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COMMUNIST CHINA'S PROGRESS IN METEOROLOGICAL OBSERVATION TECHNIQUES AND INSTRUMENTS RESEARCH IN THE PAST DECADE

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During the past decade, the meteorological workers of China have made substantial achievements in establishing an observational network and in developing new observational services and scientific researches. This article attempts to describe briefly the researches in radiosonde instruments, micrometeorological instruments, and the quality of the works directly related to the large observatories.

I. IMPROVEMENT AND STANDARDIZATION OF OBSERVATIONAL METHODS

In old China, the observational stations were insufficient in number, different in system, and unsystematic in the use of instruments and in observation. Consequently, there was a lack of historical data. In 1949 the major part of China was liberated. To meet the demand for long-range national economic construction, we started planning and establishing the network of meteorological stations.

In 1951 all stations of the country carried out their observations according to the standardized observational procedures specified in the "Outline of Meteorological Observations and Reports" and in the "Outline of High Altitude Wind Measurements and Reports." This measure ended the chaos of the meteorological observational system during the past few decades.

On the basis of learning from the progressive experiences of the Soviet Union, on 1 January 1954 and 1 September of the same year, all stations of the country were required to conform to the "Ground Surface Section" and the "High Altitude Section" of the "Temporary Meteorological Observation Regulations." Thus all related meteorological observational techniques were standardized throughout the nation.

In the past decade, due to the continuously elevated level of the political consciousness of the meteorological workers, all systems and regulations were strictly observed; this resulted in an improvement in the quality and quantity of work of most of the observational stations and also raised their work skills to the proper level.

Assisted by the meteorological organizations, the industrial departments of China have built several plants to manufacture all the instruments and supplies for ground surface and high altitude observational stations, so that a timely supply of all material and instruments can be guaranteed.

II. CALIBRATION OF METEOROLOGICAL INSTRUMENTS

In the past ten years, calibration of instruments was well developed. Early in 1952, standard barometers made by the Soviet Union were used to calibrate the mercury barometers produced in China.

Some administration areas provides standard mercury barometers for calibration. In 1954 we formally commenced production of meteorological barometers and hair hygrometers and started the calibration of temperature and humidity. After the production of sonding instruments, we also established the work of calibration.

In 1955, regional calibration centers were established so that thermometers, barometers, and hygrometers could be calibrated periodically. Up to now, all basic instruments used by observational stations have been calibrated; hence, the accuracy of observational data can be guaranteed.

Because of the increase in the number of meteorological instrument factories, the variety of items produced, the increasing demand from various service stations and, at the same time, for meeting other requirements for the national economic construction, the works of meteorological instrument calibration have been extended to every production plant, every item of product, and every province.

Together with the development of meteorological instrument calibration services, new calibration procedures and facilities are continuously increasing. In 1957 the large anemometer wind tunnel for experimental calibration was manufactured.

The capacity of controlling flow velocity is 0.6-38 meters per second. In 1957 we bagan to use the compensating absolute sunshine recorder as the standard to calibrate the sunshine recorders.

In 1958 we made large experimental instruments which can simultaneously control temperature, humidity and pressure, and we also constructed a small wind tunnel for calibrating wind velocity. Since progress in the abovementioned respects during the past several years reflects the quantity and quality of observational stations in China, it is worthwhile to discuss separately the methods of calibration, facility, standard and accuracy.

A. Temperature:

The standard thermometers used are standard copper wire resistor thermometers. These thermometers are calibrated according to the following procedures:

(1) fixed point comparison;

(2) comparison with the previously existing first-grade standard glass thermometer calibrated by the Bureau of Standards of France;

(3) comparison with the high accuracy thermometers newly purchased by various related services.

The above calibration results showed that the thermometers were accurate.

(4) In 1958 thermometers used in various stations were sent to the Committee of Measurement of the Soviet Union for calibration. The results were consistent.

The standard thermometers ordinarily used for calibration in various service stations are the 1/10 graduation laboratory type made of glass and mercury and manufactured in Russia. Thermometers of 0°C to -58°C are the glass type made of mercury-thallium alloy.

