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HIGH-EXPLOSIVE ARGON FLASH LIGHT SOURCE

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ABSTRACT

An HE argon extremely high-intensity flash system has been developed for use in test vehicles released from high altitudes. This flash system allows the use of nontracking-type plate cameras during daylight operations.

Case No. 613.71

HIGH-EXPLOSIVE ARGON FLASH LIGHT SOURCE

INTRODUCTION

The primary optical instrumentation for the Sandia Corporation test program for impact information conducted at Nevada Test Site consists of fixed-plate cameras and electronic flash light sources in the test vehicle. To insure recording of impact on these fixed-plate cameras, the capping shutters must be opened several seconds before impact which has necessitated night operations to prevent extreme background density on the plates.

Recently, however, daylight operations appear to be feasible with the use of an HE argon flash to replace electronic light sources.* Previous work at Sandia Corporation indicated that if HE argon flashes would register on 649-GH film (a slow film), this system would have the following advantages:

1. HE argon flash duration is extremely short (10-20 μsec depending on tube length).
2. HE argon flash would afford very little time delay (2×10^{-6} sec).
3. Kodak 649-GH emulsion has the highest resolution of any film (1500 lines per mm), and it is a high contrast film. Both of these qualities tend to increase the accuracy of measurements.
4. The HE argon unit is small, 7 inches long, 3 inches in diameter, making it easy to handle.

HE ARGON OPERATIONAL UNIT

A cross section of the complete flash unit is shown in Fig. 1. The chief consideration in the design was to make the unit vacuum-tight. This normally very simple problem was complicated by the fact that a regular sealed glass tube could not be used because the explosive has to be inside with the argon gas,† and this would mean sealing a small glass tube with the explosive only inches away from the sealing flame.

For safety reasons and hookup procedures the detonator is kept outside the sealed portion of the unit. Thus the detonator is plugged in just before the flash unit is installed in the test vehicle. The beryllium-copper sealing diaphragm between the main explosive charge and the detonator does not adversely affect the speed or power of the explosion.

ENVIRONMENTAL TESTS

Four flash units were given environmental tests which closely simulated high-altitude flight in an aircraft. These tests covered temperature, leakage (vacuum) and vibration. All four units passed these environmental tests satisfactorily. See Appendix D for further details.

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* Attempts at filtering and the use of a slow film all failed to prevent background daylight from obscuring the electronic flashes.

† To prevent attenuating the shock wave (and, thereby, the light) by having it pass through glass.

