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NOAA Technical Memorandum NWS T&EL 10

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

Analysis of Cloud Sensors: A Manual Height Measurement System

Systems
Development
Office

Test and
Evaluation
Laboratory

Sterling, Va.

March 1971

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Test and Evaluation Laboratory. Observations Techniques Development and Test Branch.

NOAA Technical Memorandum NWS T&EL 10

ANALYSIS OF CLOUD SENSORS: A MANUAL HEIGHT MEASUREMENT SYSTEM

Prepared by the Staff,
Observation Techniques Development and Test Branch

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ABSTRACT

Cloud height reports are required at weather stations which make observations in support of aircraft operations. Many stations use automatic ceilometers for this purpose. Manual techniques (ceiling lights and ceiling balloons) are used as secondary systems for those stations and primary systems for the rest. This report discusses the limitations of current manual methods of cloud measurements, and introduces an updated manual system. The latter uses a small portable, manually operated electronic ceilometer. The system is described, and some experiences with installation and operation are discussed.

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LIST OF FIGURES

1.0 INTRODUCTION

The Systems Development Office has undertaken a project which has as its goal the development of objective measurements of aviation terminal weather. First steps within that program are directed toward collecting information about the performance of current sensor technology.

Responsibility for the project has been assigned to the Observation Techniques Development and Test Branch, part of the Test and Evaluation Laboratory. The work is being carried out in the laboratory facilities at the Sterling Research and Development Center, Sterling, Va. There, a variety of weather sensors are being assessed for their objective observation potential. Priority is being given to instruments that measure visibility and clouds.

Some results have been produced which are not directly aligned with the project goal of objective techniques. One such byproduct is the subject of this report; a manual technique for measuring cloud height. Although not fully evaluated, we are at this time bringing this technique to the attention of the field staff of the National Weather Service. Our purpose in doing so is to demonstrate early in our work that the problems of weather observing are being brought into focus; that solutions are being sought and found.

In this report a specific sensor is discussed in detail and some opinions expressed regarding its performance. Since our concern was primarily with the measurement technique and not the hardware involved, our comments cannot be considered a complete test and evaluation. We recognize, also, that there may be similar sensors on the market. Our comments, therefore, cannot be used as a measure of merit of the sensor discussed as compared to other similar products.

2.0 CURRENT MANUAL METHODS OF CLOUD MEASUREMENT

Aviation weather observations are taken at approximately 1,000 locations in the United States. National Weather Service personnel conduct the observational program at nearly 300 of these. Observations at the remaining locations are provided primarily by the Federal Aviation Administration and the airlines.

Cloud height observations are required at all locations which make observations in support of aircraft operations. For this purpose, reporting stations are equipped with cloud height measuring systems. The sophistication of the systems depends on the operating agency and air traffic density. Equipment is usually one or more of the following: automatic rotating-beam ceilometer (RBC); automatic fixed-beam ceilometer (FBC); ceiling balloon, and ceiling light.

As of February 1, 1970, the National Weather Service was responsible for 280 commissioned RBCs. Most of them were at National Weather Service facilities, the remainder at Federal Aviation Administration Flight Service Stations. Reporting stations without automatic ceilometers are required to use manual systems in accordance with Federal Meteorological Handbook #1 (FMH #1); ceiling balloons during day and ceiling light at night. In a memorandum dated Dec. 18, 1967, to National Weather Service Regional Directors, the Associate Director, Meteorological Operations, stated the National Weather Service standard on backup cloud height measuring equipment. He wrote, in part:

> "Where cloud-height measurements are required in support of aircraft operations, reporting stations should be equipped with two independent cloud-height measuring systems wherever such is feasible, as follows:
>
> (a) Each Rotating-Beam Ceilometer (RBC) system (including the RBC with dual detectors) should be supported by (1) a Fixed-Beam Ceilometer (FBC), or (2) ceiling balloons for daytime use and a ceiling light for nighttime use.
>
> (b) In the absence of an RBC system, each Fixed-Beam Ceilometer should be supported by ceiling balloons for daytime use and a ceiling light for nighttime use.
>
> (c) The minimum cloud-height equipment at an airport will be ceiling balloons for daytime use and a ceiling light for nighttime use."

Since FBC systems are being phased out, item (b) above has limited application.

2.1 Limitations of Ceiling Light

The ceiling light method of cloud height measurement relies on a vertically pointing light projector. In older systems the light source was an incandescent lamp with a peak intensity of 500 candela. Newer systems use a tungsten-halogen lamp with 1,300 candela peak intensity.

The observer, standing a specified distance from the projector, determines the visual elevation angle of the reflected light with a hand held clinometer. When a sky cover layer is present in the projected beam, he is required to center the cross-hairs of the clinometer on the brightest portion of the light beam spot. The cross-hairs are centered on the upper limit of the light beam penetration when the sky is completely obscured by a surface based layer. The observer must make three measurements, determine the average angular reading, and look up this value in an appropriate table to obtain cloud height. Ceiling light measurements have the same weight and significance, according to FMH #1, as those obtained with an automatic ceilometer. There are several limitations unique to the ceiling light. They are:

(a) The light can only be used at night.

