Heated Diagnostic Radiology Exam Table

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1. Abstract

Clinical X-ray examinations sometimes require patients to remain still for over an hour. A common patient complaint is that X-ray examination tables are uncomfortable, specifically they are too hard and too cold. Patient discomfort is undesirable because an uncomfortable patient is more prone to moving during a long procedure. The objective of the client and our team is to create a device that can provide patient comfort while at the same time preserving patient safety and radiolucency. The focus of our work is to create a device to modify the current hard laminate surface of the X-ray table through the addition of padding and heat. Our team designed and constructed an X-ray table heating pad composed of polyethylene padding, a particle board and polyethylene tubing conduit, and a heating element and pump. Despite modeling the expected radiolucency, testing showed that our prototype produced small, but undesirable artifacts. Therefore, future work entails researching alternatives to the polyethylene and particle board tubing conduit.

2. Motivation

Many patients complain that common X-ray examination tables are uncomfortable. The most common complaint is that the tabletop is either too hard, too cold, or a combination of both. In the interest of patient comfort, our client believes that a tabletop can be designed and built to rectify these problems. This will be especially useful in long examinations where the patient is being X-rayed for an extended period of time.

3. Background

3.1 Diagnostic X-rays

X-rays are electromagnetic waves that are produced when fast-moving electrons collide with substances in their path. X-rays are similar to light rays except that they have 1/10,000 the wavelength. This short wavelength allows them to penetrate very dense substances to produce images that can be recorded on photographic film or digitally. X-ray imaging is useful diagnostically because differences in composition and density between body structures produce images of varying intensity on the X-ray film. Structures, such as bone, appear white, while other tissues, such as air-filled lungs, appear darker or black.

3.2 X-Ray Attenutation

X-ray attenuation, which is an indication of the radiolucency of a material, is characterized by the linear attenuation coefficient (μ). The linear attenuation coefficient is an inherent property of the material that can only be changed by altering the material composition. As a general rule, materials composed of atoms with high atomic numbers will attenuate more than materials composed of atoms with low atomic numbers. The less a material attenuates upon excitement by an X-ray, the more radiolucent it will appear in an X-ray image. An important aspect of the mass attenuation coefficient is its dependence on photon energy (Figure 1)

