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U. S. NAVAL TECHNICAL MISSION TO JAPAN
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RESTRICTED

From: Chief, Naval Technical Mission to Japan.
To : Chief of Naval Operations.

Subject: Target Report - Bomb Components, Description and Operation of Japanese Type 3 Photoelectric Fuse.

Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

1. Subject report, covering Target 0-24 of Fascicle 0-1 of reference (a), is submitted herewith.

2. The investigation of the target was accomplished by Lt. Comdr. R.A. Cooley, USNR, 1st. Lt. E. Graham, USMCR, bomb disposal officer, and Lt.(jg) F. Purdy, USNR, interpreter and translator. The report was written by Lt. Comdr. R.A. Cooley, USNR.

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DESCRIPTION AND OPERATION OF JAPANESE TYPE 3 PHOTOELECTRIC FUSE

"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945

FASCICLE O-1, TARGET O-24

NOVEMBER 1945

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

ORDNANCE TARGETS

DESCRIPTION AND OPERATION OF JAPANESE TYPE 3 PHOTOELECTRIC FUSE

This report concerns the Japanese Type 3 fuse which was used operationally on 250 and 800 kilogram aircraft bombs to cause detonation of bombs 18 to 45 feet above the earth. This fuse functions in daylight or dark.

Operation depends on transmitting from the fuse a beam of pulsing light which is reflected back to the fuse and activates a photoelectric cell, which, in connection with an electric circuit, causes detonation at a desired height.

The fact that this fuse is sensitive only to light pulsing within a certain frequency range and may drop for up to 30 seconds before arming makes it a formidable weapon to counter and a valuable device for exploitation in military applications if it is as reliable as claimed by Japanese naval officers.

This fuse required the development of two new vacuum tubes and appears to represent an example of an original and appreciable accomplishment by Japanese engineers.

TABLE OF CONTENTS

REFERENCES

Japanese Personnel Interrogated:

Capt. Iwao ARISAKA, IJN, of the Branch of the First Naval Technical Arsenal at KANAZAWA. Assisted in fuse development. Graduated from the Japanese Naval School in 1922 and after some sea duty took graduate work in the electrical engineering department of TOHOKU Imperial University. On finishing his work at the University in 1934, became communications officer on the aircraft carrier HOSHO for about a year, and then served at the First Naval Technical Laboratory at OPPAMA continuously to the present, except for a period of about six months spent in NEW YORK CITY as an electrical inspector for a purchasing firm in JAPAN. Period spent in NEW YORK, about 1940 was terminated when his nation's credit was frozen in the UNITED STATES. Was very obliging in presenting information and appeared to have a good understanding of the fuse.

Lieut. Kojiro ISHII, IJN, of the Branch of the First Naval Technical Arsenal at KANAZAWA. Assisted in the development of the fuse. Graduated from the engineering department of the TOHOKU Imperial University in 1941, and after spending one month working for a vacuum tube manufacturing firm (SUMITOMO Co.), reported to KOKUGIJITSUSHO (old name for First Naval Technical Arsenal) as a technical lieutenant (junior grade). Showed a practical knowledge of the fuse, and supplied the information on vacuum tube characteristics presented in this report.

Comdr. TAKAGI, IJN, of the Branch of the First Naval Technical Arsenal at KANAZAWA. Assisted in the development of the fuse.

Japanese Personnel Who Assisted in Gathering Documents and/or Equipment:

All those listed above.

Other Japanese Personnel Concerned:

Lieut. Tadashi SATO, IJN, of the Branch of the First Naval Technical Arsenal at KANAZAWA. Was given most credit for the invention, but was said to be too ill with tuberculosis for questioning.

Professor S. ASADA of the Science Department of OSAKA Imperial University. Was said to be very familiar with details of the fuse.

Miscellaneous References:

Bill of lading No. 1A-46 ComSerDiv 102, dated 5 October 1945, for shipment of 12 Type 3 fuses to BuOrd and six Type 3 fuses to CincPac by #1 air priority authority authorised by ComFifthFleet.

Letter of transmittal, dated 8 October 1945, for OinC, Team 21, NavTechJap, to ComFifthFleet for forwarding preliminary technical report to BuOrd and CincPac.

LIST OF ILLUSTRATIONS

INTRODUCTION

The purpose of this report is to present sufficient detailed information on the Japanese Type 3 fuse to aid the development of bomb disposal procedures, and to aid in the exploitation of a principle well-known but relatively recently reduced to a practical basis.

