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Arm Cavity Baffle Shift with Alignment Target

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1 Introduction

The purpose of this technical note is to calculate the offset of the Arm Cavity Baffle (ACB) when a target is placed in the center of the beam hole opening. A counter weight will be added to the opposite side of the target to partially offset the lateral motion due to the induced hanging tilt. The combination of the target and counter weight cause the ITMY ACB to shift down and to the left, as viewed from the ITM viewport adapter; the shift is down and to the right for the ITMX ACB. Therefore, to account for the offset caused by the target and counter weight, the target cross-hairs must be off-set up and to the right for the ITMY ACB, and up and to the left for the ITMX ACB.

2 Calculation

2.1 Parameters

The parameters used in the calculation are shown in the diagram below

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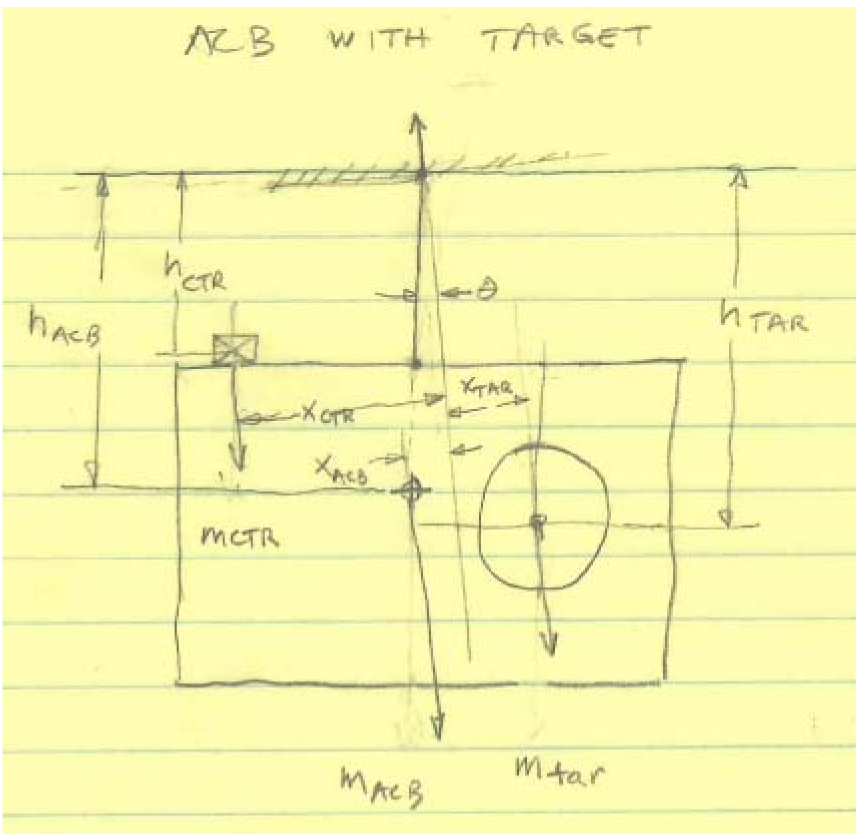
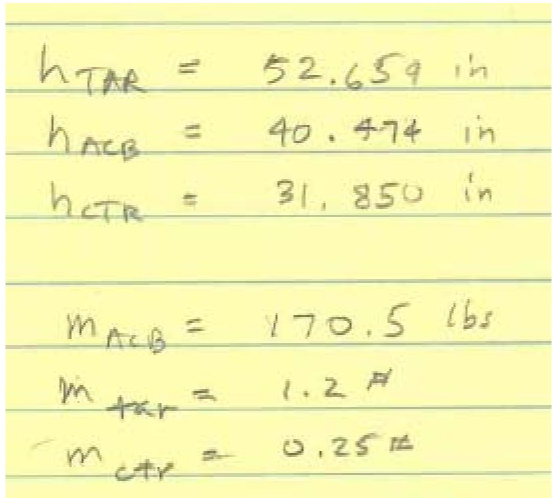


Figure 1: Parameters used for Calculation

The height and weight values are shown below.


h_{TAR} = 52.659 in

h_{ACB} = 40.474 in

h_{CTR} = 31.850 in

m_{ACB} = 170.5 lbs

m_{tar} = 1.2 #

m_{ctr} = 0.25 #

2.2 Horizontal Shift

2.2.1 Torque Balance

The offset load of the ACB target and counter weight will cause the baffle to pivot about the top of the flexure rod by an angle theta, resulting in the horizontal positions of the CG of the Baffle, the target, and the counter weight to shift. The torque balance about the pivot point uniquely defines the vertical tilt angle.

