PROJECT CROSSWINDS

by

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INTRODUCTION

Aviation development is contingent upon the development of adequate equipment, both in aircraft and in facilities. In some cases, the development of aircraft has required the development of new airports, of facilities, or a renovation of existing airports and facilities. The prime requirement of an airport is an adequate landing strip which will handle the majority of aircraft. The crosswind effect of the wind upon aircraft is a major consideration.

PURPOSE

Frequency distributions of crosswind components to a runway are usually computed by using the individual wind observations. It was the purpose of this project to investigate the use of summary cards of wind distributions to produce a frequency distribution of crosswinds. To accomplish the objective of the investigation, i.e., to determine the feasibility of using SMAR Summaries or Summary Cards to produce crosswind components, it was necessary to compute the crosswind components from individual observations and then from summary cards. The following sections describe the procedures followed in this investigation.

COMPUTATION OF CROSSWINDS

There are at least three possible ways to use the SMAR Summary. These must be compared to the computation of crosswinds from the individual wind observations. As an illustration, Quonset Point, R. I., S.M.A.R. (Summary of Monthly Aerological Records) No. 14788, Mar. 1945-Dec. 1952 is used. There are two Runways: 160-340, and 050-230. Table 2 is a copy of the S.M.A.R. Tabulation, Page 1, Frequency of Wind Speed Groups (Knots). In Table 3, these frequencies have been reduced to percentage frequencies, usually termed percentages.

Chart 1 shows the crosswind components computed from the individual wind observations.

Chart 2 shows the crosswind components obtained through procedures outlined in NAVAER 50-1C-518.

Chart 3 shows the crosswind components calculated by desk calculator. The assumption is made that the weight of the class interval is at the center of the interval. Trigonometric sine functions are then applied and class intervals of ten knots are established for the crosswinds.

Chart 4 shows the crosswind components for Runway 16-34 calculated graphically by plotting the data on a base plate [circular contingency wind rose] as shown in NAVAER 50-1C-518. Runway 16-34 was then marked on the base plate. A pair

of dividers was then used to determine the crosswind components for each sector area of the circular contingency wind rose (base plate).

The charts may be compared. The median for Charts 2, 3 and 4 are 1, 2, and 3 knots negative, respectively.

Chart 5 shows the crosswind components for Runway 05-23 computed according to the method shown in NAVAER 50-1C-518.

The straight lines shown on the arithmetic probability paper indicate that the crosswind components and the winds at Quonset Point are normally distributed.

Appendices 1, 2, 3 and 4 give the procedures for computation of values placed on Charts 1, 2 (and 5), 3, and 4.

Uses of the charts are illustrated in Charts 6, 7, 8.

Appendix 1

Determination of Crosswind Components from the Individual Winds of the Station Record.

1. The runway is 34.
2. The winds are given in 16 points of the compass or in degrees from north.
3. The difference in angles between the runway and each wind direction is determined.
4. The sine of this angle is determined.
5. The product of the wind speed and the sine of the angular difference is the crosswind component.
6. Class intervals are established preferably -05.0 to + 04.9 mph. (or knots) and then ten mph. on either side of this interval.
7. Each crosswind component is then distributed among the class intervals.
8. Calms are distributed to the central class interval shown in (6) above.
9. Fig. 1 shows the representation of one calculation.
10. Table 1 shows the percentage frequency and the cumulated percentage frequency distribution of these computed crosswinds.

Appendix 2

Determination of Crosswind Components by use of a Circular Contigency Wind Rose.

The SMAR table on wind distribution has class intervals of calm, 0-2, 3-7, 8-12, 13-20, 21-30, 31-40 and > 40 knots. Table 2 gives the S.M.A.R. table for Quonset Point, Rhode Island.

A base plate (polar coordinate diagram) [Fig. 2] is plotted from the SMAR frequencies as shown in NAVAER.

These may be actual or percentage frequencies. The latter are shown in Table 3. This provides a circular contingency wind rose. 7, 12, 20, 30 and 40 knots are the upper limits of the class intervals shown in the S.M.A.R. Summary. If other summaries use other class intervals, then the upper limits of those class intervals must be used. Acetate strips of (2 x 7) or 14, (2 x 12) or 24, (2 x 20) or 40, (2 x 30) or 60, (2 x 40) or 80 knots are prepared and a line is marked lengthwise down the center. The scale of the acetate strips and the base plate must be the same. By consequently placing these strips on the base plate (center line on the runway in question), the class interval of the excessive crosswinds are those outside (not under) the strips. Those frequencies to the right of the strip will be considered as positive crosswinds; those to the left as negative. These can be also identified by the direction from which they come. By counting the frequencies or percentage frequencies outside of

each strip, appropriate manipulation will produce the crosswinds in each class interval. Such manipulation is now explained. For example, the winds to the right of the 3-7 interval, i.e., the 14 strip will contain all crosswinds greater than 7 knots.

These include those under the other strips. All of the winds to the right of the 8-12 interval, i.e., the strip marked 24 will include the remaining strips. Therefore, subtraction of those crosswinds outside of the 24-strip from those outside of the 14-strip will give the positive crosswinds which are greater than 7 but less than 12. The percentage frequency occurrence in each interval may then be determined, cumulated from negative to positive values and the accumulation in each interval plotted on arithmetic probability paper. Interpolation of the occurrence of any class interval value crosswind can then be determined. Too, combinations can be made. For example, the negative crosswinds (from the left of the runway) can be added to the positive crosswinds (from the right of the runway) to give the percentage occurrence of crosswinds without regard to whether they are coming from the left or the right of the runway.

Fig. 3 shows a 14-point strip for Quonset Point and the percentage occurrence of crosswinds greater than 7 knots. Fig. 4 shows a 24-strip and the percentage occurrence of crosswinds greater than 12 knots. Fig. 5 shows a simultaneous placement of the two acetate strips. The area covered by only the 24-strip will give the occurrence of crosswinds between 7 and 12 knots. This is also

determined by the difference between the crosswinds in excess of 12 knots and those in excess of 7 knots.

Table 4 shows the percentage frequency and the cumulated percentage frequency distribution for the crosswinds thus determined.

Appendix 3

Computation of Crosswind Components From Wind Summaries in the S.M.A.R. Tabulations for Quonset Point by Desk Calculator.

1. Here, Table 2, used in Appendix 2, is used again.

2. A table is set up, containing the sine of the angle of the difference between the runway and the point of the compass. Such a table is Table 5 which contains these values in Column A.

3. In the above table set up, interval for interval with Table 2 but containing the magnitude of the crosswind, the crosswind is obtained by multiplying the sine of the angle (Column B, Table 5) by the magnitude of the mean of the respective class interval. This completes Table 5.

4. Each of the crosswind components is then distributed in a frequency distribution of ten knot class intervals beginning at -95.0 to 85.1 and ascending in order, -85.0-75.1, -75.0-65.1, etc. The number of components is obtained from the respective group of Table 2. The distributed frequencies are then cumulated and plotted on arithmetic probability paper. Table 6 shows the percentage frequency and the cumulated percentage frequency of the crosswinds computed in this manner. It is from this table that Chart 3 has been constructed.

Appendix 4

Calculation of Crosswind Components at Quonset Point, Rhode Island, for Runway 34 by Graphical Methods.

1. A Base Chart (polar coordinate chart) is prepared of the wind distribution as in Appendix 2 and shown in Fig. 2.

2. Runway 34 is then drawn.

3. The frequencies in each sector area are considered to be collected at the center of each sector area.

4. The crosswind component is determined by the perpendicular distance running from the center of a sector to the runway. The magnitude of this crosswind component is distributed to a 10 knot class interval. The intervals run from -95.0 to -85.1, -85.0 to -75.1, etc. The percentage frequency is placed in this class interval. When all sector components have been distributed, summation of frequencies (or of percentage frequencies) is now made for each class interval. After this is done, cumulation from the lowest to the highest values is made; negative values are considered to be less than positive values although the magnitudes may not be necessarily smaller. For example, a crosswind of -40 is less than -30 here, although when magnitudes are considered, 40 is certainly larger than 30. If percentage frequencies have been used throughout the problem these cumulative per-

centage frequencies may be plotted immediately on arithmetic probability paper. Then occurrence of any positive or negative crosswind may be interpolated. Summation of the magnitudes of interpolated crosswinds may be made if direction is of no importance. If no prior reduction to percentage frequencies have been made, the cumulative frequencies may be converted to percentage frequencies and the latter values may then be plotted. This conversion is effected by dividing the cumulation by the total. For example, Table 7 has been developed by the above procedures. The cumulated values have been used to construct Chart 4.

CONCLUSION

It will be noted from an examination of Charts 1, 2, 3 and 4 that any one of the three graphical or pseudo-graphical methods provides a close estimate of the crosswind values computed from approximately 70,000 individual values. As an example, choose several percentage points.

At	1%,	10%,	50%,	90%,	99%
Chart 1 provides a value of	-18,	-11,	-3,	+8,	+18
Chart 2 provides a value of	-19,	-11,	-3,	+6,	+17
Chart 3 provides a value of	-16,	-10,	-4,	+7,	+16
Chart 4 provides a value of	-16,	- 9,	-2,	+6,	+17

This example shows that the maximum difference among the four results is 3 knots at any one percentage point. Too, the maximum difference between the first and any of the remaining three is only two knots.

