BAROGRAPH WITH MAGNETIC COMPASS HEADING RECORDING

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Presented at the XX OSTIV Congress, Benalla, Australia (1987)

1.0 Summary

A compass module accessory was developed and combined with the XYLON standard BAR-350 digital barograph to meet the OSTIV requirements for a barograph with combined altitude and compass heading records. A small magnetic compass was optically encoded to provide a digital output. The microprocessor in the BAR-350 barograph was used to interrogate the compass and process the output to provide a compass heading printout or indication of circling. Several flights were made to demonstrate the operation and show the type of records produced.

2.0 Introduction

In response to the OSTIV request, a digital compass module accessory for the standard XYLON BAR-350 digital barograph meeting the OSTIV requirement for a barograph with combined altitude and compass heading record was developed and flight tested.

Since the BAR-350 incorporated a microprocessor, it was possible to make the addition of the compass heading recording capability in a relatively simple and straightforward manner. The microprocessor provides the capability to interrogate the compass and process the encoded digital output to provide a compass heading printout or indication of circling.

3.0 System

The complete system, shown in **Figure 1**, consists only of a small compass module, interconnect cable and a standard BAR-350 barograph. Power is provided by the BAR-350 internal batteries, so the system is completely self-contained. The block diagram, **Figure 2**, shows the functions included in the two components.

At six second intervals, the microcomputer scans the encoder disk on the magnetic compass to determine the com-

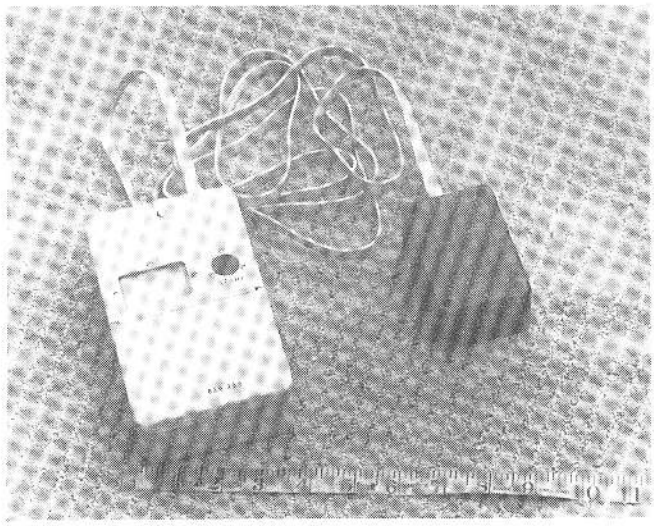


Figure 1. Complete System.

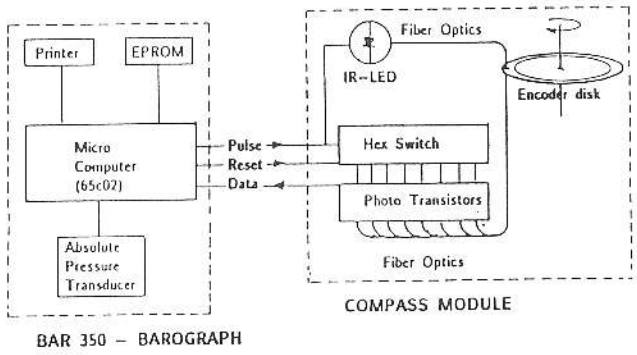


Figure 2. Functional Block Diagram.

