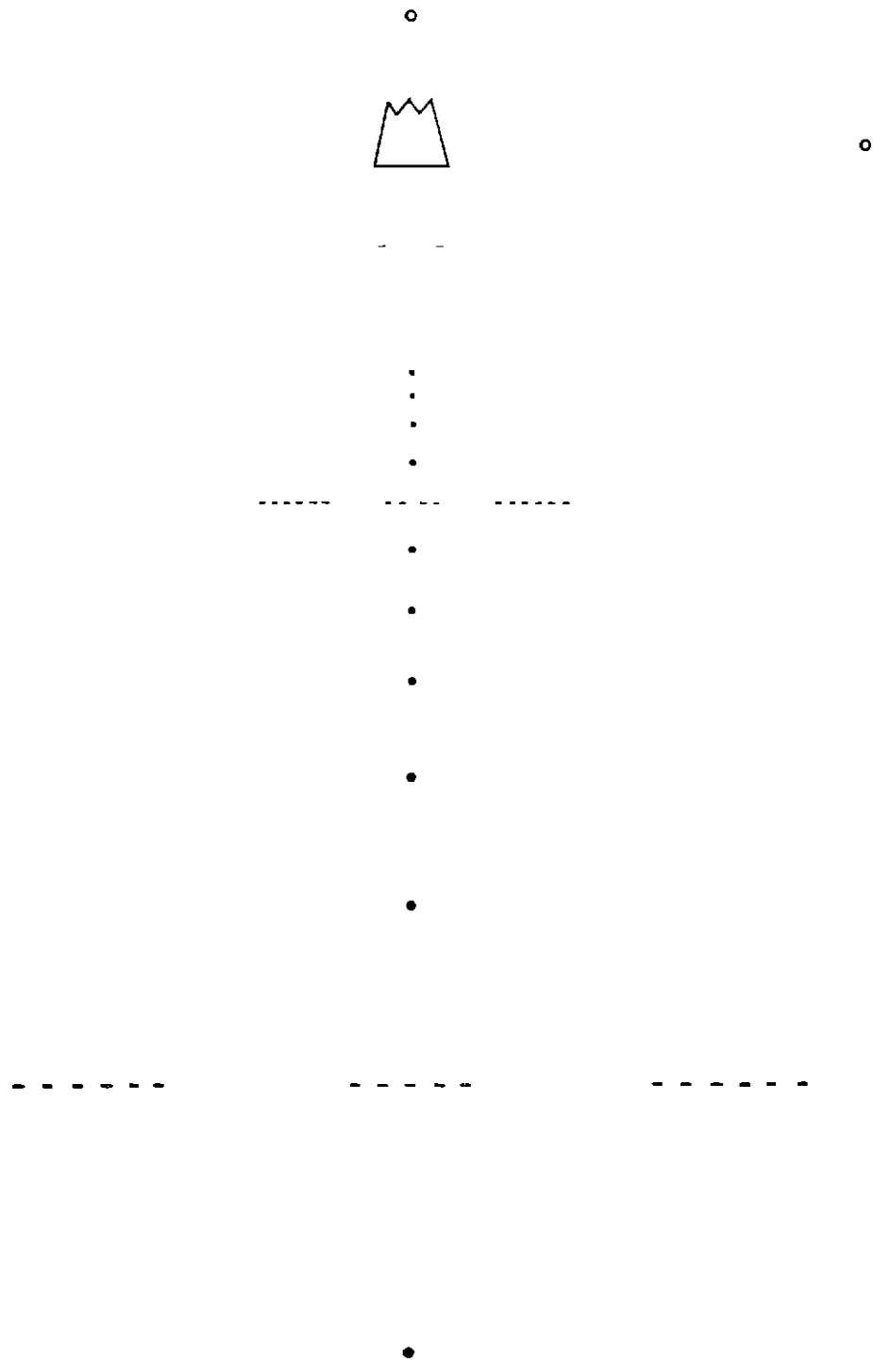

Fig 94 Situation 2

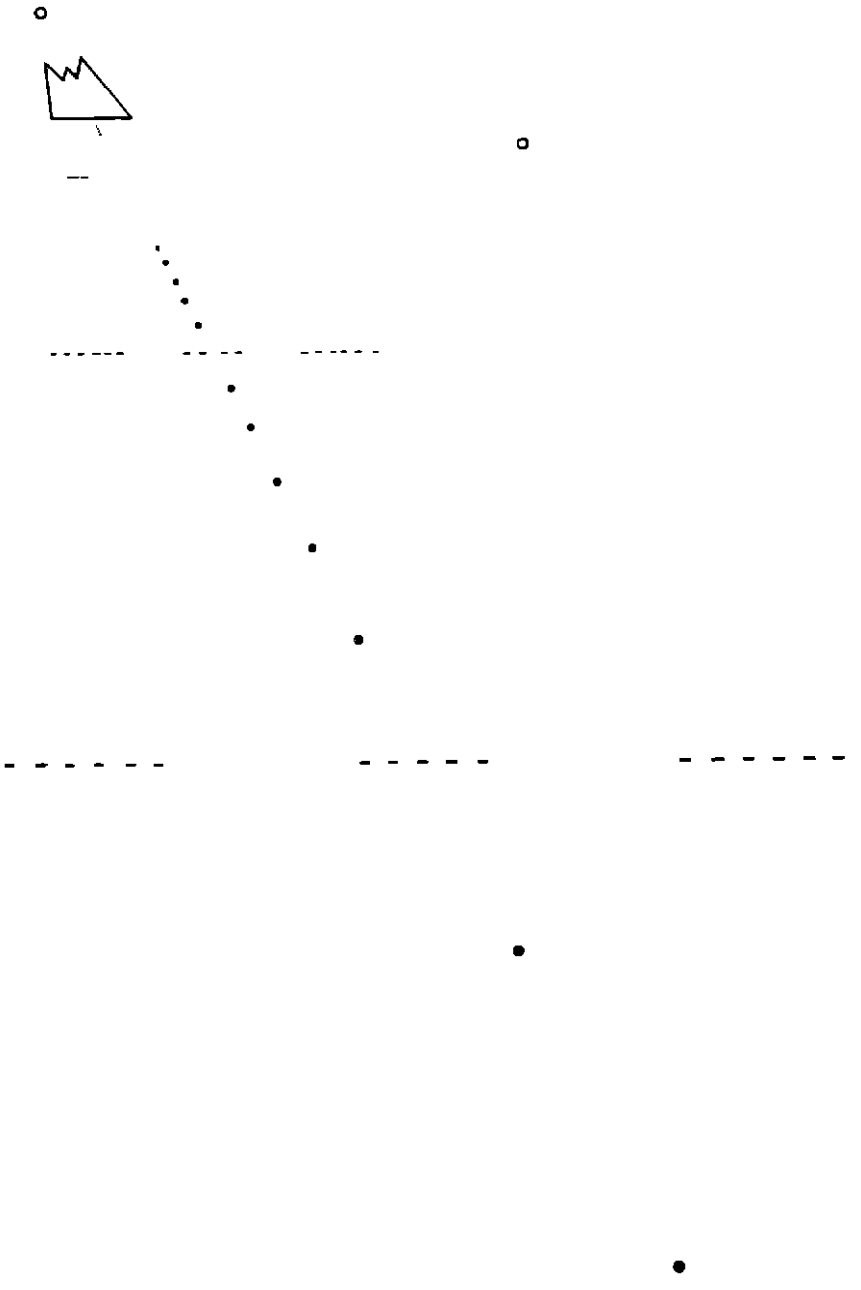

Fig. 95 Situation 3

