CLAS-NOTE 93-022

Survey of the Region 3 Box Layup Fixture

October 20, 1993
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Abstract:

I summarize our knowledge of the geometry of the box layup fixture; in particular, the three dimensional location of the 14 fiducial points on the structure.

Introduction:

The purpose of the box layup fixture is to hold the two endplates of one Region 3 drift chamber in precise location with respect to one another while the carbon fiber posts and outer carbon fiber shell are placed and permanently glued into position; thus forming the drift chamber assembly, or 'box'. To achieve this, we designed a plate and frame facility in which each plate defines a plane, with the planes intersecting one another at an angle of 60°.

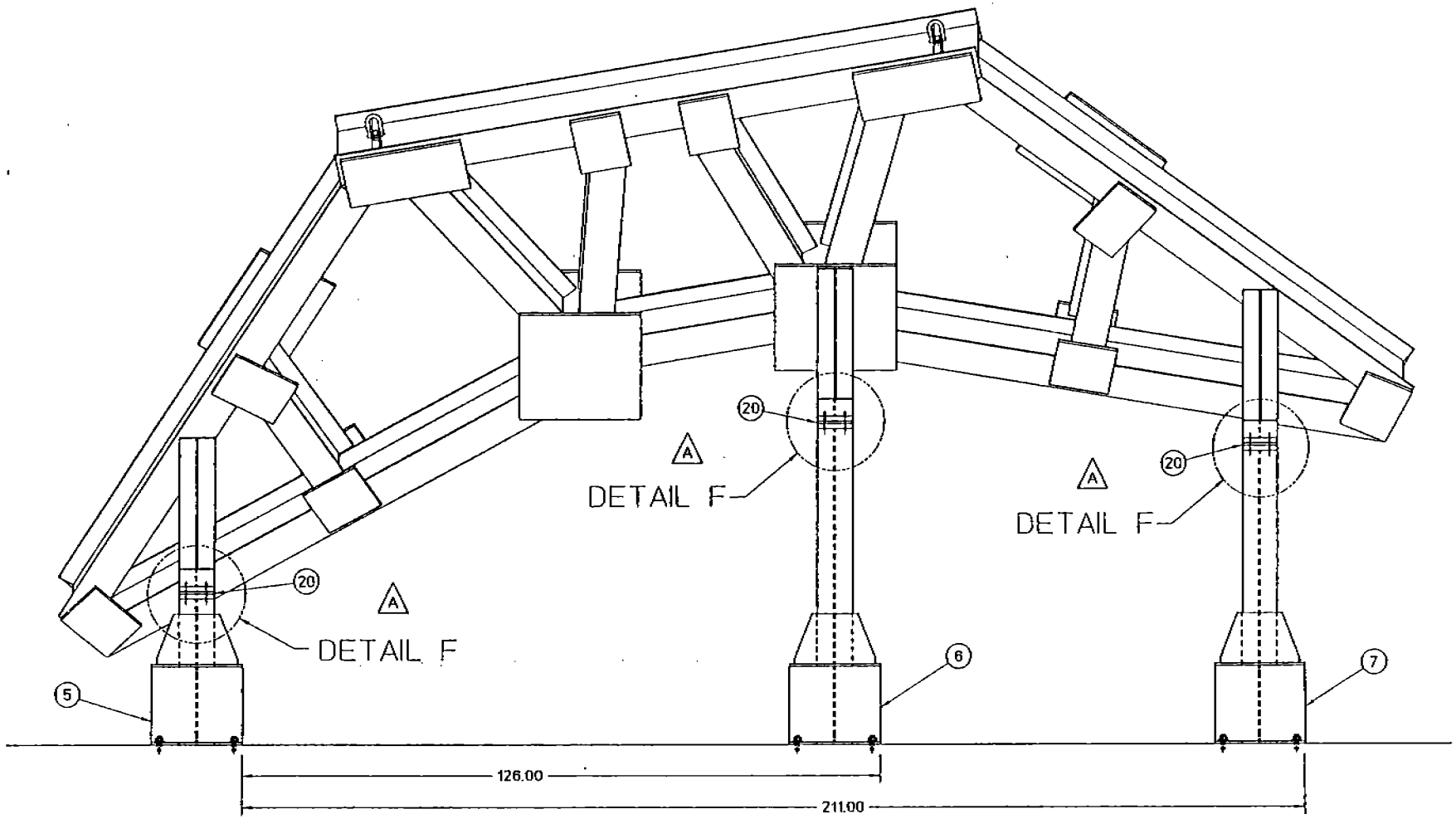
Each plate is a weldment of large steel I-beam construction with 2 small adjustable flat plates with one pin hole in each and 5 adjustable height ball holders. The 5 balls on each plate are outfitted with their own small plates capping them off. The two adjustable 'pin' plates and the five small 'ball' plates were adjusted to lie in a plane. The endplates are positioned by being pinned to the two pin plates, while resting on these two plates and the five 'ball' plates, which insures that they lie in a plane.

