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# DETERMINING THE RELATIONSHIP BETWEEN SURFACE WIND SPEED AND THE INITIAL ELEVATION ANGLE DURING RADIOSONDE RELEASES

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## 1. INTRODUCTION

Radiosonde data have been collected for many years at various National Weather Service upper air sites. With the advent of the Microcomputer Automatic Radio Theodolite system (MicroART; National Weather Service 1990), the process of obtaining upper air data has become less labor intensive and more reliable.

MicroART has greatly reduced the possibility for human error during a radiosonde flight. However, there are still a few phases of radiosonde flights that have room for human error. Some of these errors fall into the category of quality control (recognizing and deleting invalid data such as erroneous super-adiabatic lapse rates, or data corrupted by a sensor failure, for example). Another potential source of error is an incorrect estimation of the initial elevation angle during a radiosonde release. If the radiosonde operator does not estimate the initial elevation angle properly, valuable low level wind data will be lost. This paper focuses on this type of human error.

Depending on the weather conditions and the operator's experience more than 10 minutes (several thousand feet) of low level wind data can be missing from the radiosonde flight (Figure 1) if the initial elevation angle is not estimated properly. These data are valuable to the forecasters, especially during adverse weather, which is the time that estimating the initial elevation angle is often the most difficult. Also the National Meteorological Center (NMC) computer forecast models such as the Nested Grid Model (NGM) make use of this information. An improved method for determining the initial elevation angle during a radiosonde release is presented here. This method is valid for any upper air site, and should help reduce the likelihood of missing low level wind data.

## 2. PROCEDURE

Data were obtained at WSFO Portland for cases when the radiosonde operator estimated a correct initial elevation angle. These situations resulted in an instant lock onto the radiosonde signal (Table 1). An instant "lock on" is defined as a return power reading of 80 db or greater (MicroArt has a return power meter which ranges from 0 to 100 db) as soon as the MicroArt motors are turned on. During the 5 months of data gathering for this study, a "lock on" was achieved 64 times out of 152 releases. Knowing the surface wind speed, the initial elevation angle of the successful lock-on's, and by using 5 seconds as the elapsed time interval from the moment the radiosonde was released to the time that the MicroART motors were turned from "Standby" to "Near or Far Auto" tracking mode, one can use triangulation to find the vertical distance the radiosonde traveled during the 5 seconds (Figure 2). (Note, any value for elapsed time greater than zero could be used.) By using data for different surface wind speeds, one can find an average value of the vertical distance traveled per 5 seconds (Table 1 and Figure 2).

Since we have assumed for each case that the elapsed time from release to lock on was 5 seconds, the vertical distance traveled should have been almost constant. However, based on the results in Table 1, there was some variability in the values for vertical distance traveled. Actually, from the data base of 64 flights, the vertical distance traveled ranged from a minimum of 25.58 ft per 5 seconds, to a maximum of 54.99 ft per 5 seconds. This variability can be explained by looking at several factors that could not be taken into account during the triangulation process. These include: 1) the radiosondes were not released from the same spot during each release; 2) the angle that the wind was intersecting the balloon was not the same for each release; 3) the atmospheric pressure was not the same during each release; 4) the same amount of gas was not used to inflate the balloon for each flight; and 5) the actual lock on time was not 5 seconds for every flight. Any of these factors would affect the vertical distance traveled by the balloon. To compensate for these variations in vertical distance traveled per 5 seconds, an average vertical distance traveled per 5 seconds for all 64 flights was calculated. This mean value of 37.94 ft per 5 seconds was used to find the initial elevation angle for each wind speed by taking the inverse tangent of 37.94 ft per second, divided by the wind speed (Figure 3). The results of this computation are shown in Table 2.

## 3. RESULTS

It is interesting to note from Table 2 that when the surface wind speed approaches zero, the predicted initial elevation angle approaches 90°, which is exactly what one would expect during calm winds. Also note that when the surface wind speed is less than 10 kt, a change in speed of 1 kt has a substantial effect on the initial elevation angle. The change in elevation angle per knot is much less in stronger winds. For winds over 20 kt, the change in the initial elevation angle drops to only a few tenths of a degree per knot, and for surface winds over 35 kt, there is almost no change in the initial elevation angle per knot.

