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INFLUENCE OF DATA TYPE AND RATE ON SHORT ARC LUNAR ORBIT DETERMINATION

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TRW Systems

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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I

CONTENTS

ILLUSTRATIONS (Concluded)

ILLUSTRATIONS

TABLES

1. SUMMARY

This task provides an error analysis, a presentation of its findings, and a method which enables one to select optimum rates for taking counted doppler rate data and range data for a particular short arc of tracking a lunar satellite from the earth. The user of these results must have available the following information for the data taking instruments (of the DSN) and for the computation of residuals in the ODP-L:

- The relationship between counted doppler standard deviations (including all instrument, correlation, and software effects) and the doppler count interval.
- The effective range residual standard deviation, presently estimated to be 15 meters. Results are also presented for standard deviations of 10 and 5 meters.

The approximations and assumptions which were made to obtain the error analysis on TRW software are straightforward and fully discussed below. The measure used for the error is thoroughly explained. Results are presented in tables and in contour plots for use as working tools.

2. INTRODUCTION

2.1 Problem Description

This report describes an error analysis undertaken to determine the effect data sampling rates have on the determination of the Cartesian elements of the lunar orbiter for very short arcs of data. The problem arises in practice because on some trajectories the lunar orbiter goes behind the lunar disk within 15 to 20 minutes following injection. In simple cases, the problem is trivial; that is, for uncorrelated noise on separate observations the sample rate should be increased to the practical limit. However, in the present case the problem has many complicating factors; the following are pertinent:

- The data available is nondestructive counted doppler, which has a correlation of -0.5 between consecutive samples.
- The effective standard deviation for a given sample is dependent on the sample rate, and hence the data weighting in a differential correction process depends on the sample rate.
- The data weighting in differential correction derives in part from sources different from the data taking process.
- The nondestructive, counted doppler data is simulated in the TRW program by instantaneous range-rate data.
- Two data types, counted doppler and range, with differing weights must be considered.
- The source of the range data may be either integrated doppler or time delay measurement.
- There is no single variable "index of merit" which characterizes the adequacy of the determination of the Cartesian elements, and depending on the index selected, the conclusions differ.

2.2 Assumptions and Method

The error analysis was accomplished by making certain simplifying assumptions and by proceeding with a parametric analysis. The following assumptions apply:

- The correlation between consecutive samples was ignored. It has been shown (1) that ignoring this correlation is conservative.
- The results are presented in a format which permits the user to plot any data sample rate vs. standard deviation curve directly on the results charts and obtain from them an optimum operating point for those parameters for which the chart is prepared.
- The conversion from error in the counted doppler measurement to error in range-rate was assumed to be a multiplication by a constant.
- The basic results are plotted on (log-log) charts with the orthogonal axes labeled "Range-rate sample interval" and "Range-rate standard error." A separate chart is prepared for each of ten (10) Range and Range standard error combinations. The combinations are:

1. No range data
2. Two range data points $\sigma_R = 15m$
3. Two range data points $\sigma_R = 10m$
4. Two range data points $\sigma_R = 5m$
5. Three range data points $\sigma_R = 15m$
6. Three range data points $\sigma_R = 10m$
7. Three range data points $\sigma_R = 5m$
8. Four range data points $\sigma_R = 15m$
9. Four range data points $\sigma_R = 10m$
10. Four range data points $\sigma_R = 5m$

- It is assumed that the range data is not correlated with the counted doppler data.

2.3 Parametric Presentation and Error Measure

- The parametric presentation of a different chart for each of several range sample intervals and range standard deviations permits the charts to be used to develop that unique operating point along the "range sample interval" vs "range standard deviation" curve which finally optimizes the tracking situation. Two parameters have been selected as characteristic of the achieved tracking accuracy. They are:

  1) The square root of the maximum eigenvalue of the position partition (upper left 3 x 3) of the state covariance matrix, and

  2) The square root of the maximum eigenvalue of the velocity partition (lower right 3 x 3) of the state covariance matrix.

- These parameters each neglect the covariance between the determination of position alone and determination velocity alone. They further neglect the relation between mission objectives or other essential mission parameters, and the determination of position and velocity at epoch. They are not dependent on the direction of the axes of measurement and they are independent of the coordinate system used for integration.

- The orientation of the eigenvectors changes slightly across the range of the parameters, but the maximum eigenvalue is well behaved and varies sensibly and systematically over the range under study.

3. TRAJECTORY MODEL

The trajectory selected for the sample data rate analysis is described as follows:

1) The reference epoch is $17^h0^m0.6^s$ from Greenwich midnight 8/17/66.

2) The state vector at epoch in mean 1950.0 selenocentric, earth equatorial, vernal equinox coordinates was:

$x = 2324.1447$ km $\qquad \dot{x} = -0.579662222$ km/sec

$x = 90.669095$ km $\qquad \dot{y} = 1.3494068$ km/sec

$z = 616.74111$ km $\qquad \dot{z} = 0.37914168$ km/sec

3) The force model was a lunar Goudas II with mass point perturbations of the Sun, Earth, Venus, Mars, Jupiter and Saturn. The gravitational potential constants of the Goudas II model are:

$C_{20} = -2.0408\text{x}10^{-4}$ $\qquad S_{31} = 0.21\text{x}10^{-4}$

$C_{22} = 0.230\text{x}10^{-4}$ $\qquad S_{33} = 0.018\text{x}10^{-4}$

$C_{30} = 0.98\text{x}10^{-4}$ $\qquad S_{41} = 0.54\text{x}10^{-4}$

$C_{40} = 0.48\text{x}10^{-4}$ $\qquad S_{43} = 0.032\text{x}10^{-4}$

$C_{42} = 0.14\text{x}10^{-4}$

$C_{44} = 0.017\text{x}10^{-4}$

Data was taken during the first 16 minutes following epoch. The sensing instruments are located at the DSIF stations in Goldstone and Madrid.

4. STATISTICAL METHOD

4.1 Tracking Accuracy Normal Matrix

The basic information required for the analysis is the tracking accuracy normal matrix (= J matrix at JPL $J = A^T A$ matrix at TRW) which is dependent on the following factors:

- Trajectory
- Data rate
- Data type
- Data weight(s)

This matrix is developed by accumulating at each observation $(0b_i)$ the outer product square matrix of the row vector of weighted partial derivatives

$$w_i \partial(0b_i)/\partial(x_n)$$

where x_n is an element of the state (solution) vector at epoch. The weight applied to an observation is in the JPL program a function of the observing circumstances, the type of observation, and the trajectory integration method. In the TRW program, this weight is a constant for a given observation type. The justification for using the tracking accuracy normal matrix in the calculation of the differential correction, and for using its inverse as a measure of the covariance of the corrections, depends on a linear theory applying in the neighborhood of the starting estimate of the state vector. With this approximation, the weights for the given observation types may be scaled as required to obtain different tracking accuracy normal matrices. This is convenient to use in the TRW program when only one data type is present in a data set. The tracking accuracy normal matrix is accumulated for one data type for one of the applicable weights at the parameter sample rate. The similar matrix for a different weight can be obtained for the same sample rate by scaling the matrix by the ratio of the squares of the different weights. The tracking accuracy normal matrix for the combined range and range-rate data is obtained by adding the appropriate separate tracking accuracy normal matrices. The algebra is as follows:

The weights are the reciprocal standard errors for each parametric error considered

$$w_i = 1/\sigma_{\dot{R}_i}$$

$$\sigma_{\dot{R}_1} = 5 \times 10^{-4} \text{ m/sec}$$

$$\sigma_{\dot{R}_2} = 45 \times 10^{-4}$$

$$\sigma_{\dot{R}_3} = 80 \times 10^{-4}$$

$$\sigma_{\dot{R}_4} = 120 \times 10^{-4}$$

$$v_j = 1/\sigma_{R_j}$$

$$\sigma_{R_1} = 5\text{m}$$

$$\sigma_{R_2} = 10$$

$$\sigma_{R_3} = 20$$

The normal matrices are accumulated for different data rates.

For range-rate data

$$A_k = \sum_n (w_1 \partial\dot{R}_i/\partial x_n)^T (w_1 \partial\dot{R}_i/\partial X_n)$$

for observations at rate k

A_1 at 1 sample per 0.1 minute

A_2 at 1 sample per 0.5 minute

A_3 at 1 sample per 1.0 minute

A_4 at 1 sample per 1.5 minutes

For range data

$$B_\ell = \sum_n (v_1 \partial R_i/\partial x_n)^T (v_1 \partial R_i/\partial x_n)$$

for observations at rate ℓ

B_1 at 1 sample per 5 minutes (at times 1, 6, 11, and 16 minutes = 4 points)

B_2 at 1 sample per 8 minutes (at times 0, 8, and 16 = 3 points)

B_3 at 1 sample per 15 minutes (at times 1 and 16 minutes = 2 ponts)

The combined tracking accuracy normal matrix is then given by

$$J_{ijk\ell} = \left(\frac{w_i}{w_1}\right)^2 A_k + \left(\frac{v_i}{v_1}\right)^2 B|_\ell$$

The respective covariance matrix is given by $J^{-1}_{ijk\ell}$.

4.2 Interpretation of Covariance Matrix

The covariance matrix consists of 36 elements, being the variances and covariances of the six state elements x, y, z, $\dot{x}$, $\dot{y}$, $\dot{z}$ in the mean earth equator of 1950.0 coordinate system. The covariance matrix is partitioned into the position half and the velocity half. The upper-left 3 x 3 is treated as a self-contained matrix describing the position uncertainty and similarly the lower-right 3 x 3 is for velocity uncertainty. The interpretation of this partitioning is that the resulting two sets of probabilities are the marginal distributions of the original 6 dimensional probability space in the position sub-space and the velocity sub-space. They are not the conditional distributions of position (knowing velocity) and of velocity (knowing position).

The 3 x 3 covariance matrices are difficult to visualize, their interpretation is a 3 dimensional "one-sigma," error ellipsoid whose shape is determined from the covariances. The longest semi axis of this error ellipsoid is the square root of the maximum eigenvalue.(2) The square root of the eigenvalue is in units of position (meters) and velocity (meters/sec) error. The interpretation of the 3 dimensional one sigma, error ellipsoid when taken alone is that, all other noise statistics being normally distributed, approximately 25 percent of the time the actual error will fall within the ellipsoid.(3) In the cases under study the error ellipsoids are shaped like elongated very thin oval wafers.

Typical ratios for the three root-eigen values are 1 :0.35 :0.01. Thus the maximum eigen value is a reasonable single parameter measure of the separate position and velocity error. Because of the shape of the ellipsoids, the probability that a measurement will fall within this distance of the actual point is very close to normally distributed, with standard deviation somewhat greater than the maximum root-eigen value. The three eigen-values were determined with the TRW matrix abstruction program, the largest was selected and square-rooted to obtain the reported values.

5. PRESENTATION OF RESULTS

5.1 Classification of Results

The results are presented in two formats: First the basic tabulation of dependent error versus the four independent parameters; second the two sets of contour plots (one set for position and one for velocity) to be used with the range-rate sample rate versus range-rate standard deviation curves. The contour plots show constant-error contours against the $\dot{R}$ sample interval|($t_{\dot{R}}$) versus standard deviation in $\dot{R}$($\sigma_{\dot{R}}$) axes. A pair of contour charts is provided for each of 10 range and range sample rate combinations. The four independent parameters are summarized below:

$\Delta t_{\dot{R}}$ The length of interval over which doppler cycles are counted, and hence, the frequency of reporting the derived doppler data points. In the TRW program used for this analysis, the counted doppler rate is simulated with a range-rate measurement. The intervals were selected to be 6 seconds, 30 seconds, 60 seconds and 90 seconds.

$\sigma_{\dot{R}}$ The effective standard deviations in the derived doppler data points. These standard deviations are dependent on the counting interval, but the exact nature of this dependence is undetermined. Further, consecutive measurements are correlated with a correlation of -0.5 because of the non-destructive counting process, this is because a bias at the end of one counting interval is immediately compensated for by a bias of opposite sign at the beginning of the following interval. In the TRW program, standard deviations are standard deviations in range rate, and correlation effects are ignored. Standard deviations were selected to be 0.0005 m/sec, 0.045 m/sec, 0.0080 m/sec, and 0.0120 m/sec.

Δt_R	The frequency with which range samples are derived and used. Range data in the JPL system is derived by two methods: (1) Integrating the counted doppler and (2) Measuring the time delay of a modulated signal. The former measurement is correlated with the doppler, and the latter is independent. It is assumed that the latter method is used for the data source. In the TRW program range data is simulated directly. The intervals were selected to be 5 minutes, 8 minutes, 15 minutes, and range data absent.
σ_R	The effective standard deviations in range data. In the TRW program range standard deviations are simulated directly. They were selected to be 5m, 10m, and 15m.

5.2 Use of Contour Plots

The contour plots are for use with a superimposed curve which represents the relation between range-rate sample rate and the obtained effective range-rage standard deviation. This curve is obtained from a complete analysis of the JPL operating procedures (see Figure 20). The counted doppler rate standard deviation versus sample rate curve is converted to the effective range rate versus standard deviation versus sample rate curve by multiplying by a series of conversion factors. These factors can be derived from a detailed analysis of the doppler rate formulation. For the error analysis, the conversion factor was chosen to be the simple constant $c/2\ f_t$. For a more critical, one-time development of this relationship curve, it would be instructive and conservative to consider the higher order effects on this factor.

After the curves are developed and plotted on the contour plots (or plotted on a tracing overlay if this is more convenient) the plots can be examined to obtain the points on the curves where the error is minimum. This error should be interpolated from between the existing contours to obtain a numerical value for the minimum error parameterized by range sample rate. It will be necessary to obtain these minimum errors only from that plot prepared for the achievable range standard deviation (15m).

(It is assumed that range standard deviation is independent from the range sample rate. The set of parametric charts allow for subsequent improvement in the value of the range standard deviation.) When achievable range standard deviation is not the exact value for which a plot was prepared, it can be obtained by interpolating between points of different σ_R charts for the same Δt_R. It will now be possible to plot the curve "minimum error" versus "range sample rate." This curve is valid for all constraints on the instrumentation system any range sample rate on this curve can be achieved and can under the best circumstances provide the error plotted. First it is required to pick the minimum on this curve, and thereby establish the rate at which range data should be taken. Second it is required to return to the plot on which the instrumentation capability is defined and establish the range-rate data rate to use between the range points. If we were fortunate enough to happen on a range data rate equivalent to one for which the prepared charts are given, then the range rate operating point appears at the minimum error.

The foregoing analysis can be developed using either the position error curves or the velocity error curves. It is expected that the result would not differ much from the two sets. However, if it were to differ significantly or irreconcilably, then further investigation would be in order. This failure in method would confirm for the case in hand, that the use of the root eigenvalues of the selected 3 x 3 partitions of the portions and velocity covariance matrix as measures of overall system error was not justified.

As an example, the range rate sample rate vs. effective range rate standard deviation curve of Figure 21 used in conjunction with the error contours for $\sigma_R = 15\,m$ shows that minimum error in both position and velocity occurs for a counting interval $\Delta t_{\dot{R}}$ greater that 1.5 min. This would agree with the intuitive conclusion that lower error occurs at longer intervals. However, for intervals longer than about 3 minutes there is no further decrease in error, as can be noted from the shape of the curve. Comparing the minimum errors for each range sample interval (Δt_R), no conclusion can be reached as to the existence of a definite minimum value with respect to Δt_R.

5.3 Comparison of Sensitivities and Standard Deviations for One and Ten Minute Intervals

Two runs were made with the TRW program. In the first, range data was simulated at 10 minute intervals; in the second, at 1 minute intervals. The solution vector consisted of the state vector, J_2-J_4 and C_{nm}, S_{nm} for n = 2-4, m = 1-3. In addition the effects of J_5-J_7, C_{51}, S_{51} through C_{55}, S_{55}, and C_{61}, S_{61} through C_{63}, S_{63} were considered. Table 4 contains the standard deviation of each solved for variable for both runs. Table 5 compares the sensitivities of the solved for variables to the considered variables for the two runs.