$$x_{ACB} = h_{ACB}\,\theta$$
$$x_{TAR} = 0.2 - h_{TAR}\,\theta$$
$$x_{CTR} = 0.4 + h_{CTR}\,\theta$$

Torque balance

$$x_{TAR}\, m_{TAR} = x_{ACB}\, m_{ACB} + x_{CTR}\, m_{CTR}$$
$$(0.2 - h_{TAR}\,\theta)\, m_{TAR} = h_{ACB}\,\theta\, m_{ACB} + (0.4 + h_{CTR}\,\theta)\, m_{CTR}$$

$$0.2\, m_{TAR} - h_{TAR}\, m_{TAR}\,\theta = h_{ACB}\, m_{ACB}\,\theta + 0.4\, m_{CTR} + h_{CTR}\, m_{CTR}\,\theta$$

$$\theta\,(h_{ACB}\, m_{ACB} + h_{TAR}\, m_{TAR} + h_{CTR}\, m_{CTR}) = 0.2\, m_{TAR} - 0.4\, m_{CTR}$$

$$\theta = \frac{0.2\, m_{TAR} - 0.4\, m_{CTR}}{h_{ACB}\, m_{ACB} + h_{TAR}\, m_{TAR} + h_{CTR}\, m_{CTR}}$$

ACB target, lbs $m_{tarlb} := 1.2$

ACB target ctrwt, lbs $m_{ctrlb} := 0.25$

ACB, lbs $m_{bslb} = 170.5$

horiz. distance from ACB SUS to target m $x_{acbtar} := 0.2$

horiz. distance from ACB SUS to ctrwt m $x_{acbctr} := 0.4$

vertical height of target from SUS point, m $h_{tar} := 52.659 \cdot 0.0254$

vertical height of ACB CG from SUS point, m $h_{acb} := 40.474 \cdot 0.0254$

vertical height of ctr weight from SUS point, m $h_{ctr} := 31.85 \cdot 0.0254$

tilt angle of unbalanced ACB with target, rad

$$\theta := \frac{x_{acbtar} \cdot m_{tarlb} - x_{acbctr} \cdot m_{ctrlb}}{h_{acb} \cdot m_{bslb} + h_{tar} \cdot m_{tarlb} + h_{ctr} \cdot m_{ctrlb}}$$

$$\theta = 7.90567 \times 10^{-4}$$

horizontal displacement of ACB, m

$$x_{ACB} := h_{acb} \cdot \theta$$

$$x_{ACB} = 8.12734 \times 10^{-4}$$

2.3 Vertical Shift

The added weight of the target and counterweight causes the blade spring to deflect in the vertical direction proportionally to the effective spring constant and the added mass.

vertical distance blade moves, in

$$\Delta_{yin}(\theta_m) := \frac{\Delta_y(\theta_m)}{0.0254} \qquad \Delta_{yin}(\theta_m) = 3.84984$$

vertical resonant frequency based on blade depression, Hz

$$f_{0v}(\theta_m) := \frac{\sqrt{\frac{g}{\Delta_y(\theta_m)}}}{2 \cdot \pi} \qquad f_{0v}(\theta_m) = 1.59329$$

