RADC-TR-65-277
Final Report

MOBILE GROUND TRUTH LABORATORY

Harry Balmer
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TECHNICAL REPORT NO. RADC-TR-65-277
January 1966

Reconnaissance-Intelligence Data Handling Branch
Rome Air Development Center
Research and Technology Division
Air Force Systems Command
Griffiss Air Force Base, New York

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) HRB-Singer, Inc. State College, Pa.	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP
3. REPORT TITLE MOBILE GROUND TRUTH LABORATORY	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report	
5. AUTHOR(S) (Last name, first name, initial) Balmer, Harry; Cramer, William; Gray, Robert; Ranck, Frederick	

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
January 1966	86	None

8a. CONTRACT OR GRANT NO. AF30(602)-3461 b. PROJECT NO. 6244 c. Task No: 624410 d.	9a. ORIGINATOR'S REPORT NUMBER(S) None 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) RADC-TR-65-277
10. AVAILABILITY/LIMITATION NOTICES Distribution of this document is unlimited.	
11. SUPPLEMENTARY NOTES None	12. SPONSORING MILITARY ACTIVITY RADC (EMIRC) Griffiss AFB NY 13442

13. ABSTRACT

This report presents a description of the construction and equipment installation of the RADC Mobile Ground Truth Laboratory (MGTL) performed by HRB-Singer, Inc. under Contract AF30(602)-3461. The MGTL is capable of recording various radiological and meteorological data for use in studies of airborne sensor capabilities.

Modifications to a M-109 shop van are described and equipments installed in the modified van are listed and discussed.

DD FORM 1 JAN 64 1473

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Security Classification

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Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Meteorological parameters Infrared radiation Thermal targets Aerial reconnaissance Photographic intelligence						

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FOREWORD

This final report was prepared by HRB-Singer, Inc., State College, Pennsylvania, under contract AF30(602)-3461, project 6244, Task 624410. The authors are: Harry Balmer, William Cramer, Robert Gray and Frederick Ranck. The RADC Project Monitor was Keith A. Butters, EMIRC.

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ABSTRACT

This report presents a description of the construction and equipment installation of the RADC Mobile Ground Truth Laboratory (MGTL) performed by HRB-Singer, Inc., under Contract AF30(602)-3461. The MGTL is capable of recording various radiological and meteorological data for use in studies of airborne sensor capabilities.

Modifications to a M-109 shop van are described and equipments installed in the modified van are listed and discussed.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES

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I. INTRODUCTION

Contract AF 30 (602) 3461 was awarded by the U. S. Air Force Systems Command, Research and Technology Division, Rome Air Development Center, for the purpose of constructing a Mobile Ground Truth Laboratory (MGTL) capable of recording various radiological and meteorological data for use in studies of airborne sensor capabilities. Major design features were oriented to a self-sufficient unit able to operate both on and off improved roads in remote areas under various environmental conditions. The basic vehicle supplied for modification was a USAF, M-109 shop van, shown in figure 1.

Instrument types were listed in the purchase request which would enable accurate records of physical phenomena to be obtained under a wide range of weather conditions. The major contractor-supplied equipment requirements are listed below:

1. Continuous temperature recording to ±2 degrees of fahrenheit.
2. Continuous relative humidity recording to ±5%.
3. Continuous wind velocity and direction recording to ±3 mph and the nearest 15 degrees, respectively.
4. Apparent radiation temperature in the infrared spectrum from 1 to 30 microns recorded by a single channel radiometer in a form that temperatures to one degree fahrenheit may be determined. Provisions for the collection of data restricted to the 3 to 5 micron and 8 to 14 micron bands were also required.
5. A transportable, well-regulated power supply capable of providing continuous operation of all equipment in the laboratory.

6. Heating and air-conditioning of the interior of the mobile laboratory to provide a temperature maintained at 68 $\pm$10 degrees fahrenheit.

7. Target area marking devices including:

   a. A stroboscopic beacon with intensity sufficient to be seen at an altitude of 50,000 feet.

   b. Orange fluorescent marker panels.

In the interests of time and cost, no extensive design and/or development of equipment was undertaken and all equipment used was selected from currently-available commercial equipment. The major equipment items furnished in the performance of this contract are listed below together with their manufacturers.

1. Hygrothermograph, No. 5-594, Belfort Instrument Company
2. Microbarograph, No. 5-800, Belfort Instrument Company
3. Wind Speed and Direction Transmitter, type L, and recorder, type M, Belfort Instrument Company
4. Psychrometer, No. 5-PH-5A, Belfort Instrument Company
5. Mercurial Barometer, Science Associates, Inc.
6. Precision Radiometer, Mark IX, Huggins Laboratories
7. Stoll-Hardy Portable Radiometer, HL-4, Williamson Development Co.
8. Air-cooled Motor-driven generator, 15 KVA capacity, Model 15JC-3R, ONAN
9. Air Conditioner/Heater, Thermaline Zonelectric "42," General Electric
10. Strobe Beacon, Model STR-500, Kemlite Laboratories, Inc.
11. Transistorized, Battery-operated tape Recorder, Model PB-808-R, COMMODORE
12. Fluorescent Panel Markers, Safety Flag Co. of America

13. Boom Headset, BCW-02, TELEX

14. 5-drawer File Cabinet, Coles

Detailed descriptions and installation of major and minor equipment and items are contained in following sections. All equipment was either shock mounted in a permanent location within the van or provided with shock-resistant carrying boxes for storage during movements.

Initially, it was proposed to furnish a trailer mounted power supply unit. In the interests of providing better off-road capability and driver-handling, the decision was made to mount the generator directly on the truck. Several positions were considered and the final position in which the unit was mounted entailed a major modification to the van portion of the truck.

All equipment supplied conformed to contract specifications when final delivery was made. Only one piece of equipment, the Precision Radiometer required extensive study and modification to bring it within the required accuracy specifications. All other equipment was acceptable as received from the manufacturers. A detailed report of the problems and their solutions as experienced with the radiometer are contained in an appendix to this report.

A GRC-27 UHF radio set, supplied as Government Furnished Equipment, was found to be inoperable upon receipt at the contractor's facility. After extensive repair to the power supply and receiver sections of the set, these sections were operable. Upon trouble shooting investigations within the transmitter unit of the set, it was found that extensive repair and parts replacement would be required to operate this unit. It was decided that work to this extent was outside the scope of the contract, and that further work would be performed by the Contracting Agency. The set was installed in the van and hooked up to the power supply source although the transmitter was not operable.

Spare parts data was furnished for all equipment installed in the laboratory. Such spares as were furnished with the equipment or purchased for test purposes were included in delivery of the van.

Seven copies of a volume of maintenance and repair manuals were compiled and delivered with the laboratory. The contents included instructions for normal operation of the equipment, routine maintenance, recalibration procedures and other pertinent data. The main body of material consisted of commercial manuals supplied by the manufacturers with additional text to amplify procedure peculiar to operation in the mobile laboratory environment.

Acceptance testing procedures (Appendix A) were formulated by HRB-Singer and approved by the Contracting Agency. These tests were carried out, with modifications for existing weather conditions when delivery of the MGTL was accomplished. All equipment was subjected to performance tests by HRB-Singer prior to delivery to establish proper operating procedures and accuracy.

During the course of the contract, a brief period of time was devoted to a study of reduction and utilization of the data produced by the laboratory instrumentation. Consideration was given to further instrumentation which may be desirable for future installation in the laboratory. Recommendations, based on this brief study, are contained in the final section of this report.

II. ELECTRICAL POWER AND VAN BODY MODIFICATIONS

A. ELECTRICAL POWER

The MGTL has been wired for 120/240 volt operation, in addition to the 24 volts supplied from the vehicle batteries. The GRC-27 transmitter/receiver and the air conditioner/heater unit operate at 240 volts; the remainder of the equipment operates at 120 volts. Power is supplied by a 15 KVA, air-cooled, motor-driven generator, ONAN model 15JC-3R, mounted behind the cab of the vehicle. Power supplied is SINGLE phase, 3-wire. Connection from the generator to the van is through a Russell and Stoll reverse service receptacle. Commercial power may be supplied to the van by simply disconnecting the plug and inserting a second plug, which has been supplied without wire, and connected to an appropriate commercial source of power.

The line side of the power is connected to a 100-amp disconnect switch, with fuses, mounted on the left front panel inside the van. Wiring is mounted from the load side of the switch to two ammeters used to measure load on each phase. The voltmeter and frequency meter are connected directly across the 240-volt line at the disconnect switch. A circuit breaker panel has been mounted on the right front panel of the van, and all receptacle and instrument power is distributed from this point. Six separate circuits have been provided, they are:

1. Air conditioner/heater
2. Radio, transmitter/receiver, GRC-27
3. Outside power receptacles
4. Inside power receptacles
5. Overhead lights, -110 volt
6. Spare, for future additions

Two overhead lights have been wired for 24-volt operation and are controlled by a switch mounted on the left rear panel of the van. These lights should be used to provide initial illumination for access to the generator start switch. They should not be used for general lighting purposes since excessive use will drain the vehicle battery.

As a safety feature, a grounding system has been provided for operation of the van electrical system. A ground rod, mounted in the front right corner of the van, is connected to the grounding cable found on the right side of the generator. The rod should then be driven into moist earth to provide a good electrical ground for the system which will prevent any electrical shock to personnel working around the van.

Although 15 KVA of continuous power may be drawn from the motor generator, maximum power required for all existing equipments in the laboratory is approximately 8 KVA. The original purchase request for fabrication of the MGTL called for installation of photometers covering bands of the visible spectrum. Subsequent cost estimates for supplying this equipment led to the removal of the photometer requirement from this contract. However, to provide for future installation of photometers and other instrumentation, it was decided to install a generator with sufficient capacity for future expansion. All equipment recommended for future consideration would produce a maximum power requirement less than the maximum power output of the existing generator.

B. GENERATOR MOUNTING

The proposed method of generator mounting consisted of furnishing a separate trailer containing the motor-generator, which would be hauled by the van. In the interests of safety, improved off-road capability, and ease of driver handling, it was decided to mount the generator as an integral part of the truck. Several alternatives were considered.

The first alternative consisted of rigidly mounting the generator to the van body in a position above the truck cab. No additional height would have been added to the overall dimensions of the vehicle. However, it was found that placement of the generator above the truck cab would cause a shift in the center of gravity of the vehicle from 41-1/4" to 45-1/4" above the road surface. This condition would cause overturn on a 33° grade as opposed to a 45° grade in the original vehicle configuration. Inertial forces created when driving a nonsuperelevated curve could create an additional overturn hazard in the over-cab mounted configuration. Investigation of the structural members of the van body was conducted by removal of a portion of metal skin. Examination of these members negated the possibility of mounting the generator or any supporting structure directly to the van body, without considerable re-enforcing from the truck chassis.

A second alternative considered was to slide the van body to the rear, creating a gap between the van body and truck cab. In this gap, the generator could be mounted in a low position and fastened firmly to the truck frame. This solution was considered unfeasible because of interference problems encountered at the rear wheel wells and the considerable heavy work required to extend the truck frame to accommodate the overhang at the rear of the vehicle. Additional consideration was given to the increase in overall length of the vehicle as it affected ease of driver handling and roadability of the vehicle.

The third alternative considered and adopted was cutting or "notching" the van body, as shown in figure 1, to accommodate the generator between the van body and truck cab. The shock-mounted generator is now rigidly fastened to the principal frame of the vehicle carrying the truck engine, cab assembly and body. The body and cab are isolated from the principal frame to allow a minimum of vibration to be transmitted to the body from any of the rotating mechanisms.

An access door, seen open in figures 3 and 4, was cut into the front wall of the van body to allow for generator and engine maintenance. All maintenance points on the motor-generator are serviceable from this location, i.e. battery, oil fill and drain, ignition system, etc. The generator gas tank is accessible from the top and may be filled either by a standard gas pump or from gas cans with a normal hose extension.

Exhaust gases are piped from the generator engine down and to the rear to prevent intrusion of these gases into the air conditioner/heater unit mounted above the cab. All spaces between the outer and inner skin of the van body are insulated with a two-inch thickness of spun glass. The generator access door has been provided with a rubber gasket seal to prevent the intrusion of fumes and generator noise.