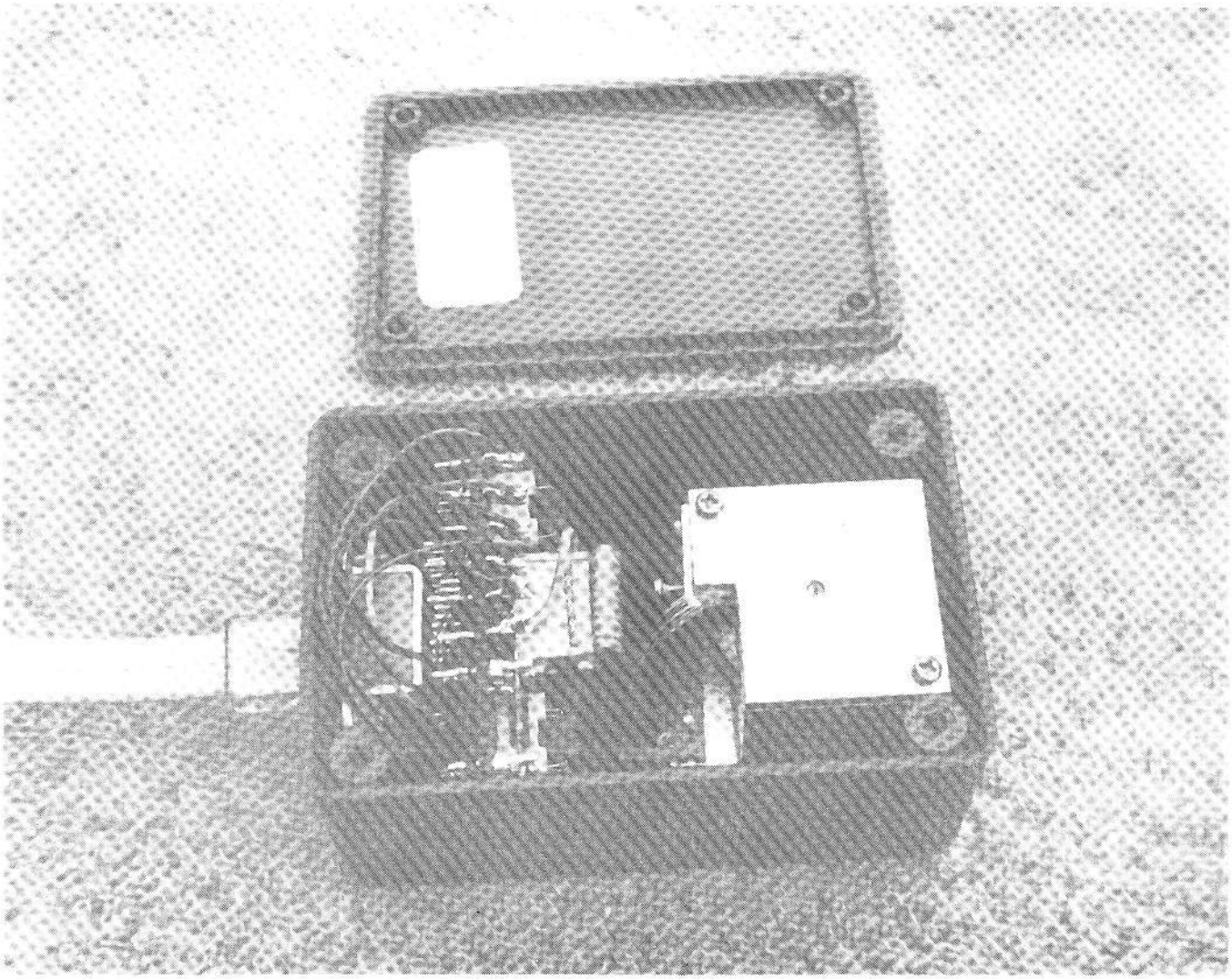


Figure 3. Compass Module.

pass heading. An algorithm in the software determines whether the headings measured during the one minute interval indicate circling or cruising. The cruising compass heading is printed along with the elapsed time and altitude at one minute intervals.

For the OSTIV application it did not appear necessary to add the complication of gimbaling the compass to correct for the errors due to pitch. The error due to roll when thermalling is not important since heading is of little interest when thermalling. The error due to pitch during dolphin flying, while significant, will generally average out to zero since there will be approximately an equal number of climbs and dives.

The technical data for both the barograph and compass module are shown in Table 1.

