UNITED STATES ARMY

TRAINING MANUAL No. 31

METEOROLOGICAL OBSERVER

INSTRUCTORS' GUIDE FOR ALL ARMS

PREPARED UNDER THE DIRECTION OF
THE CHIEF SIGNAL OFFICER

1925

WASHINGTON
GOVERNMENT PRINTING OFFICE
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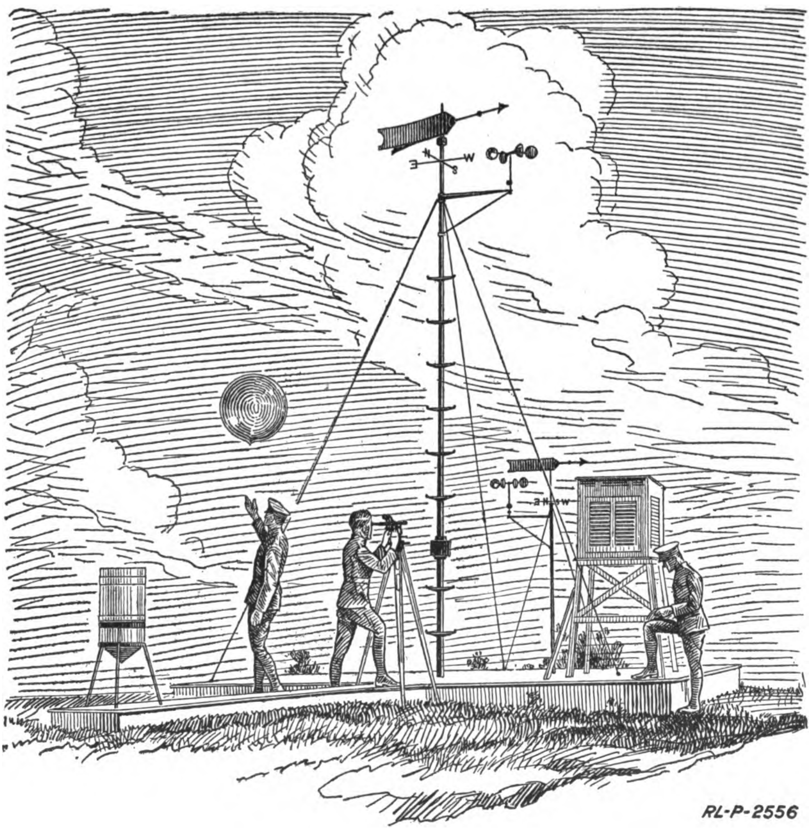

Showing the arrangement of meteorological instruments and the members of a station preparing to make a balloon run

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CERTIFICATE: By direction of the Secretary of War, the matter contained herein is published as administrative information and is required for the proper transaction of the public business.

WAR DEPARTMENT,
WASHINGTON, *August 1, 1925.*

Manuals for training in the Army are to be prepared and revised from time to time by the branches of the service concerned, and when approved, published by The Adjutant General of the Army as a series of training manuals.

In accordance with this plan there has been prepared by the Signal Corps a series of pamphlets relating to signal communication specialists.

The pamphlets in this series are titled as follows:

Training Manual No. 20—Basic Signal Communication, Students Manual.

Training Manual No. 21—Basic Signal Communication, Instructors' Guide.

Training Manual No. 30—Meteorological Observer, Students' Manual.

Training Manual No. 31—Meteorological Observer, Instructors' Guide.

A complete list of training manuals for Signal Communication Specialists may be found on the last page of this document.

This pamphlet is published for the information and guidance of all concerned.

BY ORDER OF THE SECRETARY OF WAR:

J. L. HINES,
Major General,
Chief of Staff.

OFFICIAL:
ROBERT C. DAVIS,
Major General,
The Adjutant General.

METEOROLOGICAL OBSERVER

INSTRUCTORS' GUIDE FOR ALL ARMS

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STUDENTS' MANUAL SECTION

INTRODUCTION

1. *a.* The Manual for the Meteorological Observer is an elementary text, which has been prepared for the purpose of training men assigned to the meteorological sections of the Signal Corps to become proficient observers of the elements of the weather.

b. For the convenience of the instructor the Instructors' Guide for the Training Manual consists of the exact text of the unit operations of the student's manual bound in the same volume with directions and suggestions which will assist him in presenting effectively the various unit operations to the students.

c. The information topics of the guide are printed on yellow paper just as they appear in the students' manual; the unit operations are printed on blue paper; and the suggestions for the instructor are printed on white paper. This arrangement increases the ease with which reference may be made to any particular section of the manual which it may be desired to use.

d. The Instructors' Guide also contains extensive samples of various types of questions, to be used as aids in instruction, together with a series of instruction, progress, and proficiency tests. In order to understand and to use these questions and tests to the best advantage it will be necessary for the instructor to supplement the text of this guide with a very careful study of the introduction to Training Manual No. 21, Basic Signal Communication, Instructors' Guide (revised edition).[1] In this introduction there will be found a detailed explanation of the various types of questions and tests used in the different manuals, together with directions for preparing and scoring them.

2. The requirements which this guide must fulfill are:

a. It must present an analysis of the steps in training meteorological observers in the Signal Corps, so that officers in time of war can quickly train such men for duty with the units in the field.

b. It must provide explicit directions so that the students can readily follow these steps; and directions for the instructor, which will permit him to train efficient observers in the minimum time.

c. It must provide tests by which instructors can determine the progress of their students throughout the course as well as their proficiency upon its completion. Thus the term "meteorological observer" will come to mean just as "expert rifleman" does, a soldier who can do various specified things in a certain time and with a given degree of accuracy.

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[1] This same introduction is also reprinted in Manual No. 25, Message Center Specialist, Instructors' Guide (edition of 1925).

d. The instruction so outlined must be of such a nature that it can be given under conditions as they actually exist in the service.

e. It must provide methods of instruction for our peace-time Army (Regular, National Guard, and Reserve), and also for the R. O. T. C. and C. M. T. C.) which will require no change of any kind for the training of these same kinds of specialists in the larger Army which a national emergency may demand.

3. The analysis of the steps in training meteorological observers is divided into: (*a*) Skill, (*b*) knowledge.

a. Under *skill* the observer must satisfactorily learn to accomplish the following:

(1) To read all weather instruments.
(2) To record all such readings.
(3) To set up, level, and prepare a theodolite for observation.
(4) To inflate a balloon and follow same with a theodolite.
(5) To make wind aloft and ballistic determination.
(6) To prepare messages containing meteorological information.
(7) To keep clean and in good working order all meteorological instruments.
(8) To make minor repairs to such meteorological instruments.

b. *Knowledge*.—The requirements of a basic private Signal Corps (see Training Manual No. 21 for specifications of basic private Signal Corps) plus the following:

(1) An understanding of the principles involved in construction of all meteorological instruments.
(2) Elementary meteorology.
(3) Care of storage batteries.
(4) Meteorological reports and records.
(5) Methods of interpolation as applied to meteorological data.

4. This manual should furnish the commanding officer of any meteorological unit with the details of what the observer must know and be able to do within the minimum specifications above. The instruction, progress, and proficiency tests provided in the instructor's guide are designed for the use not only of the instructor, but also for commanding officers, and may be used by the latter in testing the proficiency of individuals or in selecting men for various assignments.

5. *a*. THE METEOROLOGICAL OBSERVER is the result of several years of experiment and research by a number of instructors who have had experience in teaching both officers and enlisted men as meteorological observers.

b. Efficient meteorological observers can be obtained only through frequent and systematic practice, corresponding to the methods used for making a unit proficient in close order drill. This manual seeks to do for the meteorological observer what drill regulations do for the Infantrymen by the use of close order drill. It also attempts to go beyond the scope of the drill regulations, since it not only specifies *what* should be done, but also *how* it should be done. Accordingly the instructor is furnished as much information as it is possible to obtain in order to bring the student to a high standard of proficiency. In peace training it is desirable that the meteorological observer progress as far as possible. For this reason the capable student who desires to study the more technical details of this subject should be encouraged to take up parallel readings in books listed in Information Topic No. 4.

c. As a conclusion to this course for meteorological observers the instructor should require each student actually to take charge of the station for as many days as time will permit. At least all students who have successfully passed the proficiency tests should be required to perform this duty, assuming full responsibility for the entire station work. Students may be assigned to this work in groups or in pairs depending on the size of the class and the time available.

6. As a means of comparing the scores of a class in some of the tests furnished in this instructor's guide with a previous class, the following results in tests of a class of meteorological observers are furnished.

Meteorological test scores

Cases	Instruction test No. 1, Inf. Met'l. U. O. No. 1.	Instruction test No. 2, Inf. U. O. No. 2	Instruction test No. 3, Inf. U. O. No. 3	Instruction test No. 4, Inf. U. O. No. 4	Instruction test No. 5, Inf. U. O. No. 5	Progress test No. 1, Part II, max. 222 points	Progress test No. 1, Part I, max. 55 points	Progress test No. 2, Part I, 51 points passing	Progress test No. 2, Part II	Total of progress test No. 2, Parts I and II, in terms of percentage, 62% passing.	Proficiency test No. 1, Part II, max. 101	Proficiency test No. 1, Part I, max. 96 points	Army Alpha scores
1	36	26	41	36	38	152	27	65	79	72	87	45	148
2	42	36	26	45	40	186	A	53	79	66	91	69	110
3	37	49	33	40	A	A	50	A	A	A	89	67	121
4	39	38	38	29	A	A	A	A	A	A	A	71	89
5	37	37	45	45	45	173	A	88	71	80	81	77	A
6	39	34	29	44	A	A	43	A	A	A	93	35	119
7	36	42	45	49	33	164	51	75	76	76	81	55	151
8	40	39	36	31	38	167	43	31	84	63	87	52	122
9	28	20	21	27	40	199	15	51	71	61	78	42	81
10	36	28	29	33	A	A	22	35	79	57	82	32	63
11	A	29	33	40	A	A	38	A	A	A	82	34	74
Average scores	37	34.3	34	38	39	173	36	44	77	68	85	53	108

NOTE.—This form may be used as a sample for the instructor in keeping records on the various tests used throughout this manual. "A" denotes absence from class.

7. Notification of errors and suggestions for the improvement of this manual should be addressed to the Chief Signal Officer of the Army.

METEOROLOGICAL OBSERVER

INSTRUCTORS' GUIDE FOR ALL ARMS

UNIT OPERATIONS

THERMOMETERS, READING AND RECORDING

Equipment.

One standard instrument shelter.
One sling psychrometer—wet and dry bulbs.
One pair of maximum and minimum thermometers.
One thermograph.
A supply of recording sheets for thermograph.
One bottle of register ink for thermograph.

Information.

In meteorology it is constantly necessary to make measurements of temperature. Temperature may be defined as the degree of sensible heat or cold of a substance. The substance most frequently measured by the meteorologist is the atmosphere. In addition, the temperatures of many other substances are measured, such as that of the earth at various depths, from the surface down; and of water at the surface and at various depths in wells, rivers, lakes, and oceans. The science or art of measuring the temperature of substances is known as *thermometry* and the instrument with which the measurements are made is called a thermometer.

Thermometers.—The type of thermometer most usually met with is the kind frequently used in households to ascertain room temperatures. These are called liquid-in-glass thermometers.

The operation of all thermometers depends upon the fact that most substances expand upon being heated, and that in addition, all these substances expand a different amount per degree of heat. The liquid-in-glass thermometer consists of a long tube of glass terminating in a bulb and partially filled with a liquid such as mercury. If the liquid and glass were heated or cooled, and both expanded or contracted the same amount per degree, then no change would be noted in the height of the mercurial column. But it so happens that mercury expands more than glass, and when the thermometer is heated, although both substances expand, the mercury expands more than does the glass. Consequently, the mercury rises. If the thermometer is cooled the mercury falls. The liquids commonly used are, mercury, freezing at 39° below zero, Fahrenheit; and alcohol, freezing at about 100° below zero, Fahrenheit. Alcohol is sometimes colored to make it more readily seen.

Thermometer scale.—The temperature scale as used ordinarily has been arbitrarily chosen. Thus, the zero of the Fahrenheit scale is 32° below the freezing point of water (or melting point of ice). The temperature of steam at ordinary pressure (or the point at which water boils) is taken at 212°.

The range of the scales of individual thermometers used in meteorology varies considerably. They seldom read over 130° above zero or lower than 80° below zero, Fahrenheit. Those in the Signal Corps range between 40° below zero and 120° above zero, Fahrenheit.

In order to make sure that thermometers will register accurately and that they will continue to do so, great care is used in their construction. The tubes are laid away to age for a year or two, or by a shorter method they are subjected to a process of heating and cooling alternately. This ageing of the tubes allows sufficient time for certain slight molecular changes to take place in the glass. After a year or two these changes are negligible, certainly for meteorological work.

The scale and figures must both be etched on the glass tube, although the scale may also be placed on the metal back. Whenever the black paint has fallen out of the etched scale and figures, the marks should be reblackened.

Bulb.—The bulb of the thermometer is made in the shape of a sphere or a cylinder. The bulb end usually hangs down, and thus it is common practice to speak of the opposite end as the "top" of the mercurial or alcohol column. This expression, "the top of the column," is used no matter in what position the thermometer is placed.

Sensitive thermometer.—A sensitive thermometer is one which measures or shows *quickly* a slight rise or fall in temperature.

Sensible thermometer.—A sensible thermometer is one which measures *very slight changes* in the temperature in any substance.

For meteorological work, thermometers should be sensitive rather than sensible, as one-tenth of a degree is the smallest fraction considered when measuring the temperature of the air.

Sensitiveness.—To secure sensitiveness in a thermometer—

a. One must have a liquid which conducts heat readily so that all the liquid in the bulb will quickly assume the same temperature.

b. The bulb should be large as compared with the bore of the tube, since an increase or decrease in the temperature will then cause a correspondingly large change in the volume of the liquid, which will either be forced up into the tube or drawn down from the tube into the bulb.

c. If the bulb is made in the cylindrical form there will be more surface exposed than if the same size bulb was made in the spherical form. Any change in temperature of the air will consequently be communicated to all the liquid in the bulb more quickly if it is cylindrical in form than if it is spherical.

Forms of thermometers.—The various forms of thermometers used in meterorological work are:

a. The ordinary liquid in glass thermometer, usually called the dry bulb. The word ordinary is not used in the sense of being cheap, but with the meaning that the thermometer will simply tell the current temperature of the air, or the temperature at the instant of reading. This instrument may also be called an "indicating thermometer."

b. Registering thermometers, or those which register the highest and lowest temperatures.

c. Recording thermometers, usually called thermographs, which make a continuous record of the temperature for every instant of time.

The registering thermometers used in the Signal Corps are of two kinds: Those which register the highest or maximum temperature, and those which register the lowest or minimum temperature. These thermometers are generally known as the maximum and minimum thermometers. (See fig. 1.)

Thermometers are exposed in a specially constructed shelter similar to that illustrated in figure 2. In such a shelter they will assume the temperature of the air better than when exposed anywhere at random.

Questions.

(1) *What probably happens while a thermometer tube is "ageing"?*

(2) *Suggest some good methods for reblackening the etched figures and scale marks on a thermometer.*

Temperature is measured by the following instruments: Sling psychrometers, maximum and minimum thermometers, and thermographs. The whirling psychrometer is composed of two thermometers, exactly alike, except that one has its bulb incased in a wrapping of cloth and is called the "wet-bulb," while the other has its bulb uncovered and is called the "dry-bulb."

Question.

(3) *What is the reason for using a "wet-bulb" as well as a "dry-bulb" thermometer?*

Directions.

1. *The dry-bulb thermometer.*—Open the door of the shelter carefully and swing or whirl the dry or indicating thermometer a few times. Then bring the instrument to rest and quickly read it in degrees and tenths by noting just where the top of the mercurial column comes on the scale, and record this reading. See Figures 2

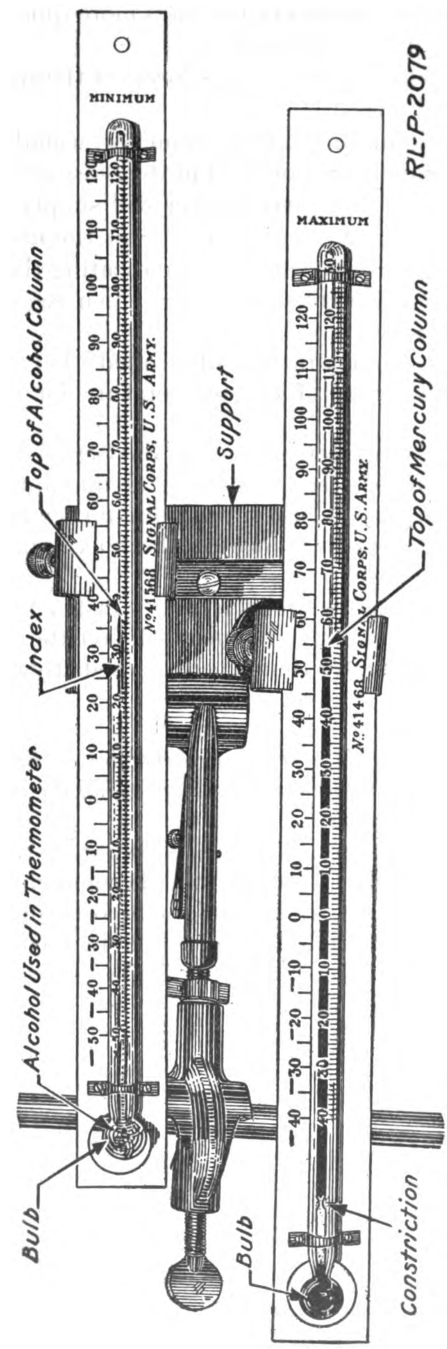

Fig. 1.—Maximum and minimum thermometer

and 3. This instrument is read to the nearest tenth. The scale marks are given for every degree, but the tenths must be estimated.

Questions.

(4) *What is the purpose of the observer in swinging or whirling the thermometer? Should both the wet and dry bulbs be whirled? Why?*

(5) *Why should the thermometer reading be taken in tenths of a degree rather than in quarters or eighths?*

(6) *Is there any special name for tne curvea top of the mercury column in a thermometer?*

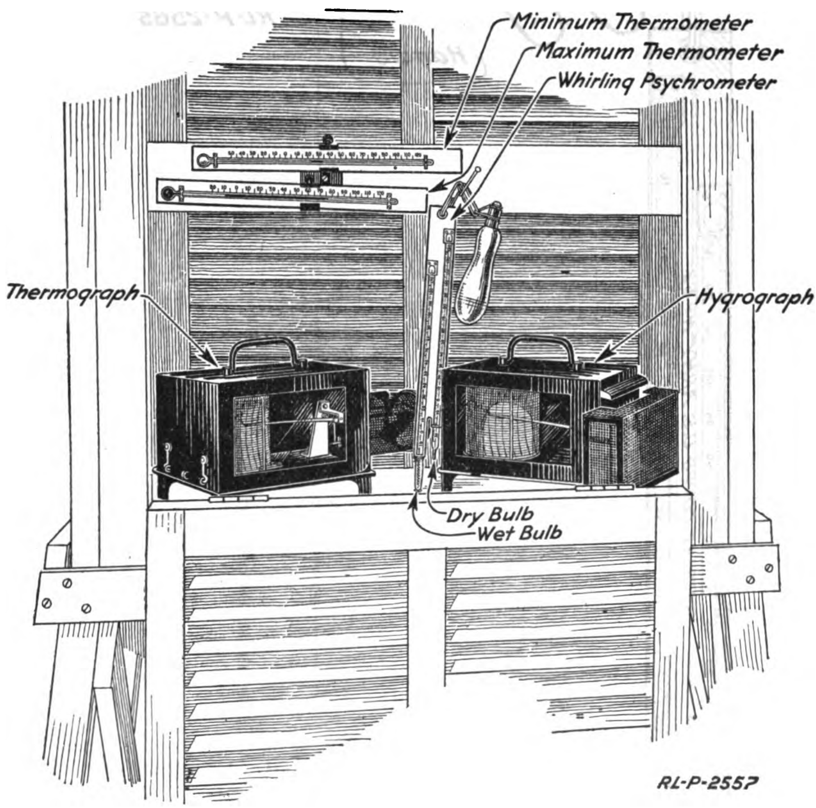

Fig. 2.—Instrument shelter, containing instruments

Information.

Common errors.—Mistakes are often made in reading thermometers. The most usual which occur are:

a. Error of parallax.—This is an error in reading the thermometer due to the fact that the stem of the thermometer is not at right angles with the line of sight. In Figure 4 the mercury is actually at 75.0°. Accordingly, when making the observation the eye should be in the

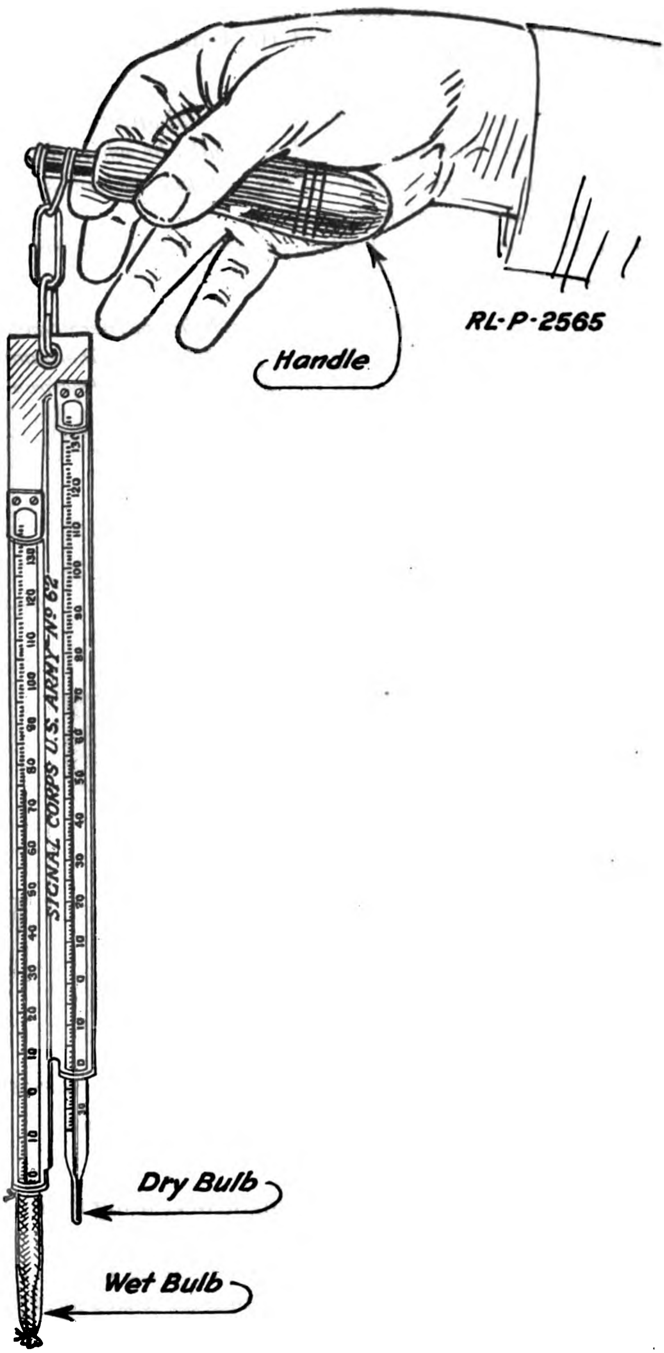

Fig. 3.—Whirling psychrometer

line AB. When the eye is too high, as at C, the observer will read 76.1°; when too low, as at D, the observer will read 73.9°. These two incorrect readings illustrate errors due to parallax. To prevent this error, precautions must always be taken, no matter whether the thermometers are exposed in a horizontal or a vertical position.

b. Error in mistaking the graduations or in assigning the wrong values to graduations.—Observers often mistake 68° for 63°, and vice versa. This mistake occurs because at 5°, 15°, 25°, 35°, etc., there are long marks; and if the mercury column is observed 3° higher than, say, 60°, it may be read as 68°. A few examples are given to show

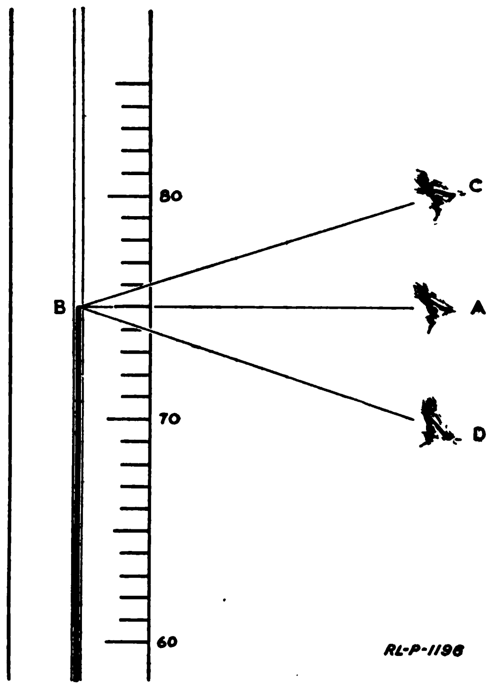

Fig. 4.—Showing error of parallax

how tenths are estimated. If the top of the column or the index is exactly midway between two degree marks, say, between 61° and 62°, the temperature is obviously 61.5°. With practice the other parts of a degree may also be quickly and accurately estimated. The greatest error occurs when the temperature is one-tenth above or below a degree mark, because the observer does not take into consideration the width of the degree mark itself. A few examples for practice in estimating tenths are given in Figure 5.

The maximum thermometer is exactly like the ordinary indicating thermometer except that it is made with a constriction or narrow place near its bulb end as shown in Figure 6.

The operation of the instrument is as follows: When the temperature rises, the mercury in the bulb expands and is forced past the constriction and into the tube. The mercury will continue to rise as long as the temperature rises. When the temperature falls, the mercury contracts, but it can not, as in the case of the indicating thermometer, go back into the bulb, since it can not pass the constriction unaided. The top of the column, therefore, indicates the maximum temperature since the last time the instrument was set, providing the thread of mercury is continuous and the instrument vertical. This instrument must be set each time after it has been read, and the highest temperature recorded. To set the thermometer, one must give it a whirling motion, so that the mercury will be forced back into the bulb. When the mercury has been forced

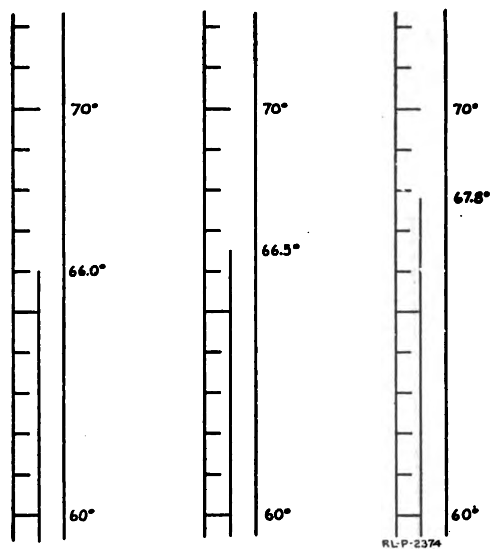

Fig. 5.—Examples in estimating tenths

back and fills the bulb, the top of the mercury column will indicate the current temperature.

Directions.

(2) *a.* Read the maximum or highest temperature by observing the maximum thermometer. To do this, disengage the maximum thermometer and slowly lower it to a nearly vertical position, bulb end down. Read the top of the mercurial column and record this reading.

b. Set the instrument by simply whirling it. To whirl the maximum thermometer, place the index finger of the right hand on the instrument and give it a spin. This will cause the mercury to be forced back into the bulb. When the mercury reads the same as that in the dry thermometer, the instrument is set. It should then be replaced in its original position; that is, nearly horizontal. (See fig. 1.)

Questions.

(7) *What forces the mercury back into the bulb when the maximum thermometer is being set by whirling?*

(8) *When the maximum thermometer has been properly set, just why should the mercury read the same as in the dry thermometer?*

(9) *What is the purpose of the constriction in the tube just above the bulb?*

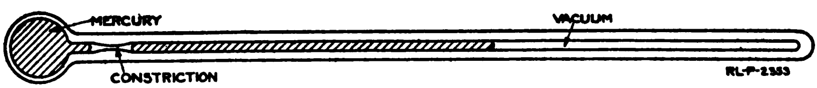

Fig. 6.—Longitudinal section of maximum thermometer

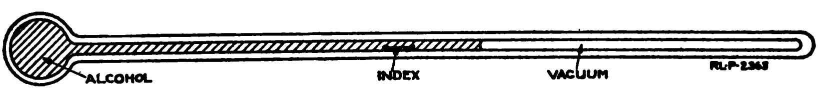

Fig. 7.—Longitudinal section of minimum thermometer

Information.

Minimum thermometer.—The minimum thermometer is shown in Figure 1, together with the maximum thermometer, and in more detail in Figure 7. The minimum thermometer is made exactly like an ordinary thermometer, except that the liquid used is always alcohol, and that in the tube there is a small index shaped like a dumbbell. This index is made of steel or of colored glass so that it may be readily seen. The little balls at either end do not fill up the entire bore of the tube as a piston would, but are smaller than the bore in order that the index may move freely.

The minimum thermometer is exposed in the instrument shelter in a nearly horizontal position, bulb end to the left. Its operation is as follows: As the temperature rises, the alcohol in the bulb expands and is forced up into the tube. The top of the alcohol column will then rise and the alcohol will pass by the index, but without moving it in the least. As the temperature falls, the liquid contracts and the portion in the tube recedes into the bulb. In receding, the top of the alcohol column finally reaches the right-hand ball of the index, and then with the further recession of the alcohol the index is pulled down toward the bulb. This continues until the temperature reaches its lowest point. Then, if the temperature rises, the alcohol again rises in the tube, leaving the index at the lowest point. The reason that the top of the alcohol column causes the index to recede is due to the phenomenon of "surface tension"; that is, the molecules at the surface have a greater attraction for each other than do those in the interior of a liquid. The result is that the surface molecules act similarly to a stretched membrane. The top of the alcohol column as it recedes reaches the index and pushes it toward the bulb end. When the temperature rises, the top of the column moves in an opposite direction, and the index is left at the lowest point, since there is then no force acting upon it which will tend to push it either way.

To read the minimum thermometer, read the degree of temperature at the right-hand end of the index. After the thermometer has been read it must be set. This is done by raising the bulb end of the instrument. This causes the index to slide to the top of the alcohol column, where it will be stopped. The instrument is replaced in its nearly horizontal position, and is then ready to record the lowest temperature for the next period. Readings are taken as many times a day as required, but the reading taken is simply the lowest temperature since the last time the instrument was set. The exact time of occurrence of the lowest temperature can not be told by this instrument, nor can the time of the highest temperature be told by the maximum thermometer.

Directions.

3. Read the minimum or lowest temperature by leaving the minimum thermometer in its nearly horizontal position and reading the position of the right-hand end of the index; that is, the end of the index farthest from the bulb. Record this reading.

4. Set the instrument by raising the bulb end and allowing the index to slide toward the top of the alcohol column. Replace the instrument in its original position; that is, nearly horizontal. (See fig. 1.)

Questions.

(10) *What are the principal differences in construction between the maximum and minimum thermometers?*

(11) *Explain what it is which causes the index to slide down and follow the dropping of the column of liquid in the thermometer tube.*

(12) *What are molecules?*

(13) *What is meant by "act similarly to a stretched membrane?"*

Information.

General instructions for reading all thermometers.—The work must be done quickly, as heat radiated from the observer's body will cause the thermometer to read too high. Since the object in reading the thermometer is to get the temperature of the free air, the thermometer is immersed in this gas (the air) under the best conditions for obtaining the temperature, and care must be taken so that the readings will not be changed by outside causes. The readings may be disturbed by the observer allowing his body to radiate its heat to the thermometer. Some inexperienced observers, when handling the thermometer, finger the bulb and thus make the temperature rise. This should be avoided. To guard against errors, the observer should make use of certain checks by means of which he may be sure that his observations are reasonably correct.

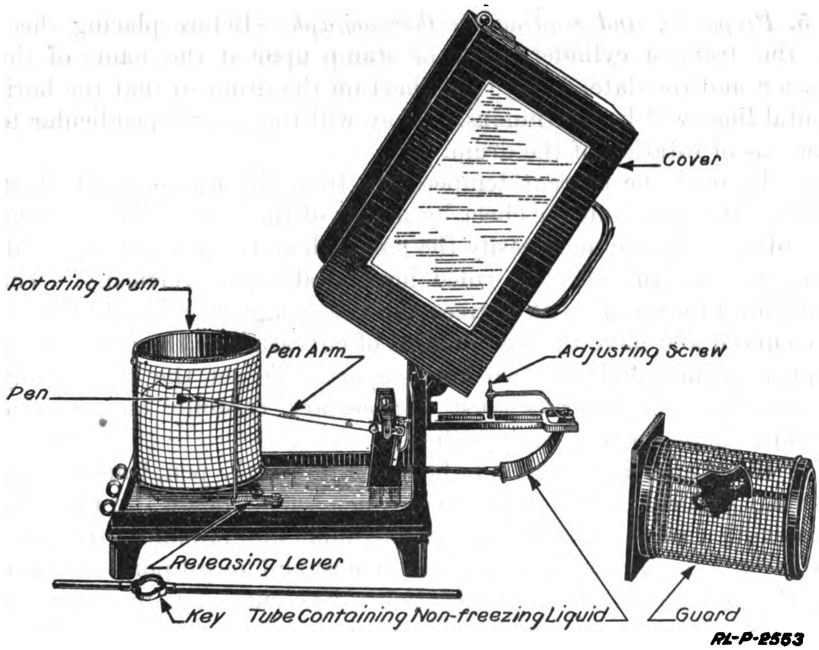

Fig. 8.—Thermograph, cover open and guard detached

Questions.

(14) *What is meant by the phrase "heat radiated from the observer's body?"*

(15) *What are some of the "checks" which the observer can use in order to test the accuracy of his work?*

THERMOGRAPH

See Figure 8. The thermograph is, as its name implies, an instrument which makes a continuous record of the temperature. It consists of a thermometer which is in the form of a curved metallic tube filled with alcohol. This tube is constructed with a tendency to bend. As the temperature rises, the alcohol within the tube increases in volume, and this tends to straighten out the tube. When the temperature falls the alcohol decreases in volume, thus allowing the tube to assume a sharper curve. A pen arm is connected to the tube by a series of linkages. Any movement of the tube is communicated to the pen, which rises and falls as the temperature rises and falls, thus leaving a trace upon a sheet which is wrapped upon a rotating drum or cylinder. (See fig. 9.) Inside this cylinder is a clock which propels the cylinder in a clockwise direction at the rate of one revolution in seven days.

Directions.

5. *Preparing and reading the thermograph.*—Before placing sheet on the drum or cylinder, write or stamp upon it the name of the station and the date. Place the sheet on the drum so that the horizontal lines will be continuous. They will then be perpendicular to the axis of rotation of the drum.

6. To read the current temperature from the thermograph, first remove the pen from the sheet by means of the lever. This is done in order to observe more easily the point where the pen last recorded. The thermograph sheet is ruled horizontally and vertically. The horizontal lines represent degrees and are straight; the vertical lines are curved and have the same radius of curvature as the pen. They represent time and are two hours apart. To set the pen at any desired time the observer must, if necessary, carefully estimate the distance between the two-hour lines.

7. When an observation is to be taken, touch the pen, thus making a small vertical mark in the trace which will indicate the time the observation was taken. Read the maximum and minimum temperature from the sheet by observing the highest and lowest points reached by the pen since the last observation. The current temperature is, of course, the present position of the pen.

8. Change the sheet every Monday morning at an hour fixed by local regulations. At the same time wind the clock, set the pen in reference to temperature and time, and ink it.

Questions.

(16) *In the absence of any specific local regulations what reasons should guide the observer in deciding upon a regular time for changing the sheet and winding the clock of the thermograph?*

(17) *Of what special use is the thermograph?*

(18) *Name in order the various steps which must be taken in the weekly preparation of a thermograph.*

(19) *Explain by a sketch just why care must be taken to avoid inaccuracies due to lost motion in the gears when setting the drum on a thermograph.*

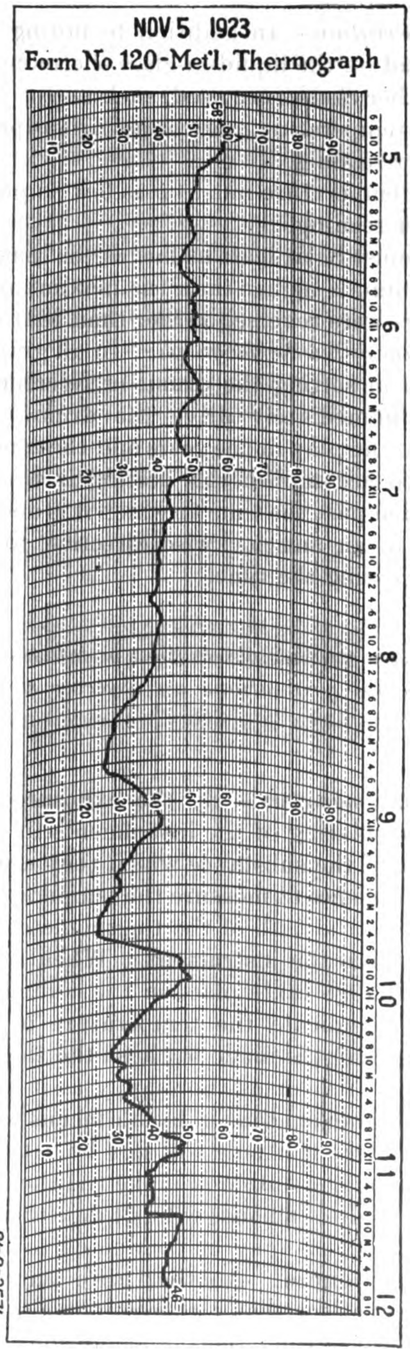

Fig. 9.—Showing a record made by thermograph

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Information.

Checks on observation.—In addition to noting whether or not the temperatures read on the liquid-in-glass thermometers agree with the thermograph, other checks are used, such as—

a. Maximum temperature must be as high as present and preceding dry thermometer reading.

b. Minimum temperature must be as low as present and preceding dry thermometer reading.

c. Minimum must be at least as low as the maximum temperature. When the minimum is higher than the maximum, it probably means that the readings were reversed rather than that they were wrong.

Setting the drum of the thermograph.—In all graph instruments, care should be taken in setting the drum, in reference to time, that the clockwork will immediately drive the drum. This precaution is necessary, due to the play in the gears and the consequent lost motion. The best way to accomplish this setting is to turn the drum in a clockwise direction past the time at which it is desired to set it. Then turn the drum in an anticlockwise direction to exactly the proper vertical line indicating the time.

Questions.

(20) *Why must a weather observation be taken quickly?*

(21) *What are the precautions an observer should take in order to minimize errors?*

Information.

Exposure of thermometers.—By the exposure of thermometers is meant the proper placing of the instruments in such a way that the real temperature of the substance which they are to measure may be obtained. If one wishes to measure the temperature of a cup of water, one simply plunges the bulb of the thermometer into the water, stirs rapidly, and watches the instrument. When a point is reached beyond which no change takes place in the column, the reading of the thermometer will indicate the temperature of the water. In the case of air, the attempt is made to cause the thermometer to take up the temperature of the air as thoroughly as it did in the case of the cup of water. However, that is by no means a simple matter. To hang a thermometer on a pole will not be satisfactory, because the sun may shine upon the bulb and make the thermometer very warm. To hang it on the side of a house will not do either, since the heat from the interior of the house may be conducted to the thermometer and an error thus introduced. Another error enters into this kind of exposure due to the fact that a thermometer continually radiates as well as takes in heat. Under certain conditions, then, a thermometer hung in the free air may actually read higher or lower than the true air temperature. Accordingly, the solution of the problem of how to expose a thermometer is to hang it so that the air may have free access to it, and the sun may not. Neither must the thermometer have great freedom to radiate its own heat.

To meet these two conditions the thermometer is hung in an instrument shelter. (See fig. 2.) This shelter consists of a cubical box, the sides of which are made of slats so arranged that the sun can not shine in, although the air may have free access. It is also double roofed and is painted white to reflect the sun's rays. In thermometry the things to remember are that a thermometer will only indicate its *own* temperature, and that what one tries to do in measuring the temperature of a substance is so to place the thermometer in contact with the substance that the instrument will take upon itself the temperature of the object being measured. The shelter is set up on legs in order that its floor will be 4 feet above the ground, and the thermometers are hung inside about eye high; that is, about 5 feet above the ground.