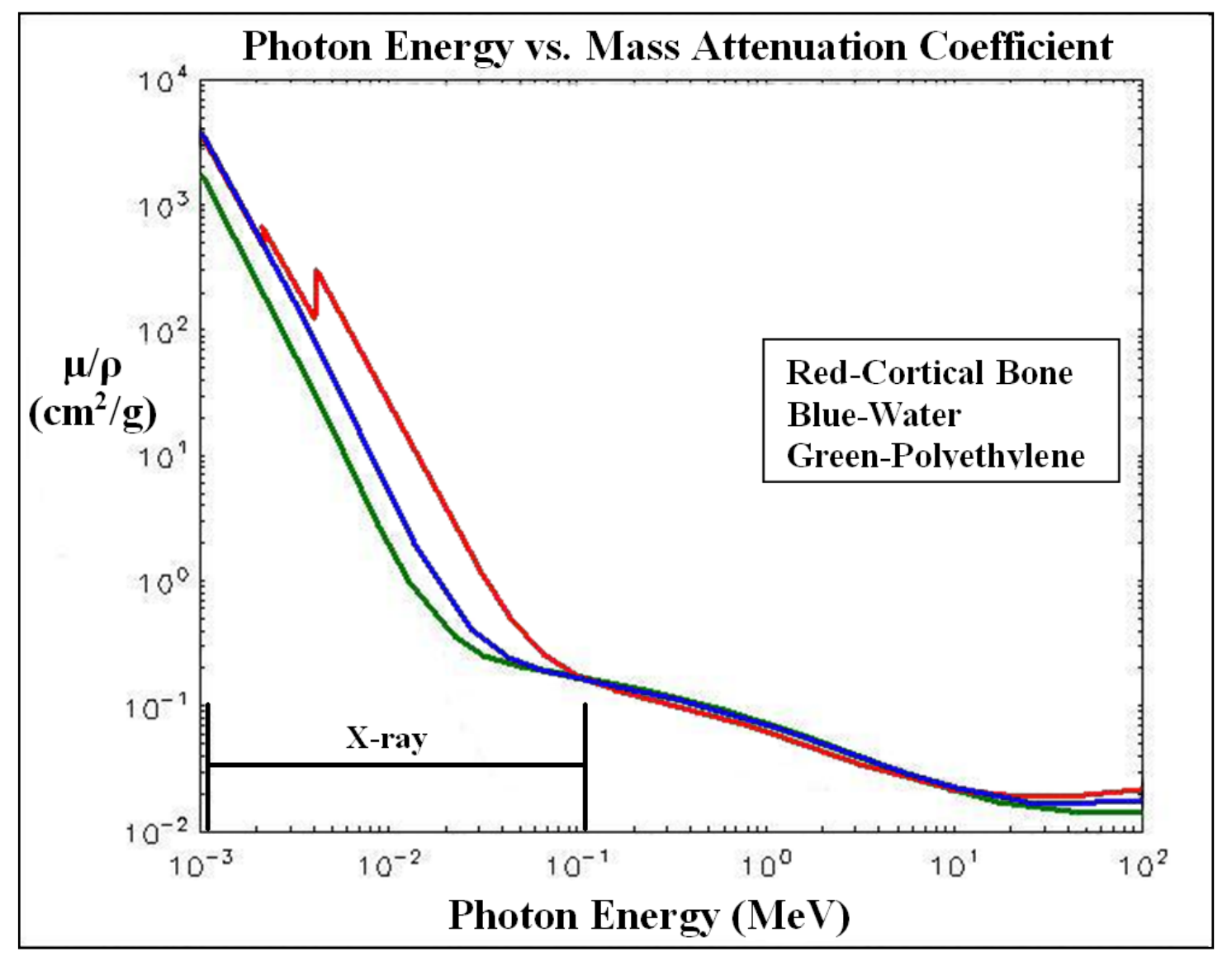

Figure 1 – Mass Attenuation Depends on Photon Energy

$$\left[1-\left(\frac{I}{I_O}\right)\right]\cdot 100 = e^{\left(-\left(\frac{\mu}{\rho}\right)*\Delta x\cdot\rho\right)}$$

Equation 1: Exponential Law of Attenuation

$\left[1-\left(\frac{I}{I_O}\right)\right]\cdot 100 =$ Percent loss of intensity of the incident X-ray beam
(μ/ρ) = Mass attenuation coefficient
Δx =Thickness of the material
ρ =Density of the material

4. Design Criteria

Safe for the patient
- No possibility of burns
- No leaking fluids
- Easily sterilizable