THE REPORT

HISTORY OF DEVELOPMENT

The principle of the fuse (see below) is not new, but the reduction of the idea to a practical and reliable mechanism represents an appreciable achievement which required, among other things, the development and manufacture of a new photocell and thyratron tube. It was said that the development of the fuse commenced in earnest at the Branch of the First Technical Arsenal of the Navy, KANAZAWA, in November of 1943 and that the fuse was being used operationally nine months later in July 1944. The number of fuses manufactured or used is not known, but it was said to have been probably less than 1500. Fuses were inspected which were numbered serially up to 1685, but it was stated that misleading numbering was used purposely.

The main difficulties to be overcome had been: (1) the manufacture of a photocell which did not show "peaks"; i.e., a photocell whose current output reliably followed a smooth curve as the light intensity increased, and (2) the manufacture of a thyratron tube which was capable of withstanding the vibration encountered. The first difficulty was solved by the introduction of a grounded grid into a cesium photocell; i.e., the new tube PL 50 V1 was especially made for this fuse. The second difficulty of vibration effects was solved by shortening and strengthening the elements of a thyratron; i.e., the argon thyratron XB-767A was especially made for this fuse.

PRINCIPLE OF OPERATION

As indicated in Figure 1, the time of arming of the type 3 fuse may be set before take-off at any value between zero and 30 seconds. After arming, the point of detonation of the bomb is determined principally by how good a light reflector the target surface is.

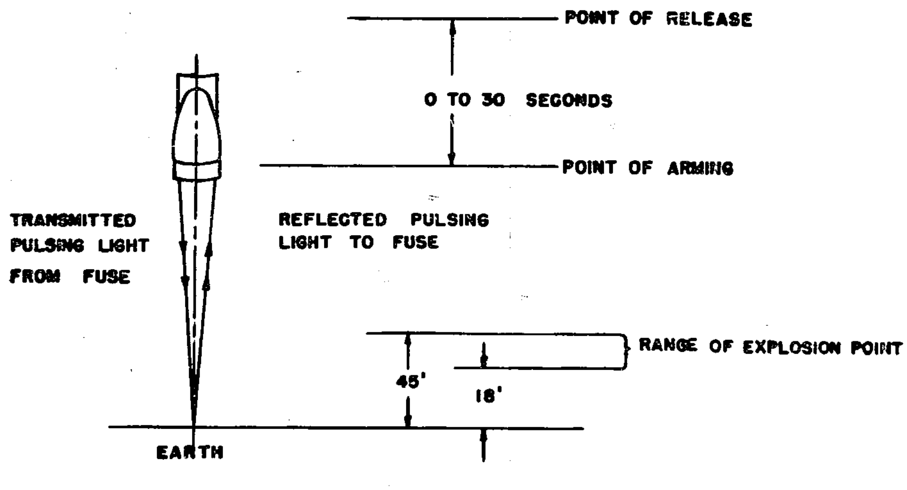

Figure 1
Principle of Type 3 Fuse

A pulsing light source of 900 to 1000 cycles per second is located in the fuse, and light from this source is directed toward the earth during the falling of the bomb. The pulsing light from the bomb strikes the earth and is reflected back to a photoelectric cell in the fuse. The current from the photoelectric cell is amplified by an electronic two-stage amplifying circuit, tuned to 900 to 1000 cycles per second, and connected to a thyratron tube. As the bomb nears the earth the photoelectric cell receives more and more reflected light so that its current, which is amplified, increases until it triggers a thyratron. Figure 2 shows a schematic block diagram of the fuse. When the thyratron triggers, enough current passes through a squib to detonate the high explosive charge of the bomb. The characteristics of the circuit are such that the bomb explodes within the desired height range above the earth. Since the amplifying circuit is sensitive only to light pulsing at 900 to 1000 cycles per second, a non-pulsing light will not activate the fuse and it may be used during daylight or at night.