4.0 Compass Module

The compass module is a magnetic compass with a digital output that can be connected to the BAR-350 barograph to provide a heading record in parallel with the standard BAR-350 altitude vs. time record. The photograph of the compass module with cover removed, **Figure 3**, shows the magnetic compass, encoder disk with fiber optics read-out and the associated prototype electronics.

4.1 Operating Principle

The sensing unit is a small eddy current damped magnetic compass with jewel bearing pivots. The jewel bearings and small mass result in static friction error considerably less than the required compass accuracy of + /-5 degrees. A fiber optics array from an infra-red emitting diode illuminates an eight ring encoder disk attached to the compass. A second fiber array transmits light to eight photo transistors, generating an eight bit code and corresponding 2 degree resolution.

The compass heading is read at six second intervals by a reset signal followed by a series of eight pulses sent from the BAR-350. Since each pulse duration is only 1 millisecond and the current approximately 30 milliamperes, the average power supplied by the BAR-350 internal batteries, is negligable.

The BAR-350 microprocessor converts the eight bit encoder data to the compass heading and processes the 10 heading readings using a programmed algorithm so that the heading is printed at the same one minute interval as for altitude.

4.2 Conversion Algorithm

It is possible to use a variety of different algorithms to process the 10 compass headings to the print-out at the one

