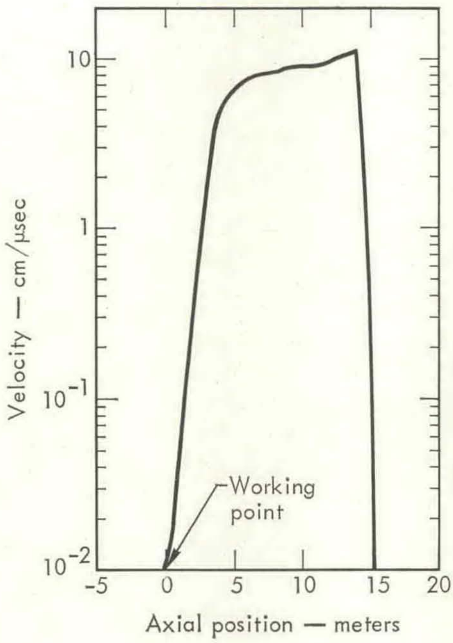

Fig. 14c.

Fig. 14 shows (a) pressure, (b) density, and (c) velocity conditions representing Marvel at 100 μsec. These conditions are used as initial conditions for the Tensor-Pufl calculations that simulate Marvel at later times.

experimentally observed attenuation of the air shock. In this calculation, approximately 5% of the initial energy was thermally transferred to the walls of the tunnel during the 1.85 msec it took the shock to travel 122 meters down the tube. This heat transfer was due almost exclusively to the turbulent convective heat flux. During this same interval, approximately 50% of the total initial energy was deposited in the surrounding alluvium by the radial ground shock.

Heat fluxes were also considered in the last two calculations, TP3 and TP4; in addition a mass flux was calculated by use of equations A5 and A6, with a turbulent transpiration coefficient of $\eta = 0.2$ [*Rose and Offenhartz*, 1959]. Figure 15 indicates that in comparison with the experimental data, too much attenuation is taking place too soon in the TP3 calculation. In TP3, the ablated mass is allowed to *instantaneously* enter and homogeneously mix within a total Pufl zone. Reasonable variations in the value of η did not substantially alter these TP3 results, which indicated too much attenuation was taking place too soon.

The TP4 calculation is exactly like TP3, except that an attempt was made to treat radial turbulent diffusion of ablated wall material (see appendix B), as opposed to its instantaneous mixing. Figure 15 indicates that the TP4 calculation more closely matches the experimental data at late times than does the TP2 calculation.

The TP3 and TP4 calculations indicate that mass addition was significant in attenuating the flow of high energy down the tunnel. Comparison of these calculations indicates that the time-dependent mixing prescription (TP4) is more realistic than the instantaneous mixing (TP3). However, the data indicate that even less mixing should be occurring at early times than is calculated by the TP4 calculation. This suggests a pressure dependence for the mixing rate that would require longer times for mixing when the pressure inside the pipe is high than when the pressure is low. Uncertainties in the time dependence of the radial turbulent diffusion of ablated material and the accuracy of the

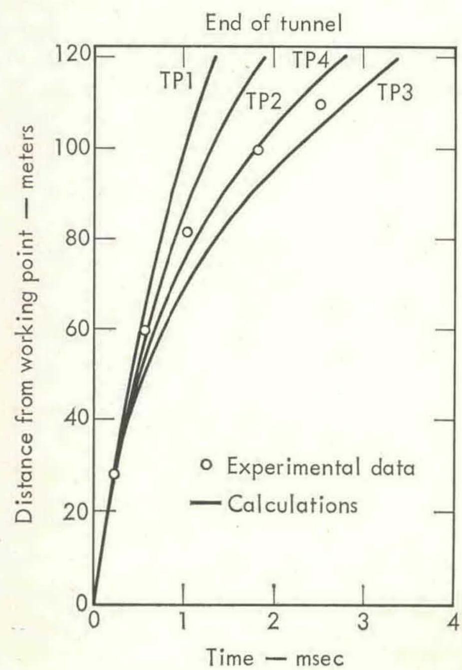

Fig. 15. Air-shock time of arrival showing experimental data and calculations that consider various physical phenomena.

ablation parameters limits the accuracy of shock prediction, particularly with one-dimensional calculation. In the following, the TP4 calculation is used for comparisons with the experimental data that was discussed in section 2.

Experimental shock TOA and the peak mean stress obtained from the stress-history gages that were located in the four alcoves, are given in Table 2. Table 2 also includes data from the cavity gas-pressure instrumentation in the fourth alcove. Results from the TP4 calculation are given in the last two columns of Table 2. At locations farther from the tunnel, the rise time of the pressure pulse is greater. Therefore, for consistency, the shock arrival time from the calculation is taken to be the time at which a pressure of at least 400 bars arrives at the specified location. The calculated peak pressures and their arrival times are given in the last column of Table 2.

The experimental results of the two free-field slifers and the four stress-history gage measurements are summarized in Figure 16. The two stress-history gages, which were located at a distance of 7.5 meters from the center line of the tunnel, saturated (>15 kb) at the time of arrival of the ground shock. The two gages located at 29.3 meters gave identical arrival times and similar peak pressures. Since the two gages were not saturated, their results are considered credible. Figure 16 also shows the calculated arrival times at specific positions for (1) pressures in excess of 100 bars, (2) pressures in excess of 400 bars, and (3) peak pressures. The magnitude of the peak pressure is indicated at each position. The TP4 calculation was terminated at 20 msec. However, when extrapolated, the calculation indicates the peak pressure and appears to be in agreement with the later time measurements (for both arrival and magnitude of the pressure) from the two gages located at 29.3 meters.

Generally, the TP4 calculation compares favorably with the experimental measurements from the alcoves (Table 2) and the 'free field' (Figure 16). This comparison in the surrounding media is sparse; a more complete comparison along with more data would have been desirable to put the calculations on a firmer basis. However, we believe that the existing comparison indicates that the calculations reasonably approximate the propagation of energy into the surrounding media and that the energy initially propagated from the canister into the alluvium approximately 50 times slower than it propagated down the air tunnel.

Figure 17 shows the position-time history of the contact surface (the rock–gas-air interface) from the TP4 calculation. After the air shock reaches the end of the tunnel, a reflected shock propagates back up the tunnel and interacts with the contact surface. This interaction impedes but does not reverse any appreciable mass flow down the tunnel. Although the cal-

TABLE 2. Stress History Gages and Cavity Pressure Gage Locations and Data

Gage No.	Alcove No.	Directed Toward	Distance from Centerline of Tunnel, meters	Distance from Working Point, meters	Experimental		TP4 Calculational	
					TOA, msec	$\hat{\sigma}_r$, kb	TOA,* msec	Peak Pressure,† kb
1	1	Tunnel	1.0	29.6	0.41	···‡	≤0.4	>30 at ~0.5
2		Tunnel	3.6	29.6	1.74	···‡	1.4	>5.0 at 1.8
3		Working point	6.0	29.4	5.75	0.5	4.0	~1 at 5.5
4	2	Tunnel	1.0	59.7	0.92	···‡	0.9	>15 at ~1.0
5	3	Tunnel	1.0	81.4	1.53	···§	1.4	>7 at 2.2
6	4	Tunnel	1.0	99.7	2.07	1.75	2.0	~3 at 3.2
C‖	4	Tunnel	0.5	100.0	2.1	1.8	1.8	>5.0 at 2.0

* Time of arrival for 400-bar pressure.
† Peak pressure at time of arrival (msec).
‡ Stress exceeded instrument range (15 kb).
§ No data; gage inoperable.
‖ Cavity gas-pressure instrumentation.