NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SOME MEASUREMENTS AND POWER SPECTRA OF RUNWAY ROUGHNESS

By James H. Walls, John C. Houbolt, and Harry Press

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SUMMARY

Measurements of actual runway roughness obtained by a profile-survey method (engineer's level) are presented. Data were obtained from a survey of a relatively rough runway and a smooth runway. The results of this study are presented as roughness profiles of the runways surveyed and in the form of power spectra.

INTRODUCTION

The frequency of occurrence of large load applications in routine ground airplane operations has caused a growing concern in regard to the roughness of landing and taxiing surfaces. In order to obtain information on this problem, it was thought desirable to make detailed measurements of the roughness characteristics of actual runway surfaces. As one of the initial steps in this study, measurements were made of two runways available to the National Advisory Committee for Aeronautics at Langley Field, Va. The two runways selected were known to be of very different degrees of roughness; one runway was considered relatively smooth whereas the other was considered rather rough - possibly rough enough to preclude active use. The measurements made are presented here directly as elevation profiles. In addition, the power spectra of the runway elevations were also determined and are presented in order to permit a description of the frequency characteristics of the runway roughness.

SYMBOLS

D	distance over which moving average is taken
L	wavelength, ft
m	number of uniformly spaced points over the frequency range at which power estimates are desired

n	number of equally spaced elevations taken over the runway
x	distance, ft
X	arbitrary value of x, ft
Δx	space interval, ft
$y(x)$	random function of distance (runway height)
$R(X)$	autocorrelation function
$\Phi(\Omega)$	power-spectral density function, defined by equation (1), $\frac{\text{ft}^2}{\text{radian/ft}}$
X	displacement distance, ft
Ω	reduced frequency, $2\pi/L$, radians/ft
σ	root-mean-square value of y; $\sqrt{\overline{y^2(x)}}$

SURVEY OF VARIATIONS IN RUNWAY HEIGHT

A diagram of the landing and parking strips that presently exist at Langley Field is presented in figure 1 and shows the extent of the two surveys made. Runway 17-35 was chosen because it is considered representative of a satisfactorily smooth runway; the other runway chosen, 12-30, is considered rough and is used only for parking. Both runways are of standard concrete construction.

The roughness measurements were made by means of a surveyor's level, rod, and tape. This means was selected because it could be applied directly without the delays attendant on the development of special instrumentation. In using this technique it was necessary to select an interval at which elevations would be obtained. It was thought that the frequency range between 0.5 and 35 cycles per second would be the region of principal concern for most airplanes. At a landing speed of 100 miles per hour this would correspond to wavelengths between about 300 and 4 feet. As a consequence, a reading interval of 2 feet was selected. This choice was dictated by two considerations: first, it was expected that there would be little variation in runway height at wavelengths less than 4 feet and, second, the communications sampling theorem (ref. 1), which states that sampling a disturbance at intervals of one-half the shortest wavelength present completely specifies the disturbance.

Only 1,400 feet at the south end of runway 35 was surveyed so as not to interfere with ground traffic from runway 7. Visual observation suggested that except for the initial 100 feet, which is a sloping macadam overrun, this 1,400 feet is fairly representative of the remainder of the runway. Three thousand feet or nearly all of runway 12 was covered. The two surveys were conducted with greater ease than was originally expected. Approximately 6 hours was spent on runway 35 and slightly more than twice that time was spent on runway 12. This means that on an average about 115 readings per hour were obtained. The pace was steady but not hurried. Detailed runway elevations are given in table I, and figure 2 shows the runway profiles. These elevations are plotted about a zero arithmetic mean.

POWER SPECTRA OF RUNWAY HEIGHT

Definition of the Power Spectrum

In addition to the actual runway-height profiles, it appeared desirable, because of the random character of the height fluctuations, to determine the power spectra of runway height. These power spectra would provide a description of the frequency content of the runway height variations and be directly applicable to the calculation of airplane responses in the frequency plane.

Since the runway roughness under consideration here is a space disturbance rather than a disturbance in time, it is desirable to define the power-spectral density function in terms of the frequency argument Ω in radians per foot rather than the conventional argument ω in radians per second. In terms of this frequency argument, the power-spectral density function of the disturbance $y(x)$ is defined in the following manner:

$$\Phi(\Omega) = \lim_{X \to \infty} \frac{1}{2\pi X} \left| \int_{-X}^{X} y(x) e^{-i\Omega x} \, dx \right|^2 \tag{1}$$

where the bars indicate the modulus of the complex quantity. Equation (1) may be used to evaluate the power-spectral density function from observed data, but, in practice, the power-spectral density function may be determined more conveniently and less tediously through use of a related function, the autocorrelation function $R(\chi)$, defined by

$$R(\chi) = \lim_{X \to \infty} \frac{1}{2X} \int_{-X}^{X} y(x) y(x + \chi) dx \tag{2}$$

The autocorrelation function has the symmetrical property $R(X) = R(-X)$ and is reciprocally related to the power-spectral density function by the Fourier cosine transformation in the following manner:

$$\left.\begin{aligned} \Phi(\Omega) &= \frac{2}{\pi}\int_0^\infty R(X)\cos \Omega X \, dX \\ R(X) &= \int_0^\infty \Phi(\Omega)\cos \Omega X \, d\Omega \end{aligned}\right\} \qquad (3)$$

From the foregoing it is seen that

$$R(0) = \overline{y^2(x)} = \sigma^2 = \int_0^\infty \Phi(\Omega)d\Omega \qquad (4)$$

where σ is the root-mean-square value (or standard deviation) of the disturbance and is a convenient measure for a comparison of the overall roughness of the two runways surveyed.

Evaluation of Power Spectra

The actual evaluations of the power spectra were made by means of the numerical-calculation procedure derived by Tukey in reference 2. This procedure is also described and discussed in reference 3.

As a preliminary to these power-spectrum calculations, it appeared desirable to make some modifications to the actual measured profiles. Examination of these profiles (fig. 2) indicated that the runway height exhibited large changes in elevation at very long wavelengths. These large changes at low frequencies have a tendency to complicate and distort power estimates at the higher frequencies because of the effective filter characteristics of the numerical estimators. Since, in the present study, there was little interest in the longer wavelengths, it was decided to avoid these adverse affects by removing the longer wavelengths. One simple and convenient way of prefiltering a disturbance is by the use of moving averages. This means was used in the present study to filter out some of the longer wavelengths. A moving average of the runway height for a 300-foot distance, as defined by

$$y_m(x) = \frac{1}{150} \sum_{K=-75}^{K=75} y(x + K\,\Delta x)$$

was determined for each of the runways and is shown as the dashed curve in figure 2. The variations of runway height about this moving average were then determined and are shown in figure 3. As can be seen roughly from a comparison of figures 2 and 3, the main effect of this operation is the removal of the low-frequency components of the height variations.

The actual filtering effects of this operation on the spectrum estimates are derived in detail in the appendix. The attenuation function for the spectrum introduced by the moving average is given by

$$\left(1 - \frac{\sin \frac{\Omega D}{2}}{\frac{\Omega D}{2}}\right)^2$$

where D is the distance over which the average is taken. The attenuation function is shown as a function of $\Omega D/2$ in figure 4. A separate scale for wavelength L is also shown for the present value of $D = 300$ feet. It can be seen from the figure that the principal effect of the moving average in the present case is to attenuate the effects of the longer wavelengths, with the attenuation factor decreasing from 1 at 300 feet to 0.490 at 400 feet and 0.132 at 600 feet.

The actual steps involved in the numerical estimation of the spectra (ref. 2) are as follows:

1. The autocorrelation coefficients were determined from the successive values of elevation y_1, y_2, . . . y_n according to the following numerical form of equation (2):

$$R_r = \frac{1}{n - r} \sum_{q=1}^{n-r} y_q y_{q+r} \qquad (r = 0, 1, 2, \ldots m) \qquad (5)$$

where $R_r = R(\chi)$; $\chi = r\,\Delta x$.

2. Initial or "raw" estimates of the power density were then determined by use of the following numerical form of equation (3):

$$L_r = \frac{\Delta x}{\pi}\left(R_0 + 2\sum_{q=1}^{m-1} R_q \cos\frac{qr\pi}{m} + R_m \cos r\pi\right) \tag{6}$$

where $L_r = L(\Omega)$; $\Omega = \frac{r\pi}{m\ \Delta x}$. These estimates have an effective filter which has the undesirable character of appreciable side-band areas and thus permits a wide diffusion of power.

3. Final or "smoothed" estimates of power density, which are estimates based on a more desirable and sharper filter, were then determined from

$$\left.\begin{aligned}\Phi_0 &= 0.54L_0 + 0.46L_1 \\ \Phi_r &= 0.23L_{r-1} + 0.54L_r + 0.23L_{r+1} \\ \Phi_m &= 0.46L_{m-1} + 0.54L_m\end{aligned}\right\} \tag{7}$$

The values of Φ_r obtained in the foregoing manner can roughly be considered to be estimates of the average power over the frequency interval $\frac{(r - 1)\pi}{m\ \Delta x} < \Omega < \frac{(r + 1)\pi}{m\ \Delta x}$. The distances of 1,400 and 3,000 feet covered in the survey and the interval Δx of 2 feet lead to values of n of 701 and 1,501, respectively, for the two runways. Evaluation was made with $m = 40$. The autocorrelation coefficients obtained are shown in figure 5 and the resulting power estimates are plotted as a function of the reduced frequency Ω in figure 6. Each point in the present case represents the average power in a frequency interval $\pm \frac{\pi}{80}$ about the value plotted. For clarity in presentation, some of the power estimates at the higher frequency are not shown but were used in obtaining the faired curves. A scale of wavelength L is also shown in figure 6. The root mean square of runway height σ, which is a convenient measure of the average roughness power, is listed in figure 6 for each of the runways in the figure.

It may be recalled that the spectra of figure 6 represent the spectra of the runway height variations about the moving average. The effects of the moving-average operation on the derived spectra have been shown in the appendix to be equivalent to multiplying the actual spectra by the attenuation function $\left(1 - \frac{\sin \frac{\Omega D}{2}}{\frac{\Omega D}{2}}\right)^2$. In principle, then, it would appear that the effects of the moving-average operation could be removed by dividing the spectra of figure 6 by this attenuation function. However, in practice this cannot be done explicitly, since the spectrum estimates are averages of the power over finite band widths. A good approximation of the effect may be obtained, however, by dividing the faired spectrum estimates of figure 6 by the attenuation function and then averaging the resultant spectra over each of the band widths. It may be seen that these operations would have a negligible effect for the range of frequencies covered in figure 6.

DISCUSSION

Examination of figures 2 and 3 indicates that the runway heights fluctuate in a random manner, with variations of as much as several inches for each runway. The profile for runway 12 on both figures shows wider fluctuations, particularly at the longer wavelengths. The overall variations in height at the wavelengths of principal interest are best compared in figure 3, where the effects of the very long wavelengths (greater than 300 feet) have been largely removed by the moving average. It is clear from this figure that runway 12 is appreciably rougher than runway 35, as was to be expected. The height profiles of figures 2 and 3, representing what may be considered as a satisfactory and an unsatisfactory runway, provide representative runway inputs for response calculations.