In its present configuration, the van body and generator may be easily transferred to another truck chassis with no modification other than the addition of four clips to the new frame for mounting of the generator.

C. OTHER BODY MODIFICATIONS

An observation platform has been installed on the roof of the van to provide a surface for observation and instrument operation from an elevated position. The platform is reached by a ladder permanently attached to the rear of the van body on the road side. The platform is constructed from a 4' x 8' sheet of 3/4 " exterior grade plywood, painted and treated with silicon carbide granules to provide a nonslip work surface. The platform is supported on three plates rigidly bolted to the van roof. All bolt holes are sealed to prevent leakage into the van interior.

Four vibration isolators have been installed on the forward portion of the van roof for the mounting of the strobe beacon. These isolators are so placed as to readily accept the light when it is installed in the operating position. Four additional isolators have been installed in the interior of the van body to provide a vibration-isolated storage position for the beacon during transportation and long movements of the MGTL.

Six other vibration isolators were used in the installation of the GRC-27 radio set in the interior of the van body. Four isolators were rigidly fixed to the floor and two to the road side wall to provide vibration isolation for the radio rack in addition to providing rugged and dependable mounting of the equipment. The various components of the radio set are securely fastened to the shock mounted cabinet by screws provided with the cabinet.

The air conditioner/heating unit was rigidly mounted in the upper front surface of the van body. The unit was mounted sloping slightly forward to facilitate condensation accumulated during the air conditioning phase of operation. The hole cut to accept the unit was framed around it's perimeter by steel channel members to provide a rigid mounting surface.

Rear view mirrors originally furnished with the M-109 Shop van were, in the opinion of the contractor, undesirable for on-road use and were of no value for back-up in off-road maneuvering. The standard small, round mirrors were replaced with large, rectangular, "West-Coast" type mirrors, which provide a greater rear viewing area and enhanced road safety and off-road maneuverability of the vehicle.

To provide remote operation of instrumentation a connector panel was fabricated on the road-side of the van body. All recorders are wired to bulkhead connectors from the interior of the van. Cables running from remote instrument locations are connected to the recorders through the exterior of the connector panel. All connectors are mil-spec, Aniphenol connectors. Plugs are also provided for the boom headset for remote radio communications.

Remote cable pay out and take-up has been facilitated by the installation of a cable reel, which in operation may be mounted to the rear of the connector panel on the exterior of the van body. A second bracket has been provided on the interior of the van for storage of the cables on the reel.

FIG. 1 ROAD SIDE, MGTL

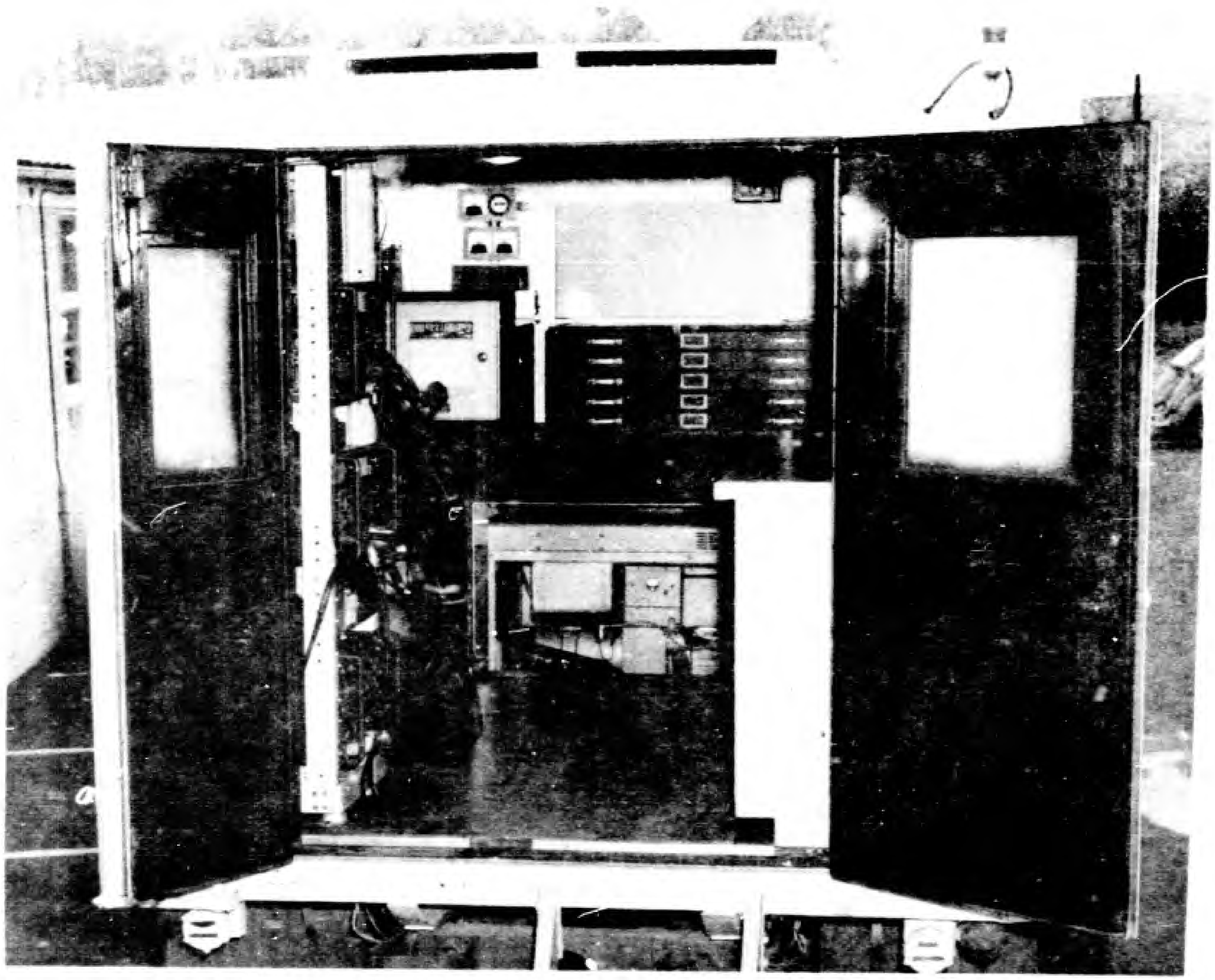

FIG. 3 INTERIOR VIEW, MGTL

FIG. 2 BERM SIDE, MGTL

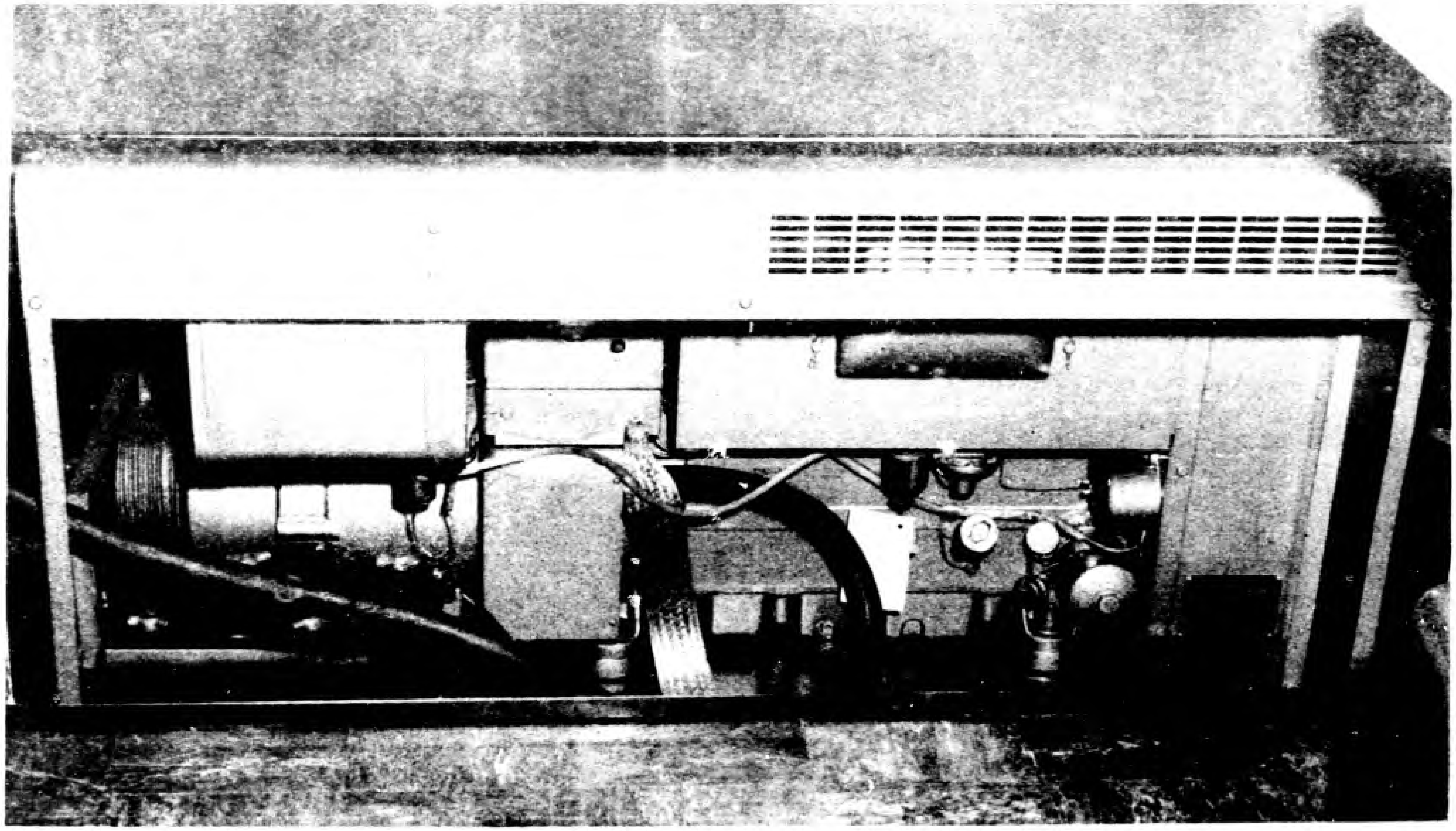

FIG. 4 SERVICING HATCH, ONAN GENERATOR

III. METEOROLOGICAL INSTRUMENTATION

Five pieces of equipment for the measurement of weather phenomena have been provided. All weather instruments have been provided with shock resistant wooden boxes to prevent damage during transportation and to provide convenience in carrying equipment to and from remote locations.

No modifications were made to any of the instruments listed in this section. Tests were conducted in conjunction with known data from a weather facility adjacent to the contractor's facility. Instruments were laboratory tested for accuracy and were also set-up in an outdoor environment to determine operation under actual weather conditions.

A. HYGROTHERMOGRAPH

This instrument records changes in both temperature and relative humidity on a single dual channel chart. Air temperature is sensed by a bimetal assembly, which expands or contracts with temperature changes. Humidity is sensed by the expansion or contraction of a human hair element. The Hygrothermograph mechanism is enclosed in a metal case, that is open on three sides, to allow free air passage and a window on its other end for viewing the chart record. A hinge allows the case to be opened for free access to the mechanism for cleaning and servicing the instrument. A handle is provided on top the case to enable the operator to move the instrument with ease and safety.

The Bimetal assembly consists of two dissimilar metals clamped together and react to temperature changes at different speeds. This causes an expansion or contraction to occur which, like the Bourdon assembly,affects the pen's position on the temperature scale. These elements are mounted on a rigid bracket within the open area of the case, which allows free air movement about the element.

The humidity sensing portion of the Hygrothermograph is a Banjo spread human hair element, which reacts very accurately to variations in relative humidity. High humidity causes the hair element to lengthen which moves the pen to the high humidity portion of the chart; with the decrease of humidity, the hair length shortens and the pen drops on the scale.

The chart drive is a clock-type, spring-driven drum with a number of various time periods available. The mechanism chosen was a 29-hour drive and corresponding chart graduated from $+10^{\circ}$ to $+110^{\circ}F$ in temperature and from 0 to 100% in relative humidity. A weekly chart and drive is available and other lower temperature ranges are also available from the manufacturer.

