1881

CONIFEROUS FOREST BIOME

U.S. ANALYSIS OF ECOSYSTEMS

INTERNATIONAL BIOLOGICAL PROGRAM

INTERNAL REPORT 64

A MULTIPOINT ENVIRONMENTAL TEMPERATURE RECORDER

by

H. Richard Holbo
Oregon State University

BIOME CENTRAL OFFICE • AR–10 • UNIVERSITY OF WASHINGTON • SEATTLE, WASHINGTON 98195 • TELEPHONE (206) 543–2757

ABSTRACT

A multipoint environmental temperature recorder is described. Some of the many features that recommend the application of this recorder to field studies are multiple input capability, efficient use of chart paper, reliability, and low power consumption from batteries. Design considerations and electrical details are provided.

INTRODUCTION

The first requirement of many environmental studies is often for temperature records. It is desirable to have this information taken at least on an hourly basis in order to describe the variation in temperature with time. Also it is usually of interest to sample a number of positions in the environment simultaneously. In most cases, battery power must be used.

In consideration of the number of sensors and the frequency of sampling, it was decided to design a device that would have the capability of sequentially switching the sensors into a common recorder. The availability of a battery-operated temperature recorder from Rustrak (TM, Rustrak Instrument Div., Gulton Industries, Inc., Manchester, N.H.) provided a convenient nucleus for the total package.

In the completed instrument, hourly sampling was controlled by a cam-operated switch, which was in turn driven by a clock mechanism. Another cam on the same shaft caused a stepping switch to scan serially each of the sensors for one-minute intervals. A chart speed was selected so that the measured value of each input would be displayed for about 0.25 cm. Data are tabulated from the chart simply by knowing the scan sequence of the sensors.

Figure 1 is a functional block diagram of the temperature recorder. Technical details about the recorder, the sensors, and the performance of the instrument are given in the following sections.

RECORDER DESIGN

The central element of the recorder design is the Rustrak model 2133 thermistor probe recorder. This unit contains a bridge circuit and recording galvanometer. As applied by the manufacturer it would normally provide the capability of recording continually from only one thermistor sensor.

The intent here is to extend the capability of the recorder to 11 sensors, and to restrict the sampling from a continuous record to hourly intervals to extend the life of the chart. Data tabulation is facilitated by committing one additional interval to making a reference mark on the chart for separation of each hourly record.

The bridge circuit (Figure 2) used with the thermistor probe is an integral part of the Rustrak 2133 temperature recorder. The manufacturer supplies interchangeable probes, however, so that it is possible to use various thermistors in conjunction with the same bridge circuit. This is better than using a separate bridge for each thermistor, particularly in terms of measurement precision.

Scanning between the thermistors is accomplished by a 12-position stepping switch actuated by a cam-operated microswitch. Closure of the microswitch is made at one-minute intervals. Since the current requirement of the stepping switch is large and the duration of microswitch contact closure is difficult to control with the cam, it is advantageous to operate the stepping switch through a switching transistor (Figure 3). The switching time of the transistor is controlled by an *RC* circuit such that current is applied to the stepping switch for only enough time to ensure that it advances to the next position. In this way a great saving in battery power is effected, and the average battery drain is reduced by a factor of 1/10 or more.

Hourly sampling of the sensors is controlled by a cam-operated microswitch. Closure of the microswitch applies power to the recorder and the scanning circuits. Both the hourly cam and the one-minute interval cam were machined from aluminum and are mounted on the same shaft. The clock mechanism driving this shaft is available as a replacement chart drive unit for recorders of various kinds. The one chosen for this application makes one shaft revolution per hour, and is battery powered. The clock battery is separate from the main battery and would normally be replaced twice a year. The clock also could be operated from the main battery.

The time during the hour at which sampling takes place can be selected for convenience. The front panel is removed to allow access to the clock battery terminals. Just as the cam starts into a sampling period the battery is then disconnected, thus stopping the clock mechanism. It is restarted by reconnecting the battery at the time in the hour that sampling is desired. This might be at the hour, or on the half-hour, for instance. Other sampling intervals (half-hourly, quarter-hourly, etc.) could be devised by substituting different cams.

