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MEMORANDUM REPORT No. 913

**A Spectrograph With Space -
Time Resolution And Its
Application To The Study Of
Exploding Tungsten Wire**

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**DEPARTMENT OF THE ARMY PROJECT No. 5B0304009
ORDNANCE RESEARCH AND DEVELOPMENT PROJECT No. TB3-0134**

BALLISTIC RESEARCH LABORATORIES



ABERDEEN PROVING GROUND, MARYLAND

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A SPECTROGRAPH WITH SPACE - TIME RESOLUTION AND ITS
APPLICATION TO THE STUDY OF EXPLODING TUNGSTEN WIRE

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GEHauver/arc
Aberdeen Proving Ground, Md.
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ABSTRACT

A high-speed framing camera has been adapted for spectrographic studies. With this instrument it is possible to study simultaneously spectral characteristics as a function of both time and position in object space. Time-space resolved spectrograms of exploding tungsten wire were obtained, and the results are included in this report.

INSTRUMENTATION

A Beckman and Whitley Model 189 framing camera has been adapted for spectrographic studies. Optically, this camera is similar to the Bowen 76-lens camera¹ and to the framing camera described by Brixner². The objective lens forms an image on a rotating mirror which directs the reflected beam into a series of relay lenses, in sequence. The relay lenses form effectively still images along the film plane. In its present application with a 5000 RPS mirror-turbine assembly, the camera records at a rate of about 1,200,000 frames per second with effective exposure times of approximately 0.2 microsecond.

For spectrographic studies, the original lens was removed and a 20-inch focal length Bausch and Lomb Tessar in conjunction with a plane diffraction grating was substituted, as shown in Figure 1. The grating was a 7500 lines per inch Wood's replica which had the useful property of strongly favoring one of the first order spectra. A length of approximately two inches of the grating was used. The objective lens was used at unit magnification, and imaged the favored first order of the dispersed beam at the rotating mirror. For a given setting of the optical system, approximately 750 angstroms of the spectrum can be observed. Thus, the visible spectrum can be covered in about four separate steps.

OBSERVATIONS ON EXPLODING TUNGSTEN WIRES

The framing camera spectrograph has been used to observe exploding tungsten wires.⁽³⁾ The circuit shown in Figure 2 was used to explode 13.5 millimeter lengths of 0.002 inch diameter tungsten wire. As indicated in Figure 2, a 5.0 microfarad condenser was used, and was charged to 9.5 kilovolts. The discharge was triggered with a 5022 hydrogen Thyatron in order to synchronize the event with the camera.

A normal framing camera record of an exploding tungsten wire is shown in Figure 3. For this record, the light from the camera was attenuated by a neutral density filter with an attenuation factor of 100. Two concentric, expanding regions of luminosity are observed, and are separated by a narrow, intensely bright band. The boundary of the outer region initially expands at a rate of 2.3 millimeters per microsecond. This expansion velocity decreases to 0.85 millimeters per microsecond in 3.0 microseconds. The luminosity in this region disappears in approximately 8.0 microseconds on both framing and streak camera records. The current pulse through the exploding wire has also been measured to have a half period of 8.0 microseconds. The inner region, bounded by the bright band of luminosity, expands at an initial rate of 0.77 millimeter per microsecond, and the luminosity in this region persists after the light from the outer luminous region has disappeared. The outer region of luminosity is preceded by a non-luminous or faintly luminous shock which was not of sufficient intensity to be seen in the framing camera spectrogram. This shock also does not show on the framing camera record in Figure 3, but

could be observed on streak camera records. A streak record showing the shock (indicated by arrows) appears in Figure 4.

For spectrographic studies with the framing camera, the wire was placed perpendicular to the spectrograph slit. A slit width of 0.005 inch was used. A high pressure mercury arc served to provide the reference spectrum. A framing camera spectrogram of exploding tungsten wire appears in Figure 5, and frames 4 and 10 of this spectrogram also appears in Figure 6. Frame 4 is characteristic of the early spectra. The intensely bright boundary between the two luminous regions observed in Figure 3 is shown to emit a strong continuum. The inner region appears to have a weak continuous background with a few broadened lines superimposed. The spectral lines in Frame 4 which can be associated with the inner region are:

W 4302] ----- broadened, unresolved
W 4294] ----- broadened, unresolved
W 4269.8] ----- broadened, unresolved
W 4269.4] ----- broadened, unresolved
W 4008.8
Ca (?) 3953

The outer region seen in frame 4 also shows broad lines. The measured wavelengths of these lines correspond to those of nitrogen and oxygen in the spark spectrum of air. The lines are so broad and poorly defined, that the weaker ones which populate this spectral region may be responsible for what appears to be a weak continuum. The nitrogen and oxygen lines located in the spectral region from 3900 to 4700 angstroms, shown in Figure 6a, are listed in Table 1 along with those found in the region from 5000 to 5950 angstroms. There was no evidence of molecular spectra due to either N_2 or O_2 .

