DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE WEATHER AGENCY (AFWA)
OFFUTT AIR FORCE BASE, NEBRASKA

AFWA/CC
106 Peacekeeper Dr STE 2N3
Offutt AFB NE 68113-4039

31 AUG 1999

Mr. John Greenewald, Jr.

Dear Mr. Greenwald

We received your Freedom of Information Act request, dated 28 Jun 99, referred to our office by 11 CS/SCSR and received in our office on 12 Aug 99. In accordance with DoD 5400.7-R, your fee category of "Other" results in assessable search and duplication costs of less than $15.00; therefore, we have waived your fees.

Attached is the document, Radioactivity Fall-out and Radex Plots, responsive to your request for which Air Force Weather Agency is the releasing/denial authority.

If you have any questions concerning your request, please refer to AFWA #99-005 when you contact us. The point of contact in this agency is Arline Rockwood, HQ AFWA/SCB, at the above address or at phone (402)294-6265.

Sincerely

Charles W. French

CHARLES W. FRENCH, Colonel, USAF
Commander

Attachment
AWSM 105-33, Radioactivity Fall-out and Radex Plots, 2 June 1952

AWSM 105-33

AIR WEATHER SERVICE MANUAL

RADIOACTIVITY FALL-OUT AND RADEX PLOTS

2 JUNE 1952

DEPARTMENT OF THE AIR FORCE

AIR WEATHER SERVICE
MANUAL 105–33*

HEADQUARTERS
AIR WEATHER SERVICE
WASHINGTON, D. C., *2 JUNE 1952*

Foreword

1. General. AWS Manual 105–33 is published for the information and guidance of all concerned.

2. Purpose. This manual outlines methods for determining areas which may be contaminated with radioactive particles after explosion of an atomic bomb.

3. Scope. The procedures contained in this manual are intended as a guide to construction of radioactivity fall-out and RADEX plots.

4. Supply of Manuals. Additional copies of this manual may be obtained in accordance with the provisions of paragraph 4a of AWS Letter 5–3. The stock of this manual will be located at Wilkins Air Force Base, Shelby, Ohio.

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* This manual supersedes AWSM 105–33, "Radioactivity Ground Fall-Out Plot," dated 1 August 1951.

Contents

Section 1000

GENERAL

1100. PURPOSE

This manual has been prepared to give instructions to Air Weather Service personnel on some of the methods used to locate potential radioactive areas after the explosion of an atomic bomb.

1200. FALL-OUT

The term "fall-out" refers to contaminated, radioactive material in the bomb cloud which, when acted upon by gravity and winds aloft, drops to lower levels. This material is composed of particles of the bomb itself, plus—if the bomb explodes near enough to the surface—particles of earth or water carried aloft by the explosion.

1210. In the early days of atomic weapons, it was popularly believed that fall-out, and consequent contamination of the earth's surface, was a very serious danger. The radiation hazard was overemphasized at the expense of the blast and thermal effects, which are actually of much more importance in producing casualties. As more information became available, and after further tests, the original conception proved to be erroneous. In fact, in "The Effects of Atomic Weapons" (U.S. Government Printing Office, page 35, paragraph 2.30) it is concluded that: "Only in exceptional circumstances would fall-out constitute a hazard upon reaching the ground." These circumstances would occur if the bomb burst near the ground, in which case great amounts of dirt and debris would be sucked up into the cloud. The same situation might exist if the bomb were exploded at low levels over water.

1300. REQUIREMENT FOR THIS MANUAL

According to U.S. opinion, the greatest *total* destruction is *not* obtained from a low level burst, and such use of an atomic bomb would be an uneconomical employment of an expensive weapon. If we assume that all other potential users of atomic bombs share this belief, and then further assume that there is small likelihood of an accidental low-level burst, then calculation of fall-out (at least for the surface) would be of little or no value.

1310. Recognition of even a remote possibility of either a deliberate or accidental low-level explosion sets up a requirement for predicting potential areas of contamination on the surface, or at levels aloft where some contamination is possible regardless of the height of the explosion. Air Force base radiological defense plans usually include a reference to the base weather station as the local agency responsible for predicting areas of contamination. This manual has been published to serve as a guide in preparing such predictions.

1400. TYPES OF BURSTS

Based on the location of the fireball with respect to the surface of the earth, there are three types of atomic bomb explosions. Features of each are briefly discussed below, and illustrated in a very general manner in figure 1.

1410. Air Burst—the fireball, assumed to be about 500 feet in diameter, does not intersect the earth's surface. Particles in the bomb cloud are very light, and ascend to great heights (probably to the tropopause). Very little, if any, surface contamination exists. Nearly all of the damage and casualties are caused by the blast and thermal effects of the bomb, and no fall-out computation for the surface is normally required.

1420. Surface Burst — the fireball intersects the surface, and the explosion point is at or above the surface, but below 500 feet. In this case it is probable that large quantities of fairly large particles are sucked up by the bomb cloud, some of which reach the tropopause. These particles fall out at fairly large distances from the explosion point, depending (among other things) on weather conditions.

1430. Sub-Surface Burst—the point of explosion is below the surface. This type of burst results in a tremendous amount of material being blown aloft, and contamination *near* the explosion point is very heavy.

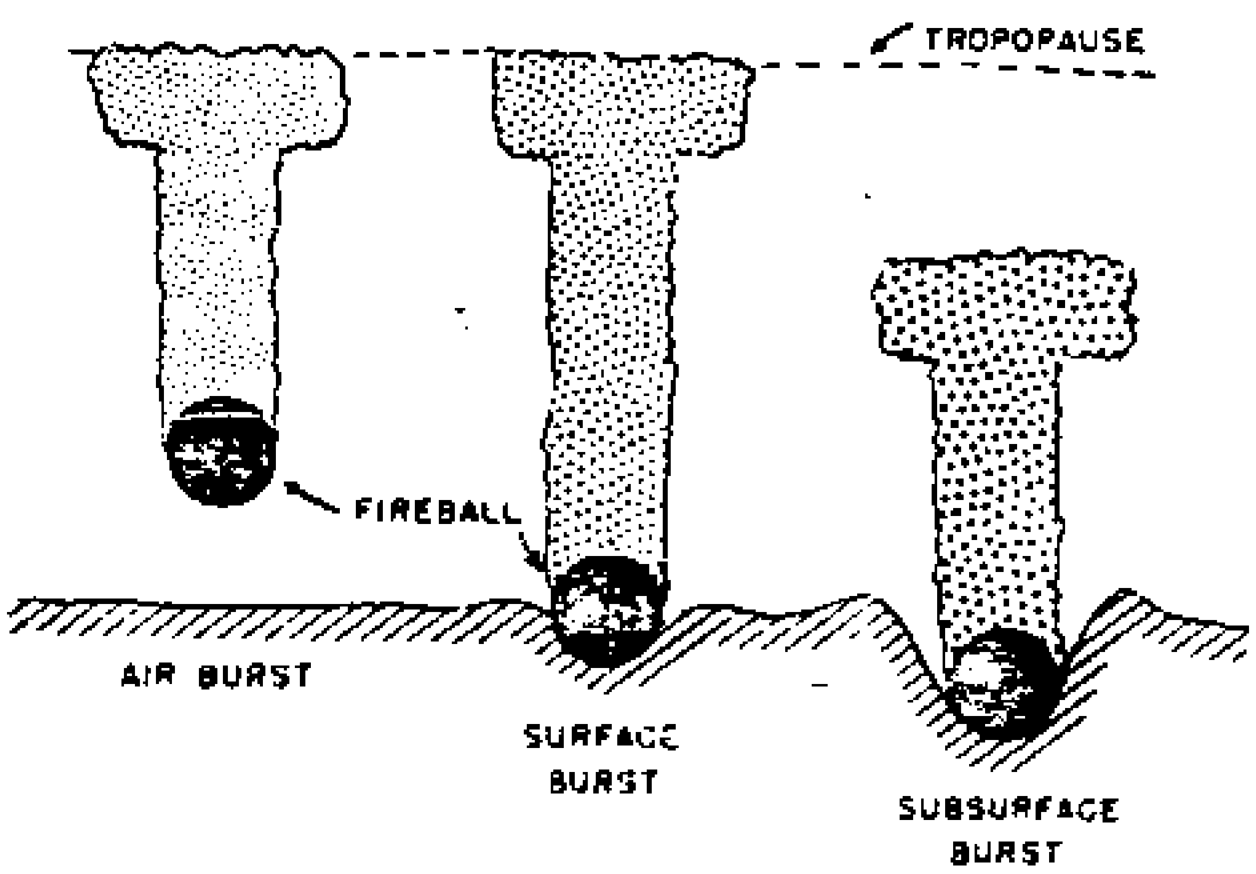


FIGURE 1. *Probable height of burst and relative contamination.*

1500. SURFACE BURST

Large amounts of material can be carried for long distances following a surface burst. Fall-out plots made for this type of burst will often show a large area of contamination. The distance a particle will move from the origin depends upon the following considerations:

1510. *The size of the particle.* When acted on by the same wind, large particles will fall out sooner (closer to the burst point) than small ones.

1520. *The wind speed.* A particle acted upon by a 75 knot wind will be blown farther from the origin than if the wind were only 20 knots.

1600. RADIOACTIVITY PLOTS

There are two basic plots which can be used to locate areas of fall-out. Other systems are used, but they are usually adaptations of those described below.

1610. *Ground fall-out plots.* In this method, all fall-out is assumed to have terminated. The plot gives the maximum probable area of surface contamination and, by considering particle size, this area is subdivided into portions where "heavy" and "light" contamination can be expected.

1620. *Radex plots.* These consist of—

1621. Ground radex plots, which can be made *for any time* after the explosion, before or after complete fall-out. This latter case is another method for determining ground fall-out, although radex plots do not define separate areas of heavy and light contamination.

1622. Air radex plots, which are made for a selected level in the air, at a specified time. These plots are obviously of considerable significance in the operation of aircraft near the vicinity of a bomb burst.

1700. OTHER CONSIDERATIONS

1710. For purposes of radioactivity plotting, a contaminated particle is assumed to have a constant and unvarying amount of radioactivity, and the largest particles are assumed to have the most radioactivity. Actually, there is a natural decay of radioactivity exponentially with time. That is, the amount of radioactive energy in a particle five minutes after the explosion is a great deal more than remains in the same particle 30 minutes later. The ground fall-out and radex plots given in this manual do not take this decay into account; they merely establish the location of radioactive particles. Although the actual amount of radiation present in these locations could be measured by "meter readers," such a determination is the responsibility of agencies other than base weather stations.

1720. If rain or snow occurs along the path of the smaller particles, they will adhere to the falling precipitation and fall out closer to the origin point. The plots discussed in this manual make no attempt to take into account this decrease in the area of contamination.

1730. As a final simplification, the plots given in this manual assume that the winds aloft over the explosion point are not affected by the explosion itself, and vertical currents are disregarded. This may or may not be the case, since it seems reasonable to assume that the tremendous thermal effects of a burst would alter the vertical wind structure, but the nature and extent of the effect is obviously an intricate problem beyond the scope of this manual.

1800. USE OF THIS MANUAL

The background, uses and limitations of radioactivity plots, as outlined in section 1000, should be thoroughly understood by weather forecasters and observers before proceeding to make the actual plots. Section 2000 of this manual gives a suggested list of equipment.

1810. The basic diagram in radioactivity plotting is a wind vector diagram. This is explained in section 3000.

1820. Section 4000 gives detailed instructions for making ground fall-out plots; section 5000 gives the procedures for Radex plots. Each of these sections contains running examples, all of which employ the same wind vector diagram constructed in section 3000.

1830. The tables contained in section 6000 will materially speed up the production of plots, and the appendices are also designed for quick reference.

Section 2000

EQUIPMENT

2100. GENERAL

The material listed in this section should be assembled into a kit to be kept in a convenient location in the base weather station.

2110. *Maps.* Large scale maps of the local area (extending at least 200 miles radially from the base) should be procured. Standard Aeronautical Flight Charts (FC Series), which have a scale of 1: 1,000,000 will probably be the easiest to use. However, it may be more advantageous to employ other types of maps to meet local requirements.

2120. *Tracing Paper.* Sheets of a good grade of tracing paper should be obtained. These should be about 24 x 24 inches. Two sheets will normally be required for each plot.

2130. *Protractor.* A protractor, preferably 4 to 8 inches in diameter and either 180° or 360°, will be required.

2140. *Compass.* An ordinary drafting compass will be needed in making Radex Plots.

2150. *Scales.* A steel or celluloid straightedge, large triangle, or T-square should be obtained. It will be found helpful to mount a map scale applicable to the base map to be used. Appendix B gives details on construction of map scales.

2160. *Twenty Degree Marker.* A twenty-degree angle, cut from cardboard (or, preferably, plexiglass), will be useful in making ground fall-out plots. Mark the line bisecting this angle, as shown in figure 2.

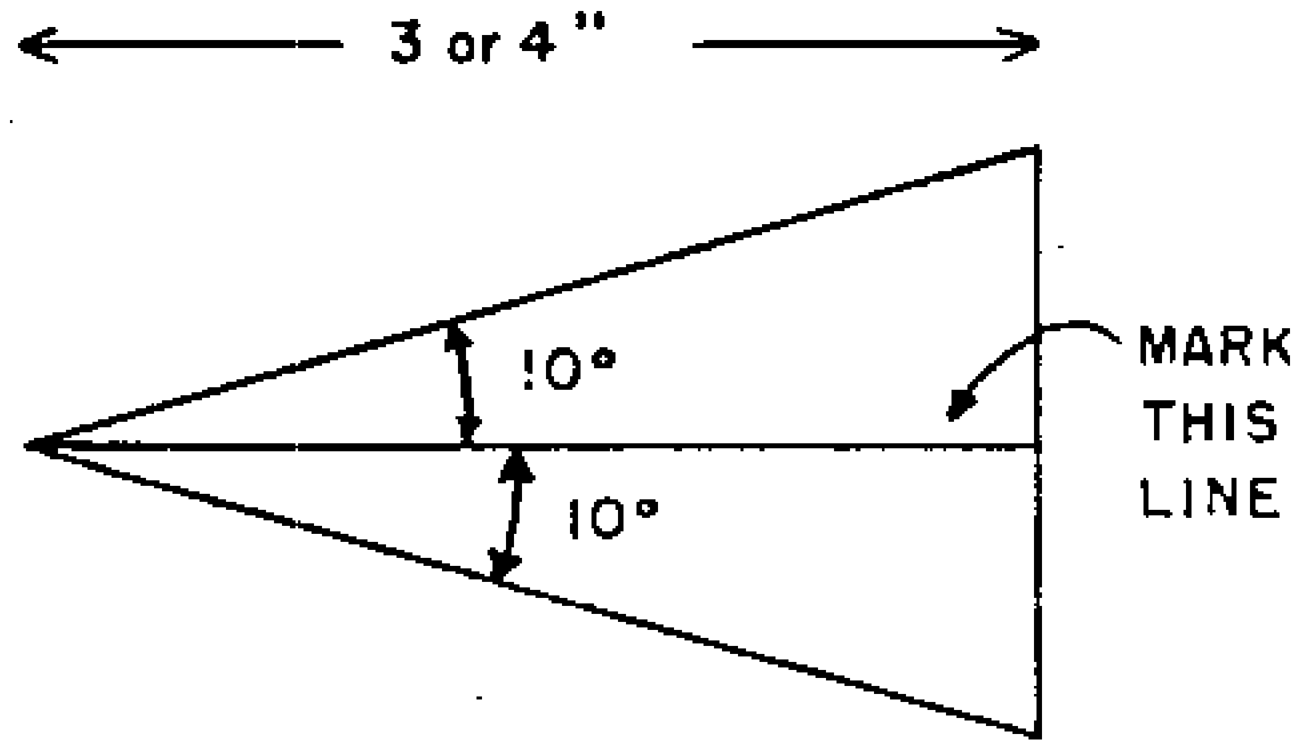


FIGURE 2. *Twenty degree marker.*

2170. *Pencils.* Black 3-H or 4-H pencils and red and blue pencils should be available.

2200. DATA SHEETS

The data sheets illustrated in figures 3 and 4 may be locally duplicated and used for tabulating data. Different sheets are required for ground fall-out and radex plots since procedures vary slightly.

2300. MANUALS

2310. *AWSM 105-33.* One copy of this manual should be kept in the kit.

2320. *AWSM 50-1.* One copy of this manual ("Radiological Defense for Weather Forecasters") should also be available as a reference for radiological defense officers, and as a source of information on more advanced techniques.

2330. *AWSM 105-21.* One copy of this manual ("Upper Wind Codes") should be available for decoding wind data to be used in the wind vector plot. This manual contains decoding instructions on all upper wind codes, U.S. and foreign.

GROUND FALL-OUT DATA SHEET

COMPUTED__________________195 BY__________ BASE WEATHER STATION________

Column #	1	2	3	4	5	6	7	8	9
	Wind			Vectorial sum	Divided by	Mean wind speed	Distances		
	Direction Deg True	Speed					Min	Mean	Max
		Knots	MPH						
Sfc									
5,000									
10,000									
15,000									
20,000									
25,000									
30,000									

WINDS ALOFT DATA: TIME________________ STATION__________________________

REMARKS:

FIGURE 3. *Ground fall-out data sheet.*

RADEX PLOT DATA SHEET

________________LEVEL

TIME AFTER BURST____________HRS

COMPUTED______________195___ BY________________ BASE WEATHER STATION____________________

Column #	1	2	3	4	5	6	7	8	9	10
	Wind			Vectorial sum	Divide by	Mean wind speed	Time of fall (hours) (ground plot)	Time after burst-hours air radex	Displacement (Miles)	Dispersion radius (Miles)
	Direction Deg True	Speed								
		Knots	MPH							
SURFACE										
5,000										
10,000										
15,000										
20,000										
25,000										
30,000										

Winds aloft data: Time________________ Station____________________

Remarks:

FIGURE 4. *Radex data sheet.*

Section 3000

WIND VECTOR DIAGRAM

3100. GENERAL

The methods presented in this manual are graphical. The basic construction is the wind vector diagram, which will be discussed in this section.

3110. When a particle falls to the ground from a given height, it is acted on by gravity and by winds. The influence of gravity, for all practical purposes, is constant with space and time. On the other hand, the influence of the winds is more complicated, since winds vary considerably not only with height but also with time. Ideally, to compute the effect of the winds, wind forces from the given height to the ground should be integrated over the time of descent of the particle. This procedure is not only impossible under most operating conditions, but it is also unnecessary for practical purposes. As a substitute for the integrated wind, in this manual we will use the mean, or average wind between the given height and the ground or another given height. This wind is obtained graphically from the wind vector diagram.

3200 WIND DATA

The first step in constructing the wind vector diagram is to tabulate winds aloft for each 5,000 foot level above the surface, as well as the surface. In examples in this manual, the top of the bomb cloud is assumed to be 30,000 feet, so no winds are tabulated above that level.

3210. The best source of wind data is the latest teletype winds aloft report, although winds may be estimated from constant pressure charts or cloud movements. The example in the next paragraph is a winds aloft report from Mitchel Air Force Base, and this example will serve as the basis for all further illustrations of radioactive plots in the remainder of this manual.

3211. *Example*: The latest winds aloft report is as follows:

HEM03	*03617*	3515	23420	3318	43322	*3226*	63128
3033	82935	2938	*02835*	22635	42330	—	62240
82335	*02348*	*52448*	*02669*	52772			

Note. Winds extracted for the data sheet in Figure 5 are italicized above. The 15,000 foot wind is determined by interpolation between the 14,000 and 16,000 foot winds. (Missing winds may also be interpolated). Wind Data are tabulated in columns 1 and 2 of the data sheet, as shown below:

Column #	1	2	
	Wind		
	Direction Deg True	Speed Knots	
Sfc	360	17	
5000	320	26	
10000	280	35	
15000	225	35	
20000	230	48	
25000	240	48	
30000	260	69	

FIGURE 5. *Data sheet, columns 1 and 2 completed.*

3212. Heights in winds aloft messages are given for levels above sea level, while computations in this manual are based on heights above ground. For stations at high altitudes, adjustment of the winds aloft messages will be necessary in order to obtain the proper basic data for heights above the ground. For example, if a station is located at 10,000 feet above sea level, a group will be included in its winds aloft report giving wind data for 15,000 feet above sea level. This wind would be tabulated in the 5,000 foot space, since it is actually the wind 5,000 feet above the ground. Similarly, wind data from other levels will be reduced to heights above the surface.

3213. Some winds aloft messages from foreign meteorological services are in metric units of height; these units should be converted to feet, and the values for the data sheet then obtained by interpolation.

3214. The complete upper wind code is contained in AWSM 105-21. For convenience, an abstract of the Upper Wind Code used in the United States is included as appendix C.

3215. In the event that wind speeds are available in miles per hour record them in column 3, and make no entries in column 2.

3300. KNOTS TO MILES PER HOUR

Tables 2 and 3 of this manual, which are used in later computations, are based upon wind speeds in miles per hour, while upper wind reports give wind speed in knots. It is possible, of course, to construct new tables based on knots, but due to the convenience of working with statute miles in later operations, units of miles per hour have been retained. Thus the next step is to convert column 2 entries from knots to miles per hour, using table 1, page 48, and recording the results in column 3. When this step has been completed, the data sheet becomes:

Column =	1	2	3
	Wind		
	Direction Deg True	Speed	
		Knots	MPH
Sfc	360	17	20
5000	320	26	30
10000	280	35	40
15000	225	35	40
20000	230	48	55
25000	240	48	55
30000	260	69	80

FIGURE 6. *Data sheet, column 3 completed.*

3310. As indicated in AWSM 105-21, some foreign meteorological services report wind speeds in meters per second. These may be converted to miles per hour by applying the relationship:

1 meter per second = 2.2 miles per hour

3400. WIND VECTORS

Using the information in columns 1 and 3 of the data sheet, the next step is to construct a wind vector diagram on a sheet of tracing paper.

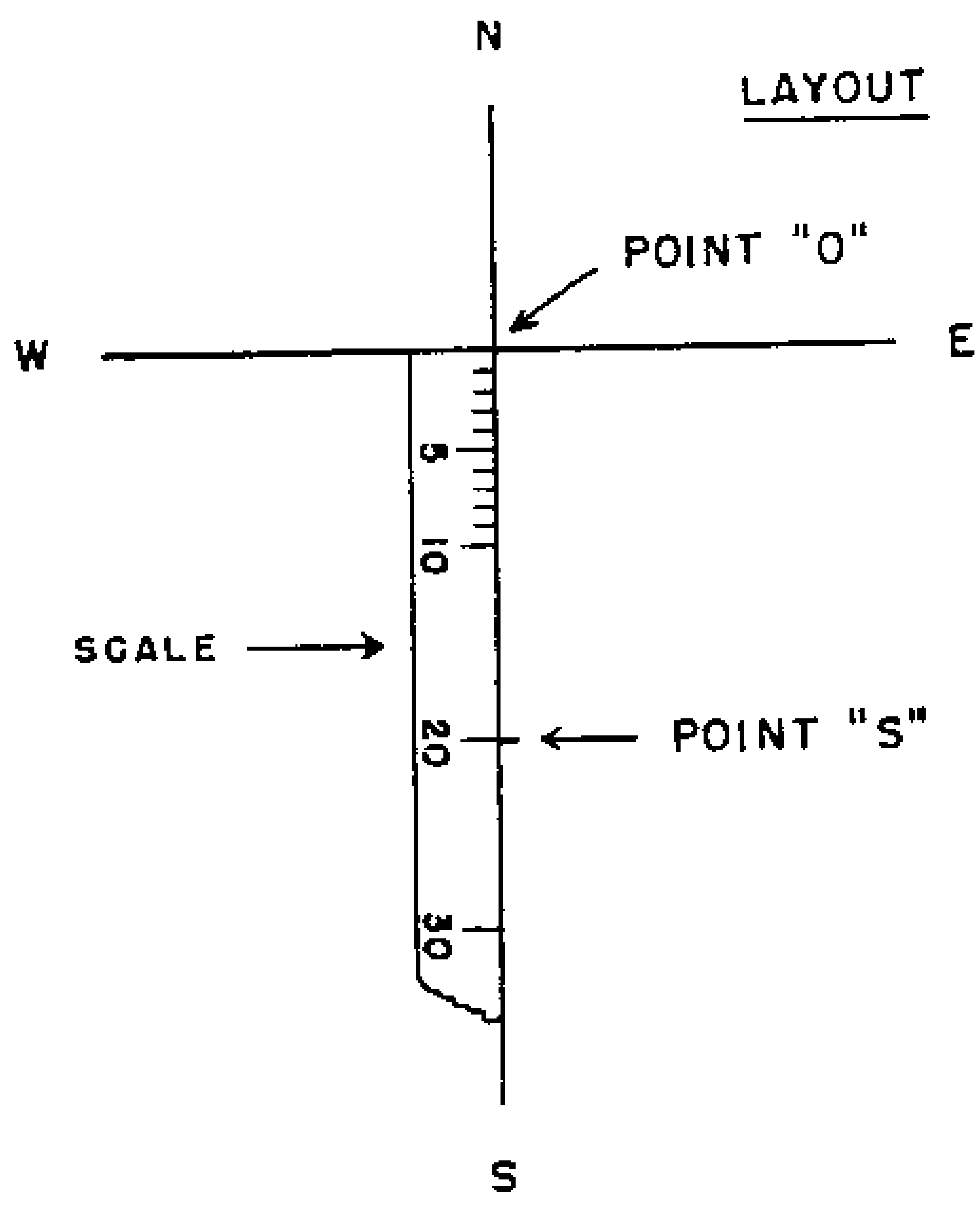
3410. Draw two lines at right angles on the tracing paper in black pencil. Label the intersection point as "O", and the appropriate axes as "N" (North), "E" (East), "S" (South), and "W" (West), as shown in figure 7.