Heats the patient

Radiolucent
- Must not interfere with diagnosis

Cushions the patient
Costs less than $200

5. Beam Intensity Loss Simulation

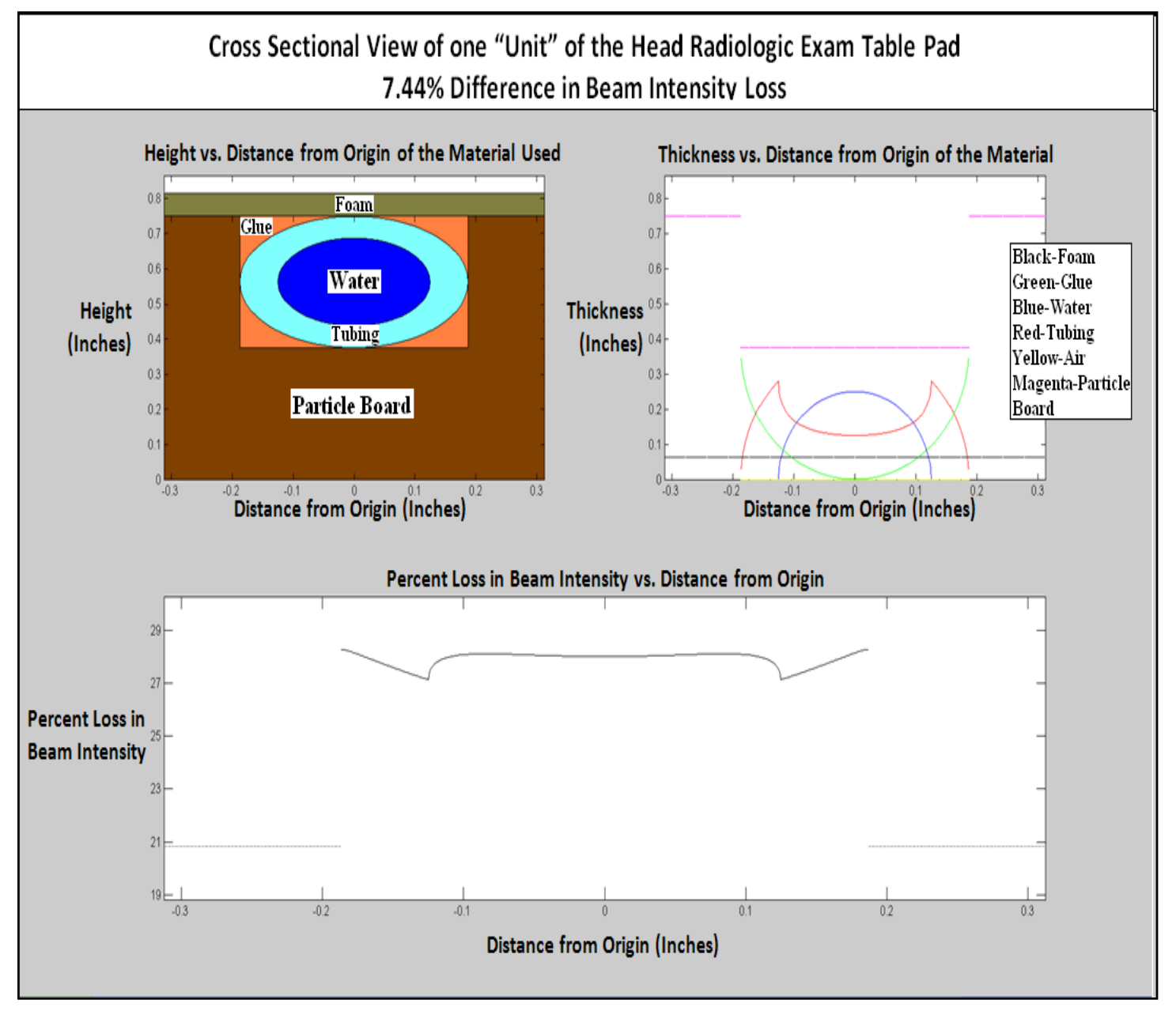
Cross Sectional View of one "Unit" of the Head Radiologic Exam Table Pad
7.44% Difference in Beam Intensity Loss