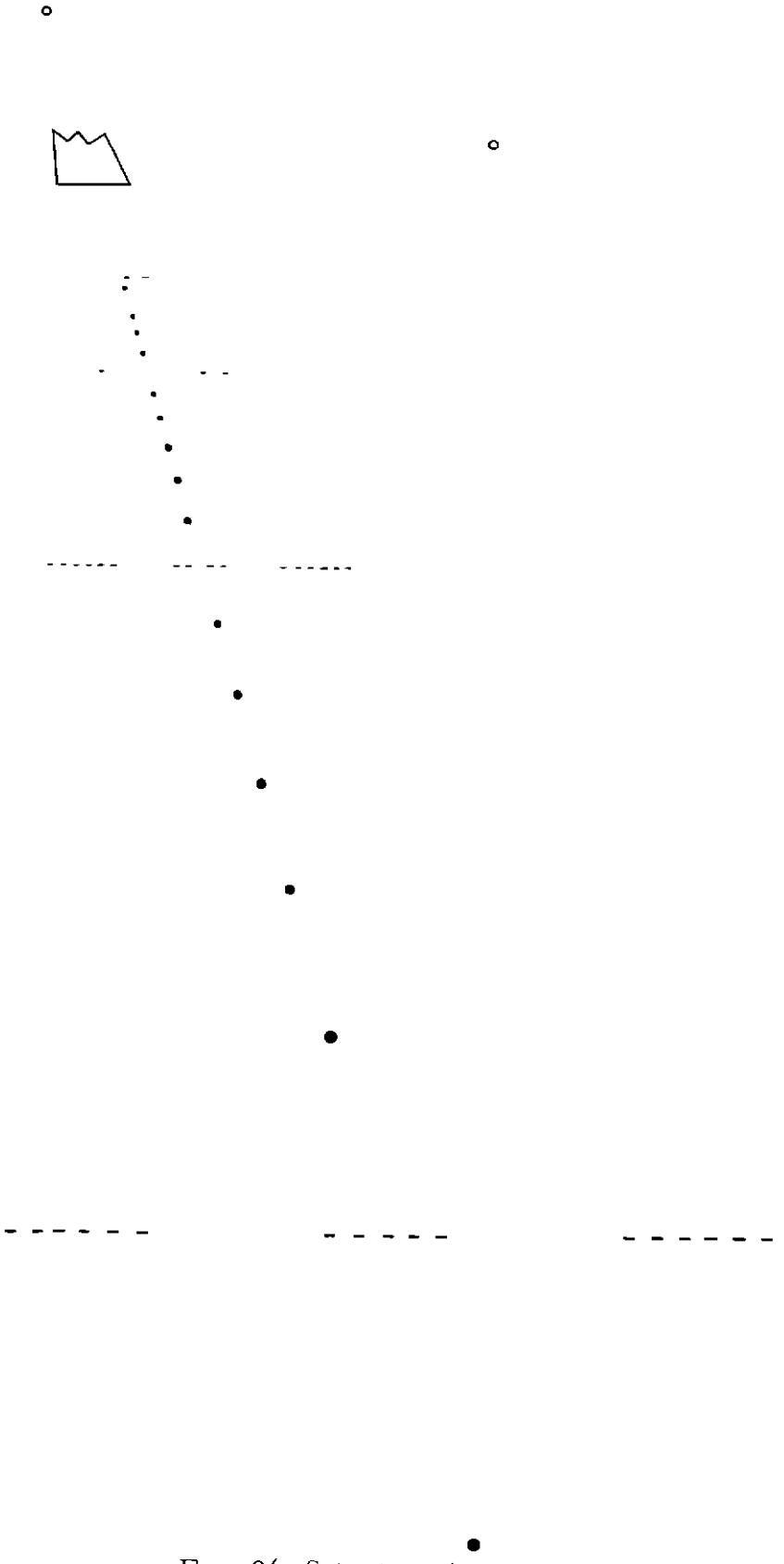

Fig 96 Situation 4

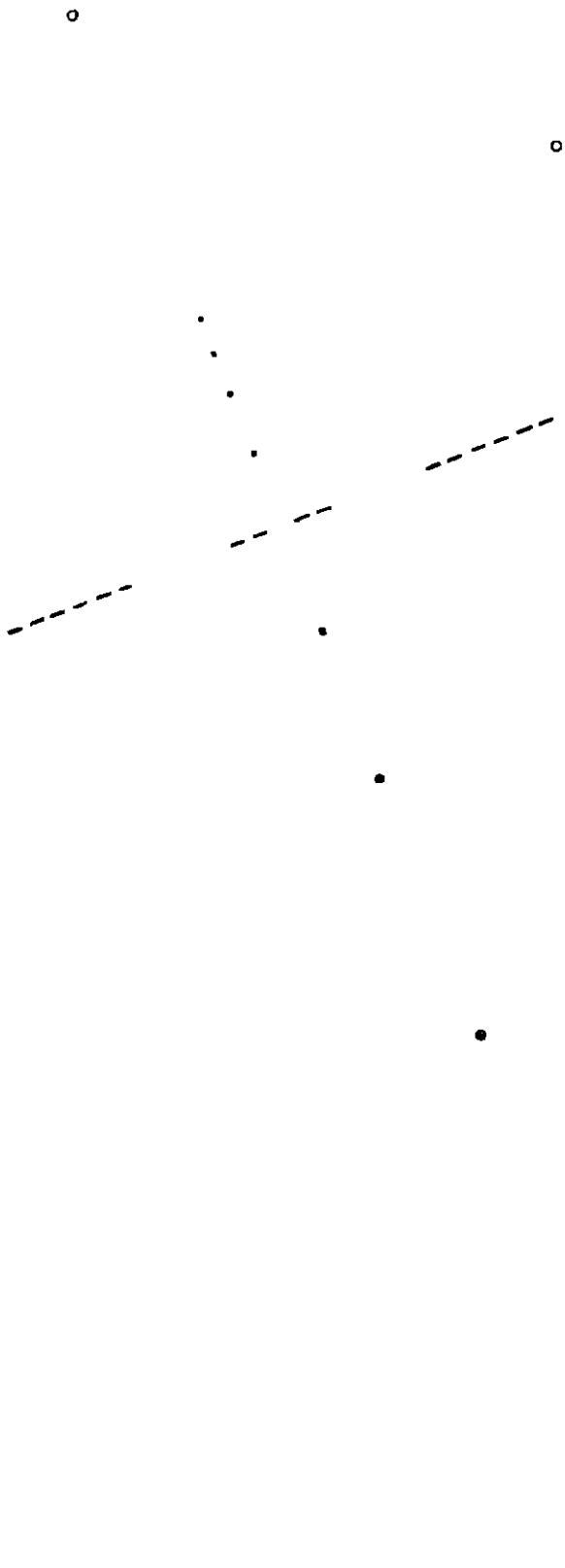

Fig 97 Situation 5

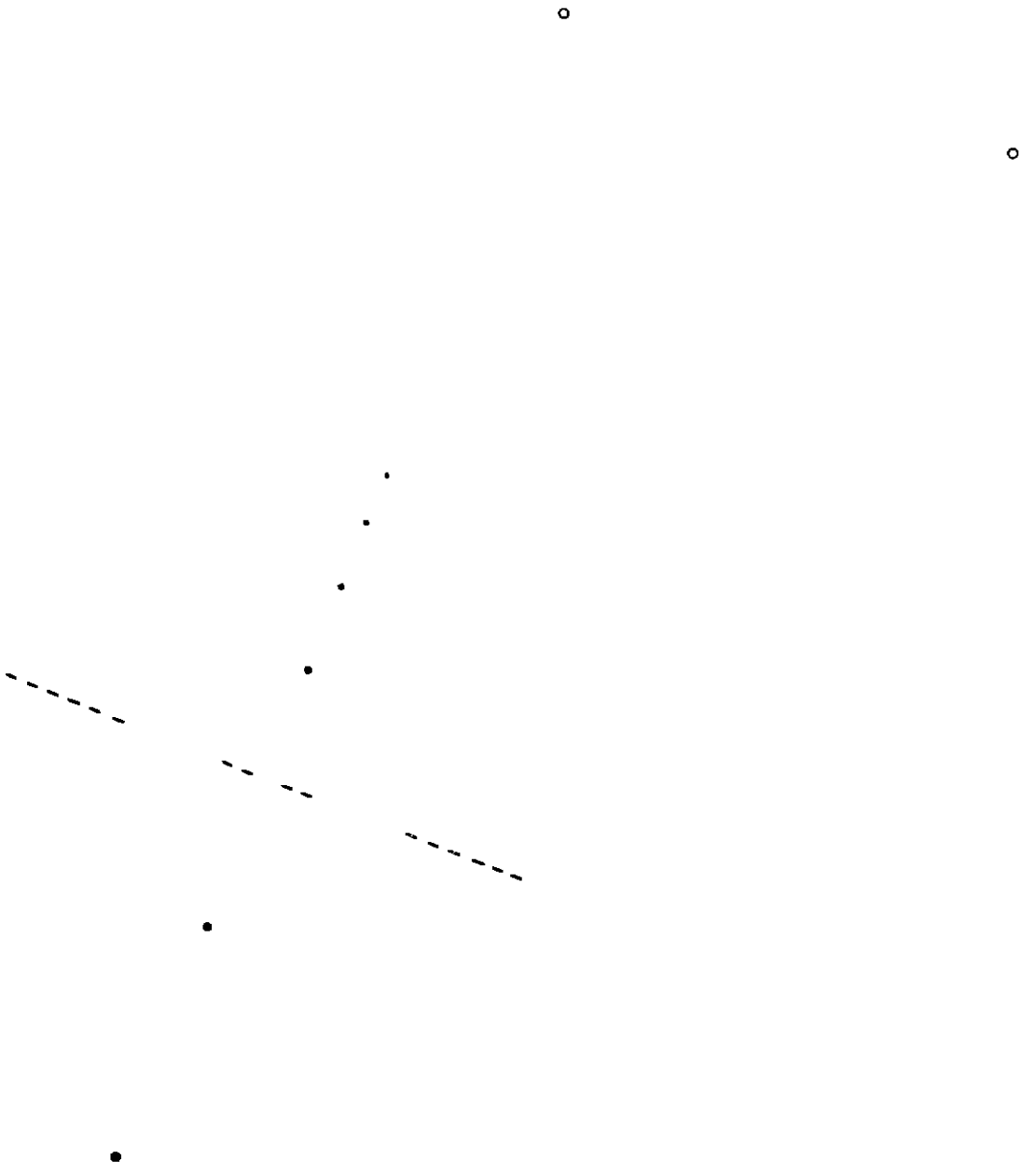

