High-Speed Photography Using Ultraviolet Radiation to Eliminate Visible Light Masking in Self-Illuminating Events

PAPER E—9

By R. WAYNE ANDERSON

In most high-speed, self-illuminated events such as arc welding, Plasmatron studies and combustion of solid fuels, the intensity of the illumination masks many of the important details that occur during the event. To eliminate this undesirable overexposure, a method has been devised to filter out light in the visible spectrum and make higher-speed photographs using only the near ultraviolet light produced in events of this nature. In cases where insufficient ultraviolet light is produced by the event, there are other methods of producing enough ultraviolet to make higher-speed exposures. These techniques have also been used to penetrate flame barriers and to produce sufficient contrast between incandescent materials in high-temperature furnaces.

IN PHOTOGRAPHING self-illumined events such as arc welding, plasmajets, solid and liquid fuel burners and explosives, the very intensity of the flames produced masks most of the important details which occur inside the flame barrier of the event.

A number of techniques have been employed to minimize these masking effects with varying degrees of success. One such method is to underexpose at the expense of many important details where higher illumination levels are necessary. Another method is to use lights which produce a higher intensity of illumination than that produced by the event. This method entails the use of expensive and complicated arc or gas discharge tubes, spark sources, or in cases where an explosion can be tolerated, an argon flashbomb.

In several studies of self-illuminated events which have been carried on at The Dow Chemical Company, a simple, inexpensive method of eliminating these masking effects has made it possible to record details inside the flame barrier, which would normally be obscured by the flame. This method utilizes only the near ultraviolet radiation produced by the event to make the exposure.

Presented on October 17, 1960, at the Fifth International Congress on High-Speed Photography in Washington, D.C., by R. Wayne Anderson, Photo Laboratory, The Dow Chemical Co., Midland, Mich.

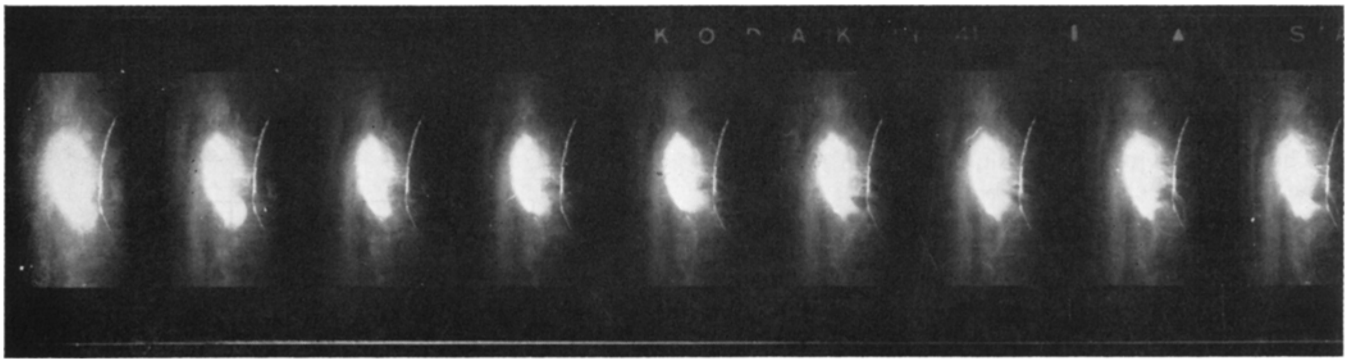

Fig. 1. Arc-welding magnesium. Eastman high-speed camera at 3000 frames/sec stopped down to *f*/22. Tri-X Negative film used with normal development. Better exposures would probably have been achieved with slower film or neutral density filters.