3420. Wind directions (column 1) are given in degrees clockwise from true north (N). The wind direction is the direction from which the wind is blowing. That is, a wind of 270° is blowing from 270°, or from the west. This wind would be drawn from point "O" toward the east (E).

3421. Use the protractor for laying off the wind directions, and use the scale of the base map for plotting wind speeds, i.e., if 1 inch on the base map equals 10 miles (distance), then 1 inch on the tracing represents 10 miles per hour (speed).

3430. The first vector to be drawn is the surface wind. Using point "O" as the origin, lay off the surface wind direction with the protractor (unnecessary in this case, since the direction line is already drawn—360° is the line O to S). Lay off the wind speed, using the scale described in appendix B, and mark the end of this line as "s".

Example: The surface wind speed is 20 miles per hour, from 360°.



AS DRAWN ON TRACING PAPER

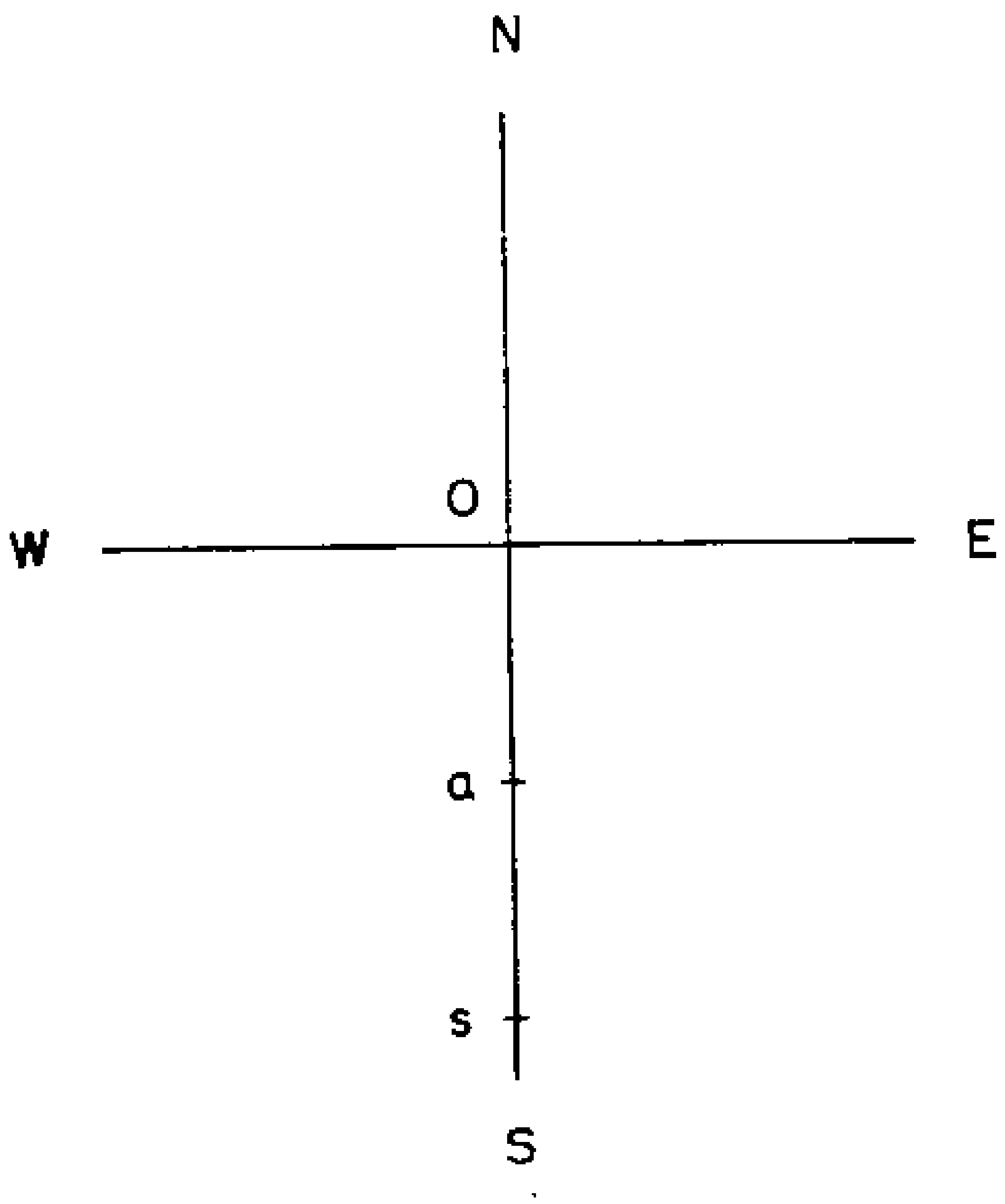


FIGURE 8. *Surface wind speed vector bisected.*

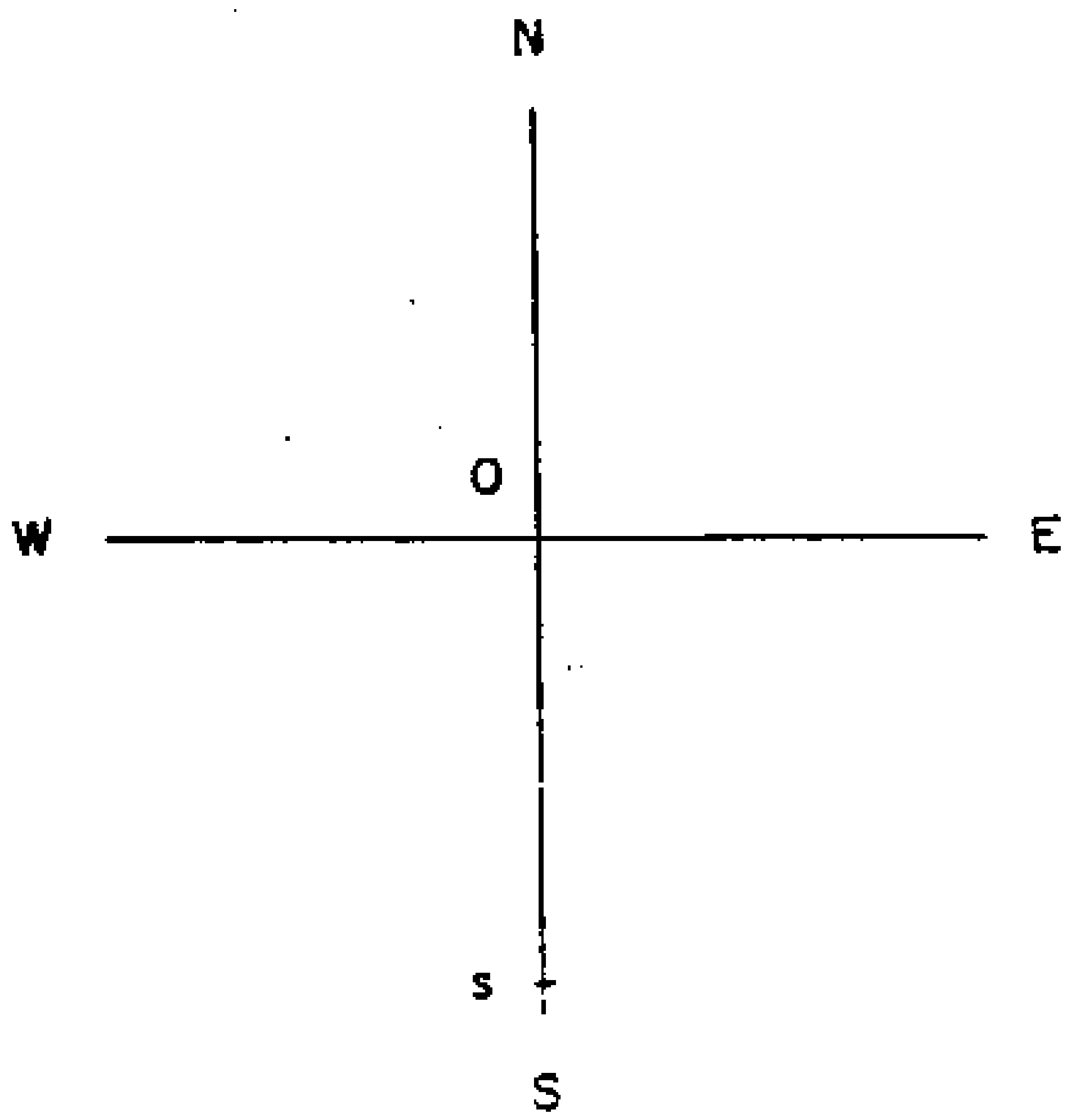


FIGURE 7. *Surface wind speed vector.*

3440. Bisect this vector, and mark its midpoint as "A". The reason for this step is explained in paragraph 3460.

3450. If the surface wind speed is calm, (reported as OO), mark the origin point "O" as both "s" and "a".

3460. The next wind vector to be drawn is the 5000 foot wind. The actual 5000 wind is assumed to be the mean wind for the layer from 7500 to 2500 feet, and hence is assumed to cause the drift of particles as they pass through that layer. Similarly, the surface wind speed is assumed to control the drift of particles as they fall from 2500 feet to the surface. Note that this layer is only *half* as thick as the layer represented by the actual 5000 foot wind. Therefore, in the wind vector diagram, the surface wind vector is *halved*, which is the reason for bisecting it as directed in paragraph 3440. The actual 5000 foot wind vector is then plotted, using point "a" as the origin (and NOT point "O"). Mark the end of this vector as "5".

Example: Surface wind 260°, 20 mph.
5000 foot wind 320°, 30 mph.

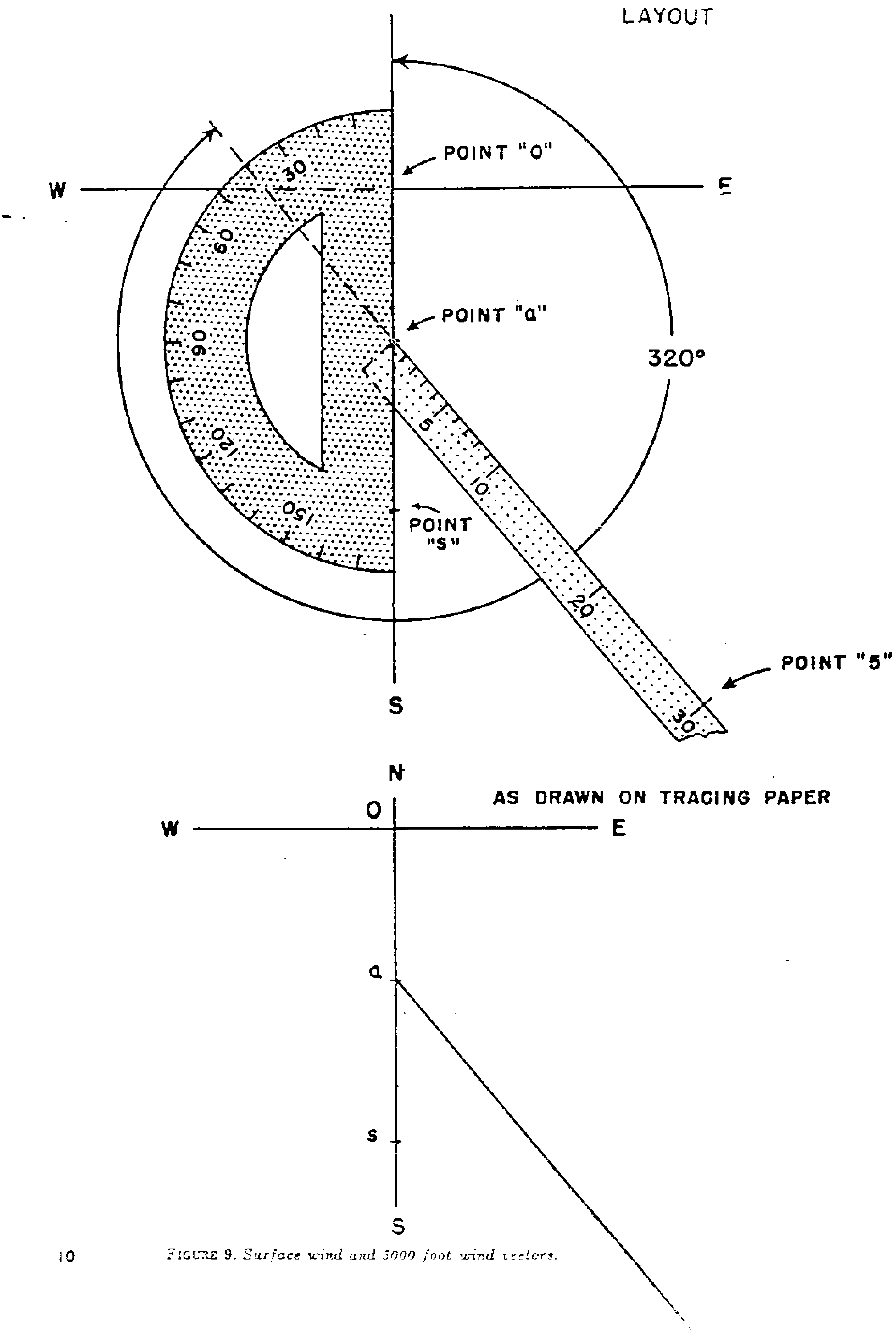


FIGURE 9. *Surface wind and 5000 foot wind vectors.*

3470. The next step is to draw the 10,000 foot wind vector. In this case, the 10,000 foot actual wind represents the mean wind from 12,500 to 7,500 feet, a thickness of 5,000 feet. The actual 5,000 foot wind, as previously explained, represents the mean wind from 7,500 feet to 2,500 feet, also a thickness of 5,000 feet. Hence in this case the 5,000 and 10,000 foot winds act through the same thickness of layer, and point "5" is used as the origin for the 10,000 foot wind vector.

Example: Surface wind, 360°, 20 mph.—5000 foot wind, 320°, 30 mph.
10,000 foot wind, 280°, 40 mph.

(See figure 10.)

3480. Using point "10" as the origin, draw the 15,000 foot wind vector, and mark its end as "15". Proceed similarly for the remaining vectors as tabulated below:

Point used as origin	Draw wind vector for	Mark end as
15	20,000 feet	20
20	25,000 feet	25
25	30,000 feet	30

3490. Returning to the original example data, the completion of this step is as shown in figure 11.

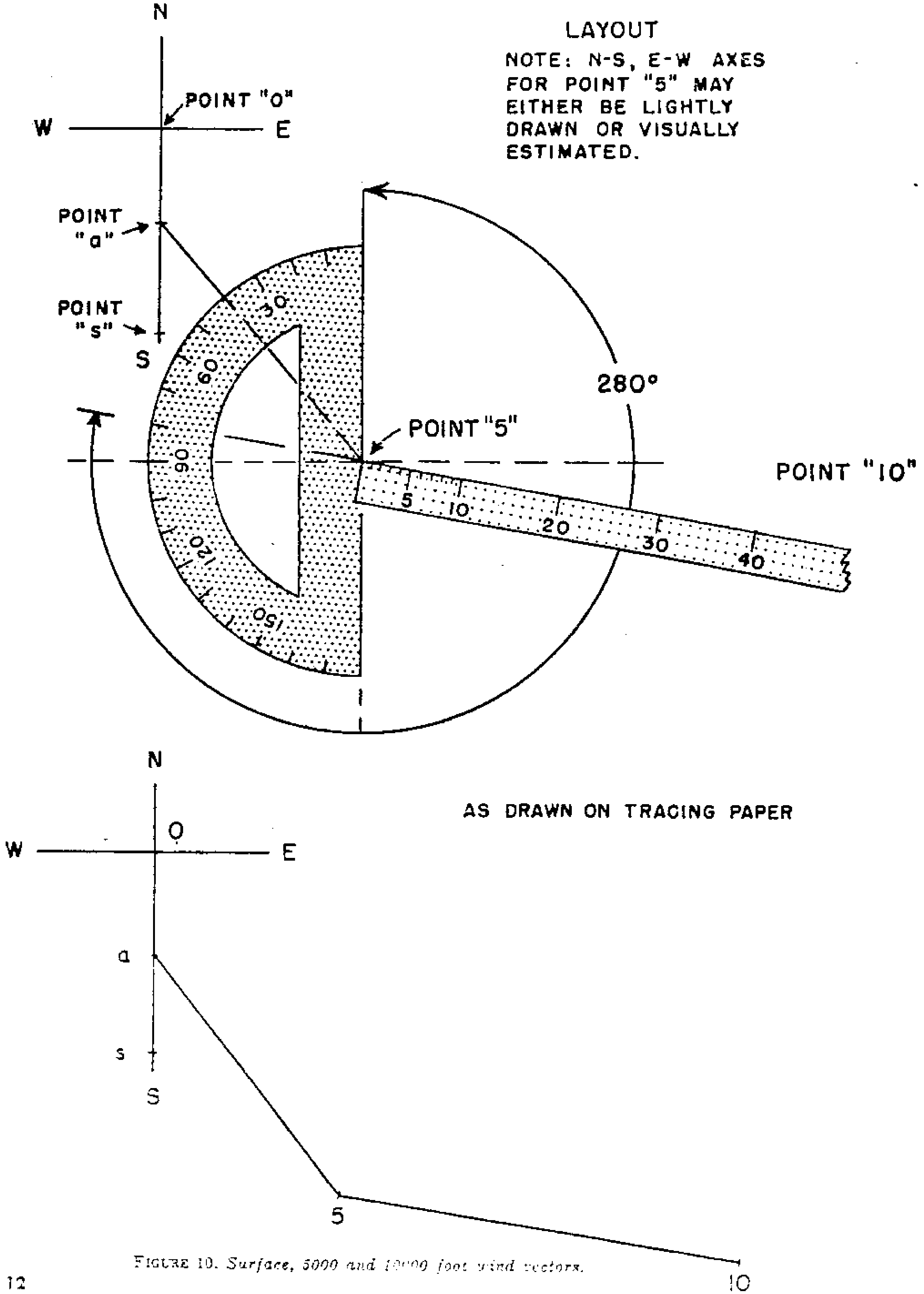


FIGURE 10. *Surface, 5000 and 10000 foot wind vectors.*

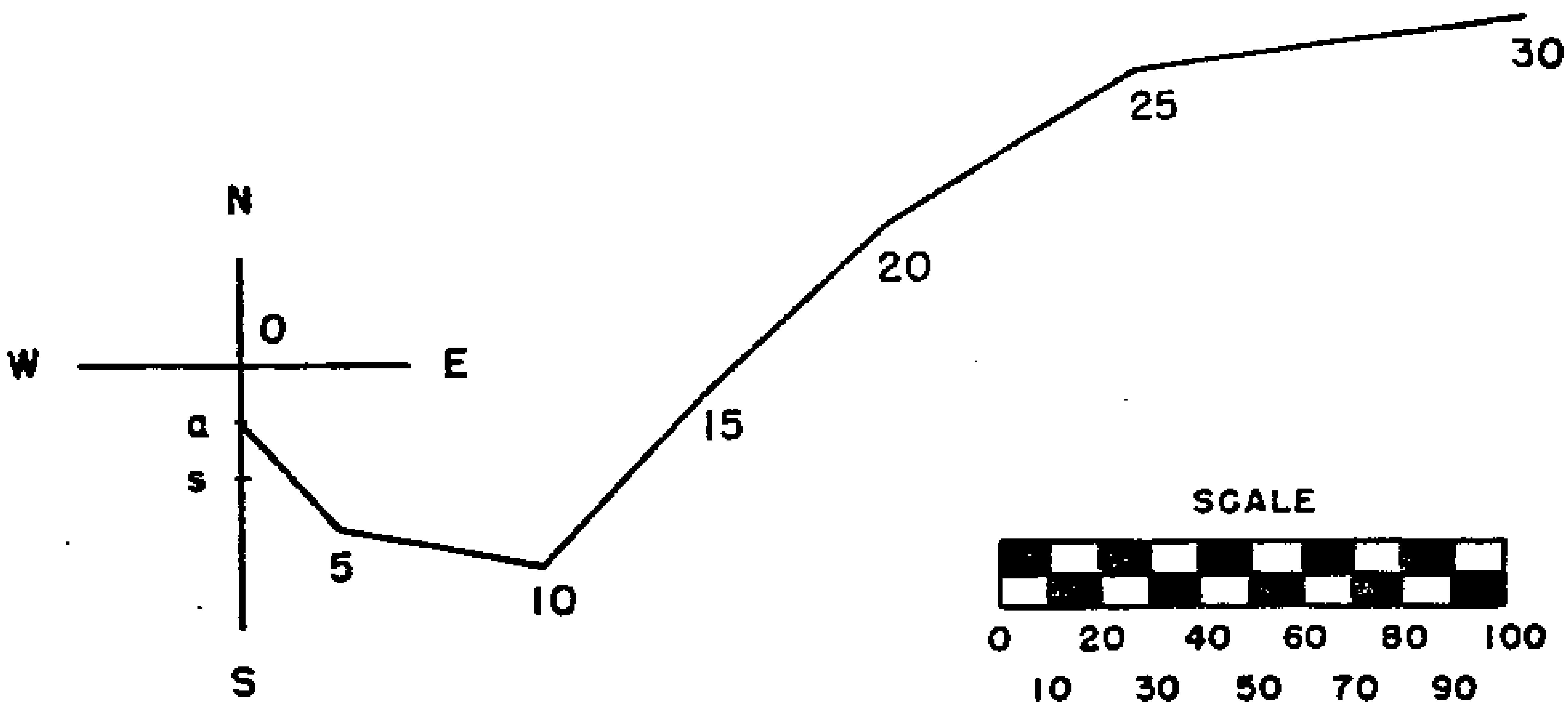


FIGURE 11. *Completed wind vector diagram.*

Section 4000

GROUND FALL-OUT PLOT

4100. GENERAL

In order to determine the position of a particle on the surface after it has fallen from a given height, it is necessary to know two things:

4110. The mean wind speed and direction in the layer from the given height to the ground, and the mean wind direction in that same layer.

4120. The rate of fall of the particle. This determines how long the mean wind in the layer will influence the particle.

4130. Figure 12 illustrates graphically the trajectory of particles from 20,000 feet. These particles are acted upon by the mean wind from 20,000 feet to the surface, and will move away from the origin in the direction of, and proportional to the speed, of that wind. Heavy particles, however, will fall out faster than light particles. The mean wind, therefore, will exert less effect on the heavy particles, and they will fall out closer to the origin than light particles. For the purposes of the ground fall-out plot, it is assumed that all the particles in the cloud can be divided into three classes—small, medium, and large sized. From Stokes' Law, the rate of fall of a particle in air, influenced by gravity, is $0.35d^2p$, where d is the diameter of the particle in microns, and p is its density.

4140. Knowing the rate of fall of the three sizes of particles from a given height, and the mean wind from the surface to that height, three points can be computed which will represent the limiting ranges of displacement for each of the three sizes of particles on the ground. That is, the majority of small particles will fall out between point "A" and point "B" on Figure 12, the majority of all medium-sized particles around point "B," and the majority of large particles between point "C" and point "B." A certain amount of dispersion of the particles is to be expected, and it has been found experimentally that the particles will scatter about ten degrees on each side of the mean linear displacement (line CBA). Thus, in figure 12, the Plan view shows a triangle with an angle of 20° to indicate the probable dispersion of the particles.

4200. MEAN WINDS

In constructing the ground fall-out plot, the first step is to find the mean wind between the surface and each of the consecutive 5,000 foot levels. This involves an analysis of the wind field, which can be done mathematically. However, for the purposes of this manual, a solution involving strict mathematical procedures is not necessary. The determination of contaminated areas is an approximation by the very nature of the problem, and the methods outlined below, although a simplication and not strictly accurate, satisfy the practical requirements for an acceptable solution.

