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 USING OPTICAL TOOLING
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 FROM: A. A. Abbatiello

Abstract

Optical tooling has been evaluated for the measurement of physical dimensions of radioactive parts through hot cell windows. Instruments were set up outside of a four foot thick lead glass window and by means of a grid plate which had been accurately scribed, a "contour map" or calibration chart of the window variations was recorded. Although the window was not specially selected, the readings were within 1.0% of the true dimension without using correction factors. One of the calibration chart with the window reduced the error to $\pm 0.1\%$. The method is considered feasible and sufficiently fast for a wide variety of hot cell measurements.

A pin point light source is suggested as a simple check for selective assembly of lead glass laminates during manufacture of hot cell windows to provide control of optical properties.

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Table of Contents

	<u>Page</u>
I. Introduction	4
II. Description	7
III. Equipment Required and Cost	8
IV. General Procedure	9
V. Discussion of Results	11
VI. Summary	13
VII. Acknowledgements	14
VIII. Bibliography	15
IX. Appendices - Data Sheets	32
A. Grid Plate Outside Cell	33
B. Grid Plate 6 Inches Inside Cell	35
C. Grid Plate 9 Feet 9 Inches Inside Cell	42

List of Figures

<u>Figure No.</u>	<u>Description</u>	<u>Page</u>
1	4507 Hot Cell Test	5
2	Optical Tooling Mounted Outside Cell	6
3	Transit Square is Adjusted Perpendicular to the Alignment Scope	16
4	Transit Square is Set with Optically Flat Reference Surface	17
5	Transit Square is Aligned with Grid Plate Preparatory to Taking Vernier Reading	18
6	Calibration Chart for Plate Located in Front of Window	19
7	Calibration Chart for Plate Located 6 Inches Inside Cell	20
8	Calibration Chart for Plate Located 9 Feet 9 Inches Back from Cell Window	21
9	Linear Dimensions of Grid Plate as Recorded for Various Plate Locations	22
10	Measurement of a Part Inside Cell	23
11	Plot of Grid Plate Deviations, H-18 and H-16 Lines	24
12	Plot of Grid Plate Deviations, H-14 and H-12 Lines	25
13	Plot of Grid Plate Deviations, H-10 and H-8 Lines	26
14	Plot of Grid Plate Deviations, H-6 Line	27
15	Data Taken Using Vernier Height Gage, Precision Level and Optical Micrometer	28
16	Plot of Reading Dispersion Taken at Different Times	29
17	Deviation of Point Source Reflection Indicating Imperfect Alignment of Glass Layers	30
18	Time Exposure of Pin Point Light Reflections in Cell Window	31

I. Introduction

The dimensional measurements of irradiated parts has become one of the problems connected with reactor development. These measurements are important to determine stress, creep, and metallurgical effects on activated parts which have become radioactive and therefore inaccessible to ordinary measuring tools. A number of measurement methods have been considered (1), one of which is optical tooling working through hot cell windows. The principal advantages of this system are 1) the instruments are not subject to contamination, 2) convenient and comfortable working areas can be utilized, 3) the cell interior is entirely free for useful working space, and 4) acceptable accuracy is attainable. Essentially, optical tooling is measuring by means of a telescope (called a transit square) which is capable of moving in horizontal and vertical planes. It is referenced from an independent optical control line and may be aligned with the object point to be located in space. Direct readings taken from a vernier scale mounted on the carriage are subtracted to obtain the net distance. In the cases where measurements are made through windows, a calibration factor for optical distortion is then applied to obtain a correct reading. Optical tooling (2) has been in use in aircraft plants for years, and is now being applied in other industries requiring accurate location of widely separated points as on large assembly jigs, heavy machinery fabrications, and shipbuilding.

The purpose of this test was to determine the feasibility of taking accurate measurements with an optical tooling system through a 4 ft thick lead glass window. The locations and amount of variations in the glass as they affected the readings were desired as well as the time required to take typical measurements, and a general evaluation of the method.

Arrangements were made for the use of Cell No. 1 in the 4507 building which is a new, high-activity facility equipped with a 20 in. high x 36 in. wide lead glass window 4 ft thick (see Figs. 1 and 2). This particular cell had just been completed but had not been used for hot duty, and therefore was ideal for this purpose. A complete set of optical tooling instruments was obtained on loan from the manufacturer as well as instructions in their use (3).

Availability was the prime consideration in selecting this window. It is probably representative of present normal production, with no special effort made to assemble a window for minimum optical distortion. The planning of hot cells which would require facilities for accurate measurements of components, should include a suitably located window of known properties to take maximum advantage of this measuring system.

NOTE:
EACH SCALE IS VERNIER
READING TO .001"

4507 HOT CELL TEST

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SK-AAA-1554
8-23-57

FIG.1

Optical Tooling Mounted Outside Cell - Fig. 2

II. Description

Measurement by the use of optical tooling requires that the points on the object to be measured be visible, perpendicular to the window surface through which it is viewed, and capable of being turned so that the points lie in a plane parallel to the window. A cell equipped with a lift and turntable would be most useful for the larger parts which would be encountered in a typical reactor program. Smaller parts might be adequately handled by manipulators, or merely set up in front of the window and properly oriented.

In order to sweep the vertical plane front area of the hot cell window, a transit-type instrument is held in a plumb position and perpendicular to the window surface, as shown in Figs. 1 and 2. Mechanical means are provided to move the instrument in horizontal and vertical directions to cover the complete window area. An alignment scope generates a reference line to which the transit scope is set perpendicularly at the vertical plane and elevation of interest, as shown in use in Fig. 3.

An optically flat mirror, magnetically held on a steel optical flat mounted on the wall at the side of the window, provides the vertical reference plane from which the transit square and alignment scope are positioned. This system is used to establish a horizontal plane at each new elevation. (See Fig. 1, part 4, and Fig. 4)

A. Fundamental Points of Alignment

The following describes the basic points which are used in this optical tooling system:

1. The tooling bar is positioned parallel to the front of the hot cell window in a convenient location. The transit scope and alignment scope are set respectively 90° from and parallel to the window (Fig. 2).
2. The optically flat mirror mounting bar (straight edge) is placed in a vertical position beside the window and adjusted parallel with its front surface. The optical mirror is held magnetically to align the transit scope perpendicular to the plane of the optical flat (Fig. 4).
3. Without disturbing the previous setup, the alignment scope is positioned from the transit scope and adjusted to bring it square by means of the built in transit scope mirror, thus providing a fixed reference line parallel to the front of the window. This control reference line is then available for all subsequent measurements at that level.