Table 1. Identified Spectral Lines of Nitrogen and Oxygen

Brackets denote wavelengths which are unresolved		
N 3919.1	O 4317.1]	N 5001.4]
N 3955.9	O 4319.6]	N 5005.2]
N 3995.0	O 4414.9]	N 5045.1
N 4035.0]	O 4418.0]	N 5175.9
N 4043.5]	N 4447.0	N 5495.7
O 4069.9]	N 4601.5]	N 5535.2
O 4072.2]	N 4607.1]	N 5666.6
O 4075.9]	N 4613.8]	N 5679.5
O 4119.3	N 4621.4]	N 5710.7
N 4176.2	N 4630.5]	N 5931.8
N 4236.9	N 4643.1]	N 5941.9

In frame 10 (See Figure 6b), the lines of nitrogen and oxygen have disappeared, leaving only the luminosity which had been associated with the inner region. This appears to consist of lines superimposed on a weak continuum. Tungsten lines are identified throughout this spectrum, and most of them are labeled in Figure 6b. Most of these lines appear somewhat broadened and poorly defined. In many cases, the identified lines are due to two or more unresolved wavelengths in the tungsten spectrum. Table 2 lists the lines which were identified.

Table 2. Lines identified in the spectrum shown in Figure 6b.

Brackets denote wavelengths which are unresolved.

W 4460.5	W 4241.4	W 4008.8
W 4306.9	W 4240.1	W 3980.6
W 4302.1	W 4204.4	W 3965.1
W 4294.6	W 4203.8	W 3964.9
W 4294.1	W 4168.7	W 3953.2
W 4269.8	W 4137.5	W 3952.9
W 4269.4	W 4136.4	W 3952.5
W 4268.1		W 3952.3
W 4266.5	W 4102.7 (?)	W 3951.9
W 4263.3	W 4074.4	Ca(?) 3933

DISCUSSION

Time-resolving power is defined as the smallest time-difference that can be measured. For the framing camera which has been described, the smallest measurable time-difference is the time between mid-point of successive exposures. However, there is some uncertainty about the time at which an event occurs, since each framing camera exposure is an integrated picture of what occurs during a time interval of approximately 0.2 microsecond. Space-time resolved spectrograms, therefore, do not provide continuous time coverage or the degree of time resolution that can be obtained with streak-type cameras. However, the added feature of space resolution in many cases makes it possible to obtain much additional information from a single record, and also brings out features which might not be evident in spectrograms with time resolution alone. The observations on a special case of an exploding wire indicate the information that may be obtained from a single space-time resolved spectrogram. For spectrographic studies, streak and framing cameras would be utilized best when information from one supplements that obtained with the other.

