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EXPOSURE OF MEN TO INTERMITTENT PHOTIC STIMULATION UNDER SIMULATED IFR CONDITIONS

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The medical literature is replete with apocryphal, anecdotal and documented reports dealing with the problem of alteration of consciousness, disorientation, nausea, distraction, annoyance or other symptoms related to flashing or flickering lights in the environment. The possibility of a compromise of air safety by such an effect has naturally stimulated several investigators to examine the problem as it exists in the aviation environment.

The problem was brought into focus by a question raised by Burnham [5] regarding the possible effects on epileptic passengers of sunlight being chopped by helicopter rotors. Van Wulfften Palthe, in reply to Burnham's query, pointed out that the small number of light sensitive epileptics probably did not warrant a general warning to the public about the possible effects of flicker in helicopters, but that elipeptics should be warned by their physicians of the danger of having a seizure thus triggered. Berry and Eastwood [2] quote a personal communication from a helicopter passenger who was incapacitated inflight by sunlight flickering through a helicopter rotor. These authors also cite two cases of photically-induced *grand mal* seizures; one was a B–36 tail gunner who looked at the sun through a propeller while in flight and another was a pilot standing on the ramp who looked at the sun through a propeller of a C–54 while the airplane's engines were being shut down. Franks [8] described one incident of pilot syncope encountered while landing into the sun.

Johnson [11] studied 102 Navy helicopter pilots and found that 25 of them were bothered by flicker while inflight, though none had ever terminated a flight for that reason. The principal complaints occurred as a result of operation in or near clouds. One pilot felt that flicker contributed to a near accident. Electroencephalographic examination revealed abnormalities in only two of the subjects. Twenty-two of the pilots became drowsy or went to sleep during photic stimulation in the clinic and their EEG's were compatible with a lowered state of vigilance. None showed paroxysmal activity during photic stimulation. Others [9] have reported similar findings when subjects were exposed to flashing lights, though they attributed the drowsiness to the nature of the task rather than to a specific effect of intermittent light stimulation.

Watson and Hunter [22] reported that 5 of a group of 100 airplane pilots showed abnormal EEG's in response to flashing lights; 8 complained of annoyance by propeller flicker, 2 said discomfort was accompanied by confusion, and 12 reported being distracted by the rotating beacon. These authors recomended that all pilots and trainees be tested for light sensitivity and those found sensitive should be excluded from flight operations.

Aitken, Ferres, and Gedye [1] exposed 10 subjects to flashing lights of different frequencies and allowed the subjects to express a "preference" for one frequency, thus establishing the least annoying rate of flash. The highest preference was for the lowest test frequencies of 1 and 1.33 flashes per second. These investigators further found that change in skin conductance was linearly related to the flash frequency. Johnson, Ulett, and Gleser [12] also found that the frequency range of 8.5–24 flashes per second was most effective in establishing a photic driving response in the EEG. These workers also reported that there was no correlation between the amount of resting activity and that evoked by photic stimulation.

Orlansky,[17] in a review of the literature, reached the conclusion that the behavioral effects of photic stimulation were shown primarily by epileptics. He further expressed the opinion that such epileptics only show the effect in the laboratory, and then only when resting and cooperating in the experiment. Orlansky was of the opinion that flashing lights pose a negligible threat to normal people.

It seems clear from the literature that a variety of symptoms ranging from annoyance to *grand mal* seizures can be precipitated by flashing lights. The purpose of this study was to determine whether or not a group of normal young men showed any electroencephalographic changes during and following photic stimulation as it might occur in flight.

I. Method.

Ten young men, all volunteers, who had no history of syncope or seizure were exposed to intermittent photic stimulation at each of three frequencies.

All experiments were carried out in a Beechcraft Bonanza cockpit that was situated in an environmental chamber. Six channels of monopolar EEG were recorded together with lateral and vertical electro-oculograms. Frontal, parietal and occipital leads were attached to the scalp conventionally over each hemisphere. The leads on each side were referenced to the ipsilateral earlobe. Leads were also attached at the outer canthi and above and below the eyes. Airplane engine noise, taped in the cockpit of a Beechcraft T–34, was played back through a speaker located in the mockup cockpit throughout each experiment. A red fixation light was mounted on the instrument panel, which otherwise was empty. The EEG's were recorded on a Grass Model VI electroencephalograph located outside the chamber. The terminal board was attached to the back of the left seat, directly behind the subject. The connecting cable was passed through a small port in the chamber. One occipital channel was recorded on magnetic tape for computer analysis. The chamber walls were draped with black velvet, insofar as practicable, to reduce reflections. The mockup and a subject are shown in Figure 1.