As another example, suppose that 15 knots crosswinds plus or minus, that is, 15 knots from the right or left is an allowable range of crosswinds. From Chart 1, it is seen that 95.5% of the time, crosswinds equal to or less than 15 knots occur, i.e., 98.0% - 2.5%. From Chart 2, the crosswinds in this range occur 98.6% - 3.2% or 95.4% of the time. From Chart 3, 98.6% - 1.2 or 97.4$ of the time crosswinds occur within this range. The percentage from Chart 4 is 98.5% - 1.2 = 97.3%. The maximum difference is about 2%. This is believed to be a typical example of the results

of the four procedures.

The conclusion is that estimates of the frequency distribution of crosswind components to any particular airport runway can be obtained by use of wind summaries or wind summary cards. These estimates are comparable to those obtained by use of the individual observations of the wind. The cost is considerably less. For example, the cost to produce the crosswind components for two runways, 70,000 observations, by use of machine methods will be $600.00 per station for two runways. This cost is reduced by a factor of 5 if graphical procedures which utilize wind summaries are used. The cost is reduced by a factor of at least 20 if summary cards and electronic computing machines are used.

Table 1. Percentage Frequency and Cumulated Percentage Frequency of Crosswinds Computed from Approximately 70,000 Individual Wind Observations. These are crosswinds to Runway 34, March 1945 to December 1952, inclusive.

Class interval (Knots)	-42.5	-37.5	-32.5	-27.5	-22.5	-17.5	-12.5	-07.5	- 2.6	2.5
	-37.6	-32.6	-27.6	-22.6	-17.6	-12.6	-07.6	- 2.6	+ 2.4	7.4
Percentage frequency	0.00	0.00	0.01	0.18	1.12	5.03	19.01	36.61	21.58	12.57
Cumulative percentage frequency	0.00	0.00	0.01	0.19	1.31	6.34	24.04	55.62	77.20	89.77
Class interval	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	42.7	
	12.4	17.4	22.4	27.4	32.4	37.4	42.4	47.4	52.4	
Percentage frequency	6.29	2.87	0.72	0.26	0.05	0.02	0.01	0.00	0.01	
Cumulative percentage frequency	96.06	98.93	99.65	99.91	99.96	99.98	99.99	99.99	100.00	

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SUMMARY OF MONTHLY AEROLOGICAL RECORDS

Table 2

PAGE 1

QUONSET POINT, R. I. (STATION) | 9.1M (ELEVATION) | 41/35N (LATITUDE) | 71/25W (LONGITUDE) | Mar 1945 Thru Dec 1952 (PERIOD OF RECORD)

DIR. CODE	FREQUENCY OF WIND SPEED GROUPS (KNOTS)								FREQUENCY OF TOTAL CLOUD AMOUNTS IN TENTHS												WIND DIR.
	3-7	8-12	13-20	21-30	31-40	> 40	CALM	TOTAL	0	1	2	3	4	5	6	7	8	9	10	TOTAL	
11	1188	1951	1698	428	71	1		5337													N
12	682	1536	1675	503	81	4		4481													NNE
22	646	1125	933	172	22			2898													NE
32	429	373	204	26	4	1		1037													ENE
33	479	379	160	44	12	7		1081													E
34	346	302	175	64	14	1		902													ESE
44	605	550	298	151	25	4		1633													SE
54	603	1009	730	137	30	4		2513													SSE
55	1349	2841	1895	213	26	1		6325													S
56	2023	2662	1547	202	13	1		6448													SSW
66	2931	3802	1853	175	6			8767													SW
76	2133	1430	324	25				3912													WSW
77	2014	2059	850	100				5023													W
78	1229	2313	1610	274	8			5434													WNW
88	1562	1917	1083	119	6	2		4689													NW
18	1360	1799	1142	203	6	1		4511													NNW
00							3545	3545													CALM
	19579	26048	16177	2836	324	27	3545	68536													TOTAL
	28.6	38.0	23.6	4.1	.5	.0	5.2	100.0													% OF TOT

DIR. CODE	FREQUENCY OF WEATHER								FREQUENCY OF CEILINGS (FEET)												WIND DIR.
	RAIN	RAIN SHOWERS	DRIZZLE	ZR. ZL. E. EW. IC	SNOW SG. SW. SP	HAIL. AP	THUNDER	NO WEATHER	0-150	151-350	351-550	551-1050	1051-2050	2051-3050	3051-10500	10501-20500	20501-30500	>30500 AND UNLIM.	< 6/10 CLOUDS	TOTAL	
																					N
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																					NNW
																					CALM
																					TOTAL
																					% OF TOT

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MONTH

SUMMARY OF MONTHLY AEROLOGICAL RECORDS

Table 3

PAGE 1

QUONSET POINT, R. I. — STATION
9.1M — ELEVATION
41/35N — LATITUDE
71/25W — LONGITUDE
Mar 1945 Thru Dec 1952 — PERIOD OF RECORD

DIR. CODE	FREQUENCY OF WIND SPEED GROUPS (KNOTS)								FREQUENCY OF TOTAL CLOUD AMOUNTS IN TENTHS												WIND DIR.
	3-7	8-12	13-20	21-30	31-40	> 40	CALM	TOTAL	0	1	2	3	4	5	6	7	8	9	10	TOTAL	
11	1.73	2.85	2.48	.62	.103	.001		7.784													N
12	1.00	2.24	2.44	.73	.118	.006		6.534													NNE
22	.942	1.64	1.36	.25	.032			4.224													NE
32	.626	.544	.298	.038	.006	.001		1.513													ENE
33	.70	.55	.23	.06	.017	.010		1.567													E
34	.50	.44	.26	.09	.020	.001		1.311													ESE
44	.88	.80	.43	.22	.036	.006		2.372													SE
54	.88	1.47	1.07	.20	.043	.006		3.339													SSE
55	1.97	4.15	2.76	.31	.038	.001		9.229													S
56	2.94	3.88	2.26	.29	.019	.001		9.390													SSW
66	4.28	5.55	2.70	.25	.009			12.789													SW
76	2.94	2.09	.47	.04				5.54													WSW
77	2.94	3.00	1.24	.15				7.33													W
78	1.80	3.37	2.35	.40	.01			7.57													WNW
88	2.28	2.80	1.58	.17	.009	.003		6.842													NW
18	1.98	2.62	1.67	.30	.009	.001		6.580													NNW
00							5.172	5.172													CALM
	28.388	37.994	23.598	4.118	.469	.037	5.172	99.776													TOTAL
								100.0													% OF TOT

DIR. CODE	FREQUENCY OF WEATHER								FREQUENCY OF CEILINGS (FEET)												WIND DIR.
	RAIN	RAIN SHOWERS	DRIZZLE	ZR. ZL. E. EW. IC	SNOW SG. SW. SP	HAIL. AP	THUNDER	NO WEATHER	0-150	151-350	351-550	551-1050	1051-2050	2051-3050	3051-10500	10501-20500	20501-30500	>30500 AND UNLIM.	< 6/10 CLOUDS	TOTAL	
																					N
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																					CALM
																					TOTAL
																					% OF TOT

Table 4. Percentage Frequency Distribution of Crosswind Components to Runway 34, Quonset Point, Rhode Island, S.M.A.R., March 1945 - December 1952.

Class interval (Knots)	-40.1	-40.0	-30.0	-20.0	-12.0	- 7.0
		-30.1	-20.1	-12.1	- 7.1	+ 6.9
Percentage frequency	0.01	0.02	0.57	6.08	18.98	65.08
Cumulative percentage frequency	0.01	0.03	0.60	6.68	25.66	90.74
Class interval	+ 7.0	+12.0	+20.0	+30.0	+40.0	
	+11.9	+19.9	+29.9	+39.9		
Percentage frequency	7.01	1.69	0.49	0.04	0.02	
Cumulative percentage frequency	97.75	99.44	99.93	99.97	99.99	(100.00)

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SUMMARY OF MONTHLY AEROLOGICAL RECORDS

Table 5

PAGE 1

QUONSET POINT, R. I.