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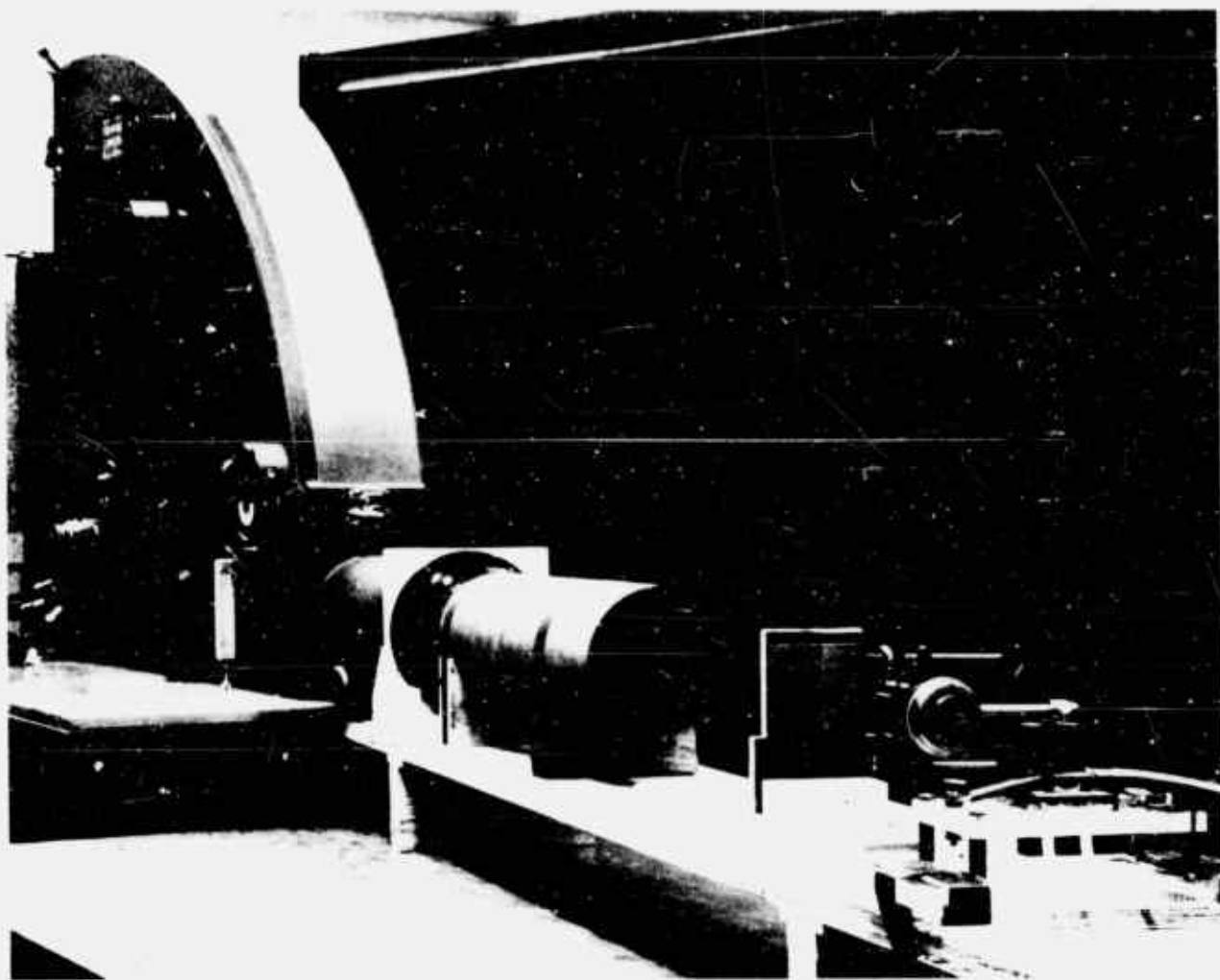


Figure 1. Framing Camera Spectrograph





The above streak record has been retouched
to clearly show the faintly luminous shock.

Figure 4. Streak Camera Record of Exploding
Tungsten Wire. Time is directed from
left to right, and the shock is
indicated by arrows.