Testing indicated that accuracy was within manufacturer's quoted ranges of $\pm 1^{\circ}F$ and $\pm 3\%$ RH as compared to Contract Specifications of $\pm 2^{\circ}F$ and $\pm 5\%$ RH.

B. MICROBAROGRAPH

This instrument furnishes a record of barometric pressure inked on a rectangular chart. The chart and chart drive chosen for this contract records a 29-hour period and is scaled for a range of 28.5 to 31.0 inches of mercury, although the instrument is calibrated for a range of 27.25 to 32.25 inches of mercury. For recording above or below the chart range, the pen must be repositioned. The chart scale is 2.5 inches per inch of Hg and readings may be accurately estimated to 0.005 inches of Hg.

Changes in atmospheric pressure are sensed by an opposed bellows assembly, which expands or contracts. This movement is transmitted and magnified through a mechanical linkage to trace the recording. The instrument is fully temperature compensated by an adjustable bimetal assembly.

A glass paneled case is secured to the base by a hinge which allows the case to swing away for easy access to the mechanism. A latch on the base mates with a stud on the case and locks the cover in the closed position.

Tests conducted verified instrument accuracy to be ± 0.005 inches of Mercury, which was considerably higher accuracy than contract specifications.

C. WIND SPEED AND DIRECTION TRANSMITTER AND RECORDER

The Wind Transmitter is an instrument which measures wind direction and speed and electrically transmits the values to a remote recorder.

Wind speed is measured by a three bladed rotor fastened to the armature of a magneto located in the nose of the transmitter. The speed of rotation of the rotor is directly proportional to the speed of the wind striking the blades; and when this generated voltage is measured by a voltmeter that is calibrated in terms of wind speed, the speed of the wind is indicated.

Wind direction is measured by a vane tail which is mechanically connected to a synchronous motor. This synchro electrically transmits the position of the vane to another synchro in an indicator or recorder; thus,angular displacements are measured, transmitted, indicated and/or recorded.

The transmitter is designed to be mounted on a support and requires a .125-volt power source for operation. It is 30 inches long and weighs approximately 10 pounds and is properly suppressed not to cause radio interference.

The support chosen consists of a telescoping, two-section mast which is supported by a tripod base and when fully extended reaches a height of thirteen feet. Provision is made for three-point guying if necessary.

Data is displayed on a dual element recorder which simultaneously inks records of wind direction and speed on a 100-foot double channel chart. These values are also indicated visually by flag type pointers, attached to the recording pens which move across the graduated scales.

The recorder consists of a direction mechanism, speed mechanism, chart drive mechanism, chart and ink well mounted on a rigid metal frame. The frame is supported by four rollers which slip into notches on the tracks of the case and allow the recorder mechanism to slide forward for inspection and servicing. A fluorescent light is provided for chart illumination.

The wind direction mechanism consists of a type 1F synchro that is mechanically connected to a pair of pens by a gear train and two ratchet and pawl assemblies. This gear train converts 360° of synchro rotation into 40° of pen movement. The direction portion of the chart is divided into 5° increments. When the wind direction indicated is North, the pens are resting at opposite margins. A change in wind direction from North moves one of the pens across the chart, following the direction of the wind shift. When this pen reaches the opposite margin and if the wind shift continues past that North indication, the synchro unlatches and the pen returns towards its starting (North) position, to be picked up again by the synchro. A change in the direction of wind shift will carry the pen back to its starting (North) position. If the wind continues past that North indication, the opposite pen will take up the recording task.

The wind speed portion of the recorder consists of a voltmeter and single pen. Wind speed causes a voltage to be generated by the transmitter's magneto which is directly proportional to the wind speed. A dual range capability has been provided. They are 0 - 120 mph and 0 - 150 mph.

The chart advance mechanism consists of a synchronous motor operating a sprocketed metering roll that engages holes in the chart center and causes the chart to advance. A chart switch on the recorder side plate allows the operator to choose a chart feed rate in either inches per hour or inches per minute.

Accuracy of the unit is a percentage of wind speed and/or transmitter output voltage and will yield ±2% at 120 MPH or less than ±3 MPH over the usable range of the instrument. Direction accuracy is less than ±5 degrees at the recorder.

D. ELECTRIC PSYCHROMETER

As a check and back-up instrument, a hand-held, battery-operated electric psychrometer has been provided. In this instrument a motor-driven fan provides a uniform air passage of 1000 feet per minute across the bulbs of wet and dry bulb thermometers. Charts provided with the instrument allow rapid conversion of the wet and dry bulb temperatures to dew point and relative humidity readings. Accuracy of the instrument is better than ±1% RH. Its range of operation is from $+10^{\circ}$ to $+110^{\circ}$F.

E. MERCURIAL BAROMETER

For calibration of the recording microbarograph, a laboratory-type mercurial barometer has been provided. Its intended use is for pre- and post-operational checks on the accuracy of the recording instrument.

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IV. RADIOMETERS

A. STOLL-HARDY PORTABLE RADIOMETER

GENERAL DESCRIPTION:

The Stoll-Hardy portable radiometer is for rapid measurement of the temperature of surfaces having an emissivity of essentially unity.

Temperatures up to a maximum of 100°C above or below ambient temperatures may be measured. Scale ranges of 10°C, 30°C, 100°C are provided on the meter with linear scale divisions. The X range is provided to allow the user to select a convenient range to suit a particular problem. For instance, a range of 20°C can be made by adjusting the X range to read on the 10°C scale times two. The X range can be adjusted to read in Fahrenheit. The Test position on the range selection switch measures the load voltage of one of the batteries in the plate circuit of the D. C. amplifying tube. The meter switch selects the meter polarity to permit reading temperatures above (plus position) or below (minus position) ambient temperature. Three zero balance controls are used for coarse, medium and fine zero adjustment. The aluminum ambient temperature body serves as a blackbody reference source for the radiometer head. A thermometer calibrated in °C is used to measure the temperature of the aluminum ambient temperature body. Before measuring the temperature of a surface and while the radiometer head is still inserted in the aluminum ambient temperature body, the meter must be zeroed. In measuring the temperature of a surface, the radiometer head is removed from the aluminum ambient temperature body and placed just touching or pointing toward the object whose temperature is to be measured. The reading of the meter is added (taking account of sign as determined by the meter switch) to the reading of the thermometer in the aluminum ambient temperature body to determine the unknown temperature.

The act of making a measurement necessitates delivering some heat to the radiometer head. If this heat is allowed to enter the head for a sufficient period of time, it will heat up the head and cause a shift in the zero position. Also, in order to make a measurement, the head must be moved to a different location, where temperature conditions are different than those in the ambient temperature body. Thus, thermal gradients will be set up in the radiometer head, which will cause slow shifts in the zero. These shifts can best be minimized by taking measurements rapidly and rhythmically. The zero balance should be noted and corrected if necessary before each measurement. The batteries in the instrument will not operate properly at extremes of temperature. Provisions for keeping the instrument warm must be made if the temperature is below zero degrees F.

The Stoll-Hardy portable radiometer should be placed in the environment in which it will be operating two hours before it is to be used. This will allow the aluminum ambient temperature body to assume the temperature of its environment. Approximately 15 minutes before the instrument is to be used, it should be turned on. This will allow the instrument to stabilize before radiation temperatures are actually measured.

CALIBRATION:

For calibration, a body of unit emissivity and a known temperature (Leslie Cube) was used. On the 10°C range, the linear meter scale over this small temperature interval corresponded to the blackbody radiation curve, so that preparation of a calibration curve was not necessary. For the 30°C and 100°C ranges, preparation of calibration curves was necessary since the linear meter scale did not approximate the blackbody radiation curve to the degree of accuracy required.

The curvature of the calibration curve arises because the exchange in energy between the sensitive thermistors in the radiometer head and the surface to be measured is proportional to the difference of the fourth powers of the absolute temperature.

To calibrate a range, the meter was set to zero with the radiometer head in place in the ambient temperature body, and the difference in temperature between the Leslie Cube and the ambient temperature body was calculated. The radiometer head was then held facing the cone of the Leslie Cube, and the meter reading was noted. If the meter reading did not correspond to the computed difference, the screwdriver adjustment for that particular range at the right of the meter was adjusted until the meter reading did correspond to the calculated difference. This basic calibration was done for both the 30 degree C and 100 degree C ranges.

Once this basic calibration was completed, calibration curves were then prepared. Unfortunately, a calibration curve for one ambient temperature body temperature is not adequate for other ambient temperature body temperatures. This results from the fact that exchange in energy between the surface to be measured and the thermistors in the radiometer head is proportional to the fourth powers of the absolute temperature. Since it was impractical to prepare calibration curves for every ambient temperature body temperature at which the instrument might conceivably be operating, calibration curves were prepared for ambient temperature body temperatures which were separated by approximately 10 degree C. intervals, over the ambient temperature range the instrument was expected to be operating. When operating between any of the ambient temperature body temperatures for which the instrument was calibrated, interpolation can be used to get the correct temperature.

In order to get the data to prepare the calibration curves, the Stoll-Hardy portable radiometer was placed in an environmental chamber held at the desired ambient temperature. The ambient temperature body's temperature was allowed to stabilize at the temperature of the environmental chamber. The Leslie Cube's temperature was then varied over the desired range and readings taken. The liquid in the Leslie Cube was stirred while readings were being taken to prevent temperature gradients from occurring in the liquid. At low ambient temperatures the radio B batteries must either be warmed if put in the environmental chamber or left outside at room temperature.

The Stoll-Hardy portable radiometer will give true radiation temperatures only when surfaces of unit emissivity are being measured. From this true radiation temperature the flux density (watts/cm^2) of the radiation from the surface can be determined easily by using a blackbody radiation curve. When the temperature of a surface is being measured whose emissivity is not close to unity, the true temperature of this surface cannot be determined. The reading obtained is the equivalent blackbody temperature of the surface and from this reading the flux density (watt/cm^2) of the radiation from the surface can be determined by the use of a blackbody radiation curve.

MODIFICATIONS:

The flashlight battery supplying current to the heater in the DC amplifying tube (CK6088) has been replaced by a mercury battery. This battery has much better load voltage and temperature stability than does the flashlight battery supplied with the instrument. Its capacity is 14,000 mah. The load voltage of this battery should be approximately 1.3 v's.

The bias voltage across the radiometer head has been reduced to approximately 90 v's (2, XX30 radio "B" batteries) to enable the Stoll-Hardy to operate in ambient temperature environments of up to 55°C without danger of damaging thermistors in the radiometer head. This voltage should not be changed because this will change the sensitivity of the radiometer head to incoming radiation and thus invalidate the calibration curves.

To provide for cold weather operation a warmer has been supplied for use with the radio "B" batteries. During cold weather the batteries are to be placed in an insulated box together with the warmer, to insure reasonable accuracy of the instrument.

Further modifications outside the scope of this contract are suggested in a following chapter.

FILTERS:

No calibration curves need be prepared for filters that are used with the Stoll-Hardy portable radiometer. To obtain the true radiation temperature of a surface in the case of a surface whose emissivity is unity or the equivalent blackbody temperature of a surface whose emissivity is not unity, a reading can be taken without the filter in place. To get the % of the total energy which lies in a particular portion of the spectrum, the filter can be placed over the radiometer head. The attenuation of the radiation caused by the filter must be taken into account.

B. HUGGINS PRECISION RADIOMETER

The precision radiometer selected was a solid-state device consisting of an optical head, a control/indicator unit, and a Sandborn Single channel recorder with a preamplifier.

Because of the numerous difficulties experienced with the instrument during the course of the contract, a special appendix is in preparation outlining the problems encountered, their solutions and data accumulated during the numerous tests performed in bringing the instrument to contract specifications and installing it in the MGTL. A brief description of the instrument and an outline of the final installation will be presented at this time. The instrument description presented is premodification.

The principal components and configuration of the Optical Head are shown schematically in Figure 5 . Energy emitted by the source object is collected and focused by the primary-secondary mirror optics. Focal adjustment for various object distances from infinity to 12 inches is provided by axial movement of the secondary mirror. This axial movement is controlled through a rack and pinion linkage with the focus adjust knob at the base of the Optical Head.