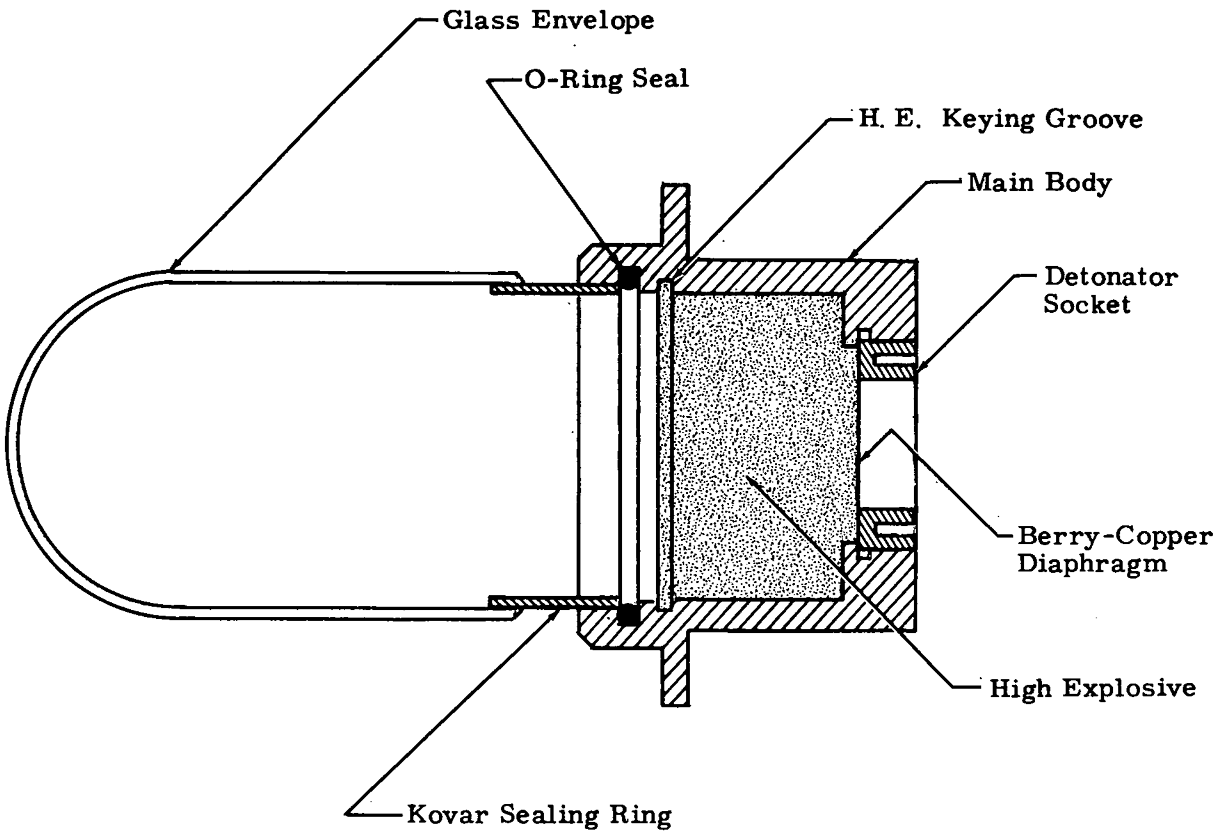

Fig. 1a - HE Argon Flash Unit

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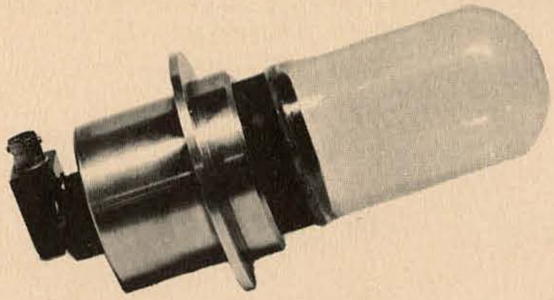

Fig. 1b - Assembled HE Argon Unit

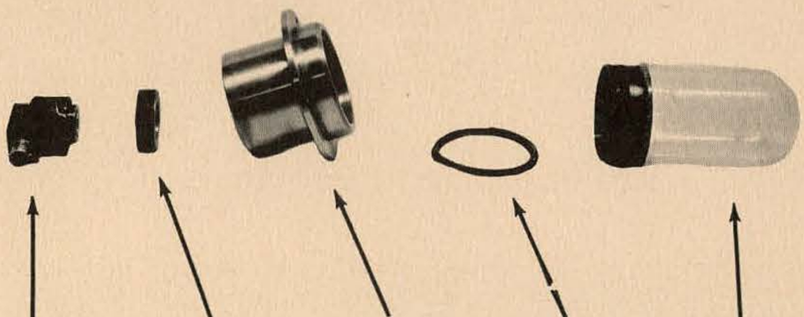

Fig. 1c - Exploded View of HE Argon Unit

FILLING AND INSTALLATION

The argon gas was placed in the flash unit by making the assembly between the glass envelope and the brass shell in an argon atmosphere. Figure 2 shows the type of box used to contain the argon atmosphere.

Installation in a test vehicle requires a hole at least five inches in diameter to clear the detonator and cabling. The flash assembly is fastened to a mounting fixture by three screws and is installed in the test vehicle after its placement in the aircraft.

