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OPERATION GREENHOUSE

SCIENTIFIC DIRECTOR'S REPORT

ANNEX 1.9 AIR-DROP INSTRUMENTATION

PART III—DISC CAMERA

GRADED

AUTHORITY OF

NUCLEAR EXPLOSIONS

1951

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Air-drop Instrumentation

Part III—Disc Camera

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AIR-DROP INSTRUMENTATION

Part III—Disc Camera

by

Staff of

Edgerton, Germeshausen & Grier, Inc.

Approved by: FREDERICK REINES
Director, Program 1

Approved by: ALVIN C. GRAVES
Scientific Director

Edgerton, Germeshausen & Grier, Inc.
~~Boston, Massachusetts~~

August 1954

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ILLUSTRATIONS (Continued)

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Abstract

The disc camera was designed for use in aircraft to determine the growth characteristic of the fireball and so the yield. The instrument has three separate optical systems and can record three separate streak images of the fireball on a rotating glass photographic plate. Each streak image shows the growth of the fireball along a diameter with respect to time; the three traces are displaced radially to avoid confusion. The shutters are opened at approximately −3 sec, and a phototube pulser circuit is arranged to close them before one revolution of the disc after zero time.

The angular velocity of the photoplate at the time of exposure is determined by marker pips recorded on the photoplate. The marker generator is gated by a phototube and is turned off by a time delay.

Time to minimum can be determined directly from the streaks, and by the use of the scaling laws, Bhangmeter yield can also be determined.

For Operation Greenhouse two cameras were operated in phototowers. Good records were obtained on the first two shots. On George shot, which was a daylight test, the photocell in the fiducial marker did not function and no records were obtained. The cameras were not operated on Item shot. The yields derived compare favorably with those from the other fireball determinations and with radiochemistry.

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Chapter 1

Introduction

1.1 GROUND INSTRUMENTATION

The disc camera has been described in detail in an Operation Ranger report (see References). For Operation Greenhouse the three shutters of the disc camera were opened at −2.5 sec by a signal from a local timer and were closed at approximately +30 msec by a delayed pulse from a fiducial marker. The fiducial marker was gated with light from the initial burst occurring at zero time. The fiducial marker also pulsed a velocity marker which produced a series of velocity marks for about 100 msec on the periphery of the photographic plate. These velocity marks make it possible to determine the exact speed of rotation of the photographic plate.

For Dog and Easy shots a 250 cycles/sec velocity marker was used to record a series of timing marks, and for George shot a 500 cycles/sec velocity marker was used.

Two disc cameras were used for each of the first three shots in Operation Greenhouse. The cameras were placed approximately 34,600 ft from zero for Dog shot, 44,000 ft from zero for Easy shot, and 81,000 ft from zero for George shot.

For Dog shot all three lenses of one camera were set at f/6.3 and were equipped with yellow Wratten 12 filters. These filters were used because excessive exposure of the photographic plate can cause image spreading and fogging to the extent that the concentric traces of the image merge and become unreadable, and also because the early light from the fireball is predominately blue. The filter effectively compresses the range of light to be recorded. In the other camera the apertures were adjusted to f/8, and neutral density 1.0 Wratten 12 filters were used. Thus all the images on each photographic plate were at equal exposures and the two cameras differed by a factor of 20. The exposure was intended to burn a heavy image in order to assure sharp-edged streaks, although some fogging of the photographic plate was expected.

For Easy shot all three lenses were set at f/5.6 so that heavier images could be obtained. As for Dog shot, all lenses were equipped with Wratten 12 filters, and in addition one camera had ND 1.0 filters on all three lenses.

The cameras were elevated 9° from the horizontal. With the exception of one of the two cameras used for Easy shot (which was offset 6° to the right of the zero aiming point), the cameras were offset 5° to the right of the zero aiming point. The cameras were aimed in this manner to separate the three streaks on the photographic plate.

1.2 AIR-DROP INSTRUMENTATION

No disc cameras were installed on the striking aircraft for any of the tests at Greenhouse. However, for a B-50D aircraft installation, the camera is placed in the lower forward turret and aimed downward. The velocity marker is installed in one of the racks, and the fiducial marker is mounted so that its photocell looks downward.

A radar altimeter or some other accurate means of measuring range must also be included in the aircraft. A record of the range should be maintained for the period that the streak is recorded by the disc camera.

[redacted]

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1.3 EVALUATION OF DISC STREAKS [redacted]

1.3.1 Determination of Fireball Diameter

A typical disc streak record of a fireball is shown in Fig. 1.1. The start of each trace is obscured by scattered light in the print, but the original negative shows an easily defined

Fig. 1.1 Typical Disc Streak Record

fireball streak. By measuring the angular distance between any two velocity marks located on the periphery of the photoplate, the speed of rotation of the photoplate can be determined.

With the aid of a microscope or other magnifying device the beginning of the streak, or zero time, can be located for each streak. Using this point as a time reference the width of the streak (diameter of the fireball image) for different angles (intervals of time) can be measured very accurately.

In order to determine the diameter at any instant, the following parameters must be known: (1) distance from the camera lens to zero, (2) focal length of the lens, and (3) width of the streak at the time of interest. Using the values of these parameters and the optical proportional law, the diameter of the fireball can be determined.

Because of the large field of coverage possible with this camera, lenses having long focal [redacted] can be used. With such a lens, large streak images are recorded, thereby increasing the accuracy of the fireball radius measurement at any instant. From the calculations, a plot of fireball radius vs time can be constructed for each of the three streaks.

The fireball growth is recorded along three different diameters. If a ground burst or low altitude burst is being recorded, the vertical diameter grows less slowly than the other two after the ground strike. Also, if a depression or bulge (such as a "jet") appears on the fireball, the diameter through this irregularity may grow more slowly or may grow faster. Therefore the three curves of fireball radius vs time may not be identical. In Operation Greenhouse it was found that images formed from jets were very faint and could be ignored. From the radius curves, conclusions can be drawn as to the shape of the fireball at any instant.

In order to determine the radius of the fireball by this method, the range between the lens of the disc camera and the center of the fireball must be known within 0.5 per cent. For an air drop, range can be computed from known height of the striking aircraft above the terrain, known height of the burst above the terrain, and known trail angle. The customary uncertainties in the last two quantities do not introduce excessive error.

1.3.2 Determination of Time to the Minimum

The point of minimum brightness of the fireball can be located, in some cases, on each streak with a densitometer. Then, by using the relationship of time per degree of revolution of the photoplate determined in Sec. 1.3.1 and by using the beginning of the streak as a reference, time to the minimum can be calculated. This procedure was followed successfully on the Dog shot of Operation Buster. For Operation Greenhouse, however, the shutters of the disc camera closed at or before minimum time and the measurement of time to the minimum could not be made.

1.3.3 Determination of Yield

Yield can be determined by the application of the scaling laws to the variation in fireball radius with respect to time. The curves of fireball radius vs time described in Sec. 1.3.1 can be used. [redacted]

Chapter 2

Disc Camera Construction

2.1 DISC CAMERA UNITS

The disc camera, illustrated in Fig. 2.1, consists of four major assemblies: (1) body, (2) optical and shutter, (3) marker light, and (4) connector housing. Three optical and shutter assemblies and one connector housing assembly are mounted on the body assembly. The marker light assembly is mounted inside the connector housing assembly and protrudes from the back of the body assembly.

The disc camera weighs 21 lb, and its overall dimensions are $16\frac{1}{4}$ in. in diameter and $8\frac{1}{2}$ in. in width. The camera is mounted on a U-shaped casting by two trunnions located on the body assembly.

Each of the four assemblies is described in the following subsections.

2.1.1 Body Assembly

The body assembly, shown in Figs. 2.2 and 2.3, consists of a body casting on which is mounted at the center a rotor shaft, two bearings, a photodisc hub, a disc clamp assembly, and a gear cup assembly that encloses the other units. The rotor shaft, the photodisc hub, and the disc clamp assembly are driven by a Delco motor mounted on the front of the camera through a motor pinion and rotor gear.

The photodisc hub, protruding from the back of the camera, provides a platform on which to mount the photoplate. A plate cushion is cemented on the photodisc hub to protect the photoplate. The flange portion of the photodisc hub is chamfered to prevent binding and chipping of the photoplate when the photoplate is removed from the camera. For these same reasons the edges of the inside diameter of the photoplate, which is a glass disc $\frac{1}{4}$ in. thick and $13\frac{1}{2}$ in. in diameter, are rounded slightly.

[redacted]

The disc clamp assembly fits over the photodisc hub as shown in Fig. 2.3 and screws on to the rotor shaft. A plate cushion is cemented on the surface of the disc clamp assembly that is in contact with the photoplate. When the disc clamp assembly is tightened, it effectively fastens the photoplate to the rotor shaft so that the photoplate rotates at the same speed as the rotor shaft.

