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A SERIES OF RADIOMETEOROGRAPH SOUNDINGS DURING FEBRUARY–APRIL 1937

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LABORATORY PROCEDURE AND RESULTS OF ASCENTS

By C. HARMANTAS

INTRODUCTION

The release of 31 radio sounding balloons at the Massachusetts Institute of Technology during the months of February, March, and April 1937 was a joint program of the Harvard Blue Hill Observatory and the Institute. The Blue Hill Observatory having developed the meteorograph wished to demonstrate its reliability and to show that it could be operated and consistent results obtained by persons other than the inventor. The Meteorological Department of the Institute having a program of upper-air research, particularly in connection with hurricanes, wished to test this instrument, acquire familiarity with its operation, and decide if it would be suitable for use in its investigations. In addition it was thought advisable to see if the records could be evaluated in a sufficiently short time to be used for synoptic purposes, to compare results with those of the airplane meteorograph, and to decide whether the radio instrument could supplant the airplane. For these purposes launchings were made from the Massachusetts Institute of Technology at the same time the airplane took off from east Boston. Particular attention was given to the development of techniques for preparing and launching the radio instrument and to the reduction of these operations to a routine procedure.

It was originally intended to release an instrument each morning for 30 days in succession, with the hope that in this period both good and bad weather with strong winds and precipitation would be experienced. However, most of the ascents were made in fair weather with clear skies and light winds. In order to make as many tests as possible in bad weather, the schedule was broken several times when fair weather prevailed over long periods. Finally, after 24 instruments had been released, and only 2 stormy days had been encountered, the series was stopped and the remaining instruments were subsequently released in stormy weather only over a period of 4 weeks.

The results obtained from these ascents, even from those made in bad weather, justify use of this instrument for synoptic as well as research purposes. While the instrument needs improving, especially on the matter of "contacts", the present deficiencies are not very serious and should not prevent the use of the instrument even in its present state.

INSTRUMENT

A very brief description of the instrument will be given here; and the reader is referred to the Bulletin of the American Meteorological Society, May 1936, for complete details.

The conventional, but tiny, meteorograph elements carry affixed to them short arms which describe an arc on the surface of a narrow cylinder as each element is actuated by its respective force. These elements are mounted about the cylinder at such angles that their pens do not interfere. In addition, there is a dummy pen resting on the cylinder, but fixed in position and serving as a point of reference. A helix of fine wire is wound on the surface of the cylinder, embedded in insulation, then ground down flush with the cylindrical surface so that the wire is exposed and a smooth surface made for the pen arms to slide on.

The cylinder is revolved by a clock at the rate of two revolutions per minute. As the revolving helix comes under any one of the pens an electric circuit is closed which gives out a radio signal when in flight or actuates a recorder relay when in the laboratory. As long as all pens remain stationary they will be at a constant distance from the reference line and their contacts will have the same relationship with respect to time. If a pen should move, contact will be made either sooner or later than at its previous position. This variation in time is a measure of the change in the meteorological element actuating that pen. Contacts are recorded in a similar fashion. To facilitate readings, instead of using a revolving drum, paper is fed at a constant rate past a moving pen. The pen itself is carried across the paper on an endless chain at such a rate that it returns to the starting edge after each revolution of the helix. Each time that a contact is made by the instrument, a relay trips the pen and a mark is left on the paper. As long as all motions are uniform, distances between contacts on the paper are a measure of time and of the magnitude of the element to be measured. It follows that contacts must be positive and sharp either at "make" or "break", otherwise measured distances will be inaccurate and errors will result.

Theoretically the instrument has an accuracy of 0.1° C. in temperature, and in these experiments this accuracy has often been attained. However, in some cases contacts have varied in length as well as missed altogether for considerable periods. This variation in contact length reduced accuracy to about 1° C. Pressure contacts have also given some trouble, although not as much as those of temperature. In actual flight, contacts from the pressure element fall on a regular curve, and whenever contacts are imperfect the curves can be smoothed over short intervals without loss of accuracy. Humidity contacts were the least troublesome because the range for humidity was so large that variance in contact length caused a discrepancy of less than 1 percent. It was found that a large range of the humidity pen was an impediment to rapid evaluation. As a result, the humidity pens of the later instruments had a smaller range, the contact error for humidity then being of about the same proportion as for temperature. It may well be that a heavier wire on the helix or a different type of pen will give better contacts; at any rate, more work should be done on the instruments to improve them.

CALIBRATIONS

All the meteorographs were calibrated in the Massachusetts Institute of Technology pressure-temperature calibration chamber, in which calibrations for temperature, for pressure at room temperature, and for pressure at low temperature were made for each instrument. At Harvard one instrument was calibrated at a time, but if a chamber could accommodate several instruments, and a recorder were available for each, all could be calibrated in the same time that would be required for one. The Massachusetts Institute of Technology chamber is a large one, but only one recorder was available; nevertheless four instruments were calibrated at a time.

Wires were led out from each instrument to a panel near the recorder. When a steady state was reached within the chamber, an instrument was switched on for about a minute, or until the complete cycle was covered, then disconnected and another instrument switched on. After all instruments had thus recorded, the chamber was cooled (for a temperature calibration), and a sufficient time allowed until a steady state was reached; the above procedure was then repeated.