FIRST OPERATIONAL TEST

All ten HE argon assemblies were installed in the test vehicle, and the operation was conducted December 17, 1955, at Yucca Lake. Four in the forward net at Station 70.0, four in the middle net at Station 257.0, and two in the after net at Station 281.0.

It was orginally planned to have the glass envelope of the assemblies protrude two inches from the skin to provide a larger angle of coverage. This would place an aerodynamic drag on the glass envelopes computed as follows:

$$\text{Drag} = C_{D_o} \, qS$$

where C_{D_o} = drag coefficient, $q = 1/2 \ V^2$, and S = cross-section area.

$$(\text{at sea level} \quad = .002378 \text{ slugs/ft}^3)$$

From a curve of C_{D_o} vs Mach number:

$$\text{at Mach } 1.5, \ C_{D_o} = 1.40,$$

$$\text{at Mach } 1.0, \ C_{D_o} = 2.15.$$

It was estimated that this test vehicle would reach a velocity of Mach 1.5. These conditions give a q of 3.47×10^3 slug ft/sec^2. Thus, drag = 135 lbs.

Even by supporting the glass envelope with a rubber ring, it was felt that the envelope would not hold up under such a drag force. Therefore, it was decided to place the flash units flush with the skin with no plexiglass windows. The 3-1/4-inch diameter hole in the skin gave only a 30° field of view which showed the entire bulb; by increasing the hole size to 5 inches, the field increases to 60° which will normally put the light on at least at two stations.

The test vehicle fell far short behind Station 2. Range Plot showed impact to be 7750 feet from Station 1 and 7550 feet from Station 3. The stadia rod lights were easily found on Plates 1A and 3D. Careful examination showed net flashes on Plate 1A but none on 3D. The flash images were extremely weak on Plate 1A but marginally useful. Plot showed that the flash unit was looking directly at Station 1, but had an angle of 34° with Station 3. This cut out approximately 1/3 of the light which probably accounts for the argon flash not appearing on Plate 3D.