Some of them are made in other countries. After comparison with the platinum resistor thermometers mentioned above and after adding the error correction values, the accuracy of all these calibration thermometers can be maintained at ± 0.02°C.

During the calibration of thermometers, total submergence into the liquid in a tub (water was used for temperatures above 0° and alcohol for sub-zero temperatures was carried out. The readings were taken several times by two different individuals to reduce the habitual errors and probable errors. After repeated experimentation, the maximum deviations between various calibrated points did not exceed 0.02°C.

B. Pressure:

The standard barometers recently used are of the siphon mercury type. In 1956 two such barometers were brought by a special staff to the General Geophysics Observatory of Leningrad for comparison with the regional standard mercury barometers of that observatory.

In 1956 Dr. Tso-kuan-i-nan [Japanese Scientist], a Japanese specialist, brought two Frotin barometers and a high precision box barometer to Calcutta, Hong Kong, and Tokyo for calibration. When visiting China, he brought these same barometers for comparison with our standard barometers.

It was found that the deviation between the corrected values of our standard barometers and the corrected values of those calibrated with the Soviet barometers was 0.04mm. For guaranteeing the accuracy and reliability of the standard of barometers, we have been trying to make standard barometers with a still higher degree of accuracy.

C. Wind Velocity:

For calibrating and experimenting on anemometers, we completed the construction of wind tunnels in 1956. They are of the wooden, closed, cyclic type and are divided into two testing areas: namely, fone for testing wind velocity ranging from 0.3~16 meters per second and one for testing wind velocity ranging from 0.6~38 meters per second. The turbidity is less than 0.2 percent. On the same cross section of the same testing area, the variation of velocity is less than two percent. The accuracy of velocity control is within the ± 0.2-meters-per-second limit.

Besides the large wind tunnels mentioned above, we constructed some small wind tunnels in 1958. The range of velocity was from 1 to 28 meters per second. They were constructed for testing the general small anemometers.

D. Radiation Instruments:

In 1957, two compensating radiometers were ordered from Sweden as standard sets. It was found, by comparison, that the deviation is less than 0.2 percent. The ordinary standard instruments used for calibration are the selected, direct electric heat radiometers made in the Soviet Union. Comparisons are made periodically with the compensating absolute radiometers to guarantee the accuracy of measurement.

E. Miscellaneous:

For guaranteeing better calibration of temperature, humidity, and pressure instruments, we installed the large combined heat, humidity and pressure control facility in 1958 so that temperature, humidity and pressure of the experimental area can be adjusted simultaneously. Temperature control ranges from -60°C to + 50°C; pressure control can be as low as 50 mb or less. The temperature of the testing area is homogeneous; the stability of accuracy is 0.1°C.

III. DEVELOPMENT OF SMAL METEOROLOGICAL INSTRUMENTS

The history of the development of small-scale meteorological observation is confined to the past two or three years. This type of observation did not exist before liberation. During the early part of the First Five-Year Plan, sporadic observations were carried out, but both quantitatively and qualitatively they were far below the standard of the period after 1958.

Pilot production of instruments did not begin until even later. For keeping pace with the leap forward movement of agriculture and industry, pilot production of instruments becomes the immediate task.

The following, few, small instruments discussed in this article are already being utilized by various services and have undergone a long period of field tests. According to the experimental results recently obtained, the adequacy of their capacities has been proved. Those in pilot production have shown good results in laboratories, but they are not cited below unless they have been tested in the field for a certain length of time.

A. Termocouple:

The thermocouple that is used consists of columbium and magnesium filaments. For graduation readings, the circuit is illustrated in Figure 1.

Other features of the instruments are listed as follows:

1. The switch is connected to all points. Similar resistors are attached to the loop which is connected to the ammeter, thereby providing a common test line.

2. The contact point 1 of the thermocouple (Figure 3) is first connected to the end 2 of a small metal tube, which is enclosed in a glass tube 3.