At first considerable difficulty was encountered in identifying the various elements. With only one instrument in the chamber all changes are shown on the record as they occur; and identification is easily made. In the method just outlined only a few points are recorded from each instrument and as the record is discontinuous, time is required for orientation. For a pressure-temperature calibration, the humidity record is not needed, and if it were disconnected, confusion would be considerably reduced in multiple calibrations. The instruments are now manufactured so as to facilitate this; the humidity pen is constructed so that for either a temperature or pressure calibration it may be placed in the "off" position. Furthermore, for a temperature calibration, the pressure remains constant, and conversely the temperature remains constant in a pressure calibration.

It follows that, besides the line of reference contacts, there will be one more line which will not vary. For any one instrument there will be three contacts throughout the calibration, two of which will be separated by a constant distance, and the remaining contact is that of the element being calibrated. By considering each instrument separately, points are easily identified by the above process of elimination and marked with a distinguishing color. There is a further saving in time when multiple calibrations are made: whatever computations are required for the reduction of pressure data will be applicable to all instruments alike, hence such computations are made only once.

Having identified the various elements and determined their distances from the reference line, calibration curves are plotted in the same way as for an airplane meteorograph with the following variations: both temperature and pressure elements on the instrument have a range of two or more turns of the spiral, while the recorder gives deflections as though from only one turn. Parallel reference lines are plotted on paper at distances equal to the *recorder cycle*, and measured deflections from the recorder are plotted a corresponding distance from the appropriate reference line. With only three such reference lines for the entire range of an element no question arises as to which reference line is to be used for any point.

Humidity calibrations are made in a separate chamber; all four pens are allowed to make contacts but three of them are separated by constant distances. The varying contact is that of humidity while the remaining three are identified by noting their relative positions and by referring to the calibration curves of pressure and temperature.

The temperature element of the instrument is excellent and its calibration curve is almost a straight line. In addition these elements are so uniform that their calibration curves have approximately the same slope. The comparison of all curves showed a maximum difference of 2° C. If a tolerance of 1° were permissible, the instrument, in capable hands, could be used without calibration for an ordinary synoptic ascent.

RELEASING

Prior to release, the instrument was placed in the pressure chamber and the pressure was first reduced to about 50 millibars and then allowed to return to atmospheric pressure. Inasmuch as pressure calibrations were made after the aneroid had been exercised, it was thought desirable to release the instrument with the aneroid in the same state as during calibration. A few tests made lately showed that the differences between readings in either state were less than the precision with which they can be read. However, further tests should be made before the above procedure may be considered an unnecessary refinement.

The radio is attached to the meteorograph and the assembly is tested and carried to the instrument shelter where it remains for about 5 minutes in order to acquire a steady state in the proper environment. Meanwhile the radio receiver and recorder are started and the signals are observed as the contacts are made. If contacts are satisfactory, the instrument is attached to the inflated balloon and released.

BALLOONS AND LAUNCHING

At the beginning of the series, two balloons were used: one filled to about 1,000 grams lift serving as the tractor and another with approximately 600 grams (depending upon the weight of the instrument) to act as a parachute. Both balloons being alike the larger one was expected to burst and the smaller one to check the speed of descent of the instrument. In two instances the descent was followed; in both cases the rate of fall was slow enough to indicate that the second balloon was intact. The two balloons were tied as closely together as possible. Previous ascents with long leads between the balloons proved unsatisfactory, because turbulence acting on the balloons separately caused violent and irregular motions of the instrument. With both balloons tied together there is always a fear that fragments from the burst balloon may tear the smaller one and that the instrument may then fall freely to the ground. The fact that one instrument was found on the sidewalk in a thickly settled district shows that this fear is not groundless. The last six instruments were released with one balloon each and with a parachute inside of the balloon. With this method there is a probability that the lines may foul, preventing the chute from opening; even if it is fastened below the balloon, there is danger of the parachute icing in stormy weather. One balloon with a parachute is to be preferred, but the design and location of the parachute should receive further study.

Launchings were made from the roof of the Guggenheim Building. This was not a favorable location because of the maze of antennae wires and the close proximity of taller buildings. The balloons were filled in a penthouse and then carried to the lee side and launched. Difficulties were experienced in handling and launching the balloons even in moderate winds. It is fortunate that at no time was the wind stronger than 25 miles an hour, otherwise it is feared there would have been many failures. It is essential that some form of launching device be used and that more experiments be made with parachutes to develop a suitable method of fastening in order to insure safety.

Rates of ascent vary over wide values depending upon whether one or two balloons are used. According to the instrument manufacturer, high rates of ascent are desirable in order to get as great an altitude as possible before the radio signal becomes too weak to record. With the new battery system developed in the Massachusetts Institute of Technology laboratory, radio signals can be heard for several hours. Therefore lower rates of ascent can now be used with the following advantages: (1) The temperature indications being made once every 30 seconds, a more detailed picture of temperature variations will be available. (2) The hair hygrometer with its characteristic high lag will now have more time to acquire the correct reading. (3) Less hydrogen will be required and greater altitude will be reached.

The unsatisfactory readings from the hair hygrometer in these tests as compared with those from the airplane meteorograph are wholly due to the high rates of ascent of the balloon. As far as the temperature element is concerned, its characteristics are such that slower rates of ascent and consequently reduced ventilation will not affect its readings.