Questions.

(22) *What points should the observer keep in mind in deciding upon a suitable location for setting up a thermometer shelter in the following situations?*

a. In a mountain station much exposed to wind and storms.

b. On a tall building in a large city.

c. On shipboard.

d. In a village or a small town.

e. In a temporary situation frequently changed, as with an exploring party.

(23) *a. Describe in detail the construction of the standard instrument shelter, including dimensions.*

b. Explain clearly why the shelter is made this way.

c. What color should the shelter be painted? Why?

(24) *Why do thermometers exposed on a doorpost give inaccurate temperatures of the air?*

(25) *If one bulb were larger than another, which would read higher, if both were hung in sunshine?*

(26) *Is air colder in the sunshine or in the shade?*

(27) *Why do different substances having the same temperature feel to the touch as though they had different temperatures?*

(28) *What other type or types of thermometers besides the Fahrenheit are most frequently used?*

SUGGESTIONS FOR THE INSTRUCTOR

1. *a*. After unit operation No. 1 has been completed and all the questions in the text have been answered by each student, the instructor may give the following instruction test or devise another one similar to it. For convenience this test is divided into two parts: Part I—Performance, Part II—Information. This test is designed to assist the instructor in determining which men fall below the general average of the class and consequently need further instruction. It is also designed to show the student what particular items of information he has failed to acquire during the instruction period.

b. As a result of the classroom work, the student should have learned how (1) to set, read, and record the dry-bulb, maximum, and minimum thermometer; (2) how to set and prepare the thermograph; and (3) how to name the important parts of the various instruments and equipment used in this unit operation.

c. After the papers have been scored the instructor should point out precisely in what particulars each student has failed, and, if the results are unsatisfactory, repeat the test after an interval of a day or two.

d. It will not be necessary to administer this entire test at one time. If the instructor prefers to do so, Part I of the test may be given on one day and Part II on another, whichever way best fits in with his schedule of instruction.

e. The directions for the student in Part I may either be typewritten, mimeographed, or read aloud by the instructor. Allow the student sufficient time to read the instructions, if written, or to thoroughly to understand them if given orally by the instructor. Part II of the test may be either typewritten, mimeographed, or placed on the blackboard.

INSTRUCTION TEST NO. 1

PART I.—PERFORMANCE

PROBLEM 1

PREPARATION OF THE THERMOGRAPH FOR OPERATION

Equipment.

One table.
One thermograph.
Supply of record sheets.
One bottle of recording ink.

Procedure.

Place the thermograph upon the table with the supply of record sheets and recording ink. See that the record sheet is removed from the thermograph. The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

Perform the following operations carefully and neatly, but at the same time as quickly as you can.

1. Change the sheet on the thermograph.
2. See that the clock is properly wound.
3. Set the pen for 68°, 8.30 a. m. Monday.
4. Start the drum so as to avoid play in the gears.
5. Ink the pen.

As soon as these five operations have been completed report at once to the instructor.

Directions for scoring.

	Points
1. The maximum possible score for problem 1 if all five operations are successfully performed is	10
2. For each one of the five operations which is performed correctly credit the student with	2

3. Allow no partial scores for any of the five separate operations—that is, score each either 2 or 0.

PART II.—INFORMATION

Equipment.

Pencils.

Mimeographed or typewritten test questions.

Procedure.

1. Furnish each student with a pencil and a copy of the test questions which are given under Part II.

2. Read over aloud the directions which appear at the beginning of the test. This will be necessary for only the first few tests of this sort, as the students soon become familiar with this type of examination.

3. As soon as the directions have been read and understood, call the class to attention, state clearly the number of minutes that will be allowed for the test, and give the command "Begin." Thirty minutes will be allowed for Part II of this test.

4. At the end of 30 minutes from the command "Begin," call "Time." See that all papers are collected and that the names of the students are properly recorded.

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a *plus* sign (+) on the line to the right. If what it says is *not true*, put a *minus* sign (–) on the line to the right.

Samples:

Thermometers are instruments by means of which we can measure the temperature of the air. + ------

The liquid in a thermometer bulb is a mixture of common salt and ether. – ------

Begin here.

1. Thermometers are exposed in a special shelter to protect them from extremes of heat and cold. ------
2. Temperature is measured by means of sling psychrometers, barometers, and thermographs. ------
3. The sling psychrometer is composed of two thermometers, a wet-bulb and a dry-bulb. ------
4. Temperature is usually read and recorded in degrees and tenths of a degree. ------
5. The scale marks on the standard thermometer are indicated by lines for every half degree. ------
6. When reading a thermometer the scale should be at right angles to the line of sight. ------
7. In reading a thermometer to tenths it is quite unnecessary to take into account the width of the degree mark itself. ------
8. The maximum thermometer is set by whirling. ------
9. The minimum thermometer is set by lowering the bulb end. ------
10. The difference between the readings of the maximum and minimum thermometers gives the current true temperature. ------
11. The observer should be careful not to handle a thermometer by the bulb. ------
12. The flat metal tube of the thermograph is usually filled with mercury. ------
13. The cylinder of the thermograph revolves once every 168 hours. ------
14. As the temperature rises mercury tends to increase in volume, but alcohol tends to decrease. ------
15. The horizontal lines on a thermograph sheet represent degrees. ------
16. The vertical lines on a thermograph sheet represent time and are spaced two hours apart. ------

17. When making a check on observations it should be noted that the minimum must be at least as low as the maximum. ......

18. When the minimum is higher than the maximum the most probable explanation is not that readings have been accidentally reversed, but rather that they were both wrong to begin with. ......

Directions to the student.

Below are a number of sentences from which certain words or numbers have been omitted. Each word which has been omitted is indicated by a short dotted line inclosed in parentheses, thus (.....................). Fill in each blank space with a word or a number which will make good sense and at the same time be technically correct. A word spelled with a hyphen, like armor-plated or back-fire, counts as one word.

19. Temperature may be defined as the (....................) of (....................) of a substance.

20. The operation of all thermometers depends upon the fact that most substances (....................) on being heated, and that in addition all these substances (....................) a different amount per (....................) of heat.

21. In accordance with the above statement, when the thermometer is heated the mercury (....................); and if the thermometer is cooled, the mercury (....................).

22. In the construction of thermometers, the liquids commonly used are (....................), which freezes at (..............) degrees (....................) zero, and (....................), which freezes at about (....................) degrees below zero.

23. The zero of the Fahrenheit scale is (....................) degrees (....................) the freezing point of (.............................).

24. The point at which (....................) boils is marked on the Fahrenheit scale as (....................) degrees above (....................).

25. The range of the thermometers used in the Signal Corps is from (....................) degrees below (....................) to (....................) degrees (....................).

26. The bulb end of a thermometer usually hangs (...................) and the end of the mercurial column opposite the bulb is called the (....................) of the column no matter in what ....) the thermometer is placed.

27. A thermometer which measures a slight change in (.....................) quickly is called a (....................) thermometer.

28. A thermometer which measures very slight (________________) in (____________________) is called a (____________________) thermometer.

29. For meteorological work, thermometers need to be (______________________) rather than (____________________) since (______________________) of a degree is the smallest fraction considered when measuring the temperature of the (____________________).

30. If the bulb of a thermometer is made in the (________________) form, there will be more surface exposed than if it is made in the (____________________) form.

31. A so-called "ordinary" thermometer measures the (____________________________) temperature of the air. This instrument may also be called an (____________________) thermometer.

32. Registering thermometers are those which (________________) the (____________________) and the (____________________) temperatures.

33. Recording thermometers are usually called (________________) and make a (__________________) record of the (________________).

34. Registering thermometers are of two kinds; those which register the highest or (____________________) temperature, and those which measure the (____________________) or (____________________) temperature.

35. The sling (____________________) is composed of two (____________________), one of which is called the (____________________) and the other the (____________________).

36. If when reading a thermometer, the eye of the observer is not at (____________________) angles with the stem of the thermometer there is very likely to be an error due to (____________________).

37. The maximum thermometer is made with a (____________________) in the stem near the (____________________).

38. The liquid in a minimum thermometer is always (____________________) and in the tube is a small movable (____________________).

39. The minimum thermometer is exposed in the shelter in a nearly (____________________) position, with the (____________________) end to the (____________________) side.

40. In reading all thermometers, the observer should work (____________________) as (____________________) radiated from the (____________________'s) (____________________) will cause the (____________________) to read too (____________________).

41. The (____________________) is an instrument which makes a continuous (____________________) of the temperature.

42. The problem of exposing a thermometer is to hang it up so that the (....................) may have free access to it and the (....................) may (....................).

43. The instrument shelter is made with a (....................) roof, and is painted (....................) to (....................) away the sun's rays.

44. The shelter is set up so that its floor will be (....................) feet (....................) the ground and the thermometers are hung inside about (....................) feet (....................) the ground.

Directions for scoring Part II. Points

1. The maximum possible score for Part II of this test is...... 97
2. The minimum score required to pass Part II is............ 81

3. *a.* The score for the true-false (plus-or-minus) questions is obtained as follows: Add up the number of the questions which have been correctly answered; then add up the number of questions to which the wrong response has been given. Subtract the number wrong from the number right. This difference will be the net score. If the number wrong should be greater than the number right, call the difference *zero;* that is, do not assign a score of less than zero. Do not pay any attention to omitted questions. For a further explanation of this method of scoring see the "Introduction" to Manual No. 25 (edition of 1925) or Manual No. 21 (revised edition.)

b. The score for the completion questions is obtained by allowing 1 point for each blank space which has been filled in with a word or number which makes sense and at the same time is technically correct. There is no additional penalty for omissions.

BAROMETERS, READING AND RECORDING

Equipment.

One mercurial barometer with vernier.
One barograph.
One aneroid barometer.
Copies of Form No. 79 and Form No. 80 (see Inf. Topic No. 2).
One vessel of mercury.
One glass syringe.
One glass tube one-fourth inch in diameter.

Information.

Atmospheric pressure.—The atmosphere presses down upon the earth. This phenomenon, called atmospheric pressure, is one of the elements of the atmosphere that must be studied and the results recorded. Although the atmosphere exerts pressure and this pressure frequently changes, yet these changes are not nearly so evident as the fact that the atmosphere varies in temperature or that it

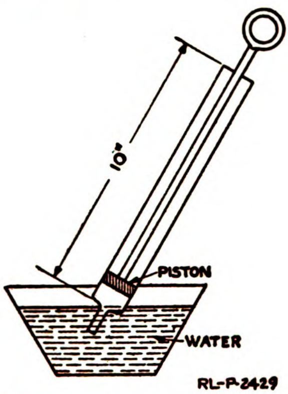

Fig. 10.—Syringe in position to draw water

moves, making the wind. Since the observation of atmospheric pressure is so very important, the measuring of this phenomenon should be done with great care.

There are many common operations performed daily which show that the atmosphere exerts pressure. Figure 10 represents an ordinary syringe. By pushing the piston in as far as it will go, immersing the end in a vessel of water, and pulling the piston to the upper end of the syringe, one can fill the instrument with water. The pulling up of the piston does not of itself draw up the water. This movement is caused by the air outside pressing down upon the surface of the liquid. The water is forced up the tube of the syringe for the reason that as one pulls up on the piston the tendency is to form a vacuum above the level of the water. This is the same as saying that when no pressure is being exerted upon the water from inside the cylinder the pressure upon the water from the outside will force it up into the tube following the piston. This simple experiment indicates that the atmosphere exerts pressure.

Questions.

(1) *Just why is it so important to measure the pressure of the air?*

(2) *Explain how water can be raised from a well or cistern by means of an ordinary suction pump.*

(3) *About how many feet can water be raised by such a pump?*

The science of measuring the pressure of the air with a barometer is called *Barometry.*

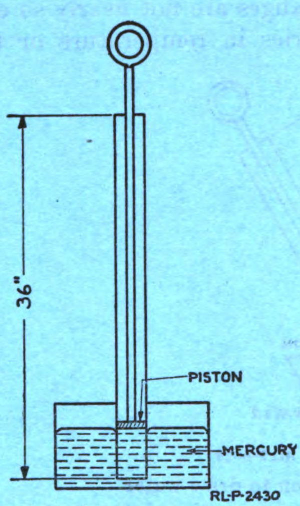

Fig. 11.—Barometer tube fitted with piston, with which tube may be filled

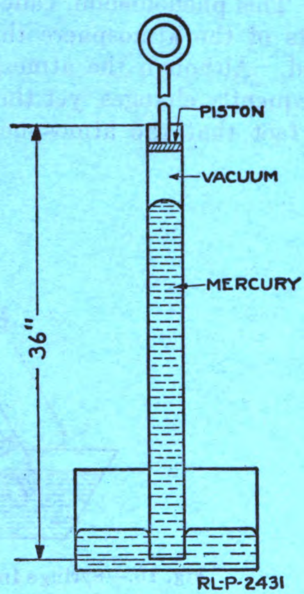

Fig. 12.—Barometer tube filled with mercury; piston at top above vacuum

A barometer may be made as follows: Take a tube with a quarter-inch bore, open at both ends and mount it as shown in Figure 11, its lower end being immersed in mercury and at this end a piston. Now let an upward pull be exerted on the piston. It will be found that the mercury will follow the piston up the tube in the same manner as did the water in the case of the syringe. But when the mercury has reached a height of about 30 inches above the level of the mercury in the cistern, it will remain at that level; and even though the piston is pulled much higher, the mercury will still stand at about that level, as shown in Figure 12. The tube and piston would be a good barometer if the piston did not leak and if a suitable scale were made to measure the height of the column of mercury, for that height represents the pressure of the air. A column of mercury with a cross section of 1 square inch and 30 inches high weighs about 15 pounds. The air at sea level then presses down upon the earth with a pressure of about 15 pounds per square inch. Air pressure varies, and consequently the height of the mercurial column changes. This variation attends the weather changes, the column falling in general when a storm approaches and rising as the storm recedes.

Question.

(4) *Explain why the mercury stands at the level shown in Figure 12.*

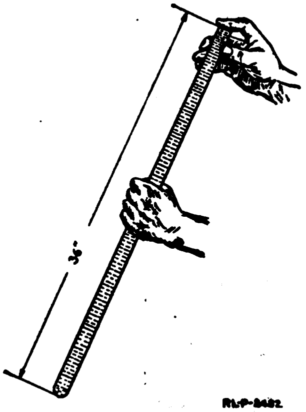

Fig. 13.—Barometer tube filled with mercury which is kept in by finger

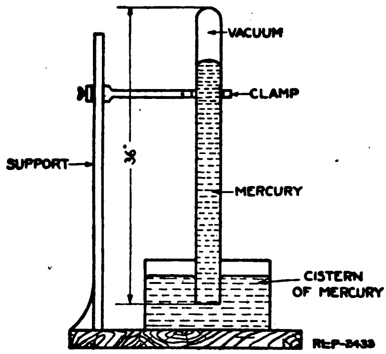

Fig. 14.—Barometer tube inverted in cistern of mercury

Information.

Construction of barometers.—Barometers are not, however, made in the manner just described. They are made in effect as follows: Take a glass tube 36 inches long, one-fourth inch in diameter, and closed at one end and fill it with mercury. Then press the finger tightly over the mouth of the tube, taking care that no air is inclosed. (See fig. 13.) Still keeping the finger over the mouth of the tube, invert the latter, and immerse its open end, with the finger still in place, in a vessel of suitable size containing mercury. Remove the finger slowly and then mount the tube and cistern of mercury, as shown in Figure 14. The mercury will fall a short distance; that is, until the height of the top of the mercurial column above the surface of the mercury in the cistern is about 30 inches, providing the operation is performed at or near sea level.

The barometers used by the Signal Corps are essentially as shown in Figure 14, but with the following additions:

a. A brass tube surrounding the glass tube.

b. Slits in the brass tube through which the top of the mercury column may be observed.

c. A suitable scale with a vernier for measuring the height of the mercury.

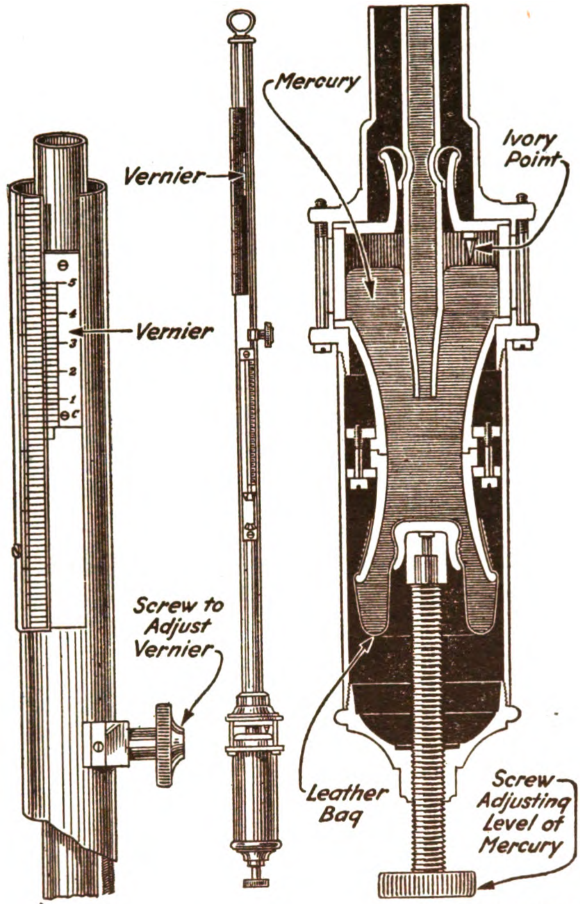

Fig. 15.—Showing vernier, barometer, and cistern of standard barometer

d. An ivory point to indicate the zero of the scale.

e. An adjustable bottom for the cistern which is so arranged that the level of the mercury in the cistern may be lowered or raised as required.

f. Other accessories built in to facilitate handling the instrument.

g. A case in which it may be exposed.

Directions.

1. Figure 15 shows a barometer as just described, a longitudinal section of the lower part of a barometer and a vernier. Note the ivory point which is the zero of the scale and the flexible leather bag forming the bottom of the cistern. Operate the screw and observe how the level of the mercury may be raised or lowered until it just touches the ivory point.

Information.

The barometer is usually equipped with a scale about 6 inches long, attached to the brass tube with the 30-inch mark just 30 inches above the ivory point. It is not necessary to have a longer scale than this, because the variation of the top of the mercurial column is only a few inches when kept at one station. The variation in the height of the mercury is much higher, of course, if the instrument is carried from a low level to a very high altitude. The instrument makers equip the instruments with scales to suit the elevation of the station at which the barometer will be used. Alongside the main scale is a small movable metal scale, called the vernier. This vernier may be moved up or down by turning the adjusting screw. On the other side of the glass tube is a companion piece which is the same size as the vernier, and which is also operated by the screw. This piece is always at the same height as the vernier.

The barometer should be exposed in the office of the observer, not outside. The reason for this being that the pressure inside the building is the same as that outside. In fact, an inside exposure is better than an outside one, since it will not be necessary to correct for exposure to the wind. The barometer is hung within a box that is moderately tight, the door of which should always be kept closed, except when readings are being taken. The reason for this is that the attached thermometer will indicate as nearly as possible the temperature of the contained mercury. The box should be fastened securely to the wall by screws or by some other means, at a height which will bring the top of the mercurial column about 5 feet above the level of the floor. By suitable surveys to the nearest correct bench mark, the height of the instrument above mean sea level should be ascertained as soon as it has been erected. Oftentimes a geological survey bench mark is not immediately available. In this case railway levels may be used, or this data may be taken from Government contour maps and used until more correct levels may be run.

Fastening the barometer box to the wall is usually a good installation in permanent buildings, but in camps, and especially in time of war, the barometer must often be hung in temporary huts which are very unstable, and good readings can not be obtained when there is considerable wind. This difficulty can be obviated by setting a post in the ground, cutting the floor away from it and mounting the barometer upon the post. The instrument will then be free from building vibration.

Questions.

(5) *a. What causes the mercury to rise and fall in the tube of a barometer?*

b. What causes the mercury to rise and fall in the tube of a thermometer?

(6) *Explain just what it is that is measured by the barometer?*

(7) *What is a bench mark?*

(8) *Will a barometer read the same if it is taken from a warm room and set up outside the building in a position where the temperature is 20° colder?*

(9) *If the temperature in the room is the same as that outside, will the barometer read the same in both situations?*

(10) *What is likely to be the effect on the reading of a barometer if it is taken from the street level to the roof of a 20-story office building?*

(11) *Will the barometer, other things being equal, read the same in dry air as in moist air?*

(12) *Why is mercury generally used in the construction of a barometer?*

(13) *What special precaution should be taken in setting up and caring for a barometer in the field, especially under combat conditions?*

(14) *Explain those points the observer should keep in mind in deciding upon a suitable location for setting up the various barometers under the following circumstances:*

a. In a mountain station, much exposed to wind and storms.

b. On a tall building in a large city.

c. On shipboard.

d. In a village or small town.

e. In a temporaty situation frequently changed, as with an exploring party.

Instruments.

The instruments used in the Signal Corps for measuring atmospheric pressure are the mercurial barometer, the barograph, and the aneroid barometer.

a. The mercurial barometer (see fig. 16) consists essentially of a glass tube, sealed at the top, filled with mercury, and having its lower end immersed in a cistern of mercury. The instrument is so made that the pressure of the free air is communicated to the mercury in the tube and hence measured.

b. The barograph consists of a corrugated vessel from which the air has been exhausted, which is attached, through a series of linkages, to a pen that writes or traces upon a cylinder or drum. Upon this drum is a suitably ruled sheet of paper which passes under the pen. Both drum and sheet are made to rotate by means of clockwork within the drum. (See fig. 17.)

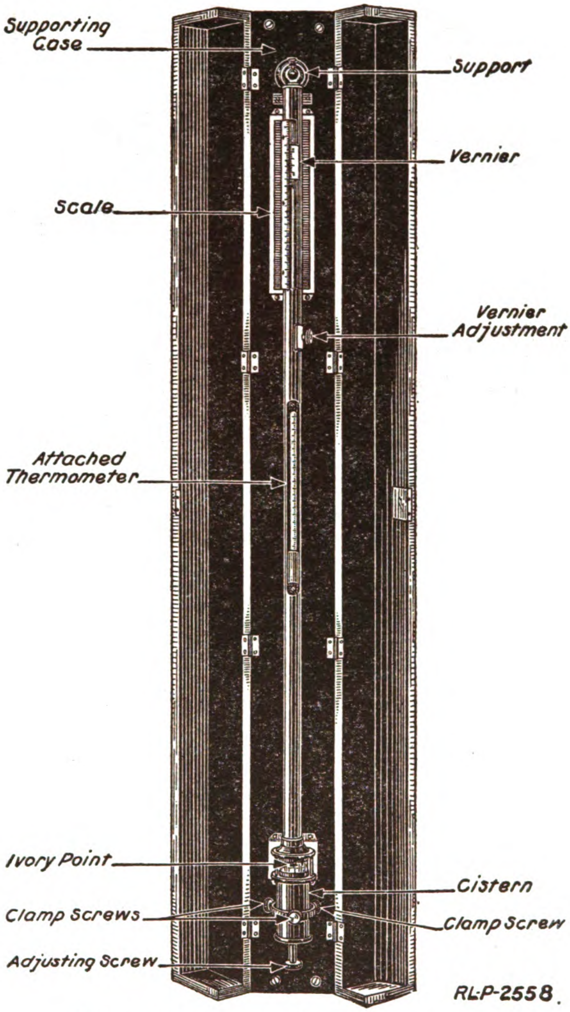

Fig. 16.—Barometer in box, cover open

c. The aneroid barometer is a small indicating instrument constructed on a principle similar to that of the barograph. The instrument does not record, but simply indicates by the movement of a small hand or pointer the air pressure at the place where it is installed. (See fig. 18.)

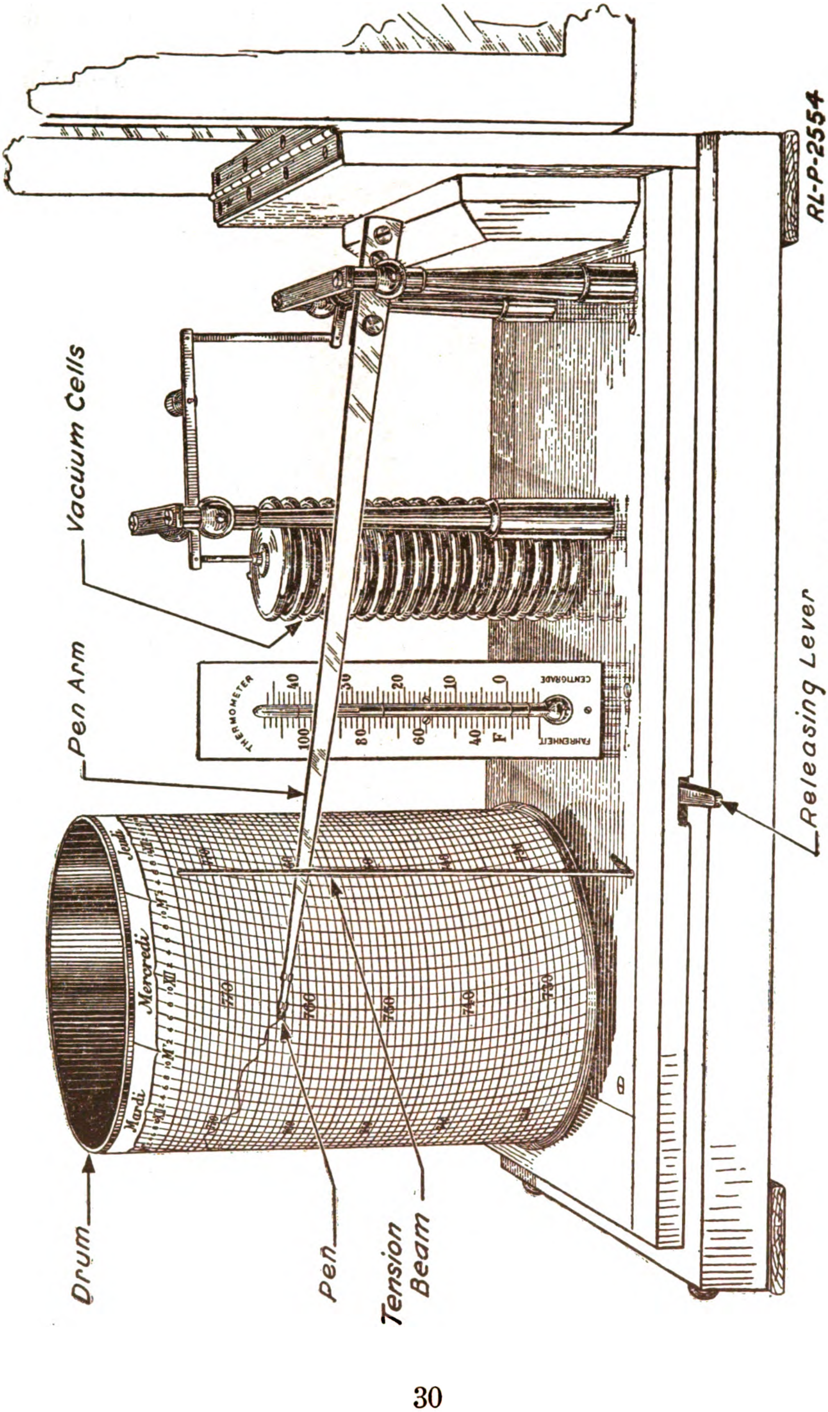

Fig. 17.—Barograph, cover open

Questions.

(15) *What is meant in the first paragraph by the phrase "the pressure of the free air"?*

(16) *Should a barometer be absolutely vertical when hanging in a shelter?*

(17) *Why should the door of the barometer box be kept closed?*

(18) *Does the temperature as indicated by the (attached) thermometer give the temperature of the mercury in the barometer?*

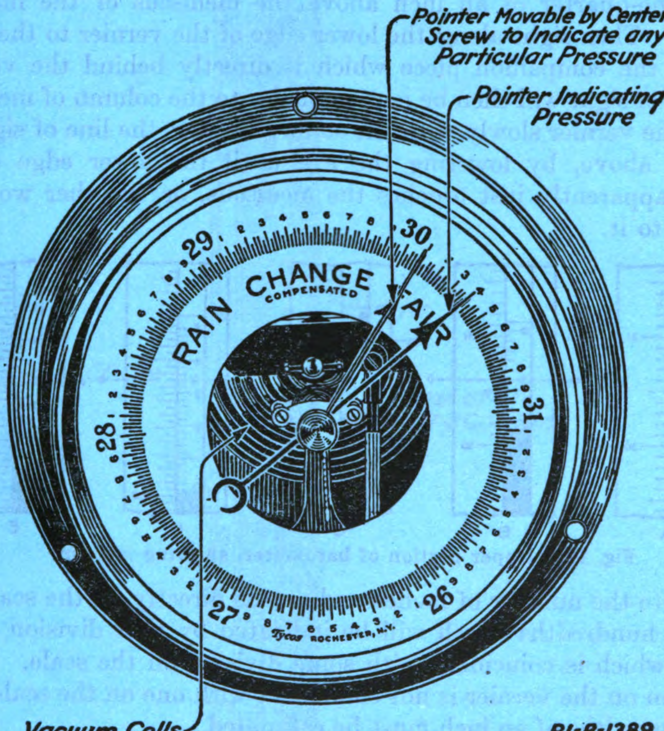

Fig. 18.—Aneroid barometer

(19) *What points should be considered in selecting a suitable place in which to install a mercurial barometer?*

(20) *What is the difference between a barograph and a thermograph?*

(21) *What is the chief advantage in using an aneroid barometer?*

Information.

The vernier.—Every reading of the mercurial barometer, illustrated in Figure 16, involves the use of the vernier. A knowledge of its construction and of the principle upon which it operates is consequently necessary.

The simplest vernier is shown in Figure 19, A, B, C, D, and E, diagrammatically, and attached to the barometer as in Figure 20. The vernier in Figure 19, A, has ten divisions which are equal to nine divisions on the scale of the barometer. Therefore, one division on the vernier is equal to nine-tenths of a scale division, and the difference between the two is one one-hundredth of an inch (0.01 in.).

Directions.

2. To use the vernier in reading a barometer, first raise the vernier about one-quarter of an inch above the meniscus of the mercury column. Then sight along the lower edge of the vernier to the lower edge of the companion piece which is directly behind the vernier. The line of sight will then be perpendicular to the column of mercury. Lower the vernier slowly with the screw, keeping the line of sight, as directed above, by lowering the eye until the lower edge of the vernier apparently just touches the meniscus, or, in other words, is tangent to it.

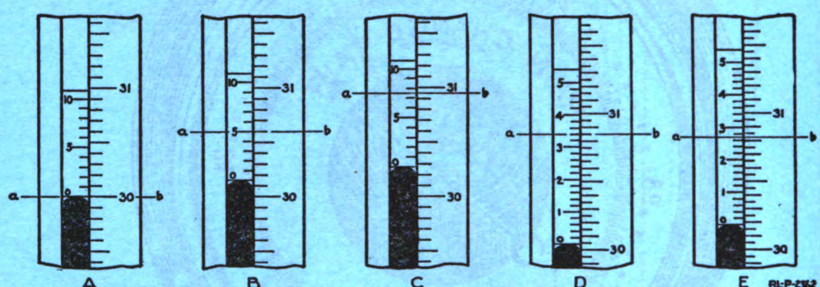

Fig. 19.—Upper portion of barometer, showing mercury

3. Note the number of inches and tenths directly on the scale and add the hundredths which will be indicated by that division of the vernier which is coincident with some division on the scale. When a division on the vernier is not coincident with one on the scale, then the thousandths of an inch must be estimated.

Information.

The verniers used on barometers in the Signal Corps are designed so that even finer readings may be made by means of them. Twenty-five divisions on the vernier are equal to twenty-four on the scale. Therefore, one division on the vernier is one twenty-fifth smaller than a scale division; and since a scale division is one-twentieth of an inch, a vernier division is accordingly one five-hundredths of an inch smaller than a scale division. There is an important difference in the use of this vernier as compared with the simpler one first described. The observer must note whether the lower edge of this vernier is above a tenth or a multiple of a tenth mark, or above a

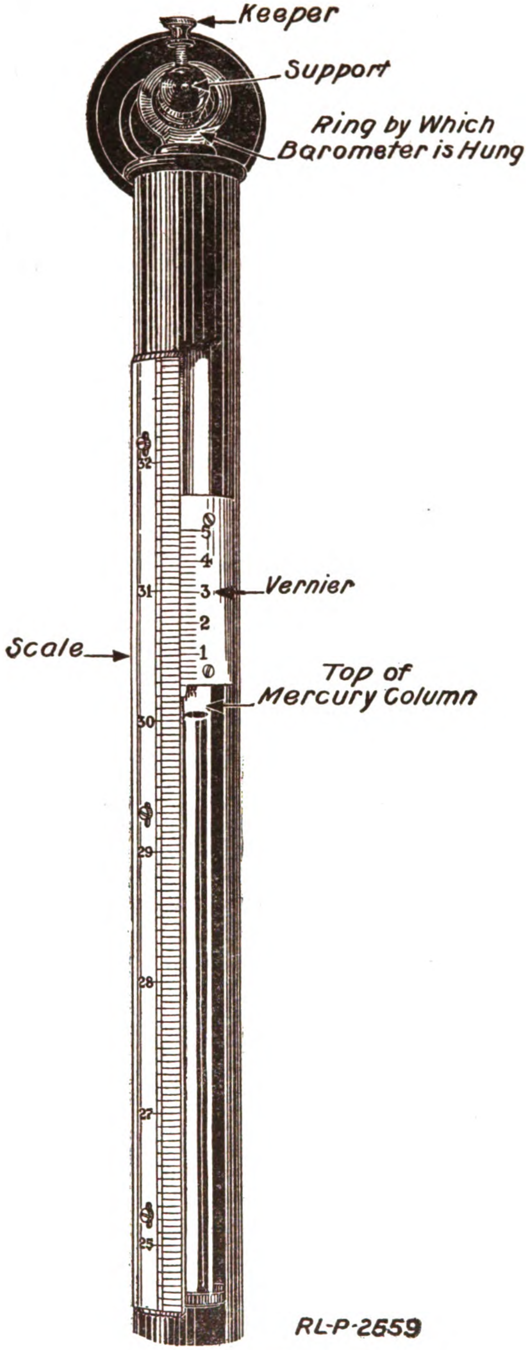

Fig. 20.—Showing vernier

twentieth mark, or an odd multiple of a twentieth mark, as one, three, five, seven-twentieths. The reading of the vernier is added to the reading of the scale found to the nearest 0.050 of an inch.

Question.

(22) *Explain the principle upon which the vernier works.*

Directions.

4. The student can demonstrate the principle of a vernier for himself by making one out of two slips of paper and then sliding them over each other until he understands the principle involved. The two slips of paper should be of equal length, about 3 or 4 inches long, with one slip divided into 10 divisions, and the other into 9.

Questions.

(23) *What are the units into which the scale of the barometer is divided?*

(24) *What is smallest fraction of an inch which may be read by the vernier?*

Directions.

To read a mercurial barometer.—5. A barometer reading is made as follows: Proceed to the barometer case, open the door, and immediately read the attached thermometer to the nearest half degree.

6. Lower the barometer cistern. Then by means of the adjusting screw bring the level of the mercury in the cistern up to the ivory point, at the same time lightly tapping the instrument.

7. Raise the vernier above the top of the mercury column and then lower it so that the line of sight from the bottom of the front vernier to the bottom of the back vernier just grazes the meniscus of the mercury, and at the same time tap the instrument lightly.

8. Read the vernier to the nearest one-thousandth of an inch and record this as the observed reading.

Questions.

(25) *How can the position at which the ivory point just touches the level of the mercury in the cistern be determined?*

(26) *Why should the instrument be tapped lightly when adjusting the level of the mercury?*

(27) *What error would result from not adjusting the screw at the bottom of the barometer?*

Information.

Corrections, reductions, and interpolation.—After the reading is taken it must be reduced to station pressure and to sea level pressure. To do this certain corrections and reductions must be applied. These are as follows:

a. Sum of corrections, which includes corrections for scale error capillarity, and gravity. This is given on Form No. 79 (see information topic No. 2), which is usually found in the barometer box.

b. Temperature reduction, which when applied will give station pressure.

c. Reduction to sea level.

In some of the operations of reducing observations, it is necessary in using tables to perform the operation called "Interpolation." In general, tables used in meteorology have values in vertical columns at the left-hand called the "side argument" and values in a horizontal row at the top called the "top argument." At the intersection of the horizontal rows and vertical columns are values denoting certain things. For instance, in Form No. 80 (see information topic No. 2), at the top there is a row of figures, representing pressures from 24 inches to 31 inches. This is called the top argument of that table. At the left there is a column of temperatures from 16° to 105°, called the side argument of that table. This table, contained in Form No. 80, is called the "Correction of mercurial barometer for temperature." The temperature of the mercury when the barometer is read is the side argument; the observed pressure in the top row is the top argument. The value representing the correction to be added to or subtracted from the observed reading is found at the intersection of the column under the top argument with the row containing the side argument.

Directions.

9. Assume that the observed pressure read from the barometer is 29.000 inches and the temperature as read from the thermometer attached is 72.0°, then following the column down from 29.0 inches until the finger reaches the row opposite 72.0, will be found the value .114 inch. This is the value to be subtracted from the observed reading, which will make the proper temperature reduction; that is to say, the application of this correction will reduce the height of the barometer to what it would be if the temperature were 32°.

10. The next value after 29.00 inches is 29.500 inches. If the observed reading were some value between 29.0 inches and 29.5 inches and the temperature 72°, then one would have to resort to interpolation to find the right correction value to be subtracted from the observed reading. Interpolation, then, means the process of extending the tables to include values not given therein for observed readings which can not be found exactly in the top and side arguments.

11. Let the observed barometric reading be 29.250. It will be observed that the value of the correction opposite 72° and under 29.0 inches is .114, and the correction under 29.500 inches is .116 inch.

Since the observed reading is 29.250 inches, or halfway between the values 29.0 and 29.5 inches, the correction must be halfway between .114 and .116 or .115. This process is interpolation by inspection. In many cases however, some further calculation is necessary in order to arrive at the right correction.

12. Let the observed barometer reading be 29.332 and the temperature of the attached thermometer 84.5°. Problem: Find the temperature correction. This can not be taken out of the table directly nor found by inspection. It will therefore be necessary to resort to calculation in order to determine it.

13. See Table I below. This table is an excerpt from Form No. 80, and contains the corrections for barometer readings 29.0 and 29.5 when the temperature is 84.5°. This excerpt is extended for values between 29.0 inches and 29.5 inches in even tenths.

TABLE I

	29.0	29.1	29.2	29.3	29.4	29.5
84.5	.146	--------	--------	--------	--------	.49

14. See Table II below. This table shows the interpolated values between 29 inches and 29.5 inches, which are underscored. The underscored values were found as follows:

TABLE II

	29.0	29.1	29.2	29.3	29.4	29.5
84.5	.146	.147	.147	.148	.148	.149

15. The difference between 29.0 and 29.5 inches is 0.5 inch, and the difference between the correction .146 and .149 is .003 inch. It is evident that the correction must increase in the same proportion as the barometric readings increase. Therefore, as the difference between 29.0 and 29.5 is .500, and the difference between 29 and 29.1 is .100, the correction to correspond to 29.1 is .146 increased by one-fifth of the difference between .146 and .149. This value is 0.1466, since one-fifth of .003 is .0006, which added to .146 gives the value .147 to the nearest thousandth. The correction for 29.2 would be two-fifths of .003 added to .146, and so on for the remainder of this little extended table.

TABLE III

	29.0	29.1	29.2	29.3	29.332	29.4	29.5
84.5	.146	--------	--------	--------	--------	--------	.149

16. From this example it is seen then that interpolation means simply extending the table already given. Next, consider Table III above. Here the values in the table are those taken from Form No. 80 as in Table I, but the expansion now has to do with a top argument in the thousanths. The problem is to find the value of the underlined space, or that corresponding to 29.332 inches. Therefore, one should proceed in exactly the same manner as was done in finding the interpolated values in Table II. Subtract the value 29.000 inches from 29.332 inches and the value 29.000 inches from 29.500. The value of the correct temperature reading, therefore, may be found by multiplying .003 by $\frac{.332}{.500}$. The result of this multiplication is .0019. This added to .146 gives .1479, or, to the nearest thousandth .148.