4. A change to another elevation is made by repositioning the magnetically mounted wall mirror (Item 4, Fig. 1) along the steel optical flat, and repeating the perpendicular setting of the transit scope to this mirror. The alignment scope is then raised and positioned from the transit scope, thus establishing a new reference line in a plane parallel to the front of the window, and at the elevation desired for the new set of measurements (Fig. 3 and Fig. 5)

B. Methods of Checking Accuracy

Instrument checking for basic accuracy may be performed at the work location. The method used, called plunging and turning 180°, commonly employed in surveying, has inherent advantages because it can be used without disturbing the work setup. Turning 180° and plunging has the further advantage of using the opposite side of the optically flat mirror built into the transit scope, and thereby proving the instrument axis to lie in a plane which agrees with the reference line generated by the alignment scope.

III. Equipment Required

The equipment listed below was selected and set up in the 4507 cell for an evaluation of this optical measuring system through a typical hot cell window on a full scale basis. Note that Item 6 is a standard tooling bar commercially available, which was used for this test. On the assumption that full scale testing proves the acceptability of this system, a precision horizontal-vertical combination bar, designated Item 7, would be substituted for Item 6 in a reactor disassembly hot cell to be so equipped. The combination tooling bar (Item 7) would be designed to provide easier manipulation in the vertical plane than was available with the standard tooling bar.

Equipment for Hot Cell Optical Tooling

Item numbers refer to Fig. 1

<u>Item</u>	<u>Equipment</u>	<u>Description</u>	<u>Cat. Page</u>	<u>Price</u>
1	Mod. 233-2	Stand	16	\$ 790.00
2	Mod. 89	Base	12	220.00
3	Mod. 81	Alignment Scope	12	565.00
4	Mod. 185	Mirror	17	175.00

Equipment for Hot Cell Optical Tooling (Con'd)

<u>Item</u>	<u>Equipment</u>	<u>Description</u>	<u>Cat. Page</u>	<u>Price</u>
5	Mod. 75	Optical Transit Square	6	1600.00
5a	Mod. 194	Vial	10	50.00
5b	Mod. 190	Optical Micrometer	10	160.00
5c	Mod. 192	Auto Collimation Unit	10	125.00
5d	Mod. 188	Glass Auto-reflection Target	9	110.00
6		A 10 ft Horizontal Tooling Bar		<u>2020.00</u>

NOTE: The above items are used for the test setup.

TOTAL of Items for Test Setup \$5815.00

7	To Be Designed	Combination Precision Horizontal and Vertical Tooling Bar, Estimated		\$5000.00
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NOTE: Item 7 would replace Item 6 above for a permanent hot cell installation, and Item 6 cost (\$2020) would be deducted if Item 7, the combination tooling bar, is substituted.

The above prices and estimates are from the Brunson Instrument Catalog No. A2230, or were furnished by Mr. W. W. Alto, Chief Engineer of the Brunson Instrument Company, August 16, 1957.

IV. General Procedure

The method used in taking the data follows the plan outline below. Optical tooling instruments were set up at the cell and the window was calibrated by observing a scribed plate. The plate had been scribed into 2 in. squares to an accuracy of ± 0.001 in., with a line width of about 0.002 in.

Readings were made at three different locations and for the following purposes:

1. The plate was suspended in front of the cell window outside the cell, as shown in Fig. 3. Measurements were taken at 2 in. intervals to ascertain that the plate had been scribed accurately. These measurements also served as check points to insure that the instruments were being operated correctly. The readings are shown in Fig. 6.

2. The plate was next suspended inside the cell about 6 in. from the window and the dimensional location of the grid lines plotted as read by the vernier scales on the tooling bar. This set of measurements recorded the displacement deviations from the true normal for this specific window. These are recorded in Fig. 7.
3. The plate was next moved to a point $9\text{-}3/4$ ft behind the cell window. This represents the most distant point to be reached within the cell and consequently, the maximum effect of window deviations. The deviations measured (showing the sum of displacement and wedge) represent the difference between the indicated value and the true distance. These values and the direction in which they differ have been recorded in Fig. 8.

Since the grid had been accurately scribed, the readings taken on the vernier scales, representing all the correction factors as read through the instruments, were recorded on the data sheet. In most cases the readings were greater than the original distances on the plate indicating a slight "magnifying effect" from the window (Fig. 9). Thus, each reading with the plus sign indicates that the reading was oversized, and is so indicated in the calibration charts of Figs. 6, 7, and 8. When the correction factors are applied, it is necessary to change the sign.

The detailed steps for setting the instruments, checking their accuracy, and taking the measurements are as follows. In many cases it takes no longer to perform the operation than to describe it.

1. Verticalize (plumb) the spindle of the transit square (Item 5, Fig. 1) using the Model 194 vial precision level.
2. Auto-collimate the transit square scope into the wall mirror. This is done by turning on the light, focusing at infinity, and looking for the transit target image in the mirror. Move the scope (angularly) to bring the cross hairs and their mirror image into coincidence.
3. Position the alignment scope (Item 3, Fig. 1) square with the mirror in the transit square (Item 5, Fig. 1).
4. Move the transit square to the measurement position and observe its position through the alignment scope to assure proper orientation of the transit square. Adjust the transit square, if required, by means of the screws provided. Take the object measurement reading on the vernier scale and record. All measurements in this horizontal plane can be taken with this alignment scope setting.

5. Each time the optical transit square is to be raised or lowered to a new horizontal plane, repeat operations 1, 2, and 3. When the new control reference line has been established, all subsequent readings at this elevation are made with the transit square aligned to the alignment scope.

A. Typical Example of Measuring a Part

A cylinder was placed in the cell at a point about 5 ft back from the cell window and the diameter was recorded using the optical tooling instruments. The table below shows a first and second try, with the cylinder moved to a new position for the second test in order to view through a different portion of the window. The cylinder was approximately 6.800 in. in diameter and has a shiny surface, not considered the ideal for best accuracy, but was used as an example of practical system evaluation. A view of a part inside the cell is shown in Fig. 10.