STATION | ELEVATION | LATITUDE | LONGITUDE | PERIOD OF RECORD

A α°	B sin α	DIR. CODE	FREQUENCY OF WIND SPEED GROUPS (KNOTS) 3-7	8-12	13-20	21-30	31-40	> 40	CALM	TOTAL	FREQUENCY OF TOTAL CLOUD AMOUNTS IN TENTHS 0	1	2	3	4	5	6	7	8	9	10	TOTAL	WIND DIR.
20	.3420	11	1.7	3.4	5.5	8.6	12.0	15.4															N
42.5	.6756	12	3.4	6.8	10.8	16.9	23.6	30.4															NNE
65.0	.9063	22	4.5	9.1	14.5	22.7	31.7	40.8															NE
87.5	.9990	32	5.0	9.9	16.0	25.0	35.0	45.0															ENE
110.0	.9336	33	4.7	9.3	15.0	23.3	32.7	42.0															E
132.5	.7373	34	3.7	7.4	11.8	18.4	25.8	33.2															ESE
155.0	.4067	44	2.0	4.1	6.5	10.2	14.2	18.3															SE
177.5	.0436	54	0.2	0.4	0.7	1.1	1.5	2.0															SSE
200.0	-.3420	55	-1.7	-3.4	-5.5	-8.6	-12.0	-15.4															S
222.5	-.6756	56	-3.4	-6.8	-10.8	-16.9	-23.6	-30.4															SSW
245.0	-.9063	66	-4.5	-9.1	-14.5	-22.7	-31.7	-40.8															SW
267.5	-.9990	76	-5.0	-9.9	-16.0	-25.0	-35.0	-45.0															WSW
290.0	-.9336	77	-4.7	-9.3	-15.0	-23.3	-32.7	-42.0															W
312.5	-.7373	78	-3.7	-7.4	-11.8	-18.4	-25.8	-33.2															WNW
335.0	-.4067	88	-2.0	-4.1	-6.5	-10.2	-14.2	-18.3															NW
357.5	-.0436	18	-0.2	-0.4	-0.7	-1.1	-1.5	-2.0															NNW
000.0		00																					CALM
																							TOTAL
										100.0													% OF TOT

α = Direction of Runway minus Direction of Wind.
Direction of Runway is 340.0

DIR. CODE	FREQUENCY OF WEATHER RAIN	RAIN SHOWERS	DRIZZLE	ZR. ZL. E. EW. IC	SNOW SG. SW. SP	HAIL. AP	THUNDER	NO WEATHER	FREQUENCY OF CEILINGS (FEET) 0-150	151-350	351-550	551-1050	1051-2050	2051-3050	3051-10500	10501-20500	20501-30500	> 30500 AND UNLIM.	< 6/10 CLOUDS	TOTAL	WIND DIR.
																					N
																					NNE
																					NE
																					ENE
																					E
																					ESE
																					SE
																					SSE
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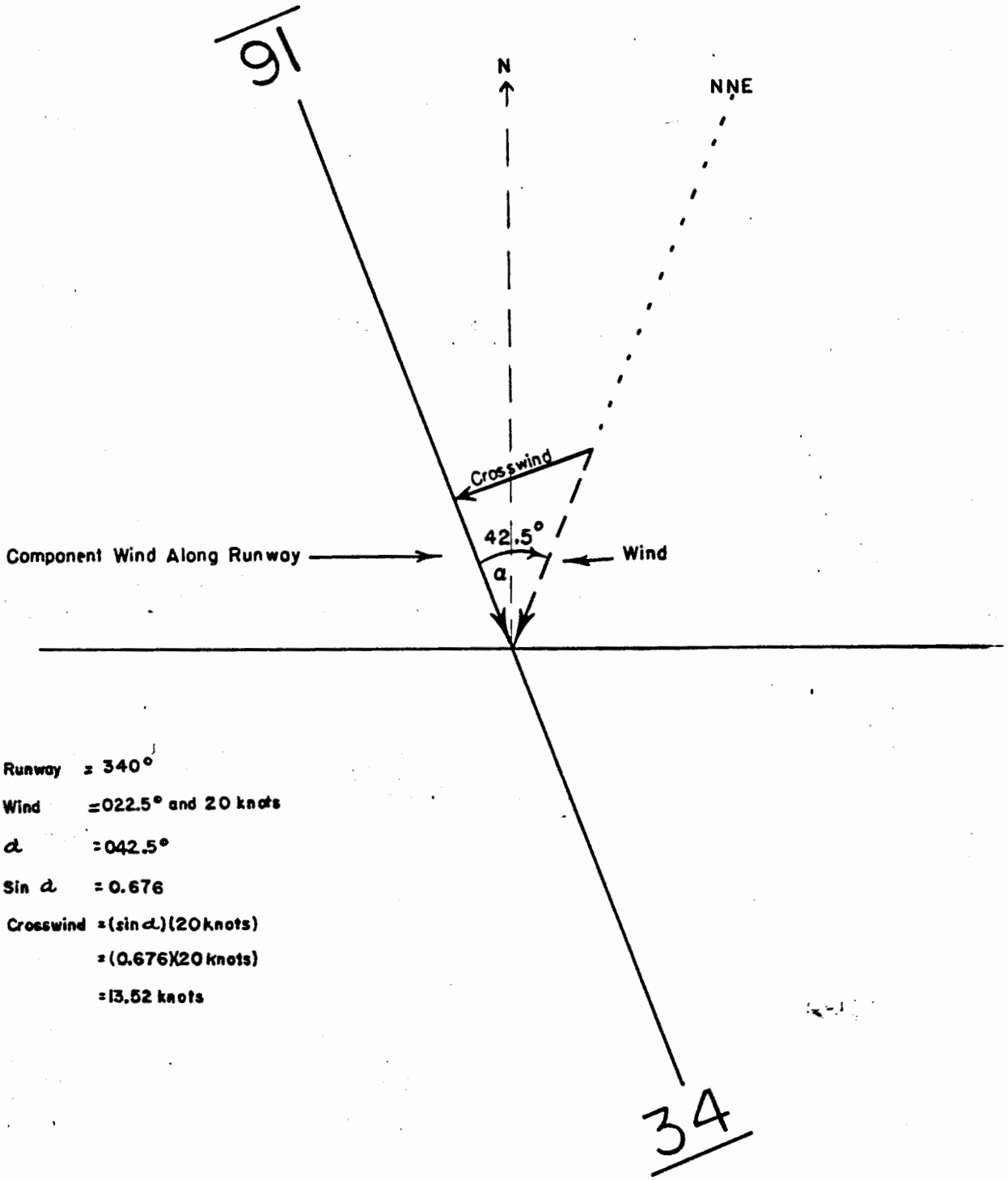
																					NW
																					NNW
																					CALM
																					TOTAL
																					% OF TOT

Table 6. Percentage Frequency and Cumulated Percentage Frequency of the Crosswinds to Runway 34, Quonset Point, Rhode Island, March 1945-December 1952. Computed by Desk Calculator from S.M.A.R. No. 14788.

Class interval (Knots)	-45.0	-35.0	-25.0	-15.0	- 5.0	+ 5.0	+15.0	+25.0	+35.0
	-35.1	-25.1	-15.1	- 5.1	+ 4.9	+14.9	+24.9	+34.9	+44.9
Percentage frequency	0.01	0.02	1.23	32.68	49.92	14.67	1.38	0.10	0.07
Cumulated percentage frequency	0.01	0.03	1.26	33.94	83.86	98.53	99.88	99.98	99.99

Table 7. Percentage Frequency and Cumulated Percentage Frequency Distribution of Crosswinds to Runway 34 at Quonset Point, Rhode Island, March 1945-December 1952. Computed graphically from base chart or circular contingency wind rose.

Class interval	-45.0	-35.0	-25.0	-15.0	-05.0	+ 5.0	+15.0	+25.0	+35.0	+45.0
	-35.1	-25.1	-15.1	-05.1	+04.9	+ 4.9	+24.9	+34.9	+44.9	+54.9
Percentage frequency	0.01	0.06	1.13	29.02	56.90	11.42	1.39	0.05	0.01	
Cumulated percentage frequency	0.01	0.07	1.20	30.22	87.02	98.54	99.93	99.98	99.99	