The power requirement of the recorder is approximately 0.167 ampere-hour per day. This is less than the self-discharge rate of most lead-acid storage batteries. The anticipated length of service on a fully charged 70-Ah lead-acid car battery for this recorder is 3-4 months. Alternatively, a zinc-carbon battery could be employed. The Burgess charts for a no. 6 telephone cell, nominal voltage 1.5 V, suggest a life of 3 months, certainly as long as 6 weeks, when discharged at 0.167 ampere-hour per day. In this instance eight cells would be connected in series to obtain the desired 12 V.

The chart speed selected for the recorder was 15 cm per hour. Thus, for a 1-min scan interval, the value of any given sensor would be displayed for 0.25 cm. For other chart speeds the length of each sensor's trace in centimeters would be calculated: (chart speed in centimeters per hour × scan interval in hours), where 1 min = 0.0167 hour.

Most commonly available stepping switches have 12 positions (see Figure 4). This may be more or less than needed in a given study, but was thought acceptable in view of the simplicity afforded. Committing one of these 12 to a reference mark interval ensures separation of successive hourly scans, and leaves 11 positions for use in scanning sensors.

Since there are 12 positions in the scanning sequence 12 minutes are required to complete a scan, which in turn requires 3.05 cm of chart each hour. This amounts to 73 cm per day. Since there are 1920 cm to a roll of chart paper, the chart must be changed every 26 days of continuous operation. The chart speed and length of service may be adjusted by changing the gear train assembly in the recorder drive mechanism.

Selection of a temperature range for the recorder was based upon anticipated extremes in the environment. To maintain the greatest amount of resolution, however, the range should be as small as possible. A range from -10°C to 40°C was chosen. To match this 50°C range a chart paper having 50 divisions (Rustrak style A) was selected.

Manufacturers specifications claim a ±2.0% of range accuracy for their recorder, which means in this case that the absolute temperature will be known to ±1°C. Their claim to stability (this might be called resolution or precision) is ±0.5% of range, or ±0.25°C. One should thus expect to have comparability between readings, either within a scan or between successive scans, of no better than 0.5°C.

SENSOR DESIGN

The major problem in adapting the Rustrak model 1331 sensors, or any sensor, to measuring air temperature is in minimizing the errors caused by solar radiation. The usual procedure is to shield the sensor from the sun using reflective materials. Caution must be exercised, however, to ensure that other errors are not introduced. Of course, no modification of the sensor is required to measure soil temperatures, and the like.

The radiation shield design used in this study is based upon a commercially available model.[1] The shield consists of a series of

---

[1] C. W. Thornthwaite Associates, Route 1, Centerton, Elmer, NJ 08318

parallel sheets of metal arranged in such a way as to protect the sensor from solar radiation by making the surfaces facing away from the sensor highly reflective, while the inner surfaces are treated to be nonreflective. The flow of air through this shielding must not be impeded. The sheets are large in surface area with respect to their heat capacity, so that they tend to be close to air temperature. The sensor is exposed to the air within this assembly and the assembly is mounted on a bracket for support at the appropriate position in the environment (see Figure 5).

PERFORMANCE TESTS

A series of tests were run on the recorder with the sensors in water baths. Complete analyses, sensor by sensor, were not run. The general results of the tests can be summarized as follows:

1. The mean temperatures of the measurements from sensors attached to the recorder tend to be higher (1.0°C) than the actual temperature of the bath. This is perhaps of no consequence.

2. Somewhat more variability exists between sensors than was implied by the manufacturer, so the sensors are not truly interchangeable. The discrepancies among sensors is in the order of 1°C at temperatures near freezing. Successive scans in the same bath show at least 0.25°C precision for any given sensor, however. The discrepancies were more pronounced at low temperatures (0°C) than at higher temperatures.