A more detailed comparison of the characteristics of the runway height variations is possible from the spectra of figure 6. The overall height fluctuations as represented by the root-mean-square values of 0.057 feet for runway 12 and 0.021 feet for runway 35 indicate that runway 12 is almost three times as rough as runway 35. By comparing the spectra it can be seen that runway 12 has 10 times the power of runway 35 at the longer wavelengths (300 to 500 feet) and about twice the power at the shorter wavelengths (below 50 feet). The rapid decrease of power with increasing frequency displayed by both spectra is perhaps generally typical of runway height spectra and provides a guide to a representative spectrum shape. Inasmuch as the spectra of figure 6 represent satisfactory and unsatisfactory levels of runway roughness, the heights of the spectra provide an initial guide toward the establishment of criteria for runway roughness.

CONCLUDING REMARKS

As an initial step in the study of runway roughness, data were obtained from a survey of a relatively smooth runway and a runway which is considered rough. A surveyor's level, rod, and tape were used to obtain these data. In general, this method was found to be quick and relatively inexpensive. The results obtained are presented as profiles of runway height. The power spectra of runway height were also determined and are presented. These results provide an initial guide toward establishment of criteria for runway roughnesses and are suitable for airplane response calculations.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 13, 1954.

APPENDIX

EFFECT OF MOVING AVERAGES ON THE POWER SPECTRUM OF A RANDOM FUNCTION

Consider a random function $f(x)$. The centered moving average of $f(x)$ over the interval D is defined by

$$g(x) = \frac{1}{D} \int_{x-\frac{D}{2}}^{x+\frac{D}{2}} f(x_1)dx_1 \tag{A1}$$

The deviation of the disturbance about its moving average is then given by

$$h(x) = f(x) - g(x) = f(x) - \frac{1}{D} \int_{x-\frac{D}{2}}^{x+\frac{D}{2}} f(x_1)dx_1 \tag{A2}$$

The spectral properties of $h(x)$ as compared with those of $f(x)$ are of concern; specifically, the effects on the spectrum of $f(x)$ introduced by the operation of equation (A2).

The "finite" Fourier transform of equation (A2) may be written

$$H(\Omega) = \int_{-X}^{X} h(x)e^{-i\Omega x}dx = \int_{-X}^{X} f(x)e^{-i\Omega x}dx - \frac{1}{D} \int_{-X}^{X}\int_{x-\frac{D}{2}}^{x+\frac{D}{2}} f(\eta)e^{-i\Omega x}d\eta\ dx \tag{A3}$$

If the order of integration of the double integral term is interchanged, there results

$$H(\Omega) = \int_{-X}^{X} f(x)e^{-i\Omega x}dx - \frac{1}{D} \int_{\eta-\frac{D}{2}}^{\eta+\frac{D}{2}} \int_{-X}^{X} f(\eta)e^{-i\Omega x}d\eta\ dx \tag{A4}$$

The x-integral of the second term may now be evaluated to give

$$H(\Omega) = \int_{-X}^{X} f(x)e^{-i\Omega x}dx - \frac{\sin\frac{\Omega D}{2}}{\frac{\Omega D}{2}} \int_{-X}^{X} f(\eta)e^{-i\Omega\eta}d\eta = \left(1 - \frac{\sin\frac{\Omega D}{2}}{\frac{\Omega D}{2}}\right)F(\Omega) \tag{A5}$$

where $F(\Omega)$ is the "finite" Fourier transform of $f(x)$

$$F(\Omega) = \int_{-X}^{X} f(x)e^{-i\Omega x}dx \tag{A6}$$

The power spectrum of $h(x)$ follows directly from equation (A5) in accordance with the following equation:

$$\Phi_h(\Omega) = \lim_{X\longrightarrow\infty} \frac{1}{2\pi X} \left|H(\Omega)\right|^2 = \lim_{X\longrightarrow\infty} \frac{1}{2\pi X} H(\Omega)H(-\Omega) \tag{A7}$$

Substitution of equation (A5) into this equation yields the following simple result:

$$\Phi_h(\Omega) = \left(1 - \frac{\sin\frac{\Omega D}{2}}{\frac{\Omega D}{2}}\right)^2 \lim_{X\longrightarrow\infty} \frac{1}{2\pi X} F(\Omega)F(-\Omega) = \left(1 - \frac{\sin\frac{\Omega D}{2}}{\frac{\Omega D}{2}}\right)^2 \Phi_f(\Omega) \tag{A8}$$

The squared term on the right side of this equation is the effective spectrum attenuation function or transfer function introduced by the moving-average process defined by equation (A2). It is shown plotted as a function of $\Omega D/2$ in figure 4. Also shown in the figure is a scale of wavelength for $D = 300$ feet, the value used in the present study.

As a matter of added interest, an alternate derivation of equation (A8) may be given which is slightly more involved but which is more general in the sense that the function $g(x)$ does not have to be functionally related to $f(x)$. Equation (A1) may also be written

$$g(x) = \frac{1}{D} \int_{-\infty}^{\infty} f(x_1)k(x - x_1)dx_1 \tag{A9}$$

where

$$k(x) = 1 \qquad (-D/2 \leqq x \leqq D/2)$$

$$k(x) = 0 \qquad \text{(elsewhere)}$$

Now, from equation (A2) the power spectra of $h(x)$ and $g(x)$ can be shown to be related in the following manner (ref. 4):

$$\Phi_h(\Omega) = \Phi_f(\Omega) + \Phi_g(\Omega) - \Phi_{fg}(\Omega) - \Phi_{gf}(\Omega) \tag{A10}$$

where $\Phi_f(\Omega)$ and $\Phi_g(\Omega)$ are the power spectra of $f(x)$ and $g(x)$, respectively, and $\Phi_{fg}(\Omega)$ and $\Phi_{gf}(\Omega)$ are the cross spectra of $f(x)$ and $g(x)$ defined in the following manner:

$$\left.\begin{aligned} \Phi_{fg}(\Omega) &= \lim_{X \to \infty} \frac{F(-\Omega)G(\Omega)}{2\pi X} \\ \Phi_{gf}(\Omega) &= \lim_{X \to \infty} \frac{F(\Omega)G(-\Omega)}{2\pi X} \end{aligned}\right\} \tag{A11}$$

where $F(\Omega)$ is defined by equation (A6) and

$$G(\Omega) = \int_{-X}^{X} g(x)e^{-i\Omega x}dx \tag{A12}$$

The cross spectra in general have both real and imaginary terms, in contrast to the simple power spectra which are always real.

In order to determine the spectrum of $h(x)$, it is necessary to evaluate each of the spectra on the right side of equation (A10). Considering $\Phi_g(\Omega)$ first, it can be seen from equation (A9) that $g(x)$ is related to $f(x)$ by the conventional convolution or Duhamel integral and is thus obtained by a linear operation on $f(x)$. Using the simple relation between spectra of an input disturbance and an output response for linear systems, there is immediately obtained the following relation between $g(x)$ and $f(x)$:

$$\Phi_g(\Omega) = \Phi_f(\Omega)\left(\frac{\sin \frac{\Omega D}{2}}{\frac{\Omega D}{2}}\right)^2 \qquad \text{(A13)}$$

where the squared term represents the amplitude of the frequency-response function for the operation defined by equation (A9).

The cross-spectra terms may be evaluated in the following manner. From equations (A9), (A11), and (A12), for example,

$$\Phi_{fg}(\Omega) = \lim_{X \to \infty} \frac{F(-\Omega) \int_{-X}^{X} \left[\frac{1}{D} \int_{-\infty}^{\infty} f(x_1)k(x - x_1)dx_1\right] e^{-i\Omega x}dx}{2\pi X} \qquad \text{(A14)}$$

In the limit, this equation reduces to

$$\Phi_{fg}(\Omega) = \Phi_f(\Omega) \frac{\sin \frac{\Omega D}{2}}{\frac{\Omega D}{2}} \qquad \text{(A15)}$$

The cross spectrum in this case has no imaginary term reflecting the lack of any introduction of a phase shift by the linear operation defined by equation (A2). In the present case

$$\Phi_{fg}(\Omega) = \Phi_{gf}(\Omega) \qquad \text{(A16)}$$

Substituting the results of equations (A13), (A15), and (A16) into equation (A10) yields the same result as given by equation (A8).

REFERENCES

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TABLE I.- BASIC RUNWAY HEIGHT DATA

(a) Runway 35

Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft
0	-0.808										
2	-.753	112	0.062	222	0.020	332	0.043	442	0.101	552	0.061
4	-.651	114	.072	224	.017	334	.048	444	.107	554	.075
6	-.614	116	.074	226	.012	336	.059	446	.106	556	.077
8	-.550	118	.076	228	.009	338	.060	448	.112	558	.083
10	-.533	120	.086	230	.019	340	.067	450	.107	560	.084
12	-.501	122	.095	232	.030	342	.071	452	.100	562	.086
14	-.480	124	.102	234	.033	344	.079	454	.083	564	.092
16	-.457	126	.095	236	.029	346	.085	456	.092	566	.092
18	-.439	128	.090	238	.034	348	.089	458	.092	568	.090
20	-.424	130	.081	240	.029	350	.098	460	.091	570	.087
22	-.411	132	.071	242	.031	352	.106	462	.092	572	.086
24	-.388	134	.055	244	.035	354	.106	464	.096	574	.087
26	-.359	136	.047	246	.039	356	.093	466	.097	576	.087
28	-.334	138	.024	248	.034	358	.116	468	.097	578	.086
30	-.311	140	.027	250	.027	360	.111	470	.103	580	.082
32	-.287	142	.021	252	.023	362	.102	472	.099	582	.084
34	-.313	144	.024	254	.025	364	.091	474	.096	584	.082
36	-.293	146	.027	256	.022	366	.083	476	.105	586	.079
38	-.257	148	.031	258	.030	368	.082	478	.105	588	.079
40	-.231	150	.030	260	.031	370	.076	480	.099	590	.070
42	-.209	152	.023	262	.022	372	.071	482	.105	592	.067
44	-.194	154	.013	264	.017	374	.068	484	.104	594	.065
46	-.186	156	.002	266	.015	376	.067	486	.098	596	.059
48	-.169	158	-.003	268	.004	378	.067	488	.093	598	.051
50	-.149	160	-.007	270	-.003	380	.067	490	.097	600	.045
52	-.131	162	-.013	272	-.011	382	.085	492	.087	602	.055
54	-.115	164	-.006	274	-.017	384	.086	494	.082	604	.057
56	-.099	166	-.003	276	-.011	386	.086	496	.096	606	.039
58	-.087	168	-.001	278	-.005	388	.079	498	.097	608	.031
60	-.073	170	.001	280	-.004	390	.071	500	.096	610	.031
62	-.062	172	-.008	282	-.007	392	.067	502	.103	612	.035
64	-.057	174	-.013	284	-.013	394	.061	504	.097	614	.036
66	-.054	176	-.017	286	-.019	396	.059	506	.089	616	.038
68	-.053	178	-.013	288	-.025	398	.057	508	.082	618	.040
70	-.052	180	-.005	290	-.027	400	.058	510	.081	620	.041
72	-.048	182	.001	292	-.015	402	.062	512	.077	622	.033
74	-.039	184	.001	294	-.013	404	.062	514	.079	624	.035
76	-.024	186	.003	296	-.011	406	.069	516	.076	626	.039
78	-.013	188	.006	298	-.015	408	.077	518	.073	628	.043
80	.000	190	.012	300	-.008	410	.074	520	.068	630	.049
82	.015	192	.012	302	-.007	412	.071	522	.067	632	.046
84	.024	194	.019	304	-.006	414	.069	524	.073	634	.041
86	.031	196	.020	306	-.003	416	.069	526	.082	636	.043
88	.029	198	.020	308	.005	418	.071	528	.080	638	.048
90	.029	200	.031	310	.009	420	.082	530	.082	640	.049
92	.065	202	.019	312	.006	422	.083	532	.075	642	.054
94	.130	204	.019	314	.013	424	.082	534	.066	644	.053
96	.080	206	.022	316	.013	426	.086	536	.062	646	.049
98	.054	208	.023	318	.012	428	.097	538	.067	648	.043
100	.009	210	.021	320	.013	430	.102	540	.067	650	.041
102	.026	212	.024	322	.022	432	.108	542	.066	652	.037
104	.043	214	.027	324	.029	434	.110	544	.056	654	.033
106	.045	216	.028	326	.032	436	.106	546	.055	656	.036
108	.053	218	.026	328	.033	438	.098	548	.052	658	.035
110	.067	220	.023	330	.043	440	.099	550	.056	660	.041