It is also interesting to note that from the time the balloon was released until "lock on" was achieved, the ascension rate of the balloon averaged only about 500 feet per minute (Figure 2). At first glance, this would seem much slower than the 800-1000 ft per minute ascension rate common with MicroART soundings. However, MicroART calculates an average ascension rate from the surface to 400 mb. This average ascension rate does not reflect the ascension rate within the first few seconds of flight when the balloon starts (at time zero) with an ascension rate of zero and accelerates upward for only a few seconds before a "lock on" is achieved. Also, changes in atmospheric density as the balloon rises alter its buoyancy relative to the surrounding air. The net result is usually an increase in ascension rate as the balloon rises. Therefore, it should not be surprising that the balloon does not achieve this 800-1000 ft per minute average ascension rate within the first few seconds of flight.

For this study, we found that instant lock on's for a particular wind speed could be achieved with initial elevation angles that varied by as much as 4° (i.e., for a 5 kt surface wind, a lock on was achieved with an initial elevation angle of 38°, as well as with an initial elevation angle of 42°). The reason for this is that the tracking antenna uses a conical scanning system that looks at an area 4° wide (National Weather Service Training Center 1987). This is another reason why the vertical distance traveled by the radiosonde was variable.

An informal field evaluation indicates the initial elevation angle predictor correctly forecast the initial elevation angle about 90% of the time. One primary cause for missed instant lock on's was related to radiosondes released during nearly calm wind conditions. In calm winds, the balloon tends to rise directly above the tracking dome.

The other main cause of incorrect initial elevation angle predictions was due to radiosondes released during instances of erratic surface wind speeds. One can minimize data loss associated with erratic surface winds by knowing how much change there is in the initial elevation angle for wind speeds that are slightly higher or lower than the current winds. This will allow the radiosonde operator to know where to search should there not be an instant lock on. In addition, operational use of Table 2 indicated that if the wind was fluctuating between two speeds the best success was obtained by using the higher of the two initial elevation angles.

Figure 4, the 0000 UTC 27 June 1992 Portland, ME (PWM) sounding, shows a typical instant lock on signature. The surface winds at PWM were from 210° at between 5 and 6 kt. Based on Table 2, an initial elevation angle of 40° was chosen, and an instant lock on was achieved.

## 4. CONCLUSION

The predicted surface elevation angles discussed in this paper should work for any upper air site. Since winds do not always blow at a constant speed, and because MicroART has a hard time tracking radiosondes that are directly overhead, there will still be times that immediate lock on's do not occur, and low level wind data will be missing. It is the belief of the author, however, that the use of the predicted surface elevation angles derived in this paper will help reduce the occurrences of lost low level wind data during most radiosonde flights. This information should be especially helpful to radiosonde operators who are new to the job, and to all radiosonde operators during adverse weather situations.

A final note, the National Weather Service office in Portland Maine inflates the upper air balloons with between 1,500-2,000 grams of helium per flight. At locations that inflate the balloons with significantly more or less helium gas, the numbers presented in this paper may not work as well. However, the method presented in this paper can still be utilized to recalculate values in Table 2, which are more appropriate for these locations.

## References

National Weather Service, 1990: MicroART Training Guide (for VIZ Radiosondes). U. S. Dept. of Commerce, NOAA/NWS, Office of Systems Operations, Silver Spring, MD, 277 pp.

National Weather Service Training Center, 1987: ARTS 1 & 2 Training Manual, NOAA/NWS, Kansas City, MO, Theory Chapter, p. 11.