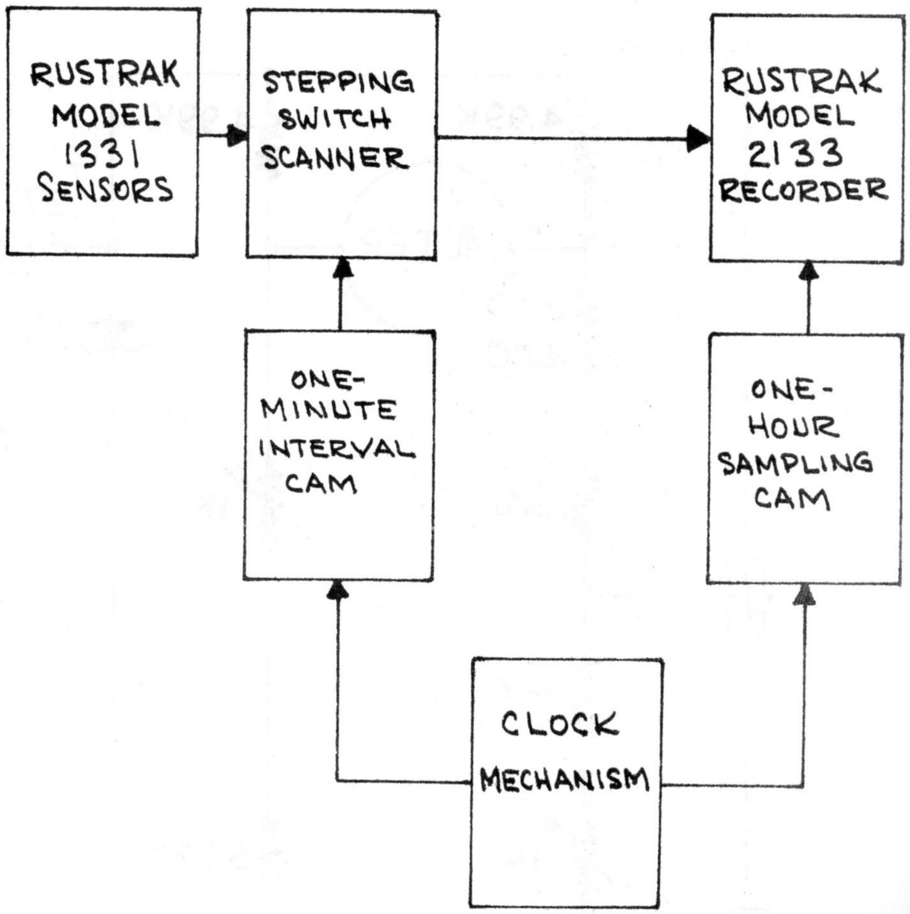

Figure 1. Functional block diagram of the environmental recorder.