Fig 98 Situation 6

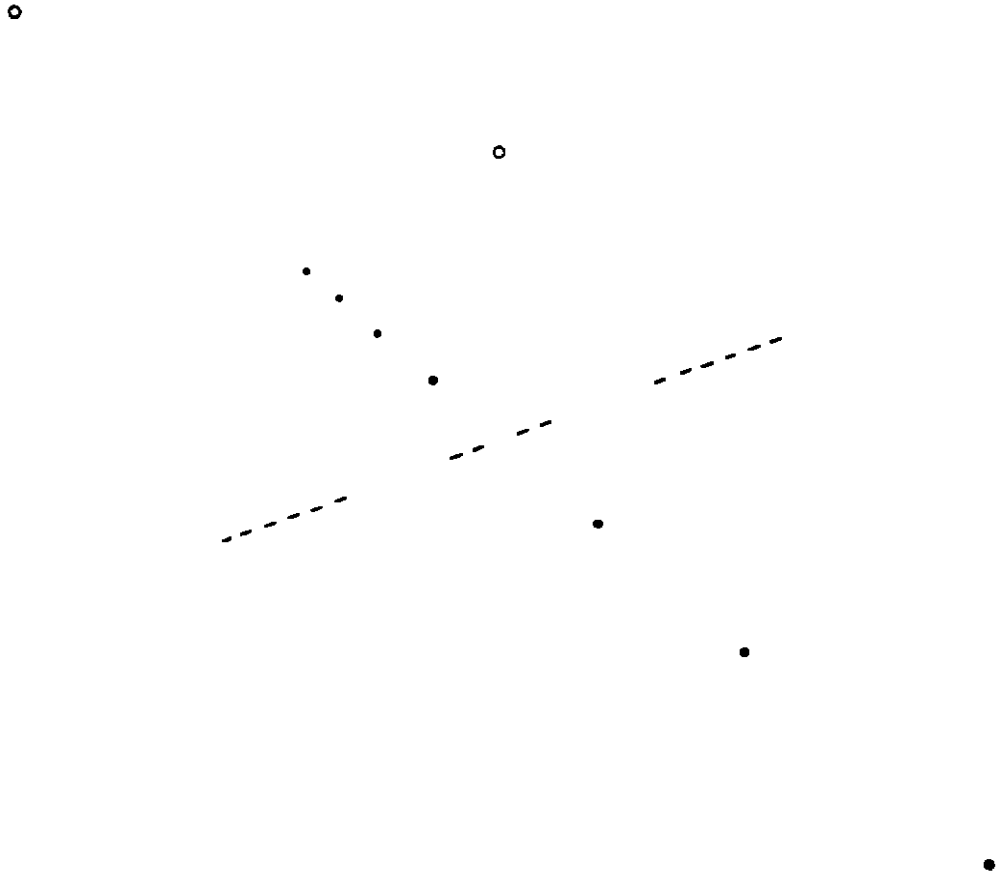

Fig 99 Situation 7

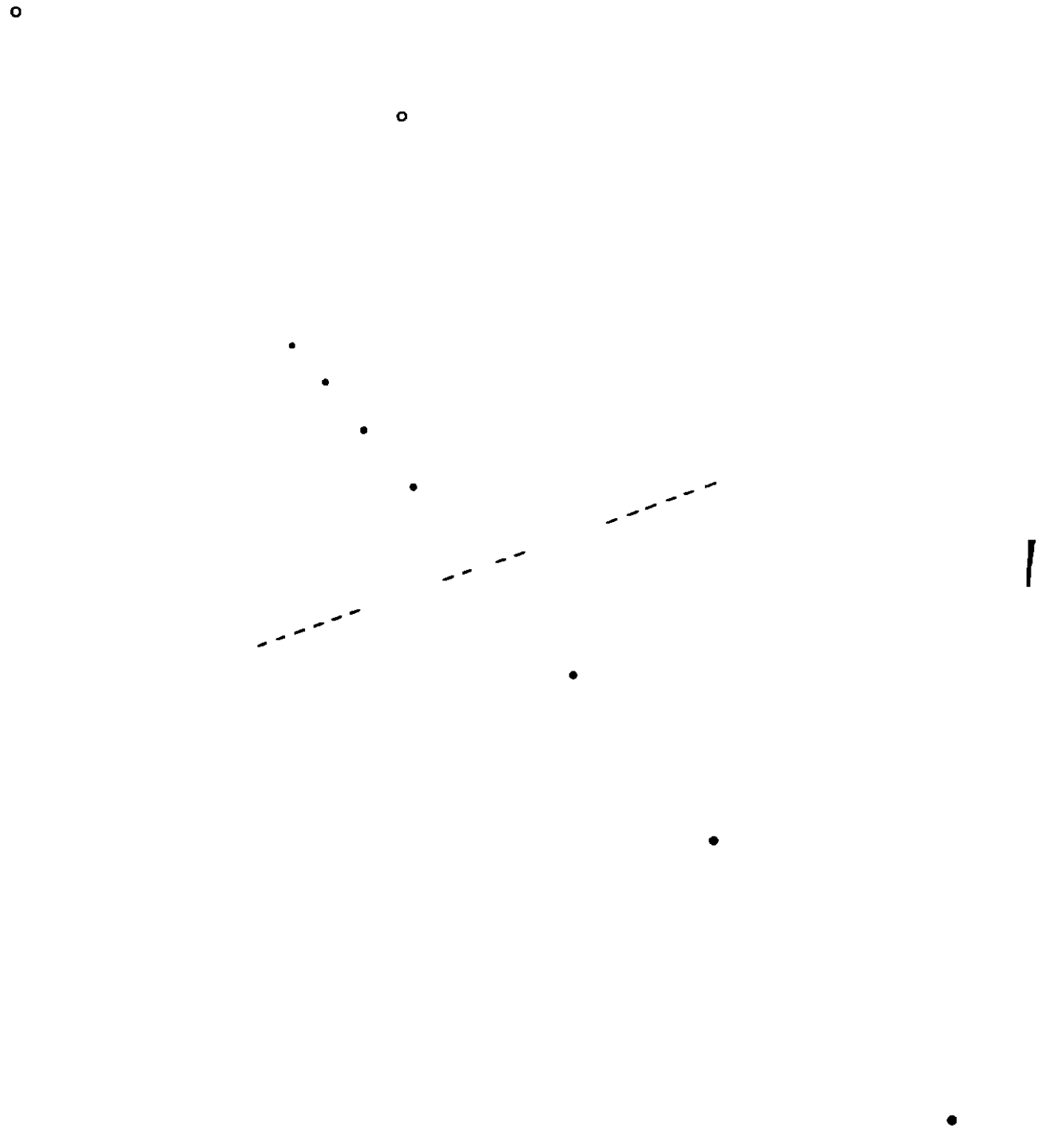

