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Survey of the 15-Ft Bubble Chamber Fiducials

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I. Introduction

The success of the Fermilab 15-Ft. Bubble Chamber as a instrument for high energy physics research depends critically on the accuracy with which elementary particle tracks can be reconstructed in space using the information recorded on the bubble chamber photographs. There are six cameras located at the top of the bubble chamber. Each camera views the track sensitive volume of the chamber through three concentric hemispherical windows and a wide angle distorting camera lens. Normally a subset of three cameras is used to photograph the tracks each bubble chamber cycle; these three views are then used for stereoscopic reconstruction of the bubble chamber tracks in space from the two dimensional images on the film. Since the camera positions and the distortion coefficients of the lens-window system are only approximately known, we have placed a set of 107 fiducial reference marks on the bubble chamber walls. Most of these fiducials are photographed by each camera along with the tracks. The fiducials are then used to determine the optical constants of each camera so that accurate track reconstruction in space is possible.

Some of the machines used to measure 15-Ft. bubble chamber film have an accuracy of 1 μ (10^{-6}m) in each of the two dimensions on the film. With an average fiducial demagnification of 89 on the film, this corresponds to a distance of 3.5 mils(0.0035 inch) in space. Ideally the positions of the fiducials on the chamber walls should be measured to this accuracy or better.

The fiducials were surveyed in February 1973, before the chamber was cooled down or expanded for the first time, and all physics results to date have been based on this survey. Since that time the chamber has been cycled from room temperature to 25^{0}K and back over a dozen times and has been expanded about three million times while cold. Also the four fiducials on the nose cone flange(B7,F7,DD6, and DD8) where removed in March 1976, while searching for a leak, and replaced in only approximately their original positions. These reasons provided ample justification to repeat the fiducial survey in February-March 1978.

This second survey has shown that the chamber dimensions have remained remarkably stable over the five year life of the bubble chamber. However, the bottom row(I) fiducials have moved an average of about 20 mils since the 1973 survey. Also there are systematic differences between the surveys which were caused by improper zeroing of the theodolite vertical angle scale during at least one of the surveys.

II. Fiducial Description and Survey Method

Fiducials are located inside the 15-Ft.Bubble Chamber in nine rows and 12 columns. The rows are labeled with a letter; starting at the top with row A, 40 inches above the chamber center and proceeding alphabetically downward to row I at the bottom, 72 inches below the chamber center, as shown in Figure 1. The 12 columns of fiducials are spaced 30^0 apart and are labeled with a number (1 through 12). These numbers start with one at the downbeam(north) end of the chamber and increase counterclockwise with four on the west side of the chamber and seven at the upbeam (south) end of the chamber. The nose at the upbeam end of the chamber means that there are no fiducials C7,D7, or E7. Fiducials B7 and F7 are on the nose cone flange as well as two additional fiducials DD6 and DD8 which are at the same height as the D row fiducials. Figure 1 also shows the position of the T2 theodolite used to survey the chamber fiducials.

The fiducials are draftman's transfer lines' applied directly on the scotchlite using the standard glue which comes on the transfer sheets. The seemingly random orientation, width, and length of the fiducial arms in the chamber were carefully calculated to give(as closely as possible) 1.5mm arm length, 15μ (geometrical) line width, and 90^0 crossing angle on film in each of the six views.

Both the 1973 and 1978 fiducial surveys were done in essentially the same manner. After the bubble chamber piston and cylinder (Z section) have been removed from the bottom of the chamber, a standard survey stand is placed on top of a special survey plat-

form I beam which is then bolted to the bottom flange of the chamber(see Figure 1). The I beam platform is very heavy and rigid to provide a stable support for the theodolite. The same platform was used for both surveys.

A Wilde T2 Theodolite is placed on the survey stand at a convenient height and the horizontal and vertical angles of all the fiducials are measured several times. The distance between the reference point on the top of the T2 Theodolite and several fiducials in the A and D rows is measured several times using a stick micrometer. The height of the theodolite above the survey platform is also measured.

The theodolite is then removed and a one-inch diameter steel ball is placed on the survey stand in the same approximate position. The stick micrometer is then used to measure the distance between the ball and each fiducial. These measurements are repeated several times. In order to make these distance measurements accurately it is essential to place the end of the stick mike exactly on the fiducial. By making a special small end for the stick mike and by using a step ladder inside the chamber for the surveyor at the fiducial end of the stick mike, consistent distance measurements were obtained.

The final required measurement is the distance of the reference point above the theodolite optic axis for the T2 used. This was measured by the surveyors with a second theodolite in a separate set up. The distance was 1.188"(1.183") inch in the first (second) survey.

The coordinate system, used to report the survey measurements, was approximately centered on the center of the bubble chamber sphere with the Z axis vertically upward and the X axis along the hadron beam direction. The Y axis is positive to the left, looking downstream, which gives a right handed coordinate system.

The specific coordinate system used for survey number one (1973) is as follows:

1) Vertical axis (z axis direction). Up as defined by level in T2 Theodolite.

2) Zero in horizontal angle. The scribe mark on the center of the north(down beam) end of the survey platform I Beam was taken to have horizontal angle equal zero. The positive x axis is taken in this direction $\perp$ to the z axis defined above.

3) Y axis is defined $\perp$ to the x and z axes, positive to the west to make a right handed coordinate system.

4) The x=y=0 point was defined to be at the T2 position, directly above(as measured with the T2) a centering target inserted in the ¼" diameter hole in the center of the survey platform I beam.

5) The z=0 point was taken at the nominal center of the sphere, 77.469" above the survey platform I beam which was bolted to the flange at the bottom of the cone. The average of measurements at the north and south ends of the I beam was used.

The same prescription was followed for survey #2(1978). Section IV includes a discussion of why this prescription did not result in exactly the same coordinate system and the procedure used to correct this. Since all 15-ft. physics experiments to date have used the survey #1 coordinate system, I have chosen to express the new measurements in the 1973 system.

III. Calculation of Fiducial Positions

Four steps are required to reduce the raw survey measurements to the desired positions of each fiducial in the bubble chamber coordinate system. At least two complete sets of measurements of the horizontal and vertical angles and distances for each fiducial are required to achieve reliable results. First the two(or more) sets of measurements are compared and obvious recording errors are corrected. Such errors include angles that are ten minutes off or distances that differ by one inch, etc. The measurements are then averaged, which reduces the random errors below those involved with each observation. The difference between measurements of the same quantity yields an estimate of these errors. The exact posi-

tion of the steel ball relative to the theodolite center is then determined using the distance measurements of the subset of chamber fiducials to the T2 reference point together with the averaged angle and distance measurements for those fiducials. Finally, the x,y, and z position of each fiducial are calculated in the coordinate system defined in the previous section.

All raw survey measurements are punched on computer cards and then processed with a computer program. This program first converts the raw angles measured in degrees, minutes, and seconds to degrees and decimal fractions. The horizontal angle is redefined to be positive counterclockwise (as the positive x axis is rotated toward the positive y axis) instead of the usual surveyor's convention of being positive clockwise. Some of the angle measurements in the 1978 survey were taken with the theodolite inverted, i.e., with it rotated 180^0 in horizontal and then vertical angles. Averaging a set of normal angles with an inverted set will correct for certain misalignments in the theodolite. These inverted angle measurements are redefined by subtracting 180^0 from the horizontal and vertical angles and then adding 360^0 if the result is negative. The difference of each possible pair of measurements is calculated and printed, as well as histograms, averages, and distribution widths for the horizontal angle(α), vertical angle(β), and distance (d) differences. For convenience in checking the angle differences are converted to mils on a 75" radius sphere. Recording and keypunch errors are obvious from this computer output. The input cards are corrected and the program rerun until all such errors are corrected.

In the 1978 survey, four complete sets of angle measurements were made. Two of these were normal and two were inverted. This checking program showed that pairs of β measurements had average differences which exceeded 1.5 degrees in some cases, but the expected small distribution width about this average. The surveyors then discovered that the theodolite vertical angle scale had been improperly zeroed before the measurements. After properly zeroing the vertical angle scale, two more normal sets of β measurements

were made. The fiducial checking computer program was then modified to add the required amount to the vertical angle in measurements one through four so that the average β of that set was the same as the average of the two final sets. This problem shows the need to make several measures of the fiducials and to check these measurements quickly with the computer program while the survey equipment is still set up in the bubble chamber.

The results of the fiducial checking program usually show which measurements should be used and which should be rejected. Another similiar program is used to average the acceptable data. The same raw survey data cards are used and the same transformations and corrections, as described above, are used. This program also calculates an estimated error on each angle and distance measurement.

The next step is to determine the position of the steel ball, used to measure distances, relative to the theodolite center. For six fiducials in the A row and six fiducials in the D row, the distance between the reference point at the top of the T2 Theodolite and the fiducial was measured. The distance between this reference point and the theodolite optic axis is known from a separate measurement. This information, together with the averaged angles and ball distance to the 12 fiducials is input to another computer program. This program varies the ball position relative to the T2 center(3 parameters) to minimize the sum of the squares of the differences between the expected ball to fiducial distance and the distance actually measured. The non-linear fitting program VARMIT[2] is used for this.

The final step is to use the averaged fiducial angle and distance measurements and the position of the steel ball to calculate the x,y, and z positions in the coordinate system defined in the last section. Two simple transformations are also made: The horizontal angle is redefined so that the scribe mark on the north end of the survey platform has zero horizontal angle, and a constant is added to the z coordinate so that z=0 is at the design center of the bubble chamber sphere, 77.469" above the survey platform. These calculations are done by the same program which

averages the fiducial measurements and a copy of this output is supplied to each high energy physics group which is interested in 15-ft. bubble chamber physics experiments. A copy of this output for the 1978 survey appears as Appendix B to this memo.

IV. Comparison of the 1973 and 1978 Surveys

To compare the results of the two surveys it is necessary to be sure that both are expressed in the same coordinate system. While the prescription given in section II was followed in both cases, small changes in the leveling of the chamber or the way the survey platform was bolted to the chamber make significant changes to the fiducial position differences between the two surveys. To account for possible changes in the coordinate system the following transformation was made on all the fiducials:

$$\begin{aligned} X' &= X + \Omega_3 Y - \Omega_2 Z - X_0 \\ Y' &= Y - \Omega_3 X + \Omega_1 Z - Y_0 \\ Z' &= Z + \Omega_2 X - \Omega_1 Y - Z_0 \end{aligned} \qquad (1)$$

Here X,Y, and Z are the coordinates of the fiducial in the survey 2 coordinate system; Ω_1, Ω_2 and Ω_3 are infinitesimal rotations about the X,Y and Z axes; X_0, Y_0 and Z_0 are a translation of the origin; and X', Y', and Z' are the fiducial coordinates in the new system. We then define χ^2 as follows:

$$\chi^2 = \sum_{\substack{\text{all} \\ \text{fiducials} \\ \text{used in fit}}} (X'-X_1)^2 + (Y'-Y_1)^2 + (Z'-Z_1)^2$$

where X_1, Y_1, and Z_1 are the fiducial coordinates from survey #1. The linear least-squares fitting program LINSQ[3] was used to find the following values of the six rotation and translation parameters which minimized χ^2:

$$\begin{aligned} \Omega_1 &= -0.245 \text{ mr} & X_0 &= 0.6 \text{ mil} \\ \Omega_2 &= 0.238 \text{ mr} & Y_0 &= 39.7 \text{ mil} \\ \Omega_3 &= -0.845 \text{ mr} & Z_0 &= 21.9 \text{ mil} \end{aligned}$$

The first two parameters Ω_1 and Ω_2 represent a possible change in the level of the bubble chamber of 0.342 mr(1 minute 10 seconds)

or 23 mils at the 67.5" radius support skirt. If the beam direction is defined as north, this says that the NW part of the chamber is low now, compared to 5 years ago. The other four parameters can be explained by small differences in bolting the survey platfrom to the chamber and in measuring the T2 height above the platform.

In order to understand the importance of this transformation it is helpful to define σ, the root-mean-square(RMS) deviation between the two surveys:

$$\sigma = (\chi^2/N)^{\frac{1}{2}}$$

where N is the number of fiducials used in the fit. With no change of the coordinate system σ = 73.6 mils; after the above translation σ = 22.2 mils. These numbers represent the difference between two surveys. To get the error on each survey, they should be multiplied by $(2)^{-\frac{1}{2}}$. Then, since this represents the error on all three(X,Y,Z) coordinates, they should be multiplied by $(3)^{-\frac{1}{2}}$ to get the error on a single coordinate. The resulting value for the error on a single coordinate and a single survey is 9.08 mil which is 2.6 times the goal of 3.5 mil and thus represents 2.6μ on film. Possible causes of this error are random or systematic errors in the survey and dimensional changes in the bubble chamber body.

Possible systematic errors between the two surveys include: a difference in the vertical angle zero(β_0), a difference in the scale of the distance measurement (perhaps caused by a temperature difference of the bubble chamber body between the surveys), and differences in the three lengths giving the ball position relative to the T2 position. Unfortunately absolute values of these five parameters cannot be determined by comparing the two surveys, only their difference betweem surveys can be found. Since the bubble chamber is cylindrically symmetric and the survey measurements were made in essentially spherical coordinates, it is useful to re-express the differences between the two surveys in cylindrical and spherical coordinate systems. Figure 2 shows the definitions used; the origin was chosen at the (1978 survey) T2 theodolite position.

The differences (survey 2 - survey 1) in these coordinates are given in Table I. Rather than giving the information for each fiducial, the data for each horizontal row has been averaged, see Figure 1 for the locations of the fiducial rows. The "3 coordinate RMS" for each row is defined as:

$$\text{"3 coordinate RMS"} = \left[\frac{1}{N}\sum_{i=1}^{N}(\Delta\rho_i)^2+(\Delta Z_i)^2+(\rho_i\Delta\alpha_i)^2\right]^{\frac{1}{2}}$$

$$\text{or} \qquad = \left[\frac{1}{N}\sum_{i=1}^{N}(R_i\Delta\beta_i)^2 + (\Delta R_i)^2+(\rho_i\Delta\alpha_i)^2\right]^{\frac{1}{2}}$$

where the sum runs over all fiducials in that row. The "average RMS" for each coordinate is defined, for example

$$\text{"}\Delta\rho\text{ average RMS"} = \left[\frac{1}{N}\Sigma\ (\Delta\rho_i)^2\right]^{\frac{1}{2}}$$

where the sum runs over all fiducials in the chamber used in the fit.