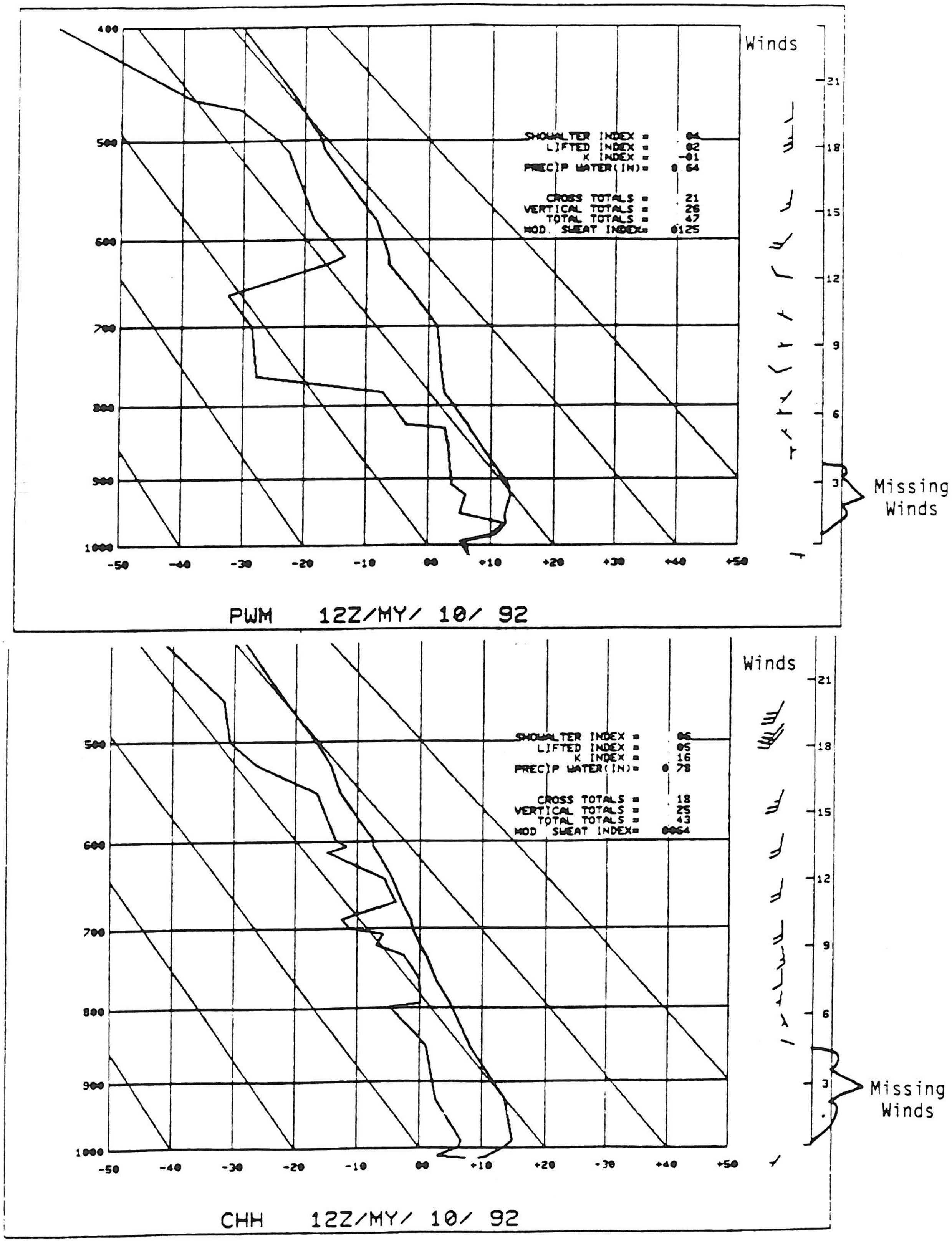


**Figure 1.** Examples of soundings with missing low level winds.

**TABLE 1.** Examples of correctly estimated initial elevation angles (Sample size = 64 flights). See Figure 2 for computation of vertical distance.

| SFC WIND (kt) | INITIAL ELEVATION ANGLE | VERTICAL DISTANCE TRAVELED (ft/5 sec) |
|---|---|---|
| 3 | 50.2 | 30.4 |
| 4 | 43.0 | 31.5 |
| 5 | 42.6 | 38.8 |
| 6 | 35.8 | 36.5 |
| 7 | 33.5 | 39.1 |
| 8 | 29.6 | 38.4 |
| 10 | 25.5 | 40.2 |
| 13 | 23.7 | 48.1 |
| 15 | 19.5 | 44.8 |
| 16 | 21.1 | 52.2 |
| 22 | 14.2 | 47.0 |

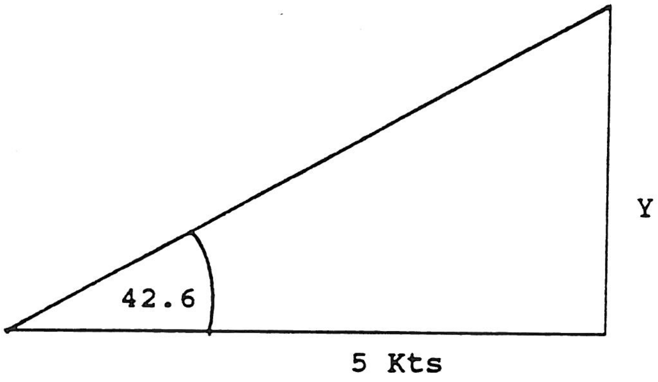
Average Vertical Distance traveled for all 64 flights = 37.94 ft/5 sec.