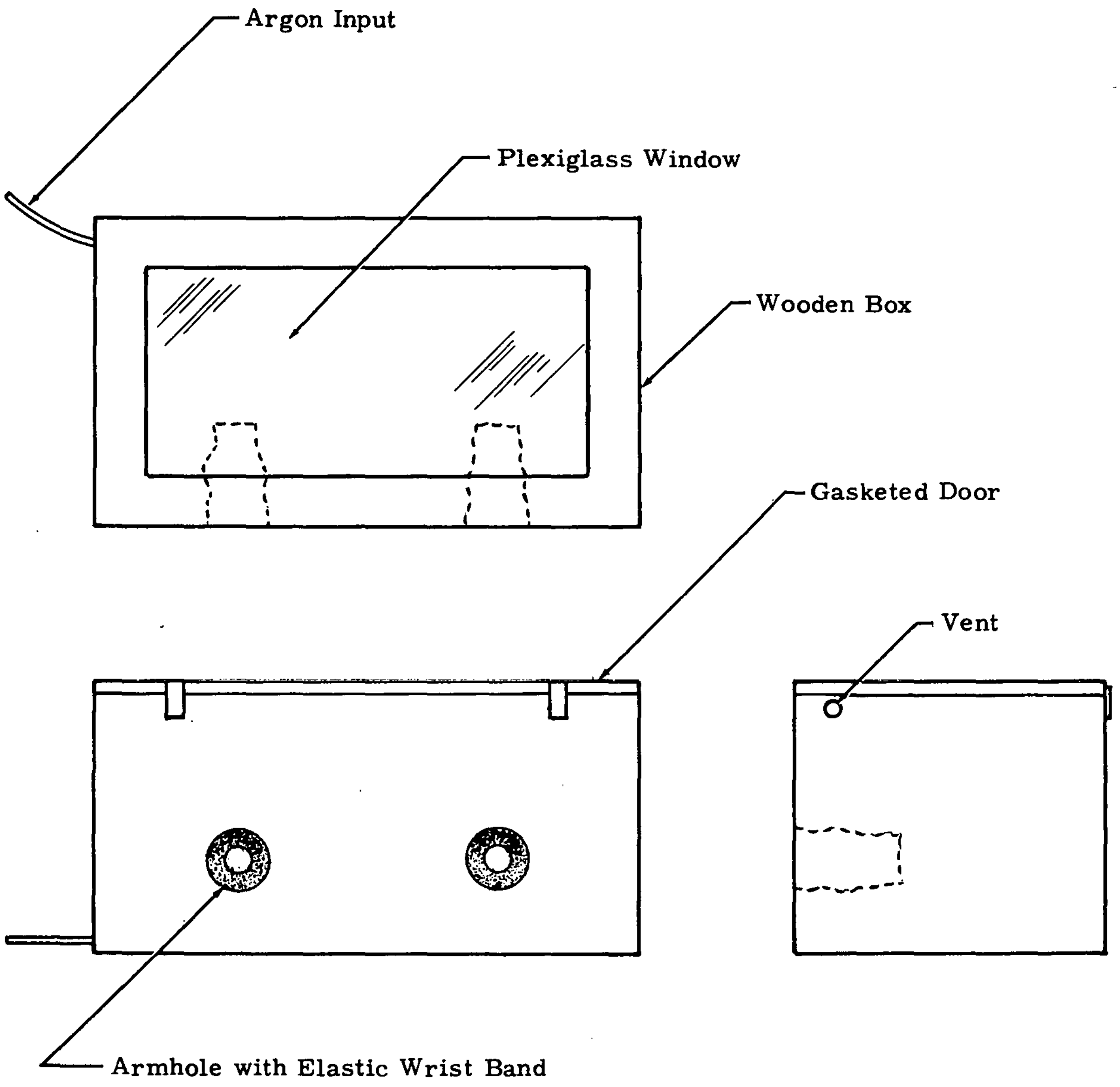

Fig. 2 - Loading Box

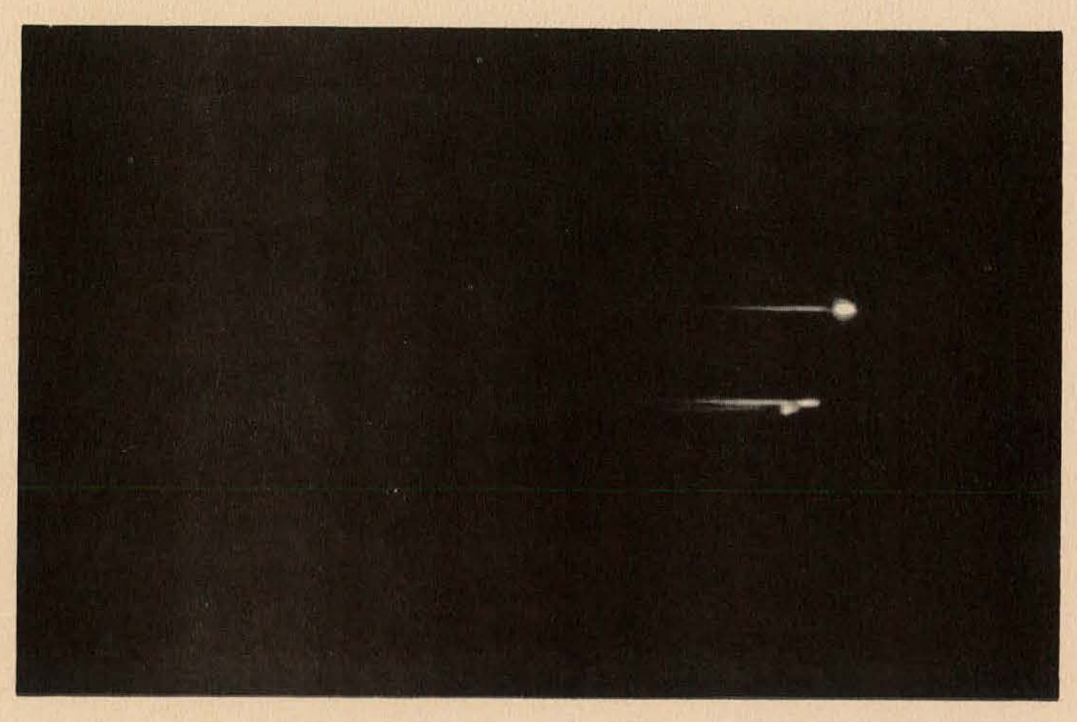

Fig. 3 - Operation 17-46 Fastax Ribbon Camera
40-Inch Focal Length 1000 in/sec.

Measurements taken on the argon flashes by the 10 x 12 comparator and calculations showed that the position and angle of the flash nets agreed closely with data obtained from other systems.

The Fastax ribbon film clearly showed that flashes in all three nets operated. The sequence and time difference were easily measured. Figure 3 is a reproduction of this record. Note the break in the light streak, caused by a blanking out of the light as the shock wave went through the end of the glass tube. Thus, there was strong evidence that the glass envelopes had survived the high velocities with the accompanying shock waves.

Operational procedures for shutter opening and stadia rods were as follows: A shutter-opening switch was set up so the operator could stand next to the Askania at A-3. This switch opened all the plate camera shutters, and by means of a timer, fired one side of the refraction stadia rod. The switch was closed approximately 1-1/2 seconds before impact. This called for an angle of elevation of 13° from A-3 which was read from the Askania elevation dial by the switch operator.

Immediately after impact, shutters were closed. The stadia rods were set up at the crater and fired by hand, using radio communication between the shutter-switch operator and the stadia-rod operators. The total time of exposure on the plates was approximately 3-1/2 seconds, which at 11 gave very little background density.

The stadia lights were Press 25 flashbulbs with two networks on each stadia rod, 12 bulbs in series in each net fired by a 28-v Nicad battery.