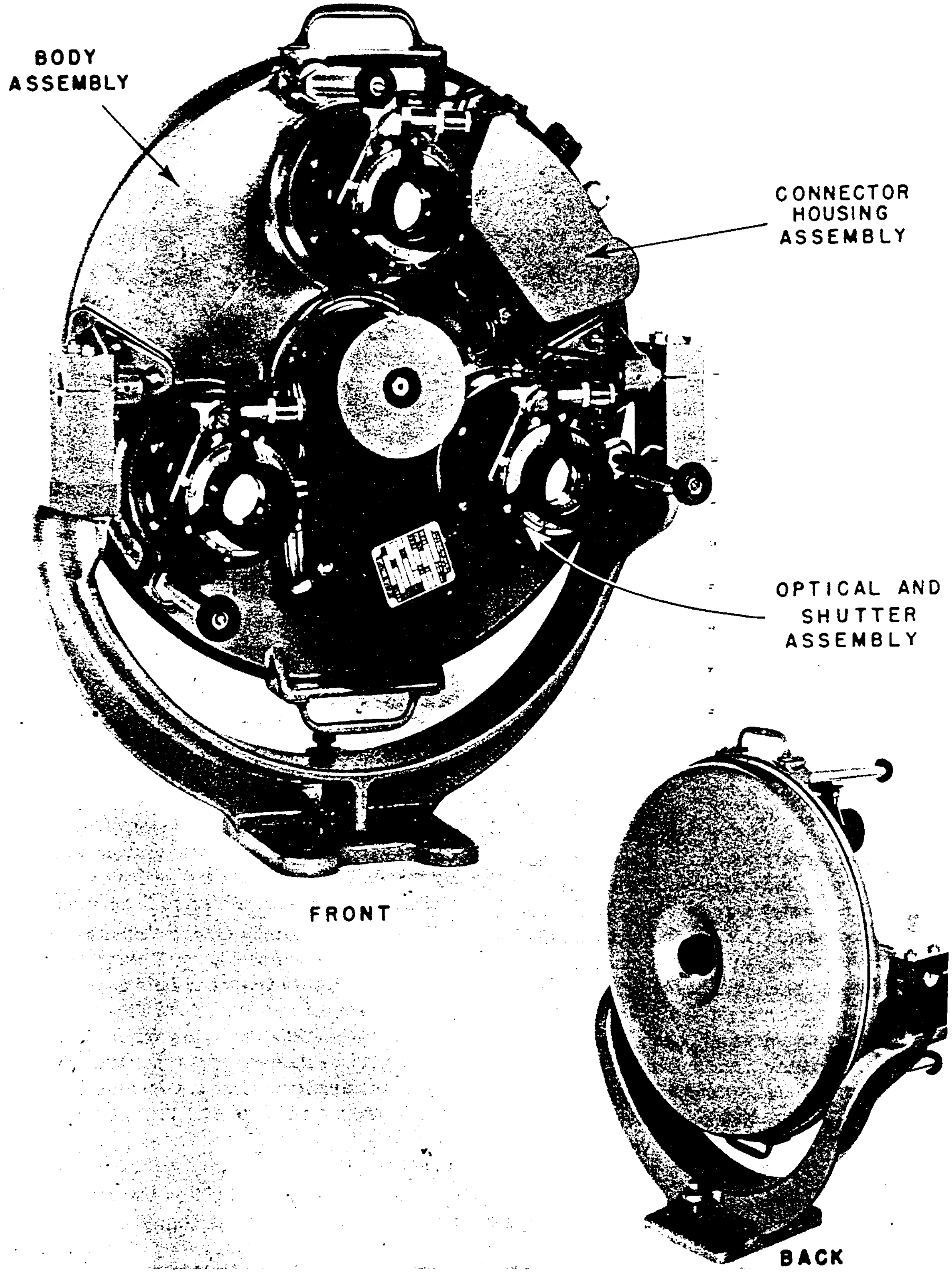
In order to reduce spreading of the image and fogging of the film, three light shields, one for each optical and shutter assembly, are mounted on the back of the body casting. A cover dome assembly completely covers the back of the disc camera (Fig. 2.4) to provide a lighttight and airtight compartment for the photoplate. The cover is securely fastened to the camera by tightening the cover nut, which is attached on the outside of the cover.

Two trunnion assemblies are mounted on the front of the disc camera as shown in Fig. 2.2. By means of these units the camera can be positioned in elevation to any desired angle.

To install or remove the photoplate from the disc camera it is necessary to place the camera on a table with its front end facing the table top. To prevent any damage to the optical and shutter assemblies, or to any other part of the camera, three camera posts that are spaced 120° apart are located on the front of the camera. When the camera is in this inverted position, only the ends of these posts, each having a rubber grommet, rest on the table.

Two handles are located on the edge of the body casting, as shown in Fig. 2.2. The camera can be conveniently carried by grasping these handles.

To absorb the light from the image, the entire back surface of the body casting is [redacted]



[redacted] Fig. 2.1 Disc Camera

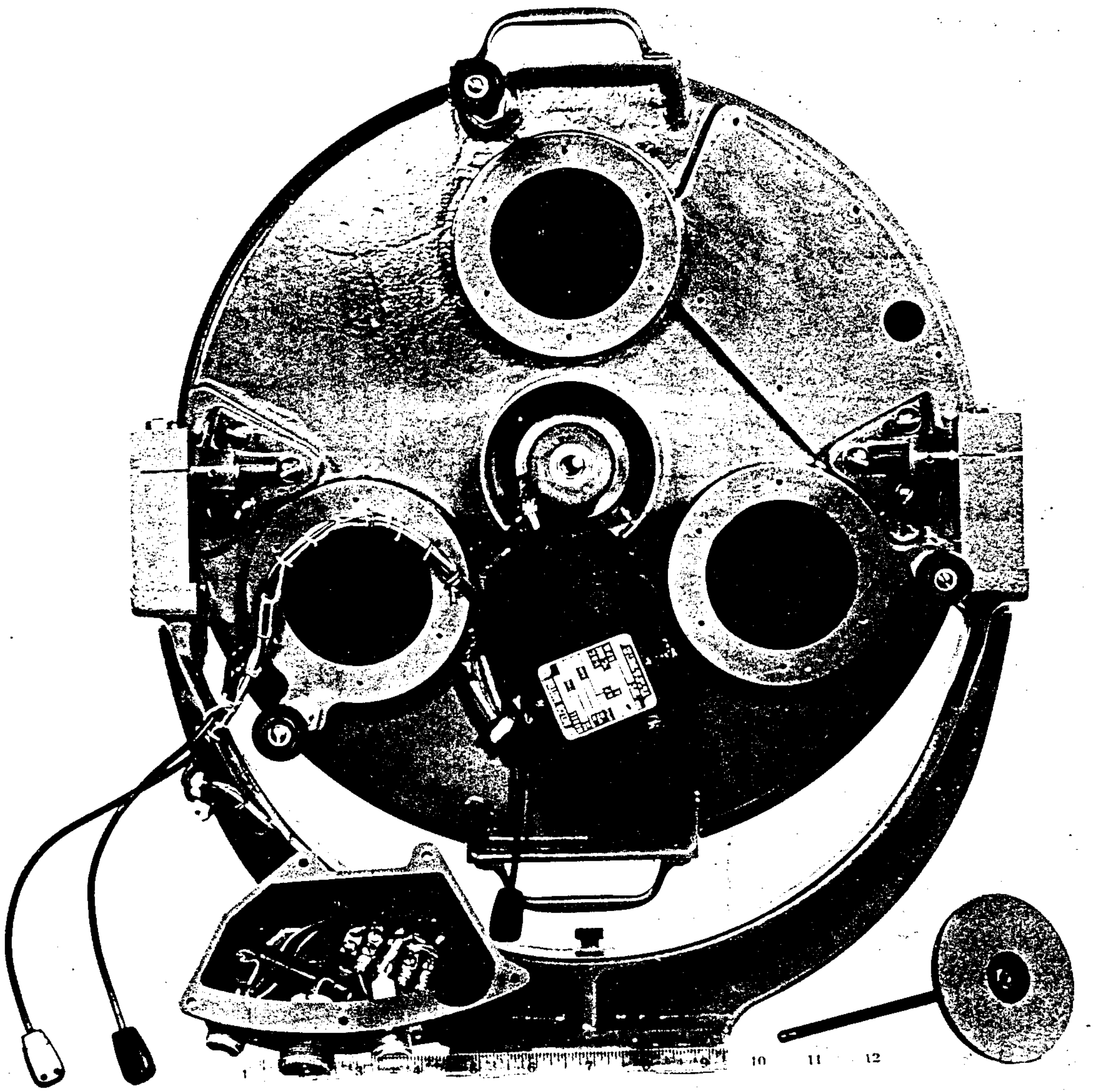


Fig. 2.2 Disc Camera Body Assembly

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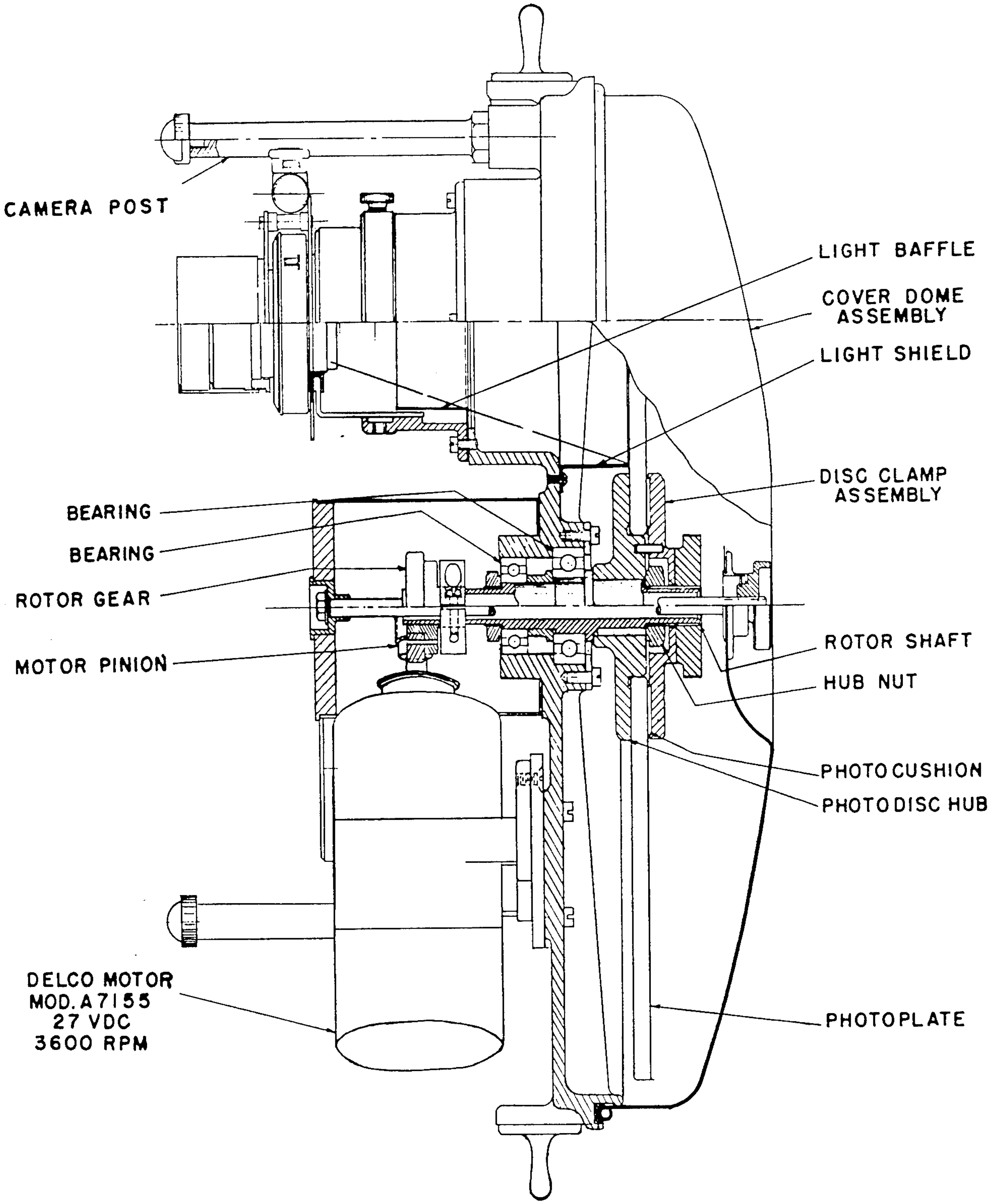


