Project Design Specifications—Phantom for Microwave Ablation Testing

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Problem Statement:

Microwave ablation is a medical treatment for many abdominal cancers *in vivo*. Thin antennas positioned in the tumor cells deliver microwave energy to destroy the tumor cells. This method has achieved some clinical success; however, improvements for devices and ablation techniques are in demand. The current tissue models are heterogeneous and inconsistent and impede device development. Dr. Brace is currently developing new ablation devices and desires a reliable medium to test his innovations. Our collective goal is to create a phantom for microwave ablation that is nearly transparent, mirrors the dielectric and thermal properties of a liver, and provides visual identification of ablation zones.

Client Requirements:

- Reproducible
- Homogenous
- Ideally transparent
- Cost effective
- Similar conductivity and permittivity to the liver
- Clearly marks ablation area

Design Requirements:

1) Physical and Operational Characteristics

a) *Performance requirements:* The phantom must be able to withstand high temperatures without melting or deforming (160-180 degrees Celsius). It must mimic the liver when subjected to a 2.45 GHz microwave frequency. Ideal permittivity of the phantom should be 45 ± 5 F/m and conductivity 1.7 ± 0.2 S/m. It must distinguish ablation areas when the temperature exceeds the threshold of 50^{o} C.

b) *Safety:* The phantom must not produce harmful gases or liquids when heated. No hazardous materials can be used.

c) *Accuracy and Reliability*: The phantom must perform consistently for repeated tests. The results need to be within a range specified by the client.

d) *Life in Service*: The phantom may be utilized for one time use only if readily producible. If reusable, it must remain stable and accurate while providing desired amounts of testing for cost.

e) *Shelf Life*: For one time use, the phantom must be able to sit refrigerated or at room temperature for one week.

f) *Operating Environment*: The phantom must be able to perform in standard laboratory conditions. During ablation, it must withstand very high temperatures exceeding 160^{o} C.

g) *Ergonomics*: The phantom solution must be easily produced and portable.

h) *Size*: The phantom must be approximately the size of a human liver.

i) *Weight*: Weight restrictions are not specified but should be easily handled by one person.

j) *Materials*: The base gel will consist of the Dow Corning Dielectric Silicon Gel and the indicator will be made of ovalbumin (egg white).

k) *Aesthetics*, *Appearance, and Finish*: The phantom does not need to model after the appearance of the liver.

2) Product Characteristics

a) *Quantity*: Enough phantoms must be produced for tests and demonstrations.

b) *Target Product Cost*: Total cost must be within $20-$30 for several ablations.

3) Miscellaneous

a) *Standards and Specifications*: The phantom must mimic the properties of the liver. Thus, it must have a dielectric constant of 43.3, electrical conductivity of 1.68 S/m, thermal conductivity of 0.564 W/mK, wavelength of 1.8 cm, density of 1,050 kg/m^3, and perfusion rate of 1,000 mL/min Kg.

b) *Customer*: Dr. Brace would like a phantom he could use to reliably determine differences in microwave ablation devices.

c) *Patient Related Concerns*: N/A

d) *Competition*: Microwave ablation devices are currently tested on animal livers and excised human liver tissue. Other types of gel phantoms exist, but none for microwave ablation.