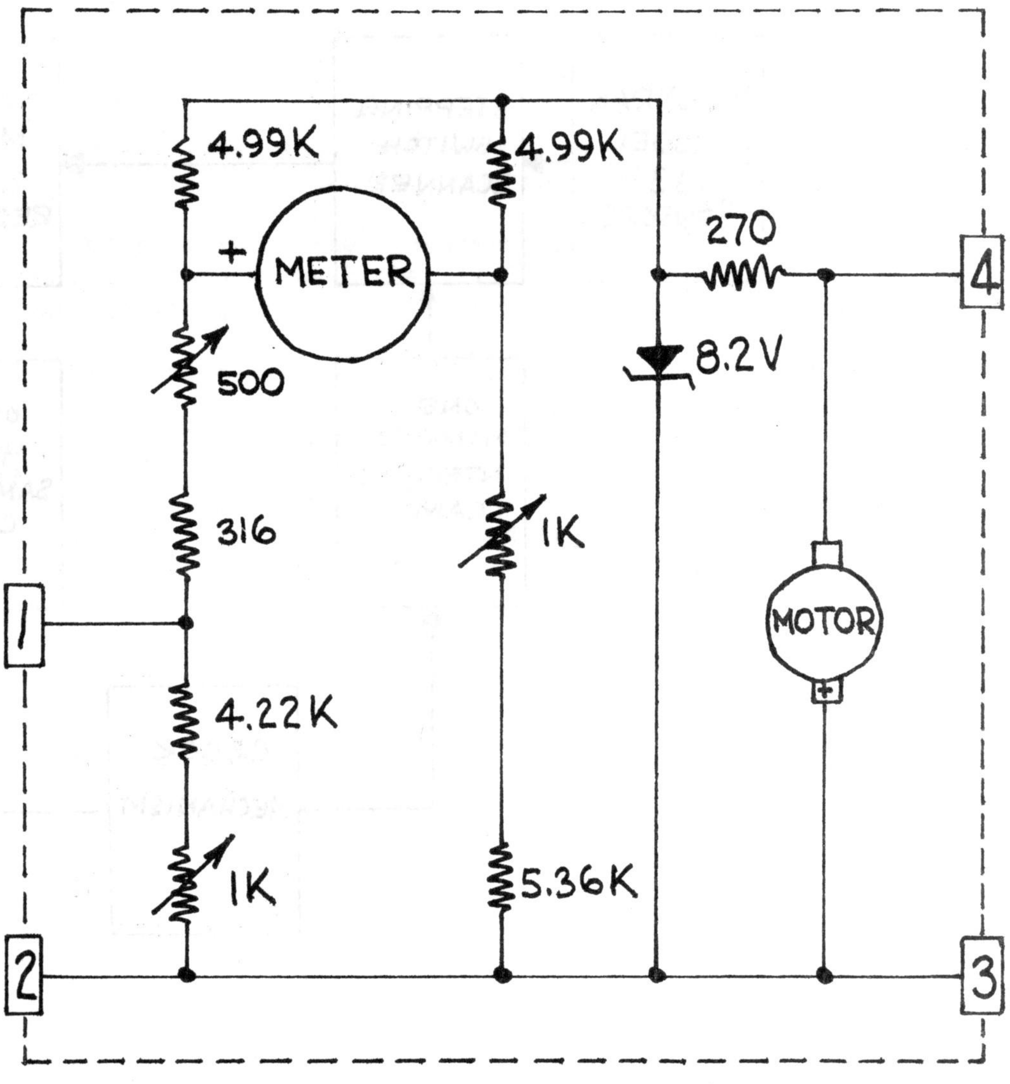

Figure 2. Thermistor bridge circuit in the Rustrak model 2133 recorder. Numbers in squares are for reference to connections in Figure 4.

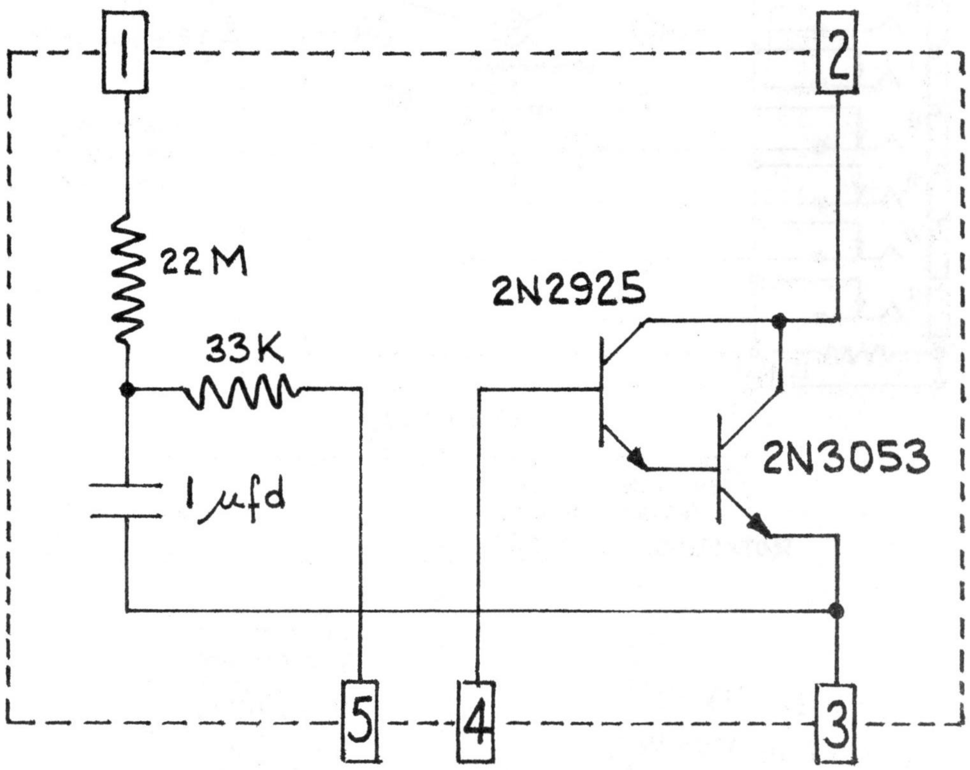

Figure 3. Driver circuit for the stepping switch scanner. Numbers in the squares are for reference to connections in Figure 4.