SAFETY AND HANDLING

The construction, use, and handling procedures for HE argon flash were reviewed with Mr. H. B. Lambert, 3171. Mr. J. A. Maxim, 5261, worked out the electrical hookup to be used in the test vehicle.

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APPENDIX A

FLASH REQUIRED TO WORK AT 1500 FEET

In an attempt to calculate the light output required to show on 649-GH at 1500 feet, experimental results of uniflash and HE argon are used.

The HE argon unit at 5000 feet produced an image approximately equal in density to the image produced by uniflash at 600 feet. Using the uniflash system as a standard, the HE argon flash was measured as producing 54,000 lumen-seconds of light with a peak lightout of 5×10^9 lumens. Assuming that the light required to give a usable flash image is proportional to some power of the distance factor using the data at 600 feet and 5000 feet, an empirical formula can be set up to calculate the light output of a flash required to impress an image of 649-GH at some specified distance.

420 lumen-seconds at 600 feet

54,000 lumen-seconds at 5000 feet

$$\text{Distance factor} = \frac{5000}{600} = 8.33$$

$$\text{Light factor} = \frac{54,000}{420} = 128$$

Thus,

$$8.33^X = 128$$

$$X = 2.29$$

Distance factor is raised to the 2.29 power to determine the light required.

Light required = (distance factor) 2.29 x 420 at 1500 feet

$$\left(\frac{1500}{600}\right) 2.29 \times 420 = 8.15\ (420) = 3420 \text{ lumen-seconds} = 97 \text{ watt-seconds.}$$

Since

$$35 \text{ lumens} \cong 1 \text{ watt} \quad ,$$

this calculation is very approximate and makes several broad assumptions; however, it is felt it gives a close enough idea of light requirements to be useful.