4210. In order to determine the mean wind

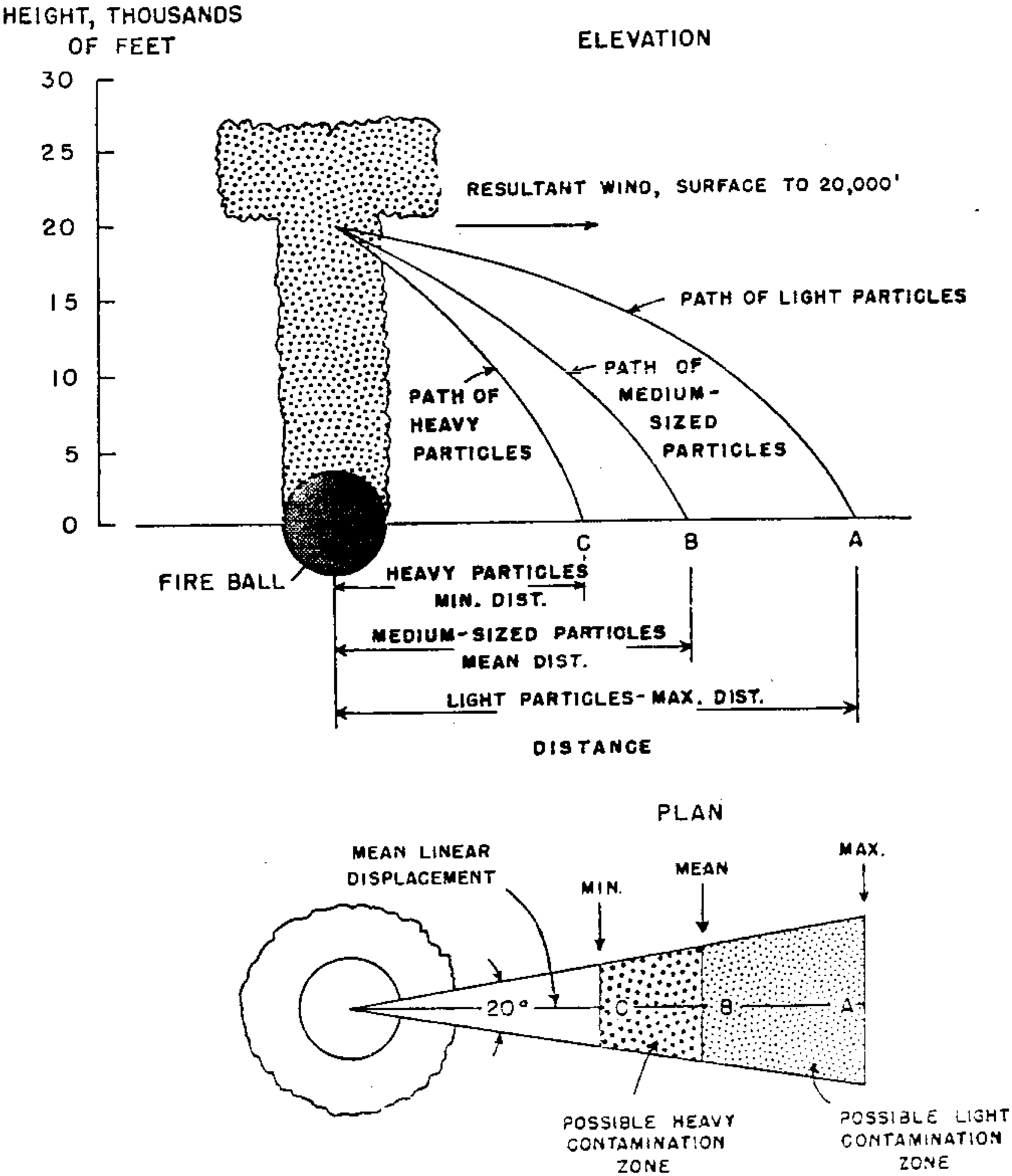


FIGURE 12. *Basic principles, ground fall-out plot.*

from the surface to 5,000 feet, the pertinent portion of the wind vector diagram given in figure 10, and a diagrammatic sketch, are given below:

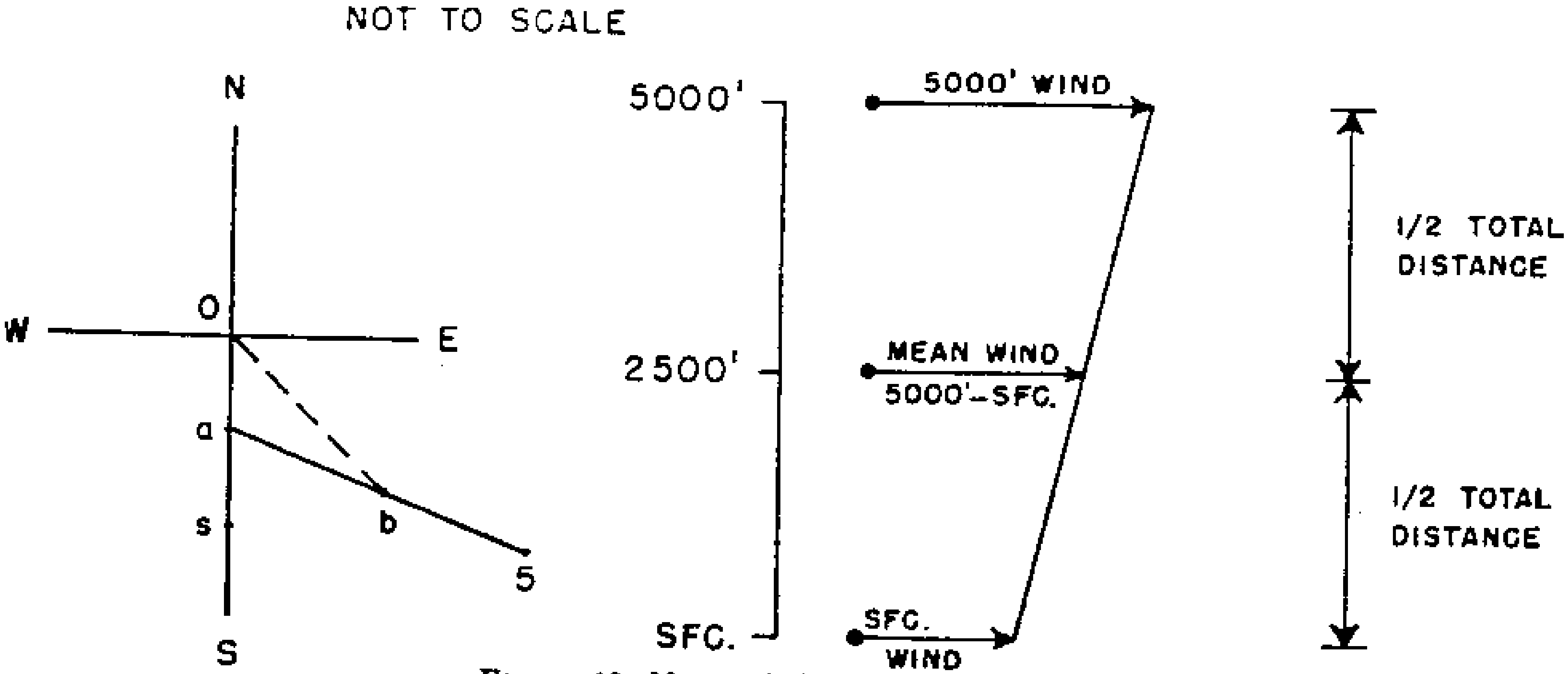


FIGURE 13. *Mean wind, surface to 5000'.*

In line with the approximation discussed in paragraph 4200, we will assume, for purposes of this manual, that wind direction and speed vary uniformly between the surface and 5,000 feet. As a further approximation, made solely for simplification, we will assume that in the fall of a particle from 5,000 feet to 2,500 feet, the particle is acted on by the 5,000 foot wind; and in its further fall from 2,500 feet to the surface, by the surface wind. In other words, we are assuming that the "net" wind acting on the particle is one-half of the 5,000 foot wind plus one-half of the surface wind. The 5,000 foot wind is represented on the wind vector diagram as a5, and half of that vector is ab. The surface wind is represented by Os, and half of that vector is Oa. The vectorial sum of ab and Oa is represented on the diagram by the dotted vector Ob. This is the mean wind vector from the surface to 5,000 feet; its direction is the direction of Ob, and its speed is represented by the length of Ob.

4220. Having determined the mean wind vector between the surface and 5,000 feet, the next step is to construct the mean wind vector between the surface and 10,000 feet. In that layer, a particle will be acted upon half of the time by the mean wind between 10,000 and 5,000 feet, and the other half of the time by the mean wind between 5,000 feet and the surface. The applicable portion of the wind vector diagram, and a diagrammatic sketch are given below:

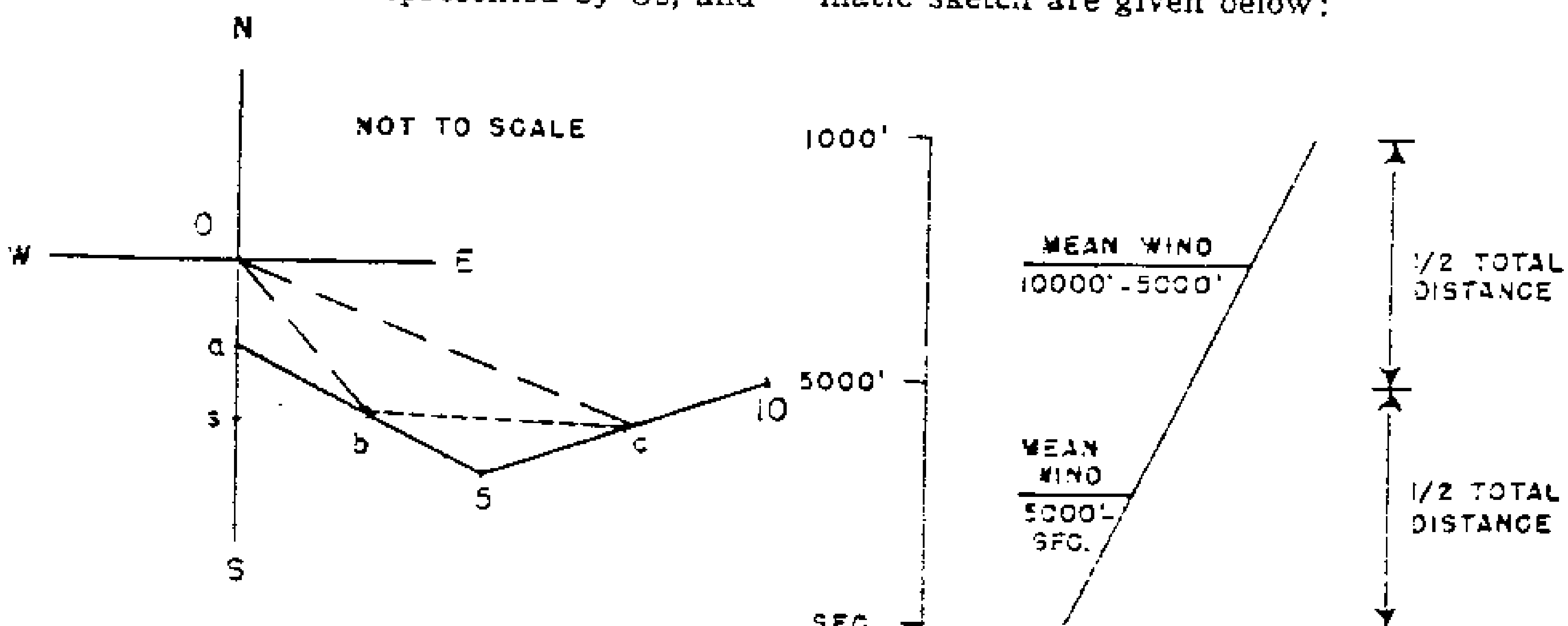


FIGURE 14. *Mean wind, surface to 10,000'.*

4221. The mean wind from the surface to 5,000 feet is represented by vector Ob (dashed). The mean wind from 5,000 feet to 10,000 feet is represented by vector bc (dotted). Since each of these mean winds acts on the particle for half of the time, the mean wind from the surface to 10,000 feet can be written as—

> One-half vector Ob plus one-half vector bc, or
> One-half (vector Ob plus vector bc)

Vector Oc (dashed) is the vectorial sum of vector Ob and vector bc. Hence, ½ vector Oc is equivalent to the mean wind from the surface to 10,000 feet. Thus, if we measure the length of the vector Oc and divide it by 2, we have obtained the value of the mean wind speed from the surface to 10,000 feet; the direction is the same as the direction of vector Oc.

4230. In order to obtain the mean wind speed from the surface to 15,000 feet, the same reasoning is followed. The applicable portion of the wind vector diagram, and a diagrammatic sketch are drawn below (see fig. 15).

4231. Between 15,000 feet and the surface, we will assume that a particle will be acted upon by—the mean wind between 15,000 and 10,000 feet, for one-third of the time, the mean wind between 10,000 and 5,000 feet, for one-third of the time, the mean wind between 5,000 feet and the surface for one-third of the time, Vector cd (dotted) represents the mean wind from 15,000 to 10,000 feet. Vector bc (dotted) represents the mean wind from 10,000 to 5,000 feet. Since each of these vectors acts for one-third of the time, the mean wind between 15,000 feet and the surface can be written as—

> One-third vector Ob plus one-third vector bc plus one-third vector cd, or
>
> One-third (vector Ob plus vector bc plus vector cd)

Since vector Od (dashed) is the vectorial sum of Ob, bc, and cd, one-third the length of vector Od will be the mean wind speed from the surface to 15,000 feet; the direction of the mean wind will be the same as the direction of Od.

4240. Similar reasoning can be applied to find the remaining mean wind speeds from the surface to the remaining levels at 5,000 foot intervals. The table (top next page) gives the fractional part of the total time of descent that the mean wind within a layer acts on a falling particle. For ground fall-out

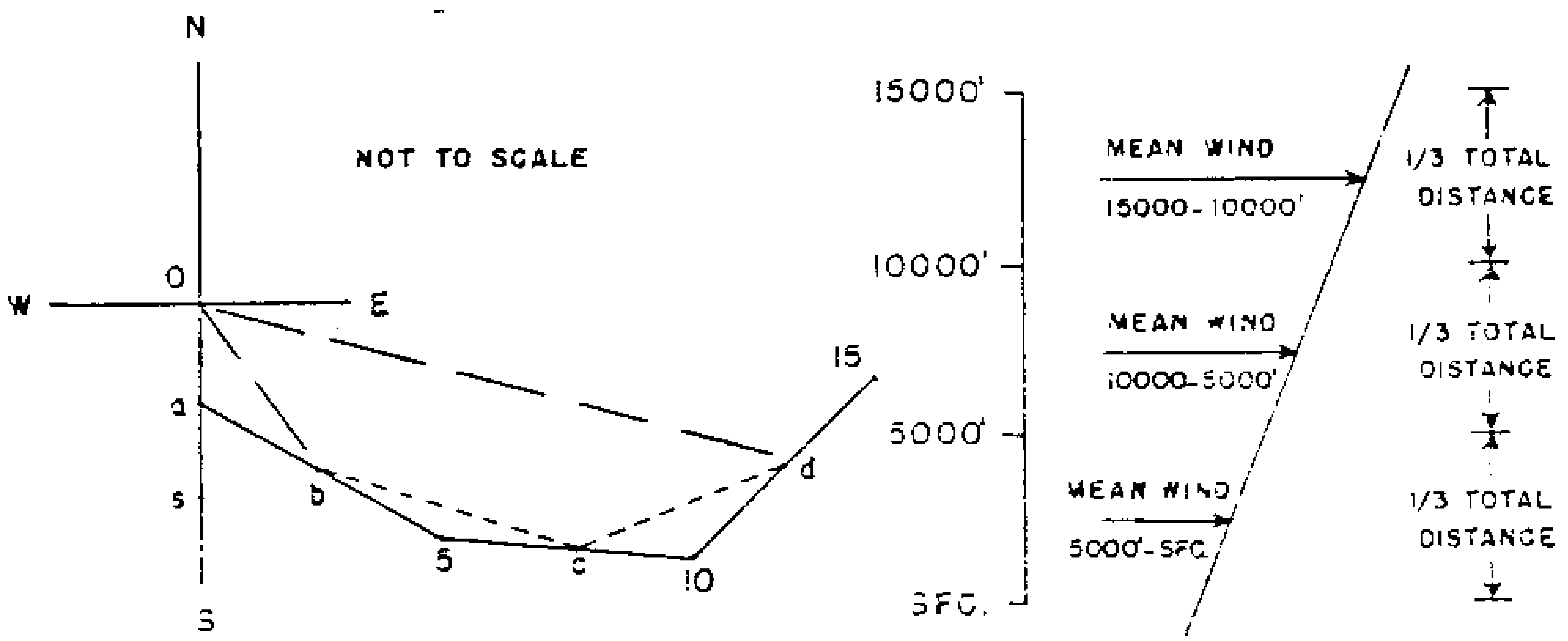


FIGURE 15. *Mean wind, surface to 15,000 feet.*

computations, a list of divisors to be applied to the total values of the lines measured from the origin to the midpoint of each of the wind vectors, is included. (Column 5 of the ground fall-out data sheet incorporates these divisors).

Layer	Ob	Oc	Od	Oe	Of	Og
0—5,000	1	1/2	1/3	1/4	1/5	1/6
5,000—10,000		1/2	1/3	1/4	1/5	1/6
10,000—15,000			1/3	1/4	1/5	1/6
15,000—20,000				1/4	1/5	1/6
20,000—25,000					1/5	1/6
25,000—30,000						1/6
Divide by	1	2	3	4	5	6

4250. The theory contained in the preceding paragraphs on the approximate method of determining mean wind speeds results in the following simplified procedure. Vectors a5, 5–10, 10–15, etc., are bisected, and the mid-points are labelled as follows:

Bisect Vector	and mark midpoint
a–5	b
5–10	c
10–15	d
15–20	e
20–25	f
25–30	g

4260. Vectors are now drawn, in red pencil, from the origin point "0" to points b, c, d, e, f, and g. Figure 16 shows the completion of this step for the running example:

4300. VECTORIAL SUM

Returning to the Ground Fall-Out Data Sheet, column 4 is now completed. This is done by measuring the *total* length of vectors Ob, Oc, Od, Oe, Of and Og, employing the same scale used to lay out the wind vector diagram, and recording the results in column

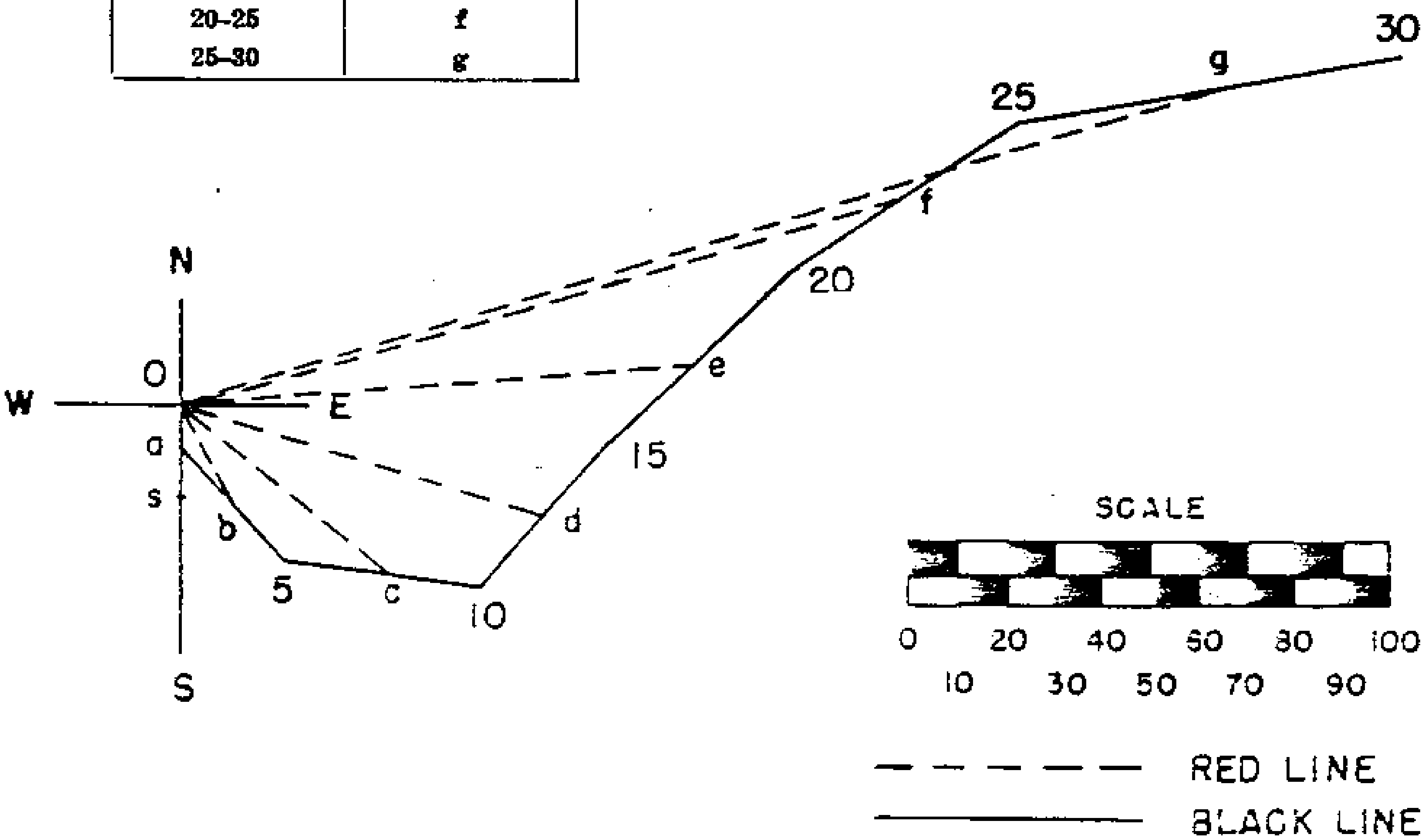


FIGURE 16. *Completed wind vector analysis.*

4. Note that no entry is made on the horizontal line for "surface" data. Results for the running example are as shown in figure 17.

4400. MEAN WIND SPEEDS

As explained in paragraph 4200, each of the values in column 4 must be divided by the corresponding number listed in column 5, and the result tabulated in column 6, in order to obtain the mean wind speeds from each of the levels to the surface. This division need only be carried out to the nearest mile per hour. See figure 18.

Column #	1	2	3	4
	Wind			Vectorial sum
	Direction Deg True	Speed		
		Knots	MPH	
Sfc	360	17	20	
5,000	320	26	30	24
10,000	280	35	40	54
15,000	225	35	40	77
20,000	230	48	55	109
25,000	240	48	55	159
30,000	260	69	80	225

FIGURE 17. *Data sheet, column 4 completed.*

Column #	1	2	3	4	5	6
	Wind			Vectorial sum	Divided by	Mean wind speed
	Direction Deg True	Speed				
		Knots	MPH			
Sfc	360	17	20			
5,000	320	26	30	24	1	24 Ob
10,000	280	35	40	54	2	27 Oc
15,000	225	35	40	77	3	26 Od
20,000	230	48	55	109	4	27 Oe
25,000	240	48	55	159	5	32 Of
30,000	260	69	80	225	6	38 Og

FIGURE 18. *Data sheet, column 6 completed.*

4500. DISTANCES

The final entries for the data sheet are now obtained from table 2. This table lists three distances for each level (one distance for each of the three particle sizes—small, medium, and large) for various mean wind speeds. To use table 2, enter the "Mean Wind Speed" column with the value of Ob given in column 6 of the data sheet. Record the three values in table 2 (opposite the value of Ob) in columns 7, 8 and 9, respectively, of the data sheet. Proceed similarly for each mean wind speed; be sure to use the proper columns in table 2, i.e., Oc columns for mean wind speed Oc, Od columns for mean wind speed Od, etc. When this step is completed, the ground fall-out data sheet is as shown in figure 19.

Column #	1	2	3	4	5	6	7	8	9
	Wind			Vectorial sum	Divided by	Mean wind speed	Distances		
	Direction Deg True	Speed					Min	Mean	Max
		Knots	MPH						
Sfc	360	17	20						
5,000	320	26	30	24	1	24 Ob	2.2	3.1	7.4
10,000	280	35	40	54	2	27 Oc	4.9	6.8	17.0
15,000	225	35	40	77	3	26 Od	6.5	9.9	24.1
20,000	230	48	55	109	4	27 Oe	9.2	13.5	33.3
25,000	240	48	55	159	5	32 Of	13.7	20.1	49.6
30,000	260	69	80	225	6	38 Og	19.0	28.5	71.4

FIGURE 19. *Completed ground fall-out data sheet.*

4600. TRACING

Returning to the original tracing, lay a new sheet of tracing paper over the first, and trace the *red* line Ob, Oc, Od, Oe, Of and Og on the new tracing paper in black pencil, as well as the original N–S and E–W lines. Mark the points as indicated in the following figure, which shows the completion of this step for the running example.