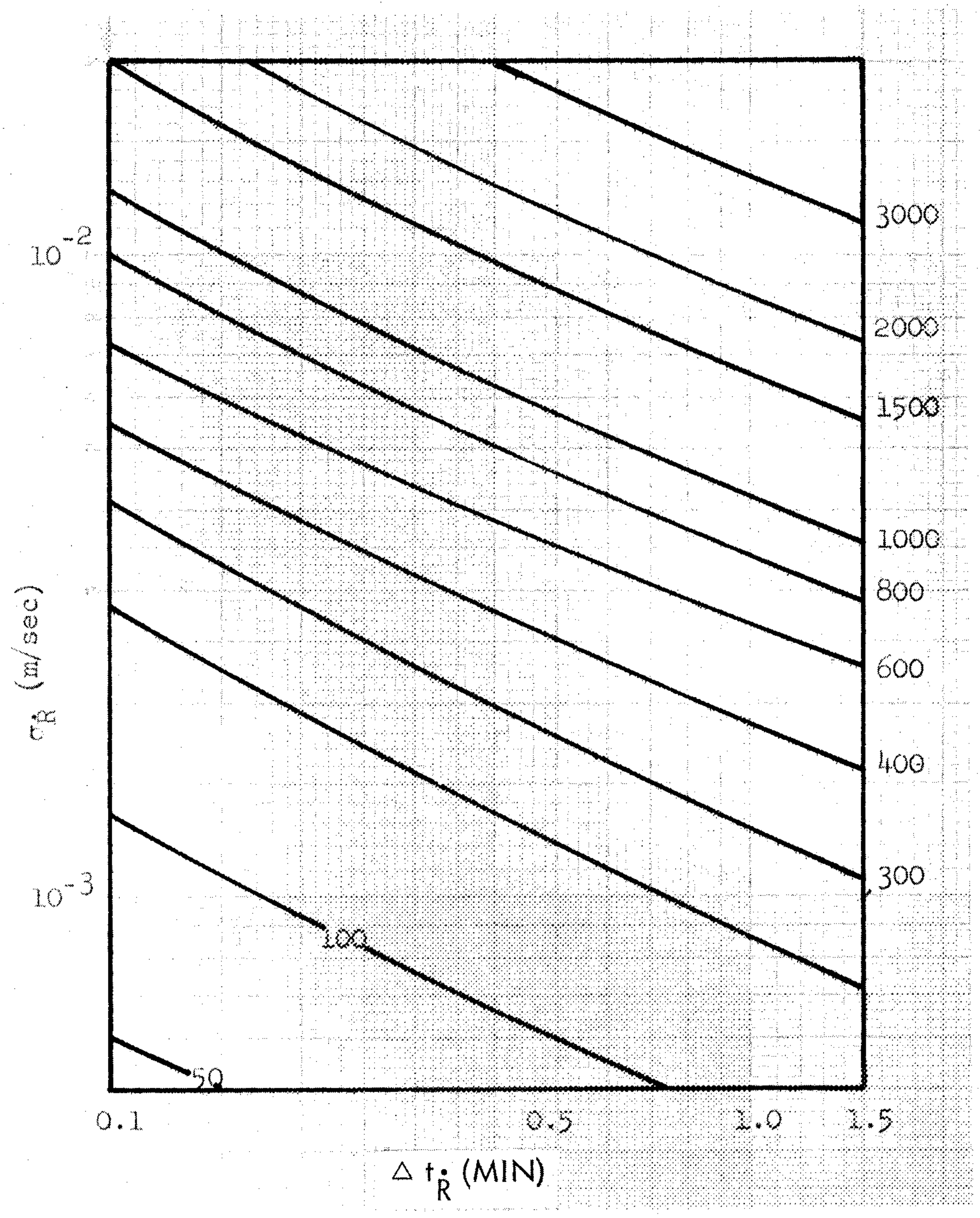


Figure 1. Position Error Contours in Meters No Range Data, $\Delta t_R = \infty$(0 pts)

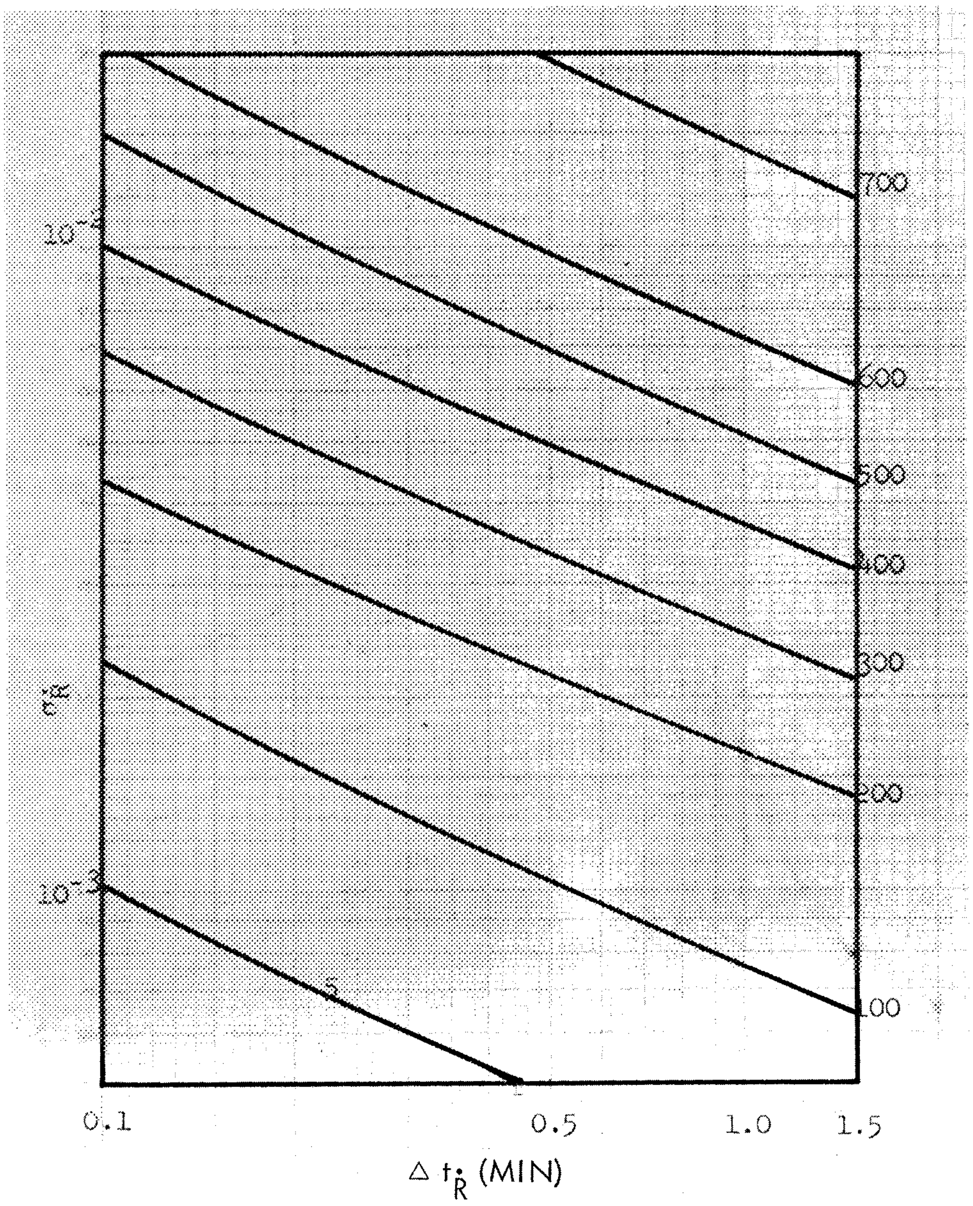


Figure 2. Position Error Contours in Meters for σ_R = 15m, Δt_R = 15 min (2 pts)

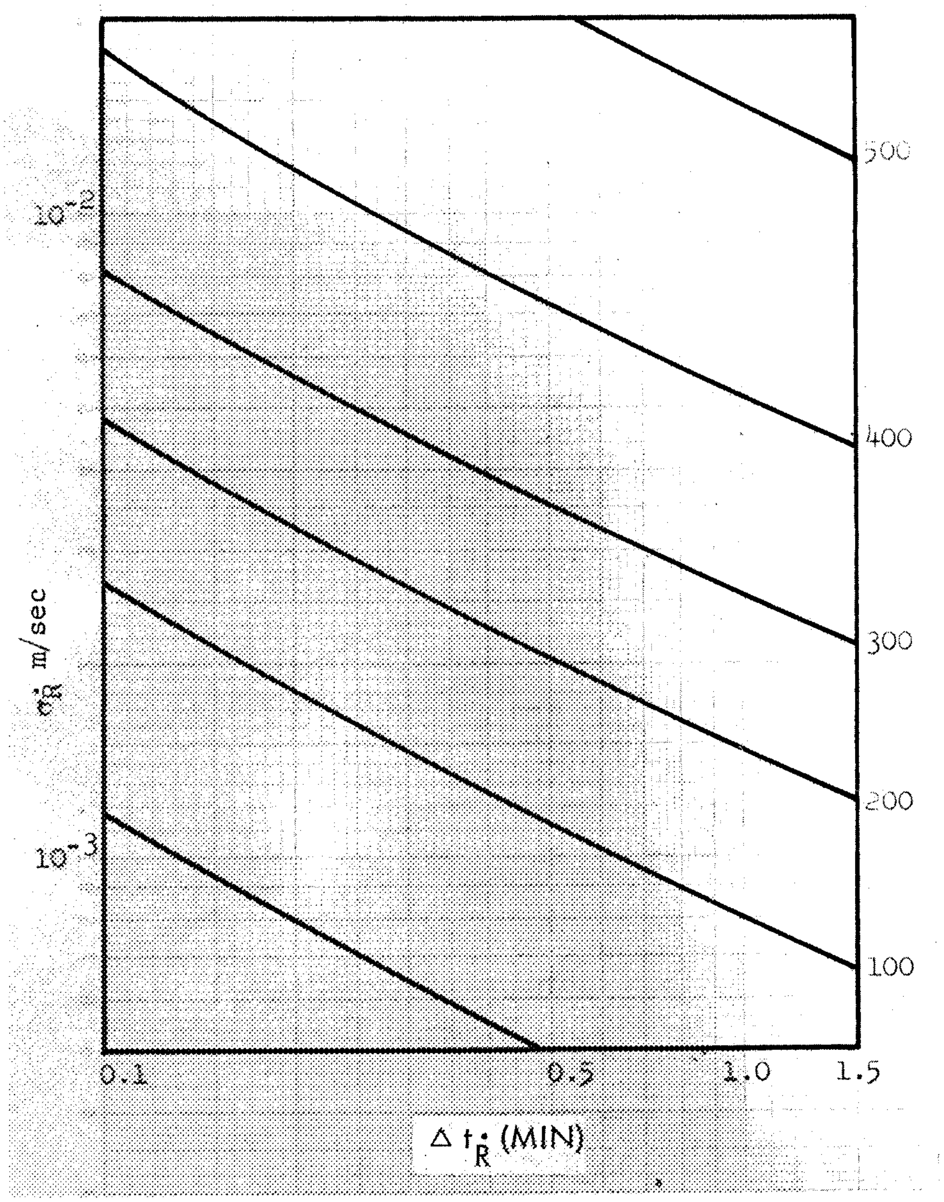


Figure 3. Position Error Contours in Meters for σ_R = 10m, Δt_R = 15 min (2 pts)

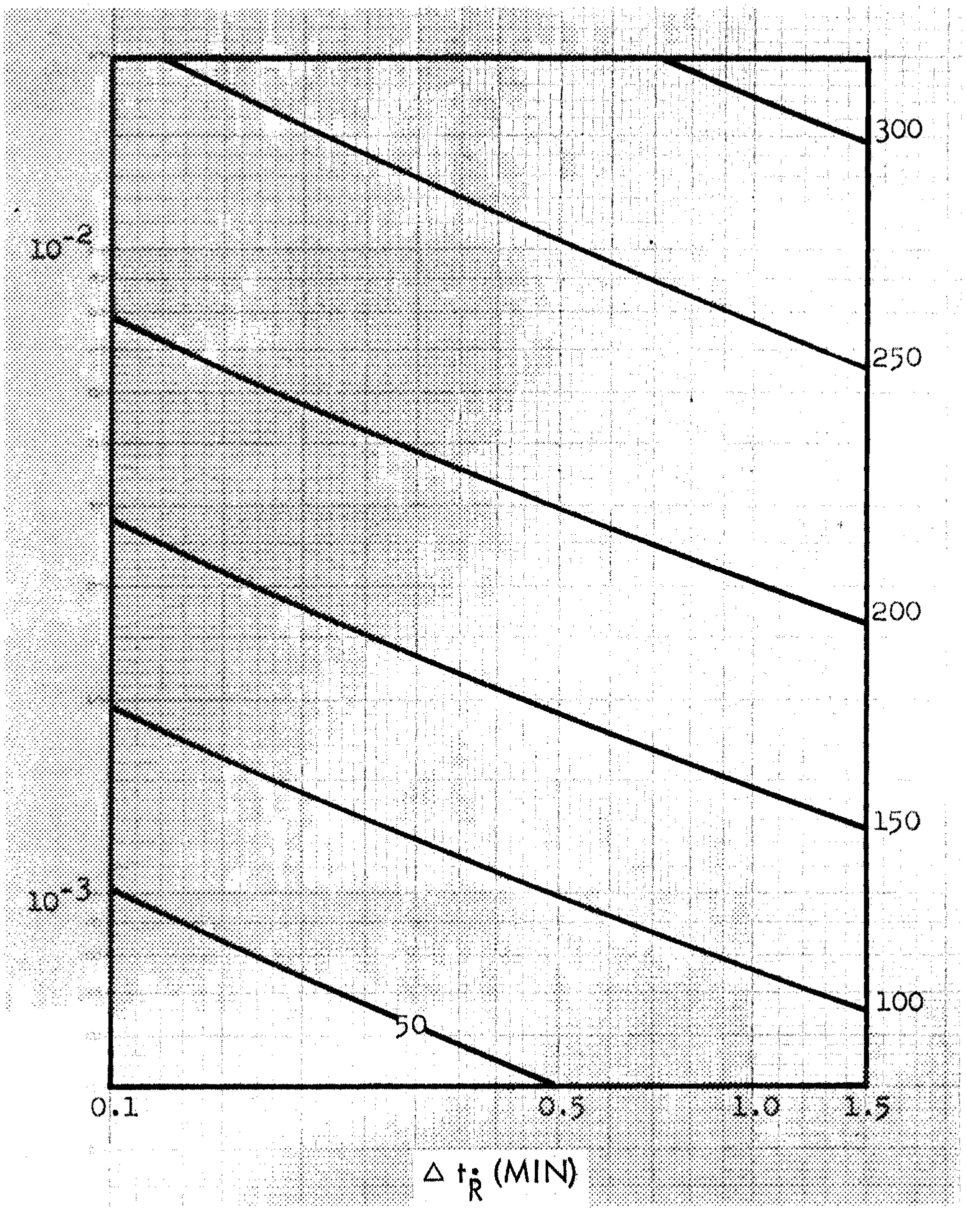


Figure 4. Position Error Contours in Meters for $\sigma_R = 5$ m, $\Delta t_R = 15$ min (2 pts)

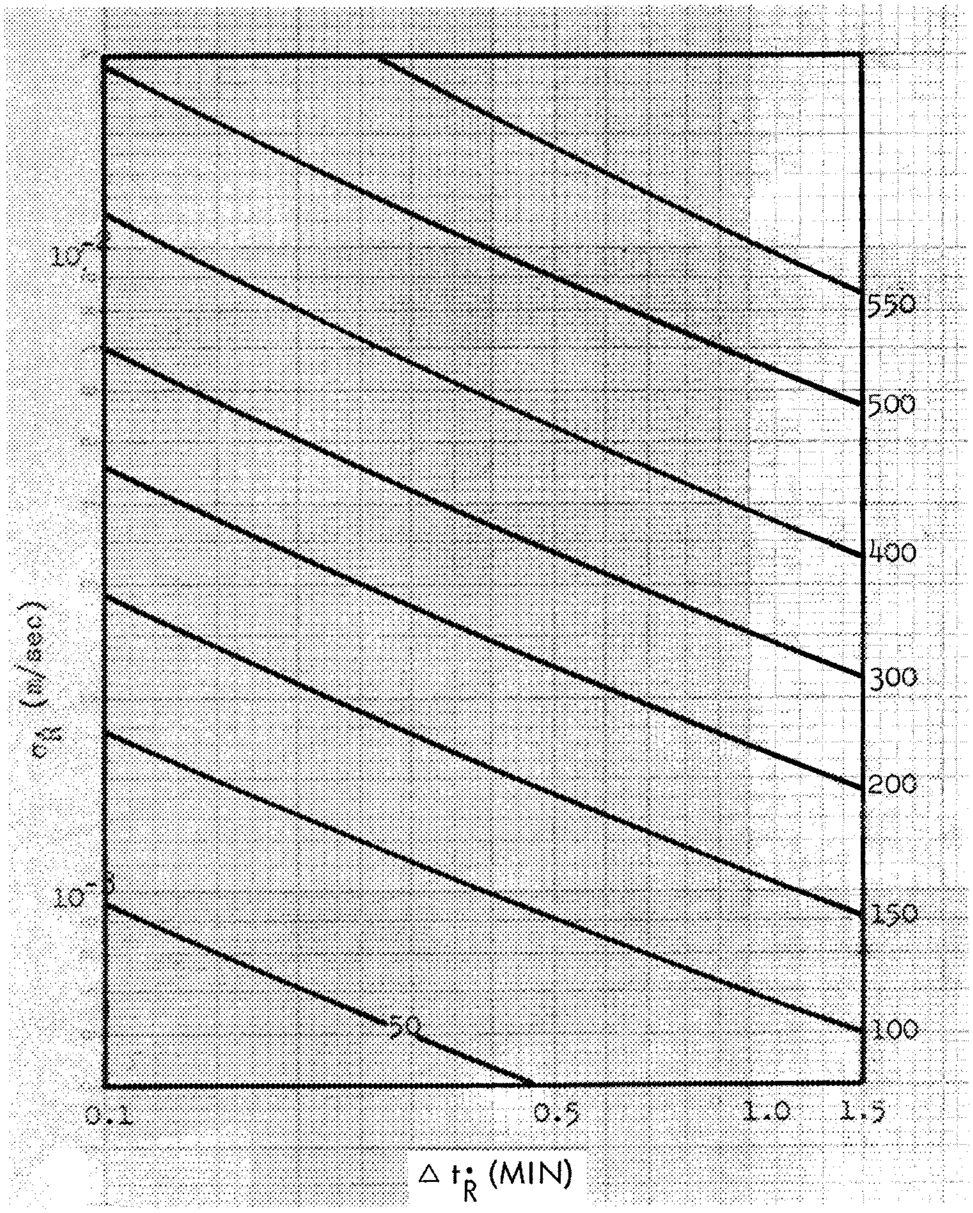


Figure 5. Position Error Contours in Meters for σ_R = 15m, Δt_R = 8 min (3 pts)