Fig. 2.3 Detailed Diagrammatic View of Disc Camera Body Assembly

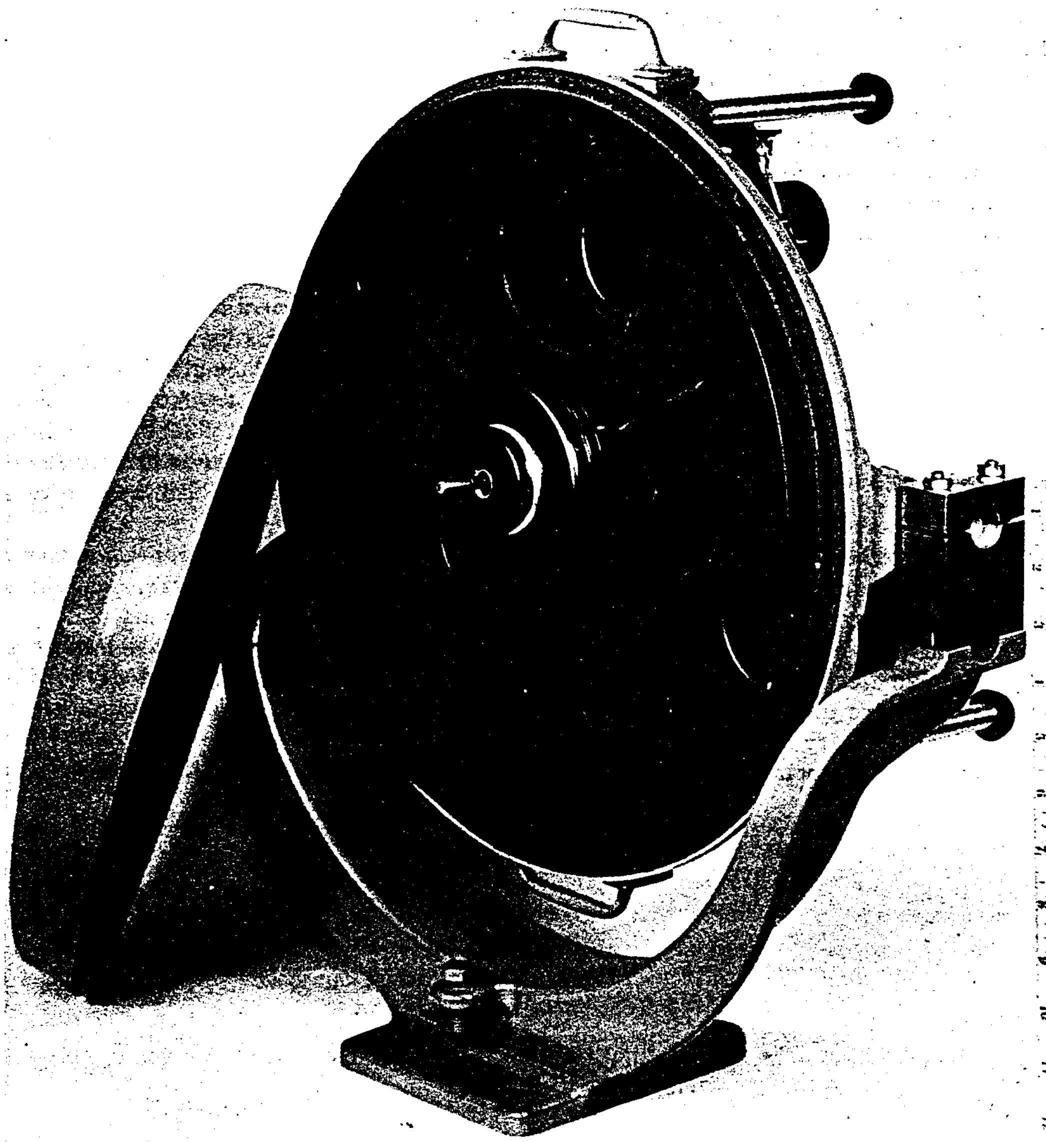


Fig. 2.4 Disc Camera with Cover Dome Assembly Removed

[redacted]

2.1.2 Optical and Shutter Assembly

One of the three identical optical and shutter assemblies is illustrated in Figs. 2.5 and 2.6. The lenses are Ektars, of focal length 127 mm and relative aperture f/4.7. The focusing tube, which fits in the focusing barrel and is secured with the focusing lock screw, is used to focus the camera and to support the Kodak supermatic shutter, the Heiland press master coil, and the filter assembly. The Kodak supermatic shutter is operated by the Heiland press master coil and extension nut.

The filter assembly consists of a filter cell and a filter. The filter fits inside the lower section of the filter cell, which is screwed on the filter cell mounting plate. A light baffle located inside the focusing barrel directs the light from the image to the photoplate and prevents scattering of the light to other parts of the camera interior.

2.1.3 Marker Light Assembly

The marker light assembly, shown in Fig. 2.7, consists of a marker tube, a spark gap, and a lens system. The assembly is mounted inside the connector housing assembly so that the end containing the lens system faces the photoplate. When an electrical signal is applied to the spark gap, an arc is developed across the gap. The light from the arc is focused by the lens system on to the photoplate.

2.1.4 Connector Housing Assembly

The connector housing assembly, shown in Figs. 2.1, 2.8, and 2.9, consists of a housing, three amphenol connectors, a terminal strip, and a resistor. The marker light assembly is installed as shown in Figs. 2.8 and 2.9.

Shutter control is obtained from the fiducial marker through the shutter trigger box, and the marker light output is obtained from the velocity marker through the pulse transformer box. The power input to the motor control connector is 28 volts direct current.

The wiring diagram for the disc camera is shown in Fig. 2.10.

2.2 DISC CAMERA TEST EQUIPMENT

No special equipment is available to test the disc camera. To focus the camera after an installation, a ground glass plate is inserted in the camera in place of a photoplate. The focusing tube is then adjusted until the star image of the light on the zero tower is clearly seen on the ground glass plate through a 10× magnifying glass.

To make a check of the proper functioning of the fiducial and velocity markers and the shutters, the camera is set up for normal operation. A chemical SM flash bulb is then flashed a few feet in front of the camera, and a record of the flash is obtained on the photoplate. After removing and developing the photoplate, the traces and the velocity marks on the plate are checked.

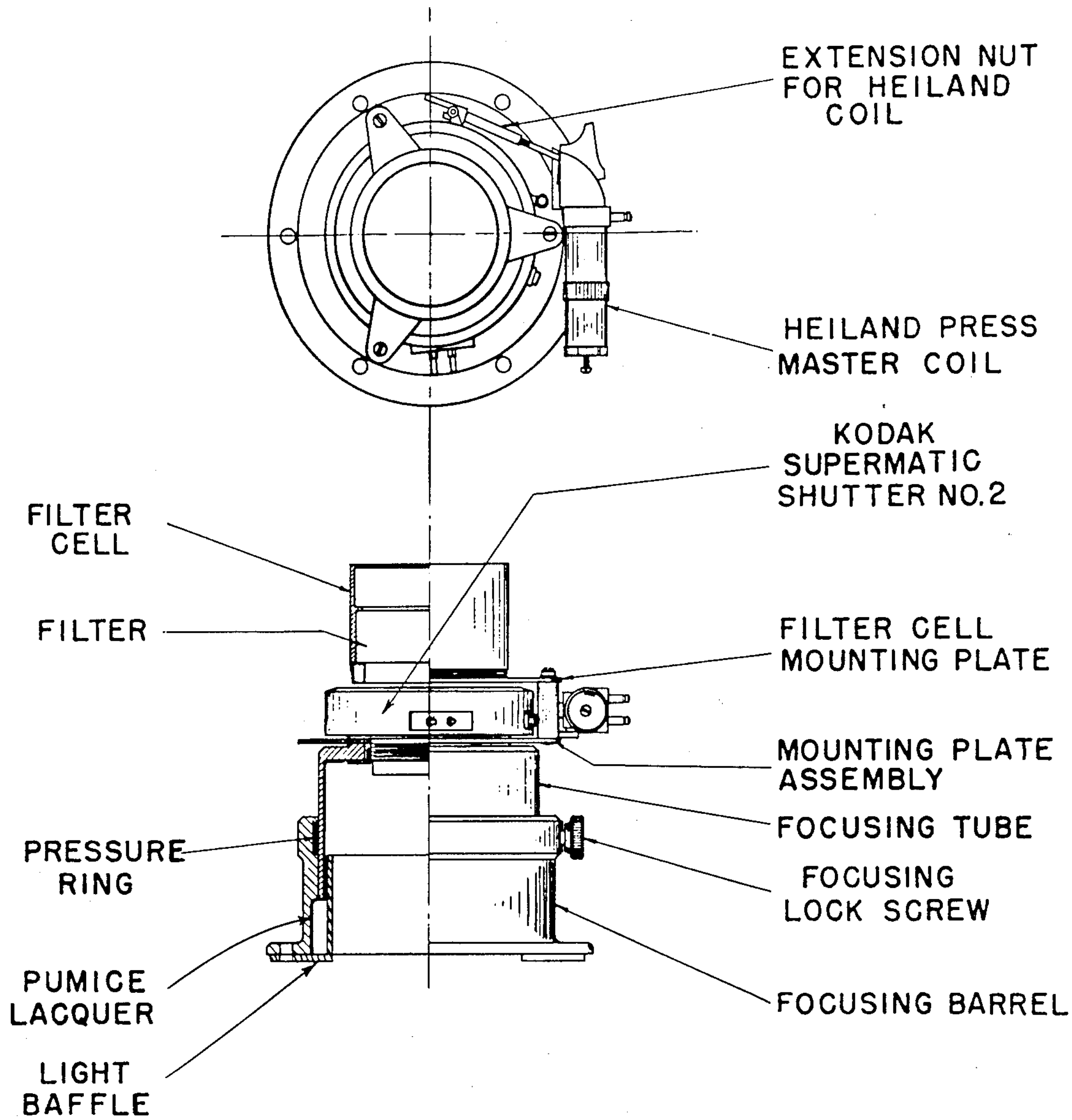
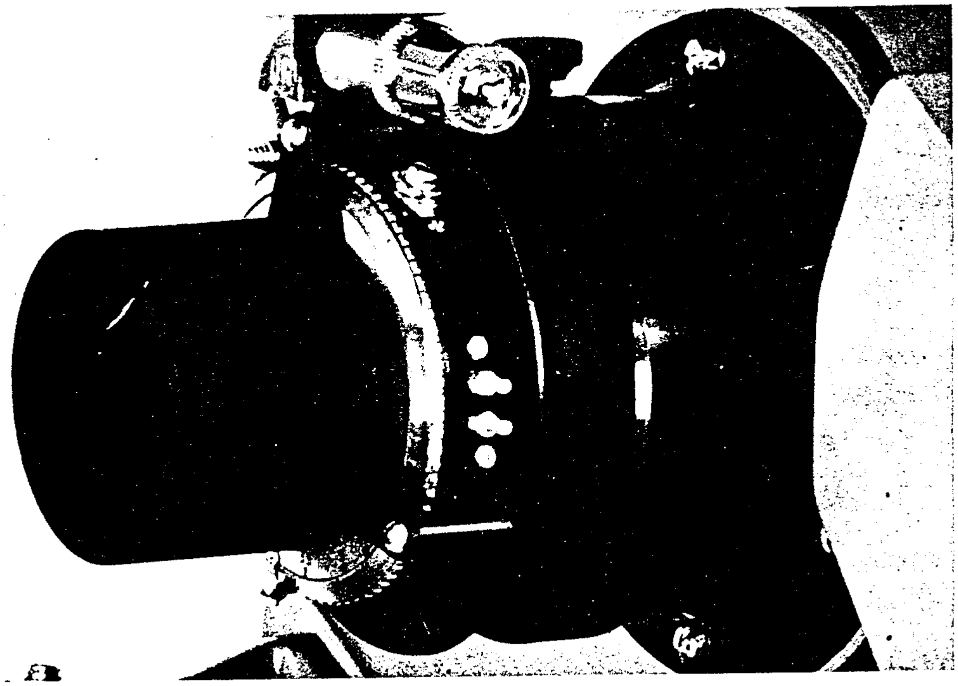