A field stop having a .020" hole is located at the focal plane and accurately defines the angular receiving beam (2.4 milliradians; 0.14 degree) of the instrument. The field stop is mounted at the apex of a small heated conical cavity that extends forward from the focal plane. The cavity is maintained at an accurate temperature between 50° and 55°C, thereby providing a temperature reference for the radiometer. A reflecting chopper that modulates the incoming energy at a 200 cps rate is located immediately in front of the reference cavity. When the chopper is in the closed position, energy radiated from the reference cavity is reflected through the field stop to the detector. The resultant modulated energy passing through the field is reimaged at the detector by the image transfer optics that consist of two small spherical mirrors. Centrally located between these two mirrors is a specially shaped aperture stop whose function is to block any spurious modulated energy that might radiate from the internal instrument parts -- thus making the radiometer insensitive to environmental temperature. Two eight-position filter wheels are located between the detector and the transfer optics. Wheel position is both indicated and adjusted by two concentric knobs at the rear of the Optical Head.

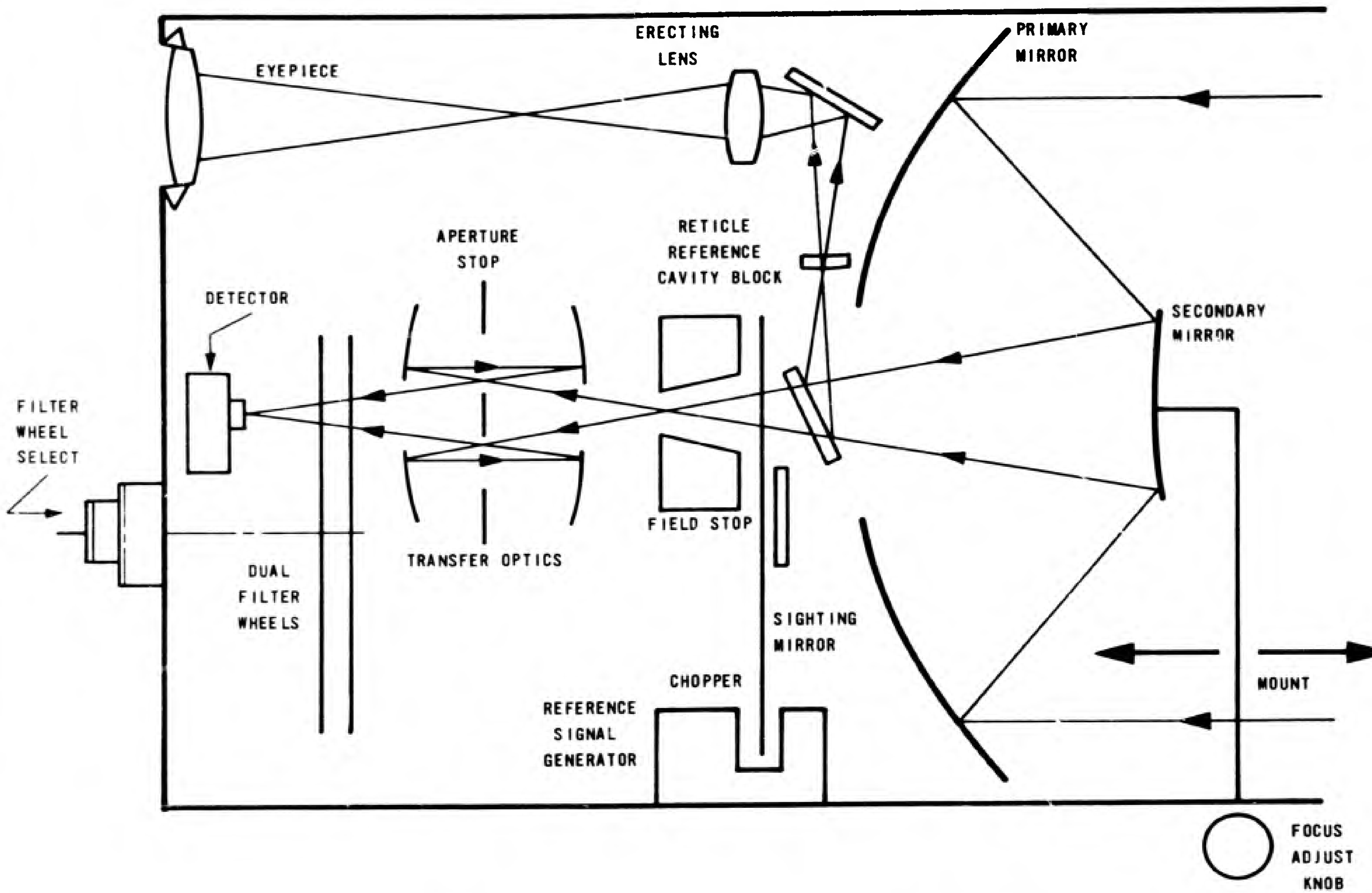

FIG. 5 SCHEMATIC, OPTICAL HEAD, PRECISION RADIOMETER

The detector supplied is a ferroelectric bolometer, having a D^* (500,100,1) of approximately 1 x 10^8 watts/cm². Three filters are provided. They are a 3-5μ bandpass, 8μ cuton, and 13.5μ cutoff.

The detector is mounted on a heated block that is maintained at a temperature of approximately 50°C to avoid changes in detector response with ambient temperature.

Aiming and focusing of the Optical Head are accomplished with the use of the sighting optics. A small sighting mirror is installed just behind the primary mirror which, when rotated to a 45° position, redirects the field image from the field stop to the sighting reticle, erecting lens, and eyepiece for direct viewing. The sighting reticle contains a circle that has the same diameter as the field stop (.020"), hence permitting the object area to be visually determined. The total sighting field is approximately 10X larger than the receiving beam to aid in object identification and the optical axis is indicated by a small center dot on the reticle. Aiming is accomplished without parallax because the sighting system uses the primary radiometer optics.

In figure 6 the voltage output developed by the detector cell (this voltage is a function of the difference between the radiation of the reference cavity and the radiation of the object being viewed) goes directly to a preamplifier contained in the Optical Head. A 6-step attenuator on the front panel of the Indicator/ Control Unit allows for the proper setting of the radiation level that will be shown on the front panel meter. The signal is amplified and then internally calibrated by a 2-to-32 gain adjust. In the TRANSIENT mode the signal goes directly through amplification and then to a rear panel output connector that may be utilized for scope presentation; however, in the NORMAL mode the signal goes through a bandpass filter, a phase shifter and an amplifier. The latter two elements of the circuit are internally adjusted at the factory. This narrow band

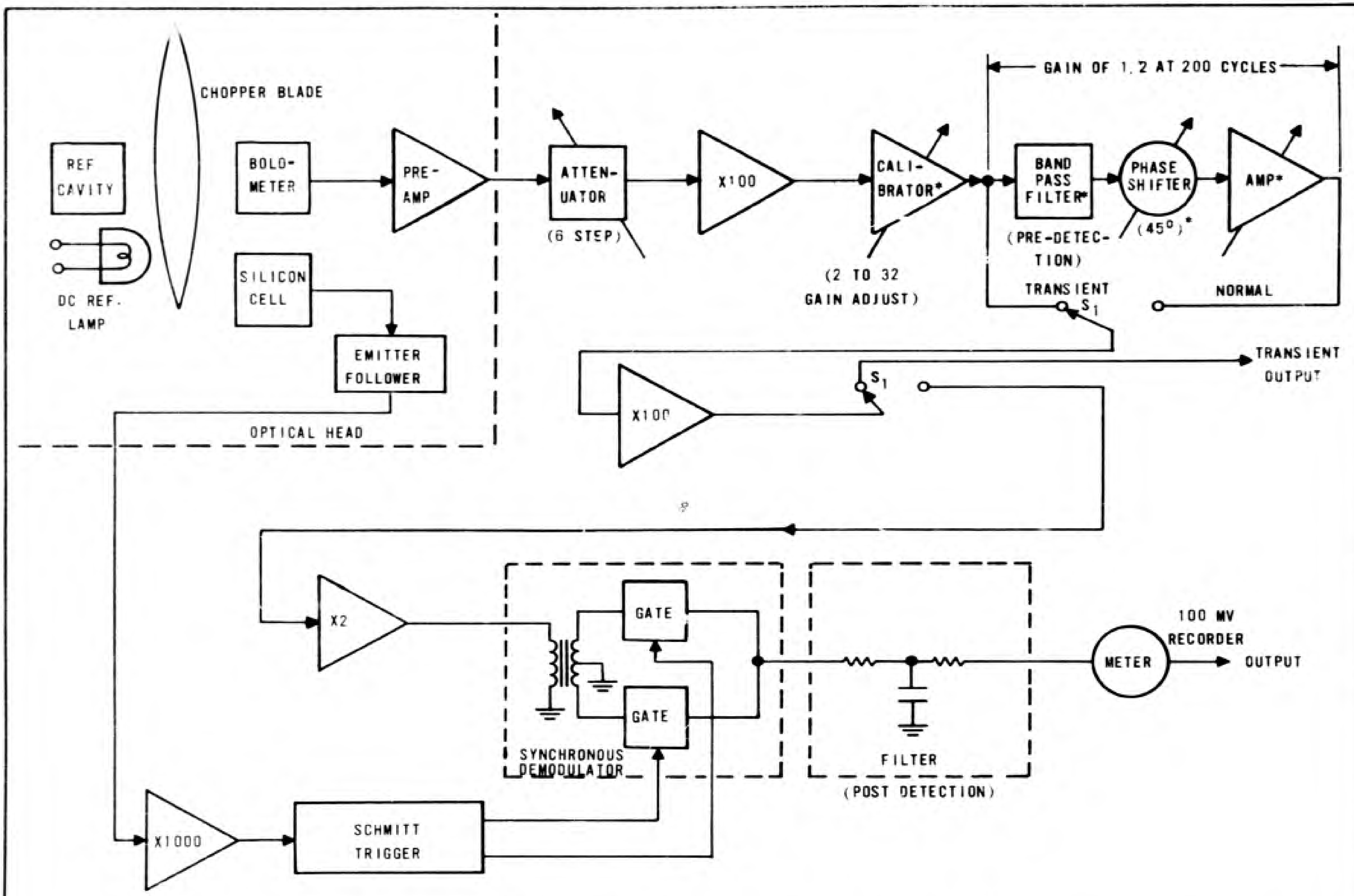

FIG. 6 BLOCK DIAGRAM, INDICATOR/CONTROL UNIT, PRECISION RADIOMETER

AC amplified signal that is centered about 200 cycles is fed directly to a synchronous detector circuit.

A DC reference lamp with a silicon cell and an emitter follower transistor stage are located in the Optical Head. The light rays from the reference lamp that fall on the silicon cell are chopped at the same rate as the light rays that fall on the detector cell. The "AC" signals created at the silicon cell provide an interference-free reference signal. These signals are then amplified, go through a Schmitt trigger for wave shaping, and then are used to gate a synchronous demodulator. The amplified narrow band signal from the detector is thereby demodulated and the full wave DC output is smoothed by a narrow band, low pass DC filter. This output is fed directly to the meter and the 100 millivolt output jack on the rear panel.

Permanent recordings are produced by a single channel recorder which reads millivolts per centimeter. Calibration of the recorder to read directly in watts/cm^2 may be accomplished by use of the console indicator.

The single channel recorder consists of four subunits, an AC-DC preamplifier, driver amplifier, power supply and recorder. The system will record 1 mv/cm to 2V/cm AC and 1 mv/mm to 2V/mm DC over a 5 cm plastic coated paper tape. A hot-wire stylus provides a permanent trace. A time-marker trace is provided in the margin and will provide automatic or manual time marking. Chart speeds range from 5 mm/sec to 100 mm/sec. Other ranges of chart speeds are available by manufacturer's modification.

Final Testing and Installation Procedures are outlined below. Detailed data and discussion may be found in Appendix A to this report.

The required accuracy of the precision radiometer was set at $\pm 1^{\circ}F$ determination at ranges between $-10^{\circ}C$ and $+50^{\circ}C$ temperatures. It was found that this criteria can be obtained if care is used in conducting measurements.