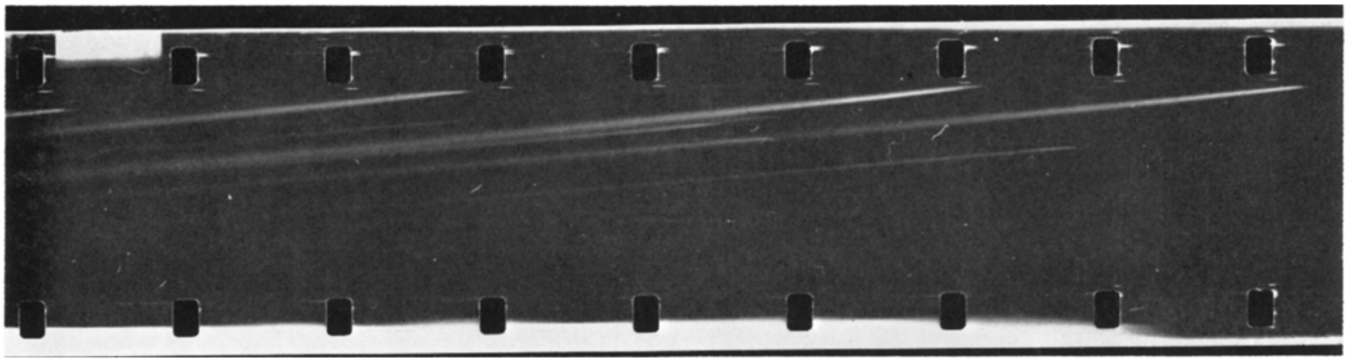

Fig. 2. Burning metal particle. Prism removed from Kodak high-speed camera to operate as a streak camera. Tri-X negative, writing speed, 75 ft/sec, used in this case to eliminate after-glow and measure the true burning time of particles.

It has long been recognized that many self-illuminating events such as these produce high-level ultraviolet radiation strong enough to necessitate protective devices to shield personnel in the immediate vicinity, for example, face shield, goggles and protective clothing worn by arc welders to prevent serious burns to skin and eyes. But I have been unable to find any reports of attempts to utilize this ultraviolet source to make photographic exposures.

Experimental high-speed pictures, using only the radiation produced by the events to make the exposure, have been successfully recorded using a Corning #7–54 ultraviolet transmitting filter which transmits only the wavelengths of light between 2200 and 4000 A. This filter effectively rejects all visible light, which would normally be used in making the exposures.

Most photographic emulsions are sensitive in the near ultraviolet region. High-speed pictures have been taken at 3000 frames/sec, with the lens stopped to *f*/22, and using Tri-X negative film when shooting high-speed movies of arc welding and Plasmatron studies. In an experimental test using explosives, adequate exposures were obtained at *f*/8 when shooting at 3000 frames/sec with both C-3 and T.N.T. In these tests the ultraviolet light produced lasted for about 2 msec.

In most cases only one or two rolls have been made of each of the types of self-illuminating events mentioned earlier. However, the results tend to establish this technique as a good method to record details which would normally be obscured by the flame barrier. It is certain that anyone who is regularly working with self-illuminated events could use this method to his advantage as a simple, inexpensive way to record many details which are ordinarily lost.

Figures 1–7 show comparative results when using self-produced ultraviolet radiation and the visible illumination to photograph the same event.

In the film from which Fig. 1 was taken it was possible to note the break-up of the welding rod and the flow of molten metal in the arc as the weld is formed. In another, a burning strand of solid fuel was photographed in slow motion at 64 frames/sec and many of the details, such as melting of the binding agent and the disintegration of the fuel, could be observed. A vacuum or blower system is a great help in this type of study to keep smoke out of the picture area. The small particles of ash and un-

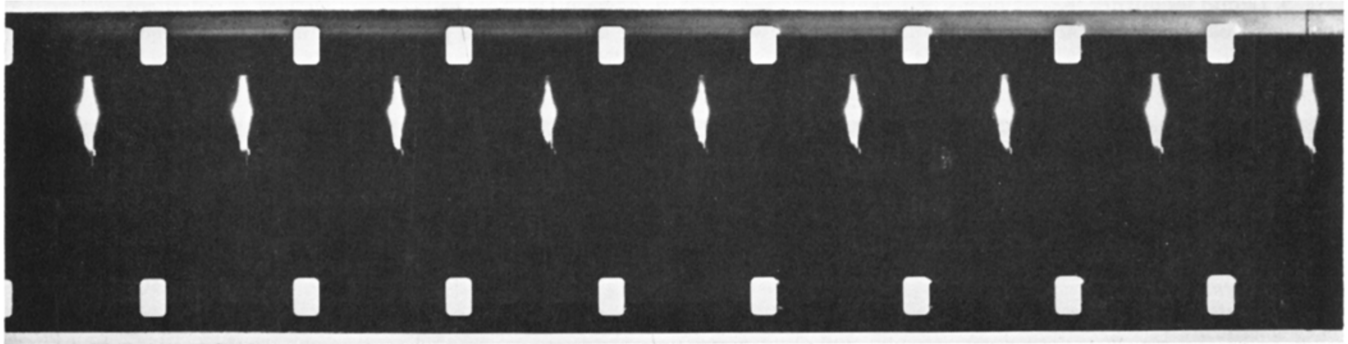

Fig. 3. Plasmatron. Kodak high speed, 3000 frames/sec, *f*/22, Tri-X negative film.