A Grimes red rotating beacon and an Air-Guard Strobe Light were mounted on the top of the mockup, out of the subjects' direct vision. The anti-collision lights were powered from outside the chamber. A 36 inch aluminum propeller was mounted to the shaft of a large floor-stand electric fan and placed in front of the mockup. A 200 watt incandescent lamp was mounted behind the propeller.

The Grimes light yielded a flash frequency of 1.5 fps, the strobe light a frequency of 1.0 fps, and the propeller a flicker of 10 fps, as determined with a stroboscope.

The chamber could be filled with fog by cooling it to 60° F and then releasing steam into it; the steam, upon condensation, raised the temperature to 70° F, where it was maintained.

Experiment I with the Grimes light was divided into two parts, with fog and without fog. Each part was divided into three 10 minute phases, (1) in the darkened room with no beacon, (2) in the dark with the beacon, and (3) a recovery period in the dark with the beacon off.

Experiment II with propeller flicker was carried out at the same location as previously described. However, in this experiment the room was lighted and no fog was introduced. The subject sat in the cockpit as before looking through the propeller at the light.

Experiment III with the strobe light was carried out under the same conditions as Experiment I, except that the part without fog was omitted.

The collected records were examined by a neurologist-electroencephalographer who rendered an opinion as to the relationship of the stimulus to the electroencephalogram and as to the clinical normality of the record.

The taped channel of occipital EEG was subjected to power spectrum analysis in a computer. Filtering, in this case, was done to reveal shifts in alpha rhythm.

II. Results.

Analysis of the records taken in Experiment I revealed no evidence of seizure, no nystagmus, and no photic driving. Three of the subjects reported that they became drowsy during beacon stimulation; these reports were compatible with their EEG's. Two of the subjects had physiologically abnormal EEG's, with the abnormalities showing up in all experimental phases, but all records were clinically normal. The abnormalities consisted of a shifting occipital asymmetry in one case and 1–3/sec high voltage slow waves in the other. In the latter case, the cause of the slow changes could not be identified but there was no behavioral correlate; it was felt that it was possibly an artifact related to some sort of field change. Two other subjects volunteered their opinion of the beacon. One said it was annoying, the other said he was bored. One subject felt that he may have slept in the pre-

