DEVELOPMENT OF A TRANSDUCER FOR THE MEASUREMENT OF TEMPERATURE OF AIR BLAST FLOW FIELDS

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Air-driven shock tubes have been used for many years to simulate the blast environment produced by nuclear weapons. These blast simulators range from small, laboratory scale shock tubes, which are used to study detailed characteristics of blast fields, to very large blast simulators, which can subject full-scale military equipment to a specific blast environment. Regardless of the scale of the facility, the customary methods of measuring, flow history data are through the use of pressure gauges. By employing static and stagnation pressure history data and the assumption that the environment consists entirely of ideal gas, the Mach number and dynamic pressure histories of the blast environment can be inferred. When an ideal gas is used as the working fluid in the shock tube, the flow characteristics at a point can be completely described with three measurements. In order to determine the particle velocity, density, and temperature histories of the flow field, a third measurement technique must be used to supplement the static and stagnation probes.

In an attempt to obtain this third quantity the U.S. Army Research Laboratory (ARL) is studying several concepts of a probe to directly measure the temperature of the flow field. Recent advances in thermocouple technology have made possible the measurement of temperature in highly transient environments. A Chromel-Alumel thermocouple with a wire diameter of 0.0254 mm is being employed in each of the concept probes. The probe which has the most promise of success is a modified stagnation pressure gauge mount with the thermocouple bead positioned in the center of the cavity. This device directly measures the stagnation temperature of the flow field. Through use of the Pitot Equations and the assumption that the flow into the probe is isentropic, the measured static and stagnation pressures can be used with the measured stagnation temperature to completely describe the flow history at the instrumentation position.

Temperature probe development is supported through Computational Fluid Dynamics (CFD) simulation of the flow field interaction with the transducer assembly. The USA-RG2 code, developed for aerospace applications by the Rockwell International Science Center, is used by ARL to model the shock diffraction and temperature distribution inside the thermocouple cavity. CFD analysis allows some configurations to be eliminated without costly fabrication and testing. The numerical simulations may also be used to refine a concept before fabrication and testing begin.

Each of the concept probes is tested in the ARL 0.56 n7 shock tube, operated to produce a blast environment with an incident static overpressure of 70 kPa. As currently configured, this shock tube produces a step shock with a duration of approximately 50 ms which makes it ideal for testing this type of transducer. Using a static pressure probe in the tests and the Rankine-Hugoniot relations, the theoretical temperature behind the primary shock can be determined and compared to the measured temperature of the concept probe to evaluate its performance. This paper compares the measured results of the concept temperature probes with the theoretical results and the predictions of the CFD analysis. The probe with the overall best performance characteristics will ultimately be used in the ideal and non-ideal nuclear blast simulators at ARL.