The low values in the $\rho\Delta\alpha$ column of Table I show that horizontal angles were well measured with no systematic errors; in fact if we multiply the average RMS of 4.4 by $(2)^{-\frac{1}{2}}$ to get the error on a single survey of 3.1 mil, we see that the desired goal of 3.5 mils has been exceeded. The average RMS for the other coordinates are, unfortunately, up to four times larger than this desired value. A quick scan of the averages of these coordinate differences shows systematic effects which depend on fiducial height in the chamber. For example, the variation of average $\Delta\rho$ with fiducial row(i.e., Z) suggests a shift in the vertical angle zero between the two surveys.

To understand these systematic effects, we add a seventh parameter(β_0), which corresponds to a shift in the vertical angle zero between surveys 1 and 2, to the least square fit described at the start of this section. The results are given in Table II, which is in the same form as Table I. The extra parameter has reduced σ to 14.5 mil(5.9 mil for a single coordinate and a single survey) which corresponds to 1.7 μm on the film. Systematic effects have been reduced, but the "average RMS" for all other coordinates is still twice as large as for $\rho\Delta\alpha$ indicating that further improvement is possible. The fitted vertical angle zero shift between surveys is 0.44 mr or 1.5 minutes.

The next step was to expand the fit to eleven parameters by allowing the overall distance scale and the X,Y, and Z coordinates of the ball, relative to the T2, to vary. The results are shown in Table III. The main cause of the reduction in σ from 14.5 to 12.9 mil was the distance scale change of +0.008% which could have been due to a cooler chamber(5^0C) during the second survey. Table IV lists the values of the 11 parameters for the various fits. There are small correlations between ball X and X_0, and between ball Y and Y_0. Larger correlations are present between Z_0,β_0, and ball Z.

One obvious characteristic of Tables I through III is that the three coordinate RMS for row I fiducials is 1.5 to 1.8 times as large as for any other row. This suggests that dimensional changes have taken place near the bottom flange of the chamber. Because of the large, 6 foot diameter, hole in the bottom of the chamber, this area is less rigid than the remainder of the chamber body. Table V shows the results of the 11 parameter fit when the row I fiducials are omitted from the fit and the averages. There do not appear to be any further systematic effects above about the ±3 mil level. The distances are measured less well than the angles, indicating that more time should be invested in distance measurements in the next survey. Table VI gives $\rho\Delta\alpha$, $R\Delta\beta$, and ΔR for each fiducial from the final fit which was summarized in Table V. Omitting the row I fiducials has reduced σ to 10.4 mils or 4.2 mils for one coordinate in one survey. This translates to a 1.2μm error on the film.

The random survey errors will be reduced if the data from the two surveys can be averaged. From the above discussion, the problem of dimensional changes in the 15-ft. bubble chamber body can be handled by deleting the row I fiducial measurements in the 1973 survey. The systematic distance scale error of about 0.007% between the two surveys is unimportant; it only causes the same percentage error in the measured momentum of a track. This error is well below other sources of momentum error. The ball X, Y, and Z differences are rather unimportant as can be seen from Table IV;

ignoring them increases σ by only 5%. The vertical angle zero shift, β_0, is important and must be treated properly before the two surveys can be averaged. In the absence of additional data (i.e., a third survey), the safest guess is that the one half the zero shift occurred in each survey. This prescription was also used for the distance scale, ball X, and ball Y shifts as well. Because it is almost degenerate with Z_0 and β_0 the ball Z shift was fixed at 0.

There were actually three steps taken to average the data from the two surveys. First the measurements from each survey were modified by ½ the β_0, D, ball X, and ball Y parameters shown on the last line of Table IV. Each of these modified measurements were then fit to the original survey 1 data and transformed into that coordinate system, using equations(1). Finally the two sets of measurements were averaged. The measurements of the row I and nose cone flange (B7,F7,DD6 and DD8) fiducials in the 1973 survey were deleted before averaging, so the final positions of these fiducials came from only the 1978 survey. The random error on these fiducials is therefore $2^{\frac{1}{2}}$ times the error for the remainder of the fiducials. The fiducials that were measured in both surveys now have σ = 5.3 mils or 3.1 mils per coordinate. This translates to a 0.9 μm random error on the film per coordinate. A reasonable estimate for systematic error is 1.5 times the random error.[5]

V. Conclusion

This detailed comparison of the two surveys has yielded several important conclusions. There have been dimensional changes in the lowest part of the 15' bubble chamber body since it was built, but these were rather small (about 20 mils, see Table V) and probably occurred during the first cooldown. I estimate that the chamber dimensions have been stable since that cooldown. The fiducial survey technique is capable of giving results which are accurate enough not to degrade track reconstruction. However, more care should be used in zeroing the theodolite vertical angle scale and more time should be invested in distance measurements.

I wish to thank the survey crews led by Bill Testin (1973) and Tom Nurczyk (1978) for their dedicated efforts and Asa Newman of the bubble chamber crew for his assistance in these measurements.

FOOTNOTES

1. Normatype transfer sheet #616450-34, Keuffel & Esser Co.

2. W. C. Davidon, "Variable Metric Minimization", Argone National Laboratory Report ANL-5990, Rev. 1959 (unpublished).

3. T. Pomentale, "Linear Least-Squares Fit (LINSQ)", CERN Computer 6000 Series Program Library D-508 Amended 1969 (unpublished), available from the Computing Department, FERMILAB.

4. There have been some difficulties with securing the bottom of the northwest chamber support legs to the concrete foundation which can explain why this side of the chamber is lower now than in 1973. (G. T. Mulholland - private communication.)

5. This estimate of systematic error is obtained by assuming that all the βo error is in one survey and the other survey has no βo error and then comparing this result with the result obtained when half the βo error is assigned to each survey.

FIGURE CAPTIONS

1. 15' Bubble Chamber showing fiducial positions and the location of the T2 theodolite used in the survey.

2. Coordinate system definitions used for expressing differences between the surveys.

APPENDIX A

INSTRUCTIONS FOR SURVEYING THE 15' BUBBLE CHAMBER FUDICALS

Revised May 1978

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1. Place survey stand on the I beam survey platform and then raise platform into position and bolt to chamber bottom flange. The north end of the platform is marked. The survey stand must be on the platform before it is raised into position or there is no way to get the stand into the chamber. (This has been proved experimentally at least once.)

2. Secure the stand to the platform and set the T2 Theodolite level over the center hole about 60" above the platform and with approximately 180° of the horizontal angle scale at the scribe mark on the south end of the I beam platform (below nose cone). The vertical angle zero must be set as accurately as possible; errors in setting the vertical angle zero have caused considerable trouble in the first two surveys and is responsible for a large part of the discrepancies between them.

3. Measure the actual height of the T2 above both the north and south ends of the I beam platform.

4. Record horizontal and vertical angles and fiducial name of all fiducials and the horizontal angles of the scribe marks on each end of the I beam. Invert the T2 and repeat measurements for all fiducials and scribe marks.

5. Repeat step 4.

6. Measure the distance between the T2 reference point and fiducials A2, A4, A6, A8, A10, A12, D2, D4, D6, D8, D10, and D12. Repeat these measurements at least once. The special small end of the stick mike must be used so that it can be placed exactly on the fudicial. The bubble chamber crew will supply a step ladder, with the top end

padded with rags to protect the Scotchlite, so that the man at the fiducial end of the stick mike will be close enough to the fiducial to accurately position the small end of the stick mike on the fudicial. The T2 should be level at vertical angle = 90^{o} during these measurements.

7. The T2 should not be removed from the survey stand until steps 2-6 have been completed and the measurements checked by the responsible person.

8. Replace the T2 with a 1" ball located near to the T2 optical center (± 1/4").

9. Measure the actual height of the ball above both ends of the I beam.

10. Record distance of all fudicials to ball. Observe the same precautions as step 6.

11. Repeat step 10 three times.

12. The ball should remain in position until steps 9-11 are completed and the measurements checked by the responsible person.

13. Measure the distance between the T2 optical axis and the reference point.

Fudicials are named according to the following scheme:

1 or 2 letters indicating height in the chamber with the A row nearest the chamber top and the I row at the bottom. The two extra fiducials on the nose cone flange are labeled DD6 and DD8. A number (1 through 12) indicates the approximate horizontal angle of the fiducial.

1 is opposite nose cone = downbeam = north
4 is toward elevator = west
7 is at nose cone = upstream = south

#	Horizontal Angle	#	Horizontal Angle
1	0^{o}	7	180^{o}
2	330^{o}	8	150^{o}
3	300^{o}	9	120^{o}
4	270^{o}	10	90^{o}
5	240^{o}	11	60^{o}
6	210^{o}	12	30^{o}

Appendix B.

MEASUREMENT NUMBER 1 ANGLES ARE A NORMAL WEEK FEB 20-24,1978 DISTANCE MEAS 1, FEB20-24,1978
-.90350 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12
A	.7436	329.7178	299.9861	271.3150	240.4800	210.4369	180.2175	149.4969	122.0189	92.4592	61.4914	30.5144
	47.6142	46.6458	47.6750	47.9153	48.0636	47.7997	47.9617	47.8133	48.0231	47.7606	47.4203	47.3870
	85.719	85.962	85.697	85.908	85.890	86.006	86.035	86.155	86.011	86.023	85.953	85.649
B	.3892	330.2281	299.7344	270.7469	240.1917	210.1061	180.1189	149.9825	122.1300	92.0903	61.3247	30.9261
	57.5283	57.5031	57.4622	57.4808	57.5820	57.7383	56.3972	57.8267	57.5864	57.6083	57.5736	57.3964
	82.904	82.874	82.840	83.065	83.084	83.176	78.309	83.297	83.325	83.302	83.331	82.906
C	.2300	331.3678	299.4436	270.4753	240.1075	209.9811	0.0000	149.9400	122.4172	92.2361	61.2969	30.9647
	67.5964	67.5936	67.8070	67.7981	67.8903	67.8006	0.0000	67.7525	67.6470	67.5595	67.6439	66.6211
	79.777	79.688	79.611	79.818	80.084	80.041	0.000	80.272	80.269	80.258	80.158	80.211
D	.2100	330.2197	300.0283	269.9022	240.0753	210.1050	0.0000	150.2050	120.4528	92.6625	61.6456	31.0836
	79.5231	79.4014	79.3836	79.3247	79.4775	79.4422	0.0000	79.8886	79.3967	79.5106	79.1186	79.2914
	75.937	75.971	75.915	76.147	76.211	76.274	0.000	76.252	76.510	76.334	76.422	76.187
E	.3008	330.6119	298.9056	270.8700	240.0931	211.0811	0.0000	150.2153	120.7208	92.3550	62.3117	31.1336
	90.2156	90.0553	90.3570	89.8403	90.2436	89.9875	0.0000	90.1111	90.1306	90.0033	90.1836	90.0497
	72.518	72.592	72.391	72.703	72.845	72.959	0.000	72.932	73.190	73.097	72.758	72.593
F	.5950	330.8006	299.6786	271.0833	241.3389	210.9286	181.1461	150.3819	119.5608	92.7936	62.2022	31.3044
	101.7000	101.9589	101.7811	101.7278	101.6483	101.6250	99.6161	101.7286	101.3561	101.6700	101.7070	101.7661
	69.141	68.945	69.087	69.037	69.304	69.355	65.711	69.478	69.753	69.423	69.337	69.175
G	.9411	330.9467	299.5928	270.9706	240.6375	210.9464	180.4478	150.3022	120.4347	92.9753	62.4344	31.5072
	114.8356	114.9189	114.8170	114.7320	114.4908	114.4497	114.3267	114.2453	114.1389	114.2675	114.5356	114.7295
	64.827	64.796	64.894	65.032	65.135	65.271	65.202	65.449	65.513	65.422	65.208	65.017
H	.5169	331.4675	299.5272	270.8281	240.8453	210.7942	180.3028	150.0834	120.0414	92.6469	61.9825	31.2333
	133.5167	130.5670	130.6217	130.4303	130.2820	130.2656	130.1347	129.8367	130.0922	129.8267	130.0561	129.9606
	63.025	63.103	63.096	63.076	63.225	63.207	63.077	63.258	63.275	63.250	63.176	63.106
I	1.1986	329.8061	299.1672	271.3806	240.4425	210.6108	180.4778	149.2278	120.6731	92.6175	61.6769	31.3375
	144.4658	144.7525	145.1767	144.8420	144.9617	144.6947	145.0372	144.9595	144.8964	144.8417	145.2342	145.1761
	65.287	65.404	65.555	65.477	65.553	65.457	65.560	65.537	65.570	65.584	65.688	65.581

	6	8
DD	204.7514	155.5572
	79.4014	79.4686
	72.787	72.781
N	180.0603	.0317
	148.0000	148.0000
	0.000	0.000

MEASUREMENT NUMBER 2 ANGLES ARE 3 INVERTED WEEK 20-24 FEB 1978. DIST=MEAS 2 MAR 4,1978
.01249 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12