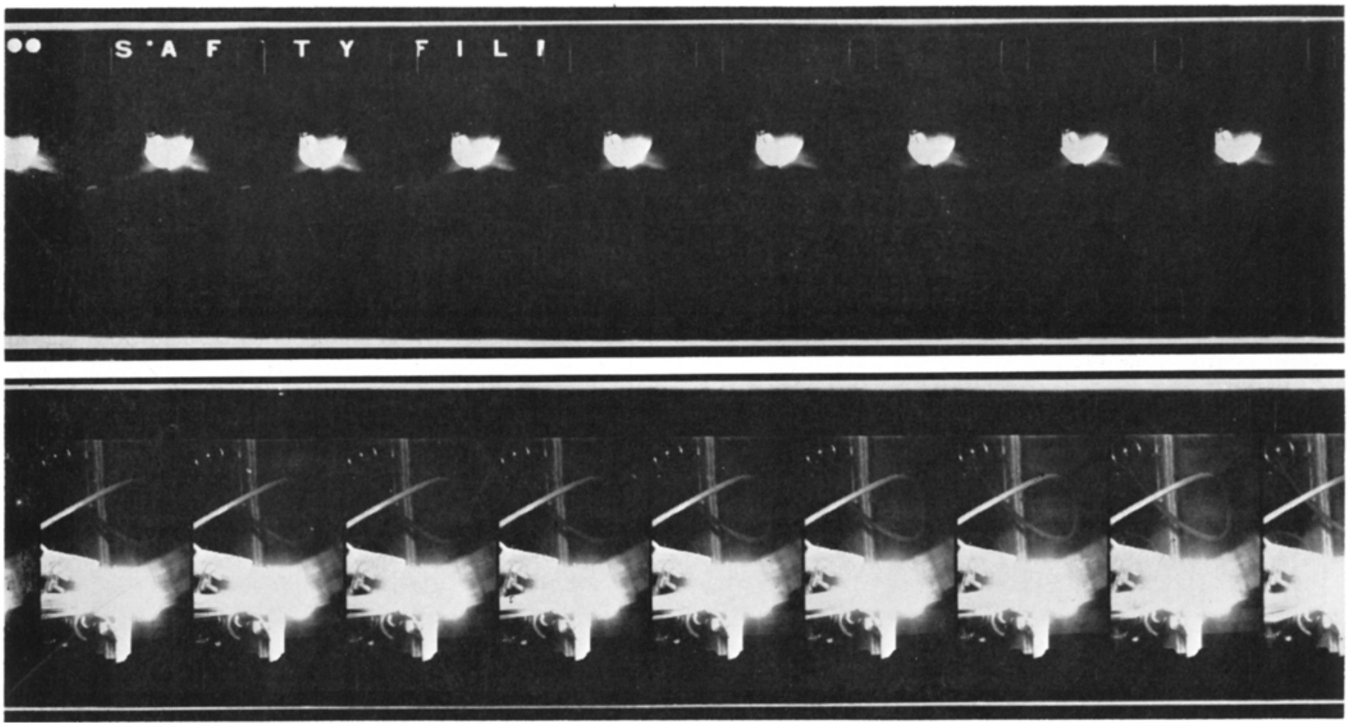

Fig. 4. Solid fuel. Cine special Tri-X (negative), 64 frames/sec at *f*/22, 1 R.S.P. Spot used as auxiliary spot in visible light in lower photograph. The upper strip was photographed in ultraviolet light; the lower, in visible light.