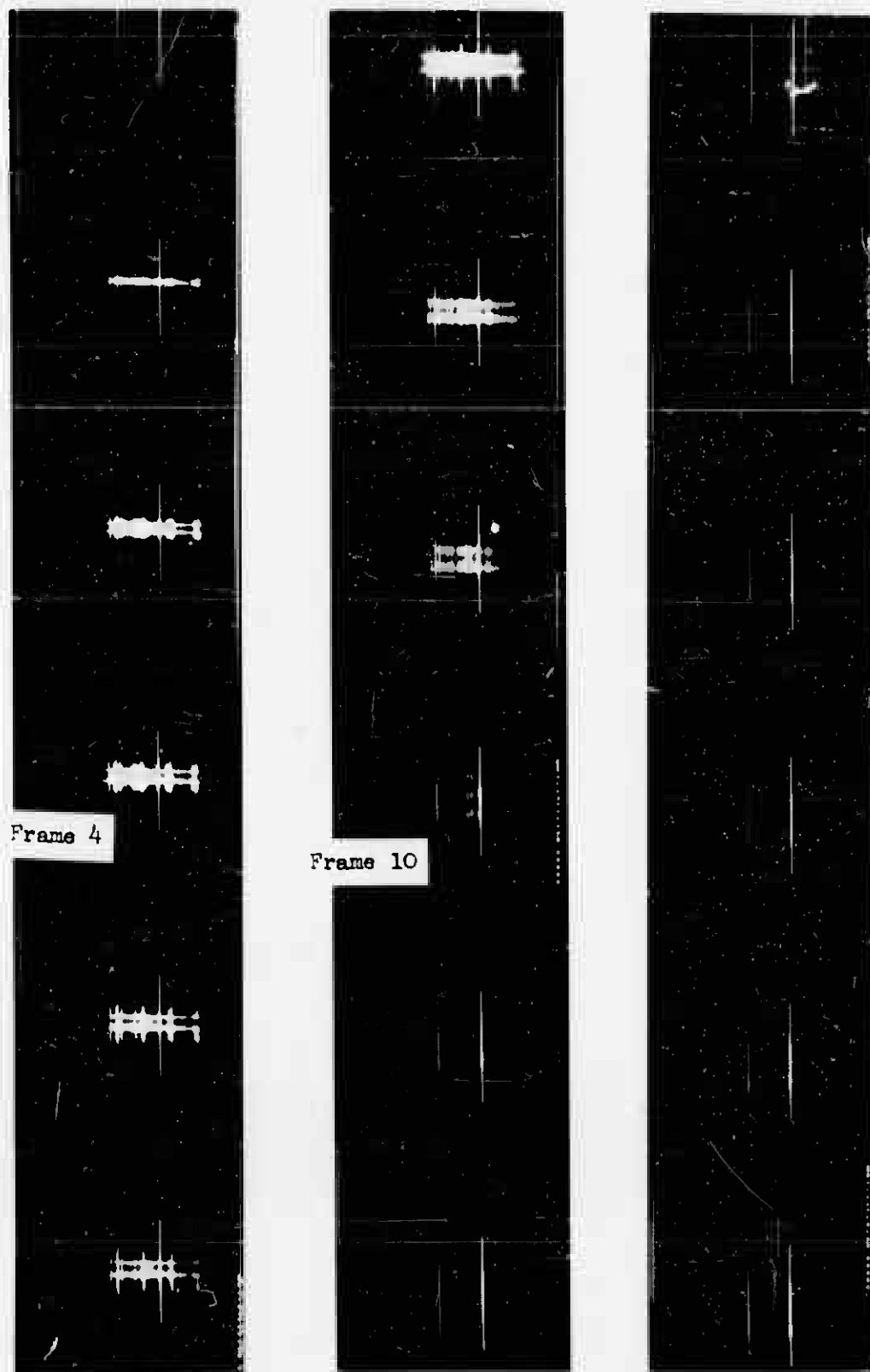


Figure 5. Framing Camera Spectrogram of
Exploding Tungsten Wire

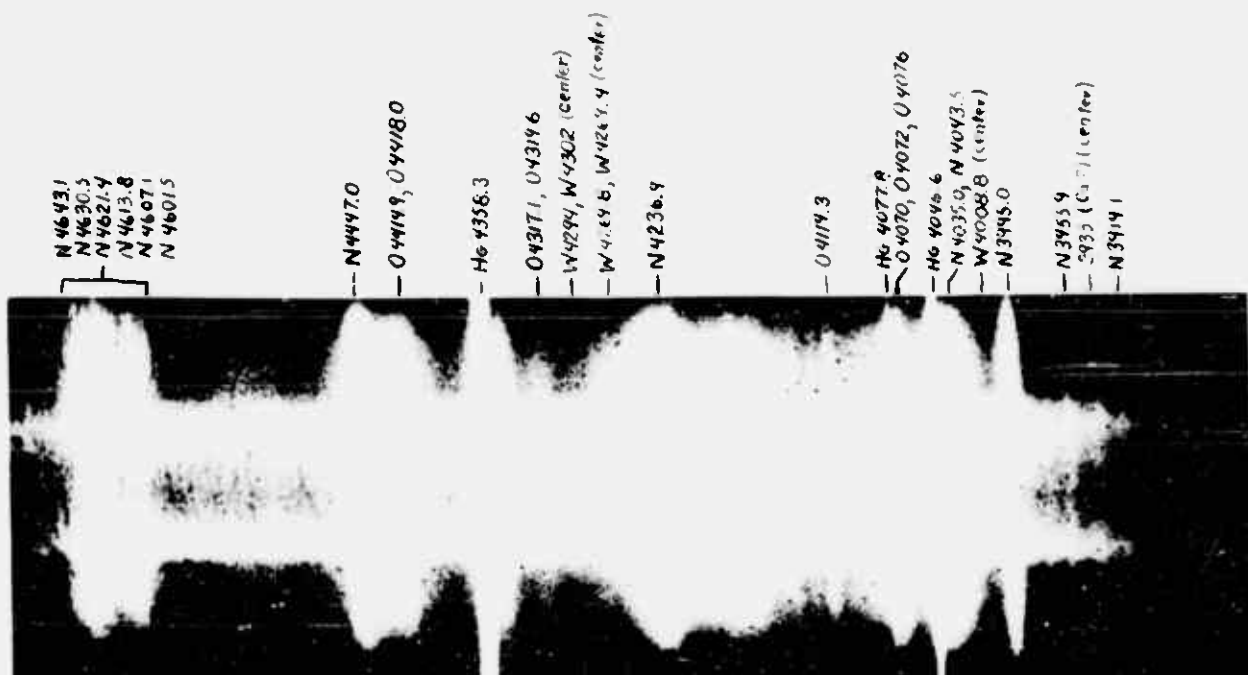


