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MASTER

FAST SHOCK TUBE ASSEMBLIES

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We have developed unique explosively driven devices to be used as fast-shock tubes or as particle launchers. Such drivers produce a highly symmetrical pressure wave that can be used to launch particles. We have achieved shocks in these devices of approximately 18 km/s, and plan to use these devices to accelerate particles in a "shockless" particle launch.

1. INTRODUCTION

We have designed and tested a number of devices that are used as either fast shock tubes or as particle launchers. Shock velocities as high as 18 km/s have been measured in these devices. The shock tubes are driven by high explosives (HE) and use low-density foam as a working fluid.

These devices were designed to investigate the physics of hypervelocity flow. The "shockless" acceleration suggested by McCall[1] is of particular interest.

2. EQUIPMENT

We have built two versions of explosively driven devices. One relies on the detonation velocity of the explosive (~8.8 km/s) to produce shock velocities of approximately 8.8 km/s in a foam working fluid, and the other is designed with an explosive lens and will produce shock velocities in the working fluid up to 18 km/s.

The slower version of the fast shock tube is shown in Fig. 1. The HE used in the device is PBX 9501**.[2] This device functions by initiating a Reynolds RP 1 detonator[3] to light the initiation cap. The PBX 9501 in the initiation cap burns symmetrically, thus lighting the PBX 9501 main charge. The detonation proceeds down the cylinder at the detonation velocity of PBX 9501 (8.8 km/s) as well as in a radial direction, which compresses the working fluid in the center of the device.

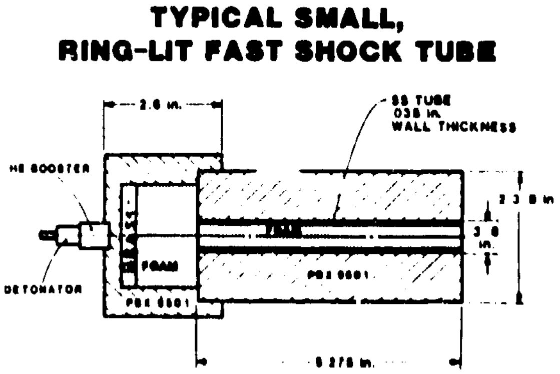

FIGURE 1

If the working fluid is selected carefully, a shock will form as material is driven in the direction of the detonation. This shock will, in the limit, have

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** PBX 9501 HMX/Estane/BDNPA-F 95/2.5/2.5 wt%

the detonation velocity of the explosive, although it will have a somewhat faster velocity near the initiation head because of transient effects. We have used this device with the working fluid either contained in thin-walled metal tubes or in direct contact with the explosive.

In all cases the working fluid was rigid foam with a density of 0.3 gm/cm^3. This density was selected to give near-optimal performance in the device. If the density is too high, the axial velocity will swallow the shock and it will not propagate down the tube; if it is too low, the tube will close off. Some of the working fluid should escape in the opposite direction of the propagating shock thus enhancing momentum of the shock.

We have used several foams; they are poly(4-methyl petene-1) (TPX), polyurethane, and polystyrene. Each of these materials had a unique advantage. The TPX foam had very fine cell structure and a high hydrogen-to-carbon ratio. There is some feeling that a high percentage of hydrogen in the foam might be desirable. Because the TPX foam was very expensive to produce, we changed the driving fluid to a polyurethane foam. One disadvantage of the polyurethane foam is that it is a complex mixture and will be more difficult to understand than simpler chemical species. The cell structure in the polyurethane foam is also coarser than one might like. Our most recent change is to polystyrene foam. Polystyrene is composed entirely of carbon and hydrogen, and for this reason may have a better possibility of being understood. Its cell structure is also smaller. In the final analysis, the device does not appear to be too sensitive to the working fluid, so long as it has a density of about 0.3 g/cm^3.