MEASUREMENT NUMBER 2 ANGLES ARE 3 INVERTED WEEK 20-24 FEB 1978. DIST=MEAS 2 MAR 4,1978
.01249 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12
A	.7464	329.7178	293.9928	271.3139	240.4864	210.4386	180.2164	149.5008	122.0189	92.4494	61.4944	30.5117
	47.6203	46.6403	47.6667	47.9019	48.0575	47.7897	47.9439	47.7967	48.0103	47.7533	47.4153	47.3919
	85.746	85.984	85.716	85.875	85.866	85.940	85.979	86.115	86.024	86.022	85.952	85.661
B	.3903	330.2297	299.7392	270.7481	240.1964	210.1100	180.1239	149.9847	122.1281	92.0903	61.3294	30.9289
	57.5344	57.4953	57.4475	57.4722	57.5753	57.7350	56.3878	57.8180	57.5808	57.6022	57.5708	57.4022
	82.907	82.901	82.856	83.066	83.053	83.132	78.256	83.233	83.308	83.284	83.341	82.932
C	.2317	330.3692	299.4472	270.4742	240.1136	209.9856	0.0000	149.9386	122.4156	92.2308	61.2983	30.9639
	67.5950	67.5894	67.7994	67.7930	67.8844	67.7919	0.0000	67.7439	67.6405	67.5625	67.6486	66.6272
	79.795	79.713	79.625	79.820	80.044	79.992	0.000	80.207	80.229	80.223	80.165	80.218
D	.2106	330.2247	300.0328	269.9092	240.0789	210.1108	0.0000	150.2053	120.4533	92.6644	61.6486	31.0853
	73.5303	79.3992	79.3822	79.3225	79.4817	79.4308	0.0000	79.8800	79.3886	79.5094	79.1228	79.2997
	75.942	76.013	75.944	76.144	76.173	76.215	0.000	76.187	76.486	76.318	76.415	76.205
E	.3036	330.6169	298.9111	270.8789	240.0986	211.0839	0.0000	150.2186	120.7192	92.3539	62.3125	31.1358
	90.2269	90.0511	90.3567	89.8339	90.2453	89.9842	0.0000	90.1092	90.1169	90.0019	90.1833	90.0628
	72.586	72.635	72.406	72.716	72.803	72.908	0.000	72.961	73.171	73.103	72.780	72.607
F	.6003	330.8094	299.6794	271.0931	241.3453	210.9306	181.1467	150.3836	119.5639	92.7986	62.2064	31.3092
	101.7108	101.9508	101.7828	101.7292	101.6464	101.6286	99.6078	101.7242	101.3478	101.6655	101.7128	101.7747
	69.174	68.970	69.104	69.025	69.283	69.324	65.713	69.442	69.720	69.415	69.324	69.174
G	.9461	330.9547	299.6028	270.9775	240.6453	210.9486	180.4456	150.3028	120.4389	92.9767	62.4397	31.5133
	114.8494	114.9139	114.8255	114.7355	114.4967	114.4564	114.3253	114.2428	114.1355	114.2700	114.5380	114.7392
	64.875	64.832	64.916	65.040	65.119	65.277	65.197	65.426	65.510	65.422	65.240	65.059
H	.5275	330.4742	299.5350	270.8392	240.8581	210.8006	180.3081	150.0975	120.0428	92.6508	61.9911	31.2492
	130.5336	130.5742	130.6283	130.4378	130.2905	130.2719	130.1389	129.8380	130.0967	129.8361	130.0630	129.9794
	63.048	63.116	63.114	63.086	63.208	63.183	63.067	63.237	63.270	63.252	63.183	63.088
I	1.2036	329.8292	299.1789	271.4003	240.4600	210.6161	180.4808	149.2364	120.6933	92.6289	61.7014	31.3613
	144.4903	144.7569	145.1803	144.8458	144.9778	144.7008	145.0392	144.9678	144.8850	144.8533	145.2369	145.1983
	65.717	65.433	65.574	65.471	65.553	65.429	65.540	65.527	65.573	65.586	65.697	65.620

	6	8
DD	204.7597	155.5608
	79.3978	79.4475
	72.771	72.727
N	180.0431	.0753
	148.0000	148.0000
	0.000	0.000

MEASUREMENT NUMBER 3 ANGLES ARE 3 NORMAL WEEK FEB 20-24,1978. DIST=MEAS 3 MAR 4,1978
-.83730 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12

MEASUREMENT NUMBER 3 ANGLES ARE 3 NORMAL WEEK FEB 20-24,1978. DIST=MEAS 3 MAR 4,1978
-.83730 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12
A	.7425	329.7222	299.9908	271.3139	240.4825	210.4403	180.2131	149.4947	122.0244	92.4494	61.4919	30.5094
	47.6222	46.6455	47.6816	47.9053	48.0680	47.7958	47.9514	47.8066	48.0244	47.7655	47.4225	47.3961
	85.752	85.989	85.714	85.877	85.866	85.938	85.983	86.107	86.017	86.020	85.961	85.662
B	.3878	330.2306	299.7386	270.7444	240.1933	210.1053	180.1178	149.9792	122.1269	92.0861	61.3250	30.9283
	57.5328	57.4958	57.4541	57.4830	57.5841	57.7411	56.3941	57.8258	57.5875	57.6086	57.5775	57.4053
	82.913	82.895	82.859	83.067	83.063	83.129	78.247	83.235	83.306	83.284	83.338	82.938
C	.2311	330.3700	299.4436	270.4694	240.1106	209.9800	0.0000	149.9353	122.4167	92.2303	61.2964	30.9633
	67.5911	67.5936	67.8066	67.7950	67.8900	67.8016	0.0000	67.7539	67.6411	67.5686	67.6528	66.6264
	79.796	79.706	79.623	79.816	80.044	79.991	0.000	80.211	80.231	80.224	80.166	80.221
D	.2072	330.2233	300.0272	269.9031	240.0750	210.1019	0.0000	150.2019	120.4467	92.6614	61.6447	31.0839
	79.5278	79.3958	79.3850	79.3222	79.4811	79.4344	0.0000	79.8847	79.3941	79.5133	79.1211	79.2980
	75.941	76.013	75.941	76.146	76.179	76.239	0.000	76.185	76.484	76.321	76.415	76.200
E	.3025	330.6150	298.9100	270.8719	240.0928	211.0734	0.0000	150.2117	120.7161	92.3506	62.3067	31.1347
	90.2186	90.0505	90.3619	89.8436	90.2436	89.9847	0.0000	90.1080	90.1275	90.0040	90.1869	90.0555
	72.586	72.636	72.410	72.713	72.809	72.906	0.000	72.968	73.170	73.101	72.784	72.606
F	.5964	330.8025	299.6764	271.0867	241.3400	210.9244	181.1422	150.3781	119.5622	92.7961	62.2031	31.3014
	101.7061	101.9466	101.7861	101.7286	101.6450	101.6258	99.6061	101.7236	101.3455	101.6678	101.7058	101.7700
	69.173	68.969	69.108	69.020	69.282	69.319	65.713	69.441	69.722	69.421	69.325	69.176
G	.9447	330.9483	299.5972	270.9731	240.6347	210.9425	180.4433	150.2937	120.4322	92.9739	62.4347	31.5050
	114.8375	114.9130	114.8169	114.7344	114.4908	114.4525	114.3241	114.2386	114.1347	114.2694	114.5355	114.7322
	64.871	64.828	64.916	65.037	65.114	65.278	65.197	65.423	65.511	65.421	65.239	65.057
H	.5217	330.4653	299.5247	270.8306	240.8428	210.7878	180.2975	150.0894	120.0372	92.6397	61.9822	31.2317
	130.5194	130.5619	130.6186	130.4333	130.2894	130.2664	130.1311	129.8383	130.0853	129.8286	130.0619	129.9636
	63.050	63.119	63.114	63.085	63.207	63.180	63.068	63.235	63.270	63.254	63.181	63.096
I	1.1897	329.8133	299.1675	271.3853	240.4506	210.6039	180.4692	149.2200	120.6786	92.6131	61.6886	31.3439
	144.4586	144.7530	145.1622	144.8466	144.9664	144.6989	145.0344	144.9603	144.8875	144.8405	145.2319	145.1841
	65.317	65.432	65.575	65.475	65.547	65.432	65.541	65.528	65.577	65.585	65.693	65.624

	6	8
DD	204.7547	155.5581
	79.4003	79.4583
	72.769	72.729
N	180.0278	.0658
	148.0000	148.0000
	0.000	0.000

********** DO NOT MIX DATA ON THIS PAGE WITH DATA FROM OTHER PAGES WHEN DETERMINING YOUR OPTICAL CONSTANTS. **********
SUPVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

AVERAGE OF 1973 AND 1978 SURVEY FIDUCIAL POSITIONS (WARM) EXPRESSED IN THE 1973 SURVEY COORDINATE SYSTEM

MEASUREMENT NUMBER 4 ANGLES ARE A INVERTED WEEK 20-24 FEB 1978
.82739 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12
A	.7444	329.7200	299.9889	271.3175	240.4861	210.4428	180.2150	149.4919	122.0200	92.4517	61.4975	30.5142
	47.6185	46.8316	47.6746	47.9035	48.0563	47.7952	47.9438	47.8029	48.0213	47.7713	47.4149	47.3896
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	.3892	330.2281	299.7361	270.7489	240.1997	210.1056	180.1228	149.9844	122.1294	92.0894	61.3319	30.9311
	57.5327	57.4910	57.4543	57.4743	57.5763	57.7318	56.3841	57.8188	57.5849	57.6104	57.5771	57.4049
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C	.2342	330.3686	299.4492	270.4761	240.1100	209.9836	0.0000	149.9394	122.4189	92.2367	61.2992	30.9664
	67.5960	67.5766	67.7857	67.7933	67.8807	67.7929	0.0000	67.7446	67.6379	67.5707	67.6513	66.6110
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D	.2133	330.2228	300.0350	269.9033	240.0767	210.1086	0.0000	150.2061	120.4531	92.6650	61.6525	31.0875
	79.5313	79.3849	79.3696	79.3224	79.4757	79.4327	0.0000	79.8838	79.3929	79.5110	79.1254	79.2921
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E	.3033	330.6153	299.9106	270.8736	240.0953	211.0844	0.0000	150.2200	120.7253	92.3539	62.3164	31.1411
	91.2238	90.0416	90.3482	89.8407	90.2327	89.9810	0.0000	90.1068	90.1204	90.0096	90.1927	90.0610
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F	.6017	330.8061	299.6831	271.0911	241.3411	210.9317	181.1489	150.3836	119.5681	92.8017	62.2078	31.3108
	101.7116	101.9427	101.7754	101.7307	101.6410	101.6221	99.6066	101.7229	101.3502	101.6666	101.7166	101.7738
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
G	.9422	330.9494	299.6006	270.9744	240.6419	210.9483	180.4531	150.3106	120.4450	92.9789	62.4419	31.5136
	114.8463	114.9141	114.8116	114.7318	114.4996	114.4538	114.3188	114.2391	114.1388	114.2696	114.5443	114.7443
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
H	.5247	330.4678	299.5375	270.8344	240.8494	210.8008	180.3158	150.1050	120.0572	92.6553	61.9922	31.2386
	130.5360	130.5616	130.6224	130.4366	130.2966	130.2677	130.1366	129.8391	130.1054	129.8429	130.0738	129.9793
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I	1.1933	329.8231	299.1744	271.3886	240.4517	210.6183	180.4900	149.2469	120.6828	92.6292	61.6911	31.3508
	144.4838	144.7543	145.1724	144.8491	144.9791	144.6988	145.0393	144.9713	144.8991	144.8591	145.2499	145.2010
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	6	8
DD	204.7578	155.5650
	73.3946	79.4568
	0.000	0.000
N	180.0775	.0350
	148.0000	148.0000
	0.000	0.000

MEASUREMENT NUMBER 5 VERTICAL ANGLES MEAS 1 MAR 1,1978
0.00000 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12
A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

MEASUREMENT NUMBER 5 VERTICAL ANGLES MEAS 1 MAR 1,1978
0.00000 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12
A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	47.6308	46.6581	47.6858	47.9119	48.0578	47.7861	47.9447	47.8044	48.0106	47.7597	47.4269	47.4003
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	57.5397	57.5089	57.4614	57.4814	57.5775	57.7292	56.3861	57.8219	57.5836	57.6089	57.5794	57.4078
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	67.5972	67.5975	67.8092	67.7933	67.8853	67.7933	0.0000	67.7464	67.6372	67.5706	67.6533	66.6303
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	79.5289	79.4036	79.3836	79.3261	79.4744	79.4378	0.0000	79.8806	79.3919	79.5167	79.1231	79.3006
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	90.2211	90.0497	90.3517	89.8372	90.2439	89.9883	0.0000	90.1119	90.1219	90.0117	90.1850	90.0525
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	101.7042	101.9444	101.7803	101.7289	101.6461	101.6292	99.6114	101.7314	101.3481	101.6700	101.7139	101.7633
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	114.8353	114.9019	114.8114	114.7306	114.4900	114.4558	114.3350	114.2458	114.1453	114.2747	114.5344	114.7264
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
H	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	130.5111	130.5531	130.6153	130.4286	130.2864	130.2775	130.1506	129.8456	130.1011	129.8317	130.0550	129.9567
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	144.4567	144.7422	145.1639	144.8372	144.9703	144.7114	145.0494	144.9689	144.8931	144.8489	145.2303	145.1739
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	6	8
DD	0.0000	0.0000
	79.3983	79.4492
	0.000	0.000
N	0.0000	0.0000
	148.0000	148.0000
	0.000	0.000

MEASUREMENT NUMBER 6 VERTICAL ANGLES MEAS 2 MAR 1,1978
0.00030 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12
A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	47.6300	46.6519	47.6906	47.9103	48.0506	47.7933	47.9500	47.8053	48.0181	47.7603	47.4244	47.3972
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	57.5383	57.5022	57.4603	57.4811	57.5814	57.7350	56.3983	57.8208	57.5822	57.6075	57.5767	57.4036
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	67.5964	67.5922	67.8053	67.7958	67.8861	67.7986	0.0000	67.7434	67.6361	67.5678	67.6514	66.6289
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	79.5283	79.4019	79.3847	79.3222	79.4800	79.4342	0.0000	79.8883	79.3925	79.5192	79.1172	79.2964
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	90.2197	90.0478	90.3533	89.8381	90.2411	89.9889	0.0000	90.1119	90.1175	90.0078	90.1836	90.0514
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	101.7025	101.9458	101.7819	101.7292	101.6444	101.6314	99.6164	101.7319	101.3492	101.6703	101.7064	101.7683
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	114.8344	114.9078	114.8125	114.7264	114.4931	114.4569	114.3331	114.2456	114.1389	114.2725	114.5300	114.7297
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
H	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	130.5125	130.5506	130.6169	130.4261	130.2864	130.2750	130.1483	129.8469	130.0964	129.8347	130.0514	129.9636
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	144.4550	144.7406	145.1631	144.8358	144.9717	144.7078	145.0469	144.9733	144.8961	144.8467	145.2339	145.1681
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	6	8
DD	0.0000	0.0000
	79.4019	79.4486
	0.000	0.000
N	0.0000	0.0000
	148.0000	148.0000
	0.000	0.000

MEASUREMENT NUMBER 7 ANGLES ARE AVERAGES OF MEAS 1 AND 4. DISTANCES ARE MEAS 2.
0.00010 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12