Question

(28) *What is meant by each of the following phrases or statements?*
(*a*) "*Enter the table.*"
(*b*) "*Interpolation may be necessary.*"
(*c*) "*Add algebraically.*"

Information

Barograph.—This instrument, as its name implies, is one which records the changing pressure of the air by means of a pen moving up and down on a revolving cylinder. (See fig. 17.) The varying pressure of the air is transmitted to the pen by means of a series of levers that are connected to seven or more vessels which are exhausted of air. These little vessels are each about 2 inches in diameter and three-tenths inch thick. They are placed one on top of the other and connected together, thus forming a series of exhausted vessels about 4 inches high. Inside of each vessel is a spring which keeps it from entirely collapsing as the air is withdrawn from it. As the air pressure decreases, the springs within the vessels are pushed outward and move the pen down. As the pressure increases, the sides of the vessels are pushed together, and this motion communicated to the pen makes it move upward.

In the latest barographs the barometric element consists not of several vessels but of one, and looks like a corrugated cylinder.

The barograph (see fig. 17) should be installed in the office at nearly the same level as the barometer, and in the shade. It is read to the nearest hundredth of an inch. This reading is the station pressure, and no temperature correction need be applied.

Questions.

(29) *Why should the barograph be installed in the shade?*

(30) *Why do the "little vessels" mentioned above tend to collapse as the air is drawn out?*

Directions.

17. The sheet of the barograph should be changed every Monday, and the following procedure should be observed:

a. Take a barometer reading and obtain the station pressure.

b. Remove the old sheet, and write at the end of the barometric trace the station pressure.

c. Put on a new sheet, first carefully dating it, and stamping thereon the name of the station, taking precaution that the horizontal lines are continuous where the ends of the sheet meet.

d. The station pressure must be written on the sheet near the point where the trace will begin.

e. Wind the clock, and set the pen at station pressure.

f. Take up lost motion in the gears.

g. Ink the pen.

Information.

Care of the barometer.—The following precautions must be observed in regard to the barometer: The barometer case must always be kept closed except at the time of observation. The attached thermometer must be read immediately upon opening the door. The barometer must never be moved except to change its position permanently or to clean it. The scales should be dusted, but not polished, as so doing may change the position of the scale. The barometer should not be cleaned except by an inspector, or by some one having authority from the office of the chief signal officer.

Installing barometer.—*a.* Barometers should be installed with the greatest care. They are shipped with the mercurial column screwed up as far as possible without straining the chamois bag comprising the bottom of the cistern.

b. Remove the instrument from the packing box, *cistern uppermost.* Carry the barometer to the place of installation, which should have been previously prepared, and carefully reverse it and hang it up.

c. Then lower the mercury column by unscrewing the bottom screw until the level of the mercury in the cistern is about at the ivory point.

d. When a barometer must be moved, screw the mercury up as far as possible, care being taken not to exert too much force; then remove it from the case and mount it. It may be carried safely about in an inverted position.

When readings of the mercurial barometer are taken, they should always be compared with the barograph readings. Figure 21 shows a record made by a barograph.

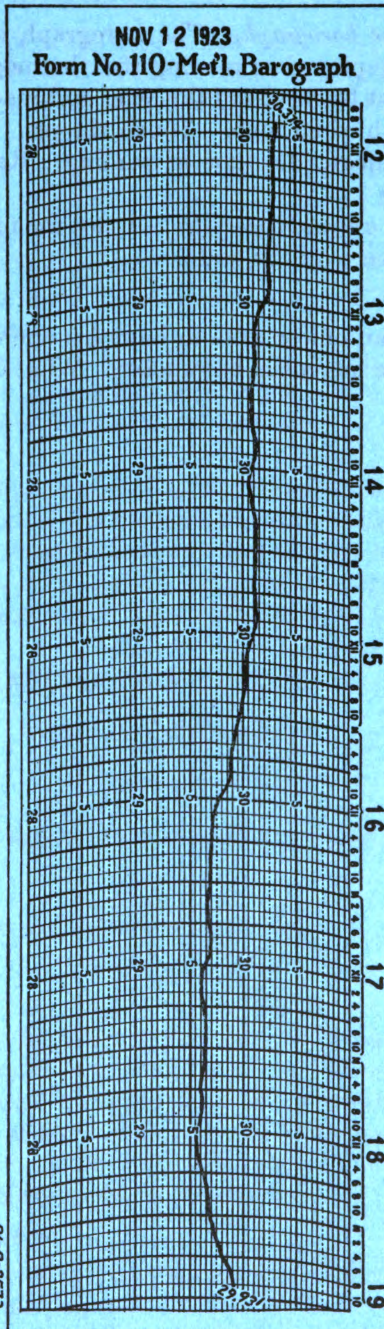

Fig. 21.—Showing record of a barograph

Directions.

18. *To read the barograph.*—The barograph is read in a manner similar to that employed in reading the thermograph. Remove the pen from the sheet by means of the lever and read the pressure to the nearest hundredth of an inch. Touch the pen, making a small vertical mark to indicate the time of reading. Return the pen to its proper position.

19. *To read the aneroid barometer.*—Read the pressure by noting the position of the pen over the scale.

Question.

(31) Suppose an officer asks to have his aneroid barometer set to the reading of the mercurial barometer. What corrections should be applied?

SUGGESTIONS FOR THE INSTRUCTOR

1. *a*. After unit operation No. 2 has been completed and all the questions in the text have been answered by each student, the instructor may give the following instruction test, or devise another one similar to it.

b. As a result of the classroom work, the student should have learned how (1) to make an observation with a mercurial barometer; (2) to read and set a barograph; (3) to read an aneroid; (4) to use Forms Nos. 79 and 80 in making necessary corrections, reductions, and interpolations; (5) how to name the important parts of the various instruments and equipment.

c. After the papers have been scored the instructor should point out in precisely what particulars each student has failed and, if the results are unsatisfactory, repeat the test after an interval of a day or two.

d. The general scope, purpose, and method of administering this test are similar to those of the instruction test for unit operation No. 1. To avoid repetition, these details are omitted here, and the instructor is referred to page 17 with the suggestion that he again read carefully paragraphs *a* to *e*, and apply this information to the following test.

INSTRUCTION TEST NO. 2

PART I.—PERFORMANCE

PROBLEM 1

READING BAROMETER AND MAKING ADJUSTMENTS

Equipment.

One standard mercurial barometer and box.

Pencil and blanks for recording.

Procedure.

Prepare in advance the above equipment, conveniently situated.

The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

Perform the following operations carefully and neatly, but at the same time as quickly as you can.

1. Open the door of the box containing the barometer and take and record as quickly and accurately as you can the reading as indicated by the barometer.

2. Leave the instrument as you found it.

3. As soon as you have completed this record, report at once to the instructor.

PROBLEM No. 2

TO MAKE ALL NECESSARY CORRECTIONS AND REDUCTIONS OF BAROMETRIC READING

Equipment.

Supply of paper.
Copies of Forms 79 and 80.
Pencil.
Record of readings just taken.

Directions to the student.

1. With Forms 79 and 80 make all necessary corrections for the reading you have just taken in problem 1.

2. Make the necessary reductions.

3. As soon as you have completed these operations report at once to the instructor.

Directions for scoring.

Problems 1 and 2.—1. *a.* If reading in problem 1 has been correctly made and recorded, credit student with ---------------- 5

b. If corrections and reductions in problem 2 have been correctly made, credit student with -------------------------- 5

2. Allow no partial score for either problem.

PART II.—INFORMATION

Equipment.

Pencils.
Mimeographed or typewritten test questions.

Procedure.

1. Furnish each student with a pencil and a copy of the test questions which are given under Part II and proceed as directed on page 23.

2. At the end of 25 minutes from the command "Begin" call "Time." See that all papers are collected and that the names of the students are properly recorded.

Directions to the student.

Below are a number of questions and unfinished statements. After each question or statement are several words, numbers, or phrases, each preceded by a *number*. Only *one* of these answers is correct. Write the *number* of the correct answer on the *dotted line* at the right of each question.

Read the following question. Note *how* it is answered.

Sample: Camp Alfred Vail is located in (1) New York; (2) New Jersey; (3) Washington; (4) Maryland. 2

Begin here:

1. The mercury in the tube of a barometer rises and falls principally because it is acted upon by (1) heat and cold; (2) pressure of air; (3) surface tension; (4) capillarity. ------

2. The door of the barometer case should be kept closed (1) when the sun shines directly on the bulb; (2) when a change in the weather seems likely; (3) except when making an observation; (4) between sunset and sunrise. ------

3. The small barometer which does not record but merely indicates by the movement of a small pointer is called (1) a barometer; (2) an asteroid; (3) an airograph; (4) an aneroid. ------

4. The curved top of the column of mercury is called the (1) tangent; (2) parallax; (3) meniscus; (4) mercury-arc. ------

5. The verniers used on barometers in the Signal Corps are designed so that 25 divisions on the vernier are equal to how many on the scale? (1) 24; (2) 25; (3) 26; (4) 24/25. ------

6. On a Signal Corps barometer a vernier division is what part of an inch smaller than a scale division? (1) 1/5; (2) 1/50; (3) 1/500; (4) 1/5000. ------

7. When reading a barometer, the attached thermometer is read to what part of a degree? (1) Nearest whole degree; (2) nearest half degree; (3) nearest tenth degree; (4) nearest hundredth degree. ------

8. A mercurial barometer is usually read to what part of an inch? (1) 0.01; (2) 0.0001; (3) 0.1; (4) 0.001. ------

9. A barograph is read to what fraction of an inch? (1) 0.0001; (2) 0.001; (3) 0.01; (4) 0.1. ------

10. A column of mercury with a cross section of 1 square inch and 30 inches high weighs about how many pounds? (1) 15.0; (2) 14.0; (3) 13.9; (4) 15.2. ------

Directions to the student.

Below are a number of sentences from which certain words or numbers have been omitted. Each word which has been omitted is indicated by a short dotted line inclosed in parentheses, thus (--------------------). Fill in each blank space with a word or a number which will make good sense and at the same time be technically correct. A word spelled with a hyphen, like armor-plate or back-fire, counts as one word.

11. The mercurial barometer consists essentially of a glass tube (....................) at the top, filled with (....................) and having its (....................) end immersed in a cistern of (....................).

12. The (....................) consists of a corrugated (....................) exhausted of (....................) to which is attached a pen that traces upon a (....................).

13. In reading a mercurial barometer, by means of the adjusting (....................) bring the level of the mercury in the (....................) up to the (....................) point and at the same time lightly (....................) the instrument.

14. After the barometer reading has been taken, it must be reduced to (....................) pressure and to (....................) (....................) pressure.

15. Certain corrections must also be applied which include corrections for scale (....................), (....................), and (....................).

16. The "sum of corrections" which includes the three mentioned above is given on Form No. (....................) which is usually found in the (....................).

17. When making a temperature correction with Form No. 80, the barometer reading will be found at the (....................) of the form and the (....................) at the (....................).

18. Add the "total correction" to the barometer reading, and the results will be the ("....................) (....................").

19. This last should be compared with the (....................) reading and should agree to within one or two (....................) of an (....................).

20. The barograph is made up of a series of little vessels (....................) or more in number, which are (....................) of air. These little vessels are about (....................) inches in (....................) and (....................) inches thick. Inside each vessel is a (....................), which is to keep it from (....................) when the (....................) is drawn out.

21. When readings of the mercurial barometer are taken they should always be compared with the (....................) readings.

22. The scales of the mercurial barometer should be dusted, but not (....................), as to do so might change the (....................) of the (....................).

23. Barometry is the science of measuring the (....................) of the (....................) with a (....................).

24. Air (....................) varies with changes in the weather, the mercurial column in general (....................) when a storm approaches and (....................) as the (....................) recedes.

25. The barometer is usually equipped with a scale about (....................) inches long, the 30-inch mark being attached to the brass tube just (....................) inches (....................) the (....................) point.

26. The height of the barometer above mean (..................) level should be ascertained as soon as the instrument is erected by means of suitable (....................) to the (....................) correct (....................) mark.

Directions for scoring Part II.

	Points
1. The maximum possible score for Part II of this test is.....	65
2. The minimum score required to pass Part II is............	50
3. *a. Recognition type questions.*—For each question correctly answered..	1
b. Completion type questions.—For each space correctly filled in	1

HYGROMETERS, READING AND RECORDING.

Equipment.

One sling (whirling) psychrometer.

One hygrograph.

A supply of record sheets for the hygrograph.

One bottle of register ink.

One small beaker or similar vessel with water at current air temperature.

A small quantity of clean muslin cloth without sizing.

One spool of stout cotton thread, about No. 16 or No. 20.

One copy of tables for dewpoint, relative humidity, absolute humidity, and vapor pressure.

Information.

Hygrometry.—Hygrometry is the science of measuring the humidity of the air. The air may be the free open air, or the air contained in any room or vessel. In the Signal Corps, the humidity of the free air is the phenomenon usually dealt with.

The factors controlling humidity are temperature, pressure, and a source of water vapor. The water vapor contained in the air is derived from the evaporation from all exposed surfaces of rivers, lakes and oceans, damp soil, and plants. This water vapor exists as a colorless gas. It has a specific gravity of about six-tenths that of air and is very unevenly distributed over the surface of the earth, being more plentiful in the vicinity of sources of moisture.

The more humid parts of the United States are the western slope of the Coast Range and the Eastern States. In the plateau region and east of the Rockies within 500 miles of the Mississippi it is very dry. This condition is due to the fact that the moist air from the Pacific Ocean, as it is borne eastward over the Rockies by the prevailing westerly winds, gives up its moisture on the western slope where it condenses and falls as rain. This leaves the air comparatively dry on the eastern slope of the Rockies and in the plateau regions.

The amount of moisture in the air is spoken of in two ways: As absolute humidity and as relative humidity. By absolute humidity is meant the actual weight of water vapor for a certain volume of air. This may be stated as so many grains per cubic foot or so many grams per cubic meter. Another method of expressing absolute humidity is by stating the amount of moisture in the air in terms of the pressure which it exerts; that is, as so many inches of mercury.

A common form of expression is to say that the air is very moist or very dry. This is not strictly correct, but the phrases are often used, even in scientific works, and one should thoroughly understand the physical condition to which reference is made. When one says that the air is very moist, the expression seems to indicate a certain attribute of the air, whereas, the amount of water vapor which exists does not depend upon the air, but upon the temperature of the surroundings. To illustrate: Take a box a cubic foot in volume, keep the box at a temperature of 60°, and place a vessel of water in the bottom of the box. Only a certain amount of the water will be evaporated, but if the temperature were raised, then somewhat more water would be evaporated. If the temperature were lowered, then some of the moisture contained in the air would condense on the sides of the box. The same thing would happen if in the beginning the box were filled with dry air instead of being vacuous space; that is, the same amount of water vapor would exist in a vacuum at 60° as in a cubic foot of air at 60°. This conception brings us to a definition of relative humidity, which is expressed in per cent. If a certain space is saturated with moisture, it is said to be saturated, or to have 100° humidity. If it contains only one-half of the saturation amount, the humidity is said to be 50°.

Questions.

(1) *What is meant by the term humidity?*

(2) *What is water vapor?*

(3) *What is a gas?*

(4) *What is specific gravity?*

(5) *If water vapor has a specific gravity which is six-tenths that of air, will it sink or float in air or just what will happen?*

(6) *Locate the following: The Coast Range; the Eastern States; the plateau region; the Rockies.*

(7) *What do the terms "absolute" and "relative" mean with regard to humidity?*

(8) a. *How many grains are there in an ounce?*

(*b*) *What is the weight in grams which is equivalent to 1 ounce?*

(9) *What is the general relationship between the temperature and the amount of water vapor in the air?*

(10) *What is the purpose in measuring the humidity?*

INSTRUMENTS TO MEASURE HUMIDITY

Humidity is measured by means of different instruments which are called by various names—the whirling psychrometer, the wet and dry bulb thermometer, and the hygrograph. The whirling psychrometer and the wet and dry bulb thermometer are the same instrument. (See fig. 3.) This instrument consists of two thermometers mounted side by side and as nearly alike in construction as possible. The bulb of the wet-bulb is wrapped in muslin, and when in an upright position it is slightly lower than the dry-bulb. The muslin, which is wrapped around the wet-bulb, must be carefully chosen so that the cloth is free from sizing and clean. In operation, the observer wets the muslin by simply dipping the thermometer in a glass of clean water which is at the temperature of the air at the time of the observation. The observer then whirls the two thermometers together, during which operation the water on the wet-bulb evaporates. As evaporation is a cooling process, the temperature of the wet-bulb will become lower than that of the dry-bulb, and the difference between the two readings is, therefore, a measure of the water vapor in the air. This may be readily seen by the fact that in very

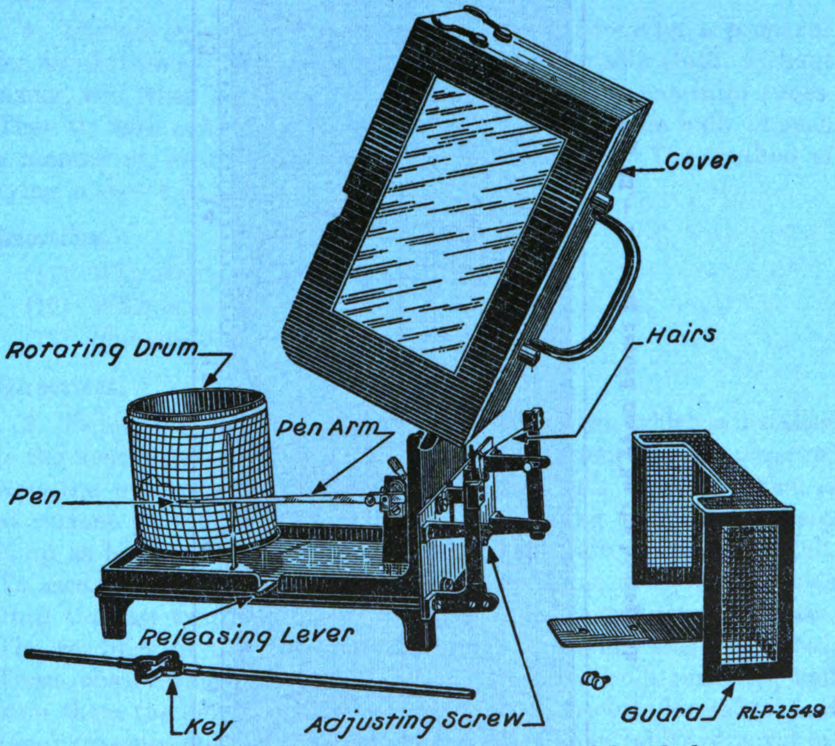

Fig. 22.—Hygrograph, cover open and guard detached

wet weather the evaporation would be slow and in dry weather very rapid. Accordingly a large difference between the wet and dry bulb readings would indicate low humidity, while a small difference would indicate a high humidity.

The reading of the dry-bulb also gives the current temperature of the air. This is always best ascertained by whirling the thermometer.

The hygrograph has the general appearance of the thermograph, and barograph, and is, as its name indicates, an instrument which makes a continuous record of the changing humidity. (See fig. 22.)

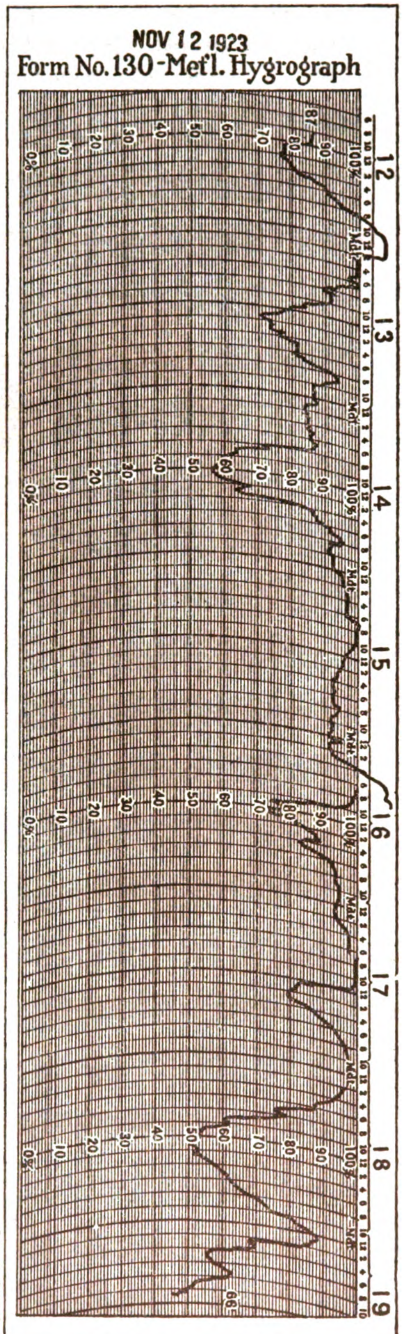

Fig. 23.—Showing record made by the hygrograph

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The hygrograph operates upon the following principle: A strand of human hair about 6 inches long is taken and its natural oil removed by immersing it in an alkaline solution. (When the hair has been deprived of its oil it will change its length as the humidity changes.) The strand of hair is then connected to a pen which is made to raise and lower by the shortening and elongating of the hair, and at the same time to write upon a revolving cylinder, thus giving a record of the relative humidity. Figure 23 shows a record made by a hygrograph.

Directions.

1. The wet bulb of the sling or whirling psychrometer is prepared for use as follows: Take a short piece of clean muslin cloth, without sizing, and wrap it around the bulb about one and one-third times. Then tie with strong thread, both above and below the bulb, in such a manner as to make it fit as snugly as possible. The method of tying is shown in Figure 3.

Questions.

(11) *Why should the muslin be without sizing?*
(12) *What is sizing?*
(13) *How can it be removed from the cloth?*

Directions.

2. To measure the humidity with this instrument, which is installed in the thermometer shelter with the other thermometers, the observer wets the wet-bulb by simply immersing the bulb in water which is at current air temperature. Commence whirling at once, and keep it up as long as the temperature of the wet-bulb continues to fall. To ascertain this point, readings should be taken every few seconds until the last two readings of the wet-bulb thermometer are alike. The readings of the dry-bulb thermometer should then be noted. These observations are called the wet and dry bulb readings, and from them the dew point, relative humidity, absolute humidity, and vapor pressure may be obtained from Smithsonian tables or psychrometric tables.

Questions.

(14) *What is the reason for wetting the bulb of the wet-bulb thermometer?*
(15) *What would be the effect of wetting with alcohol instead of water?*
(16) *Why should the psychrometer be whirled? Why not hold it still?*
(17) *What is the simplest way to provide a supply of water at current air temperature?*

(18) *What is the meaning of each of the following terms?*
a. Dewpoint.
b. Relative humidity.
c. Absolute humidity.
d. Vapor pressure.

Directions.

Hygrograph—To set the instrument.—3. As was explained above, the pen is connected by a series of linkages to a bundle of hairs which are hygroscopic, and as the humidity rises and falls the pen rises and falls. The humidity thus recorded is relative humidity in per cent. To set the hygrograph, make a reading with the whirling psychrometer and adjust the pen of the instrument to correspond. (See fig. 3.)

Questions.

(19) *What is meant by the term hygroscopic?*
(20) *What is the purpose of the bundle of hairs in the hygrograph?*
(21) *Could anything else be substituted for the bundle of hairs?*

Directions.

To change the sheet.—4. The sheet on the hygrograph should be changed in a similar manner to that of the thermograph and barograph. The operations are as follows:

a. Take a humidity reading by the sling or whirling psychrometer and determine from the tables the relative humidity.

b. Remove the sheet and write at the end of the trace the relative humidity just determined.

c. Put on a new sheet, having previously dated it, wind up the clock and set the pen for time and humidity.

d. Ink the pen.

e. Before leaving the instrument be sure that the clock is going, and that the pen is marking and has proper contact with the sheet.

Information.

Exposure of instruments.—All the instruments used to measure humidity of free air should be exposed in the instrument shelter which contains the thermometer. Good readings may be obtained, however, by means of a hand whirling psychrometer when the observation is made in the shade.

Questions.

(22) *When is the humidity highest or lowest, morning or afternoon?*
(23) *Is the humidity high or low in an ice box?*
(24) *How should instruments to measure humidity be exposed in battle conditions when no instrument shelter is available?*
(25) *Are there any checks which may be used to test the correctness of observation?*

SUGGESTIONS FOR THE INSTRUCTOR

1. *a.* After unit operation No. 3 has been completed and all the questions in the text have been answered by each student, the instructor may give the following instruction test, or devise another one similar to it.

b. As a result of the classroom work, the student should have learned how (1) to measure humidity by means of the psychrometer; (2) to make the necessary use of psychrometric tables; (3) to read and set the hygrograph; (4) how to name the important parts of the various instruments and equipment.

c. As with Instruction Tests Nos. 1 and 2, the instructor should point out in precisely what particulars each student has failed; and if the results are unsatisfactory, repeat the test after an interval of a day or two.

d. For further directions the instructor should refer back to page 11, paragraphs *a* to *e*.

INSTRUCTION TEST NO. 3

PART I.—PERFORMANCE

PROBLEM No. 1

PREPARATION OF PSYCHROMETER FOR USE

Equipment.

One psychrometer with wet-bulb stripped of muslin wrapping.
One piece of thread.
One piece of new muslin.
One beaker of water at current temperature.

Procedure.

The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem in Part I of the test. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

1. Prepare the wet-bulb of this psychrometer for immediate use.
2. As soon as you have completed this operation report at once to the instructor.

PROBLEM No. 2

DETERMINE DEW POINT, HUMIDITY, AND VAPOR PRESSURE

Equipment.

One standard thermometer shelter equipped with sling psychrometer.

Writing paper.
Small table.
Copy of Smithsonian tables.
Pencil and blanks for recording.

Directions to the student.

1. Open the door of the shelter, take and record, as quickly as you can, the temperature as indicated by the wet and dry bulb thermometers.
2. Replace the instruments as you found them.
3. By means of psychrometric tables, obtain the following:
   a. Dew point.
   b. Relative humidity.
   c. Absolute humidity.
   d. Vapor pressure.
4. As soon as you have completed these operations report at once to the instructor.

Directions for scoring problems 1 and 2.

1. *a.* If psychrometer has been properly wrapped with muslin and properly immersed in the beaker of water, as prescribed in problem No. 1, credit student with five points.

b. For correct reading of the thermometers, and correct determination of *a*, *b*, *c*, *d*, as prescribed in problem No. 2, credit student with five points.

2. Allow no partial score for separate problems.

PART II.—INFORMATION

Equipment.

Pencils.
Mimeographed or typewritten test questions.

Procedure.

1. Furnish each student with a pencil and copy of the test questions which are listed under Part II, and proceed as directed on page 18.
2. At the end of 15 minutes from the command "Begin," call "Time." See that all papers are collected and that the names of the students are properly recorded.

Directions to the student.

Each of the following questions can be answered by a single word, phrase, or number. Write the answer on the short dotted line.

Sample: Zero on the Fahrenheit scale is how many degrees below the freezing point of water? 32

1. What is the science of measuring the humidity of the air called?

....

2. In the Signal Corps the humidity of what sort of air is usually measured? ....

3. What third factor controls humidity in addition to a source of water vapor and temperature? ....

4. What color is the gas known as water vapor?

....

5. As compared with air, what is the proportionate density of water vapor? ....

6. Absolute humidity is expessed by stating the weight of water vapor in what units per cubic meter? ....

7. When a certain space is saturated with moisture it is said to have what per cent humidity? ....

8. What is another name frequently applied to the combination of a wet with a dry bulb thermometer? ....

9. In taking an observation with the wet-bulb, with what should the temperature of the water with which the muslin is wet correspond?

....

10. What is the name of the instrument which makes a continuous record of the relative humidity? ....

11. What is the substance or material which forms an essential part of this instrument and which makes the pen raise or lower?

....

12. What term is applied to the humidity when its amount is compared with saturated air as a standard? ....

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and if what it says is *true* make a plus sign (+) on the line to the right. If what it says is *not true* put a minus sign (−) on the line to the right of the statement.

13. The more humid parts of the United States are the eastern slope of the Coast Range and a belt about 100 miles wide in the plateau region. ......

14. By absolute humidity is meant the actual volume of water vapor for a certain volume of air. ......

15. Absolute humidity may be expressed by giving the amount of moisture in the air in terms of the pressure which it exerts. ......

16. The muslin wrapping of the wet-bulb should be carefully changed before every observation. ......

17. The reading of the dry-bulb gives the current temperature of the air. ......

18. In taking the temperature with the wet-bulb, the instrument should be whirled until the mercury ceases to fall. ......

19. The sensitivity of the hydrograph depends upon the hygroscopic character of an important part of the mechanism. ------

20. The reading recorded by the hydrograph is absolute humidity in per cent. ------

21. There is an essential difference between the record sheet of the hydrograph and that of the thermograph and barograph; namely, that it is changed every 24 hours. ------

22. In measuring humidity by means of whirling the wet and dry bulbs, the instrument should be whirled while the observer stands in the shade. ------

Directions for scoring Part II.

1. The maximum possible score for Part II of this test is 22 points.
2. The minimum score required to pass Part II is 15 points.
3. *a. Single-word questions.*—Allow 1 point for each question correctly answered.

b. True-false (plus-or-minus) questions.—Score as directed on page 22.

WIND VANE, ANEMOMETERS, SUNSHINE RECORDER, AND QUADRUPLE REGISTER

Equipment.

One wind vane, flared tail type.

One trench vane.

One quadruple register with suitable electrical connection and source of current.

One sunshine recorder.

One Dines pressure tube anemometer (anemo-biagraph) with direction recorder attachment.

One Robinson cup anemometer.

One wind velocity scale.

One hand anemometer, preferably with attached stop watch.

One bottle of register ink.

A supply of quadruple register sheets and other recording sheets for the different instruments.

Information.

Wind.—Air in motion near the earth's surface and parallel with it is called wind. The atmosphere has an altitude of several miles and is always in motion. These motions are in every conceivable direction, but only those motions having a horizontal direction are known as wind. Motions in a vertical direction are generally known as air currents. Measurements of wind are of three kinds, direction, velocity, and force or pressure; but in the Signal Corps only the direction and velocity of the horizontal motions are measured.

The phenomenon of wind has important bearings on military operations, the more important of which are: Gas warfare, the direction and control of artillery fire, and aviation.

Questions.

(1) *Why is it important to measure the wind?*

(2) *Are there other causes of wind in addition to that mentioned above?*

(3) *Specify, in as much detail as possible, how the phenomenon of the wind affects military operations.*

(4) *Does the same phenomenon affect the activities of civil life?*

Information.

There are two elements of wind to be measured: Direction and velocity. The instrument which measures direction is called a wind vane or anemoscope; and that which measures velocity, an anemometer.

Direction of wind.—The direction of the wind is generally measured by means of a wind vane. A wind vane is familiar to everyone, but those used in the Signal Corps are of a slightly different type from those in common use. This point of difference is found in the construction of the tail of the vane, which may be described as a flared tail. See figure 24, which shows one view of a wind vane as the observer sees it when looking at its side, and another view as he looks down upon it from directly above. A wind vane of this construction is more sensitive than a wind vane with a straight tail, as the flared tail enables a very light wind to turn the vane, thus indicating the true wind direction. Wind vanes are ordinarily extremely light. If they are too heavy, a change of wind direction will, on account of the momentum of the vane, tend to swing the instrument beyond the point of equilibrium and thus too much oscillation will result. The vane should be balanced perfectly, and the bearings should be as near frictionless as practicable.

A trench vane is shown in figure 25. This type is used in all situations where its inconspicuous design makes it particularly valuable.

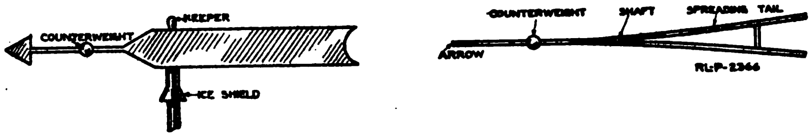

Fig. 24.—Side elevation and plan of wind vane

While the wind vane is the common instrument in use to measure the wind direction, many other devices can be used in time of emergency, such as streamers, flags, smoke, and dust thrown in the air. A fair measurement may be made by wetting one's finger and then holding it up and noting which side is cooled the most. The cooler side will be the direction from which the wind is blowing.

The direction of the wind is denoted in the same way by the meteorological observer as by the layman; that is, the direction of the wind is named according to the direction *from* which it comes. Thus wind blowing from the north is a north wind; wind blowing from the east is an east wind, etc. It should be noted that the wind vane points into the wind; that is, it points to the direction from which the wind is blowing. On weather maps and charts the direction of the wind is indicated also by arrows, but in this case these are drawn to fly *with* the wind; that is, they point in the direction to which the wind is blowing. This distinction is important and should be carefully noted.

The wind vane will show direction in two ways: First, by simply indicating it to the observer; second, by making a record upon some kind of recording apparatus. When a quadruple register is used the wind vane is in electrical connection with it. Figure 26 shows a quadruple register with a revolving drum and the pen arms. The four pen arms mark the wind direction, and the instrument is so arranged that the direction of the wind is recorded every minute. If the wind were blowing from the north the north pen arm would

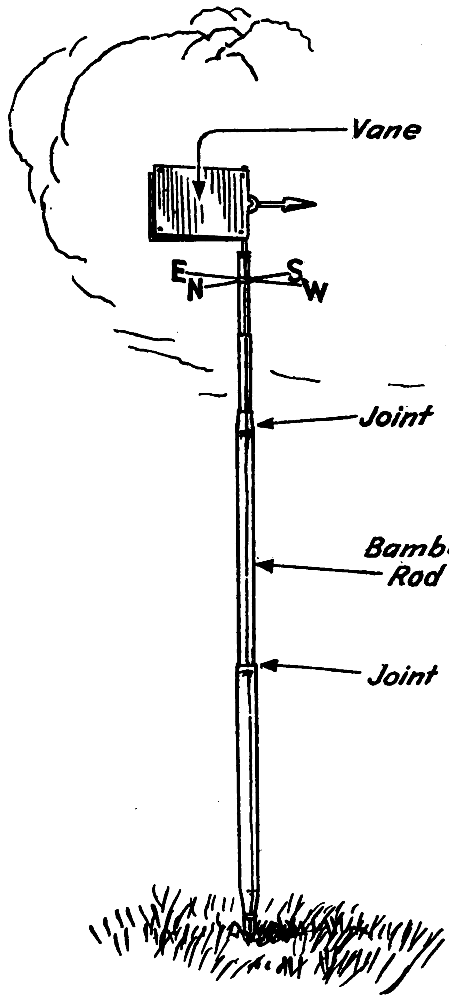

Fig. 25.—Trench wind vane

record; if blowing from the east, the east pen would record, and so on. But if the wind were blowing from the northeast, both the north and east pens would record at the same time. Thus the instrument will leave a record of two dots for the semicardinal points and a record of one dot for the cardinal points. Such a record is shown in Figure 27, which represents a part of a record taken from the quadruple register. The vertical lines are five minutes apart; that is to say, it takes five minutes for the length of the sheet between the two vertical lines to pass beneath the pens. Therefore, if the direction arms make a record every minute there will be five dots within a five-minute space.

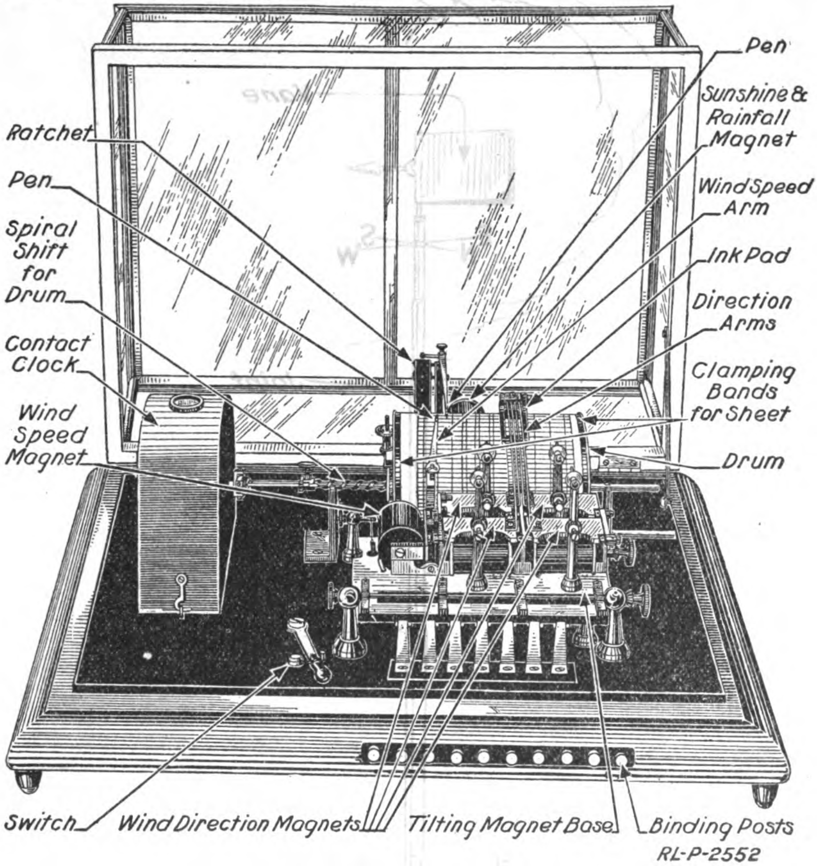

Fig. 26.—Quadruple register

Questions.

(5) *Explain the following terms:*

Momentum.

Oscillation.

Friction.

