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PRELIMINARY REPORT ON THE PINEX AT TREAT*

by

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ABSTRACT

The neutron image of a GETR fuel pin was observed in a pinhole experiment (Pinex) performed at TREAT. The signal amplitude, recorded with intensified television cameras, compared well with expectations. The results carry favorable implications for continued development of nonredundant pinhole array techniques, as well as for refinement of single pinhole experiments, as diagnostic tools for the LMFBR safety program.

I. INTRODUCTION

At last year's meeting in Albuquerque we pointed out the potential of nonredundant pinhole arrays (NRPAs) for collecting three-dimensional information with improved efficiency. In the same session we also discussed likely recording instrumentation--intensified television and intensifier-film cameras--for NRPA experiments. The most important uncertainty in potential applications to fuel pin imaging revolved around adequate sensitivity.[1]

Subsequent to that meeting we have performed two experiments at TREAT, as well as continuing work in the laboratory. The first experiment, a "piggyback" during some of the R-series, essentially radiographed the hodoscope. Fifteen of the beams emanating through the hodoscope collimator projected onto a scintillator that was viewed by an intensified camera system. We

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demonstrated that during high-power transients the cameras could be operated in the TREAT environment with little detrimental effect from background radiation. There was also no evidence for EMP interference. The observed signal amplitude verified that our expectations regarding camera sensitivity were reasonable, though no accurate calibration could be obtained. (This experiment is discussed in Ref. 2.)

These results encouraged us to attempt a second experiment, one with a single pinhole as an imaging aperture. The main objective was to obtain a reference point for a future MRPA experiment. Specifically we desired (1) a calibration, (2) an indication of available scene contrast, and (3) experience with a pinhole experiment (Pinex) at the TREAT reactor. Another important, though secondary, objective was to image the fuel pin for its own sake.

With help from RD&D of ERDA, from RAS Division of Argonne National Laboratory, and from the TREAT staff, a brief block of time in the TREAT schedule was dedicated specifically to the Pinex. HEDL provided an old test pin and capsule from its inventory.

II. THE EXPERIMENTAL ARRANGEMENT

The experiment geometry is sketched in Fig. 1. The most significant components of Fig. 1 are described briefly below.

A. The Pinhole

The pinhole design followed criteria scaled from those established for experiments at the Nevada Test Site. The tapered pinhole had a kennertium central region, followed by regions of brass and then of polyethylene. The total pinhole thickness was 75 cm. The critical parameters (taper angle: 89.3°; diameter: 0.5 mm; and central section thickness: 10 mm) were chosen after a study with the PINHOLE code of their effects on resolution and field of view.

To increase the vertical field of view we used three parallel pinholes whose fields of view in the fuel pin plane we calculated to overlap at the ∿ 10% points. To increase versatility and minimize the number of transients, we prepared spare center sections of 0.75 mm and 1.0 mm diameter apertures.

We embedded the pinholes into a block (see insert to Fig. 1) having a fast neutron attenuation equivalent to, and a gamma-ray attenuation a few decades greater than that of the reactor wall. The block was inserted into the south side of the reactor wall approximately as shown in Fig. 1. The remainder of the cavity was filled with concrete blocks, some boreated polyethylene, and lead bricks. Alignment was accomplished with an alignment capsule (in the test section), an alignment pinhole in the block, and a telescope. The alignment was confirmed with the real pinhole and a laser beam.

B. The Recording Instrumentation

The front end of the experiment resembled that described in Ref. 2. Two doubly intensified vidicon television systems* and two intensifier-film cameras viewed scintillators through a folded optical path from the protection of a lead cave. The double intensifier, a generation II channel plate intensifier followed by a proximity focused diode, provided increased sensitivity approaching the statistical limit.

The camera box communicated via a cable bundle with a trailer parked adjacent to the reactor building. Functions inside the box were controlled from the trailer, with remote control from the reactor control room. The camera signals were branched to video tape recorders in the trailer and to a live display in the TREAT control building. We also recorded several timing and monitoring signals on oscilloscopes for post event diagnosis of the recording system performance.