Fig 100 Situation 8

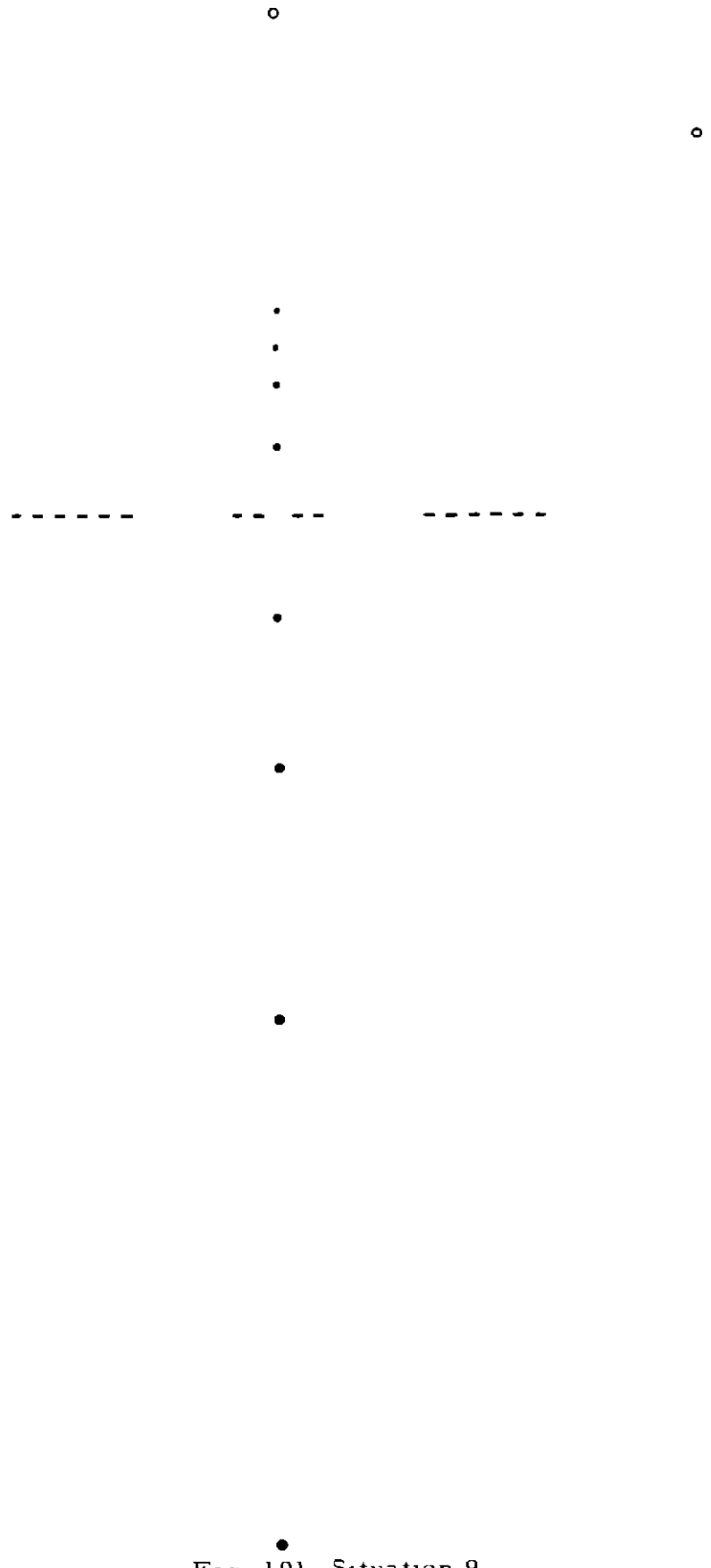

Fig 101 Situation 9

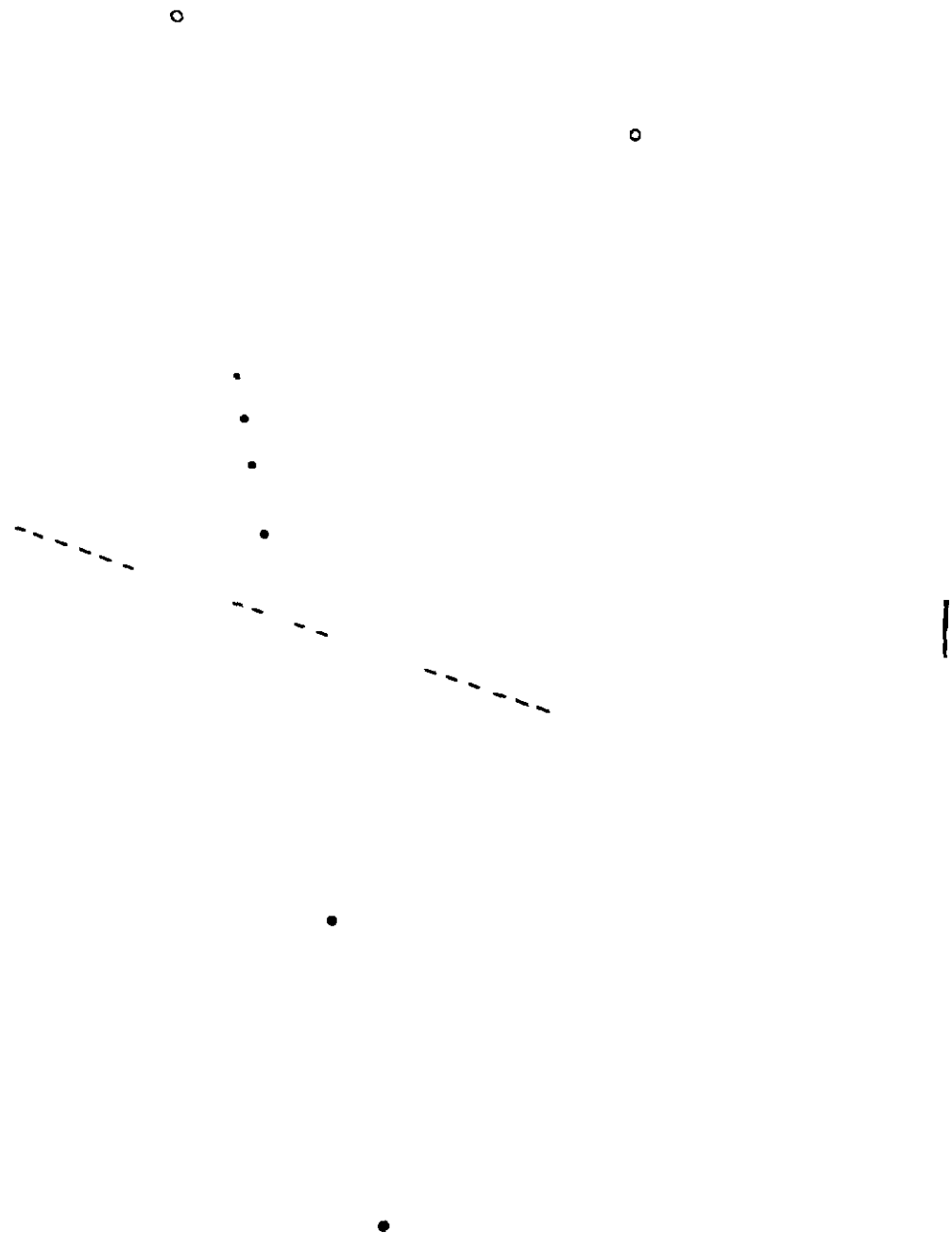

Fig 102 Situation 10