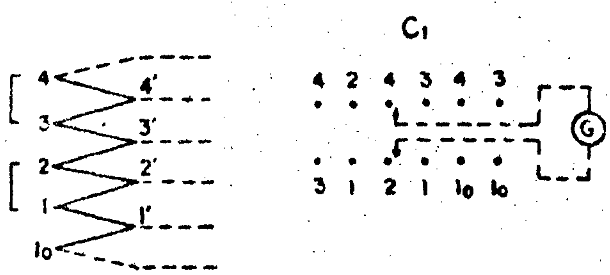


Figure 2.

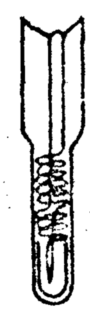


Figure 3.

The glass tube is closed by means of insulating material. The shape of the glass tube is similar to that of the ordinary sling dry and wet bulb thermometer, and one end is larger than the other. Hence it can substitute for the glass thermometer used in the Assman sling psychrometer.

3. The lead-out from the thermocouple on the upper end of the glass tube is in the form of a coil; the exterior diameter of the coil is in contact with the inner wall of the glass tube to guarantee that the wire, before reaching the contact point, has a good chance of exchanging heat with the glass wall, so that the error generated by the

heat transferred from the metal wire to the contact point can be eliminated.

The capacities of the thermocouple are as follows:

1. When making graduation observations, the relative accuracy of the temperature of the dry and wet bulb is $\pm 0.02^{\circ}C$.

2. When reading the absolute values of temperature, the accuracy is similar to the ordinary sling dry and wet thermometers which can be maintained within $\pm 0.05^{\circ}C$.

3. The time lag coefficient of the dry and wet bulb is about 30 seconds.

B. Resistance Thermometer:

$$\ln R = \ln A + \frac{b}{T}. \qquad (1)$$

The circuit for measuring temperature is a non-equivalent bridge as illustrated in Figure 4 where r_1 is the resistance thermometer, and R_2 is a fixed resistor. When the temperature of the resistance thermometer is $t_o{}^{\circ}C$, $r_1 = R_2$, and t_o is determined as is required. R_3 and R_4 are two fixed resistors, (μA) designates the microammeter, (V) is the voltmeter, E is the electricity source, R_5 is the resistor connected to the ammeter in series, r is the voltage-regulating resistor.

For facilitating the procedure of comparison or calibration in the field we take the following steps to guarantee the accuracy of observation:

1. Characteristics of linear calibration: When $r_1 = R_2$, the current passing through r_2 is I_o, the current passing (μA) is $i = 0$; when $r_1 \neq R_2$, the current passing (μA) is i. If the following conditions are satisfied:

i
$$\frac{r}{r_2} = m \simeq \frac{b}{4} \frac{1}{273 + t_0} - \frac{1}{2}, \qquad (2)$$

ii
$$\left(\frac{i}{I_0}\right)^2 \ll 1, \qquad (3)$$

iii
$$R_3 \ll R_s, \qquad (4)$$

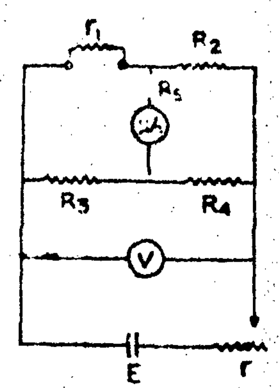


Figure 4.

within the interval $t_o + 15^o$ and $t_o - 15^oC$, the relation between the reading on the resistance thermometer and the reading on the ammeter is a linear function. In equation (2), r is the sum of the internal resistance of the ammeter and the fixed resistor R_3.

2. Direct graduation reading of temperature:

When reading the graduation directly, a reference heat-sensitive resistor is used as a substitute for the fixed resistor R_2, and the reference resistor is maintained below t_o°C; let r_1 vary for the calibration. The result obtained is also a linear calibration. If t_o changes, the line of calibration changes its slope. If the variation of the reference temperature is within the interval $t_o \pm 10^oC$, the relative error does not exceed $\pm 0.01^oC$ after the calibration of its sensitivity.

Figure 5 is the circuit when used practically. I is the switch, II, III, IV are relays, r_7 is the reference dry bulb, r_8 is the reference wet bulb. When reading the graduation, relay III and relay IV go upward. When the switch is connected to the dry bulbs r_4, r_5, r_6, relay II is connected to r_8. When relay III and relay IV go downward, relay II goes up and we can obtain the reading of the temperature of the reference dry bulb; when relay II goes down, we can obtain the reading of the temperature of the reference wet bulb. A in the figure is located near the observation point, while the switch and relay II are automatically controlled.

