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TITLE: LOS ALAMOS EXPERIMENTAL CAPABILITIES: ANCHO CANYON HIGH EXPLOSIVES AND PULSE POWER FACILITIES

AUTHOR(S): CHARLES E. MORRIS, M-6

SUBMITTED TO:

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Los Alamos National Laboratory
Los Alamos, New Mexico 87545

LOS ALAMOS EXPERIMENTAL CAPABILITIES: ANCHO CANYON HIGH EXPLOSIVES AND PULSE POWER FACILITIES*

Charles E. Morris

Los Alamos National Laboratory
Los Alamos, New Mexico USA

The Los Alamos National Laboratory dynamic testing facilities are operated by the Explosives Technology and Applications Division (M-Division.) There are five groups that have dynamic testing facilities. The facilities located at Ancho Canyon are operated by M-6, the Shock Wave Physics Group. The facilities described represent only a portion of our dynamic testing facilities at Los Alamos. When needed, other M-Division resources can be focused on a given project to provide critical skills and facilities to supplement M-6 resources.

Many Ancho Canyon test facilities were built in the early 1950s to characterize high-pressure/high-temperature properties of materials. In the 1950s, high-velocity guns we use today were not available. What was available at Los Alamos was the most advanced, high-explosive (HE), fabrication technology anywhere. There was an in-house capability to fabricate high-quality, precision-finished pieces of virtually every practical explosive. HE testing facilities were built to exercise this capability. Ancho Canyon has three active HE firing sites (Fig. 1). Firing Point 57 is used for material characterization studies and has a load limit of 250 kg. Typical HE shots range from 0.1 kg to 50 kg. Firing Point 6 is an NSF-user facility for the National High Magnetic Field Laboratory. The HE load limit of this site is identical to Firing Point 57. Pulsed high magnetic field (200-T) experiments are conducted at this firing poi. Firing Point 88 is our newest HE firing point. This facility has a 1000-kg HE load limit, and represents the only test facility in the United States where high-energy HE pulsed power experiments are conducted.

For material characterization, to complement our HE firing sites, we have a variety of gun facilities (Fig. 2) that span the same pressure range as our HE firing sites. A single-stage, 50-mm, compressed gas gun with a maximum velocity of 1 km/s is used for our low-pressure experiments. For the high-pressure experiments, a 29-mm, 2-stage light gas gun is used to achieve velocities up to 7.7-km/s. Intermediate pressure range experiments can be conducted on a single-stage, dual gas/powder breech 80-mm gun. This gun is located at another technical area and will be located in the near future at the new Material Science Building that is under construction. This gun will be available to outside users working on collaborative research efforts.

The viability of our HE firing sites is dependent upon our in-house capability to make precision HE components (Fig. 3). CJ pressures range from 39 GPa for PBX 9501 to 14 GPa for baratol. PBX 0533 is a baratol replacement, which has approximately the same CJ pressure as baratol. Precision plane wave lenses are available with diameters ranging from 51 mm to 305 mm and simultaneities varying from a few 10 ns for our smallest lenses to a few 100 ns for our longest lens. The quality of our explosive components allows us to make precision plane-wave one-dimensional (1D) shock wave experiments up to several 100-GPa pressure.

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Custom detonator systems also allow us to perform experiments with complex geometries. For example a linear detonator system up to 30-cm long (Fig. 4) was used in a pulse power experiment to expand a cylindrical liner that functioned as part of an opening switch, to interrupt 15 MA of current. The quality of cylindrically divergent detonation wave is related to the simultaneity of the slapper detonator system and the number of discrete detonator points per unit length. The greater the number of detonator points for a given diameter, the better the quality of the cylindrical detonation wave. A schematic of the slapper detonator used in the cylindrical detonator system is shown in Fig. 5. A strong current pulse vaporizes the copper bridge and accelerates the flier through the barrel with sufficient velocity to detonate the PETN explosive pellet. The HE components and detonator systems just described are precision HE components. Planar and cylindrical tile systems for areal detonation of HE are available. The plane wave lens costs are a few hundred dollars for small plane wave lenses, a few thousand dollars for the largest plane lens, and ten thousand dollars for the linear detonation system.