<u>Reading</u>	<u>First Try</u>	<u>Second Try</u>
Right side of cylinder, vernier reading	48.959	44.488
Left side of cylinder, vernier reading	42.160	37.664
Difference (cylinder diameter uncorrected)	6.799 in.	6.824 in.
Because this object was at 5 ft, use 1/2 cor- rection (from table)	- 0.022	- 0.018
Corrected diameter =	6.777 in.	6.806 in.
% Accuracy	6.777/6.800 = 99.7%	6.800/6.806 = 99.9%

V. Discussion of Results

With the grid plate hung outside the cell, readings were taken along the H-10 line and the H-2 line at 2 in. intervals. It is obvious from an examination of the chart of Fig. 6 and the data sheets shown in Appendix A, that the plate had been scribed to the required accuracy and the instruments could reproduce the results to ± 0.001 in.

With the plate hung 6 in. from the window inside the cell, readings were again taken using the procedure outlined and the data were plotted on Fig. 7 and tabulated in Appendix B. As can be seen in Fig. 7, the deviations are random and vary from about -0.004 in. to $+0.013$ in. for the various 2 in. increments. These deviations are shown by two different methods. On the calibration chart, Fig. 7, the values are determined from the data sheets. For instance, the horizontal distance along the H-12 line read $+0.006$ in. more than the true 2.000 in. which it should have read between the 22 and 24 in. vertical line. The other method of showing the relative differences was by plotting the cumulative difference from the left edge for each horizontal line on the plot of grid plate deviations (Figs. 11 to 14). The average increase for these values is about 0.045 in. total in the 34 in. horizontal distance with the plate hung 6 in. inside the cell. This magnifying effect is about 0.13%. From the readings obtained with the optical micrometer, the position of each end of the horizontal lines with respect to its adjacent line above was determined and the difference shown on the calibration chart (Fig. 7).

The plate was moved to a point 9-3/4 ft back from the cell window to obtain data at the maximum possible distance and consequently the maximum measuring error for this cell. Readings for each of the horizontal lines at 2 in. intervals were again taken, the values were recorded on the data sheets in Appendix C, and plotted in the grid plate deviations (Figs. 11 to 14).

In this case a precision level was mounted on the tooling bar and used to level the table after it had been positioned with the vertical height gage (see Fig. 15). The vertical deviations read with the optical micrometer were tabulated on the data sheets and the vertical difference between each pair of points was recorded on the calibration chart (Fig. 7).

Although the instruments may appear complex, they were surprisingly easy to operate. During the calibration of the cell window, the complete cycle of raising the tooling bar, precise leveling, squaring with the optical wall mirror, and taking 18 sets of readings on the horizontal scale using the transit square, and also taking 18 corresponding points vertically with the optical micrometer attachment, were made in about one hour. Operators were trained rapidly in the use of these instruments. During the course of this test, four different assistants were used, some for as little as one day, and each was able to learn the technique and apply it.

The reproducibility of the results was determined by taking a set of readings along the same horizontal line on three different occasions when the instruments had been removed and replaced. These data, plotted in Fig. 16, show a dispersion of about 0.030 in. for length measurements of 20 in. to 30 in., which indicates a

reproducibility of about $\pm 0.1\%$. Further improvement probably could be obtained by using a more permanent setup with refinements such as floor plates having dowel bushings mounted in the floor. This would have the added advantage of making it easy to remove the instruments for use at other installations, or to free the window when other work is in progress. Working area may be provided directly in front of the window without interfering with the optical tooling since the distance over which the instruments operate may be increased considerably without appreciable loss of accuracy. A permanently mounted optical flat at the side of the window would aid in maintaining a common reference plane as the basic starting point.

Normal cell illumination using mercury vapor lamps is adequate. The refraction of light from curved surfaces did not appear to be a serious problem. By slowly moving the transit square cross-hair across the point under observation, it was possible to first straddle the point and then center it. Shiny surfaces on some of the objects measured made it more difficult to locate the exact point, but with care, this was still done reasonably well. Oxidized surfaces which present a grey shade are easier to distinguish.

No special effort was made to use a selected window; the one tested merely happened to be available, and therefore high optical accuracy was not expected. It is of interest to note that a pin point light source revealed noticeable variations, as shown in Figs. 17 and 18, although the window is of acceptable accuracy. If all laminates are parallel and assembled into a parallel pack, the light source images would lie in a straight line when viewed from any position. The point reflection alignment was not consistent for different areas of this window. The use of a simple light source appears useful as an aid when assembling windows because the alignment of each laminate could be checked easily as it is being placed.

Other minor improvements which would aid instrument operation would be direction arrows on the transit carriage thumb screws to minimize confusion in operation. Also, a 1 in. direct reading dial indicator mounted on the carriage and engaging saw tooth contact areas at 1 in. intervals on the tooling bar would make it unnecessary for the operator to read a vernier scale.

VI. Summary

1. The method proposed for linear measurements through hot cell windows is considered feasible on the basis of the equipment and methods used in a hot cell test at the 4507 building. A photo of the components is shown in Fig. 2 and views of them in use are shown in Figs. 3, 4, and 5.

2. The accuracy of measurements taken through this particular window without correction is about 99% and 99.87% respectively for readings taken 9-3/4 ft and 6 in. inside the cell window.
3. By using the calibration chart produced for this window during the test (Fig. 8), accuracy can be improved to about 99.9% (or $\pm 0.1\%$ variation for the long cell distances, which approaches the practical accuracy of routine shop measurements in non-radioactive work using conventional methods). As the work is brought closer to the window, errors are proportionately reduced.
4. The rate of taking measurements is high for hot cell work. It may be compared to dimensions obtained using a cathetometer, or surface plate and vernier height gage.
5. A pin point light reflection test is a simple method to evaluate a window for potential accuracy, and might be developed further to assist the manufacturer in selectively assembling glass sections for best precision.
6. A liquid-filled window (like zinc bromide) having the minimum number of light refracting surfaces would be preferred for measuring purposes. Since optical tooling is used perpendicular to the viewing surface, chromatic aberration is not a problem. Because of the lower density of zinc bromide, however, greater thickness would be necessary to obtain equivalent shielding.
7. Operators can be rapidly trained in the use of these instruments.

VII. Acknowledgements

The assistance of Mr. W. W. Alto, Chief Engineer of the Brunson Instrument Company, is acknowledged for the contribution of the idea of an optically flat reference surface from which to align the transit scope for different elevations. Mr. A. N. Brunson, President of the Brunson Instrument Company, Kansas City, Missouri, provided the instruments which were loaned for this test. The excellent cooperation of this company and its employees is acknowledged.

The assistance of Mr. R. J. DeBakker in setting up the equipment is acknowledged, as well as the cooperation of Messrs. D. E. Ferguson and C. P. Johnston for the use of the cell. Credit is also due to Messrs. T. E. Crabtree, H. W. Hoover, C. K. McGlothlan, and J. J. Platz for help in operating the equipment and taking data.

