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An Analysis of Marvel—A Nuclear Shock-Tube Experiment

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Marvel, a nuclear-driven shock-tube experiment, consisted of a 2.2-kT nuclear explosive detonated 176 meters underground at one end of a 122-meter long, 1-meter diameter horizontal tunnel. Vaporization of material in the immediate vicinity of the explosive provided the source of high-energy driven gas. The driven gas was the ambient atmospheric air in the tunnel. Marvel was conducted as an experimental and calculational study of the time-dependent flow of energy in the tunnel and surrounding alluvium. This paper describes (1) the design of Marvel, (2) the dynamic and postshot experimental results, and (3) a numerical simulation of the experiment. Experimental and calculational results indicate the following. The high-energy air shock traveled down the tunnel nearly 50 times faster than the shock in the surrounding alluvium. Over the first 30 meters of the tunnel, the shock had a velocity of approximately Mach 380; during its 4-msec transit of the 122-meter tunnel, it attenuated to approximately Mach 30. Significant ablation of material from the tunnel walls had the primary effect in attenuating the air shock. The source energy was preferentially channeled down the tunnel, and a cone-shaped cavity resulted.

Marvel, a nuclear shock-tube experiment, consisted of an air-filled, horizontal tunnel 1 meter in diameter and 122 meters long, at a depth of 176 meters below the surface. A 2.2-kT nuclear energy source was located at one end of this tunnel. The Marvel experiment was directed by the Lawrence Radiation Laboratory and conducted at the Atomic Energy Commission testing facility near Mercury, Nevada.

We have developed experimental and calculational experience with nuclear energy sources that were placed in nearly spherically symmetric initial geometries. These sources have been located at specific depths to produce either cavities [*Rodean*, 1968; *Butkovich*, 1965; *Rogers*, 1966] or craters [*Cherry*, 1967] in various geological media. Marvel was located well below cratering depth in alluvium. The purpose of Marvel was to develop improved experimental and calculational capabilities for understanding the propagation of energy in a nonspherical initial geometry.

Before Marvel, it was not known whether a nonspherical initial geometry would result in significant nonspherical energy deposition. If the energy deposition were sufficiently nonspherical, the pattern and intensity of the outgoing shock, the cracked regions, and the final cavity shape would also be nonspherical. Thus, by suitable design of the initial emplacement configuration, it might be possible to produce cavities and cracked regions in other than spherical shapes. For instance, the deposition of nuclear energy could be tailored to local geological conditions for mining, gas stimulation, and other applications [*Rodean*, 1968; *Butkovich*, 1965].

Marvel was an initial Plowshare effort in nonspherical source studies. Consequently, the development of new experimental techniques was required to monitor the exotic range of gas-dynamic flow variables encountered.

If the surrounding medium is not severely layered, an experiment can be simulated numerically by one-dimensional calculations until the shock reaches the surface. However, the one-dimensional approach is not adequate for nonspherical experiments. The flow of high-energy gas from the source region and the propagation of the shock wave into the surrounding solid medium are two very different types of flow. To simulate these two flows, a calculation was developed that simultaneously considers the basic physics of high-energy gas dynamics and of rock mechanics.

A dominant feature of Marvel was the combining of ideas from both the calculational and