To reduce the cost of HE experiments, several options are available (Fig. 6). For example, castable HE can reduce the cylindrical detonator costs from 50% to 75% (Fig. 7). The costs savings is primarily due to the elimination of a significant fraction of the HE machining costs. The kinds of castable HE are limited; however, the quality of the detonator system is competitive with current PBX explosives systems. Formable explosives are inexpensive relative to high-quality PBX explosives and can be assembled into various geometries without machining. The detonation velocity and energy are somewhat less than the best PBX explosives, but HE systems made with these explosives can be quite inexpensive. Where HE systems with the highest performance standards are not required, these explosives provide an attractive option. Comp C has the highest detonation pressure (26 GPa) and nitromethane the lowest detonation pressure (13 GPa). The cost of plane wave lenses can be considerably reduced if the simultaneity requirements can be relaxed. The plane wave lens system in Fig. 8 used Detasheet, although this is not mandatory. For this plane-wave lens, the type of HE, plate thickness, and inclination angle are chosen to achieve simultaneous impact of metal plate upon the acceptor HE. In principle, these lenses can be scaled from a few centimeters to a few meters.

These are a variety of options using HE to tailor the input stress into an experimental assembly. The options discussed can be used in either cylindrical or spherical geometry. The "typical geometry" illustrated in Fig. 9 has been used by a variety of laboratories to study blast-wave propagation in spherical geometry. If desired, the blast-wave amplitude can be varied by selecting HE with different CJ pressures. An alternative method of varying the loading pulse amplitude and shape can be achieved by insertion of an air gap between the HE and the rock sample. To vary the risetime of the loading wave, fused quartz can be positioned between the rock being studied and the HE. The ramp loading is due to the presence of anomalous elastic precursor in fused quartz that is ramp-shaped. The risetime of wave into the rock can be varied by choosing quartz spacers of different thicknesses. High-pressure/short-duration pulses can be achieved by accelerating a metal liner through an air gap. Pressures greater than the in-contact geometry can be achieved with this configuration. These examples illustrate there are a variety of options of how pulse shapes can be varied by using different experimental geometries.

In Ancho Canyon a number of pulsed power capacitor systems have been utilized in experimental programs (Fig. 10). At Firing Point 6, 1,000 kJ of energy have been used to generate initial magnetic fields that were explosively compressed to 200 T. These pulsed magnetic fields were used to characterize high-temperature superconductors. At Firing Point 88, a 2,400-kJ capacitor system has been used in a variety of pulse power experiments directed at developing an intense X-ray source for radiation transport studies.

The capacitor banks can be configured in a number of parallel and series combinations to tailor the pulse for different applications. There are two plasma focus experiments, which use either a 72-kJ or 260-kJ capacitor bank, and finally, a 50-kJ capacitor bank is used for isobaric expansion studies on metals. These experiments are directed toward the characterization of the thermophysical properties of metals at high temperature. The isobaric expansion experiment uses a capacitor bank similar in size to the exploding wire experiments previously used to characterize rocks in cylindrical geometry.

At Ancho Canyon a number of diagnostics are used to characterize the response of materials to dynamic loading (Fig. 11). Over the last several years VISARs have been extensively used. A VISAR modification that has proven particularly useful is the fiber-optic target probe (Fig. 12). Optic fibers are used to transport the optical signal to the target and back to the VISAR. Probe diameters of 6 to 12 mm are typical. The compact size and fiber-optic coupling allows utilization of the probe in difficult-to-access experimental geometries. Fast-transit digital recorders are used to record the data. Our most commonly used recorders have 1/2 to 2-ns time resolution with a 500-mhz bandwidth. Another probe that has been particularly effective in the verification program is the Axially-Symmetric Magnetic (ASM) probe (Fig. 13). This passive probe senses the change in flux in a pick-up coil to infer the velocity of a conductor that can be buried in an insulator. Some high-resolution, blast-wave profiles have been measured using this probe.

Many of our routine equation-of-state measurements use high-speed optical cameras to record data. Rotating-mirror, sweep, and framing cameras, and electronic converter sweep and framing cameras are available. Other diagnostics that are used include electromagnetic velocity gages (Dremin loops), optical-fiber diagnostics, manganin gages, and a wide variety of flash x-ray equipment. M-8, another dynamic testing group in M-Division, uses flash x-ray diagnostics as their principal diagnostic tool. A listing of their flash x-ray equipment is given in Fig. 14.