(b) Background illumination from urban and terminal areas may make recognition of the reflected light difficult, or in some reported cases, "virtually impossible."

(c) Subjective judgment and skill are factors in the use of the ceiling light method.

2.2 Limitations of Ceiling Balloons

Ceiling balloons are usually 10-gram spherical balloons inflated with helium. Several colors are available, the choice based on the nature of the sky background against which the balloon is to be viewed. In some cases, larger pilot balloons inflated with hydrogen or helium may be used. These have a greater ascent rate and require a larger volume of inflating gas.

In operations, the observer releases the inflated balloon. Watching the balloon continuously, he determines the length of time that elapses between release and entry into the base of the clouds or obscuring phenomena aloft. The point of entry is considered as midway, in the observer's judgment, between the time the balloon first begins to fade and the time of complete disappearance. Ascent rate tables are used to determine the heights of layers aloft. Balloon measurements are given less weight and significance by FMH #1 than ceilometer, ceiling light, or pilot reports.

Problems with the balloon method include:

(a) Balloon rate of ascent is only assumed and may vary.

(b) Use of 10-gram balloons is limited to daylight only. Thirty-gram pilot balloons can be used at night with lights attached, but results are considered estimated heights rather than measurements.

(c) Uncertainty whether balloon enters side or base of cloud, or rises in clear area between cloud elements.

(d) Method cannot be used under many precipitation and wind conditions.

(e) Preparation of balloon, and ascent, are time consuming.

(f) Logistics problems. Storage of gas cylinders (possibly explosive) and need for a suitable inflation area present difficulties.

(g) Subjective judgment by the observer creates a problem in accuracy.

3.0 MANUAL METHOD OF CLOUD MEASUREMENT UPDATED

As part of our study of cloud measurement sensor technology, an automatic fixed-beam ceilometer was obtained from a German manufacturer. The manufacturer brought to our attention and made available for our use, another instrument which relied on a manual technique for cloud height measurement. The unit was a scaled-down, manually operated version of his automatic system.

3.1 Description of System

The Ceiloscope is a small, portable, manually-operated, fixed-beam ceilometer consisting of a projector and receiver (fig. 1). The instrument is manufactured by Impulsphysik GmbH, Hamburg, Germany. The manufacturer's U.S. representative is Dietrich Scientific Instruments, Inc., 642 Coral Drive, Cape Coral, Florida 33904. Approximate cost of a single system is $7,430* with a quantity discount of about 12%. Using the triangulation method of cloud measurement, the system is designed to measure cloud heights from 30 to 2,000 feet. The description and discussion of the system in this report is limited to the sensor originally furnished by the manufacturer. It is our understanding that later models have some modifications, none of which alter the measuring technique.

3.1.1 Projector

The projector is within an outer aluminum housing to protect the light source, optical system and power supply (fig. 2). The top part of the housing contains a circular clear cover glass, 12 inches in diameter, sloped to promote water runoff. A circular heater designed to melt ice, snow, and frost is mounted on the main frame under the cover glass. An adjustable thermostat controls the temperature.

The light source is a General Electric FT-230 Xenon flash lamp. The lamp power supply, which in the unit tested required 220 VAC, flashes the lamp at a rate of about 5 pulses per second. The manufacturer states that the projector can also be supplied for 110 VAC and 12 VDC. A 10", front-surfaced mirror with a 3-1/4" focal length, is used to collimate the light beam. Beam collimation is adjusted by removing the projector outer housing, and turning a control which moves the mirror vertically with respect to the lamp.

*Duty paid.