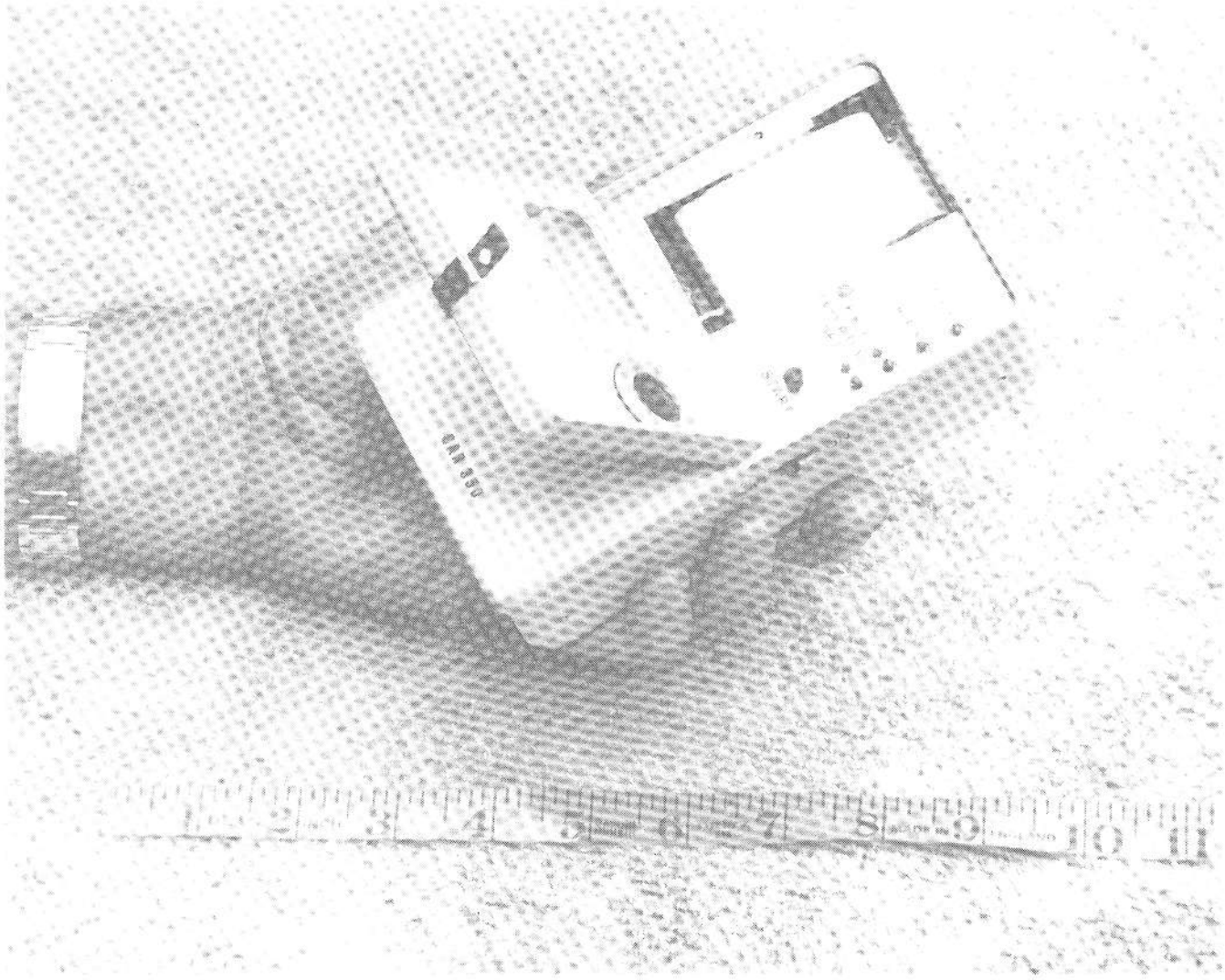


Figure 4. BAR-350 Barograph.

minute interval. Since the BAR-350 is microprocessor controlled, the algorithm can be easily modified and programmed into the EPROM as is the barograph calibration. The appropriate algorithm should be determined by how the data are to be used and by flight experience.

The algorithm used to meet the stated OSTIV requirements is very simple.

If the sum of the absolute values of the 10 angular heading changes between successive readings during the one minute interval, is greater than 400 degrees, no print-out of compass heading occurs. Otherwise, the compass heading at the end of each one minute interval is printed.

The absence of a printed compass heading indicates that the sailplane has been circling during the prior one minute interval. By not printing for the circling case, it is easier to scan the record and note times when thermalling occurred. The selection of 400 degrees as the threshold for a circling indication permits a single 360 degree turn to be made to check for a thermal and still print out the course being flown if the pilot elects to continue after the single circle. As noted earlier, the microprocessor and EPROM permits the use of many different algorithms if desired.

4.3 Installation in Sailplane

As with other compasses, it is desirable to mount the sensor in a location that is as free from magnetic disturbance as practical. However, the location does not also have to be one that is visible to the pilot. The small size (3-1/4 x 2-1/4 x 1-1/2 inches) and small 5 conductor BAR-350 interconnect cable with plug terminations permits installation remote from the barograph. A crossed dipole compensator is available for installations where it is not practical to mount the compass in an interference free location.

5.0 XYLON BAR-350 Barograph

The BAR-350 digital barograph, shown in **Figure 4,** has been in use in the USA for two years and it's barograms are accepted by the SSA. The BAR-350 is the result of applying precision sensor instrumentation and microprocomputer technology to develop a barograph that is small, accurate and convenient to use. This convenience of use has resulted in it's being used on ordinary flights to just provide flight evaluation data in addition to the normal use on badge or record flights and motorglider contests.

The incorporation of an electronic field elevation setting and the stored calibration results in a barogram that presents actual altitude directly. The form of the barograph makes flight analysis very simple and direct. The printed output altitude resolution is 50 feet. The use of an alternate software program results in a metric output with a resolution of 10 meters.

The motorglider model also records the motor operation time to an accuracy of 0.1 minute, greatly simplifying motorglider contest data evaluation.

The only changes necessary to accomodate the compass module are software modifications and addition of a connector for the compass module connection.