In summary, Ancho Canyon testing facilities have comprehensive material characterization capabilities. These include HE firing sites, a full complement of gun facilities, and a variety of pulse power capacitor bank systems of various energies. The explosive fabrication capability at Los Alamos allows the design and testing of unique HE experimental assemblies. Depending on the hydrodynamic requirements, these explosive systems can vary widely in cost. Our experience over the years has enabled us to develop a comprehensive set of diagnostics to monitor these experiments.

ANCHO CANYON HIGH EXPLOSIVES FIRING SITES

Firing Point 57

Material Characterization Studies
250-kg High Explosives Capacity

Firing Point 88

High Explosives Pulsed Power Experiments
500-kg High Explosives Capacity

Firing Point 6

National High Magnetic Field Laboratory
NSF User Facility
250-kg High Explosives Capacity

GUN FACILITIES

Single-Stage Gun

Compressed Gas Gun
51-mm-diameter Bore
1-km/s Maximum Velocity

Single-Stage Gas/Powder Gun

Dual Gas/Powder Breech
80-mm-diameter bore
2-km/s Maximum Velocity
Located at TA-35

Two-Stage Light Gas Gun

Powder Breech
29-mm-diameter Bore Launch Tube
3 to 7.7-km/s Velocity Range

PRECISION HIGH EXPLOSIVES COMPONENTS

High Explosives

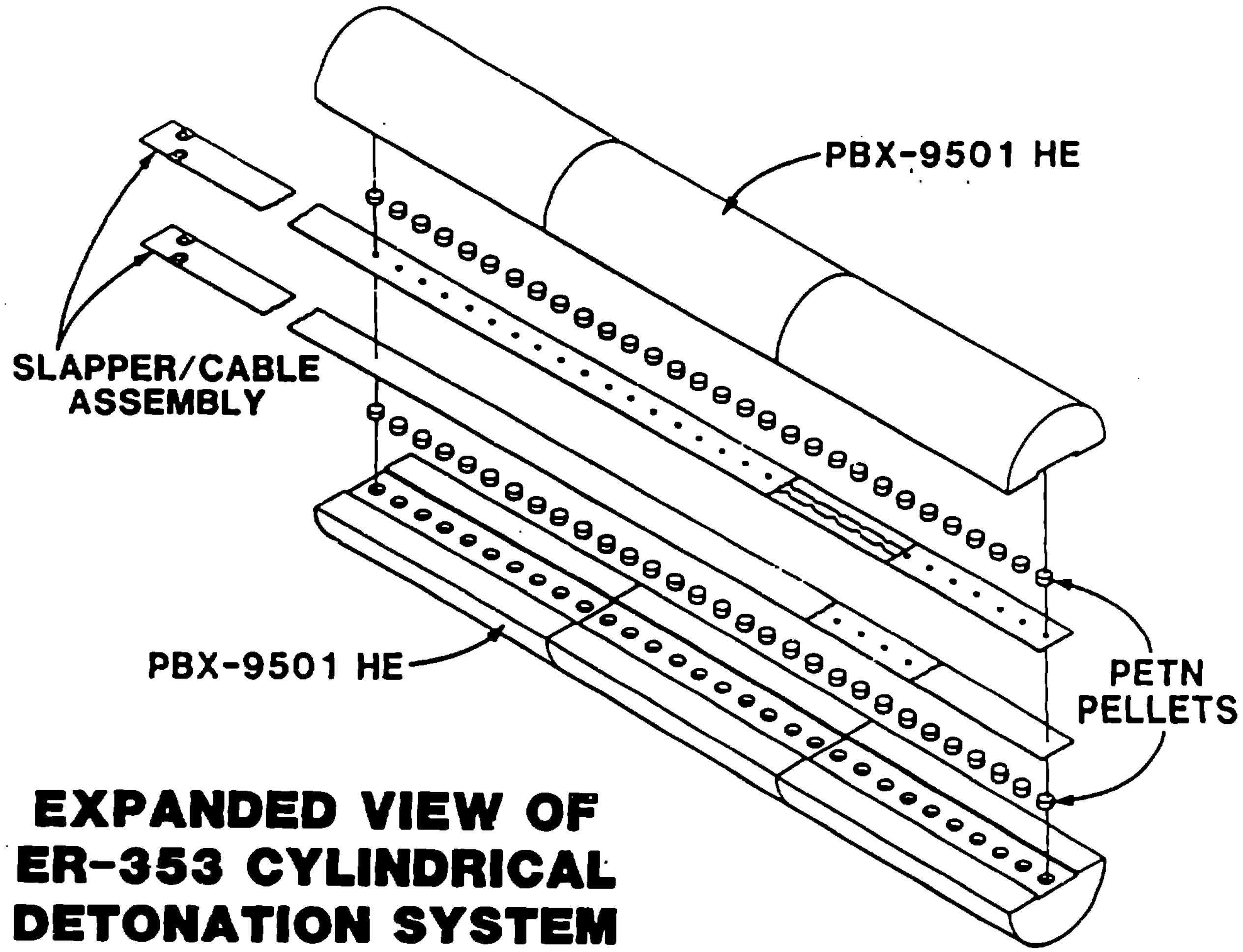
PBX 9501
Comp B
TNT
Baratol
PBX 0533

Plane Wave Lenses

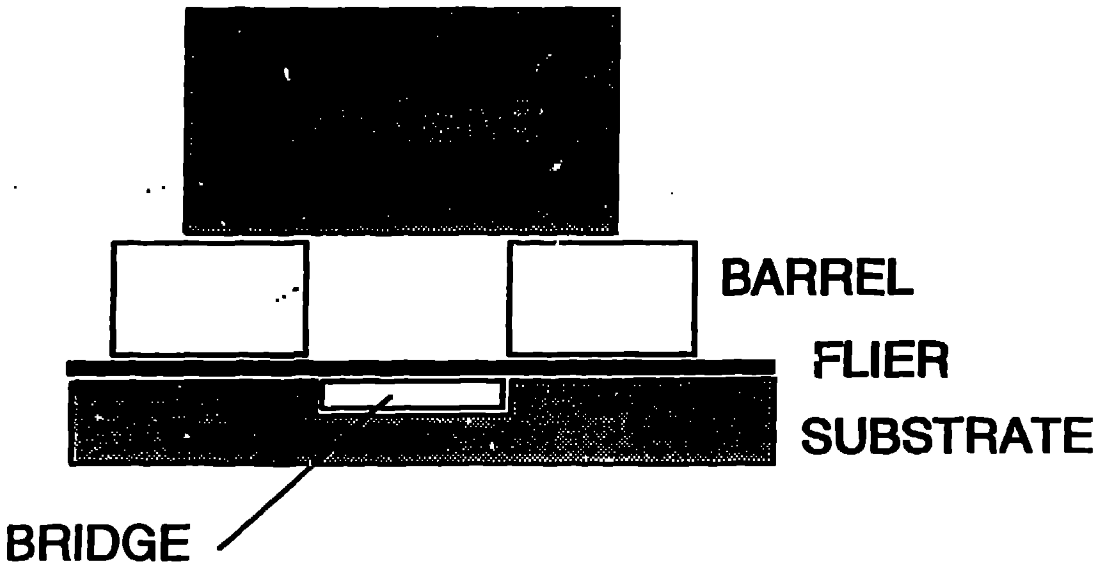
51-mm to 305-mm-diameter Lenses

Detonators

Standard and Custom Detonator Systems



EXPANDED VIEW OF ER-353 CYLINDRICAL DETONATION SYSTEM


BARREL
FLIER
SUBSTRATE
BRIDGE

INEXPENSIVE HIGH EXPLOSIVES SYSTEMS

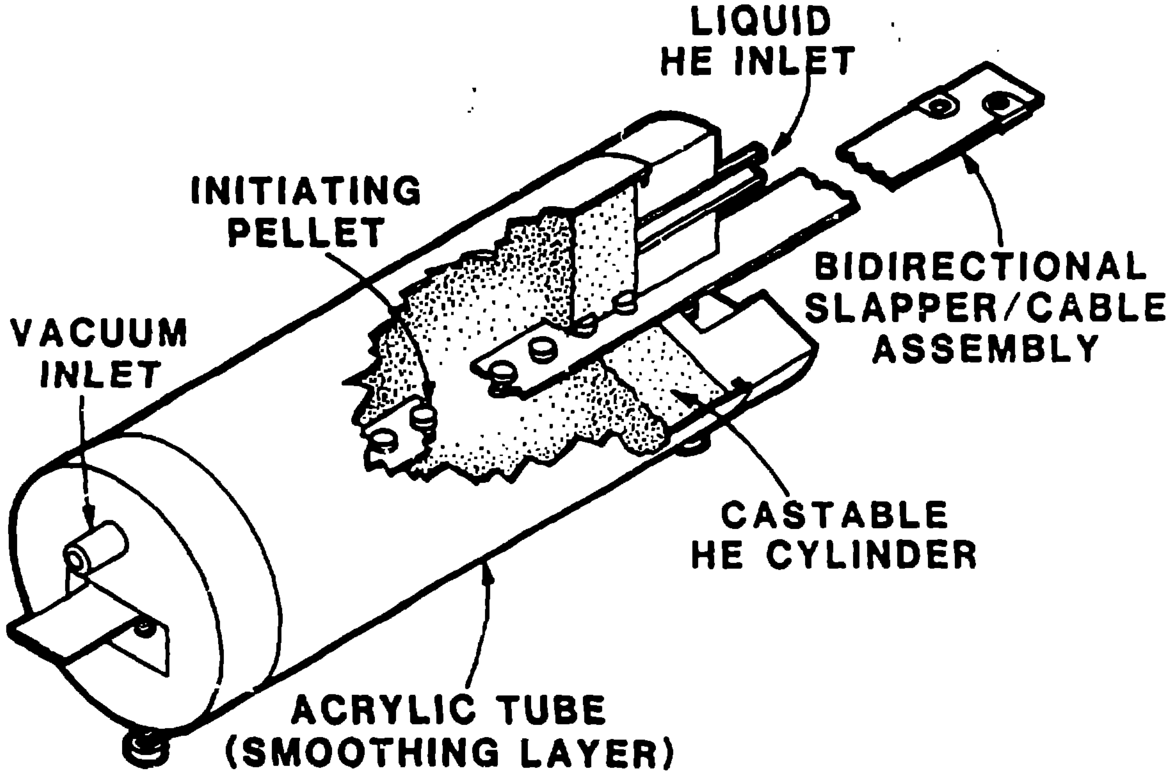
Castable High Explosives

Formable High Explosives

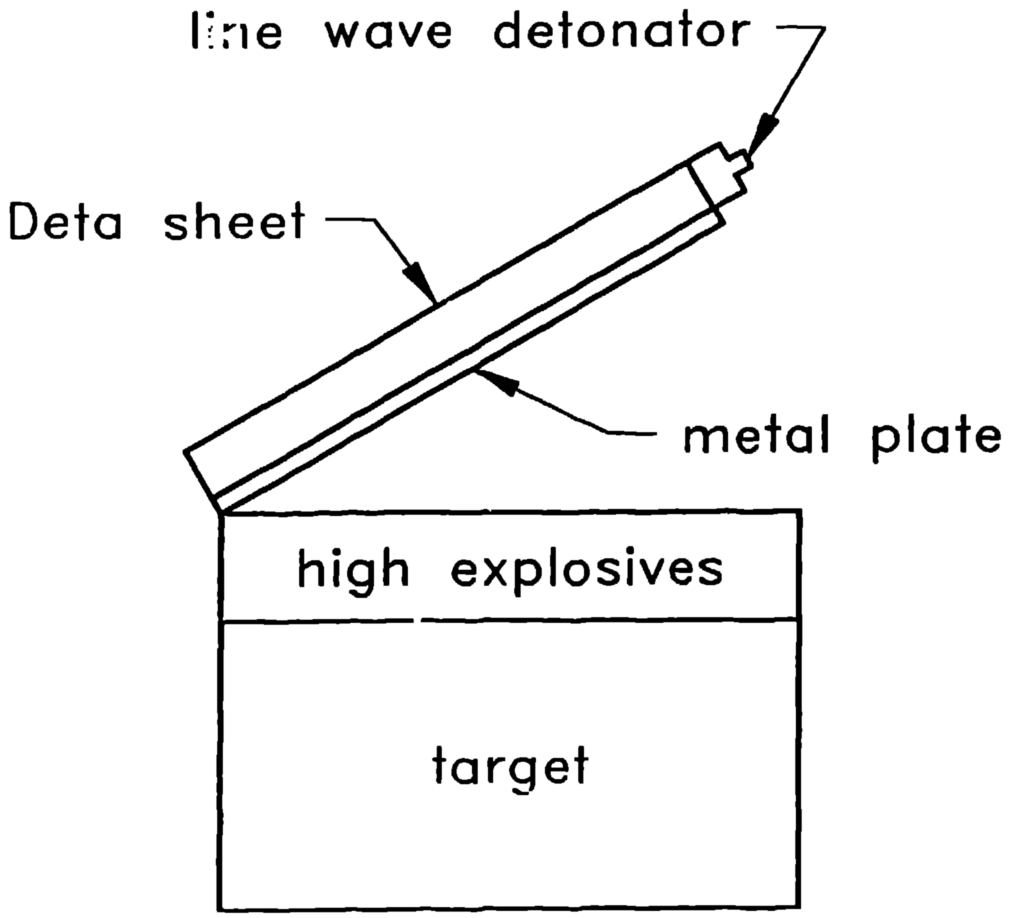
- Comp C