TABLE I.- BASIC RUNWAY HEIGHT DATA - Continued

(a) Continued

Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft
662	0.041	772	0.069	882	0.119	992	0.104	1,102	-0.003	1,212	-0.114
664	.046	774	.068	884	.122	994	.100	1,104	-.005	1,214	-.112
666	.049	776	.074	886	.116	996	.088	1,106	-.003	1,216	-.111
668	.052	778	.080	888	.115	998	.081	1,108	-.004	1,218	-.113
670	.052	780	.083	890	.122	1,000	.072	1,110	-.005	1,220	-.111
672	.049	782	.088	892	.125	1,002	.072	1,112	-.008	1,222	-.112
674	.047	784	.091	894	.123	1,004	.079	1,114	-.014	1,224	-.111
676	.046	786	.089	896	.123	1,006	.082	1,116	-.020	1,226	-.113
678	.046	788	.088	898	.123	1,008	.085	1,118	-.023	1,228	-.109
680	.038	790	.088	900	.122	1,010	.088	1,120	-.027	1,230	-.103
682	.036	792	.082	902	.122	1,012	.090	1,122	-.029	1,232	-.102
684	.035	794	.083	904	.115	1,014	.095	1,124	-.033	1,234	-.101
686	.040	796	.079	906	.112	1,016	.096	1,126	-.041	1,236	-.111
688	.045	798	.079	908	.105	1,018	.094	1,128	-.048	1,238	-.115
690	.056	800	.079	910	.105	1,020	.092	1,130	-.060	1,240	-.114
692	.067	802	.080	912	.108	1,022	.086	1,132	-.067	1,242	-.113
694	.071	804	.080	914	.112	1,024	.083	1,134	-.064	1,244	-.117
696	.067	806	.073	916	.113	1,026	.081	1,136	-.065	1,246	-.123
698	.070	808	.082	918	.113	1,028	.082	1,138	-.062	1,248	-.130
700	.072	810	.091	920	.112	1,030	.077	1,140	-.065	1,250	-.134
702	.071	812	.098	922	.110	1,032	.076	1,142	-.068	1,252	-.140
704	.075	814	.093	924	.114	1,034	.069	1,144	-.068	1,254	-.138
706	.072	816	.105	926	.113	1,036	.069	1,146	-.071	1,256	-.141
708	.071	818	.107	928	.115	1,038	.069	1,148	-.071	1,258	-.139
710	.066	820	.106	930	.112	1,040	.066	1,150	-.071	1,260	-.142
712	.062	822	.100	932	.112	1,042	.069	1,152	-.077	1,262	-.142
714	.059	824	.099	934	.112	1,044	.062	1,154	-.075	1,264	-.148
716	.059	826	.099	936	.109	1,046	.057	1,156	-.074	1,266	-.151
718	.058	828	.102	938	.103	1,048	.049	1,158	-.073	1,268	-.150
720	.053	830	.102	940	.098	1,050	.050	1,160	-.074	1,270	-.154
722	.046	832	.093	942	.089	1,052	.042	1,162	-.074	1,272	-.156
724	.042	834	.090	944	.086	1,054	.029	1,164	-.077	1,274	-.159
726	.042	836	.094	946	.084	1,056	.030	1,166	-.075	1,276	-.163
728	.046	838	.098	948	.089	1,058	.027	1,168	-.081	1,278	-.161
730	.048	840	.107	950	.096	1,060	.023	1,170	-.080	1,280	-.163
732	.056	842	.112	952	.102	1,062	.023	1,172	-.078	1,282	-.164
734	.051	844	.118	954	.106	1,064	.022	1,174	-.078	1,284	-.168
736	.048	846	.123	956	.105	1,066	.028	1,176	-.078	1,286	-.174
738	.049	848	.123	958	.109	1,068	.029	1,178	-.075	1,288	-.177
740	.055	850	.128	960	.109	1,070	.026	1,180	-.077	1,290	-.179
742	.055	852	.127	962	.107	1,072	.027	1,182	-.080	1,292	-.181
744	.060	854	.127	964	.110	1,074	.027	1,184	-.081	1,294	-.191
746	.059	856	.130	966	.112	1,076	.029	1,186	-.080	1,296	-.197
748	.052	858	.136	968	.121	1,078	.027	1,188	-.081	1,298	-.204
750	.051	860	.132	970	.119	1,080	.025	1,190	-.083	1,300	-.205
752	.050	862	.130	972	.115	1,082	.022	1,192	-.090	1,302	-.206
754	.047	864	.126	974	.108	1,084	.015	1,194	-.089	1,304	-.204
756	.047	866	.123	976	.098	1,086	.014	1,196	-.088	1,306	-.209
758	.048	868	.117	978	.091	1,088	.013	1,198	-.089	1,308	-.214
760	.052	870	.115	980	.088	1,090	.013	1,200	-.091	1,310	-.214
762	.052	872	.106	982	.085	1,092	.012	1,202	-.093	1,312	-.213
764	.059	874	.097	984	.086	1,094	.010	1,204	-.101	1,314	-.215
766	.062	876	.098	986	.089	1,096	.012	1,206	-.103	1,316	-.217
768	.065	878	.102	988	.098	1,098	.011	1,208	-.111	1,318	-.218
770	.069	880	.110	990	.103	1,100	.005	1,210	-.110	1,320	-.218

TABLE I.- BASIC RUNWAY HEIGHT DATA - Continued

(a) Concluded

Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft
1,322	-0.221	1,352	-0.247	1,382	-0.238
1,324	-.223	1,354	-.245	1,384	-.233
1,326	-.221	1,356	-.245	1,386	-.230
1,328	-.219	1,358	-.253	1,388	-.223
1,330	-.217	1,360	-.250	1,390	-.219
1,332	-.219	1,362	-.243	1,392	-.217
1,334	-.223	1,364	-.233	1,394	-.215
1,336	-.229	1,366	-.231	1,396	-.215
1,338	-.232	1,368	-.235	1,398	-.211
1,340	-.229	1,370	-.241	1,400	-.209
1,342	-.231	1,372	-.243		
1,344	-.232	1,374	-.241		
1,346	-.238	1,376	-.240		
1,348	-.238	1,378	-.241		
1,350	-.241	1,380	-.239		

TABLE I.- BASIC RUNWAY HEIGHT DATA - Continued

(b) Runway 12

Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft
0	0.214										
2	.224	112	0.071	222	-0.058	332	-0.210	442	-0.381	552	-0.487
4	.220	114	.062	224	-.047	334	-.220	444	-.377	554	-.480
6	.223	116	.053	226	-.041	336	-.238	446	-.369	556	-.480
8	.222	118	.050	228	-.057	338	-.241	448	-.365	558	-.475
10	.225	120	.052	230	-.068	340	-.231	450	-.364	560	-.465
12	.220	122	.048	232	-.069	342	-.226	452	-.385	562	-.450
14	.220	124	.050	234	-.077	344	-.228	454	-.388	564	-.439
16	.221	126	.041	236	-.097	346	-.231	456	-.371	566	-.431
18	.212	128	.034	238	-.098	348	-.238	458	-.362	568	-.428
20	.212	130	.031	240	-.105	350	-.244	460	-.359	570	-.422
22	.212	132	.036	242	-.108	352	-.235	462	-.358	572	-.432
24	.213	134	.039	244	-.105	354	-.232	464	-.344	574	-.427
26	.226	136	.034	246	-.115	356	-.235	466	-.338	576	-.428
28	.230	138	.023	248	-.118	358	-.240	468	-.328	578	-.420
30	.232	140	.015	250	-.124	360	-.247	470	-.332	580	-.416
32	.214	142	.012	252	-.118	362	-.251	472	-.356	582	-.410
34	.201	144	.014	254	-.110	364	-.251	474	-.360	584	-.424
36	.185	146	.025	256	-.110	366	-.245	476	-.360	586	-.423
38	.174	148	.038	258	-.121	368	-.241	478	-.364	588	-.410
40	.174	150	.042	260	-.135	370	-.240	480	-.367	590	-.407
42	.171	152	.022	262	-.140	372	-.238	482	-.377	592	-.408
44	.168	154	.011	264	-.145	374	-.242	484	-.372	594	-.408
46	.162	156	.009	266	-.146	376	-.254	486	-.374	596	-.371
48	.156	158	.009	268	-.150	378	-.276	488	-.368	598	-.368
50	.151	160	.011	270	-.148	380	-.274	490	-.372	600	-.364
52	.152	162	.019	272	-.148	382	-.272	492	-.374	602	-.368
54	.144	164	.014	274	-.148	384	-.279	494	-.372	604	-.366
56	.143	166	.000	276	-.161	386	-.285	496	-.370	606	-.368
58	.141	168	-.010	278	-.166	388	-.292	498	-.379	608	-.368
60	.140	170	-.008	280	-.172	390	-.290	500	-.390	610	-.365
62	.150	172	-.007	282	-.178	392	-.295	502	-.397	612	-.370
64	.144	174	-.002	284	-.180	394	-.295	504	-.405	614	-.364
66	.152	176	.004	286	-.197	396	-.292	506	-.415	616	-.368
68	.153	178	-.006	288	-.205	398	-.299	508	-.427	618	-.365
70	.148	180	-.007	290	-.206	400	-.316	510	-.429	620	-.360
72	.145	182	-.018	292	-.218	402	-.323	512	-.430	622	-.356
74	.135	184	-.020	294	-.223	404	-.327	514	-.441	624	-.344
76	.130	186	-.030	296	-.226	406	-.325	516	-.446	626	-.328
78	.132	188	-.028	298	-.206	408	-.316	518	-.455	628	-.326
80	.138	190	-.030	300	-.204	410	-.310	520	-.460	630	-.317
82	.135	192	-.026	302	-.217	412	-.301	522	-.462	632	-.308
84	.131	194	-.025	304	-.226	414	-.308	524	-.462	634	-.300
86	.120	196	-.038	306	-.221	416	-.315	526	-.469	636	-.299
88	.110	198	-.058	308	-.220	418	-.319	528	-.481	638	-.298
90	.106	200	-.068	310	-.221	420	-.324	530	-.494	640	-.294
92	.104	202	-.058	312	-.221	422	-.324	532	-.509	642	-.288
94	.104	204	-.060	314	-.218	424	-.335	534	-.521	644	-.288
96	.095	206	-.069	316	-.209	426	-.344	536	-.527	646	-.295
98	.085	208	-.068	318	-.209	428	-.358	538	-.528	648	-.286
100	.069	210	-.061	320	-.196	430	-.359	540	-.528	650	-.285
102	.083	212	-.066	322	-.188	432	-.355	542	-.528	652	-.274
104	.084	214	-.073	324	-.189	434	-.365	544	-.525	654	-.264
106	.081	216	-.081	326	-.191	436	-.374	546	-.521	656	-.251
108	.078	218	-.075	328	-.201	438	-.383	548	-.508	658	-.255
110	.075	220	-.064	330	-.197	440	-.386	550	-.500	660	-.262