On the basis of known properties of the PNL 59 test pins we estimated a neutron flux of ∿ 1.0 mr per TV frame on the scintillator. Camera calibrations at LASL with a flash x-ray source

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*The TV cameras were MTI model VC24, with a GE model Z7986 fiber optic vidicon tube. All of the intensifiers were manufactured by ITT Electro-optics.

indicated a peak video signal from the pin as 50-100 mV above the scene background, and above a camera noise level of 5-10 mV for a transient of 1000 MW.

To maintain simplicity we operated the TV systems in a continuous mode (16-ms fields) and gated only the intensifier-film (IF) cameras. To establish relative timing we recorded the IF camera gates, the SAFE II signal from TREAT control, and a single pulse flashlamp gate on oscilloscopes.

C. The Fuel Pin

The GETR fuel pin, PNL-59-10, was made of natural UO_2 mixed with 25% PuO_2. The pin had a power coupling factor of 0.72×10^{-4} $w/cm^3/w$ of reactor power. (A recheck prior to the experiment showed a 10% lower value.) The pin, described in detail in Ref. 3, was encapsulated in a standard TREAT pressure vessel. The fuel (5.5-mm diameter) was surrounded by 0.4-mm-thick steel clad, followed by 1.2 mm of NaK, contained by aluminum (3.7 mm). Most of the remaining inner capsule (to a diameter of 28.6 mm) was filled with steel.

III. PRELIMINARY RESULTS

A sequence of photographs recorded with one of the intensified TV systems is shown in Fig. 2. Each TV frame includes images projected through two of the pinholes. The intensity difference in the images arises from a difference in the pinhole diameters (0.75 mm, top, and 0.50 mm, bottom). The data in Fig. 2 are not intensity normalized, i.e., photographic brightness and contrast were adjusted for good visibility of the pin.

Comparable data were obtained with a second TV system that viewed images from the 0.50-mm pinhole and a lower one 0.75 mm in diameter. Images were also recorded with two gated, intensifier-film cameras. These data are not presented (and have not been analyzed) for reasons of expediency.

The peak video signal amplitude (pin above background) during 1000 MW transients was slightly less than 10 mV in both cameras, consistent with expectations. The background signal amplitude was roughly twice as great, with most, but not all, arising from scene background inside the reactor.

To check the apparent expansion of the pin after failure, we plan to examine the digitized data. Because of the low signal-to-noise ratio, we anticipate that integration over several lines will be necessary. Preliminary analyses are suggestive of an ∿ 50% expansion in the pin diameter occurring on a time scale of 30-60 ms.

IV. PRELIMINARY CONCLUSION

A. Implications for NRPA Experiments

We believe the results to be very favorable toward continuation of NRPA system development. The sensitivity of an NRPA system (assume 15 pinholes) will increase roughly 15 times, with an ∿ 3.5-fold improvement in the signal-to-noise ratio.

The scene contrast should be improved, in that background contributions originating either behind or in front of the plane of interest should decrease in the reconstruction. Namely, focusing on the pin, or a pin in a bundle, will disperse background from noncoplaner sources. We have also shown in earlier laboratory experiments that substantial improvement can be made by Fourier filtering of the defocused components.

The ease with which this experiment was fielded should carry over to NRPA situations. We anticipate relatively minor modifications in the recording trailer or in the front end.

The most significant difficulty will deal with the design and construction of the NRPA block. The north slot at TREAT appears more than adequate in size for a 15-pinhole array. The south slot may be usable, but with some compromise in the properties that characterize good pinhole blocks and good NRPAs.

B. Pinex as a Diagnostic Tool

From the preliminary results we feel that a single pinhole experiment could be a valuable tool in itself, at least for some types of experiments. An ideal combination could prove to be a Pinex in one slot to provide high spatial resolution data during the peak of a transient, and a hodoscope in a second slot to provide continuous time information at points identifiable with a Pinex image.

We stress again that pin data for its own sake was a secondary objective of our initial Pinex at TREAT. We believe that by shifting the accent, much better data can be obtained.

We also believe that a second Pinex, with some parameters changed according to this past experience, may be desirable to further optimize the system prior to a full fledged NRPA endeavor.

