P-22: Hydrodynamic and X-Ray Physics

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Introduction

The mission of the Hydrodynamics and X-Ray Physics Group (P-22) is to solve challenging experimental physics problems relevant to our national security, aiming to reduce the threat of war by helping to ensure the reliability of our nuclear-weapons stockpile and by limiting the proliferation of weapons of mass destruction. Our experiments focus on the hydrodynamic properties of materials as they undergo explosive and implosive forces. For nuclear weapons and other highly dynamic systems, knowledge of material behavior under extreme physical conditions is important for developing computational models. Our x-ray capability is predominantly involved in the diagnosis of dynamic material behavior.

To fulfill its mission, P-22 maintains and develops a creative multidisciplinary team, broad physics and engineering capabilities, and state-of-the-art technologies. Experimental efforts in P-22 cover a wide range of physics disciplines, including hydrodynamics, x-ray spectroscopy and imaging, plasma physics, radiation hydrodynamics, optics and fiber optics, microwaves, electromagnetics, atmospheric physics, and atomic physics. In support of these experiments, P-22 has expertise in a variety of engineering disciplines, including analog and digital electronics; electro-optics instrument design and fabrication; high-voltage, low-inductance pulsed-power engineering; and fast-transient data recording. P-22 is also the home of the Pegasus II Pulsed-Power Facility (Fig. 1) and of the future Atlas High-Energy Pulsed-Power Facility (Fig. 2). These high-energy experimental facilities provide a valuable laboratory test bed for the investigation of dynamic material properties.

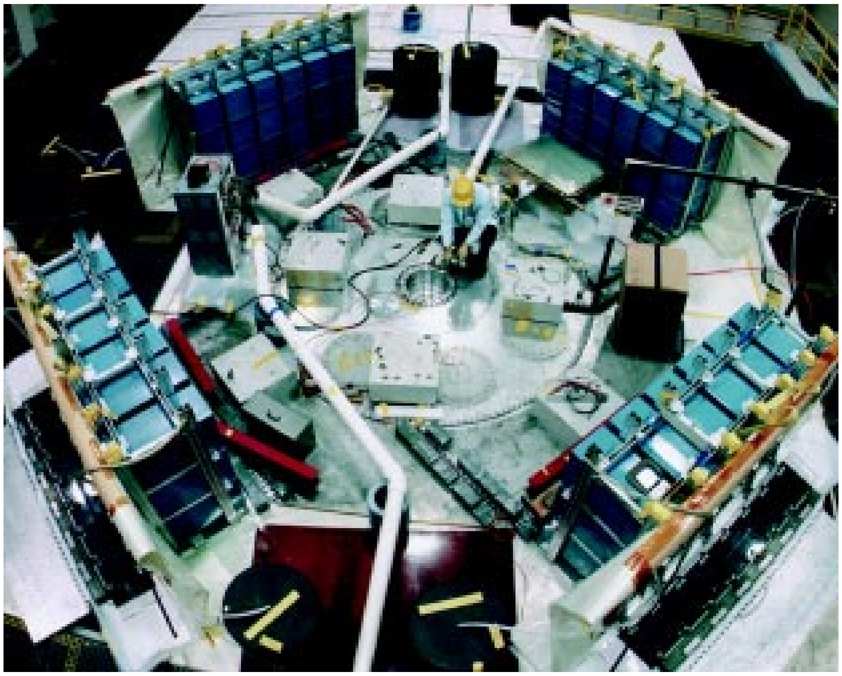

***Fig. 1** View of the upper half of Pegasus II. The facility consists of 144 energy-storage capacitors arranged as a two-stage Marx bank with a maximum erect voltage of 100 kV.*

Fig. 2 The Atlas capacitor bank will be housed in 12 oil tanks that are arranged around a centrally located target chamber. Each oil tank will contain up to two removable maintenance units and up to 32 capacitors.

The mainstay of P-22 has traditionally been its support of the nuclear-weapons program. P-22 continues this tradition by supporting science-based stockpile stewardship (SBSS), which is the foundation of the present Los Alamos nuclear-weapons program. SBSS requires the development of complex experiments on diverse facilities to address the relevant physics issues of the enduring stockpile. In P-22, we support SBSS by applying the scientific and engineering expertise that we developed for the nuclear test program to investigate and understand primary and secondary weapons-physics issues that are crucial in a world without nuclear testing.

Nevada Test Site

P-22 is deeply involved in protecting and archiving the volatile test data it took during more than three decades of underground nuclear testing at the Nevada Test Site (NTS). Our goal is to bring the group's data to a stable and readily accessible state. These data will be used to benchmark all future calculational tools. The archiving activities constitute a significant effort in P-22 and involve individuals responsible for the original execution of underground nuclear tests as well as trainees. Many of the numerical algorithms developed for analyzing the information from underground tests have been ported to modern computer platforms as part of our effort to preserve this valuable and unique data.