TABLE I.- BASIC RUNWAY HEIGHT DATA - Continued

(b) Continued

Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft
662	-0.275	772	-0.090	882	0.004	992	0.080	1,102	0.198	1,212	0.061
664	-.282	774	-.078	884	.002	994	.074	1,104	.206	1,214	.055
666	-.288	776	-.070	886	.006	996	.075	1,106	.219	1,216	.062
668	-.284	778	-.078	888	.008	998	.076	1,108	.216	1,218	.072
670	-.278	780	-.085	890	.009	1,000	.074	1,110	.222	1,220	.071
672	-.269	782	-.096	892	.002	1,002	.082	1,112	.234	1,222	.064
674	-.269	784	-.104	894	.003	1,004	.093	1,114	.257	1,224	.072
676	-.282	786	-.109	896	.003	1,006	.095	1,116	.281	1,226	.075
678	-.278	788	-.111	898	.012	1,008	.102	1,118	.254	1,228	.076
680	-.281	790	-.107	900	.020	1,010	.104	1,120	.241	1,230	.062
682	-.278	792	-.100	902	.015	1,012	.099	1,122	.233	1,232	.057
684	-.266	794	-.100	904	.009	1,014	.101	1,124	.231	1,234	.051
686	-.264	796	-.088	906	.002	1,016	.104	1,126	.226	1,236	.050
688	-.261	798	-.082	908	.005	1,018	.113	1,128	.223	1,238	.049
690	-.254	800	-.077	910	.006	1,020	.111	1,130	.218	1,240	.051
692	-.246	802	-.074	912	.016	1,022	.110	1,132	.208	1,242	.047
694	-.245	804	-.078	914	.018	1,024	.121	1,134	.198	1,244	.043
696	-.230	806	-.069	916	.015	1,026	.141	1,136	.192	1,246	.051
698	-.218	808	-.068	918	.016	1,028	.141	1,138	.188	1,248	.052
700	-.205	810	-.074	920	.023	1,030	.150	1,140	.186	1,250	.048
702	-.188	812	-.065	922	.026	1,032	.156	1,142	.186	1,252	.047
704	-.182	814	-.066	924	.030	1,034	.158	1,144	.179	1,254	.041
706	-.182	816	-.068	926	.030	1,036	.152	1,146	.170	1,256	.029
708	-.182	818	-.056	928	.034	1,038	.143	1,148	.172	1,258	.010
710	-.187	820	-.060	930	.040	1,040	.136	1,150	.170	1,260	.006
712	-.187	822	-.049	932	.028	1,042	.132	1,152	.173	1,262	.000
714	-.189	824	-.045	934	.034	1,044	.126	1,154	.172	1,264	-.009
716	-.183	826	-.047	936	.030	1,046	.121	1,156	.168	1,266	-.022
718	-.175	828	-.040	938	.035	1,048	.132	1,158	.166	1,268	-.010
720	-.180	830	-.048	940	.034	1,050	.138	1,160	.172	1,270	-.011
722	-.186	832	-.046	942	.042	1,052	.137	1,162	.166	1,272	-.009
724	-.181	834	-.038	944	.046	1,054	.145	1,164	.155	1,274	-.004
726	-.175	836	-.034	946	.054	1,056	.154	1,166	.153	1,276	.008
728	-.164	838	-.036	948	.051	1,058	.166	1,168	.160	1,278	.006
730	-.160	840	-.031	950	.055	1,060	.172	1,170	.159	1,280	.010
732	-.158	842	-.022	952	.055	1,062	.156	1,172	.158	1,282	.016
734	-.150	844	-.015	954	.059	1,064	.154	1,174	.154	1,284	.023
736	-.159	846	-.009	956	.059	1,066	.150	1,176	.145	1,286	.026
738	-.160	848	-.018	958	.064	1,068	.156	1,178	.141	1,288	.035
740	-.164	850	-.027	960	.061	1,070	.170	1,180	.136	1,290	.044
742	-.148	852	-.028	962	.063	1,072	.169	1,182	.128	1,292	.076
744	-.128	854	-.031	964	.060	1,074	.179	1,184	.122	1,294	.080
746	-.093	856	-.024	966	.059	1,076	.181	1,186	.105	1,296	.076
748	-.060	858	-.020	968	.055	1,078	.190	1,188	.096	1,298	.080
750	-.053	860	-.026	970	.053	1,080	.196	1,190	.090	1,300	.084
752	-.105	862	-.023	972	.059	1,082	.203	1,192	.078	1,302	.080
754	-.120	864	-.028	974	.068	1,084	.216	1,194	.072	1,304	.082
756	-.123	866	-.030	976	.062	1,086	.201	1,196	.073	1,306	.077
758	-.127	868	-.022	978	.054	1,088	.185	1,198	.070	1,308	.080
760	-.125	870	-.014	980	.058	1,090	.176	1,200	.072	1,310	.078
762	-.125	872	-.012	982	.080	1,092	.190	1,202	.072	1,312	.078
764	-.120	874	-.008	984	.084	1,094	.205	1,204	.062	1,314	.087
766	-.121	876	.000	986	.080	1,096	.204	1,206	.059	1,316	.115
768	-.116	878	.001	988	.079	1,098	.190	1,208	.054	1,318	.130
770	-.100	880	.006	990	.077	1,100	.180	1,210	.060	1,320	.142

TABLE I.- BASIC RUNWAY HEIGHT DATA - Continued

(b) Continued

Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft
1,322	0.151	1,432	0.480	1,542	0.472	1,652	0.474	1,762	0.355	1,872	0.259
1,324	.162	1,434	.482	1,544	.475	1,654	.480	1,764	.353	1,874	.264
1,326	.175	1,436	.480	1,546	.475	1,656	.497	1,766	.349	1,876	.256
1,328	.185	1,438	.482	1,548	.474	1,658	.477	1,768	.351	1,878	.260
1,330	.199	1,440	.494	1,550	.459	1,660	.463	1,770	.358	1,880	.258
1,332	.215	1,442	.495	1,552	.459	1,662	.456	1,772	.355	1,882	.255
1,334	.222	1,444	.490	1,554	.464	1,664	.450	1,774	.348	1,884	.252
1,336	.239	1,446	.484	1,556	.459	1,666	.459	1,776	.342	1,886	.245
1,338	.252	1,448	.490	1,558	.452	1,668	.454	1,778	.335	1,888	.240
1,340	.260	1,450	.484	1,560	.442	1,670	.451	1,780	.323	1,890	.236
1,342	.269	1,452	.480	1,562	.445	1,672	.446	1,782	.322	1,892	.235
1,344	.276	1,454	.475	1,564	.447	1,674	.440	1,784	.330	1,894	.232
1,346	.290	1,456	.473	1,566	.449	1,676	.437	1,786	.317	1,896	.229
1,348	.304	1,458	.458	1,568	.435	1,678	.449	1,788	.331	1,898	.227
1,350	.320	1,460	.452	1,570	.423	1,680	.466	1,790	.334	1,900	.225
1,352	.328	1,462	.451	1,572	.439	1,682	.455	1,792	.340	1,902	.215
1,354	.333	1,464	.453	1,574	.454	1,684	.434	1,794	.332	1,904	.228
1,356	.339	1,466	.457	1,576	.459	1,686	.418	1,796	.326	1,906	.213
1,358	.345	1,468	.470	1,578	.453	1,688	.415	1,798	.334	1,908	.196
1,360	.349	1,470	.479	1,580	.443	1,690	.414	1,800	.337	1,910	.189
1,362	.358	1,472	.480	1,582	.451	1,692	.406	1,802	.341	1,912	.190
1,364	.369	1,474	.480	1,584	.452	1,694	.402	1,804	.331	1,914	.198
1,366	.376	1,476	.473	1,586	.452	1,696	.402	1,806	.330	1,916	.203
1,368	.377	1,478	.472	1,588	.442	1,698	.402	1,808	.327	1,918	.210
1,370	.372	1,480	.469	1,590	.442	1,700	.411	1,810	.333	1,920	.214
1,372	.376	1,482	.457	1,592	.441	1,702	.413	1,812	.338	1,922	.210
1,374	.384	1,484	.453	1,594	.434	1,704	.412	1,814	.343	1,924	.208
1,376	.395	1,486	.448	1,596	.427	1,706	.401	1,816	.358	1,926	.200
1,378	.403	1,488	.451	1,598	.431	1,708	.399	1,818	.354	1,928	.196
1,380	.412	1,490	.451	1,600	.434	1,710	.393	1,820	.341	1,930	.195
1,382	.400	1,492	.450	1,602	.444	1,712	.395	1,822	.322	1,932	.195
1,384	.389	1,494	.455	1,604	.454	1,714	.396	1,824	.319	1,934	.181
1,386	.382	1,496	.458	1,606	.473	1,716	.383	1,826	.316	1,936	.180
1,388	.382	1,498	.455	1,608	.462	1,718	.384	1,828	.321	1,938	.191
1,390	.383	1,500	.441	1,610	.461	1,720	.381	1,830	.322	1,940	.198
1,392	.384	1,502	.433	1,612	.461	1,722	.385	1,832	.322	1,942	.183
1,394	.392	1,504	.430	1,614	.462	1,724	.392	1,834	.313	1,944	.171
1,396	.394	1,506	.425	1,616	.474	1,726	.393	1,836	.313	1,946	.169
1,398	.397	1,508	.428	1,618	.467	1,728	.392	1,838	.316	1,948	.172
1,400	.402	1,510	.423	1,620	.472	1,730	.390	1,840	.322	1,950	.174
1,402	.403	1,512	.420	1,622	.470	1,732	.380	1,842	.320	1,952	.181
1,404	.417	1,514	.420	1,624	.463	1,734	.371	1,844	.331	1,954	.166
1,406	.416	1,516	.420	1,626	.472	1,736	.374	1,846	.327	1,956	.163
1,408	.425	1,518	.419	1,628	.470	1,738	.362	1,848	.327	1,958	.172
1,410	.424	1,520	.430	1,630	.470	1,740	.360	1,850	.332	1,960	.166
1,412	.434	1,522	.431	1,632	.474	1,742	.350	1,852	.337	1,962	.172
1,414	.444	1,524	.425	1,634	.482	1,744	.351	1,854	.328	1,964	.172
1,416	.444	1,526	.430	1,636	.492	1,746	.361	1,856	.319	1,966	.166
1,418	.454	1,528	.443	1,638	.482	1,748	.370	1,858	.313	1,968	.172
1,420	.445	1,530	.438	1,640	.474	1,750	.365	1,860	.316	1,970	.166
1,422	.454	1,532	.441	1,642	.457	1,752	.360	1,862	.313	1,972	.171
1,424	.454	1,534	.450	1,644	.452	1,754	.368	1,864	.302	1,974	.170
1,426	.460	1,536	.456	1,646	.460	1,756	.376	1,866	.289	1,976	.155
1,428	.462	1,538	.468	1,648	.468	1,758	.354	1,868	.285	1,978	.154
1,430	.475	1,540	.471	1,650	.476	1,760	.354	1,870	.264	1,980	.161