With two balloons the rate of ascent varied from 150 to 200 meters per minute, while with one it increased to 300 meters and more. An ascensional rate of 100 meters per minute would be satisfactory except in the cases of temperature inversions and icing conditions. Rates of ascent have been observed to decrease at temperature inversions; and balloons have ceased climbing and have even descended when in clouds under icing conditions. Whenever, in the operator's judgment, these conditions prevail, higher rates of ascent should be used if soundings are desired through and above the cloud layer. A few cases occurred where the balloons descended several kilometers and then rose again. At first thought it would seem to be some instrumental defect, but both temperature and humidity traces showed corresponding changes. Irrespective of which "climb cycle" was evaluated, the results were the same.

In June 1936 some preliminary tests of the radio meteorograph were made at Elmira, N. Y., during which Jaumotte meteorographs were released simultaneously with the radio instruments. In one instance a radio instrument showed pressure and temperature changes corresponding to a descent of about 2 kilometers and then a resumption of ascent. Luckily the Jaumotte instrument accompanying this ascent was recovered; it too showed a similar behavior. The record is shown in figure 1.

EVALUATIONS

Rapid evaluation of the recorded signals is important if the data are to be used for synoptic purposes. For this reason the recorder should show incoming signals in such a form that the operator can pick out suitable points. If signals are received on a tape recorder, even a skilled observer cannot select desirable points by inspection alone. Evaluation of all signals is unnecessary and requires considerable time. A drum recorder similar to a chronograph is better than a tape recorder in that signals are shown to better advantage, but with the drum it is necessary to wait until the ascent is completed before starting evaluation. It is for these reasons that the more expensive recorder described earlier (p. 219) is used. Not only are the signals shown in the most desirable method but evaluation can be started almost immediately after the instrument has been launched.

A copy of a record is shown in figure 2. If the traces of an airplane meteorograph record were moved closer together so that they intersected, the result would be very similar. It is important that the elements be identified before the evaluation is started. This can be done in one of two ways: (*a*) With known surface data (i. e. temperature), refer to the calibration curve and measure the distance from the reference line to the temperature reading. This same distance set off on the record will be found between two contacts; one will be temperature the other reference. Their relative positions will be the same as on the calibration curve. This is repeated with the pressure reading. (*b*) By waiting a few minutes after launching, identification is quickly made by inspection; contacts made by the reference pen will be on a straight line. Those made by the temperature element will form a line sloping to the right as temperature decreases while pressure contacts will form a line sloping to the left. Having identified them, a colored line is drawn across the contacts of each element. By having a different color for each element there will be no confusion of distances in the evaluation. From this point on, the evaluation is the same as in airplane meteorograph procedure. Points are selected and numbered on the temperature and humidity traces, and corresponding ones set on those of pressure and reference. To determine the value of an element at a given point, its distance from the reference line is measured with a pair of dividers, this same distance is set off on the calibration curve, and the value is then read off the scale. For any one measurement there can be read about three values, only one of which will be correct. For example, on the trace in figure 2 the correct temperature for point number 3 is read as $-4.5°$ C. The other values are -28.2 and -41.7. Their separation is so great that no ambiguity arises as to which value is correct. Furthermore the readings of the preceding points indicate on which cycle the temperature should be read. If there is a large gap in the record, the time scale as well as the corresponding values of pressure will guide in the selection of the proper reading.

The speed of evaluation is greatly increased by using thin tracing paper in the recorder. When the thin paper record is placed over the calibration curve, the values of the selected points can be read off directly. With the clock running steadily so that the reference contacts fall on a straight line, this method is the speediest yet developed.