In addition, P-22 continues to participate in experiments performed underground at NTS, both to maintain our readiness to support a resumption of nuclear testing should the need arise, and to study the physics of weapons performance and materials (Fig. 3). These experiments increase our understanding of weapons science by allowing improvements in code calculations and in estimates of the severity of problems and changes occurring in the nuclear stockpile as it ages.

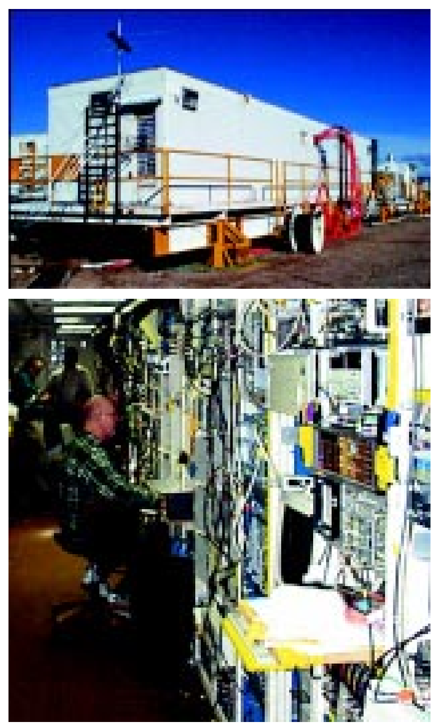

Fig. 3 P-22 data recording trailer at the NTS U1A underground test facility. The trailer uses modern fiber-optic systems and state-of-the-art digitizers and timing systems to gather and record data from explosive experiments located almost 1,000 ft below ground.

At present, we are supporting the Los Alamos Dynamic Experimentation (DX) Division on experiments to measure the properties of material ejected from shocked plutonium. These experimental efforts are discussed in detail in a research highlight in Chapter 2. By performing these experiments underground at NTS, the plutonium is handled and contained in a manner similar to that used for underground nuclear tests, maintaining the readiness training necessary to support the potential for future nuclear tests.

Above-Ground Experiments

In support of the Weapons Program's above-ground experiments (AGEX-1), we have been developing diagnostics to study the physics of high-pressure shock waves. Among the diagnostics currently under development are

- visible-wavelength and infrared pyrometers to determine the temperature history of the back surface of a shocked material under conditions where this surface either releases into free space or is tamped by an anvil,
- low-energy x-ray sources for imaging of shock-produced low-density material (ejecta), and
- a technique for measuring the speed at which moving, high-density material can produce a fiber-optic signal.

We anticipate development of several other techniques to study material phases, including

- a very-short-pulsed laser and an ultrafast streak camera to determine by either second harmonic generation or reflectivity whether the surface of a shocked sample has melted, and
- an x-ray diffraction technique to measure phase changes at the surface of a shocked sample.

These diagnostics will be used to study shocks produced by explosives, flyer plates, gas guns, and the Pegasus capacitor bank.

In other AGEX-1 work, we are supporting the development of the Dual-Axis Radiographic Hydrotest Facility (DARHT) by studying the beam physics of DARHT's prototype, the Integrated Test Stand (ITS). We have built and successfully fielded a magnetic spectrometer to measure the beam energy as a function of time in the 70-ns ITS pulse. In addition, we are developing a microwave interferometry diagnostic to nonintrusively measure the beam electron density and properties of the expanding target plasma created in the interaction of the electron beam and bremsstrahlung converter. We are also participating in the development of new nonintrusive beam diagnostics for the 2-μs injector of the DARHT second axis.

High Energy Density Physics

The High Energy Density Physics (HEDP) program has been conducting experiments of interest to the weapons community at the 4.6-MJ Pegasus II Pulsed-Power Facility, which can be used as a radiation driver or as a hydrodynamic driver in convergent geometry (Fig. 4). Experiments are being performed to investigate a wide range of phenomena, including nonsymmetrical hydrodynamic flow, the behavior of materials undergoing large strains at high strain-rates, frictional forces at interfaces with differential velocities on the order of kilometers per second, instability growth at interfaces in materials with and without material strength, and ejecta formation of shocked surfaces. In addition, we are pursuing pulsed-power research on liner stability, current joints, and power-flow channels to ensure optimal performance for the future Atlas facility and for advanced, high-current, explosive pulsed-power systems. P-22 has already provided pulsed-power and diagnostic expertise to Procyon, Ranchito, and Ranchero, the Laboratory's existing high-explosive pulsed-power systems.

P-22 is the future home of Atlas, the next-generation 23-MJ pulsed-power facility. Atlas will provide advanced equation-of-state (EOS), material property, and hydrodynamic capabilities for weapons-physics and basic research. 1996 marked the official start of the Atlas construction project, with the first dollars arriving for detailed facility design. A major milestone in the project, approval of the DOE critical decision (CD-3) that authorized the start of construction, was reached during 1998. Research and development (R&D) activities since 1996 have been centered on component development, prototype design and testing, and preliminary design of Atlas experiments that will provide an understanding of the scaling of physical phenomena from present data to higher energies. Physics issues of interest are material properties at high strains and strain rates, EOS measurements at high pressures, hydrodynamic response and EOS of strongly coupled plasmas, and interface physics. The Pegasus and Atlas facilities and the current and anticipated research activities are described in detail in a research highlight in Chapter 2 of this progress report.