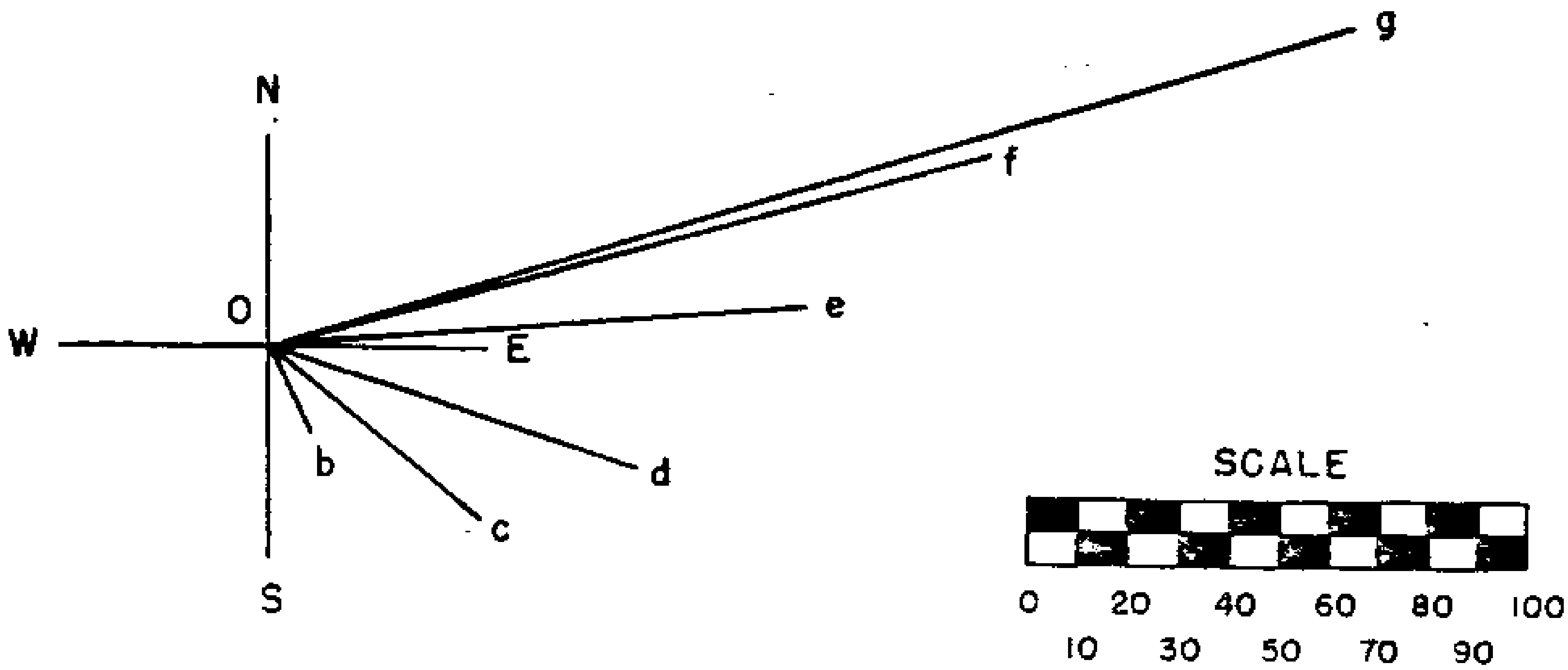


FIGURE 20. *Second tracing.*

4610. The three distances tabulated in columns 7, 8 and 9 of the data sheet for each line are now laid off along the line to which they pertain. In order to illustrate this process line Ob will be extracted from figure 20 and expanded. See figure 21.

4700. DISPERSION ANGLE

The points plotted in paragraph 4610 represent "concentration limits" of large, medium and small particles. However, as previously explained in paragraph 4140, some dispersion of the particles is known to exist, and this spread has been observed to sweep out a triangular area 20 degrees in width with apex at the origin.

4710. The twenty degree marker described in paragraph 2160 (or a protractor) can be used to draw lines 10° on each side of line Ob.

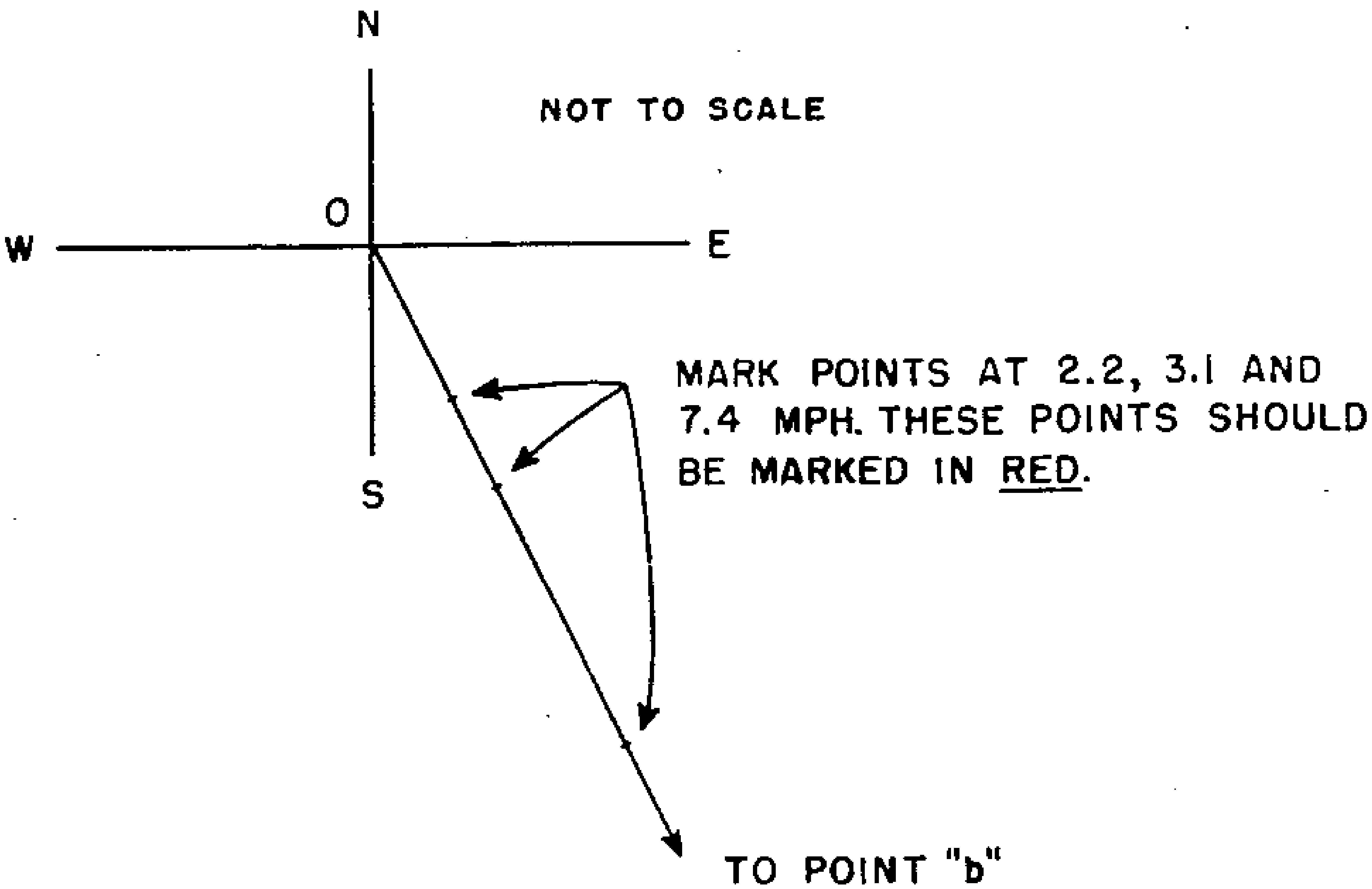


FIGURE 21. *Distances plotted on line Ob. Not to scale.*

Use black pencil for these lines, which need only be extended just past the last point plotted on line Ob (column 9 value). When the dispersion lines are drawn for line Ob the figure becomes:

4720. Perpendiculars to line Ob are now drawn in black pencil, at the points plotted from data in columns 7, 8 and 9, and extended to the dispersion lines drawn 10° on etither side of line Ob. The figure in paragraph 2710 now becomes—

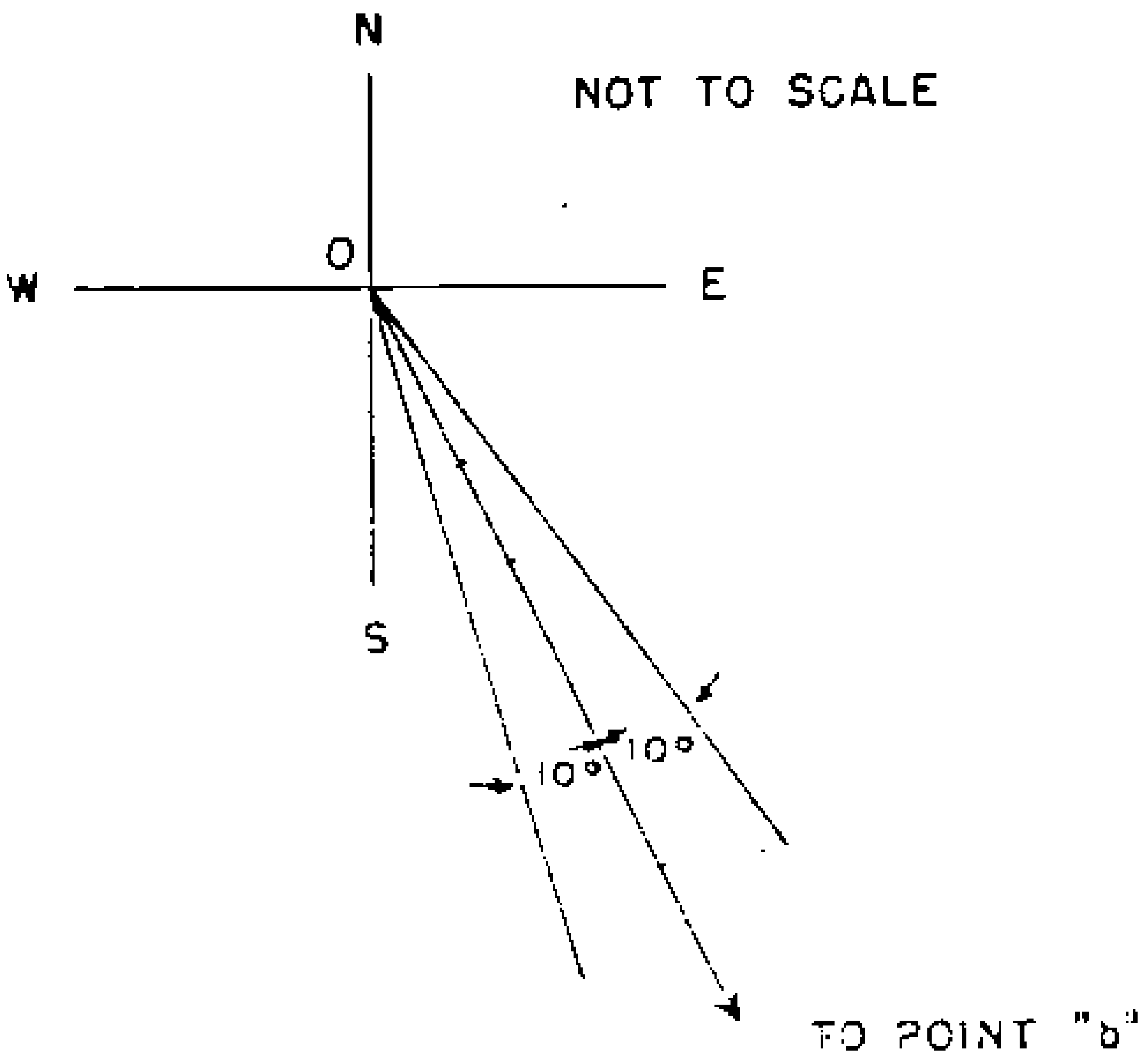


FIGURE 22. *Twenty degree dispersion lines for line Ob.*

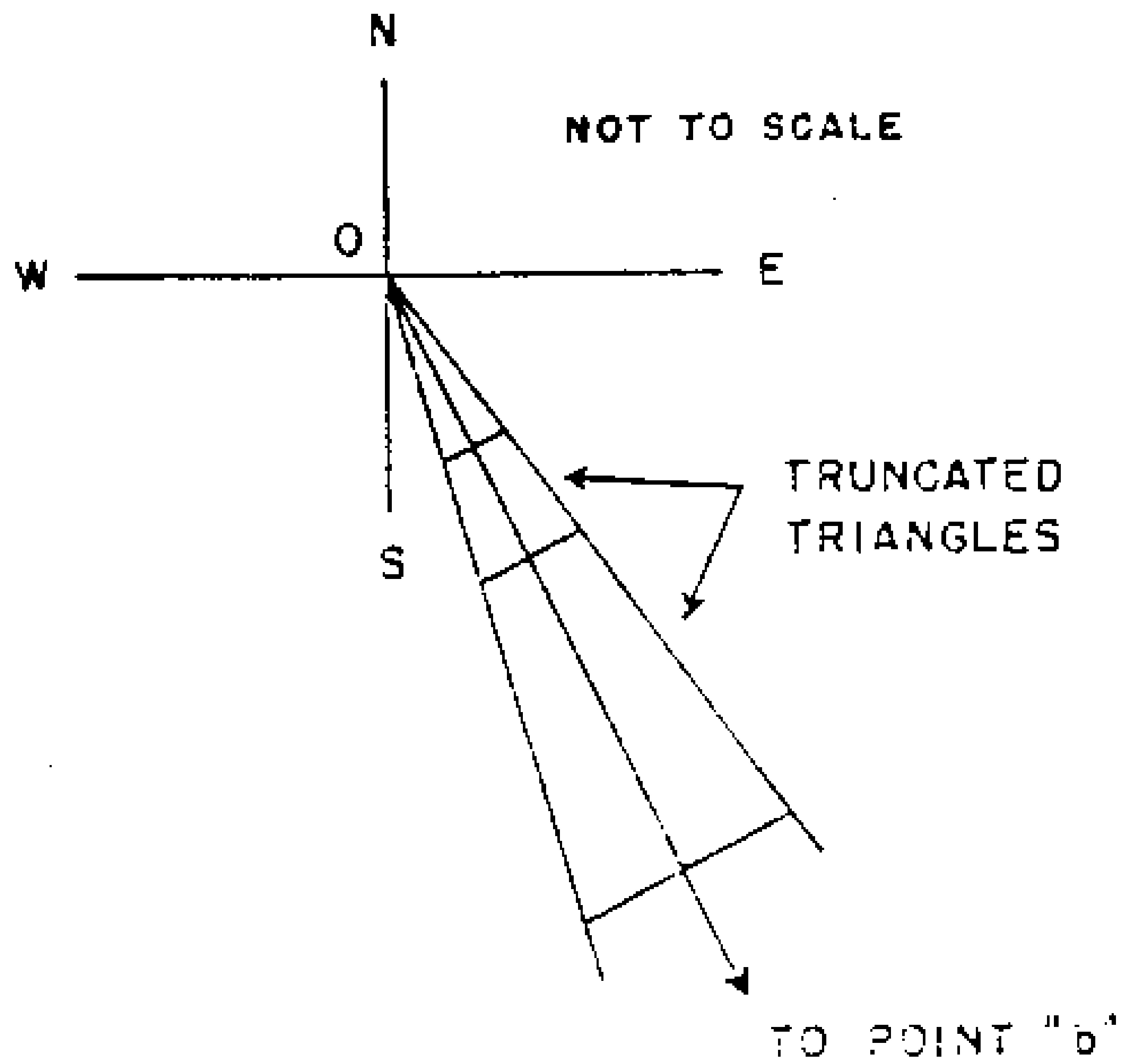


FIGURE 23. *Perpendiculars drawn.*

4730. The figure now consists of a large triangle with vertex at "O," containing two truncated triangles. An expanded view is shown below. The truncated triangle nearest point "O" is shaded in *red;* the truncated triangle farthest from "O" is shaded in *blue.* (See fig. 24.)

4740. A similar procedure is now followed for line Oc. At the completion of this step the figure is as shown in figure 25.