Figure 2 – Original Design Simulation

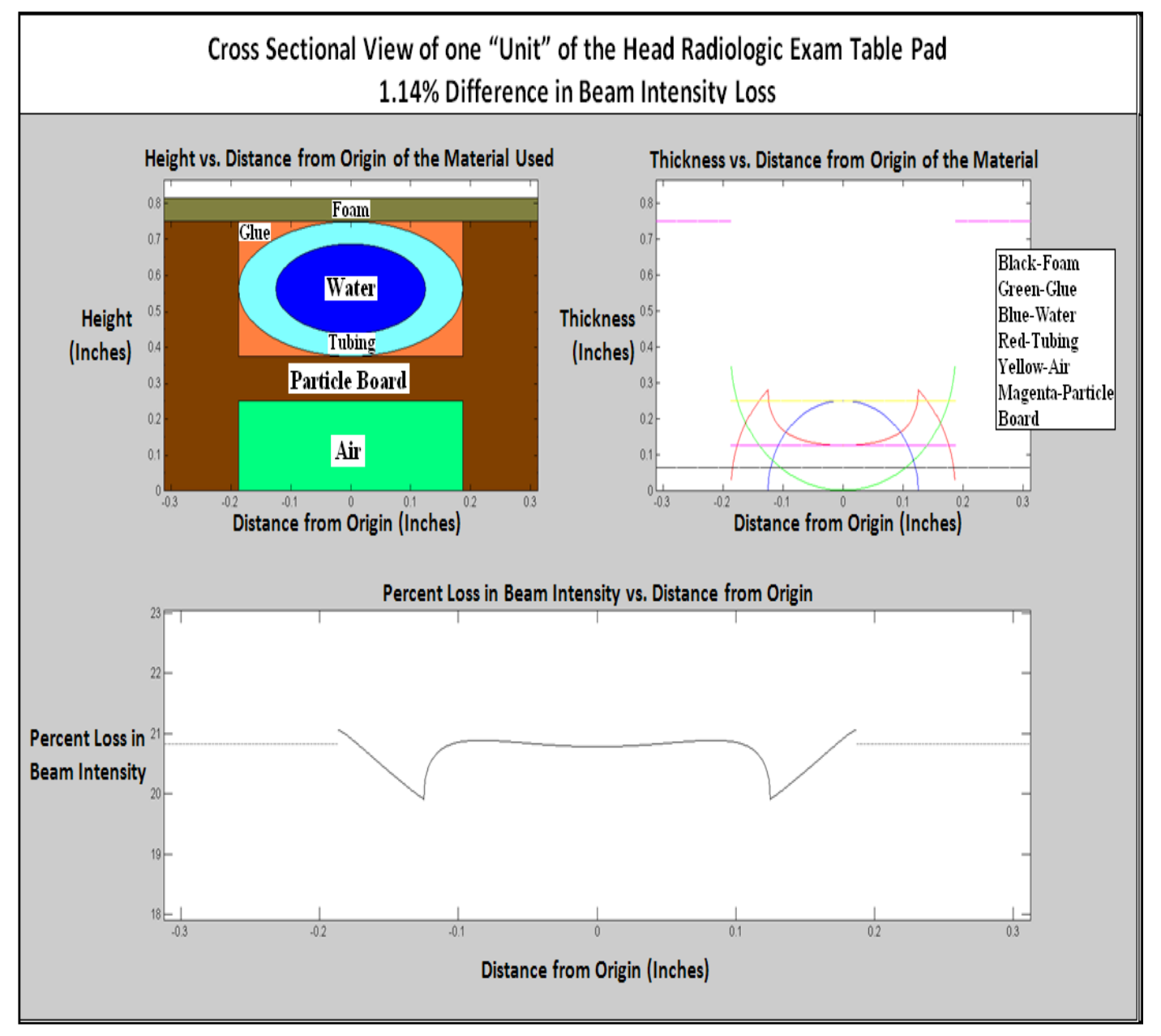
Cross Sectional View of one "Unit" of the Head Radiologic Exam Table Pad
1.14% Difference in Beam Intensity Loss

Figure 3 – Back Cut Design Simulation

6. Final Design

6.1 Padding - Fine Cell Polyethylene

- 1/16 inch thick
- Oil, water, and chemical resistant
- FDA approved non-toxic
- Sterilizable
- Comfortable
- No anatomical distortion

6.2 Heating Element and Pump

- 300 Watt resistive were heating coil
- 1 Inch diameter copper pipe
- Maximum water temperature = 46.1 C
    - Surface temperature = 35 C
- Temperature controlled by dimmer switch
- Variable speed pump in series with heating element and tubing conduit drives system
- Pipe insulation retains heat
- Newton's law of cooling governs heat transfer of system