From case study: for a 5 kt surface wind, an instant lock on was attained at an initial elevation angle of 42.6 degrees.

elapsed time = 5 seconds

1 kt = 1.687809 ft/sec

$$\text{Tangent} = \frac{\text{Opposite}}{\text{Adjacent}}$$



**Converting 5 kt to ft/sec:**

(5 kt)(1.687809 ft/sec/kt) = 8.439045 ft/sec

**5 sec of flight:**

(8.439045 ft/sec)(5 sec) = 42.195 ft/5 sec

**Solving for Y:**

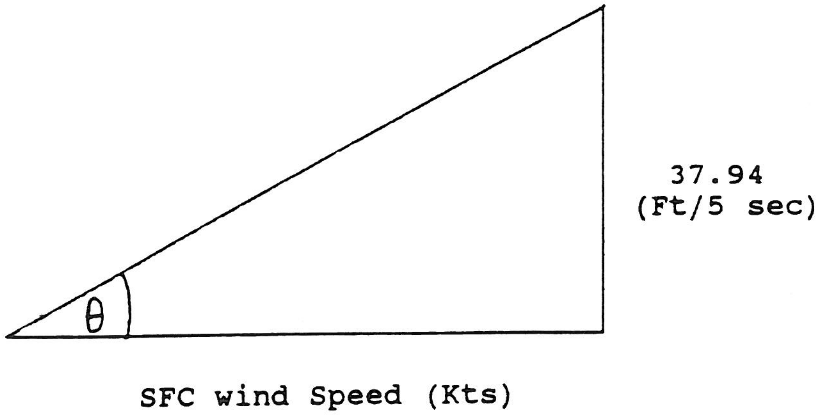
$$\text{Tan } 42.6 = \frac{Y}{42.195 \text{ ft/5 sec}} \qquad Y = (\text{Tan } 42.6)(42.195 \text{ ft/5 sec})$$

Y = 38.8 ft/5 sec

**Calculating ascension rate:**

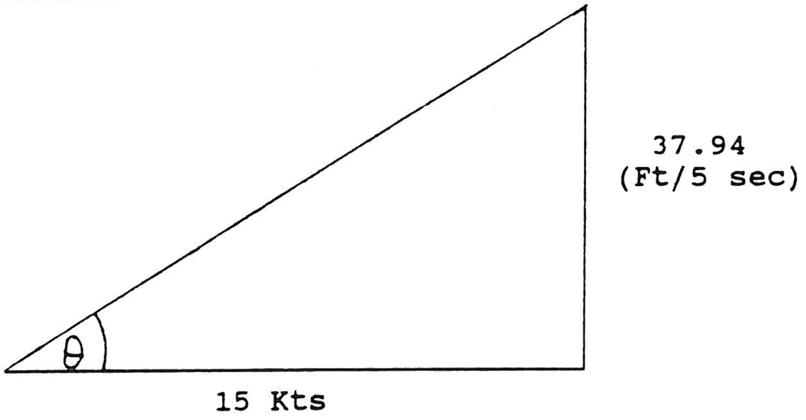
(12)(38.8 ft/5 sec) = 465.6 ft/min

**Figure 2.** Computation of vertical distance traveled.



Using 37.94 ft as the average vertical distance traveled by the radiosonde for the first 5 seconds of flight, and by converting the surface wind speed to ft per 5 seconds, the initial elevation angle ($\Theta$) can be calculated.

**For a surface wind of 15 kt:**



1 kt = 1.687809 ft/sec

$$\text{Tan} = \frac{\text{Opposite}}{\text{Adjacent}}$$

$$\text{Tan}\ \Theta = \frac{37.94\ \text{ft/5 sec}}{[(15\ \text{kt})(1.687809\ \text{ft/sec/kt})(5\ \text{sec})]}$$

$$\Theta = \text{Tan}^{-1}\ \frac{37.94\ \text{ft/5 sec}}{[(15\ \text{kts})(1.687809\ \text{ft/sec/kt})(5\ \text{sec})]}$$