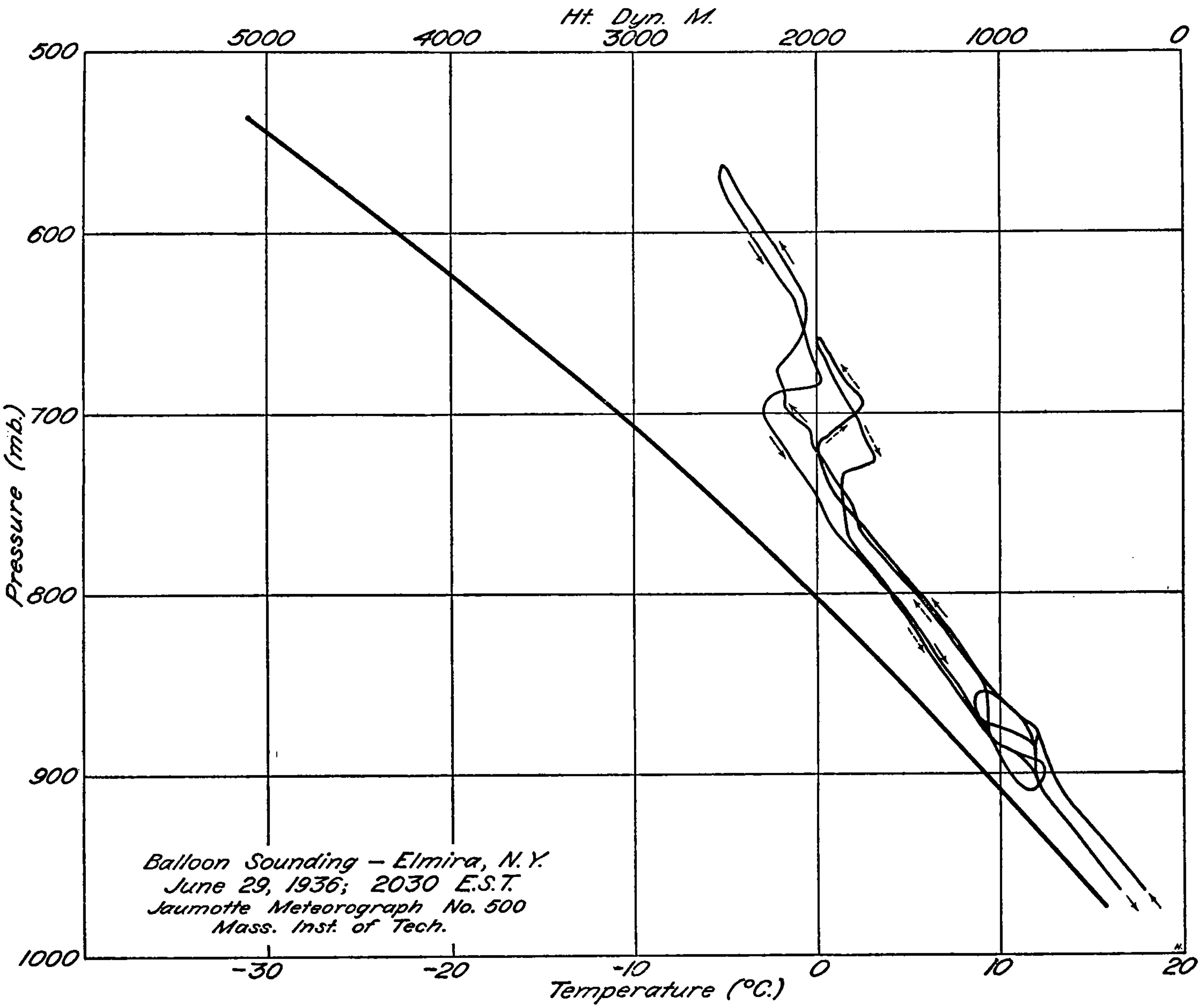

FIGURE 1.

RESULTS

The results obtained are shown in table 1. A brief description of the various items will be made although for the most part the table is self-explanatory.

The variation in weight is due mostly to the different types of A and B batteries and of insulation used.

Although no great attempt was made to launch instruments at an exact time, the table shows only a few minutes variation from 6 a. m. Delays of about 10 minutes occurred when hydrogen tanks were changed, or occasionally when a balloon required patching. It is evident that radio instruments can be launched on schedule with more regularity than airplane soundings.

Under "time legible" is the number of minutes during which the records were of legible quality; the remaining portion had large gaps or weak and irregular contacts. Evaluation of this latter part has been deferred.

A theoretical ceiling of about 20 kilometers is expected considering the amount of gas used and the weight of the instrument; only eight reached an altitude approximately equal to this. The cause for the remaining instruments having low heights is assigned in a few cases to faulty balloons but mostly to the poor quality of contacts and radio performance. An abrupt increase to higher altitudes after February 24 is due to a change in the type of batteries used in the radio transmitter.

Under the column "clarity of contacts" is described the condition of that portion of the record which was evaluated. There were only a few records, and those were short ones, in which contacts were of excellent quality. In the majority of cases, however, contacts were reasonably clear and interruptions, if any occurred, were short, and evaluation could easily be made. There were six records in which one or more elements failed to record for a considerable period, or contacts in general were so irregular that evaluation was made tedious. Four instruments gave such poor records that evaluations were quite difficult and results were of questionable accuracy.