Runway = 340°

Wind = 022.5° and 20 knots

α = 042.5°

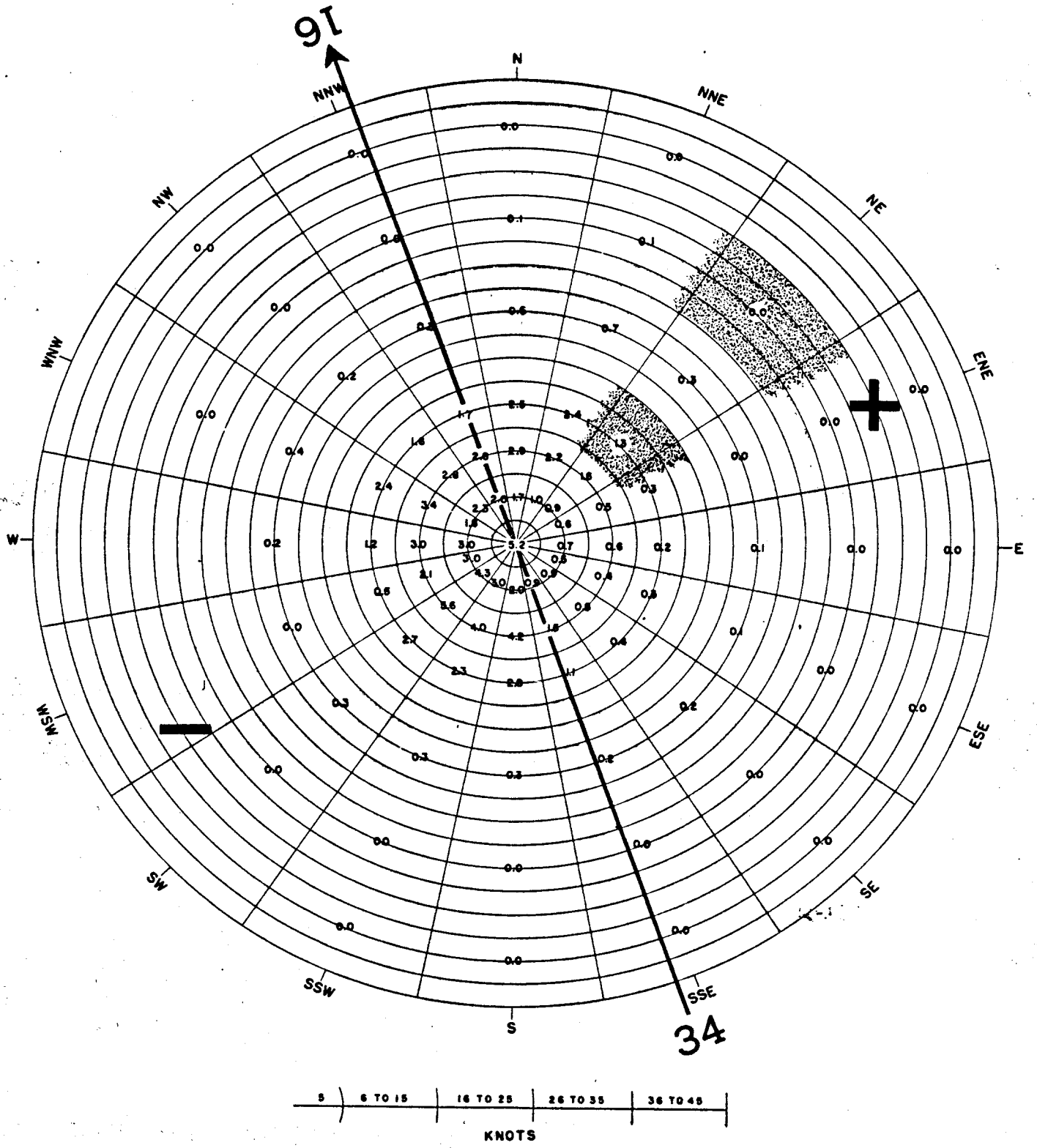
Sin α = 0.676

Crosswind = (sin α)(20 knots)

= (0.676)(20 knots)

= 13.52 knots

Fig. 1. Computation of a Crosswind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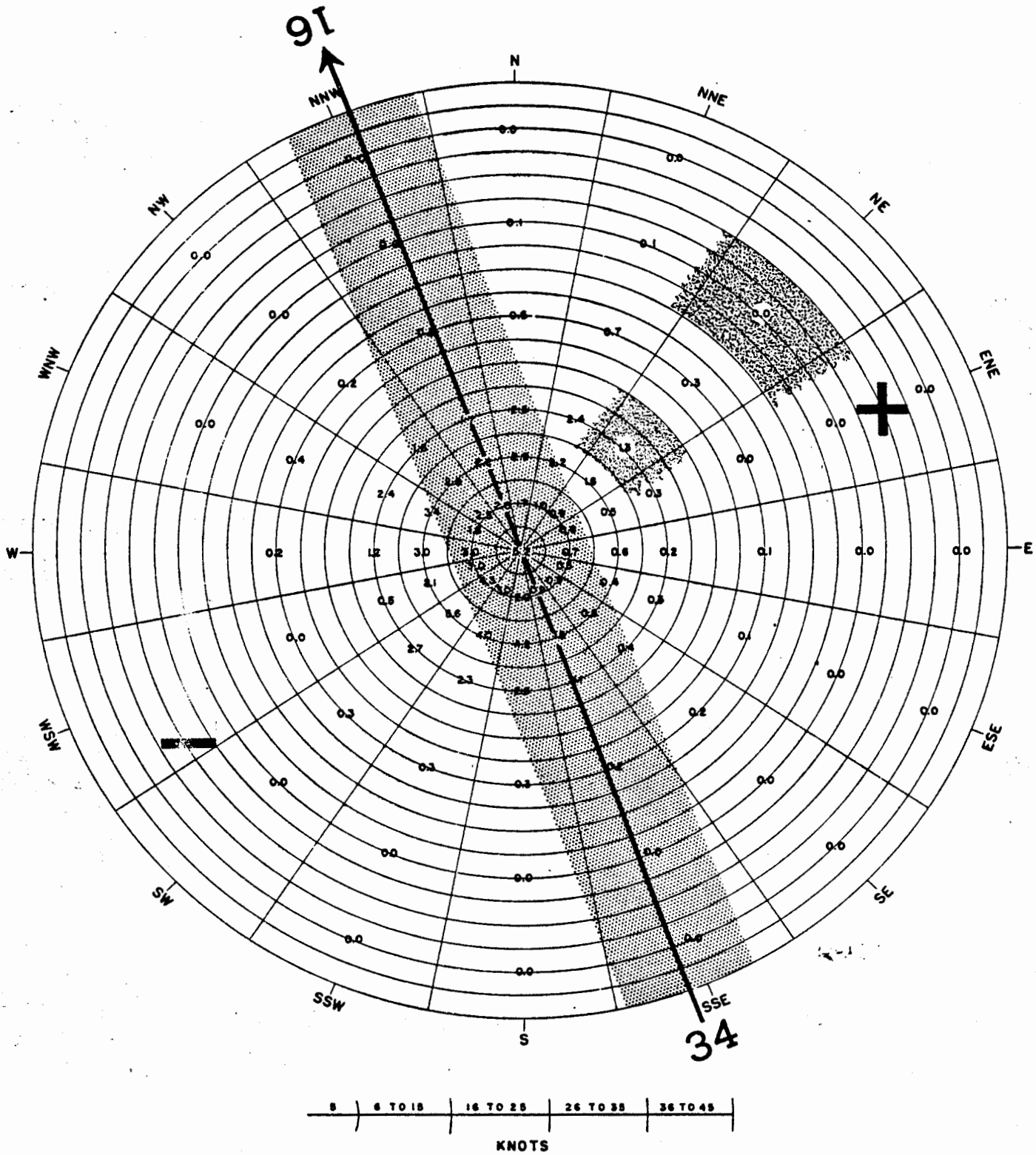
16
34
5
6 TO 15
16 TO 25
26 TO 35
36 TO 45
KNOTS

Fig. 2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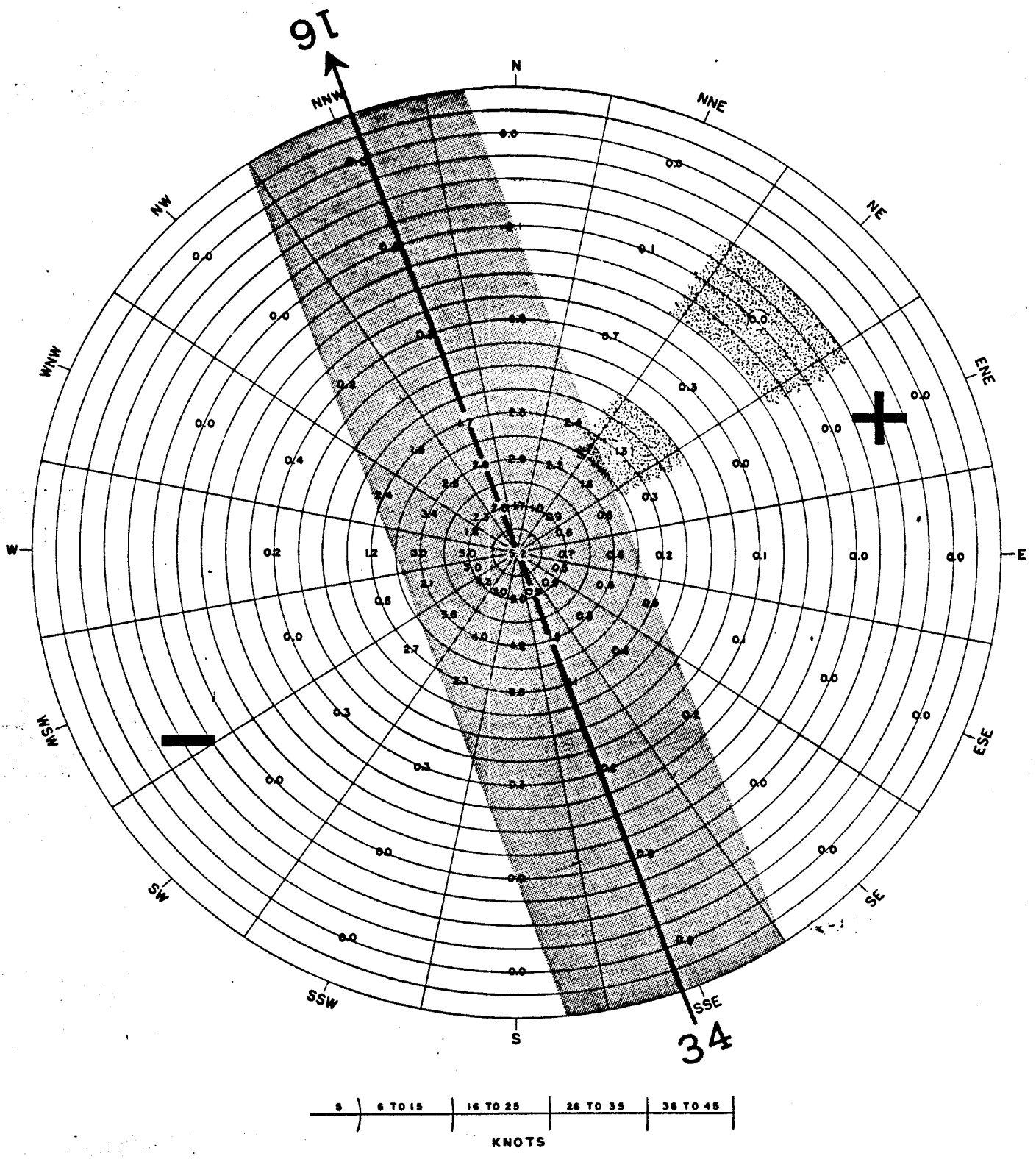
16
34
5
6 TO 15
16 TO 25
26 TO 35
36 TO 45
KNOTS