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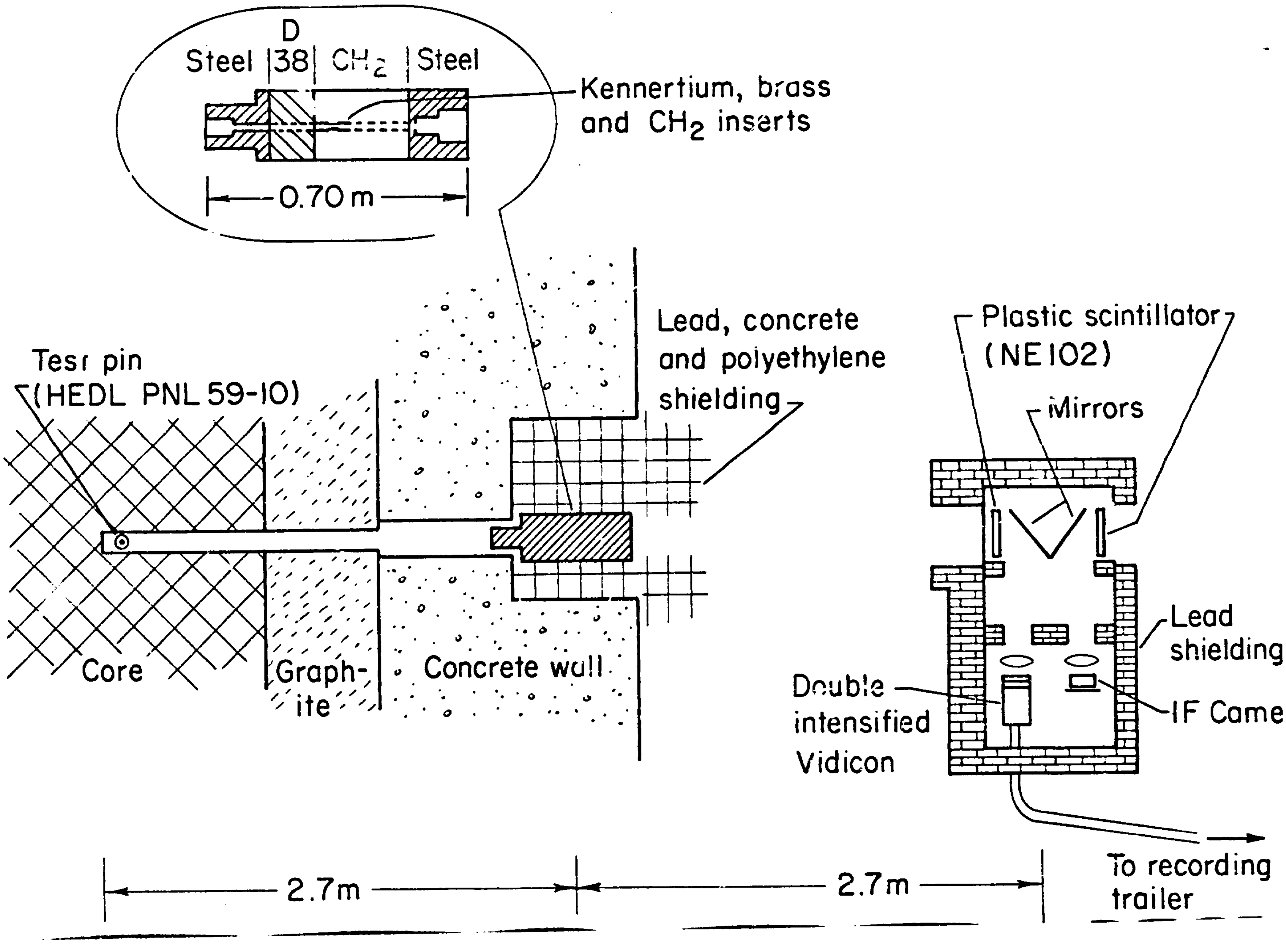
TREAT PINEX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CH2
Steel
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Double intensified Vidicon
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To recording trailer
