$$u_1 - u_o = \pm\sqrt{(P_1-P_o)(V_o-V_1)} \tag{5}$$

From this relation a family of curves can be plotted in the P-u plane, once an equation of state is given, that represents the locus of equilibrium P, u states attainable by a shock transition from a given initial state. Except for the end states the transition states do not lie on this curve but on the straight line joining the end states, analogous to the Rayleigh line in the P-V plane. Those curves with positive slope are pertinent to forward-facing shock fronts (i.e. shock fronts travelling in the +x direction); those with negative slope pertain to backward-facing waves.

For rarefaction waves, which reduce the stress and accelerate the material in the direction opposite to that of propagation, the relation between stress and mass velocity is given by the Riemann integral*:[8]

$$u_1 - u_o = \pm \int(dP/\rho c) \tag{6}$$

where c is the local sound speed.

This relation can also be represented in the P-u plane as a family of curves, and, as for shocks, forward-facing waves are described by the curves with positive slope, while backward-facing waves are described by those with negative slope.

Where the effect on the R-H curve of the entropy change inherent in the shock transition is small the two families of curves are the same and no distinction need be made. All transitions from a given initial state must lie on one of the two curves passing through that state.

For example, consider the reflection of a forward-facing shock in material A at an interface with material B, assumed to possess smaller shock impedance than A. (Figure 3.) The initial shock is represented by P_1, u_1 and lies on the P-u curve of material A centered on (0,0).

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*This result is a consequence of assuming constant entropy and therefore does not hold across shock fronts.

Reflection of the shock at the boundary produces a backward-facing rarefaction in A and a forward-facing shock in B. The common state at the interface must lie on the intersection of the appropriate curves centered respectively on (P_1, u_1) and $(0,0)$, i.e. the final state is (P_2, u_2).

If material B were a free surface the reflected rarefaction would have carried material A to zero pressure and the free-surface velocity, u_{fs}. Note that if the p-u curves for shocks and rarefactions are the same the free-surface velocity is just twice the particle velocity prior to reflection. This result is frequently used to infer particle velocities from measured free-surface velocities for well-behaved materials.

The P-u plane is an indispensable tool for qualitative or semi-quantitative analysis of complex wave interactions and a set of curves for known materials is to be found in virtually all experimental laboratories.

II. EXPERIMENTAL TECHNIQUES

A. Production of Plane Stress Waves

The principal tool for producing plane stress waves for the study of constitutive relations is the single stage compressed gas gun. For precisely controlled impacts these devices are at present unsurpassed.[12-14]

Existing guns vary considerably in their design; nevertheless there are certain common features. They are all smooth bore, usually having been drilled to close tolerances from a solid forging or casting. They use compressed nitrogen or helium as the driving gas, pressurized up to about 6000 psi. Substantially improved performance would result from the use of hydrogen, but handling and safety problems have discouraged use of this gas. Siegel has given an exhaustive treatment of the gas dynamics in guns of this type.[15]

The projectile diameters vary from 2-1/2" to 6"; the barrel lengths from about 10' to 100'. The velocities achieved vary from about