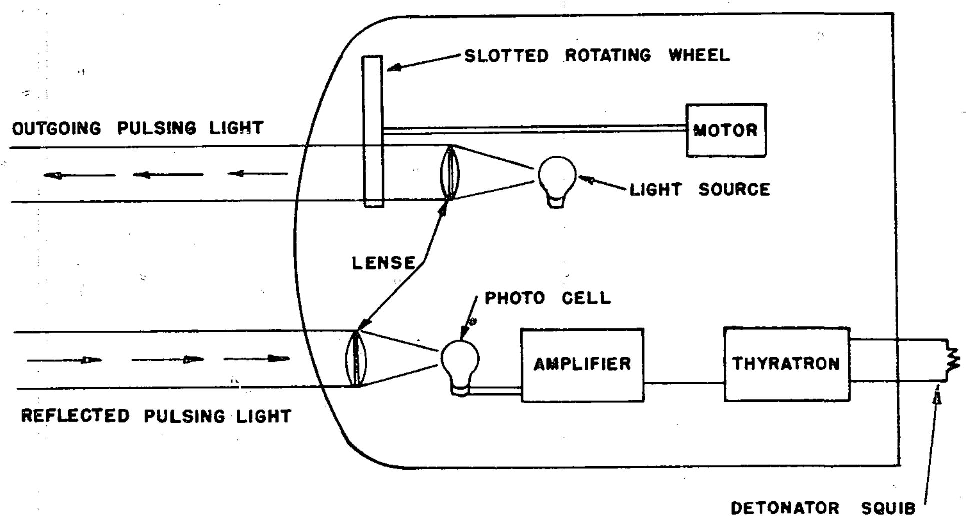

Figure 2
BLOCK DIAGRAM OF TYPE THREE FUSE

DESCRIPTION OF TYPE 3 PHOTOELECTRIC INFLUENCE FUSE

As shown in the photographic Figures 3 and 4, the casing of the influence fuse is about 13 inches high and 10 inches in diameter. The device is painted black, and has three transparent glass windows in the forward end, one about five inches in diameter, and two about two inches in diameter. There are two electrical three-prong sockets near the base as well as a fitting for an arming turbine-type propeller. A hinged door, about three inches by three inches, is located on the side of the casing.

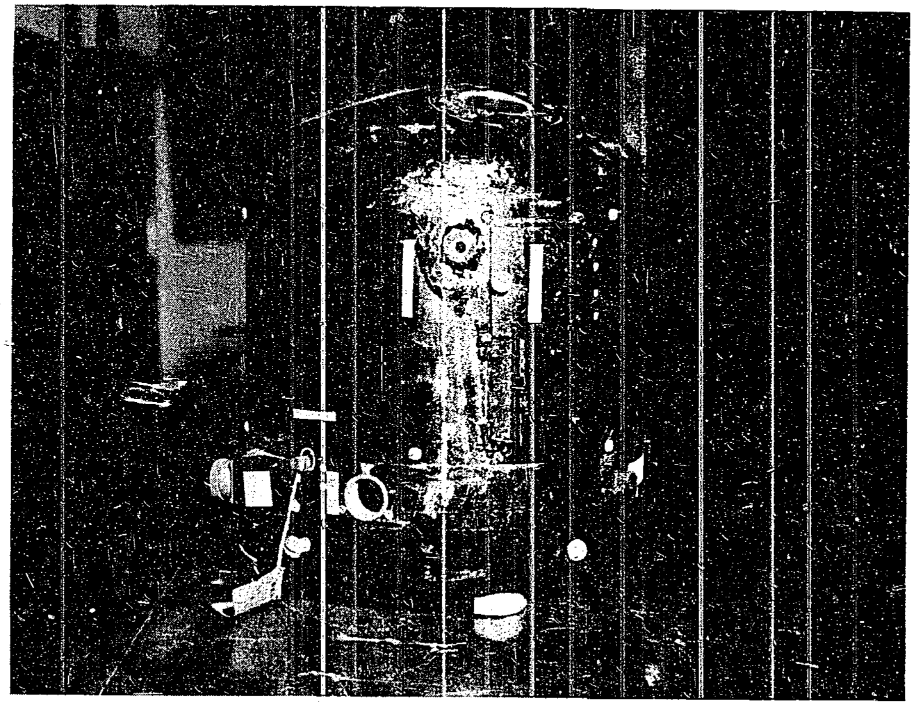

Figure 3, Above:
Side View of Type 3 Fuse

Figure 4, Left:
Top View of Type 3 Fuse

Figure 5 shows (looking down on the fuse) some of the external safety devices.