The assumption that time duration is constant would introduce some error, probably on the high side, so cutting this in half still gives 48.5 watt-seconds requiring 25 vf at 2000 v which makes a large package.

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APPENDIX B

ELECTRONIC FLASH THEORY

The light furnished by the tube depends on its loading expressed in watt-seconds and on the tube's efficiency. Loading is given by the expression:

$$\text{Loading in watt-seconds} = \frac{CV^2}{2}$$

where C = capacity in microfarads, and V = voltage across the condensers in kilowatts.

Average flash-tube efficiency = 35 lumen/watt; therefore, approximate total light output in lumen-seconds = 35 (watt-second loading). For the uniflash system, the tube is working out of six microfarads at 2000 v.

$$\text{Loading} = \text{watt-seconds} = \frac{CV^2}{2} = \frac{6(2)^2}{2} = 12 \text{ watt-seconds.}$$

$$\text{Total light output in lumen-seconds} = 35(12) = 420.$$

The duration of the flash is approximately proportional to the discharge capacity and is given by the formula:

$$T = \frac{CR}{10^6} \text{ (very approximate)}$$

where T = time in seconds, C = capacity in microfarads, and R = apparent resistance of flash tube during discharge.

The value of R for the average flash tube is 6 ohms; however, this is not constant, being high at the beginning of the flash and decreasing rapidly.

From the loading and time formulas it is seen that although a low-voltage flash system can be small and still put out a large amount of integrated light, the time duration makes it unusable. For example: A 500-v system would have a theoretical duration of 4.8 milliseconds.

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APPENDIX C

THEORY OF HE ARGON SYSTEM

Muraour has conclusively proved that the intense light generated in the HE argon system is due to the shock wave precipitated by the explosion and not to the process of explosion.* (Recent high-speed schlieren and framing camera studies make this obvious.) The luminosity of a shock wave depends markedly on the gas through which the shock is traveling. Thus, argon gives more light than air, and xerion gives more light than argon. The criterion for light production appears to be the density of electron excitation states in the molecule. Light is emitted when atoms return to the lower electronic energy state after the energy state of the ion has been raised by inelastic collision with another atom or with a high-energy electron. Since the energy difference is of the order of a few tenths of an electron volt, such collisions are rare in cool gases and do not become important until temperatures of 2000-3000°C are reached. The total cross section for excitation is a rapidly increasing function of molecular energy (i.e., heat) for those atoms having closely packed energy states at low energies. For example, oxygen has 79 emission lines between 4000 and 7000 angstrom units, nitrogen has 83, while argon has 249. If the near ultraviolet and violet regions are not included, the comparison becomes even more striking. The gas behind a shock which has a strength less than about 30 will not emit significant amounts of visible light. As the shock becomes stronger, the amount of light given off increases rapidly.

Therefore, any arrangement which will increase shock strength will increase the amount of light. For example, the straight sides of a tube tend to contain the shock, preventing spherical divergence from rapidly reducing the shock strength. By the same token a shaped charge which produces a very high temperature should produce a higher light intensity than an unshaped charge.

A slight contamination of air in argon permits certain "forbidden" transitions which then increase the luminosity of the shock front. Approximately 1 per cent of air in the argon is sufficient to insure that these transitions occur.

Figure 4 shows photographs of several HE argon flashes taken during the development of the units.