- Detasheet
- Nitromethane

Plane Wave Lenses

CYLINDRICAL DETONATOR USING CASTABLE HE

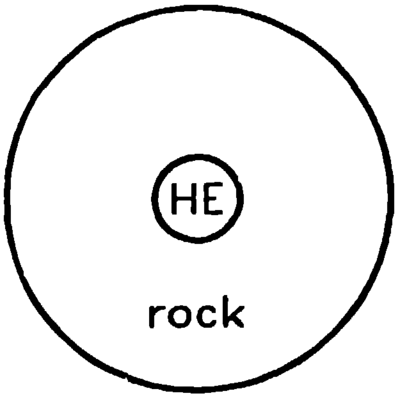


Inexpensive Plane Wave Lens

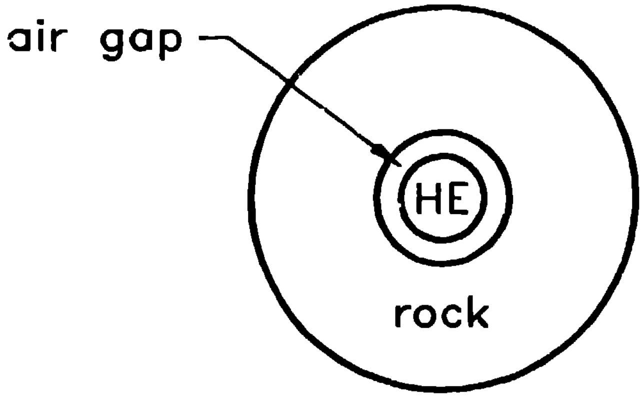


Pulse Shaping with High Explosives

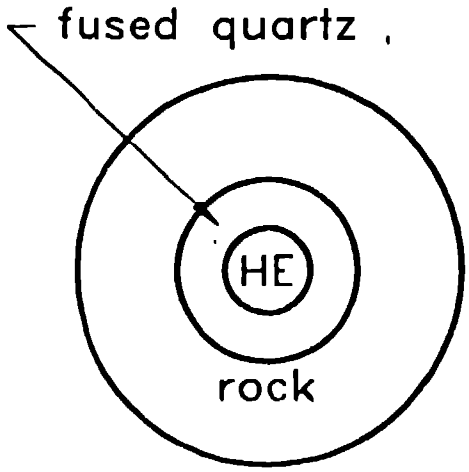
Typical Geometry



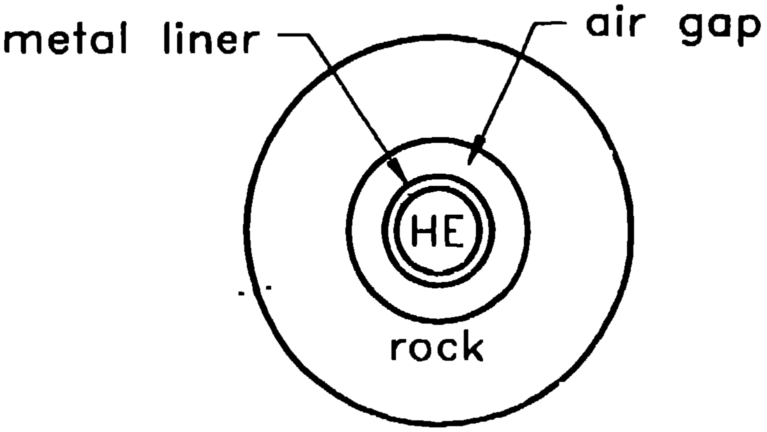
Pulse Attenuation



Ramp Loading



High Amplitude – Short Pulse



PULSED POWER CAPACITOR SYSTEMS

Firing Point 6
National High Magnetic Laboratory

300 kJ at 20 kV
700 kJ at 20 kV

Firing Point 88
Explosive Pulse Power Site

Four Modules, 600 kJ at 20 kV