Fig. 3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NNE
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SSW
SW
WSW
W
WNW
NW
NNW
16
34
5
6 TO 15
16 TO 25
26 TO 35
36 TO 45
KNOTS

Fig. 4

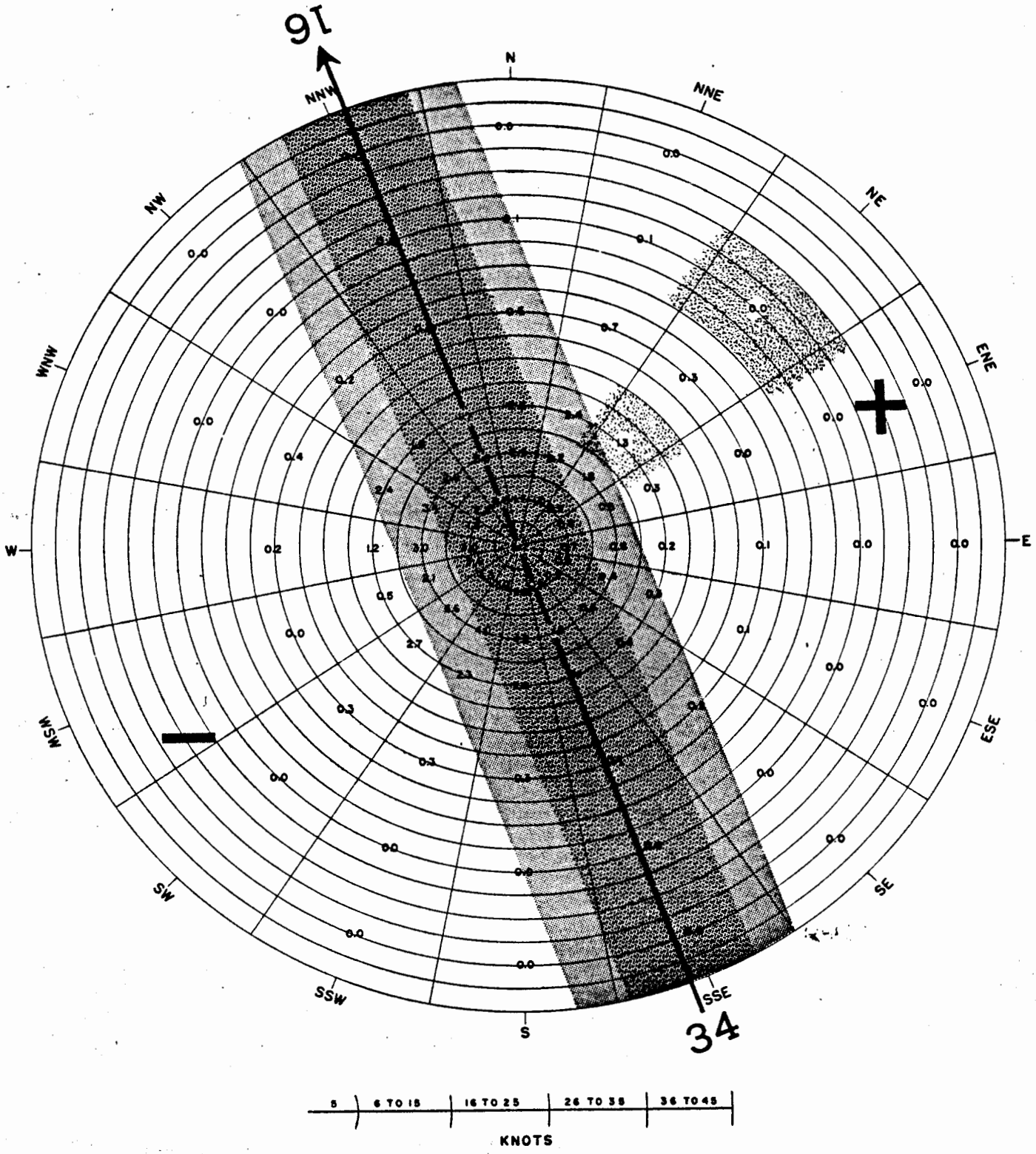
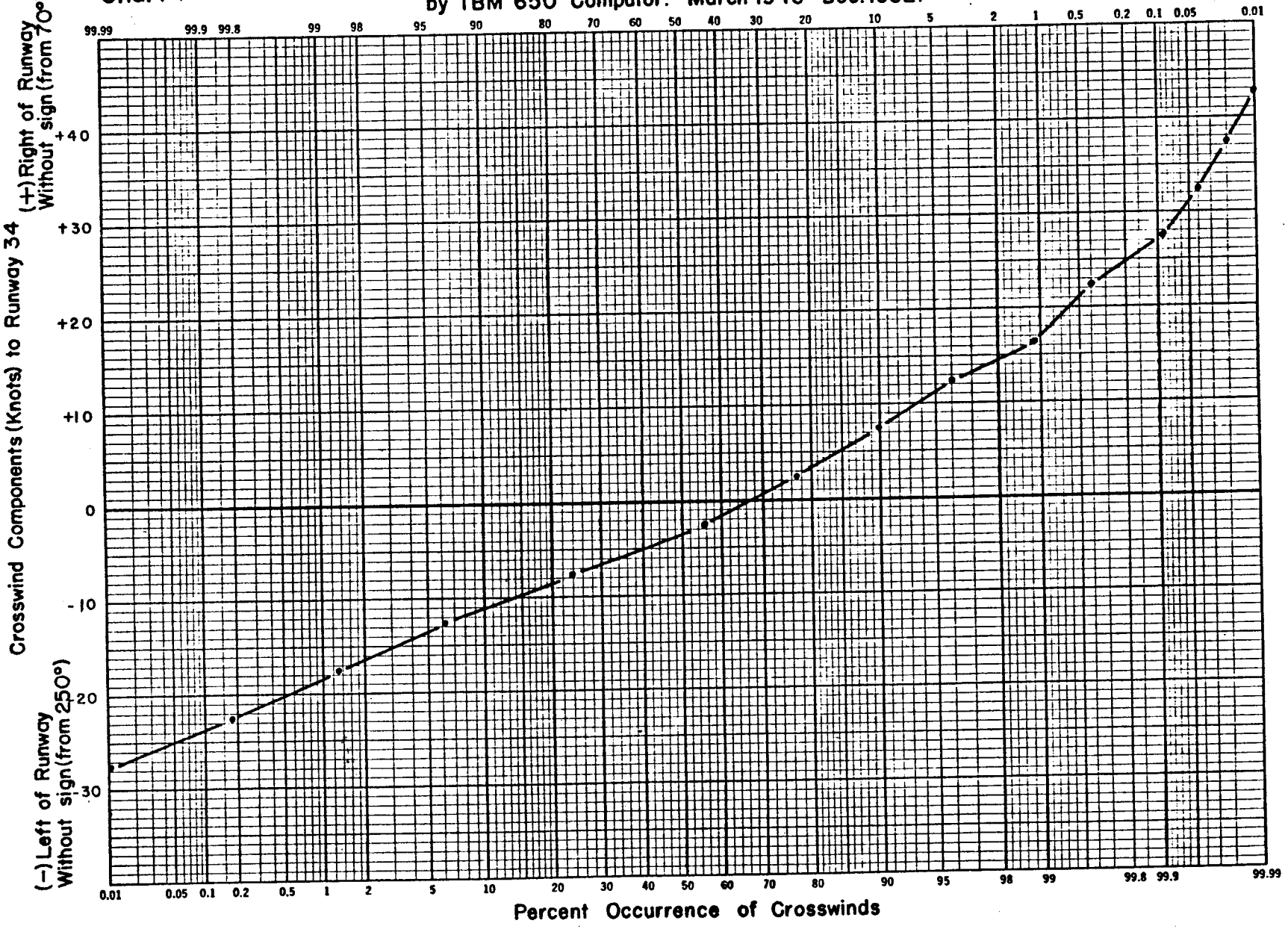

N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
16
34
5
6 TO 15
16 TO 25
26 TO 35
36 TO 45
KNOTS