effective spring constant, N/m

$$k := \frac{m_{mp}(m_{bslb}) \cdot g}{\Delta_y(\theta_m)}$$

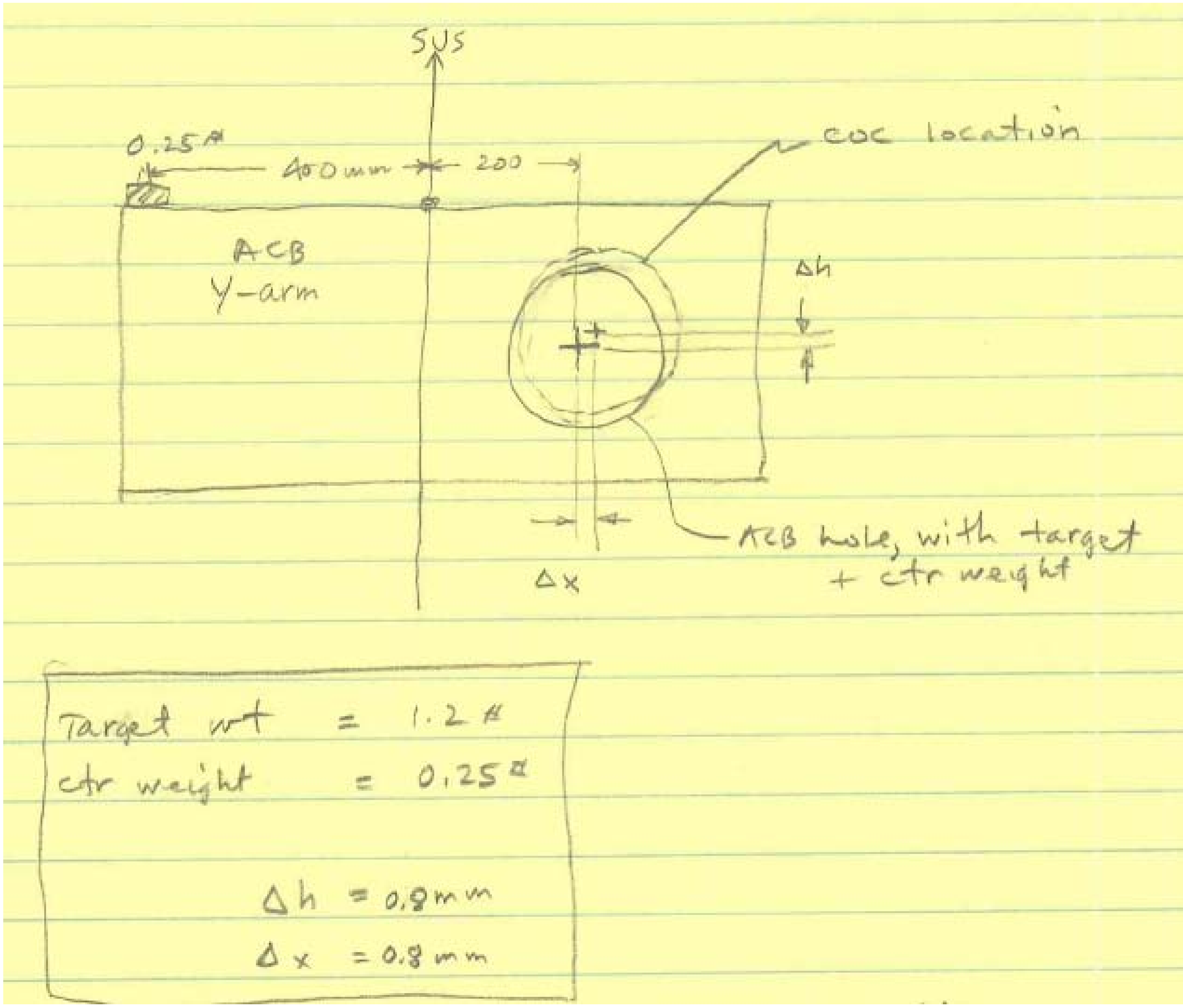
$$k = 7.74935 \times 10^{3}$$

height change due to ACB target-ctrwt, m

$$\Delta h := m_{tartkg} \cdot \frac{g}{k}$$

$$\Delta h = 8.31611 \times 10^{-4}$$

The figure below shows the shift of the ACB with respect to the initial alignment, which was centered on the ITM behind the baffle.



Therefore, to account for the offset caused by the target and counter weight, the target cross-hairs must be off-set--up and to the right for the ITMY ACB, and up and to the left for the ITMX ACB.