Plasma Focus Laboratories

72 kJ at 20 kV
260 kJ at 120 kV

Isobaric Expansion Experiment

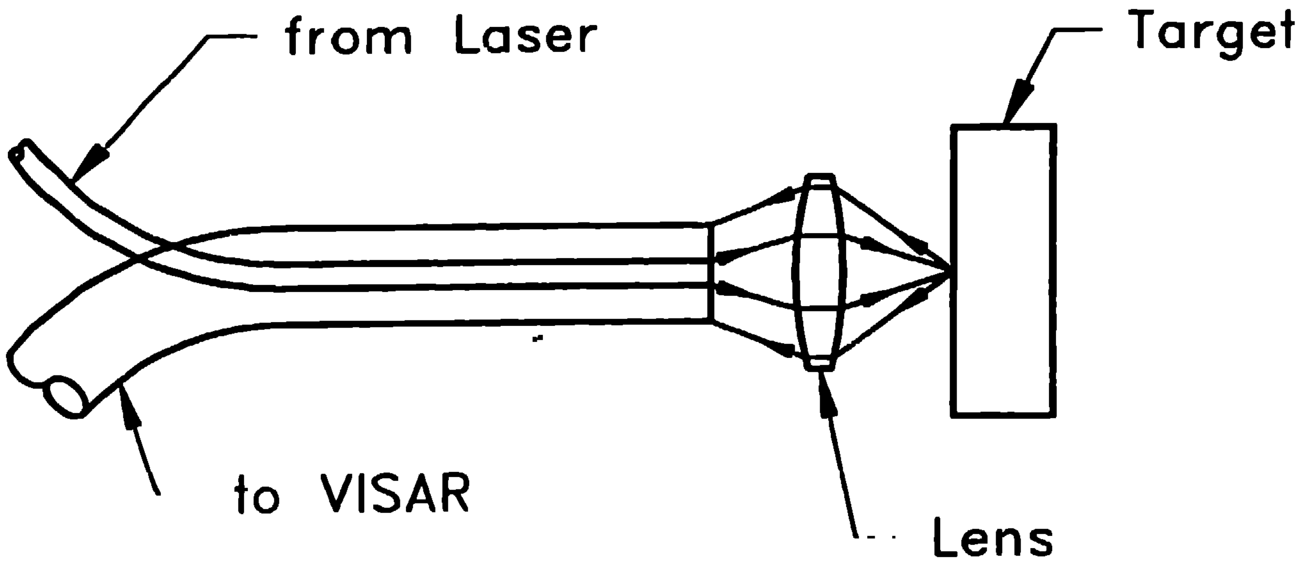
50 kJ at 20 kV

DYNAMIC TESTING DIAGNOSTICS

VISAR
Fast Transient Records
ASM Probe
Cameras (Sweep, Framing, Electronic)
Electromagnetic Velocity Gages
Optical Fiber Diagnostics
Manganin Gages
Flash X-Ray

VISAR

Fiber Optic Target-Probe



M-8 FLASH X RAYS

- **PIXY**: 6 MV, 110 R at 1 m, 8 mm spot
- 4 ea.: 2.3 MV heads, 0.5 R at 1 m, 5 mm spot
- 12 ea.: 450 KV heads, 20 mR at 1 m, 5 mm spot
- 16 ea.: 150 KV heads, 1.6 mR at 1 m, 3 mm spot