Cloud droplet camera

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CLOUD DROPLET CAMERA

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Subject: Cloud Droplet Camera

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SUMMARY

A camera has been developed to photograph droplets in a cloud from an aircraft in flight. The images obtained are shadowgraphs and are six times the natural sizes. Single or successive photographs a few seconds apart may be taken. Compensation for movement of the aircraft relative to the droplets during the exposure is effected by a rotating prism in the optical system. Standard 5 inch Aero Super XX film is used. A 58 foot roll accommodates 125 exposures.

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CLOUD DROPLET CAMERA

INTRODUCTION

In connection with the study of the meteorological conditions associated with the formation of ice on an aircraft in flight it is desirable to know the size distribution of the droplets in the cloud being studied. It is also desirable to know the total number of droplets and the water content per unit volume.

The camera to be described was developed to provide a record of the sizes of the droplets existing in a cloud through which the aircraft is passing.

DESCRIPTION

It is necessary to mount the camera proper as far forward in the aircraft as possible, so as to photograph droplets that are in relatively undisturbed air, and beyond the skin effect of the aircraft. The method of mounting the camera is peculiar to the type of aircraft. The unit mentioned in this report is suspended beneath the flooring in the nose section of an RY3 aircraft (modified Liberator). Because of possible heavy landing shocks, it is necessary to suspend the mounting plate on four substantial Lord shock mounts. The mounting is so positioned that the objective lens of the camera just protrudes through the skin of the aircraft. (Figure 10).

The method used to photograph the droplets is based on the shadowgraph principle, as used in ballistics. The relatively moving particles are photographed as they pass under the objective lens, in a thin focal plane, at approximately the focal length distance from the lens. This method is illustrated in figure 1. Any light striking the edge of the droplet is either refracted or deflected. Thus the image of the droplet appears on the photographic negative as a white spot against a black background. At the centre of the white image, an extremely small black dot may be noted. This is due to the small amount of light that strikes normal to the droplet surface, thus passing through its centre.

Since the droplets may have a minimum diameter of a few microns, it is necessary to have the images magnified sufficiently for actual measurement. This magnification is limited by the camera's physical dimensions.

The layout of the camera is shown in figure 2.

The camera as constructed for the RY3 consists of the following:

1. Light Source
2. Prism Box
3. Camera Body
4. Control Circuit
5. Remote Control Panel

1. Light Source

This consists of a tubular housing outside the skin of the aircraft figures 9 and 10 and is suspended from the mounting plate. The unit contains an oil filled condenser, pilot electrode and main electrodes. The spark illumination was chosen for its short duration and because it gives a form of nearly monochromatic light in the blue and violet region. Light in this part of the spectrum improves the resolving power of the particular lens now in use.

The main spark is fired by ionizing its gap by means of a pilot electrode. The aircraft's D.C. supply operates an inverter which in turn delivers 110v at 400 cycles. This A.C. power supply figure 7 is divided into two parts, one which provides a pilot spark and the other which controls the output to the main spark. The schematic diagram of the power supply is shown in figure 3. The firing circuit is operated by applying 150v D.C. on the control grid of the strobotron. After the strobotron is ignited, the charged condenser (C3) is shorted to ground through the primary of an ingition coil.

2. Prism Box

This unit is the heart of the camera, and contains the optical components necessary to photograph the droplet figure 8. Since the droplet will move, relative to the camera, along a path several times its own diameter during the few microseconds of spark discharge, it is necessary to provide some means of counteracting this motion. The stopping of the photographic image is made possible by a counter rotating prism, whose speed is a function of the true air speed of the aircraft.

Let β = angular velocity of the rotating prism required to stop image

V = velocity of droplet relative to the aircraft in inches/sec.

r = distance from lens to focal plane in inches

$\alpha = \frac{V}{r}$ radians/sec.

x = distance from lens to centre of rotating prism

y = distance from film plane to centre of rotating prism

Then it can be shown that

$$\beta = \left(\frac{x + y}{2y}\right) \alpha$$

Inserting the physical dimensions of this particular camera there results

$$\beta = 0.541\ \alpha$$

$$= 0.541\ \frac{V}{r} \text{ radians/sec.}$$

Since it is necessary to know the required rate of rotation of the prism (R.P.M.) in terms of the true air speed of the aircraft in miles per hour a conversion constant (K) must be determined.