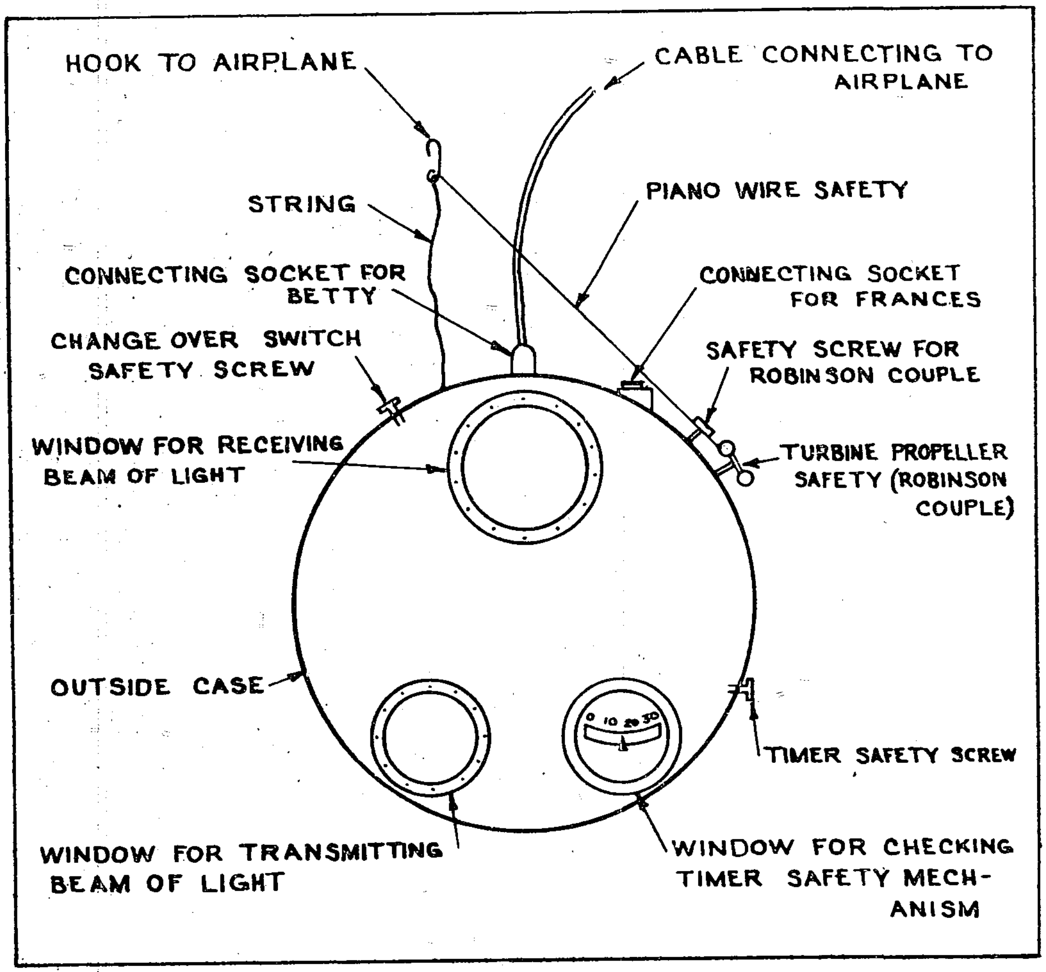

Figure 5
EXTERNAL SAFETY DEVICES OF FUSE

DETAILS OF OPERATION

The following steps are listed in the chronological order in which they would occur, from the time the fuse was unpacked, until it detonated over a target:

1. After the fuse is removed from its packing box, remove the base plate by unscrewing three screws.

2. Unscrew all screws with red circles.

3. Remove turbine-type propeller and install.

4. Install 12 volt and two 67.5 volt dry batteries by making connections to binding posts and replacing supports (screws with red circles).

5. Remove hood of fuse case by unscrewing 12 screws on side and install vacuum tubes and photo-cell and replace hood.

6. Set grid bias of XB 767 at five volts, and insert plug leading to squib into test meter. Vibrate fuse by hand and observe no deflection of meter needle if fuse is satisfactory. Cease vibration and set grid bias of XB 767 A at 12 volts.

7. Adjust timer according to predicted height of drop (normally to 15 seconds) by disengaging timer switch and by turning wheel.

8. Install safety pin on timer.

9. Replace base of fuse with wooden supports still mounted.

10. Install piano safety wire by inserting one end in turbine propeller and attaching other end to connecting string.

11. Plug fuse cable into bomb detonator socket, and secure fuse to bomb by screws.

12. Place complete bomb or bombs in airplane bomb rack. Type 1 bomber (BETTY) can carry four 250 kg, or one 800 kg bomb, and GINGA bomber (FRANCES) can carry two 250 kg, or one 800 kg bomb.

13. Connect 12 volt plug from airplane to three prong plug socket of fuse. If Type 1 bomber, use recessed socket. If GINGA bomber, use protruding socket.

14. Connect piano wire and string from fuse to airplane.

15. See Figure 6. Bombardier operates control board as follows. Turn main switch to "ON". Set bomb switch to bomb "1" position and turn bomb switch "1" to "ON". If all is well, should get half scale deflection on d.c. ammeter of control board. Turn bomb switch "1" to "OFF" and test bombs 2, 3, and 4 similarly, and then turn all switches on control board to "OFF".