MEASUREMENT NUMBER 7 ANGLES ARE AVERAGES OF MEAS 1 AND 4. DISTANCES ARE MEAS 2.
0.00010 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12
A	.7440	329.7189	299.9875	271.3163	240.4831	210.4399	180.2163	149.4944	122.0194	92.4554	61.4944	30.5143
	47.6163	46.6387	47.6748	47.9119	48.0600	47.7975	47.9527	47.8081	48.0222	47.7659	47.4176	47.3883
	85.746	85.984	85.715	85.875	85.866	85.940	85.979	86.115	86.024	86.022	85.952	85.661
B	.3892	330.2281	299.7353	270.7479	240.1957	210.1058	180.1208	149.9835	122.1297	92.0899	61.3283	30.9286
	57.5305	57.4970	57.4533	57.4776	57.5791	57.7351	56.3906	57.8227	57.5856	57.6094	57.5754	57.4006
	82.907	82.901	82.856	83.066	83.053	83.132	78.256	83.233	83.308	83.284	83.341	82.932
C	.2321	330.3682	299.4464	270.4757	240.1088	209.9824	0.0000	149.9397	122.4181	92.2364	61.2981	30.9656
	67.5912	67.5851	67.7963	67.7959	67.8855	67.7968	0.0000	67.7486	67.6425	67.5651	67.6476	66.6161
	79.795	79.713	79.625	79.820	80.044	79.992	0.000	80.207	80.229	80.223	80.165	80.218
D	.2117	330.2213	300.0317	269.9028	240.0760	210.1068	0.0000	150.2056	120.4529	92.6637	61.6490	31.0856
	79.5272	79.3931	79.3766	79.3236	79.4766	79.4375	0.0000	79.8862	79.3948	79.5108	79.1220	79.2918
	75.942	76.013	75.944	76.144	76.173	76.215	0.000	76.197	76.486	76.318	76.415	76.205
E	.3021	330.6136	298.9081	270.8718	240.0942	211.0828	0.0000	150.2176	120.7231	92.3544	62.3140	31.1374
	90.2197	90.0484	90.3526	89.8405	90.2381	89.9843	0.0000	90.1090	90.1255	90.0065	90.1881	90.0554
	72.586	72.635	72.406	72.716	72.803	72.908	0.000	72.961	73.171	73.103	72.780	72.607
F	.5983	330.8033	299.6808	271.0872	241.3400	210.9301	181.1475	150.3828	119.5644	92.7976	62.2050	31.3076
	101.7058	101.9508	101.7783	101.7293	101.6447	101.6236	99.6113	101.7258	101.3531	101.6683	101.7118	101.7700
	69.174	68.970	69.104	69.025	69.283	69.324	65.713	69.442	69.720	69.415	69.324	69.174
G	.9417	330.9481	299.5967	270.9725	240.6397	210.9474	180.4504	150.3064	120.4399	92.9771	62.4382	31.5104
	114.8409	114.9165	114.8143	114.7319	114.4952	114.4518	114.3227	114.2422	114.1388	114.2686	114.5400	114.7369
	64.875	64.832	64.916	65.040	65.119	65.277	65.197	65.426	65.510	65.422	65.240	65.059
H	.5208	330.4676	299.5324	270.8313	240.8474	210.7975	180.3093	150.0972	120.0493	92.6511	61.9874	31.2360
	130.5263	130.5643	130.6220	130.4334	130.2893	130.2666	130.1356	129.8379	130.0988	129.8348	130.0650	129.9700
	63.048	63.116	63.114	63.086	63.208	63.183	63.067	63.237	63.270	63.252	63.183	63.088
I	1.1960	329.8146	299.1708	271.3846	240.4471	210.6146	180.4839	149.2374	120.6779	92.6233	61.6840	31.3442
	144.4748	144.7534	145.1745	144.8455	144.9704	144.6968	145.0383	144.9654	144.8977	144.8504	145.2420	145.1886
	55.317	65.433	65.574	65.471	65.553	65.429	65.540	65.527	65.573	65.586	65.697	65.620

	6	8
DD	204.7546	155.5611
	79.3980	79.4627
	72.771	72.727
N	180.0431	.0753
	0.0000	0.0000
	0.000	0.000

********** DO NOT MIX DATA ON THIS PAGE WITH DATA FROM OTHER PAGES WHEN DETERMINING YOUR OPTICAL CONSTANTS. **********
SUPVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

MEASUREMENT NUMBER 8 ANGLES ARE AVERAGES OF MEAS 2 AND 3. DISTANCES ARE MEAS 3.
0.00000 DEG HAS BEEN ADDED TO VERTICAL ANGLES
MEASURED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12
A	.7444	329.7200	299.9918	271.3139	240.4844	210.4394	180.2147	149.4978	122.0217	92.4494	61.4932	30.5106
	47.6212	46.6429	47.6742	47.9036	48.0628	47.7928	47.9476	47.8017	48.0173	47.7594	47.4189	47.3940
	85.752	85.989	85.714	85.877	85.866	85.933	85.983	86.107	86.017	86.020	85.961	85.662
B	.3890	330.2301	299.7389	270.7463	240.1949	210.1076	180.1208	149.9319	122.1275	92.0882	61.3272	30.9286
	57.5336	57.4955	57.4508	57.4776	57.5797	57.7380	56.3910	57.8219	57.5842	57.6054	57.5742	57.4037
	82.913	82.895	82.859	83.067	83.063	83.129	78.247	83.235	83.306	83.284	83.338	82.938
C	.2314	330.3696	299.4454	270.4718	240.1121	209.9828	0.0000	149.9369	122.4161	92.2306	61.2974	30.9636
	67.5930	67.5915	67.8030	67.7940	67.8872	67.7968	0.0000	67.7489	67.6408	67.5655	67.6507	66.6268
	79.796	79.706	79.623	79.816	80.044	79.991	0.000	80.211	80.231	80.224	80.166	80.221
D	.2089	330.2240	300.0300	269.9061	240.0769	210.1064	0.0000	150.2036	120.4500	92.6629	61.6467	31.0846
	79.5290	79.3975	79.3836	79.3223	79.4814	79.4326	0.0000	79.8823	79.3914	79.5114	79.1219	79.2989
	75.941	76.013	75.941	76.146	76.179	76.209	0.000	76.135	76.484	76.321	76.415	76.200
E	.3031	330.6160	298.9106	270.8754	240.0957	211.0817	0.0000	150.2151	120.7176	92.3522	62.3096	31.1353
	99.2228	90.0508	90.3593	89.8387	90.2444	89.9844	0.0000	90.1086	90.1222	90.0050	90.1851	90.0592
	72.586	72.636	72.410	72.713	72.809	72.906	0.000	72.968	73.170	73.101	72.784	72.606
F	.5983	330.8060	299.6779	271.0899	241.3426	210.9275	181.1444	150.3808	119.5631	92.7974	62.2047	31.3053
	101.7085	101.9487	101.7844	101.7289	101.6457	101.6272	99.6069	101.7239	101.3467	101.6667	101.7093	101.7723
	69.173	68.969	69.108	69.020	69.282	69.319	65.713	69.441	69.722	69.421	69.325	69.176
G	.9454	330.9515	299.6000	270.9753	240.6400	210.9456	180.4444	150.3013	120.4356	92.9753	62.4372	31.5092
	114.8435	114.9135	114.8212	114.7350	114.4937	114.4544	114.3247	114.2407	114.1351	114.2697	114.5368	114.7357
	64.971	64.828	64.916	65.037	65.114	65.278	65.197	65.423	65.511	65.421	65.239	65.057
H	.5246	330.4697	299.5299	270.8349	240.8504	210.7942	180.3028	150.0935	120.0400	92.6453	61.9867	31.2404
	130.5265	130.5680	130.6235	130.4355	130.2900	130.2692	130.1350	129.8382	130.0910	129.8323	130.0625	129.9715
	63.050	63.119	63.114	63.095	63.207	63.180	63.068	63.235	63.270	63.254	63.181	63.096
I	1.1967	329.8213	299.1732	271.3928	240.4553	210.6100	180.4750	149.2282	120.6860	92.6210	61.6950	31.3521
	144.4744	144.7550	145.1712	144.8462	144.9721	144.6998	145.0368	144.9640	144.8862	144.8469	145.2344	145.1912
	65.317	65.432	65.575	65.475	65.547	65.432	65.541	65.528	65.577	65.585	65.693	65.624

	6	8
DD	204.7572	155.5594
	79.3990	79.4529
	72.769	72.729
N	180.0278	.0658
	3.0000	0.0000
	0.000	0.000

SURVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

THE FOLLOWING AVERAGES COME FROM:

MEASUREMENT NUMBER 1 ANGLES ARE A NORMAL WEEK FEB 20-24,1978 DISTANCE MEAS 1, FEB20-24,1978
MEASUREMENT NUMBER 2 ANGLES ARE A INVERTED WEEK 20-24 FEB 1978 DIST=MEAS 2 MAR 6 1978

SURVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

THE FOLLOWING AVERAGES COME FROM:

MEASUREMENT NUMBER 1 ANGLES ARE A NORMAL WEEK FEB 20-24,1978 DISTANCE MEAS 1, FEB20-24,1978
MEASUREMENT NUMBER 2 ANGLES ARE B INVERTED WEEK 20-24 FEB 1978. DIST=MEAS 2 MAR 4,1978
MEASUREMENT NUMBER 3 ANGLES ARE B NORMAL WEEK FEB 20-24,1978. DIST=MEAS 3 MAR 4,1978
MEASUREMENT NUMBER 4 ANGLES ARE A INVERTED WEEK 20-24 FEB 1978
MEASUREMENT NUMBER 5 VERTICAL ANGLES MEAS 1 MAR 1,1978
MEASUREMENT NUMBER 6 VERTICAL ANGLES MEAS 2 MAR 1,1978
MEASUREMENT NUMBER 7 ANGLES ARE AVERAGES OF MEAS 1 AND 4. DISTANCES ARE MEAS 2.
MEASUREMENT NUMBER 8 ANGLES ARE AVERAGES OF MEAS 2 AND 3. DISTANCES ARE MEAS 3.

MEASUREMENTS 7 AND 8 ARE AVERAGES OF THE ACTUAL MEASUREMENTS (1-6) AS FOLLOWS:

MEASURE	HORIZONTAL ANGLE	VERTICAL ANGLE	DISTANCE
7	0.5*(M1+M4)	0.5*(M1+M4)	M2
8	0.5*(M2+M3)	0.5*(M2+M3)	M3

ANGLES AND DISTANCES ARE THE AVERAGE OF MEASUREMENTS 7 AND 8. THE ERROR IS MEASURE 7 MINUS THE AVERAGE. THE BALL RADIUS OF 0.500 INCH IS INCLUDED IN THE DISTANCE.

MEASURE 1 DISTANCES WERE MADE WITH THE BALL IN A SLIGHTLY DIFFERENT POSITION (ABOUT 25-30 MILS NORTH) AND POOR SETTING OF THE STICK MIKE ON THE FIDUCIAL, SO THEY ARE NOT USED.

THE ZERO OF THE VERTICAL ANGLE SCALE WAS UNCORRECTLY SET FOR MEASUREMENTS 1 THROUGH 4. THESE MEASUREMENTS WERE CORRECTED AS SHOWN USING THE AVERAGE ZERO OF MEASURES 5 AND 6. THERE ARE STILL REMAINING SYSTEMATIC VARIATIONS BETWEEN THE FIRST 4 AND THE LAST 2 VERTICAL ANGLE MEASUREMENTS. FOR EXAMPLE, THE DIFFERENCE BETWEEN THE AVERAGE OF MEASURES 1 AND 4 AND MEASURE 5 HAS A SIGMA OF 10 MIL (AT A 75 INCH RADIUS).
MEASUREMENTS 1-4 ARE USED BECAUSE THEY GIVE A LOWER RMS WHEN COMPARED TO SURVEY 1 THAN THE AVERAGE OF M5 AND M6

.0706 DEG HAS BEEN SUBTRACTED FROM THE HORIZONTAL ANGLE AVERAGE TO DEFINE ZERO AS THE SCRIBE MARK ON THE NORTH END OF THE SURVEY PLATFORM I BEAM (CALLED N 8 HERE).

MEASURED POSITION OF BALL CENTER RELATIVE TO T2 POSITION.

	X	Y	Z
ORIGIONAL COORDINATE SYSTEM	-.1610	.0016	-.7551
ROTATED COORDINATE SYSTEM	-.1610	.0014	-.7551

THE NOMINAL CHAMBER CENTER (IN Z) WAS TAKEN TO BE 17.3440 INCHES ABOVE T2 POSITION.

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SUPVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

AVERAGE OF 1973 AND 1978 SURVEY FIDUCIAL POSITIONS (MARM) EXPRESSED IN THE 1973 [illegible]

SURVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

AVERAGED HORIZONTAL ANGLE (DEG)/ VERTICAL ANGLE (DEG)/ BALL TO FIDUCIAL DISTANCE (INCHES) FOR EACH FIDUCIAL.