The design goal for dimensional accuracy is to define the location of two points on each endplate within .002" of true position in 3 dimensions; these being the pin locations. The five ball plates were also required to be coplanar within .002". These goals arose from our desire to keep all sources of systematic error in locating tracks to below .002". We were not able to achieve this goal. As finally measured, we determined that the pin locations were within .010" of ideal. A combination of after-installment surveys and calibration tracking runs will be necessary to regain the accuracy goal.

Construction and Survey:

The box layup fixture for Region 3 was assembled and roughly aligned in May and June, 1993. A large weldment was fabricated, consisting of two planes and stands to hold them at 60° with respect to one another. Figure 1 is a drawing of the structure. The pin to pin distance was measured on the Endplate Layup Fixture. The pin plates on each plane were adjusted to be the proper distance apart using a rod and plate fixture. Each plate was then laid horizontally and the two pin plates were adjusted to lie in the same horizontal plane. At this time the five extra balls were added, and their heights were adjusted such that their capping plates would lie in the same plane as the two pin plates.

The two large weldments were then placed on their support structure and aligned to close to 60° relative angle using a large angle iron fabricated for this purpose. A series of measurements and adjustments were then performed to bring the fixture into tolerance. Measurements were performed by the CEBAF survey group in which each of the 14 fiducial points were located three dimensionally using a triangulation method and two precision theodolites. Also, cross distances between various of the seven points on one plate to various of the seven on the other were measured using precison stick micrometers.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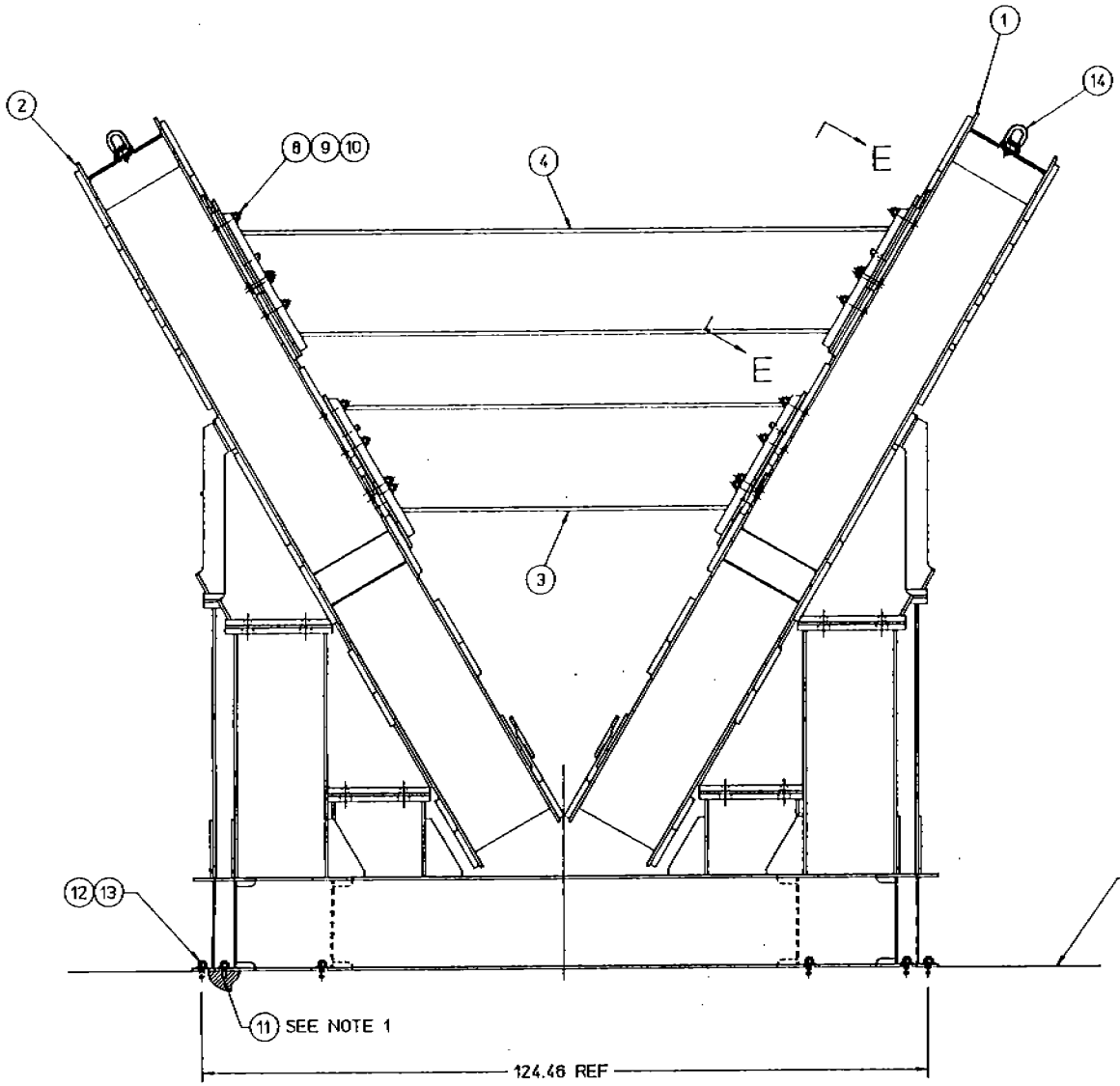
REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APPROVED
	A	ATTACHMENT OF STRUCTURAL ASSY TO BASE REVISED FROM WELDED TO BOLTED CONNECTION. ITEM NO. 15, 16 & 17 DELETED. ITEM NO. 20, 21, 22 & 23 ADDED. DET A, VIEW B-B, DET C & VIEW D-D DELETED. DET F ADDED.	2FEB93	J. E. O'MEARA
	B	CHANGED WELDMENTS TO REFLECT LATEST CHANGES.	02/25/93	[illegible]



These "stick-mike" measurements greatly facilitated the "move to ideal" adjustments of the structure.

The CEBAF alignment and survey group made five surveys of the structure; on July 1, July 22, Aug. 3, Aug. 16 and Aug. 31. Adjustments to the position were made after each survey except after the latest one on Aug. 31, because we have concluded that the fixture is dimensionally accurate enough to begin construction of the drift chamber boxes. The pupose of this memo is to document and analyse the survey data.

Geometry:

Figure 2 is a plan view of the box layup fixture, illustrating the location of the seven locating points on each plate. The superstructure consists of two large 'plates', the southernmost one called the 'left-hand' plate because it's on the left when viewed along the axis toward the west. The five ball locations on this plate are called LH1, LH2, LH3, LH4, and LH5 as one progresses from east to west. The two 'pin' plates are called pads, LHEPAD and LHWPAD for the eastern and western one respectively. The naming convention is the same for the right-hand side, except note that the pins are numbered 1 - 5 as one goes from west to east. A convenient coordinate system is illustrated on Figure 2, with the z axis between the two plates, x running from one plate to the other, and the y axis being up (- gravity) and out of the page.

Analysis: Fitting to a Plane

The equation for a plane (2-dimensional) surface can be written:

$$A*(x-x_0)+B*(y-y_0)+C*(z-z_0)=0.$$

This is the equation for a plane which passes through x_0, y_0, z_0 and is perpendicular to N = (A,B,C).