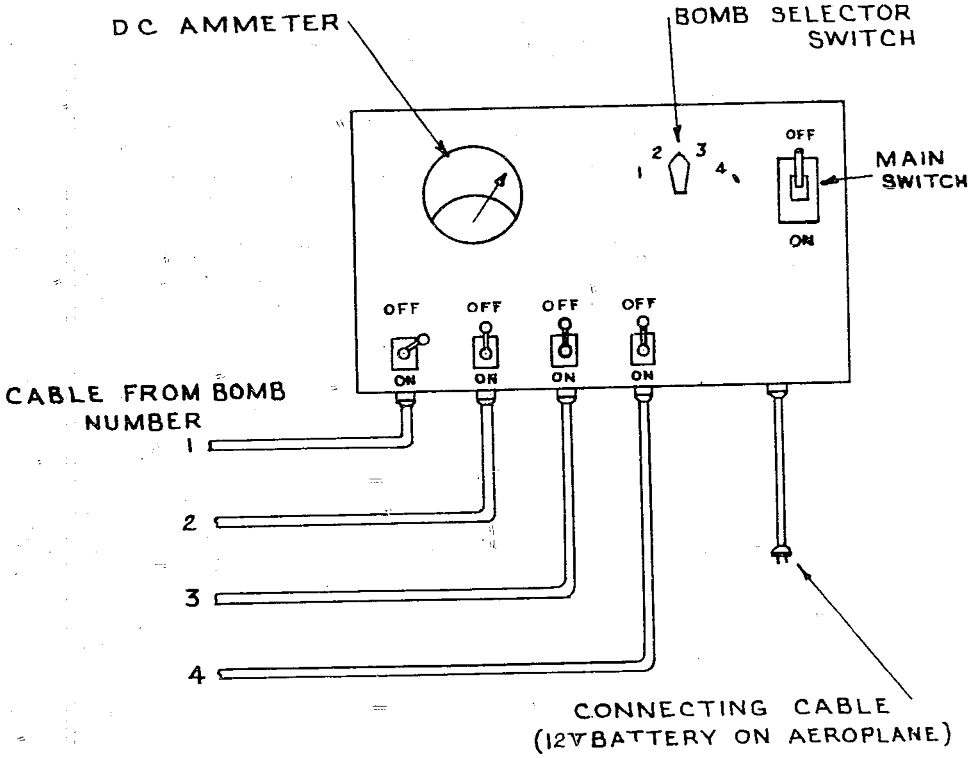

Figure 6
CONTROL BOARD IN AIRPLANE

16. Remove red-topped safety screw near turbine propeller.

17. Remove turbine propeller safety pin.

18. Remove timer safety pin.

19. Plane takes off.

20. About one minute prior to coming over target, bombardier preheats tube filaments by turning main switch of control board to "ON".

21. Release bomb.

a. String tension changes position of change-over switch so that 12 volt and 135 volt power is available to fuse.

b. Piano wire separates from bomb, and allows turbine propeller to turn and fall off.

c. Twelve volt supply plug from plane disconnects.

d. Motor starts turning and fuse light goes on. After motor turns for 15 seconds (depending on zero to 30 second setting) all safety controls are removed and high voltage is on tube plates.

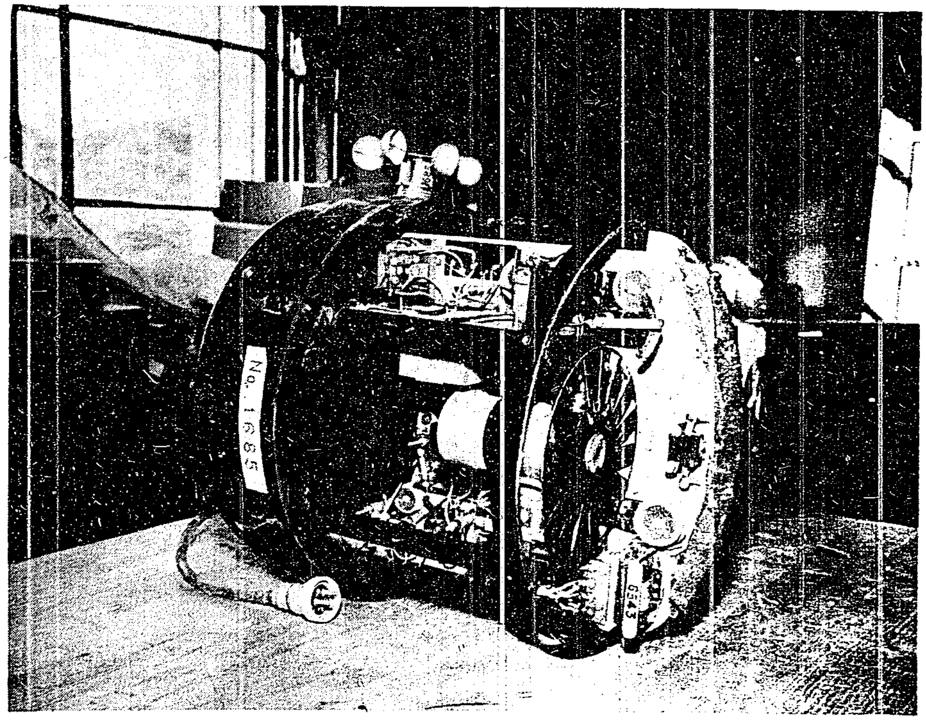

Figure 7
View of Fuse Showing Disc With Slotted Segments For Making Pulsed Light of About 1000 Cycles per Second.