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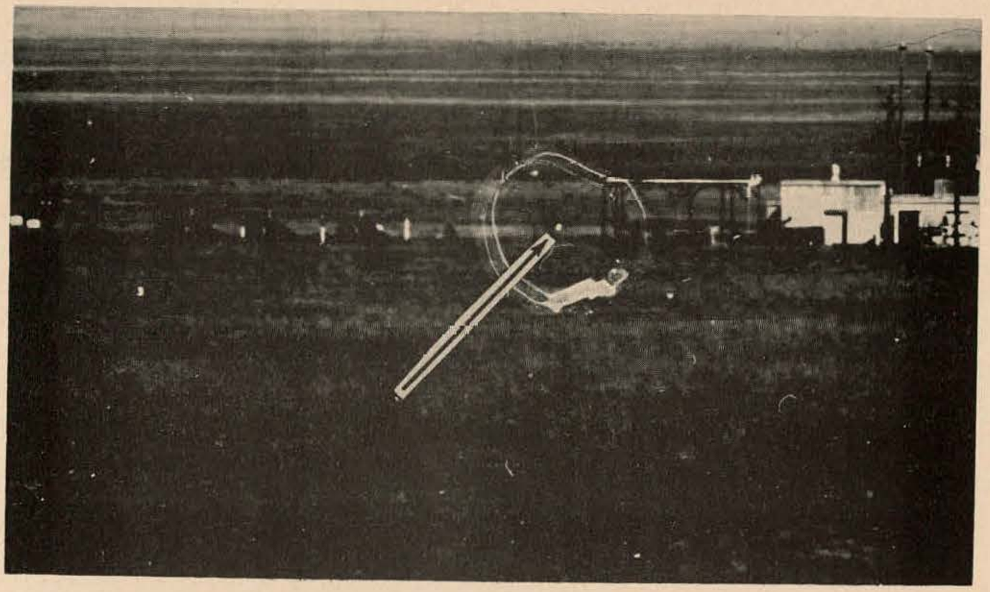
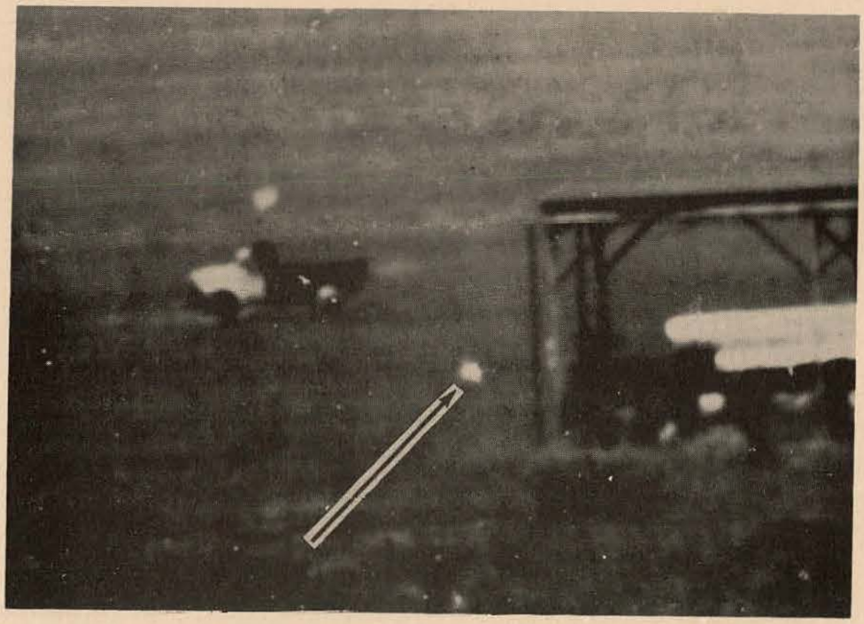
* Muraour, Henri, "Ondes de Choc et Luminosites de Detonation", Chimie & Industrie, Vol. 47, No. 1, pp. 3-15, January 1942. "Shock Waves and Luminosities of Detonation".