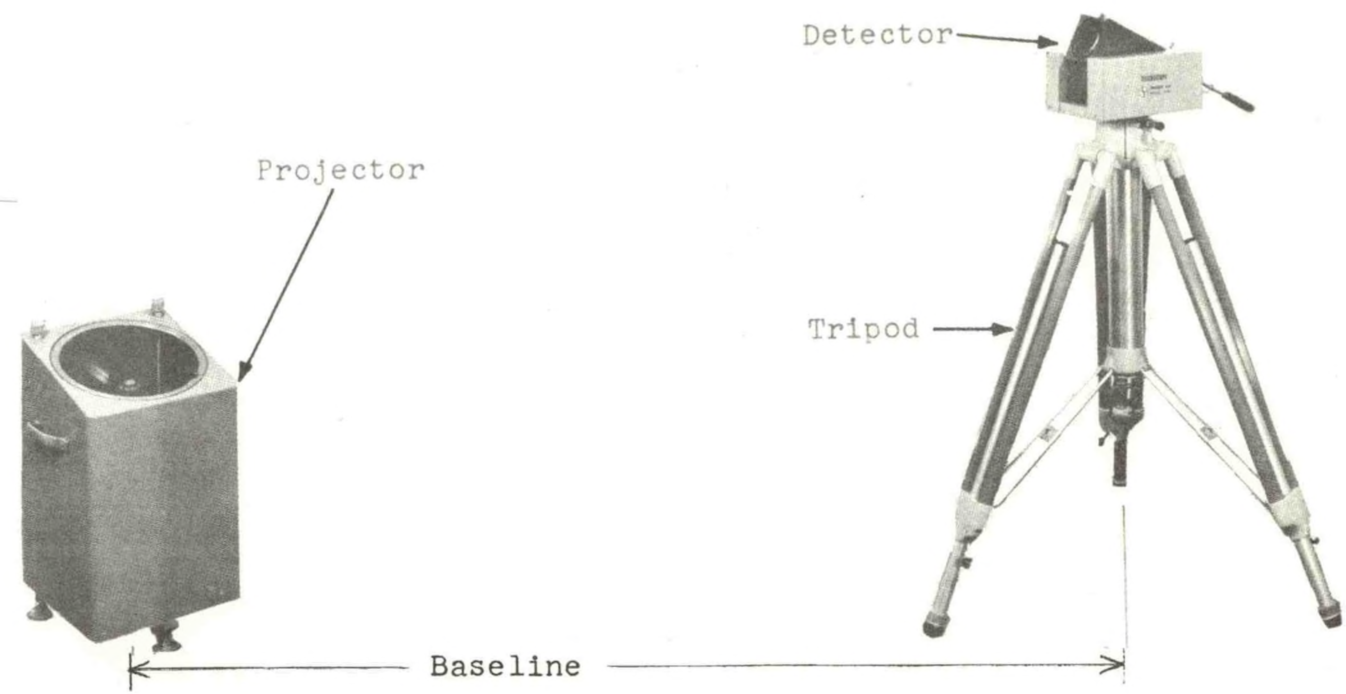

FIGURE 1. CEILOSCOPE SYSTEM

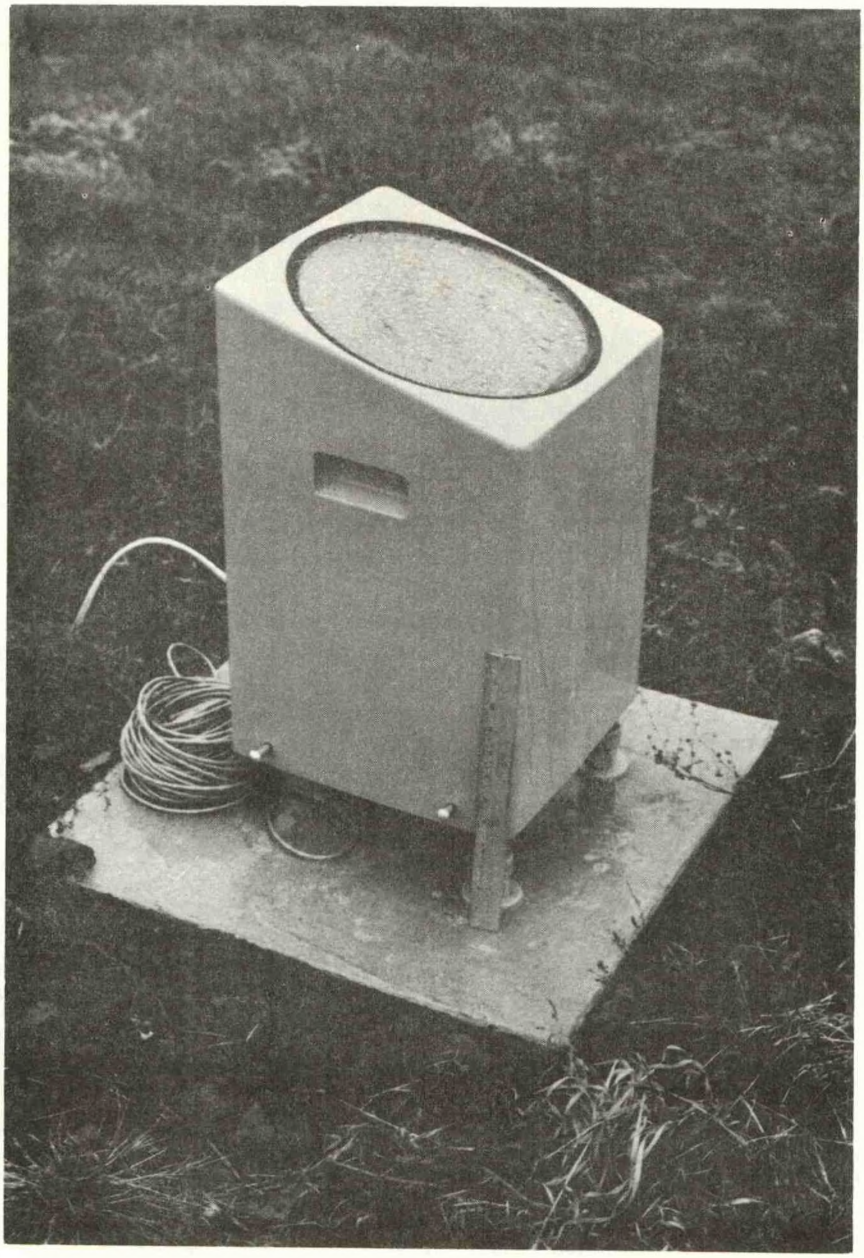

FIGURE 2. CEILOSCOPE PROJECTOR

The projector requires a near-level area about two feet square. It sits on three leveling feet with knurled adjusting nuts. A circular bubble level is mounted within the outer housing. The level is visible through the cover glass to permit leveling the unit without removing the outer housing. Since the Ceiloscope is considered portable equipment, there are no provisions for permanently installing the projector.

Overall dimensions of the projector are: height 23"; width 12-3/4"; depth 12-3/4". Weight of the unit is 70 pounds.

3.1.2 Receiver

The receiver consists of electronics, optics, and power supply compartments combined in a single unit (figs. 3, 4, and 5). The portable model we used came with a sturdy tripod. This item would not be needed in a permanent installation. The manual scanner is the central element in the receiver. It is hinged at the rear which allows it to be tilted to a 90° angle as it vertically traverses the projector beam. In its 0° position, the optics compartment sits atop a circular bubble level which is used to level it. When scanning, a handle is pulled from its stored position and used as a lever. This handle, in its extended position, also serves as a counterbalance. The electronics and power supply compartments are readily released for inspection or maintenance (fig. 6). Overall dimensions of the aluminum receiver housing are: height 6-1/4"; width 8-1/4"; depth 13". Weight is 25 pounds.

The objective lens is 3-1/2" in diameter and has a focal length of 11-3/4". The projected light, reflected from a layer aloft, passes from the objective lens down the scanner barrel to a front-surfaced mirror positioned at a 45° angle. The mirror reflects the light to a secondary lens which focuses the ray, through a rectangular aperture, onto a photodiode in the receiver. The diode is an EG&G type SGD-444. Spectral response is from 0.30 to 1.13 microns. This covers the entire visible spectrum plus parts of the infrared and ultraviolet. The spectral energy distribution of the projector Xenon lamp is within the response range of the photodiode.

The receiver amplifier is entirely solid state. It is made of integrated circuits mounted on plug-in module cards. The circuitry consists of a four-stage wideband amplifier, a white noise amplifier and monostable multivibrator for the output. The four-stage broadband amplifier is designed to recognize only pulses of light. This discriminates against noise received during daytime operation. The white noise amplifier controls the gain of the four-stage broadband pulse amplifier. The overall gain of the pulse amplifier is approximately 1,000. A sensitivity control serves the dual purpose of accommodating