	1	2	3	4	5	6	7	8	9	10	11	12
A	.6737	329.6489	299.9191	271.2445	240.4132	210.3691	180.1449	149.4256	121.9500	92.3819	61.4233	30.4419
	47.6188	46.6408	47.6745	47.9077	48.0614	47.7951	47.9502	47.8049	48.0198	47.7627	47.4182	47.3911
	85.749	85.987	85.715	85.876	85.866	85.939	85.981	86.111	86.021	86.021	85.957	85.661
B	.3185	330.1585	299.6665	270.6765	240.1247	210.0362	180.0503	149.9122	122.0581	92.0185	61.2572	30.8581
	57.5321	57.4963	57.4546	57.4776	57.5794	57.7366	56.3908	57.8223	57.5843	57.6074	57.5748	57.4022
	82.910	82.898	82.858	83.067	83.058	83.131	78.252	83.234	83.307	83.284	83.340	82.935
C	.1612	330.2983	299.3753	270.4032	240.0399	209.9120	0.0000	149.8678	122.3465	92.1629	61.2272	30.8940
	67.5921	67.5883	67.7997	67.7950	67.8864	67.7958	0.0000	67.7487	67.6416	57.5653	67.6491	66.6214
	79.796	79.710	79.624	79.818	80.044	79.992	0.000	80.209	80.230	80.224	80.166	80.219
D	.1397	330.1521	299.9603	269.8339	240.0059	210.0360	0.0000	150.1340	120.3809	92.5928	61.5773	31.0145
	73.5281	79.3953	79.3801	79.5230	79.4790	79.4350	0.0000	79.8843	79.3931	79.5111	79.1220	79.2953
	75.942	76.013	75.943	76.145	76.176	76.212	0.000	76.186	76.485	76.320	76.415	76.203
E	.2320	330.5442	293.8338	270.8031	240.0244	211.0117	0.0000	150.1458	120.6498	92.2828	62.2413	31.0658
	90.2212	90.0496	90.3559	89.8396	90.2413	89.9843	0.0000	90.1088	90.1239	90.0057	90.1866	90.0573
	72.586	72.636	72.408	72.715	72.806	72.907	0.000	72.965	73.171	73.102	72.782	72.607
F	.5278	330.7341	299.6088	271.0180	241.2708	210.8533	181.0754	150.3113	119.4932	92.7269	62.1343	31.2359
	101.7071	101.9498	101.7814	101.7291	101.6452	101.6254	99.6091	101.7248	101.3499	101.6675	101.7105	101.7711
	69.174	68.970	69.108	69.023	69.283	69.322	65.713	69.442	69.721	69.418	69.325	69.175
G	.8730	330.8792	299.5278	270.9033	240.5693	210.8759	180.3769	150.2333	120.3672	92.9056	62.3672	31.4392
	114.8422	114.9150	114.8177	114.7334	114.4945	114.4531	114.3237	114.2414	114.1370	114.2691	114.5384	114.7363
	64.873	64.830	64.916	65.039	65.117	65.278	65.197	65.425	65.511	65.422	65.240	65.058
H	.4522	330.3981	299.4606	270.7625	240.7783	210.7253	180.2355	150.0248	119.9741	92.5776	61.9165	31.1676
	131.5264	130.5661	130.6227	130.4345	130.2896	130.2679	130.1353	129.8380	130.0949	129.8336	130.0637	129.9707
	63.049	63.118	63.114	63.086	63.208	63.182	63.068	63.236	63.270	63.253	63.182	63.092
I	1.1258	329.7474	299.1015	271.3181	240.3806	210.5417	180.4089	149.1622	120.6114	92.5516	61.6190	31.2776
	144.4746	144.7542	145.1729	144.8459	144.9712	144.6983	145.0375	144.9647	144.8920	144.8486	145.2382	145.1899
	55.317	65.433	65.575	65.473	65.550	65.431	65.541	65.528	65.575	65.586	65.695	65.622

	6	8
DD	204.6853	155.4897
	73.3995	79.4578
	72.770	72.728
M	173.9649	0.0000
	0.0000	0.0000
	0.000	0.000

SURVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

ERRORS IN THE HORIZONTAL ANGLE AVERAGE (MILLIDEGREES)/ VERTICAL ANGLE AVERAGE (MILLIDEGREES)/
AND BALL TO FIDUCIAL DISTANCE AVERAGE (MILLS) FOR EACH FIDUCIAL

SURVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

ERRORS IN THE HORIZONTAL ANGLE AVERAGE (MILLIDEGREES)/ VERTICAL ANGLE AVERAGE (MILLIDEGREES)/
AND BALL TO FIDUCIAL DISTANCE AVERAGE (MILLS) FOR EACH FIDUCIAL

	1	2	3	4	5	6	7	8	9	10	11	12
A	.21	.56	2.15	-1.18	.69	-.21	-.76	1.67	1.11	-2.99	-.63	-1.88
	2.45	2.10	-.33	-4.15	1.41	-2.34	-2.55	-3.25	-2.41	-3.25	.64	2.86
	-3.0	-2.5	1.0	-1.0	0.0	1.0	-2.0	4.0	3.5	1.0	-4.5	-.5
B	-.07	1.04	1.81	-.83	-.42	.90	0.00	-.76	-1.11	-.83	-.56	-.00
	1.54	-.75	-3.73	.02	.29	1.47	.15	-.40	-.75	-2.00	-.61	1.54
	-3.0	3.0	-1.5	-.5	-5.0	1.5	4.5	-1.0	1.0	0.0	1.5	-3.0
C	-.35	.69	-.49	-1.94	1.67	.21	0.00	-1.39	-.97	-2.92	-.35	-.97
	.92	3.21	3.35	-.96	.85	.02	0.00	.16	-.82	.22	1.54	5.36
	-.5	3.5	1.0	2.0	0.0	.5	0.0	-2.0	-1.0	-.5	-.5	-1.5
D	-1.39	1.39	-.83	1.67	.49	-.21	0.00	-.97	-1.46	-.42	-1.18	-.49
	.92	2.17	3.49	-.61	2.38	-2.41	0.00	-1.93	-1.72	.29	-.05	3.56
	.5	0.0	1.5	-1.0	-3.0	3.0	0.0	1.0	1.0	-1.5	0.0	2.5
E	.49	1.18	1.25	1.81	.75	-.56	0.00	-1.25	-2.71	-1.11	-2.22	-1.04
	1.54	1.20	3.35	-.89	3.14	.09	0.00	-.19	-1.65	-.75	-1.51	1.89
	0.0	-.5	-2.0	1.5	-3.0	1.0	0.0	-3.5	.5	1.0	-2.0	.5
F	.00	1.32	-1.46	1.32	1.32	-1.32	-1.53	-.97	-.69	-.14	-.14	-1.18
	1.34	-1.03	3.07	-.19	.50	1.82	-2.21	-.96	-3.25	-.82	-1.23	1.20
	.5	.5	-2.0	2.5	.5	2.5	0.0	.5	-1.0	-3.0	-.5	-1.0
G	1.87	1.74	1.67	1.39	.14	-.90	-2.99	-2.57	-2.15	-.90	-.49	-.62
	1.27	-1.51	3.49	1.54	-.75	1.34	.99	-.75	-1.86	.57	-1.58	-.61
	2.0	2.0	0.0	1.5	2.5	-.5	0.0	1.5	-.5	.5	.5	1.0
H	1.87	1.04	-1.25	1.81	1.53	-1.67	-3.26	-1.87	-4.65	-2.92	-.35	2.22
	.09	1.89	.71	1.06	.36	1.27	-.33	.16	-3.94	-1.23	-1.23	.78
	-1.0	-1.5	0.0	.5	.5	1.5	-.5	1.0	0.0	-1.0	1.0	-4.0
I	.35	3.33	1.18	4.10	4.10	-2.29	-4.44	-4.58	4.03	-1.18	5.49	3.96
	-.19	.78	-1.65	.36	.85	1.54	-.75	-.68	-5.75	-1.72	-3.80	1.34
	0.0	.5	-.5	-2.0	3.0	-1.5	-.5	-.5	-2.0	.5	2.0	-2.0

	6	8
DD	1.32	-.83
	.50	-4.91
	1.0	-1.0
N	-7.64	-4.72
	0.00	0.00
	0.0	0.0

********** DO NOT MIX DATA ON THIS PAGE WITH DATA FROM OTHER PAGES WHEN DETERMINING YOUR OPTICAL CONSTANTS

SURVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978
DO NOT USE THESE VALUES FOR YOUR OPTICAL CONSTANTS BECAUSE THEY ARE NOT EXPRESSED IN THE SAME COORDINATE SYSTEM AS THE 1973 SURVEY

POSITION OF EACH FIDUCIAL (WARM) RELATIVE TO NOMINAL CHAMBER CENTER. X/Y/Z/R (INCHES).

	1	2	3	4	5	6	7	8	9	10	11	12
A	62.8717	53.5602	31.3987	1.3759	-31.3723	-54.6645	-53.5574	-54.6668	-33.6636	-2.6313	30.0734	53.9646
	-.7393	31.3622	54.5620	63.3325	55.2548	32.0318	.1608	-32.2969	-53.9778	-63.2580	-55.2119	-31.7139
	41.0319	41.2660	39.9887	39.8793	39.7445	40.1154	39.9837	40.2194	39.8953	40.1397	40.4320	40.2315
	74.5383	74.5330	74.5787	74.8549	74.9463	74.9900	75.0883	75.1608	75.0898	74.9646	74.7497	74.4078
B	63.4913	60.2586	34.3723	.8229	-34.7813	-60.6447	-64.9312	-60.7460	-37.1771	-2.4650	33.6357	59.5994
	-.3864	34.5683	60.3430	69.6904	60.5470	35.0643	.0570	-35.1960	-59.3618	-69.9406	-61.3282	-35.6103
	25.8729	26.9195	26.9754	27.0951	27.0041	26.8785	25.8112	26.8287	27.1323	27.0565	27.0886	27.0530
	74.5073	74.5032	74.5010	74.7768	74.8659	75.0316	69.8733	75.1572	75.1140	75.0321	75.0087	74.5121
C	73.3641	63.6798	35.9988	.5181	-36.9351	-64.0670	0.0000	-64.0753	-39.5941	-2.7886	35.5263	62.8480
	-.2064	36.3197	63.9520	73.5297	64.0764	36.8581	0.0000	-37.1913	-62.5192	-73.8338	-64.6946	-37.6049
	12.9064	12.8862	12.6055	12.7120	12.7083	12.8241	0.0000	12.9676	13.0947	13.1621	13.0031	14.3170
	74.4910	74.4254	74.4625	74.7208	75.0433	75.0171	0.0000	75.2131	75.1520	75.0497	74.9439	74.6256
D	74.3825	64.5660	37.1677	-.2165	-37.4108	-64.8551	0.0000	-65.0411	-37.9892	-3.3888	35.6139	63.9361
	-.1814	37.0490	64.4796	74.6870	64.8128	37.4985	0.0000	-37.3489	-64.8005	-74.8343	-65.8042	-38.4387
	-3.5957	-3.4065	-3.3890	-3.2627	-3.4458	-3.3714	0.0000	-3.9629	-3.2772	-3.4750	-2.9651	-3.2416
	74.4696	74.5184	74.5020	74.7585	74.9142	74.9913	0.0000	75.1065	75.1866	74.9916	74.8821	74.6717
E	72.4228	63.1219	34.8885	1.0190	-36.4162	-62.6012	0.0000	-63.4000	-37.3415	-2.9118	33.8618	62.0714
	-.2933	35.6484	63.3604	72.7000	63.1368	37.6319	0.0000	-36.3891	-63.0159	-73.0450	-64.3368	-37.3933
	-17.6236	-17.4068	-17.7933	-17.1405	-17.6509	-17.3240	0.0000	-17.4828	-17.5023	-17.3513	-17.5808	-17.4154
	74.5369	74.5532	74.4872	74.7002	74.9930	75.0679	0.0000	75.1623	75.3108	75.1340	74.7992	74.5282
F	67.7231	58.8755	33.4597	1.2032	-32.7228	-58.5268	-65.0565	-59.3104	-33.7606	-3.2416	31.7618	57.9154
	-.6238	32.9933	58.8787	67.7154	59.6970	34.9697	1.2212	-33.8146	-59.6881	-68.0580	-60.0745	-35.1245
	-31.3781	-31.6276	-31.4688	-31.4052	-31.3742	-31.3704	-28.3601	-31.5134	-31.1086	-31.4138	-31.4296	-31.4538
	74.6418	74.5331	74.6762	74.6533	74.9590	75.0491	70.9798	75.1948	75.3007	75.0282	74.8704	74.6832
G	59.0147	51.5124	29.1471	.9358	-29.2878	-51.3415	-59.8228	-52.1276	-30.3972	-3.0377	27.6269	50.5583
	-.3992	28.6959	51.4591	59.3473	51.9125	30.6979	.3935	-29.8136	-51.8790	-59.8479	-52.7718	-30.9084
	-44.6685	-44.7338	-44.6929	-44.6861	-44.5003	-44.5459	-44.3854	-44.3842	-44.2873	-44.3623	-44.5380	-44.6450
	74.0190	74.0142	74.1286	74.2955	74.3839	74.5832	74.4915	74.6732	74.6779	74.5588	74.3757	74.1933
H	48.1996	41.9415	23.7207	.6439	-23.7411	-41.8306	-48.6811	-42.4528	-24.3893	-2.2012	22.9162	41.6138
	-.3804	23.8279	41.9937	48.3833	42.4420	24.8622	.2001	-24.4857	-42.2876	-48.8957	-42.9480	-25.1732
	-58.5501	-58.6391	-58.7154	-58.5753	-58.5708	-58.5650	-58.3889	-58.2311	-58.4441	-58.1722	-58.2832	-58.1152
	75.8384	75.9303	75.9845	75.9765	76.1282	76.1432	76.0208	76.1095	76.1498	76.0239	75.9382	75.7838
I	38.2472	32.8841	18.3733	.8753	-18.7838	-32.9115	-37.9634	-32.6430	-19.3983	-1.6969	17.9601	32.2732
	-.7516	19.1795	33.0084	38.0416	33.0395	19.4187	.2709	-19.4883	-32.7859	-38.0787	-33.2428	-19.6088
	-70.9248	-71.2182	-71.6438	-71.3775	-71.5639	-71.3111	-71.6384	-71.5680	-71.5313	-71.4751	-71.7859	-71.6651
	80.5837	80.7542	80.9936	80.8868	81.0298	80.9045	81.0763	81.0391	81.0428	81.0035	81.1226	81.0083

	6	8
DD	-64.9925	-65.0583
	23.8731	-29.6629
	-3.9557	-4.0375
	71.6385	71.6155

SURVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

MEASUREMENT ERRORS FOR EACH FIDUCIAL POSITION. X/Y/Z/U (MILLS). U=SQRT(DX**2+DY**2+DZ**2)

1	2	3	4	5	6	7	8	9	10	11	12

[illegible] [illegible] -7[illegible] [illegible]	[illegible] [illegible] -71.[illegible] 80.7547	[illegible] [illegible] -71.6448 80.9936	.8753 [illegible] -71.3775 80.8865	-13.7[illegible] [illegible] -71.5633 81.0738	-32.3115 [illegible] -71.3111 80.9045	-37.9636 .7797 -71.63[illegible] 81.0763	-32.6433 [illegible] -71.55[illegible] 81.0331	-19.[illegible] [illegible] -71.5313 81.0428	[illegible] [illegible] -71.4751 81.0035	17.9[illegible] [illegible] -71.7859 81.1226	[illegible] [illegible] -71.6651 81.0083