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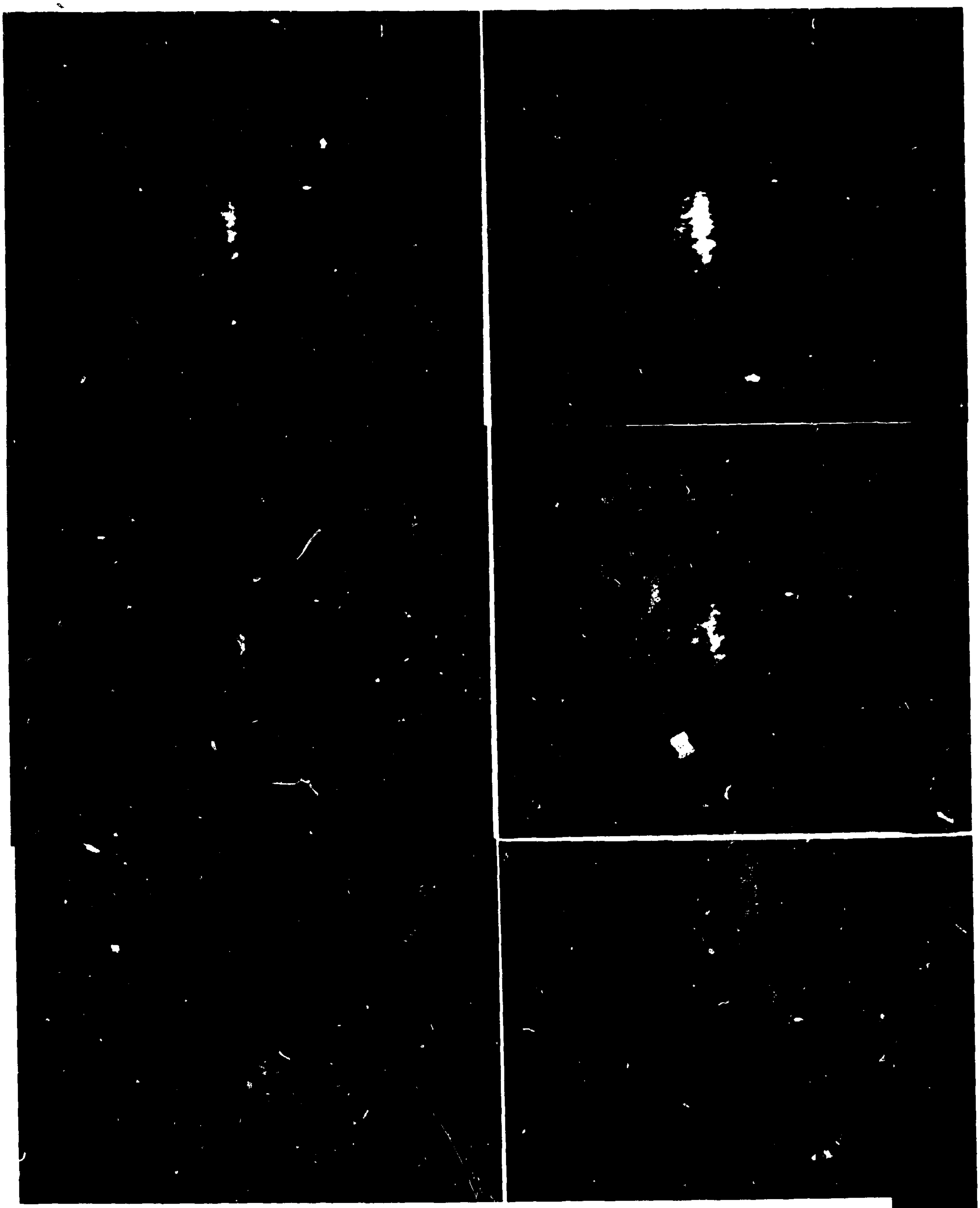

Fig. 2. A sequence of 6 TV frames recorded over the peak of TREAT transient #1848. The sequence begins at the upper left. The frame at the upper right is #4 in the sequence, and occurs just after the peak of the transient, and just