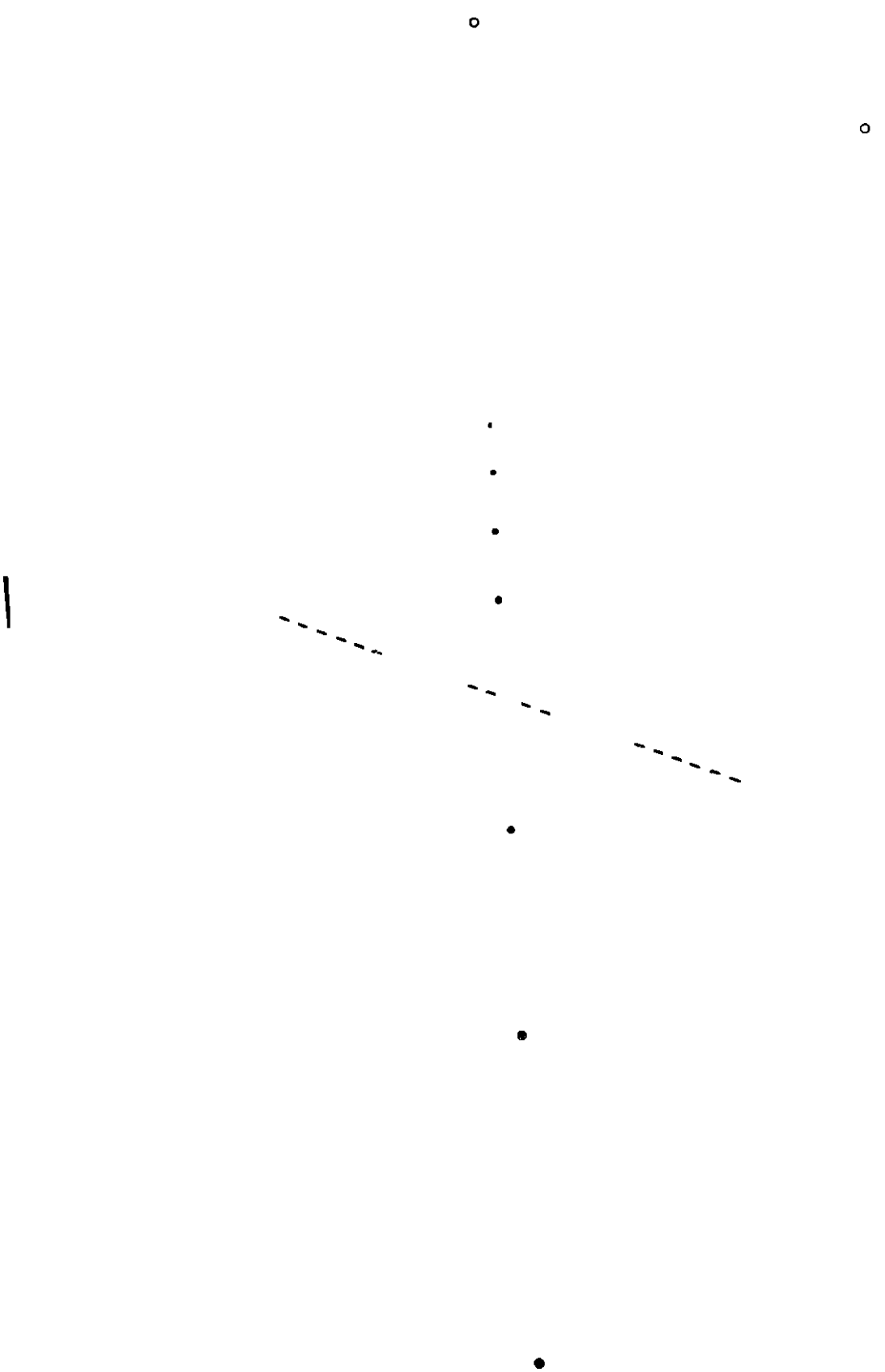

Fig 103 Situation 11

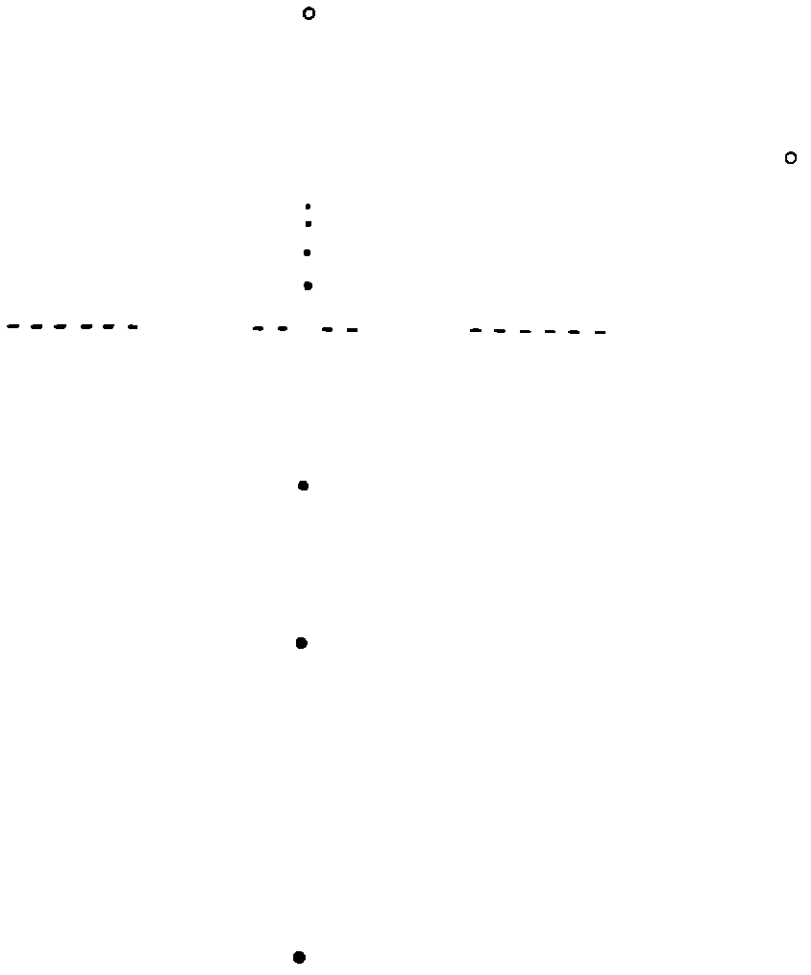

Fig 104 Situation 12