	6	8
DD	-64.9925 23.8731 -3.9557 71.6385	-65.0583 -29.6629 -4.0375 71.6155

SURVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

MEASUREMENT ERRORS FOR EACH FIDUCIAL POSITION. X/Y/Z/U (MILLS). U=SQRT(DX**2+DY**2+DZ**2)

	1	2	3	4	5	6	7	8	9	10	11	12
A	3.3 .2 3.4 4.7	2.4 1.5 2.8 4.0	2.1 1.4 .8 2.6	1.3 4.2 4.6 6.4	1.0 1.3 1.6 2.2	2.1 1.3 2.7 3.6	3.0 .8 3.1 4.4	3.9 2.7 4.5 6.6	2.1 3.1 3.6 5.2	3.3 3.3 3.7 5.9	1.7 3.0 3.1 4.7	2.7 2.3 3.1 4.7
B	2.8 .1 2.5 3.7	2.3 1.7 1.8 3.4	2.5 2.9 4.6 6.0	1.0 .4 .3 1.1	2.2 3.7 2.7 5.0	1.6 1.3 2.0 2.8	3.7 .0 2.5 4.5	.9 .9 .7 1.5	1.3 1.1 1.1 2.0	1.0 1.5 2.4 3.1	.9 1.2 1.1 1.9	2.4 1.4 2.5 3.7
C	.7 .4 1.2 1.4	3.2 2.0 4.3 5.7	1.1 1.8 4.3 4.8	2.5 1.9 1.4 3.5	1.9 1.1 1.1 2.5	.4 .3 .2 .6	0.0 0.0 0.0 0.0	1.8 1.8 .8 2.7	1.2 1.1 1.1 2.0	3.8 .5 .3 3.8	.6 .9 2.0 2.3	2.9 2.0 6.9 7.7
D	.5 1.8 1.2 2.2	1.0 1.6 2.8 3.4	1.3 1.6 4.5 5.0	2.2 1.0 .8 2.5	1.6 2.6 3.2 4.4	2.6 1.5 3.2 4.4	0.0 0.0 0.0 0.0	1.1 1.2 2.5 3.0	1.7 1.3 2.3 3.1	.5 1.5 .5 1.6	1.4 .7 .1 1.5	2.3 1.4 4.7 5.4
E	.0 .6 2.0 2.0	.9 1.3 1.5 2.2	1.7 1.9 4.2 4.9	2.3 1.5 1.1 3.0	1.7 2.6 4.0 5.1	.9 .8 .1 1.2	0.0 0.0 0.0 0.0	3.1 2.2 .2 3.9	3.0 1.8 2.1 4.1	1.4 1.0 1.0 2.0	2.7 2.2 1.9 4.0	.8 1.2 2.4 2.8
F	.6 .0 1.6 1.7	.9 1.4 1.2 2.0	1.8 2.0 3.7 4.6	1.6 2.4 .6 3.0	1.4 .9 .6 1.8	2.3 1.9 2.2 3.7	.4 1.7 2.5 3.1	.7 1.0 1.1 1.7	1.0 1.2 3.9 4.2	.2 2.9 1.1 3.2	.3 .5 1.5 1.6	1.1 1.3 1.4 2.2
G	1.9 1.9 1.6 3.1	1.9 1.8 1.8 3.2	1.7 1.7 3.6 4.3	1.4 1.5 1.7 2.7	1.1 2.0 1.3 2.6	.8 .9 1.4 1.9	.5 3.1 1.0 3.3	1.8 2.4 1.0 3.2	2.0 1.4 2.0 3.1	.9 .5 .6 1.3	.6 .8 1.7 1.9	.9 .7 .8 1.4
H	.8 1.6 .7 1.9	1.6 1.2 1.9 2.7	1.0 .7 .6 1.3	1.5 .9 1.0 2.0	1.2 .8 .4 1.4	1.5 1.4 1.4 2.5	.4 2.8 .4 2.8	1.0 1.4 .7 1.9	3.7 3.2 3.4 5.9	2.5 1.2 1.2 3.0	.6 1.0 1.2 1.7	2.8 2.3 2.7 4.5
I	.2 .2 .1 .3	1.3 2.0 .7 2.4	1.0 1.4 1.2 2.1	2.7 1.2 1.7 3.4	2.5 2.1 2.5 4.2	1.7 1.6 1.6 2.8	.8 2.9 .6 3.1	1.7 2.6 .6 3.2	3.6 5.0 4.2 7.4	.8 1.6 1.2 2.2	3.7 3.8 3.0 6.0	2.0 2.4 1.9 3.6

	6	8
DD	1.1 1.6 .7 2.0	1.4 1.1 6.1 6.4

********** DO NOT MIX DATA ON THIS PAGE WITH DATA FROM OTHER PAGES WHEN DETERMINING YOUR OPTICAL CONSTANTS. **********
SURVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

1978 SURVEY FIDUCIAL POSITIONS (WARM) EXPRESSED IN THE 1973 SURVEY COORDINATE SYSTEM. USE THESE VALUES FOR YOUR OPTICAL CONSTANTS IF YOU WISH TO IGNORE THE 1973 SURVEY. DATA FOR NOSE CONE FLANGE FIDUCIALS (B7,F7,D06,AND DD8) IS VALID ONLY FOR FILM TAKEN AFTER MARCH 1976. (CODE 2D).
X/Y/Z (INCHES).

	1	2	3	4	5	6	7	8	9	10	11	12
A	62.8625	53.5235	31.3427	1.3125	-31.4288	-54.7015	-63.5674	-54.6494	-33.6278	-2.5877	30.1101	53.9814
	-.7353	31.3580	54.5393	63.2846	55.1792	31.9364	.0579	-32.3924	-54.0554	-53.3094	-55.2358	-31.7174
	40.0268	41.2664	39.9898	39.8759	39.7319	40.0922	39.9509	40.1808	39.8562	40.1052	40.4066	40.2170
B	63.4846	60.2224	34.3143	.7570	-34.8395	-60.6814	-64.9380	-60.7232	-37.1339	-2.4129	33.6806	59.6225
	-.3736	34.5733	60.3260	59.6450	60.4715	34.9670	-.0437	-35.2934	-59.4393	-69.9888	-61.3458	-35.6060
	25.8693	25.9222	26.9785	27.0931	26.9921	26.8547	25.7781	26.7880	27.0911	27.0205	27.0626	27.0388
C	73.3603	63.6362	35.9409	.4520	-36.9932	-64.1021	0.0000	-64.0478	-39.5452	-2.7301	35.5770	62.8756
	-.1971	36.3308	63.9398	73.5875	64.0026	36.7612	0.0000	-37.2882	-62.5954	-73.8789	-64.7073	-37.5948
	12.9037	12.8900	12.6098	12.7109	12.6966	12.8000	0.0000	12.9258	13.0522	13.1251	12.9767	14.3030
D	74.3824	64.5343	37.1129	-.2800	-37.4659	-64.8871	0.0000	-65.0097	-37.9348	-3.3258	35.6691	63.9632
	-.1573	37.0648	64.4722	74.6480	64.7424	37.4049	0.0000	-37.4426	-64.8715	-74.8760	-65.8129	-38.4235
	-3.5982	-3.4023	-3.3843	-3.2637	-3.4574	-3.3955	0.0000	-4.0050	-3.3199	-3.5125	-2.9917	-3.2555
E	72.4259	63.0946	34.8378	.9603	-36.4668	-62.6302	0.0000	-63.3664	-37.2854	-2.8473	33.9190	62.1058
	-.2675	35.6653	63.3545	72.6653	63.0706	37.5435	0.0000	-36.4782	-63.0829	-73.0829	-64.3436	-37.3763
	-17.6266	-17.4032	-17.7894	-17.1417	-17.6627	-17.3477	0.0000	-17.5243	-17.5444	-17.3862	-17.6075	-17.4305
F	67.7295	58.8535	33.4158	1.1519	-32.7674	-58.5505	-65.0523	-59.2759	-33.7043	-3.1782	31.8184	57.9510
	-.5987	33.0110	58.8749	67.6843	59.6372	34.8881	1.1334	-33.8969	-59.7489	-68.0929	-60.0798	-35.1076
	-31.3822	-31.6256	-31.4663	-31.4076	-31.3860	-31.3938	-28.3930	-31.5534	-31.1491	-31.4496	-31.4558	-31.4733
G	53.0242	51.4970	29.1124	.8944	-29.3230	-51.3587	-59.8144	-52.0936	-30.3447	-2.9783	27.6803	50.5932
	-.8783	28.7105	51.4548	59.3141	51.8587	30.6255	.3139	-29.8867	-51.9337	-59.8795	-52.7774	-30.8947
	-44.6746	-44.7345	-44.6931	-44.6905	-44.5133	-44.5686	-44.4173	-44.4217	-44.3252	-44.3961	-44.5633	-44.6600
H	43.2118	41.9332	23.6971	.6149	-23.7651	-41.8398	-48.6694	-42.4203	-24.3417	-2.1481	22.9643	41.6519
	-.3653	23.8377	41.9881	48.3582	42.3963	24.8012	.1332	-24.5473	-42.3339	-48.9233	-42.9543	-25.1637
	-58.5584	-58.6430	-58.7190	-58.5825	-58.5848	-58.5871	-58.4185	-58.2651	-58.4784	-58.2032	-58.3072	-58.1308
I	38.2624	32.8825	18.3602	.8578	-18.7970	-32.9133	-37.9489	-32.6118	-19.3559	-1.6500	18.0030	32.3105
	-.7419	19.1847	33.0014	38.0198	33.0010	19.3633	.2163	-19.5384	-32.8249	-38.1027	-33.2501	-19.6040
	-70.9353	-71.2252	-71.6507	-71.3870	-71.5789	-71.3326	-71.6656	-71.5987	-71.5622	-71.5034	-71.8088	-71.6815

	6	8
DD	-63.0179	-65.0334
	23.7795	-29.7565
	-3.9818	-4.0778

********** DO NOT MIX DATA ON THIS PAGE WITH DATA FROM OTHER PAGES WHEN DETERMINING YOUR OPTICAL CONSTANTS. **********
1973 SURVEY FIDUCIAL POSITIONS (WARM) REPEATED HERE FOR COMPLETENESS. THE DATA FOR THE RON I FIDUCIALS SHOULD BE IGNORED BECAUSE OF CHAMBER BODY DIMENSIONAL CHANGES DURING THE FIRST COOLDOWN (I'M CHANGED THE HOSE)

********** DO NOT MIX DATA ON THIS PAGE WITH DATA FROM OTHER PAGES WHEN DETERMINING YOUR OPTICAL CONSTANTS. **********
1973 SURVEY FIDUCIAL POSITIONS (WARM) REPEATED HERE FOR COMPLETENESS. THE DATA FOR THE ROW I FIDUCIALS SHOULD BE IGNORED BECAUSE OF CHAMBER BODY DIMENSIONAL CHANGES DURING THE FIRST COOLDOWN (I8 CHANGED THE MOST).
DATA FOR NOSE CONE FLANGE FIDUCIALS (87,F7,DD6,AND DD8) IS VALID ONLY FOR FILM TAKEN BEFORE MARCH 1976. (CODE 1).
X/Y/Z (INCHES).

	1	2	3	4	5	6	7	8	9	10	11	12
A	62.8536	53.5013	31.3275	1.3099	-31.4208	-54.6990	-63.5501	-54.6278	-33.6084	-2.5844	30.1052	53.9650
	-.7294	31.3493	54.5214	63.2603	55.1586	31.9329	.0553	-32.3732	-54.0266	-63.2674	-55.2249	-31.7047
	40.0286	41.2710	39.9985	39.8884	39.7378	40.1141	39.9603	40.1909	39.8624	40.1198	40.4005	40.2171
B	63.4695	60.2038	34.3046	.7537	-34.8338	-60.6740	-64.9923	-60.7162	-37.1211	-2.4244	33.6685	59.6034
	-.3786	34.5649	60.3179	69.6300	60.4580	34.9641	-.2130	-35.2886	-59.4030	-69.9737	-61.3358	-35.5949
	25.8724	26.9269	26.9820	27.1005	27.0018	26.8773	26.8409	26.8071	27.0958	27.0246	27.0711	27.0475
C	73.3390	63.6262	35.9304	.4535	-36.9863	-64.0990	0.0000	-64.0311	-39.5279	-2.7286	35.5675	62.8639
	-.1861	36.3257	63.9307	73.5726	63.9858	36.7540	0.0000	-37.2795	-62.5817	-73.8659	-64.6919	-37.5860
	12.9035	12.8960	12.6106	12.7212	12.7060	12.8112	0.0000	12.9327	13.0631	13.1406	12.9795	14.2983
D	74.3702	64.5261	37.1135	-.2842	-37.4642	-64.8830	0.0000	-65.0113	-37.9306	-3.3281	35.6680	63.9561
	-.1623	37.0627	64.4717	74.6384	64.7387	37.4090	0.0000	-37.4457	-64.8751	-74.8811	-65.8029	-38.4156
	-3.5904	-3.4039	-3.3867	-3.2602	-3.4521	-3.3870	0.0000	-3.9972	-3.3087	-3.5103	-2.9847	-3.2527
E	72.4200	63.1016	34.8336	.9670	-36.4677	-62.6441	0.0000	-63.3800	-37.2870	-2.8452	33.9198	62.1054
	-.2646	35.6636	63.3592	72.6587	63.0763	37.5549	0.0000	-36.4893	-63.0919	-73.0936	-64.3391	-37.3809
	-17.6249	-17.4026	-17.7820	-17.1354	-17.6616	-17.3372	0.0000	-17.5246	-17.5342	-17.3854	-17.6022	-17.4182
F	67.7483	58.8682	33.4172	1.1570	-32.7678	-58.5587	-65.0675	-59.2775	-33.7053	-3.1834	31.8323	57.9706
	-.5970	33.0154	58.8724	67.6923	59.6520	34.8953	1.0433	-33.8984	-59.7614	-68.1186	-60.0926	-35.1152
	-31.3884	-31.6281	-31.4693	-31.4119	-31.3915	-31.4013	-28.1730	-31.5537	-31.1497	-31.4606	-31.4677	-31.4816
G	53.0531	51.5086	29.1227	.8977	-29.3250	-51.3786	-59.8325	-52.1112	-30.3502	-2.9755	27.6940	50.6039
	-.8790	28.7106	51.4622	59.3310	51.8760	30.6441	.3163	-29.8971	-51.9558	-59.9033	-52.7854	-30.9022
	-44.6876	-44.7406	-44.6980	-44.6943	-44.5153	-44.5803	-44.4390	-44.4339	-44.3304	-44.4130	-44.5735	-44.6760
H	48.2264	41.9492	23.7087	.6189	-23.7642	-41.8515	-48.6840	-42.4324	-24.3449	-2.1384	22.9793	41.6692
	-.3644	23.8404	41.9911	48.3688	42.4178	24.8209	.1377	-24.5545	-42.3428	-48.9411	-42.9724	-25.1660
	-58.5714	-58.6580	-58.7237	-58.6003	-58.5895	-58.6018	-58.4365	-58.2799	-58.4916	-58.2206	-58.3235	-58.1515
I	33.2833	32.8901	0.0000	.8704	-18.7941	0.0000	-37.9735	-32.5979	0.0000	-1.6444	18.0200	32.3280
	-.7408	19.1831	0.0000	38.0435	33.0172	0.0000	.2218	-19.5371	0.0000	-38.1262	-33.2661	-19.6059
	-71.9651	-71.2461	0.0000	-71.4105	-71.6021	0.0000	-71.6983	-71.6694	0.0000	-71.5363	-71.8373	-71.7196

	6	8
DD	-65.0253	-65.0550
	29.8289	-29.8060
	-3.8609	-3.9604

THE FOLLOWING FIDUCIAL POSITIONS (WARM) COME FROM THE 1978 SURVEY AND ASSIGN ALL THE SYSTEMATIC ERROR TO THE 1978 SURVEY (SO THAT THEY CAN BE USED WITH THE ABOVE MEASUREMENTS). DATA FOR THE ROW I FIDUCIALS APPLY FOR ALL FILM; DATA FOR THE NOSE CONE FLANGE FIDUCIALS (87,F7,DD6,AND DD8) IS VALID ONLY FOR FILM TAKEN AFTER MARCH 1976. (CODE 2Z1).