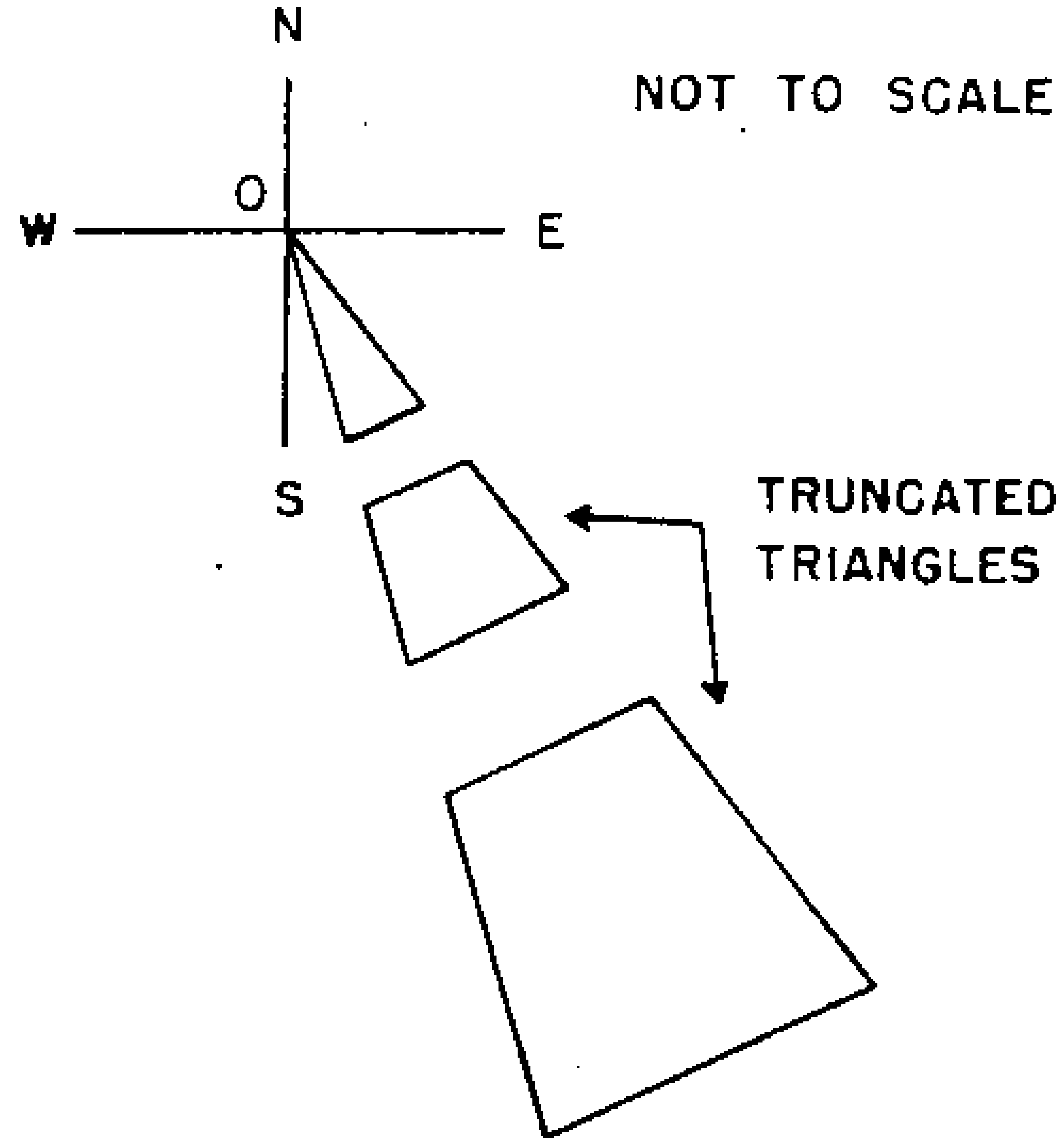


FIGURE 24. *Expanded view.*

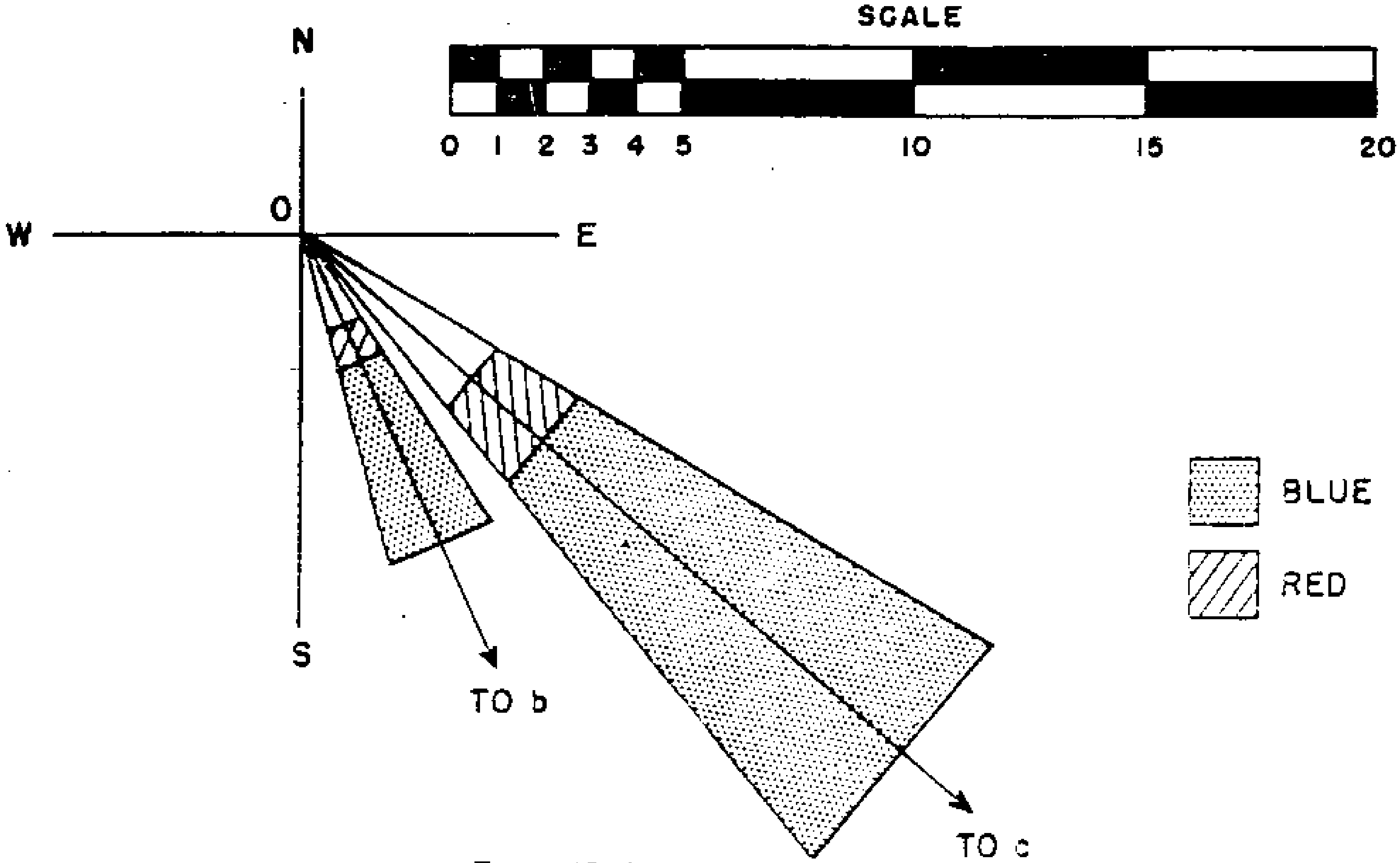


FIGURE 25. *Areas for Ob and Oc.*

4750. When the same procedure is followed for line Od, the figure becomes—

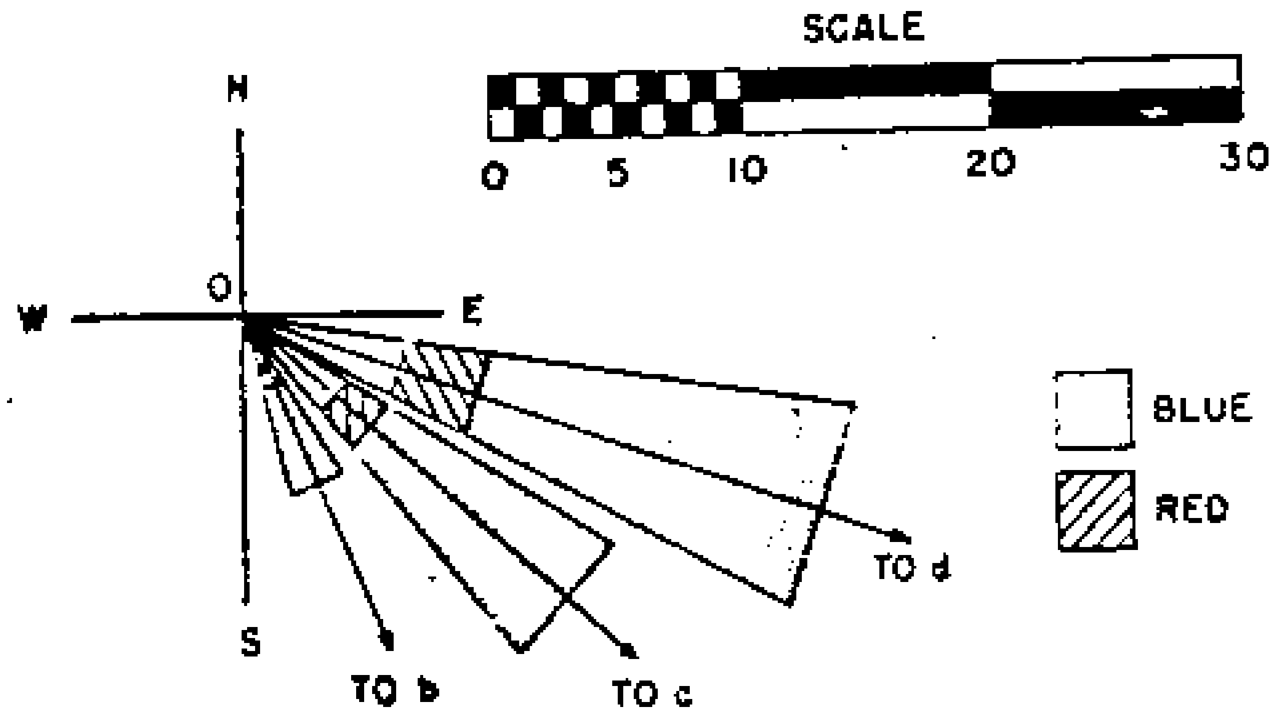


FIGURE 26. *Areas for Ob, Oc and Od.*

4760. After adding the area for line Oe, the drawing becomes—

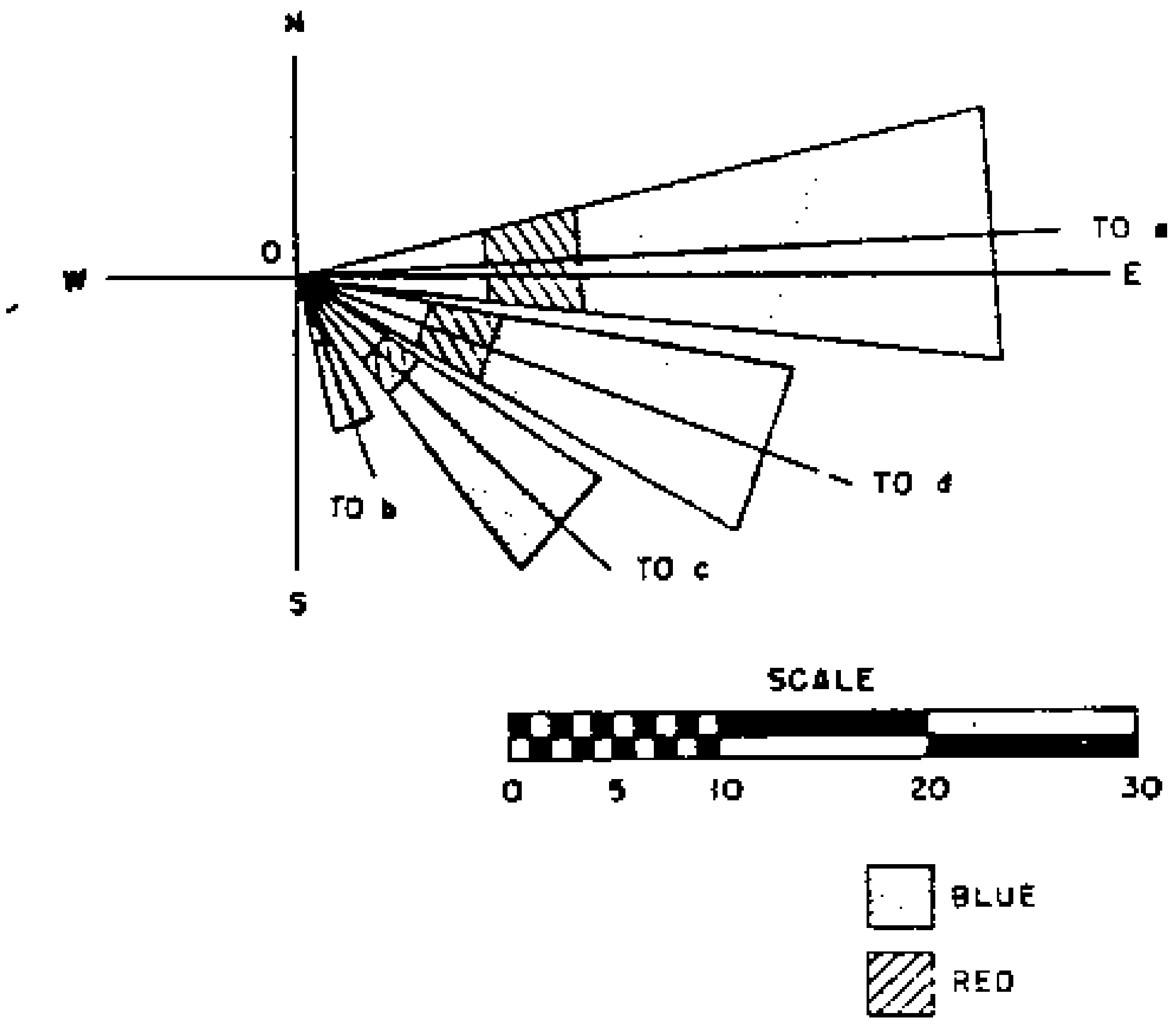


FIGURE 27. *Areas for Ob, Oc, Od and Oe.*

4770. When the areas for lines Of and Og are added, the drawing appears as given in figure 28.

4800. OUTLINING AREAS

The figure now consists of a series of red and blue truncated triangles, some of which overlap. A smooth curve is drawn in *red* pencil around all the *red* truncated triangles. Next, a smooth curve in *blue* pencil is drawn around all the *blue* truncated triangles and outside the *red* line previously drawn. The *red* line encloses the area of possible heavy contamination, and the *blue* line encloses the area of less intense, but still possibly dangerous contamination. (See figure 29.)

4810. The area around the origin point "O" is obviously highly contaminated. Consequently, a circle is drawn with a radius of one and 1½ miles (with the center at "O"). This circle may be shaded in red, if desired. The area within the circle would, of course, be seriously damaged by blast and thermal radiation in addition to being highly contaminated.

4820. Up to this point we have been considering the movement of contaminated particles thrown up to great heights by the explosion. However, some of the radioactive cloud, composed of extremely small particles, remains near the surface and is presumably acted upon only by the winds in the lower levels. In figure 12, this portion is shown by the lower part of the stem, or columnar cloud. FOR THE PURPOSES OF THIS MANUAL, we will call this lower portion the "stem cloud", and we will compute its position separately; this is the last step in constructing the basic ground fall-out plot. It should be noted that the dissipation of this "stem cloud" will be controlled by turbulence, terrain, etc.

4830. Since the ground fall-out plot has the greatest significance when it reveals the maximum fall-out, the time of the stem cloud plot should be determined by the time of fall of the smallest particles from the top of the cloud. Values of small-particle time of fall from various levels are tabulated below:

Cloud top	Small particles, time to reach ground, hours
5,000	0.31
10,000	0.62
15,000	0.94
20,000	1.25
25,000	1.56
30,000	1.87
35,000	2.19
40,000	2.50
45,000	2.81
50,000	3.13

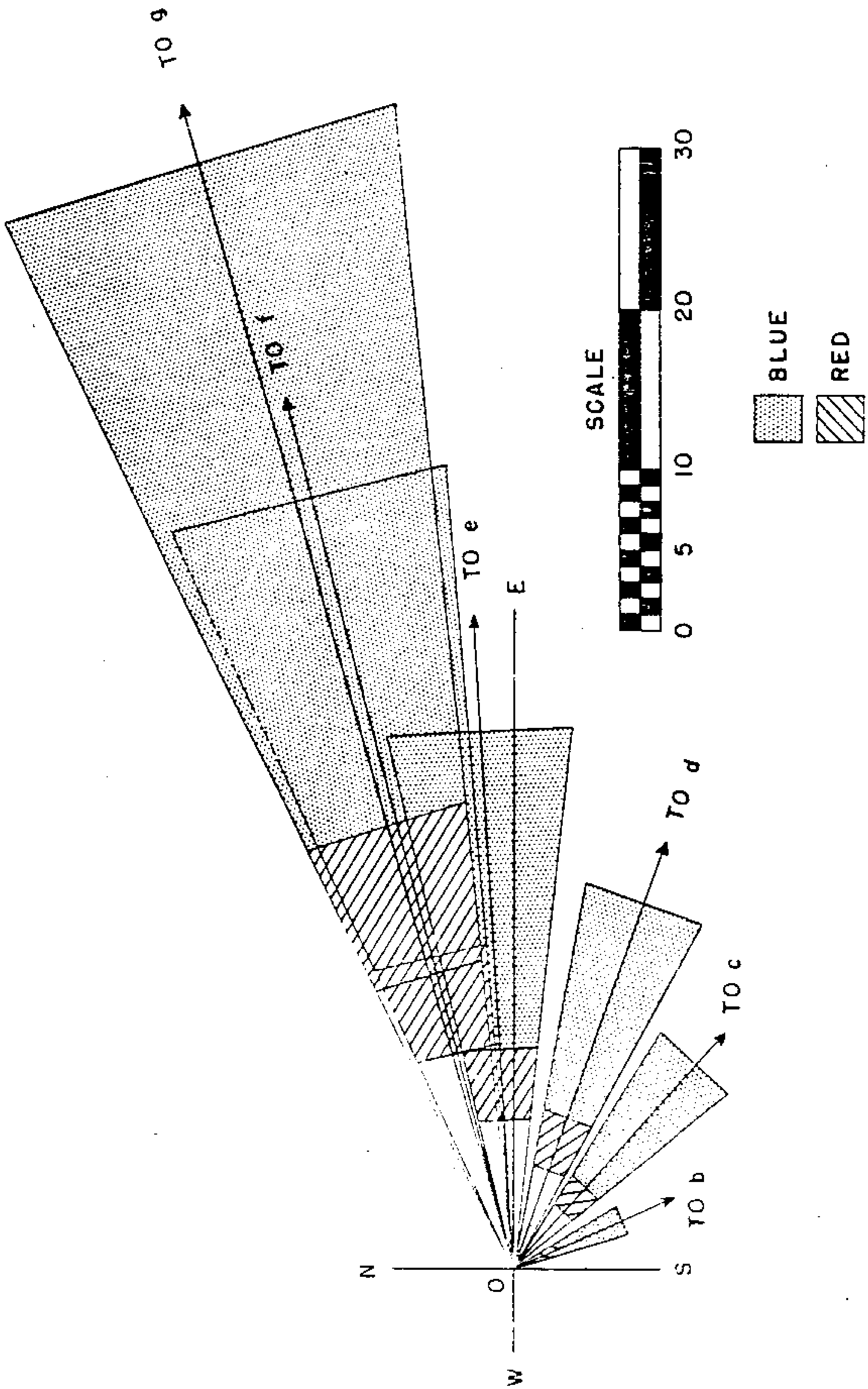


FIGURE 28. *Areas for Ob, Oc, Od, Oe, Of and Og.*

Since the cloud top in the example was stated to be 30,000 feet, we will construct the plot of the surface position of the stem cloud at 1.87 hours. The distance to the center of cloud is 1.87 x 20 (the surface wind direction is 360°).

4840. The stem cloud will disperse to a certain extent during the 1.87 hours. It has been observed that the dispersion area will be included in a circle whose radius is one-fifth of the displacement distance from "O". Hence, in this example, a circle is drawn (with center at the point located in paragraph 4830) of radius 37.6 divided by 5 or 7.5 miles. This is illustrated in figure 29.

4850. The minimum radius of this circle is 1.5 miles. That is, if surface wind speed multiplied by time in hours, and divided by 5, is *less* than 1.5, the circle is still drawn with a radius of 1.5 miles.

4860. As an optional procedure, shading may be added to the area enclosed by the red line (in red), and the area between the blue and red lines (in blue). Completion of this step is shown in figure 29.

4900. COMPLETING THE GROUND FALL-OUT PLOT

The last step is to transfer *the red and blue smooth curves, and the cloud circles,* from the second sheet of tracing paper to the base map This is done by placing the original point "O" of the tracing over the surface explosion point (actual or assumed), and lining up the N–S, E–W axes of the tracing with those of the base map. If desired the red and blue areas can be indicated by shading on the base map. Figure 30 shows the areas computed in the running example transferred to a portion of World Aeronautical Chart 310 (Hudson River), Scale 1: 1,000,000.

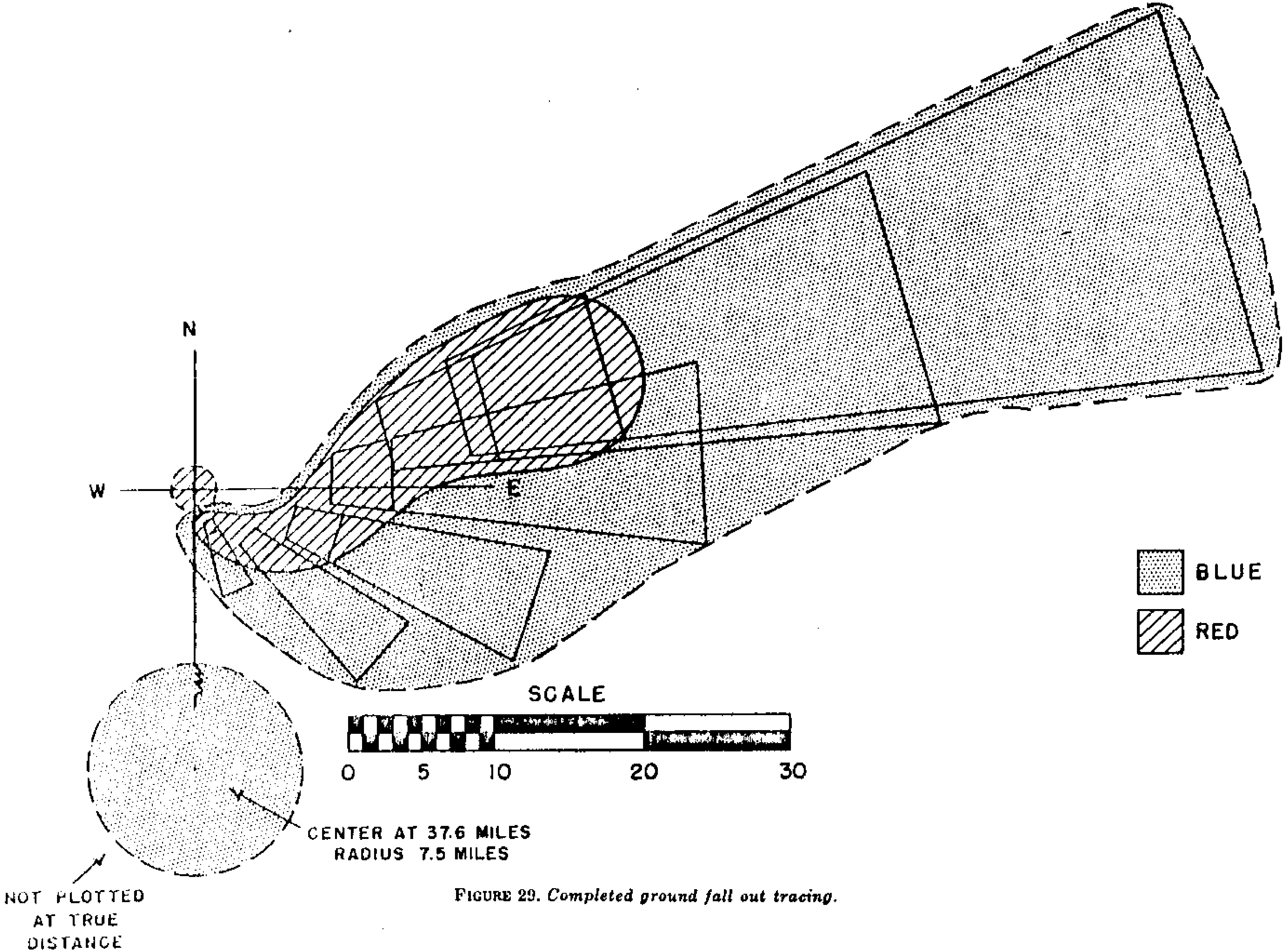


FIGURE 29. *Completed ground fall out tracing.*

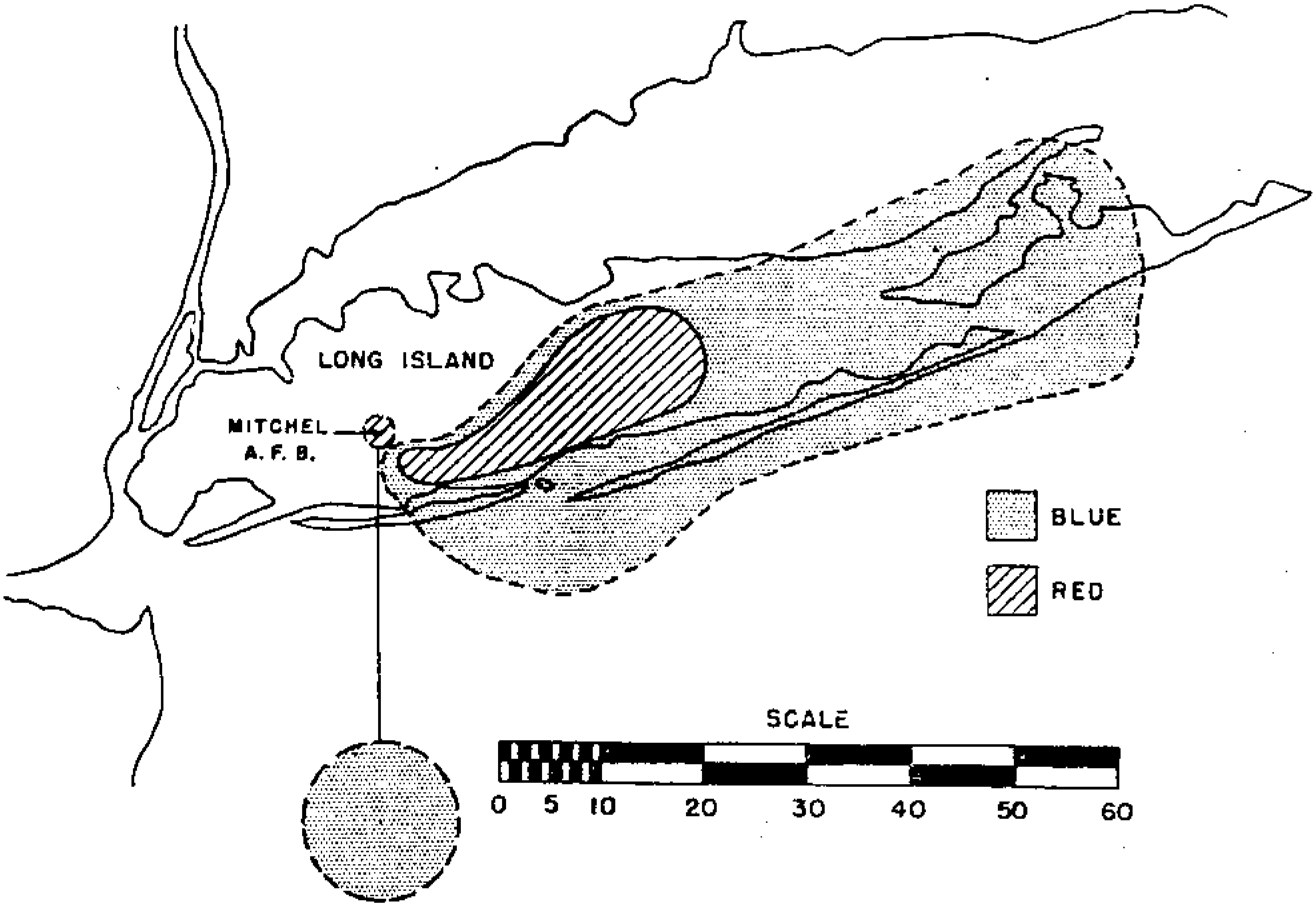


FIGURE 30. *Completed ground fall out plot transferred to base map.*

Section 5000

RADEX PLOTS

5100. GENERAL

Another method of determining fall-out area is called the RADEX plot. The theory and methods underlying the Radex plot are fundamentally the same as those used for ground fall-out, except that the RADEX plot is made for a specified level (either the surface or some level aloft) at a specified time. Instead of a table of distances, as used in ground fall-out plots, the Radex plot involves a table of fall-out *times*.

5200. FALL-OUT TIMES

Table 3 gives time, in hours, for particles to fall from one level to another. The column for each height of origin is subdivided into two vertical rows, headed "L" and "S". The "L" column gives the time for particles in the size range large-to-medium to fall out *to* the levels indicated in the horizontal rows *from* the levels indicated in the vertical columns. The "S" column gives the fall-out times for particles in the medium-to-small size range.

Examples: Large-to-medium particles will require 0.08 hours to fall from 5,000 feet to the surface; medium-to-small particles falling from 15,000 feet will take 0.08 hours to reach 10,000 feet, 0.16 hours to reach 5,000 feet and 0.24 hours to reach the surface.

5300. TIME OF PLOT

Ground fall-out plots are constructed to show the results of the total fall-out. *Ground Radex plots* may also be drawn to show complete fall-out, but the need may exist to construct a ground Radex plot for an intermediate time between burst and complete fall-out. Each problem will be illustrated below.

5400. GROUND RADEX PLOT, COMPLETE FALL-OUT

This plot, when completed, will show essentially the same affected area as the ground fall-out plot shows, except that no distinction between heavy and light contamination zones will appear. The problem states that the top of the bomb cloud reaches 30,000 feet. Table 3 indicates that the time required for complete fall-out will be 1.87 hours.

5410. The preliminary tracing for a ground Radex plot is drawn in exactly the same manner as in ground fall-out. Procedures set forth in paragraphs 3200 through 4400 are followed step by step. The result is the wind vector diagram shown in figure 31, and the data sheet completed as illustrated in figure 32.

5420. Vectors Ob, Oc, Od, Oe, Of and Og are now traced on a second sheet of tracing paper, paralleling procedures for ground fall-out plot as given in paragraph 4600. This step produces figure 33.

5430. Column 7 of the data sheet is now completed. The "S" column of Table 3 is used to determine the time factors, since *all* particles from each level are assumed to have fallen out. As the plot is to be made for 1.87 hours after explosion, that value is entered on the horizontal line headed "Surface". For later use in finding the position of the stem cloud at the time of the radex plot.

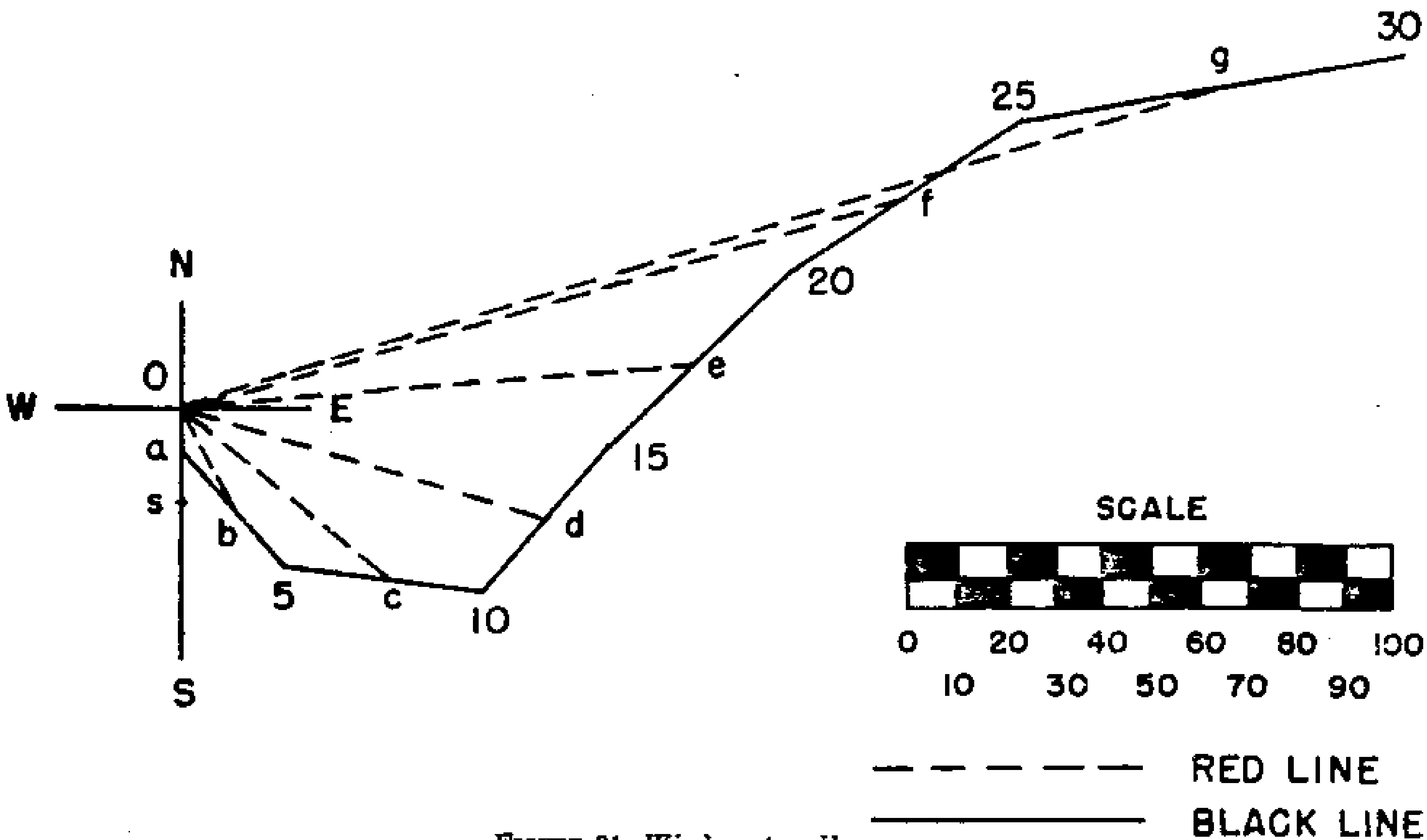


FIGURE 31. *Wind vector diagram.*

Column #	1	2	3	4	5	6
	Wind			Vectorial sum	Divide by	Mean wind speed
	Direction Deg True	Speed				
		Knots	MPH			
Sfc	360	17	20			
5,000	320	26	30	24	1	24 Ob
10,000	280	35	40	54	2	27 Oc
15,000	225	35	40	77	3	26 Od
20,000	230	48	55	109	4	27 Oe
25,000	240	48	55	159	5	32 Of
30,000	260	69	80	225	6	38 Og

FIGURE 32. *Ground radex plot, column 6, completed.*

5440. Entries are now made in column 9 of the data sheet. (Column 8 is used only for Air Radex plots). Values in column 6 are multiplied by the appropriate entries in column 7, and the result entered in column 9. For the "Surface" line, the entry in column 7 (i.e., 1.87) is multiplied by the surface wind speed (20 mph) from column 3. At the completion of this step, the data sheet becomes as shown in figure 34.