The complete review of this report and the many helpful comments of Mr. D. B. Trauger are gratefully acknowledged; also the assistance and encouragement of Messrs. M. Bender, W. F. Boudreau, and F. R. McQuilkin are appreciated.

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Transit Square Is Set With Optically Flat Reference Surface - Fig. 4.

Transit Square is Aligned With Grid Plate Preparatory to Taking Vernier Reading - Fig. 5

NOTE: All readings are shown in thousandths of an inch, thus $+0.007 = +7$. + Means an oversized reading and - means undersized.

1. H-2 corresponds to the horizontal line near the lower edge of the window and is about 54.8" above floor level.
2. H-14 is a similar horizontal line 12.000" above H-2 and is the upper limit of the test set-up, about 66.8" above floor.

Fig. 6. Calibration Chart for Plate Located in Front of Window.

22.909	H-18	$\begin{array}{ c } \hline -4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +2 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline +5 \\ \hline \end{array}$	$\begin{array}{ c } \hline -2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	$\begin{array}{ c } \hline +1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +1 \\ \hline \end{array}$	$\begin{array}{ c } \hline -4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +9 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +7 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline ? \\ \hline \end{array}$	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	22.948
20.899	H-16	$\begin{array}{ c } \hline -1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline -2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +7 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline +2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline -1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline +2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline +7 \\ \hline \end{array}$	$\begin{array}{ c } \hline +13 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline +5 \\ \hline \end{array}$	20.942
18.901	H-14	$\begin{array}{ c } \hline -1 \\ \hline \end{array}$	$\begin{array}{ c } \hline -1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +5 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline -2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +5 \\ \hline \end{array}$	$\begin{array}{ c } \hline +2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline +5 \\ \hline \end{array}$	$\begin{array}{ c } \hline +10 \\ \hline \end{array}$	$\begin{array}{ c } \hline +1 \\ \hline \end{array}$	$\begin{array}{ c } \hline -9 \\ \hline \end{array}$	18.937
16.920	H-12	$\begin{array}{ c } \hline -2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +9 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	$\begin{array}{ c } \hline -2 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline +2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline +10 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +27 \\ \hline \end{array}$	16.946
14.904	H-10	$\begin{array}{ c } \hline +7 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline +5 \\ \hline \end{array}$	$\begin{array}{ c } \hline +1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +9 \\ \hline \end{array}$	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	$\begin{array}{ c } \hline +5 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +10 \\ \hline \end{array}$	$\begin{array}{ c } \hline -4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +11 \\ \hline \end{array}$	$\begin{array}{ c } \hline +34 \\ \hline \end{array}$	14.919
12.863	H-8	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	$\begin{array}{ c } \hline +5 \\ \hline \end{array}$	$\begin{array}{ c } \hline -3 \\ \hline \end{array}$	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	$\begin{array}{ c } \hline -1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +7 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline -1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +7 \\ \hline \end{array}$	$\begin{array}{ c } \hline +1 \\ \hline \end{array}$	$\begin{array}{ c } \hline +4 \\ \hline \end{array}$	$\begin{array}{ c } \hline +15 \\ \hline \end{array}$	12.885
10.851	H-6	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline -2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline -2 \\ \hline \end{array}$	$\begin{array}{ c } \hline +7 \\ \hline \end{array}$	$\begin{array}{ c } \hline +2 \\ \hline \end{array}$	$\begin{array}{ c } \hline -4 \\ \hline \end{array}$	$\begin{array}{ c } \hline -2 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline +8 \\ \hline \end{array}$	$\begin{array}{ c } \hline 0 \\ \hline \end{array}$	$\begin{array}{ c } \hline +8 \\ \hline \end{array}$	$\begin{array}{ c } \hline +5 \\ \hline \end{array}$	$\begin{array}{ c } \hline +3 \\ \hline \end{array}$	$\begin{array}{ c } \hline +6 \\ \hline \end{array}$	$\begin{array}{ c } \hline -1 \\ \hline \end{array}$	$\begin{array}{ c } \hline \end{array}$	10.870
		0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	
DISTANCE ALONG WINDOW (in.)																				

NOTE: All readings are shown in thousandths of an inch, thus +.007 = +7. + Means an oversized reading and - means undersized.

1. H-6 corresponds to the horizontal line near the lower edge of the window and is about 54.8" above floor level.
2. H-18 is a similar horizontal line 12.000" above H-6 and is the upper limit of the test set-up, about 66.8" above floor.

Fig. 7. Calibration Chart for Plate Located 6" Inside Cell.