(6) *Name and explain any methods, besides those mentioned in the text, which could be used in obtaining wind directions without a wind vane.*

(7) *Would the direction of clouds give the direction of the wind at the surface?*

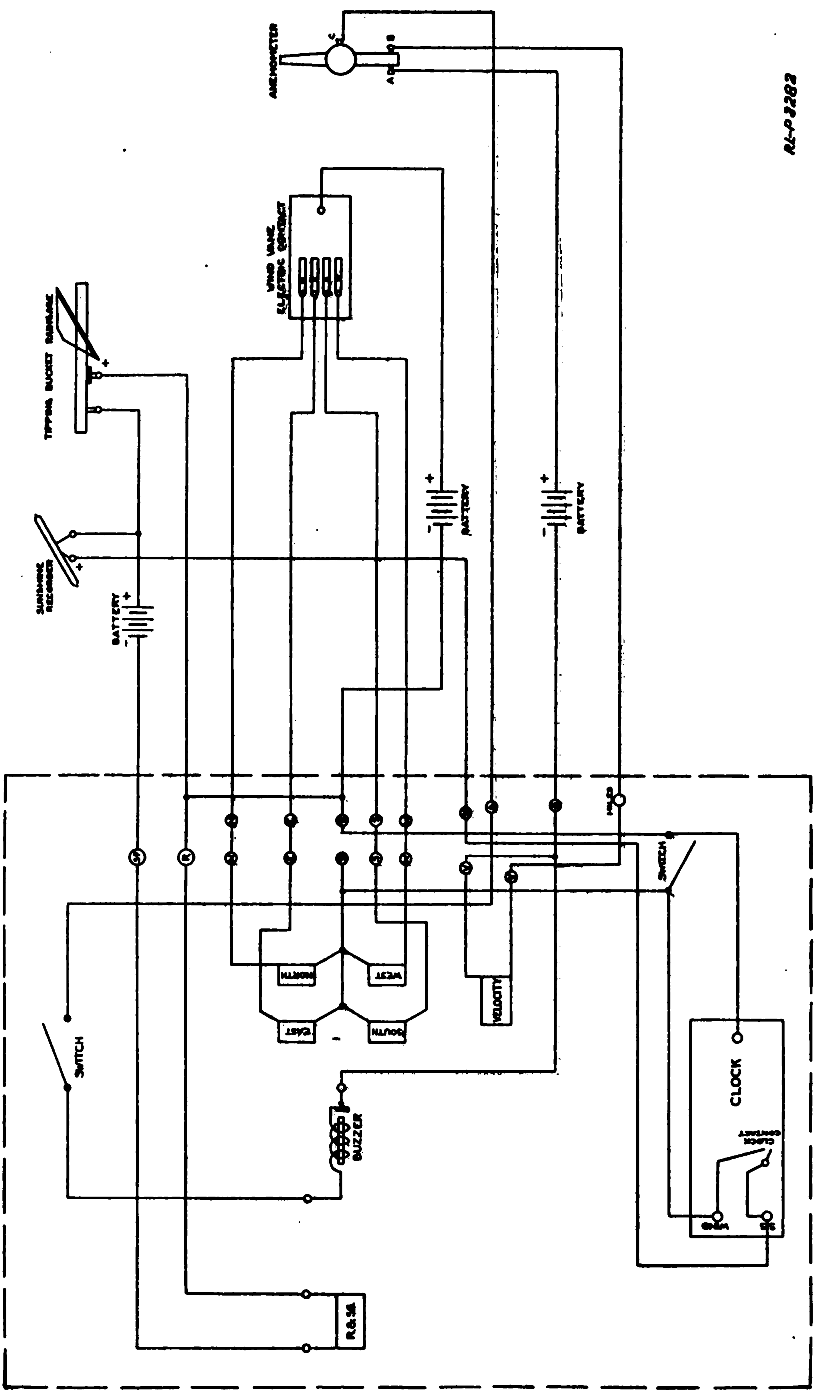

Fig. 26, A.—Wiring diagram of quadruple register

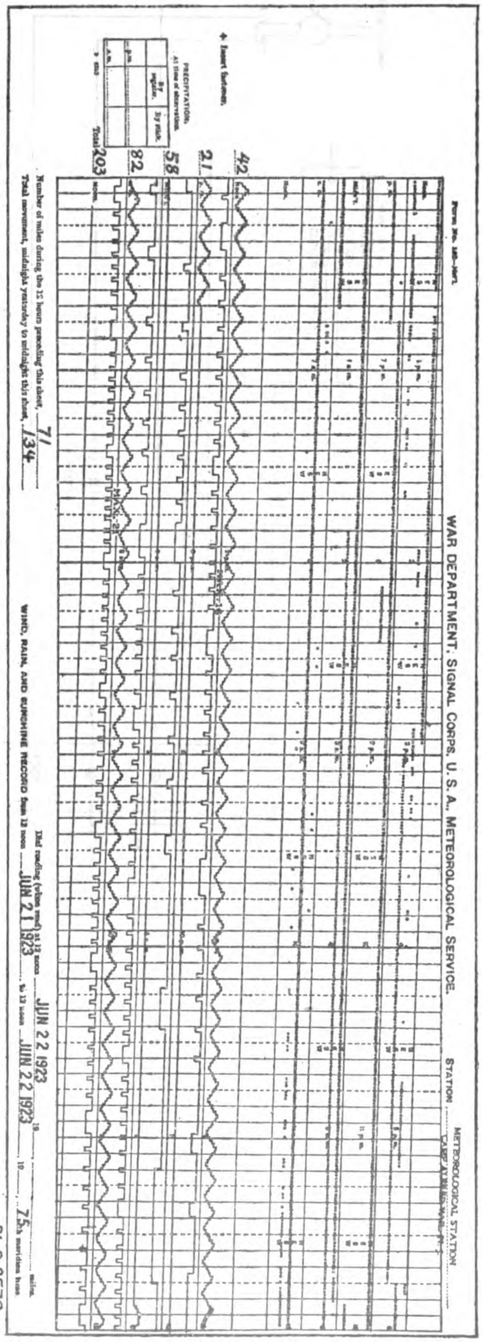

Fig. 27.—Record from quadruple register, Form 102

(8) *Explain why the wind vane points into the wind?*
(9) a. *What are the cardinal points?*
b. *The semicardinal points?*
(10) *In setting up a wind vane, how would these points be determined?*
(11) *How should the observer decide where to set up his wind vane?*

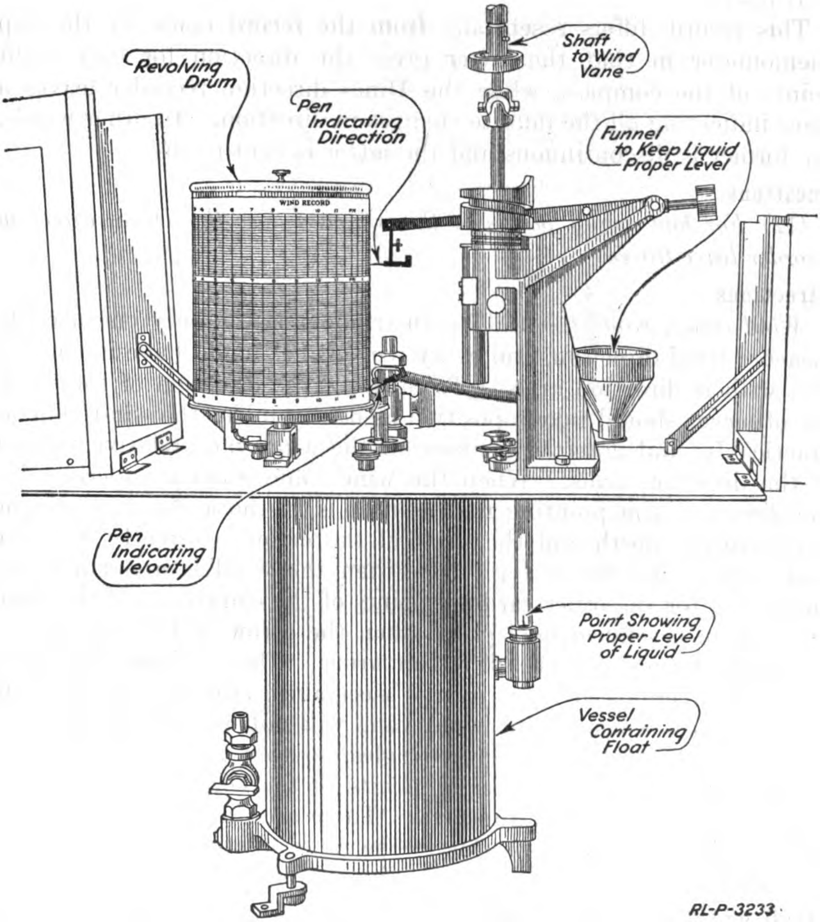

Fig. 28.—Dines anemo-biagraph or pressure tube anemometer

Information.

Another recording device for registering the wind direction is the direction recorder attached to the Dines pressure tube anemometer. In this device the shaft of the wind vane extends downward through the roof into the room containing the direction recorder to which it is directly connected.

This recorder (see fig. 28) consists of a drum driven by a clock. On the drum is a sheet upon which the record is made by a pen. The pen is carried on a pivoted lever having a roller engaging with the cam surface of a spiral groove. This groove is made in a cylinder which is rotated by the wind vane; and the rotation of the cylinder causes the pen to be raised or lowered, thus indicating the direction. See figure 29, which shows a record of wind direction made by this instrument.

This record differs essentially from the record made by the cup anemometer in that the latter gives the direction for only eight points of the compass, while the Dines direction recorder leaves a trace indicating all the infinite changes in direction. In other words, the former is discontinuous and the latter is continuous.

Questions.

(12) *For how many points of the compass does the Dines direction recorder leave traces?*

Directions.

Wind vanes, reading.—1. This instrument is the only one used to measure wind direction, and every wind vane should have in connection with it direction arms. To measure the direction of the wind, the observer should take a position as nearly under the wind vane as practicable, and note the position of the wind vane relative to that of the direction arms. When the wind vane exactly superimposes the direction arm pointing north—that is, if the arrow of the vane points to the north and the shaft of the arrow is directly over the shaft supporting the letter "N"—then the wind is a north wind; and so on, for the other cardinal points of the compass. If the wind blows from a semicardinal point, then the arrow will exactly bisect the angle formed by the direction arms. The cardinal and semicardinal directions are thus easily ascertained, but the chances are that on most occasions the wind vane will not exactly superimpose the direction arm or bisect the angles, so that the observers must estimate which one of the eight points of the compass most nearly represents the true wind direction. There are times when the direction is difficult to measure, due to the rapid fluctuation of the wind. At such a time, the mean of the various directions observed must be taken as the true wind direction. The observer must always remember that the wind vane points into the wind; that is to say, points the way from which the wind is blowing.

Question.

(13) *Explain the following expressions:*

a. The wind vane superimposes the direction arm.

b. Bisect the angle.

c. Rapid fluctuations of the wind.

d. The mean of the various directions observed.

e. Cardinal and semicardinal points.

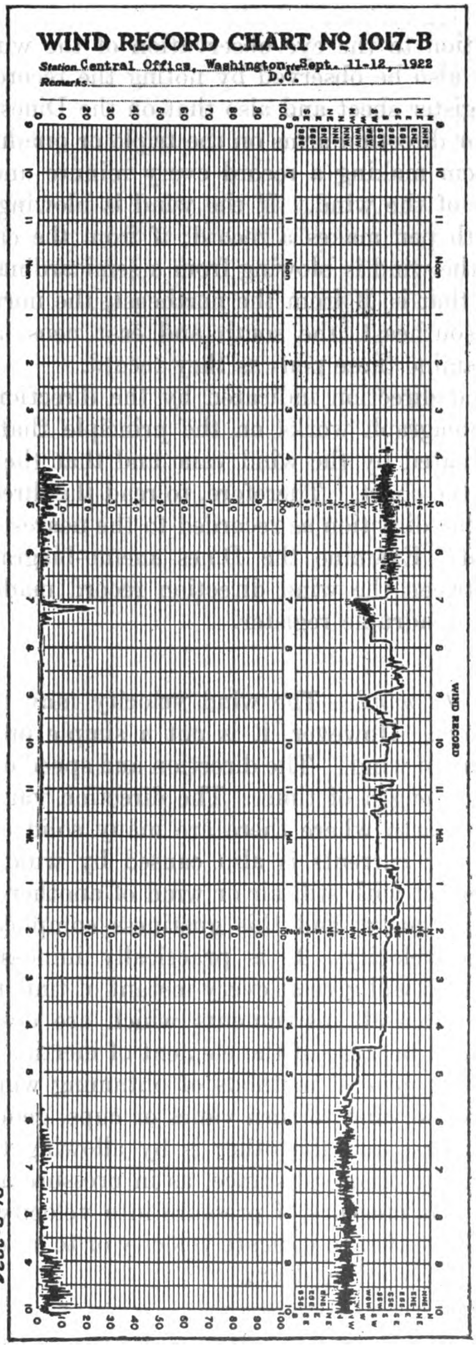

Fig. 29.—Record from Dines anemo-biagraph

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Directions.

2. In addition to the eye observation of the wind direction, this element may also be observed by noting the record on the triple or quadruple register sheet and also that on the Dines anemo-biagraph. There are four direction arms on the triple or quadruple register, one or two of them making a record every minute and thus indicating the direction of the wind. If the wind is blowing from the north, then the north pen makes a record; if from the east, the east pen, etc. But if the wind is blowing from a semicardinal point, then two pens record; that is, if from the northeast, the north and east pens; if from the southeast, the south and east pens, and so on. (See fig. 30.) Examine these pens as they record.

3. The wind direction indicated by the direction recorder of the Dines anemobiagraph works on the principle that the pen is continuously actuated by the wind vane and that the pen is always in contact with the chart. Therefore, to read the direction simply note on the sheet the direction as recorded to the nearest cardinal or semicardinal point. Examine the Dines anemo-biagraph and note the difference between the wind direction record made by it and that made by the quadruple register.

Information.

Velocity of the wind.—The wind velocity may be measured in a variety of ways. However, it is not a simple problem because of the very nature of wind. The direction and speed of wind are seldom steady for any length of time. The direction varies greatly at the surface of the earth where there are many solid deflecting objects. Deflection of air currents is also caused by wind of one direction coming in contact with still air or wind of another direction. Wind is more or less gusty, and this gustiness complicates the problem of finding the velocity. It is practically impossible to make an instrument which will give at every instant of time the exact velocity of the wind, since all instruments which are designed to do this defeat the object because of the element of inertia.

There are two general methods of obtaining wind velocity. One is by allowing the wind to turn vanes or cups, generally called rotation anemometers; and the other is by allowing the wind to blow against a plate or other substance, as in pressure anemometers, and transforming this measure of pressure into velocity. These anemometers are made either to indicate velocity or to actuate a pen writing a record upon a recording drum.

Questions.

(14) *Explain the following expressions:*

a. Deflecting objects

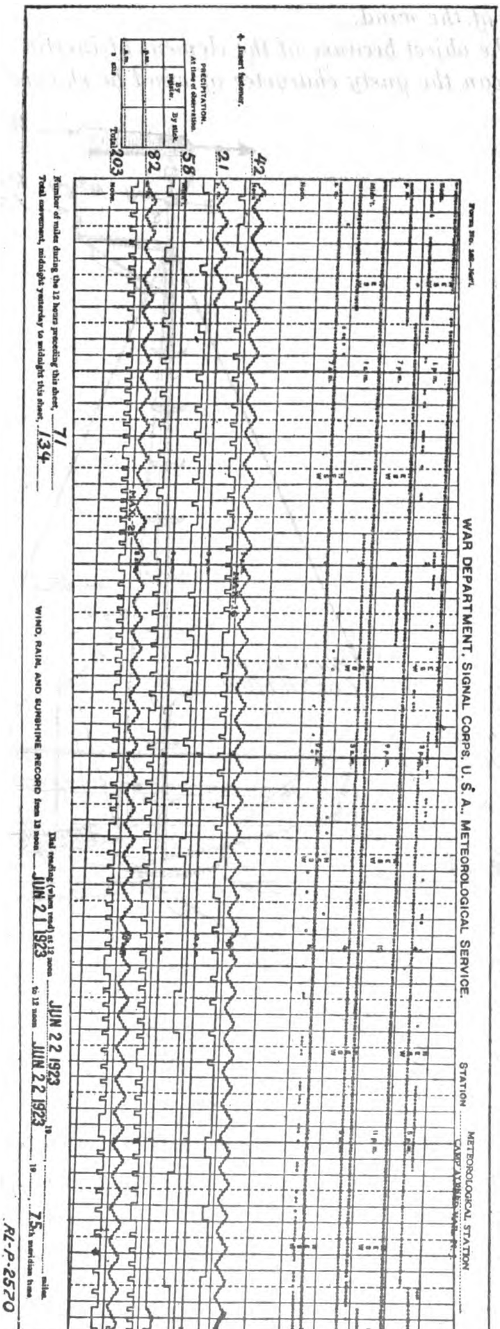

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Fig. 30.—Showing a portion of Form 102—Met'l record of wind direction.

b. Gustiness of the wind.
c. Velocity of the wind.
d. Defeat the object because of the element of inertia.

(15) *How can the gusty character of wind be shown?*

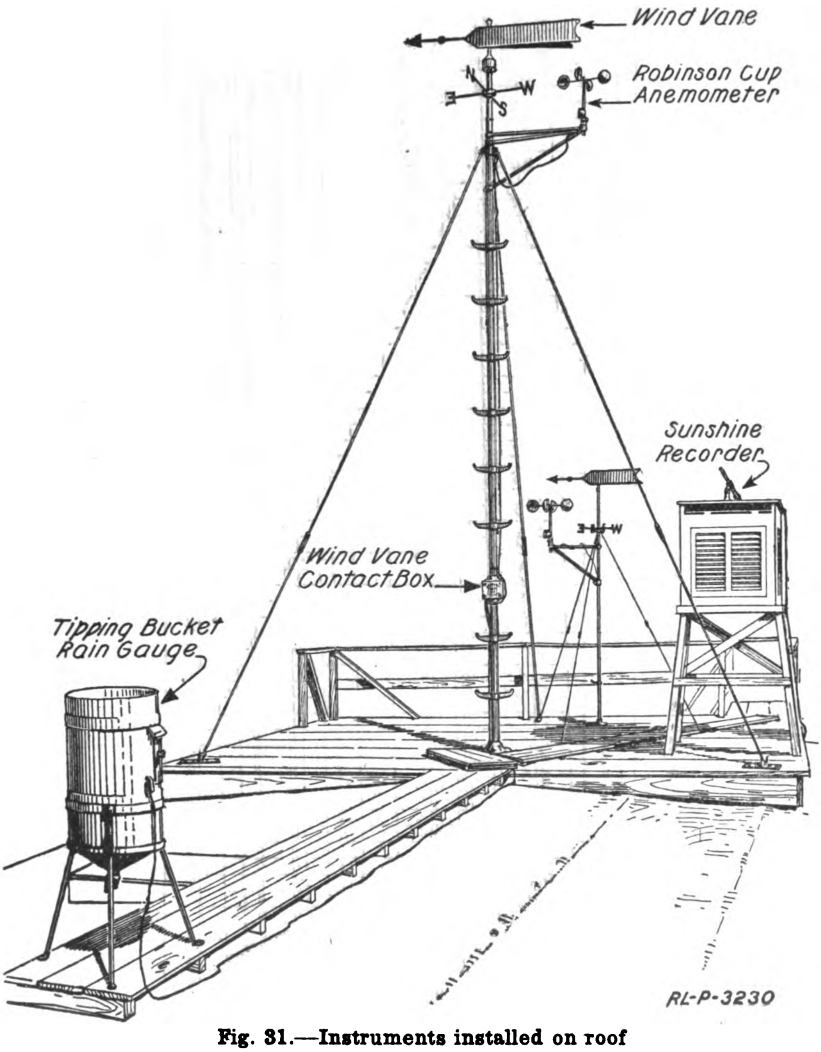

Fig. 31.—Instruments installed on roof

(16) *What effect would an obstacle have on the direction and velocity of wind?*

(17) *How can wind velocity be estimated without an instrument?*

Information.

The Robinson cup anemometer is the type of rotation anemometer used. (See fig. 31 and fig. 32.) The cups rotate on a vertical axis, and the shaft upon which the cups revolve is geared by a system of toothed wheels to two dial wheels superimposed, one upon the other. The upper one has 100 teeth and the lower one 99 teeth, both being actuated by one gear. Therefore, when the upper one has made one complete revolution, the lower one has gone one tooth farther. The gearing is so designed that when 10 miles of wind has passed the station, one dial moves one scale division in reference to the other. The velocity of the wind may be read in three ways when using the Robinson cup anemometer.

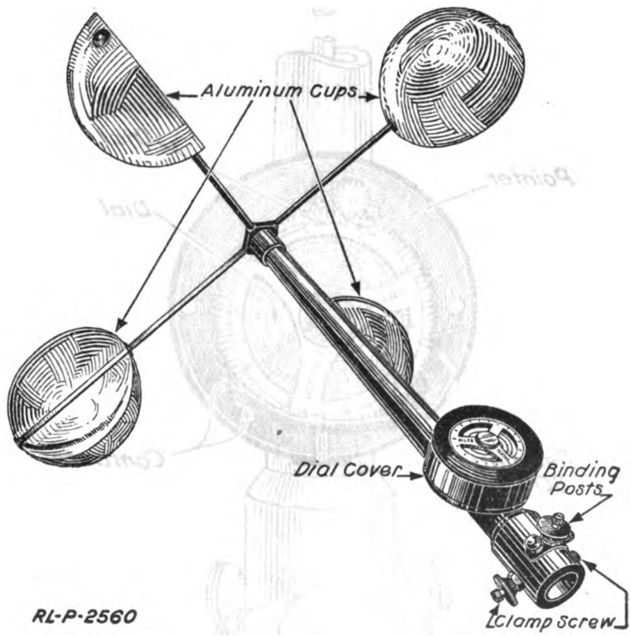

Fig. 32.—Anemometer

a. Take a reading of the dials at a certain instant, and then after an interval of five minutes has elapsed read the dials again. Subtract the first value from the second, multiply by 12, and the result will be miles per hour. To read the dials, first read the hundreds and tens from the lower dials and the units and tenths from the upper dial. (See fig. 33.) The total of the dial readings is 803.3.

b. One of the gears in the anemometer is made with six contacts. These contacts are connected to a buzzer and a source of current, and in the circuit is a push button. When the button is pushed, a complete circuit will be made, and consequently a buzz will occur every time the gear above referred to makes a contact. The number of buzzes in one minute gives the velocity of the wind in miles per hour.

c. The upper dial has ten pins set in its outer edge. These pins pass a spring which is depressed every time a mile of wind passes

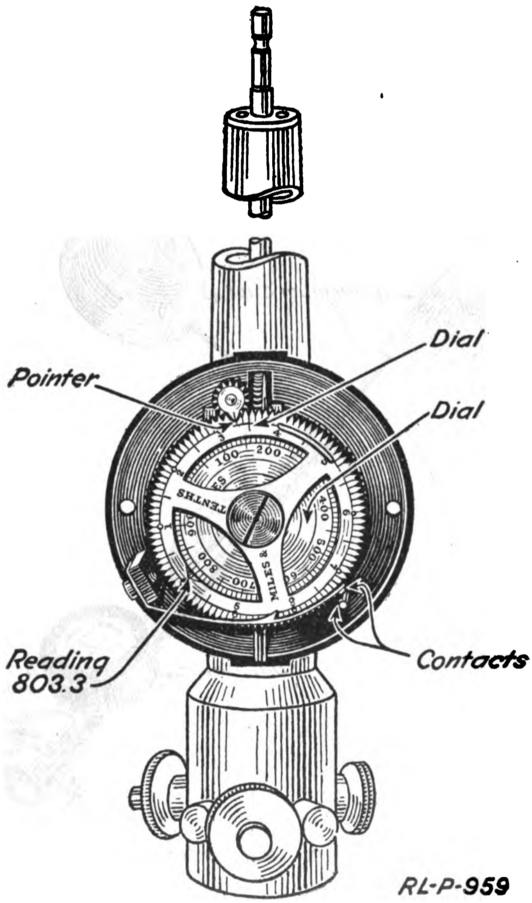

Fig. 33.—Portion of anemometer showing dial

the station and causes the pins to make an electrical contact that closes a circuit in the quadruple register. Thus a pen is act ated which traces a record of the wind velocity. This record is shown in Figure 34, which is a portion of Form 102, used on the quadruple register. The vertical lines are five minutes apart, and the record, marked "VV," is the record of velocity. In general, the time that is consumed while a particular mile of wind passes the station is the time from "make to make" or from "open to open." Two pins are connected, the ninth and tenth pins. This means that the circuit will be closed during the period from the time of closing the contact at the ninth mile and the opening of the contact at the tenth mile. This arrangement makes it very convenient in counting up the number of miles in a six-hour period. Examine the register and note carefully how these contacts are made.

Questions.

(18) *Explain the following expressions:*

a. Vertical axis.

b. Geared by a system of toothed wheels.

c. One complete revolution.

d. These contacts are connected to a buzzer and a source of current, and in the circuit is a push button.

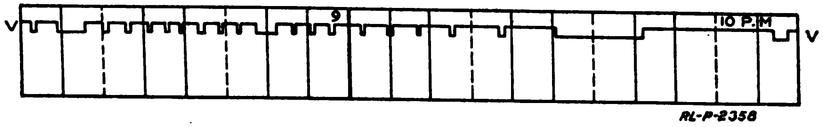

Fig. 34.—Portion of wind velocity record, Form 102—Met'l.

e. "Make to make."

f. "Open to open."

(19) *Does the Robinson cup anemometer exhibit the gusty character of wind?*

Directions.

Anemometer.—4. The anemometer which is connected up with the quadruple register is the Robinson anemometer, and the velocity of the wind by this instrument may be read in three ways:

a. The anemometer is connected up with a push button and buzzer. Push the button, holding it depressed for a minute, and count the number of buzzes which occur in that length of time. This number will be the velocity of the wind in miles per hour.

b. By using the quadruple register, this anemometer is also connected so that a record of velocity is recorded upon the quadruple register sheet. The record is similar to the one in Figure 35. The velocity of the wind is taken as the average velocity for the last five minutes. Measure the number of miles and parts of a mile during the last five-minute period and multiply the result by 12. This will be the velocity of the wind. If it has taken five minutes for 1 mile, then it is evident that the velocity of the wind is 12 miles per hour. If it takes more than five minutes for a single mile to be recorded, then the observer must place the minute scale upon the sheet

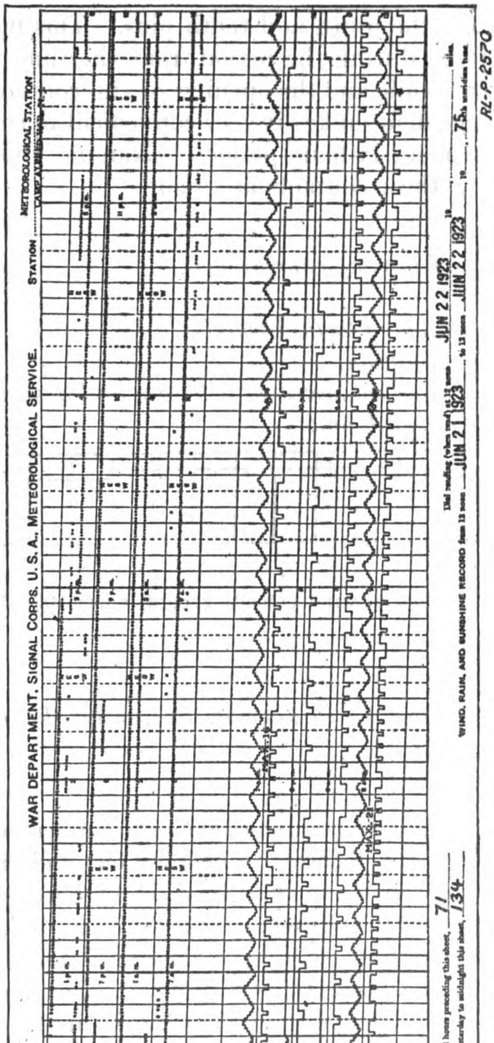

Fig. 35.—Showing record of wind velocity

to find exactly how many minutes and parts of a minute it has taken for the last mile to run. Divide this figure into 60 and the result will be velocity in miles per hour. Figure 36 illustrates a wind velocity scale. The minute scale is at the end, and is used to ascertain the number of minutes consumed during the running of any certain mile of wind. The larger part of the scale may be used in determining velocities of wind of more than or less than 12 miles per hour. This scale was devised by the United States Weather Bureau.

c. The velocity may also be ascertained thus: Read the dial to miles and tenths twice, the readings being taken five minutes apart. Subtract the first dial reading from the second, and multiply the remainder by 12. The result will be the velocity in miles per hour.

5. To obtain the velocity from Dines anemo-biagraph. This instrument records, as accurately as practicable, the instantaneous

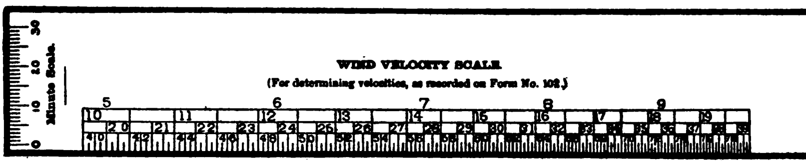

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Fig. 36.—Wind velocity scale

velocity of the wind in miles per hour, and the observer simply reads the velocity to the nearest whole mile, as indicated on the sheet.

In the case of the quadruple register, or Dines anemo-biagraph, it is possible to go back to any particular time and ascertain the velocity of the wind at that time, if desired.

Question.

(20) *Suppose that the Dines anemo-biagraph indicates the following wind velocities. If the observer simply reads the velocities to the nearest whole mile, how should each of these be read?*

a. 0.4 miles per hour.
b. 0.5 miles per hour.
c. 0.6 miles per hour.
d. 1.4 miles per hour.
e. 1.5 miles per hour.
f. 1.6 miles per hour.

Information.

Portable or hand anemometer, description.—This instrument consists essentially of the following parts:

a. A pin wheel of the horizontal axis type.

b. A revolution counter, geared in and calibrated to read in meters of air passed.

c. A stop watch.

These three parts are assembled in a single apparatus of such a size, shape, and weight as to make it portable and convenient for operation with one hand. (See fig. 37.)

The pin wheel is mounted on adjustable pivot bearings and encircled by a heavy metal band for protecting the paddles of the rotating element. One end of the shaft is a worm which transmits the motion of the rotating element, through a tangential gear and shaft, to the revolution counter on the lower end of handpiece.

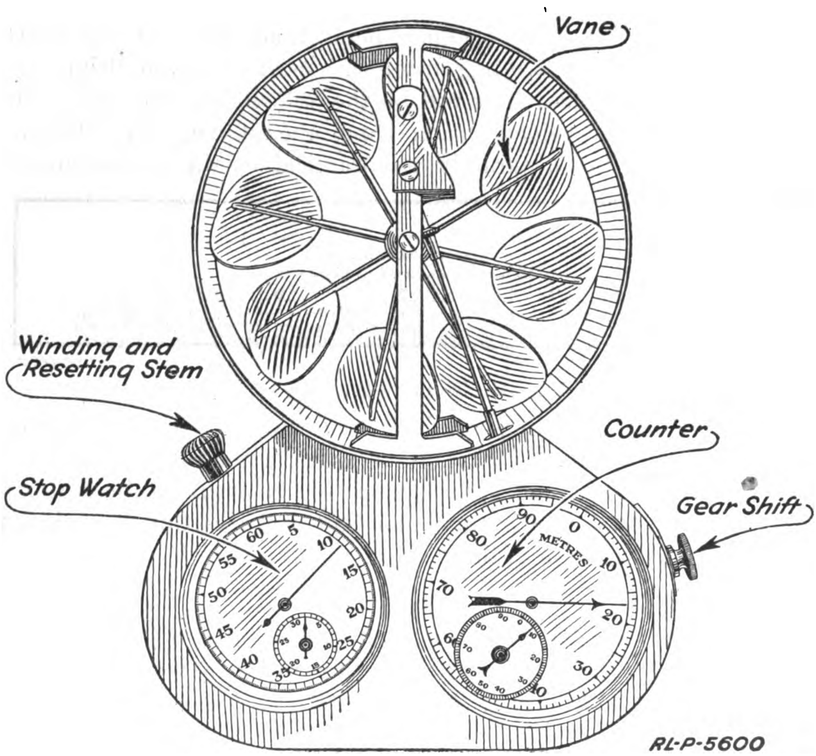

Fig. 37.—Hand anemometer

The revolution counter has two hands—the longer making 1 revolution per 100 meters; the shorter making 1 revolution to 100 of the longer. Mounted on the periphery of the counters is a knurled button for disengaging the shaft from the counter mechanism. In the back cover is a small hole through which a socket key may be inserted for resetting the counter to zero. This, however, can only be accomplished when the knurled button is moved to the position marked A.

In practice, to set the hands indicating meters, push the knurled button to A, then insert the key, and bring both hands approximately to zero. Push the button back to M, withdraw the key, and bring the hands to the exact zero mark by blowing against either side of the pin wheel to produce the desired result.

On the hand piece to the left of the counter and below the wind gauge is a stop watch. Projecting from the side of the stop watch is a small lever for starting and stopping the watch. Resetting is accomplished in the usual way by pressing the winding stem.

Pivoted on the wind gauge is a thumb piece, the upper extremity of which supports the shaft carrying the tangential gear; the lower extremity engages the stop watch lever. Pressing the thumb to the right, engages the tangential gear with the worm on the wind gauge, thus establishing a connection with the counter. At the same time the stop watch is started. Pressing the thumb piece to the left disengages the tangential gear and stops the watch.

Some hand anemometers do not have a watch attached, in which case it is necessary to use a separate stop watch when making observations with the instrument.

Questions.

(21) *Explain the following expressions:*

a. A pin wheel of the horizontal axis type.

b. A revolution counter, geared and calibrated to read in meters.

c. A stop watch.

d. Adjustable pivot bearings.

e. Worm (shaft or gear).

f. Tangential gear.

g. Periphery of the counters.

h. Knurled button.

Directions.

6. *Hand anemometer.*—To measure wind velocity by the hand anemometer, proceed as follows:

a. By means of the lever throw the vanes out of gear with the meter (and with the stop watch, if there is one).

b. Press the stem of the stop watch, bringing the hands to zero.

c. By means of the key, set the hands of the meter.

d. After the above have been completed and the anemometer has been placed so that its axis of rotation is parallel to the direction of the wind, throw the lever which allows the vanes to operate the meter and at the same time start the watch.

e. At the end of a minute read the meter and reduce the results to miles per hour. Meters per minute multiplied by 0.037 equals miles per hour.

NOTE.—If the anemometer does not have a stop watch attached, a separate stop watch must be used in connection with the instrument.

Questions.

(22) *a. How many feet equal 1 meter?*

b. How many meters equal 1 mile?

(23) *About what is the velocity, in miles per hour, of each of the following winds?*

a. Breeze.

b. Wind.

c. Storm.

d. Gale.

e. Hurricane.

(24) *If the terms used in question 23 are too vague or indefinite; suggest better phrases of description.*

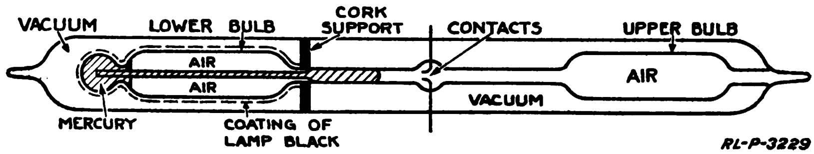

Fig. 37, A.—Longitudinal cross section of sunshine recorder

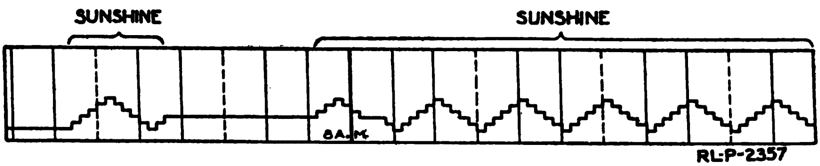

Fig. 37, B.—Sunshine record

Information.

Sunshine recorder.—The sunshine recorder consists of a glass tube in which are two bulbs at either end, connected by a smaller glass tube, which extends down into a black bulb. This is shown by longitudinal cross-section drawing, Figure 37, A. There is a small amount of mercury in the black bulb, and the two bulbs are partially exhausted of air. The space between the inner bulbs and the outer tube is exhausted of air. The operation of this instrument is as follows:

When the sun appears, either in the morning or from behind a cloud, the sunshine striking upon the black bulb heats it up by reason of the fact that the lampblack coating is a good absorber of heat. The air in the black bulb expands, forcing the mercury up the tube and closing the contacts in the middle of the instrument. The circuit is then complete except for the contact in the clock, which is closed every minute. When this contact occurs a mark is made by the sunshine pen on the quadruple register perpendicularly to the length of the sheet. This operation continues until five steps are made when the record is reversed. The five steps are then made in the opposite direction. (See fig. 37, B.).

This sunshine record is sometimes called a stepwise record because it consists of a series of steps, each step representing one minute of sunshine. When the sun goes under a cloud or sets at night, the record stops and the pen simply draws a straight line. There will be a lag of a half minute to a minute in the operation of the record, due to the fact that it takes an appreciable length of time as soon as the sun appears to heat up the air and force the mercury up to the contacts. Likewise, when the sun disappears, it takes an appreciable length of time for the lampblack to radiate off enough heat to di-

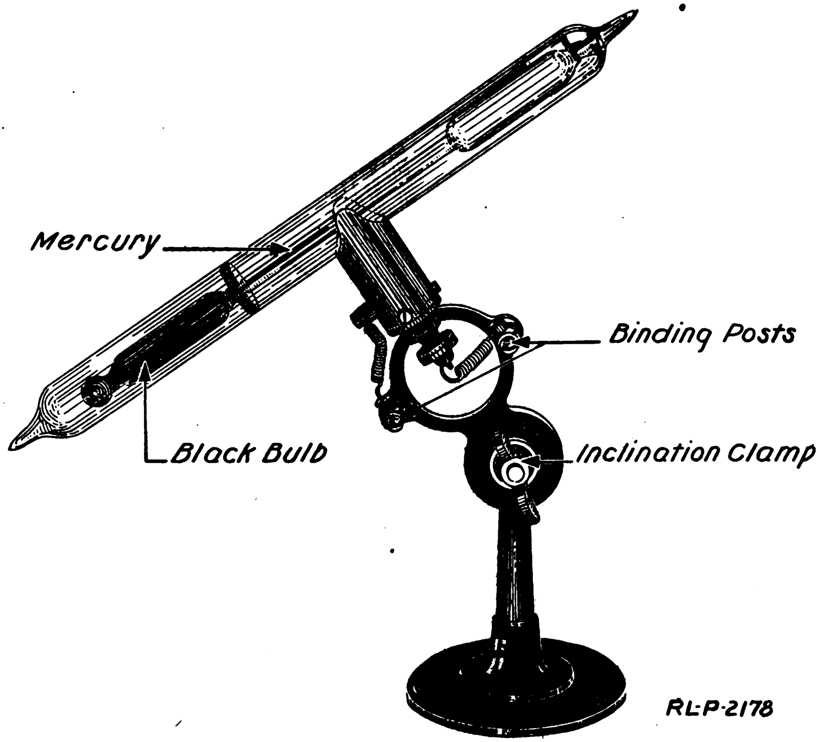

Fig. 37, C.—Sunshine recorder (side view)

minish the column of air in the black bulb, allowing the air in the upper bulb to force the mercury down into the lower bulb. It will be found that there will be a period of time, about a half to three-quarters of an hour, depending upon the atmospheric conditions, after sunrise and before sunset, when the instrument will not operate. This is due to the fact that the sun's rays, early in the morning at sunrise and late in the evening at sunset, have to pierce through a great depth of atmosphere, thereby losing the intensity of their effect. In order to have a complete record, the observer must make eye observations as to a clear or cloudy sunrise or a clear or cloudy sunset. If the sun rises clear, then the record should be supplemented with a note that sun did rise clear, and also at the time of sunset a similar entry should be made.

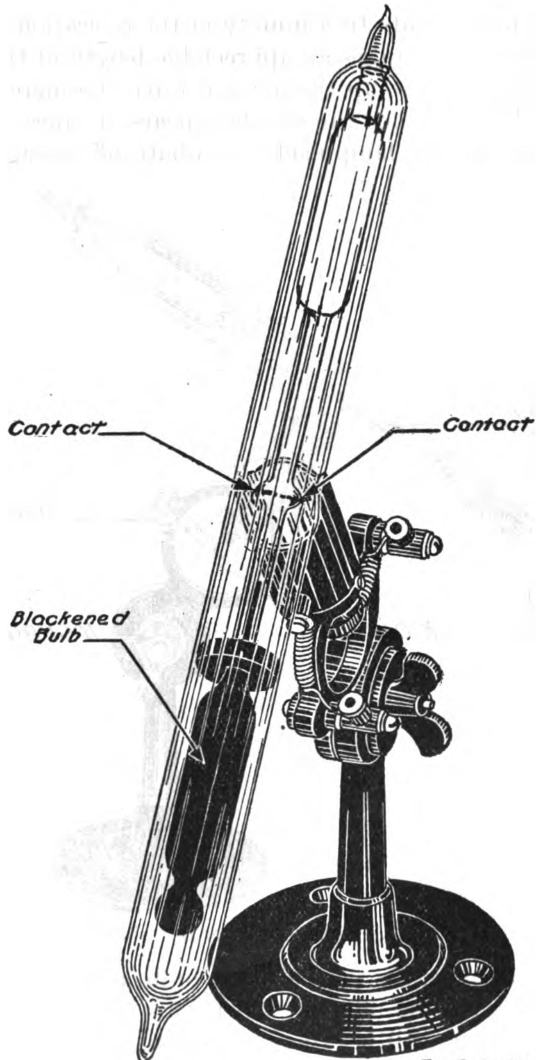

Fig. 37, D.—Sunshine recorder (top view)

Sunshine recorder, adjustment of.—The sunshine recorder works best when the tube has a slant of about 45°. In summer it will be necessary to adjust it to a steeper angle and in winter to one less steep. This is made necessary by the fact that the sun's rays are more direct in summer than in winter. When a sunshine recorder is received at a station after having been transported for a number of miles it is probably out of adjustment. This adjustment consists in part in having the right amount of air both in the upper and lower tubes so that when inclined at an angle of 45° the instrument works properly. Adjusting, in addition to changing the slant of the instrument, includes the transfer of air from the upper to the lower tube, or vice versa, when necessary.