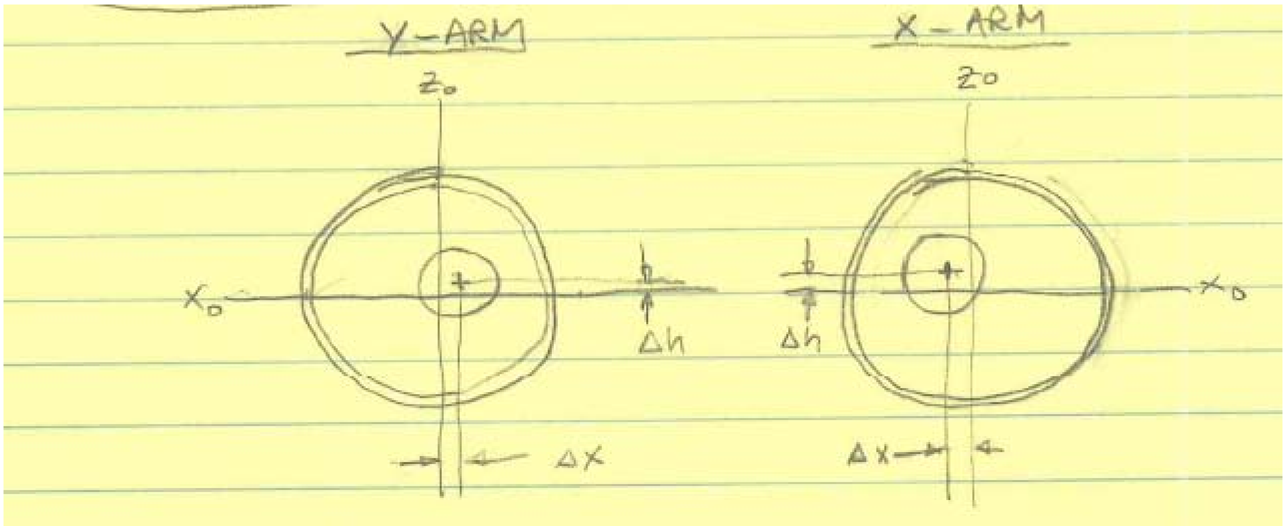


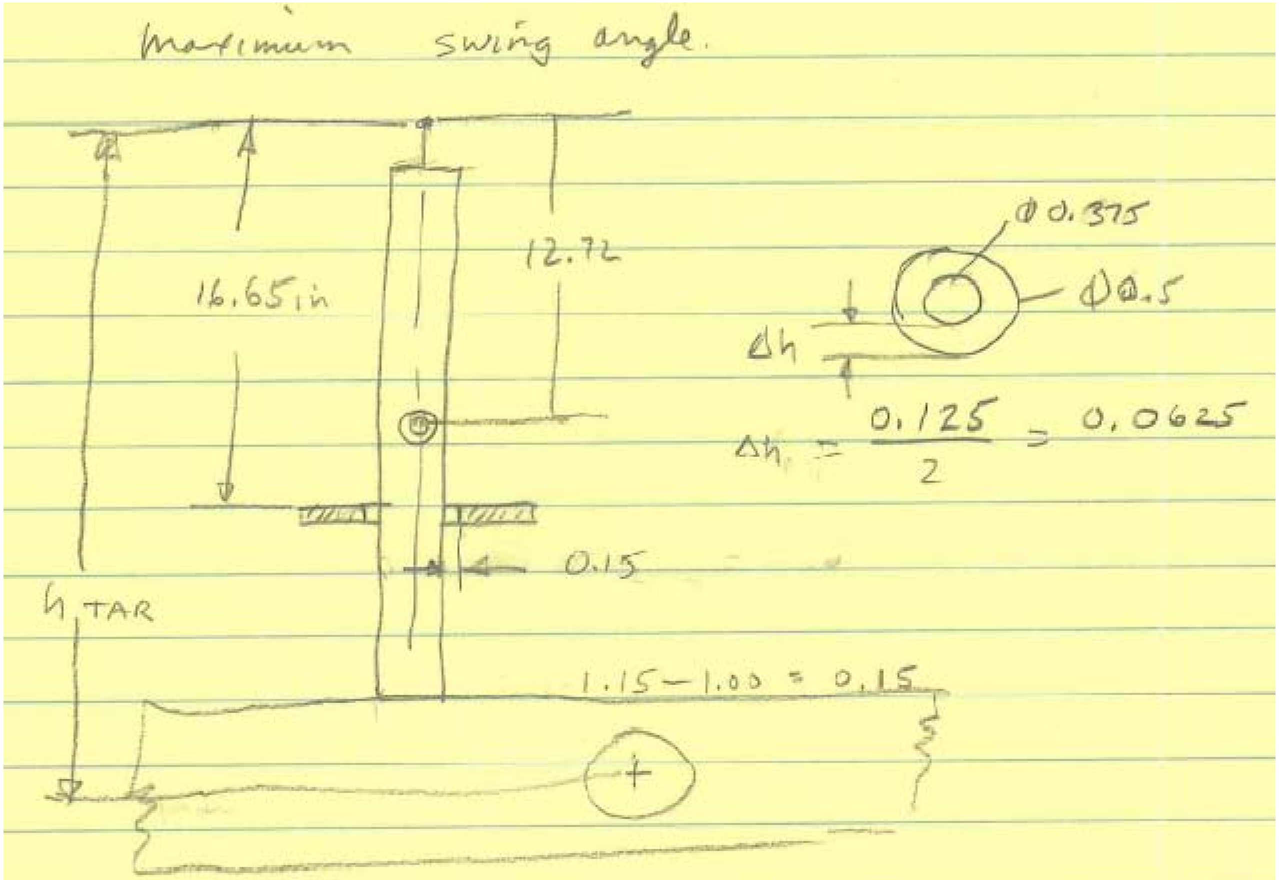
Figure 2: ACB Target Offset for ITM X and ITMY arms

3 Maximum Target Weight

The target weight must be small enough so that the ACB does not hit the earth quake stops in the vertical direction or in the horizontal direction during the alignment procedure.