VERTICAL (in.)	H-18	$\frac{+18}{+60}$	$\frac{+12}{+67}$	$\frac{+13}{+54}$	$\frac{+18}{+45}$	$\frac{+23}{+46}$	$\frac{+15}{+48}$	$\frac{+9}{+45}$	$\frac{+24}{+56}$	$\frac{-2}{+56}$	$\frac{+22}{+50}$	$\frac{+12}{+66}$	$\frac{+16}{+44}$	$\frac{+10}{+44}$	$\frac{+16}{+53}$	$\frac{+45}{+56}$	$\frac{+58}{+73}$	$\frac{+20}{+73}$	$\frac{-57}{-57}$
	H-16	$\frac{+8}{+5}$	$\frac{+11}{+7}$	$\frac{+3}{+7}$	$\frac{+26}{+6}$	$\frac{+24}{+11}$	$\frac{+21}{+7}$	$\frac{-2}{+15}$	$\frac{+18}{+16}$	$\frac{+8}{+27}$	$\frac{+10}{+1}$	$\frac{+13}{+6}$	$\frac{+13}{+31}$	$\frac{+14}{+43}$	$\frac{+16}{+32}$	$\frac{+18}{+39}$	$\frac{+63}{+50}$	$\frac{+71}{+50}$	$\frac{+48}{+48}$
	H-14	$\frac{+11}{+16}$	$\frac{+9}{+8}$	$\frac{+14}{+14}$	$\frac{+18}{+20}$	$\frac{+36}{+19}$	$\frac{0}{+18}$	$\frac{+20}{+9}$	$\frac{+22}{+27}$	$\frac{+14}{+14}$	$\frac{+36}{+29}$	$\frac{+8}{+32}$	$\frac{+6}{+18}$	$\frac{+22}{+20}$	$\frac{+4}{+20}$	$\frac{+24}{+22}$	$\frac{+66}{+18}$	$\frac{+51}{+32}$	$\frac{+6}{+6}$
	H-12	$\frac{+3}{+4}$	$\frac{+2}{+12}$	$\frac{+3}{+2}$	$\frac{+23}{+15}$	$\frac{+24}{+6}$	$\frac{+8}{+4}$	$\frac{+14}{+16}$	$\frac{+20}{+9}$	$\frac{+21}{+9}$	$\frac{+15}{+11}$	$\frac{+12}{+9}$	$\frac{+8}{+12}$	$\frac{+21}{+19}$	$\frac{+11}{+9}$	$\frac{+26}{+18}$	$\frac{+50}{+21}$	$\frac{+4}{+12}$	$\frac{+15}{+15}$
	H-10	$\frac{+2}{+15}$	$\frac{+23}{+16}$	$\frac{+5}{+13}$	$\frac{+17}{+4}$	$\frac{+19}{+19}$	$\frac{+10}{+13}$	$\frac{0}{+10}$	$\frac{+18}{+10}$	$\frac{+10}{+13}$	$\frac{+8}{+22}$	$\frac{+5}{+27}$	$\frac{+19}{+31}$	$\frac{+8}{+48}$	$\frac{+12}{+33}$	$\frac{+31}{+34}$	$\frac{+45}{+41}$	$\frac{0}{+37}$	$\frac{-57}{-57}$
	H-8	$\frac{+17}{+14}$	$\frac{+27}{+6}$	$\frac{+1}{+22}$	$\frac{+12}{+24}$	$\frac{+15}{+19}$	$\frac{+17}{+21}$	$\frac{+17}{+48}$	$\frac{+14}{+52}$	$\frac{+10}{+56}$	$\frac{+11}{+44}$	$\frac{+9}{+51}$	$\frac{+15}{+54}$	$\frac{+27}{+54}$	$\frac{+12}{+68}$	$\frac{+34}{+54}$	$\frac{+23}{+46}$	$\frac{+4}{+32}$	$\frac{+31}{+31}$
	H-6	$\frac{-6}{-6}$	$\frac{+8}{+8}$	$\frac{+26}{+26}$	$\frac{+16}{+16}$	$\frac{+2}{+2}$	$\frac{+13}{+13}$	$\frac{+14}{+14}$	$\frac{+9}{+9}$	$\frac{+24}{+24}$	$\frac{+8}{+8}$	$\frac{+16}{+16}$	$\frac{+18}{+18}$	$\frac{+15}{+15}$	$\frac{+16}{+16}$	$\frac{+32}{+32}$	$\frac{+26}{+26}$	$\frac{+8}{+8}$	$\frac{-8}{-8}$
		0	2	-4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
		DISTANCE ALONG WINDOW (in.)																	

NOTE: All readings are shown in thousandths of an inch, thus $+0.014 = +14$. + Means an oversize reading and - means undersized.

1. H-6 corresponds to the horizontal line near the lower edge of the window and is about 54.8" above floor level.
2. H-18 is a similar horizontal line 12.000" above H-6 and is the upper limit of the test set-up, about 66.8" above floor.

Fig. 8. Calibration Chart for Plate Located 9 ft 9" Back from Cell Window.

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Measurement of a Part Inside Cell Fig.10.

QRB-1014-57

FIG 11

010

+

PLOT OF GRID PLATE DEVIATIONS

PLOT OF GRID PLATE DEVIATIONS

AAA-10-14-57

FIG 12

PLOT OF GRID PLATE DEVIATIONS

FIG. 13

PLOT OF GRID PLATE DEVIATIONS

AAA 10-15-57

FIG. 14

Data Taken Using Vernier Height Gage, Precision Level and Optical Micrometer - Fig. 15.

NOTE:

1. ALL READINGS WERE TAKEN AT THE H-6 LINE WHICH WAS THE LOWEST LINE ON THE PLATE VISIBLE THRU THE WINDOW.
2. THE INSTRUMENTS HAD BEEN REMOVED AND REPLACED EACH DAY.
3. THE GRID PLATE WAS LOCATED 9 FT 9" BACK OF THE CELL WINDOW.

LEGEND

- + OCT. 4 RUN
- x OCT 7 RUN
- o OCT 9 RUN

PLOT OF READING DISPERSION TAKEN AT DIFFERENT TIMES

FIG. 16

DEVIATIONS OF POINT SOURCE REFLECTIONS
INDICATING IMPERFECT ALIGNMENT OF
GLASS LAYERS OF CELL No 1.

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Time Exposure of Pin Point Light Reflections in Cell Window - Fig. 18

IX. Appendix

Data Sheets

- A. Outside Cell
- B. Inside Cell, 6 in. From Window
- C. Inside Cell, 9 ft, 9 in. From Window

APPENDIX A

Data Sheet . . . No. 1
Plate Location . Outside Cell
Grid Line . . . H-2
Data Taken . . . September 24, 1957
Taken By A. A. Abbatiello and J. J. Platz

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change for 2" Incr</u>	<u>Cumulative From Left Edge</u>
0	27.884	Zero Point	.000
2	29.885	+ .001	+ .001
4	31.885	+ .000	+ .001
6	33.885	+ .000	+ .001
8	35.887	+ .002	+ .003
10	37.886	- .001	+ .002
12	39.886	.000	+ .002
14	41.885	- .001	+ .001
16	43.885	.000	+ .001
18	45.885	.000	+ .001
20	47.885	.000	+ .001
22	49.886	+ .001	+ .002
24	51.886	.000	+ .002
26	53.886	.000	+ .002
28	55.886	.000	+ .002
30	57.886	.000	+ .002
32	59.887	+ .001	+ .003
34	61.887	.000	+ .003

NOTE: This was the first set of readings. Better operation of the instruments subsequently gave more accurate readings.

Incr is abbreviation for increment.