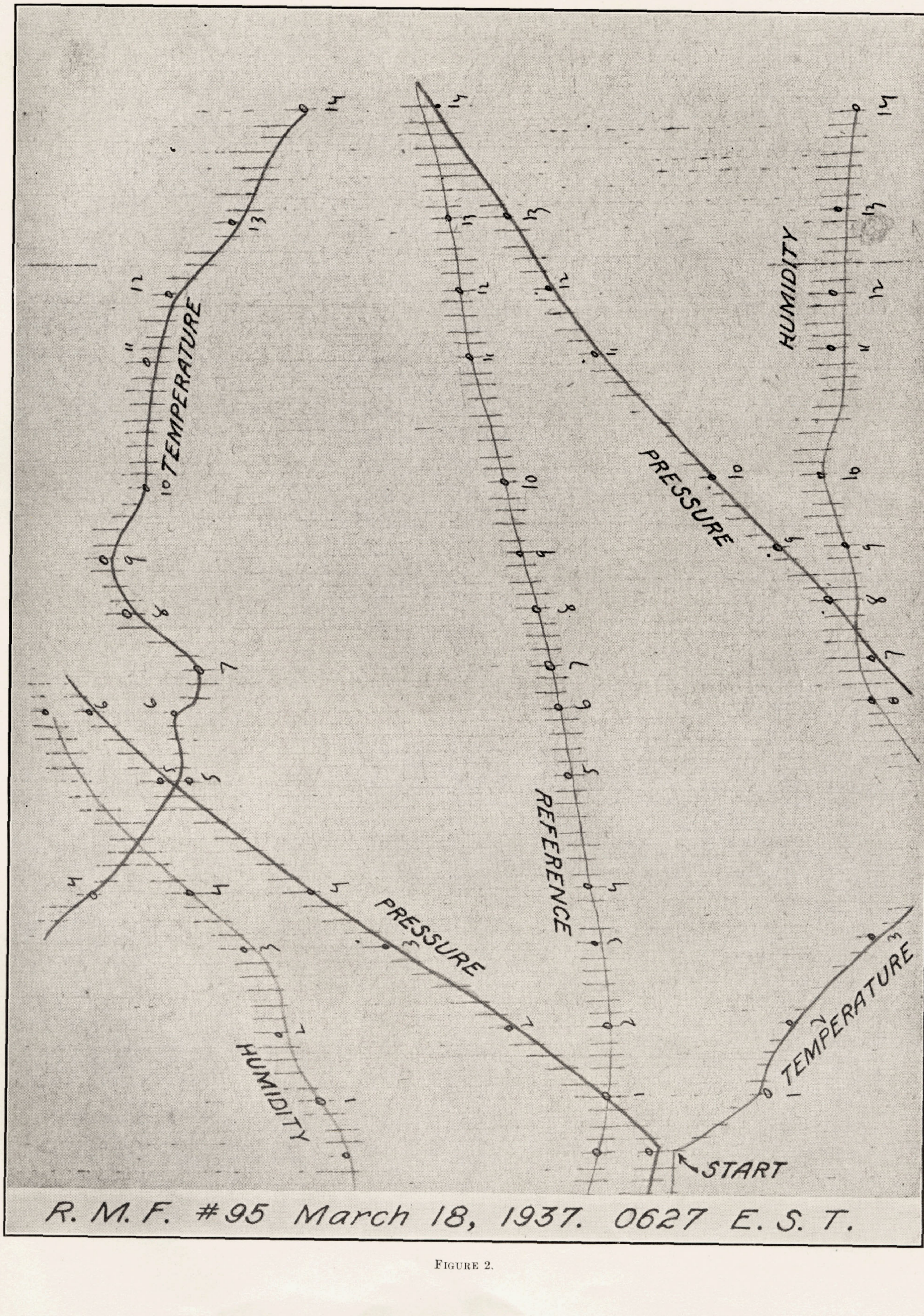
TEMPERATURE
PRESSURE
HUMIDITY
PRESSURE
REFERENCE
HUMIDITY
TEMPERATURE
START
R. M. F. #95 March 18, 1937. 0627 E. S. T.

FIGURE 2.

TABLE 1.—*Summary of Harvard-Massachusetts Institute of Technology radiosonde experiments*