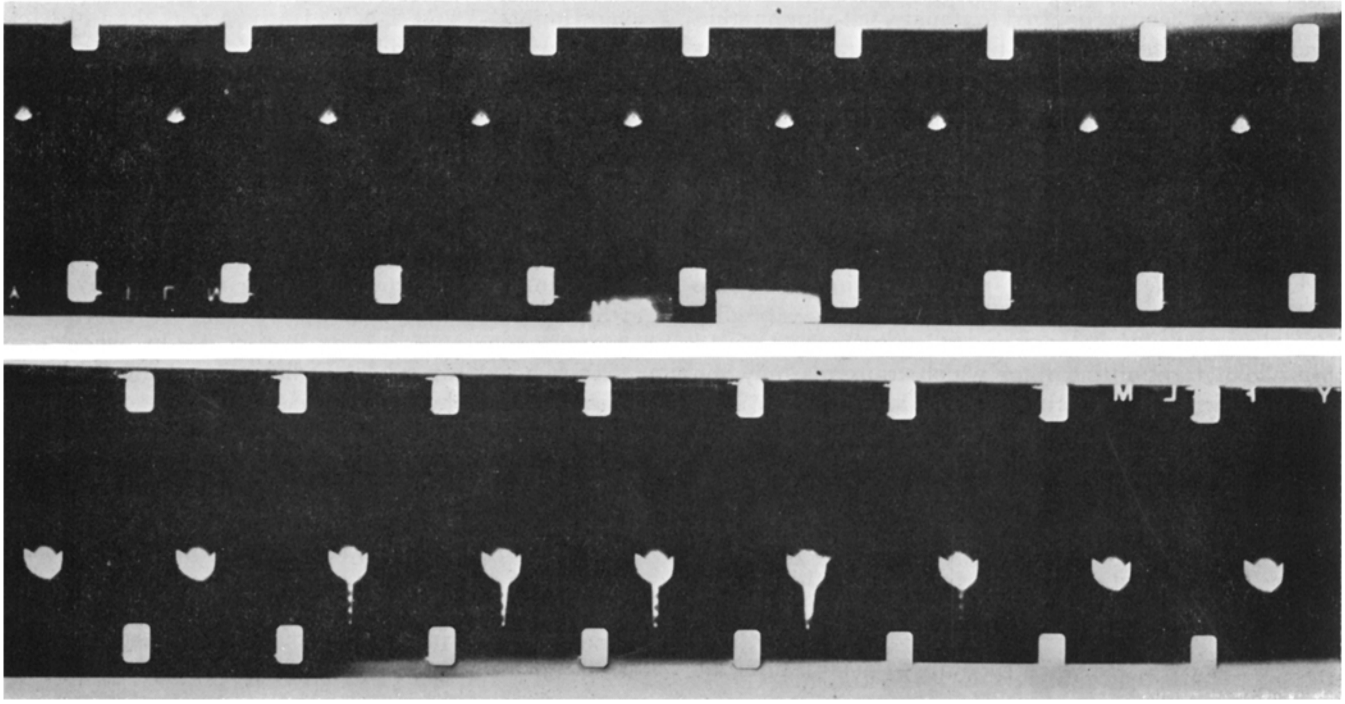

Fig. 5. Liquid jet burner. Kodak high-speed 3000 frames/sec, Tri-X negative at *f*/8. Note better definition, lack of reflections and masking in target area of the upper picture when the ultraviolet filter was used. The upper strip was photographed in ultraviolet light; the lower, in visible light.

burned materials, which we call smoke, reflect ultraviolet light and may obscure details which would otherwise be visible.

In a high-speed study of a ceramic target being subjected to a high-temperature jet burner, it seemed that the ultraviolet was produced at the target. This may not be true as the jet was not burning steadily but pulsing due to oscillation in an excessively long fuel line. The pulsing could be seen in the target area as the spot heated and cooled.

The use of ultraviolet transmitting filters in the photography of self-illuminating events is not suggested as a cure-all for the many problems encountered when photographing events of this nature.

A great deal more work will have to be done before the full value of this technique can be evaluated. Exposure parameters must be defined in the widely varying levels of ultraviolet radiation produced by dissimilar self-illuminating events. There are probably a number of ultraviolet transmitting filters which would do as well, if not better, than Corning 7-54 which has been used in these tests. Perhaps filters with a narrower transmission band, or with a sharper cutoff in the near ultraviolet, would give better results. An interesting experiment might be to use three cameras: one using ultraviolet light, one using visible light, and one using infrared film to cover all phases of an event of this nature.