5.1 Operating Principle

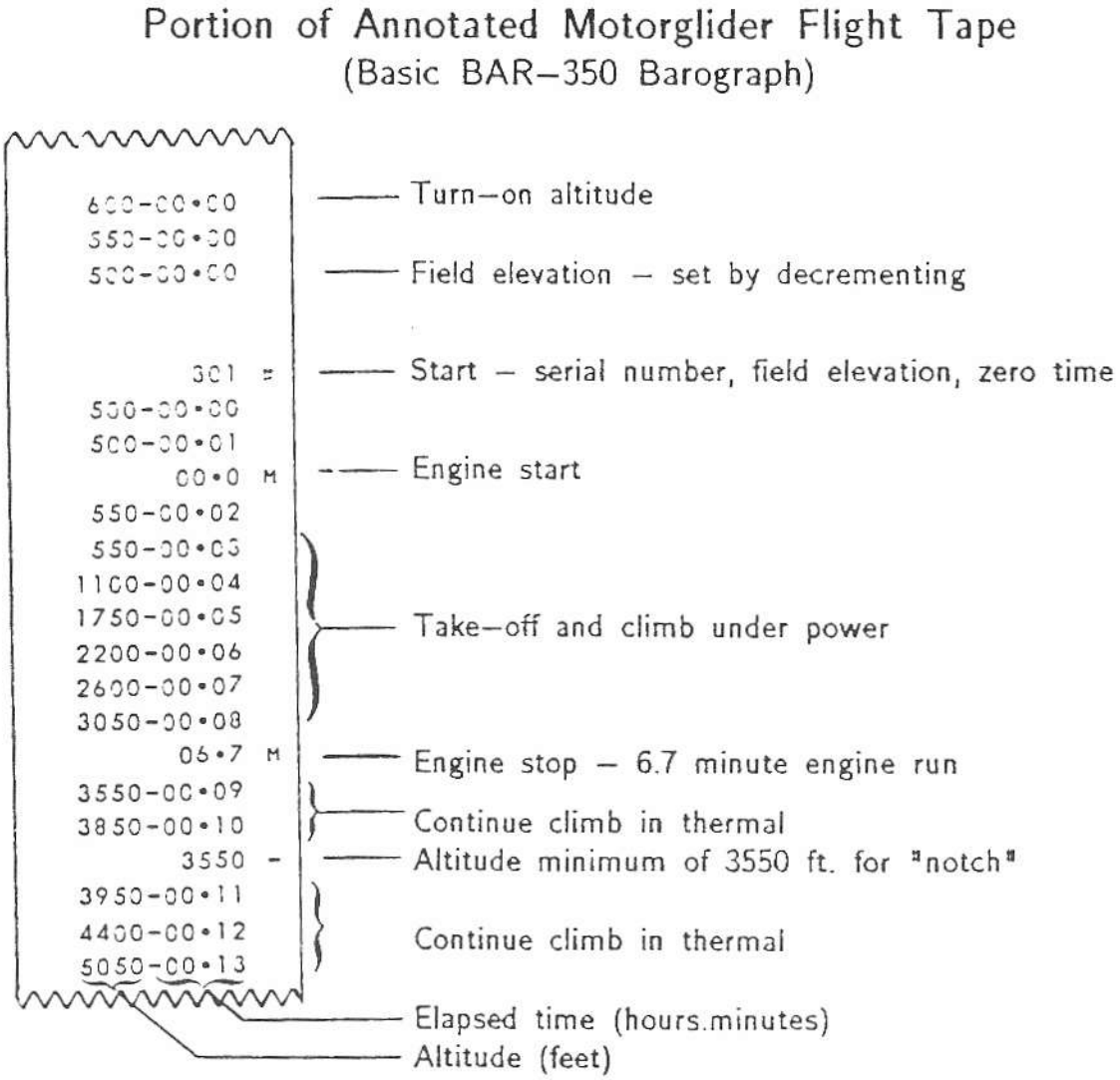
The BAR-350 employs an evacuated, temperature compensated bellows to sense the change in pressure with altitude. Expansion of the bellows with increasing altitude results in a signal which is converted by a micro-processor system with quartz crystal timing to drive a digital character printer.