5450. Dispersion Radius. The values in column 9 locate points along each displacement bearing line where particles are concentrated. However, to account for dispersion, the values in column 9 are divided by 5 and the results entered in column 10. The column 10 values will be used as radii of circles centered at the points defined by data in column 9.

5451. The *minimum* value to be entered in column 10 is 1.5 miles.

5452. It should be noted that in ground fall-out plots (see paragraph 4000), dispersion covered an area 10° each side of the displacement line. The concept of dispersion radius employed in Radex plots gives a slightly different result, as shown in figure 35. Thus in the case of ground fall-out, a 20° dispersion is assumed, while in the ground Radex plot, the dispersion angle is 22° 38′, a relatively minor discrepancy.

5453. *Example.* The completed ground radex data sheet is illustrated in figure 36.

5460. *Laying off Distances.* The distances tabulated in column 9 are now laid off along the corresponding line on the overlay, using the scale of the diagram. A distance of 7.4 miles is laid off along Ob; 16.7 miles along Oc, etc. For locating the stem cloud, see paragraph 5480.

5470. *Drawing Dispersion Circles.* The next step is to draw circles centered at the points located in paragraph 5460, with radii equal to the values tabulated in column 10. For example: A circle with radius 10.0 miles is drawn centered at the point 49.9 miles along Of. (Again, the minimum radius of these circles is 1½ miles). A dashed circle, radius 1.5 miles, is drawn with center at the origin point "O" to indicate the original position of the bomb cloud.

5480. *Stem Cloud Positions:* (See also paragraph 4820).

5481. The position of the stem cloud at the time of the plot must be indicated. Its distance from the origin is 37.4 miles, as tabulated in column 9; its direction is that of the surface wind (360°), and its radius of dispersion is given in column 10. This cloud position is drawn as a dashed circle. The plot now appears as illustrated in figure 37.

5482. The next step is to draw a smooth curve around all the solid circles and to include also the small dashed circle at impact point. The area inside the smooth curve is shaded in blue, and indicates the region of probability of greatest contamination.

5483. The completed overlay is shown in figure 38. If drawn on thin tracing paper, it may be used as an overlay on a base map, or if desired, the shaded area may be transferred to the base map by the procedure outlined in paragraph 4900.

5484. Comparison: Figure 39 shows a comparison between the results obtained by constructing a ground fall-out plot and by constructing a ground radex plot for complete fall-out time. It should be noted that the two systems are in close agreement.

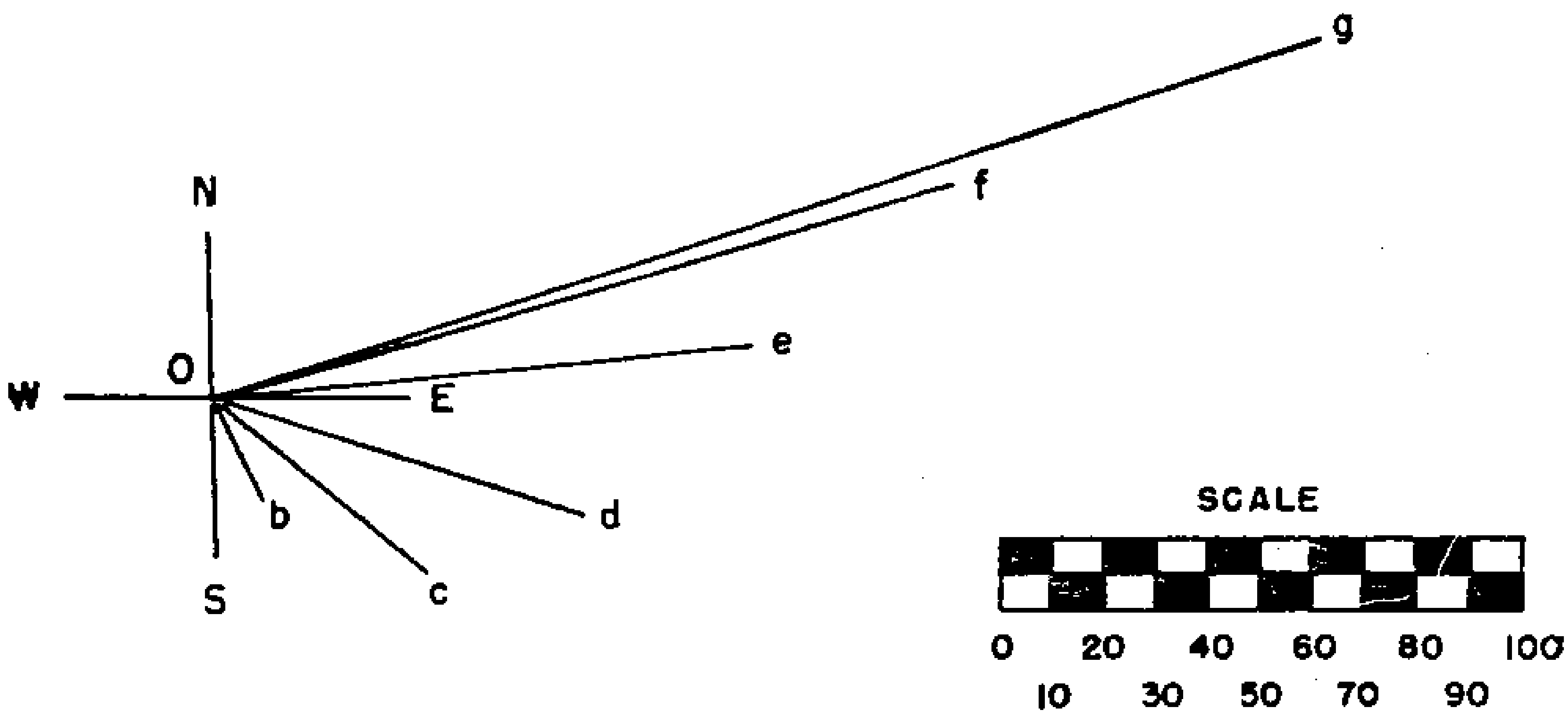


FIGURE 33. *Second tracing.*

Column #	1	2	3	4	5	6	7	8	9
	Wind			Vectorial sum	Divide by	Mean wind speed	Time of fall (hours) (ground plot)	Time after burst (hours) (air plot)	Displacement (Miles)
	Direction Deg True	Speed							
		Knots	MPH						
Surface	360	17	20				1.87		27.4
5,000	320	26	30	24	1	24 Ob	.31		7.4 Ob
10,000	280	35	40	54	2	27 Oc	.62		16.7 Oc
15,000	225	35	40	77	3	26 Od	.94		24.4 Od
20,000	230	48	55	109	4	27 Oe	1.25		33.8 Oe
25,000	240	48	55	155	5	32 Of	1.56		49.9 Of
30,000	260	69	80	225	6	38 Og	1.87		71.1 Og

FIGURE 34. *Ground radex plot, column 9 complete.*

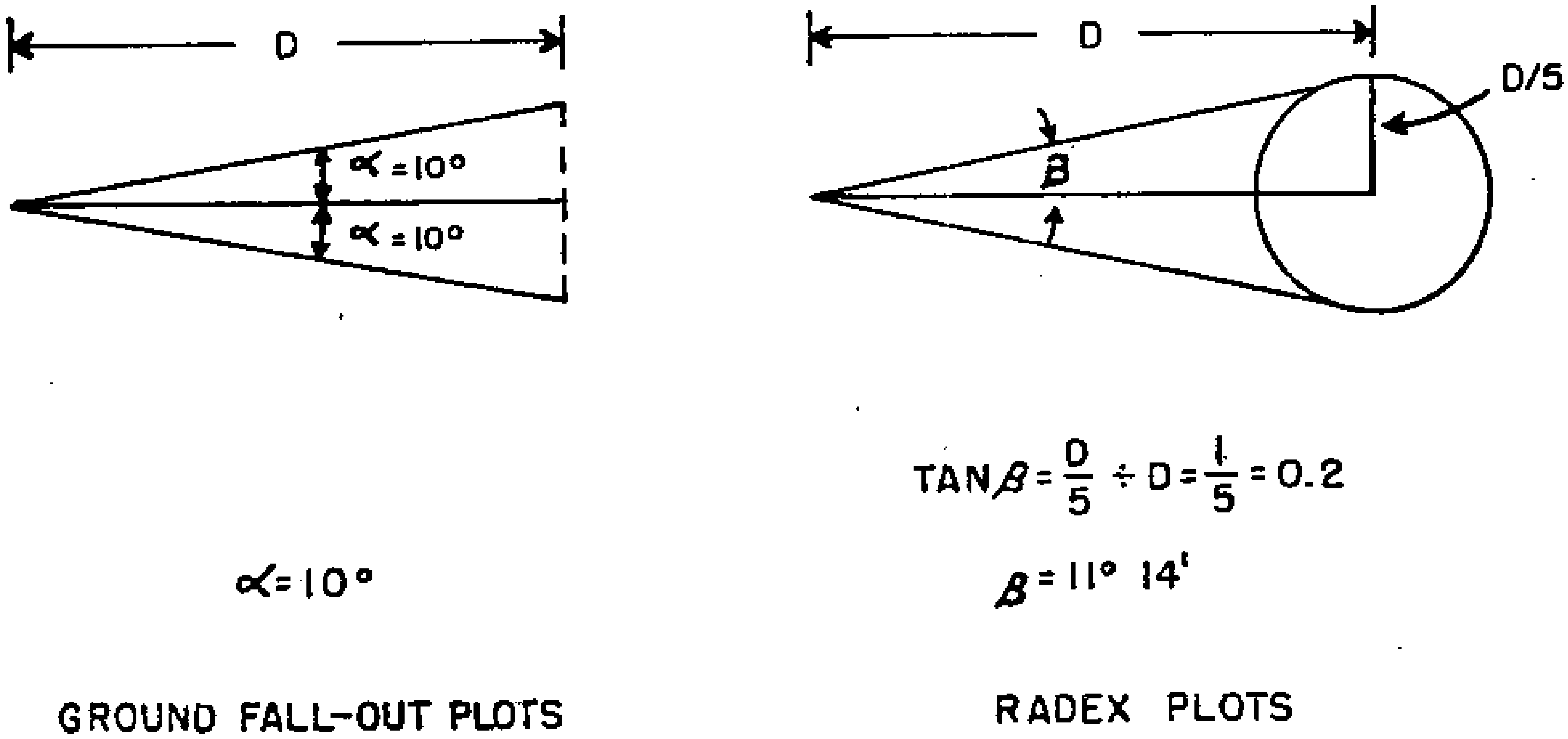


FIGURE 35. *Dispersion computations.*

RADEX PLOT DATA

SURFACE LEVEL

TIME AFTER BURST 1 HR 52 MIN

COMPUTED 1 Feb 1952 BY T-SGT G. R. Jones BASE WEATHER STATION Mitchel AFB

Column #	1	2	3	4	5	6	7	8	9	10
	Wind			Vectorial sum	Divide by	Mean wind speed	Time of fall (hours) (ground plot)	Time after burst (hours) (air plot)	Displacement (Miles)	Dispersion radius (Miles)
	Direction Deg True	Speed								
		Knots	MPH							
SURFACE	360	17	20				1.87		37.4	7.5
5,000	320	26	30	24	1	24 Ob	.31		7.4 Ob	1.5
10,000	280	35	40	54	2	27 Oc	.62		16.7 Oc	3.3
15,000	225	35	40	77	3	26 Od	.94		24.4 Od	4.9
20,000	230	48	55	109	4	27 Oe	1.25		33.8 Oe	6.8
25,000	240	48	55	155	5	32 Of	1.56		49.9 Of	10.0
30,000	200	69	80	225	6	38 Og	1.87		71.1 Og	12.2

Winds aloft data: Time 0300Z Station Mitchel

Remarks:

FIGURE 36. *Complete ground radex data sheet.*

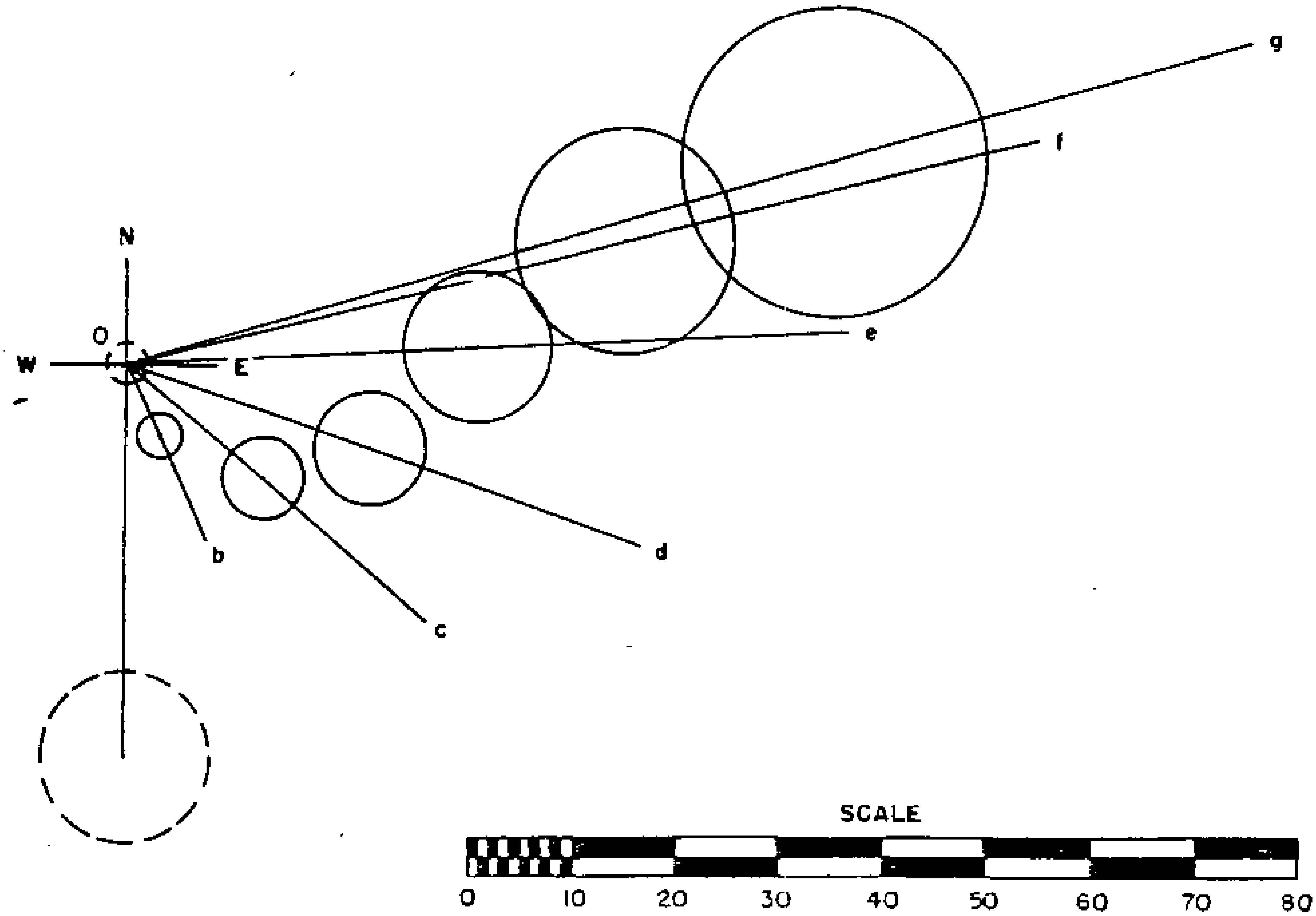


FIGURE 37. *Ground radex plot, areas located.*

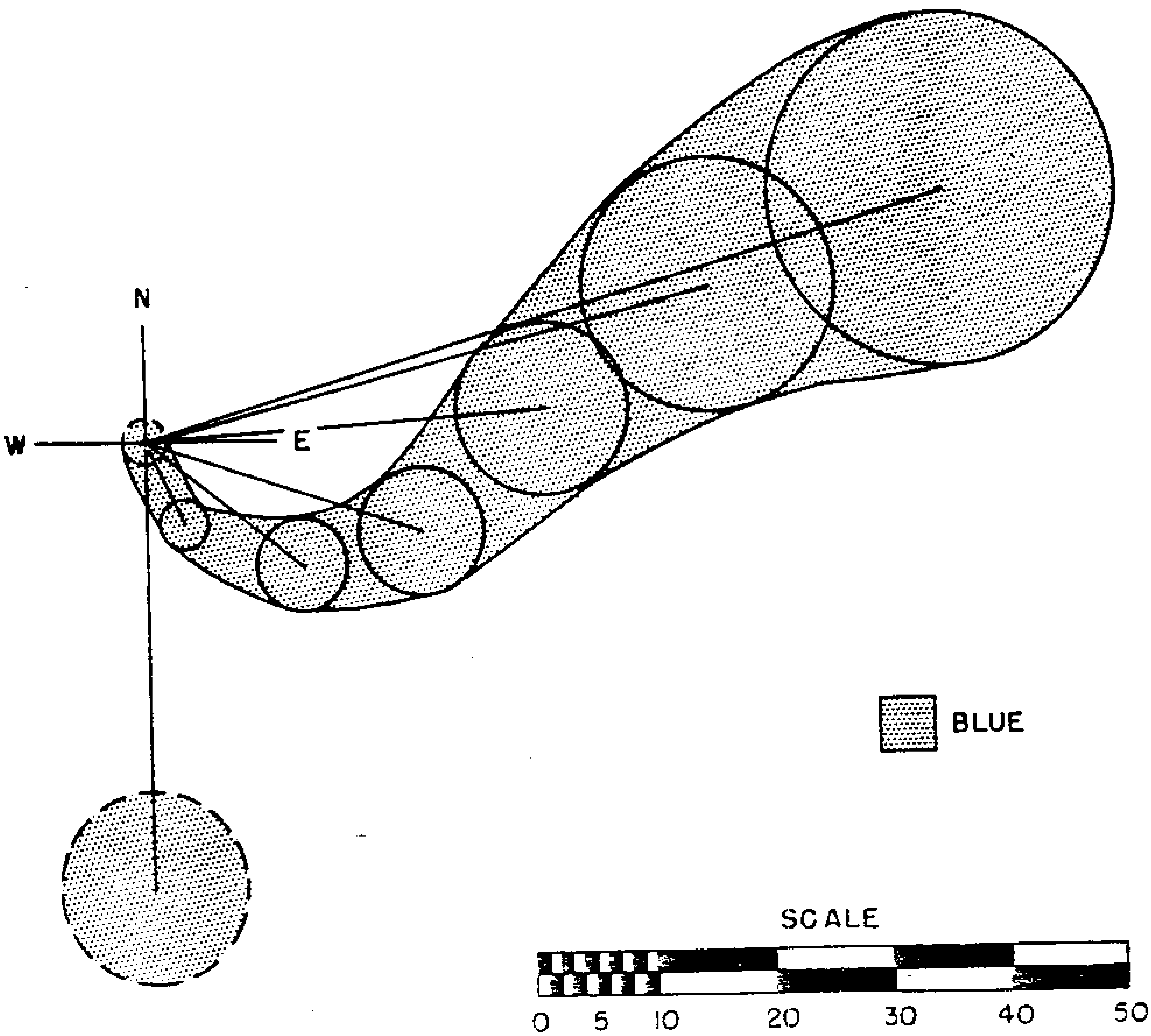


FIGURE 38. *Complete ground radex plot (complete fall-out).*

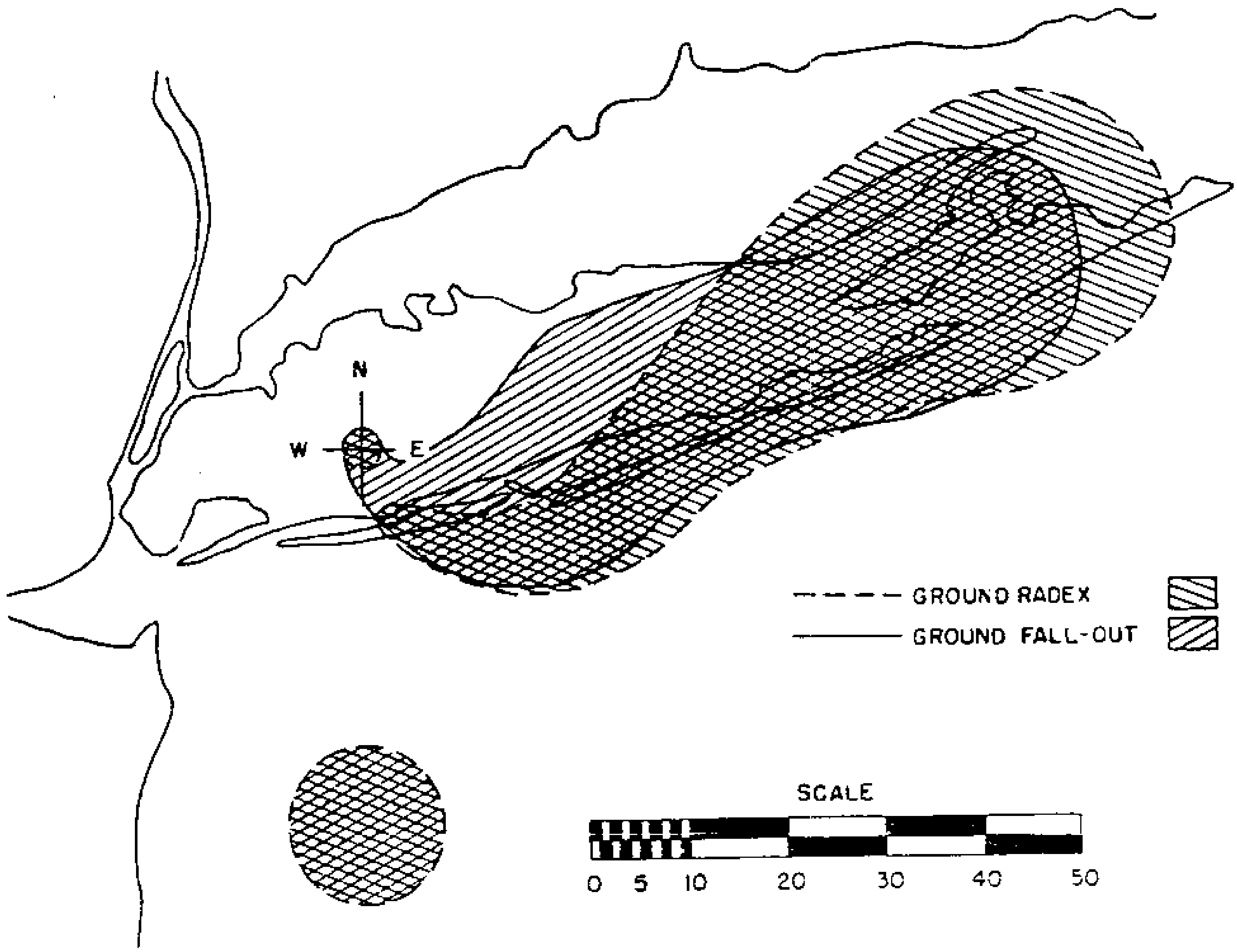


FIGURE 39. *Comparison, ground fall out vs. ground radex.*

RADEX PLOT DATA

SURFACE LEVEL

TIME AFTER BURST ____ HRS

COMPUTED 1 February 1952 BY T-SGT G. R. JONES BASE WEATHER STATION Mitchel AFB

Column #	1	2	3	4	5	6	7	8	9	10
	Wind			Vectorial sum	Divide by	Mean wind speed	Time of fall (hours) (ground plot)	Time after burst (hours) (air plot)	Displacement (Miles)	Dispersion radius (Miles)
	Direction Deg True	Speed								
		Knots	MPH							
Surface	360	17	20				0.25		5	1.5
5,000	320	26	30	24	1	24 Ob	0.31		7.4	1.5
10,000	280	35	40	54	2	27 Oc	0.62		16.7	3.3
15,000	225	35	40	77	3	26 Od	0.94		24.4	4.9
20,000	—									
25,000	—									
30,000	—									

Winds aloft data: Time 0300Z Station Mitchel

Remarks:

FIGURE 41. *Complete data sheet, ground radex 0.25 hours after burst.*

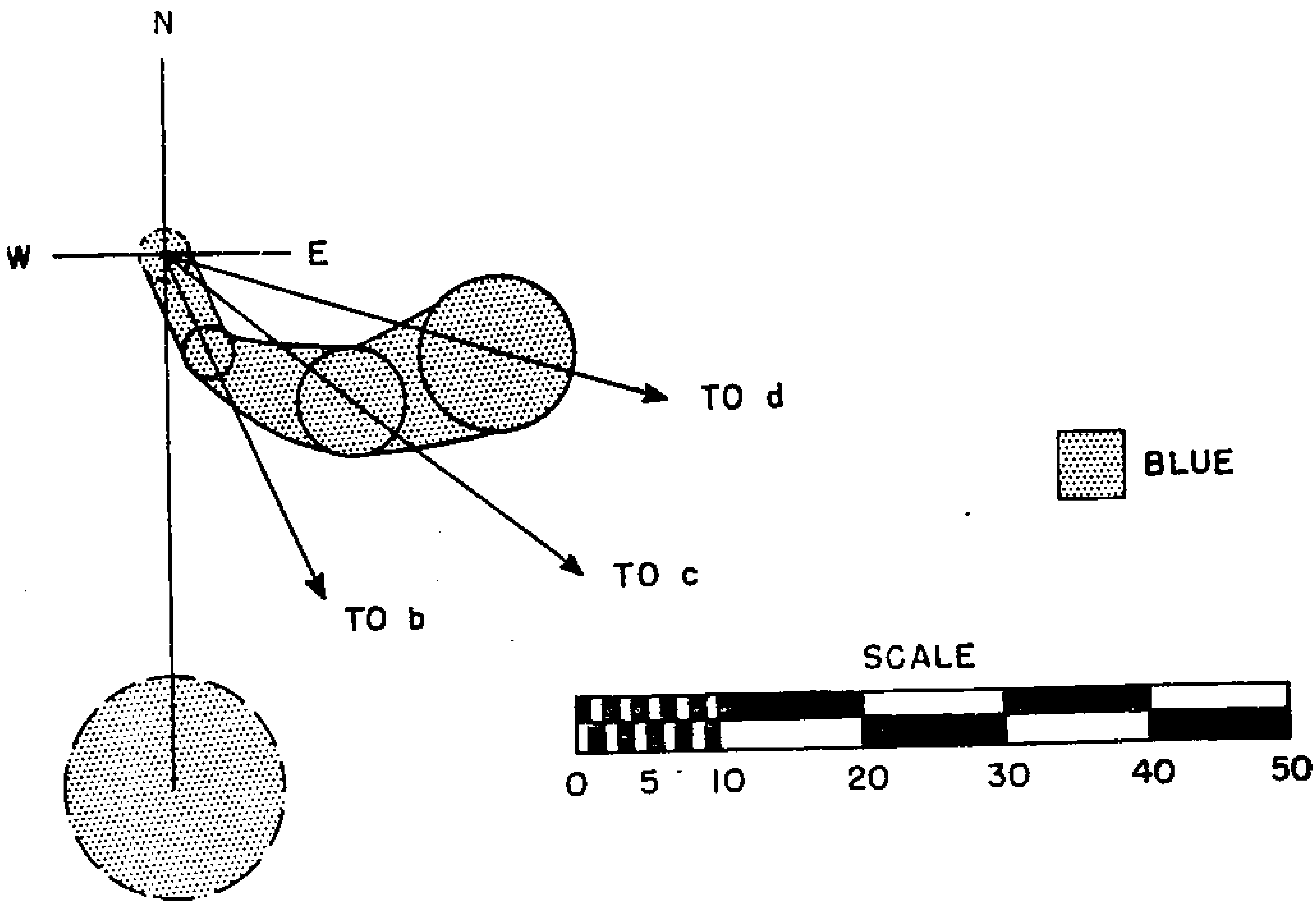


FIGURE 42. *Final ground radex plot 0.25 hours after burst.*

a level which is a multiple of *5,000* feet. The example illustrated below is an air Radex plot for the 10,000 foot level, 30 minutes after the burst. Wind and other data are the same as those in preceding examples.

5610. *Wind Vector Diagram.* There are two alternatives involved in this step:

5611. If a ground Radex, or ground fall-out plot has already been made, the wind vector diagram previously constructed can be used, modified as explained in paragraph 5630.

5612. If no other fall-out computations have been made, a modified wind vector diagram is constructed, as outlined in paragraph 5620.

5620. The air Radex plot will be made for the 10,000 foot level. Hence the mean winds from the surface to 10,000 feet will have no effect on the particles falling to 10,000 feet from above, and can be ignored.

5621. Assuming a uniform (linear) variation of wind speed and direction from 10,000 to 15,000 feet, it follows that in its fall from 15,000 feet to 12,500 feet, a particle is acted upon by the 15,000 foot wind; and in its fall from 12,500 to 10,000 feet, the 10,000 foot wind will govern its movement. The mean wind in the layer from 15,000 to 10,000 is thus half of the 10,000 foot wind plus half of the 15,000 foot wind. Drawing the wind vectors and a diagrammatic sketch, we obtain figure 43. The mean wind vector is one-half of (5 to 10) plus one-half of (10 to 15).

Since: one-half of (5 to 10) = c to 10
and: one-half of (10 to 15) = 10 to d,

the mean wind vector from 15,000 to 10,000

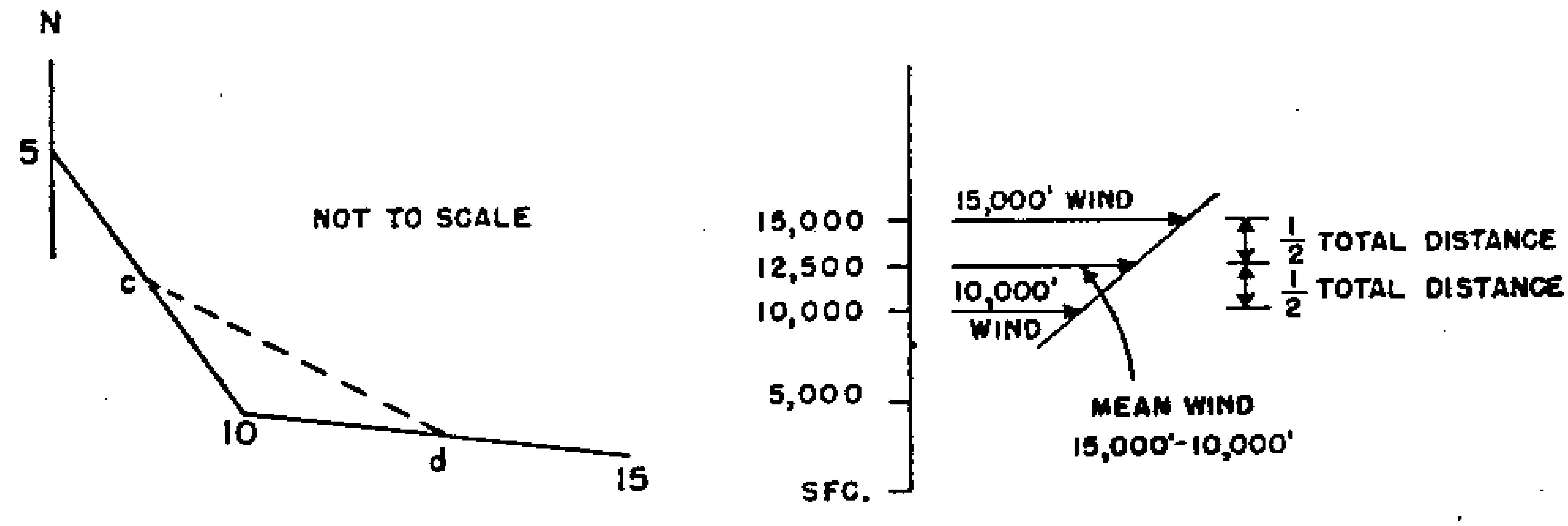


FIGURE 43. *10000 and 15000 foot wind vectors.*

feet is represented by the vectorial sum of c to 10 and 10 to d, or vector cd (dashed). Its direction is the same as the direction of cd, and its speed is represented by the length of cd.

5622. Between 20,000 feet and 10,000 feet, particles will be acted on half of the time (between 20,000 and 15,000 feet) by the mean wind from 20,000 to 15,000 feet. The other half of the time (between 15,000 and 10,000 feet), the particle will be governed by the mean wind from 15,000 to 10,000 feet. The applicable portion of the wind vector diagram, and a diagrammatic sketch, are shown in figure 44. The mean wind from 10,000 to 15,000 feet is cd. The mean wind from 15,000 to 20,000 feet is vector de (dotted). Since each of these mean winds acts half the time, the mean wind from 10,000 to 20,000 feet can be written as:

> One-half vector cd plus one-half vector de, or
> One-half (vector cd plus vector de).

Since vector ce is the vectorial sum of vectors cd and de, it follows that one-half of vector ce is the mean wind vector between 20,000 and 10,000 feet. Its direction is the direction of ce, and its speed is one-half the length of ce.

5623. Between 25,000 and 10,000 feet, the particle will be acted on by—the mean wind from 25,000 to 20,000 feet, for one-third of the time, the mean wind from 20,000 to 15,000 feet, for one-third of the time, the mean wind from 15,000 to 10,000 feet, for one-third of the time. The applicable portion of the vector diagram and a diagrammatic sketch are given in figure 45.

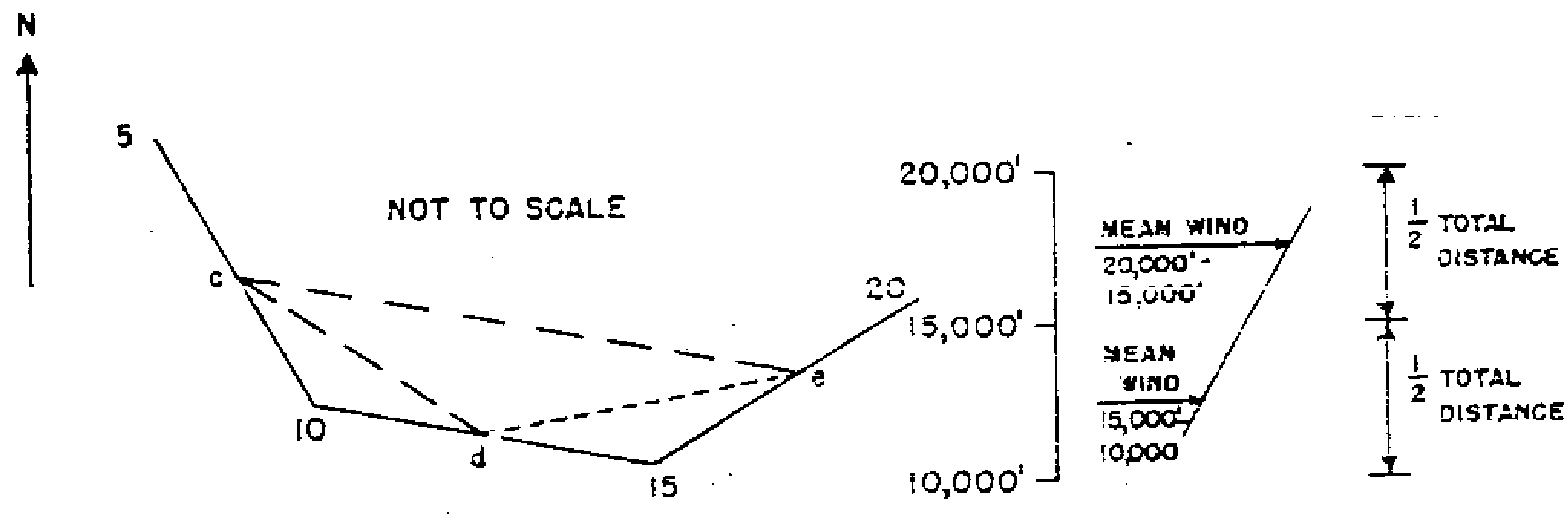


FIGURE 44. *10000, 15000 and 20000 foot wind vectors.*

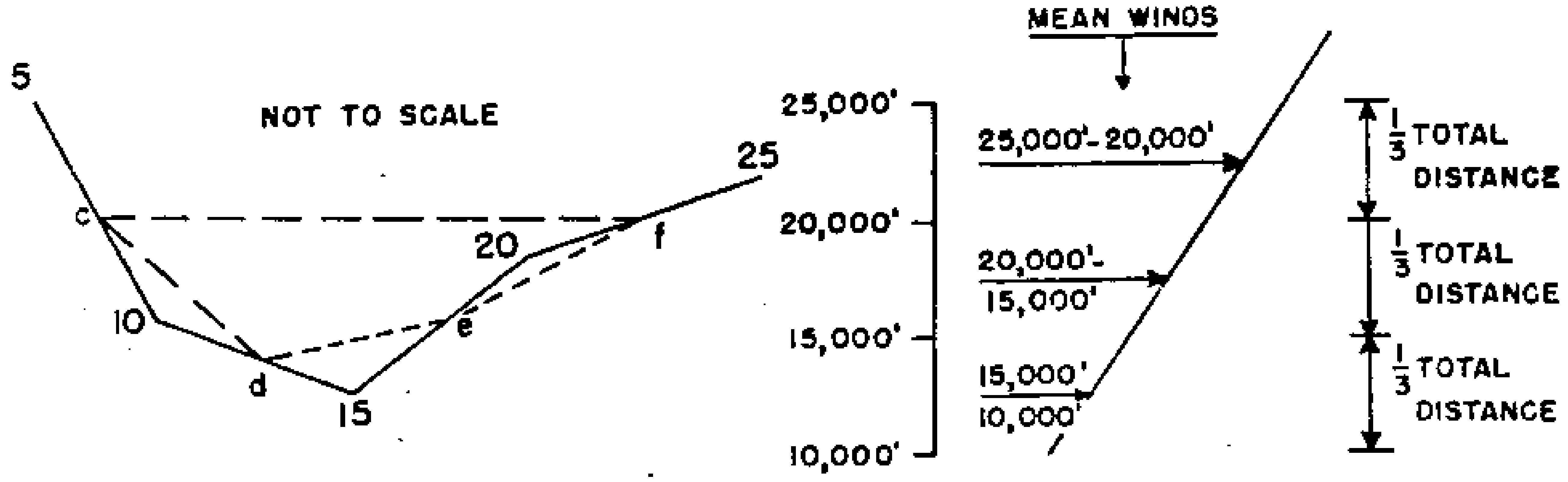


FIGURE 45. *10000, 15000, 20000 and 25000 foot wind vectors.*

Vector cd is the mean wind from 15,000 to 10,000 feet, vector de (dotted) is the mean wind from 20,000 to 15,000 feet, and vector ef is the mean wind from 25,000 to 20,000 feet. Since each of these mean winds acts one-third of the time, the mean wind between 25,000 feet and 10,000 feet can be written as:

One-third cd plus one-third vector de plus one-third vector ef, or

One-third (vector cd plus vector de plus vector ef).

Vector cf is the vectorial sum of cd, de and ef, so that one-third of vector cf is the mean wind speed from 10,000 to 25,000 feet. Thus, dividing the length of vector of by 3 gives the value of the mean wind speed; its direction is the same as the direction of cf. Similar reasoning can be applied to determine remaining mean wind vectors for other layers.

5624. It should now be apparent that, for practical purposes, the process described in Section 4000 for obtaining mean wind speeds has been followed exactly, except that the origin point "O" must be moved out to point "c", for an air radex plot at 10,000 feet.

5625. A tabulation showing the "first vector" to be drawn, and the point to be used as the "new" origin for air Radex plots at various levels follows:

For air radex plots at	First wind vector drawn	Origin point at
5,000	0–5	b
10,000	5–10	c
15,000	10–15	d
20,000	15–20	e
25,000	20–25	f
30,000	25–30	g
35,000	30–35	h
40,000	35–40	i

5630. Thus, if a wind vector diagram has already been drawn for either a ground fall-out or a ground Radex plot, a new tracing can be made, beginning with the origin point given in paragraph 5625, copying the remaining wind vectors, and drawing the bearing vectors from the new origin point.

5631. Assuming that this has been done in the example under discussion, the new tracing becomes as shown in figure 46.

5460. *Mean Wind Speed.* The air Radex data sheet is now filled in, as shown below:

5650. *Particle Location.* To determine which particles will be at 10,000 feet 30 minutes (0.5 hours) after burst, examine the data for the level in Table 3. The procedure as given in paragraph 5513 is followed except

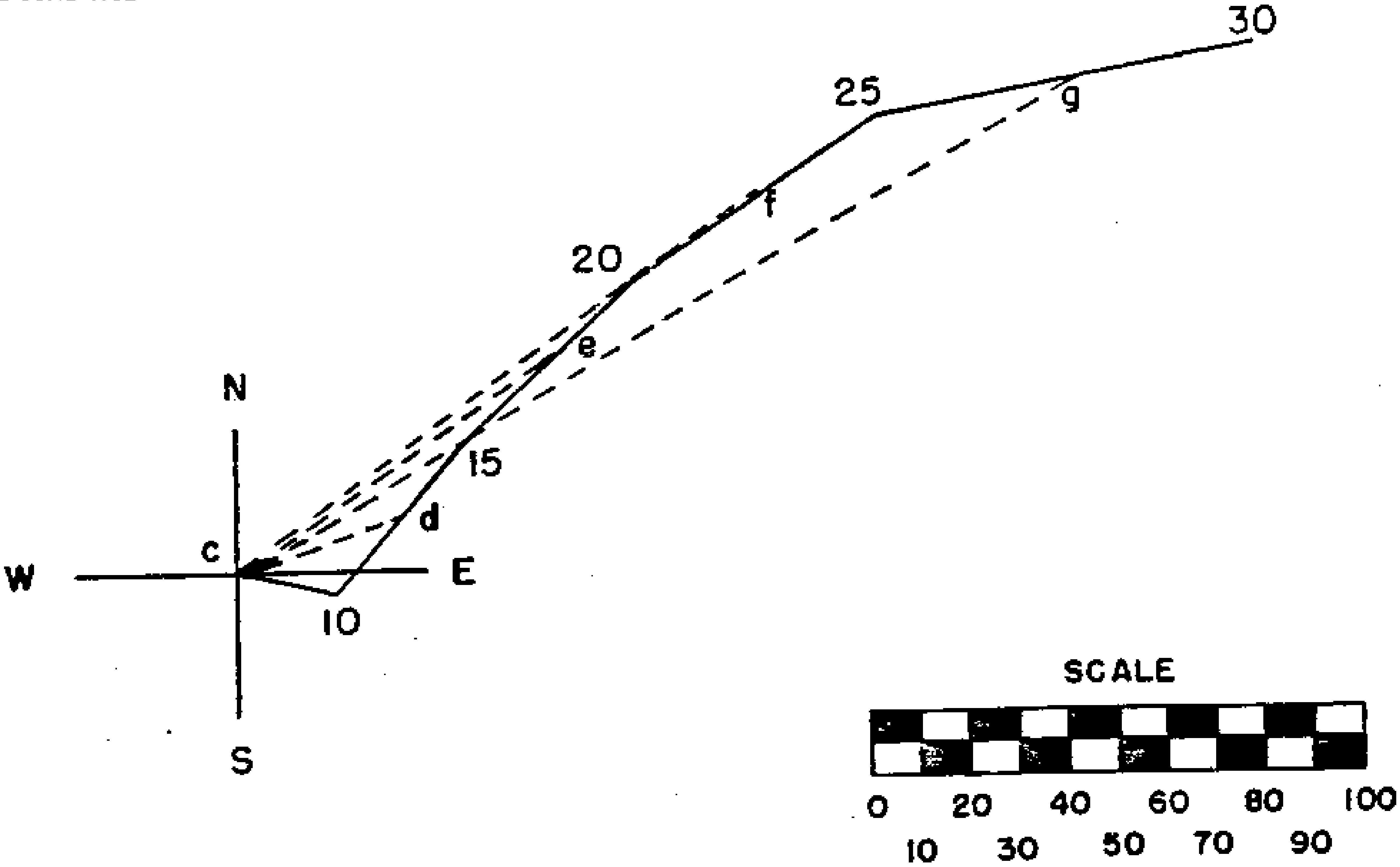


FIGURE 46. ***Wind vector analysis air radex at 10000.***

that table 3 is entered at the 10,000 foot level and the time interval used is 0.50 hours. Since all particles from 15,000 feet will have fallen *through* the 10,000 foot level in 0.31 hours, we can ignore any further computations for that level. Some particles from 20,000, 25,000 and 30,000 feet will be *at* 10,000 feet 30 minutes after the burst. Thus we will be concerned with locating only particles from these three levels.

5651. Column 8 of the data sheet is filled in as 0.5 hours. (Note: Column 7 is not used for Air Radex Plots). The time 0.5 is also inserted opposite surface wind speed for later use in locating the bomb cloud at the time of the Radex plot.

5652. Column 9 is completed by multiplying values in column 6 by those in column 8.

5653. Column 10 is completed by dividing each column 9 value by "5". The minimum radius of dispersion is 1.5 miles. Upon completion of this step, the final data sheet is as shown in figure 48.

5660. Returning to the tracing, the distances tabulated in column 9 of the data sheet are now laid off along the appropriate lines ce, cf, and cg, respectively.

Column #	1	2	3	4	5	6
	Wind			Vecto speed	Divide by	Mean wind speed
	Direction Deg True	Speed				
		Knots	MPH			
10,000	280	35	40			
15,000	225	35	40	35	1	35 cd
20,000	230	48	55	80	2	40 ce
25,000	240	48	55	132	3	44 cf
30,000	260	69	80	233	4	58 cg

FIGURE 47. *Data sheet column 6 complete.*

RADEX PLOT DATA

10,000 Feet LEVEL

TIME AFTER BURST 30 Min.

COMPUTED 1 February 1052 BY T-SGT G. R. Jones BASE WEATHER STATION Mitchel AFB

Column #	1	2	3	4	5	6	7	8	9	10
	Wind									
	Direction Deg True	Speed		Vectorial sum	Divide by	Mean wind speed	Time of fall (hours) (ground plot)	Time after burst (hours) (air plot)	Displacement (Miles)	Dispersion radius (Miles)
		Knots	MPH							
10,000	280	35	40					.5	20(cloud)	4
15,000	225	35	40	35	1	35 cd				
20,000	230	48	55	80	2	40 ce		.5	20	4
25,000	240	48	55	132	3	44 cf		.5	22	4.4
30,000	200	60	80	233	4	58 cg		.5	29	5.8

Winds aloft data: Time 0300Z Station Mitchel

Remarks:

FIGURE 48. *Completed data, sheet air radex plot, 10,000 feet.*

5661. These three points are then used as the centers of circles with radii equal to the values tabulated in column 10. The *minimum* radius is 1½ miles.

5670. *Stem Cloud Positions.* The displacement of the 10,000 foot radioactive cloud is computed by multiplying the wind speed at 10,000 feet (40 mph) by the time of the plot (0.5 hours). Direction is given by the direction of the 10,000 foot wind. The radius of the dispersion circle is determined by dividing the displacement distance by 5 (minimum radius 1.5 miles). For this example, a dashed circle of 4 miles radius is drawn with center 20 miles from point c, along the 10,000 foot wind vector.

5680. The foregoing steps result in the diagram shown in figure 49. After enclosing the solid circles with a smooth curve and shading in the encompassed area, the completed air radex plot is as shown in figure 50. This plot can be transferred to a base map, which should be clearly marked with the level for which the plot has been made, as well as the time after burst.