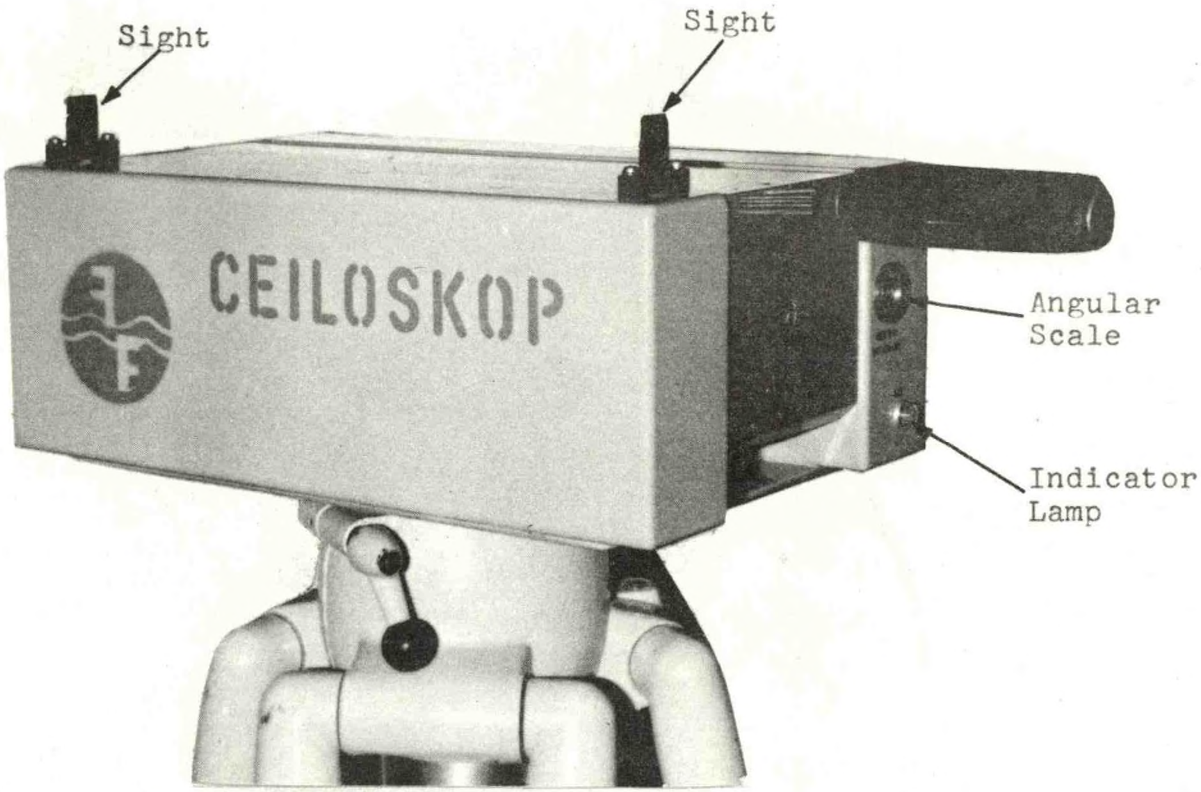

FIGURE 3. CEILOSCOPE RECEIVER

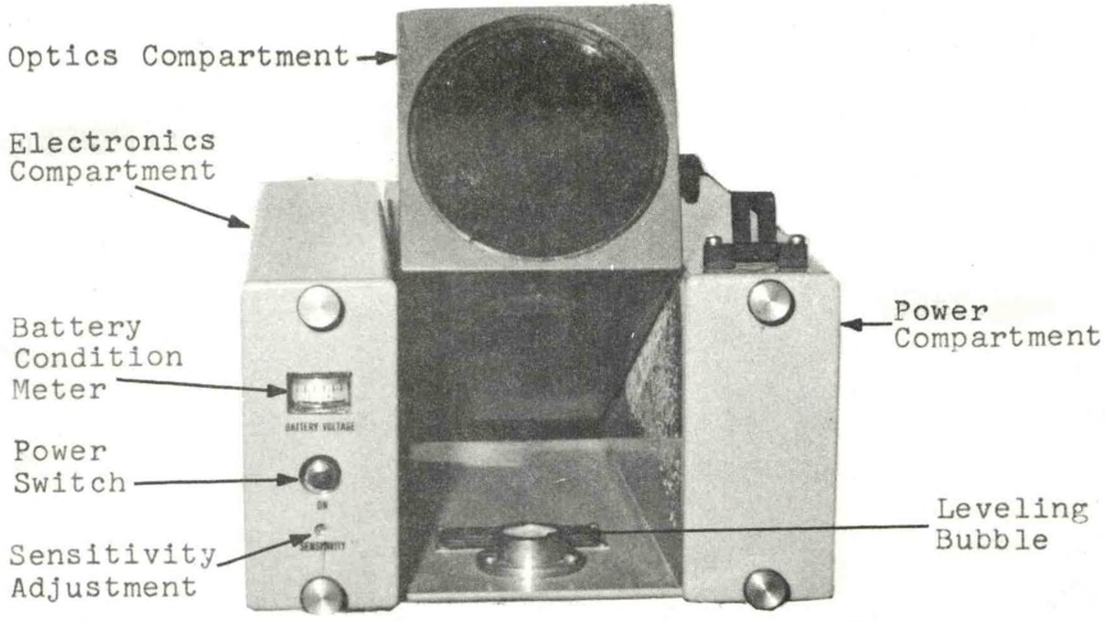

FIGURE 4. CEILOSCOPE RECEIVER, FRONT VIEW

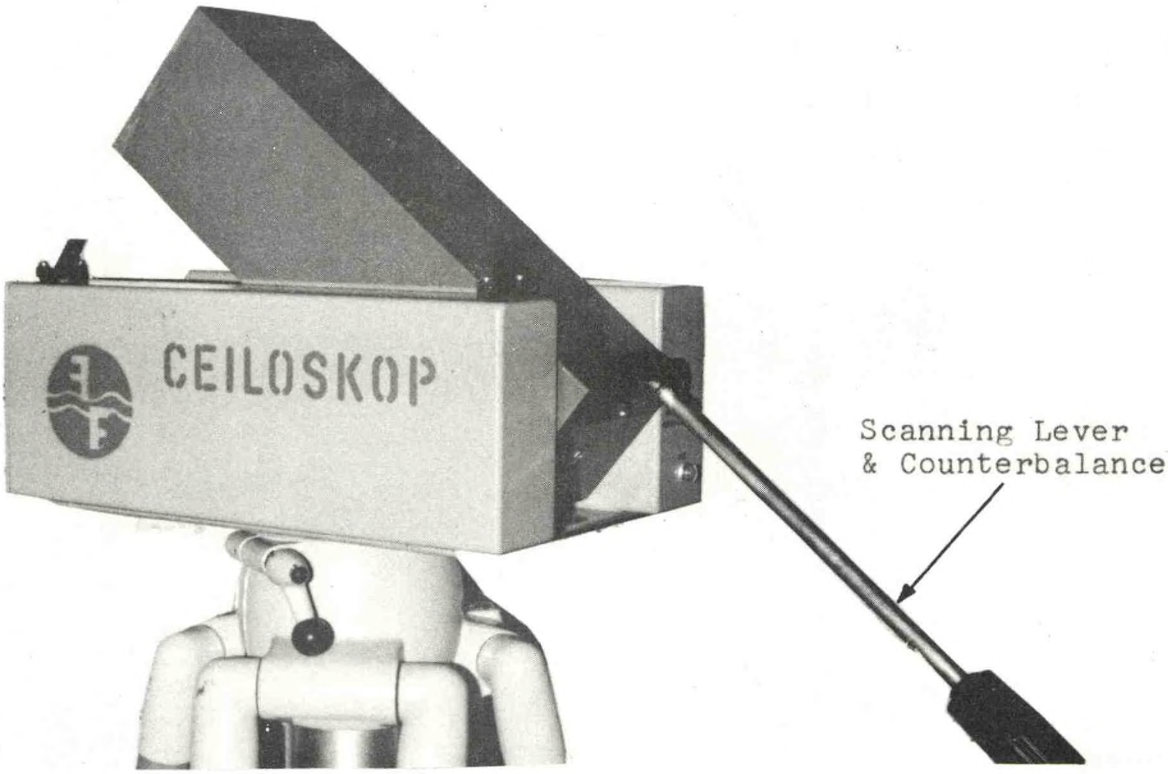

FIGURE 5. CEILOSCOPE RECEIVER, SIDE VIEW

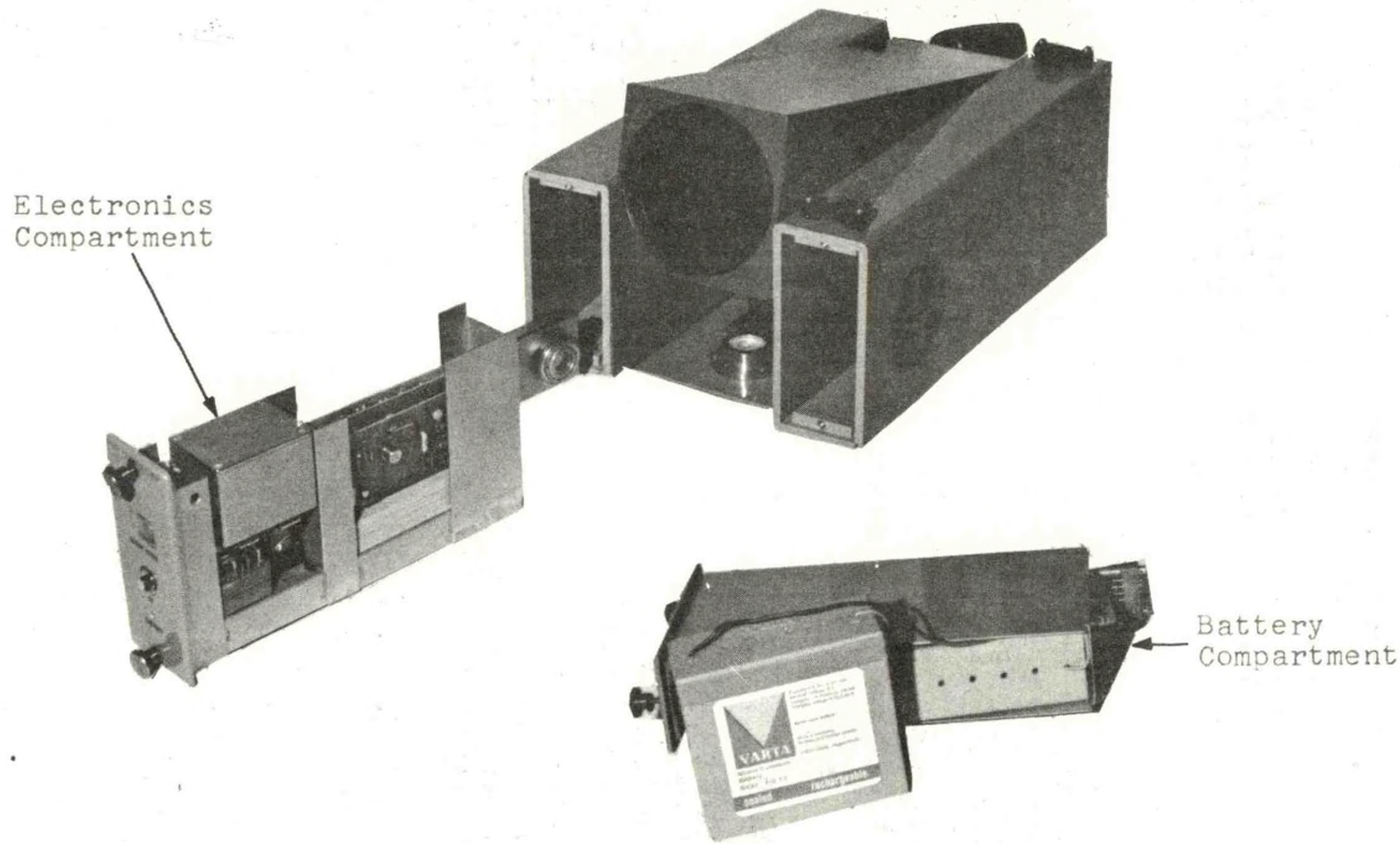

FIGURE 6. CEILOSCOPE RECEIVER, POWER AND ELECTRONICS COMPARTMENTS REMOVED

battery drain, and selecting a favorable signal to noise ratio. The pulse amplifier output triggers a monostable multivibrator which, in turn, drives a relay. The relay flashes the indicator lamp mounted in the rear of the amplifier housing. When a reflection from a layer aloft is detected, the indicator lamp flashes at a rate synchronous with that of the projected light. The lamp is adjacent to a scale which indicates the elevation angle of the scanner.