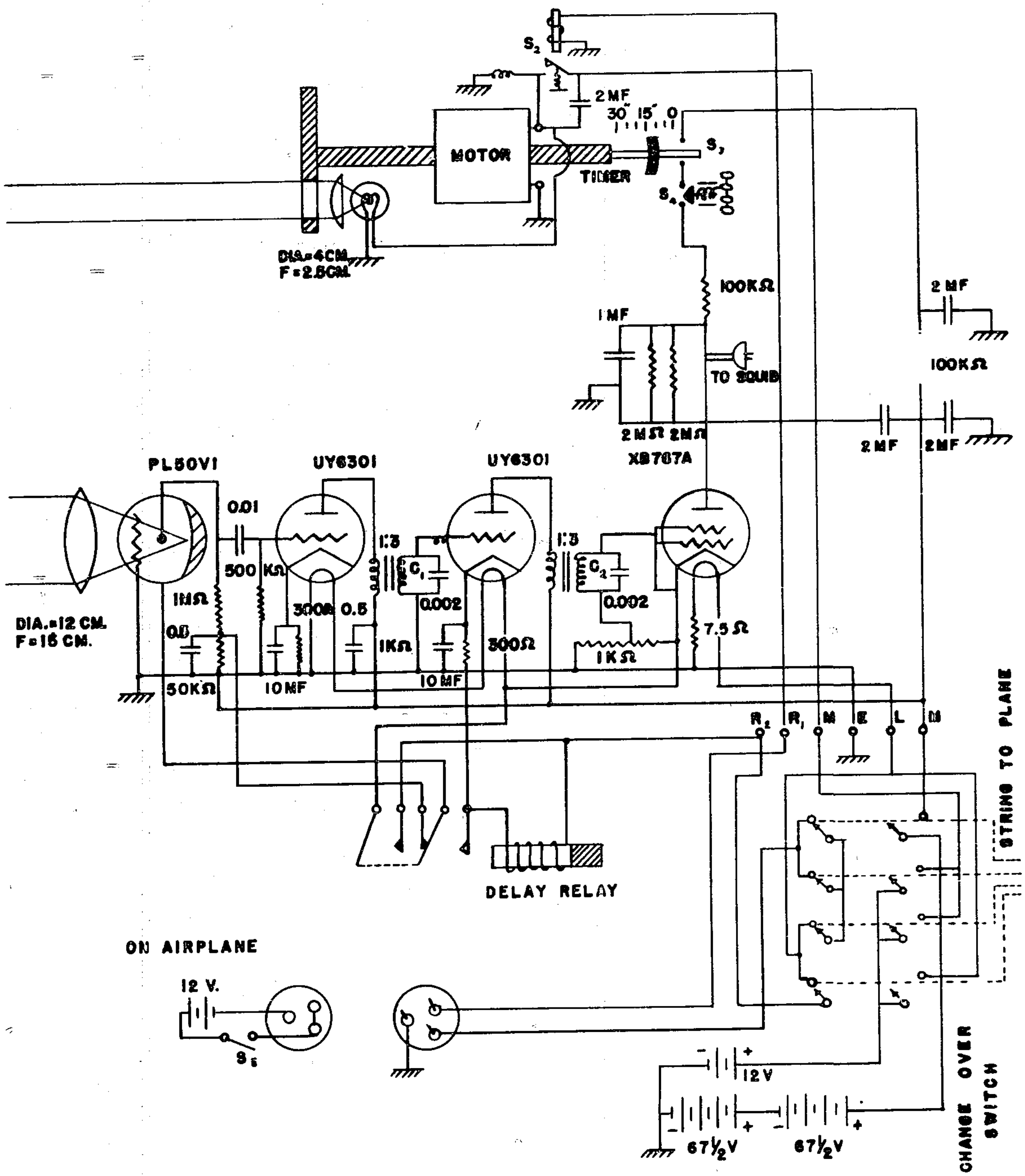

Figure 8
ELECTRONIC CIRCUIT AND MECHANICAL DETAILS
OF TYPE 3 FUSE

ELECTRONIC CIRCUIT AND MECHANICAL PARTS

A. Source of Pulsed Light.

Figure 8 shows schematically the essential elements of the influence fuse mechanism. The light source is a 50 watt 12 volt lamp. To obtain an intense parallel beam of light a collimating lens of 4cm diameter and 2.5cm focal length lies forward of the lamp. In front of the lens is a disc with slotted segments (see Figure 7). The disc is rotated through a gear by a 6 watt 12 volt d.c. motor turning at 3600 rpm. The slots and gear are so designed that a pulsing light of about 900 to 1000 cycles per second is transmitted for reflection.