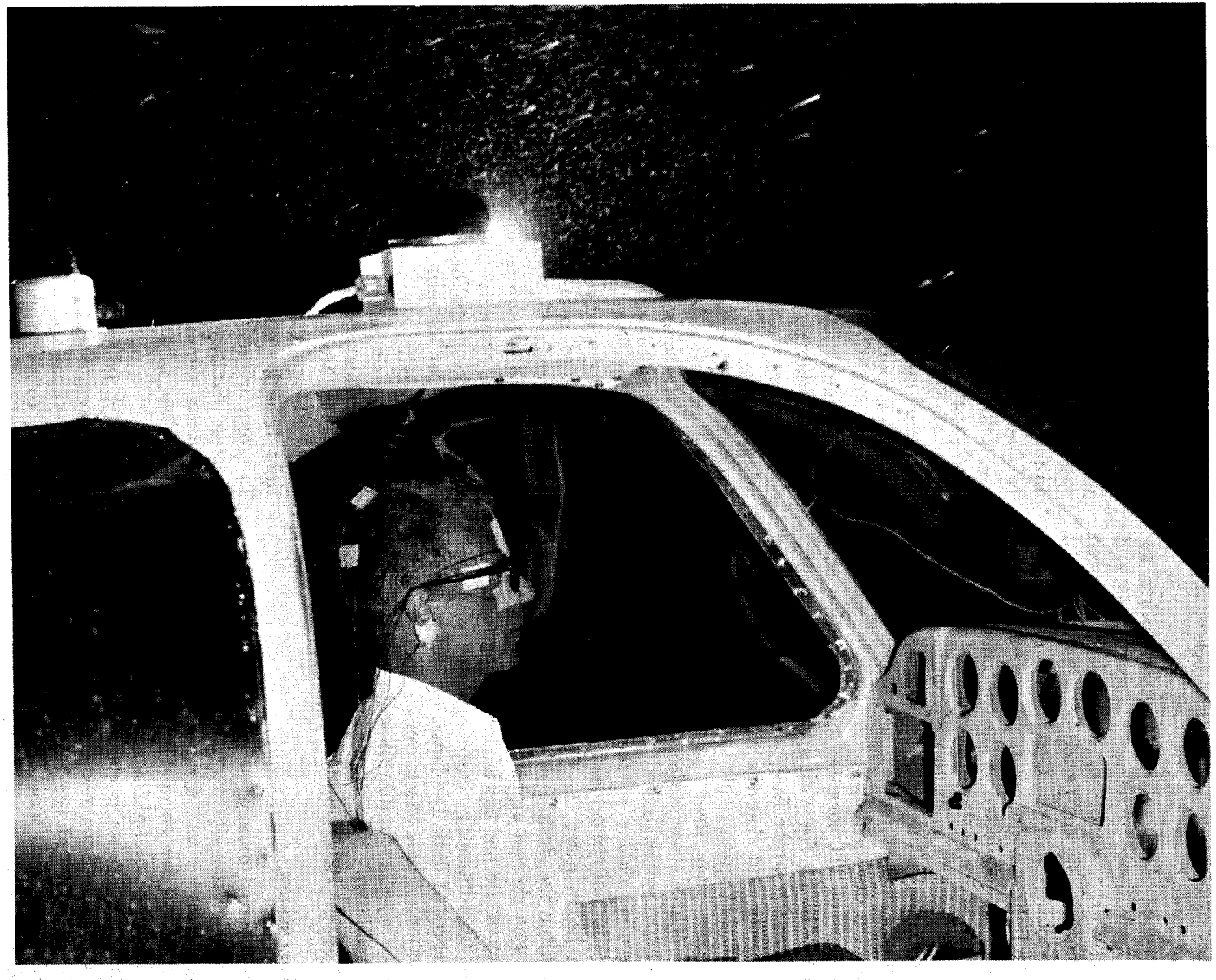

FIGURE 1. Subject seated in the Bonanza cockpit mockup. Steam has just been introduced into the chamber and is beginning to condense above the cockpit.

stimulation period in the fog. His EEG confirms his impression.

The computer analysis of one occiptal record showed a shift in the power of alpha from a frequency of 10/sec to 8/sec during beacon stimulation in the fog.

Experiment II, involving a 10/sec flicker, revealed no evidence of seizure, no nystagmus, and no photic driving. Six of the subjects reported drowsiness during the period of stimulation and in the recovery period. One subject complained that the light was annoying. Three subjects who claimed to be unaffected by the experimental situation showed EEG slowing consistent with light sleep. Three of the six drowsy subjects showed sleep spindles. One other subject who claimed drowsiness showed parietal assymetry that was accentuated during flicker.

Experiment III consisted of stimulation at a frequency of 1.0 fps with a very high intensity, brief duration strobe flash in the fog. Seven of the subjects said that the light was irritating; three of that group stated that they could not have taken more than the ten minutes of exposure. Three other subjects said that they were not bothered by the light.

A peculiar pacing of the alpha rhythm was observed in 8 of the subjects (Fig. 2). The interruption began after the flash started and persisted after the flash had ended. Seven of the people who showed alpha pacing complained of irritation while one disclaimed discomfort.

The high-intensity flash apparently caused some degree of dark de-adaptation and pupillary constriction. These effects caused the instrument panel to appear to dim then brighten as the pupil redilated. The pupil pulsed at the frequency of the light but out of phase with it.

III. Discussion.

The reported cases of seizures precipitated by detuned television sets [3, 4, 13, 51, 18] sunlight passing through trees [6, 14] and flicking light switches off and on [10] have few correlates in aviation. If the same incidence of light-sensitive individuals exists among pilots as is claimed for the general population, then one would expect to find that 0.01% [9] to 6% [22] of the total number of pilots are affected. This means that 50 to 30,000 of the 500,000 pilots in the U.S.A. should be sufficiently photically-sensitive that abnormal EEG's could be demonstrated. Medical certification statistics show that up through 1963, 113 pilots had been medically grounded by reason of epilepsy. If the accepted ratio of 5% [9] holds true in these cases, then about 6 of those 113 pilots should be photically sensitive.

The literature seems to establish that only peculiarly susceptible individuals are seriously affected by intermittent light.[7, 11, 17] The low incidence of such individuals in the population appears to be the chief reason why no accidents in-flight have ever unequivocally been attributed to flashing lights. One case reported by Tang and Dille [19] dealt with a general aviation pilot who experienced vertigo while taking off into the sun. He lost consciousness while attempting to land and crashed, but received only minor injuries. Laboratory studies revealed certain abnormal EEG features but no adverse effect of photic stimulation. The case was believed to be one of true labyrinthine vertigo.