TABLE I.- BASIC RUNWAY HEIGHT DATA - Continued

(b) Continued

Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft
1,982	0.142	2,092	0.005	2,202	-0.142	2,312	-0.117	2,422	-0.128	2,532	-0.134
1,984	.132	2,094	.003	2,204	-.138	2,314	-.109	2,424	-.125	2,534	-.128
1,986	.122	2,096	-.006	2,206	-.118	2,316	-.110	2,426	-.131	2,536	-.126
1,988	.124	2,098	-.016	2,208	-.122	2,318	-.115	2,428	-.128	2,538	-.132
1,990	.134	2,100	-.024	2,210	-.130	2,320	-.115	2,430	-.130	2,540	-.134
1,992	.129	2,102	-.032	2,212	-.144	2,322	-.117	2,432	-.130	2,542	-.132
1,994	.119	2,104	-.041	2,214	-.152	2,324	-.119	2,434	-.134	2,544	-.124
1,996	.113	2,106	-.038	2,216	-.178	2,326	-.139	2,436	-.128	2,546	-.126
1,998	.115	2,108	-.032	2,218	-.182	2,328	-.140	2,438	-.122	2,548	-.130
2,000	.123	2,110	-.030	2,220	-.188	2,330	-.152	2,440	-.120	2,550	-.135
2,002	.125	2,112	-.034	2,222	-.189	2,332	-.160	2,442	-.118	2,552	-.132
2,004	.120	2,114	-.036	2,224	-.179	2,334	-.166	2,444	-.109	2,554	-.142
2,006	.102	2,116	-.043	2,226	-.198	2,336	-.162	2,446	-.106	2,556	-.145
2,008	.102	2,118	-.039	2,228	-.197	2,338	-.160	2,448	-.118	2,558	-.140
2,010	.102	2,120	-.033	2,230	-.204	2,340	-.159	2,450	-.120	2,560	-.157
2,012	.092	2,122	-.032	2,232	-.209	2,342	-.136	2,452	-.120	2,562	-.152
2,014	.076	2,124	-.046	2,234	-.204	2,344	-.045	2,454	-.138	2,564	-.148
2,016	.071	2,126	-.045	2,236	-.206	2,346	-.175	2,456	-.138	2,566	-.150
2,018	.074	2,128	-.048	2,238	-.189	2,348	-.217	2,458	-.140	2,568	-.149
2,020	.090	2,130	-.050	2,240	-.185	2,350	-.190	2,460	-.141	2,570	-.146
2,022	.092	2,132	-.048	2,242	-.178	2,352	-.168	2,462	-.144	2,572	-.140
2,024	.091	2,134	-.060	2,244	-.216	2,354	-.166	2,464	-.146	2,574	-.137
2,026	.090	2,136	-.057	2,246	-.219	2,356	-.148	2,466	-.148	2,576	-.138
2,028	.080	2,138	-.055	2,248	-.228	2,358	-.146	2,468	-.148	2,578	-.138
2,030	.072	2,140	-.056	2,250	-.222	2,360	-.145	2,470	-.152	2,580	-.139
2,032	.072	2,142	-.048	2,252	-.238	2,362	-.144	2,472	-.157	2,582	-.134
2,034	.071	2,144	-.047	2,254	-.248	2,364	-.145	2,474	-.160	2,584	-.131
2,036	.056	2,146	-.041	2,256	-.277	2,366	-.151	2,476	-.162	2,586	-.129
2,038	.058	2,148	-.047	2,258	-.316	2,368	-.151	2,478	-.162	2,588	-.128
2,040	.053	2,150	-.053	2,260	-.325	2,370	-.156	2,480	-.157	2,590	-.128
2,042	.052	2,152	-.039	2,262	-.342	2,372	-.158	2,482	-.150	2,592	-.128
2,044	.045	2,154	-.038	2,264	-.340	2,374	-.152	2,484	-.141	2,594	-.138
2,046	.045	2,156	-.046	2,266	-.331	2,376	-.144	2,486	-.134	2,596	-.139
2,048	.040	2,158	-.039	2,268	-.340	2,378	-.146	2,488	-.136	2,598	-.147
2,050	.040	2,160	-.037	2,270	-.350	2,380	-.149	2,490	-.138	2,600	-.160
2,052	.036	2,162	-.025	2,272	-.366	2,382	-.151	2,492	-.140	2,602	-.169
2,054	.034	2,164	-.029	2,274	-.386	2,384	-.147	2,494	-.145	2,604	-.184
2,056	.030	2,166	-.051	2,276	-.391	2,386	-.141	2,496	-.141	2,606	-.197
2,058	.005	2,168	-.065	2,278	-.400	2,388	-.139	2,498	-.144	2,608	-.216
2,060	-.009	2,170	-.058	2,280	-.397	2,390	-.139	2,500	-.146	2,610	-.231
2,062	.000	2,172	-.050	2,282	-.391	2,392	-.141	2,502	-.148	2,612	-.248
2,064	.016	2,174	-.061	2,284	-.384	2,394	-.138	2,504	-.146	2,614	-.257
2,066	.018	2,176	-.069	2,286	-.368	2,396	-.138	2,506	-.146	2,616	-.273
2,068	.015	2,178	-.078	2,288	-.352	2,398	-.139	2,508	-.145	2,618	-.286
2,070	.024	2,180	-.072	2,290	-.341	2,400	-.139	2,510	-.144	2,620	-.306
2,072	.032	2,182	-.076	2,292	-.321	2,402	-.138	2,512	-.144	2,622	-.320
2,074	.037	2,184	-.085	2,294	-.295	2,404	-.129	2,514	-.140	2,624	-.324
2,076	.021	2,186	-.095	2,296	-.263	2,406	-.129	2,516	-.146	2,626	-.337
2,078	.018	2,188	-.097	2,298	-.220	2,408	-.125	2,518	-.143	2,628	-.354
2,080	.013	2,190	-.100	2,300	-.186	2,410	-.119	2,520	-.148	2,630	-.367
2,082	.016	2,192	-.111	2,302	-.158	2,412	-.117	2,522	-.148	2,632	-.369
2,084	.011	2,194	-.119	2,304	-.142	2,414	-.124	2,524	-.148	2,634	-.357
2,086	.008	2,196	-.127	2,306	-.132	2,416	-.128	2,526	-.138	2,636	-.338
2,088	.004	2,198	-.124	2,308	-.119	2,418	-.130	2,528	-.140	2,638	-.332
2,090	.004	2,200	-.138	2,310	-.118	2,420	-.128	2,530	-.134	2,640	-.328

TABLE I.- BASIC RUNWAY HEIGHT DATA - Concluded

(b) Concluded

Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft	Distance along runway, ft	Runway elevation, ft
2,642	-0.334	2,702	-0.246	2,762	-0.166	2,822	-0.179	2,882	-0.168	2,942	-0.126
2,644	-.344	2,704	-.242	2,764	-.168	2,824	-.196	2,884	-.170	2,944	-.124
2,646	-.358	2,706	-.239	2,766	-.162	2,826	-.188	2,886	-.168	2,946	-.131
2,648	-.360	2,708	-.235	2,768	-.158	2,828	-.190	2,888	-.160	2,948	-.128
2,650	-.371	2,710	-.225	2,770	-.152	2,830	-.181	2,890	-.149	2,950	-.130
2,652	-.372	2,712	-.214	2,772	-.158	2,832	-.179	2,892	-.147	2,952	-.126
2,654	-.370	2,714	-.201	2,774	-.150	2,834	-.171	2,894	-.148	2,954	-.128
2,656	-.360	2,716	-.185	2,776	-.148	2,836	-.176	2,896	-.145	2,956	-.131
2,658	-.355	2,718	-.185	2,778	-.158	2,838	-.170	2,898	-.154	2,958	-.140
2,660	-.344	2,720	-.174	2,780	-.160	2,840	-.168	2,900	-.143	2,960	-.138
2,662	-.339	2,722	-.148	2,782	-.160	2,842	-.157	2,902	-.127	2,962	-0.134
2,664	-.334	2,724	-.124	2,784	-.158	2,844	-.164	2,904	-.121	2,964	-.140
2,666	-.325	2,726	-.154	2,786	-.158	2,846	-.158	2,906	-.128	2,966	-.136
2,668	-.321	2,728	-.187	2,788	-.151	2,848	-.162	2,908	-.138	2,968	-.124
2,670	-.319	2,730	-.211	2,790	-.146	2,850	-.172	2,910	-.128	2,970	-.128
2,672	-.312	2,732	-.220	2,792	-.148	2,852	-.175	2,912	-.138	2,972	-.124
2,674	-.308	2,734	-.229	2,794	-.150	2,854	-.179	2,914	-.131	2,974	-.128
2,676	-.304	2,736	-.228	2,796	-.151	2,856	-.176	2,916	-.135	2,976	-.126
2,678	-.296	2,738	-.218	2,798	-.144	2,858	-.176	2,918	-.125	2,978	-.124
2,680	-.285	2,740	-.215	2,800	-.151	2,860	-.171	2,920	-.127	2,980	-.118
2,682	-.278	2,742	-.200	2,802	-.167	2,862	-.172	2,922	-.134	2,982	-0.115
2,684	-.273	2,744	-.200	2,804	-.166	2,864	-.171	2,924	-.127	2,984	-.104
2,686	-.261	2,746	-.188	2,806	-.168	2,866	-.168	2,926	-.127	2,986	-.100
2,688	-.252	2,748	-.179	2,808	-.165	2,868	-.170	2,928	-.132	2,988	-.108
2,690	-.257	2,750	-.175	2,810	-.175	2,870	-.160	2,930	-.130	2,990	-.117
2,692	-.249	2,752	-.152	2,812	-.179	2,872	-.155	2,932	-.130	2,992	-.116
2,694	-.250	2,754	-.146	2,814	-.188	2,874	-.131	2,934	-.128	2,994	-.108
2,696	-.249	2,756	-.152	2,816	-.168	2,876	-.130	2,936	-.128	2,996	-.118
2,698	-.250	2,758	-.161	2,818	-.173	2,878	-.135	2,938	-.129	2,998	-.118
2,700	-.250	2,760	-.163	2,820	-.167	2,880	-.162	2,940	-.125	3,000	-.104