Difficulties were experienced in conducting tests for accuracy since a constant source temperature was required. Extraneous atmospheric effects presented problems in maintaining source temperature.

The test source chosen was a Leslie Cube, located at a distance of 3 feet from the collecting optics of the radiometer. At this distance, the central portion of the blackbody cone completely filled the radiometer field-of-view. The temperature of the Leslie Cube could be maintained at a known point by filling it with a liquid of the desired temperature. Temperature of the source was measured and recorded to the nearest 0.1°C.

Although laboratory testing indicated that an accuracy of 1°F could be obtained when installed in the MTGL, the radiometer failed to operate properly and readings with errors greater than 20°C were obtained. Initial investigations traced the source of wide fluctuations to a voltage change caused by intermittent operation of other equipment in the van. It was felt that the voltage drop encountered at full load, exceeded the normal operating range of the radiometer. Accordingly, a Sola Constant Voltage transformer was installed between the radiometer and the normal line current. Some smoothing effect was gained by this addition; however, gross errors were still in evidence when the radiometer was operated from the MGTL power supply.

Two general solutions were recognized. The first entailed rigid frequency regulation of the line current to the radiometer as a whole or the chopper motor which was found to be the major component affected. These solutions were reserved for second consideration because of long delivery times of the necessary regulators in both cases and the size and of a regulator necessary to operate the entire unit.

The second solution entailed replacing the narrow 200 cps bandpass filter by one having a somewhat wider bandpass. A new filter was obtained and installed and, although some readjustments were required, no noticeable decrease in sensitivity was found. Upon installation in the MGTL, the instrument operated in an acceptable manner.

V. OTHER EQUIPMENT

Several additional equipment items were installed in the MGTL. Descriptions and modifications to these items are presented in this section.

A. STROBE BEACON

For the purpose of providing an identifiable signal for night aircraft operations, a flashing strobe beacon, shown in figure 7, was placed on the forward portion of the van roof. Operational mounting position is shown in figure 1. The beacon is a one piece, self-contained unit, producing high intensity flashes through a fresnel lens. The unit operates from 117V, 60 cycle, AC current and produces approximately 10,000 to 20,000 candlepower per flash, depending on the rate, which may be set at any position between 1 flash per second and seven flashs per second. The light source is a xenon-filled, quartz discharge tube. The conical reflector was fabricated to help reduce the flash effect on the eyes of personnel working around the van. Testing of the beacon revealed that during tests involving aircraft operating a low altitudes this shield must be removed to ensure aircraft acquisition of the beacon at long range. The beacon is readily visible at ranges greater than 50,000 feet against any background.

The beacon, as originally fabricated, contained no provision for discharge of the capacitor bank when maintenance is required. To provide some measure of operator safety a 2000 ohm, 50 watt resistor and switch were installed to allow for manual discharge of the high voltage capacitor bank. This installation is shown in figure 8.

B. AIR CONDITIONER/HEATER

A General Electric R4B 701 air conditioner with 15,000 BTU cooling capacity was modified to include a 4.5 kw heater unit with a capacity of 15,300 BTU of heating. Because of cool weather at the time of delivery, no tests

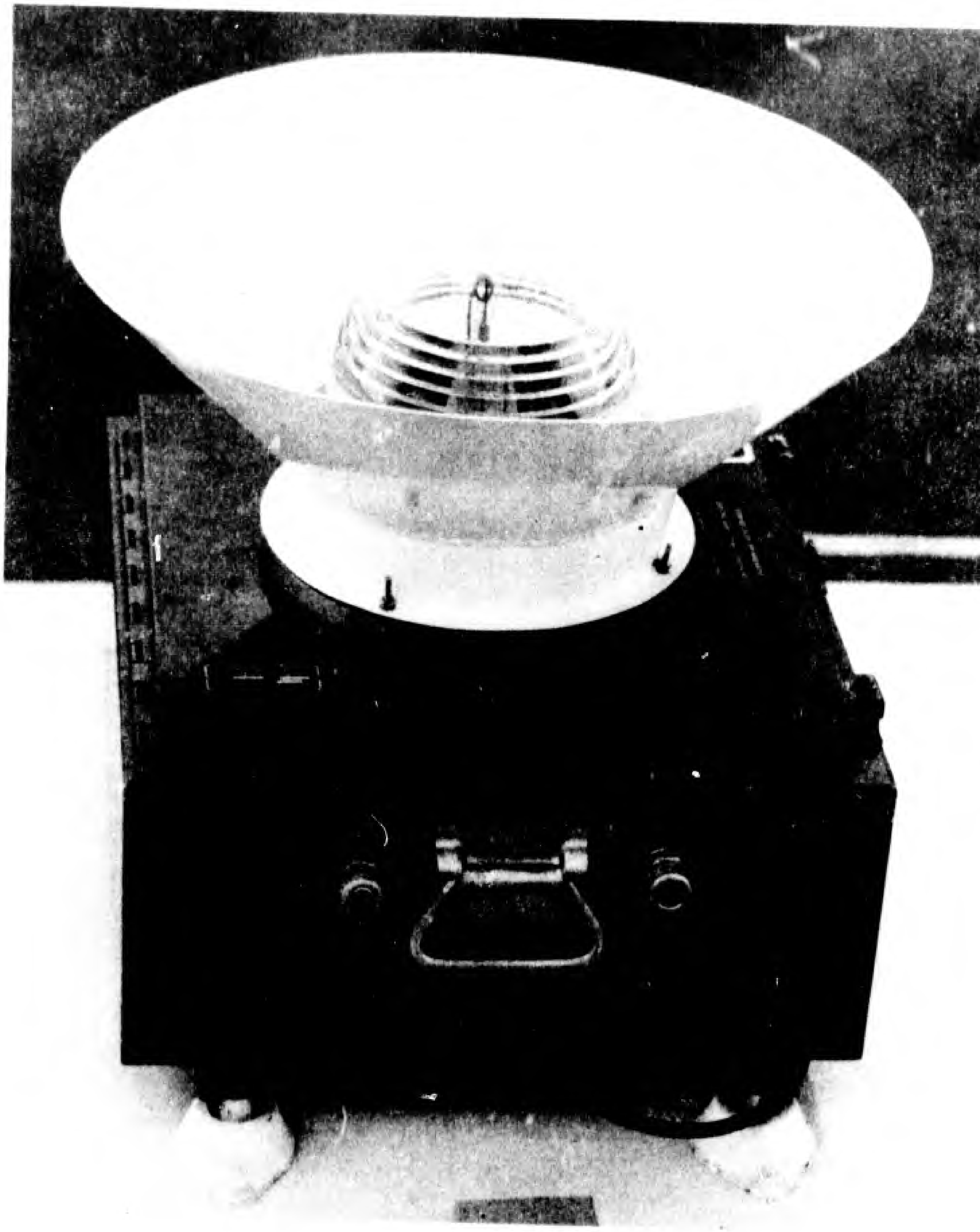

FIG. 7 STROBE BEACON

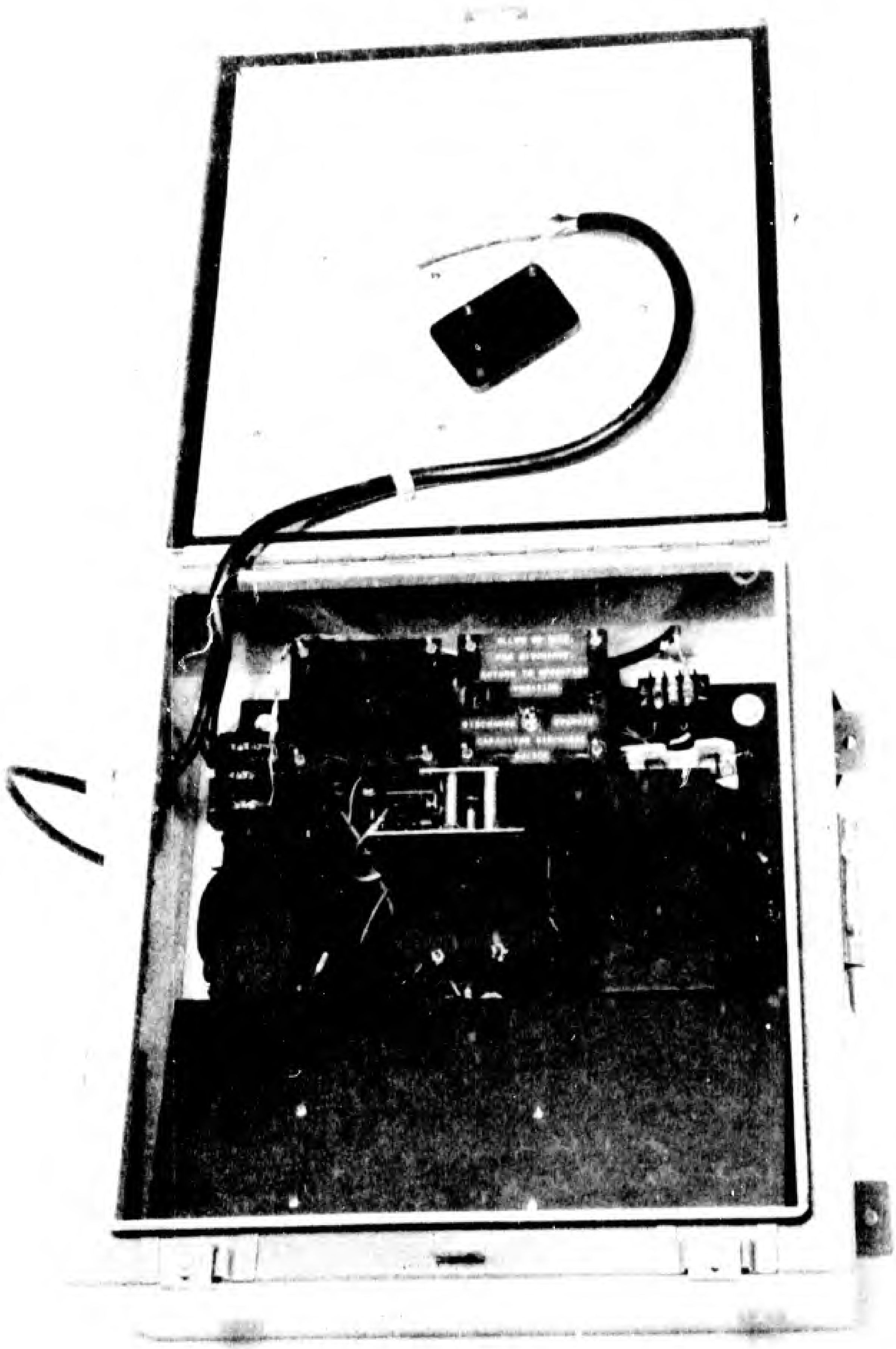

FIG. 8 CAPACITOR DISCHARGE SWITCH, STROBE BEACON

were conducted on the air conditioner portion of the unit other than to insure proper operation. Empirical calculations indicate the unit should be capable of maintaining the interior of the van below 68°F in any climatic conditions encountered in the continental U. S.

Operation of the heating unit during the winter period indicates a temperature above 68°F can be maintained during subzero weather even through periods of opening and closing of the rear doors of the van.

C. PORTABLE TAPE RECORDER

A small, battery-operated tape recorder was included in the equipment supplied for the purpose of providing the van operator with an instantaneous note-taking capability. This recorder operates on two 1-1/2 volt "C" batteries and has a tape capacity sufficient for 15 minutes of records. The mike-button operation of the recorder allows the operator to record only when a note is to be taken. The 15-minute recording capacity should be sufficient for several hours of notes.

D. MARKER PANELS

Four all-weather, fluorescent marker panels, 15 by 3 feet have been supplied for day light, pin-point marking of target sites. They will not be affected by water, freezing temperature or Solar heating.

E. MISCELLANEOUS

Accessories, such as mercury thermometers, cables, extra batteries, charts, etc., have been supplied and placed in the cabinets and drawers below the operator's work surface.

A five-drawer, map case was mounted in the forward part of the van to provide adequate storage for large charts, papers and other material.

A tool-kit was supplied with the van equipment and contains all necessary electrical and mechanical hand tools necessary for routine operation and maintenance of the van equipment.