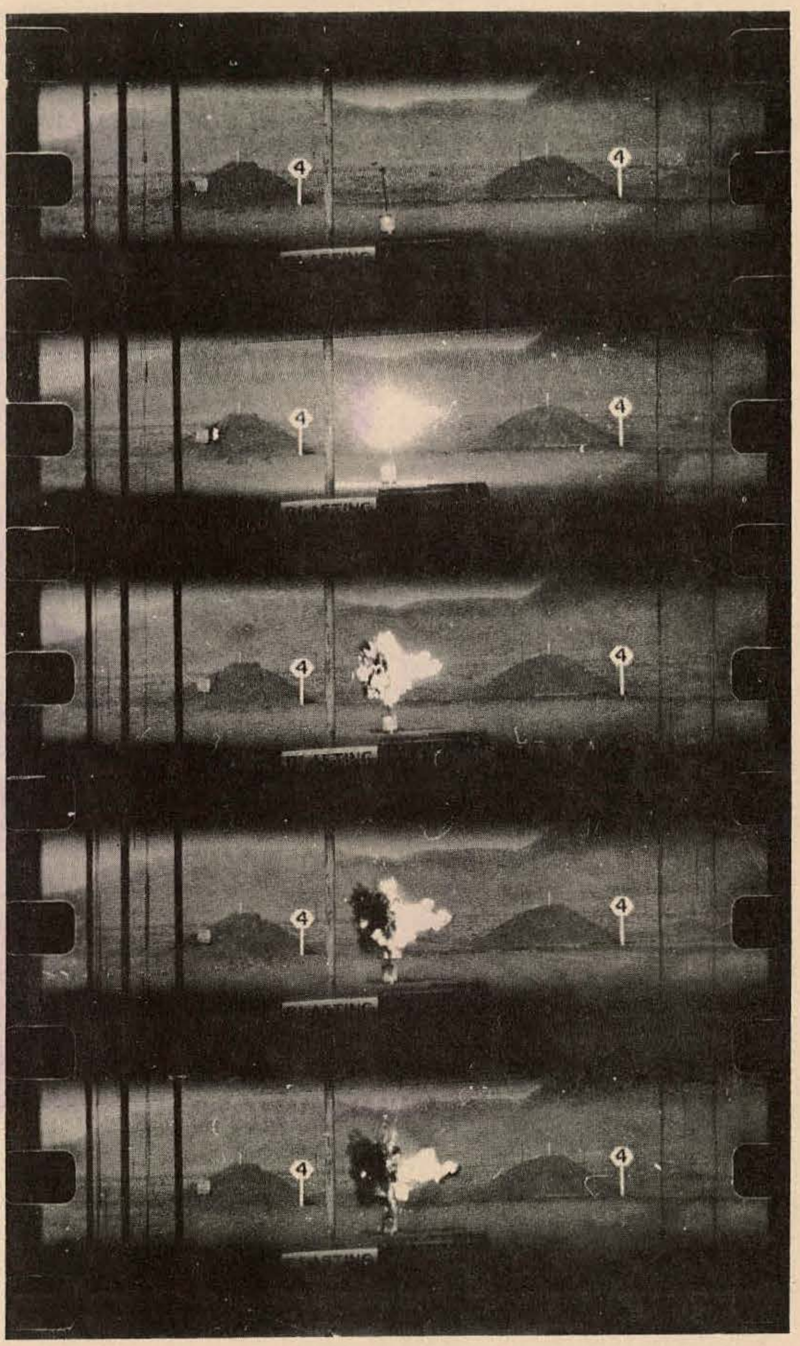
2-inch OD tube 3-inch long 20-ounce Comp C
3000 ft (plastic)
649-GH film
4-5 sec at f11 using 12-inch lens

Fig. 4a - HE Argon



2-inch OD 3-inch long glass tube rounded end
20-ounce Comp C
3000 ft
649-GH film
4-5 sec at f11 using 12-inch lens
20X blowup

Fig. 4b - HE Argon



Fastax pictures 3000 frames/sec
2-inch tube OD 3-inch length
2-ounce Comp C shaped
2-inch lens f8

Fig. 4c - HE Argon