The fitting method consists of minimizing the sum of the squares of the distances of each point (x_i, y_i, z_i) from the plane. If N = (A,B,C) is the normal vector to the plane, then the distance from point i to the plane is

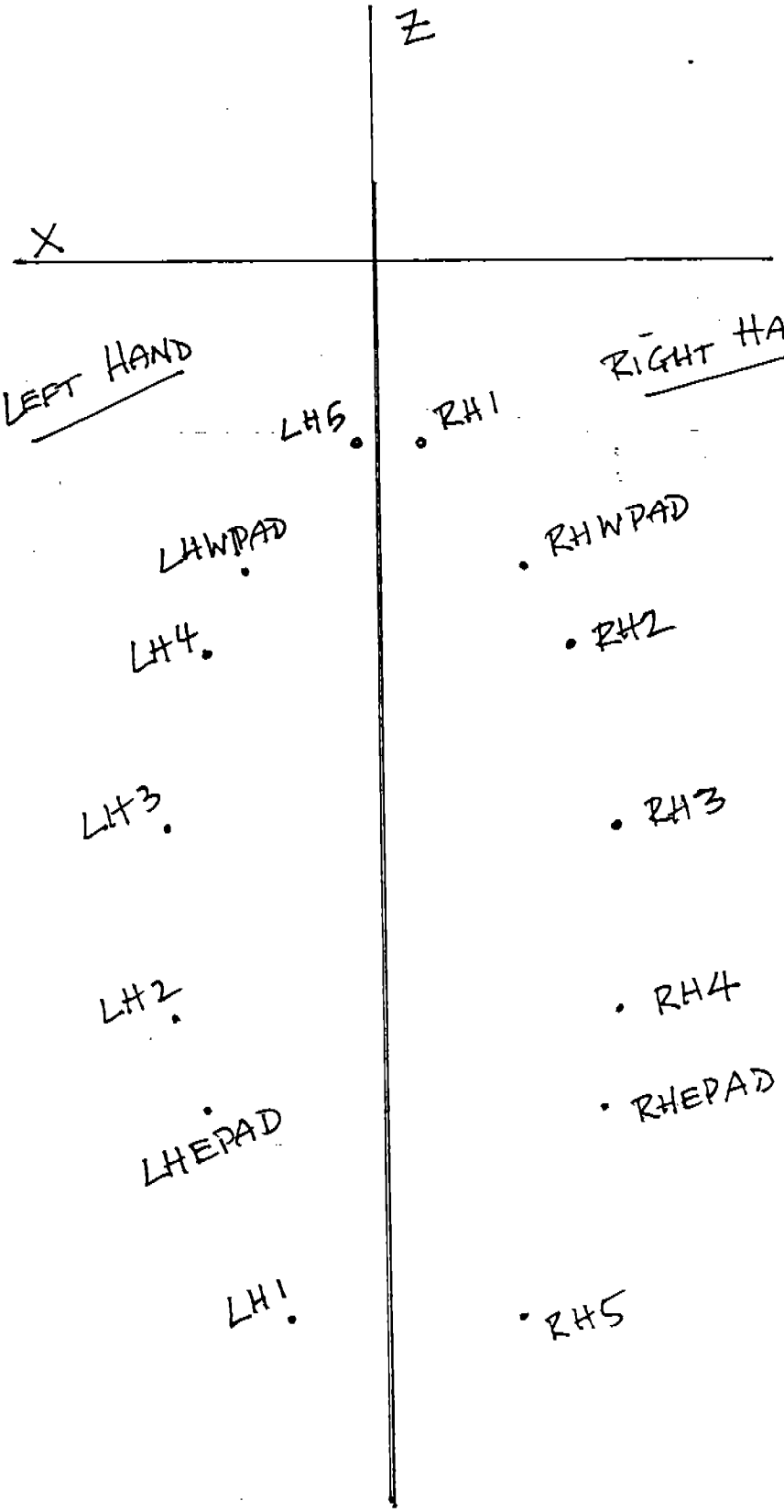
$$DIST(i) = A*(x_i-x_0)+B*(y_i-y_0)+C*(z_i-z_0)$$
$$\text{or, } DIST(i) = A*x_i+B*y_i+C*z_i-(A*x_0+B*y_0+C*z_0)$$
$$\text{or, } DIST(i) = A*x_i+B*y_i+C*z_i-D$$

where D is the distance from the origin (0,0,0) to the plane.