3. The construction of the thermometer:

The resistor is enclosed in a 3-mm- diameter glass tube; the lead-out is a columbium or magnesium copper wire, It is wound in the form of a coil within the glass tube (see section on thermocouples). The dry bulb is painted white to avoid radiation effects.

4. Construction of the cover:

During field observations, a radiation cover is used to avoid radiation. The construction of the radiation cover is illustrated in Figure 6, 1 is a 12-cm- diameter aluminum disc with a shining upper surface and dark-painted under surface. 2 is a 1-mm- thick plastic plate. 3 is a heat-sensitive resistor, 4 is a 2-cm- thick white rubber sheet. The gaps between 1 and 2 and between 2 and 4 are 7.5 mm.

5. Capacities of the instrument:

i. The time -lag coefficient of the wet bulb is about 35 seconds.

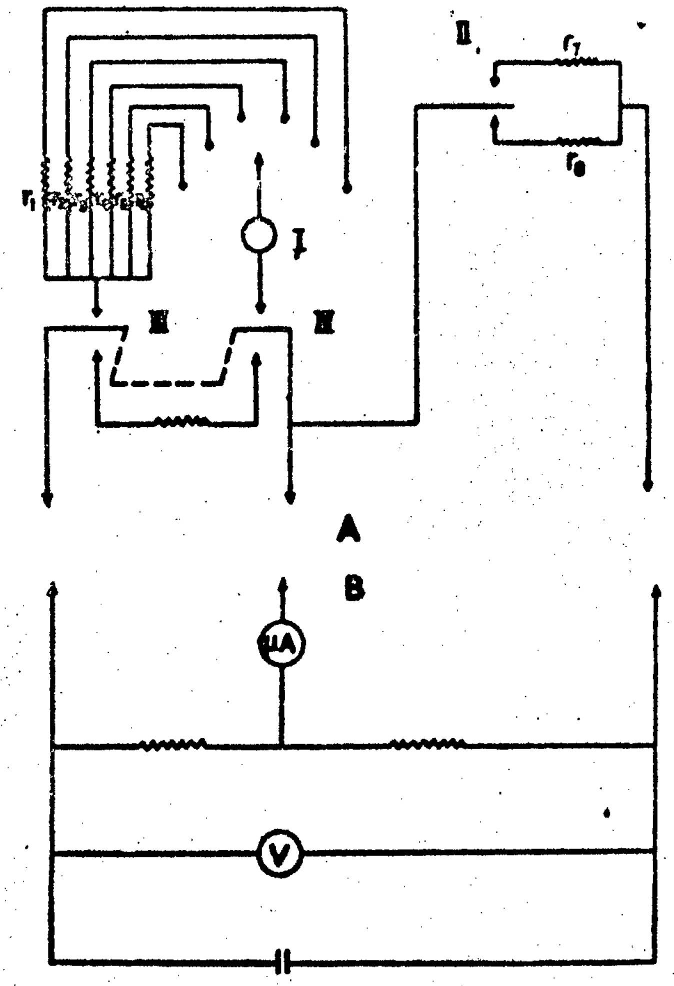
ii. When wind velocity reaches three meters per second, the difference of the values between the dry bulb and wet bulb approaches its maximum. When wind velocity is one meter per second, the difference of the values between the dry bulb and the wet bulb is 0.03°C less than its maximum.

iii. When the wind velocity exceeds one meter per second, the relative error is less than 0.01°C; but if the wind velocity is less than one meter per second and if the sun is strong, illogical results are obtained.

iv. If the properties of the heat-sensitive resistor change, the slope of the calibration line does not vary and only horizontal displacement occurs. This is the reason why, when working in the field, the checking of one point is sufficient for obtaining a new calibration line.

v. Errors of the dry and wet bulb are less than ± 0.1°C; but if the wind velocity is less than one meter per second and the sun elevation is comparatively low, the error can be as large as 0.3°C. This is the common defect of the radiation cover.