APPENDIX A

Data Sheet No. 2
Plate Location . . Outside Cell
Grid Line H-10
Data Taken September 26, 1957
Taken By A. A. Abbatiello
 and J. J. Platz

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change for 2" Incr</u>	<u>Cumulative From Left Edge</u>
0	27.841	Zero Point	.000
2	29.841	.000	.000
4	31.840	- .001	- .001
6	33.840	- .000	- .001
8	35.840	- .000	- .001
10	37.839	- .001	- .002
12	39.840	+ .001	- .001
14	41.840	.000	- .001
16	43.840	.000	- .001
18	45.840	.000	- .001
20	47.841	+ .001	.000
22	49.841	.000	.000
24	51.841	.000	.000
26	53.841	.000	.000
28	55.841	.000	.000
30	57.841	.000	.000
32	59.842	+ .001	+ .001
34	61.842	.000	+ .001

APPENDIX B

Data Sheet No. 3
 Plate Location . . 6" Inside Cell Window
 Grid Line H-18
 Date Taken October 1, 1957
 Taken By A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cummulative Change From Left Edge</u>	<u>Vertical Vernier Reading</u>	<u>Total Height</u>
0	27.912	Zero Point	± .000	22.888 + .021	22.909
2	29.908	- .004	- .004		
4	31.910	+ .002	- .002		
6	33.910	± .000	- .002		
8	35.915	+ .005	+ .003		
10	37.913	- .002	+ .001		
12	39.915	+ .002	+ .003		
14	41.921	+ .006	+ .009		
16	43.922	+ .001	+ .010		
18	45.923	+ .001	+ .011		
20	47.919	- .004	+ .007		
22	49.928	+ .009	+ .016		
24	51.932	+ .004	+ .020		
26	53.936	+ .004	+ .024		
28	55.938	+ .002	+ .026		
30	57.945	+ .007	+ .033		
32	59.948	+ .003	+ .036	22.888 + .060	22.948

NOTE: The tooling bar was positioned by means of the vertical height gage. The optical micrometer was then adjusted to read the H-line location.

APPENDIX B

Data Sheet No. 4
 Plate Location . . 6" Inside Cell Window
 Grid Line H-16
 Date Taken October 1, 1957
 Taken By A. A. Abbatiello
 and E. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cummulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>	<u>Total Height</u>
0	27.911	Zero Point	± .000	+ .011	20.888	20.899
2	29.910	- .001	- .001	+ .012		
4	31.914	+ .004	+ .003	+ .013		
6	33.912	- .002	+ .001	+ .014		
8	35.919	+ .007	+ .008	+ .017		
10	37.922	+ .003	+ .011	+ .019		
12	39.924	+ .002	+ .013	+ .020		
14	41.928	+ .004	+ .017	+ .020		
16	43.928	± .000	+ .017	+ .021		
18	45.927	- .001	+ .016	+ .026		
20	47.930	+ .003	+ .019	+ .027		
22	49.932	+ .002	+ .021	+ .031		
24	51.936	+ .004	+ .025	+ .036		
26	53.942	+ .006	+ .031	+ .041		
28	55.945	+ .003	+ .034	+ .046		
30	57.952	+ .007	+ .041	+ .049		
32	59.965	+ .013	+ .054	+ .051		
34	61.965	± .000	+ .054	+ .054	20.888	20.942

NOTE: Reading in Vertical Optical Mike column indicates a slope of the grid line, these are not deviations in the glass.

APPENDIX B

Data Sheet No. 5
 Plate Location . . 6" Inside Cell Window
 Grid Line H-14
 Date Taken October 2, 1957
 Taken By A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cummulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>	<u>Total Height</u>
0	27.922	Zero Point	.000	+ .013	18.888	18.901
2	29.921	- .001	- .001	+ .015		
4	31.920	- .001	- .002	+ .018		
6	33.922	+ .002	± .000	+ .018		
8	33.923	+ .001	+ .001	+ .020		
10	37.928	+ .005	+ .006	+ .023		
12	39.928	± .000	+ .006	+ .022		
14	41.932	+ .004	+ .010	+ .029		
16	43.935	+ .003	+ .013	+ .029		
18	45.933	- .002	+ .011	+ .032		
20	47.938	+ .005	+ .016	+ .034		
22	49.940	+ .002	+ .018	+ .036		
24	51.943	+ .003	+ .021	+ .039		
26	53.946	+ .003	+ .024	+ .038		
28	55.949	+ .003	+ .027	+ .041		
30	57.954	+ .005	+ .032	+ .045		
32	59.964	+ .010	+ .042	+ .047		
34	61.965	+ .001	+ .043	+ .049	18.888	18.937

APPENDIX B

Data Sheet . . . No. 6
 Plate Location . . 6" Inside Cell Window
 Grid Line . . . H-12
 Date Taken . . . October 2, 1957
 Taken By . . . A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cummulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>	<u>Total Heights</u>
0	27.935	Zero Point	.000	+ .032	16.888	16.920
2	29.933	- .002	- .002	+ .033		
4	31.934	+ .001	- .001	+ .034		
6	33.935	+ .001	± .000	+ .034		
8	35.944	+ .009	+ .009	+ .037		
10	37.948	+ .004	+ .013	+ .039		
12	39.954	+ .006	+ .019	+ .040		
14	41.952	- .002	+ .017	+ .040		
16	43.952	± .000	+ .017	+ .042		
18	45.955	+ .003	+ .020	+ .040		
20	47.957	+ .002	+ .022	+ .044		
22	49.959	+ .002	+ .024	+ .042		
24	51.965	+ .006	+ .030	+ .050		
26	53.965	± .000	+ .030	+ .050		
28	55.969	+ .004	+ .034	+ .051		
30	57.972	+ .003	+ .037	+ .052		
32	59.982	+ .010	+ .047	+ .058		
34	61.986	+ .004	+ .051	+ .058	16.888	16.946

NOTE: Precision level was not used.

APPENDIX B

Data SheetNo. 7
 Plate Location . 6" Inside Cell Window
 Grid Line . . . H-10
 Date Taken . . . October 2, 1957
 Taken By A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cummulative Change From Left Side</u>	<u>Vertical on Optical Mike</u>	<u>Vertical Vernier Reading</u>	<u>Total Height</u>
0	27.938	Zero Point	0	+ .016	14.888	14.904
2	29.945	+ .007	+ .007	+ .013		
4	31.945	± .000	+ .007	+ .016		
6	33.945	± .000	+ .007	+ .011		
8	35.950	+ .005	+ .012	+ .016		
10	37.951	+ .001	+ .013	+ .016		
12	39.960	+ .009	+ .022	+ .019		
14	41.956	- .004	+ .018	+ .020		
16	43.961	+ .005	+ .023	+ .021		
18	45.961	± .000	+ .023	+ .020		
20	47.965	+ .004	+ .027	+ .022		
22	49.967	+ .002	+ .029	+ .021		
24	51.971	+ .004	+ .033	+ .025		
26	53.972	+ .001	+ .034	+ .029		
28	55.974	+ .002	+ .036	+ .027		
30	57.984	+ .010	+ .046	+ .027		
32	59.980	- .004	+ .042	+ .030		
34	61.991	+ .011	+ .053	+ .031	14.888	14.919

NOTE: No precision level used.