Fig. 2.5 Diagrammatic Sketch of Optical and Shutter Assembly

[redacted]



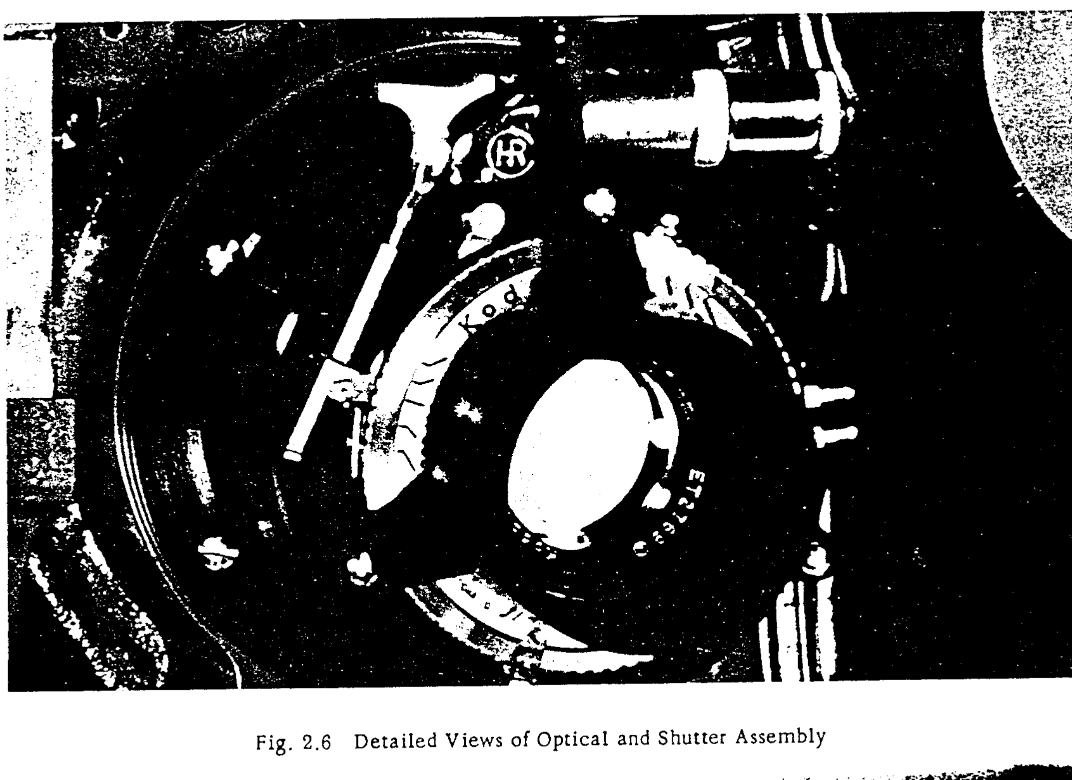


Fig. 2.6 Detailed Views of Optical and Shutter Assembly

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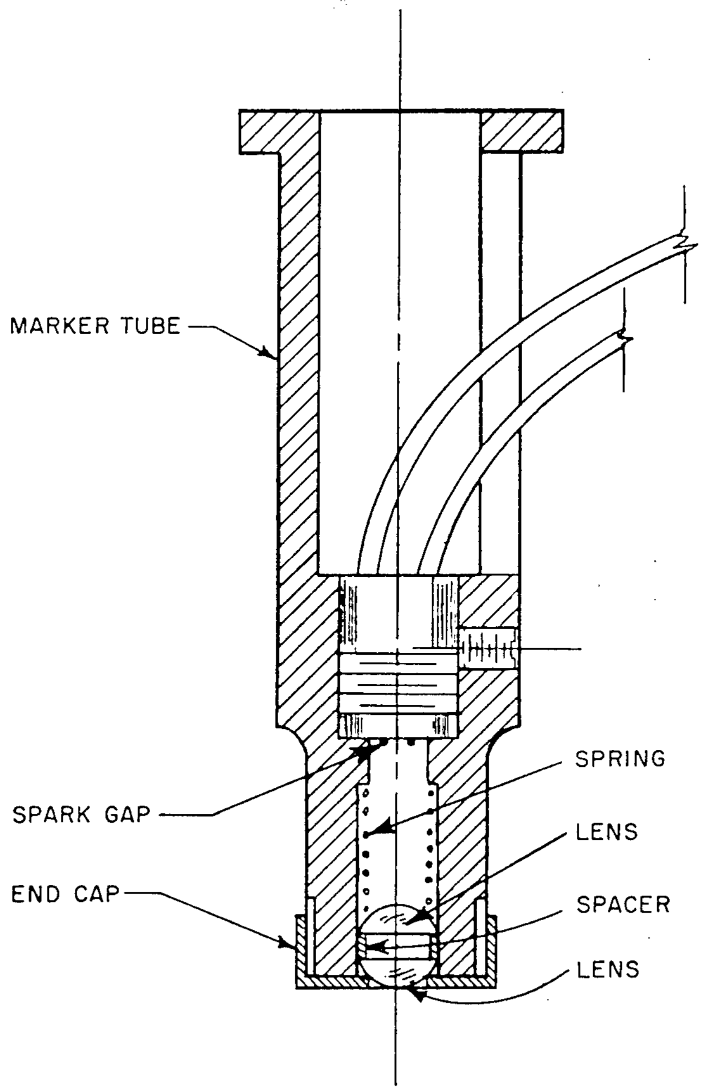

Fig. 2.7 Cross-sectional Diagrammatic Sketch of Marker Light Assembly

[redacted]

