LA-UR-19-20885
Approved for public release; distribution is unlimited.

Title: Radiographic Magnification Differences Due To Grid Placement at DARHT

Author(s): Warthen, Barry J.
Carroll, James Lamond
Disterhaupt, Jennifer Lynn Schei

Intended for: DARHT Technical Note

Issued: 2019-02-04

Radiographic Magnification Differences Due To Grid Placement at DARHT

Barry Warthen, J-4

James Carroll, P-21

Jennifer Schei, P-21

Los Alamos National Laboratory

January 2019

1 Introduction

In 2015, it became apparent that the radiographic grid, which has been used to calibrate the dimensional scale of DARHT radiographs, was not centered at the location where the objects have been centered along the beamline. Instead of the grid center being placed at 133.0 cm, the grid downstream face was placed at this location, putting the grid center at 132.75 cm. This offset produced an error of 0.188% in the dimensional scaling of the radiographic images processed, using the assumption that the grid and objects had the same center. The Air Force Target (AFT) had the same holder as the grid, while the Circular Resolution Target (CRT) used a holder that correctly placed the object center at 133.0 cm.

These erroneous holders were used until October 2015. Starting in November 2015, new holders were used that placed all static target objects in the correct location, with their center at 133.0 cm.

This paper will show the derivation of the scaling correction, explain how old radiographs are being processed to account for the difference in location, and provide the details of how to correct radiographic images processed with the erroneous scale factor.

2 Background

The drawings in Figure 1 show how various plate radiographic targets are held in place at DARHT. The location for the grid and AFT, using the erroneous bracket, is upstream (toward the source) of the object center such that the downstream target face is located at the object center (133.0 cm). The targets are 5 mm thick; therefore, the target center is located half the thickness, 2.5 mm, toward the source from the center of the object center, at 132.75 cm.

The CRT holder correctly places the target center at the object center location (133.0 cm). Figure 2 shows the two different holders with red arrows pointing to the screw holes centering the targets. It can be seen that the grid and AFT downstream face is placed at the object center while the CRT center is placed at the object center. Figure 3 shows the AFT and grid holder and screw location such that the downstream face is placed at the object center. Figure 4 shows the CRT holder and screw location such that the target center is placed at the object center.

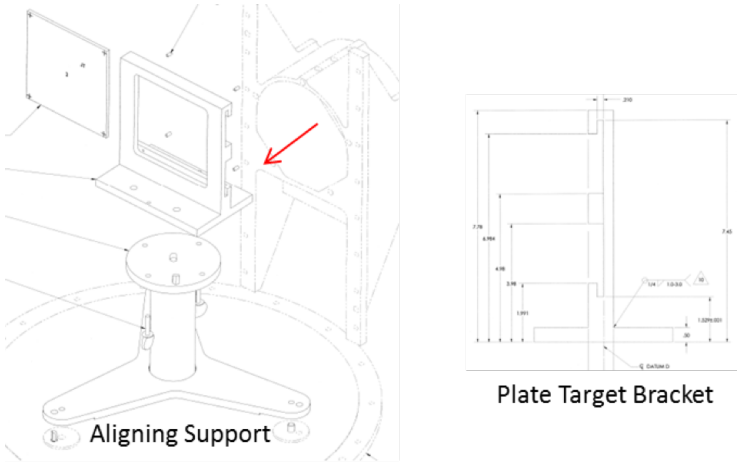


Figure 1: The DARHT aligning support and bracket used to accurately locate the plate radiographic targets.