If the mercury stands too high in the tube, it means that there is too much air in the lower bulb, and some of it must be forced into the upper bulb. To accomplish this, hold the instrument at an angle of 45° with the blackened bulb pointing downward, and rotate the instrument, keeping the longitudinal section of the instrument in the same plane and always parallel to itself.

If the mercury stands too low, then some of the air in the upper bulb must be forced into the lower bulb. To accomplish this, first hold the instrument in an inverted position and tap it, thus causing all the mercury in the tube to fall into the clear bulb. If only a small portion of mercury falls into the clear tube, more may be made to do so by jerking the instrument up and down. Invert the instrument so that the blackened bulb points directly downward. The mercury falling into the small tube connecting the two bulbs will seal the air in the tube, and then by making a quick motion downward this mercury will carry part of the air that was in the upper bulb into the lower bulb.

More critical adjustments may be made by inclining the instrument more or less in its supports. If when the sun is shining a shade is placed over the instrument, the mercury should leave the contact within less than a minute. Likewise when the shade is removed, the sun shining upon the instrument should cause the mercury to close the contact in less than a minute. Do not attempt to make these adjustments except when the sun is quite high, say, between 10 a. m. and 2 p. m.

Questions.

(25) *Why is mercury used in the sunshine recorder?*

(26) *Can the sunshine recorder be used without connecting it with the quadruple register?*

(27) *What is meant by calling the sunshine record a "stepwise record?"*

(28) *For what purpose is lampblack used on the sunshine recorder?*

Directions.

7. Adjust the sunshine recorder for winter use.
8. Adjust the sunshine recorder for summer use.
9. Assume that there is too much air in the lower bulb. Force some of it into the upper bulb.

Questions.

(29) *a. Why does the sunshine recorder work best when the tube has a slant of about 45°?*

b. What is a slant of 45°?

(30) *Why is it necessary to adjust the sunshine recorder for summer and for winter use?*

(31) *Why does the right amount of air in the upper and lower tubes have any effect on the proper working of the instrument?*

(32) *Why is mercury used instead of alcohol in the sunshine recorder?*

(33) *How is the sunshine recorder connected with the quadruple register?*

(34) *Is the sunshine recorder sheltered in any way?*

Information.

Quadruple register.—This register is called the quadruple register because a record is made of four elements of the atmosphere. It is sometimes called the triple register because of the fact that one pen records two elements. The register is shown in Figure 26 with the cover raised. Figure 26A shows a wiring diagram of a quadruple register. The quadruple register consists of an aluminum base upon which is mounted a clock for driving the drum. On this drum is a record sheet upon which are recorded the following four elements of the atmosphere: Wind direction, wind velocity, sunshine, and rainfall. The magnets whose armatures operate the pens, and which are connected electrically to the wind vane, anemometer, sunshine recorder, and tipping bucket rain guage, are all placed in the open.

Directions for the quadruple register.

(10) Examine the quadruple register carefully and note which pen records two elements and name the elements which it records.

(11) Examine the clock for driving the drum. See how the drum is set and which stem is used for winding the clock.

(12) Trace the connections, using the wiring diagram as a guide, for the wind direction record, the wind velocity record, sunshine record, and rainfall.

(13) Examine the register for inking the pen. See how this is done, but take care not to injure the instrument.

(14) Connect the quadruple register so that it will record the four elements of the atmosphere; that is, wind direction, wind velocity, sunshine, and rainfall.

Questions.

(35) *Why is the quadruple register sometimes called the triple register?*

(36) *How is the drum on the quadruple register operated?*

(37) *What four elements does the quadruple register record?*

(38) *Should the quadruple register be placed outside in the open?*

SUGGESTIONS FOR THE INSTRUCTOR

1. *a.* After unit operation No. 4 has been completed and all the questions in the text have been answered by each student, the instructor may give the following instruction test or devise another one similar to it.

b. As a result of the classroom work, the student should have learned how (1) to make observations with the wind vane; (2) to read, set, and manipulate the Dines anemo-biagraph; (3) to read, set, and manipulate the Robinson anemometer; (4) to read, set, and manipulate the portable anemometer, (5) and how to name the important parts of the various instruments and equipment.

c. The instructor should follow the usual plan of pointing out in just what particulars each student has failed and, if the results are unsatisfactory, repeat the test after an interval of a day or two.

d. The method of administering the test calls for no special directions.

INSTRUCTION TEST NO. 4

PART I.—PERFORMANCE

PROBLEM No. 1

MEASURING WIND VELOCITY WITH HAND ANEMOMETER

Equipment.

One portable hand anemometer, with stop watch attached.
Pencil and paper.

Procedure.

The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem in Part I of the test. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

Perform the operation as quickly as you can.

1. Measure the wind velocity by means of the hand anemometer.
2. Repeat the operation three times: i. e., make three observations in all.
3. Reduce the result of each observation in miles per hour and take the average of the three.
4. As soon as you have completed this operation, report to the instructor.

Directions for scoring.

1. If the work is correctly done, credit the student with 5 points.
2. Allow no partial score.

PROBLEM No. 2

THE QUADRUPLE REGISTER

Equipment.

One quadruple register.
Supply of record ink.
Record sheets.

Procedure.

1. Prepare the quadruple register for this problem by removing the record sheet and disconnecting one or more of the wires from the binding posts.

Directions to student.

Perform the following operation carefully and at the same time as quickly as you can. Complete the necessary operations for the proper functioning of the quadruple register. As soon as you have completed these operations, report at once to the instructor.

1. Connect the proper wires to the proper binding posts of the quadruple register if necessary.
2. Ink the pens.
3. Place new record sheet upon the quadruple register, wind the clock, and start the drum.

Directions for scoring.

	Points.
1. The maximum possible score for problem No. 2 is	12
2. The minimum score required to pass problem 2 is	7
3. *a* If all connections have been properly made	2
b. If the pens have been properly inked	5
c. If the record sheet has been properly placed on the register, the clock properly wound, and the drum started	5
4. Allow no partial scores for any of the separate operations; that is, either allow full credit for *a*, *b*, or *c* as indicated above, or score	0

PROBLEM No. 3

THE SUNSHINE RECORDER

Equipment.

One sunshine recorder.

Procedure.

Prepare the sunshine recorder so that it is set for neither winter nor summer use.

Directions to the student.

Perform the following operations as quickly as you can. As soon as you have completed these operations report at once to the instructor.

1. Set the sunshine recorder for summer use.
2. Set the sunshine recorder for winter use.

Directions for scoring.

1. If the student has properly performed the settings as directed, credit him with 5 points.
2. Allow no partial score.

PART II.—INFORMATION

Equipment.

Pencils.
Mimeographed or typewritten test questions.

Procedure.

1. Furnish each student with a pencil and copy of the test questions which are given under Part II.
2. As soon as the directions have been read over by the students and understood, call the class to attention, announce the number of minutes that will be allowed, and give the command "Begin."
3. At the end of 30 minutes from the command "Begin" call "Time." See that all papers are collected and that the names of the students are properly recorded.

Directions to the student.

Each of the following questions can be answered by a single word, phrase, or number. Write the answer on the short dotted line.

1. Air in motion near the earth's surface and parallel with it is called what? ....
2. What name is applied to air movements in a vertical direction? ....
3. In the Signal Corps, what measurement of the horizontal motions of air is made in addition to direction? ....
4. A difference in what is a primary cause of motions of the air? ....
5. What is another name for a wind vane? ....
6. What is another name for this instrument? ....
7. If the wind blows from a semicardinal point the arrow of the vane will do what to the angle formed by the direction arms? ....
8. When the wind direction fluctuates rapidly what is taken as the true direction? ....
9. Attached to the Robinson anemometer are two dial wheels. How many teeth has the lower one? ....
10. In the above instrument, how many miles of wind must pass the station in order that one dial may move one scale division in reference to the other? ....

11. What is the name of the instrument that measures the velocity of wind? ------------------

12. With what sort of tail should the wind vane be supplied? ------------------

13. When judging the direction of the wind by means of the wet finger test, how will the finger feel on the side toward which the wind is blowing? ------------------

14. With reference to the direction of the wind, how does the arrow of the weather vane point? ------------------

15. The vertical lines on the triple register record are how many minutes apart? ------------------

16. What word is needed to complete this phrase? Dines pressure tube. ------------------

17. In how many ways may the wind velocity be read by this instrument? ------------------

18. If the instrument indicates that in a given five-minute period 3.1 miles of wind have passed the station, what is the rate in miles per hour? ------------------

19. One of the gears is made with a number of contacts. How many are there? ------------------

20. The upper dial has a number of pins set in its outer edge. How many are there? ------------------

21. A triple register record sheet is used in connection with this device. How far apart in minutes are the vertical lines? ------------------

22. On the triple register sheet how is the record of velocity marked? ------------------

23. Two of the pins in the upper dial are connected. Which are they? ------------------ and ------------------

Directions to the student.

Below are a number of questions and unfinished statements. After each question or statement are several words, phrases, or numbers each preceded by a number. Only *one* of these answers is correct. Write the *number* of the correct answer on the dotted line to the right.

24. As air becomes heated it (1) contracts; (2) expands; (3) becomes denser; (4) becomes heavier. ------

25. The direction of the wind is named according to the direction (1) to which it is blowing; (2) from which it is coming; (3) of the bisected angle; (4) the same way the arrow points on the map. ------

26. The quadruple register makes what sort of record for the semi-cardinal points? (1) One dot; (2) two dots; (3) dot and dash; (4) dash dot dash. ------

27. The triple register makes what sort of record for the cardinal points? (1) Dash dot; (2) dot dot; (3) dot; (4) dot dash dash. ......

28. How many wind directions are indicated by the record of the cup anemometer? (1) 32; (2) 16; (3) 8; (4) 4; (5) 0. ......

29. How many wind directions are indicated by the record of the Dines instrument? (1) 8; (2) 32; (3) 128; (4) all. ......

30. At what intervals are direction records made on the triple register? (1) 120 seconds; (2) 90 seconds; (3) 60 seconds; (4) 30 seconds. ......

31. At what intervals is the recording pen in contact with the chart in the direction recorder of the Dines anemo-biagraph? (1) Every 10 seconds; (2) every 30 seconds; (3) every 60 seconds; (4) continuously. ......

32. What is the name of the wind-measuring device in which the wind is permitted to turn vanes or cups? (1) Twisters; (2) tortographs; (3) rotation ammeters; (4) rotation anemometers. ......

33. In reading wind velocity on the anemo-biagraph the observer reads to which of the following? (1) Nearest 0.1 mile; (2) nearest 1.0 mile; (3) nearest 0.01 mile; (4) nearest 0.5 mile. ......

34. On the revolution counter of the hand anemometer are two hands or pointers. The longer one makes one revolution per how many meters? (1) 1.0; (2) 10.0; (3) 100.0; (4) 1,000.0. ......

35. When the longer hand or pointer has gone around 1,000 times, how many times has the shorter one gone around? (1) 10; (2) 100; (3) 10,000; (4) 100,000. ......

36. The lower bulb of the sunshine recorder is covered with (1) black paint; (2) lampblack; (3) black paper; (4) ink. ......

37. The sunshine recorder works best when the tube has a slant of about (1) 30°; (2) 90°; (3) 10°; (4) 45°. ......

38. In the summer the sunshine recorder should be kept at (1) steeper angle; (2) horizontal; (3) less steep than in winter; (4) perpendicular. ......

39. If the mercury stands too high in the tube it means (1) that there is too much air in lower bulb; (2) that there is too little air in the lower bulb; (3) that the mercury has been subjected to greater temperature; (4) that the instrument is out of order. ......

40. When the sun goes under a cloud the sunshine recorder (1) ceases to function; (2) the mercury falls; (3) records cloudiness; (4) the record stops and the pen on the quadruple register draws a straight line. ......

Directions for scoring Part II.

	Points
1. The maximum possible score for Part II is	40
2. The minimum score required to pass Part II is	33
3. *a. Single-word questions.* For each question correctly answered	1
b. Recognition questions. For each question correctly answered	1

RAIN GAUGE

Equipment.

One standard rain gauge.
One measuring stick.
One tipping bucket.
One quadruple register.
A supply of record sheets for the quadruple register.

Information

Precipitation.—Precipitation includes all forms of falling moisture; these are rain, snow, hail, and sleet. Dew and frost are forms of moisture appearing upon the ground and surfaces of objects, but are not included in precipitation, as they are formed on the spot and are not precipitated. The cloud particle is a very small drop of water, and the rain drops are made up from these cloud particles. The actual size of the drops varies from one one-thousandth of an inch to as much as one-fourth of an inch. The heavier the rain the larger the drop, is a universal rule. Rain may be said to begin in the formation of clouds, which are formed in a variety of ways, one of which is the cooling of the air when convection takes place. This causes condensation and the formation of cloud particles, which become larger as condensation increases, and finally become so large that they are no longer maintained in the air by the rising currents, but fall and may eventually reach the ground. There are, of course, many cases where rainfall does not actually reach the ground, but as in the case of very high waterfalls, the moisture is evaporated and forms vapor before the ground is reached.

Observations of precipitation include the time of beginning and ending; but intervals of 15 minutes or less when no precipitation occurs are usually disregarded except at the actual time of the observation, when the beginning and ending is very carefully made so that the journal recording such times will not conflict with the kind of weather at the time of the observation.

Measurement of precipitation.—As precipitation consists of rain, snow, sleet, and hail, and since each has a different density, it is evident that there must be some standard. This standard is rain; that is to say, all forms of precipitation are so measured that the amount that has fallen is measured and entered the same as though an equal amount of moisture in the form of rain had occurred. Rain is measured in an instrument consisting of a can with vertical sides, the top of which is in the shape of a funnel leading the rain into a smaller tube which has one-tenth of the cross section of the opening of the can. Therefore, the height of the water in the small tube will be ten times as high as the actual amount of rainfall. Rain can then be measured to the nearest one-hundredth of an inch, as one-tenth of an inch of the measuring stick would be equal to one one-hundredth of an inch actually having fallen upon the ground. (See figs. 38, 39, 40.)

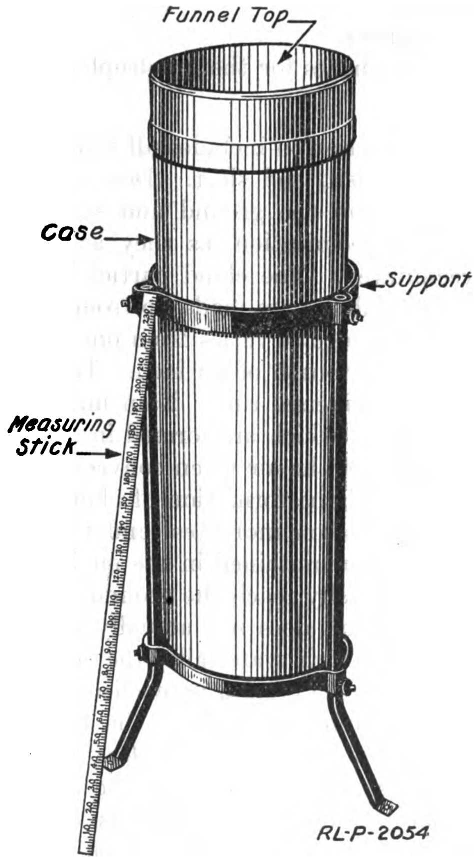

Fig. 38.—Rain gauge, 8-inch

Questions.

(1) *Explain the following:*

a. Convection.

b. Condensation.

c. Evaporation.

d. Cross section.

e. Density.

(2) *Arrange in order of density: Rain, snow, sleet, hail.*

Directions.

To measure rain.—1. Precipitation is measured at the time of taking regular surface observations; and in the event of no rain having occurred since the last observation, a zero should be recorded

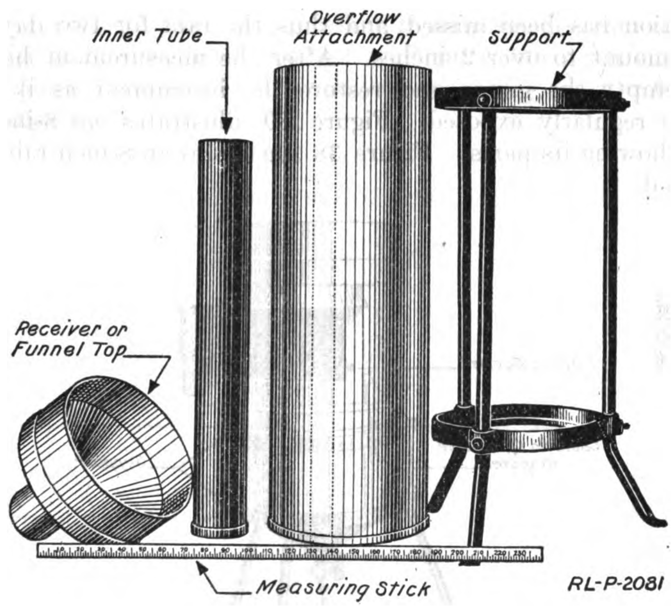

Fig. 39.—Rain gauge, 8-inch, showing parts

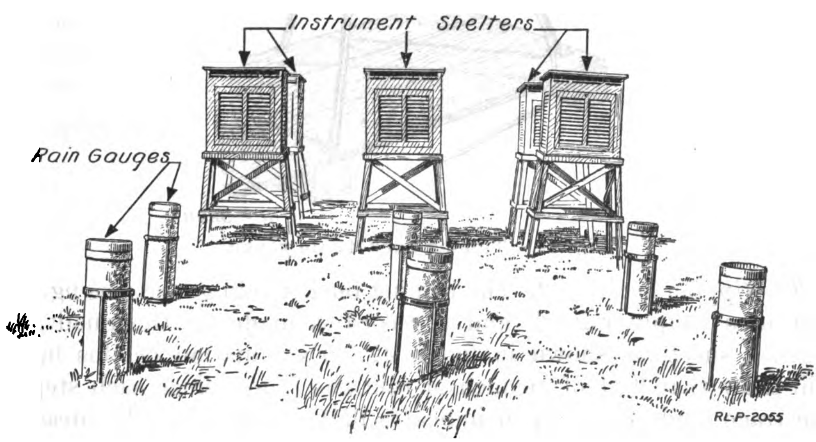

Fig. 40.—Showing rain gauges exposed near instrument shelters

on the proper form and not a dash. To measure rain, simply insert the measuring stick into the inner tube of the rain gauge and read off on the stick, at the point to which it has been wetted, the amount in inches and hundredths. If the amount is exactly 2 inches, it means that the inner tube has been entirely filled and that probably there is some rain in the overflow attachment. If this is the case, measure and add it to the 2 inches previously measured. It is very seldom that 2 inches or more will fall in 24 hours, but it may be that due to the illness of the observer or to some other cause, an observation has been missed, and thus the rain for two days may easily amount to over 2 inches. After the measurement has been made, empty the gauge and restore the instrument as it should be when regularly exposed. Figure 39 illustrates an 8-inch rain gauge, showing its parts. Figure 38 illustrates an 8-inch rain gauge assembled.

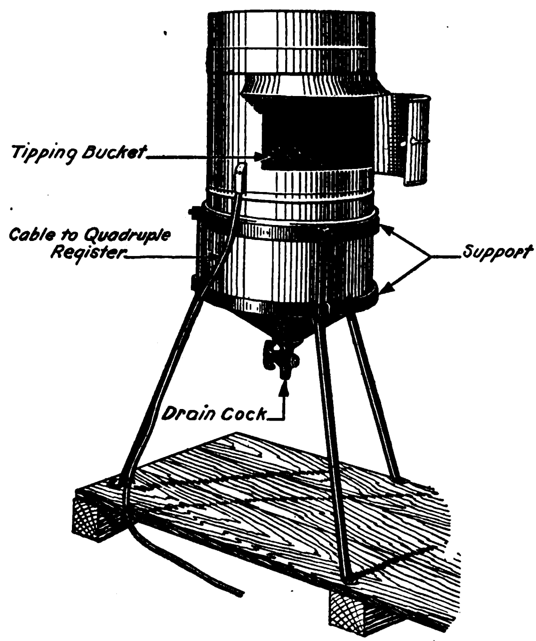

Fig. 41.—Tipping bucket rain gauge

The tipping bucket.—2. The tipping bucket rain gauge (see fig. 41) measures simply rainfall and a record is made on the quadruple register sheet, as shown in figure 42. Examination of this figure will show that 0.51 of an inch of rain has fallen, since each step in the trace made by the pen indicates 0.01 of an inch. To measure rain by a tipping bucket, the observer must carefully examine the sheet since the last observation and count every step made by the pen. A stick measurement may also be made with this gauge. A tube is provided which is one-tenth the area of the receiver of the gauge, and the rain, after it has passed into the receiver and through the tipping bucket, is collected in the bottom of the gauge, by means of a stopcock and may be allowed to run into the tube and a measurement taken in the same manner as in the case of an 8-inch gauge.

Examine the rain gauge carefully and pour a small quantity of water into it. Observe the action.

In very dry countries it is necessary to measure the rain immediately after it has occurred and not wait until the regular time of observation, as considerable evaporation may take place before the catch is measured.

Question.

(3) *At what seasons of the year does the most rain fall at the observer's own station?*

(4) *About how many inches of rainfall per year in the following localities?*

a. New York.
b. Key West.
c. Prescott, Ariz.

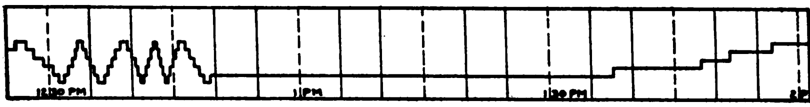

Fig. 42.—Showing a portion of Form 102, record of rainfall

d. San Francisco.
e. Seattle
f. Chicago.
g. St. Louis.
h. Portland, Me.

Information.

Snow.—Snow is formed by condensation taking place at temperatures below freezing, when the vapor goes immediately into the crystalized form. The smallest snow unit is the crystal, which is always formed upon the hexagonal pattern. An aggregation of these crystals makes the snowflake.

Measurement of snow.—Snow is measured in two ways: First, it is melted and the water equivalent obtained; second, the actual depth of snow is measured to the nearest one-tenth of an inch and so recorded. The actual depth of the snow bears no definite relation to its equivalent amount of water. Sometimes snow is very dense, and 5 inches of snow may be equivalent to 1 inch of water; on the other hand, snow may be light and fluffy, and it may take 20 inches of snow to equal 1 inch of rain. But on the average throughout the year, the ratio of 10 to 1 is approximately correct; that is to say, 10 inches of snow is equivalent to 1 inch of water. This ratio should not be used in measuring snow except in extreme necessity, because where a good measurement of snow may be obtained it may be readily reduced to water by melting.

Questions.

(5) *Explain the following:*
a. Vapor.
b. Crystal.
c. Hexagonal pattern.
d. An aggregation of crystals make the snowflake.
(6) *What is the temperature of melting snow?*
(7) *a. What are the regions of greatest snowfall in the United States?*
b. Of the least?

Directions.

To measure the amount of snow.—3. For this experiment, only the overflow attachment has been exposed and the amount of snow caught in it is measured. This operation may be performed in two ways:

a. The first method: Fill up the inner tube with water; pour all of it into the overflow attachment. When the snow has become a very liquid slush, pour it back into the inner tube until this is full. Throw this away. Pour the remainder into the inner tube and measure it. This measure will be the water equivalent of the snow.

b. The second method: Melt the snow which has been caught in the overflow attachment, pour it in the inner tube, and measure it the same as in the case of rain.

To measure the depth of snow.—4. The actual depth of snow, in addition to its water equivalent, will also be measured. To do this it is necessary to keep some place at the observatory swept clean so that the depth of newly fallen snow may easily be measured. This is done by means of the rain-gauge measuring stick, but care in this case must be taken so that the actual inches and tenths are measured. It may very often happen that wind has caused a certain amount of drifting, and to correct this measurements must be made at several places and an average taken. Also, the amount of snow caught in the overflow attachment may be erroneous, due to wind. It may then be necessary to discard the amount so caught and either estimate the correct amount, or else go to some place which has been sheltered from the wind and proceed as follows: Invert the overflow attachment and push it down over the spot selected; then slide a piece of tin or cardboard under the mouth of the can, thereby cutting out a section representing the correct amount of snowfall, measuring this as described above. The rule that 10 inches of snow make 1 inch of rain may be used in an emergency.

Information.

Hail.—An individual hailstone consists of concentric layers of ice and snow, resembling an onion in structure. The theory of the formation of hail has never been fully verified, but it seems very plausible. The theory is that a small snowflake falls down to a region which is above the freezing point, taking upon itself a coating of water which freezes upon the snowflake due to the low temperature. The flake is then carried up by an ascending current into a region of snow where it receives another layer of snow and again falling receives another coating of ice. This process goes on until the hailstone becomes too heavy to be carried upward or to remain suspended in the air, and consequently falls to the ground. The size of hailstones varies all the way from very small pellets to the size of an orange. Hail always occurs in connection with thunderstorms.

Sleet.—Sleet is composed of frozen drops of rain, and a condition may occur when the precipitation is entirely composed of sleet, or a combination of sleet and rain. This definition of sleet must not be confused with that of a "sleet storm," as this term is applied to that condition when rain occurs and the ground and all exposed objects are below the freezing point. The rain, falling upon the ground and the surfaces of objects, forms a coating of ice, which phenomenon has no definite name in meteorology. It is, however, known as a "sleet storm" in the United States, although the term "silver thaw" is sometimes used.

Measurement of sleet and hail.—Sleet and hail are measured in the same way as snow; that is, they are first reduced to water and the amount of the water then measured. Sometimes the depth of hail is also obtained when the ground is generally covered.

Questions.

(8) *Explain the following:*

a. Concentric layers.

b. Pellets.

(9) *At what season of the year or under what conditions is hail most likely to form and to be precipitated?*

(10) *a. How far south will hail fall?*

b. Will hail be precipitated south of the frost line?

Directions.

To measure hail and sleet.—5. The method just described in measuring snow, direction 3, is applied in measuring the water equivalent of hail and sleet, or any other combination of the different forms of precipitation.

Information.

Measurement of precipitation in general.—When rain or snow falls in a calm, it is certain that the measurement obtained in a gauge is then very accurate; but if wind is blowing, the catch will not be as accurate, and the amount measured may then be questioned. In general, the higher the velocity of the wind, the less the gauge will catch. The difficulty in measuring rain, as just pointed out, is accentuated in the case of snow. A moderate amount of wind will make a greater variation in the amount of snow caught than in the case of rain under the same conditions. In some cases the gauge may be located in such a way in relation to buildings and other obstructions and also in relation to any wind that may be blowing at the time that very little snow is caught in the gauge. Also, it will be very difficult to find a location that represents the true amount of snowfall. It will then be necessary to make a number of measurements and to take an average. If the observer has a suspicion that the gauge does not hold the true amount of snow, he should throw away the amount which has been caught and go to some place which has been sheltered more or less from the wind. A sample from such a locality will probably represent the true depth of the snowfall. The observer should take the gauge and invert it over the place selected, pushing it down to the ground. By inserting a piece of cardboard underneath he may cut out a section of the snow which will be much nearer to the actual amount of snow which has fallen than the amount which was previously caught in the gauge. This should be melted, and the water equivalent obtained in the manner previously described.

Questions.

(11) *What effects may rain and other forms of precipitation have on the operations of an army?*

(12) *Why should some sheltered place be selected to measure depth of snowfall?*

SUGGESTIONS FOR THE INSTRUCTOR

1. *a.* After unit operation No. 5 has been completed and all the questions in the text have been answered by each student, the instructor may give the following instruction test, or devise another one similar to it.

b. As a result of the classroom work, the student should have learned how (1) to set up a standard rain gauge; (2) to measure rain and all other forms of precipitation by means of the gauge; (3) to measure rain by means of the tipping bucket and to read the accompanying record on the quadruple register; (4) to name the important parts of the various instruments and equipment.

c. As with previous instruction tests, the instructor should follow the suggestions and directions for test No. 1.

INSTRUCTION TEST NO. 5

PART I.—PERFORMANCE

PROBLEM NO. 1

MEASURING PRECIPITATION

Equipment.

One standard rain gauge containing a quantity of water in excess of 2 inches.

One measuring stick.

Pencil and paper.

Procedure.

The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem in Part I of the test. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

Perform the following operation carefully and neatly, but at the same time as quickly as you can.

1. The standard rain gauge is supposed to contain the precipitation for the past 24 hours.
2. Measure the amount and record it.
3. As soon as you have completed this operation report at once to the instructor.

Directions for scoring.

1. If student has made correct measurement of precipitation, credit him with 5 points.
2. Allow no partial score.

PART II.—INFORMATION

Equipment.

Pencils.

Mimeographed or typewritten test questions.

Procedure.

1. Furnish each student with a pencil and copy of the test questions which are given under Part II.
2. As soon as the directions have been read over by the students and understood, call the class to attention, announce the number of minutes that will be allowed, and give the command "Begin."
3. At the end of 20 minutes from the command "Begin" call "Time." See that all papers are collected and that the names of the students are properly recorded.

Directions to the student.

Below are a number of statements, and just to the right of after each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a *plus* sign (+) on the line to the right. If what is says is *not true*, put a *minus* sign (−) on the line to the right.

1. Precipitation includes dew but not frost. ------
2. A cloud particle is relatively rather large, about two-tenths inch in diameter. ------
3. Observations of precipitation include the time of beginning and ending. ------
4. All forms of precipitation are referred to rain as a standard. ------
5. In a rain gauge, the smaller tube has one-tenth the cross section of the opening of the can. ------
6. The height of the water in the small tube will be one-tenth as much as the actual amount of rainfall. ------
7. "No precipitation" is indicated in the record by a dash, thus (—). ------
8. The inner tube of the gauge holds exactly 2 inches. ------
9. It frequently happens in the vicinity of New York City that from 4 to 6 inches of rain will fall in 24 hours. ------
10. In very dry countries rain should be measured immediately after it has occurred. ------
11. Snow is usually formed by condensation at a temperature slightly above 32° F. ------
12. The smallest snow unit is the crystal, which is always formed upon the hexagonal pattern. ------

Directions to the student.

Each of the following questions can be answered by a single word, phrase, or number. Write the answer on the short dotted line.

13. Snow is measured in two ways: The water equivalent is obtained, or else we measure what? ....

14. To what degree of exactness is this second measurement made? ....

15. In estimating the water equivalent of snow, what is a fair average number of inches of snow for 1 of rain? ....

16. Of what sort of layers is the individual hailstone formed? ....

17. Hail always occurs in connection with what? ....

18. What name is applied to precipitation in the form of frozen drops of rain? ....

19. What is another name sometimes used for a "sleet storm"? ....

20. Under what conditions must rain or snow fall in order for the observer to be quite sure that the measurement obtained in a gauge is quite accurate? ....

Directions for scoring Part II.

1. The maximum score for Part II of this test is 20 points.
2. The minimum score required to pass Part II is 16 points.
3. *a. True-false (plus or minus) questions.* Score as directed on page 22.

b. Single-word questions. Allow 1 point for each question correctly answered.

SUGGESTIONS FOR CONDUCTING PROGRESS TEST NO. 1

1. For convenience, this progress test is divided into two parts. Part I—Performance; Part II—Information.

It is designed to measure the progress that students have made in the first five unit operations, and for this reason a considerable amount of the subject matter of the first five instruction tests has necessarily been incorporated in this progress test. It will not be necessary to administer this entire test at one time. If the instructor prefers to do so, Part I may be given on one day and Part II on another, whichever way best fits with the schedule of instruction. The directions for the student in Part I may be either typewritten, mimeographed, or read aloud by the instructor. Allow the student sufficient time to read and understand the directions before giving the command, "Begin." Part II of the test may also be either typewritten, mimeographed, or placed on a blackboard.

Procedure—General, for Part I.

2. The instructor should record, to the nearest second, the time consumed by each student in the completion of each problem in Part I of this test. These records will provide the instructor with information which will show which students have fallen below the general average of the class in speed and consequently require further practice. Emphasis should be placed more upon the accuracy of the work than upon the rapidity with which it is performed. Be sure, however, that everyone clearly understands the time limit set for each problem.

Scoring—General, for the entire test.

	Points
3. *a.* The maximum possible score for Part I is	55
The maximum possible score for Part II is	184
The total score for the whole test is	239
b. The minimum score required to pass the whole test is	170

c. The total score for Part I is the sum of the points received for problems 1 to 8. The exact assignment of points is explained in detail at the end of each problem.

d. The questions of Part II will be scored in the same manner as were similar questions in the various instruction tests.

PROGRESS TEST NO. 1

PART I.—PERFORMANCE

PROBLEM I.

READING TEMPERATURE OF THE DRY AND WET BULB AND MAXIMUM AND MINIMUM THERMOMETERS

Equipment.

One instrument shelter.
One dry and wet bulb and maximum and minimum thermometer.
One pencil.
One blank form (Form No. 2—Met'l.).

Directions to the student.

1. Open the door of the shelter and take and record the reading of the temperature of the dry and wet bulb and the maximum and minimum thermometer.
2. Replace the instruments as you found them, after resetting maximum and minimum thermometers.
3. As soon as completed, report at once to the instructor.
4. Time allowed for this problem, 4 minutes.

Directions for scoring.

	Points
1. If all thermometers have been correctly read to within a reasonable degree of accuracy within the time limit, credit student with	5
2. If instruments have been properly replaced and reset	5
3. No partial scores allowed.	

PROBLEM No. 2

PREPARATION OF THERMOGRAPH FOR OPERATION

Equipment.

One table.
One thermograph.
Supply of record sheets.
One bottle of recording ink.

Directions to the student.

1. Perform the following operations carefully and neatly.
a. Change the record sheet.
b. Start the drum so as to avoid play in the gears.
c. Set the pen for 68°, 8.30 a. m., Monday.
d. Ink the pen.
e. Wind the clock.

2. As soon as you have completed these five operations, report at once to the instructor.

3. Time allowed for this problem 5 minutes.

Directions for scoring.

	Points
1. Credit student for all five operations correctly performed within the time limit, with	10
2. No partial scores allowed. If any one of the operations is performed incorrectly, score the whole problem	0

PROBLEM NO. 3

READING BAROMETER AND MAKING ADJUSTMENTS

Equipment.

One standard mercurial barometer and box.
Pencil and blanks for recording.

Directions to the student.

1. Open barometer box, adjust instrument, and take present barometric pressure reading.

2. As soon as you have completed this record, report at once to the instructor.

3. Time allowed for this problem, 2 minutes.

Directions for scoring.

	Points
1. If reading has been correctly made and recorded in the required time, credit student with	5

2. No partial score allowed.

PROBLEM NO. 4

CORRECTIONS AND REDUCTIONS OF INSTRUMENT READINGS, USING FORMS NOS. 79 AND 80

Equipment.

Supply of paper.
Copies of Forms Nos. 79 and 80.
Pencil.
Records of readings just taken in problem No. 3.

Directions to the student.

1. Make all necessary corrections for the readings furnished you.

2. Make the necessary reductions.

3. As soon as you have completed these operations report at once to the instructor.

4. Time allowed 4 minutes.

Directions for scoring.

	Points
1. If corrections have been properly made within the time limit, credit the student with	2
2. If reductions have been properly made within the time limit, credit with	2

3. Allow no partial scores.

PROBLEM No. 5

PREPARATION OF PSYCHROMETER FOR USE

Equipment.

One psychrometer with wet bulb stripped of muslin wrapping.
One piece of thread.
One piece of new muslin.
One beaker of water at current temperature.

Directions to the student.

1. Prepare the wet bulb of this psychrometer for immediate use.
2. As soon as you have completed this operation report at once to the instructor.

Directions for scoring.

	Points
1. If psychrometer has been properly wrapped with muslin, credit student with	2
2. If it has been properly immersed in the beaker of water, credit student with	2

3. Allow no partial scores.

PROBLEM No. 6

DETERMINING DEW POINT, HUMIDITY, AND VAPOR PRESSURE

Equipment.

One standard thermometer shelter, equipped with sling.
Psychrometer.
Writing paper.
Small table.
Copy of psychometric tables.
Pencil and blanks for recording.

Directions to the student.

1. Open the door of the shelter and take and record as quickly as you can, the temperature as indicated by the wet and dry bulb thermometers.
2. Replace the instruments as you found them.
3. By means of psychrometric tables, obtain the following:
a. Dew point.

b. Relative humidity.

c. Absolute humidity.

d. Vapor pressure.

4. As soon as you have completed these operations, report at once to the instructor.

5. Time allowed for this problem, 10 minutes.

Directions for scoring. Points

1. *a*. For correct reading of the thermometers, credit the student with 5

b. For correct determination of 3, *a*, *b*, *c*, *d*, credit the student for each correct item with 2

2. Allow no partial scores.

PROBLEM No. 7

MEASURING WIND VELOCITY WITH HAND ANEMOMETER

Equipment.

One portable hand anemometer, witn stop watch attached.

Pencil and paper.

Directions to the student.

Perform this operation as quickly as you can.

1. Measure the wind velocity by means of the hand anemometer.

2. Repeat the operation three times; i. e., three observations in all.

3. Reduce the result of each observation to miles per hour and take the average of the three.

4. Time allowed for this problem, 10 minutes.

5. As soon as you have comoleted this operation, report to the instructor.

Directions for scoring. Points

1. If work is correctly done, credit student with 5

2. No partial scores allowed.

PROBLEM No. 8

MEASURING PRECIPITATION

Equipment.

One standard rain gauge containing quantity of water in excess of 2 inches.

One measuring stick.

Pencil and paper.

Directions to the student.

1. The standard rain gauge is supposed to contain the precipitation for the past 24 hours.

2. Measure the amount and record it.

3. As soon as you have completed this operation report at once to the instructor.

4. Time allowed for this problem, 3 minutes.

Directions for scoring. Points

1. If student has made and recorded the correct measurement of precipitation, credit him with........................... 4

2. No partial scores allowed.

PART II—INFORMATION

NOTE.—Ninety minutes will be allowed for Part II of this test.

Directions to the student.

Below are a number of sentences from which certain words have been omitted. Each word which has been omitted is indicated by a dotted line. Fill in each blank space with a word which will make good sense and at the same time be technically correct. A word spelled with a hyphen, like to-day, counts as *one* word.

1. Temperature may be defined as the (....................) of (....................) of a substance.

2. The operation of all thermometers depends upon the fact that most substances (....................) on being heated, and that in addition all these substances (....................) a different amount per (....................) of heat.

3. In accordance with the above statement, when the thermometer is heated the mercury (....................); and if the thermometer is cooled, the mercury (....................).

4. In the construction of thermometers the liquids commonly used are (................) which freezes at (................) degrees (................) zero, and (........................) which freezes at about (................) degrees below zero.

5. The zero of the Fahrenheit scale is (....................) degrees (................) the freezing point of (................).

6. The point at which (....................) boils is marked on the Fahrenheit scale as (....................) degrees above (....................).

7. The range of the thermometers used in the Signal Corps is from (....................) degrees below (....................) to (....................) degrees (....................).

8. The bulb end of a thermometer usually hangs (...............) and the end of the mercurial column opposite the bulb is called the (....................) of the column, no matter in what (........................) the thermometer is placed.

9. A thermometer which measures a slight change in (--------------------) quickly is called a (--------------------) thermometer.

10. A thermometer which measures very slight (----------------) in (----------------) is called a (----------------) thermometer.

11. For meteorological work thermometers need to be (--------------------) rather than (--------------------) since (--------------------) of a degree is the smallest fraction considered when measuring the temperature of the (--------------------).

12. If the bulb of a thermometer is made in the (----------------) form there will be more surface exposed than if it is made in the (--------------------) form.

13. A so-called "ordinary" thermometer measures the(-------------------) temperature of the air. This instrument may also be called an (--------------------) thermometer.

14. Registering thermometers are those which (----------------) the (----------------) and the (----------------) temperatures.

15. Recording thermometers are usually called (----------------) and make a (----------------) record of the (----------------.

16. Registering thermometers are of two kinds: Those which register the highest or (----------------) temperature, and those which measure the (----------------) or (-------------) temperature.

17. The sling (--------------------) is composed of two (--------------------), one of which is called the (--------------) and the other the (--------------------).

18. If when reading a thermometer, the eye of the observer is not at (--------------------) angles with the stem of the thermometer there is very likely to be an error due to (--------------------).

19. The maximum thermometer is made with a (----------------) in the stem near the (--------------------).

20. The liquid in a minimum thermometer is always (--------------------) and in the tube is a small movable (--------------------).

21. The minimum thermometer is exposed in the shelter in a nearly (--------------------) position, with the (--------------------) end to the (--------------------) side.