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VI. RECOMMENDATIONS AND CONCLUSIONS

A. SUGGESTED EQUIPMENT ADDITIONS

Several items of equipment are recommended for addition to the instrumentation of the MGTL. These items could materially enhance the data base collected with a small additional expenditure. They are:

1. Soil Moisture meter
2. Soil Temperature meter
3. Precision Aneroid Barometer
4. Rain Gauge
5. Haze Meter or other instrumentation for determining atmospheric particle content.

These instruments would provide the data necessary to provide initial determinations of the true affecting variables in remote sensing. It is also recommended that addition of the proposed photometers be accomplished at the earliest possible date.

B. RECOMMENDED DATA COLLECTION AND STUDIES FOR THE MGTL

During the brief study conducted on data collection and reduction procedures for the MGTL, it became obvious that the true nature of the factors affecting the collection of visual and infrared reconnaissance data are not known. The effects of wind, rain, soil moisture, atmospheric gradients, and other phenomena act in such combination that the major variables are not readily separable. It is therefore recommended that the first studies to be conducted should be concerned with identifying which of the many phenomena are the major variables. These studies should be conducted at regular intervals over a period of at least a year and preferably several years. Measurements of all factors would be collected and subjected to detailed computer analysis to determine which of the many measurements taken do not contribute significantly to the variations in an infrared or visual image. Computer programs are readily available which would perform the initial analysis of the meteorological data. One of those available is the Multiple Regression Coefficient with Parsimony which will rank the data collected with respect to its relative importance. Further studies of atmospheric phenomena with respect to reconnaissance would then be facilitated since those factors which are related directly to the image could be used and others which may not contribute significantly or are dependent directly on other phenomena may be disregarded.

C. SUGGESTED MODIFICATIONS ON STOLL-HARDY PORTABLE RADIOMETER

General Observations -- Approximately 75% of the drift observed in the Stoll-Hardy portable radiometer originates in the radiometer head. Approximately 25% of the drift originates in the DC amplifying tube and associated circuitry. In discussing possible modifications, modifications to the head and to the remaining circuitry will be discussed separately. It is obvious that if any substantial improvement in the radiometer is going to be made, the considerable amount of drift which originates in the head must be eliminated. The modifications to the radiometer head will be discussed first.

RADIOMETER HEAD

General Discussion -- For the thermal-type radiation detector to provide a measure of the radiant energy or power incident upon it, the device must change in temperature by a measurable amount as a result of the absorption of the radiation. This means, in general, that the sensitive element must have relatively poor thermal connection to its surroundings except by absorption of radiation. The heat capacity of the element must be sufficiently low so that equilibrium temperature can be established rapidly, resulting in a reasonably short time constant of response to radiation.

The thermal detector element in operation will change in temperature as a result of variations in any of several sources of heat transfer, including the radiation from the source of interest. At any instant, the net flow of heat into the element may be represented by:

$$W(t) = W_r + W_{op} + W_s - W'_r - W_c \pm W'_c$$

where

W_r = heat flow due to radiation from surroundings to element, watts.

W_{op} = heat flow due to operating conditions, such as joule heating by bias current, cooling due to Peltier effect, etc., watts.

W_s = heat flow due to radiation from source under observation, watts.

W'_r = heat flow due to radiation from element to surroundings, watts.

W_c = heat flow due to conduction between element and surroundings, watts.

W'_c = heat flow due to convection to the element from its environment or from the element to its environment, depending on whether the thermal detector is above or below its environment in temperature.

In general, it is desirable to maintain all heat flow except that from the observed source invariant, so that the observed element temperature change represents that due to radiation from the source only.

$$W(t) = W_o + W_s(t) \qquad \text{where} \qquad W_o = \text{constant}$$

PRESENT DESIGN FEATURES OF STOLL-HARDY RADIOMETER WHICH CAUSE DRIFT IN METER READING

(1) When the ambient temperature changes, the ambient temperature body and the thermal detectors (thermistors) do not change temperature at the same rate. Ambient temperature body (blackbody) lags behind the thermistors. This is due to the differing thermal capacities of the two bodies.

Conditions -- Radiometer head inserted in the ambient temperature body.

(2) When the bias batteries for the radiometer head are turned on, current flowing through the thermistors causes joule heating of the thermistors which causes drift in the meter reading.

Conditions -- Immediately after radiometer is turned on and for a period of time thereafter. Radiometer head inserted in ambient temperature body.

(3) Noise is generated in the Radio "B" Batteries due to chemical reactions causing slight fluctuations in the meter readings.

Conditions -- When radiometer is either in or out of the ambient temperature body.

(4) When radiometer head is taken from the ambient temperature body, heat from the individual's hands causes the radiometer head to warm up causing drift in the meter readings.

Conditions -- When radiometer head is taken from the ambient temperature body.

(5) Load voltage of batteries supplying current to filament in the DC amplifying tube drops with time changing the amplification of the tube.

(6) Load voltage of batteries supplying current to the DC. amplifying tube and associated circuitry drops with time changing the null position for the meter and also amplification factor of the tube.

SUGGESTED CHANGES IN DESIGN TO REMEDY ABOVE CONDITIONS

(1) and (4)

The ambient temperature body and the radiometer head should be designed into one unit.

(2)

Voltage across the bridge circuit in the radiometer head should be reduced, thus reducing the meter drift caused by joule heating. Since reducing the DC bias voltage will reduce the sensitivity of the radiometer head to radiation, the DC. signal voltage from the radiometer head should be electronically chopped and amplified in AC amplifiers. Using AC amplifiers will also reduce effects from (5) and (6). With AC amplifiers, high sensitivity can be obtained by increasing the total amplification of the AC. amplifiers rather than trying to get a large signal change from the radiometer head itself.

(3) (5) and (6)

Mercury batteries should be used for all voltage sources.

NOTE:

Considerable reduction in the drift characteristics would result if bias voltage across the radiometer head were reduced considerably and the DC signal from the head were electronically chopped and amplified in AC amplifiers and converted back to DC. for meter purposes.

D. CONCLUSION

The Mobile Ground Truth Laboratory should contribute significantly to the understanding of the factors affecting reconnaissance imagery. It will provide on-the-spot data to correlate actual ground conditions with image appearance. The knowledge gained from its use will ultimately increase the utility of infrared reconnaissance by providing interpreters with valuable background knowledge for flight planning and interpretation.