Figure 6a. Frame 4 of Figure 5.

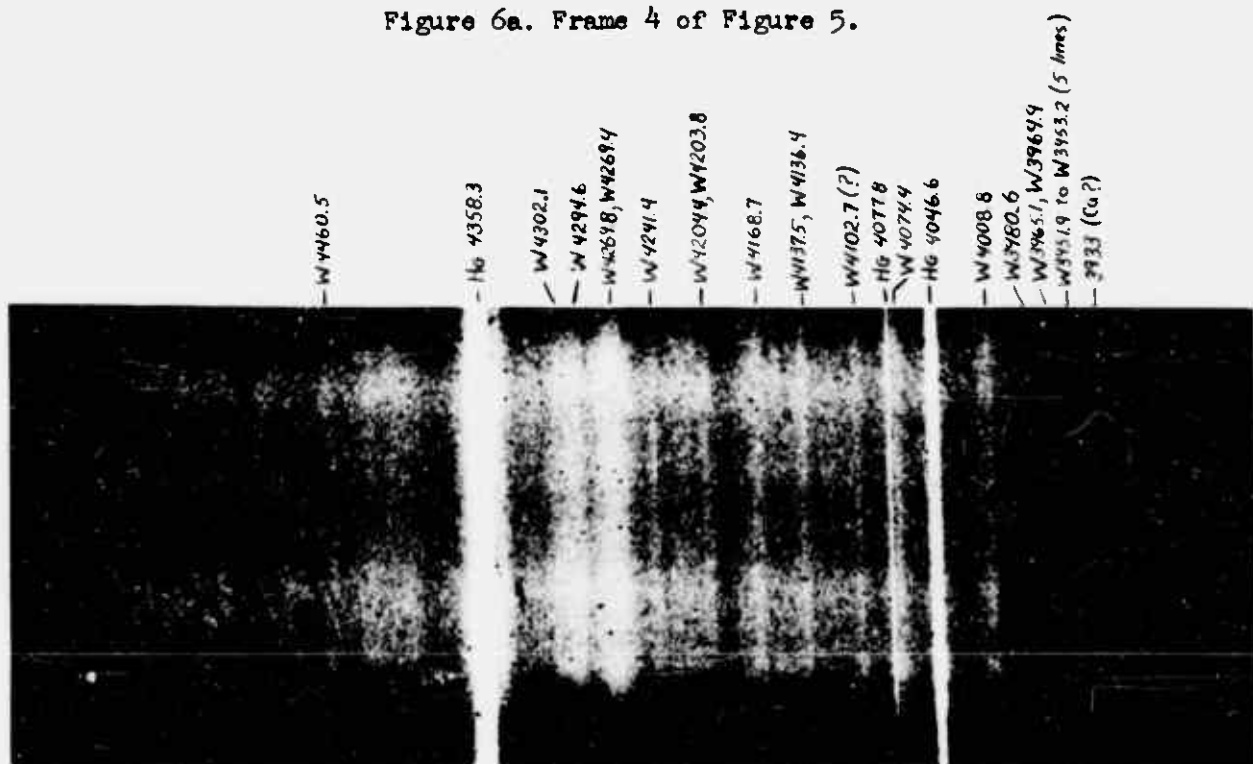


Figure 6b. Frame 10 of Figure 5.

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