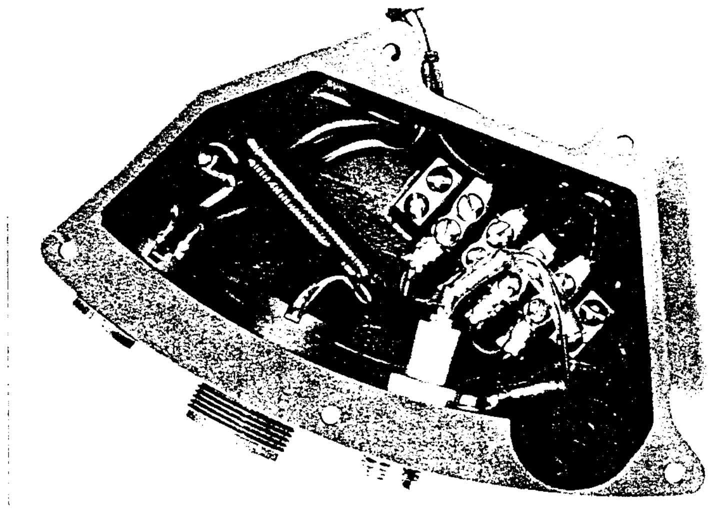

Fig. 2.8 Connector Housing Assembly

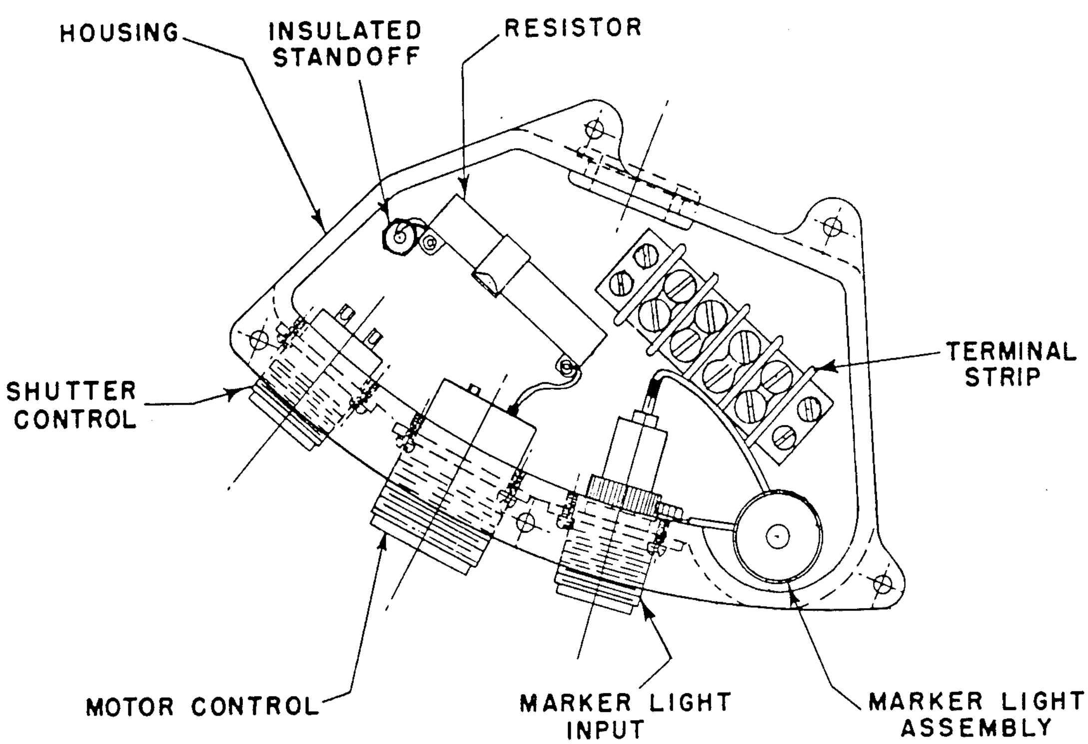

Fig. 2.9 Detailed Diagrammatic View of Connector Housing Assembly

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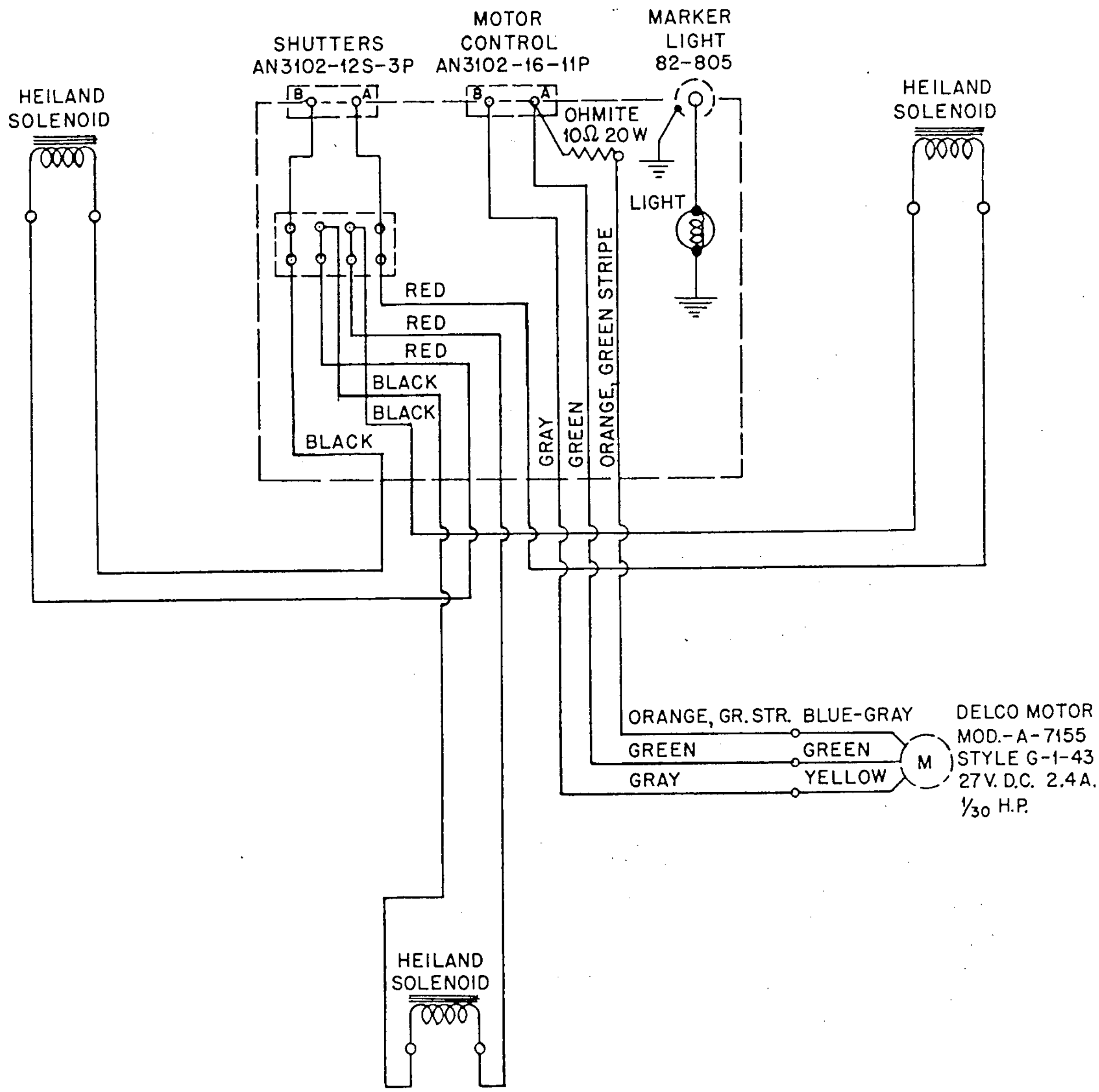

Fig. 2.10 Disc Camera Wiring Diagram

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Chapter 3

Operation

3.1 GROUND OPERATION

The disc camera is set up and connected to other units as shown in the block diagram of Fig. 3.1. Operation of the disc camera is entirely automatic after the installation.

Timing signals are supplied to the fiducial and velocity markers, the shutter trigger box, and the disc camera motor. At –5 min power is supplied to the fiducial and velocity markers in order to bring their components to the normal operating temperature. At –15 sec the camera motor is turned on. It will reach a constant speed before zero time. At –2.5 sec the shutters of the disc camera are opened by the action of the shutter trigger box.

[redacted]

At zero time the fiducial marker sends a signal to the velocity marker. The velocity marker then marks the photoplate at constant time intervals for approximately 50 msec. The first mark appears on the photoplate at approximately +10 msec. A 250 cycles/sec marker frequency was used for Dog and Easy shots. This frequency, which agrees with the nominal motor speed, is derived from a compensated 1000 cycles/sec fork that is good to one part in 10^5. A pulse transformer box increases the voltage applied to the marker light assembly in the disc camera.

Also at zero time, a 30-msec delay signal from the fiducial marker is applied to the [redacted]
ter tr[redacted]

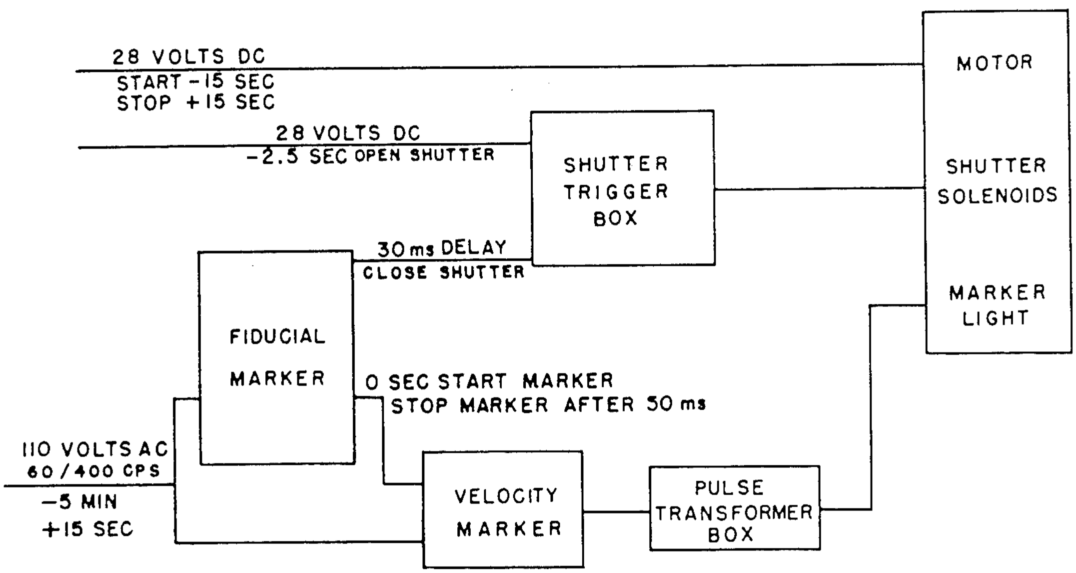

Fig. 3.1 Block Diagram of Ground and Air-drop Disc Camera Installation

ters of the disc camera close through the action of the Heiland solenoids. At +15 sec power supplied to the camera motor and to the fiducial and velocity markers is shut off.

The disc camera is taken to the darkroom before the photoplate is removed from the camera for processing.

3.2 AIR-DROP OPERATION

Connections to the disc camera installed in the strike aircraft are similar to those for the ground operation. The block diagram of the disc camera with respect to other units is shown in Fig. 3.1.

If a local timer is not available on the strike aircraft, the fiducial and velocity markers are turned on at approximately –5 min by a member of the crew. Provision is made to start the camera motor automatically before zero. This operation is accomplished by a signal from the bombsight. At approximately –2.5 sec the bombsight also opens the shutter automatically.

As for the ground operation after zero time, a 30-msec delay signal from the fiducial marker is applied automatically to the shutter trigger box, which allows the Heiland solenoids on the disc camera to close the shutters. Also, at +50 msec the velocity marker automatically ceases to mark the photoplate.

Any time after +10 sec a member of the crew shuts off the power supplied to the camera motor and to the fiducial velocity markers.

[redacted]

[redacted]

Chapter 4

Results, Conclusions, and Recommendations

4.1 RESULTS

The results of disc camera operation on the first three Greenhouse shots are given in Table 4.1.

Presence of the jets on the fireball, which was expected to confuse the edge of the streaks and invalidate the readings, turns out to be no problem because the image of the jets is much less dense than the image of the fireball itself.

TABLE 4.1 DISC CAMERA YIELD

Shot	Viewpoint	Camera Location	Distance to Zero (meters)	Calculated Yield (kt)	Official Yield (kt)
Dog	Aniyaanii	K60	10,542	74 ± 15%	82.9
Easy	Piiraai	N62	13,415	49.5 ± 15%	46.7
George	Parry	B229	24,725		214.5
Item					45.7

4.1.1 Dog Shot

The disc camera operated properly for Dog shot, and two good streak records were obtained. The two records and the data sheet for each record are shown in Figs. 4.1 to 4.4. One trace out of the six has fuzzy edges, indicating poor focus or dirt on the lens. The five good traces were measured individually and were found to agree to within less than 3 per cent spread for any one point.