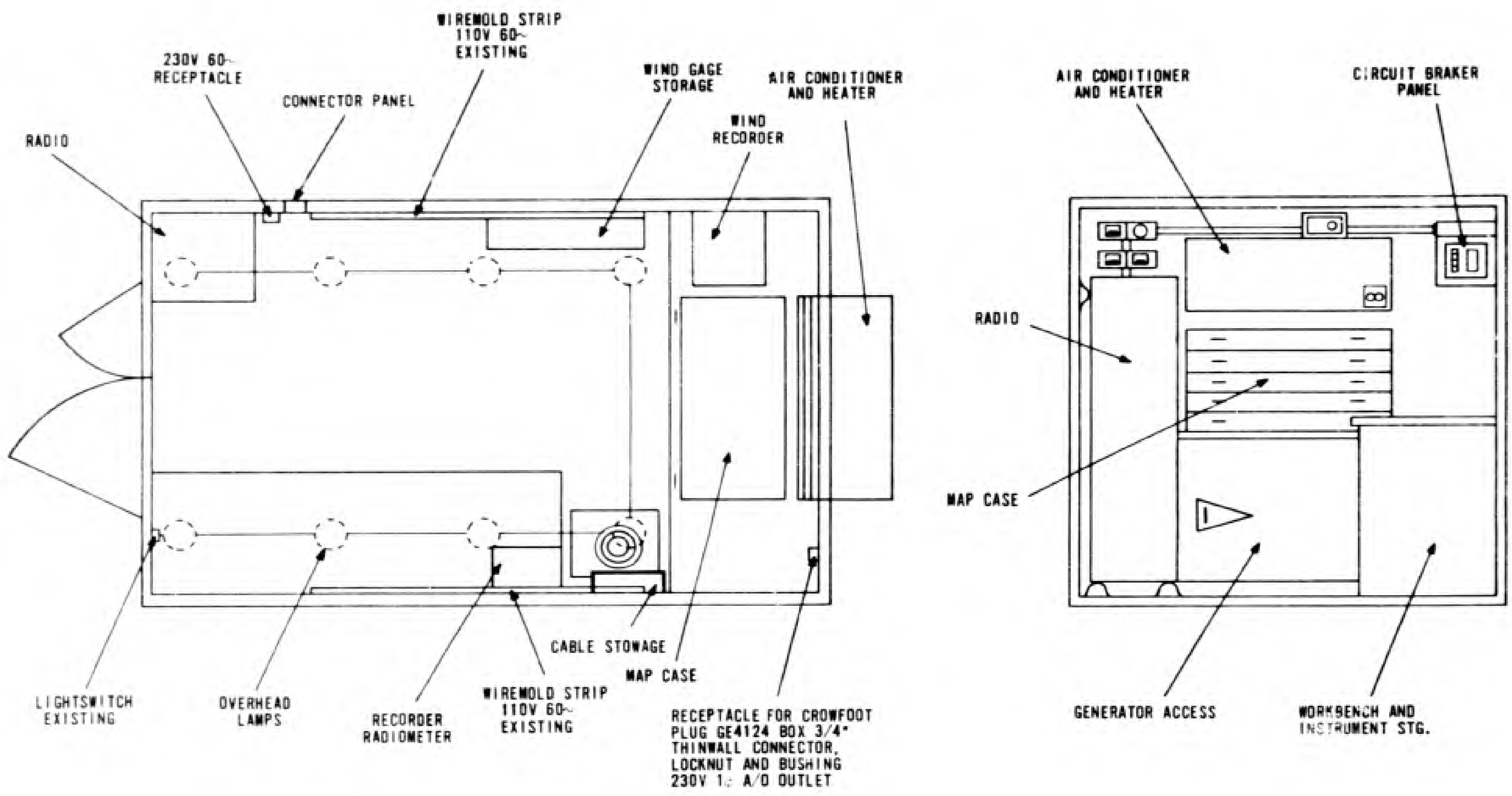

FIG. 9 EQUIPMENT LOCATION, MOBILE GROUND TRUTH LABORATORY

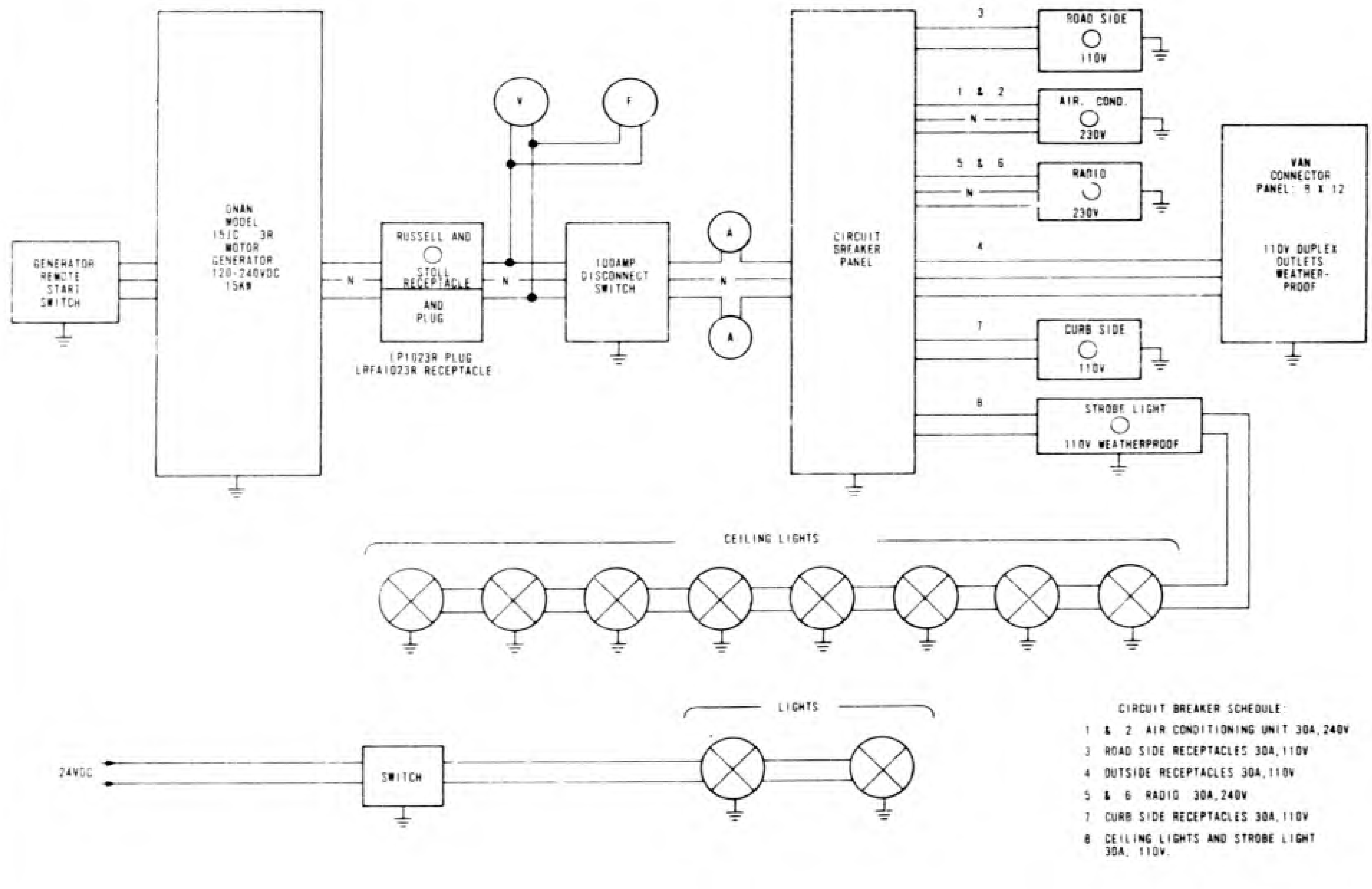

FIG. 10 ELECTRICAL SYSTEM, MOBILE GROUND TRUTH LABORATORY

APPENDIX A

PROCEDURES FOR THE ACCEPTANCE TESTING OF THE MOBILE GROUND TRUTH LABORATORY

HRB-SINGER, INC.
State College, Pennsylvania

PROCEDURES FOR THE ACCEPTANCE TESTING OF THE MOBILE GROUND TRUTH LABORATORY

Prepared for
Rome Air Development Center
Griffiss Air Force Base
New York

Contract No. AF30(602)-3461

22 September 1964

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TABLE OF CONTENTS

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I. INTRODUCTION

The tests and test procedures presented in this report are designed to provide proof of conformance to requested characteristics, operational performance and initial calibration or calibration checks. Wherever possible, manufacturer's recommended procedures for calibration have been incorporated within the test program. Procedures to prove operational usability were chosen to closely approximate the anticipated operating environment within the limits of time and economy.

Accuracy requirements of the measuring instruments supplied by the contractor are as follows:

1. An instrument for continuously recording temperature in ^{o}F with an accuracy of $\pm 2^{o}F$.

2. An instrument for continuously recording barometric pressure in inches of mercury with a reading accuracy of ± 0.02 inches (6.76 millibars).

3. An instrument for continuously recording relative humidity in percent with a reading accuracy of $\pm 5\%$.

4. An instrument for continuously recording wind velocity in miles per hour with an accuracy of ± 3 miles per hour and the nearest 15 degrees in direction.

Each of the above four instruments should record data so that it can be read in increments of 15 minutes.

5. A single channel radiometer is to be supplied for measuring the apparent radiation temperature in the infrared spectrum between one micron and 30 microns. Filters will also be required for this radiometer so that data may be collected in the 3 to 5 and 8 to 14 microns regions of the spectrum.

Data shall be recorded so that temperatures may be determined to at least one degree Fahrenheit.

The above instruments (1 through 5) shall be capable of operation at any time during the day or night and shall be portable in the sense that no more than 1/2 hour is needed for two men to carry it, set it up and operate it. This measuring equipment shall be mounted or installed so that it can endure being transported over terrain which can only be traveled with four wheel drive and be operated at a maximum distance of 100 feet from the mobile laboratory. Suitable calibrating equipment shall be provided with the various measuring devices, and recorders shall be equipped so that a time mark or blip can be marked remotely on the chart to signal the start and end of runs by the aircraft when the chart speed will permit.

Because of the low rate of chart movement (about 1 inch/hr.) and the time between the start and finish of an aircraft pass, it was considered impractical to make a blip or mark on the chart while it is recording. Doing this would make the chart so cluttered that extracting the recorded data would be difficult.

Since the meteorological recorders can be synchronized and are the continuous recording type, the start and finish of an aircraft pass will be verbally recorded on magnetic tape and later played back and made a separate permanent printed record. The time of the aircraft passes can then be included when meteorological data is extracted from the recording charts. Using a tape recorder will also allow the ground personnel to make notes of any peculiarities during passes of the aircraft. These notes will later be transferred and made a part of the permanent records. Testing of the recorder will essentially be a matter of talking into the microphone to record and playing back through the speaker system.

Additional items supplied by the contractor and adapted for the Ground Truth Laboratory include a ground signal marker, an electrical power plant and heating-cooling equipment.

Requirements for the ground signal marker are that the night marker be a stroboscopic light of sufficient intensity to be visible to an aircraft at 50,000 feet altitude and that the day markers be four orange flourescent panels 5 yards by 1 yard in size.

The electrical power source must be transportable and well regulated. Voltage fluctuations must be kept within the power requirements of the installed equipment and the source must be such that all equipment can be operated continuously and simultaneously without any mutual interference.

The heating and air conditioning equipment must be capable of maintaining an inside temperature of $68^{\circ}F \pm 10^{\circ}F$ regardless of the outside temperature and amount of equipment in operation. The air must be filtered to the extent required to keep the internal equipment of the Mobile Laboratory such as the recorders and the radio in operation.

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II. TESTING AND/OR CALIBRATING OF CONTRACTOR SUPPLIED EQUIPMENT

Methods of testing and adjusting instruments are outlined based on the standards and test equipment available at the contractor's facility. For instruments where elaborate setups are necessary for testing the complete range of instruments, methods of demonstrating the accuracy of the instrument over a limited range with the possibility of extrapolating results are outlined. All equipment was manufactured outside HRB-Singer, Inc., and manufacturer's specifications list equipment errors well within the limits set by the Ground Truth Van requirements.

A. METEOROLOGICAL INSTRUMENTS

1. Hydrothermograph

A Belfort Instrument Company Hydrothermograph catalogue number 5-594 has been selected as the instrument for recording both temperature and relative humidity.

Testing of the temperature recording portion can be performed by visually comparing the recorder temperature with that measured by a good mercury thermometer. Restrictions on the test are that the thermometer be in close proximity to the temperature sensitive bimetal strip of the recorder and that air currents be a minimum. The measured temperatures can be compared at different times during the day as the ambient temperature changes.

If the temperature is found, upon comparison with the thermometer, to be incorrect, an adjustment may be made by turning the thumbscrew nearest the front of the case until the thermometer and instrument pen are in agreement.

A test to determine the accuracy of the relative humidity part of the hydrothermograph requires comparison with a good psychrometer. For this test, the one provided with the van is satisfactory. Requirements for the test are primarily that the psychrometer be operated as close to the hydrothermograph as possible. More care must be used in checking humidity readings than is required in making temperature tests because the relative humidity varies with both the temperature and absolute moisture content. Ventilation is necessary to avoid stratification and, as the response of the hairs is slower than that of the psychrometer thermometers, checks should not be attempted except under steady conditions of relative humidity.

Ideally this instrument would be tested and calibrated in an environmental chamber or room where the relative humidity can be varied; however, this type of facility is not available at the contractor's location. Consequently, it is suggested that the measurements from the furnished psychrometer and the hydrothermograph be compared as ambient conditions change during the day.

If after several checks an error is found in the humidity indication, the rear adjustment knob can be used to correct the humidity pen's position to the correct indication.

When proper apparatus and conditions do not exist for directly checking instrument readings, the settings can be made by wetting the hairs with distilled water. Wet the hairs by stroking them gently with a "camel's hair" brush such as used for water color painting. Continue the wetting for several minutes until no further rise of the pen can be observed. When a stable condition is reached, set the humidity pen to read 92% by means of the thumbscrew in the base of the instrument located beside the temperature setting screw. Do not set the pen to read 100% humidity as no amount of artificial wetting seems to wet the hair to the same extent as actual exposure to saturated air.

2. Microbarograph

The measurement and recording of barometric pressure will be done with a Belfort Instrument Company, Microbarograph catalogue number 5-800.

Testing and/or calibration of the instrument may be performed in one of two manners. The first and most detailed test is the one used for originally calibrating the instrument or calibrating it after a complete overhaul. This method of testing requires a two cubic foot pressure box fitted with an arm through a stuffing box for remote setting of the adjustment knob, a pressure vacuum pump capable of covering the range of 1085 to 915 millibars and standard mercurial barometer used to monitor the test pressures which are controlled by hand valves. Temperature compensation requires a pressure scaled container with view ports which is operated within the temperatures range of 32^{o}F to 100^{o}F and pressure range of 965 millibars to 1050 millibars. In addition, air circulation within the container is necessary to avoid stratification.

This test procedure is quite specialized and requires two operators. One operator controls the pressure by means of the standardized mercurial barometer; the settings of the barometer should be such that after applying the temperature and gravity corrections, the required true pressure is delivered to the pressure box. The second operator reads the instrument under test and records the data. The test consists primarily of a rough calibration and then a temperature calibration.

Rough Calibration

These calibrations should be performed with the element cover off, no fluid in the damping device and millibar chart in place.

1. Place the instrument in the pressure box directly under the knob setter and close the door.

2. Set the pressure box at 1050 mb and set the instrument at 1050 mb on the chart.

3. Decrease the pressure to 1010 mb and then to 965 mb. Take readings of the instrument as the pressure is decreased.

4. If the range of the microbarometer is in error, move the range nuts to increase or decrease the space between the temperature compensating lever and lever arm. To shorten the range of movement, increase the distance between the temperature compensating level and lever arm; to increase the range of the movement decrease the spacing. Adjustments should be made by moving the nut one "flat" for every 016 mb error at 965 mb. Be sure to tighten the opposite nut when finished.

5. If the instrument is not operating linearly, adjustment should be made in the following manner. Determine the instrument error at 1010 mb. If the reading is low, loosen the linearity adjustment screw and manually move the pen upscale on the chart at the rate of about 5 mb for each 1 mb of error; if the reading is high, move the pen downward. Tighten the adjustment screw.

6. Repeat steps "c," "d," and "e" until the instrument reads within ± 0.3 mb of correct range linearity.

Temperature Calibration

This calibration is a matter of adjusting the clamp on the temperature element to get proper temperature compensation from the right hand end of the upper bimetal strip. The left hand end is counteracted by the bottom bimetal strip which is clamped thereto.

1. Set the instrument at ambient pressure (at the start of the first cycle only).

2. Place the instrument in the heated box for 1 hour and 10 minutes with the temperature at $100^{\circ}F \pm 5^{\circ}F$.

3. Cycle the pressure in the box from 1049.0 to 966.0 mb. Take readings of the instrument and record them as the pressure changes.

4. Use the same procedures for the cold cycle holding the temperature at $32^{o}F \pm 5^{o}$ and $0^{o}F \pm 5^{o}F$.

5. Subtract algebraically the instrument reading from the true pressure for both hot (HOT DIFFERENCE) and cold cycle (COLD DIFFERENCE) for each of the two pressures.

6. Subtract algebraically the "COLD DIFFERENCE" from the "HOT DIFFERENCE" for each of the two pressures. Make a graph with the pressure as ordinate and error as abscissa. Draw a straight line connecting the errors at the two pressure readings.

7. If the plotted line is within $\pm$.4 mb error, the temperature calibration is acceptable and one can proceed to the final calibration.

8. If the error exceeds the $\pm$.4 mb limits, temperature compensation is required. Adjust the instrument in the following manner: Move the clamp of the temperature element toward the clock when the plotted line has a negative error; move the clamp away from the clock wheh the line has a positive error. A 0.15" movement of the clamp should move the nearly-vertical plotted line approximately 0.5 mb.