In cases where insufficient ultraviolet light is available, supplementary ultraviolet light could be produced by an argon flashbomb. In places where such an explosion cannot be tolerated, spark sources, exploding wires, mercury or hydrogen arc lamps, or gas discharge tubes might be used.

Gas discharge tubes produce a great deal of ultraviolet light and have been successfully used at Dow to penetrate flame barriers in gas furnaces. I have also used them when taking pictures in electric furnaces at temperatures up to 2000 C where separation of materials in the furnace is impossible due to their incandescence. Ultraviolet light photographs under these conditions can cause materials to appear much as they would if they had been cold. Sufficient contrast can be obtained to separate materials in the furnace from the background if care is taken to see that the background and the material to be photographed do not have the same reflective or absorptive characteristics in the ultraviolet region of the spectrum. A test exposure will readily determine whether a different background material is in order.

More ultraviolet light could probably be produced from flashtubes by changing the configuration of the gas discharge tube; perhaps the use of argon or hydrogen could be tried. Or, a high voltage discharge through a mercury vapor lamp might be worth studying.

There are many other uses for high-speed ultraviolet light. It is hoped that some of you will be able to use the techniques described in this paper in your fields of endeavor.

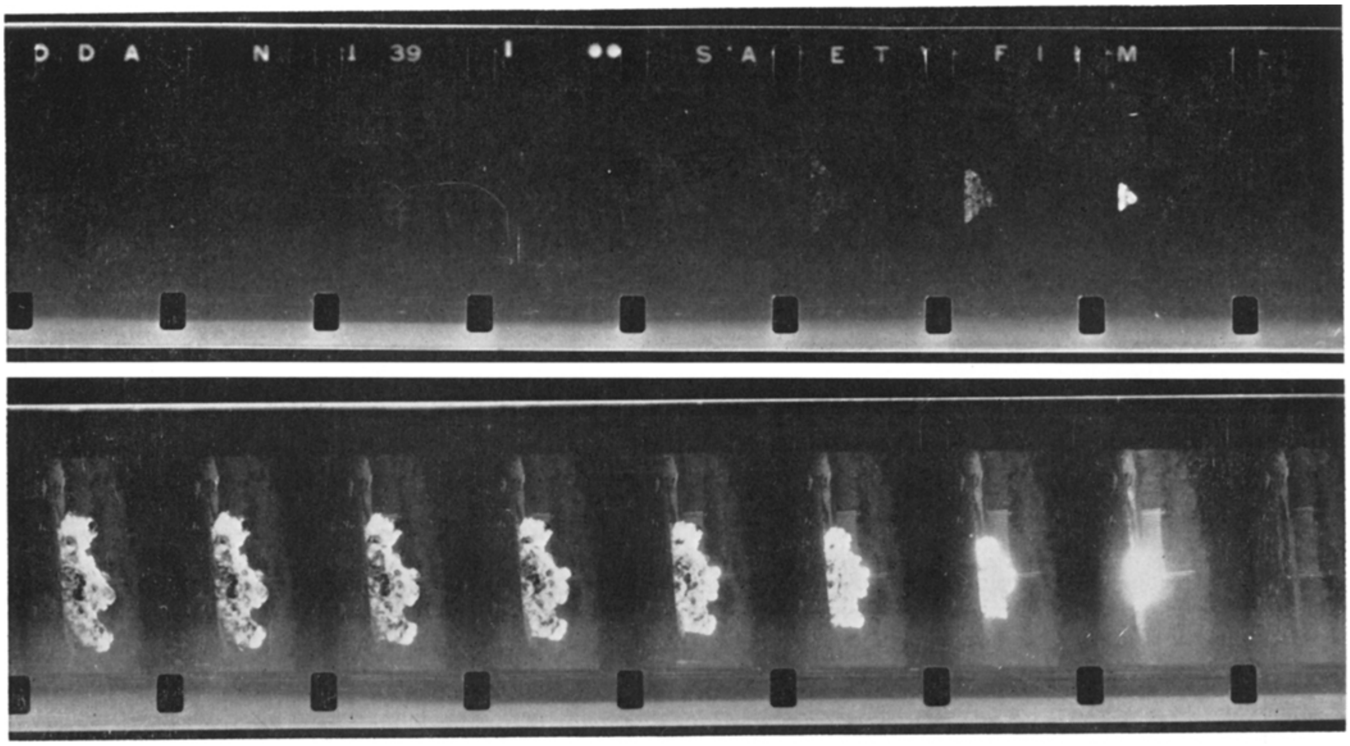

Fig. 6. Five-pound surface shot of T.N.T. 3000 frames/sec at *f*/5.6 using Tri-X negative film. Pulse of ultraviolet light gave usable exposures for 2 to 3 msec in the upper picture. The upper strip was photographed in ultraviolet light; the lower, in visible light.