Fig. 5

Quonset Point, Rhode Island
Runway 160-340

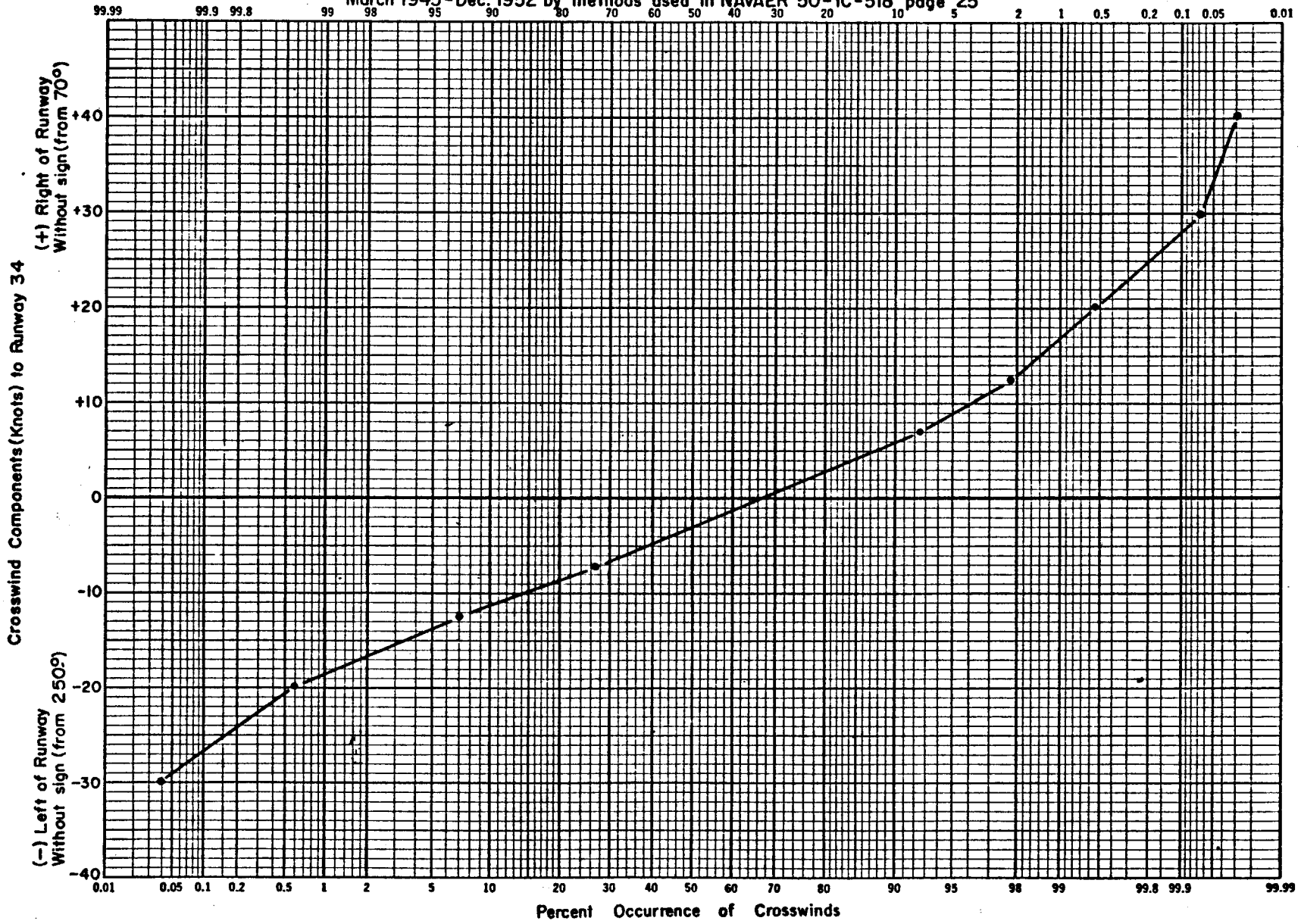
Chart I

Crosswind Components Computed from Individual Winds, Approximatly 70,000, by IBM 650 Computor. March 1945-Dec. 1952.



Quonset Point, Rhode Island
Runway 160–340
Crosswind Components Computed by Baseplate and Templates from S.M.A.R. # 14788,
March 1945-Dec. 1952 by methods used in NAVAER 50-1C-518 page 25