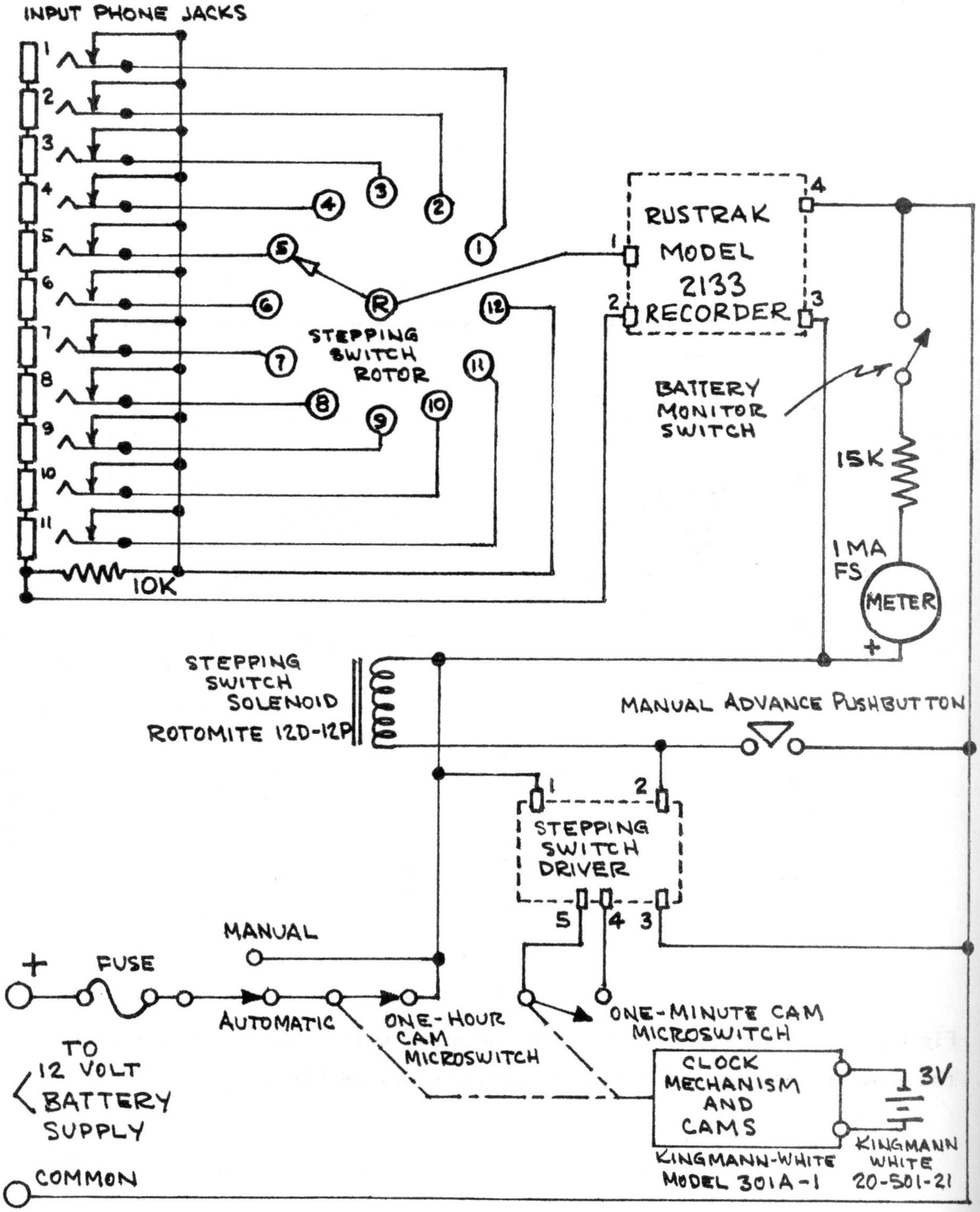

Figure 4. Schematic diagram of the environmental temperature recorder. See Figures 2 and 3 for circuit details of the Rustrak recorder and the stepping switch driver.