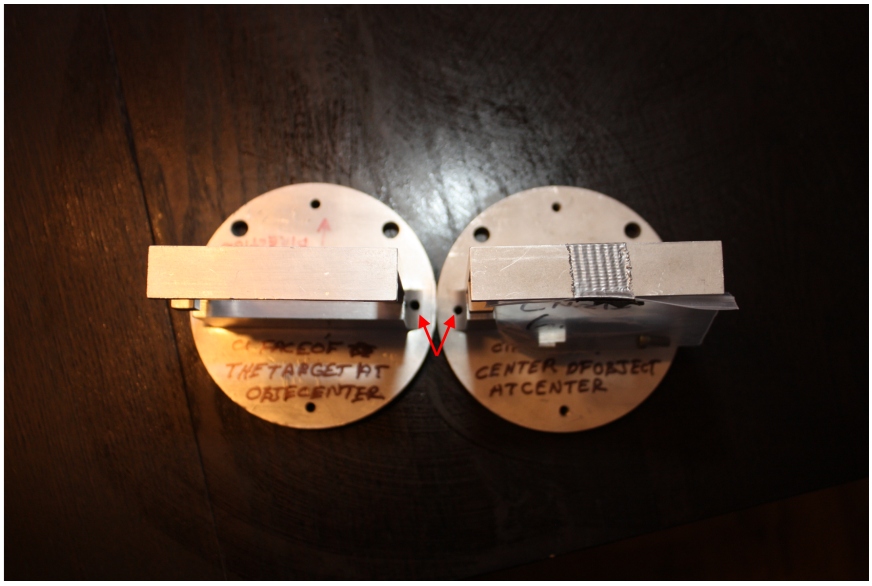


Figure 2: The grid and AFT holder is on the left and the CRT holder is on the right. The two red arrows point to the screw holes centering the objects. The grid/AFT downstream face is at the object center while the CRT center is at the object center.

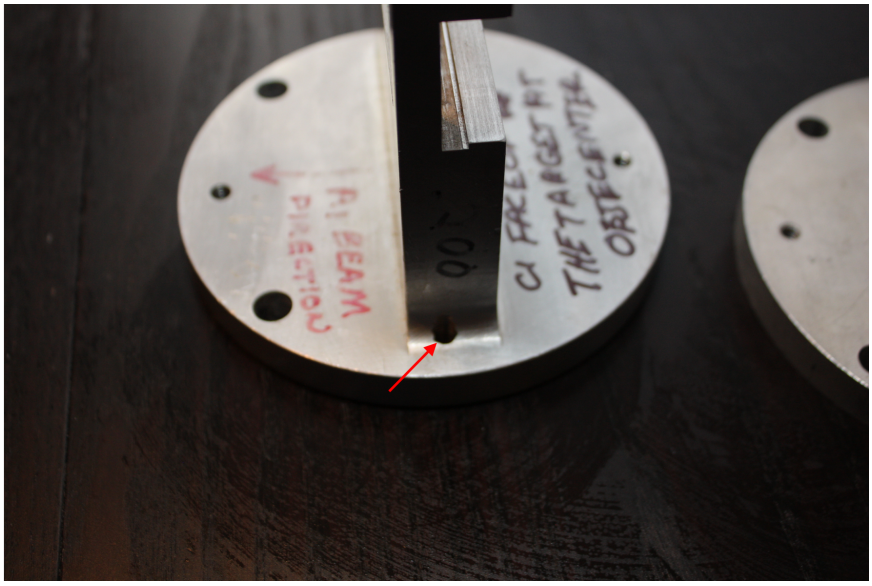


Figure 3: A picture of the AFT and grid holder. The screw hole (red arrow) puts the AFT and grid downstream face at the object center.

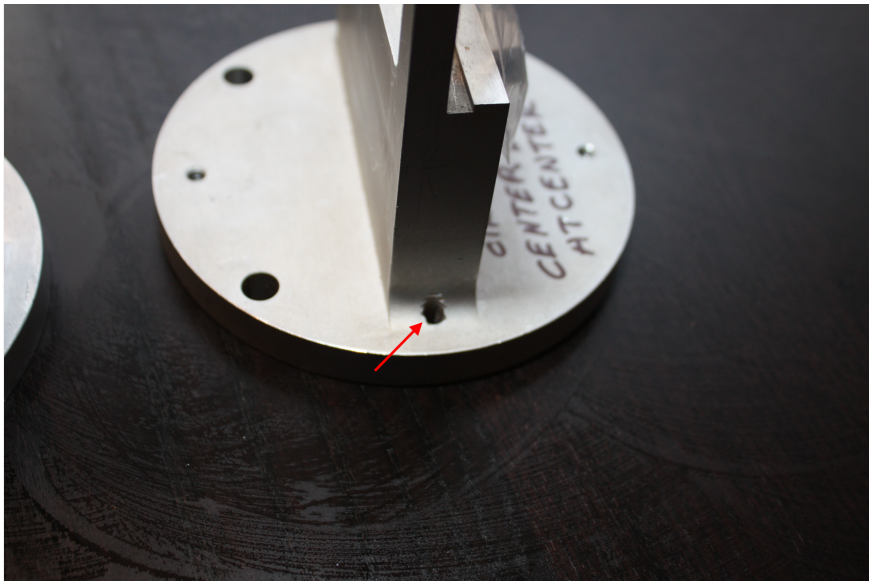


Figure 4: A picture of the CRT holder. The screw hole (red arrow) puts the CRT center at the object center.