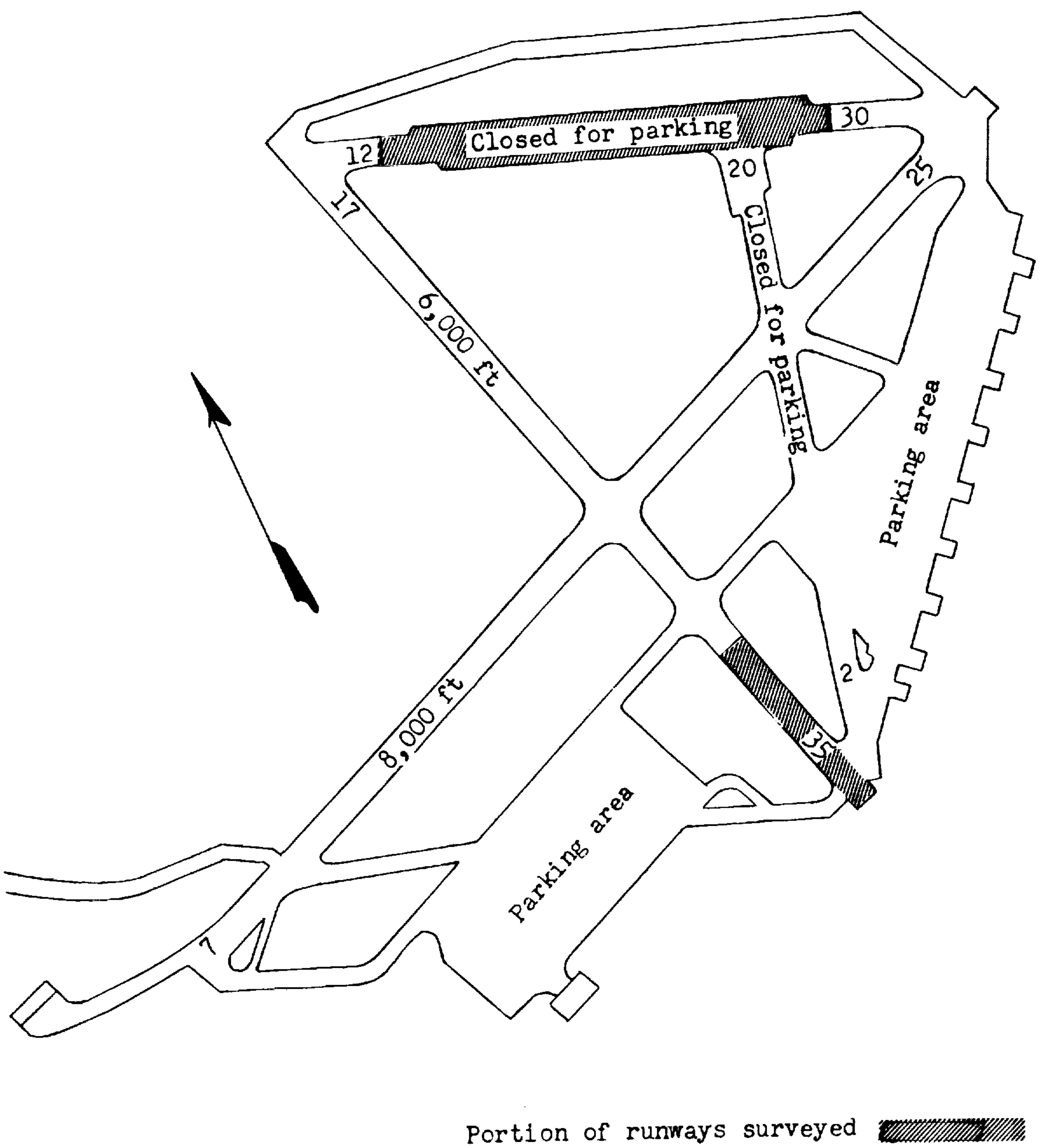


Figure 1.- Diagram of runways at Langley Field, Va.

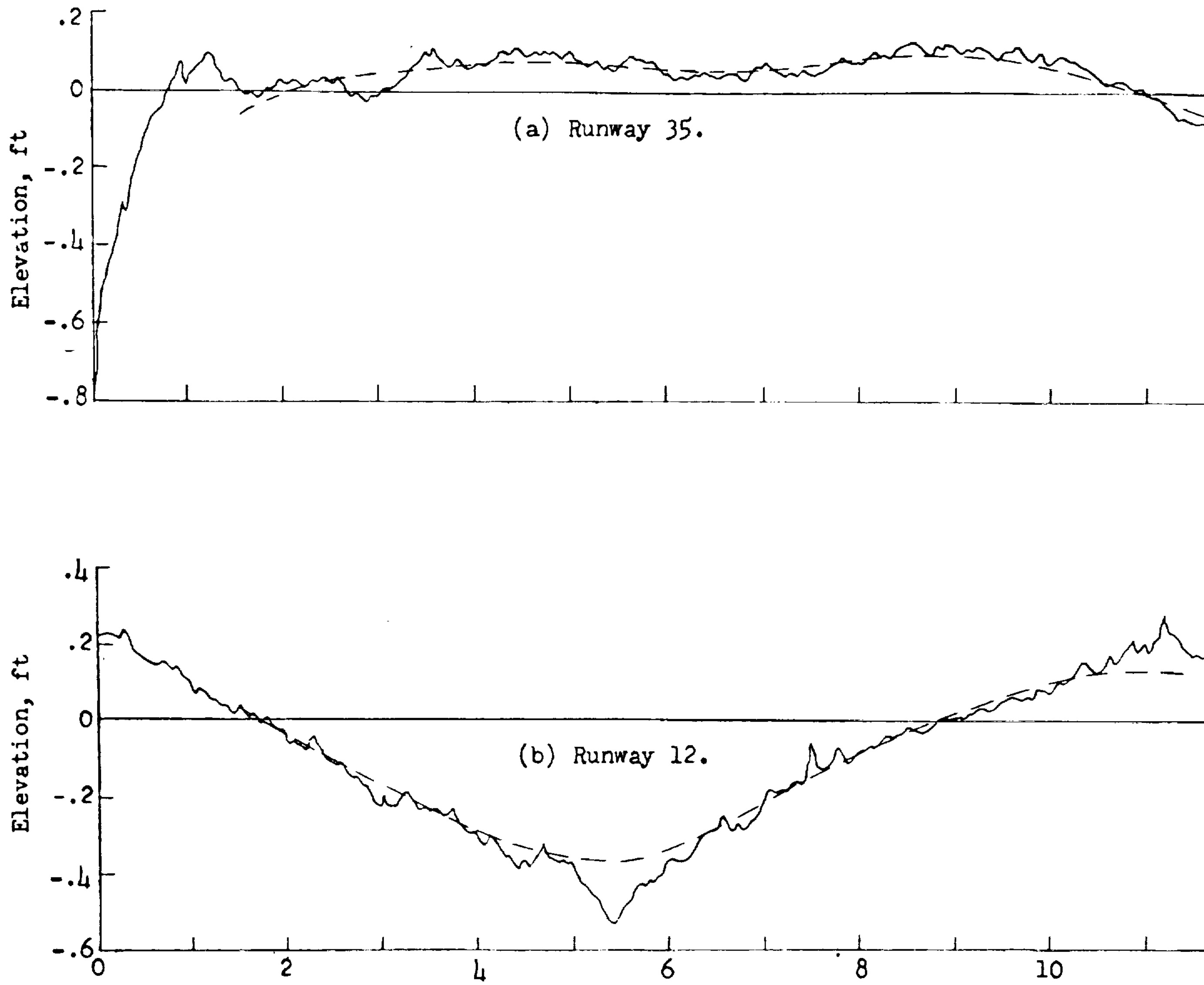


Figure 2.-

Fig 2 - 1

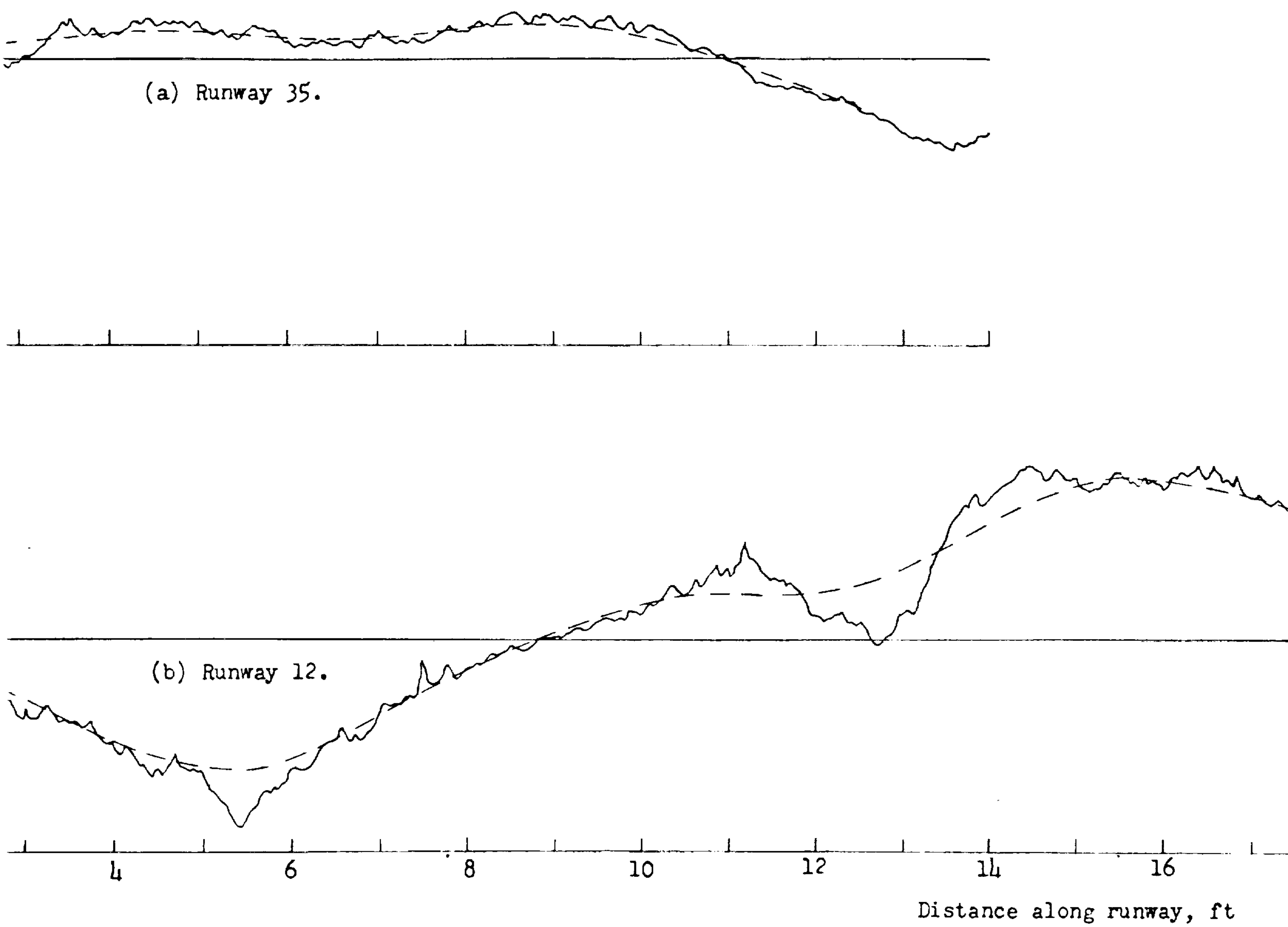
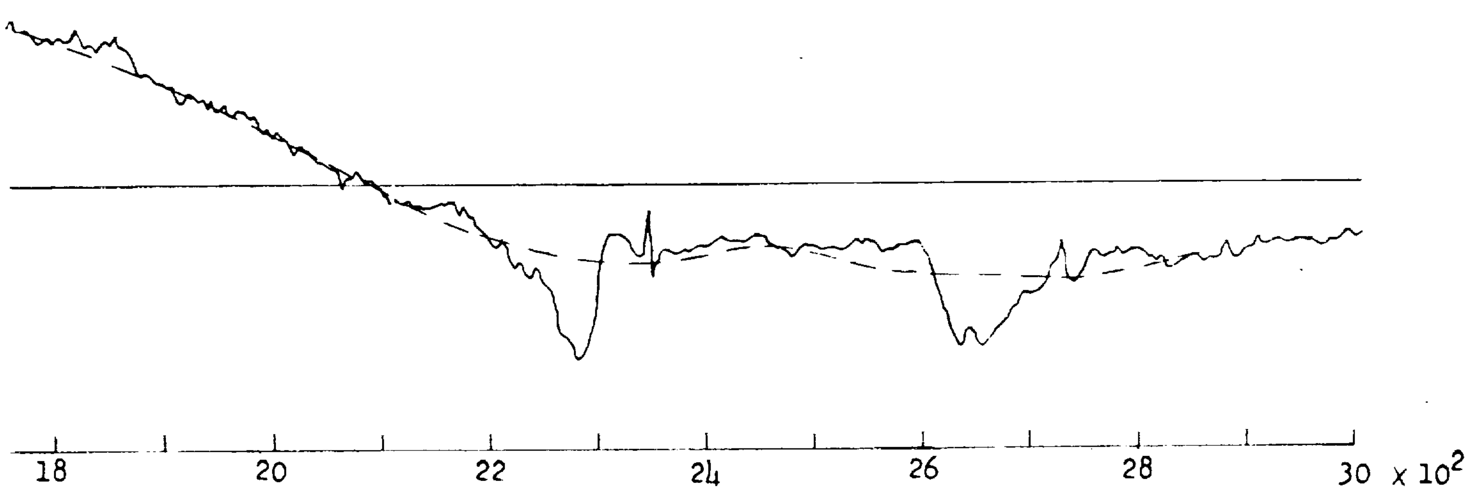


Figure 2.- Variation of runway elevation about an a

F.G 2-2



ithmetic mean.

