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Thermal Decomposition to Detonation: Understanding Reaction Violence

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Our team has been studying the thermal response of energetic materials ranging from initial processes in thermal decomposition (thermal expansion, phase changes) through the final exothermic steps in detonation. Our overarching goal is to understand how secondary high explosives release energy and how this determines reaction violence. We parse the problem into impulse and response and follow the response from endothermic decomposition through to final violent exothermic energy release. We have applied this method to a number of high explosives using small scale (several gram quantity) experiments to allow many iterations in order to focus on particular aspects of the response. A suite of diagnostics is incorporated on each experiment to extract information about the mechanisms. We measure temperature, pressure and density during the entire thermal trajectory of an experiment. The in-situ measurement of state variables in high explosives over this broad range of conditions in temperature, pressure, and time scale has necessitated the modification of a number of tools. We start with commercial off-the-shelf sensors and modify them as needed to reach the extreme conditions and rates needed. Our experience has been that simple and robust diagnostics are necessary due to the complex nature of the experiments. Our growing understanding of explosive response to an impulse has come through the intercomparison of all of the observables. We have used a combination of multiple observables and a wide dynamic range in order to develop a phenomenological understanding of mechanisms from phase change to internal deflagration and initiation. The use of many observables and wide dynamic range affords us the opportunity to test the precision and accuracy necessary in these measurements to identify such mechanisms. In this talk, I will discuss our understanding of the evolution of the thermal response of energetic materials. I will describe the evolution of our measurement capabilities. In particular, over the last decade we have applied radiographic tools at both accelerator and table-top scale. Our lab-scale asynchronous radiographic system (LARS) has advanced from a time resolution of seconds over hours to nanoseconds over microseconds. I will present our current capability and future directions.