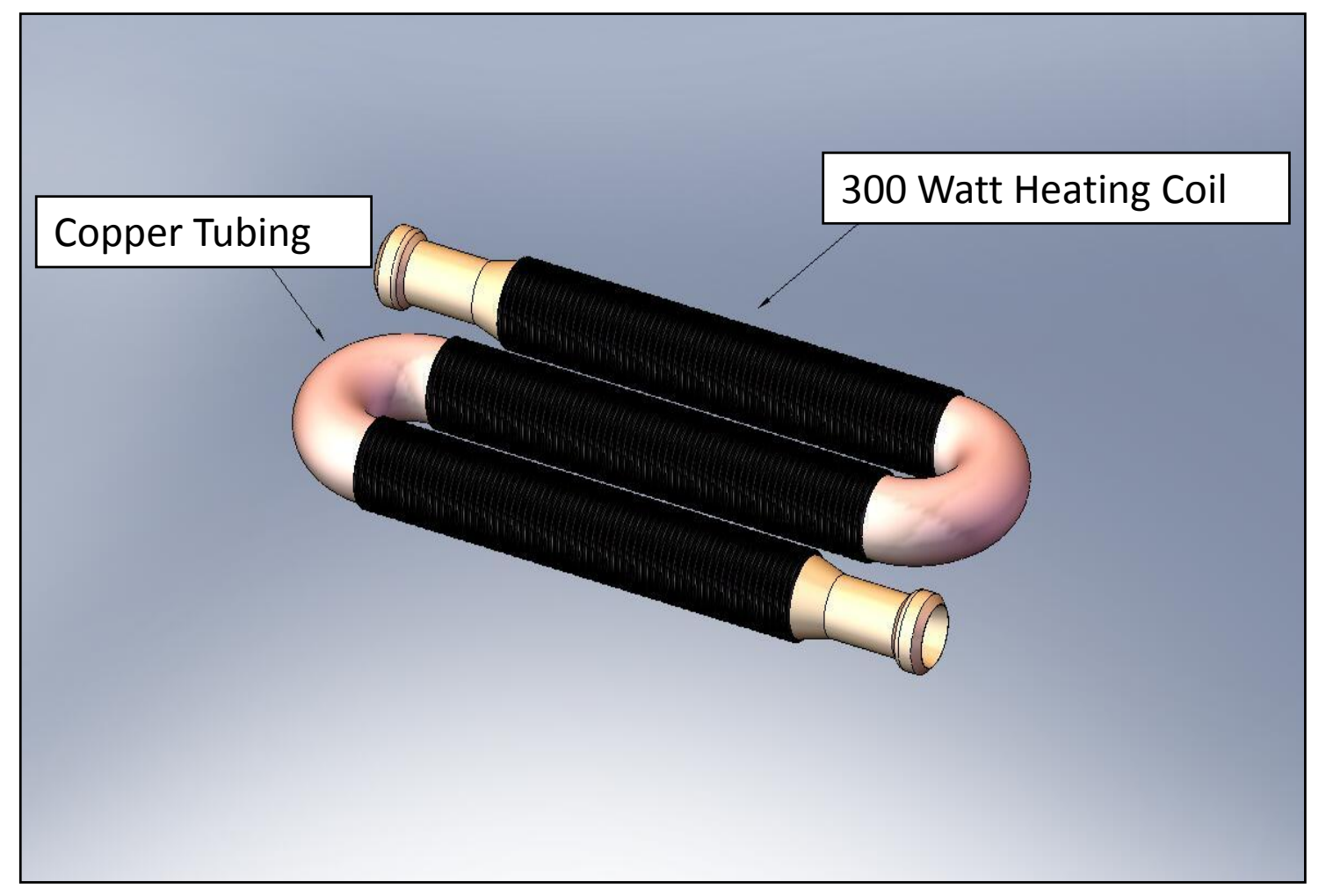

Figure 4 – Heating Element

$$\frac{Q_{tube}}{A_{tube}} = \frac{k_{tube}\cdot\Delta\cdot T}{2\cdot R_{tube}}$$

Equation 2: Newton's Law of Cooling

Q_{tube}= Heat rate across tube
T = Temperature (Kelvin)
A_{tube} = Cross-sectional area of tube
k_{tube}= Thermal conductivity of tube
R_{tube} = Radius of tube

6.3 Tubing Conduit

- 10 LDPE tubes with 1/4 inch I.D.
- Tubing inlaid in 23x32x3/4 inch particle board
- Tubes spaced 2.5 inches apart
- Square grooves filled with Liquid Nails® adhesive
- Full scale model would require 84x32x1/2 inch acrylic sheet.