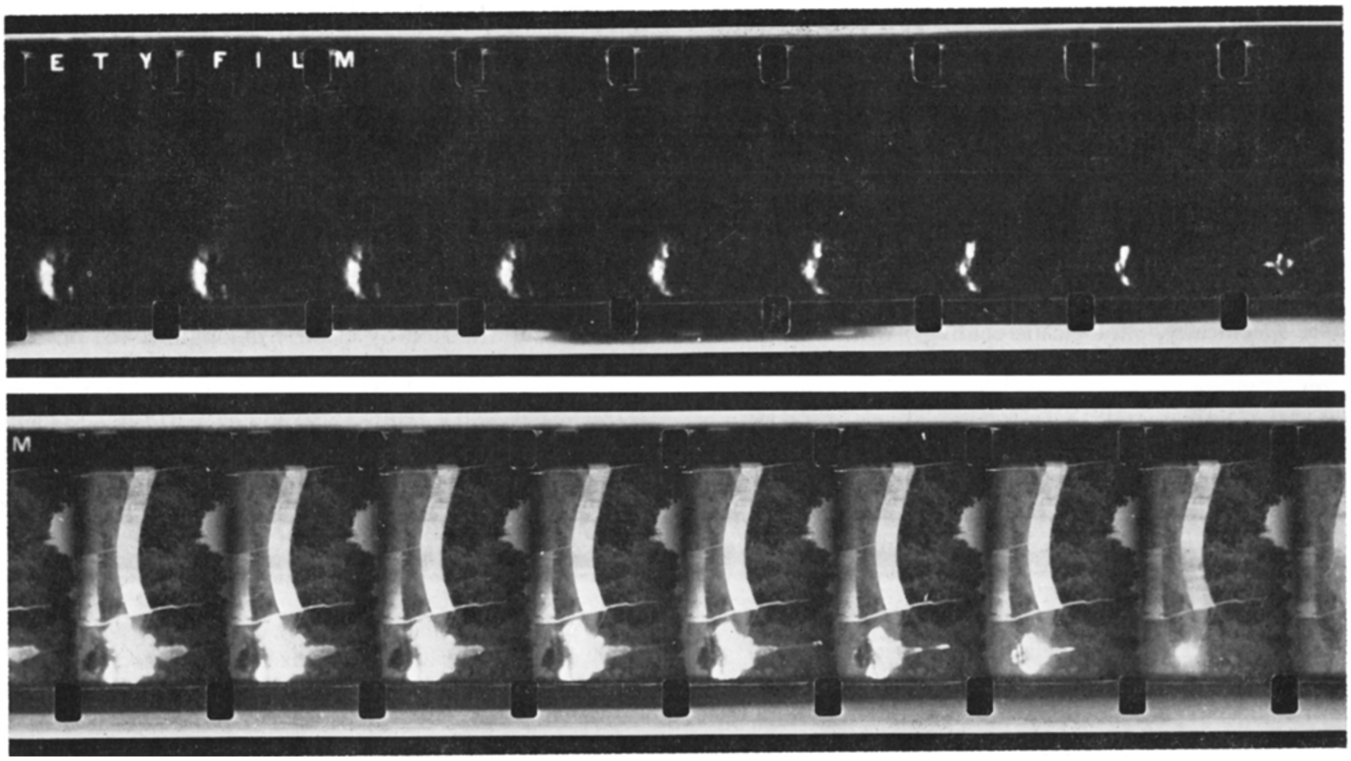

Fig. 7. Exposure was the same as that for Fig. 6. In this test, a slow-burning explosive initiated by a shaped charge was photographed. The usable life of the ultraviolet pulse was found to be much longer than when fast-burning explosives such as T.N.T. or C-3 were being tested. The upper strip was photographed in ultraviolet light; the lower, in visible light.