$$\Theta = 16.7^{\circ}$$

**Figure 3**. Computation of initial elevation angle.

**TABLE 2.** Surface wind speed versus predicted initial elevation angle (degrees).

| WIND SPEED (kt) | ELEV. ANGLE |
|---|---|
| 0 | 90.0 |
| 1 | 77.5 |
| 2 | 66.0 |
| 3 | 56.3 |
| 4 | 48.3 |
| 5 | 42.0 |
| 6 | 36.8 |
| 7 | 32.7 |
| 8 | 29.3 |
| 9 | 26.5 |
| 10 | 24.2 |
| 11 | 22.2 |
| 12 | 20.5 |
| 13 | 19.1 |
| 14 | 17.8 |
| 15 | 16.7 |
| 16 | 15.7 |
| 17 | 14.8 |
| 18 | 14.0 |
| 19 | 13.3 |
| 20 | 12.7 |
| 21 | 12.1 |
| 22 | 11.6 |
| 23 | 11.1 |
| 24 | 10.6 |
| 25 | 10.2 |
| 26 | 9.8 |
| 27 | 9.5 |
| 28 | 9.1 |
| 29 | 8.8 |
| 30 | 8.5 |
| 31 | 8.3 |
| 32 | 8.0 |
| 33 | 7.8 |
| 34 | 7.5 |
| 35 | 7.3 |
| 36 | 7.2 |
| 37 | 6.9 |
| 38 | 6.8 |
| 39 | 6.6 |
| 40 | 6.4 |
| 41 | 6.3 |
| 42 | 6.1 |
| 43 | 6.0 |
| 44 | 5.8 |
| 45 | 5.7 |
| 46 | 5.6 |
| 47 | 5.5 |
| 48 | 5.4 |
| 49 | 5.2 |
| 50 | 5.1 |

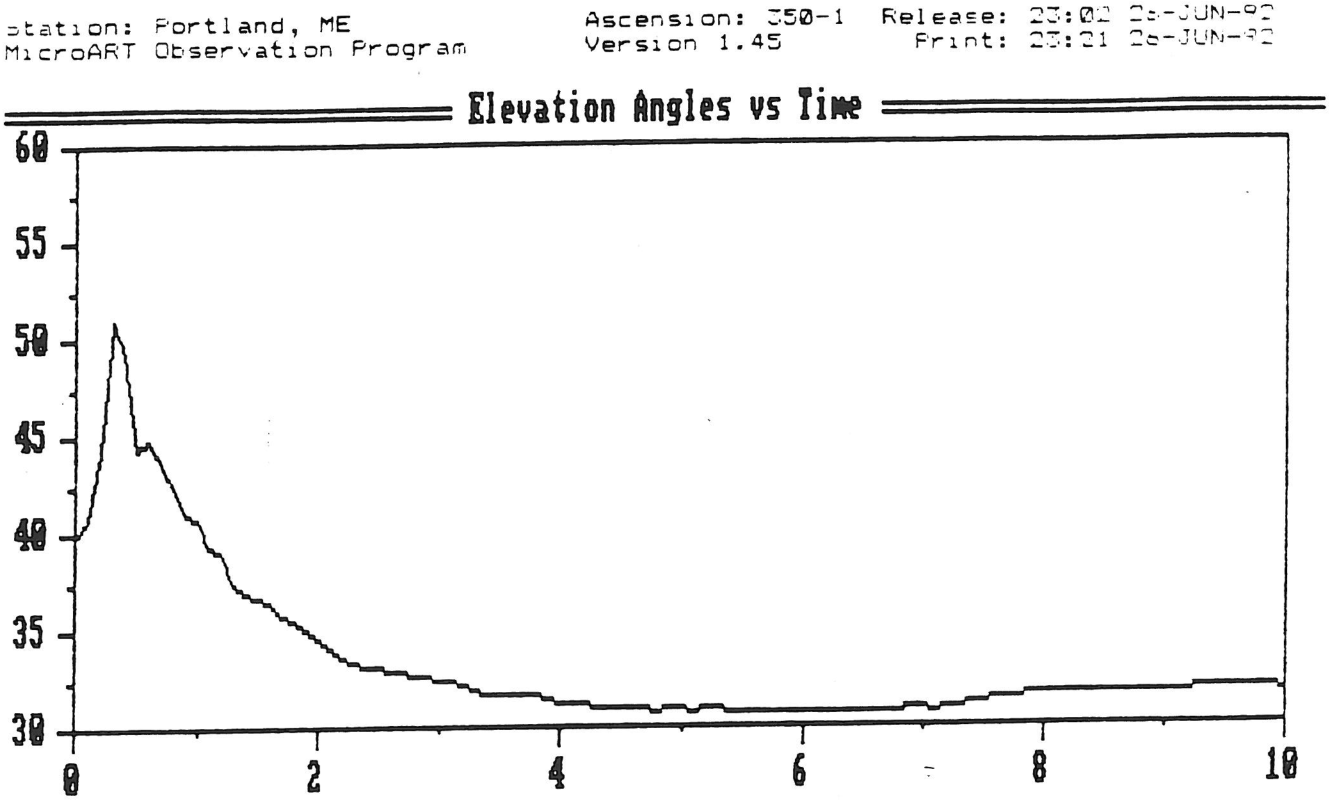


**Figure 4**. Plot of elevation angle (°) vs. time (minutes) for the 0000 UTC 27 June 1992 sounding at Portland, ME.