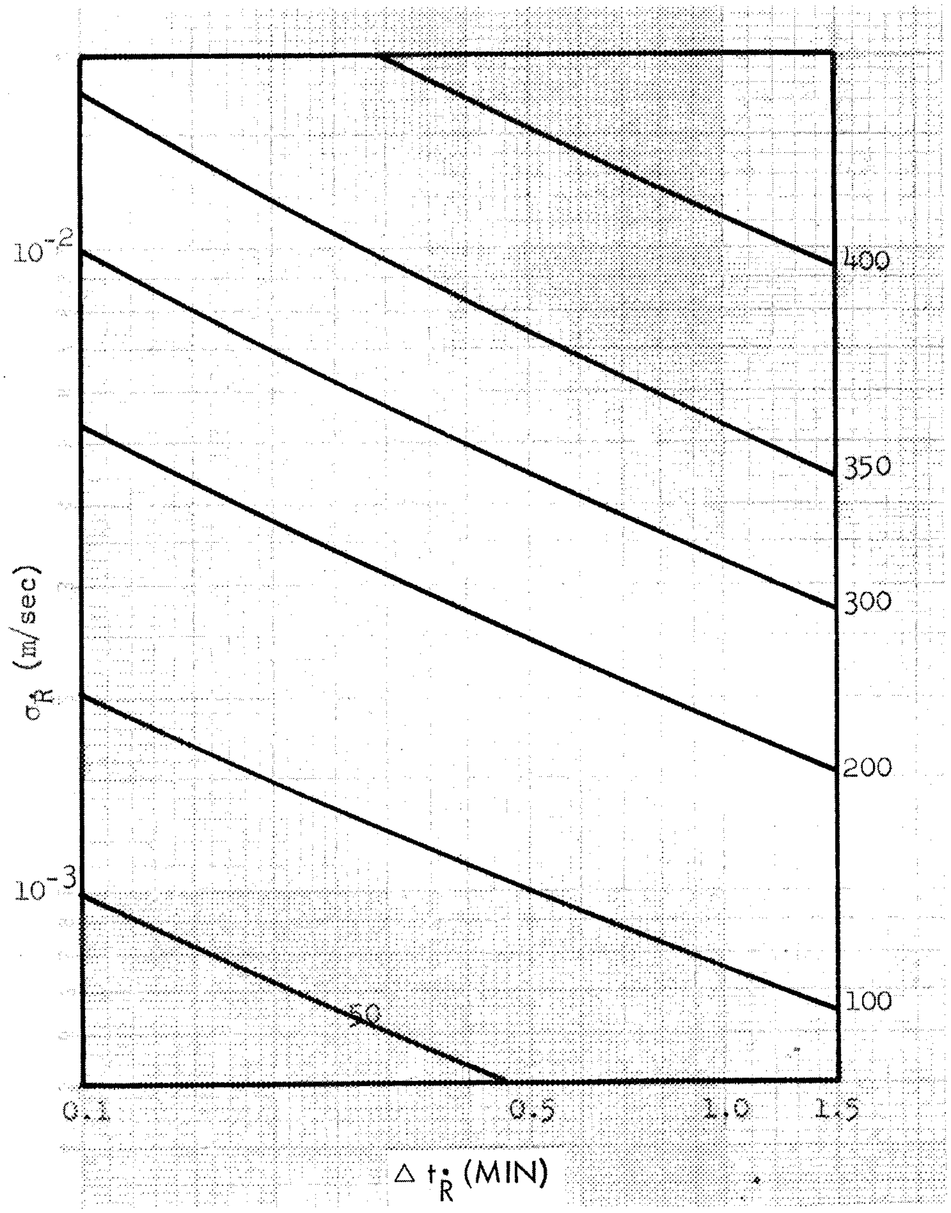


Figure 6. Position Error Contours in Meters for σ_R = 10m, Δt_R = 8 min (3 pts)

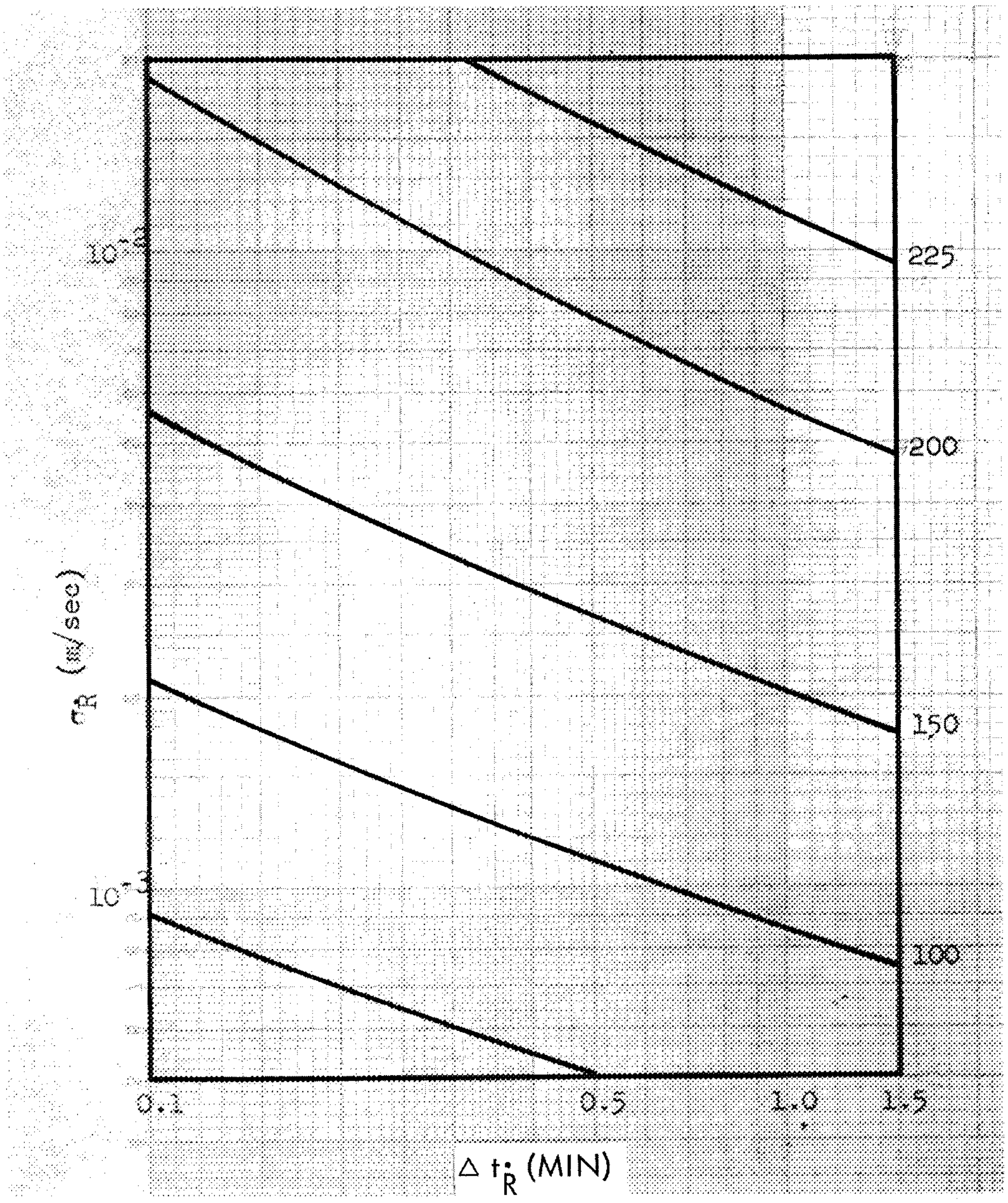


Figure 7. Position Error Contours in Meters for $\sigma_R = 5$ m, $\Delta t_R = 8$ min (3 pts)

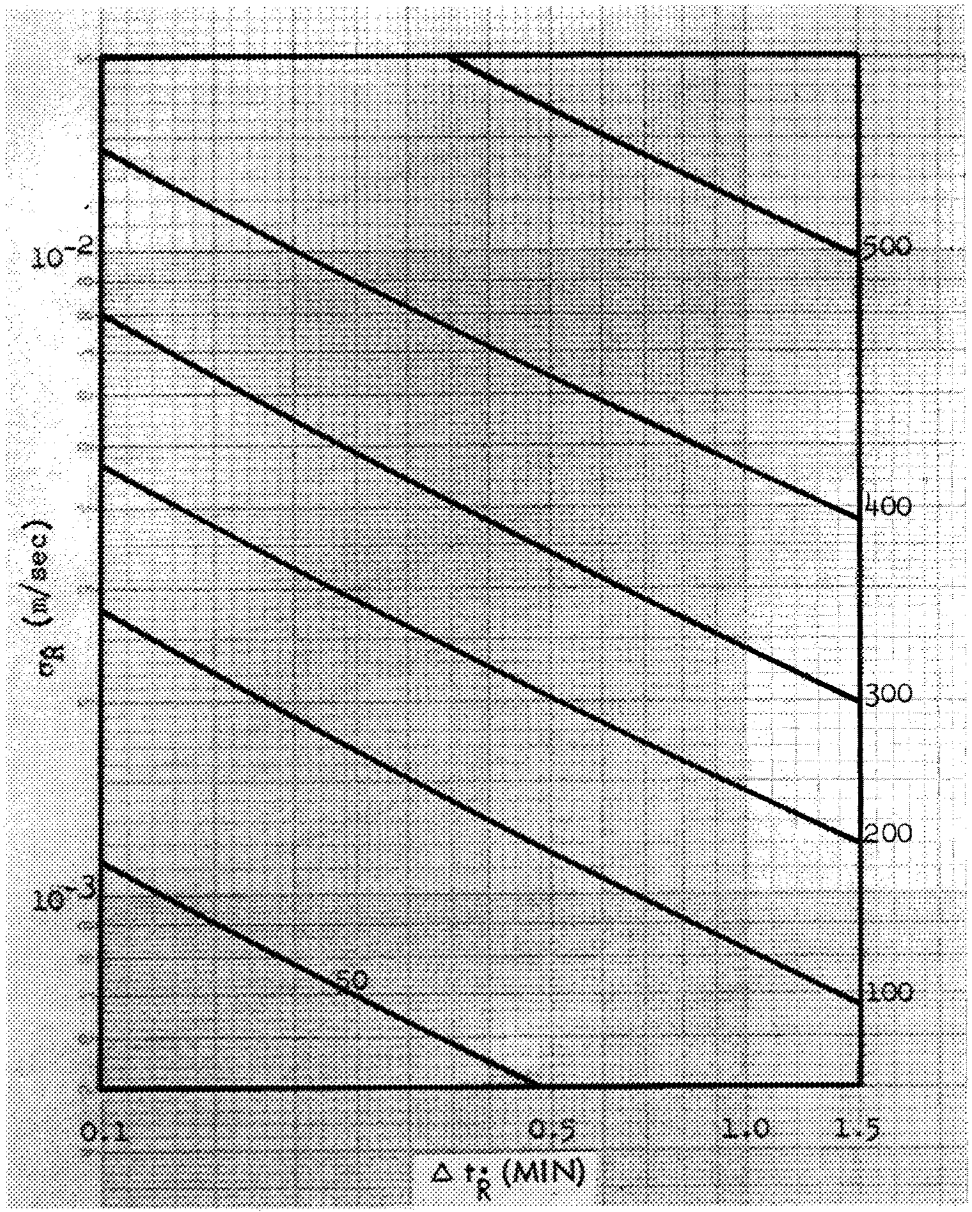


Figure 8. Position Error Contours in Meters for σ_R = 15m, Δt_R = 5 min (4 pts)

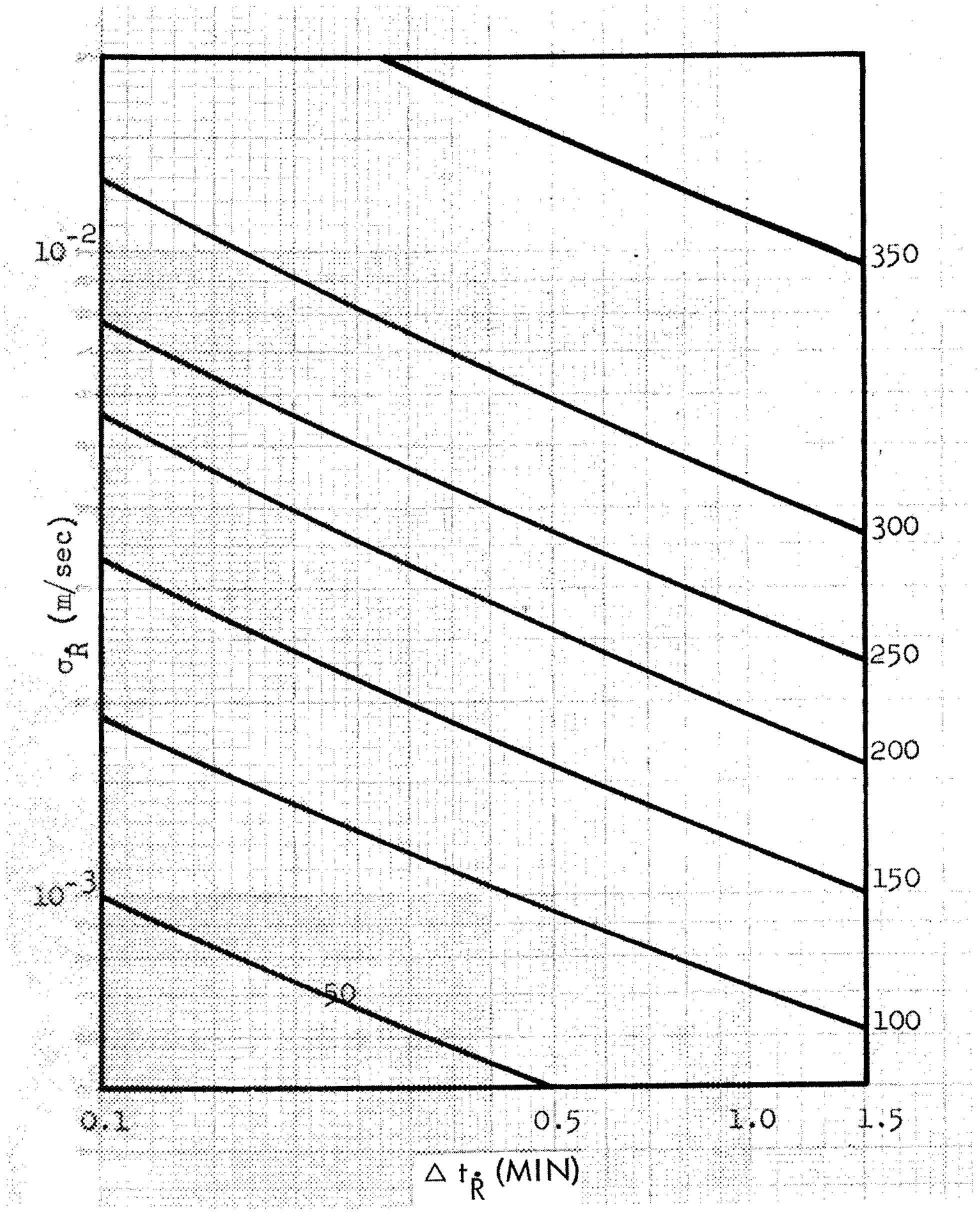


Figure 9. Position Error Contours in Meters for $\sigma_R = 10$m, $\Delta t_R = 5$ min (4 pts)