I	33.2906	32.9072	18.3755	.8608	-18.8087	-32.9362	-37.9767	-32.6354	-19.3687	-1.6490	18.0185	32.3358
	-.7414	19.1987	33.0257	38.0431	33.0269	19.3843	.2176	-19.5528	-32.8493	-38.1305	-33.2736	-19.6169
	-71.9499	-71.2396	-71.6660	-71.4033	-71.5969	-71.3519	-71.6859	-71.6191	-71.5820	-71.5220	-71.8260	-71.6973

	B 7	F 7	DD 6	DD 8
	-64.9243	-65.0656	-65.0186	-65.0356
	-.0429	1.1347	29.7818	-29.7577
	25.7830	-28.3956	-3.9778	-4.0737

********** DO NOT MIX DATA ON THIS PAGE WITH DATA FROM OTHER PAGES WHEN DETERMINING YOUR OPTICAL CONSTANTS. **********
SUPVAY 2 MEASUREMENTS AVERAGED AND FIDUCIAL POSITIONS CALCULATED JUNE 7,1978

AVERAGE OF 1973 AND 1978 SURVEY FIDUCIAL POSITIONS (WARM) EXPRESSED IN THE 1973 SURVEY COORDINATE SYSTEM.
ONE HALF OF THE SYSTEMATIC DIFFERENCES (BETWEEN THE SURVEYS) HAS BEEN ASSIGNED TO EACH SURVEY. (SEE TM 795).
DATA FOR NOSE CONE FLANGE FIDUCIALS (87,F7,DD6,AND DD8) IS VALID ONLY FOR FILM TAKEN AFTER MARCH 1976.
I (WES SMART) RECOMMEND THAT THESE VALUES BE USED FOR DETERMINING YOUR OPTICAL CONSTANTS. (CODE 12A).
X/Y/Z (INCHES).

	1	2	3	4	5	6	7	8	9	10	11	12
A	62.8580	53.5124	31.3351	1.3112	-31.4248	-54.7002	-63.5587	-54.6386	-33.6181	-2.5860	30.1077	53.9732
	-.7323	31.3537	54.5304	63.2725	55.1689	31.9347	.0566	-32.3858	-54.0410	-63.2884	-55.2303	-31.7111
	43.0277	41.2687	39.9942	39.8821	39.7349	40.1031	39.9556	40.1859	39.8593	40.1125	40.4036	40.2170
B	63.4771	60.2131	34.3095	.7553	-34.8366	-60.6777	-64.9311	-60.7197	-37.1275	-2.4186	33.6745	59.6129
	-.3761	34.5691	60.3219	69.6375	60.4648	34.9656	-.0433	-35.2910	-59.4237	-69.9812	-61.3408	-35.6226
	25.8708	26.9246	26.9803	27.0968	26.9969	26.8660	25.7806	26.7976	27.0934	27.0225	27.0668	27.0432
C	73.3497	63.6312	35.9357	.4528	-36.9807	-64.1026	0.0000	-64.0334	-39.5351	-2.7294	35.5723	62.8698
	-.1366	36.7283	63.9352	73.5801	63.9942	36.7576	0.0000	-37.2838	-62.5836	-73.8724	-64.6996	-37.5904
	12.9036	12.8930	12.6102	12.7161	12.7013	12.8056	0.0000	12.9292	13.0577	13.1329	12.9731	14.3006
D	74.3763	64.5302	37.1133	-.2821	-37.4650	-64.8850	0.0000	-65.0105	-37.9327	-3.3270	35.6685	63.9621
	-.1598	37.0638	64.4720	74.6432	64.7405	37.4070	0.0000	-37.4441	-64.8733	-74.8785	-65.8079	-38.4196
	-3.5943	-3.4031	-3.3855	-3.2620	-3.4548	-3.3913	0.0000	-4.0011	-3.3143	-3.5114	-2.9882	-3.2541
E	72.4230	63.0981	34.8387	.9637	-36.4672	-62.6372	0.0000	-63.3732	-37.2862	-2.8463	33.9194	62.1056
	-.2660	35.6649	63.3569	72.6620	63.0734	37.5492	0.0000	-36.4837	-63.0874	-73.0883	-64.3413	-37.3786
	-17.6257	-17.4029	-17.7857	-17.1386	-17.6622	-17.3425	0.0000	-17.5244	-17.5393	-17.3968	-17.6049	-17.4244
F	67.7389	58.8608	33.4165	1.1544	-32.7676	-58.5546	-65.0590	-59.2767	-33.7048	-3.1808	31.8254	57.9608
	-.5979	33.0132	58.8736	67.6833	59.6446	34.8917	1.1340	-33.8976	-59.7551	-68.1058	-60.0862	-35.1114
	-31.3853	-31.6268	-31.4678	-31.4098	-31.3888	-31.3976	-28.3943	-31.5560	-31.1494	-31.4551	-31.4617	-31.4774
G	59.0337	51.5028	29.1175	.8960	-29.3240	-51.3686	-59.8234	-52.1024	-30.3475	-2.9769	27.6872	50.6015
	-.8787	28.7105	51.4585	59.3251	51.8674	30.6348	.3151	-29.8919	-51.9448	-59.8914	-52.7814	-30.8984
	-44.6811	-44.7375	-44.6955	-44.6924	-44.5143	-44.5745	-44.4282	-44.4278	-44.3278	-44.4046	-44.5684	-44.6680
H	43.2191	41.9412	23.7029	.6169	-23.7647	-41.8456	-48.6767	-42.4264	-24.3433	-2.1432	22.9718	41.6605
	-.3648	23.8391	41.9896	48.3635	42.4071	24.8110	.1355	-24.5509	-42.3384	-48.9322	-42.9633	-25.1648
	-58.5649	-58.6505	-58.7239	-58.5914	-58.5871	-58.5945	-58.4275	-58.2725	-58.4850	-58.2119	-58.3153	-58.1412
I	33.2765	32.8949	18.3678	.8593	-18.8029	-32.9248	-37.9628	-32.6236	-19.3623	-1.6495	18.0108	32.3232
	-.7417	19.1917	33.0136	38.0339	33.0140	19.3763	.2170	-19.5456	-32.8371	-38.1166	-33.2619	-19.6104
	-70.9426	-71.2324	-71.6583	-71.3952	-71.5879	-71.3422	-71.6757	-71.6089	-71.5721	-71.5127	-71.8174	-71.6894

	6	8
DD	-65.0183	-65.0345
	29.7806	-29.7571
	-3.9798	-4.0757

DATA BELOW FOR THE NOSE CONE FLANGE FIDUCIALS IS VALID ONLY FOR FILM TAKEN BEFORE MARCH 1976,
AND IS TO BE USED WITH THE REMAINING DATA ABOVE. (CODE 1Z2).

87	F7	DD 6	DD 8
-64.9994	-65.0609	-65.0250	-65.0539
-.2134	1.0427	29.8278	-29.8054
25.8384	-28.1717	-3.8629	-3.9625

Figure 1

0 5 FT.

FIDUCIAL	Z POSITION	FIDUCIAL	Z POSITION
A1 TO A12	+40	H1 TO H12	-59
B1 TO B12	+27	I1 TO I12	-72
C1 TO C6 C8 TO C12	+13	C7	NOT USED
D1 TO D6 D8 TO D12	-3	D7	NOT USED
E1 TO E6 E8 TO E12	-17	E7	NOT USED
F1 TO F6 F8 TO F12	-31	F7	-28
G1 TO G12	-45		

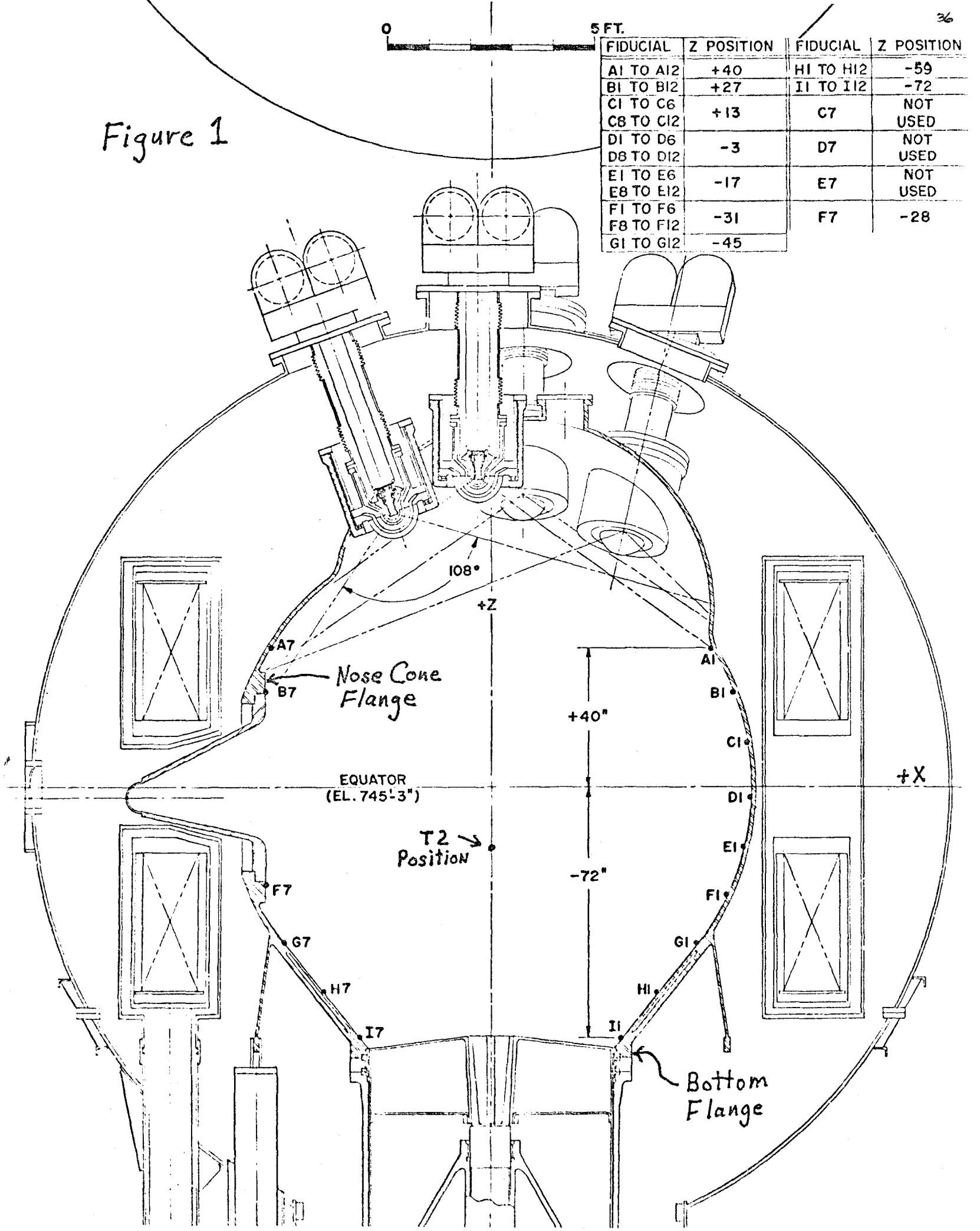
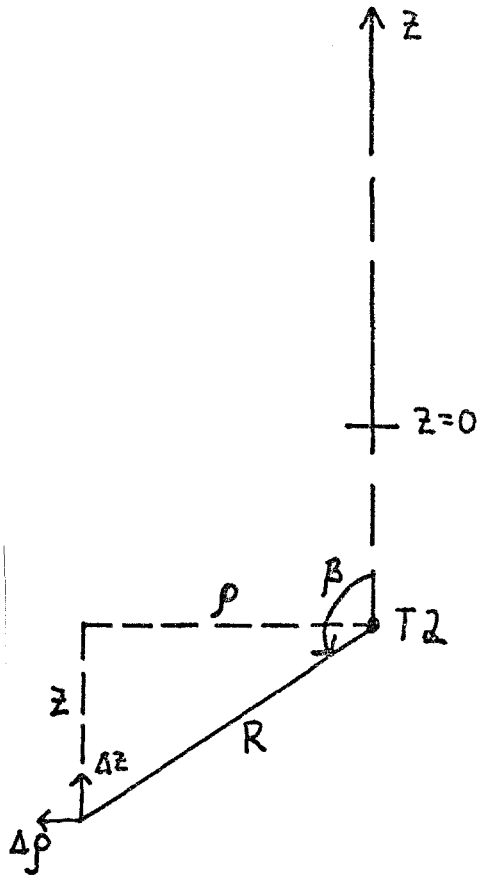
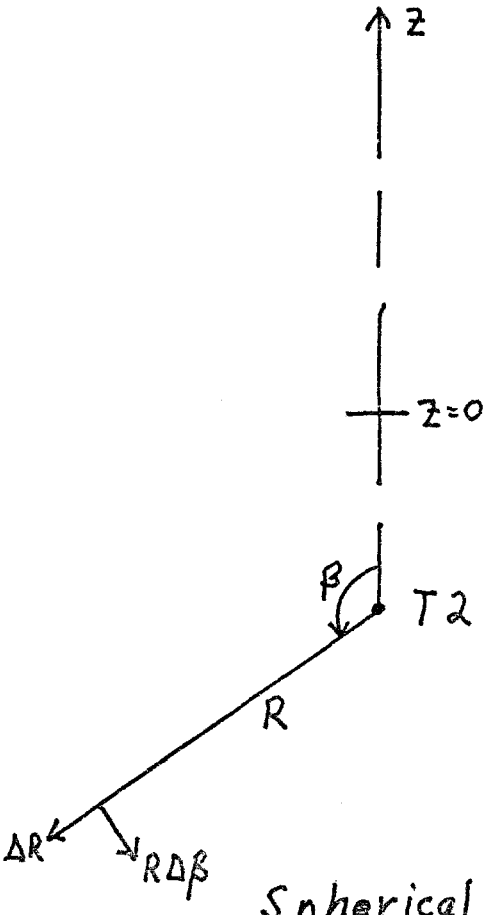