Figure 5.



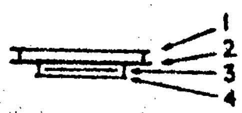


Figure 6.

C. Thermocouple Anemometer

Around each of the two contact studs of the columbium and copper filament thermocouple an insulation-resistance filament is wound 200 times. If possible, the shapes of the two coils and the colors are identical. If constant electric power is fed into one of the coils while the other coil is without electric current, the anemometer has the following properties:

(1) It can measure wind velocity within the range of 20 cm per second and 10 meters per second.

(2) On the log-scale paper, the variation of wind velocity within a range of 0.2 to 1.5 meters per second represents a straight line; [a variation] within a range of 1.5 to 10 meters per second represents another straight line.

(3) The effect of radiation can be neglected.

(4) It is not affected by a change of temperature.

(5) The inertia coefficient is 0.4 second.

(6) It can directly measure the graduation of wind velocity; the circuit for ordinary graduation thermocouples can be applied to it.

(7) The absolute value of error of measured wind velocity is less than ± 2 percent.

(8) The anemometer can be installed on the vacuum tube seat, so that it is easy to use.

(9) When the ratio between the quantity of vertical wind velocity and the quantity of horizontal wind velocity is less than 1.2 inches, the vertical anemometer can be used to measure the quantity of horizontal wind velocity.

D. Stationary Balloon Observation

Stationary balloons are used to measure temperature and humidity at altitudes lower than 500 meters. The general sonding instruments are placed in a silk spherical cover so that even in summer when the sun is strong, the instruments can be used for more than a month. The heat-sensitive resistor is used for the measurement. The non-equivalent bridge illustrated in Figure 5 can maintain the accuracy between ± 0.1°C.

IV. RESEARCHES IN HIGH ALTITUDE SONDING INSTRUMENTS

Since liberation, we have been conducting comparatively systematic research in high altitude observatory instruments and in methods of observation. Besides measuring wind velocity at high altitudes, including large-scale experiments and improvements in wind observation by means of the double theodolite, single theodolite, radio theodolite, and radar, a number of researches have also been carried out in sonding instruments used by various observatories.

The sonding instruments recently used for experiments are of the telegraph signal type. A telegraph pack is used. Signals are sent out with a small motor.

The elementary component for measuring temperature is a double-layer metal plate. At sea level when the wind velocity if five meters per second, the time-lag coefficient is about three seconds. The range of temperature measured is between +40°C and -90°C.

The elementary component for measuring humidity is a membrane. The range of measurable relative humidity is between 15 percent and 100 percent.

The elementary component for measuring pressure is an empty box. The range for measuring pressure is between 1050 and 10 mb.

For reducing the radiation error and for protecting the elementary component from direct contact with rain, indoor and field experiments have been carried out in assembling the elementary components and in the design of the box in which the components are kept. Improvement have been made.

Results of laboratory experiments show that the radiation error of the sonding instruments is very small, reaction of elementary components to temperature and humidity is rapid, and the elementary components are well protected from rain if the rain is of average magnitude.

According to field experiments and in reference to the records obtained from other sonding instruments in the same period, the results are similar to those obtained in laboratories.

Further experiments should be conducted.

Above is a brief summary of the development of meteorological instruments in China since the [beginning of] national construction. From the viewpoint of our establishing a foundation for the further production of meteorological instruments on the basis of no previous production at all, we are successful.

Before the national construction, there was no production of meteorological instruments. Now we can basically solve some problems concerning the largest quantity of instruments used by observation stations and observatories.

Nevertheless our achievement in making meteorological instruments is still behind the requirement for the construction of socialism. In future development, the emphasis should be placed equally on the instruments used by various stations and the instruments for research. Much more work should be done in developing small climatic instruments, agricultural meteorological instruments, radio meteorological instruments, and special instruments for scientific researches and inspections in line with the rapid development of technology and industry during the socialist construction of our great Motherland, so that the ever-increasing requirements and demands during the construction of socialism can be met.

Our progress in meteorological instruments shall be rapid and continuous. We confidently expect that, in the near future, our work in meteorological instruments will arrive at a new stage.

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