7. Testing/Results

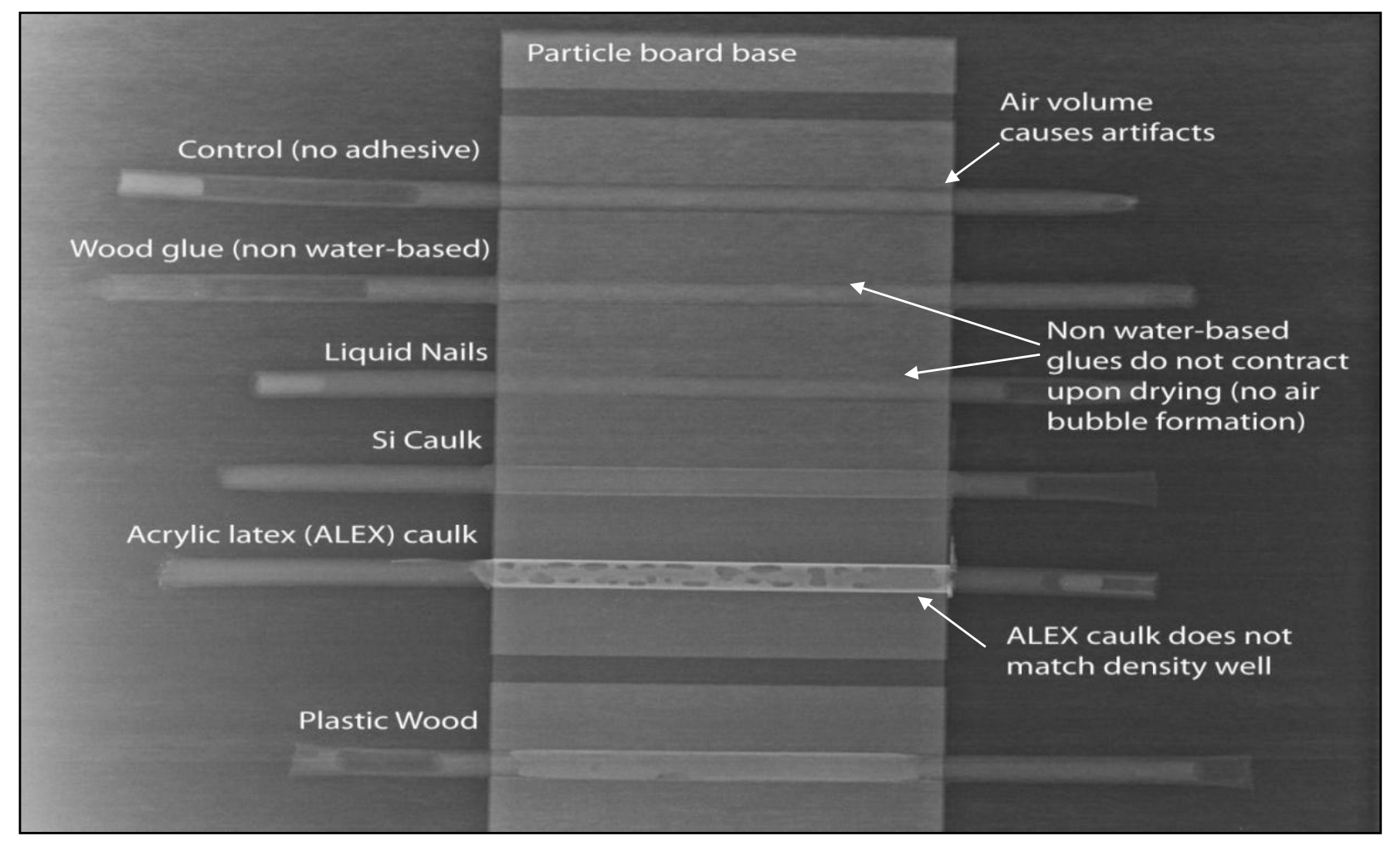

Figure 5– Testing of Different Fillers with Original Design

7.1 Testing of different fillers with original design

- Vertical edges produced artifacts
    - MatLab simulation did not account for these vertical edges
    - Adhesive fillers were used to correct
- Non-water based compounds dried without air gaps
    - Liquid Nails® performed the best (Figure 6)