It appears, further, from the literature that susceptible people are sensitive to only a narrow range of frequencies, generally between 8 and 30 flashes per second.[3, 18] Most flashing lights in aviation are below or above that range. Rotating lights and flashing strobe lights operate at a frequency between 1 and 2 per second. Propellers generally are turning at a higher frequency. A three-bladed propeller running at 2000 rpm would produce a flicker of 100 fps. Further, the airplane would have to be a single engine type and headed properly in order for the pilot to be behind the propeller and in the exact relation to the sun for his eyes to receive the flicker.

Further still, the intensity of the light apparently enters into the effectiveness of the stimulus, as indicated by some television-induced seizures.[4, 15, 18] Most anticollision lights are mounted out of direct sight of the pilot, thus the emitted light from his own plane is lost in the distance. In fog, when back-scatter is produced, the greatest liability occurs.[11] The experiments in this study showed clearly that the subjects only complained of annoyance by the lights while in the fog.

Finally, laboratory studies have shown that photically-induced paroxysms occur most readily when the eyes are closed and the flash frequency is close to the resting rhythm,[16,17] a condition not likely to occur under IFR conditions at night. The flight task itself might interfere with the triggering of seizures in pilots.

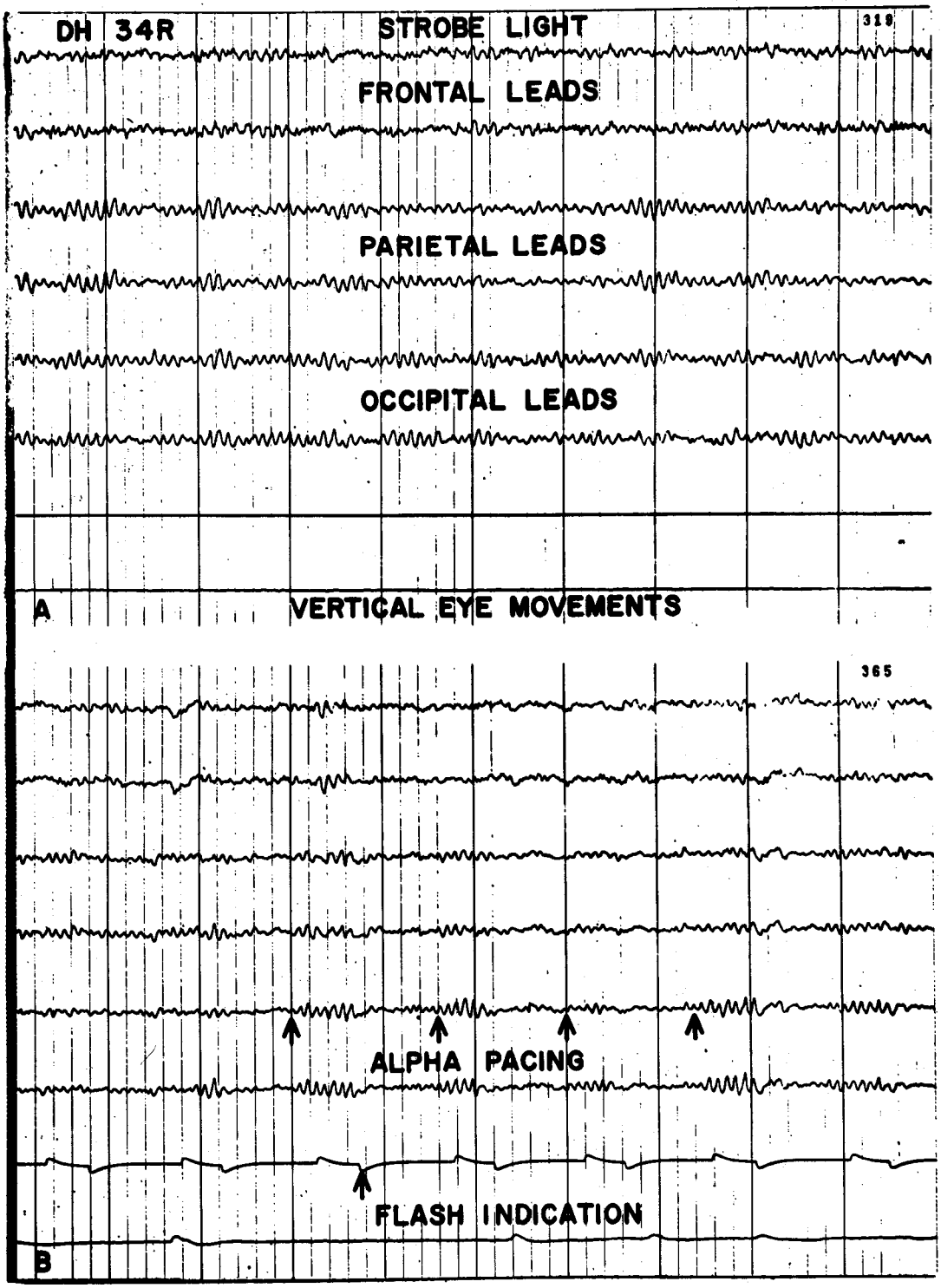

FIGURE 2. A characteristic segment of a record taken before (A) and during (B) strobe light stimulation. Alpha pacing is shown best in the occipital leads. Lateral eye movements were not recorded during this particular experiment so that the flash could be indicated on that channel. Flashes were indicated by manually pressing the calibrate button on the recorder; thus, the deflections indicate the onset of the flash but do not indicate its duration which was only a few milliseconds. Note that the subject looks up slightly with most flashes, as indicated by the small deflections of the vertical eye movement recording in (B).

When all of these factors are taken into consideration, the statistical probability of a susceptible pilot encountering just the right intensity of light at just the right time is very slight.

Factors operating to increase susceptibility to flicker or flash are anxiety,[21] repeated exposure [20] and fatigue.[11]