The widths of the traces were averaged to reduce the random errors caused by reading the streaks. The traces showing the vertical fireball diameter were in agreement with the other traces prior to ground contact. After ground contact the vertical diameter traces departed from them. Figure 4.5 shows this portion of the fireball growth curve, which can be interpreted as proving that the fireball does not bounce. That is, ground contact occurs at a radius essentially equal to the tower height.

The curve of fireball radius vs time for Dog shot, an average of the five good streaks, is plotted in Fig. 4.6. For times greater than 10 msec the radii measurements are good to better than ±0.5 per cent and the time measurements to better than ±0.1 per cent. The reduction of this curve to a yield figure involves a comparison with the radius vs time curve from previous shots. For comparison purposes a Sandstone-Trinity curve derived from Houghten's data is plotted in Fig. 4.6 on a 1-kt basis. Ranger Shot F fireball growth is also plotted in this figure. We cannot be sure that these calibrations are correct in view of the apparent 2 per cent discrepancy in Eastman yardsticks employed at Ranger and on Dog shot at Greenhouse.

To compare Dog shot with the two calibration curves, note that the slope of the Dog shot curve, 0.370, differs very little from the Ranger Shot F value of 0.372 and a little more from the Sandstone val[redacted]. By t[redacted] laws, for Dog shot the yield is determined to be [redacted]

[redacted]

Edgerton, Germeshausen & Grier, Inc. **FILM DATA SHEET**

Operation GREENHOUSE	Shot D	Date 5-8-51	~~Film~~/Plate ND-K☐G 288
Camera DISC	Camera Location K60	Rack Position KD2	

Camera Data	Camera Setting	Processing
EGG No. 4	Color Filter 12 (2)	Location
Ser. No. 4	ND Filter none	Developer D-76
Neg. Size 13¼ diam.	Aperture (set) 6.3 (3)	Time 3m, 45s
Lens Type Ektar (3)	Eff. Apert. 6.3	Temperature 68°
Aperture (max) 4.7	Shutter Time & Trig.	Proc. Machine Tray
Focal Length (nominal) 127 mm	Vel.Mkr.Ser.No. 16	Gamma
Ser. No. ET 2769 outer, EI 3823 mid, ET 2768 inner	Zero Mkr.Ser.No. —	**Prints**
Emulsion Type MF	Power Set 24 v	Fine Grain
Emulsion No. 5.0. 872	Nominal Speed	Dupe Neg.
Dist. to (ground) 34,584.6 ft.	Aiming Vert. up 9°	Release
10,542. m.	Aiming Horiz. rt. 5°	

Scale Factors

Effective Focal Length 127 mm.	Velocity Markers 250 cps
Distance Opt. Axis 10,542	Speed at Zero 1192 rpm = 140μs/degr.
Reference Marks	Speed Terminal 1192
Magnification 83,010	Exposure Duration Streak

Primary Object ________ Time of Interest 0-30 ms

Exposure Comments

Source Emittance for Exposure Setting ________ watts/m^2

Analysis:

Remarks: GARDNER NO. 8-000 (13 7/16) 4 -
INNER TRACE IS VERTICAL DIAMETER
CAMERA DROPPED ON PARRY APRON; PLATE OK

Fig. 4.1 Data Sheet for Camera No. 4 [redacted]

ND-K□G288

Fig. 4.2 Streak Record for Dog Shot Obtained from Camera No. 4

[redacted]

[redacted]

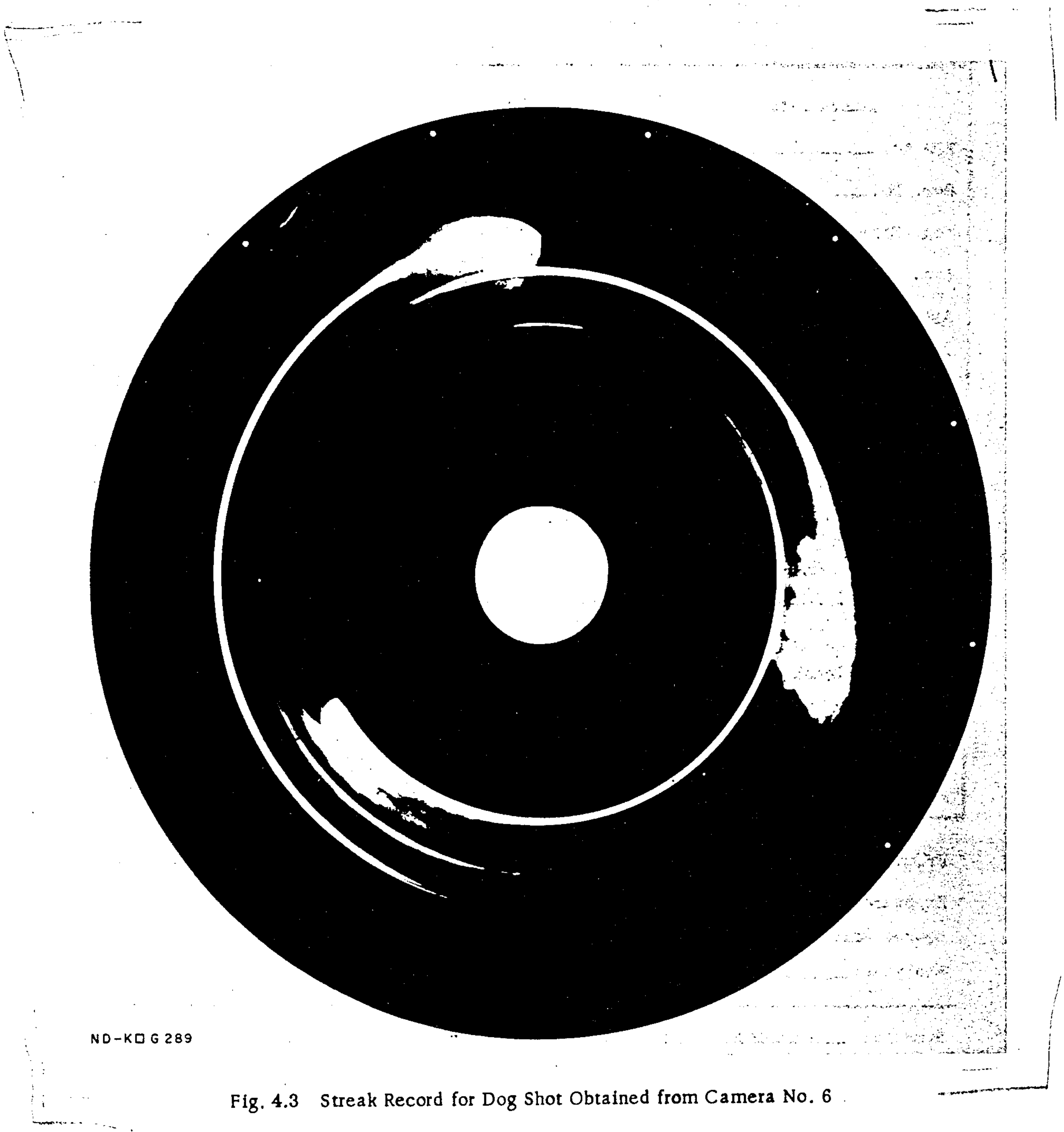

Fig. 4.3 Streak Record for Dog Shot Obtained from Camera No. 6

[redacted]

Edgerton, Germeshausen & Grier, Inc. FILM DATA SHEET

Operation GREENHOUSE | Shot D | Date 4-8-51 | ~~Film~~/Plate XD-KG289

Camera DISC | Camera Location K60 | Rack Position XD2

Camera Data		Camera Setting		Processing	
EGG No.	6	Color Filter	12(3)	Location	
Ser. No.	6	ND Filter	1 (3)	Developer	D-76
Neg. Size	13½" diam.	Aperture (set)	8 (3)	Time	3m, 45 s
Lens Type	Ektar (3)	Eff. Apert.	25	Temperature	68° F
Aperture (max)	4.7	Shutter	Time & Trig.	Proc. Machine	Tray
Focal Length (nominal)	127 mm	Vel.Mkr.Ser.No.	16	Gamma	
Ser. No.	EI 4450 outer ET 2802 mid ET 2763 inner	Zero Mkr.Ser.No.	—	**Prints**	
Emulsion Type	MF	Power Set	24 v	Fine Grain	
Emulsion No.	5.0. 872	Nominal Speed		Dupe Neg.	
Dist. to (ground)	34,584.6 ft. 10,542 m.	Aiming Vert.	up 9°	Release	
		Aiming Horiz.	24.5°		

Scale Factors

Effective Focal Length	127 mm.	Velocity Markers	200 cps
Distance Opt. Axis	10,542 m	Speed at Zero	1195 rpm = 139 μs/degr.
Reference Marks		Speed Terminal	1195
Magnification	83,010	Exposure Duration	streak

Primary Object ____ Time of Interest 0-40 ms

Exposure Comments ____

Source Emittance for Exposure Setting ____ watts/m^2

Analysis: ____

Remarks: GARDNER NO. B-000 (13 7/16) 4-
INNER TRACE IS VERTICAL DIAMETER

Fig. 4.4 Data Sheet for Camera No. 6 Used for Dog Shot

[redacted]