Chart 2

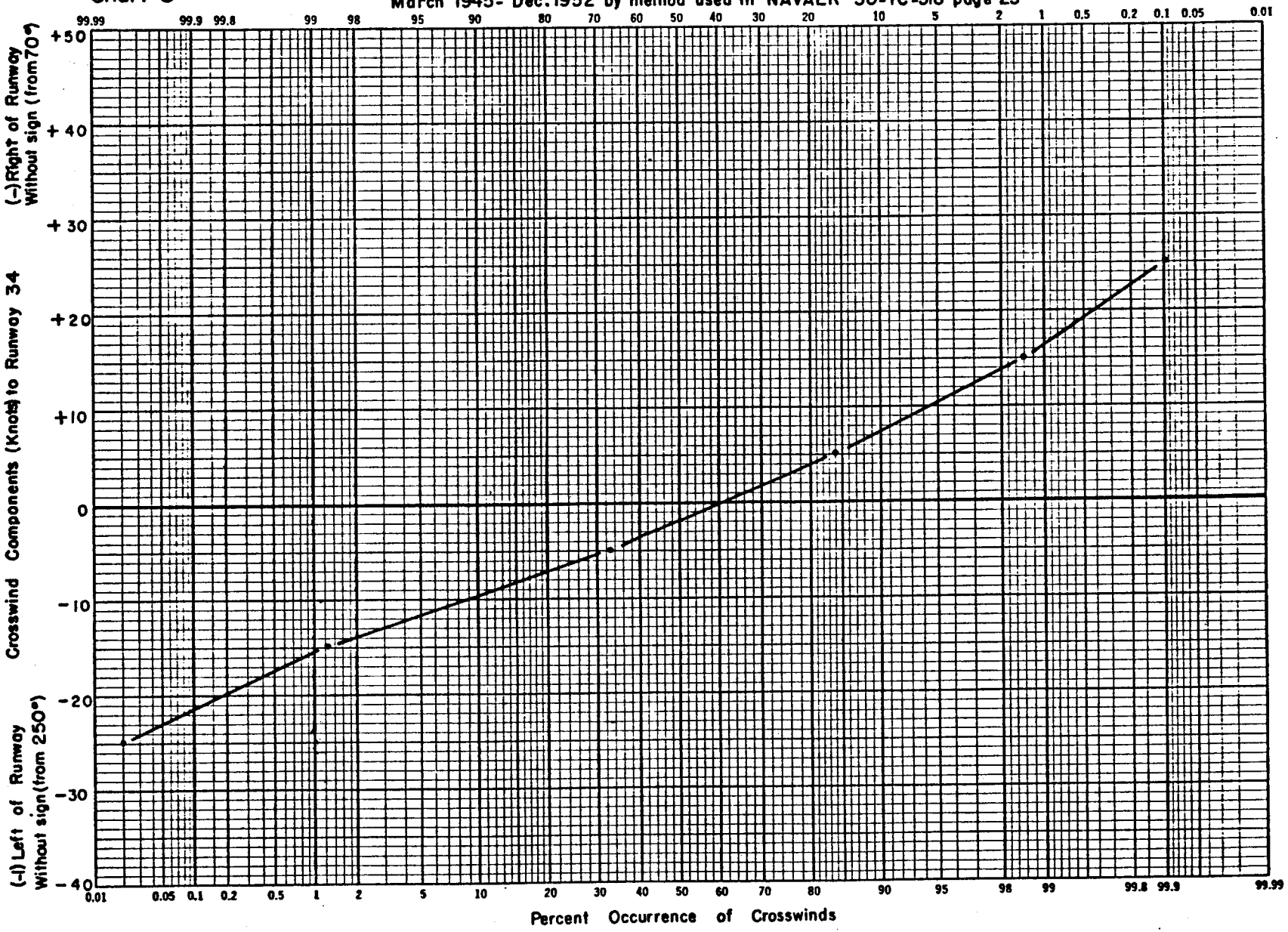


Quonset Point, Rhode Island

Runway 160-340

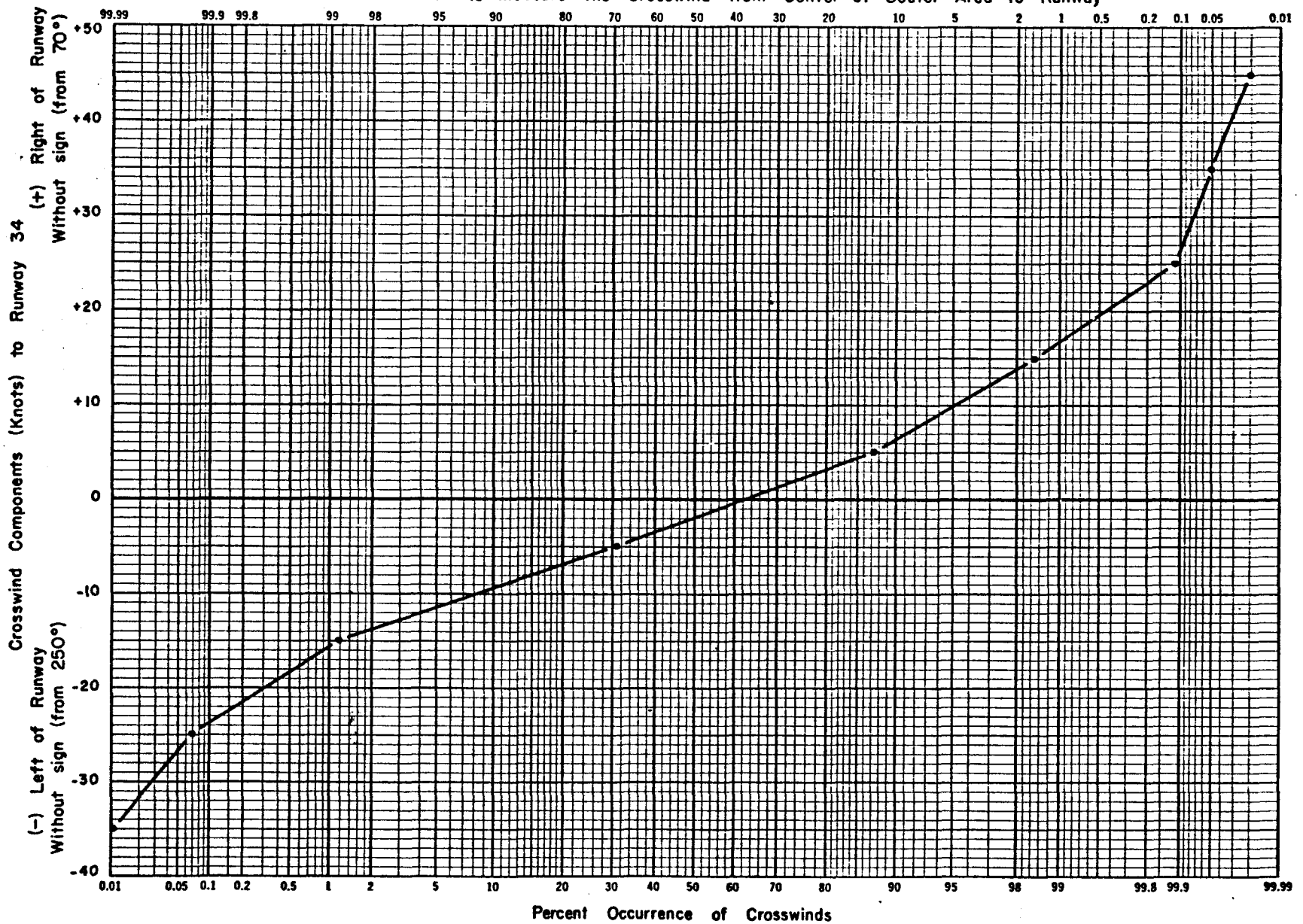
Crosswind Components Computed with desk calculator from S.M.A.R. #14788, March 1945- Dec. 1952 by method used in NAVAER 50-1C-518 page 25

Chart 3



Quonset Point, Rhode Island
Runway 160 - 340
Crosswind Components Computed Graphically from Base Plate (Contingency Wind Rose)
Dividers used to Measure the Crosswind from Center of Sector Area to Runway

Chart 4



Quonset Point, Rhode Island
Runway 50-230

Chart 5

Crosswind Components Computed by Baseplate and Templates from S.M.A.R. # 14788
March 1945 – Dec. 1952 by method used in NAVAER 50-1C-518 - page 25