Date, 1937	Inst. no.	Wgt. g	Time release	Balloons and filling	Time legible	Total time	Max. altitude dyn. m.	Strat. alt.	Min. temp.	Contacts (clarity of record)	Rate of ascent m. p. s.	Batteries A	Batteries B	Loss of signal due to—	Time transm.	Remarks
Feb. 17	62	450	602	800–500	------	------	------	------	------	G	------	1	2E	Crash------	------	Crashed against bld. P & T pens off. R & F pens on. Good contacts.
18	64	480	550	800–500	51	67	7, 660	------	−41. 2	G	170–160	1	2E	W. S------	745	Very good record, but short.
19	71	475	6C9	800–500	49	69	9, 340	------	−53. 2	G	185	1	2E	W. S------	1, 002	Ref. off. Reconstructed from calibration record and 2 pts that showed during flight. Pres. cont. variable in length.
[1] 22	66	450	618	900–600	75	75	6, 320	------	−26. 8	G	------	1	2E	W. S. j------	850	Excel. R & P cont. Good T cont. Balloon rose and then fell due to icing. Floated for a time and acquired former altitude after 25 minutes.
23	70	480	552	900–600	38	38	7. 650	------	−42. 3	G	200	1	2E	W. S. j------	750	Good P & T contacts. T fair, but variable, double cont.
24	63	480	615	900–600	60	60	8, 350	------	−50. 3	G	160–150	1	$2E_w$	W. S. j------	------	R good. P and T fair, variable cont.
25	76	655	609	------	60	60	12, 100	10, 050	−64. 3	G	------	1	2B	W. S------	801	R good. P contact good but irregular. T contact very short and missing over portion of record.
26	75	490	600	------	63	63	15, 900	8, 100	−44. 2	F	------	1?	$2E_w$	W. S. j------	745	P cont. variable. T intermittent, poor for last 15 min.
27	72	635	555	1, 030–730	*83	118	15, 500	9, 100	−55. 5	G	------	2	$2E_w$	Distance sig. heard w	810	*Ascent only. R excellent. P wk at start, var. cont. better near midpoint. T double cont. some irreg. Clock slowed down at end.
28	73	525	604	1, 030–730	81	81	18, 760	10, 400	−54. 7	G	------	2	$2E_w$	W. S------	805	R Excellent. P & T very good. Clock slowed last 15 min.
Mar. 4	68	530	600	------	76	76	14, 880	9, 720	−60. 6	G	------	2	$2E_w$	Clock?------	------	R Excel. P fair with double cont. and gaps in record, improving to good after midpoint. T fair. Clock slowed near end.
5	79	550	600	930–630	81	81	12, 720	8, 800	−51. 7	G	------	2	2B	Clock------	------	R Excellent. P short cont. with gaps. T good.
6	81	670	625	1, 000–650	45	45	7, 160	------	−41. 1	E	160±	2	2B	Filament. S lost abrupt.	810	Very good record.
7	77	690	607	1, 000–750	0	0	------	------	------	------	------	2	2B	Filament? S lost in launch.	------	Good contacts until launched, then failed. Filament? Clock?
8	80	680	615	1, 000–650	79	121	11, 250	10, 500	−64. 8	G	------	2	2 Bi	W. S. low L?------	900	Instr. followed in descent. to 4 km.
9	82	550	617	------	102	105	21, 250	9, 250	−56. 8	F	------	2	1 Bi	W. S------	------	Ref. & P good. T fair, var. length double cont., difficult evaluation.
10	78	545	616	1, 030–600	85	98	19, 000	6, 950?	−49. 2	G	------	2	1 Bi	W. S. bat. failure--	------	Good contacts, P somewhat irregular double cont.
11	69	------	612	------	63	76	9, 680	9, 350	−53. 3	P	------	2	1 Bi	W. S. bat. failure--	830	R & H good. P double cont. and var. length. T very poor, large gaps in record. A good record. Very short R.
12	89	------	559	------	75	80	13, 800	9, 500	−55. 4	G	------	2i	1B	W. S. bat. failure--	844	T few double cont. and few irregular lengths.
13	91	------	610	------	140	160	18, 550	9, 200	−54. 8	G	------	F_1i	1B	W. S. bat. failure. + dist.?	------	All good contacts.
14	96	------	757	------	50	59	11, 550	9, 200	−51. 3	F	------	3i	1B	Clock------	945	R & P good. T quite irregular last half of record.
[2] 15	88	------	557	------	105	125	23, 700	{9, 000 or 11, 700}	−57. 7	F	------	3i	1B	W. S------	------	T irregular and wk. last half.
16	99	------	601	(5)	------	47	8, 500	------	−41. 8	------	------	3i	1B	W. S------	------	
17	97	------	601	------	93	93	18, 840	8, 000?	−53. 1	F	------	3i	1B	W. S------	------	Receiver failed after 7 minutes, reception. Repaired and reception resumed after midpt. All cont. double and irreg. Clock very slow!
18	95	------	627	------	102	120	17, 300	9, 200	−52. 8	G	155	Fi	1B	W. S------	------	R, H, & P good. T week and irreg. after quarter of flight.
[1] 25	90	------	1, 305	(3)	------	138	16, 850	9, 100	−53. 2	G	210	Fi	2B	W. S------	1, 600	R, H, & P good. T irreg. with large gaps in record. 1st flight using 1 balloon and parachute.
Apr. [1] 2	92	600	1, 423	(3)	79	79	------	------	------	P	------	3i	1B	W. S------	------	No pressure contact! No evaluation.
[1] 2	154	690	1, 655	(4)	73	73	10, 820	8, 700?	−54. 5	F	220	3	2B	W. S------	------	Ref. good but double cont. P irregular and missing. T irregular and variable.
[1] 6	152	685	951	(3)	26	74	5, 450	------	−11. 5	P	205	3	2B	Clock? W. S------	------	P and H good. T failed after 24 min. Ref. failed after 20 min. Clock slowed near end.
[1] 9	153	650	1, 345	(3)	------	58	10, 500	------	−43. 0	P	±300	(4)	2B	W. S------	------	Very poor record! Temp. very poor with large gaps. P no contacts for 1st half. Evaluation made assuming a constant rate of ascent to pstn.
16	------	695	1, 204	(3)	9½	9½	------	------	------	G	±300	3	2B	Filament?------	------	Abrupt failure! Record not evaluated approx. ht. 4 km.

[1] Rain.
[2] Snow.
[3] 1 balloon, 1,400 grams.
[4] 1 large F. Special tube.
[5] Special balloon, 2,000 grams.

After the first few days, the special effort to transmit the results as quickly as possible was discontinued. They were then transmitted about 2 hours after the instruments were launched. Actual times varied, depending upon the duration of ascent and the quality of the record. If a steady schedule of releases were maintained, results could be on the line about a half hour after the completion of the ascents.

COMPARISON OF RESULTS WITH THOSE OF AIRPLANE METEOROGRAPH

Previous comparisons between balloon soundings and those made with an airplane had been made by the Institute on three separate occasions. In the course of upper-air studies with Jaumotte instruments over St. Louis, Mo., data were compared both with those of the Weather

Bureau, and with an independent set of soundings made by the Massachusetts Institute of Technology airplane. The results from all these were in close agreement.

Similar agreement at Boston was expected with the radio meteorograph, but temperatures obtained by the airplane instruments were higher by over 2° C. The two curves when plotted on the same charts showed consistent discrepancies, with the curve from the airplane meteorograph displaced to higher temperatures. In figure 3 is shown an adiabatic chart on which simultaneous soundings by airplane and radio meteorographs are plotted. Since the radio instruments were individually calibrated, a consistent difference with the airplane meteorograph meant that either the Massachusetts Institute of Technology thermometer was in error or the calibration of the airplane meteorograph was inapplicable. Moreover the first temperature reading of flights always agreed, from which we deduce that discrepancies were not due to errors in standard thermometers but to calibrations. The airplane meteorograph was recalibrated on March 18, first in the Massachusetts Institute of Technology laboratory and later by the Weather Bureau. Due care was taken not to disturb the instrument or change its adjustment prior to these calibrations. In both cases the new temperature calibration was found to be different from that which was made in December of 1936. It was from the latter curve that temperature determinations were made during comparative tests with radio meteorographs. Since the radio soundings were made during March, the calibration made in that month would probably be more applicable than the one made in December, as the instrument could have changed in calibration either suddenly, or gradually over a period of weeks. However, the consistent variation from radio meteorograph records shows that its calibration

