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TITLE IMAGE-INTENSIFIER CAMERA STUDIES OF SHOCKED METAL SURFACES

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IMAGE-INTENSIFIER CAMERA STUDIES OF SHOCKED METAL SURFACES[*]

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ABSTRACT

A high-space-resolution image-intensifier camera with luminance gain of up to 5000 and exposure times as short as 30 ns has been applied to the study of the interaction of posts and welds with strongly shocked metal surfaces, which included super strong steels. The time evolution of a single experiment can be recorded by multiple pulsing of the camera. Phenomena that remain coherent for relatively long durations have been observed. An important feature of the hydrodynamic flow resulting from post-plate interactions is the creation of a wave that propagates outward on the plate; the flow blocks the explosive product gases from escaping through the plate for greater than 10 μs. Electron beam welds were ineffective in blocking product gases from escaping for even short periods of time.

We have used a high-space-resolution image-intensifier camera (IIC) to study the interaction of strongly shocked metal surfaces with posts and welds. The short exposure time is possible because the multichannel plate is electronically pulsed on and off, the multichannel plate has a luminance gain on the order of 1000, and the object is illuminated by very bright light sources. The electronic pulsing of the multichannel plate allows multiple exposures of a dynamic event. The development, limitations, and prior use of this camera have been reported in Refs. 1-3.

The camera we used employed type F-4113 40-mm-diameter multichannel-plate image-intensifier tubes purchased from International Telephone and Telegraph, Electro-Optical Products Division. The camera and its electronics were designed and built at Los Alamos. In Ref. 3 it was shown to resolve 11-14 line pairs per mm when the luminance gain is kept below about 1000.

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Figure 1 shows the camera and its electronics setup on an optical bench. A schematic of the image-intensifier tube is shown in Fig. 2. A multichannel plate is between a photocathode and a phosphor. The multichannel plate consists of a dense array of tiny channels, each one of which is about 10 μm i.d. and 1 mm long.

An electron, produced by a photon at the photocathode, is proximity focused on the multichannel plate. Because the channel that it enters is canted with respect to the electron's velocity vector and has an accelerating voltage across it, the electron travels through the channel making many glancing reflections. Each reflection produces secondary electrons, which cascade into more secondary electrons. The total number produced is controlled by the voltage across the multichannel plate. The electrons emerging from the channel are proximity focused to a spot on the phosphor where they are converted back to light. Thus, the multichannel plate acts as an imaging light amplifier. The plate supporting the phosphor is a fiber optics array; film is pressed against this array and no other optics are needed. The only lens in the system focuses the subject on the photocathode. We used Kodak Tri-X film, which has an ASA speed of 320 in sunlight. We used a luminance gain of 620 because higher gains produced a loss of space resolution (Ref. 3). In all cases, the illuminating light source was a volume of argon shocked by a piece of Composition B, 102 x 102 x 25.4 mm.

Figure 3a shows the initial configuration of a steel post and plate. The resolution shows the 0.8-μm machining marks in the plate. The post's diameter and length were 3.2 and 25.4 mm. The plate's thickness and diameter were 2 and 108 mm. The plate was driven by 63.5 mm of explosive PBX-9404 initiated by a P-40 planewave lens.

Usually, a fiducial for triggering the camera was established by pin switches on the front surface of the driven plate. Figure 3b shows a photograph taken with the IIC, 3 μs after fiducial. The picture's high space resolution illustrates the utility of the IIC in recording fast events. The plate was moving approximately 2 mm/μs when the action photo was taken. The post causes a wave in the plate, like a stick driven into a pond. Explosive products were not observed to penetrate through to the front of the plate. Figure 3c shows profiles from a similar experiment taken at 0.5, 1.0, 1.5, and 9.0 μs after fiducial. The multiple exposure mode of the IIC also was used in Ref. 1. Figure 3c shows that the wave grows in height and diameter as the plate moves relative to the post. This relative movement occurs because the mass per unit area is higher for the post than for the plate. At 9 μs, edge effects were influencing post-plate interactions. Experiments with hollow posts showed that, in addition to these phenomena, luminous gases are ejected from the hollow posts.

This type of experiment was performed with three types of steel: Vascomax 250, Almar 362, and 347 stainless. The first two are super strong steels. All post and plate pairs were made of the same steel. The steels investigated gave essentially the same results indicating that the hydrodynamics we observed were not affected by material strength.

In studying the response of a welded joint to an explosive load, we used Vascomax 250 steel plates that were 2 mm thick by 102 mm in diameter. A step joint with a 0.13 ± 0.03-mm step width was machined in the plates half way through their thickness. A fifty percent penetration electron beam weld was made in the plates. The weld was on the side facing a 63-mm thickness of PBX-9404. Figure 4a is a still photo of the weld. Figure 4b is an IIC photo that shows a jet of explosive products gas emerging from the welded joint 0.5 μs after shock contact with the plate's front surface. Figure 4c shows a picture taken at 3 μs. The ejecta from the joint is remarkably directional and coherent, giving the impression of a circular saw cutting through the plate.

The use of an IIC in the study of the interaction of shocked metal surfaces with posts and welds has revealed hydrodynamic phenomena that seem organized and coherent for a remarkable duration. The early phases of these processes can be calculated by hydrodynamic codes, but calculating their long-term development tends to be difficult and costly. It is often quicker, more direct, and more cost effective to resolve problems created by interactions such as those described through IIC experiments. In less symmetrical systems, numerical hydrodynamic calculations extending over even a short time duration would be quite difficult.