7.2 Testing of different fillers with original design

- With phantom, image deemed acceptable though not desirable
- Ideally, we would like no artifacts present with or without phantom

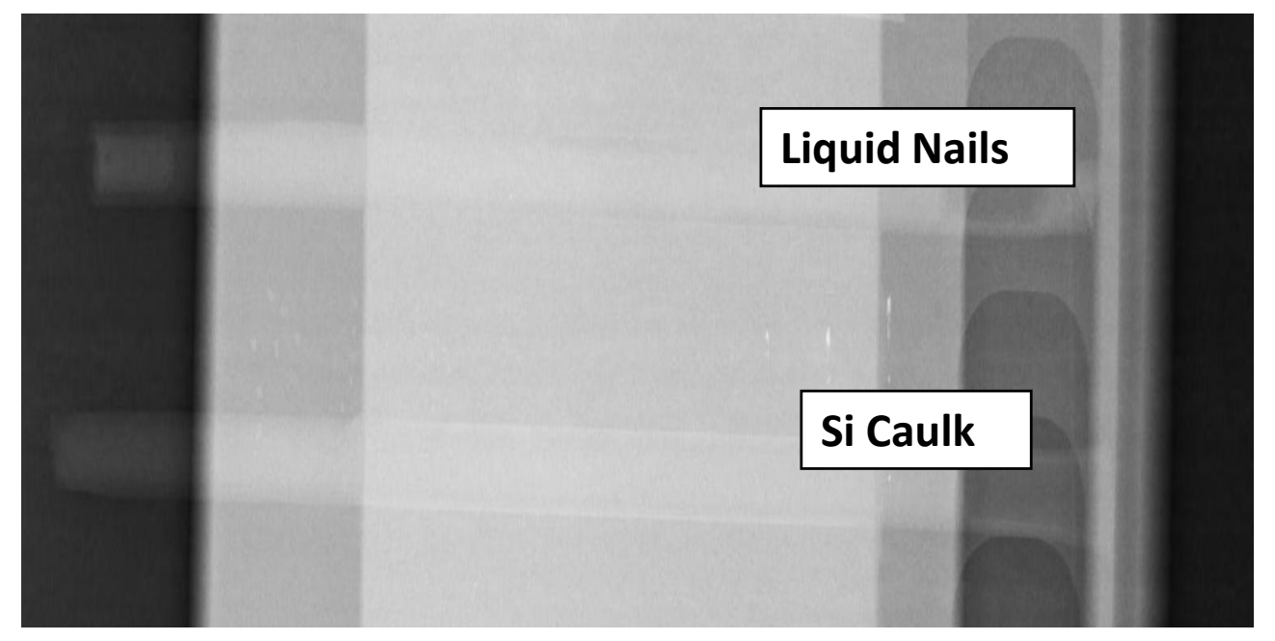

Figure 6 – Testing with Phantom

8. Expenses

Component	Our Cost	Full Cost
Heating	$83	$150
Pump	$100	$100
Tubing/ Hardware	$110	$128.3
Surface	$60	$342 (+ machining)
TOTAL	**$353**	**$702**

9. Future Work

The current design satisfies all criteria though not to a degree that would make it a commercially viable product. In addition, our design will attenuate differently at different energy levels due to the potpourri of materials used in fabricating the prototype. Therefore, future work will focus on creating a more radiolucent prototype. This work entails researching alternatives to the polyethylene and particle board tubing conduit. Water equivalent materials, like *Solid Water®* and *Plastic Water®*, would be ideal. However, these materials are expensive, limited in size, and would require complex machining. As a result, acrylic or non-expanded polystyrene may be the most appropriate choice. Both materials are excellent water equivalents for diagnostic X-ray energies, relatively cheap compared to *Solid Water®* and *Plastic Water®*, and come in the appropriate size. Unfortunately, creating the channels and threads into the material would still require complex machining. Also, the described materials would exceed our current budget. These issues would need to be addressed for a fully functional prototype to be constructed. .

10. References

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