The receiver is powered by self-contained batteries which supply 12 VDC. The batteries are nickel-cadmium and are rechargeable with a solid state battery charger available from the manufacturer. A meter on the front of the electronics compartment indicates the battery condition when the unit is turned on. Power is supplied to the amplifier by pressing a switch on the front of the electronics compartment. This latches a relay that automatically turns the power off after a period of approximately three minutes.

3.2 Installation and Operation

Installation of the Ceiloscope as a portable system is quite simple. In our tests, we placed the projector on a small concrete pad, leveled it, and ran a power cord underground from a convenient weather-proof electrical outlet. The receiver and tripod were situated on a measured baseline from the projector. The tripod was set up, the receiver placed atop and leveled, and the system was ready for operation. There are no physical or electrical connections between the projector and receiver. A permanent installation appears to be inexpensive.

The observational technique when using the Ceiloscope is elementary and requires very little time (fig. 7). The observer turns on the projector and receiver, and then moves the scanner up and down the projector beam. No lateral aiming is needed since the receiver is oriented with the aiming sights at installation. Response to the reflection of the projected light from the sky layer aloft is shown by a steady flashing (synchronous with the Xenon flash lamp) of the receiver indicator lamp. The elevation angle is given on an angular scale on the receiver (fig. 3). The cloud height is then obtained from appropriate tables. The receiver will shut down automatically, but in the system we used, the projector needed manual deactivation. As can be seen in figure 7, the observer is not required to sight up the receiver to the clouds. He need only view the receiver indicator lamp from a fixed position.