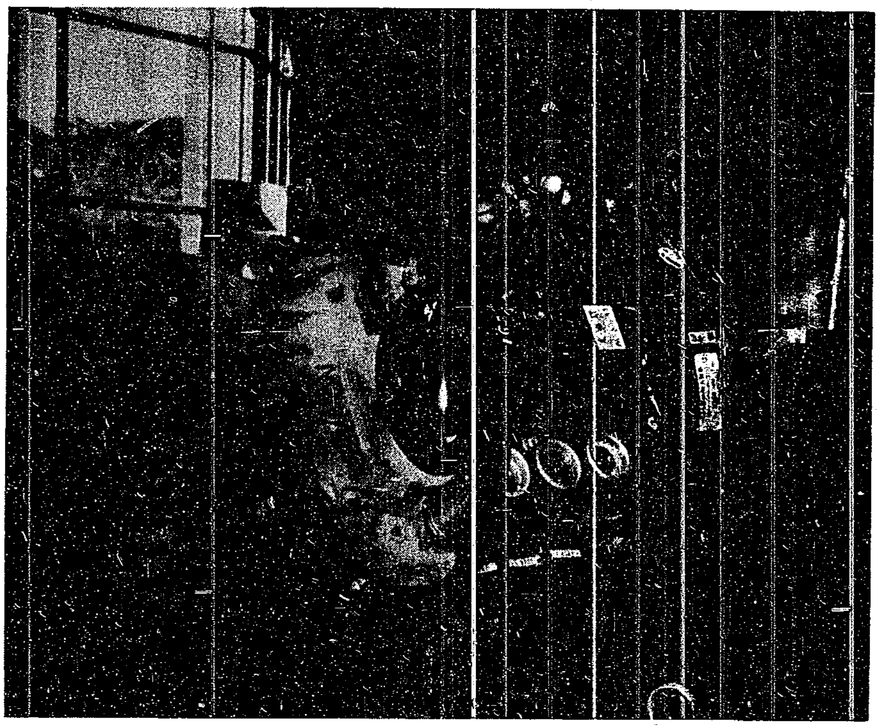

Figure 9
View of Fuse Showing Lens in Front of Photocell and the Vacuum Tubes.

The lens in front of the receiving photocell has a 12cm diameter, a focal length of 15cm and concentrates the reflected light on the photocell PL 50 V1.

B. Vacuum Tubes Used.

The cesium grid type photocell PL 50 V1 was especially designed for use in the Type 3 fuse, and was manufactured by the MAZUDA Co. at KAWASAKI near YOKOHAMA. Its physical characteristics are as follows:

Maximum length	107mm
Maximum diameter	50mm
Diameter of window	40mm
Length of socket pins	14.5mm

