DEVELOPMENT OF EQUATIONS OF STATE AND TEMPERATURE RELATIONS FOR THERMOBARIC PRODUCTS

Charles Needham, John Schneider

Applied Research Associates
4300 San Mateo Blvd, Suite A220
Albuquerque, NM 87110

The detonation model used in the ARA SHAMRC computational fluid dynamics code requires an accurate equation of state for the detonation products. The equation of state must produce the correct detonation pressure and detonation velocity for the Chapman-Jouget relations at the detonation front. It must properly represent the detonation products pressure as a function of density and internal energy density as the fireball expands. The sound speed is used in our detonation model to calculate the detonation front velocity. An iterative scheme is used to equilibrate temperatures between gasses in mixed material zones. Therefore the mathematical representation must be continuous and have continuous derivatives of both pressure and temperature.

The LSZK formulation is used for the pressure equation of state for the detonation products. It takes the form:

$$P = (\gamma - 1) * a * \rho^{b}$$

The form of this equation is sufficiently simple that the conservation equations with energy addition may be numerically integrated to determine the Chapman-Jouget conditions for any combination of the three constants in this formula. Thus when the loading density, detonation energy, detonation velocity and detonation pressure are known for any given explosive formulation, the constants can be uniquely determined.

The temperature equation takes the form:

$$T = \left[C1 * I + C2 * \left(1 - \exp\left(-(C3 * I)^{C4}\right)\right)\right]$$

The four parameters in this equation are found using a least squares technique to fit the results of CHEETAH runs. CHEETAH finds the energy for the mixture of detonation products for a given explosive at a large number of temperatures. This data is then reverse fit to temperature as a function of energy to obtain a formula compatible with SHAMRC. The resulting pressure and temperature fits are unique for each explosive mixture.