The results obtained in this study are in general agreement with those in the literature that the primary response to photic stimulation by normal subjects is drowsiness. That sensation is borne out by the subjects' EEG's. It is difficult to decide, however, how much of the drowsiness was due to the warm moist darkness and boring nature of the task and how much was due to the flashing lights. In several of the cases, drowsiness preceded the period of light stimulation and the beacon caused arousal. In other cases, drowsiness began in the pre-stimulation phase and progressed to light sleep during stimulation. Other workers [9, 17] are of the opinion that little of the drowsiness can be attributed to the light. In our population there was no photic driving of the EEG by either the Grimes beacon or the propeller-chopped light and no EEG abnormalities emerged during the period of stimulation. In one case parietal asymmetry appeared to be accentuated by propeller flicker. The strobe light did produce a peculiar pacing of some of the subjects' alpha rhythm. This interruption of the resting alpha began after the flash was over and lasted for about 1/3 of a second. Pupillary constriction and redilation together with some dark de-adaptation produced a visual sensation of fading and brightening of the surroundings. Since this light is of such a high intensity, these responses are not unexpected. In fact, they are most likely related to the experimental situation. It was not possible to drape the room completely; reflections from the floor and ceiling threw a great deal more light into the cockpit than one would normally expect in-flight.

The strobe light was also the most irritating of the three forms of stimulus. That property may be desirable since the purpose of these lights is to attract the attention of other pilots. In flight, the light would probably not affect the pilot of the aircraft on which it was mounted to the same extent that it did under these experimental circumstances.

The commonest complaint of pilots about anti-collision lights is annoyance. The manufacturers of these lights furnish a placard stating that the beacon should be turned off when flying in or near clouds (Fig. 3). Adherance to that recommendation seems to be the simplest solution to the commonest problem.

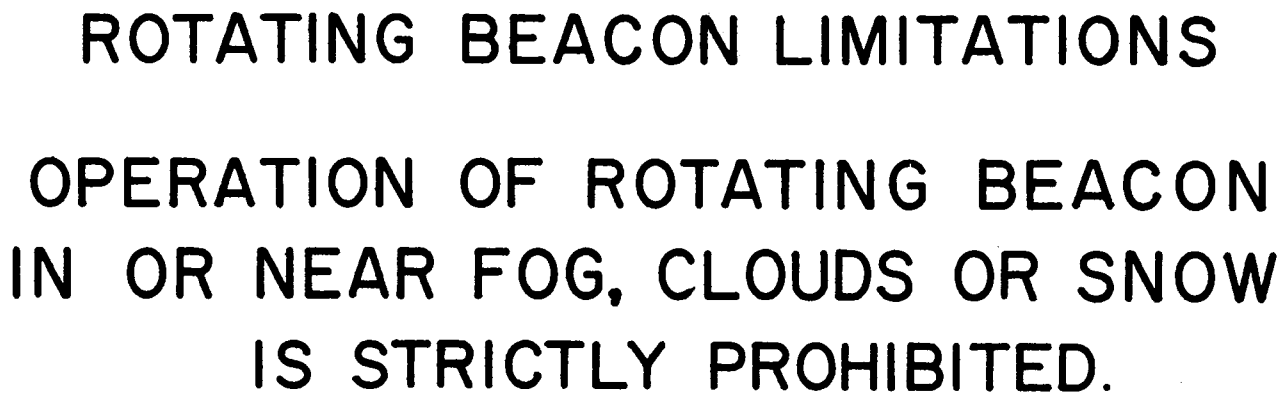

FIGURE 3. Placard furnished with red rotating beacon.

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