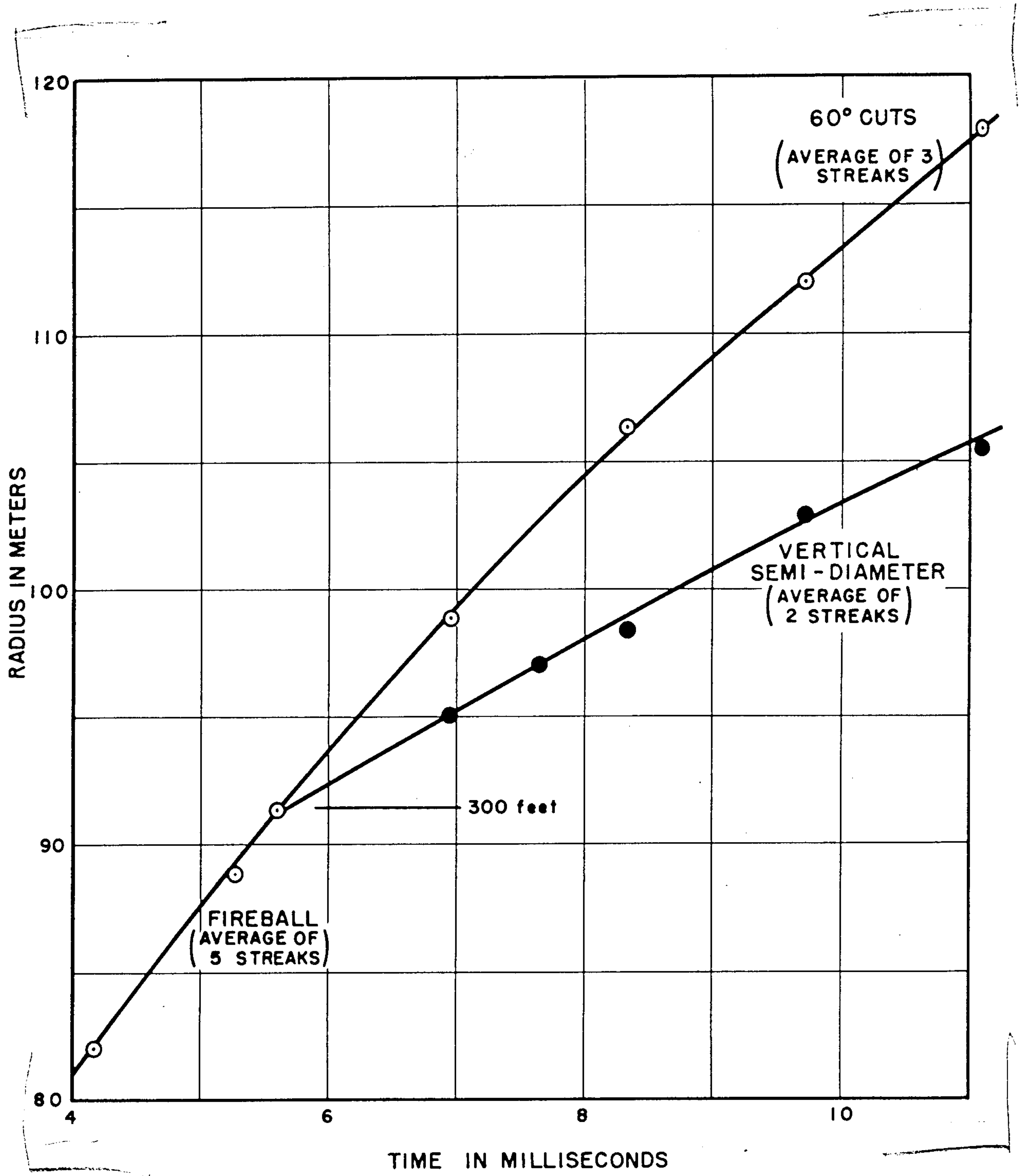

Fig. 4.5 Ground Contact of Dog Shot Fireball

[redacted]

[redacted]

approximately 74 kt. The experimental error is of the order of ±2 per cent for the Dog shot curve, but an over-all uncertainty of approximately ±15 per cent is assigned in view of the uncertainties in the calibration data.

Time to the minimum cannot be determined from the streak records for any of the first three shots at Greenhouse because the minimum regions of the traces were foggy as a result of the adjacent traces and because the shutters closed at roughly minimum time.

4.1.2 Easy Shot

Six good traces were obtained on Easy shot. The two streak records containing these traces are illustrated in Figs. 4.7 and 4.8. The data sheets for the two records are shown in Figs. 4.9 and 4.10.

The six traces were analyzed in the same manner as for Dog shot. The fireball radius vs time, which is the average of the six traces, is plotted in Fig. 4.11. To determine the yield for Easy shot, the average curve is compared with Sandstone, Ranger F, and Greenhouse Dog shots, which are also plotted in Fig. 4.11. By the use of the scaling laws, the yield for Easy shot is determined to be approximately 49.5 kt.

4.1.3 George Shot

No records were obtained on George shot because the photocell in the fiducial marker did not function properly and because the shutters did not close until approximately +20 sec, causing the streak records to become fogged. The data sheets for the two George shot records are shown in Figs. 4.12 and 4.13.

4.2 CONCLUSIONS AND RECOMMENDATIONS

Yield can be measured more accurately with the disc camera than with the Bhangmeter. With a disc camera installation, the strike aircraft can be used to determine yield during test conditions or during combat conditions. However, this system requires good visibility and no overcast between the aircraft and the burst, whereas the Bhangmeter can give results through an overcast. Timing is nowhere as critical with the disc camera as it is with high-speed cameras. Also, the angle of view of the disc camera is very much greater than can be obtained with any other camera; therefore no elaborate methods of camera mounting or test equipment are required with the use of the disc camera. The disc camera offers a useful method of measuring yield in the event of an air-drop test over the ocean. The disc camera has no particular advantages for land-based tests.

The photoplate is an inconvenient method for recording the streak images in that it is large and bulky, requires specialized treatment, and is not a standard item. A better medium should be used to receive the streak images. From the analysis of the fireball radius vs time curves for each streak, it is evident that three optical systems are not necessary; two complete optical systems should be sufficient. The shutter trigger unit should be greatly simplified and the velocity marker system and camera motor should be replaced with a governor-controlled camera motor. The Heiland solenoids used to open and close the shutters are inadequate. Better solenoids or a new technique should be used.

[redacted]

[redacted]

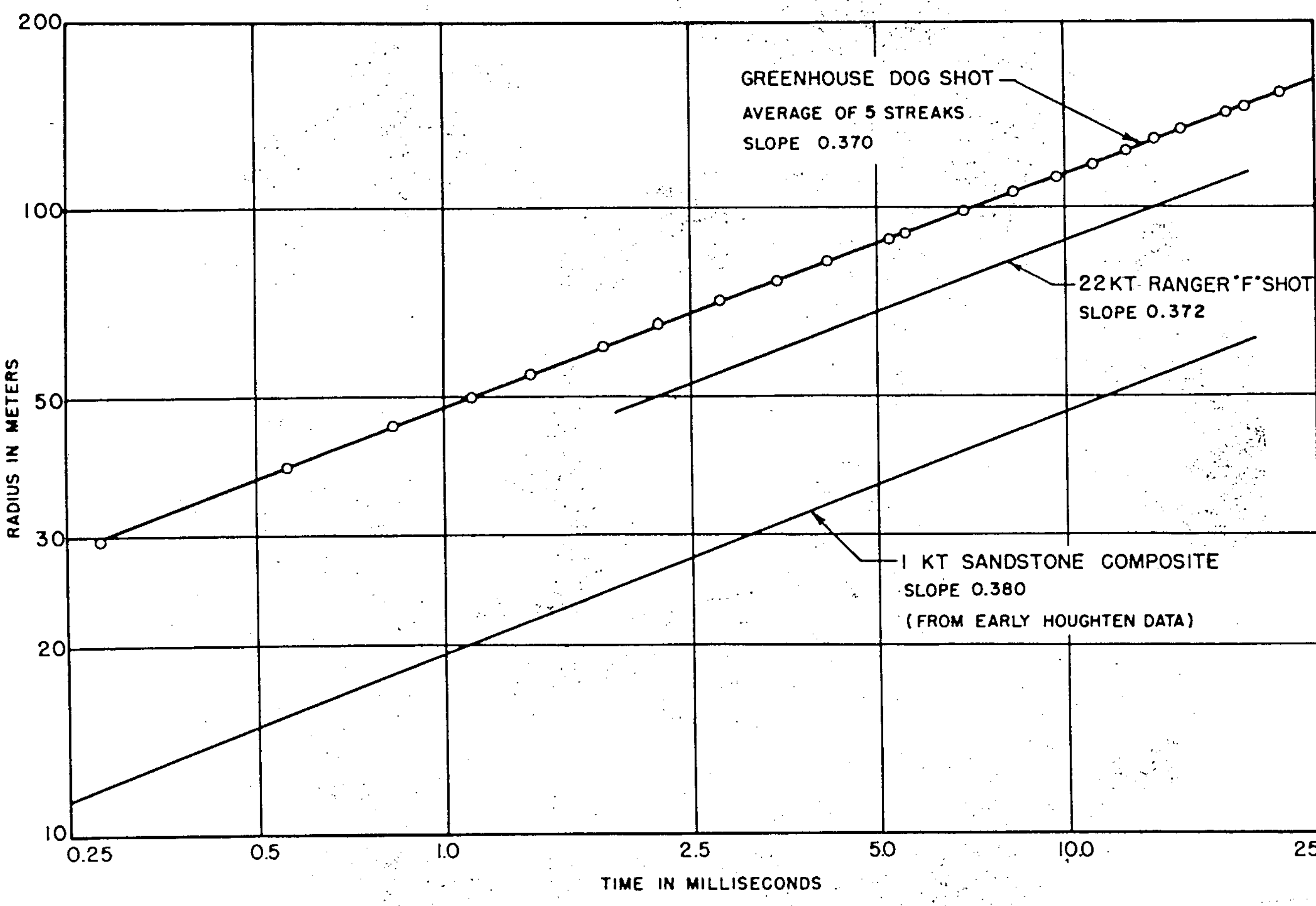

Fig. 4.6 Determination of Yield for Dog Shot

[redacted]

NE-N□G529

Fig. 4.7 Streak Record for Easy Shot Obtained from Camera No. 4

[redacted]

[redacted]

NE-NDG530

Fig. 4.8 Streak Record for Easy Shot Obtained from Camera No. 6

[redacted]

Edgerton, Germeshausen & Grier, Inc. FILM DATA SHEET

Operation GREENHOUSE	Shot E	Date 4-21-51	~~Film~~/Plate NE-N□G 529
Camera DISC	Camera Location N62	Rack Position ND1	

Camera Data	Camera Setting	Processing
EGG No. 4	Color Filter 12 (3)	Location
Ser. No. 4	ND Filter 0	Developer D-76
Neg. Size 13 ½" diam.	Aperture (set) 5.6 (3)	Time 4 m
Lens Type Ektar (3)	Eff. Apert. 5.6 (3)	Temperature 68°F
Aperture (max) 4.7	Shutter Time & Trig.	Proc. Machine Tray
Focal Length (nominal) 127 mm.	Vel.Mkr.Ser.No. 16	Gamma
Ser. No. ET 2769 outer, EI 3823 mid, ET 5671 inner	Zero Mkr.Ser.No. —	**Prints**
Emulsion Type MF	Power Set 27 v dc	Fine Grain
Emulsion No. S.O. 872	Nominal Speed	Dupe Neg.
Dist. to (ground) 44,010 ft.	Aiming Vert. up 9°	Release
13,415 m.	Aiming Horiz. rt. 6°	