The target used to calibrate the DARHT radiographs, the radiographic grid, has two interleaved grids of crosses each with spacing between the crosses of 1.0 cm. A photograph of the radiographic grid target is shown in Figure 5.

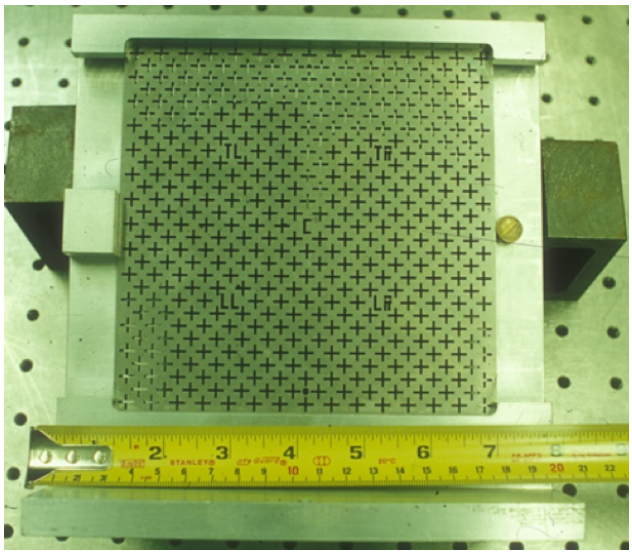
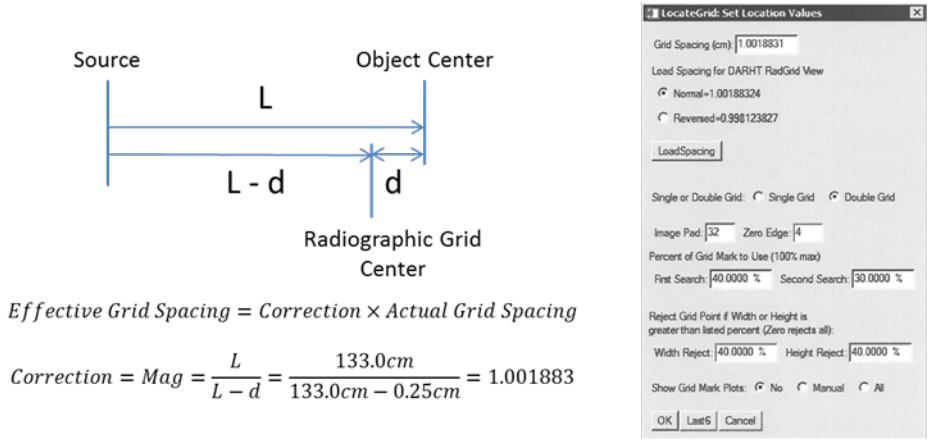


Figure 5: Photograph of the radiographic grid used to determine the dimensional scaling of DARHT radiographs.

The preprocessing of DARHT radiographs includes a step during which the radiographic images are dewarped and dimensionally scaled. The preprocessing software, DISPLAY, uses the IDL routine POLYWARP to calculate the least-squares fit that will scale and dewarp the crosses in the image of the radiographic grid onto a uniformly spaced grid. Then, the IDL function POLY_2D is used to apply the dewarping function to the DARHT radiographs.

The preprocessing software allows the user to specify the spacing of the uniform grid. Originally the default value for the grid spacing was 1.0 cm. With the incorrect grid location, the effective spacing is 1.001883 to take into account that the radiographic grid is located 2.5 mm toward the source. Figure 6 shows the equation of the effective grid spacing, given a DARHT source-to-object distance of 133.0 cm. Also shown is the window from the preprocessing software where the correct effective grid spacing can now be selected.



$$Effective\ Grid\ Spacing = Correction \times Actual\ Grid\ Spacing$$

$$Correction = Mag = \frac{L}{L-d} = \frac{133.0cm}{133.0cm - 0.25cm} = 1.001883$$

Figure 6: The value necessary to calculate the effective grid spacing is the magnification from the center of the radiographic grid location to the center of the object location.