From the preceeding equation:

$$\beta_{(R.P.M.)} = 0.541\ \frac{V}{r} \times \frac{60}{2\pi} = 19.5\ S$$

where S = velocity of droplet relative to the aircraft in miles per hour i.e., the true air speed of the aircraft. Since the tachometer drive is geared at 1:2½ instead of the standard 1:2 the reading of the tachometer indicator on the remote control panel should be

$$19.5\ S \times \frac{2.0}{2.5} = 15.6\ S$$

A commutator ring mounted on the rotating prism shaft, with an adjustable brush in contact with it, serves to synchronize the light flash with the correct position of the prism. The adjustable brush permits correction to be made for the time lag incurred in the control circuit which may be a few microseconds.

The prism box also contains the prism driving motor, tachometer generator, fixed prism and objective lens. The D.C. motor is series wound and controlled from the remote control panel. A standard aircraft tachometer transmitter is geared to the motor. The fixed prism bends the light rays 90 degrees and may be eliminated in cameras having the film plane normal to the line of flight.

The objective lens used in this camera is a standard Eastman Kodak Ektar f 4.5 enlarging lens, with a focal length of 4 inches. This lens was selected as having the highest resolving power at its maximum aperture. A large aperture is desirable in order to obtain a very thin focal plane. Definition must be good up to 5 degrees off the optical axis.

3. Camera Body

Any type of standard camera may be modified, whose film is electrically wound, and which has an automatic shut off. An F24 aerial camera is the type incorporated in the Cloud Droplet Camera described in this report. This type was chosen as being easily modified and because its magazine holds 58 feet of 5 inch width film. In the initial experiments the standard focal plane night shutter was used. Later a between-the-lens shutter was substituted. The only modifications of the camera required were to fasten a platform on a segment of the gap wheel, and to mount a micro switch on the frame of the gear box.

4. Control Circuit

When the control button on the panel, figure 5, is pressed the solenoid in the camera gear box becomes energized, and pulls the gap wheel into position. This starts the winding motor. At the end of the wind a raised portion on the gap wheel closes a micro switch for a fraction of a second. This switch energizes the shutter solenoid, figure 4, opening the shutter for 1/25 second. During this period, the solenoid armature travels further to close a second micro switch in the firing circuit. There is a period of waiting until the commutator brush on the rotating prism is shorted, which then completes the firing circuit, discharging the pilot spark.

5. Remote Control Panel

This panel, figure 5, may be mounted anywhere in the aircraft. All connections to the camera are made through two cables, one of 7 conductors, the other of 12 conductors. From this panel are controlled the inverter, high voltage power supply, prism speed, camera control button and exposure counter.

DETERMINATION OF DEPTH OF FOCUS

The shadowgraph images produced by the camera show some droplets in sharp focus and others lacking in sharpness by varying degrees. It would be desirable, therefore, to know the thickness of the layer, at the focal plane, within which all droplets produce sharp images on the film.

To determine this thickness shadowgraphs were made with the camera of a grid of 21 wires of 0.0004 inch diameter substituted for the droplets. The wires were spaced at about 0.007 inch intervals across a slot in a metal plate. The plate was set on a slope at 45 degrees to the image plane.

Figure 6 shows one of the photographs of the grid. Examination of these photographs against an arbitrary standard of sharpness revealed the number of wires in focus. The space covered by the wires in focus divided by the magnification of six gives the thickness of the layer or depth of focus in the object plane.

The depth of focus, from a series of photographs of the grid, had a mean value of 0.029 inch. Individual values varied from 0.022 inch to 0.032 inch.

DISCUSSION

The camera described was developed to provide a record of the sizes of the droplets existing in a cloud through which the aircraft is passing.

The portion of the cloud strata photographed is only about $\frac{1}{2}$ inch in diameter and this small area may not contain all of the droplet sizes existing in the cloud. For this reason provision has been made for the taking of successive photographs.

A lens with good resolving power at a large aperture was selected in order to provide good definition in a very thin focal plane. Within this thin focal plane all droplets would be in sharp focus and it may prove possible to define its depth to a useful degree of accuracy. In that case it may be possible to obtain a knowledge of the distribution of the droplet sizes and of the water content per unit volume to about the same order of accuracy.

The shadowgraphs obtained during the tests made to determine the depth of focus were of cylindrical rather than of spherical forms. However, the wires used were of approximately the same diameter as some cloud droplets. It is believed that the depth of focus shown by these tests is a first order approximation to the thickness of the layer of cloud within which all droplets produce images in focus.