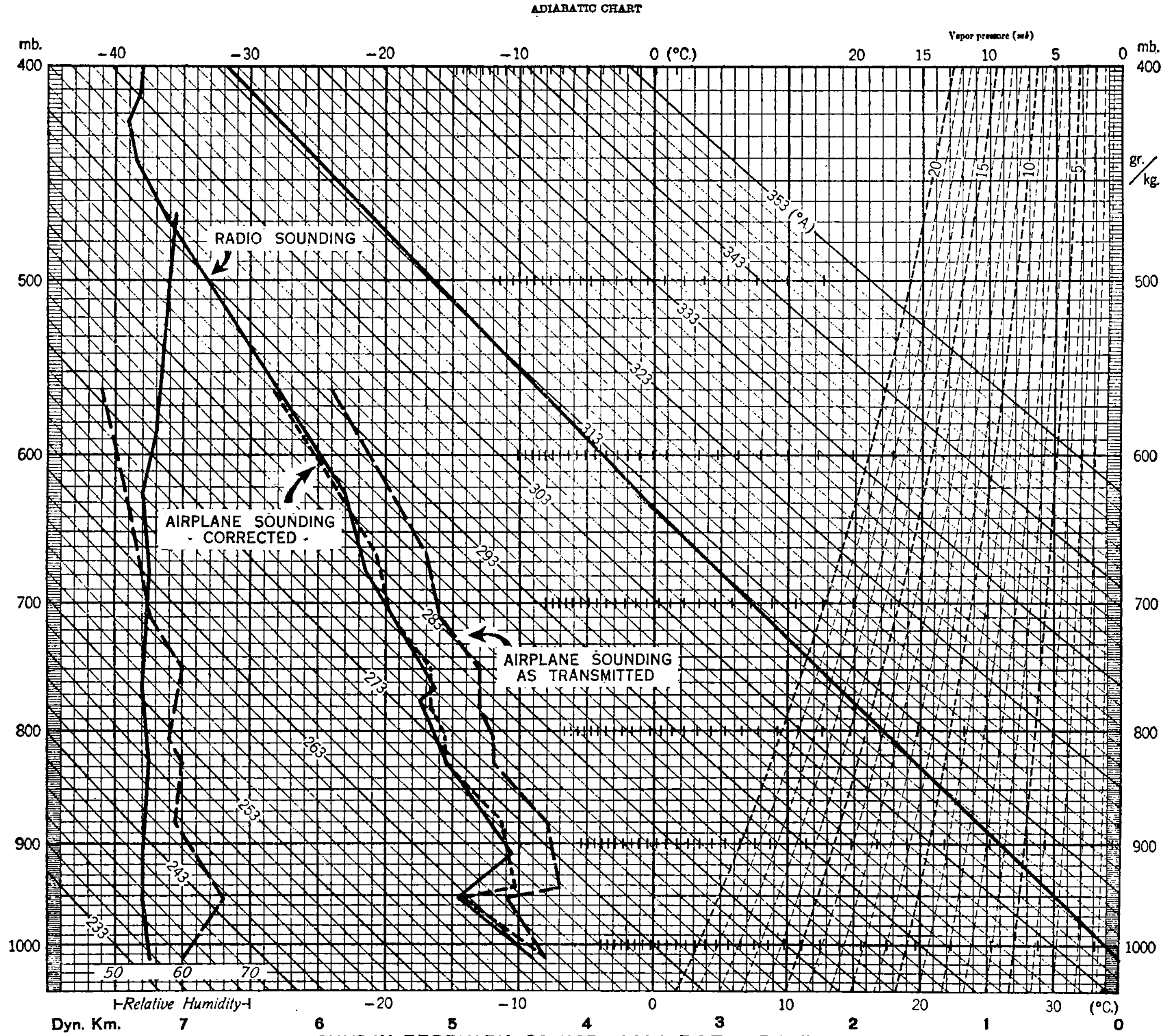

FIGURE 3.

remained unchanged during the testing period; therefore the instrument must have changed calibration before February 17, 1937.

The March and December calibration curves are shown in figure 4. If the data as transmitted (based on the December curve) are recomputed using the March calibration, results from the radio meteorograph show excellent agreement with those from the airplane instrument. On March 18 the airplane carried a different meteorograph; the results of that day, which are indicated in figure 5, show good agreement. No more comparisons could be made because the series was discontinued with that day. Additional tests were made by sending up the two meteorographs in the airplane; both showed good agreement. The record from the "questionable" meteorograph was evaluated twice; once with the calibration of March and again with that of December. With the latter calibration, the values were displaced from the March values in exactly the same manner as the radio meteorograph values were.