The initiation head has a brass plate at the end nearest the detonator to suppress any jets that might form as the detonation turns the corner. The remainder of the initiation head is filled with 0.3 g/cm^3 foam to provide a smooth transition to the foam in the shock tube.

The high-velocity version of the fast shock tube is shown in Fig. 2. The device is based on a chemical lens that is designed to produce an axial velocity of approximately 18 km/s. The design of chemical lenses has been discussed in detail by Benedick[4]. The high-velocity and main-charge components of the device in Fig. 2 are PBX 9501, the slow component is Baratol[2]. The system is lit by a ring of 36 Reynolds RP-1 detonators and functions in almost the same manner as the slower version.

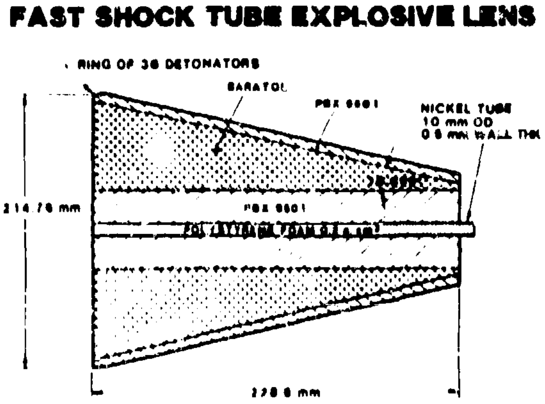

FIGURE 2

We are now working on a larger version of the unlensed device. This version will be approximatley 16 cm in diameter. We also have designed simpler versions of the lensed device that use a liquid slow component.

3. EXPERIMENTS AND RESULTS

The primary purpose of this paper is to describe the fast-shock tube devices we have designed. We do, however, wish to comment on some of the experiments we have conducted with these devices. The first series of experiments was to determine if a shock formed in the axial direction when the devices were fired. To perform this experiment micro-coax cables (0.013-in. diameter) were inserted in the working fluid. A microwave signal was then sent down the cables and reflected off the end of the cable that was being shortened by the passing shock wave. The phase shift was measured in the returning signal and the velocity of the shock determined. By conducting several experiments of this type we have shown that a shock does form on the axis, is flat, and near its predicted velocity.

We also measured the planarity of the shock as it exited from the barrel. These experiments were conducted with both noble gas flashers and with a device that measures the emission of bromoform. As a result of these experiments, we are convinced that the shocks are highly planar as they exit the shock tube.

Current experiments are centering on the use of this device to achieve "shockless" acceleration of particles. A typical experiment is shown in Fig. 3. After we have formed a shock in the shock tube, the gas is allowed to expand down the barrel. In principle the gas expands to a very low density and recompresses behind the particle. If the parameters are selected properly, the particle may be accelerated to a high velocity.

**AN EXPLOSIVELY DRIVEN
HYPERVELOCITY
MASS ACCELERATOR**

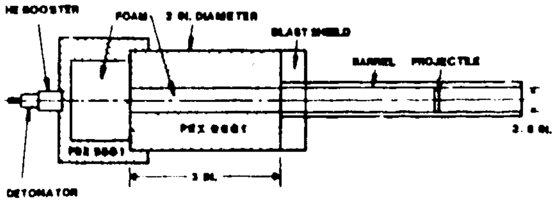

FIGURE 3

We are now conducting experiments to understand the physics of expansion of the foam, foam buildup behind the particle, and particle acceleration. Obviously, we are treating a two-dimensional problem and there are many effects to understand. However, we have conducted a number of experiments using Visar, radiography, photography, and other techniques. With these we have been able to measure the initial acceleration of the particle and determine its condition at early times.

4. CONCLUSIONS

We have designed and fabricated an explosively driven shock tube to be used in fundamental physics experiments. We have two versions of this device. One is driven near the detonation velocity of the explosive, the other is designed to operate at approximately 18 km/s. We plan to use these devices to drive "shockless" particle accelerators.

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