/SL

APPENDIX A

Operation Instructions of Cloud Droplet Camera.

All phases of camera control are from the remote control panel (Figure 5) mounted amidship in the aircraft. Prior to flight it is necessary to remove lens dust cap, set timing watch and fasten film magazine. When ready for taking pictures the procedure is as follows:

1. Start inverter by closing upper left hand switch.

2. Make sure high voltage control and prism motor control are turned to their extreme anti-clockwise position.

3. Close power supply switch and allow filaments of tubes to heat.

4. After 2 minutes, rotate high voltage control until meter reads 70 volts. This will impress approximately 4000v on condenser.

5. Close prism motor switch and adjust control until R.P.M. = 15.6 x T.A.S. (true air speed in M.P.H.).

6. Close camera switch

7. Press push button to take photograph.

If desired the push button may be held depressed, and pictures taken approximately every 10 seconds until released.

FIG. 1 & 2
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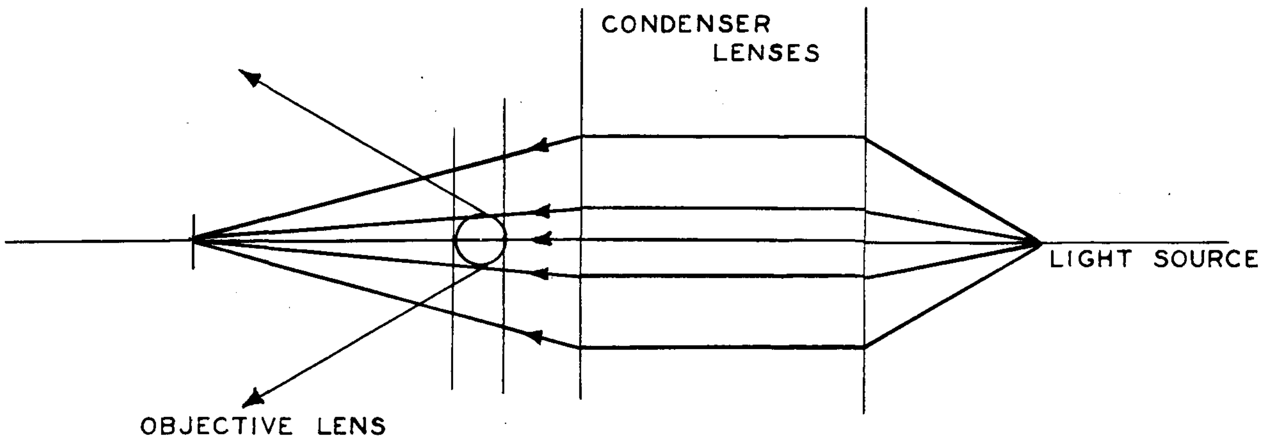
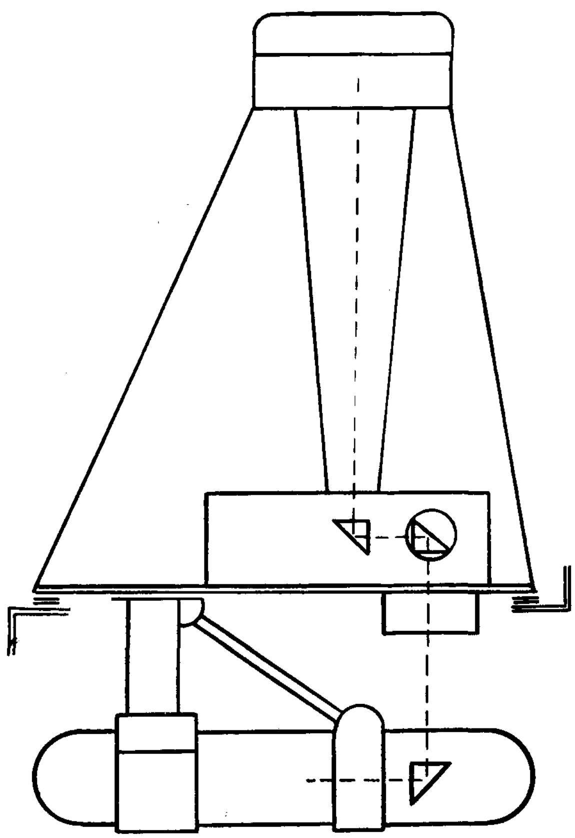