22. In reading all thermometers, the observer should work (--------------------) as (--------------------) radiated from the (--------------------'s) (--------------------) will cause the (--------------------) to read too (--------------------).

23. The (--------------------) is an instrument which makes a continuous (--------------------) of the temperature.

24. The problem of exposing a thermometer is to hang it up so that the (--------------------) may have free access to it and the (--------------------) may (--------------------).

25. The instrument shelter is made with a (------------------) roof, and is painted (------------------) to (------------------) away the (--------------------) rays.

26. The shelter is set up so that its floor will be (--------------------) feet (--------------------) the ground and the thermometers are hung inside about (--------------------) feet (--------------------) the ground.

27. Temperature is measured by means of sling (--------------------) and (--------------------).

28. The mercurial barometer consists essentially of a glass tube (--------------------) at the top, filled with (------------------) and having its (--------------------) end immersed in a cistern of (--------------------).

29. The (--------------------) consists of a corrugated (--------------------) exhausted of (--------------------), to which is attached a pen that traces upon a (--------------------).

30. In reading a mercurial barometer by means of the adjusting (--------------------), bring a level of the mercury in the (--------------------) up to the (--------------------) point and at the same time lightly (--------------------) the instrument.

31. After the barometer reading has been taken, it must be reduced to (--------------------) pressure and to (--------------------) pressure.

32. Certain corrections must also be applied which include corrections for scale (--------------------), (--------------------), and (--------------------).

33. The sum of corrections, which includes the three mentioned above, is given on Form No. (--------------------), which is usually found in the (--------------------).

34. When making a temperature correction with Form No. 80, the barometer reading will be found at the (--------------------) of the form and the (--------------------) at the (--------------------).

35. Add the "total correction" to the barometer reading, and the result will be the ("------------------").

36. This last should be compared with the (------------------) reading and should agree to within one or two (------------------) of an (--------------------).

37. The barograph is made up of a series of little vessels (.......................) of more in number, which are (..................) of air. These little vessels are about (..................) inches in (..................) and (....................) inches thick. Inside each vessel is a (..................) which is to keep it from (....................) when the (....................) is drawn out.

38. When readings of the mercurical barometer are taken, they should always be compared with the (....................) readings.

39. The scales of the mercurial barometer should be dusted, but not (....................), as to do so might change the (.......................) of the (....................).

40. Barometry is the science of measuring the (................) of the (....................) with a (....................).

41. Air (....................) varies with changes in the weather; the mercurial column in general (....................) when a storm approaches and (....................) as the (....................) recedes.

42. The barometer is usually equipped with a scale about (....................) inches long, the 30-inch mark being attached to the brass tube just (..................) inches (................) the (....................) point.

43. The height of the barometer above mean (................) level should be ascertained as soon as the instrument is erected by means of suitable (..................) to the (..................) correct (....................) mark.

Directions to the student.

Each of the following questions can be answered by a single word, phrase, or number. Write the answer on the short dotted line.

44. Temperature is usually read and recorded to what part of a degree? ....

45. The scale marks on the standard thermometer are indicated by lines to indicate what? ....

46. When reading a thermometer the scale should be at right angles to what? ....

47. The maximum thermometer is set by doing what? ....

48. The minimum thermometer is set by doing what to the bulb? ....

49. The flat metal tube of the thermograph is usually filled with what? ....

50. The cylinder of the thermograph revolves once in how often? ....

51. The horizontal lines on a thermograph sheet represent what?

----

52. The vertical lines on a thermograph sheet represent what?

----

53. When making a check on observation it should be noted that the minimum must be at least as low as what?

----

54. When the minimum is higher than the maximum the most probable explanation is that the readings have been accidentally what? --------------------

55. The mercury in the tube of a barometer rises and falls principally because it is acted upon by what? --------------------

56. When should the door of the barometer case be kept closed?

----

57. The small barometer which does not record, but which merely indicates by a small pointer, is called what? --------------------

58. What is the name of the curved top of the column of mercury?

----

59. The verniers used on barometers in the Signal Corps are designed so that 25 divisions on the vernier are equal to how many on the scale? --------------------

60. On a Signal Corps barometer a vernier division is what part of an inch smaller than a scale division? --------------------

61. When reading a barometer, the attached thermometer is read to what part of a degree? --------------------

62. A mercurial barometer is usually read to what part of an inch? --------------------

63. A barograph is read to what fraction of an inch?

----

64. A column of mercury with a cross section of 1 square inch and 30 inches high weighs about how many pounds?

Directions to the student.

Below are a number of statements, and just to the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a *plus* sign (+) on the line to the right. If what it says is *not true*, put a *minus* sign (−) on the line to the right of the statement.

65. The more humid parts of the United States are the eastern slope of the Coast Range and a belt about 100 miles wide in the plateau region. ------

66. By absolute humidity is meant the actual volume of water vapor for a certain volume of air. ------

67. Absolute humidity may be expressed by giving the amount of moisture in the air in terms of the pressure which it exerts. ------

68. The muslin wrapping of the wet bulb should be carefully changed before every observation. ------

69. The reading of the dry bulb gives the current temperature of the air. ------

70. In taking the temperature with the wet bulb, the instrument should be whirled until the mercury ceases to fall. ------

71. The sensitivity of the hygrograph depends upon the hygroscopic character of an important part of the mechanism. ------

72. The reading recorded by the hygrograph is absolute humidity, in per cent. ------

73. There is an essential difference between the record sheet of the hygrograph and that of the thermograph and barograph; namely, that it is changed every 24 hours. ------

74. In measuring humidity by means of whirling the wet and dry bulbs, the instrument should be whirled while the observer stands in the shade. ------

75. The science of measuring the humidity of the air is called hygrometry. ------

76. In the Signal Corps the humidity of the free air is usually measured. ------

77. The third factor which controls humidity, in addition to a source of water vapor and temperature, is density. ------

78. The gas known as water vapor is a faint blue-green color. ------

79. As compared with air, the proportionate density of water vapor is about four-tenths. ------

80. Absolute humidity is expressed by stating the weight of water vapor in grams per cubic meter. ------

81. When a certain space is saturated with moisture it is said to have zero per cent humidity. ------

82. The combination of a wet with a dry bulb thermometer is called a cyclometer. ------

83. The name of the instrument which makes a record of the changes in humidity is the thermograph. ------

84. When the amount of humidity is compared with saturated air as a standard, it is called absolute humidity. ------

85. Air in motion near the earth's surface and parallel with it is called a current. ------

86. Air movements in a vertical direction are called winds. ------

87. In the Signal Corps measurements of the horizontal motions of air are the only ones recorded. ------

88. A difference in temperature is a primary cause of motions of the air. ------

89. Another name for a wind vane is anemometer. ......

90. If the wind blows from a semi-cardinal point the arrow of the vane will bisect the angle formed by the direction arms. ......

91. When the wind direction fluctuates rapidly the mean is taken as the true direction. ......

92. Attached to the Robinson anemometer are two dial wheels, the lower one of which has 99 teeth. ......

93. In the above instrument, 1 mile of wind must pass the station in order that one dial may move one scale division in reference to the other. ......

94. The name of the instrument that measures the velocity of wind is the heliometer. ......

95. When judging the direction of the wind by means of the wet-finger test, the finger on the side toward which the wind is blowing will feel the warmer if it is a south wind. ......

96. With reference to the direction of the wind, the arrow of the weather vane points into the wind. ......

97. The vertical lines on the quadruple register record are five minutes apart. ......

98. If the instrument indicates that in a given five-minute period 3.1 miles of wind have passed the station, then the rate in miles per hour will be 37.2. ......

99. The upper dial of the Dines anemometer has nine pins set in its outer edge. ......

100. A quadruple register record sheet is used in connection with this device, the vertical lines of which are 10 minutes apart. ......

101. The eighth and ninth pins in the upper dial of the Dines anemometer are connected. ......

Directions to the student.

Below are a number of questions and unfinished statements. After each question or statement are several words, phrases or numbers each preceded by a number. Only *one* of these answers is correct. Write the number of the correct answer on the dotted line at the right.

102. As air becomes heated it (1) contracts; (2) expands; (3) becomes denser; (4) becomes heavier. ......

103. The direction of the wind is named according to the direction (1) to which it is blowing; (2) from which it is coming; (3) of the bisected angle; (4) the way the arrow points on the map. ......

104. The quadruple register makes what sort of record for the semicardinal points? (1) One dot; (2) two dots; (3) dot and dash; (4) dash, dot, dash. ......

105. The quadrangle register makes what sort of record for the cardinal points? (1) Dash, dot; (2) dot, dot; (3) dot; (4) dot, dash, dash. ------

106. How many wind directions are indicated by the record of the cup anemometer? (1) 0; (2) 16; (3) 8; (4) 4.

107. How many wind directions are indicated by the record of the Dines instrument? (1) 8; (2) 32; (3) 128; (4) all. ------

108. At what intervals are direction records made on the quadruple register? (1) 120 seconds; (2) 90 seconds; (3) 60 seconds; (4) 30 seconds. ------

109. At what intervals is the recording pen in contact with the chart in the direction recorder of the Dines anemobiagraph? (1) Every 10 seconds; (2) every 30 seconds; (3) every 60 seconds; (4) continuously. ------

110. What is the name of the wind measuring device in which the wind is permitted to turn vanes or cups? (1) Twisters; (2) tortographs; (3) rotation ammeters; (4) rotation anemometers.

111. In reading wind velocity on the anemobiagraph the observer reads to which of the following? (1) Nearest 0.1 mile; (2) nearest 1.0 mile; (3) nearest 0.01 mile; (4) nearest 0.5 mile. ------

112. On the revolution counter of the hand anemometer are two hands or pointers. The longer one makes one revolution per how many meters? (1) 1.0; (2) 10.0; (3) 100.0; (4) 1,000.0. ------

113. When the longer hand or pointer has gone around 1,000 times, how many times has the shorter one gone around? (1) 10; (2) 100; (3) 10,000; (4) 100,000. ------

Directions to the student.

Each of the following questions can be answered by a single word, phrase, or number. Write the answer on the short dotted line.

114. Snow is measured in two ways: The water equivalent is obtained, or else we measure what? ------------------

115. To what degree of exactness is this second measurement made? ------------------

116. In estimating the water equivalent of snow, what is a fair average number of inches of snow for 1 of rain? ------------------

117. Of what sort of layers is the individual hailstone formed?

----

118. Hail always occurs in connection with what?

----

119. What name is applied to precipitation in the form of frozen drops of rain? ------------------

120. What is another name sometimes used for a "sleet storm"?

----

121. Under what conditions must rain or snow fall in order for the observer to be sure that the measurement obtained in a gauge is quite accurate? --------------------

122. Snow is usually formed by condensation at a temperature slightly above what temperature Fahrenheit? --------------------

123. The smallest snow unit is the crystal, which is always formed upon what pattern? --------------------

124. A cloud particle or a raindrop is about what fraction of an inch in diameter? --------------------

125. All forms of precipitation are referred to what as a standard? --------------------

126. In a rain gauge, the smaller tube has a cross section of what, in proportion to the opening of the can? --------------------

127. The height of the water in the small tube will be what fraction of the actual amount of rain which falls? --------------------

128. "No precipitation" is indicated in the record by what symbol? --------------------

129. The inner tube of the rain gauge holds exactly how many inches? --------------------

CLOUDS AND STATE OF THE WEATHER

Equipment.

Pictures of cloud forms according to the international classification. (See illustration at end of unit operation No. 6.)

Information.

Formation of clouds.—Clouds are formed by the cooling of water vapor, which causes the vapor to condense into minute water particles about one one-thousandth to one four-thousandth of an inch in diameter. If this condensation occurs near the surface of the earth the formation is called "fog," if at some elevation it is called "cloud." Therefore, a fog may be considered as a low-lying cloud, and a cloud may be considered as an elevated fog.

Questions.

(1) *How are clouds formed?*

(2) *Why are some clouds white and others varying through all the shades from grayish-white to nearly black?*

Information.

Mist.—Mist is extremely fine rain. One may not be conscious that actual drops of rain are falling when out in a mist, but one's face and clothes become damp. Mist is a condition between fog and very fine drizzle. The expression "misting" is sometimes used to express the condition of mist. Mist is in all respects similar to a fog except that the particles are larger.

Question.

(3) *How is mist formed?*

Information.

Haze.—Haze may be described as that condition of the atmosphere when, owing to dust particles in the air, objects are dimly seen or are completely masked by a veil of gray or yellow, fog being absent.

Description of clouds.—There are four fundamental types of clouds: Cirrus, cumulus, stratus, and nimbus, together with the variations of these, of which the following is a complete list. It will be noted that in the table, as well as in the descriptive paragraphs which follow, the highest clouds come first and the lowest last in order.

Types	Abbreviations	Height in feet		
		Highest	Lowest	Average
Cirrus	Ci	46,000	9,000	28,000
Cirro-Stratus	Ci.-St	42,000	7,000	22,000
Cirro-Cumulus	Ci.-Cu	35,000	7,000	20,000
Alto-Cumulus	A.-Cu	27,000	2,700	12,000
Alto-Stratus	A.-St	36,000	3,800	15,000
Strato-Cumulus	St.-Cu	14,000	1,000	7,000
Nimbus	Nb	18,000	200	3,600
Cumulus	Cu	[1] 15,000 [2] 12,000	[1] 2,400 [2] 1,600	[1] 6,000 [2] 4,400
Cumulus-Nimbus	Cu.-Nb	8,000	600	4,400
Stratus	St	6,000	400	2,100

[1] Top. [2] Bottom.

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To become skillful in identifying the various cloud types one must study the sky carefully in connection with the pictures and descriptions of cloud forms. No difficulty will generally be found, but when the observer fails to identify a cloud he should ask someone more familiar with them for advice. Frequently, however, two very good observers may classify a certain cloud differently, because cloud forms merge from one type into another, and there is nearly always a chance for a difference of opinion.

Question.

(4) *Why is it difficult to agree in identifying the various kinds of clouds?*

Information.

Cirrus.—This is the highest cloud observed. It is composed of wisps of curls resembling hairy streamers, or wavy sprays, or clotted masses. It assumes the greatest variety of shapes. This type is transparent, the blue sky being seen as through a veil. There is a lower cloud which resembles the cirrus and is called "false cirrus." It is simply shreds of cumulus combed out by the wind.

Cirro-stratus.—This type is a sheet of cloud, milk-white to light gray in appearance. Like the cirrus, it has a fibrous structure and may be transparent. It causes halos around the sun and moon.

Cirro-cumulus.—This type consists of balls of clouds arranged in groups or rows which are semitransparent. The term "mackerel sky" has been frequently applied to the cirro-cumulus formation.

Alto-cumulus.—This consists of balls of fleecy clouds larger than the cirro-cumulus and varying in shade from white to gray The balls of clouds are frequently in groups and rows.

Alto-stratus.—This is a cloud veil thicker and therefore less transparent than the cirro-stratus, which it resembles somewhat. It is grayish in color, and the sun and moon may be seen faintly through it.

Strato-cumulus.—This consists of large balls or rolls of dark clouds, flat at the base, and at times covering nearly the entire sky.

Nimbus.—This is the name ascribed to all clouds from which rain is falling. It is a thick, formless cloud and is widely extended; when a break occurs an upper cloud area is usually disclosed.

Cumulus.—This is probably the best-known cloud to the layman. It consists of a dense detached cloud with a dome-like head and flat base. Where the sun shines upon it the shade is white, but in the unilluminated portions all shades of gray may be seen. The best-developed specimens of this type of cloud can be seen during the afternoons of summer.

Cumulo-nimbus.—This is the name applied to a thundercloud It is very thick, the top resembling an anvil, and the lower portion formless, from which rain is falling.

Stratus.—This is a low-lying sheet of structureless cloud of uniform thickness. It is permissible, where observations are taken when it is dark, to call the clouds "stratus" if their type can not be ascertained.

Question.

(5) *Are all clouds nearly the same distance from the earth?*

Information.

Observation of clouds.—The observation of clouds includes three elements, namely, amount, kind, and direction. The kinds of clouds have just been discussed. The amount of clouds is given on a scale of 10, 10 being the measure of all the canopy visible to the observer. If no clouds are visible, the amount is recorded as zero; if less than one-tenth, record few; if five-tenths is obscured, record 5; and if the entire canopy is obscured the amount will be 10.

To observe direction, the observer places himself so that his eye is on the line of sight of some particular point of a cloud and a stationary object on the ground. Standing firmly, the observer carefully notes from what direction the cloud is moving and the record is made for the cardinal and semicardinal points; that is, north, northeast, east, southeast, south, etc. If no direction can be observed, the direction will be recorded as zero, which means that a calm prevails where the cloud is. If there is doubt as to any of the elements, amount, kind, or direction, then a question mark will be placed after the questionable record. On most occasions there will be more than one kind of cloud. The observer should pick the two kinds which prevail in greatest amounts, recording the upper clouds first and lower clouds second.

State of the weather.—The state of the weather is the condition of the sky and is determined according to the amount of cloudiness or to the character of precipitation occurring at the time of the observation. The weather is said to be "clear" when three-tenths or less of the sky is covered with clouds; "partly cloudy" when from four to seven-tenths, inclusive, is covered; and "cloudy" when from eight to ten-tenths, inclusive, is covered. Other states of the weather are "misting," "sprinkling," "light rain," "heavy rain," "light snow," "heavy snow," "sleeting," "hailing," "threatening," and "clearing." When a light fog, light haze, or light smoke is observed and no clouds, then the weather will be recorded as clear. But the fact that there is a light fog, light haze, or light smoke will be recorded. When the sky can not be seen due to haze, fog, or smoke, the weather will be recorded as "hazy," "foggy," or "smoky."

When fog and smoke are observed, the direction from which they are blowing should be recorded; if no movement is perceptible, then zero should be recorded in the space for direction.

A dense fog, smoke, or haze is a condition when an object the size of a man can not be seen 1,000 feet away. The direction of motion of haze will not be recorded.

When a thunderstorm is prevailing at the moment of observation, or the rain is still falling, and thunder has been heard or lightning seen within the hour previous to the observation, the international symbol for thunderstorm will be entered after "state of weather." This symbol is ☈.

Directions.

1. Take an ordinary sheet of letter paper and mark the following divisions:

No.	Cloud observations			State of weather				
	Amount	Kind	Direction	Clear	Partly cloudy	Cloudy	Light rain	Light snow
Example 1	10	Cu-nb.	N.				√	
2								
3								
4								

2. On four successive days, when ordinarily different cloud conditions can be seen and observations can be made on the state of the weather, take observations, using the above form. For example, in the first observation: Suppose the entire canopy is obscured. Enter "10" in column headed "Amount." If it is noted that the cloud is very thick, resembling an anvil, this checks with the description of a cumulo-nimbus cloud, therefore enter this description in the column marked "Kind." To observe the direction, assume a position where the eye may be on a line of sight with some particular point of a cloud and a stationary object. Observe the direction in which the cloud is traveling; that is, north, south, etc. Assume in this example that it is traveling south. Enter N., therefore, in the column headed "Direction." Now assume that a light rain is falling. This is one of the classifications under state of weather. Place a check mark under column headed "Light rain."

3. Continue these observations on four different days until the four listed have been completed.

4. The instructor will place on the blackboard a circle 3 feet in diameter, to represent the visible canopy. This circle should be segmented geometrically. Estimate the proportions of certain geometric areas or segments as tenths of the whole circle.

a. As soon as the students have become proficient in estimating the proportions of the circle in tenths, the instructor will draw irregular areas within the circle and the student will continue to drill in estimating the areas of the irregular portions. These irregular portions will represent the clouds.

Questions.

(6) *When a light fog is observed and no clouds, how is the weather recorded?*

(7) *Can haze have directions?*

(8) *Which is the easiest type of cloud to recognize? Describe it.*

(9) *What three elements are recorded in taking cloud observations?*

(10) *What is the state of weather recorded as clear; partly cloudy; cloudy?*

(11) *What should be recorded when no direction in a cloud is observed?*

(12) *Is the white cloud observed at the spout of a boiling teakettle anything like fog or cloud?*

(13) *What is the conventional sign for a thunderstorm?*

(14) *What is meant by the "canopy"?*

(15) *What is meant by "segmented geometrically"?*

ILLUSTRATIONS OF CLOUD FORMATIONS

(FIG. 43)

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Mount Weather, Va. A. J. Weed.

Fig. 43–1.—Cirrus becoming detached from thunderstorm top

Tortosa, Spain. Ebro Observatory

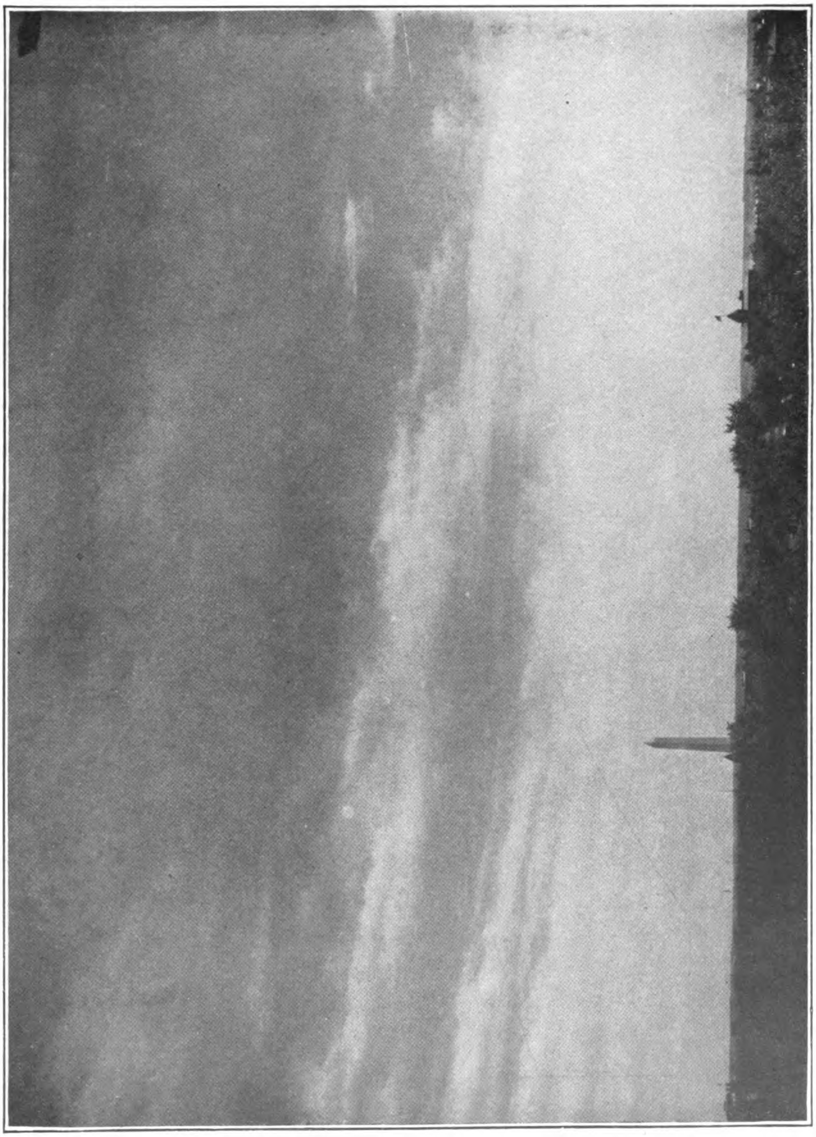
Fig. 43–2.—Dense, bunched cirrus, probably of thunderstorm origin

Mount Wilson, Calif. F. Ellerman.

Fig. 43–3.—Tufted cirrus, similar to (2) but thinner

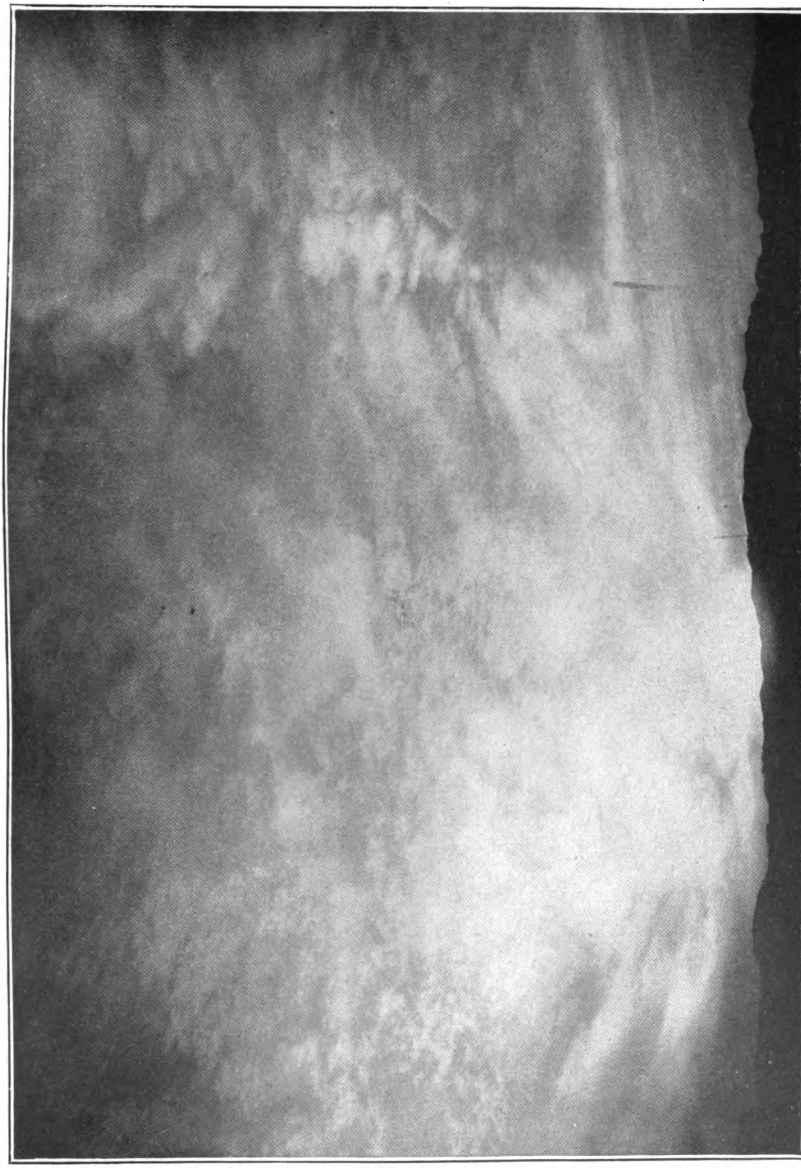
Orient, Long Island, N. Y. W. S. Davis.

Fig. 43–4.—Cirro-stratus and fibrous alto-stratus such as originate from thunderstorm tops



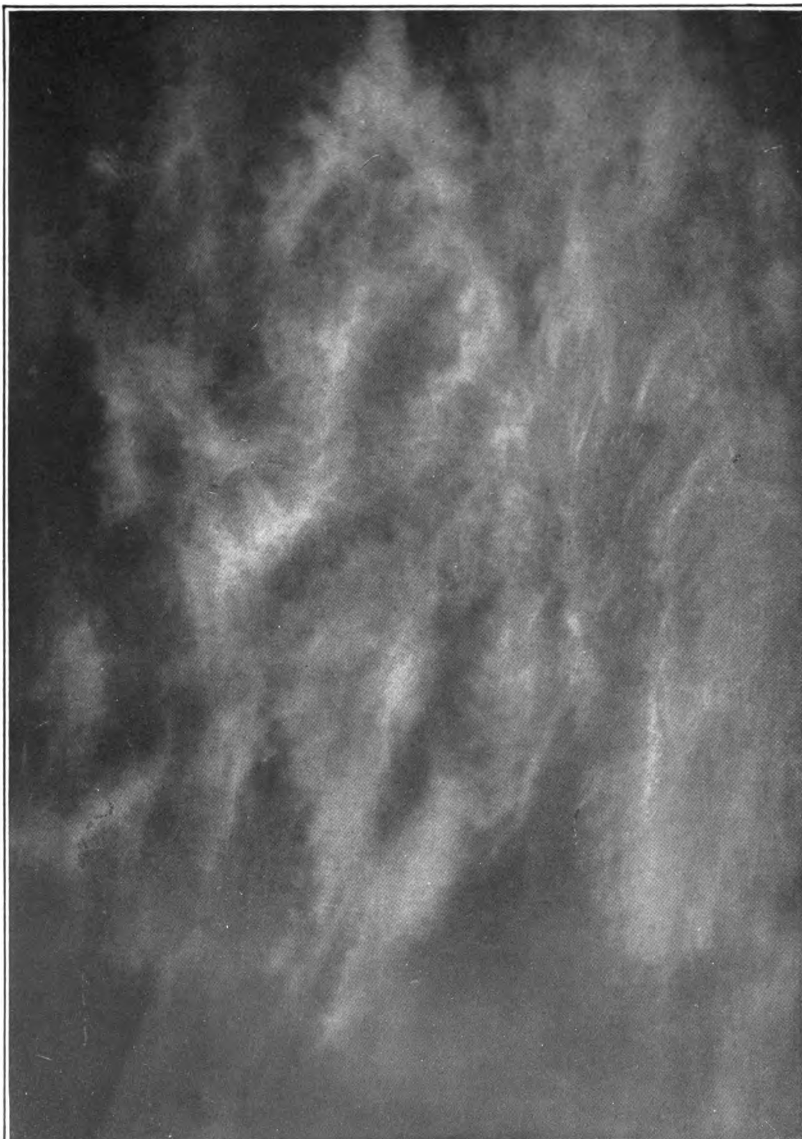
Washington, D. C. A. J. Henry

Fig. 43-5.—Cirrus merging into cirro-stratus



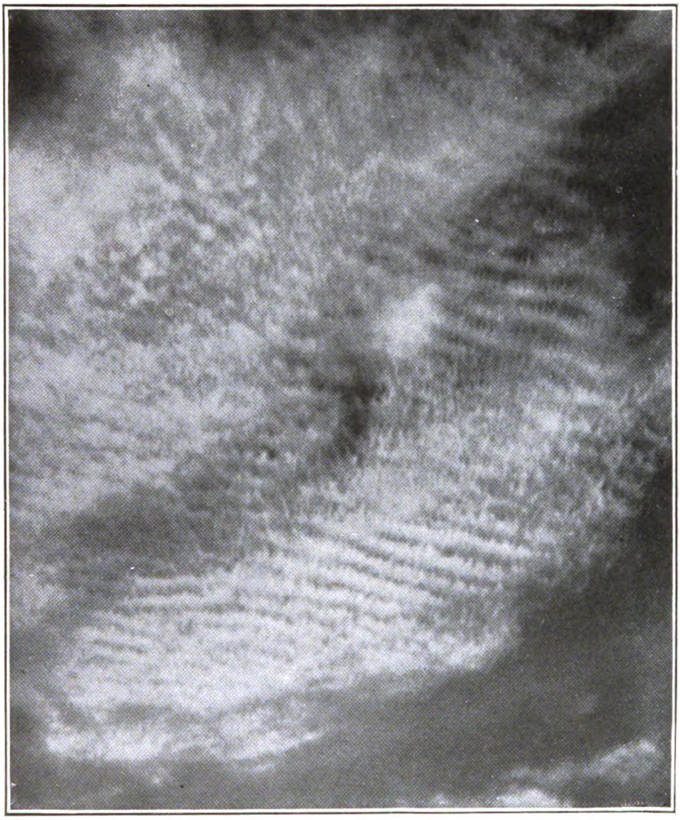
Tortosa, Spain. Ebro Observatory

Fig. 43–6.—Cirro-stratus and alto-stratus, with cirro-cumulus and alto-cumulus tops, characteristic of overflow from intense cyclones. The shadowy parts are alto-stratus, and the larger rounded tops, alto-cumulus



Atlas photographique des nuages. J. Loisel.

Fig. 43–7.—Cirrus (the detached portions) and cirro-stratus, from evaporation of such clouds as (6)



Mount Wilson, Calif. E. E. Barnard.

Fig. 43-8.—Cirro-cumulus, overhead

Mount Wilson, Calif. F. Ellerman.

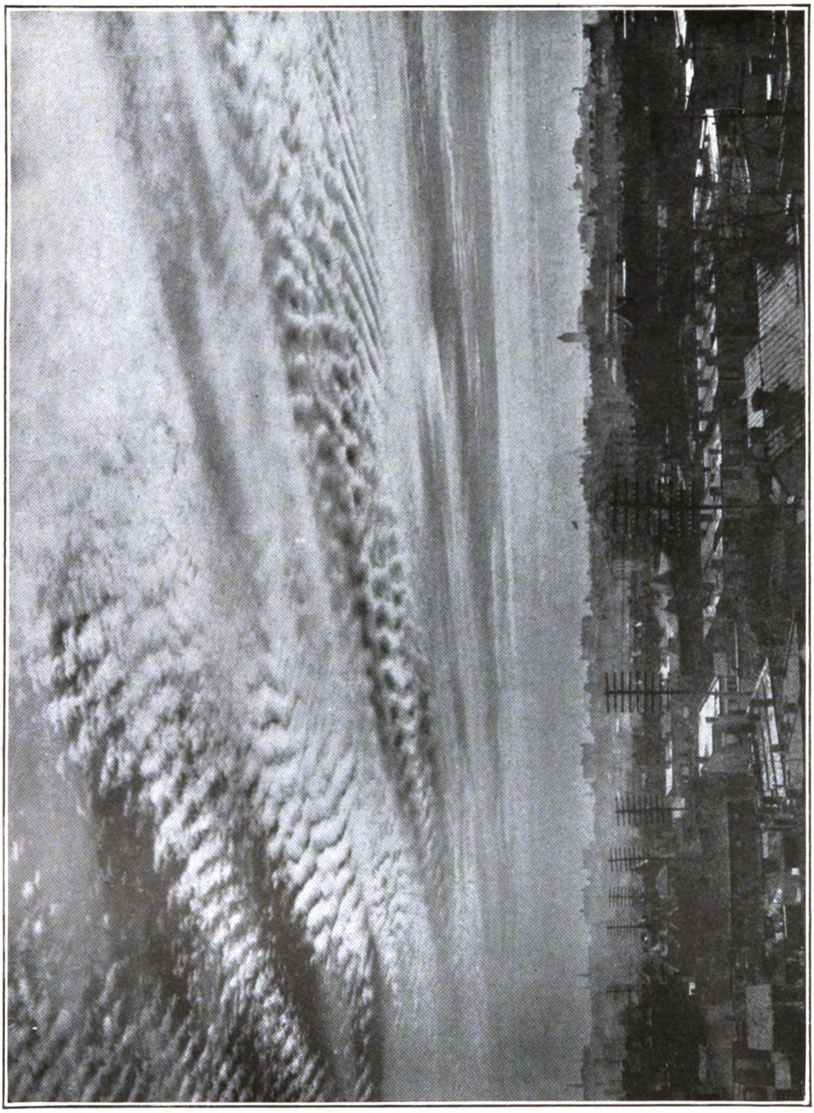
Fig. 43–9.—Cirro-cumulus, with tufted cirrus

Mount Wilson, Calif. F. Ellerman.

Fig. 43–10.—Thin, undulated alto-stratus forming above a layer of fog or stratus. (Such thin A.-St. is distinguishable from Ci.-St. by its grayness, or, if near the sun or moon, by its diffraction colors, e. g., corona, iridescence)

Tortosa, Spain. Ebro Observatory.

Fig. 43–11.—Thin alto-stratus (lower right) transforming to growing alto-cumulus, which becomes merged into dense alto-stratus (lower left). Compare small A.-Cu. with Ci.-Cu. in (8) and (9)

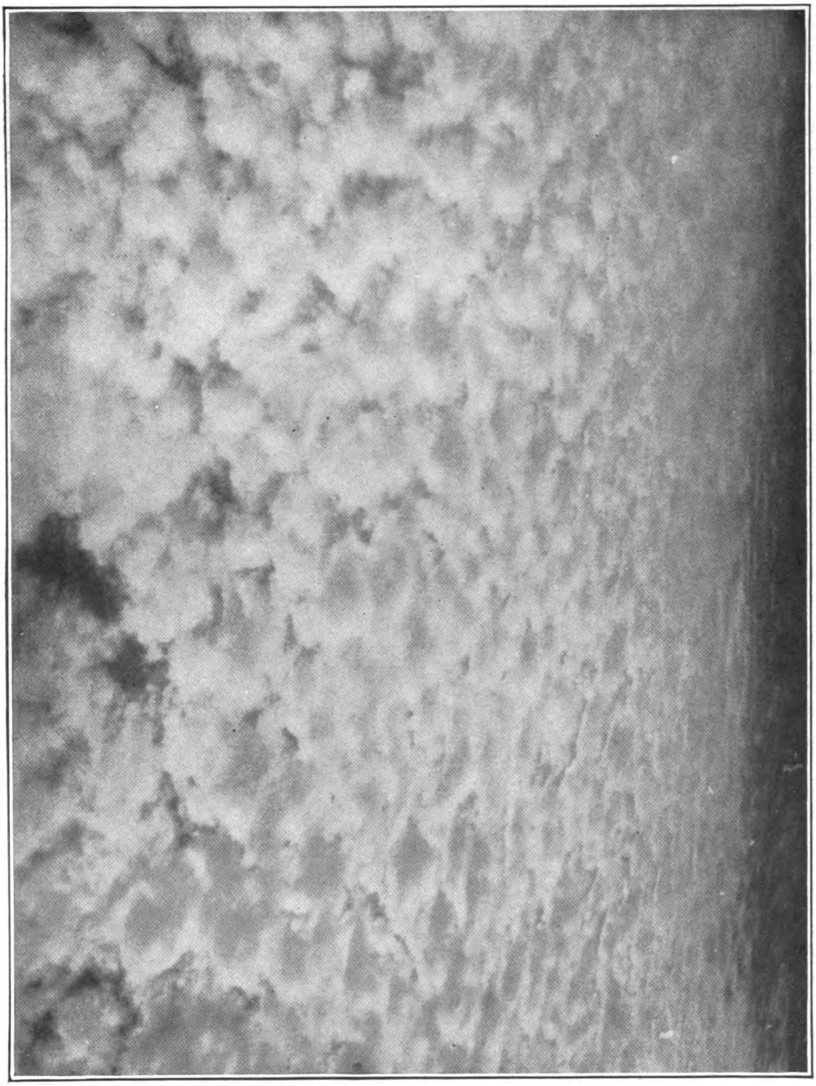


Washington, D. C. A. J. Henry.

Fig. 43–12.—Undulated alto-cumulus, locally more or less scaly

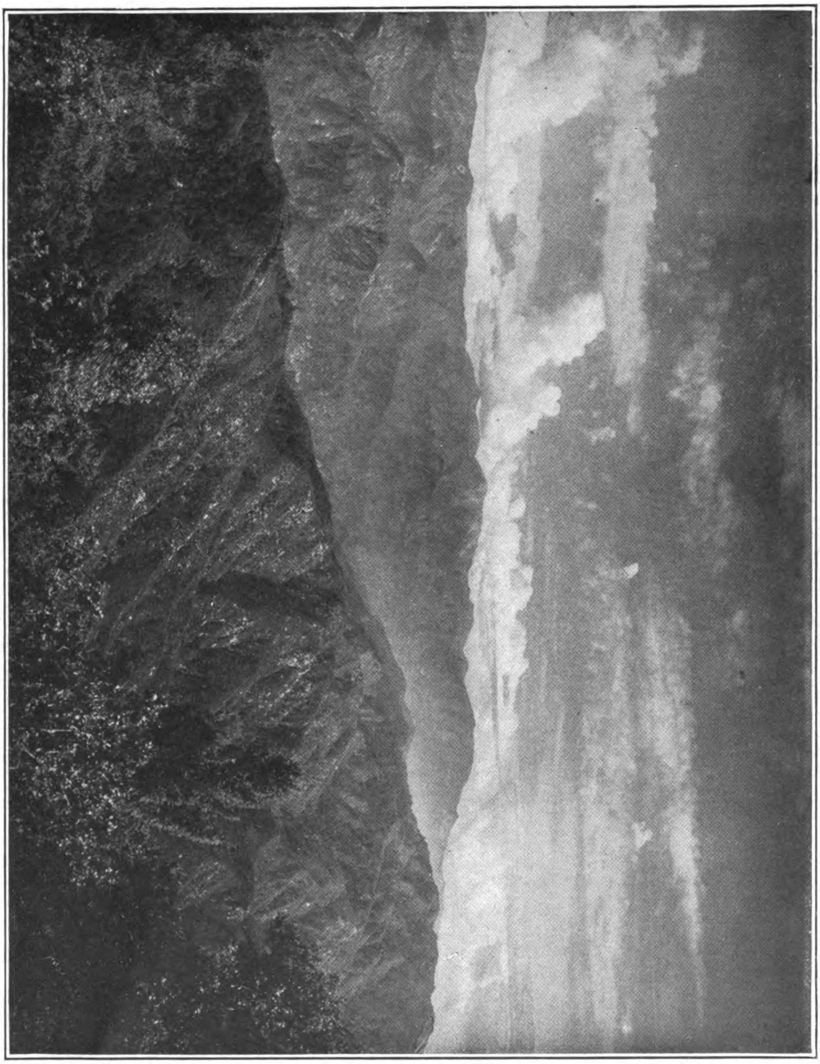
England. Wilson-Barker.