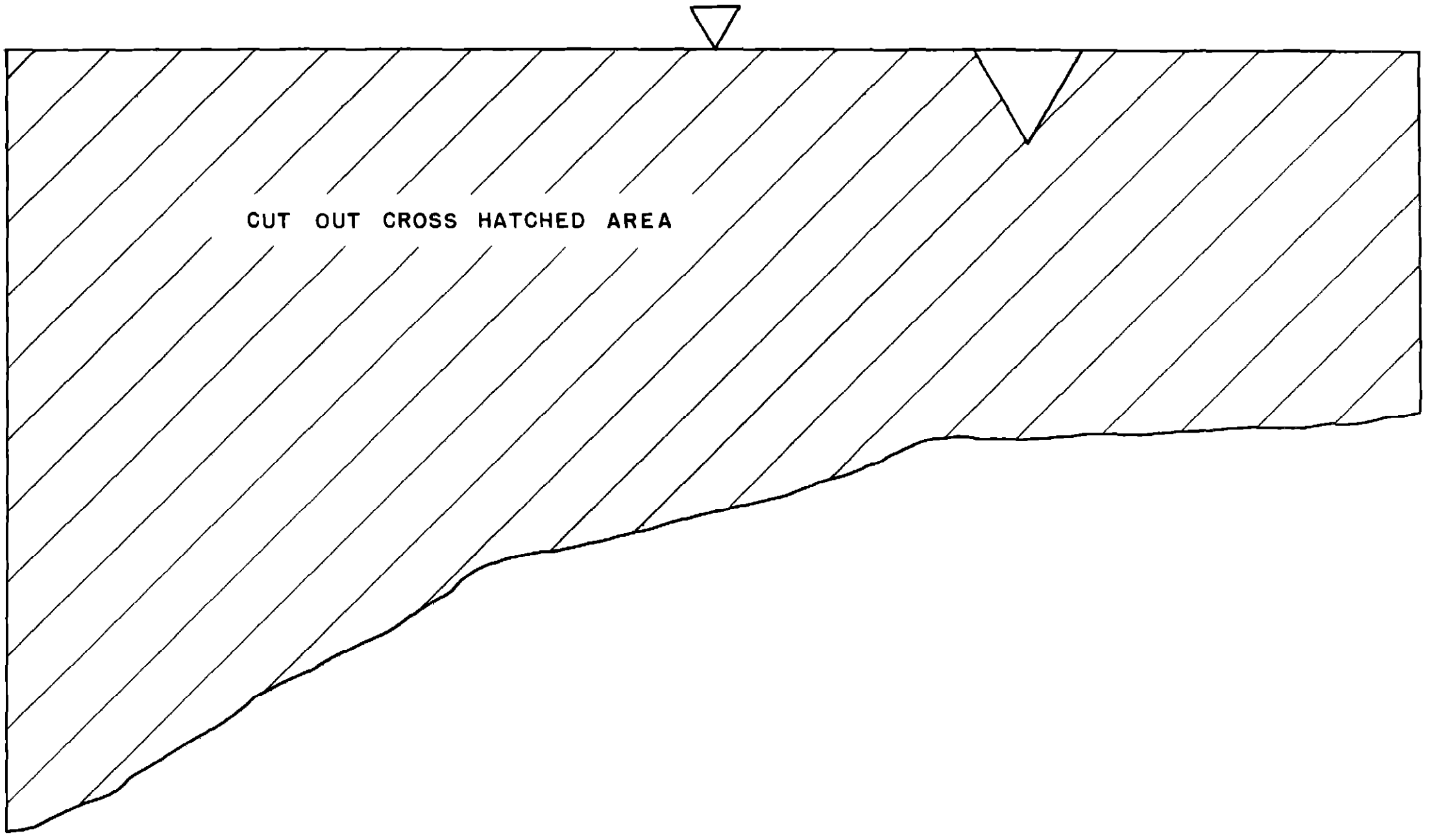

Fig. 105 Cockpit Cut-Off Diagram for DC-3 Aircraft Corrected for 5° Lowering of Nose During Approach