9. Repeat the temperature calibration beginning with step "a." The second method of testing is considerably simpler and because the aforementioned special testing equipment is not available at the contractor's facility, it is the most feasible method for checking the instrument. This method involves comparing the recorded barometric pressure with that measured by the mercurial barometer supplied with the Mobile Ground Truth Van as the ambient pressure changes during the day. The variation of the pressure over a 24-hour period should provide sufficient points for extrapolating over the recorder range to determine its accuracy.

If the recorder appears to be in error, it is recommended that adjustments be made only after a trend has been established to indicate the manner in which the instrument is incorrect. Corrections should be made by making the adjustments outlined in the first method.

3. Wind Speed & Direction Recorder

The instrument used for measuring the wind velocity and direction is a Belfort Instrument Company Type L, Wind Direction and Speed Transmitter. A Type M Recorder is used with the transmitter for providing a permanent record.

With the transmitter and recorder connected, testing of the instrument for direction can be accomplished by first using a compass to determine true North and making sure the recorder indicates North when the vane is pointed in a true North direction. Secondly, rotate the vane through 360^{o} in increments of 15^{o} and make sure the indicator pointer moves in the proper direction and the proper amount.

Detailed laboratory testing of the wind speed indicator would require a wind tunnel capable of moving the air at accurately known speeds. This type of facility is not available at the contractor's location; therefore, a test to determine that the instrument is correctly zeroed and that it does record variable wind speeds is suggested. This test can be done by using a 3-speed fan and blowing the exhaust across the wind speed transmitter. The recorder can then be checked to see that it is recording increases and decreases properly.

B. RADIATION MEASURING INSTRUMENTS

For the recorded measurement of apparent radiation temperature, a Model 3901 precision radiometer manufactured by Huggins Laboratories, Inc., will be used. This radiometer has a portable optical head and van based amplifier and recorder. In addition,a battery operated, portable, Stoll-Hardy HL4 radiometer manufactured by the Williamson Development Co. will be available. This is a completely portable, nonrecording type radiometer where the apparent temperature is observed on a meter. The calibration or testing of these radiometers requires the measurement of radiation from a source of known temperature and emissivity.

1. Model 3901 Precision Radiometer

The Precision Radiometer temperature calibration can be checked over the midrange temperatures with any good blackbody source having a known and accurately controlled temperature. The Barnes RS-12 blackbody extended source will work well in this range. The low temperature range (0-100°C) can be conveniently checked with a melted ice-water mixture or boiling water and the RS-12 source. To check the high temperature range (1000-4000°C) a high temperature furnace cavity and optical pyrometers are required. Since the radiometers will be used primarily on the low and midrange temperature scales, procedures for testing at these temperatures will be emphasized.

Test Procedure

1. Set up the Optical Head to view the appropriate source, making certain the field of view as defined by the reticle is completely filled by the source. If a controlled source such as the Barnes RS-12 blackbody is used, set the temperature about 5°C above ambient and allow sufficient time for the source and radiometer to reach a stable temperature.

2. Set the EMISSIVITY control at 100 and the radiometer indicated temperature should agree with the source temperature to within 1% of the true full scale Kelvin temperature of the appropriate range setting. The temperature of the source should then be increased in approximately 20°C

steps and the radiation temperature again measured. The radiometer should be tested over the temperature range in which it is expected to operate and if the reading is out of tolerance, adjustments should be made as follows:

3. Remove the top cover of the Indicator/Control Unit by removing two screws on each side of the cover. Corrections are to be made for the temperature range B through F first and are done as follows: Adjust the calibration potentiometer R624 on circuit board 600 located at the extreme right of the chassis (potentiometer R624 is located near the center of the board) until the indicated reading is within the specified tolerance of the true temperature.

Do not adjust the trimmer potentiometer on attenuator board 800.

After setting the main calibration potentiometer, allow the source to cool until it again reaches ambient temperature. This time adjust the source in the 0 to 100°C range and check the temperature measured by the radiometer. The temperature should be within ±3°C of the source temperature.

If the indicated reading is out of tolerance, adjust the potentiometer R726 (near the transformer on the center circuit board) until the reading is within the tolerance.

Replace the top cover and return to service.

2. <u>Stoll-Hardy HL4 Radiometer</u>

Testing or calibrating the Stoll-Hardy HL4 Radiometer requires a body of unit emissivity and maximum temperature range of 100°C above or below ambient. The source used for calibrating the Precision Radiometer low and midrange scales will also prove satisfactory for the Stoll-Hardy radiometer.

After turning the instrument on and allowing it to reach a stable temperature, adjust the meter to zero using first the 100 and then progressively the more sensitive (lower) scales.

Remove the radiometer head from the aluminum ambient temperature body and place it pointing at (and near) the temperature source. Take a reading of the meter as quickly as possible and return the head to the ambient temperature body.

Add the reading of the meter (taking account of the sign as determined by the meter switch) to the reading of the thermometer in the ambient temperature body to determine the apparent radiation temperature of the source. On the 10 (and probably the 30) range, the linear meter scale will closely correspond to the temperature curve, but for the 100 range the sensitivity should be adjusted for some convenient point on the scale, and a calibration curve prepared. This curve should be prepared under as nearly as possible the actual measuring conditions.

If the reading does not correspond to the known temperature of the source, adjust the appropriate control on the subpanel adjacent to the back of the meter. This adjustment can easily be made by means of the screw-driver adjustment at the right of the meter. The order of the calibration controls from the bottom up is the same as their order on the range switch as it is turned to the right.

C. GROUND SIGNAL MARKER

A Kemlite Strobe Beacon Model STR-500 has been selected as the ground marker for night flights.

To realistically test the efficiency of the beacon would require an aircraft containing a pilot and observer and series of flights at various altitudes and slant ranges to a maximum of 50, 000 feet above terrain. The observer would record his observation in a format designed to give relative detection and recognition values for various altitudes and distances against both open natural areas and densely lit urban area backgrounds.

Although this type of test would provide the most realistic results, there are several obvious disadvantages, the greatest of which is the expense involved in aircraft operations. Since the contractor currently has no aircraft capable of reaching an altitude of 50,000 feet, a government-furnished aircraft would be a necessity and the many problems inherent in any flight testing operation would be increased by the coordination effort required between Air Force flight operations schedules and the contractor. Weather delays and aircraft down time would also increase the complexity of a relatively simple problem.

The recommended alternative takes advantage of the mountainous terrain surrounding the Contractor's facility. Numerous readily accessible vantage points exist on the surrounding ridges where line-of-sight distances considerably greater than 10 miles are available. By selecting several of these points as a base for the Mobile Ground Truth Van, several spotters can be placed at the required distances and observations taken with little or no communications problems and the obvious advantages of no last minute flight cancellations because of weather or malfunction.

Additional testing can be made if deemed necessary at little extra expense. Since atmospheric attenuation is generally at a maximum over horizontal distances at ground level, this test would give an excellent approximation of the worst operation condition under which the aircraft might be collecting data. Two separate tests will be made, the first against an inactive natural background. The second will place the beacon in close proximity to other light sources such as street lights and building lights.

At present the beacon is set at a flash frequency of approximately one flash per seven seconds. Should poor recognition result with this setting, further testing at a higher or lower frequency of flash may be easily conducted since a simple lever adjustment of the flash rate is included in the timer mechanism.

The four orange fluorescent panels will be available for inspection, but no test is planned with them.

D. ELECTRICAL POWER PLANT

The electrical power plant selected for use with the Mobile Ground Truth Van is an Onan Electric Generating Plant Model Number 15JC-3R. Because of its weight, the van has been modified and the generator is mounted to the truck frame instead of above the cab as originally planned.

A list of all instruments and equipments requiring electrical power and an estimate of their power requirements indicates a total load of 6,900 watts. The power plant being supplied has sufficient capacity for a 100 percent increase in this load; therefore, the test procedure will be designed not to show that the power is capable of delivering full power but that the present load may be greatly increased without any interference in the operation of the instruments and equipment.

1. With the generator in operation, all instruments and equipment which require electrical power will be started.

2. A check to ascertain that all instruments and equipment are functioning properly will be made.

3. If all instruments are operating correctly,the electrical load on the generator will be increased by starting a small portable electric heater (approximately 1400 watts). If everything is working properly and,if available, a second portable heater will be started. This will make a total load increase of 40 percent and if everything operates properly, should adequately demonstrate sufficient capability of the generator.

4. If there is any interference between the instruments, they will be turned on and off one at a time to determine which instruments are interfering with each other. With this information, steps will be taken to redistribute the instruments or more adequately ground the instruments to alleviate this problem.

5. A test of the regulation of the voltage output can easily be made by plugging a VTVM or other voltage measuring meter into one of the outlets and observing the voltage as the power load is increased and decreased.

E. HEATING-COOLING PLANT

The heating-cooling plant installed in the van is capable of delivering 15,000 BTU/hr. heating or cooling. Calculations based on the volume of air to be conditioned and the insulation in the van reveals this rating should be more than adequate for satisfying the temperature requirements. Since there is no local facility where the truck can be placed in a temperature chamber and be subjected to a wide range of temperatures, it is recommended that the acceptance test be based on the ability of the heating-cooling plant to produce temperatures inside the van 20° - 25°F below ambient with the air conditioner and 20 - 25°F above ambient with the heater. Normal local temperatures at the anticipated date of the tests are around 55°F during the day and 35°F during the night. These tests would be conducted with all instruments and equipments in the van operating and the doors closed.

III. TESTING OF THE EQUIPMENT INSTALLATION AND STORAGE INTEGRITY

Since a major operational requirement of the Mobile Ground Truth Van will be its use in rough, off-road terrain, the resistance to mechanical shock of all mounted and stored equipment is of prime importance. The following simple test will provide a close approximation to actual operating conditions and provide an indication of any deficiencies in mounting and storage of equipment. Two phases of testing are planned.

A. PRELIMINARY TEST MADE BY THE CONTRACTOR

The first test will be conducted using the van with all permanently attached equipment in place, such as radio, generator, air conditioner/heater, etc. All stored or "Portable" equipment, such as radiometers, barometers, and other less rugged equipment will be replaced with suitable simulated sizes and shapes of materials such as a light balsa wood frame with a doped tissue paper covering. The above procedure would indicate any deficiencies in the storage without risking damage to the instruments.

B. RECOMMENDED TEST FOR ACCEPTANCE

The second or final test will be conducted with all equipment in place. If any change or modifications are indicated by the preliminary test, they will be made and a second preliminary test will be conducted prior to the final test.

Both tests will consist of actual operation of the van over a prescribed 10-mile course in rough terrain surrounding the Contractor's facility. Both unimproved road and off-road driving will be included. Maximum speeds used in these tests will be:

Improved Roads -- 40 mph

Unimproved Roads -- 15 mph

OFF-road -- 7.5 mph

For purposes of testing, an operator of average driving skill will be assumed and further, since it is not anticipated that this equipment will be operated under combat conditions, deliberate "torture-testing" will not be undertaken. Because of time limitations no effects of continuous use, such as metal fatigue, can be reasonably determined from these procedures. Following the drive all equipments will be set up and operated for a short period of time.

This will complete the test procedures and should satisfactorily demonstrate contractor compliance with U. S. Air Force Contract Number AF30 (602)-3461.

APPENDIX A: Check Off Sheet

Instrument or Equipment	Acceptable Error	Instrument Error	Test Acceptance
Hydrothermograph	±2°F, ±5%, relative humidity		
Microbarograph	±0.02" of Hq (6.76 millibars)		
Wind Speed & Direction	±3 miles per hour nearest 15 degrees		
Precision Radiometer	Determine radiation temperature to 1°F		
Stoll-Hardy Radiometer	Determine radiation temperature to 1°F		
Strobe Beacon	Visible at 50,000 ft. altitude or 10-mile line-of-sight		
Orange Fluorescent Panels	------------------		
Electrical Power Plant	Capable of supplying all instruments and equipments without overload or interference		
Heating-Cooling Plant	Maintaining van interior at 68°F ±10°F		
Equipment Storage & Installation	Can be driven over rough road with no equipment damage		

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