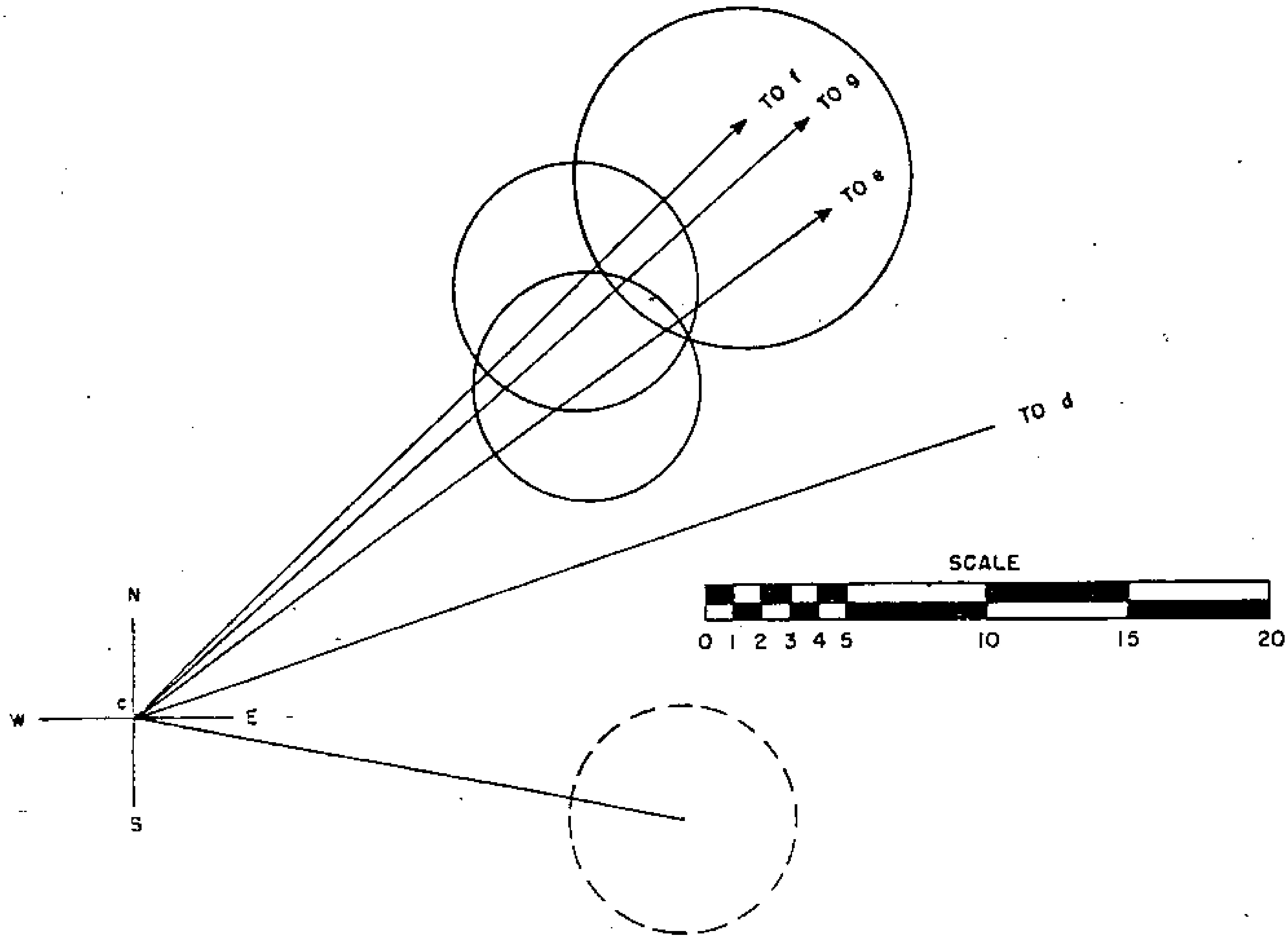


FIGURE 49. *Air radex plot.*

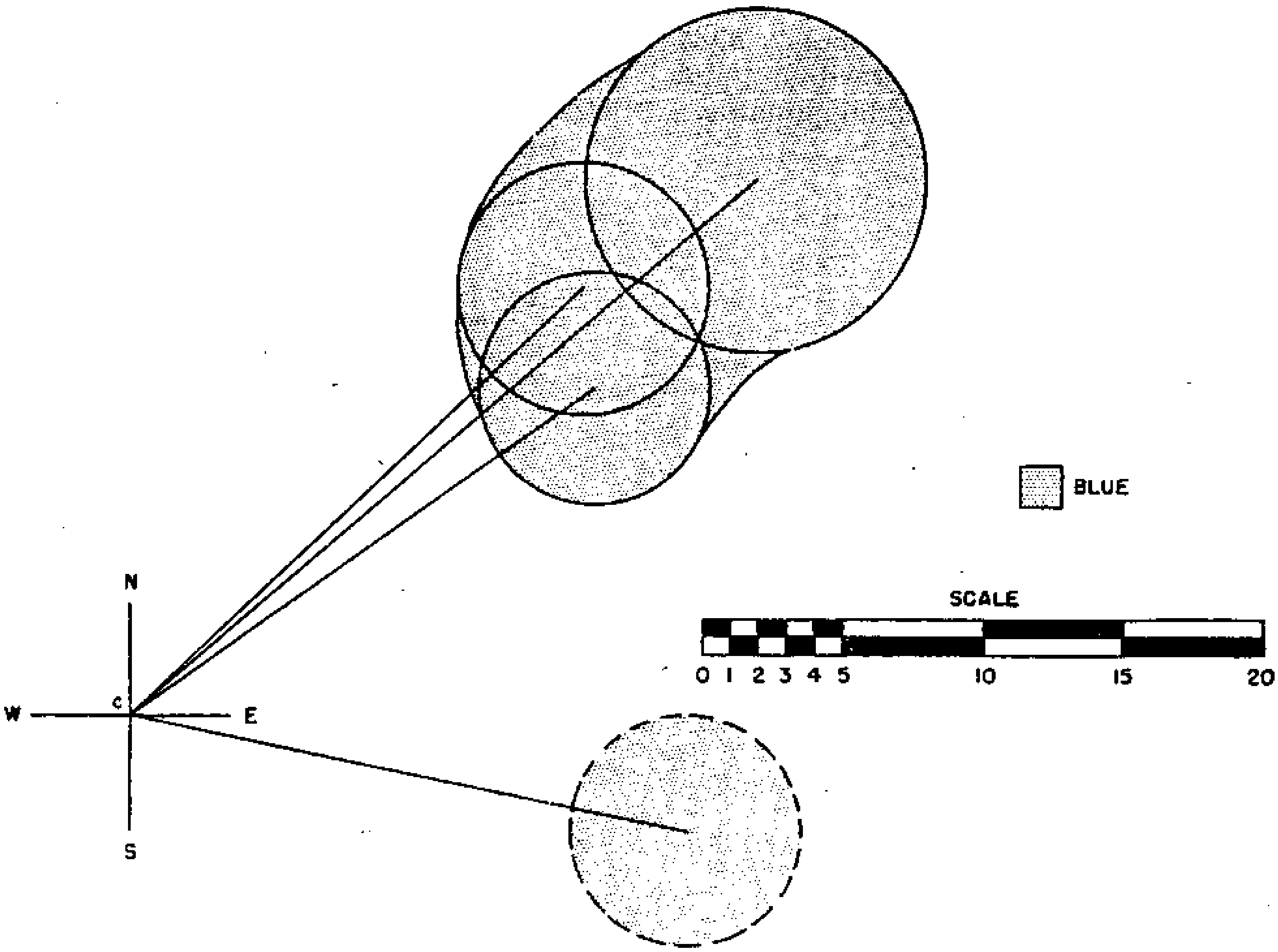


FIGURE 50. *Completed air radex plot for 10000 foot level, time 0.5 hours after burst.*

Section 6000

TABLES

6100. TABLE 1

This table is used for converting wind speeds in knots to wind speeds in miles per hour, as described in paragraph 3300.

6200. TABLE 2

(GROUND FALL-OUT PLOTS)

6210. *Surface to 30,000 feet.* This table is used for computing the *distances* in miles to which radioactive particles will be carried by the mean wind from the surface to given 5,000 foot levels. Heavy particles at a given level will fall out faster (closer to the explosion point) than medium-sized particles; medium-sized particles in turn will fall out faster than light particles. Thus, for each level three points can be determined: MIN—the minimum distance from the explosion point where large (heavy) particles will fall out; MEAN—the distance where medium-sized particles will fall out; and MAX—the distance where small (light) particles will fall out. The tables were computed by multiplying an empirical time factor, established by experience and calculation, by a mean wind speed of the wind for various levels. These time factors are listed at the end of the table, and are given in hours, tenths, and hundredths of hours. Figure 12, page 15 is a graphical explanation of table 2. The wind arrow on the figure indicates the mean wind from the surface to 20,000 feet, and is used as an example only. Actually, contamination from winds at lower levels would, of course, exist closer to the explosion point.

6220. *Above 30,000.* Table 2 has been completely worked out to include the 30,000 foot wind vector. Cases may arise (for example when the tropopause is higher than 35,000 feet) when it is desired to carry the computations higher. In such cases, the time factors listed below may be used:

Height	Vector	Mean	Min	Max
35,000	Oh	.59	.88	2.18
40,000	Oi	.68	1.00	2.50
45,000	Oj	.75	1.13	2.80
50,000	Ok	.83	1.25	3.13
55,000	Ol	.90	1.38	3.44
60,000	Om	1.00	1.50	3.75

For ground fall-out plots with cloud top above 30,000 feet, follow the same procedures as given in paragraph 3400. Continue drawing vectors 30–35, 35–40, 40–45, etc., and mark the midpoints as h, i, j, etc. After measuring the length of lines Oh, Oi, Oj, etc., divide by 7, 8, 9, etc. (respectively). The table given above may then be used. For example, assume that line Oj is measured as 360 MPH. Dividing by 9 gives a value of 40. MIN distance is obtained by multiplying 0.75 by 40; MEAN distance, by multiplying 1.13 by 40, and MAX distance, by multiplying 2.80 by 40. The procedures given in paragraphs 4500–4600 are then followed.

6300. TABLE 3

(FOR RADEX PLOTS).

This table is used to find the times of fall of particles from a given height of origin to levels below, including the surface. Particles are considered to be of two "sizes"—large to medium, (headed by "L") and medium to small, (headed by "S"). Paragraphs 5200 and 5510 give detailed explanations on the use of this table in constructing Radex plots.

Appendix A

TABLES

Table 1. Knots to Miles Per Hour

Knots	0	1	2	3	4	5	6	7	8	9	Knots
0	0	1	2	3	5	6	7	8	9	10	0
10	12	13	14	15	16	17	18	20	21	22	10
20	23	24	25	26	28	29	30	31	32	33	20
30	35	36	37	38	39	40	41	43	44	45	30
40	46	47	48	50	51	52	53	54	55	56	40
50	58	59	60	61	62	63	65	66	67	68	50
60	69	70	71	73	74	75	76	77	78	80	60
70	81	82	83	84	85	86	88	89	90	91	70
80	92	93	94	96	97	98	99	100	101	103	80
90	104	105	106	107	108	109	111	112	113	114	90
Knots	0	1	2	3	4	5	6	7	8	9	Knots

1 Knot = 1.1515 miles per hour.
Example: 46 knots = 53 miles per hour.

Table 2. Use for Ground Fall-Out Plots

Mean Wind Speed	Vector Ob			Vector Oc			Vector Od			Vector Oe			Vector Of			Vector Og			Mean Wind Speed
MPH	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	MPH
1	.1	.1	.3	.2	.3	.6	.3	.4	.9	.3	.5	1.3	.4	.6	1.6	.5	.8	1.9	1
2	.2	.3	.6	.4	.5	1.3	.5	.8	1.9	.7	1.0	2.5	.9	1.3	3.1	1.0	1.5	3.8	2
3	.3	.4	.9	.5	.8	1.9	.8	1.1	2.8	1.0	1.5	3.8	1.3	1.9	4.7	1.5	2.3	5.6	3
4	.4	.5	1.2	.7	1.0	2.5	1.0	1.5	3.7	1.4	2.0	5.0	1.7	2.5	6.2	2.0	3.0	7.5	4
5	.5	.7	1.6	.9	1.3	3.2	1.3	1.9	4.7	1.7	2.5	6.3	2.2	3.2	7.8	2.5	3.8	9.4	5
6	.5	.8	1.9	1.1	1.5	3.8	1.5	2.3	5.6	2.0	3.0	7.5	2.6	3.8	9.3	3.0	4.5	11.3	6
7	.6	.9	2.2	1.3	1.8	4.4	1.8	2.7	6.5	2.4	3.5	8.8	3.0	4.4	10.9	3.5	5.3	13.2	7
8	.7	1.0	2.5	1.4	2.0	5.0	2.0	3.0	7.4	2.7	4.0	10.0	3.4	5.0	13.4	4.0	6.0	15.0	8
9	.8	1.2	2.8	1.6	2.3	5.7	2.3	3.4	8.4	3.1	4.5	11.3	3.9	5.7	14.0	4.5	6.8	16.9	9
10	.9	1.3	3.1	1.8	2.5	6.3	2.5	3.8	9.3	3.4	5.0	12.5	4.3	6.3	15.5	5.0	7.5	18.8	10
11	1.0	1.4	3.4	2.0	2.8	6.9	2.8	4.2	10.2	3.7	5.5	13.8	4.7	6.9	17.1	5.5	8.3	20.7	11
12	1.1	1.6	3.7	2.2	3.0	7.6	3.0	4.6	11.2	4.1	6.0	15.0	5.2	7.6	18.6	6.0	9.0	22.6	12
13	1.2	1.7	4.0	2.3	3.3	8.2	3.3	4.9	12.1	4.4	6.5	16.3	5.6	8.2	20.2	6.5	9.8	24.4	13
14	1.3	1.8	4.3	2.5	3.5	8.8	3.5	5.3	13.0	4.8	7.0	17.5	6.0	8.8	21.7	7.0	10.5	26.3	14
15	1.4	2.0	4.7	2.7	3.8	9.5	3.8	5.7	14.0	5.1	7.5	18.8	6.5	9.5	23.3	7.5	11.3	28.2	15
16	1.5	2.1	5.0	2.9	4.0	10.1	4.0	6.1	14.9	5.4	8.0	20.0	6.9	10.1	24.8	8.0	12.0	30.1	16
17	1.5	2.2	5.3	3.1	4.3	10.7	4.3	6.5	15.8	5.8	8.5	21.3	7.3	10.7	26.4	8.5	12.8	32.0	17
18	1.6	2.3	5.6	3.2	4.5	11.3	4.5	6.8	16.7	6.1	9.0	22.5	7.7	11.3	27.9	9.0	13.5	33.8	18
19	1.7	2.5	5.9	3.4	4.8	12.0	4.8	7.2	17.7	6.5	9.5	23.8	8.2	12.0	29.5	9.5	14.3	35.7	19
20	1.8	2.6	6.2	3.6	5.0	12.6	5.0	7.6	18.6	6.8	10.0	25.0	8.6	12.6	31.0	10.0	15.0	37.6	20
21	1.9	2.7	6.5	3.8	5.3	13.2	5.3	8.0	19.5	7.1	10.5	26.3	9.0	13.2	32.6	10.5	15.8	39.5	21
22	2.0	2.9	6.8	4.0	5.5	13.9	5.5	8.4	20.5	7.5	11.0	27.5	9.5	13.9	34.1	11.0	16.5	41.4	22
23	2.1	3.0	7.1	4.1	5.8	14.5	5.8	8.7	21.4	7.8	11.5	28.8	9.9	14.5	35.7	11.5	17.3	43.2	23
24	2.2	3.1	7.4	4.3	6.0	15.1	6.0	9.1	22.3	8.2	12.0	30.0	10.3	15.1	37.2	12.0	18.0	45.1	24
25	2.3	3.3	7.8	4.5	6.3	15.8	6.3	9.5	23.5	8.5	12.5	31.3	19.8	15.8	38.8	12.5	18.8	47.0	25
26	2.3	3.4	8.1	4.7	6.5	16.4	6.5	9.9	24.2	8.8	13.0	32.5	11.2	16.4	40.3	13.0	19.5	48.9	26
27	2.4	3.5	8.4	4.9	6.8	17.0	6.8	10.3	25.1	9.2	13.5	33.8	11.6	17.0	41.9	13.5	10.3	50.8	27
28	2.5	3.6	8.7	5.0	7.0	17.6	7.0	10.6	26.0	9.5	14.0	35.0	12.0	17.6	43.4	14.0	21.0	52.6	28
29	2.6	3.8	9.0	5.2	7.3	18.3	7.3	11.0	27.0	9.9	14.5	36.3	12.5	18.3	45.0	14.5	21.8	54.5	29
30	2.7	3.9	9.3	5.4	7.5	18.9	7.5	11.4	27.9	10.2	15.0	37.5	12.9	18.9	46.5	15.0	22.5	56.4	30
31	2.8	4.0	9.6	5.6	7.8	19.5	7.8	11.8	28.8	10.5	15.5	38.8	13.3	19.5	48.1	15.5	23.3	58.3	31
32	2.9	4.2	9.9	5.8	8.0	20.2	8.0	12.2	29.8	10.9	16.0	40.0	13.8	20.2	49.6	16.0	24.0	60.2	32
33	3.0	4.3	10.2	5.9	8.3	20.8	8.3	12.5	30.7	11.2	16.5	41.3	14.2	20.8	51.2	16.5	24.8	62.0	33
34	3.1	4.4	10.5	6.1	8.5	21.4	8.5	12.9	31.6	11.6	17.0	42.5	14.6	21.4	52.7	17.0	25.5	63.9	34
35	3.2	4.6	10.8	6.3	8.8	22.1	8.8	13.3	32.6	11.9	17.5	43.8	15.1	22.1	54.3	17.5	26.3	65.8	35
36	3.2	4.7	11.2	6.5	9.0	22.7	9.0	13.7	33.5	12.2	18.0	45.0	15.5	22.7	55.8	18.0	27.0	67.7	36
37	3.3	4.8	11.5	6.7	9.3	23.3	9.3	14.1	34.4	12.6	18.5	46.3	15.9	23.3	57.4	18.5	27.8	69.6	37
38	3.4	4.9	11.8	6.8	9.5	23.9	9.5	14.4	35.3	12.9	19.0	47.5	16.3	23.9	58.9	19.0	28.5	71.4	38
39	3.5	5.1	12.1	7.0	9.8	24.6	9.8	14.8	36.3	13.2	19.5	48.8	16.8	24.6	60.5	19.5	29.3	73.3	39
40	3.6	5.2	12.4	7.2	10.0	25.2	10.0	15.2	37.2	13.6	20.0	50.0	17.2	25.2	62.0	20.0	30.0	75.2	40
41	3.7	5.3	12.7	7.4	10.3	25.8	10.3	15.6	38.1	13.9	20.5	51.3	17.6	25.8	63.6	20.5	30.8	77.1	41
42	3.8	5.5	13.0	7.6	10.5	26.5	10.5	16.0	39.1	14.3	21.0	52.5	18.1	26.5	65.1	21.0	31.5	79.0	42
43	3.9	5.6	13.3	7.7	10.8	27.1	10.8	16.3	40.0	14.6	21.5	53.8	18.5	27.1	66.7	21.5	32.3	80.8	43
44	4.0	5.7	13.6	7.9	11.0	27.7	11.0	16.7	40.9	15.0	22.0	55.0	18.9	27.7	68.2	22.0	33.0	82.7	44
45	4.1	5.9	14.0	8.1	11.3	28.4	11.3	17.1	41.8	15.3	22.5	56.3	19.4	28.4	69.8	22.5	33.8	84.6	45
46	4.1	6.0	14.3	8.3	11.5	29.0	11.5	17.5	42.8	15.6	23.0	57.5	19.8	29.0	71.3	23.0	34.5	86.5	46
47	4.2	6.1	14.6	8.5	11.8	29.6	11.8	17.9	43.7	16.0	23.5	58.8	20.2	29.6	72.9	23.5	35.3	88.4	47
48	4.3	6.2	14.9	8.6	12.0	30.2	12.0	18.2	44.6	16.3	24.0	60.0	20.6	20.2	74.4	24.0	36.0	90.2	48
49	4.4	6.4	15.2	8.8	12.3	30.9	12.3	18.6	45.6	16.7	24.5	61.3	21.1	30.9	76.0	24.5	36.8	92.1	49
50	4.5	6.5	15.5	9.0	12.5	31.5	12.5	19.0	46.5	17.0	25.0	62.5	21.5	31.5	77.5	25.0	37.5	94.0	50
		NOTE: This table was compiled by multiplying the numbers in the extreme left and right hand columns by the time factors given below:																	
Hours	.09	.13	.31	.18	.25	.63	.25	.38	.93	.34	.50	1.25	.43	.63	1.55	.50	.75	1.88	Hours

Table 3. Height of Origin of Fall-Out Particles

(Times of fall-out (hours))

Level of Radar Plot	5,000		10,000		15,000		20,000		25,000		30,000		35,000		40,000		45,000		50,000	
	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
45,000																			0.08	0.31
40,000																	0.08	0.31	0.16	0.62
35,000															0.08	0.31	0.16	0.62	0.24	0.04
30,000													0.08	0.31	0.16	0.62	0.24	0.94	0.33	1.25
25,000											0.08	0.31	0.16	0.62	0.24	0.94	0.33	1.25	0.41	1.56
20,000									0.08	0.31	0.16	0.62	0.24	0.94	0.33	1.25	0.41	1.56	0.49	1.87
15,000							0.08	0.31	0.16	0.62	0.24	0.94	0.33	1.25	0.41	1.56	0.49	1.87	0.58	2.19
10,000					0.08	0.31	0.16	0.62	0.24	0.94	0.33	1.25	0.41	1.56	0.49	1.87	0.58	2.19	0.66	2.50
5,000			0.08	0.31	0.16	0.62	0.24	0.94	0.33	1.25	0.41	1.56	0.49	1.87	0.58	2.19	0.66	2.50	0.74	2.81
SURFACE	0.08	0.31	0.16	0.62	0.33	0.94	0.33	1.25	0.41	1.56	0.49	1.87	0.58	2.19	0.66	2.50	0.74	2.81	0.83	3.13
	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
	5,000		10,000		15,000		20,000		25,000		30,000		35,000		40,000		45,000		50,000	

Appendix B

COMPUTATIONS FOR MAP SCALES

B1000

Map scales are usually given in "Representative Fractions", such as 1: 1,000,000, etc. This means that one unit of measurement on the map equals 1,000,000 of the same units of measurement on the earth's surface, i.e., one foot of the map equals 1,000,000 feet on the earth, one meter on the map equals 1,000,000 meters on the earth, etc.

B2000

On a map with scale 1: 1,000,000, since one inch equals 1,000,000 inches, one inch on the map is also equivalent to (1,000,000 ÷ 12) feet on the earth's surface, or (1,000,000 ÷ 12 x 5280) miles on the earth's surface, or 15.783 miles. Using this equality, ½ inch on an ordinary foot ruler equals 7.8915 miles. Obviously, using the ordinary foot ruler will result in a great deal of computations, for example, in laying off a distance of 29 miles on the map. It is much simpler to have a scale laid off in units of miles or tens of miles.

B3000

Most charts have a "bar scale" printed somewhere on the map, similar to the sample given below:

If the type of map to be used by the base weather station in computing fall-out areas has such a scale, graduated in *statute* miles, the scale may be cut out and securely mounted on a straightedge. If no bar scale is available, a scale may be constructed as described below:

B4000

Using the map scale of 1: 1,000,000 as an example, one inch equals 15.783 miles. A proportion may be set up as:

$$\frac{\text{1 in[illegible] mile (on surface)}}{\text{x in[illegible] miles (on surface)}}$$

Solving [illegible] for "x", one mile on the surface is represented by 0.06335 inches on the map. Converting this decimal to a close fractional equivalent, one mile on the surface is about one-sixteenth inch on the map.

B5000

A bar scale similar to the figure in paragraph B3000, above, can now be constructed. The spacing for the unit-miles in the first ten-mile division will be one-sixteenth of an inch; for succeeding 10-mile divisions the spacing will be ten-sixteenths (or five-eighths of an inch. Upon completion, this scale may then be glued or scotch-taped to a straightedge.

B6000

Fractional-inch close equivalents for one mile on some other commonly used map scales are:

1: 750,000—[illegible] inch
1: 500,000—[illegible] inch

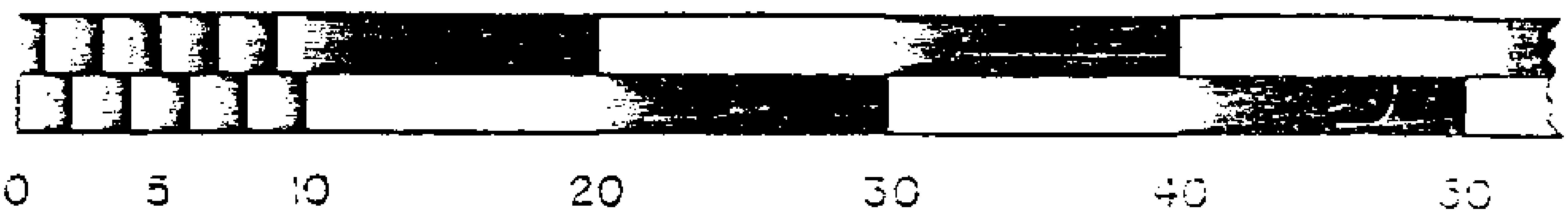


FIGURE 51. Bar scale.

Appendix C

UPPER WIND CODE

Ref. AWSM 105-21

For meaning of dd and ff, see below

Code Group	iiiGG	Oddff	ddff	2ddff	ddff	4ddff	ddff
MEANING	See Note 1 See Note 2	Surface Wind	1000 ft. Wind	2000 ft. Wind	3000 ft. Wind	4000 ft. Wind	5000 ft. Wind

Code Group	6ddff	ddff	8ddff	ddff	Oddff
MEANING	6000 ft. Wind	7000 ft. Wind	8000 ft. Wind	9000 ft. Wind	10,000 ft. Wind

Code Group	2ddff	4ddff	6ddff	8ddff	Oddff
MEANING	12,000 ft. Wind	14,000 ft. Wind	16,000 ft. Wind	18,000 ft. Wind	20,000 ft. Wind

Code Group	3ddff
MEANING	23,000 ft. Wind

(This may or may not be sent)
if it is, it will be the only
5-figure group led off by a "3"

Code Group	5ddff	Oddff	5ddff	Oddff	5ddff	____etc.
MEANING	25,000 ft. Wind	30,000 ft. Wind	35,000 ft. Wind	40,000 ft. Wind	45,000 ft. Wind	FOR EACH 5000 foot level

Note 1. iii is the station designator.

Note 2. GG is the time of release of the balloon, in Greenwich time (hours). Subtract 5 from the value of GG to get Eastern Standard Time.

dd—Wind direction in tens of degrees, measured clockwise from true North. This is the direction from which the wind is blowing.

ff—wind speed, in knots.