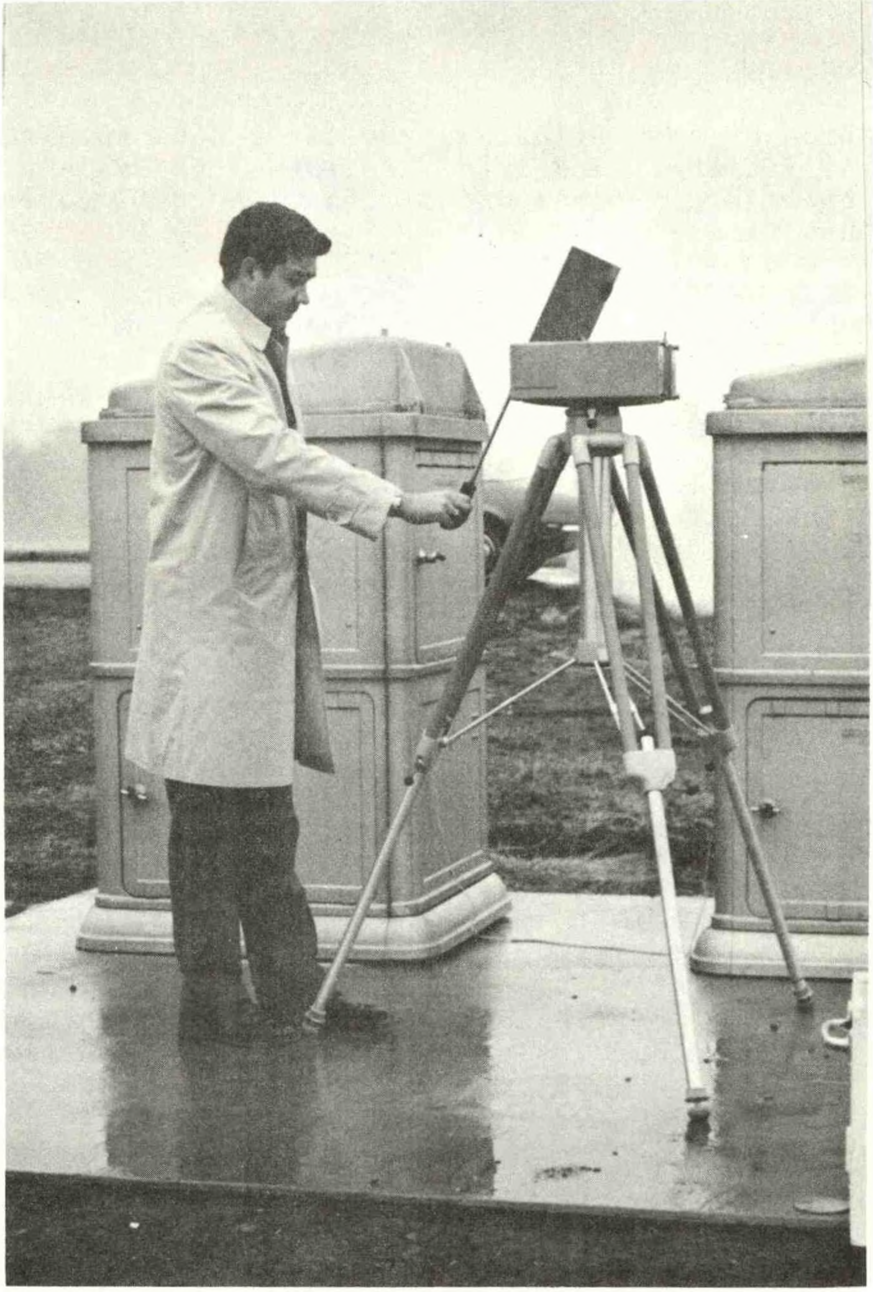

FIGURE 7. OBSERVER USING CEILOSCOPE

4.0 DISCUSSION

Our operation of the Ceiloscope was limited to an examination of the observational technique. No formal assessment of accuracy or rigorous comparisons with other ceilometers were made at that time.

4.1 Technique Performance

The Ceiloscope was installed within the cloud/visibility test facility. The sensor was operated, as time was available, during several weather periods. These included rain, snow, sleet and fog, and various sky conditions with cloud heights ranging from near the surface to above 3,000 feet. Observations were taken both day and night. The cloud heights observed with the Ceiloscope were compared to measurements from an RBC and observer's estimates, and judged to be in general agreement.

During periods of fairly heavy rain, a return was noted on the Ceiloscope between 45 and 50°. This is believed to have been refraction. We were not able to verify this with the naked eye, possibly because of the pulsing action of the instrument's projector. Because of negative experiences of this nature with other ceilometers, this led us to be suspicious of returns in the 45-50° area during precipitation.

When obscuring phenomena prevented an observation of the cloud base, vertical visibility was indicated in the upward scan of the Ceiloscope detector by the point at which the indicator lamp ceased flashing. In these cases, lack of confidence in the RBC indication used as a reference prevented a direct comparison. However the Ceiloscope's indication tended to agree with the estimate made by the observer during operation of the instrument.

The heater in the projector was found adequate to prevent accumulations of snow on the cover glass. There is no heater in the detector. Therefore, some accumulation was noted on it. However, this could be conveniently wiped off by the operator if necessary. Water on the cover glasses of projector and detector did not seem to affect the observations.

For cloud heights greater than 10 times the Ceiloscope baseline, the instrument gave only a coarse measurement. This is because leveling and aiming of the instrument became more critical as the elevation angle increased. For clouds in the instrument's range (clouds with height less than 10 times the baseline) this usually did not present a problem, but special care was needed for higher clouds.

Occasionally, a random noise pulse would be shown by a flash of the receiver indicator lamp. With very little experience it was found simple to discriminate between this and cloud return. Cloud return is a steady flash synchronous with the projector flash, while the anomalous return is always random.

Two baselines were used for our test observations; 82 feet (suggested by the manufacturer) and 318 feet. Observations on the shorter baseline were comparable to RBC measurements and observer's estimates for clouds below 1,000 feet. The longer baseline produced like results for clouds up to about 3,000 feet. The projector's intensity and the receiver's sensitivity both appear adequate for any baseline up to 400 feet. The manufacturer claims an effective height measurement up to 2,000 feet. Our impression is that the claim is conservative.

The manufacturer states that the receiver can be installed inside an office and the observation taken through a window without noticeable signal degradation. This was not investigated.

No formal environmental exposure tests were performed. The system, however, was continuously exposed to local weather for more than a month. No deterioration of appearance or in performance was noted.

4.2 Technique Potential

The greatest potential for an efficient and simple manual cloud height measuring technique is as a routine replacement for ceiling balloons and ceiling lights. Additional possibilities immediately suggest themselves. Among them are:

- To check cloud height at the point of observation when the RBC, located at some distance on the airfield, is giving questionable data.

- As a substitute for the RBC at low traffic level locations or where there is serious difficulty in the installation of an automatic ceilometer.

- As an alternative to expensive inclusion of the RBC in a no-fail power system.

- To be used as a portable system at special events for which the NWS is obligated to provide observations.