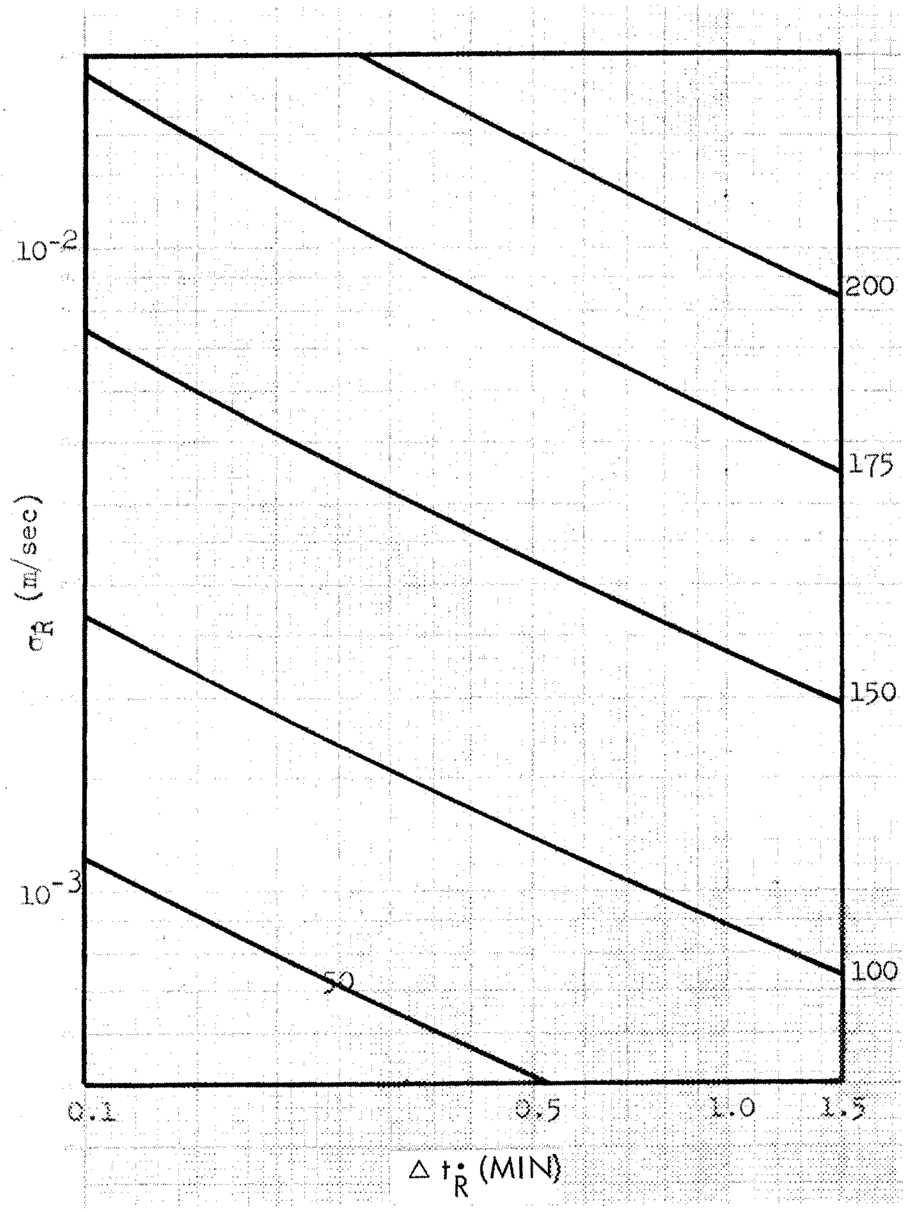


Figure 10. Position Error Contours in Meters for σ_R = 5m, Δt_R = 5 min (4 pts)

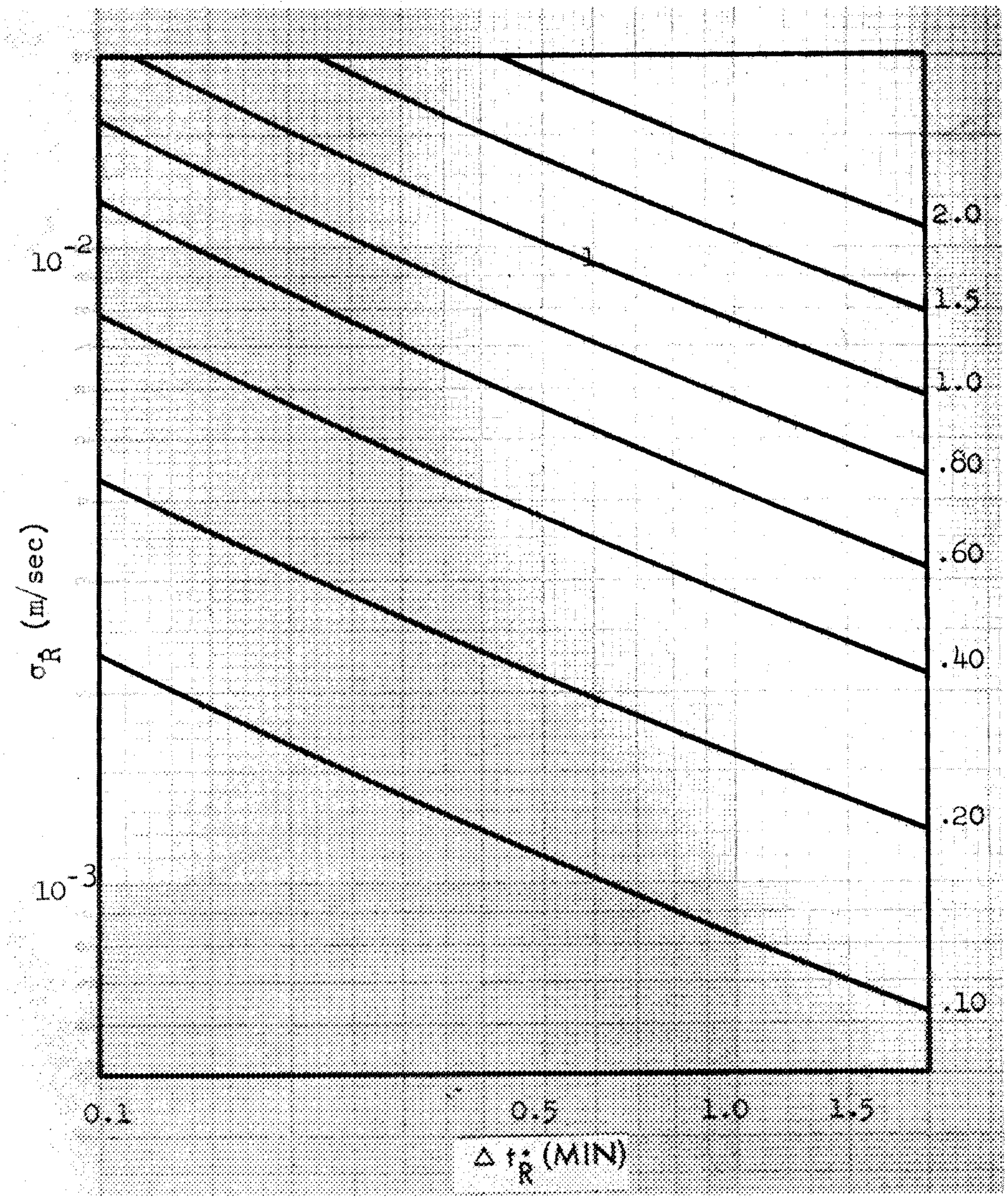


Figure 11. Velocity Error Contours in m/sec No Range Data Δt_R = (0 pts)

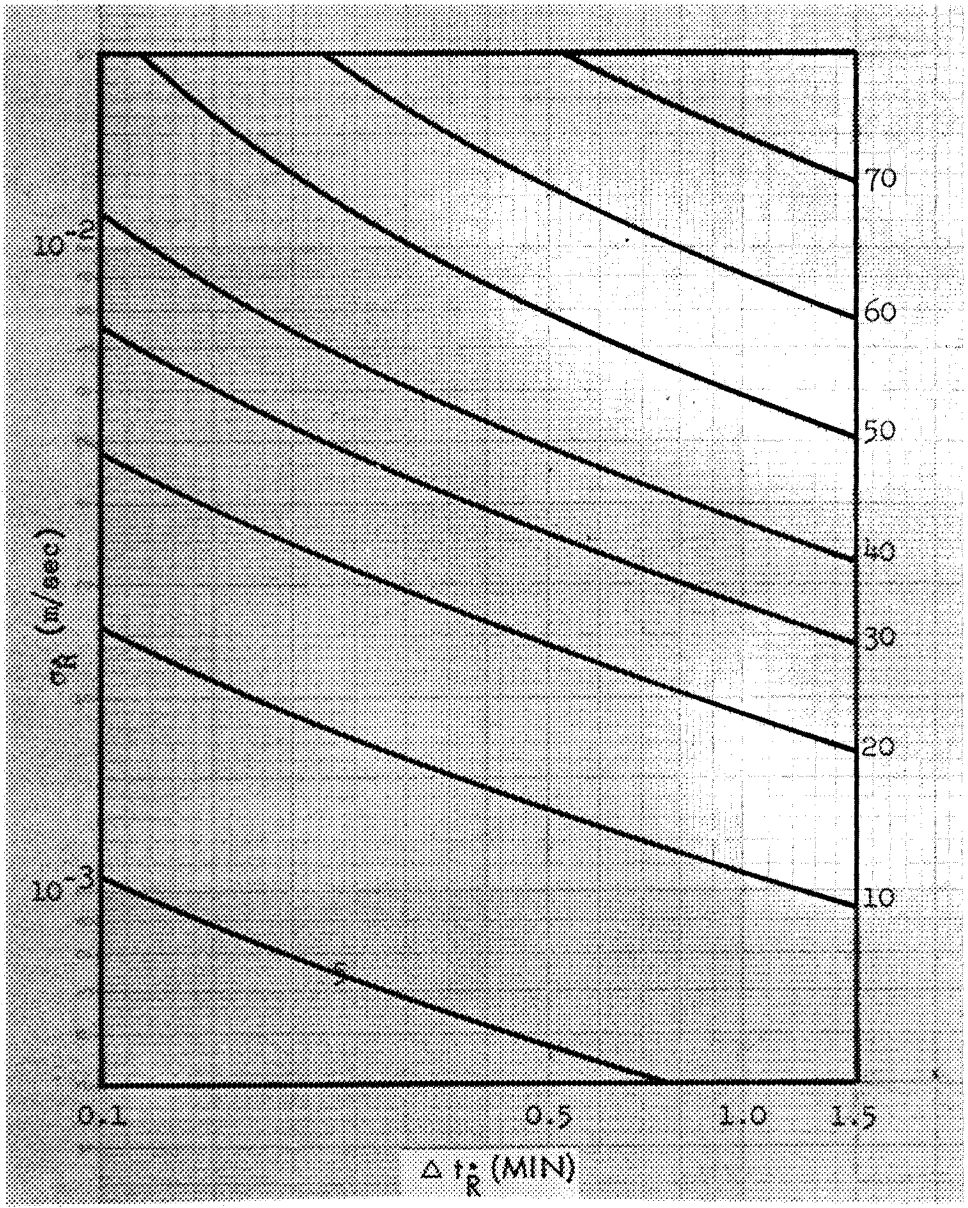


Figure 12. Velocity Error Contours in m/sec σ_R = 15m, Δt_R = 15 min (2 pts)

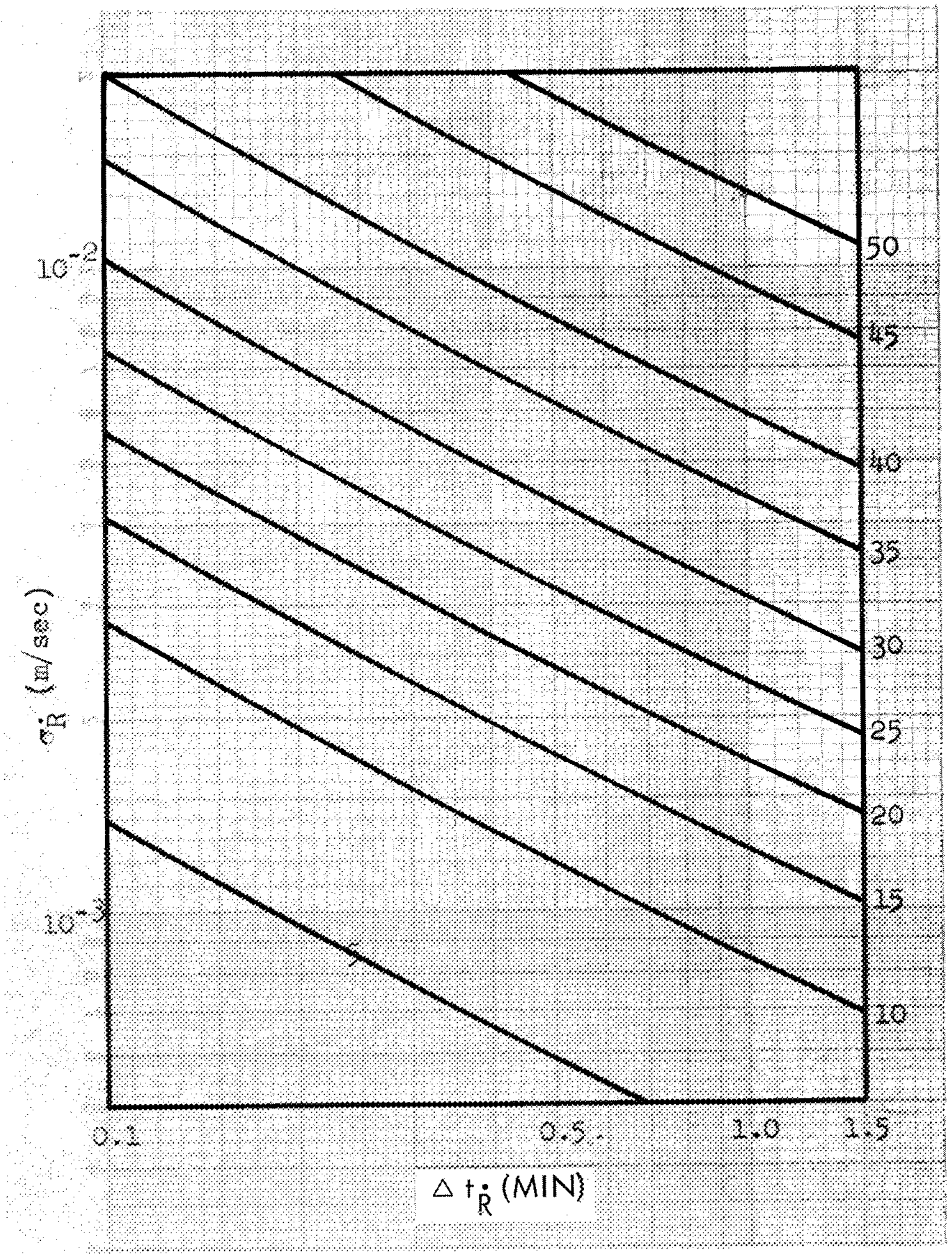


Figure 13. Velocity Error Contours in m/sec σ_R = 10m, Δt_R = 15 min (2 pts)