Fig. 43–13.—Small alto-cumulus (note shadows; compare (8) and (9)). (Even if there are no shadows, the presence of coronas or iridescent colors near the sun or moon distinguish such small A.-Cu. from Ci.-Cu.)



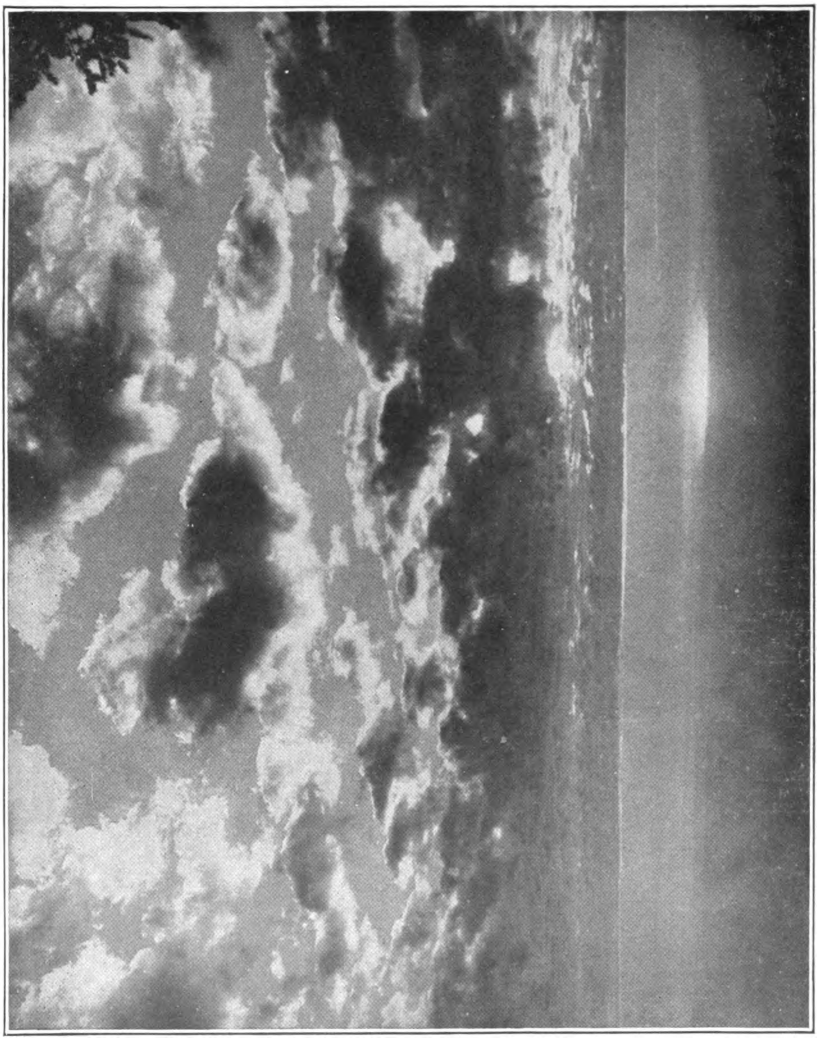
Mount Weather, Va. A. J. Weed.

Fig. 43–14.—Alto-cumulus, somewhat ragged



Mount Wilson, Calif. F. Ellerman.

Fig. 43–15.—Turreted alto-cumulus. Tall cumulus below. (Turreted A.-Cu. usually grow up from a base of thin, usually undulated A.-St.)



Mount Wilson, Calif. F. Ellerman.

Fig. 43–16.—Strato-cumulus or alto-cumulus, photographed from an altitude of about 1,750 meters. These same clouds would be called strato-cumulus by an observer nearer to them and alto-cumulus by an observer farther from them (as at sea level)

Tortosa, Spain. Ebro Observatory.

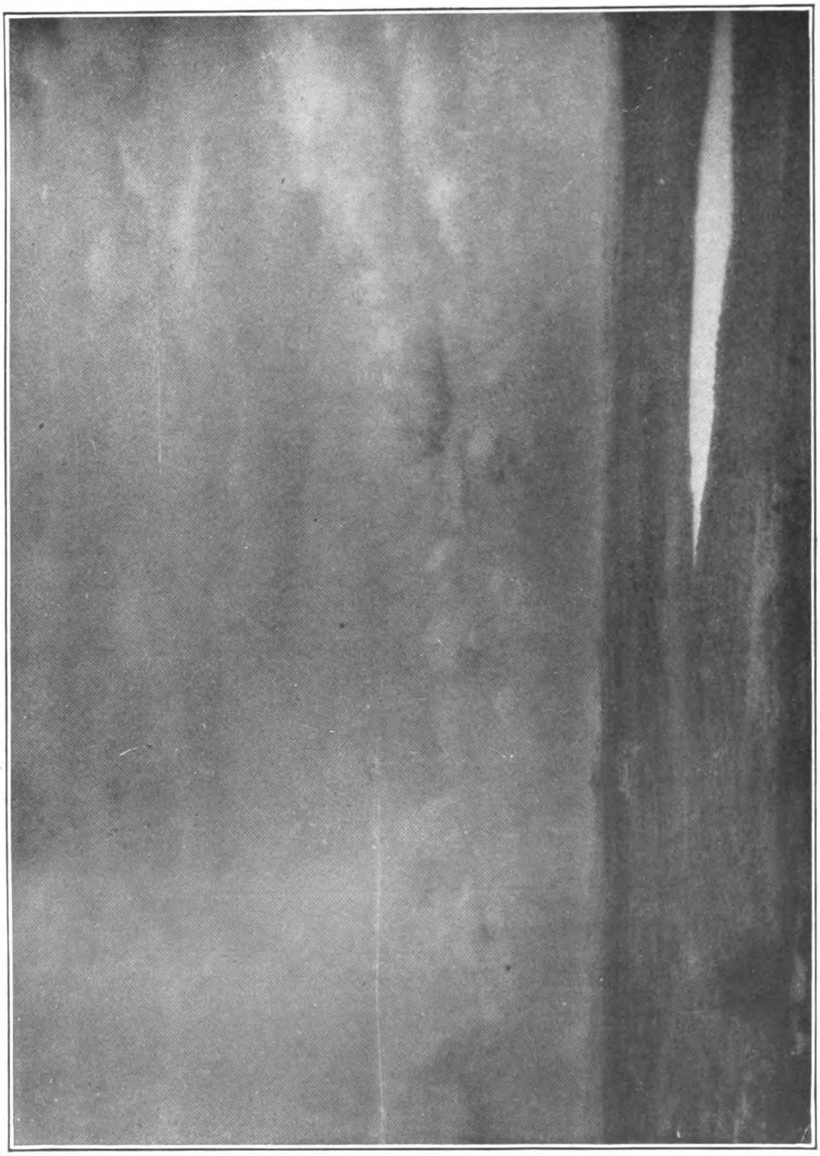
Fig. 43-17.—Ragged strato-cumulus rolls below fibrous alto-stratus. Characteristic of breaking clouds in the rear of a cyclone

Orient, Long Island, N. Y. W. S. Davis.

Fig. 43–18.—Strato-cumulus rolls, with strong east wind at surface. (Taken looking south)

Payne Field, Miss. P. W. Etkes.

Fig. 43–19.—Ragged strato-cumulus rolls at 800 meters altitude in NW. wind in winter. Inset: Same clouds viewed from height of 1,100 meters

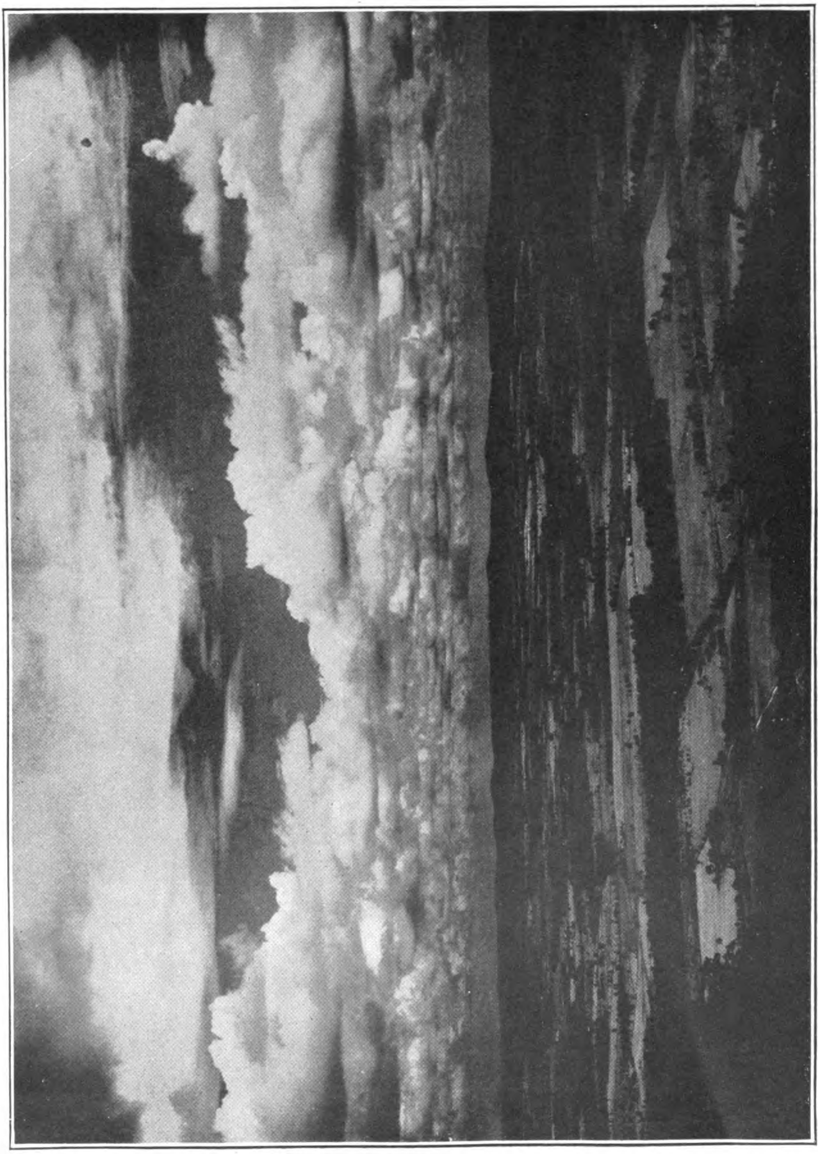


Blue Hill, Mass. C. F. Brooks.

Fig. 43–20.—Strato-cumulus or alto-stratus sheet, slightly mammilated, fed by overflow from local strato-cumulus below. Characteristic of moderate N. to NE. wind in autumn

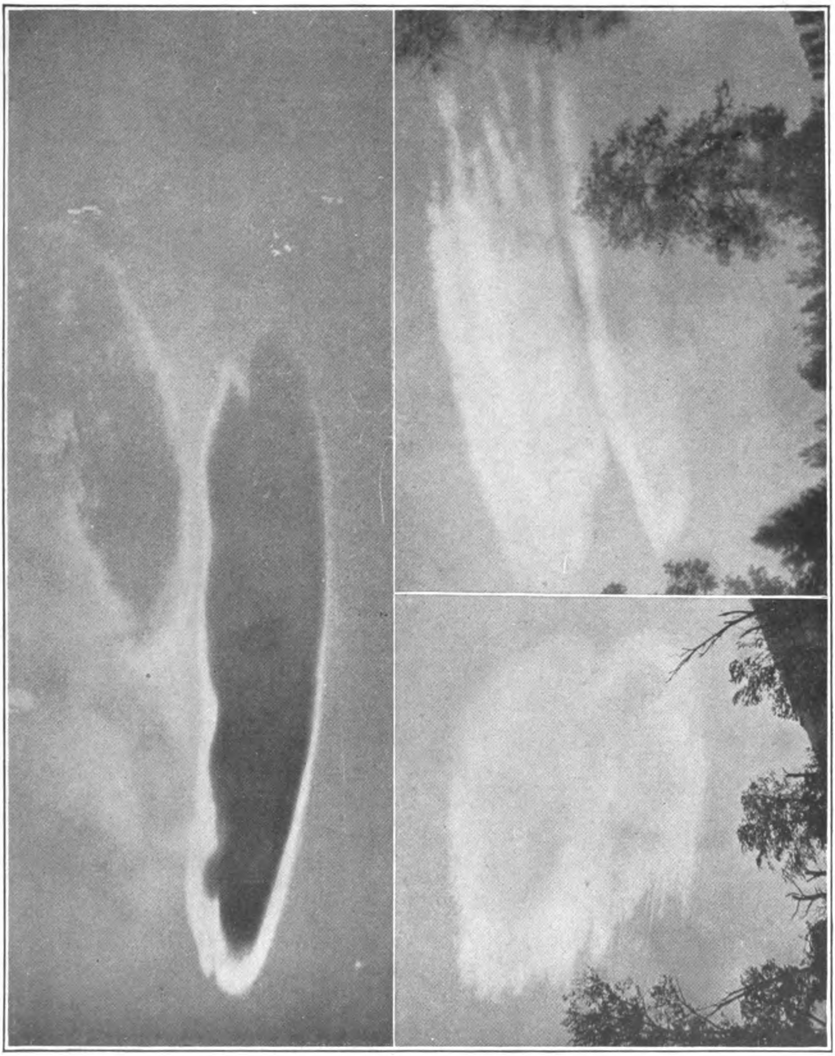
Park Field, Tenn.

Fig. 43–21.—Strato-cumulus, evaporating scaly type. (Such clouds evolve in the process of evaporation of sheets like those in (19) and (20).) (Note two airplanes)



Mount Weather, Va. A. J. Weed.

Fig. 43-22.—Cumulus and strato-cumulus below, thin alto-stratus above

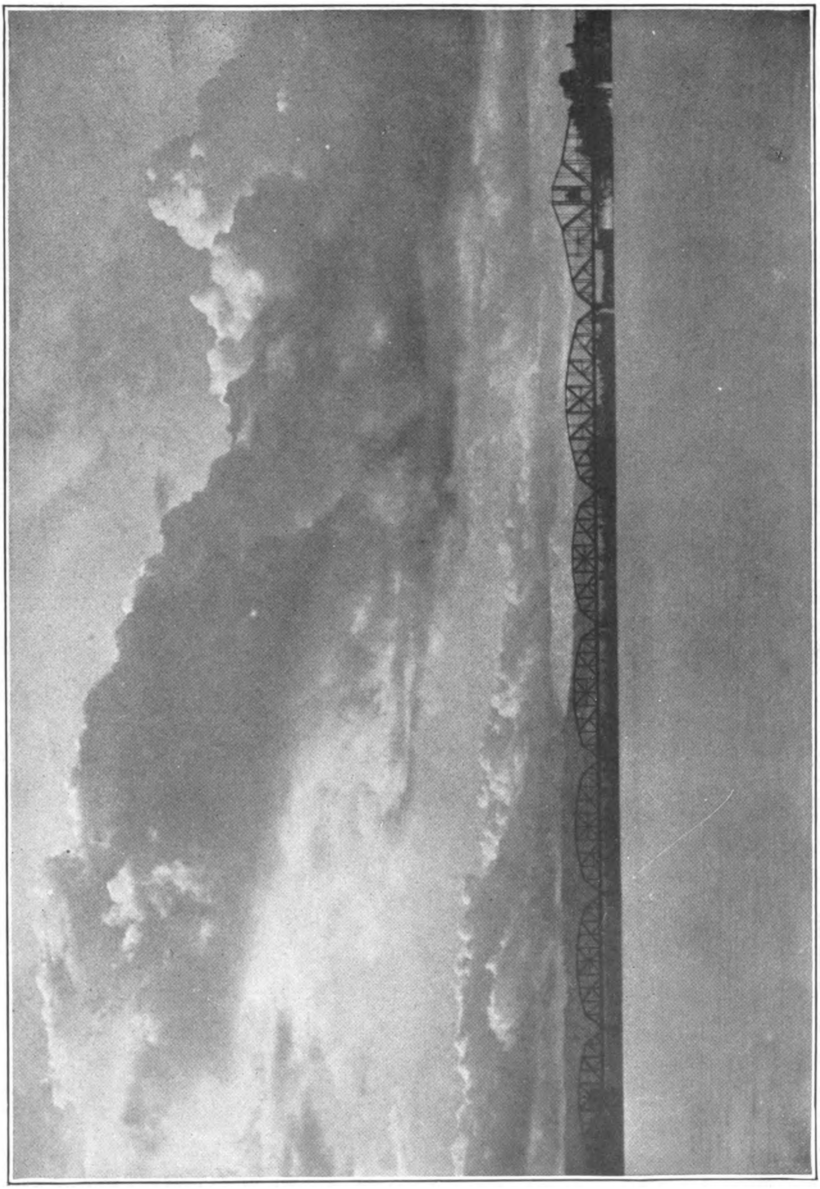


Blue Hill, Mass.; Glen Ellis Falls, N. H. (First two) C. F. Brooks.

Fig. 43–23.—Lenticular alto-stratus: Upper, standing clouds topping south wind; lower left, standing cloud in lee of Mount Washington during NW. gale; lower right, conditions unknown

Topeka, Kans. W. M. Lyon.

Fig. 43-24.—Cumulus

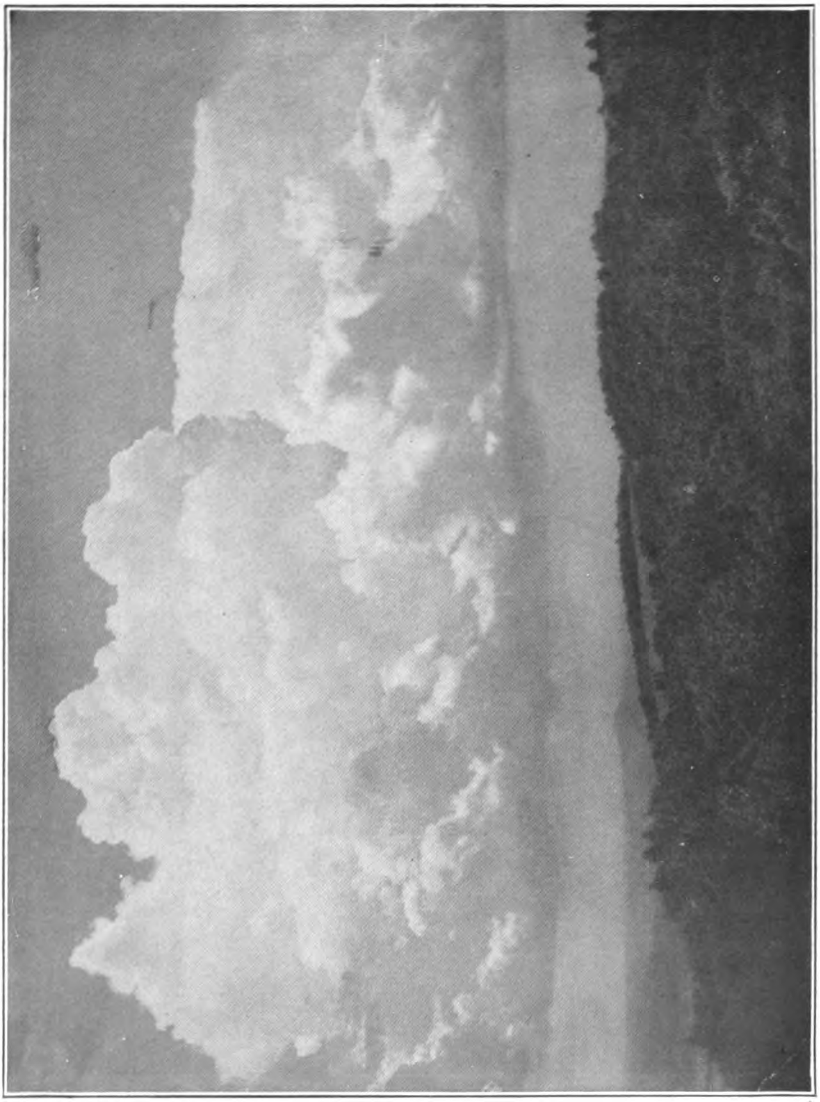


Over Columbia River near Portland, Oreg. C. A. Gilchrist.

Fig. 43–25.—Cumulus rolls. (Such clouds when they mark the front of an arriving wedge of cool air may develop thunderstorms locally)

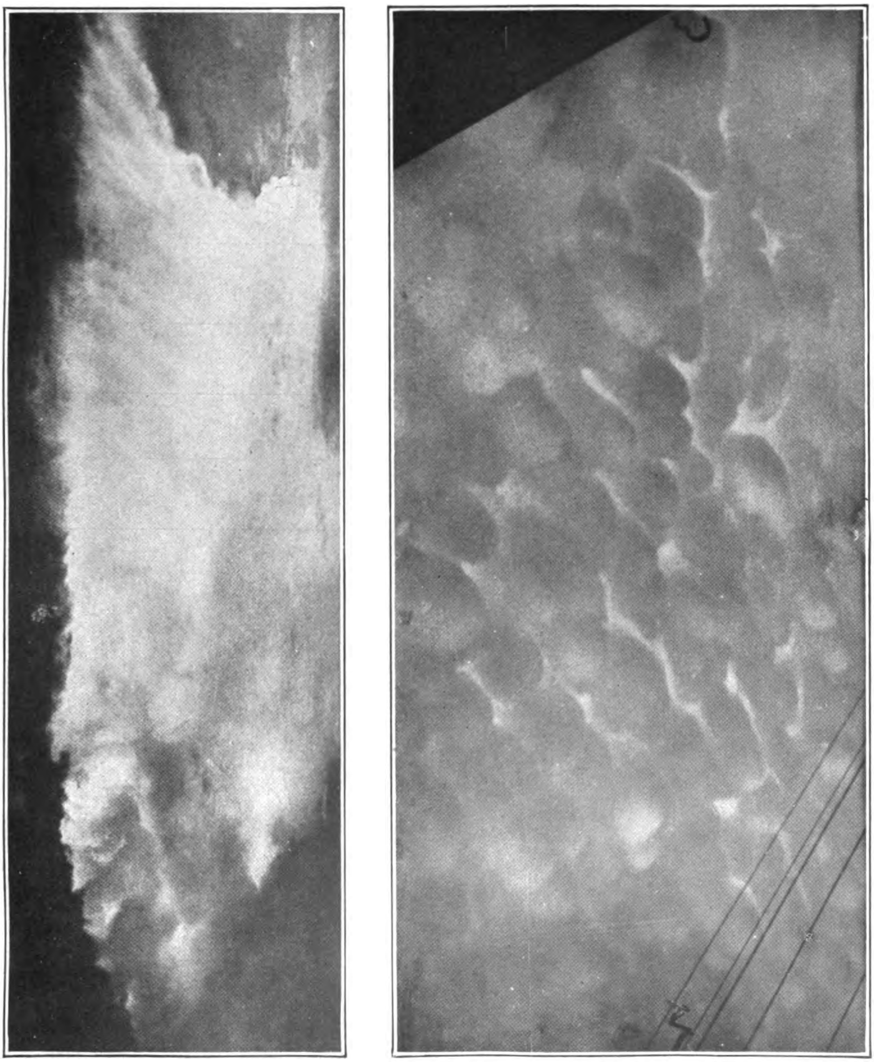
Mount Wilson, Calif. F. Ellerman.

Fig. 43–26.—Cumulo-nimbus, just grown from cumulus. Note the start of streaks of falling snow (cirrus) from portions of the top on right



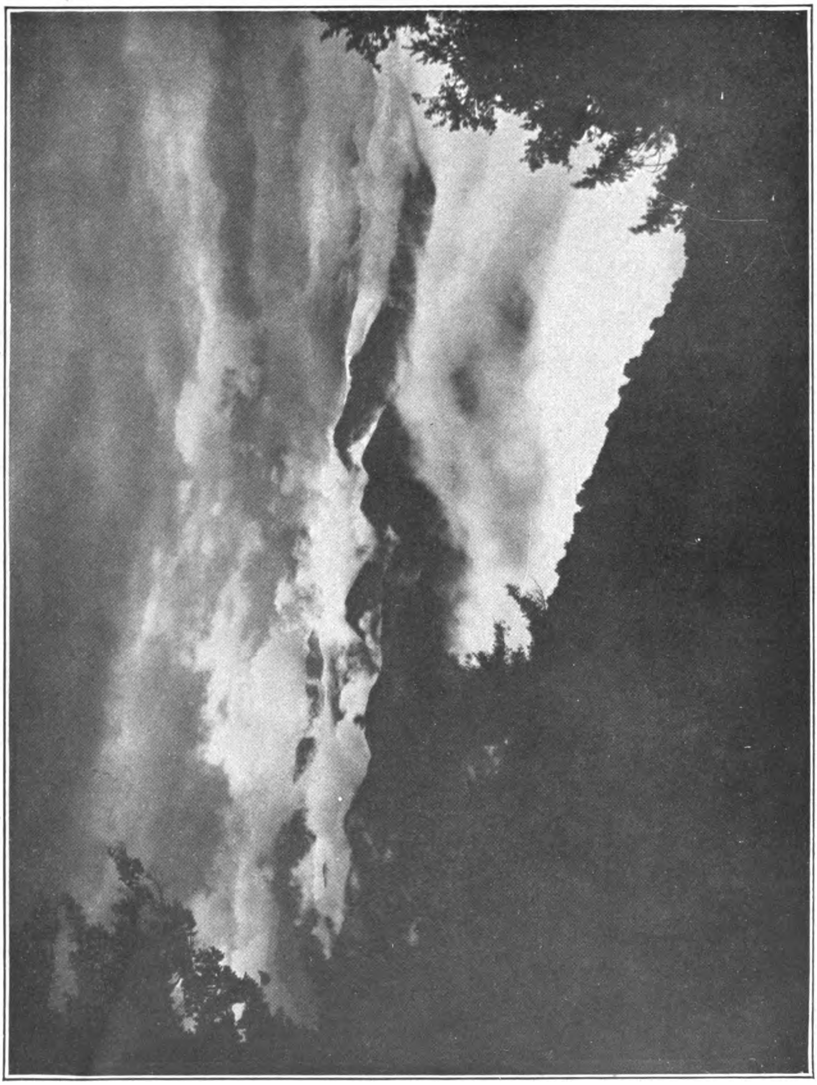
Mount Weather, Va. A. J. Weed.

Fig. 43–27.—Low cumulo-nimbus, and cumulus, characteristic of spring



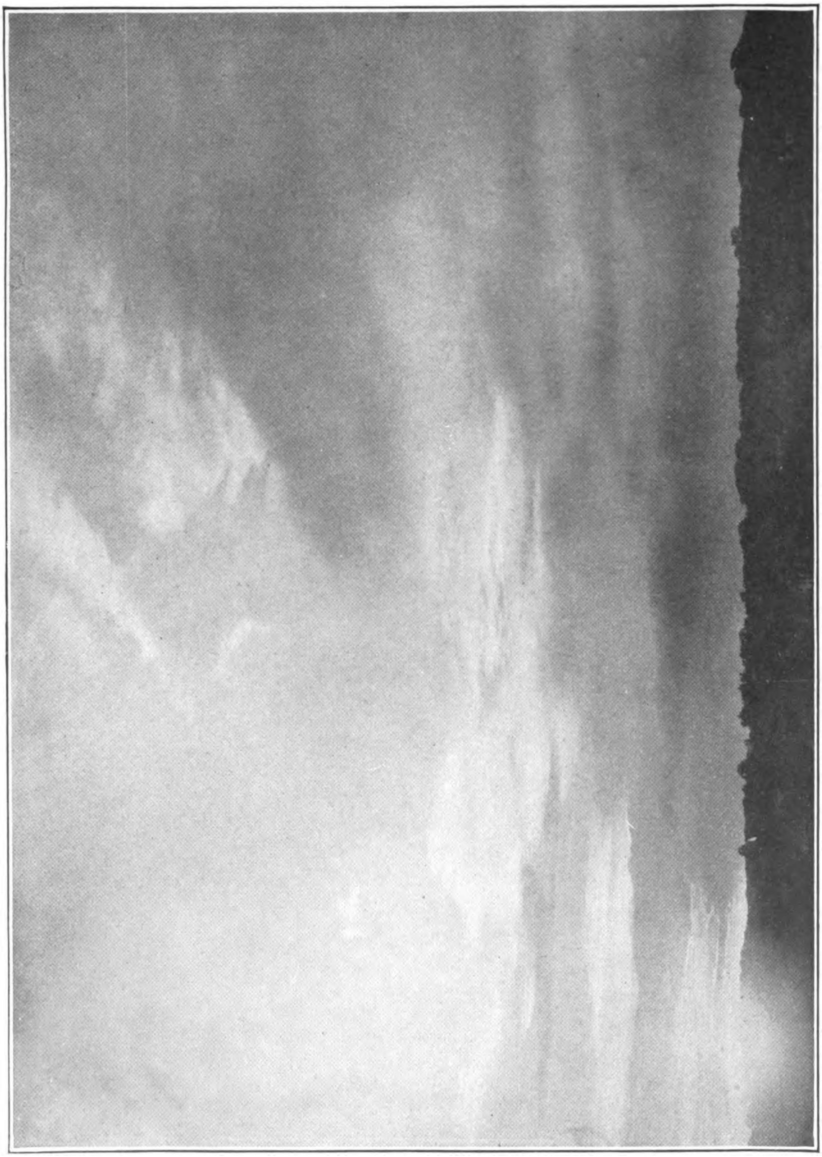
Atlas photographique des nuages. J. Loisel. Bartlesville, Okla. L. C. Twiford.

Fig. 43–28.—Anvil top of cumulo-nimbus (upper). Mammato-alto stratus on underside of cumulo-nimbus overflow in vicinity of tornado (lower)



Mount Wilson, Calif. F. Ellerman.

Fig. 43–29.—Nimbus, with fog or stratus below



Mount Weather, Va. A. J. Henry.

Fig. 43–30.—Fracto-stratus (right), under alto-stratus and cirro-stratus, apparently from local thunderstorms

Mount Weather, Va. A. J. Weed.

Fig. 43–31.—Stratus clouds at two levels; one practically on the ground

SUGGESTIONS FOR THE INSTRUCTOR

(1) Practice in naming types of clouds and their amounts should be continued throughout the course.

(2) The circumstances which will cause the greatest amount of uncertainty in the instruction in cloud forms is the naming of a cloud which is in a state of transition from one basic form to that of another. The student must be taught to use his judgment in classifying the change in form to some basic form.

(3) The instructor should encourage the students to discuss with one another the various types of clouds seen in the sky and their amounts, while going to and from the class room and on their daily walks. There can be no better instruction than this, as it facilitates the accuracy of judgment. The differences in judgment should be brought to the instructor, and he will determine for the class under which type the disputed cloud form should be designated.

(4) For the purpose of simplifying a regular observation, the observers should point out and record only three kinds of clouds which prevail in the greatest amounts.

(5) The following instruction test is furnished the instructor. The procedure of administering it and the general form is the same as that in previous unit operations.

INSTRUCTION TEST NO. 6

PART I.—PERFORMANCE

PROBLEM No. 1

CLASSIFICATION OF CLOUDS

Equipment.

Pencils.

Blank forms as shown on page 4 of this unit operation.

Directions to the student.

(1) Go immediately outside and view the sky.

(2) Mark down upon the blank form provided the amount, kind, and direction of as many different kinds of cloud formations as are prevailing at the time.

(3) Do this as quickly as possible and report to the instructor when you have finished.

Method of scoring.

(1) It is extremely difficult to score a problem such as this, due to the fact that no standard has yet been devised for measuring the student's ability in estimating cloud forms, amount, and direction. It is suggested that the instructor use as a standard the average conditions of the sky as recorded by the class. These data are also to include the observation as taken by the instructor himself.

(2) Credit the student with 5 points if his record is within 20 per cent of the average of the class. The instructor's observation should be included in the average and constitutes 70 per cent. The record should be scored on a basis of direction, amount, and forms of clouds.

PART II.—INFORMATION

Method of administering Part II is in general identical with that in previous unit operations.

Ten minutes will be allowed for Part II of this test.

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully, and if what it says is *true*, make a plus sign (+) on the line to the right If what it says is *not true*, put a minus sign (−) on the line to the right of the statement.

1. Fog is similar in nature to a cloud. ------
2. A cloud is formed by a number of hollow vesicles of water. ------
3. Haze is said to move with the surface wind. ------
4. Mist does not obscure the vision. ------
5. Fog and snow can have no direction. ------
6. Rain falls from nimbus clouds. ------
7. Cirro-cumulus and cumulus clouds are alike in regard to elevation. ------
8. The sky may be eleven-tenths obscured. ------
9. Steam and clouds are different in structure. ------
10. Hail is not a form of precipitation. ------
11. The highest cloud is called the nimbus. ------
12. The lowest clouds are called the cirrus. ------
13. The state of the weather is the condition of the atmospheric pressure. ------
14. Mist is the condition between fog and very fine drizzle. ------
15. The observation of clouds includes three elements—direction, amount, and kind. ------
16. Direction is observed by the use of a hand anemometer. ------
17. The state of the weather may be recorded as clear, partly cloudy, hazy. ------
18. The alto-stratus cloud differs from a strato-cumulus in that the latter consists of large balls or rolls of dark clouds, flat at the base, while the alto-stratus is grayish in color and the sun and moon may be seen faintly through it. ------
19. The amount of degree of cloudiness is recorded on a scale of twentieths. ------
20. Only one kind of cloud should be recorded at one observation. ------

Directions for scoring Part II.

	Points
1. The maximum possible score for Part II of this test is....	20
2. The minimum score required to pass Part II is............	15

3. *True-false (plus or minus) questions*: Score as directed on page 22.

TO MEASURE VISIBILITY

Equipment.

A steel tape.

Information.

Visibility is one of the phenomena of *atmospheric optics*, and is very important both in times of peace and war. Visibility is that quality or state of the atmosphere by reason of which objects are seen with greater or less distinctness. A change in visibility causes a corresponding change in the ability to see, depending upon the degree of transparency of the atmosphere. The variation in the visibility is brought about by the amount of haze, dust, or fog in the atmosphere or any other quality which interferes with one's ability to see. In general, then, it is the degree of transparency of the atmosphere. The atmosphere may be comparatively free of suspended solid particles, yet an object may be seen imperfectly on account of glare due to the character of its surface and to the character of surrounding surfaces. There may also be diffusion of light, and consequent indistinctness of an object is caused by turbulent conditions. In this latter case a ray of light proceeding from an object to the eye passes through portions of the atmosphere having different refractive indices, and due to turbulency these indices are constantly changing, and hence the direction of the rays are constantly changing. Objects should be chosen so that the quality of glare will not be a factor in the observation.

Visibility is measured by determining the distance. An observer with normal vision can distinguish large objects such as buildings, trees, windmills, etc.

Objects or targets by which visibility is measured should be chosen in a direction lying generally in the northern quadrant; all of the objects will then be uniformly illuminated during the greater part of the day. If a target to the east and target to the west were equally distant and of the same size and shape, then in the morning the object in the west would be seen more easily than the object in the east. Therefore, it is necessary that the objects chosen should lie to the north. It may be necessary in some cases to erect artificial targets, due to the lack of a natural target or of a structure made by man. Targets may be trees, buildings, villages, churches, etc. It is preferable that structures made by man be chosen wherever possible, because trees and even forests change their aspects during the various seasons.

Questions.

(1) *Why is it necessary to measure visibility?*

(2) *Why are structures made by man a better target than natural objects?*

(3) *What are refractive indices?*

Directions.

1. Objects will be placed or selected at distances as follows: 55 yards; 219 yards; 547 yards; 1,094 yards; 2,187 yards; 4,374 yards; 10,936 yards; 21,872 yards; 54,681 yards.

2. The degree of visibility will be designated according to the descriptive terms in the table below. If an object is visible at 1,094 yards, but not visible at 2,187 yards, the visibility then is poor; or if an object is visible at 10,936 yards, and not at 21,872 yards, the visibility then is good.

3. Take observations on the degrees of visibility on three successive days, preferably at approximately 2 p. m. List the observations as shown in the following example:

Observation No.	Degree of visibility
1	Good.
2	Poor.
3	Excellent.

Code of visibility

Descriptive term	Limiting distances		Code figures
	Meters	Yards	
Dense fog—prominent objects not visible at	50	55	Zero.
Very bad—prominent objects not visible at	200	219	One.
Bad—prominent objects not visible at	500	547	Two.
Very poor—prominent objects not visible at	1,000	1,094	Three.
Poor—prominent objects not visible at	2,000	2,187	Four.
Indifferent—prominent objects not visible at	4,000	4,374	Five.
Fair—prominent objects not visible at	10,000	10,936	Six.
Good—prominent objects not visible at	20,000	21,872	Seven.
Very good—prominent objects not visible at	50,000	54,681	Eight.
Excellent—prominent objects visible beyond	50,000	54,681	Nine.

Questions.

(1) *In which direction, that is north, south, east, or west, can the visibility be best measured?*

(2) *What causes variations in visibility?*

(3) *What factor affects visibility on the ocean where the air may be comparatively free of solid particles?*

(4) *Can you suggest another method of measuring horizontal visibility?*

(5) *Can you suggest a way in which to measure vertical visibility?*

(6) *What is meant by turbulency?*

SUGGESTIONS FOR THE INSTRUCTOR

(1) The following instruction test is provided the instructor, and the same general procedure and principles are involved as in preceding unit operations.

INSTRUCTION TEST NO. 7

PART I.—PERFORMANCE

PROBLEM No. 1

MEASURING VISIBILITY

Equipment.

Pencils.
Blank forms.

Directions for the student.

Perform the following operations carefully and neatly.

Go immediately outside and—

(1) Measure the visibility of the atmosphere and record on the blank form provided.

(2) As soon as this operation has been completed, report at once to the instructor.

Directions for scoring.

(1) Credit the student with 5 points if his report of the degree of visibility is within 20 per cent of the average of the class. The instructor's report should constitute 70 per cent in determining the average of the class.

(2) No partial score allowed.

Note for the instructor.

This problem should be repeated on at least five different days, preferably when the degree of visibility changes so that students may get sufficient practice in measuring visibility under various conditions.

PART II.—INFORMATION

Administration of Part II is identical with that in previous unit operations.

NOTE.—Ten minutes will be allowed for Part II of this test.

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a plus sign (+) on the line to the right. If what it says is *not true*, put a minus sign (−) on the line to the right of the statement.

Begin here.

1. Visibility is the quality or state of the atmosphere by reason of which objects can be seen readily or with difficulty. ------
2. Objects may be seen imperfectly on account of glare. ------
3. Objects to the north are uniformly illuminated during the greater part of the day. ------
4. A target should always be chosen which is located in a northerly direction. ------
5. Enemy observation planes would be favored by a fairly transparent atmosphere. ------
6. Bombing planes are not concerned with visibility of the atmosphere. ------
7. Visibility is measured by determining the distance an object is seen by an observer. ------
8. Targets for determining visibility may be trees, buildings, lakes, or rivers. ------
9. The same factors affect visibility on the ocean as on the land. ------
10. The code figure for visibility described as excellent is "7". ------
11. Visibility should be measured in meters and not in yards. ------
12. Visibility should be measured from a high altitude. ------
13. Particles of dust in the air should not be considered by the observer when measuring visibility. ------
14. Visibility is never measured at night. ------
15. Greater visibility is usually obtained after a heavy snowfall or heavy rain. ------

Directions for scoring Part II. Points

(1) The maximum possible score for Part II of this test is---- 15
(2) The minimum score required to pass Part II is-------- 10
(3) The score for the *true-false* (*plus*-or-*minus*) questions is obtained as directed on page 22.