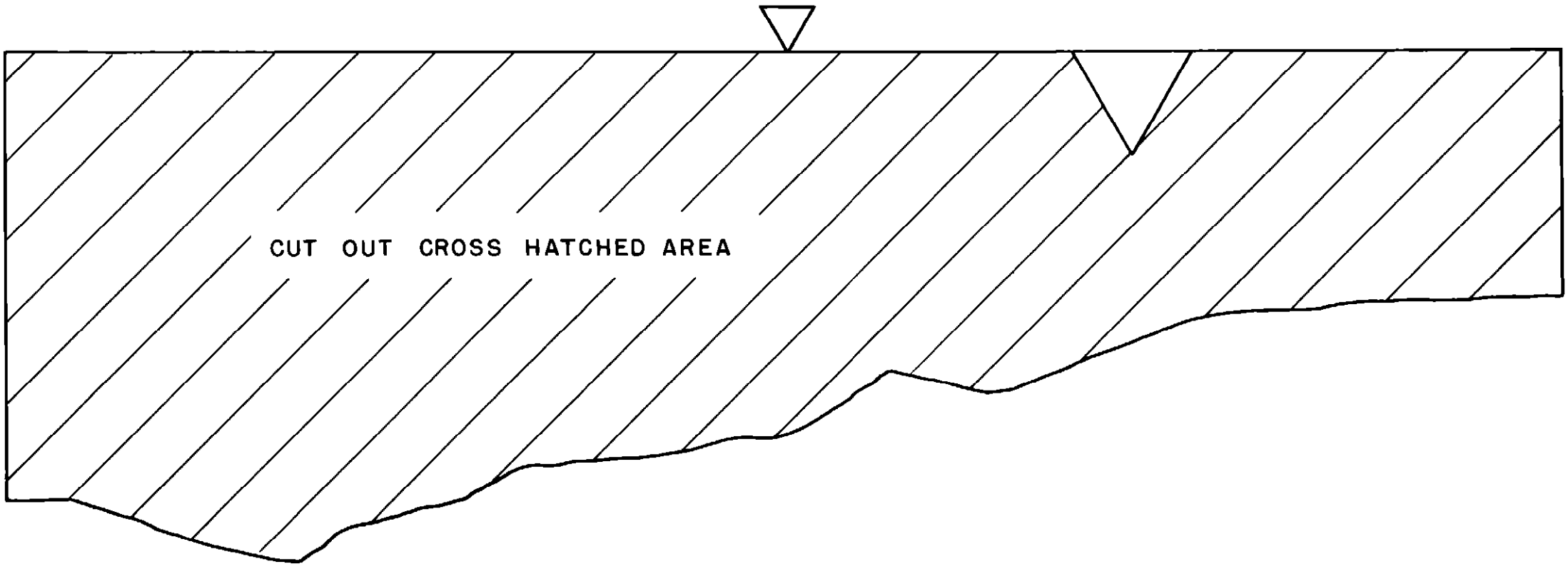

Fig. 106 Cockpit Cut-Off Diagram for DC-4 Aircraft Corrected for 5° Lowering of Nose During Approach