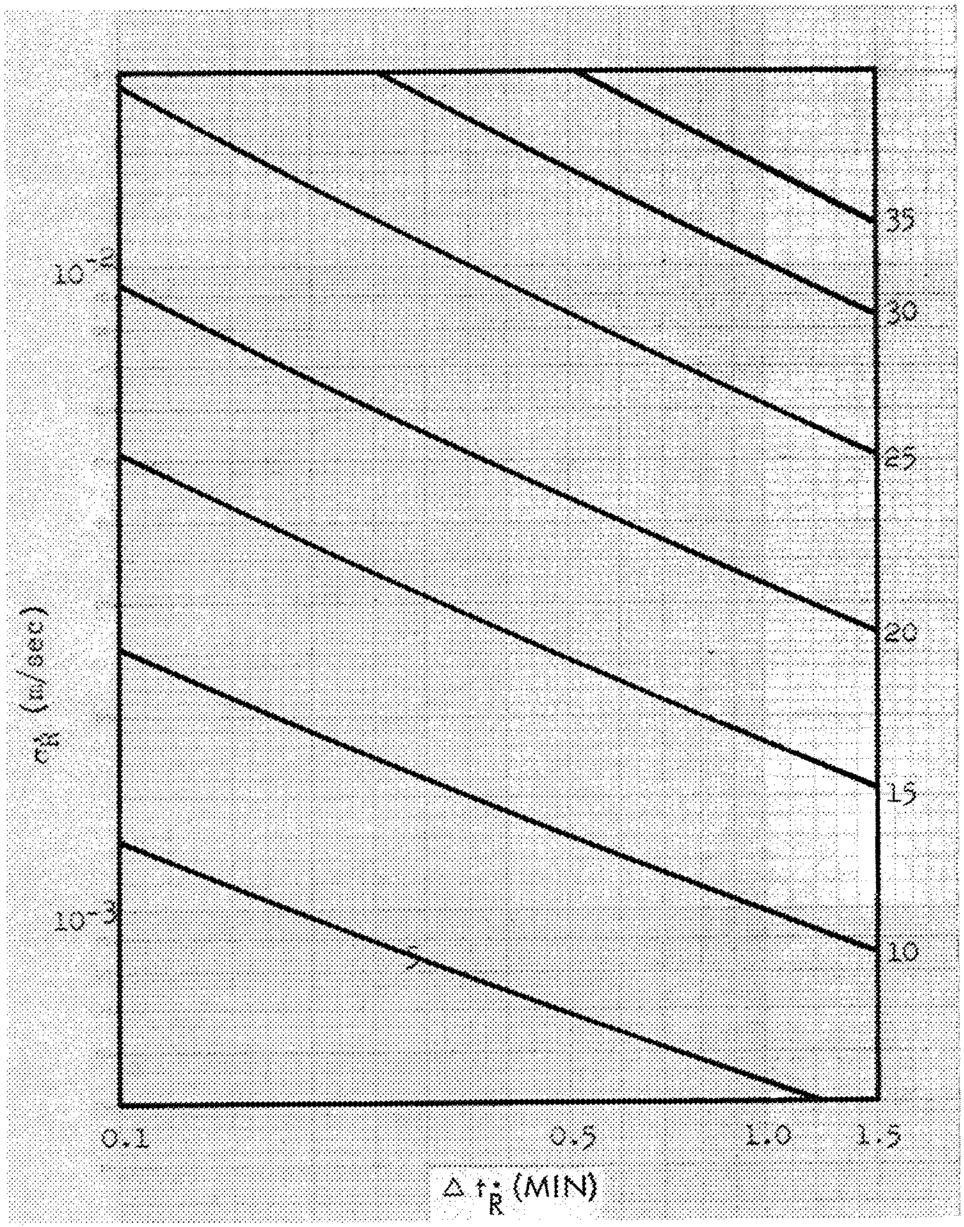


Figure 14. Velocity Error Contours in m/sec $\sigma_R = 5$m, $\Delta t_R = 15$ min (2 pts)

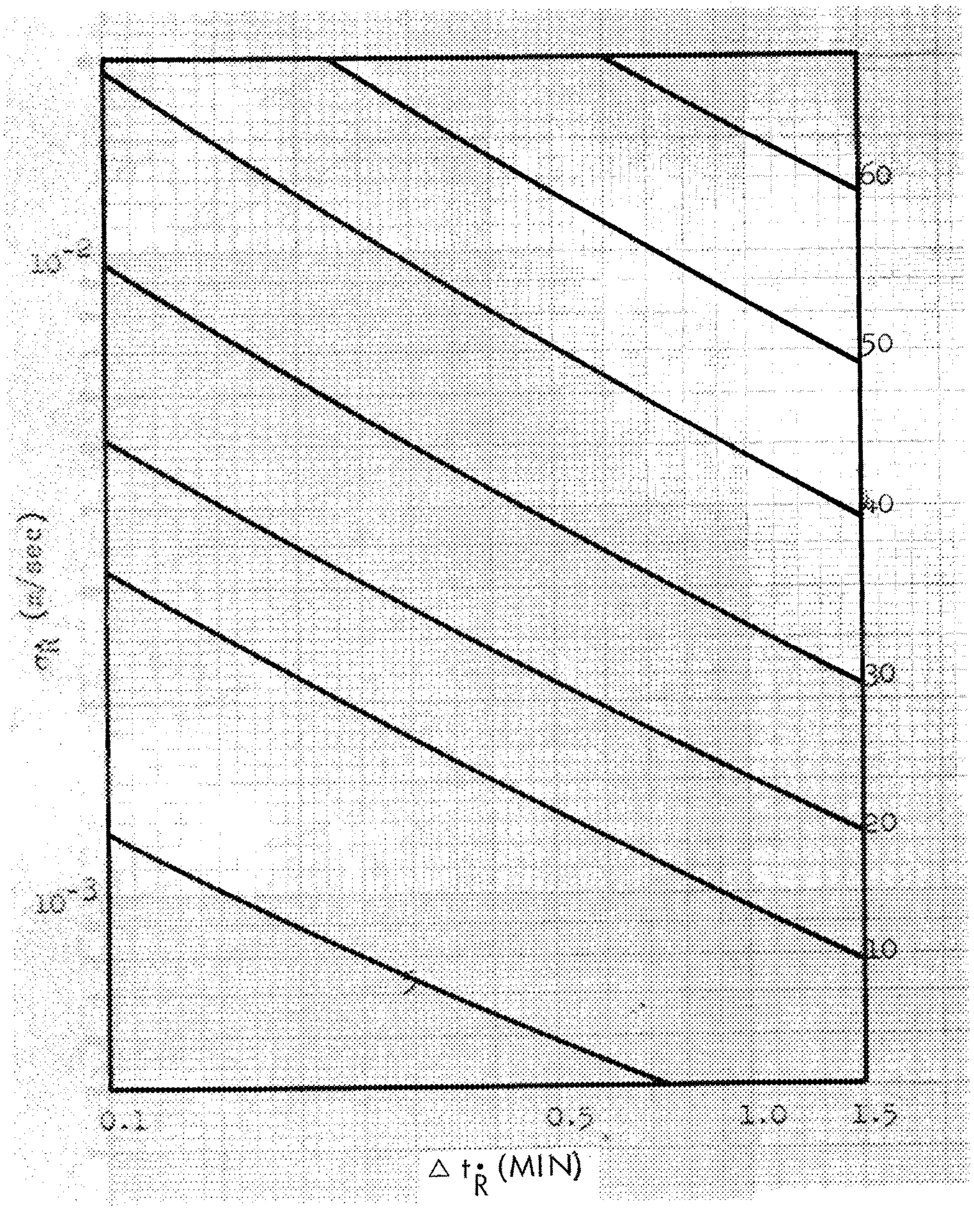


Figure 15. Velocity Error Contours in m/sec σ_R = 15m, Δt_R = 8 min (3 pts)

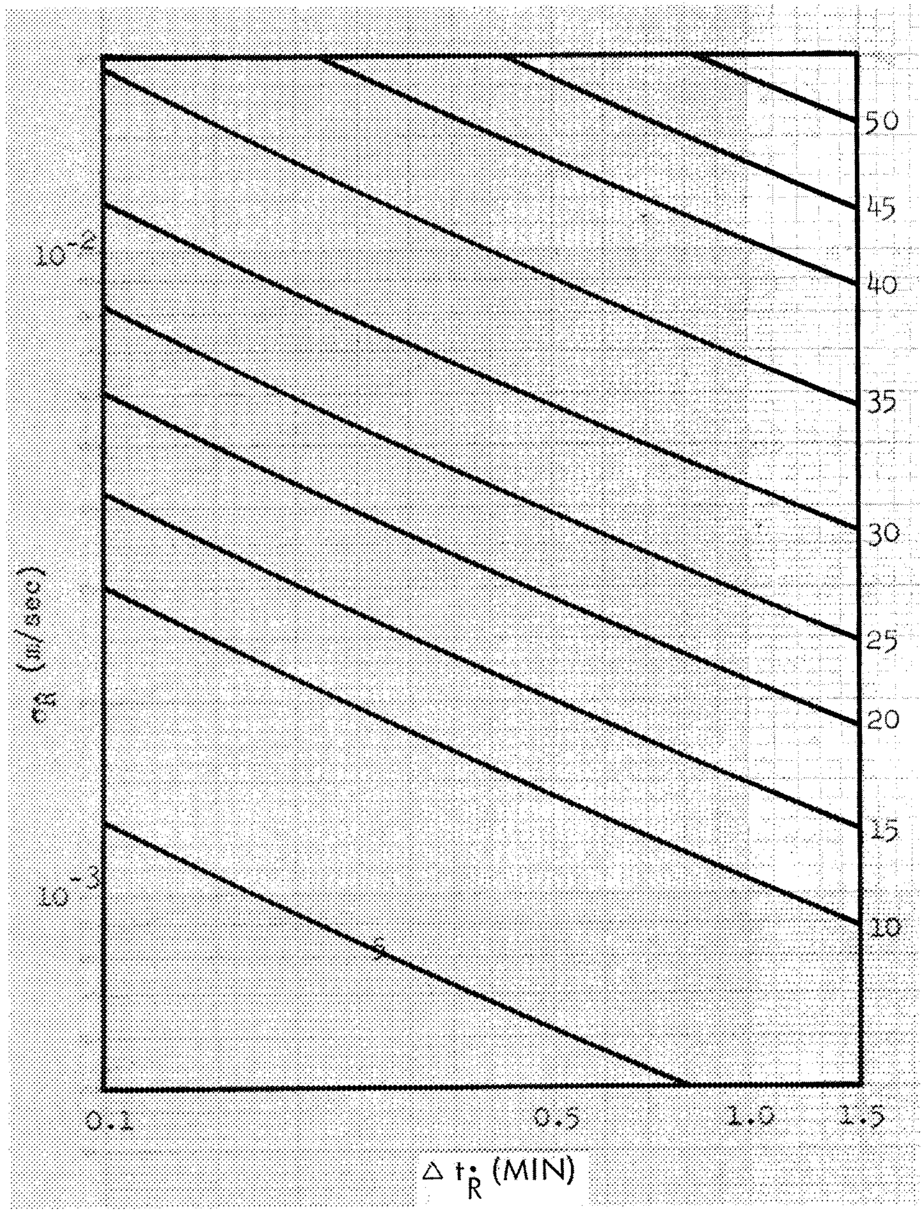


Figure 16. Velocity Error Contours in m/sec $\sigma_R = 10m$, $\Delta t_R = 8$ min (3 pts)

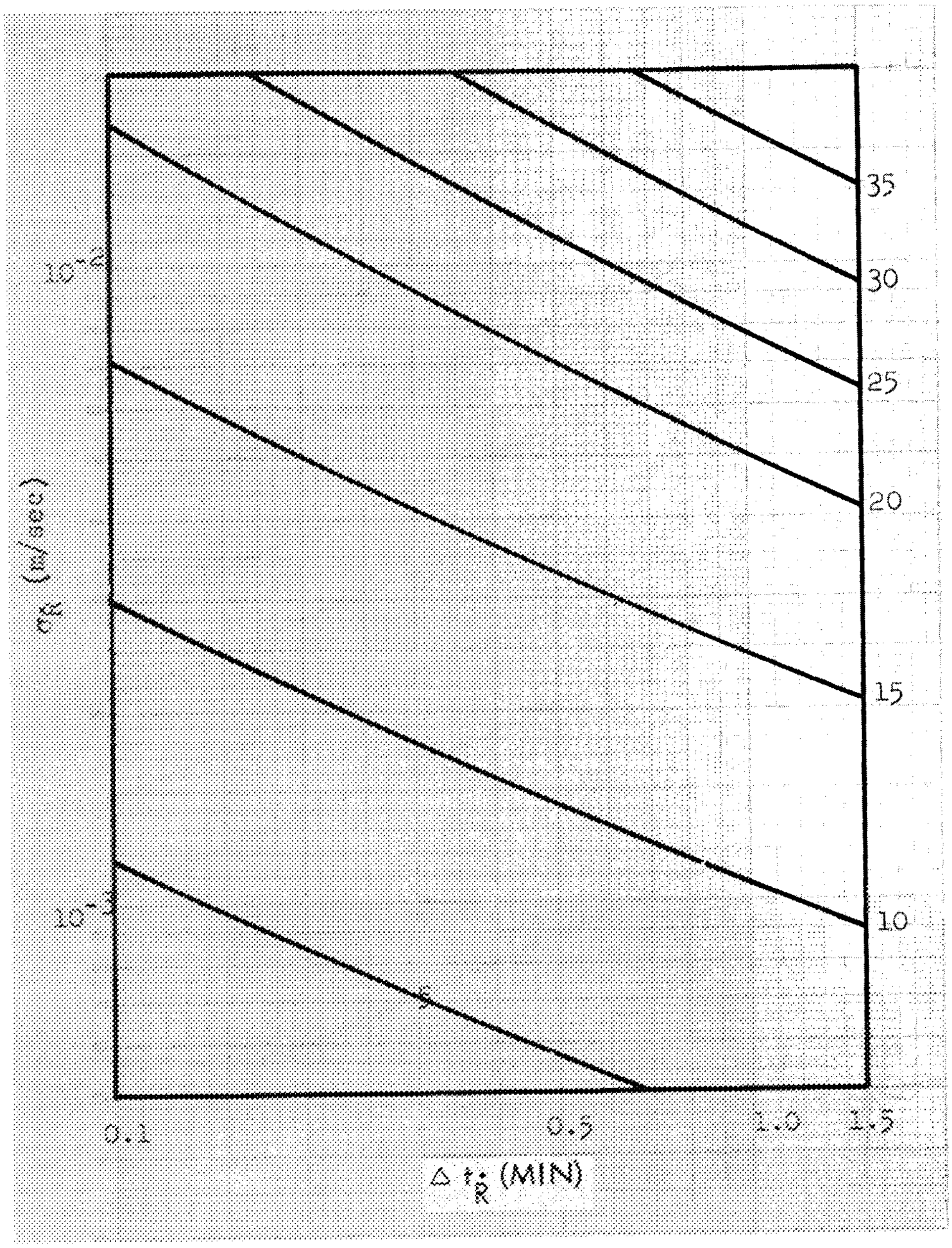


Figure 17. Velocity Error Contours in m/sec $\sigma_R = 5\text{m}$, $\Delta t_R = 8$ min (3 pts)

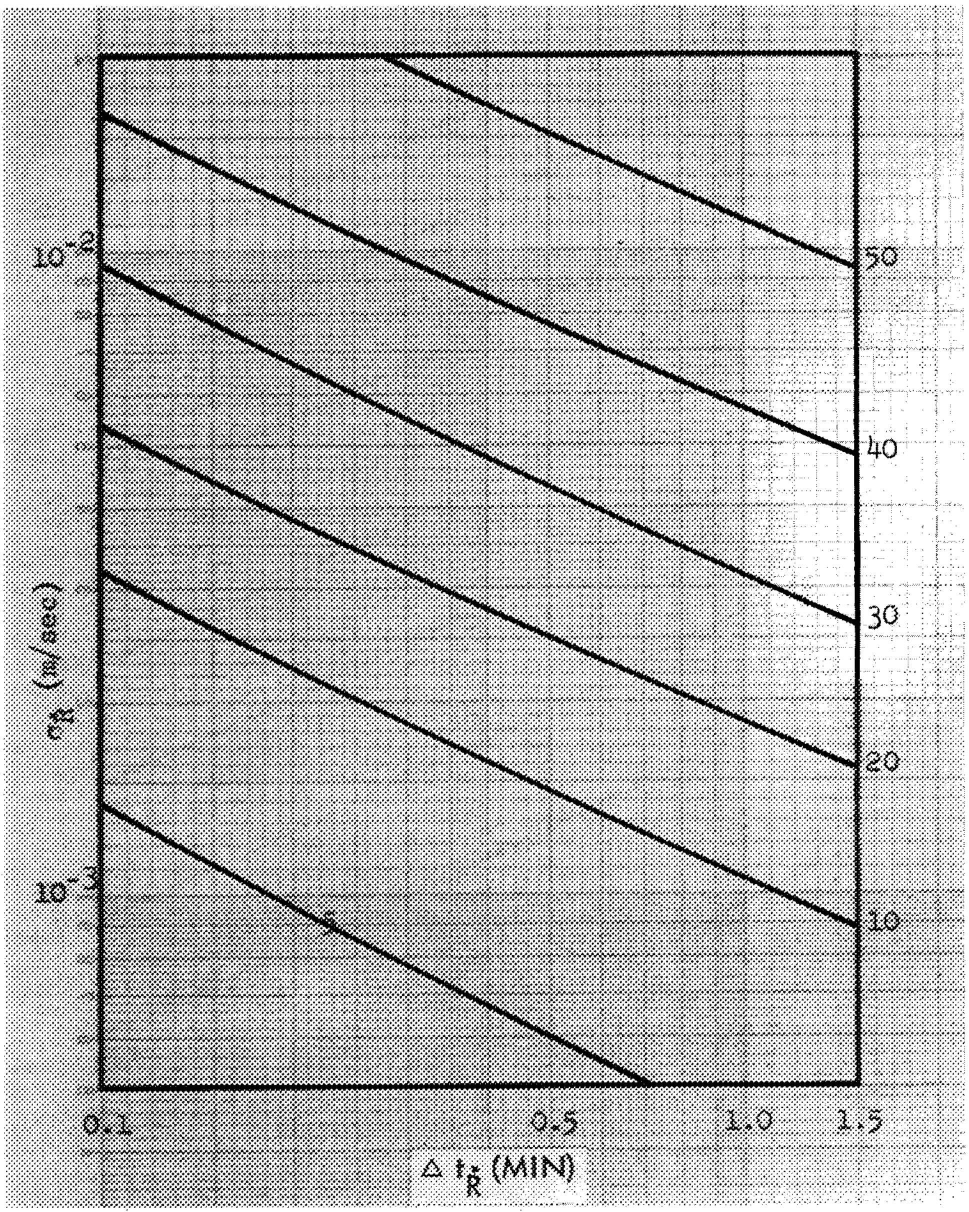


Figure 18. Velocity Error Contours in m/sec $\sigma_R = 15\text{m}$, $\Delta t_R = 5$ min (4 pts)