The reason for locating the radiographic grid at the object location is to eliminate the need to accurately measure the source-to-object and source-to-detector distances. Even when the grid is not located at the object center location, scaling the radiographs to the object location removes the source-to-detector distance from the calculation. But, with the object and grid at different locations, uncertainty in the source-to-object distance increases the uncertainty in the determination of the effective grid spacing correction. However for the geometry at DARHT, this uncertainty is negligible. Figure 7 shows a plot of the effective grid spacing correction for a source-to-object distance range of 133.0±2 cm.

For DARHT, the radius of the maximum field of view at the object is about 5.7 cm. Failing to correct for the actual location of the radiographic grid would produce a maximum radial error at the outer boundary of 107 microns, decreasing linearly to be 0 microns at the image center, for the nominal source-to-object distance of 133.0 cm. If the actual source-to-object distance was off by as much as ±2 cm, the radial error at the maximum radius would only change ±2 microns.

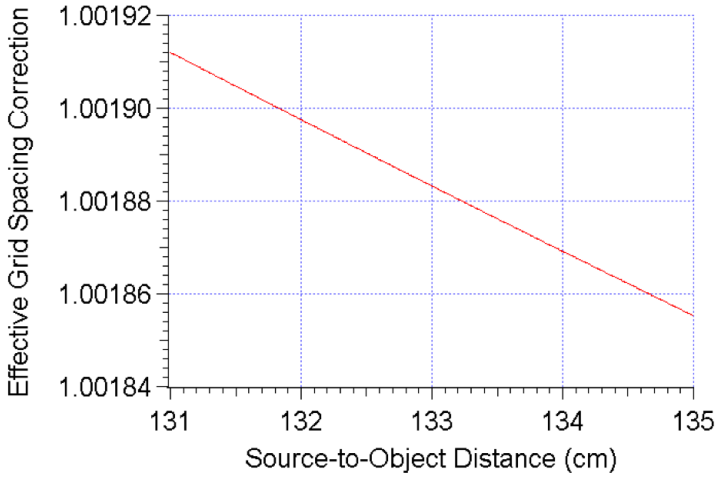


Figure 7: For fairly large uncertainty in the DARHT source-to-object distance, the variation of the effective grid spacing is very small.

3 Check of the Effective Spacing Calculation

A model of the radiographic grid has been made using the 3D tools in the Bayes Inference Engine (BIE). Two radiographic images of a DARHT Axis 1 radiograph (having 4.7625 cm of tungsten-based alloy in the bullnose) have been modeled two ways. One radiographic image is the result of preprocessing using a grid spacing of 1.0 cm and the other was preprocessed using a grid spacing of 1.00883 cm. Each image was modeled using a grid location of 133.0 and 132.75 cm (in both cases the source-to-object distance was 133.0 cm). Examples of the DARHT radiograph, the BIE forward model radiograph, and the residual image (difference between the data radiograph and the forward model) is shown in Figure 8.

The images have 100x100 micron pixels. For each case an optimizable scale was applied to the DARHT radiographic image and an optimizable system blur function was convolved with the forward model. The resulting optimizable scale factors and system blur parameters are shown in Table 1. These results show the expected and optimized scale parameter for each case, along with the error estimate.

