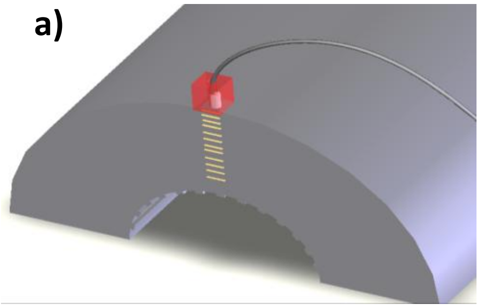
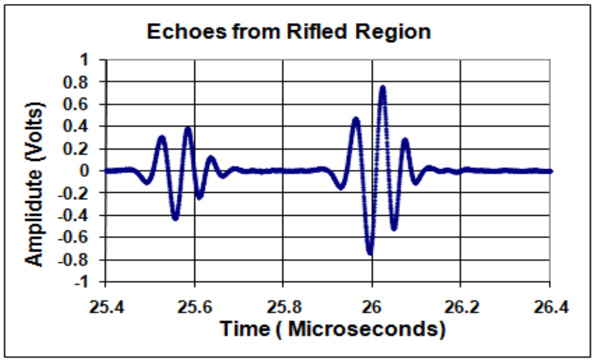
Localization & Response Time in Ultrasonic Thermometry

Initial experiments in ultrasonic thermometry were dependent upon a specific geometrical feature which was present on the inner surface of the structure being investigated. Specifically, for the measurements made on large caliber guns the rifled region gave rise to a pair of echoes corresponding to a slight gauge change in the thickness. Using this feature, it was possible to monitor the local temperature on the internal bore in the rifled region. Local temperature could be estimated simply by monitoring the variation in time-of-flight, ToF, in the echoes that resulted from a firing event. The concept and the rifled section echoes are shown in Figure 1a & 1b. The temperature estimate derived from the rifled section data are shown in Figure 1c

a)



b)



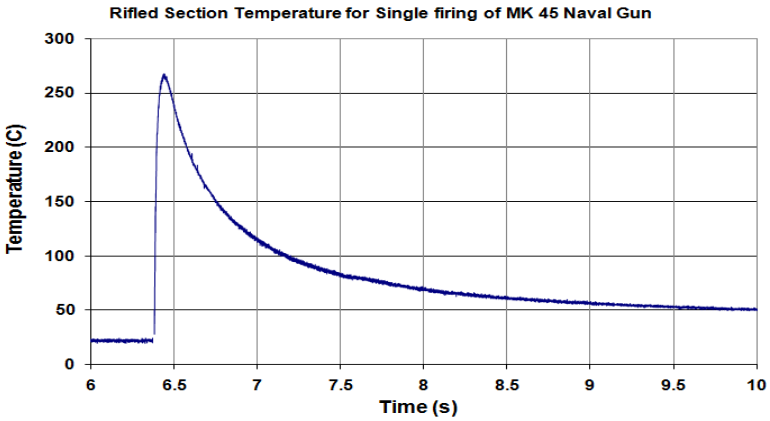


Figure 1 a) Sensor geometry; b) echoes from rifled region; c) Temperature estimates from ToF data.

In the above case, the response time of the temperature measurement is determined by the thermal mass between the echo pair (~0.050" steel) and the pulse repetition rate of the ultrasonic sensor. The results are <u>not</u> model dependent and require only a single material property parameter to convert the measured ToF to temperature. In this case the repetition rate was 2000 Hz.

An approach based on the ultrasonic method has been developed that has faster response time and is not dependent upon “structural” echoes (component gauge variation). This method combines the ToF measurement from a single echo interface, a thermal model and inversion techniques to produce simultaneous estimates of heat flux and surface temperature. The advantages of this method are that it is generally applicable when only one reflecting surface is present and the response time is limited only by the speed of sound. Thus, temperature changes can be measured on a time scale of tens of microseconds. The disadvantage of this approach is that the results are model dependent. Figure 3 shows results from large caliber gun firing data using inversion methods. In Figure 3a, the heat flux is presented while Figure 3b shows the surface temperature. Both results are derived from the same inversion procedure. No a priori knowledge regarding the profile of the unknown heat flux is required. For comparison, with previously presented rifled section data, the temperature at a depth of 0.05” is also plotted.   (see Walker et.al. IMECE 2007).

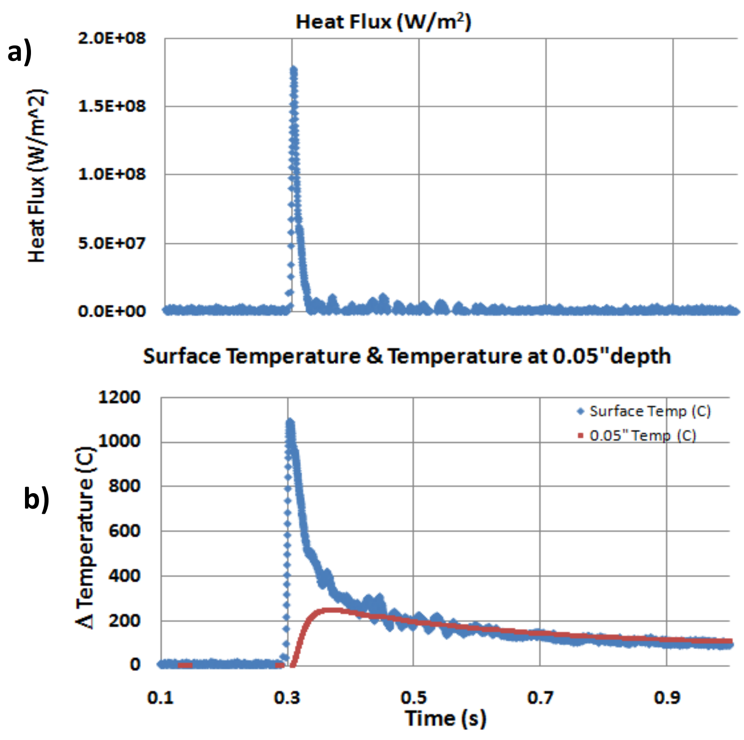


Figure 3 a) Heat Flux and b) surface temperature derived from ultrasonic ToF data sampled at 5000 times per second. The red curve in b) indicates temperature at a depth of 0.05”.