The altitude is measured every 6 seconds and printed at one minute intervals along with the elapsed time. Any altitude maximum and/or minimum occurring during the one minute interval is also determined, printed and identified by a "+" or "-" on the tape margin. This feature allows "notching" the barogram quickly with minimum altitude loss.

An automatic battery test feature is incorporated to prevent the flight being made with inadequate battery life for the planned flight duration. A battery test routine that is initiated when the initial altitude is printed after turn-on makes use of the voltage vs. capacity characteristic of alkaline batteries. If the battery voltage is low, indicating inadequate battery capacity for an 8 hour flight, a line of zeros is printed and all function buttons are deactivated.

Motorglider engine operation is indicated by a detector

Figure 5. Portion of Annotated Motorglider Flight Tape (Basic BAR-350 Barograph).



which senses the electric field around the spark plug wire. No direct connection to the engine electrical or ignition system is required and there is no indication with a windmilling propellor. Run times are recorded to the nearest 0.1 minute and start and stop shown within the minute interval in which they occur.

5.2 Official Sealing

Means for sealing with a conventional wire and lead seal is provided. The "start" button on the control panel can be actuated by pressing the rubber diaphram in the sealed cover. Once the system is started, there is also effectively an electronic seal since it cannot be stopped and restarted without the clock resetting to zero.

5.3 Calibration

The BAR-350 has an internally stored calibration. Once the field elevation has been set, the correct pressure altitude is recorded so there is no need to refer to calibration charts or tables--the calibration is built in.