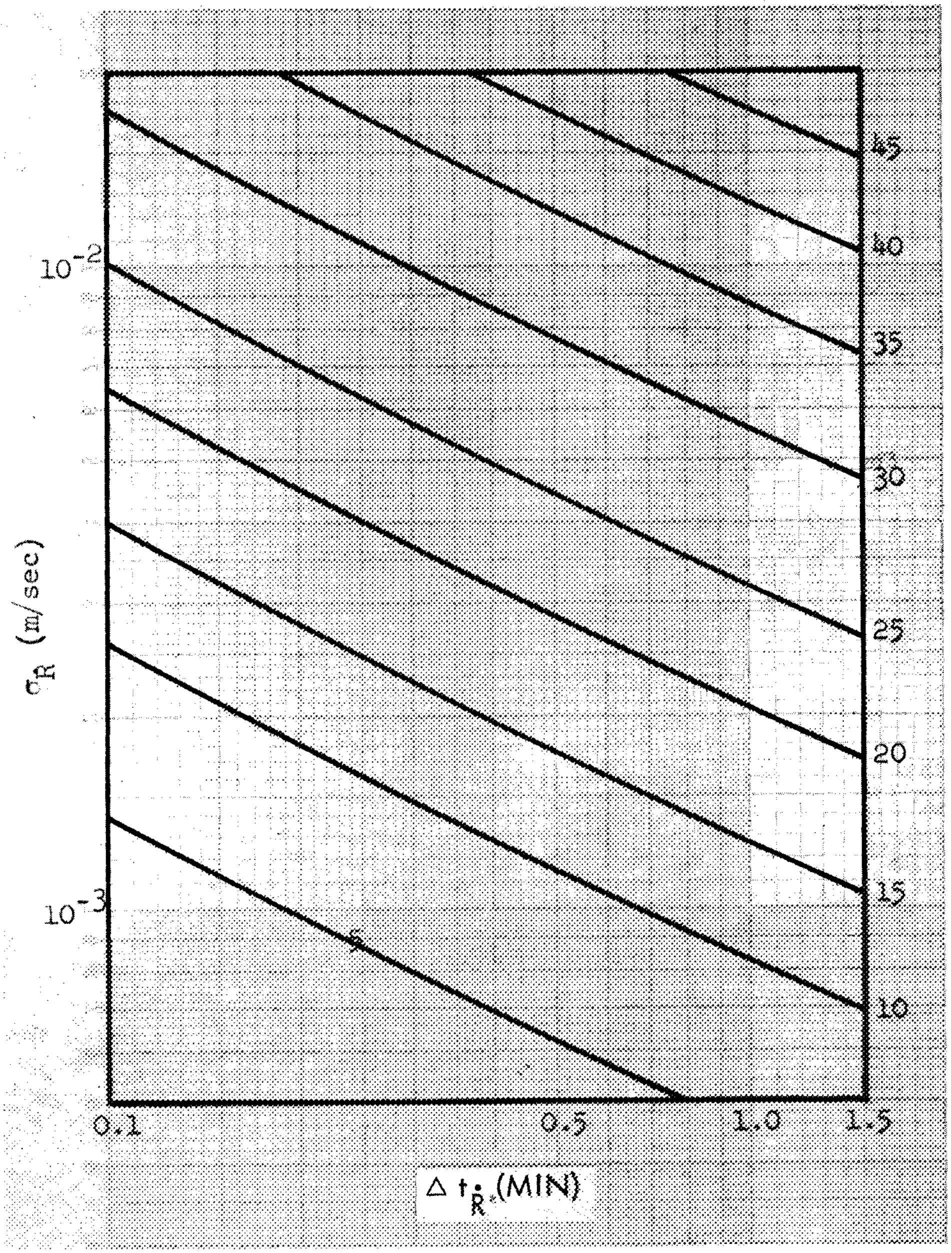


Figure 19. Velocity Error Contours in m/sec $\sigma_R = 10$m, $\Delta t_R = 5$ min (4 pts)

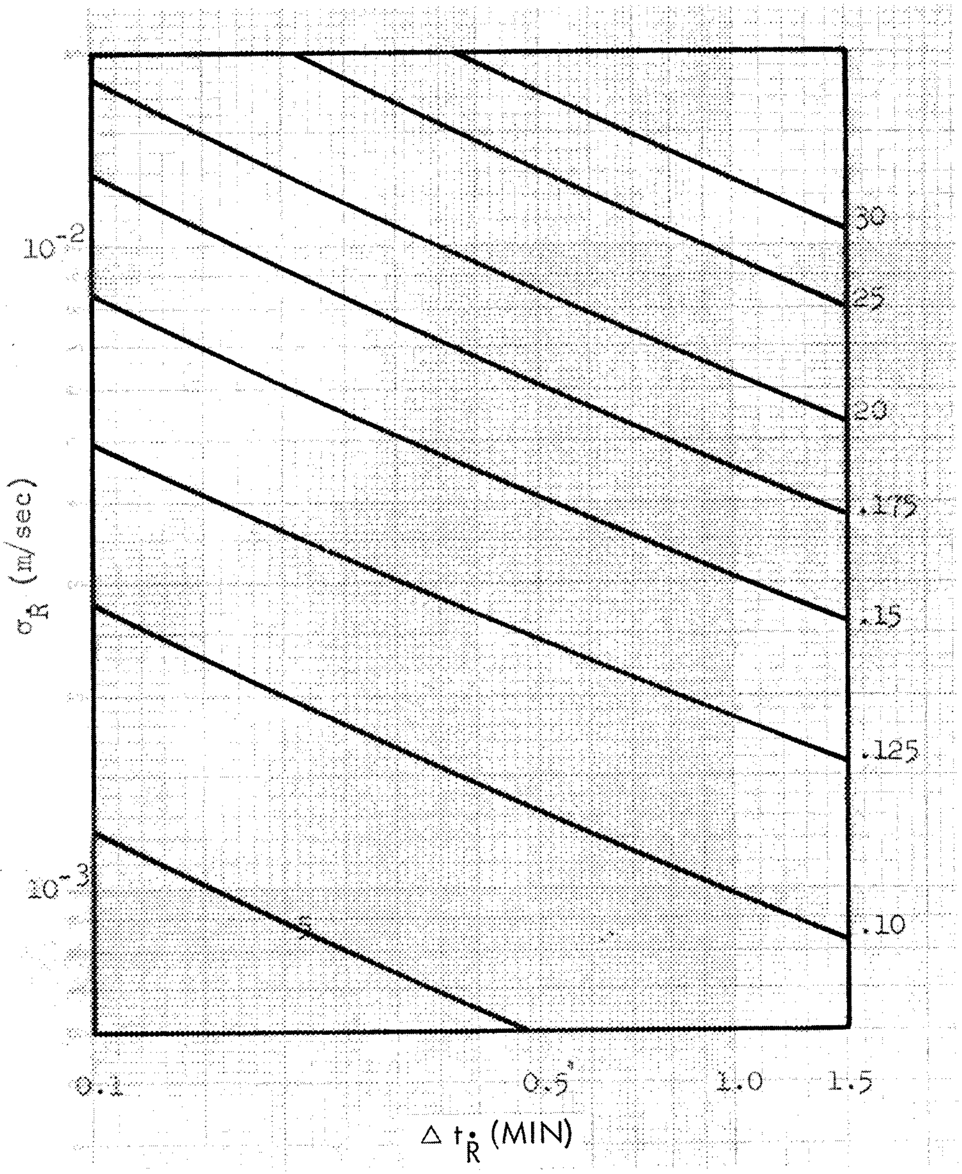
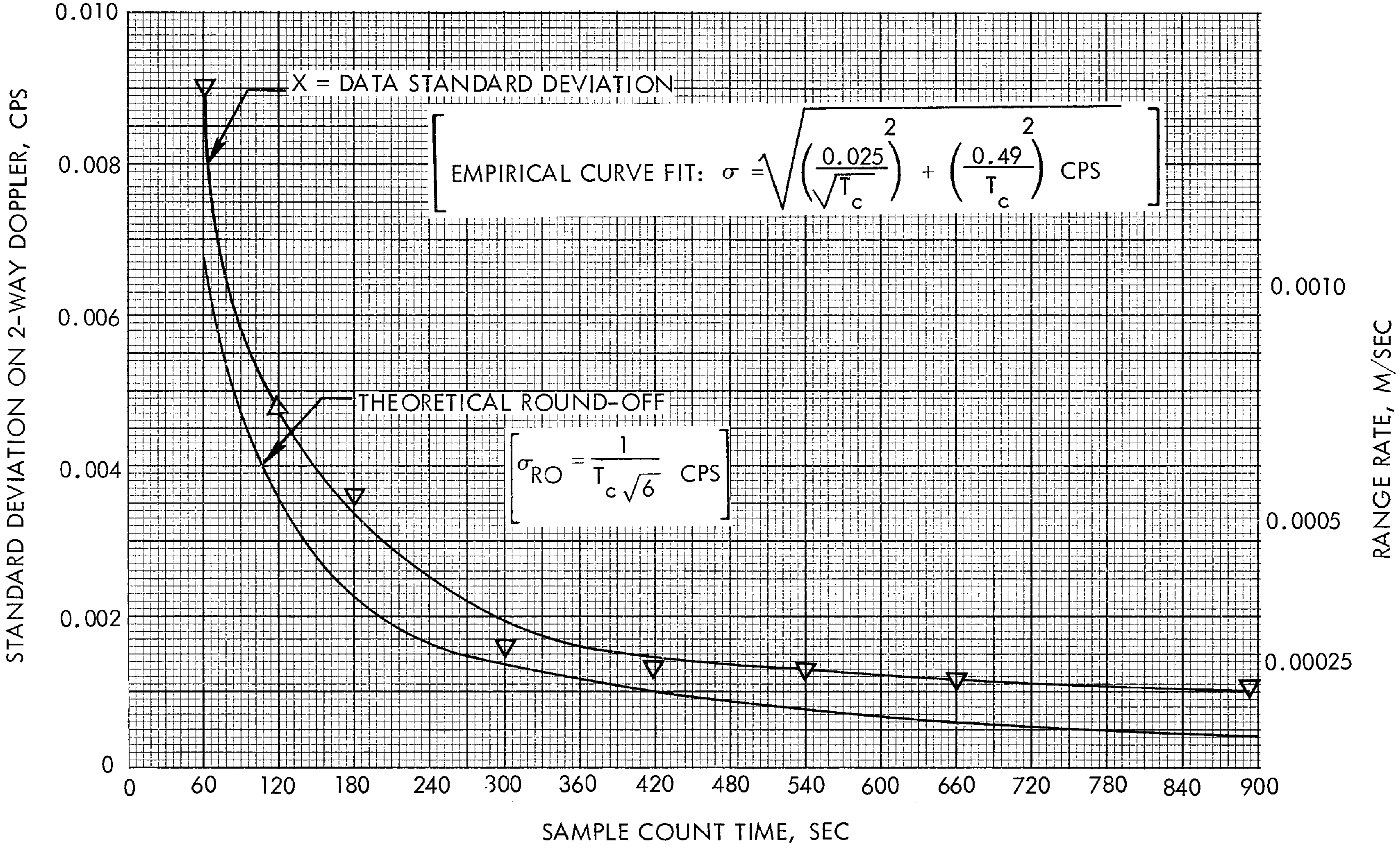


Figure 20. Velocity Error Contours in m/sec σ_R = 5m, Δt_R = 5 min (4 pts)



TAKEN FROM JPL TM NO. 33-230

Figure 21. Standard Deviation of Doppler Residuals

Table 1. Position and Velocity Error Versus $\sigma_{\dot{R}}$, $\Delta t_{\dot{R}}$, Δt_R · σ_R = 10

			$\sigma_{\dot{R}}$ m/sec							
			5×10^{-4}		45×10^{-4}		80×10^{-4}		120×10^{-4}	
$\Delta t_{\dot{R}}$ (min)	Δt_R (min)	points (count)	Pos. Error (m)	Vel. Error (m/sec)	Pos. Error (m)	Vel. Error (m/sec)	Pos. Error (m)	Vel. Error (m/sec)	Pos. Error (m)	Vel. Error (m/sec)
0.1	∞	None	41.44	.0253	373.0	.227	663.0	.404	994.2	.606
	15	2	24.445	.0214	192.90	.175	297.1	.271	369.9	.341
	8	3	24.0	.0213	185.4	.169	271.9	.249	324.6	.301
	5	4	23.83	.0213	178.6	.163	251.9	.232	292.5	.273
0.5	∞	None	87.97	.0545	791.6	.491	1407.6	.872	2110.5	1.309
	15	2	50.98	.0459	335.0	.307	423.2	.395	463.1	.446
	8	3	50.65	.0457	300.12	.276	359.8	.342	385.9	.385
	5	4	50.41	.0456	274.0	.253	318.7	.306	339.4	.346
1.0	∞	None	114.7	.0726	1032.0	.653	1835.0	1.162	2753.0	1.743
	15	2	68.22	.0617	385.6	.356	454.5	.434	485.7	.490
	8	3	67.76	.0614	335.3	.313	380.2	.374	403.9	.430
	5	4	67.33	.0610	300.6	.283	334.8	.336	355.6	.392
1.5	∞	None	130.7	.0844	1177.0	.760	2092.0	1.350	3138.0	2.026
	15	2	79.60	.0722	408.6	.380	468.0	.456	497.7	.521
	8	3	78.94	.0717	350.5	.331	389.7	.395	413.3	.463
	5	4	78.32	.0711	311.9	.298	343.1	.357	366.8	.426

Table 2. Position and Velocity Error Versus $\sigma_{\dot{R}}$, $\Delta t_{\dot{R}}$, Δt_R · $\sigma_R = 5$

			$\sigma_{\dot{R}}$ m/sec							
			$5\text{x}10^{-4}$		$45\text{x}10^{-4}$		$80\text{x}10^{-4}$		$120\text{x}10^{-4}$	
$\Delta t_{\dot{R}}$ (min)	Δt_R (min)	points (count)	Pos. Error (m)	Vel. Error (m/sec)	Pos. Error (m)	Vel. Error (m/sec)	Pos. Error (m)	Vel. Error (m/sec)	Pos. Error (m)	Vel. Error (m/sec)
0.1	∞	None	41.44	.0253	373.0	.227	663.0	.404	994.2	.606
	15	2	23.477	.0211	159.63	.146	206.2	.192	227.8	.218
	8	3	23.3	.0211	144.3	.133	176.4	.166	190.4	.188
	5	4	23.21	.0210	132.5	.122	156.7	.149	167.5	.168
0.5	∞	None	87.97	.0545	791.6	.491	1407.6	.872	2110.5	1.309
	15	2	49.79	.0451	218.2	.205	242.1	.243	256.7	.283
	8	3	49.21	.0446	184.20	.177	200.76	.213	213.79	.256
	5	4	48.66	.0441	162.6	.158	177.0	.193	191.3	.238
1.0	∞	None	114.7	.0726	1032.0	.653	1835.0	1.162	2753.0	1.743
	15	2	66.07	.0600	232.2	.225	253.1	.272	271.7	.330
	8	3	64.80	.0589	193.5	.194	210.5	.244	229.1	.308
	5	4	63.59	.0578	170.3	.175	187.6	.226	209.3	.291
	∞	None	130.7	.0844	1177.0	.760	2092.0	1.350	3138.0	2.026
	15	2	76.42	.0695	238.5	.236	260.2	.293	282.7	.363
	8	3	74.49	.0678	198.1	.206	217.4	.268	240.6	.344
	5	4	72.69	.0662	174.6	.187	195.7	.251	222.7	.328

Table 3. Position and Velocity Error Versus $\sigma_{\dot{R}}$, $\Delta t_{\dot{R}}$, Δt_R · $\sigma_R = 15$