APPENDIX B

Data Sheet . . . No. 8
 Plate Location . 6" Inside Cell Window
 Grid Line . . . H-8
 Date Taken . . . October 2, 1957
 Taken By . . . A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change for 2" Increment</u>	<u>Cummulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>	<u>Total Height</u>
0	27.928	Zero Point	.000	- .025	12.888	12.863
2	29.934	+ .006	+ .006	- .028		
4	31.939	+ .005	+ .011	- .029		
6	33.936	- .003	+ .008	- .028		
8	35.942	+ .006	+ .014	- .030		
10	37.941	- .001	+ .013	- .029		
12	39.948	+ .007	+ .020	- .026		
14	41.948	± .000	+ .020	- .023		
16	43.948	± .000	+ .020	- .022		
18	45.947	- .001	+ .019	- .022		
20	47.948	+ .001	+ .020	- .024		
22	49.954	+ .006	+ .026	- .022		
24	51.960	+ .006	+ .032	- .022		
26	53.960	± .000	+ .032	- .016		
28	55.964	+ .004	+ .036	- .017		
30	57.971	+ .007	+ .043	- .015		
32	59.972	+ .001	+ .044	- .010		
34	61.978	+ .006	+ .050	- .003	12.888	12.885

NOTE: Precision level was not used.

APPENDIX B

Data Sheet No. 9
 Plate Location . 6" Inside Cell Window
 Grid Line. . . . H-6
 Date Taken October 3, 1957
 Taken By A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cummulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>	<u>Total Height</u>
0	27.945	Zero Point	.000	- .037	10.888	10.851
2	29.948	+ .003	+ .003	- .041		
4	31.946	- .002	+ .001	- .039		
6	33.952	+ .006	+ .007	- .038		
8	35.955	+ .003	+ .010	- .044		
10	37.953	- .002	+ .008	- .048		
12	39.960	+ .007	+ .015	- .046		
14	41.962	+ .002	+ .017	- .043		
16	43.958	- .004	+ .013	- .044		
18	45.956	- .002	+ .011	- .041		
20	47.956	± .000	+ .011	- .037		
22	49.964	+ .008	+ .019	- .034		
24	51.964	± .000	+ .019	- .034		
26	53.972	+ .008	+ .027	- .033		
28	55.977	+ .005	+ .032	- .028		
30	57.980	+ .003	+ .035	- .025		
32	59.986	+ .006	+ .041	- .021		
34	61.985	- .001	+ .040	- .018	10.888	10.870

NOTE: Precision level was not used.

APPENDIX C

Data Sheet . . . No. 10
 Plate Location . 9 ft 9 in. back of Cell Window
 Grid Line. . . H-18
 Date Taken . . . October 7, 1957
 Taken By . . . A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cummulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>
0	27.962	Zero Point	Zero Point	+ .070	22.888
2	29.944	- .018	- .018	+ .072	
4	31.956	+ .012	- .006	+ .062	
6	34.969	+ .013	+ .007	+ .048	
8	35.987	+ .018	+ .025	+ .047	
10	38.010	+ .023	+ .048	+ .038	
12	40.025	+ .015	+ .063	+ .035	
14	42.034	+ .009	+ .072	+ .023	
16	44.058	+ .024	+ .096	+ .024	
18	46.056	- .002	+ .094	+ .017	
20	48.078	+ .022	+ .116	+ .022	
22	50.090	+ .012	+ .128	+ .018	
24	52.106	+ .016	+ .144	+ .020	
26	54.116	+ .010	+ .154	+ .019	
28	56.132	+ .016	+ .170	+ .025	
30	58.177	+ .045	+ .215	+ .047	
32	60.235	+ .058	+ .273	+ .047	
34	62.215	- .020	+ .253	+ .025	

NOTE: Precision level used.

APPENDIX C

Data Sheet . . . No. 11
 Plate Location : 9 ft 9" Back of Cell Window
 Grid Line . . . E-16
 Date Taken . . . October 7, 1957
 Taken By . . . A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cummulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>
0	27.985	Zero Point	Zero Point	+ .010	20.888
2	29.977	- .008	- .008	+ .005	
4	31.988	+ .011	+ .003	+ .008	
6	33.985	- .003	.000	+ .003	
8	36.011	+ .026	+ .026	+ .001	
10	38.035	+ .024	+ .050	- .010	
12	40.056	+ .021	+ .071	- .010	
14	42.054	- .002	+ .069	- .033	
16	44.072	+ .018	+ .087	- .031	
18	46.080	+ .008	+ .095	- .033	
20	48.090	+ .010	+ .105	- .044	
22	50.103	+ .013	+ .118	- .026	
24	52.116	+ .013	+ .131	- .022	
26	54.130	+ .014	+ .145	- .034	
28	56.146	+ .016	+ .161	- .031	
30	58.164	+ .018	+ .179	- .026	
32	60.227	+ .063	+ .242	- .026	
34	62.223	- .004	+ .238	- .032	

NOTE: Precision level used.

APPENDIX C

Data Sheet No. 12
Plate Location . . 9 ft 9" Back of Cell Window
Grid Line H-14
Date Taken October 11, 1957
Taken By A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cumulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>
0	27.979			+ .015	18.888
2	29.978	- .001	- .001	+ .012	
4	31.984	+ .006	+ .005	+ .001	
6	33.998	+ .014	+ .019	- .003	
8	36.016	+ .018	+ .037	- .010	
10	38.052	+ .036	+ .073	- .017	
12	40.052	.000	+ .073	- .025	
14	42.072	+ .020	+ .093	- .017	
16	44.050	- .022	+ .071	- .058	
18	46.064	+ .014	+ .085	- .032	
20	48.100	+ .036	+ .121	- .038	
22	50.108	+ .008	+ .129	- .057	
24	52.114	+ .006	+ .135	- .065	
26	54.136	+ .022	+ .157	- .066	
28	56.140	+ .004	+ .161	- .070	
30	58.164	+ .024	+ .185	- .076	
32	60.230	+ .066	+ .251	- .076	
34	62.225	- .005	+ .246	- .080	

APPENDIX C

Data Sheet No. 13
 Plate Location . . 9 ft 9" Back of Cell Window
 Grid Line H-12
 Date Taken October 10, 1957
 Taken By A. A. Abbatiello
 and C. K. McGlothlan

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cummulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>
0	27.965	Zero Point	Zero Point	- .001	16.888
2	29.968	+ .003	+ .003	+ .004	
4	31.980	+ .012	+ .015	- .013	
6	33.983	+ .003	+ .018	- .023	
8	36.006	+ .023	+ .041	- .029	
10	38.030	+ .024	+ .065	- .035	
12	40.038	+ .008	+ .073	- .034	
14	42.024	- .014	+ .059	- .044	
16	44.044	+ .020	+ .079	- .072	
18	46.065	+ .021	+ .100	- .061	
20	48.080	+ .015	+ .115	- .070	
22	50.092	+ .012	+ .127	- .075	
24	52.100	+ .008	+ .135	- .085	
26	54.121	+ .021	+ .156	- .086	
28	56.132	+ .011	+ .167	- .092	
30	58.158	+ .026	+ .193	- .094	
32	60.208	+ .050	+ .243	- .108	
34	62.212	+ .004	+ .247	- .105	

NOTE: Recheck with precision level used.