FIG. 2-3

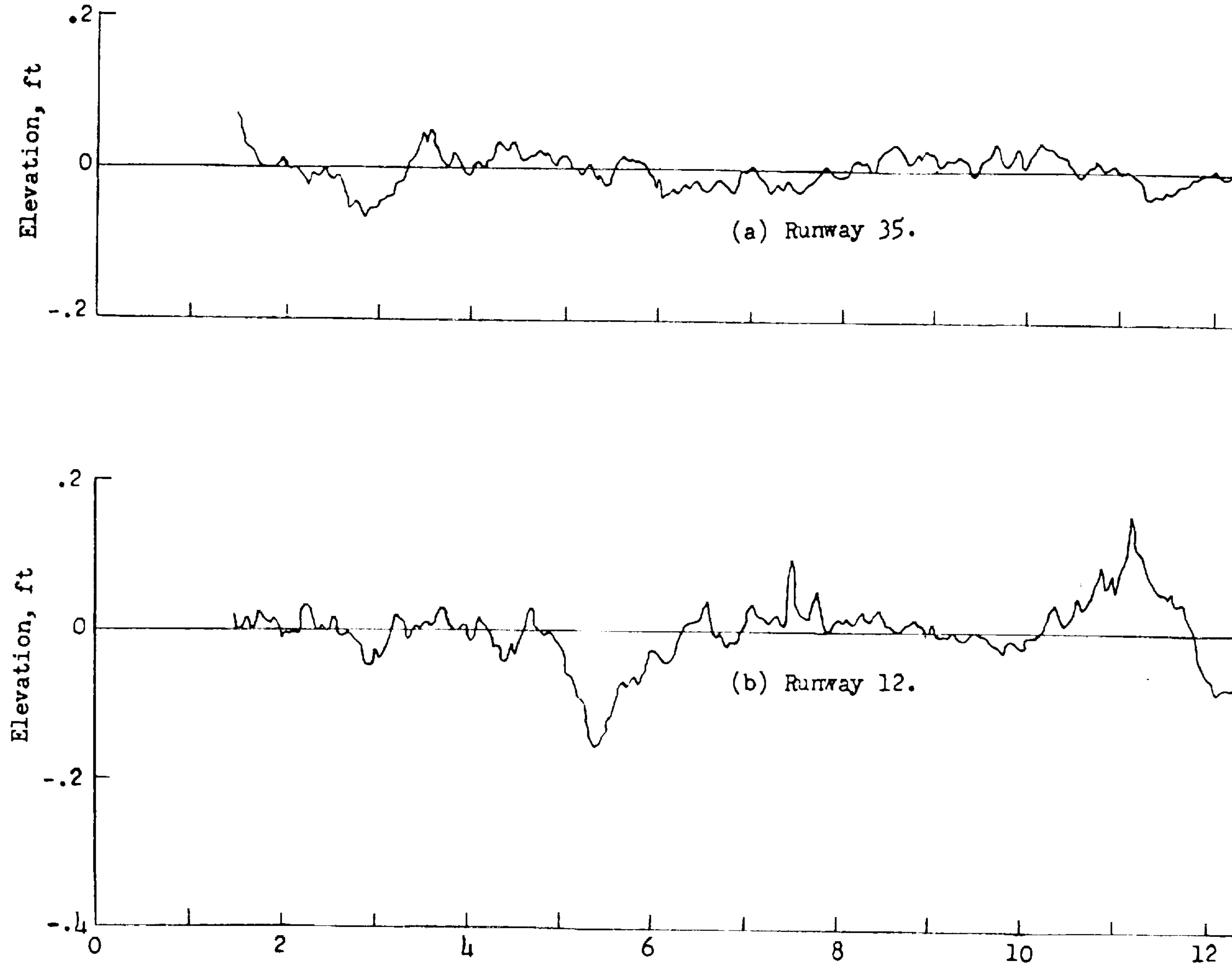


Figure 3.- Var

FIG. 3-1

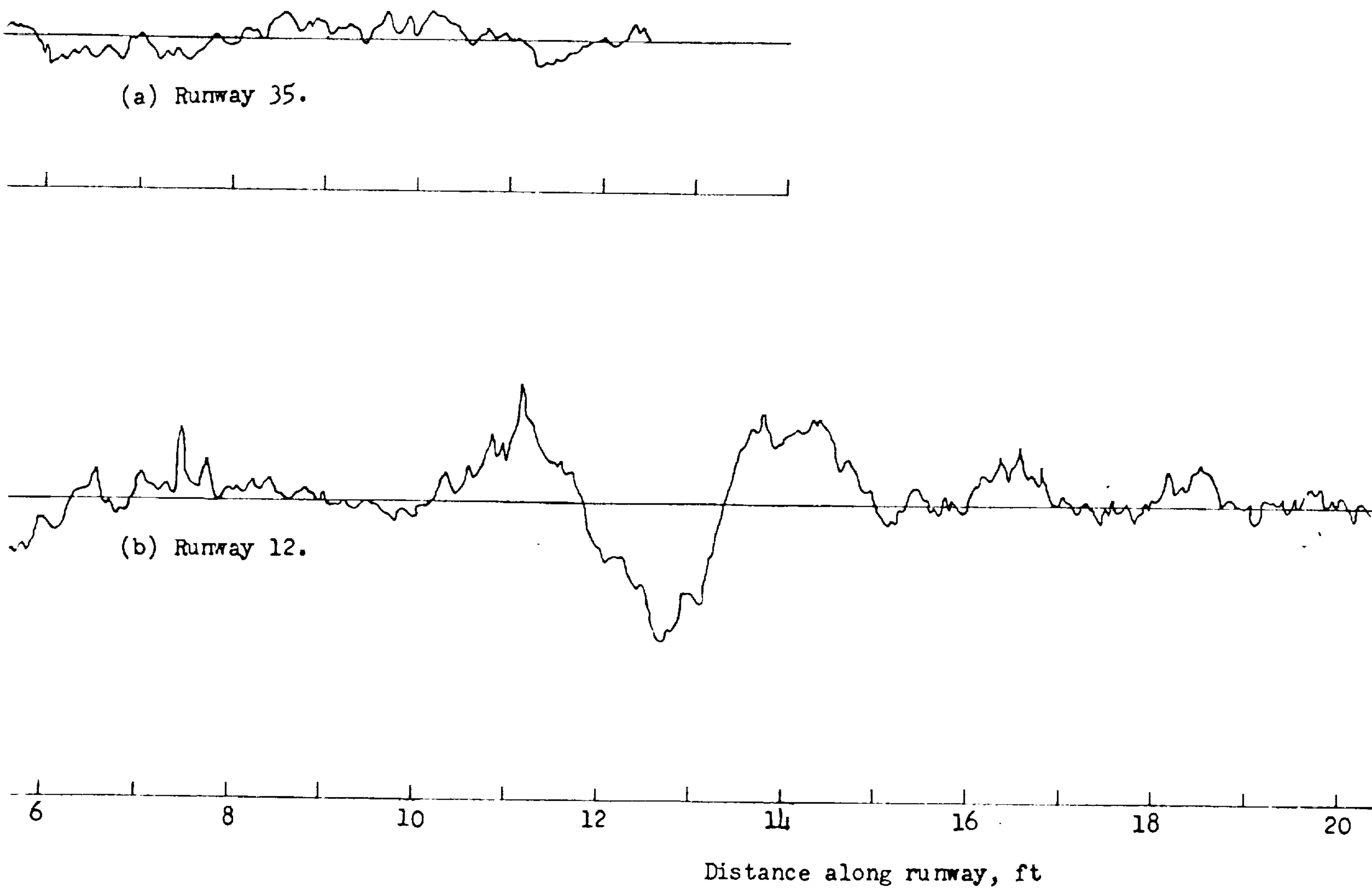
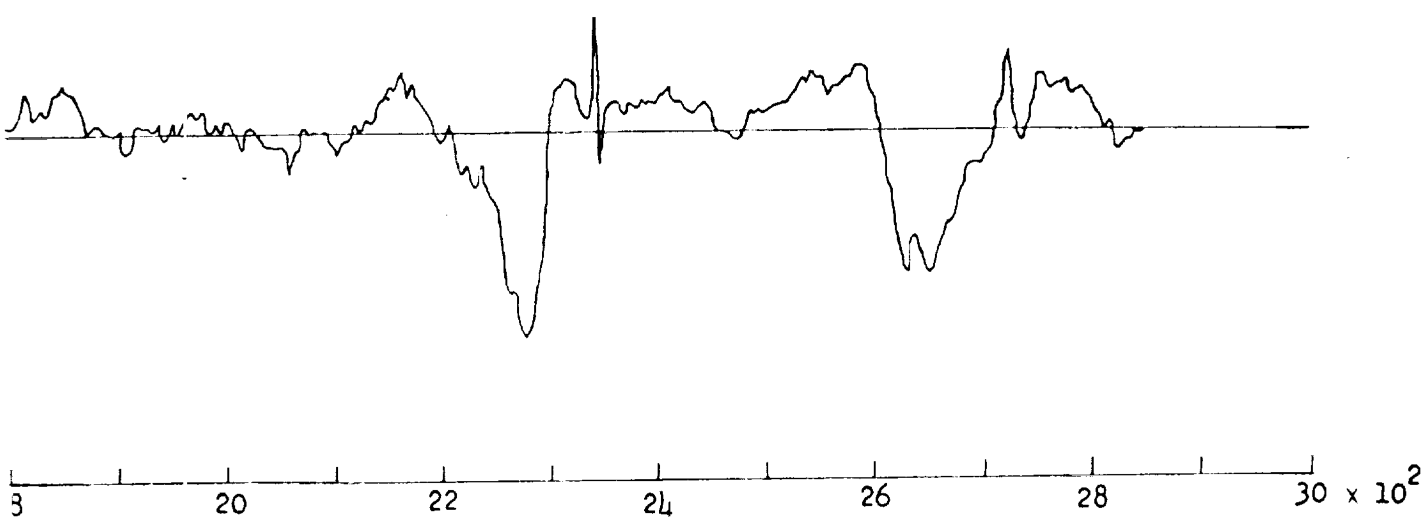


Figure 3.- Variation of runway elevation about a 300-foot moving mean

FIG 3-2



-foot moving mean.