SHADOWGRAPH PRINCIPLE

FIG 1



LAYOUT OF CLOUD DROPLET CAMERA

FIG. 2

FIG. 3
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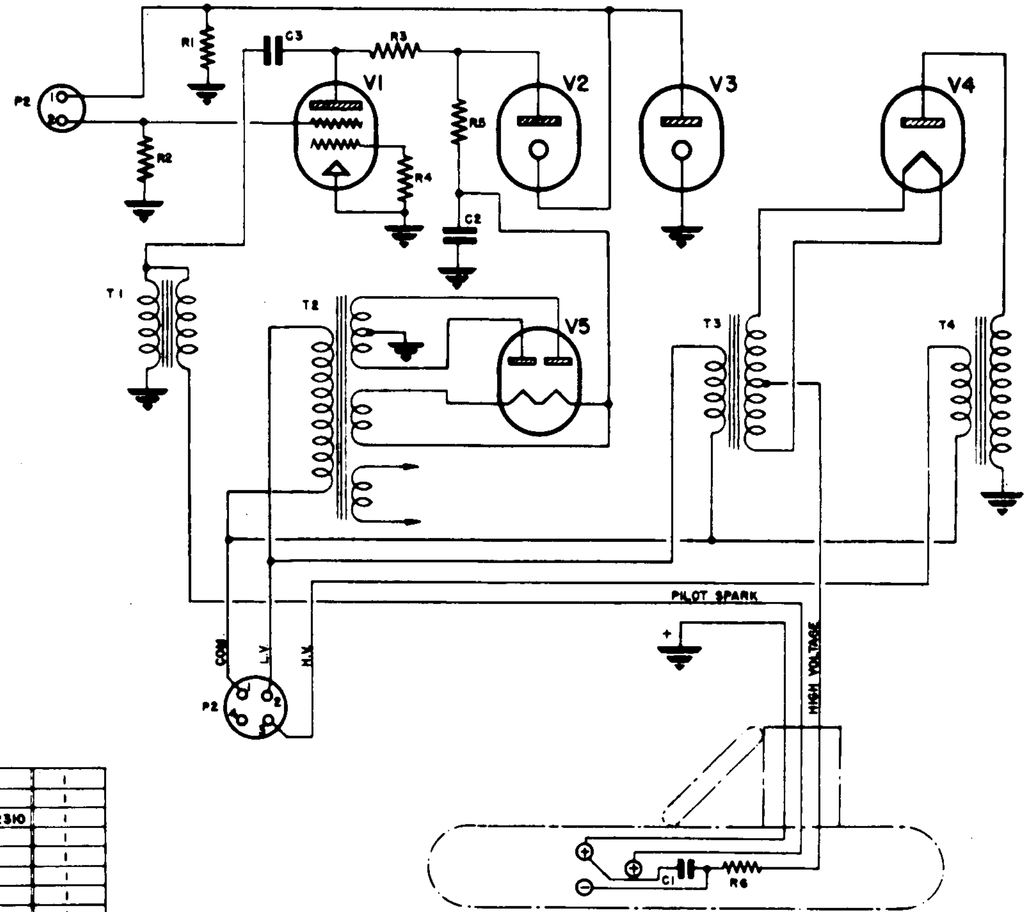

POWER SUPPLY for DROPLET CAMERA

ITEM	DESCRIPTION	Nº REQ'D.
P2	CANNON PLUG W.K.-MR-328	1
P1	" " W.K.-4-32S	1
T4	TRANSFORMER, HAMMOND PLATE Nº 12310	1
T3	" " FIL. Nº 1122	1
T2	" " Nº 270	1
T1	SPARK COIL (JEEP INGITION COIL)	1
C3	CONDENSER, 1 mfd. 400 V.	1
C2	" , 4 mfd. 400 V.	1
C1	" , 20 mfd. 400 V	1
R6	RESISTOR, 10 Ω	1
R5	" , 2 K	1
R4	" , 10 K	1
R3	" , 5 K	1
R2	" , 1 meg.	1
R1	" , 1 meg.	1
V5	TUBES, 5Y3GT	1
V4	" , 8013-A	1
V3	" , VR150	1
V2	" , VR150	1
V1	" , 631-P1	1