To determine the best plane through the 7 points, we must minimize the sum of $(DIST(i))^2$ by adjusting the values of A, B, C, and D. I used the CERNLIB routine MINSQ to perform this minimization. See the Appendix 1 for the subroutine listing which performed this call to MINSQ.

I entered the data for the measured three dimensional coordinates of the seven points of one plane into the data statement for the plane determining subroutine. The results are displayed in Table 1. For the LH plate, all points are within $17\mu m$ of the best plane. For the RH plate, all points are within $74\mu m$ of planarity. Figure 3 displays the distance of each point above or below the plane plotted versus its z value, for both the LH and RH plates.

WEST WALL



EAST WALL

Survey, Comparison to Ideals:

In this section, I compare the surveyor's 3-dimensional coordinates for each of the 14 fiducial points with their calculated ideal positions. The surveyors rotated their three dimensional measurements to the following coordinate system at our request: y axis is gravity, z axis is perpendicular to y axis and adjusted such that LHWPAD and RHWPAD are at the same z value, x axis is perpendicular to y and z and adjusted such that x(RHWPAD) = -x(LHWPAD).

The ideals are calculated assuming the following:

1) the local coordinates within the plane for each of the seven points on one side are given by an analysis of the survey data of 7/1/93. In particular, the survey group translated the seven 3-dimensional points to a new coordinate system (x',y',z') in which LH1, LH3 and LH5 (or RH1, RH3 and RH5) define a plane such that z'=0 for these three points.

2) The (x',y') system was rotated about z' to a new system (x",y") such that (y"(EPAD) - y"(WPAD))/(x"(EPAD) - x"(WPAD)) = 0.234447. This is the nominal design value for the plate.

3) LHWPAD-RHWPAD span equals 1885.986 mm (plane to plane) or 1866.672 mm (ball center to ball center). The value of 1885.986 mm is from the nominal design of the drift chambers.

4) The distance between pads on a single plate (e.g. distance from LHWPAD to LHEPAD was measured to be 3812.336 mm, some 300 microns (.012") shorter than the nominal design value of 3812.631 mm. I accounted for this by keeping the LHWPAD to RHWPAD distance at its nominal value (see point 3 above) but decreasing the ideal LHEPAD to RHEPAD distance by the ratio of 3812.336/3812.631. To accomplish this, the (x",y") coordinate system for an individual plate was oriented such that the x" distance (same as global z) between East and West pads was 3711.693 mm and the y" difference was 870.195 mm. This is consistent with **2)** above. See Table 2 for a listing of the two dimensional coordinates of the 7 points on each plate.

4) The two planes were then rotated about the x" axis by 30° to get the 3-dimensional points. Specifically; z=x", y=cos(30)*(y"+1885.986), and x=sin(30)*(y"+1885.986).

5) An additional rotation about the x axis was applied to the ideal positions to account for the fact that the box layup fixture was not designed to have the z axis perpendicular to gravity, and in fact the East pads were constructed to be higher than nominal level by 0.798 mm.

I then calculated the ideal positions of each of the fourteen points and compared to the surveyors' measured values. See Table 3 for a comparison of the ideal and measured positions. Note that the four pads are each within 0.231 mm of their nominal location.

Discussion of Results:

From Table 1 we see that the 7 points on the LH plate are coplanar to better than +- 25μm (+- .001"), while the 7 points on the RH plate are coplanar within +- 75μm (+- .003"). All 14 points contribute to planarity, but only the four pads provide 3 dimensional constraints. Table 3 reveals that the four pads are each within 231μm of their nominal positions.