Scale Factors

Effective Focal Length 127 mm.	Velocity Markers 250 cps
Distance Opt. Axis 13,415 m	Speed at Zero 1183 rpm = 140.8 μs/degr.
Reference Marks —	Speed Terminal 1183 rpm
Magnification 105,630	Exposure Duration streak

Primary Object ______ Time of Interest 0-30 ms

Exposure Comments ______

Source Emittance for Exposure Setting ______ watts/m²

Analysis: ______

Remarks: GARDNER NO. 8-000 (18 7/16) 4-15
GOOD RECORD

Fig. 4.9 Data Sheet for Camera No. 4 Used for Easy Shot

[redacted]

Edgerton, Germeshausen & Grier, Inc. **FILM DATA SHEET**

Operation GREENHOUSE	Shot E	Date 4-21-51	~~Film~~/Plate NE-ND□G530
Camera DISC	Camera Location NG2	Rack Position ND2	

Camera Data	Camera Setting	Processing
EGG No. 6	Color Filter 12 (3)	Location
Ser. No. 6	ND Filter 1 (3)	Developer D-76
Neg. Size 13¾" diam	Aperture (set) 5.6 (3)	Time 3 m
Lens Type Ektar (3)	Eff. Apert. 17.7	Temperature 68°F
Aperture (max) 4.7	Shutter Time & Trig.	Proc. Machine Tray
Focal Length (nominal) 127 mm	Vel.Mkr.Ser.No. 16	Gamma
Ser. No. EI 4450 outer, ET 1802 mid, ET 2763 inner	Zero Mkr.Ser.No. —	**Prints**
Emulsion Type MF	Power Set 24 V	Fine Grain
Emulsion No. S.O. F22	Nominal Speed	Dupe Neg.
Dist. to (ground) 44,410 ft. 13,415 m.	Aiming Vert. up 9°	Release
	Aiming Horiz. rt 5°	

Scale Factors

Effective Focal Length 127 mm.	Velocity Markers ____ cps
Distance Opt. Axis 13,415 m	Speed at Zero 1187 rpm = 140.4 μs/degr
Reference Marks —	Speed Terminal 1187 rpm
Magnification 105,630	Exposure Duration streak

Primary Object ____ Time of Interest 0-30 ms

Exposure Comments ____

Source Emittance for Exposure Setting ____ watts/m²

Analysis: ____

Remarks: GARDNER NO. 13-000 (13 7/16) 4-15
GOOD RECORD

[redacted]era No. 6 Used for Easy Shot

[redacted]

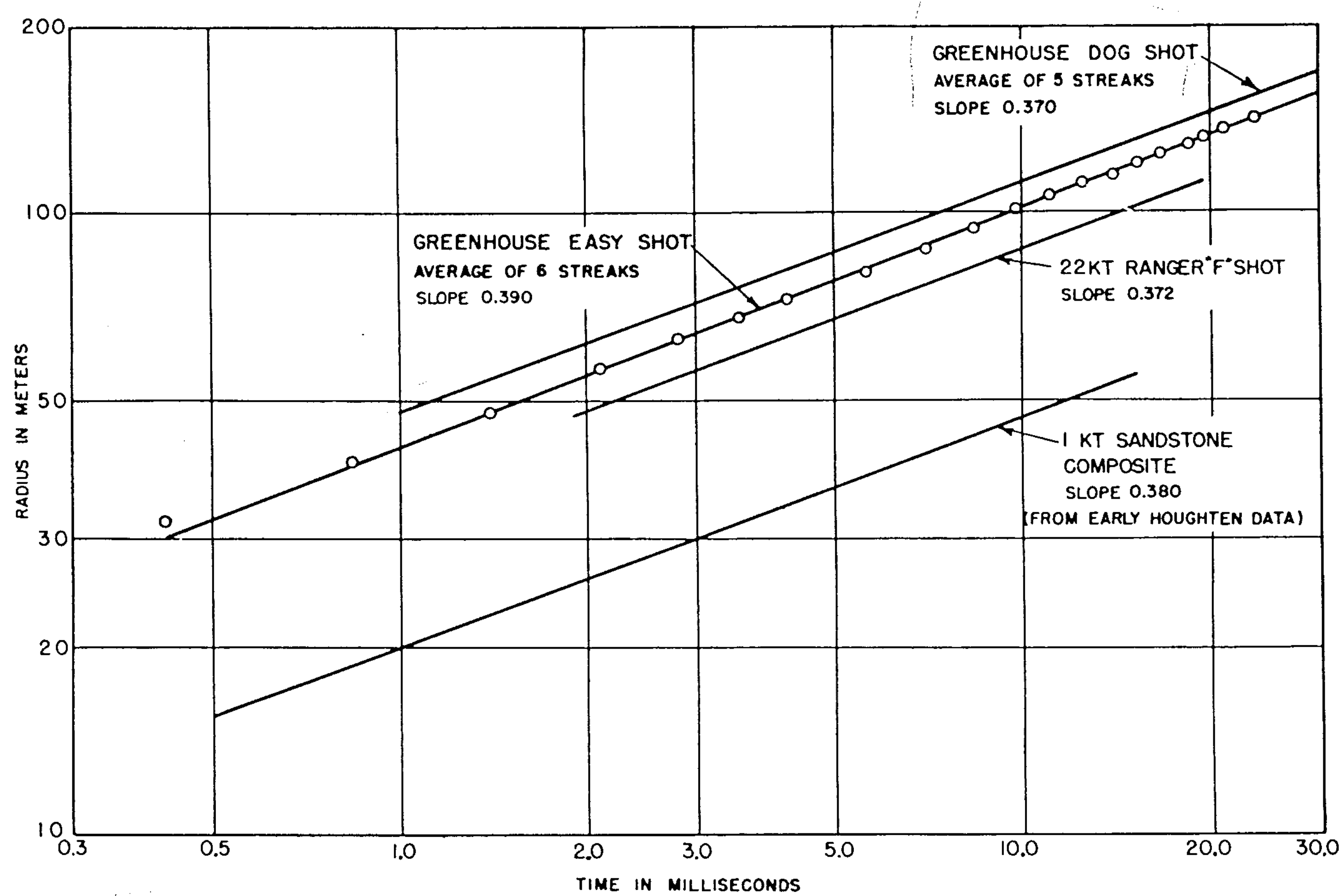

Fig. 4.11 Determination of Yield for Easy Shot

Edgerton, Germeshausen & Grier, Inc. FILM DATA SHEET

Operation GREENHOUSE	Shot G	Date 5-9-51	~~Film~~/Plate NG-806
Camera DISC	Camera Location 8229	Rack Position 8D1	

Camera Data	Camera Setting	Processing
EGG No. 4	Color Filter 12 (3)	Location
Ser. No. 4	ND Filter 1 (3)	Developer D-76
Neg. Size 13 ½" diam.	Aperture (set) 4.7	Time
Lens Type Ektar (3)	Eff. Apert. 15	Temperature 68°F
Aperture (max) 4.7	Shutter Time	Proc. Machine Tray
Focal Length (nominal) 127 mm	Vel.Mkr.Ser.No. 16	Gamma
Ser. No. ET 2769 outer, EI 3823 mid, ET 5671 inner	Zero Mkr.Ser.No. —	**Prints**
Emulsion Type MF	Power Set 26 v dc	Fine Grain
Emulsion No. S.O. 872	Nominal Speed	Dupe Neg.
Dist. to (ground) 81,120 ft.	Aiming Vert. up 9°	Release
24,725 m.	Aiming Horiz. right 5°	

Scale Factors

Effective Focal Length 127 mm.	Velocity Markers 500 cps
Distance Opt. Axis 24,725 m	Speed at Zero
Reference Marks	Speed Terminal
Magnification 194,700	Exposure Duration Streak

Primary Object ______ Time of Interest 0-50 ms

Exposure Comments ______

Source Emittance for Exposure Setting ______ watts/m²

Analysis: NONE - FOGGED

Remarks: GARDNER NO. 8-000 (13 7/16) 4- SHUTTERS DID NOT CLOSE TILL ABOUT +20 SEC - FOGGED IMAGE

Fig. 4.12 Data Sheet for Camera No. 4 Used for George Shot

[redacted]

ASSIFIED

Edgerton, Germeshausen & Grier, Inc. — FILM DATA SHEET

Operation GREENHOUSE	Shot G	Date 5-9-51	~~Film~~/Plate NG-80G
Camera DISC	Camera Location B229	Rack Position 8D2	

Camera Data	Camera Setting	Processing
EGG No. 6	Color Filter 12 (3)	Location
Ser. No. 6	ND Filter 0	Developer D-76
Neg. Size 13½" diam.	Aperture (set) 5.6	Time
Lens Type Ektar (3)	Eff. Apert. 5.6	Temperature 68°F
Aperture (max) 4.7	Shutter Time	Proc. Machine Tray
Focal Length (nominal) 127 mm	Vel. Mkr. Ser. No. 16	Gamma
Ser. No. EI 4450 outer; ET 2802 mid; EI 4229 inner	Zero Mkr. Ser. No. —	**Prints**
Emulsion Type MF	Power Set 26 v dc	Fine Grain
Emulsion No. 5.0 F72	Nominal Speed	Dupe Neg.
Dist. to (ground) 81,120 ft.	Aiming Vert. up 9°	Release
24,725 m.	Aiming Horiz. rt 5°	

Scale Factors

Effective Focal Length 127 mm.	Velocity Markers 500 cps
Distance Opt. Axis 24,725 m	Speed at Zero
Reference Marks	Speed Terminal
Magnification 194,700	Exposure Duration Streak

Primary Object ______ Time of Interest 0-30 ms

Exposure Comments ______

Source Emittance for Exposure Setting ______ watts/m^2

Analysis: NONE - FOGGED

Remarks: GARDNER NO. B-000 (13 7/16) 4-
SHUTTERS DID NOT CLOSE TILL ABOUT +20 SEC - FOGGED

Fig. 4.13 Data Sheet for Camera No. 6 Used for George Shot

[redacted]

[redacted]

LASSIFIED

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