Fig 3-3

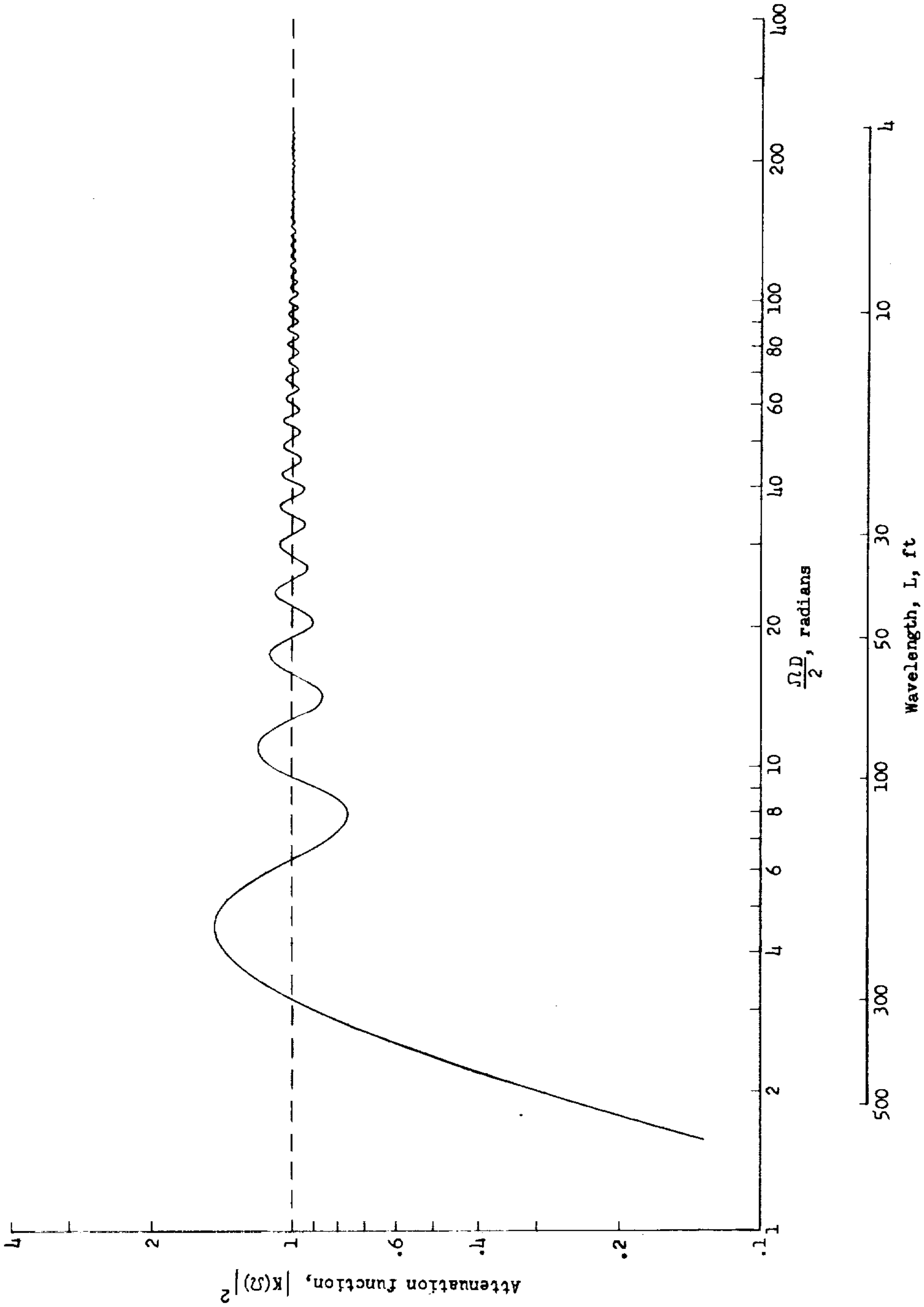


Figure 4.- Moving average attenuation function, $|K(\Omega)|^2 = \left(1 - \frac{\sin \frac{\Omega D}{2}}{\frac{\Omega D}{2}}\right)^2$.

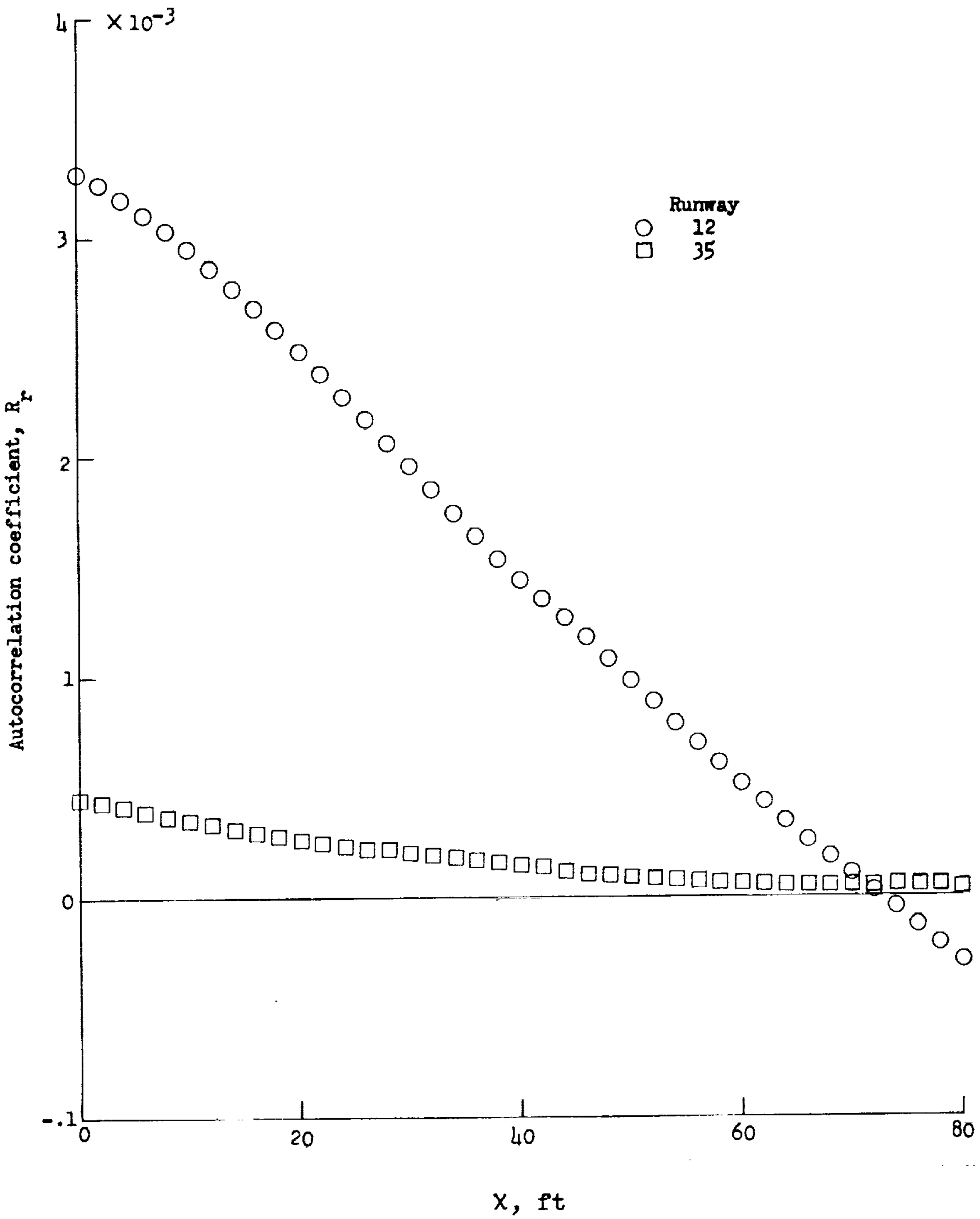


Figure 5.- Autocorrelation coefficients for runway height. $X = r\,\Delta x$.

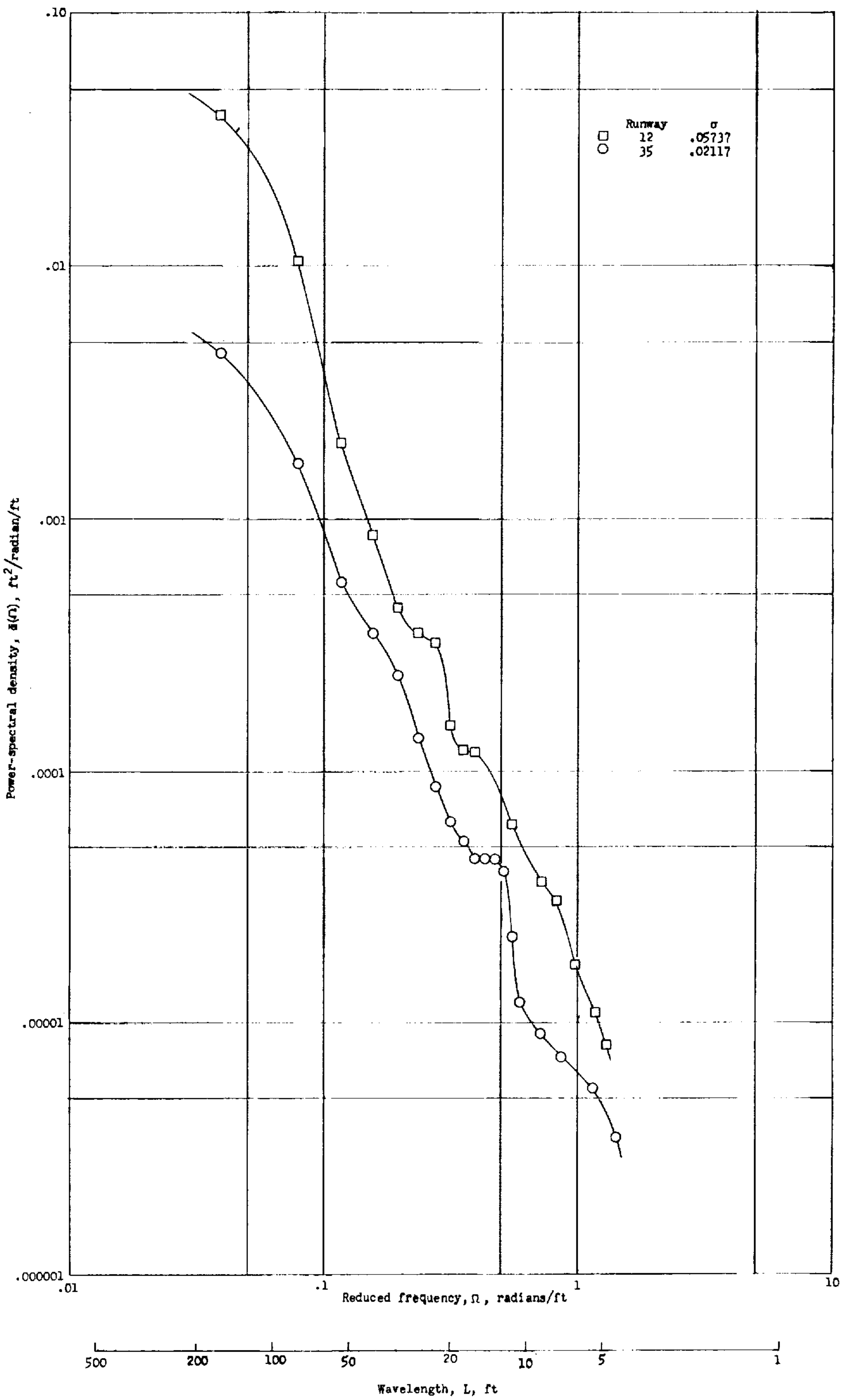


Figure 6.- Power-spectral density functions for the two runways.

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