3.1 Horizontal Displacement

The offset target weight causes the ACB to tilt and swing in the horizontal direction.



The lower earthquake stop rod defines the limiting swing angle.

$$\theta_{max_1} = \frac{0.0625}{12.72} = 5 \times 10^{-3}$$

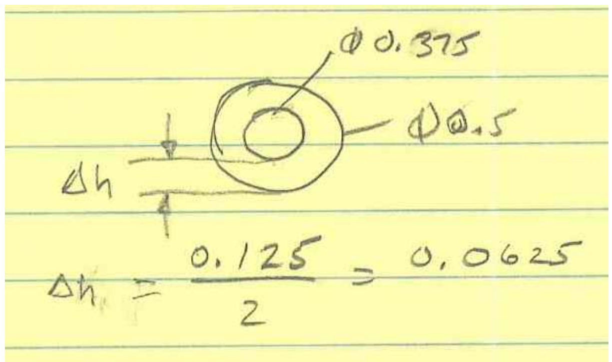
$$\theta_{max_2} = \frac{0.15}{16.65} = 9 \times 10^{-3} \text{ rad}$$

The horizontal motion of the ACB target at the maximum swing angle is

$$\Delta x_{max} = h_{TAR}\,\theta_{max} = 52.659 \times 5 \times 10^{-3} = 0.26 \text{ in}$$

3.2 Vertical Displacement

The maximum allowed vertical displacement before the ACB hits the earthquake stop is equal to the radial spacing between the earthquake stop rod and the hole in the down tube, as shown below, 0.062 in.



3.3 Maximum Target & Counter Weight

The smallest practical weight for the target is 1.2 lbs, and a 0.25 lb counter weight will be placed at the distance 400 mm from the center of the baffle to partially off-set the horizontal shift caused by the target. The total weight of the combined target is 1.45 lbs.

The result is a maximum shift of approximately 0.8 mm in both the horizontal and vertical direction.

3.4 ACB Balance Weight Accuracy

The ACB must be initially balanced to a height accuracy of 0.031 in; this is equivalent to an absolute balanced weight accuracy of < 1.3 lbs.

height change with added weight, m

$$\Delta h_{bal} := 0.031 \cdot 0.0254$$

balance weight increment to cause 0.031 in deflection, lb

$$\Delta m_{ballb} := \frac{\Delta h_{bal} \cdot k \cdot 2.025}{g}$$

$$\Delta m_{ballb} = 1.26084$$

3.5 Mounting Location of Target Counter Weight

The 0.25 lb target counterweight, shown in green in the figure below, will be fastened with a bolt through the available hole in the top plate of the ACB, approximately 400 mm from the center of the ACB.