DWG No

FIG. 4
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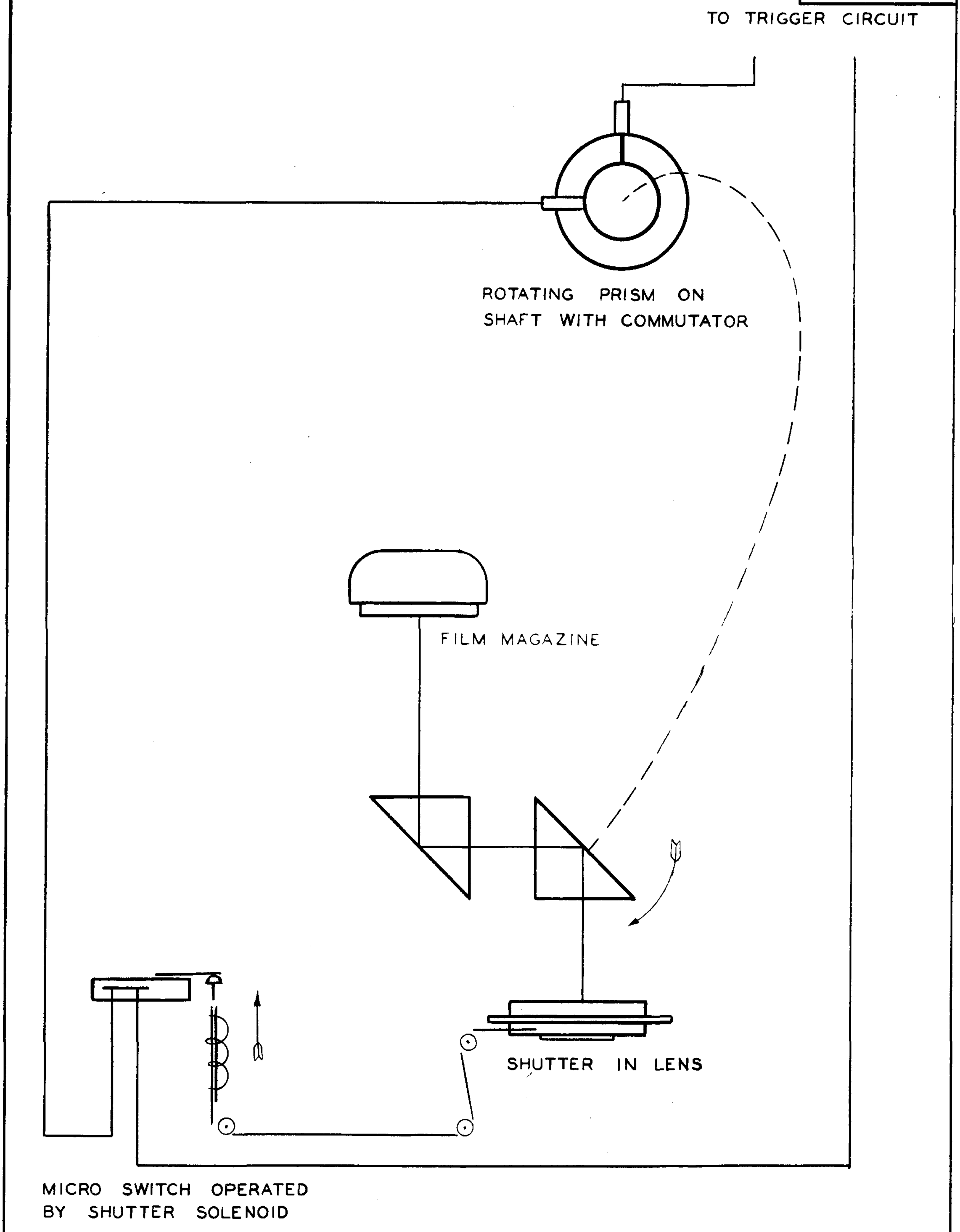
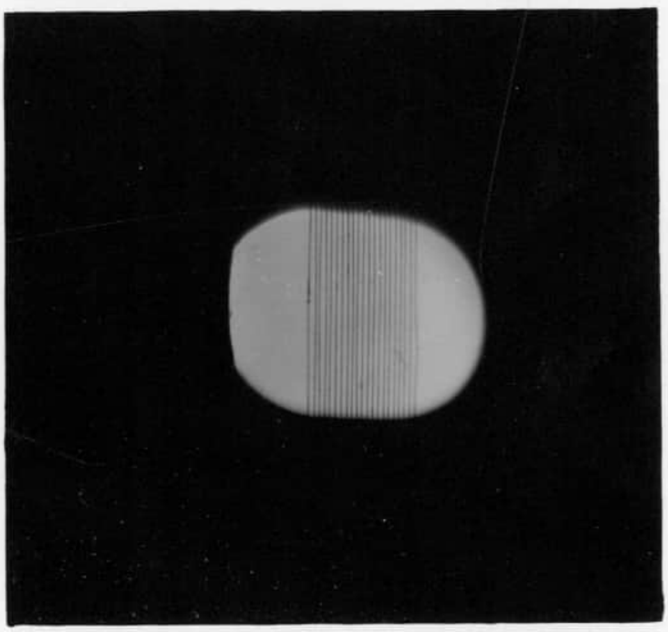