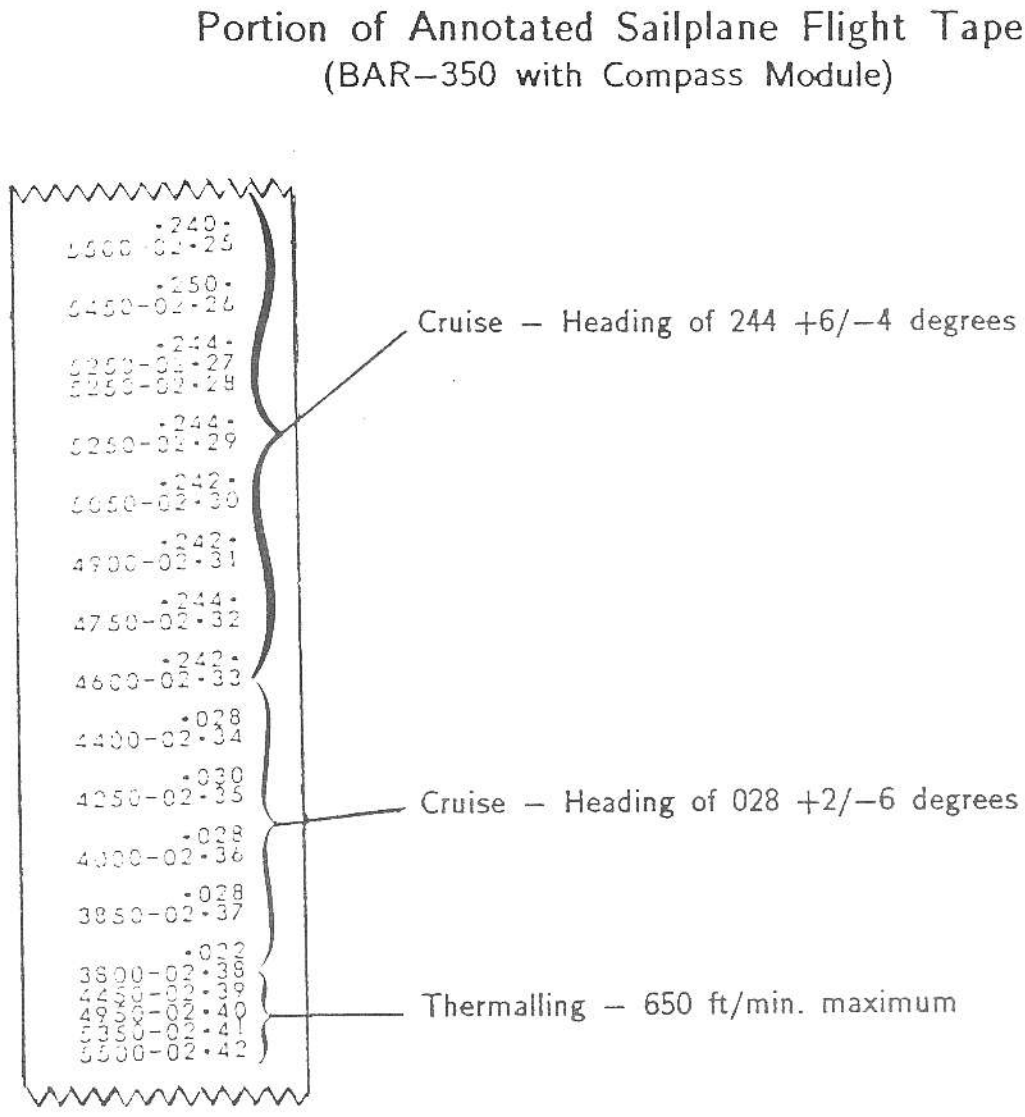
5.4 Sailplane Mounting

The BAR-350's small size and light weight facilitate sailplane mounting. In addition, insensitivity to shock and vibration eliminates the need for shock mounting.

5.5 Extreme Cold Operation

Minimum operating temperature for the BAR-350 is -7C (19F). In addition, the thermal capacity of the instrument will permit operation at lower temperature for short periods. For operation in extreme cold (wave flights) for extended periods of time, an optional passive thermal enclosure is available. This specially designed box contains phase-change thermal masses which in conjunction with excellent insulation permits operation for several hours at -65C.

Figure 6. Portion of Annotated Sailplane Flight Tape (BAR-350 with Compass Module).



6.0 Flight Records

The flight record is a digital printout on 1-1/2 inch wide plain paper tape. The heading, altitude and elapsed time are printed at one minute intervals. The serial number of the barograph is printed at the start of each record.

Portions of two annotated flight tapes are shown in figures 5 and 6. **Figure 5** is a motorglider flight using the basic BAR-350 barograph. **Figure 6** is a sailplane flight using the BAR-350 with the compass module.

7.0 Conclusions

The small size and ease of installation of the compass module combined with the modest cost results in a convenient and practical fulfillment of the OSTIV requirement.

Table I

TECHNICAL DATA

BAR-350 BAROGRAPH

Barogram Form - digital printout on 1-1/2 in. plain paper (~13 inches tape per hour of flight)

Altitude Range - 0 to 35,000 feet (0-10,000 meters)

Altitude Measurement Frequency - once every 6 seconds

Altitude Recording Frequency - each minute with intermediate maxima and/or minima

Altitude Recording Accuracy - nearest 50 ft.- (10 meters)

Barogram Identification - serial number printed at start

Maximum Recording Time - 12 hours(tape take-up spool capacity).

Tape Supply Capacity - 20 hours.

Power - four AA alkaline batteries.

Battery Life - greater than 20 hours operation with automatic low voltage protection.

Operating Temperature - -7C to +50C (19F to 120F) -- passive thermal enclosure available for extreme cold operation.

Engine Operation Recording - start and stop to nearest minute and run duration to 0.1 minutes.

Sealing - electronic and conventional wire and lead seal.

Case - Aluminum alloy with white fused epoxy coating.

Size and Weight - 2 X 3-3/4 X 6-1/4 inches and 25 oz.

COMPASS MODULE

Resolution - 2 degree.

Heading Measurement Frequency - once every 6 seconds.

Damping - Eddy current

Operating Temperature - -20C to +50C (4F to 120F).

Size - 1-1/2 X 2-1/4 X 3-1/4 inches.

Weight - 5 oz.