			$\sigma_{\dot{R}}$ m/sec							
			$5\text{x}10^{-4}$		$45\text{x}10^{-4}$		$80\text{x}10^{-4}$		$120\text{x}10^{-4}$	
$\Delta t_{\dot{R}}$ (min)	Δt_R (min)	points (count)	Pos. Error (m)	Vel. Error (m/sec)	Pos. Error (m)	Vel. Error (m/sec)	Pos. Error (m)	Vel. Error (m/sec)	Pos. Error (m)	Vel. Error (m/sec)
0.1	∞	None	41.44	.0253	373.0	.227	663.0	.404	994.2	.606
	15	2	25.844	.0218	201.85	.183	332.7	.303	445.7	.407
	8	3	25.0	.0216	197.8	.180	315.9	.288	407.8	.374
	5	4	24.59	.0215	194.0	.176	301.2	.275	377.8	.347
0.5	∞	None	87.97	.0545	791.6	.491	1407.6	.872	2110.5	1.309
	15	2	51.81	.0462	388.3	.354	547.0	.502	634.7	.592
	8	3	51.33	.0460	362.43	.331	481.6	.446	539.7	.512
	5	4	51.06	.0459	340.8	.312	434.9	.405	478.1	.459
1.0	∞	None	114.7	.0726	1032.0	.653	1835.0	1.162	2753.0	1.743
	15	2	69.10	.0622	473.6	.433	615.0	.572	681.7	.652
	8	3	68.63	.0619	428.9	.394	527.0	.497	570.4	.562
	5	4	68.32	.0618	394.6	.364	468.7	.447	502.2	.564
1.5	∞	None	130.7	.0844	1177.0	.760	2092.0	1.350	3138.0	2.026
	15	2	80.61	.0728	517.1	.475	644.6	.606	702.1	.685
	8	3	80.09	.0725	460.7	.426	546.3	.524	584.6	.593
	5	4	79.71	.0722	419.1	.390	483.3	.469	514.7	.535

TABLE 4.— STANDARD DEVIATIONS OF SOLUTION VARIABLES FOR DATA SAMPLE RATES OF ONE AND TEN MINUTES

Variable	(R = 10 min)	(R = 1 min)
X	0.80392382E 02	0.25889283E 02
Y	0.28107547E 03	0.88431961E 02
Z	0.39040269E 03	0.12322507E 03
$\dot{X}$	0.45183975E-01	0.14456795E-01
$\dot{Y}$	0.98487685E-01	0.31288486E-01
$\dot{Z}$	0.20982726E-00	0.66100215E-01
J2	0.45670816E-03	0.14596168E-03
J3	0.16380200E-04	0.51679972E-05
J4	0.36543927E-03	0.11670670E-03
C21	0.27781016E-04	0.89721665E-05
S21	0.11235017E-04	0.35817256E-05
C31	0.40795719E-05	0.13014052E-05
S31	0.79579709E-05	0.25259919E-05
C41	0.24710187E-04	0.79629086E-05
S41	0.10136381E-04	0.32205699E-05
C22	0.51926018E-05	0.16743261E-05
S22	0.24127933E-05	0.75543815E-06
C32	0.39191212E-05	0.12426455E-05
S32	0.66953415E-05	0.21533615E-05
C42	0.46469859E-05	0.14853000E-05
S42	0.18227873E-05	0.57878166E-06
C33	0.81952482E-06	0.26058456E-06
S33	0.11208674E-05	0.35982903E-06
C43	0.80348911E-06	0.26059217E-06
S43	0.62352352E-06	0.19585953E-06
C44	0.82614909E-07	0.26385447E-07
S44	0.74623010E-07	0.23516252E-07
GM	0.11392564E-07	0.36400247E-08

TABLE 5.– COMPARISON OF SENSITIVITIES OF SOLUTION VARIABLES TO CONSIDERED VARIABLES FOR ONE AND TEN MINUTE DATA SAMPLE RATES

	X		Y		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	0.16746330E 06	0.16954097E 06	0.91318966E 06	0.89303610E 06	J5
J6	-0.38801867E 05	-0.37058832E 05	-0.14306132E 06	-0.14369165E 06	J6
J7	-0.31389352E 06	-0.32150375E 06	-0.95822851E 06	-0.88931972E 06	J7
C51	0.12076347E 07	0.12126134E 07	0.33636379E 07	0.35730281E 07	C51
S51	0.57652146E 06	0.55564459E 06	0.16875722E 07	0.16455500E 07	S51
C61	0.86668604E 06	0.78424517E 06	0.20346683E 07	0.20975149E 07	C61
S61	-0.18098853E 07	-0.18285653E 07	-0.91367009E 07	-0.87590402E 07	S61
C52	-0.17643631E 08	-0.17672136E 08	0.86828664E 07	0.11022895E 08	C52
S52	-0.15252805E 07	-0.15039908E 07	-0.10135859E 07	-0.20152376E 07	S52
C62	-0.31001246E 07	-0.32349522E 07	-0.31902163E 07	-0.22982755E 07	C62
S62	0.19319155E 08	0.19159668E 08	0.43640570E 08	0.45566364E 08	S62
C53	0.55777341E 08	0.60390659E 08	-0.28550541E 08	-0.16069666E 08	C53
S53	0.32748549E 08	0.29176544E 08	0.26763722E 09	0.25814991E 09	S53
C63	0.28057034E 08	0.17658884E 08	0.55065563E 09	0.57584473E 09	C63
S63	-0.18335997E 09	-0.18708345E 09	0.11735217E 09	0.14866994E 09	S63
C54	-0.13166333E 09	-0.13212590E 09	0.46987791E 08	0.10028289E 09	C54
S54	-0.25163317E 07	0.73667854E 06	-0.45542163E 09	-0.57602875E 09	S54
C55	0.69696689E 09	0.58596459E 09	-0.24257798E 10	-0.17181834E 10	C55
S55	-0.67611214E 09	-0.61060050E 09	-0.14329185E 10	-0.20877601E 10	S55

	Z		$\dot{X}$		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	-0.23841330E 07	-0.23681717E 07	0.79948647E 01	0.11138818E 02	J5
J6	0.69500706E 05	0.76047857E 05	0.38930411E 02	0.38112044E 02	J6
J7	0.28549048E 07	0.28122848E 07	0.38897400E 01	-0.87845696E 01	J7
C51	-0.37739925E 07	-0.39315041E 07	-0.40831354E 03	-0.44548046E 03	C51
S51	-0.66581644E 06	-0.54914860E 06	-0.33774956E 02	-0.37424755E 02	S51
C61	-0.48370128E 07	-0.47974548E 07	-0.30589485E 01	-0.19092640E 02	C61
S61	0.68610748E 07	0.65899742E 07	0.15239886E 04	0.14586406E 04	S61
C52	0.96035061E 06	-0.46694284E 06	-0.54131007E 03	-0.98927075E 03	C52
S52	-0.11354282E 08	-0.10333323E 08	-0.42132293E 04	-0.40997013E 04	S52
C62	-0.86773291E 07	-0.95031166E 07	-0.67430628E 03	-0.81503902E 03	C62
S62	-0.38941515E 08	-0.40008207E 08	-0.54231540E 04	-0.58168679E 04	S62
C53	-0.15123210E 09	-0.17028959E 09	0.17462520E 05	0.16427068E 05	C53
S53	-0.34356634E 08	-0.16282052E 08	-0.51765622E 05	-0.51349713E 05	S53
C63	-0.18669312E 09	-0.18234139E 09	-0.59533379E 05	-0.66605516E 05	C63
S63	0.32906884E 09	0.31268720E 09	-0.53397644E 05	-0.58332668E 05	S63
C54	0.33640724E 09	0.28018610E 09	-0.25973561E 04	0.49554895E 03	C54
S54	-0.34369356E 09	-0.24662333E 09	0.13403320E 06	0.15556987E 06	S54
C55	0.26055979E 10	0.21820984E 10	0.27271091E 06	0.22977044E 06	C55
S55	0.92267223E 08	0.79911542E 09	0.45498554E 06	0.51748917E 06	S55

TABLE 5.— COMPARISON OF SENSITIVITIES OF SOLUTION VARIABLES TO CONSIDERED VARIABLES FOR ONE AND TEN MINUTE DATA SAMPLE RATES (Continued)

	$\dot{Y}$		$\dot{Z}$		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	-0.42019738E 02	-0.40169317E 02	0.11669723E 03	0.13200094E 03	J5
J6	0.96591837E 02	0.98251753E 02	0.12034447E 03	0.12140568E 03	J6
J7	0.81870424E 02	0.77028456E 02	-0.14054240E 03	-0.19591291E 03	J7
C51	0.14704311E 04	0.14641281E 04	-0.41537989E 04	-0.43416308E 04	C51
S51	0.78992505E 03	0.78368632E 03	-0.82855308E 03	-0.78016169E 03	S51
C61	0.42960173E 03	0.40102293E 03	-0.79473460E 03	-0.85223577E 03	C61
S61	-0.29962991E 04	-0.30109897E 04	0.11358589E 05	0.11096124E 05	S61
C52	0.45816334E 04	0.45223501E 04	-0.95918433E 04	-0.11545293E 05	C52
S52	0.72494746E 03	0.61543115E 03	-0.18638648E 05	-0.17365514E 05	S52
C62	-0.43712241E 04	-0.43944842E 04	-0.17114232E 04	-0.27543975E 04	C62
S62	0.17645410E 05	0.17423368E 05	-0.50267304E 05	-0.51449335E 05	S62
C53	-0.69614514E 05	-0.69575108E 05	0.16951793E 06	0.16507595E 06	C53
S53	0.74236105E 05	0.73246897E 05	-0.32442483E 06	-0.31407996E 06	S53
C63	0.15870464E 06	0.15724231E 06	-0.49242261E 06	-0.51174419E 06	C63
S63	0.14328032E 06	0.14227438E 06	-0.45892397E 06	-0.47857238E 06	S63
C54	0.11788146E 06	0.11600296E 06	-0.21434678E 06	-0.20214742E 06	C54
S54	-0.61132854E 05	-0.51104337E 05	0.69824954E 06	0.74686350E 06	S54
C55	0.38001348E 06	0.33563679E 06	-0.51674514E 06	-0.89831228E 06	C55
S55	-0.82213420E 06	-0.68895993E 06	0.34158997E 07	0.33002551E 07	S55

	J2		J3		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	0.78871083E 01	0.68396705E 01	-0.11200532E 01	-0.11202481E 01	J5
J6	-0.12415481E 01	-0.12414152E 01	0.49034514E 01	0.48990021E 01	J6
J7	-0.50942744E 00	-0.45724051E 00	0.90810029E 00	0.90912738E 00	J7
C51	0.13563058E 01	0.14727224E 01	-0.79665323E 00	-0.78851137E 00	C51
S51	-0.77652682E 01	-0.76234464E 01	0.36861106E 00	0.36434945E 00	S51
C61	-0.11239188E 02	-0.10907273E 02	-0.15618172E 00	-0.16587969E 00	C61
S61	-0.92054269E 01	-0.91272018E 01	0.11482242E 01	0.11471795E 01	S61
C52	0.34422012E 02	0.35642263E 02	-0.13795768E 01	-0.13108740E 01	C52
S52	0.19045936E 01	0.18692580E 01	0.97995295E 00	0.92811332E 00	S52
C62	0.46817611E-00	0.13196959E 01	-0.29870441E 01	-0.29758125E 01	C62
S62	-0.55379589E 02	-0.53023145E 02	-0.10129342E 01	-0.10411071E 01	S62
C53	-0.30306277E 03	-0.32084151E 03	-0.13295013E 02	-0.13583794E 02	C53
S53	0.29912102E 03	0.31028212E 03	0.11148041E 02	0.10924620E 02	S53
C63	0.22209396E 03	0.26579844E 03	-0.44750103E 01	-0.41005348E 01	C63
S63	0.10795220E 04	0.10912979E 04	0.37568427E 02	0.37682825E 02	S63
C54	0.82356618E 03	0.72207338E 03	0.13466652E 02	0.73450498E 01	C54
S54	-0.35719847E 03	-0.34002800E 03	-0.77942538E 01	-0.70894761E 01	S54
C55	0.23102288E 04	0.22387848E 04	0.33485127E 03	0.31749257E 03	C55
S55	0.81663244E 03	0.15748043E 04	-0.29138877E 03	-0.24691865E 03	S55

TABLE 5.— COMPARISON OF SENSITIVITIES OF SOLUTION VARIABLES TO CONSIDERED VARIABLES FOR ONE AND TEN MINUTE DATA SAMPLE RATES (Continued)

	J4		C21		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	0.34161992E 01	0.25578026E 01	0.67602845E 02	0.64773962E 02	J5
J6	-0.19075970E 01	-0.19066723E 01	0.57142363E-02	0.47934359E 02	J6
J7	-0.34652742E 00	-0.30389224E 00	-0.29346707E-01	-0.27725151E 01	J7
C51	0.11581445E 01	0.12552956E 01	0.81665076E-01	0.82105801E-01	C51
S51	-0.72233745E 01	-0.71074776E 01	-0.86879833E 00	-0.86350092E 00	S51
C61	-0.98165344E 01	-0.95569461E 01	-0.16899873E 01	-0.16640452E 01	C61
S61	-0.73442812E 01	-0.72704150E 01	-0.42607863E-00	-0.43630602E 00	S61
C52	0.25339606E 02	0.26391958E 02	0.41961772E 01	0.41673507E 01	C52
S52	-0.42849696E 01	-0.42843190E 01	0.75937413E 01	0.75551382E 01	S52
C62	-0.70049740E 01	-0.63245063E 01	0.11196399E 02	0.11255040E 02	C62
S62	-0.39953671E 02	-0.37980544E 02	-0.61405061E 01	-0.60983007E 01	S62
C53	-0.22745673E 03	-0.24066187E 03	-0.28865983E 02	-0.31016667E 02	C53
S53	0.26030269E 03	0.26881858E 03	-0.63891251E 01	-0.53414239E 01	S53
C63	0.25635884E 03	0.29200450E 03	-0.65588363E 02	-0.63650644E 02	C63
S63	0.82714066E 03	0.83719317E 03	0.98357163E 02	0.98421741E 02	S63
C54	0.61320923E 03	0.53333519E 03	0.76105006E 02	0.69749122E 02	C54
S54	-0.30359109E 03	-0.29887933E 03	0.21652405E 02	0.32168469E 02	S54
C55	0.16122998E 04	0.15311512E 04	0.28941148E 03	0.31002407E 03	C55
S55	0.32033596E 03	0.87541239E 03	0.44415101E 03	0.54287469E 03	S55

	S21		C31		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	0.33994611E-01	0.34265836E-01	0.42819926E-02	0.44299279E-02	J5
J6	0.67376092E-02	0.69724935E-02	0.63669612E-02	0.65688042E-02	J6
J7	-0.57772098E-01	-0.58945877E-01	-0.57010753E-02	-0.61152856E-02	J7
C51	0.81190611E 00	0.80998555E 00	-0.12867649E 01	-0.12869030E 01	C51
S51	0.14040224E-00	0.13813253E-00	0.47441587E-01	0.48050487E-01	S51
C61	0.76182955E-01	0.66955140E-01	0.77424502E-02	0.29912232E-02	C61
S61	-0.11243624E 01	-0.11262537E 01	0.18538831E-00	0.18311508E-00	S61
C52	-0.55168367E 01	-0.55324311E 01	0.62260575E 00	0.62201668E 00	C52
S52	0.71364899E 00	0.71937500E 00	-0.21268758E-00	-0.19353429E-00	S52
C62	-0.19851606E-02	-0.20058757E-01	-0.62010945E 00	-0.64871299E 00	C62
S62	0.88410444E 01	0.88092411E 01	-0.16473170E 01	-0.16584861E 01	S62
C53	0.81913591E 01	0.87012751E 01	0.17865580E 01	0.18312646E 01	C53
S53	-0.66619967E 00	-0.10094339E 01	-0.62139475E 00	-0.43102618E-00	S53
C63	-0.32709809E 01	-0.40798224E 01	-0.23707288E 01	-0.25469308E 01	C63
S63	-0.38961700E 02	-0.39123173E 02	0.27402556E 01	0.27356019E 01	S63
C54	-0.33581264E 02	-0.31773770E 02	0.30526545E 01	0.32821021E 01	C54
S54	0.82154452E 01	0.66896462E 01	0.12500090E 01	0.11643252E 01	S54
C55	-0.11245110E 03	-0.11927307E 03	0.31183864E 02	0.30379227E 02	C55
S55	-0.76592546E 02	-0.88914893E 02	0.89034422E 01	0.65955351E 01	S55

TABLE 5.— COMPARISON OF SENSITIVITIES OF SOLUTION VARIABLES TO CONSIDERED VARIABLES FOR ONE AND TEN MINUTE DATA SAMPLE RATES (Continued)