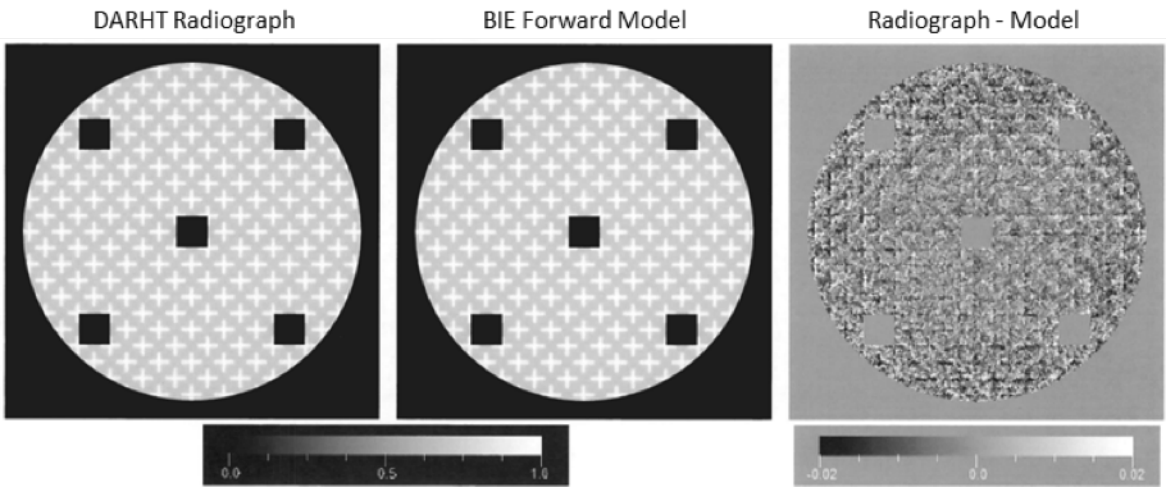


Figure 8: Examples of the DARHT radiographic grid and BIE forward model radiographs. The residual image is the difference between the data radiograph and the forward model radiograph.

Table 1: Results of varying the effective grid spacing during preprocessing and varying the BIE grid model center location.

Grid Space (cm)	Model Offset (cm)	Model Center (cm)	Optimized Scale	Scale Should Be	Scale Error %	Error at 5.7 cm (microns)
1.001883	-0.25	132.75	0.999442	1.000000	-0.056%	-31.8
1.001883	0.00	133.00	0.998351	0.998121	0.023%	13.2
1.000000	-0.25	132.75	1.001813	1.001883	-0.007%	-4.0
1.000000	0.00	133.00	1.000665	1.000000	0.066%	37.9

System Blur Bennett Scale X (cm)	System Blur Bennett Scale Y (cm)	System Blur Rotation (degrees)
0.0368	0.0379	7.72
0.0369	0.0380	7.72
0.0373	0.0379	7.73
0.0368	0.0378	7.72

4 Correction for Existing Radiographs

Prior to October 2015, the radiographic grid and AFT had the same center location (2.5 mm upstream of the object center). The CRT center was placed at the object center (133.0 cm).

For data that was taken prior to October 2015 using the incorrect holder location, and was preprocessed improperly assuming a grid spacing of 1 cm, simply scale the 2D radiograph (CRT or other data) by 1.001883. This will correct the dimensional scaling of a DARHT radiograph and then the radiograph will be magnified correctly for an object located at 133.0 cm from the source.

For data that was taken prior to October 2015 using the incorrect holder location but was corrected for in the preprocessing step, it is necessary to model the target correctly. For 2D image models of a grid or AFT, the image can be scaled by 1.001883, or the radiograph can be scaled by 0.998121. For 3D models of these two targets, locate the center of the target at the proper location (132.75 cm from the source).

Data reconstructions performed on data that was improperly scaled can be corrected by scaling the reconstruction by 1.001883 and conserving mass.

5 Conclusion

It was discovered that the grid and AFT holders put the downstream face at the object center location at DARHT. These holders were used until October 2015. Starting in November 2015, new holders were machined and used that correctly put the target center at the object center.

For data taken using the incorrect holders, the radiographs can be preprocessed correctly taking into account the grid-to-object offset without having to know the DARHT source-to-object location (133.0 cm) to better than several centimeters.

DARHT radiographs that have already been preprocessed using the assumption that the grid-to-object offset was zero can be corrected by scaling the radiographic images by 1.001883. Radiographs that are not corrected will have a radial error that varies from zero at the center of the image to about 107 microns at the edge of the field of view.

New plate target brackets have been designed and machined to place the center of the grid and AFT at the object center. These new brackets will eliminate any need to accurately measure the source-to-object distance and allow the actual grid spacing of 1.0 cm to be used during the preprocessing of the radiographs. Data taken after November 2015 should be using these holders and scaling should not be an issue.