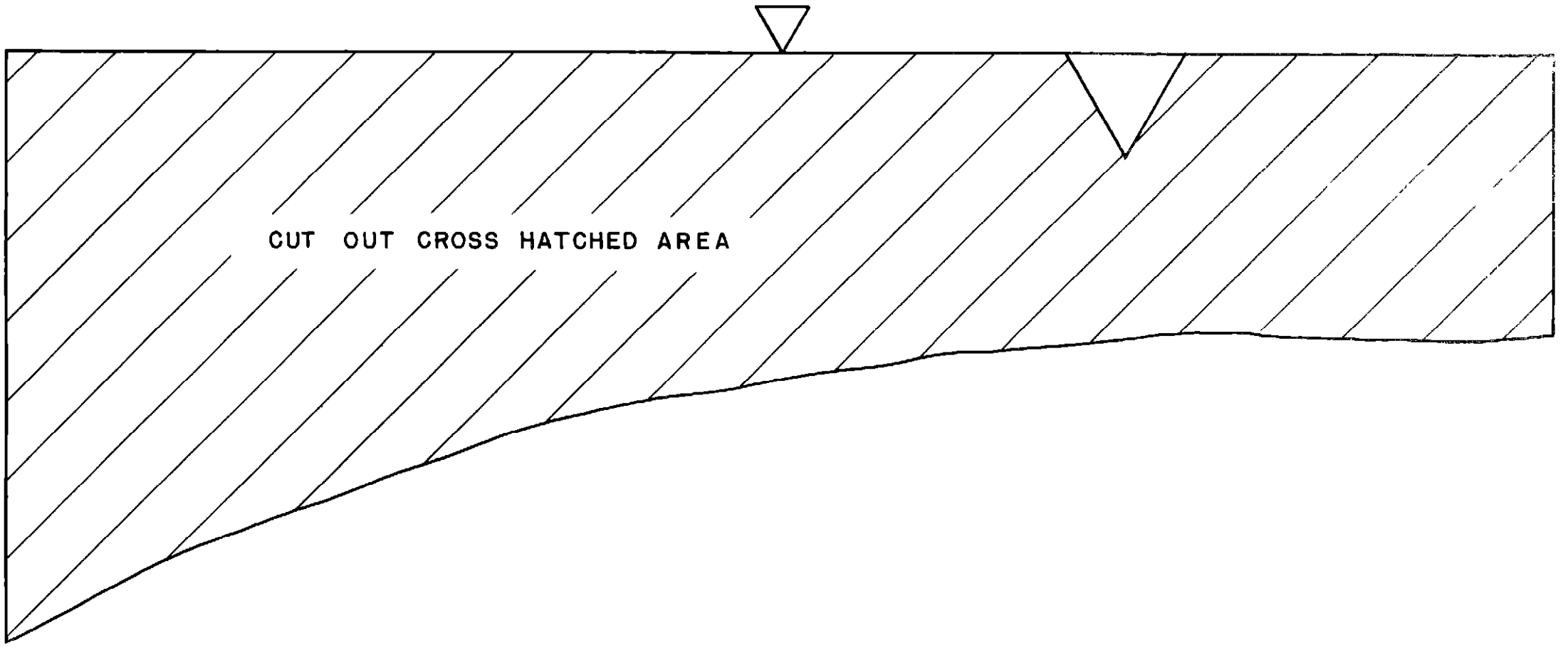

Fig. 107 Partial Cockpit Cut-Off Diagram for Lockheed Constellation Corrected for 3° Lowering of Nose During Approach

TABLE I

CONDITIONS EXISTING FOR EACH PERSPECTIVE STUDY

Situation Number	Lateral Position	Dist from Threshold (ft)	Altitude (ft)	Visibility	Airplane Attitude
1	Axis	3500	200	Unlimited	Level
2	Axis	3500	300	Unlimited	Level
3	100 ft Left of Axis	3500	200	Unlimited	Level
4	100 ft Left of Axis	3500	350	Unlimited	Level
5	Axis	3000	180	Limited	Banked
6	Axis	3000	280	Limited	Banked
7	100 ft Left of Axis	3000	180	Limited	20° Right
8	100 ft Left of Axis	3000	270	Limited	20° Right
9	Axis	3000	180	Limited	Level
10	100 ft Left of Axis	3000	180	Limited	20° Left
11	100 ft Left of Axis	3000	245	Limited	20° Left
12	Axis	3000	100	Limited	Level

TABLE II

COMPARISON OF INFORMATION FURNISHED BY EACH APPROACH LIGHT SYSTEM

	Direction	Altitude	Attitude	Lateral Position
Single Row on Center Line	Adequate if attitude is known	Inadequate	Inadequate Indication may be confused with error in lateral position	Inadequate Indication may be confused with error in attitude
Single Row Offset	Inadequate	Inadequate	"	"
Double Row	Adequate if attitude is known	Inadequate	"	"
Double Row with satellites	Adequate	Inadequate	Adequate	Adequate when attitude is level Otherwise inadequate
Funnel	Adequate if attitude is known	Inadequate	Inadequate Indication may be confused with error in lateral position	Inadequate Indication may be confused with error in attitude
Slope Line	Adequate	Adequate	Difficult to interpret if lateral error is present	Adequate
Path of Flight	Adequate	Inadequate	Adequate	Adequate when attitude is level
Multi-Line	Adequate if attitude is known	Inadequate	Inadequate Indication may be confused with error in lateral position	Adequate when attitude is level Otherwise inadequate
Calvert	Adequate	Inadequate	Adequate	Adequate when attitude is level Otherwise inadequate