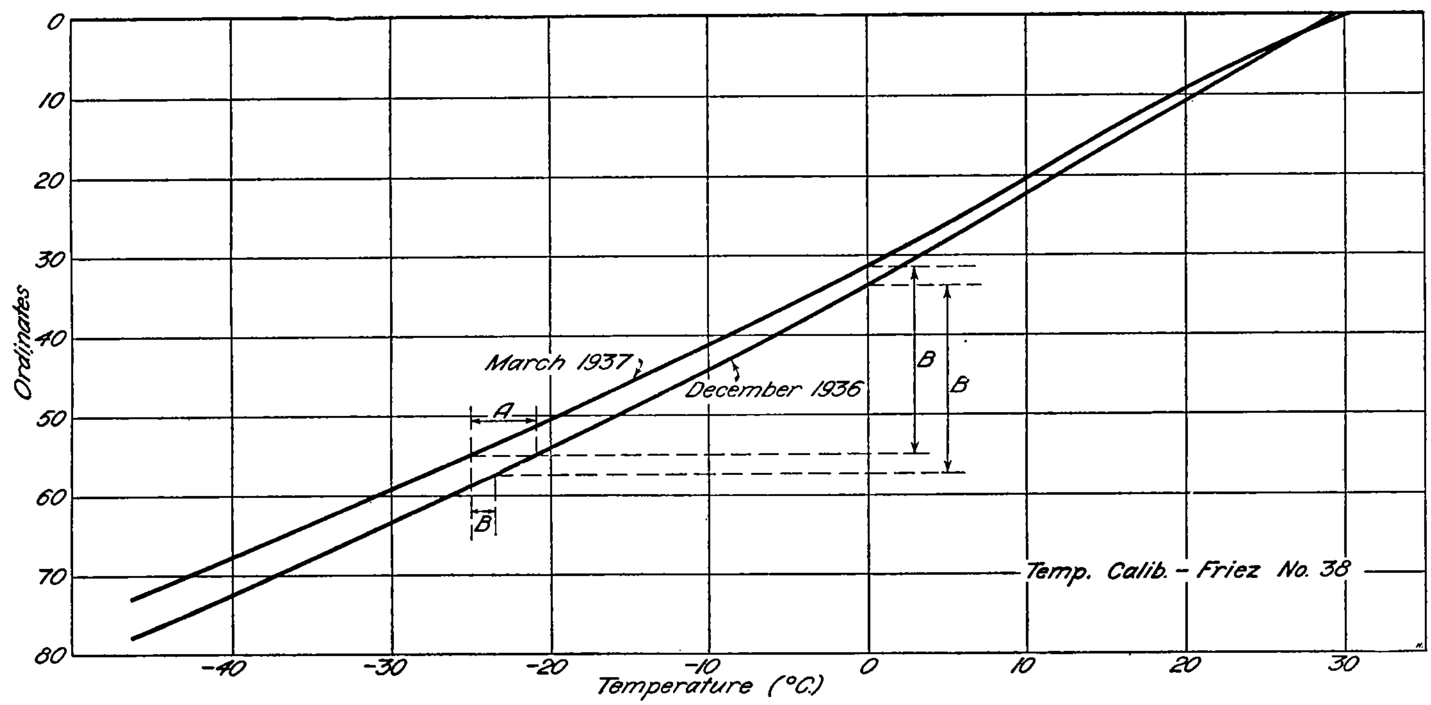

FIGURE 4.

Irrespective of the type of instrument used in making an aerological sounding, it is necessary to take check readings just before the ascent, and the reference line on the calibration curve should be established from them. A base reading made indoors, especially in winter, may lead to serious errors should the instrument be out of adjustment. By making settings at the outdoor temperature, instrument readings will be correct at the take-off and variations from true values at higher altitudes due to faulty calibration will be reduced considerably. The following example, referring to the calibration in figure 5, will make this clear: Assume a usual winter condition with a surface temperature of 0° C. and a minimum temperature of −25° C. If the base line were established from a room temperature reading (about 20° C.), the calibration curve will be used over a 45° range of temperature and the error due to faulty calibration would be 4° C. as shown at A. On the other hand, if the base line were established from zero degrees (the temperature at take off), the error would be only 1°− as indicated at B.

Although it is more difficult to establish a base from readings outdoors, it is necessary that this be done in order to reduce the magnitude of calibration errors. As an additional safeguard the instrument should be calibrated more frequently.

Furthermore, in plotting the adiabatic chart, the surface temperature should be that from the instrument and not the shelter reading. If the calibration curve is correct and the base line set from the shelter reading, both values will of course read the same. Otherwise, the initial lapse rates will be false, and depending on the error of calibration, nonexisting inversions or very steep lapse rates may be indicated.

With the exception of the additional trouble involved in the drawing of a separate calibration curve for each radio meteorograph, this instrument has certain advantages over the airplane meteorograph. Surface readings from the instrument are checked against those in the shelter. Then relative distances from all contacts are compared on the calibration curve, and any change of adjustment of the instrument will be apparent before it is released. Besides the advantage of obtaining higher altitudes than the airplane, the radio records can be evaluated with a considerable saving in time because they may be worked out simultaneously with the ascent.

NOTES ON TUBE AND BATTERY TESTS IN THE LABORATORY AND DURING FLIGHT

By D. P. KEILY

In connection with the preparation and release of the Harvard radio-meteorographs used in this series of upper air soundings, a short study was made, under controlled laboratory conditions, of the operation of the tubes and batteries supplied with the radio portion of the instrument.