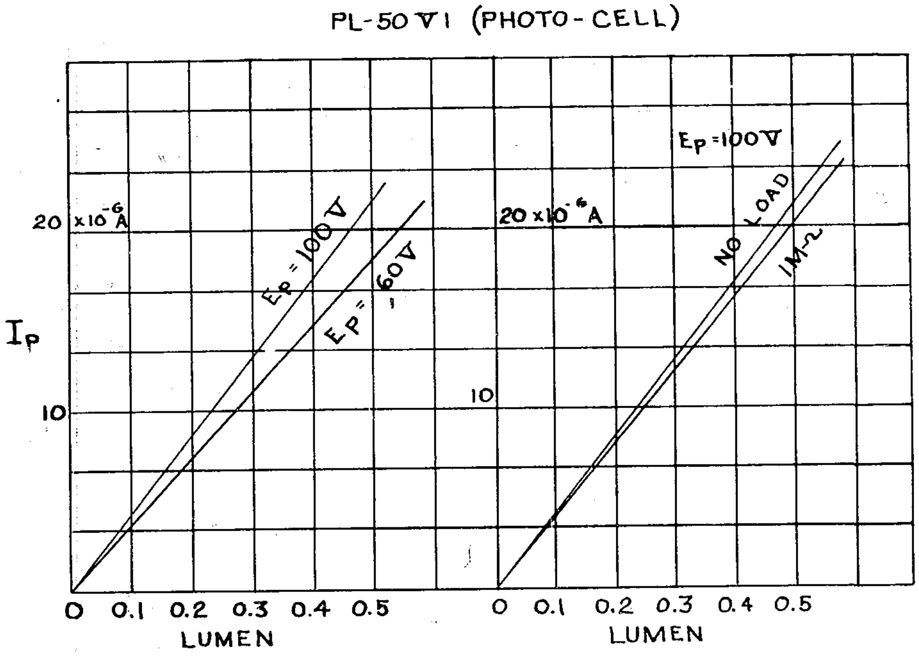

Figure 10
THE RELATION OF CURRENT AND LIGHT INTENSITY AT DIFFERENT VOLTAGES AND LOADS FOR THE PL-50VI

Some electrical characteristics of the PL 50 V1 are shown in Figure 10. The amplifying triode used in the first and second amplifying stages was also manufactured by the MAZUDA Co., and was said to be very similar to the RCA Radiotron 6301. It had the following characteristics:

Maximum length	105mm
Maximum diameter	38mm
Vf	6.3 V
If	0.6 amp
Vp	250 V
Vg	1.5 V
Ip	9 ma
μ	100
Rp	13000 ohms
Gm	7700 u mhos

The argon thyratron XB 767 A was especially developed to be free of vibration difficulties for use in the Type 3 fuse, and was manufactured by SUMITOMO Co. (TOKYO). It had the following characteristics:

Maximum length	105mm
Maximum diameter	38mm
Cathode tetrode type preheat time	30 seconds
Working temperature	15° to 35°C
Vf	6.3 v.
If	0.8 amp
Maximum peak anode current	300 ma
Maximum average anode current	60 ma
Maximum peak inverse voltage	700 v.
Maximum peak forward voltage	350 v.
Maximum voltage drop in tube	20 v.

Arc Characteristics

Control grid voltage	0 v.	1.6 to 2.9 v.	2.6 to 4.8 v.	3.5 to o.5 v.
Anode voltage	50 v.	100 v.	300 v.	500 v.

The couplings between the first and second amplifying tubes and the thyratron are tuned to 900 to 1000 cycles per second, and the overall amplication was said to be 80 db.

C. Batteries and Lamp.

The filament battery was required to have a capacity of 10 ampere hours, and for acceptance was tested at 10 amperes for 10 minutes. The vacuum tubes function satisfactorily on 11.0 volts, but lamp and motor each required at least 11.5 volts.

The lamp for the light source was designed for a one hour life rating, and, in spite of its 50 watt rating, gave 170 candle power, although the ordinary auto headlight lamp of 50 watts will give only about 40 candle power.

D. General Basis of Operation and Safety Features.

In trying to develop the Type 3 fuse so that it would be sensitive to the necessarily very small change in light intensity, a device extremely sensitive and somewhat dangerous resulted. Thus it is understandable why so many safety features were introduced into the final form. These safety features may be pointed out in going over the operation and referring to Figure 7.

Before a plane takes off with Type 3 fused bombs, three external safety pins must be removed: (1) timer safety pin, (2) safety pin in turbine propeller and (3) change-over switch safety pin. Switch S_1 (Figure 7) is closed a very few minutes before coming over the target. But since this is only for preheating the filaments of the vacuum tubes from bomber-carried batteries, safety is assured since no high voltage may reach the tube plates. As the bomb falls, the string attached to plane and fuse closes the change-over switch. But still there is little danger to the bomber, for several operations must occur before the fuse will detonate the bomb even if a properly pulsed light intensity change occured near the fuse. The string closing the change-over switch first de-energizes the solenoid and allows switch S_2 to close. This starts the motor but still two more switches, S_3 and S_4, must close before plate voltage reaches the tubes. Switch 4 is closed when the turbine propeller spins off. Switch 3 closes when the motor has turned the timer wheel the previously selected time between zero and 30 seconds.

COUNTERMEASURES

At first thought one might suggest that a search-light pulsed at the proper frequency could cause the detonation of a Type 3 fuse, but it must be realized that the fuse will not be sensitive to such light until the timer switch S_3 (Figure 7) is closed. If the height from which the bomb is to be dropped is known sufficiently accurately at the time the timer on the fuse is being set, the period during which the bomb is capable of being activated by a pulsed search light may be minimized so as to make searchlight detonation impracticable. The Japanese stated that they had not tested any countermeasures procedure on the fuse, but believed it was a quite formidable weapon in this respect.