Table 1: Results of Fit to Planarity - RH and LH Sides		
Parameter	LH side	RH side
F	.68e-3	.18e-1
Cx	-.866047	.865995
Cy	.499962	.50005
Cz	.58e-4	-.28e-3
Dist	367.274 mm	363.771 mm
Res(1)	-10 microns	3 microns
Res(2)	17	74
Res(3)	-7	66
Res(4)	-3	57
Res(5)	7	36
Res(EPAD)	6	-64
Res(WPAD)	-13	-19

Table 2: Survey Results - 2 Dimensional Constrained Points					
Name	X'	Y'	Z'	X"	Y"
LH1	0.00	0.0	0.0	-5168.828	-341.102
LH3	3035.990	2039.151	0.0	-1796.577	1074.278
LH5	6143.952	0.0	0.0	859.791	-1525.968
LH2	1810.410	1804.724	-0.042	-3044.360	1080.605
LH4	4363.983	1723.746	0.016	-554.339	508.689
LHEPAD	1196.184	1469.568	0.010	-3711.691	870.195
LHWPAD	5006.017	1331.511	0.057	0.0	0.0
RH1	0.00	0.0	0.0	-861.259	-1524.188
RH3	3112.714	2036.013	0.0	1800.573	1073.693
RH5	6142.429	0.0	0.0	5165.955	-340.071
RH2	1782.907	1721.258	0.204	556.387	508.486
RH4	4341.519	1801.274	-0.079	3051.581	1080.243
RHEPAD	4948.757	1467.912	-0.087	3711.693	870.195
RHWPAD	1138.932	1329.568	0.227	0.0	0.0

Table 3a: Survey Results - Ideal versus Measured - LH					
Name	Type	X	Y	Z	Total
LH1	Measured	791.826	776.977	4831.011	
	Ideal	791.690	776.844	4831.172	
	Difference	0.136	0.133	-0.161	0.249
LH2	Measured	1502.582	2007.751	6955.693	
	Ideal	1502.543	2007.621	6955.640	
	Difference	0.039	0.130	0.053	0.146
LH3	Measured	1499.423	2001.956	8203.547	
	Ideal	1499.379	2001.873	8203.423	
	Difference	0.044	0.083	0.124	0.156
LH4	Measured	1216.649	1511.861	9445.568	
	Ideal	1216.585	1511.792	9445.661	
	Difference	0.064	0.069	-0.093	0.132
LH5	Measured	199.394	-250.549	10859.312	
	Ideal	199.257	-250.576	10859.791	
	Difference	0.137	0.027	-0.479	0.499
LHE	Measured	1368.470	1842.321	6288.382	
	Ideal	1368.433	1842.232	6288.309	
	Difference	0.037	0.089	0.073	0.121
LHW	Measured	933.393	1087.811	9999.819	
	Ideal	933.336	1087.823	10000.000	
	Difference	0.057	-0.012	-0.181	0.190

Table 3b: Survey Results - Ideal versus Measured - RH					
Name	Type	X	Y	Z	Total
RH1	Measured	-200.154	-248.894	10861.213	
	Ideal	-200.146	-249.036	10861.259	
	Difference	-0.008	0.142	-0.046	0.149
RH2	Measured	-1216.483	1511.641	9443.785	
	Ideal	-1216.484	1511.617	9443.613	
	Difference	0.001	0.024	0.172	0.174
RH3	Measured	-1499.152	2001.427	8199.752	
	Ideal	-1499.087	2001.368	8199.427	
	Difference	-0.065	0.059	0.325	0.337
RH4	Measured	-1502.374	2007.265	6948.733	
	Ideal	-1502.362	2007.309	6948.419	
	Difference	-0.012	-0.044	0.314	0.318
RH5	Measured	-792.076	777.590	4834.008	
	Ideal	-792.205	777.736	4834.045	
	Difference	0.129	-0.146	-0.037	0.198
RHE	Measured	-1368.467	1842.011	6288.365	
	Ideal	-1368.433	1842.232	6288.307	
	Difference	-0.034	-0.221	0.058	0.231
RHW	Measured	-933.393	1087.823	10000.181	
	Ideal	-933.336	1087.823	10000.000	
	Difference	-0.057	0.000	0.181	0.189