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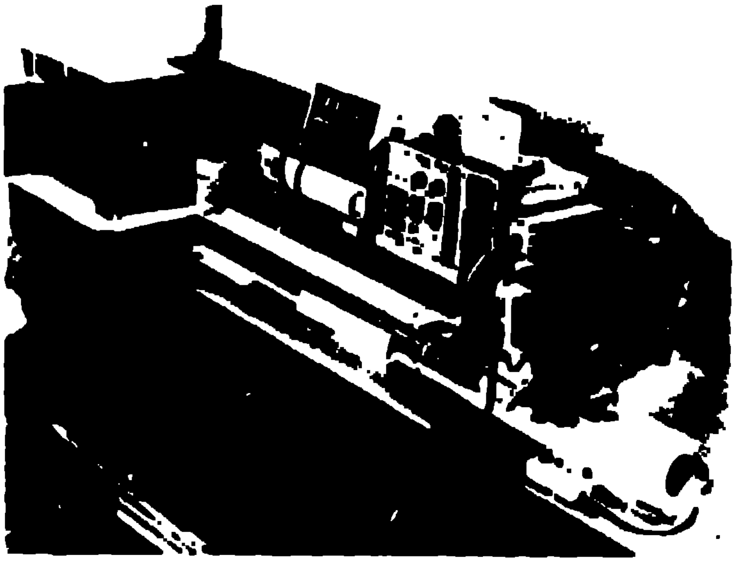

Fig. 1. Optical bench setup of IIC and its electronics.

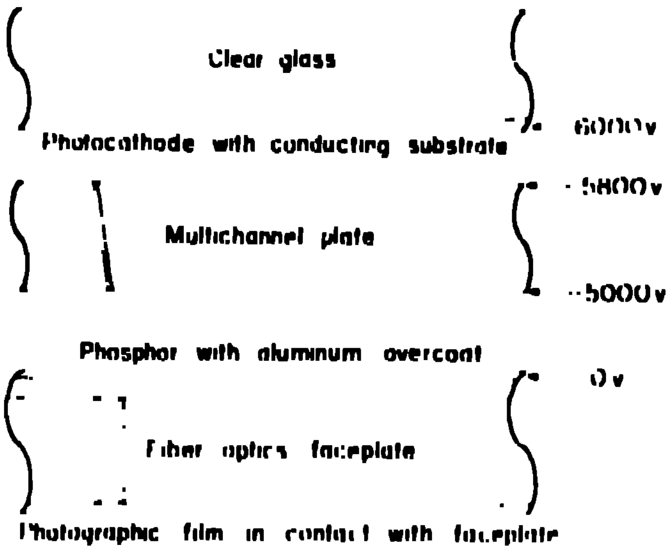

Fig. 2. Schematic of the light amplifying tube.

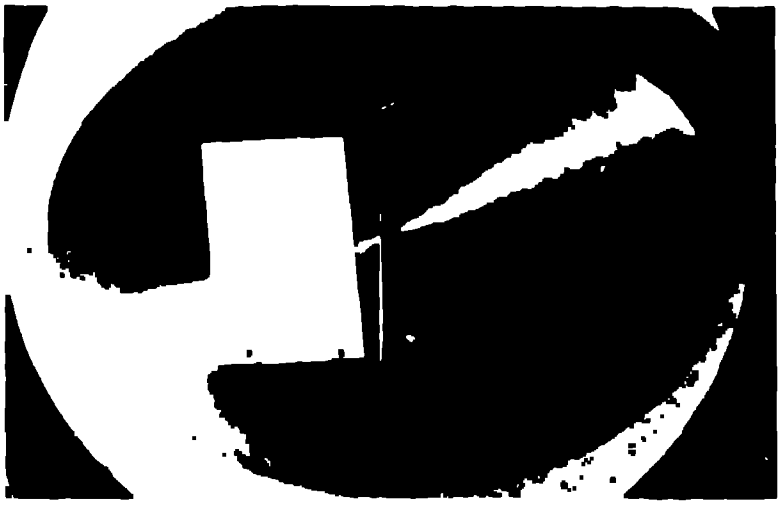

Fig. 3a. Still photo of post-plate interaction experiment.

Fig. 3b. IIC photo at 3 µs after fiducial. The plate free surface velocity is about 2 mm/µs.

Fig. 3c. IIC multiple exposure at 0.5, 1.0, 1.5, and 9.0 µs after fiducial.

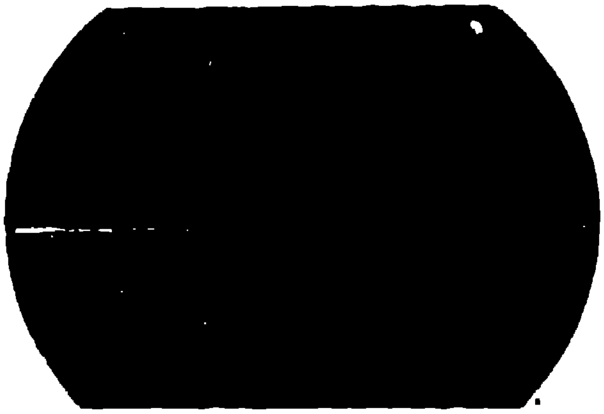

Fig. 4a. Still photo of electron beam weld on plates of Vascomax 250 steel.

Fig. 4b. IIC photo of welded plate showing emerging jet at 0.5 µs after fiducial.

Fig. 4c. IIC photo of welded plate showing coherent jet at 3.0 µs after fiducial.