	S31		C41		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	0.94774359E-02	0.92725980E-02	0.44051721E-03	0.99811199E-04	J5
J6	-0.67182972E-02	-0.66352904E-02	0.16942872E-02	0.12227251E-02	J6
J7	-0.28642418E-01	-0.27568050E-01	-0.14474941E-01	-0.12540594E-01	J7
C51	0.24200146E-01	0.27527866E-01	0.10231180E-00	0.10503789E-00	C51
S51	-0.10534588E 01	-0.10511290E 01	-0.81360548E 00	-0.80754688E 00	S51
C61	0.12475405E-00	0.12892610E-00	-0.23739213E 01	-0.23531751E 01	C61
S61	-0.22234430E-00	-0.21920294E-00	-0.37007330E-00	-0.37423217E-00	S61
C52	0.63404158E 00	0.66775925E 00	0.35201024E 01	0.35295639E 01	C52
S52	0.93999289E 00	0.94273525E 00	0.57556209E 01	0.57358523E 01	S52
C62	0.56513261E 00	0.57663655E 00	0.83116522E 01	0.83605481E 01	C62
S62	-0.13923442E 01	-0.13491111E 01	-0.47430632E 01	-0.46669845E 01	S62
C53	-0.69754719E 01	-0.71544911E 01	-0.21768058E 02	-0.23291405E 02	C53
S53	0.95735810E 01	0.97086630E 01	0.28879516E 01	0.37183437E 01	S53
C63	0.20368277E 01	0.26496517E 01	-0.36528090E 02	-0.34491105E 02	C63
S63	0.19319797E 02	0.19448262E 02	0.83056183E 02	0.83340973E 02	S63
C54	0.25391363E 02	0.22948489E 02	0.67247214E 02	0.61589023E 02	C54
S54	-0.17936807E 02	-0.17969670E 02	0.17621718E 02	0.23616422E 02	S54
C55	0.11858927E 03	0.11261861E 03	0.21445482E 03	0.22155238E 03	C55
S55	-0.22126839E 02	0.89304318E 01	0.28515181E 03	0.35574625E 03	S55

	S41		C22		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	0.34339856E-01	0.34387569E-01	0.43295356E-02	0.43196217E-02	J5
J6	0.14734811E-01	0.14690547E-01	0.30328638E-02	0.28290645E-02	J6
J7	-0.60160807E-01	-0.60476121E-01	-0.12031514E-01	-0.11873107E-01	J7
C51	0.66205393E 00	0.66341949E 00	0.15648068E-01	0.15344258E-01	C51
S51	0.17869357E-00	0.17464405E-00	0.63520600E-01	0.64173460E-01	S51
C61	0.58749377E-02	-0.91722178E-03	-0.10486523E-00	-0.10070965E-00	C61
S61	-0.17702288E 01	-0.17713027E 01	-0.12942049E-00	-0.13123584E-00	S61
C52	-0.46747317E 01	-0.46673096E 01	0.32435101E-00	0.31677398E-00	C52
S52	0.10939758E 01	0.10620166E 01	-0.99029785E 00	-0.99345392E 00	S52
C62	-0.60150386E 00	-0.58669602E 00	-0.27016085E 01	-0.26872054E 01	C62
S62	0.70443289E 01	0.70140373E 01	-0.31900954E-00	-0.30891125E-00	S62
C53	0.11424837E 01	0.13565963E 01	-0.15871048E 01	-0.18990836E 01	C53
S53	0.39985823E 01	0.34808695E 01	0.10636214E 02	0.10792055E 02	S53
C63	-0.43737487E 01	-0.48224615E 01	0.16858616E 02	0.17174013E 02	C63
S63	-0.16296437E 02	-0.16494498E 02	0.88919843E 01	0.88033095E 01	S63
C54	-0.26079611E 02	-0.27516186E 02	0.14582027E 02	0.13098345E 02	C54
S54	0.65445510E 01	0.62321259E 01	-0.68981011E 01	-0.55923657E 01	S54
C55	0.28615567E 02	0.15001260E 02	0.12376884E 03	0.11946814E 03	C55
S55	-0.16667578E 03	-0.15368879E 03	0.11205406E 03	0.12582820E 03	S55

TABLE 5.— CONPARISON OF SENSITIVITIES OF SOLUTION VARIABLES TO CONSIDERED VARIABLES FOR ONE AND TEN MINUTE DATA SAMPLE RATES (Continued)

	S22		C32		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	0.12068830E-01	0.12203045E-01	0.20014324E-01	0.20217174E-01	J5
J6	-0.10713964E-02	-0.80156232E-03	0.88266066E-03	0.11341310E-02	J6
J7	-0.22657865E-01	-0.23136424E-01	-0.38592803E-01	-0.39336991E-01	J7
C51	-0.11962097E-00	-0.12143066E-00	-0.23730370E-00	-0.23909340E-00	C51
S51	-0.58864006E-02	-0.42275134E-02	0.11653712E-01	0.12534902E-01	S51
C61	0.16706537E-01	0.14984101E-01	0.23318935E-01	0.19618464E-01	C61
S61	-0.40320368E-01	-0.41335537E-01	-0.18293666E-02	-0.43471052E-02	S61
C52	0.82692561E 00	0.81657727E 00	-0.19794150E 01	-0.19950272E 01	C52
S52	-0.27336036E-01	-0.46306854E-02	0.19693242E-00	0.21926472E-00	S52
C62	0.10693372E-00	0.85309115E-01	-0.21268448E-00	-0.23514770E-00	C62
S62	-0.21123900E 01	-0.21064498E 01	-0.67368229E 00	-0.67874894E 00	S62
C53	-0.70216580E 01	-0.68791272E 01	0.17638507E 01	0.19426177E 01	C53
S53	0.31510966E-00	0.42384866E-00	-0.61099924E 00	-0.57287488E 00	S53
C63	0.15688153E 01	0.14864298E 01	-0.36704901E 01	-0.40456809E 01	C63
S63	0.11884118E 02	0.12033819E 02	-0.51262168E 01	-0.52320792E 01	S63
C54	-0.48153044E 01	-0.27736239E 01	-0.11691870E 02	-0.10560581E 02	C54
S54	0.51177475E 01	0.42240612E 01	0.35611255E 01	0.32070468E 01	S54
C55	-0.14779996E 03	-0.14137995E 03	-0.82365374E 02	-0.84294731E 02	C55
S55	0.73999011E 02	0.62463379E 02	0.91586950E 01	0.40286485E 01	S55

	S32		C42		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	-0.48363441E-02	-0.48818571E-02	0.27302092E-02	0.26817040E-02	J5
J6	-0.76059531E-02	-0.75288495E-02	0.30017032E-02	0.31461222E-02	J6
J7	0.91468728E-02	0.91548394E-02	-0.59341408E-02	-0.55035410E-02	J7
C51	-0.31966235E-01	-0.30952362E-01	0.36297359E-01	0.37733422E-01	C51
S51	-0.94815893E-01	-0.96734384E-01	0.61135351E-01	0.62972759E-01	S51
C61	0.16459855E-00	0.16014163E-00	-0.87456737E-01	-0.85969541E-01	C61
S61	0.10820607E-00	0.11142632E-00	-0.91832789E-01	-0.90374813E-01	S61
C52	-0.85544895E 00	-0.84199721E 00	0.58861243E 00	0.60649572E 00	C52
S52	-0.17064603E 01	-0.17101537E 01	-0.76789148E 00	-0.75983261E 00	S52
C62	0.93336345E 00	0.92647523E 00	-0.30864603E 01	-0.30805518E 01	C62
S62	0.96744010E-01	0.76846849E-01	-0.34173848E-01	0.19132493E-02	S62
C53	0.16666974E 01	0.20009163E 01	-0.57751587E 00	-0.57211146E 00	C53
S53	-0.30138857E 01	-0.32330313E 01	0.98118616E 01	0.98725529E 01	S53
C63	-0.47723922E 01	-0.51999514E 01	0.14444001E 02	0.14909789E 02	C63
S63	-0.15020119E 01	-0.15040372E 02	0.11321182E 02	0.11426225E 02	S63
C54	-0.92622826E 00	-0.15541077E-00	0.10110717E 02	0.89581934E 01	C54
S54	-0.10258709E 02	-0.11340111E 02	0.57755721E 01	0.47115251E 01	S54
C55	0.17766805E 02	0.20328888E 02	0.27155998E 02	0.16654012E 02	C55
S55	-0.13355608E 03	-0.14527175E 03	0.78887400E 01	0.97597998E 01	S55

TABLE 5.— COMPARISON OF SENSITIVITIES OF SOLUTION VARIABLES TO CONSIDERED VARIABLES FOR ONE AND TEN MINUTE DATA SAMPLE RATES (Continued)

	S42		C33		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	0. 11981498E -01	0. 11978758E -01	-0. 28222872E -02	-0. 28504775E -02	J5
J6	0. 23703953E -02	0. 23272749E -02	-0. 11426636E -03	-0. 13416564E -03	J6
J7	-0. 24430786E -01	-0. 24457853E -01	0. 57809952E -02	0. 58828091E -02	J7
C51	-0. 11091165E -00	-0. 11075884E -00	0. 25528596E -01	0. 25732973E -01	C51
S51	0. 15873047E -01	0. 15240171E -01	-0. 30737074E -02	-0. 29920373E -02	S51
C61	-0. 13484367E -01	-0. 13419091E -01	-0. 49429891E -02	-0. 42820644E -02	C61
S61	-0. 36196161E -01	-0. 36951184E -01	0. 41382127E -02	0. 43447335E -02	S61
C52	0. 53085528E 00	0. 52918852E 00	0. 41600399E -01	0. 43077671E -01	C52
S52	0. 37580939E -00	0. 36575668E -00	-0. 45277702E -01	-0. 47612819E -01	S52
C62	-0. 18965459E -00	-0. 18000191E -00	0. 41780166E -01	0. 42607570E -01	C62
S62	-0. 25173068E 01	-0. 25206455E 01	0. 12328809E -00	0. 12479195E -00	S62
C53	-0. 45044802E 01	-0. 45450833E 01	-0. 10667374E 01	-0. 11001188E 01	C53
S53	0. 14847568E 01	0. 13518758E 01	-0. 14085975E -00	-0. 12696491E -00	S53
C63	-0. 26851799E 01	-0. 27504498E 01	0. 76213352E 00	0. 81705032E 00	C63
S63	0. 67383728E 01	0. 66306923E 01	0. 14442877E -00	0. 18750949E -00	S63
C54	-0. 10445994E 02	-0. 11270366E 02	0. 48716851E 01	0. 49418319E 01	C54
S54	0. 34571925E 01	0. 38756213E 01	-0. 29495754E 01	-0. 28277289E 01	S54
C55	-0. 36385380E 01	-0. 77810870E 01	-0. 16548796E 02	-0. 14407762E 02	C55
S55	-0. 27078825E 02	-0. 18238279E 02	-0. 11500406E 02	-0. 11147065E 02	S55

	S33		C43		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	0. 11277801E -02	0. 11297095E -02	-0. 72570705E -03	-0. 74076515E -03	J5
J6	0. 13657591E -02	0. 13206186E -02	-0. 26050377E -03	-0. 19330942E -03	J6
J7	-0. 24265651E -02	-0. 24162818E -02	0. 18677732E -02	0. 19473270E -02	J7
C51	0. 22740420E -02	0. 22490688E -02	0. 12020691E -03	0. 66198691E -03	C51
S51	0. 87762145E -02	0. 88065203E -02	-0. 11245835E -02	-0. 11413514E -02	S51
C61	-0. 25848061E -01	-0. 25186209E -01	0. 92292050E -02	0. 82914520E -02	C61
S61	-0. 19756231E -01	-0. 20393343E -01	0. 15077537E -01	0. 16221511E -01	S61
C52	0. 12713944E -00	0. 12485392E -00	-0. 43086540E -01	-0. 35503094E -01	C52
S52	0. 18608541E -03	-0. 14884064E -02	0. 86172733E -01	0. 87702022E -01	S52
C62	-0. 19851885E -00	-0. 19494156E -00	0. 57423482E -01	0. 56929012E -01	C62
S62	-0. 37403047E -01	-0. 35767811E -01	0. 70374575E -01	0. 74435356E -01	S62
C53	-0. 21222379E -00	-0. 27414127E -00	0. 43748290E -00	0. 53596110E 00	C53
S53	-0. 21489683E -00	-0. 19483781E -00	-0. 76735654E 00	-0. 81459733E 00	S53
C63	0. 95513382E 00	0. 10073031E 01	-0. 33703116E 01	-0. 33612207E 01	C63
S63	0. 27490364E 01	0. 27170479E 01	-0. 81639943E 00	-0. 79724020E 00	S63
C54	0. 47801910E 01	0. 43968157E 01	0. 17833664E 01	0. 17122941E 01	C54
S54	0. 71643771E 01	0. 75043023E 01	0. 46385697E 01	0. 39927490E 01	S54
C55	0. 32749823E 02	0. 30713703E 02	0. 60309666E 01	0. 33535410E 01	C55
S55	0. 10625722E 02	0. 14754011E 02	-0. 29587168E 02	-0. 32764809E 02	S55

TABLE 5.— COMPARISON OF SENSITIVITIES OF SOLUTION VARIABLES TO CONSIDERED VARIABLES FOR ONE AND TEN MINUTE DATA SAMPLE RATES (Concluded)

	S43		C44		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	-0.10193510E-02	-0.10520279E-02	0.89013035E-04	0.90941456E-04	J5
J6	0.53835240E-03	0.47587230E-03	0.34210870E-04	0.24014436E-04	J6
J7	0.16320403E-02	0.17452055E-02	-0.24172327E-03	-0.25283436E-03	J7
C51	0.89028852E-02	0.92525265E-02	-0.48782504E-03	-0.55757710E-03	C51
S51	0.18920714E-02	0.15522724E-02	0.24702429E-03	0.22050003E-03	S51
C61	-0.67667832E-02	-0.61355097E-02	-0.92578986E-03	-0.84129812E-03	C61
S61	0.87449819E-03	0.95933489E-03	-0.15618981E-02	-0.16787046E-02	S61
C52	-0.73484787E-01	-0.71691556E-01	-0.88579249E-03	-0.18240982E-02	C52
S52	0.35863932E-01	0.29226226E-01	0.22879249E-02	0.20800453E-02	S52
C62	-0.32601349E-01	-0.27048276E-01	-0.10899159E-01	-0.10634129E-01	C62
S62	0.34165736E-01	0.32478279E-01	-0.84075874E-02	-0.92389320E-02	S62
C53	0.80222329E 00	0.74453339E 00	-0.45260532E-01	-0.56447876E-01	C53
S53	0.14770059E-00	0.11574157E-00	0.15969990E-00	0.16442057E-00	S53
C63	-0.49266932E-00	-0.46047166E-00	0.13188362E-01	0.10412152E-01	C63
S63	-0.32987273E 01	-0.33209241E 01	0.96549530E-01	0.88626166E-01	S63
C54	-0.47327573E 01	-0.52084151E 01	0.55430128E 00	0.52768353E 00	C54
S54	0.55898754E 00	0.84770862E 00	0.47755694E-01	0.12735484E-00	S54
C55	0.15213743E 02	0.14659786E 02	0.63923739E 01	0.64174666E 01	C55
S55	-0.51865810E 01	-0.15465900E 01	0.96280774E 01	0.10105365E 02	S55

	S44		GM		
	R = 10 min	R = 1 min	R = 10 min	R = 1 min	
J5	0.47458415E-04	0.52693797E-04	-0.23582174E-05	-0.19902132E-05	J5
J6	-0.97820842E-04	-0.87757757E-04	0.22535809E-04	0.22629185E-04	J6
J7	-0.52092912E-04	-0.68079022E-04	0.12565214E-04	0.11020721E-04	J7
C51	-0.61098500E-03	-0.66435821E-03	-0.27144660E-04	-0.30544303E-04	C51
S51	-0.50869443E-03	-0.44992351E-03	0.16866504E-03	0.16583461E-03	S51
C61	0.10431657E-02	0.96210047E-03	0.23044323E-03	0.22160628E-03	C61
S61	-0.13498502E-03	-0.13246336E-03	0.18628842E-03	0.18296877E-03	S61
C52	-0.16615356E-02	-0.18538781E-02	-0.84073363E-03	-0.87563273E-03	C52
S52	-0.86995227E-02	-0.76995422E-02	-0.14359702E-03	-0.13687292E-03	S52
C62	0.61769206E-02	0.52838989E-02	-0.23571577E-03	-0.26142129E-03	C52
S62	-0.83013666E-02	-0.80277026E-02	0.15215027E-02	0.14609571E-02	S62
C53	-0.17281447E-00	-0.16503226E-00	0.67690384E-02	0.71622651E-02	C53
S53	-0.30585615E-01	-0.25137307E-01	-0.56047530E-02	-0.58274987E-02	S53
C63	0.46279152E-01	0.41718918E-01	-0.32339245E-02	-0.43239424E-02	C63
S63	0.45331733E-01	0.49019165E-01	-0.23988138E-01	-0.24400608E-01	S63
C54	-0.45230160E-01	0.23558136E-01	-0.18730670E-01	-0.16810220E-01	C54
S54	0.36393253E-00	0.32812313E-00	0.76782584E-02	0.76335394E-02	S54
C55	-0.88490879E 01	-0.87050512E 01	-0.32028339E-01	-0.36658106E-01	C55
S55	0.50431345E 01	0.45269563E 01	-0.34642958E-01	-0.47728075E-01	S55

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