APPENDIX C

Data Sheet No. 14
 Plate Location . . . 9 ft 9" Back of Cell Window
 Grid Line H-10
 Date Taken October 10, 1957
 Taken By A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cumulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>
0	27.968	Zero Point	Zero Point	+ .005	14.888
2	29.970	+ .002	+ .002	- .008	
4	31.993	+ .023	+ .025	- .015	
6	33.988	- .005	+ .020	- .038	
8	36.005	+ .017	+ .037	- .035	
10	38.024	+ .019	+ .056	- .039	
12	40.034	+ .010	+ .066	- .050	
14	42.034	.000	+ .066	- .053	
16	44.052	+ .018	+ .084	- .063	
18	46.062	+ .010	+ .094	- .072	
20	48.070	+ .008	+ .102	- .081	
22	50.075	+ .005	+ .107	- .087	
24	52.094	+ .019	+ .126	- .104	
26	54.102	+ .008	+ .134	- .095	
28	56.114	+ .012	+ .146	- .110	
30	58.145	+ .031	+ .177	- .115	
32	60.190	+ .045	+ .222	- .120*	
34	62.190	.000	+ .222	- .120*	

NOTE: Precision level used.

* Estimated

APPENDIX C

Data Sheet No. 15
 Plate Location . . 9 ft 9" Back of Cell Window
 Grid Line R-8
 Date Taken October 4, 1957
 Taken By A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cummulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>
0	27.951	Zero Point	Zero Point	- .010	12.888
2	29.968	+ .017	+ .017	- .024	
4	31.995	+ .027	+ .044	- .028	
6	39.996	+ .001	+ .045	- .034	
8	36.008	+ .012	+ .057	- .054	
10	38.023	+ .015	+ .072	- .052	
12	40.040	+ .017	+ .089	- .040	
14	42.057	+ .017	+ .106	- .043	
16	44.071	+ .014	+ .120	- .050	
18	46.081	+ .010	+ .130	- .050	
20	48.092	+ .011	+ .141	- .054	
22	50.101	+ .009	+ .150	- .056	
24	52.116	+ .015	+ .165	- .056	
26	54.143	+ .027	+ .192	- .062	
28	56.155	+ .012	+ .204	- .076	
30	58.189	+ .034	+ .238	- .074	
32	60.212	+ .023	+ .261	- .083	
34	62.216	+ .004	+ .265	- .063	

NOTE: No precision level used.

APPENDIX C

Data Sheet No. 16
 Plate Location . . 9 ft 9" Back of Cell Window
 Grid Line H-6
 Date Taken October 4, 1957
 Taken By A. A. Abbatiello
 and H. W. Hoover

<u>Distance on Plate</u>	<u>Vernier Reading</u>	<u>Net Change For 2" Increment</u>	<u>Cummulative Change From Left Side</u>	<u>Vertical on Opti- cal Mike</u>	<u>Vertical Vernier Reading</u>
0	27.982	Zero Point	Zero Point	- .024	10.888
2	29.976	- .006	- .006	- .030	
4	31.984	+ .008	+ .002	- .050	
6	34.010	+ .026	+ .028	- .058	
8	36.026	+ .016	+ .044	- .073	
10	38.028	+ .002	+ .046	- .073	
12	40.041	+ .013	+ .059	- .088	
14	42.055	+ .014	+ .073	- .095	
16	44.064	+ .009	+ .082	- .106	
18	46.088	+ .024	+ .106	- .094	
20	48.096	+ .008	+ .114	- .105	
22	50.112	+ .016	+ .130	- .110	
24	52.130	+ .018	+ .148	- .110	
26	54.145	+ .015	+ .163	- .130	
28	56.161	+ .016	+ .179	- .130	
30	58.193	+ .032	+ .211	- .120	
32	60.219	+ .026	+ .237	- .115	
34	62.211	- .008	+ .229	- .094	

NOTE: No precision level used.

Internal Distribution

1-4.	A. A. Abbatiello	31.	M. I. Lundin
5.	S. E. Beall	32.	H. G. MacPherson
6.	M. Bender	33.	W. D. Manly
7.	D. S. Billington	34.	E. R. Mann
8.	E. P. Blizzard	35.	F. R. McQuilkin
9.	A. L. Boch	36.	R. V. Meghreblian
10.	W. F. Boudreau	37.	A. J. Miller
11.	E. J. Breeding	38.	G. Morris
12.	R. B. Briggs	39.	A. R. Olsen
13.	W. E. Browning	40.	P. Patriarca
14.	R. S. Carlsmith	41.	A. M. Perry
15.	Roy Clark	42.	E. E. Pierce
16.	W. B. Cottrell	43.	F. Ring, Jr.
17.	G. A. Cristy	44.	A. F. Rupp
18.	F. L. Culler	45.	H. W. Savage
19.	R. J. DeBakker	46.	A. Savolainen
20.	S. E. Dismuke	47.	H. E. Seagren
21.	H. G. Duggan	48.	R. P. Shields
22.	D. W. Ferguson	49.	O. Sisman
23.	W. F. Ferguson	50.	M. J. Skinner
24.	E. A. Franco Ferraira	51.	J. A. Swartout
25.	A. P. Fraas	52.	D. B. Trauger
26.	E. J. Frederick	53.	C. D. Watson
27.	W. R. Harwell	54.	G. D. Whitman
28.	C. P. Johnston	55-56.	Central Research
29.	G. W. Keilholtz	57.	Document Reference
30.	R. B. Lindauer	58-59.	Laboratory Records
		60.	ORNL-RC

External Distribution

61. Brunson Instrument Company
Kansas City, Missouri
- 62-76. TISE, AEC