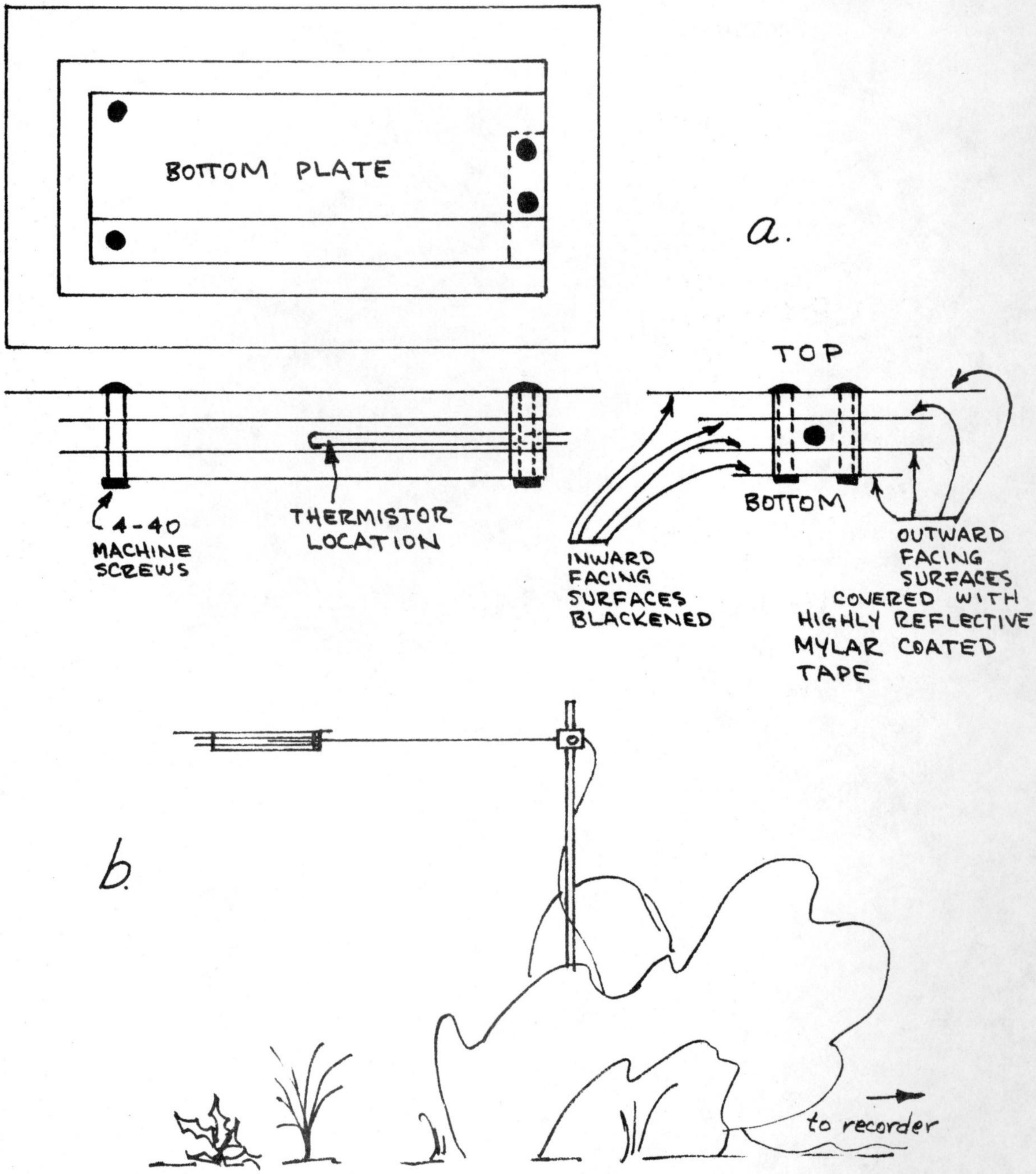

Figure 5. Radiation shield and sensor assembly. (a) Radiation shield detail, one-half scale. (b) Sensor assembly in position, one-eighth scale.