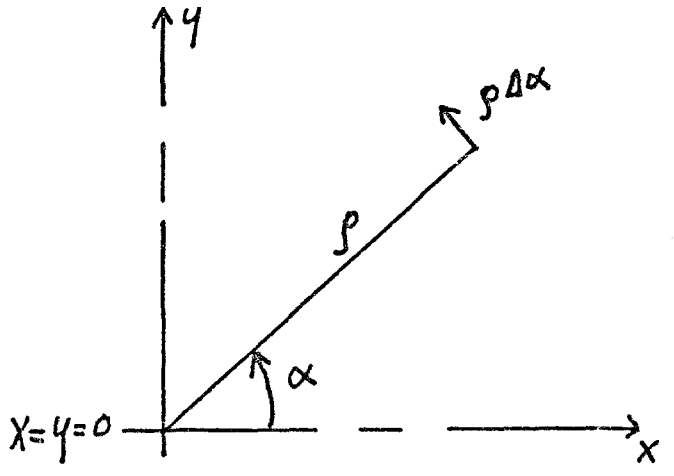
Figure 2. Coordinate System Definitions



Cylindrical Coordinates



Spherical Coordinates



Cylindrical or Spherical Coordinates

TABLE I

AFTER COORDINATE TRANSFORMATION TO SURVEY #i SYSTEM

Fiducial Row	$\Delta\rho$ Average	Δz Average	$\rho\Delta\alpha$ Average	$R\Delta\beta$ Average	ΔR Average	3 coord. RMS
A	21.5 mil	-10.5 mil	-2.5 mil	22.2 mil	8.8 mil	27.2 mil
B	16.0	-11.7	2.0	18.4	7.2	22.5
C	15.5	- 9.2	-2.1	14.4	10.9	19.9
D	4.6	- 7.7	-0.5	8.4	3.1	12.5
E	-5.0	- 8.2	0.6	8.2	-4.9	13.9
F	-12.8	3.0	0.5	-0.4	-13.2	16.0
G	-17.6	7.2	0.6	0.7	-19.0	21.0
H	-15.1	11.5	1.6	0.9	-19.0	20.8
I	-15.0	30.3	0.6	-5.1	-33.5	38.8
average	-0.7	$\equiv$ 0	0.1	7.8	-6.2	-
average RMS	16.5	14.2	4.4	13.7	17.0	22.2

TABLE II

AFTER COORDINATE TRANSFORMATION AND VERTICAL ANGLE ZERO

Fiducial Row	$\Delta\rho$ Average	Δz Average	$\rho\Delta\alpha$ Average	$R\Delta\beta$ Average	ΔR Average	3 coord. RMS
A	-4.0 mil	-10.6 mil	-2.5 mil	5.2 mil	-10.1 mil	17.0 mil
B	-3.6	- 8.9	2.0	5.6	- 7.8	14.4
C	2.1	- 4.7	-2.0	5.1	0.2	9.7
D	-1.5	- 2.7	-0.5	2.4	- 2.0	9.2
E	-4.9	- 4.1	0.6	4.1	- 4.9	11.9
F	-6.6	5.0	0.5	- 3.6	- 7.5	12.2
G	-5.5	5.5	0.6	- 2.7	- 7.3	11.8
H	3.1	5.0	1.6	- 5.8	- 0.8	10.3
I	8.9	19.0	0.6	-18.3	-10.5	28.4
average	-1.6	$\equiv$ 0	0.1	-0.6	- 5.6	-
average RMS	8.8	10.6	4.5	9.8	9.8	14.5

TABLE III

AFTER COORDINATE TRANSFORMATION PLUS 5 PARAMETERS

Fiducial Row	$\Delta\rho$ Average	Δz Average	$\rho\Delta\alpha$ Average	$R\Delta\beta$ Average	ΔR Average	3 coord. RMS
A	.9 mil	-6.9 mil	-2.6 mil	5.7 mil	-3.9 mil	14.4 mil
B	1.4	-6.1	2.0	5.9	-2.1	12.6
C	7.3	-2.6	-2.0	5.2	5.8	11.4
D	3.8	-1.5	-0.5	2.2	3.4	8.3
E	0.4	-3.8	0.6	3.8	0.4	9.1
F	-1.4	4.4	0.5	- 4.0	-2.3	10.5
G	-0.4	3.6	0.5	- 3.1	-1.8	8.1
H	7.4	1.4	1.5	- 5.9	4.7	10.9
I	11.9	14.2	0.8	-17.9	-4.8	25.6
average	3.3	$\equiv$ 0	0.1	- 0.6	0.0	-
average RMS	8.8	8.4	4.3	9.6	7.5	12.9

TABLE IV

RESULTS OF SEVERAL FITS USING DIFFERENT SETS OF PARAMETERS

	σ mil	Ω_1 mr	Ω_2 mr	Ω_3 mr	X_0 mil	Y_0 mil	Z_0 mil	β_0 mr	Ball D ppm	Ball X mil	Ball Y mil	Ball Z mil
All Fiducials	22.4	-0.245	0.238	-0.845	0.6	39.7	21.9	-	-	-	-	-
	14.5	-0.248	0.229	-0.845	0.3	39.6	50.0	0.444	-	-	-	-
	21.7	-0.245	0.238	-0.845	0.8	39.6	22.0	-	65	-	-	-
	15.5	-0.246	0.228	-0.845	0.3	39.6	12.8	-	-	-	-	-37.4
	14.5	-0.248	0.229	-0.845	0.3	39.6	47.7	0.417	-	-	-	-2.5
	13.4	-0.248	0.229	-0.845	0.6	39.6	50.6	0.450	76	-	-	-
	12.9	-0.248	0.230	-0.844	-1.8	38.3	47.7	0.417	79	-6.9	-3.1	-3.0
	12.9	-0.249	0.231	-0.844	-1.8	38.3	50.5	0.450	79	-6.9	-3.1	-
Omit Row I	19.6	-0.239	0.220	-0.845	1.1	39.6	18.8	-	-	-	-	-
	12.2	-0.239	0.215	-0.845	0.7	39.6	47.8	0.440	-	-	-	-
	19.5	-0.239	0.220	-0.845	1.2	39.6	19.0	-	28	-	-	-
	14.2	-0.239	0.214	-0.845	0.7	39.6	12.1	-	-	-	-	-34.0
	11.9	-0.240	0.216	-0.845	0.7	39.6	65.4	0.648	-	-	-	19.4
	11.0	-0.240	0.215	-0.845	0.9	39.6	50.2	0.468	70	-	-	-
	10.4	-0.242	0.221	-0.845	-1.3	38.8	65.6	0.650	70	-6.0	-2.0	17.1
	10.6	-0.241	0.220	-0.845	-1.3	38.8	50.2	0.468	72	-6.0	-2.0	-

TABLE V

AFTER COORDINATE TRANSFORMATION PLUS 5 PARAMETERS,
OMITTING ROW I FROM AVERAGES AND FIT

Fiducial Row	$\Delta\rho$ Average	Δz Average	$\rho\Delta\alpha$ Average	$R\Delta\beta$ Average	ΔR Average	3 coord. RMS
A	-3.0 mil	-1.4 mil	-2.5 mil	-0.9 mil	-3.1 mil	12.9 mil
B	-0.4	-2.4	2.1	1.8	-1.6	11.0
C	6.7	-0.7	-2.0	3.2	6.0	10.4
D	3.5	-1.5	-0.4	2.1	3.2	8.0
E	-0.2	-4.7	0.6	4.7	-0.2	9.5
F	-2.7	3.2	0.6	-2.6	-3.3	10.5
G	-2.2	3.3	0.6	-2.1	-3.3	8.5
H	6.6	3.7	1.6	-7.1	2.7	11.1
I	(14.7)	(19.1)	(0.7)	(-23.0)	(-7.3)	(30.3)
average	1.0	$\simeq$ 0	0.1	-0.2	0.0	-
average RMS	7.6	5.6	4.2	6.1	7.2	10.4
Row I omitting I8	(11.3)	(14.9)	(1.5)	(-17.8)	(-5.7)	(21.2)

WSM:ls/cs

Table VI

SURVEY 2E MINUS SURVEY 1 IN THE SURVEY 1 COORDINATE SYSTEM RHO*DELTA ALPHA/R*DELTA BETA/DELTA R (MILS). (Row I omitted from fit).

	1	2	3	4	5	6	7	8	9	10	11	12	AVG	RMS
A	-5.1	-4.3	-6.0	-4.4	-5.7	-3.6	-3.3	.8	.3	.7	1.5	-.9	-2.5	3.6
	-11.9	-.5	2.3	5.2	-2.1	-3.3	-3.8	1.9	5.9	17.8	-17.1	-5.7	-.9	8.6
	-11.4	-3.1	-4.8	-5.2	-.9	-23.9	-4.7	.7	9.9	8.3	-1.8	-.9	-3.1	8.9
B	5.8	-2.6	-6.1	-5.5	-4.2	-.8	0.0	1.1	7.2	14.3	8.1	5.6	2.1	6.6
	-2.1	1.9	-+.0	.3	1.3	8.1	0.0	5.2	6.6	-3.4	1.3	4.9	1.8	4.2
	-2.2	1.2	-4.4	-2.4	-2.4	-13.3	0.0	-9.9	18.0	1.1	-3.0	-.2	-1.6	7.6
C	-.1	-1.1	-6.4	-.8	-4.9	-6.6	0.0	-.4	-6.5	1.3	3.3	.4	-2.0	3.9
	.5	2.3	-2.1	6.9	6.5	3.5	0.0	4.0	8.9	10.5	1.1	-6.9	3.2	5.8
	10.7	-1.1	3.6	3.1	8.3	-1.7	0.0	12.6	12.6	1.6	9.2	6.6	6.0	7.7
D	5.8	-2.8	-.8	-6.7	-2.9	3.7	0.0	-1.5	-3.9	4.4	-1.4	1.4	-.4	3.7
	7.1	-3.0	-5.5	1.8	2.2	4.8	0.0	3.4	6.9	-2.3	5.4	2.4	2.1	4.5
	6.9	4.5	-2.4	7.5	3.8	2.4	0.0	-.5	-.4	-4.3	6.9	11.0	3.2	5.5
E	-2.0	5.3	-2.4	4.4	-.5	.5	0.0	-2.5	-1.6	-.2	-.3	6.1	.6	3.1
	1.3	.1	6.9	5.6	.4	9.7	0.0	-.8	9.6	2.3	5.0	12.0	4.7	6.3
	7.5	-3.4	-2.5	10.4	.6	-10.1	0.0	-8.5	-.5	-4.2	8.1	.6	-.2	6.3
F	-1.0	3.0	.7	2.5	4.1	-.1	0.0	-.2	-3.7	6.3	-3.8	-1.7	.6	3.1
	-2.0	.8	-3.1	-2.1	-2.2	-4.3	0.0	-7.6	2.7	-4.6	-7.2	-3.4	-2.6	3.6
	-12.4	-7.8	9.0	1.0	-2.4	1.3	0.0	11.4	2.1	-15.5	-9.6	-13.5	-3.3	9.3
G	1.4	5.3	3.6	.7	4.1	3.6	1.3	-.0	-4.9	-1.8	-5.9	-.2	.6	3.4
	-4.7	-2.4	-.5	1.0	4.7	1.0	-11.3	-1.7	5.1	-5.2	-3.7	-7.5	-2.1	5.0
	-3.9	1.9	2.0	3.5	2.2	-9.8	-5.3	-3.5	-2.8	-10.5	-.2	-8.5	-3.3	6.0
H	.0	5.2	7.0	1.4	8.7	8.8	3.3	.1	-.2	-8.2	-2.1	-4.9	1.6	5.3
	-7.7	-9.0	-9.3	-13.2	2.6	-3.0	-8.5	-6.2	-8.4	-6.9	-3.3	-11.9	-7.1	8.2
	1.3	-.3	9.1	3.2	7.2	.7	3.6	6.1	10.2	-.0	-5.1	-3.9	2.7	5.3
I	-.4	4.8	0.0	9.6	7.8	0.0	4.1	-5.8	0.0	-4.3	-4.7	-5.3	.7	5.7
	-17.9	-25.5	0.0	-10.8	-19.0	0.0	-12.8	-65.0	0.0	-15.1	-14.7	-26.2	-23.0	27.8
	-9.6	6.3	0.0	-4.8	3.2	0.0	-10.0	-19.6	0.0	-10.6	-7.4	-12.8	-7.3	10.4

	6	8
)D	0.0	0.0
	0.0	0.0
	0.0	0.0

ALL FIDS	.1	4.4
	-2.3	10.2
	-.7	7.6
FIT FIDS	.1	4.2
	-.2	6.1
	-.0	7.2