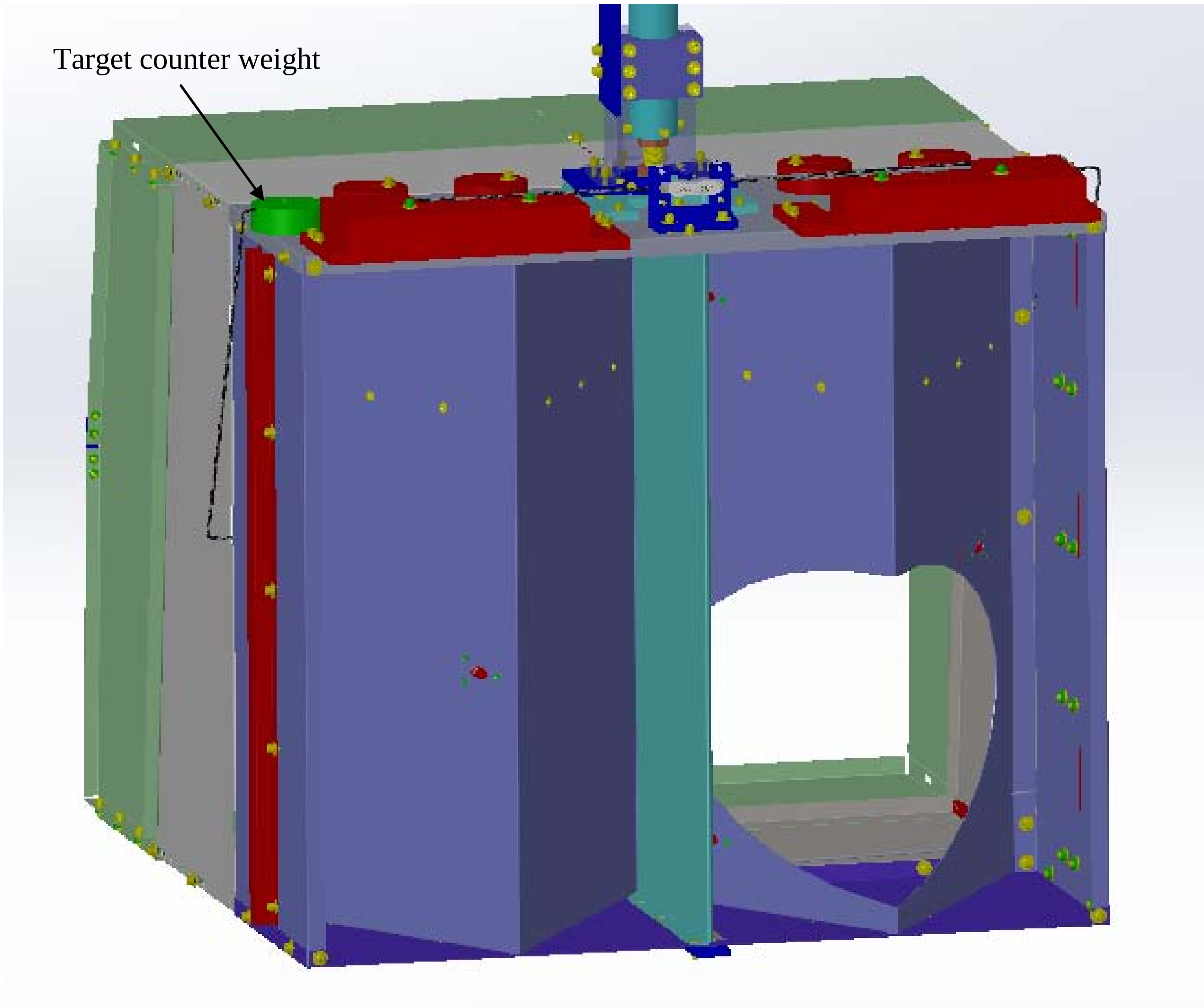


Figure 3: Mounting Position for Target Counter Weight

4 Proposed Balance Weights for As-built ACB Blades

The balanced ACB weight will be within 0.3 lbs of the measured blade support weight with the proposed variable balance weights shown in the table. This meets the required initial balance accuracy.

Table 1: Summary of Proposed ACB Balance Weights

					Variable Balance Weights, lbs					
S/N	**total measured weight, lbs**	**blade thickness, in**	**bare baffle wt, lbs**	**ctr wt slider, lbs**	**2**	**1.5**	**1.25**	**0.5**	**total balanced baffle wt, lbs**	**balance error**
1										
2										
3	171.2	0.2342	122.6	39.90	4			2	171.5	-0.3
4	169.2	0.2345	122.6	39.90	2	2			169.5	-0.3
5	169.2	0.2345	122.6	39.90	2	2			169.5	-0.3
6	167.41	0.2343	122.6	39.90			4		167.5	-0.09
7	169.41	0.234	122.6	39.90	2	2			169.5	-0.09
8	167.41	0.2336	122.6	39.90			4		167.5	-0.09
9	167.41	0.2334	122.6	39.90			4		167.5	-0.09
10	170.41	0.2337	122.6	39.90	4				170.5	-0.09
11	167.41	0.2334	122.6	39.90			4		167.5	-0.09
12	167.41	0.2338	122.6	39.90			4		167.5	-0.09
13										
14	167.41	0.2336	122.6	39.90			4		167.5	-0.09
15	167.41	0.234	122.6	39.90			4		167.5	-0.09
16	167.41	0.2335	122.6	39.90			4		167.5	-0.09
17	167.41	0.2338	122.6	39.90			4		167.5	-0.09
18	167.41	0.2336	122.6	39.90			4		167.5	-0.09
19	170.41	0.2343	122.6	39.90	4				170.5	-0.09
20	167.41	0.2335	122.6	39.90			4		167.5	-0.09