In another part of the HEDP program, P-22's plasma-physics expertise and ability to do large-scale integrated experiments have provided group members with the opportunity to participate in several collaborations with the premier All-Russian Institute of Experimental Physics at Arzamas-16 (VNIIEF), the weapons-design laboratory that is the Russian counterpart to Los Alamos. In addition to giving us the chance to learn about some of the Russians' unique capabilities, the collaborations provide Russian weapons designers with an opportunity to do peaceful basic scientific research and to integrate themselves into the world's broader scientific community. These collaborations are based on our mutual interests in high-explosive-driven pulsed power, wherein the Russians have clearly demonstrated scalability to large systems that is unmatched to date in the United States. P-22 is

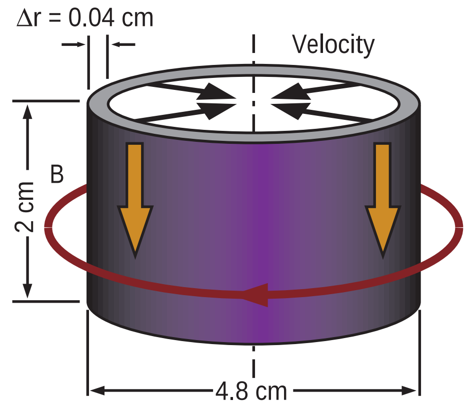

***Fig. 4** Recent research at Pegasus II has focused on hydrodynamic experiments using a standardized solid, cylindrical drive liner. Pulsed electrical currents create a strong magnetic field (B) and high current density around the liner. The interaction of the current and magnetic field produces forces that implode the liner.*

participating in several major collaborative efforts, including experiments on the Russian MAGO system, a possible candidate for magnetized target fusion; attempts to convert a frozen rare gas to a metal by compressing it in a large magnetic field; the design and testing of a thin, imploding cylinder for a megajoule x-ray source; and studies of the properties of materials at cryogenic temperatures in magnetic fields up to 1,000 T.

We are continuing to perform integrated and fundamental radiation hydrodynamic experiments using laser- and z-pinch-driven radiation sources at the Nova and Z facilities at Lawrence Livermore National Laboratory and Sandia National Laboratory, respectively (Fig. 5). We have developed diagnostics for measuring radiation flow, including x-radiography, VISAR, gated x-ray imagers, filtered x-ray diodes, a curved-crystal spectrometer for stimulated fluorescence spectroscopy, and both active and passive shock breakout techniques. Our investigations have examined integrated experiments to understand radiation flow and to evaluate the usefulness of dynamic hohlraum radiation sources for a variety of future applications.

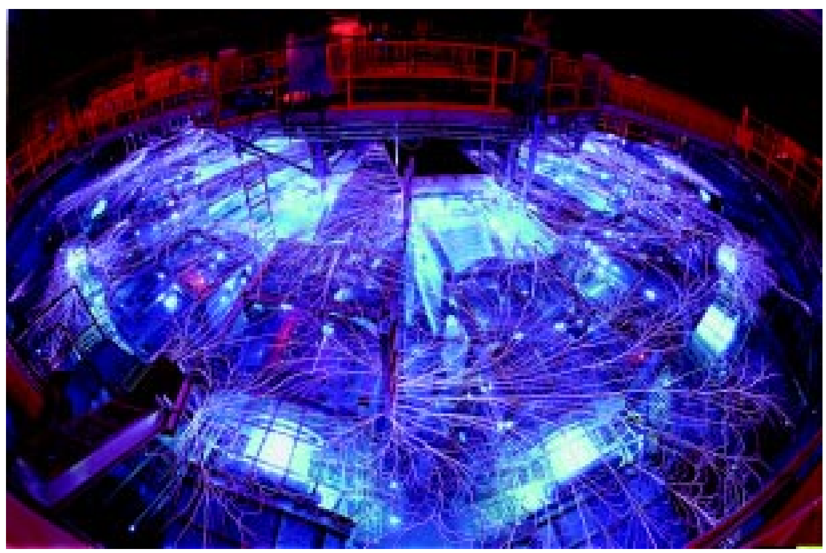

Fig. 5 ***The Z machine photographed as it is firing. Recent radiation experiments on the Z machine have set records for machine performance and provided a basis for weapons physics experiments in support of science-based stockpile stewardship.***

Future Directions

We anticipate a lot of exciting developments in the coming years. As the future operators of the Atlas facility, scheduled to come on-line in 2001, we will continue to support facility development and prepare for future research by testing our experimental designs and calculations at Pegasus and other facilities. In addition, we will focus on diagnostic development to support upcoming experiments at NTS and other AGEX-1 facilities. For further information on all of P-22's projects, refer to the project descriptions in Chapter 3. Some of our major achievements are also covered as research highlights in Chapter 2. These include experiments at the Pegasus facility and development of the Atlas facility, as well as our recent experimental collaborations at NTS.