FIRING CIRCUIT
FIG. 4

REMOTE CONTROL PANEL



DEPTH OF FOCUS
PHOTOGRAPH OF GRID

FIG. 7
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POWER SUPPLY

FIG. 8
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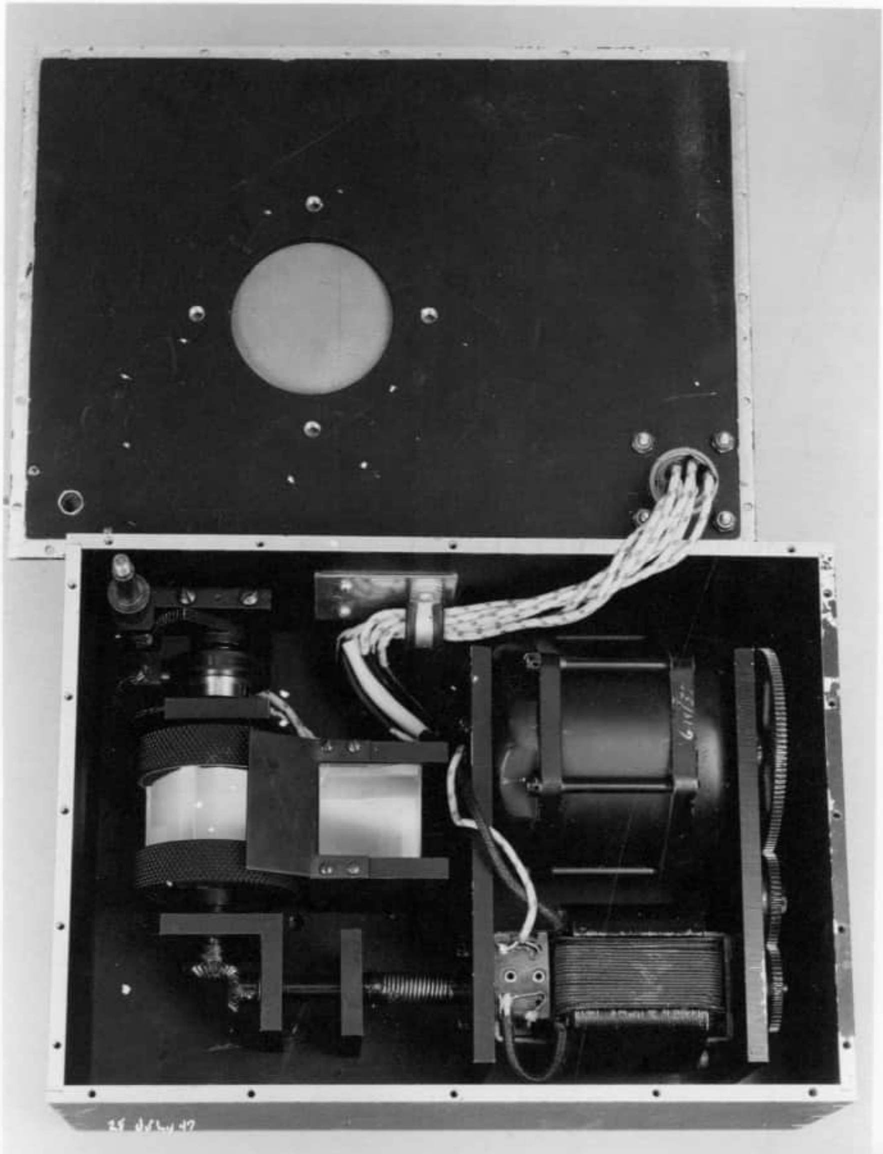

PRISM BOX

FIG. 9&10
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CAMERA ASSEMBLY

CAMERA INSTALLED ON AIRCRAFT