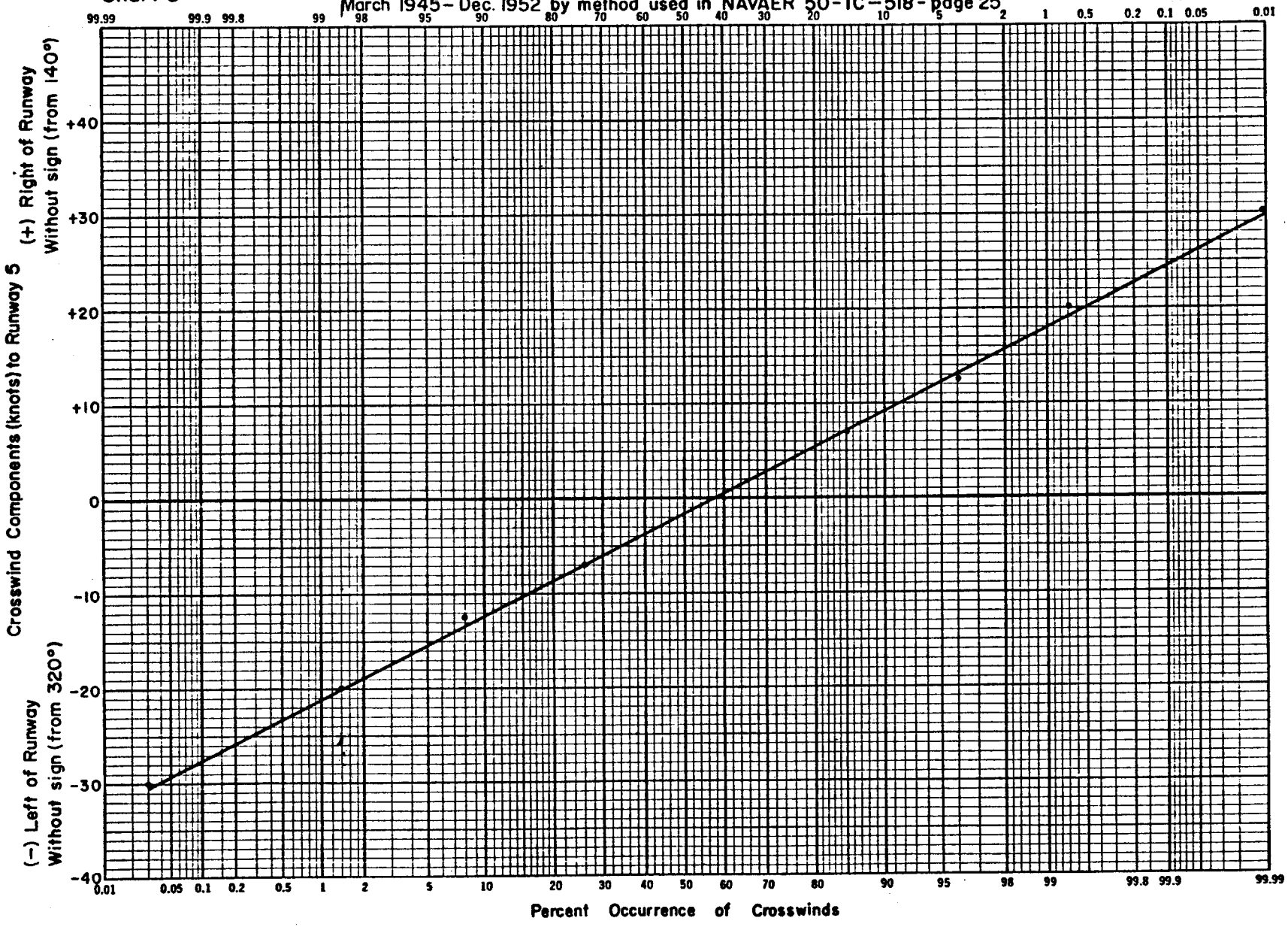


Chart 6

Crosswind Components to a Runway

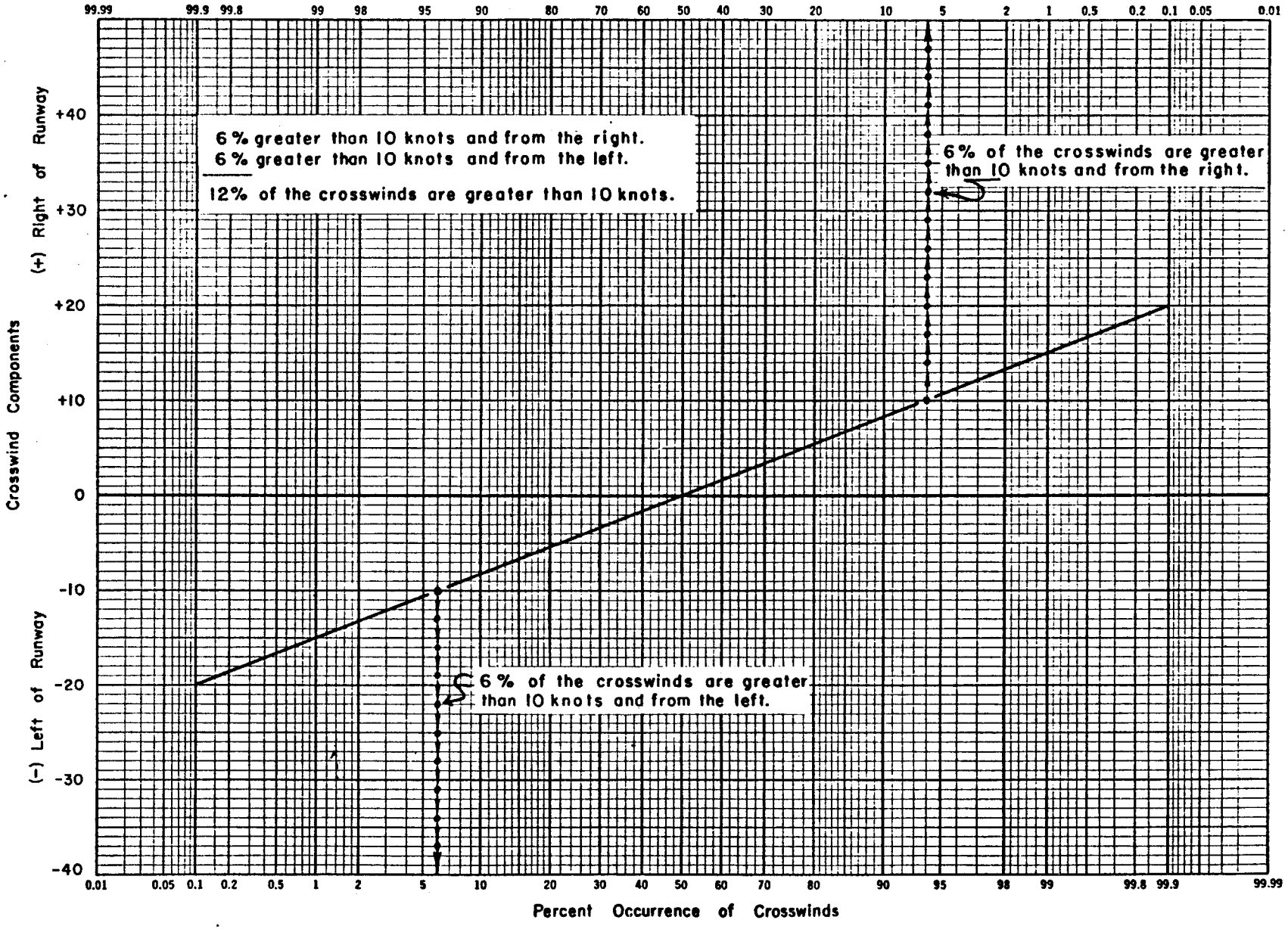


Chart 7

Crosswind Components to a Runway (Schematic)

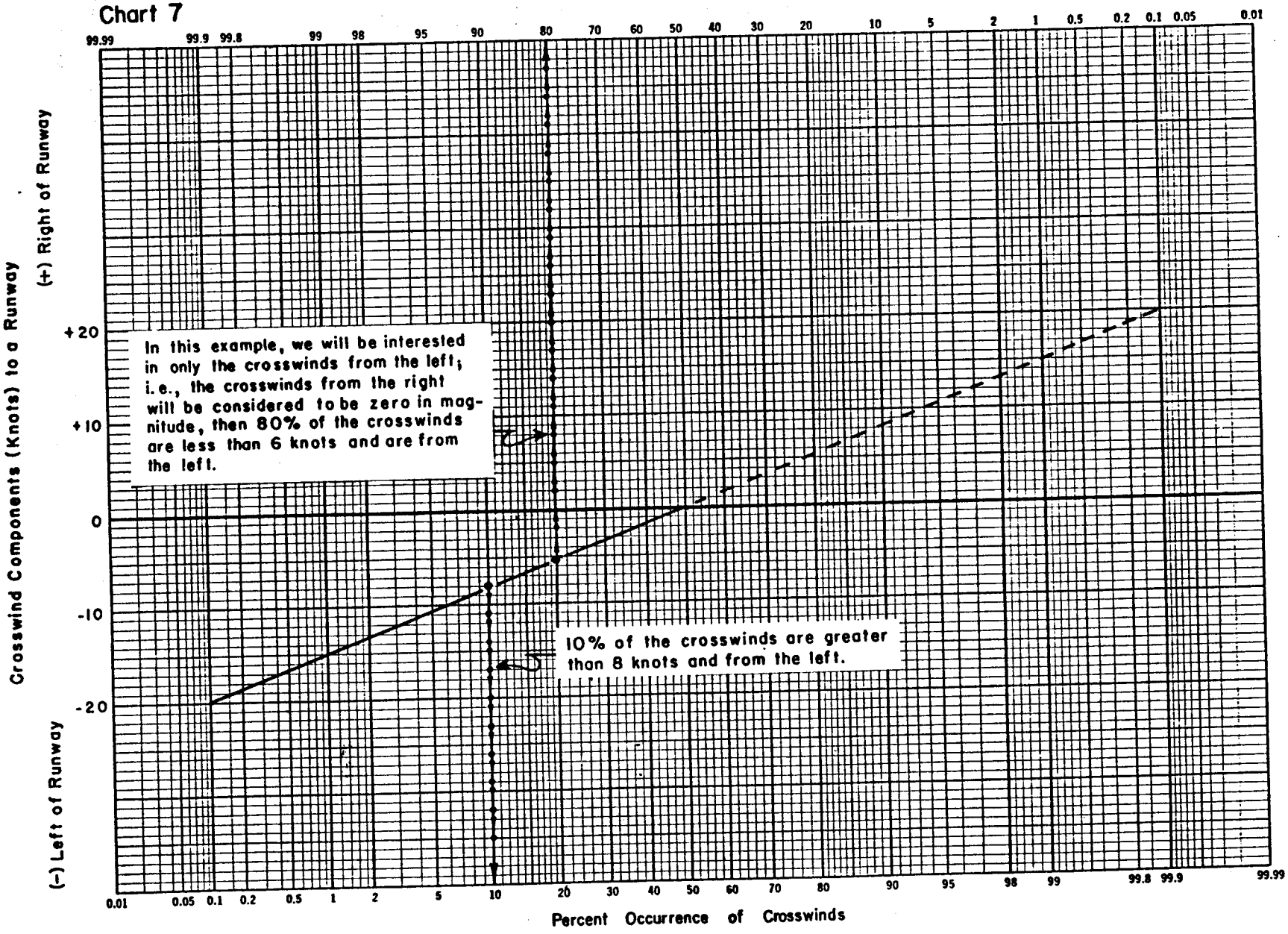
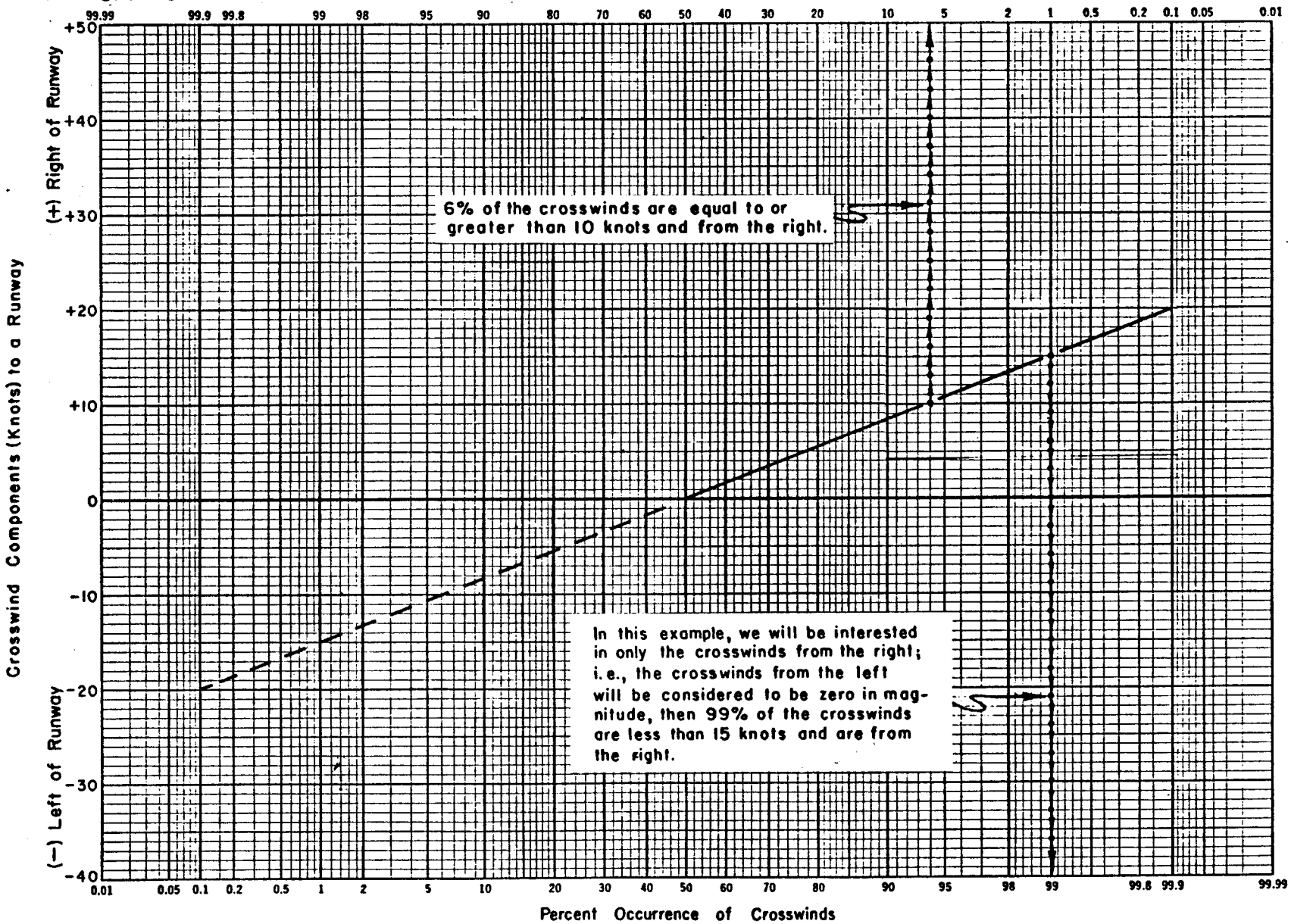


Chart 8

Crosswind Components to a Runway (Schematic)



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