TO MAKE A SURFACE OBSERVATION

Equipment.

Forms Nos. 1 and 2—Meteorological, pen, pencil, black record ink, standard barometer, dry thermometer, wet thermometer, flask of distilled water, psychrometric tables, maximum thermometer, minimum thermometer, indicating anemometer, wind vane, rain gauge, thermograph, hygrograph, barograph, quadruple register.

Information.

Weather.—In general, the word "weather" refers to everything connected with meteorological conditions. In fact, the word "weather" is synonymous with meteorology; but the word "weather" also has a restricted specific meaning. The expression "What is the weather" brings out this more narrow meaning when it refers to the condition of the sky. These varying conditions may be expressed as follows: Clear, partly cloudy, cloudy, misting, sprinkling, light rain, heavy rain, light snow, heavy snow, sleeting, hailing, threatening, and clearing. In addition, there are also the conditions of light fog, heavy fog, light haze, heavy haze, and smoke. If there is a condition of fog, haze, or smoke when the sky is obscured by these elements, then the weather will be designated as "foggy," "hazy," or "smoky." These words and phrases express the state of the weather, and the term weather in these instances is distinctly different from the broad meaning of the word which includes all the phenomena of the atmosphere. It is understood that one or more of these conditions may prevail at the same time. Thus, for instance, the sky may be partly cloudy; that is to say, that the canopy, to the extent of from four to seven tenths, may be obscured, and at the same time the rain may be falling at the point of observation or at a distance.

Weather observations in general refer to all observations made upon any elements of the atmosphere with or without instruments for measuring. Observations of wind velocity and direction at upper levels are covered under unit operations 13, 14, and 15; and only those observations which are entered in Forms No. 1 and No. 2, are treated here.

The surface observation consists in making measurements of temperature, wind, precipitation, clouds, and pressure. The observer will begin the observation 20 minutes before the time at which the observation is dated; that is to say, a noon observation will begin at 11.40 a. m. Before the taking of the observation, all materials, such as forms, pencils, and equipment listed in the beginning of this unit operation, will be carefully laid out for the purpose of accelerating the taking of the observation. It need not be understood that the observation must be taken with great speed at first, for the reason that errors will creep in; but it should be taken deliberately, with no loss of time, so that the time elapsing from the beginning to the end of all measurements will be as short as possible, and the measurements made will represent the conditions existing at approximately the same instant.

Questions.

(1) *Why is it necessary to begin a surface observation 20 minutes before the time at which the observation is dated?*

(2) *Why is it necessary to take surface observations quickly without loss of time?*

Information.

A weather observation must be made quickly in order to accomplish the purpose desired. This purpose is to measure all the weather elements as nearly together as possible so that it may be said that they have all been measured at practically the same instant. Therefore the fullest preparation is necessary so that the observations of the various elements may be made in rapid succession and the above purpose attained. The preparation consists in having all forms laid out and dated, pencils sharpened, and everything done that will aid the observer in accomplishing this task in a deliberate fashion, but without any loss of time.

The elements to be observed are: Temperature, which consists in reading the dry and wet thermometers and maximum and minimum thermometers; wind—direction, and velocity; precipitation; clouds—amount, kind, and direction; and atmospheric pressure.

An observation is called an 8 a. m., 4 p. m., or 8 p. m. observation if it is completed at one of these times. An 8 a. m. observation is supposed, theoretically, to give the conditions of the elements at exactly 8 a. m.

In winter the order of observations may be changed somewhat when the temperature is below the freezing point, as it is then permissible to moisten the wet-bulb several minutes before taking the observation so that the moisture may become frozen and the thermometer assume the temperature of the free air, after which it may be whirled and the dry and wet bulb readings obtained in the usual fashion. Particular emphasis must be given to the reading of the barometer and the subsequent reductions. The variation from the highest to lowest barometer readings is quite small, consisting of only about 2 inches. For this reason the readings must be very accurate in order to represent the changes, if any, from preceding to succeeding observations. Experience has shown that the best method by which to take and reduce the barometer observation is to proceed as follows: Read the barometer and make all the subsequent reductions, and then take a new sheet of paper, placing the readings of the attached thermometer and barometer thereon, and go through the reductions again, independent of the preceding calculations. This method is better than simply checking the old calculations by reviewing them.

As soon as the observation is reduced it should be entered on Form No. 1, with black record ink, in the neatest manner possible, care being taken in entering the figures that the figures of the present observation are placed directly under the figures of the same order of the preceding observation; that is, units under units and tens under tens.

Questions.

(3) *Why is it necessary, in recording the observation on Form No. 1, that the figures are placed directly under the figures of the same order of the preceding observations?*

(4) *What is Form No. 1 used for?*

(5) *What is Form No. 2 used for?*

Directions.

1. The following procedure is recommended for the new observer, although it may be somewhat changed to suit the circumstances at the various stations.

2. Observe and record on Form No. 2, Meteorological, the clouds with regard to amount, kind, and direction, recording them in the order of highest clouds first and lowest clouds last.

3. Read the maximum thermometer and set it. Read the minimum thermometer and set it.

4. Moisten the wet bulb of the psychrometer, whirl and read both wet and dry bulbs. Record the hygrograph reading and touch pen lightly.

5. Check the readings of the various thermometers with the preceding observations and with the thermograph. Record thermograph reading and touch the thermograph pen lightly.

6. Observe the wind vane, estimate the direction to nearest cardinal or semicardinal point, and record.

7. Measure and record precipitation, if any; after this measurement is made *be sure and empty the gauge.*

8. Check wind direction on quadruple register and measure wind velocity.

9. Read barometer, making all readings and reductions very carefully, but as quickly as possible, and comparing station pressure with the barograph record. Read the barograph record and touch pen lightly.

10. Compute relative humidity, dew point, and vapor pressure using psychrometric tables.

11. Copy observation from Form No. 2 to Form No. 1.

Questions.

(6) *Why is it necessary to "set" the maximum and minimum thermometers after reading?*

(7) *How should the maximum and minimum readings compare with the dry-bulb reading at the time that the former two are reset?*

(8) *Can the wet-bulb ever read higher than the dry-bulb?*

(9) *Give the definition of "weather" used in the restricted sense.*

(10) *Why is it necessary to empty the rain gauge after the measurement has been taken?*

SUGGESTIONS FOR THE INSTRUCTOR

(1) The following instruction test is provided for the use of the instructor, the same administration being involved as in preceding unit operations.

INSTRUCTION TEST NO. 8

PART I.—PERFORMANCE

PROBLEM No. 1

MAKING SURFACE OBSERVATIONS

Equipment.

One mercurial barometer.
One barograph.
One instrument shelter.
One thermograph.
One sling psychrometer, maximum and minimum thermometers.
One wind vane.
One rain gauge.
One anemometer.
One single or quadruple register.
Pencils.
Forms No. 1 and No. 2, Met'l.

(The above equipment constitutes the essential apparatus at a standard weather station. This station should be set up in the approved fashion and all instruments included should be in perfect working order.)

Directions to the student.

(1) Go immediately to the instrument shelter and take observations of the weather in the following order:

a. Clouds.
b. Maximum temperature.
c. Minimum temperature.
d. Wet and dry bulb reading.
e. Wind direction.
f. Rainfall.

(2) Record the observations just taken on the proper form provided.

(3) Go immediately to the quadruple or single register and check the wind direction and record the velocity as shown by the register.

(4) Read the mercurial barometer and record.

(5) Check the barometrical readings and dry-bulb readings with the barograph and thermograph, respectively.

(6) Reduce the barometrical readings to:

a. Station pressure and sea level pressure.

b. Compute the relative humidity.

c. Dew point.

d. Vapor pressure.

(7) As soon as you have completed these operations, report at once to the instructor.

Directions for scoring.

	Points
(1) Maximum possible score for Part I	18
(2) Minimum score required to pass Part I	13
(3) *a.* For successfully performing operations 1 and 6, credit	5
b. For successfully performing operations 2, 3, 4, and 5	2

(4) Allow no partial scores for any of the six separate operations.

Note for the instructor.

This problem should be repeated at regular intervals throughout the course. After the first three times that the problem has been given to the class, the instructor should introduce the time element into the problem and note and record to the nearest second the time that the command "Begin" is given and note and record the time that each individual student finishes.

PART II.—INFORMATION

Equipment and procedure for Part II is identical with that in previous unit operations.

NOTE.—Twenty minutes will be allowed for Part II of this test.

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a plus sign (+) on the line to the right. If what it says is *not true*, put a minus sign (–) on the line to the right of the statement.

1. Observations should be made without checking up. ------
2. As long as you can read your own records it is not necessary to be extra neat. ------
3. When the anemometer cups are still, the direction of the wind is recorded as minus. ------
4. If the student finds on going to the outside installation that the anemometer cups are not turning, the wind velocities are obtained by watching the quadruple register. ------
5. The dry thermometer usually indicates a temperature higher than the maximum thermometer. ------
6. The minimum temperature is always lower than that indicated by dry thermometers. ------

7. The wet-bulb temperature may be higher than the dry. ------

8. After setting the maximum and minimum thermometers they should read the same as the dry-bulb. ------

9. The reading of the attached thermometer on the barometer is always the same as the dry-bulb. ------

10. The mercurial barometer and the barograph should agree within one or two one-hundredths of an inch. ------

11. If the mercurial barometer is broken the station pressure reading may be taken from the barograph. ------

12. The state of the weather may be recorded as sleeting, sprinkling, or smoky. ------

13. The relative humidity may be over 102°. ------

14. The relative humidity may be computed as zero. ------

15. The dew point may be higher than the wet-bulb. ------

16. An 8 a. m. surface observation should start promptly at 8 a. m. ------

17. As soon as an observation is reduced, it should be recorded on Form No. 1. ------

18. Thermometer readings should always be checked with the thermograph. ------

19. The quadruple register will not record a north-northeast wind. ------

20. The wet-bulb can never read higher than the dry-bulb. ------

21. Precipitation is recorded on the quadruple register. ------

22. A weather observation must be made quickly in order to accomplish the purpose desired. -----

Directions for scoring Part II. Points

(1) The maximum possible score for Part II of this test is---- 22

(2) The minimum score required to pass Part II is----------- 19

(3) The score for the truefalse (plus-or-minus) questions is obtained as directed on page 22.

WEATHER CODES

Equipment.

Paper.

Pencil.

Weather codes used in the meteororogical section.

Information.

There are four codes used in the meteorological section in sending weather information, named as follows:

(1) The five-figure code is called "the meteorological code." This code is used in transmitting meteorological data from one station to another, including data pertaining to surface observations as well as those pertaining to the upper air.

(2) The six-figure code is used in time of war to transmit upper-air data to the Air Service, and is called "code for aviation."

(3) The seven-figure code is used to transmit weather ballistic conditions to artillery or antiaircraft artillery, and is called "code for artillery.".

(4) The word code is used in transmitting data to the Weather Bureau.

Questions.

(1) *Why is it necessary to have four different codes for use in sending weather information?*

(2) *Why are meteorological messages sent in code form?*

THE METEOROLOGICAL CODE

Information.

Meteorological messages are built up on the following code key:

MABhh
BBBDD
SSwwb
hALBM
TTHGV
HDDSS
HDDSS
HDDSS
HDDSS
HDDSS

The first three code letters indicate the designation of the observing station originating the data contained in the message. (See code designation of stations contained herein.) The letters **hh** indicate the hour message is sent. The hours of the day are numbered **1** to 24, beginning at one hour after midnight.

Examples: 2 a. m. sent as 2; 2 p. m. as 14.

BBB indicates barometric pressure, reduced to sea level. Example: 29.92 inches would be sent as 992, the first figure 2 being omitted but understood. **DD** equals wind direction to 72 points, where 72 is north, 18 east, 36 south, and 54 west. **DD** may be determined by dividing the direction, in degrees, by 5.

Question.

(1) *Why is the first figure of barometric pressure so easily understood?*

Information.

SS equals wind speed in miles per hour. The combination **ww** is present weather or weather at the time the message is sent. (See Code I.)

Examples: Partly cloudy weather will be sent as 04 or 05. Cloudy weather with dense fog, 24, 25, 26, 27, 28, or 29.

The letter **b** is barometric tendency. (See Code II.)

The letter **h** is height of base of low clouds. (See Code III.) When the message indicates that there is a low cloud, but no height is sent, the average height, given in Code III, will be used in deciphering the message. **A** is the form of low cloud. (See Code IV.) **L** is the amount of low cloud in tenths. **B** is the form of medium or high cloud. (See Code IV.) **M** is the amount of medium or high cloud, in tenths. The cloud group is omitted when **ww** indicates that there is no cloud.

TT is temperature in degrees Fahrenheit. When the temperature is below zero, subtract the number of degrees from 100.

Example: Temperature −4° F. will be sent 96.

H is humidity. (See Code V.) **G** is the state of the ground. (See Code VI.) **V** is visibility. (See Code VII.)

The last five groups of the message contain wind direction, **DD**, and speed, **SS**, at the levels **H**. (See Code VIII.) For the present (see Code V) the values of **H** 2, 3, 4, 5, and 6 only will be employed.

Question.

(2) *Why subtract the number of degrees temperature from 100?*

Information.

When for some reason it has been impossible to observe any element of the message, the letter **X** will be put in the place of each figure thus omitted. Example: If the barometer should be broken, or otherwise put out of commission, the first three elements of the second group and the last element of the third group would be **XXX** and **X**, respectively.

The following table gives the code designations of stations using meteorological data. Some of these are left blank so that when additional stations are added they may be assigned the surplus codes.

CODE DESIGNATIONS OF STATIONS

MAB	Bolling Field, D. C.	**MAC**	
MEC	Langley Field, Va.	**MED**	Camp Lewis, Wash.
MID	McCook Field, Ohio.	**MIF**	Fort Sill, Okla.
MOF	Mitchel Field, N. Y.	**MOG**	Pope Field, N. C.
MUG	Camp Vail, N. J.	**MUH**	Langin Field, W. Va.
MAH	Aberdeen Proving Ground, Md.	**MAJ**	Scott Field, Ill.
MEJ	Louisville, Ky.	**MEK**	Chanute Field, Ill.
MIK	Kokomo, Ind.	**MIL**	Selfridge Field, Mich.
MOL	Boston, Mass.	**MOM**	Crissy Field, Calif.
MUM	Fort Bragg, N. C.	**MUN**	Fort Riley, Kans.
MAN	Edgewood Arsenal, Md.	**MAP**	
MEP	Fort Eustis, Lee Hall, Va.	**MER**	
MIR	Columbus, Ohio.	**MIS**	
MOS		**MOT**	
MUT		**MUV**	
MAV	Kelly Field, Tex.	**MAW**	Schofield Barracks, H. T.
MEW	Fort Bliss, Tex.	**MEX**	France Field, C. Z.
MIX	Rockwell Field, Calif.	**MIY**	Clark Field, P. I.
MOY		**MOZ**	Kindley Field, P. I.
MUZ		**MUB**	Camp Nichols, P. I.

Question.

(3) *Note how all the code groups in the above table begin with the letter* **M**. *Why is this?*

CODE I

Information.

Present weather (**WW**)

Code No.	Sky (0)	Haze or fog: Clear sky or sky not visible (1); Sky cloudy (2)	Precipitation with—: No fog (3); F_{e1} or F_{e2} (4); F_{e3} (5); F_{e4} (6)	Local storm—: Approaching (7); Passing (8); Disappear (9)
0	Exceptionally clear	Dust haze	Drizzle	Wind only.
1	Clear	Haze	Light rain	Thunder, lightning, or both.
2	White	Fog [1]	Moderate rain	Wind and rain.
3	One-fourth covered	Wet fog [1]	Heavy rain	Thunder, lightning, and rain.
4	One-half covered	Fog [2]	Hail	Wind and hail.
5	Three-fourths covered.	Wet fog [2]	Rain and hail	Thunder, lightning, and hail.
6	Covered but with clear spaces.	Fog [3]	Sleet (R. and S. mixed)	Wind. Rain and hail.
7	Covered	Wet fog [3]	Light snow	Thunder, lightning, rain, and hail.
8	Halo	Fog [4]	Moderate snow	Tornado.
9	Aurora	Wet fog [4]	Heavy snow	Hurricane.

Wet fog[1], or fog [1]=most distant object visible 500 to 1,000 yards.
Wet fog[2], or fog [2]=most distant object visible 250 to 500 yards.
Wet fog[3], or fog [3]=most distant object visible 100 to 250 yards.
Wet fog[4], or fog [4]=most distant object visible 0 to 100 yards.

In the two figures for present weather the order is as follows: First figure will be taken from the top of the code table (to indicate the general class of weather) and the second figure from the side (to indicate the subclassification). Thus 0.6 would be "covered, but with clear spaces."

CODE II

Code for characteristic of barometric tendency (b) for last three hours:

0 = steady.
1 = unsteady.
2 = rising.
3 = falling.
4 = falling, then rising.
5 = steady, then rising.
6 = steady, then falling.
7 = falling, then steady.
8 = rising, then steady or falling.
9 = line squall—sudden rise with marked change in wind and weather.

CODE III

Code for cloud heights (h):

0 = clouds below 150 yards.
1 = clouds between 150–300 yards.
2 = clouds between 300–500 yards.
3 = clouds between 500–750 yards.
4 = clouds between 750–1,000 yards.
5 = clouds between 1,000–1,500 yards.
6 = clouds between 1,500–2,000 yards.
7 = clouds between 2,000–2,500 yards.
8 = clouds between 2,500–3,000 yards.
9 = no low clouds.

CODE IV

Code for form of low (A) and medium or high (B) cloud:

Low cloud:

A {
1 = fracto-cumulus.
2 = mammato-cumulus.
3 = low strato-cumulus below 1,200 yards.
4 = high strato-cumulus above 1,200 yards.
5 = nimbus.
6 = cumulus.
7 = cumulo-nimbus.
8 = stratus.

High cloud; medium cloud:

B:
- **1** = cirrus.
- **2** = cirro-stratus.
- **3** = cirro-cumulus.
- **4** = false cirrus.
- **5** = thin alto-stratus.
- **6** = thick alto-stratus.
- **7** = alto-cumulus low, below 3,500 yards.
- **8** = alto-cumulus high, above 3,500 yards.

CODE V

Code for humidity (H):

0 = 95–100 per cent.
9 = 90–94 per cent.
8 = 80–89 per cent.
7 = 70–79 per cent.
6 = 60–69 per cent.
5 = 50–59 per cent.
4 = 40–49 per cent.
3 = 30–39 per cent.
2 = 20–29 per cent.
1 = 10–19 per cent.

CODE VI

Code for state of ground (G):

0 = soft (from rain or thaw).
1 = soft (with snow cover).
2 = solid (dry or frozen).
3 = solid dew.
4 = solid frost.
5 = solid killing frost.
6 = solid glazed frost.
7 = solid snow cover.
8 = solid snow in patches.
9 = solid snow in deep drifts or heavy snow cover (10 inches or more).

CODE VII

Visibility (V):

0 = 0–55 yards; dense fog.
1 = 55–219 yards; very bad.
2 = 219–547 yards; bad.
3 = 547–1,094 yards; very poor.
4 = 1,094–2,187 yards; poor.
5 = 2,187–4,374 yards; indifferent.
6 = 4,374–10,936 yards; fair.
7 = 10,936–21,872 yards; good.
8 = 21,872–54,681 yards; very good.
9 = 54,681 yards and over; excellent.

CODE VIII

Code for height of upper wind (H):

1 = 200 yards.
2 = 500 yards.
3 = 1,000 yards.
4 = 1,500 yards.
5 = 2,000 yards.
6 = 3,000 yards.
7 = 4,000 yards.
8 = 5,000 yards.

Question.

(4) *In Code IV above what is a mammato-cumulus cloud?*

(5) *Does the letter A or B precede the number when a message is coded in Code IV?*

CODE DESIGNATION (A)—LOW CLOUDS

	Form	Average height yards
1	Fracto-cumulus	1, 500
2	Mammato-cumulus	2, 300
3	Low strato-cumulus	below 1, 200
4	High strato-cumulus	above 1, 200
5	Nimbus	1, 200
6	Cumulus	1, 500
7	Cumulo-nimbus	1, 500
8	Stratus	700

The above cloud heights will be used whenever the message indicates the presence of low clouds, but fails to give the height.

SAMPLE MESSAGES

Message No. 1:	Message No. 2:	Message No. 3:
MAB11	**MEC14**	**MID12**
05869	**02409**	**04033**
09060	**03313**	**14053**
00069	**180XX**	**54572**
50626	**46006**	**59523**
20221		**23915**
37215		**34439**
46812		
56426		
65927		

TRANSLATION OF CODE FORM ABOVE

	Code	Message No. 1	Message No. 2	Message No. 3
Station	MAB	Bolling	Langley	McCook.
Time	hh	11 a. m.	2 p. m.	12 noon.
Pressure	BBB	30.58	30.24	30.40.
Wind direction	DD	69 (NNW.)	0.9 (NE.)	33 (SSE.).
Wind speed	SS	9	3	14.
Weather	ww	Covered with clear spaces.	Light rain	Three-fourths covered.
Barometric tendency	b	Steady	Falling	Falling.
Height of low cloud	h		150-300	1,000-1,500.
Form of low cloud	A		Stratus	High St.-Cu.
Amount of low cloud	L	None	10/10	5/10.
Form of upper cloud	B	Thick A.-St	Unknown	A.-Cu. (low).
Amount of upper cloud	M	9/10		2.
Temperature	TT	50	46	59.
Relative humidity	H	60-69	95-100	50-59.
Ground	G	Solid	Soft	Solid.
Visibility	V	4,374-10,936	4,374-10,936	547-1,094.
Winds aloft, altitudes (yards):				
500	HDDSS	2 (N.)-21		39 (SSW.)-15.
1,000	HDDSS	72 (N.)-15		44 (SW.)-39.
1,500	HDDSS	68 (NNW.)-12		
2,000	HDDSS	64 (NW.)-26		
3,000	HDDSS	59 (WNW.)-27		

Directions.

1. The following meteorological data are furnished. Arrange it in the proper order and code it ready to transmit to another station. Visibility, 11,000–15,000; amount of upper cloud, 9/10; temperature, 46; ground, solid; relative humidity, 60–69; form of upper cloud, thick A.–St.; no low clouds; barometric tendency, steady; wind direction, 69 (NNW.); weather, covered with clear spaces; wind speed, 9; time, 11 a. m.; pressure, 30.58; station, Rockwell Field, Calif., winds, aloft; altitudes, 500 yards, 2 (N.)–21; 1,000, 72 (N.)–15; 1,500–68 (NNW.)–12; 2,000–67 (NNW.)–26; 3,000–60 (WNW.)–30.

2. Code the following data and arrange in proper form.

Station, Chanute Field, Ill.

V	1,000–2,000.
G	Solid.
TT	59.
H	95–100.
h	150–300.
A	Stratus.
M	Unknown.
B	Unknown.
L	10/10.
hh	8 a. m.
BBB	30.24.
DD	45 (SW.).
WW	Three-fourths covered.
b	Falling.

3. Decode the following messages:

MAW10	**MEP12**	**MUH16**
01444	**05869**	**98536**
05041	**14053**	**24017**
X6500	**180xx**	**X6500**
89825	**50626**	**20428**
24509	**20221**	**24509**
37212	**34439**	**42176**
	65927	**71610**
	56426	

Questions.

(6) *How are hours of the day numbered for code messages?*

(7) *Why not send date?*

(8) *Why send barometer reading reduced to sea level?*

(9) *Give two reasons why code forms are used to transmit meteorological data.*

TO CODE MESSAGES FOR AIR SERVICE, ANTIAIRCRAFT ARTILLERY, AND ARTILLERY

Information.

After a meteorological observation has been made and reduced, it is then necessary to place the results in a compact form for transmission to those who are to use them. Under war conditions, meteorological information for all units operating in the vicinity of the meteorological station is sent out by short range radio sets. Meteorological messages are sent in code for economy and also, in time of war, for secrecy.

CODE FOR AVIATION

The six-figure code is used for transmitting data to the Air Service and has the general key form as follows:

Code message key:

MEGMEG
IATTBB
lldds s
llddss

Interpretation:

First line: **M** indicates that it is a meteorological message and **EG** indicates the code designation of the station.

Second line: **I** indicates data is for aviation. **A** indicates elevation of station in hundreds of yards above sea level. **TT** indicates temperature to the nearest whole degree. **BB** indicates pressure. The number of whole inches is omitted, it being assumed that 29, 30, or 31 can be supplied by those receiving the message.

Third line: **ll** indicates level to nearest hundreds of yards. **dd** direction of wind in the 72-point scale. **ss** speed of wind in miles per hour.

The direction is given by indicating the direction from which the wind blows, as 72 equals north; 18, east; 36, south; and 54, west.

The elevations at which wind directions and velocities are required are 500, 1,000, 1,500, 2,000, and 3,000, etc.

The following is an example of a meteorological message for aviation

Message			Interpretation
MUGMUG			**MUG** indicates meteorological data sent from Camp Alfred Vail, N. J.
13	**42**	**92**	**13** (see note 1); **42** is temperature (see note 2); **92** is pressure (see note 3).
00	**16**	**14**	Wind at ground level, direction 16, speed 14 miles per hour.
05	**17**	**16**	Average wind at 500 yards, direction 17, speed 16.
10	**25**	**20**	Average wind at 1,000 yards, direction 25, speed 20.
15	**32**	**28**	Average wind at 1,500 yards, direction 32, speed 28.
20	**37**	**30**	Average wind at 2,000 yards, direction 37, speed 30.
25	**36**	**33**	Average wind at 2,500 yards, direction 36, speed 33.
30	**37**	**35**	Average wind at 3,000 yards, direction 37, speed 35.
35	**38**	**44**	Average wind at 3,500 yards, direction 38, speed 44.
40	**40**	**44**	Average wind at 4,000 yards, direction 40, speed 44.
50	**43**	**46**	Average wind at 5,000 yards, direction 43, speed 46.
60	**43**	**48**	Average wind at 6,000 yards, direction 43, speed 48.

NOTE 1.—First figure of first group means data are for use of aviation. Second figure (3) indicates that the pressure is given for the altitude of 300 yards above sea level and is the meteorological datum plane (M. D. P.). By use of the numerals from 0 to 9, levels from sea level to 900 yards above sea level may be indicated. Higher levels are indicated the same way by figures 0 to 9, but the person receiving the message will know his elevation to within 1,000 yards. Thus, if the meteorological station is 1,650 yards high, the figure 6 will be enciphered, but will be deciphered as 1,600 yards. The position of the M. D. P. is chosen by the meteorological section.

Question.

(10) *What is M. D. P. and how is it determined?*

NOTE 2.—The temperature is enciphered to the nearest whole degree Fahrenheit. If the temperature is below zero, it will be enciphered as so many degrees below 100. For example, −8° will be enciphered as 92.

NOTE 3.—Pressure is given in inches and hundredths of an inch, but the whole number of inches is omitted. Thus 29.98 is sent as

98. The judgment of the observer will enable him to supply the whole numbers. The pressure sent must be that at the level specified by the second figure of the first group. In the above message the pressure is 29.92 at the 300-yard level.

CODE FOR ARTILLERY AND ANTIAIRCRAFT ARTILLERY

The meteorological message for artillery consists of a group of letters to designate the sending station, followed by a series of groups of figures, seven figures to each group, except the first group of figures, which has five figures and indicates that the message contains meteorological data for the artillery, also the altitude and the temperature of the meteorological datum plane. Subsequent groups of figures each indicate the direction and speed of the ballistic wind and the ballistic density for a specified maximum ordinate.

In preparing the message the groups of letters will be placed first. The first letter of the message will be **M** to indicate that the message is a meteorological message. Assuming that the designation of the sending station is **AB**, these letters will form the next letters of the message. In order to give the receiving operators a better chance to catch the complete meteorological message, these first three letters will be repeated thus, **MABMAB**.

The first figure of the first group of figures will be **3**. This figure **3** indicates that the data contained in the message is for the use of the artillery. If the figure **2** is used in this place, it will mean that the data following is for the use of the antiaircraft artillery. As the aviation message and the antiaircraft artillery message contain different data from that sent in the artillery message, care should be taken not to confuse these messages. Only data contained in messages where the figure **3** follows immediately the letters designating the station should be used by the artillery. The next two figures indicate the altitude in feet of the meteorological datum plane to the nearest hundred feet above sea level. The final two figures of this group indicate the temperature in whole degrees Fahrenheit.

Each of the subsequent groups of seven figures indicates the direction and speed of the ballistic wind and the ballistic density for certain maximum ordinates. The first figure in each of these groups shows the height of the maximum ordinate to which data indicated by other figures in the group apply. The height of the maximum ordinate will be indicated by figures as follows:

0 is the level of the meteorological datum plane (M. D. P.).
1 altitude 600 feet above M. D. P.
2 altitude 1,500 feet above M. D. P.
3 altitude 3,000 feet above M. D. P.
4 altitude 4,500 feet above M. D. P.

5 altitude 6,000 feet above M. D. P.
6 altitude 9,000 feet above M. D. P.
7 altitude 12,000 feet above M. D. P.
8 altitude 15,000 feet above M. D. P.
9 altitude 18,000 feet above M. D. P.
0 altitude 24,000 feet above M. D. P.
1 altitude 30,000 feet above M. D. P.
2 altitude 36,000 feet above M. D. P.

If it is necessary to furnish data for a higher maximum ordinate than 36,000 feet, the above table may be continued by adding 6,000 feet for each increase of 1 in the code number. For instance, if the figure **3** is used the second time to indicate a maximum ordinate, it will be understood that the data for the maximum ordinate of 42,000 feet are contained in the group of figures. It should be noted that the numbers **0**, **1**, and **2** are repeated in the code used to indicate maximum ordinates. It is believed that this will not lead to confusion, as the location of the figures in the message will also indicate their value. The data for various maximum ordinates will always be sent in the order indicated above, namely, the surface data first, followed by the data for 600 feet, 1,500 feet, 3,000 feet, etc.

The second and third figures of these groups indicate the direction of the ballistic wind *on a basis of 64 points to the circle*, starting from north and measured clockwise. Thus, the figures **16** indicate that the wind is blowing from the east; the figures **32** indicate that the wind is blowing from the south; the figures **64** indicate that the wind is blowing from the north.

The fourth and fifth figures in each of these groups indicate the speed of the ballistic wind in miles per hour.

The sixth and seventh figures in each of these groups indicate the ballistic density in per cent of the density of the standard.

CODE FOR ARTILLERY

The following is an example of a meteorological message for the artillery:

MIFMIF
30368
0320899
1351199
2371599
3401599
4441699
5481898
6502198
7532298
8562497

The letter **M** indicates that the message is a meteorological message. The letters **IF** is the code designation of Fort Sill, Okla. The code letters **MIFMIF** indicate that the message contains meteorological information from Fort Sill. The figures **30368** indicate the following: The figure **3** indicates that the message contains data for the use of the artillery; the figures **03** indicate that the height of the mean datum plane is 300 feet; the figures **68** indicate that the temperature of the meteorological station is 68° F. The remaining groups of figures indicate the ballistic wind direction and speed and the ballistic density for maximum ordinates as follows (see Information topic No. 2):

Maximum ordinate	Ballistic wind direction	Ballistic wind speed	Ballistic density
Surface	32	8	99
600 feet above surface	35	11	99
1,500 feet above surface	37	15	99
3,000 feet above surface	40	15	99
4,500 feet above surface	44	16	98
6,000 feet above surface	48	18	98
9,000 feet above surface	50	21	98
12,000 feet above surface	53	22	98
15,000 feet above surface	56	24	97

Directions.

(1) Assume that meteorological data are desired by Langley Field, Va., from Camp Alfred Vail, N. J. The following data are available at Camp Alfred Vail, N. J.:

Pressure at 300 yards above sea level, 29.93.

Temperature, 45° above zero.

Wind at ground level; from the east at speed of 16 miles per hour.

Average wind at 500 yards; direction east, speed 16 miles per hour.

Average wind at 1,000 yards; direction south; speed 20 miles per hour.

Average wind at 1,500 yards; direction south; speed 28 mile per hour.

Average wind at 2,000 yards; direction west; speed 35 miles per hour.

Average wind at 2,500 yards; direction west; speed 35 miles per hour.

(2) Write the code message to be sent to Langley Field for use of the aviation unit, giving the above information available at Camp Alfred Vail, N. J.

(3) Decode the following messages:

MABMAB	**MUGMUG**
30370	**20375**
0160599	**0400498**
1161298	**1401098**
2321598	**2441298**
3321598	**3321298**
4351798	**4321599**
5402098	**5352097**
6482597	
7482697	
848297	

Questions.

(11) *Is ballistic wind direction data furnished aviation organizations? If not, why not?*

(12) *What code form is used in transmitting data to the Weather Bureau?*

(13) *What is the six-figure code used for?*

(14) *What scale is used to indicate wind direction in sending data to aviation sections? What scale is used, in sending to artillery units? Why not use the same scale for both?*

(15) *What groups of numbers in a code message for artillery indicate the maximum ordinates?*

(16) *Why is time that the message is sent omitted from aviation and artillery meteorological messages?*

SUGGESTIONS FOR THE INSTRUCTOR

1. The following instruction test is provided for the use of the instructor, and the same procedure for administration is involved as in preceding unit operations.

2. Students should be given as much practice as possible in coding and decoding messages. This practice should continue throughout the course. The instruction test provided here may be repeated from time to time as the instructor sees fit.

3. The instructor may find it more satisfactory to give the latter part of this unit operation after unit operation No. 17; that is, the coding of artillery and aviation messages. The first part of the unit operation dealing with the five-figure code should be given after the students have learned to make surface observations.

INSTRUCTION TEST NO. 9

PART I.—PERFORMANCE

PROBLEM No. 1

CODING OBSERVATIONS

Equipment.

Pencil.
Paper.
Ten surface observations to be coded.

Directions to the student.

1. Code the 10 observations as quickly as you can, remembering that accuracy is more important than speed.

2. As soon as you have completed this work report at once to the instructor.

Directions for scoring.

	Points
(1) Minimum score required to pass this problem	6
(2) For each observation correctly coded credit each student	1
(3) Allow no partial score for any separate observation.	

PROBLEM No. 2

DECODING MESSAGES

Equipment.

Pencil.
Paper.
Ten coded messages.

NOTE.—These messages may be the same as those coded by the student in problem 1 above.

Directions to the student.

1. Decode the 10 messages as quickly as you can, remembering that accuracy is more important than speed.

2. As soon as you have completed this work, report at once to the instructor.

Directions for scoring.

	Points
(1) Minimum score required to pass this problem	6
(2) For each message correctly decoded credit each student with	1
(3) Allow no partial score for any separate message.	

PART II—INFORMATION

The administration of Part II is the same as in previous unit operations.

NOTE.—Allow 26 minutes for Part II of this test.

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a *plus* sign (+) on the line to the right. If what it says is *not true*, make a *minus* (−) sign on the line to the right of the statement.

1. It is possible to send only three figures giving barometric pressure instead of four. ------
2. When it is impossible to observe any element in the surface observation it is treated in the message by sending **00.** ------
3. The seven-figure code is used to transmit weather codes to the Weather Bureau. ------
4. The first three letters of a code indicate the name of the sending station. ------
5. The hours of the day are numbered from 1 to 24. ------
6. The wind code is used in transmitting data to the aviation. ------
7. **DD** indicates cloud direction. ------
8. **SS** indicates wind speed in miles per hour. ------
9. **V** indicates velocity of the wind. ------
10. **H** indicates humidity. ------
11. In sending observations of the state of the ground as soft (with snow cover) send **G–1.** ------
12. If no low clouds are present a report on clouds is unnecessary. ------
13. Wind direction from the north is indicated by **.72.** ------
14. The date is never sent in a meteorological coded message. ------

15. Barometric readings need not be reduced to sea level in sending meteorological messages. ------

16. When temperature is zero or below, 100 should be subtracted from the temperature reading. ------

17. **M. D. P.** stands for meteorological direction position. ------

18. The aviation message and antiaircraft artillery message contain different data from that sent in the artillery messages. ------

19. Meteorological messages should only be coded when operating against an enemy. ------

20. Messages should be forwarded daily to the headquarters of the unit which the meteorological station serves. ------

Directions for scoring Part II.

	Points
(1) The maximum possible score for Part II of this test is	20
(2) The minimum score required to pass Part II is	16
(3) The score for the *true-false* (*plus-or-minus*) questions is obtained as directed on page 22.	

THEODOLITE, CARE AND SETTING UP

Equipment.

A theodolite, with tripod and case.

Information.

A theodolite is a form of telescope, mounted on a tripod for convenience, provided with a vertical and a horizontal circle graduated in degrees by means of which angles of elevation and azimuth may be measured. It is further provided with tangent screws by means of which an observer may follow moving objects such as balloons and airplanes, whose elevation and azimuth may be read at any instant.

The term "elevation" as used in the preceding paragraph is the angle, expressed in degrees and tenths, between the line of sight—that is, the line extending from the eye to the observed object—and the horizontal plane of the observer.

The term "azimuth" as used in the first paragraph is the angle expressed in degrees and tenths between the vertical plane of the line of sight and the vertical plane of the north and south line, measured in a clockwise direction from the north.

DESCRIPTION OF THEODOLITE

The theodolite consists of—

a. A right-angled prismatic telescope. (See figs. 44 and 45.)

b. Two circular limbs divided in degrees and equipped with verniers. The vertical circle is used for reading angles of elevation, and the horizontal one for reading angles of azimuth. The telescope can be moved slowly and progressively by turning the milled heads of the two tangent screws which are attached to the vertical and horizontal circles. These tangent screws can be thrown out of gear and reengaged at will, and are held in gear by the action of springs. This permits greater speed in the use of the instrument.

c. A leveling head with three leveling screws which support the entire instrument. These screws are adjusted by reference to the spirit levels fixed to the theodolite.

d. Accessories—brass covers to protect the objective, the eyepiece, and the prism when the theodolite is not in use; a sunshade; a wooden box serving as a case for the instrument, which contains a screw driver, a plumb bob, and an adjusting pin. This box also contains a shelf upon which the telescope should be placed when packing the theodolite for shipment. It is not necessary to remove the telescope from the theodolite when the theodolite is stored for short periods at the station. By sliding the shelf from the box, the theodolite may be stored in the box without removing the telescope. (See fig. 46.)

e. A wooden tripod with a metal head. This tripod head is fitted with a movable metal platform which facilitates placing the theodolite over a given point. (See fig. 47.)

Questions.

(1) *How does a theodolite differ from a telescope?*
(2) *How does a theodolite differ from a transit?*
(3) *How does the term "azimuth" differ from "elevation"?*

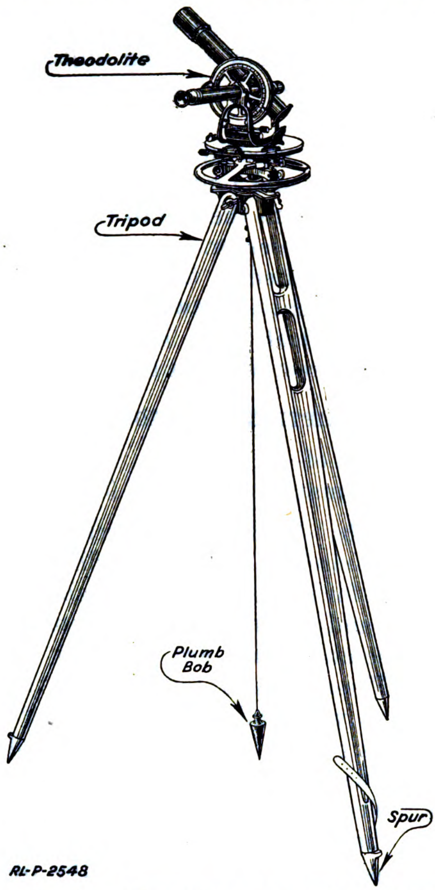


Fig. 44.—Theodolite mounted on tripod

(4) *Why is it necessary to construct the telescope of the theodolite with a right angle?*
(5) *Would it be possible to use a straight telescope at all?*

Information.

Care of the theodolite.—Special attention should be given to the care and use of the theodolite. These instruments are delicate, in addition to being rare and costly. They should never be handled by anyone who has not had thorough instruction and experience as to their proper care and use. The man in charge of the station should require a demonstration by inexperienced men as to their

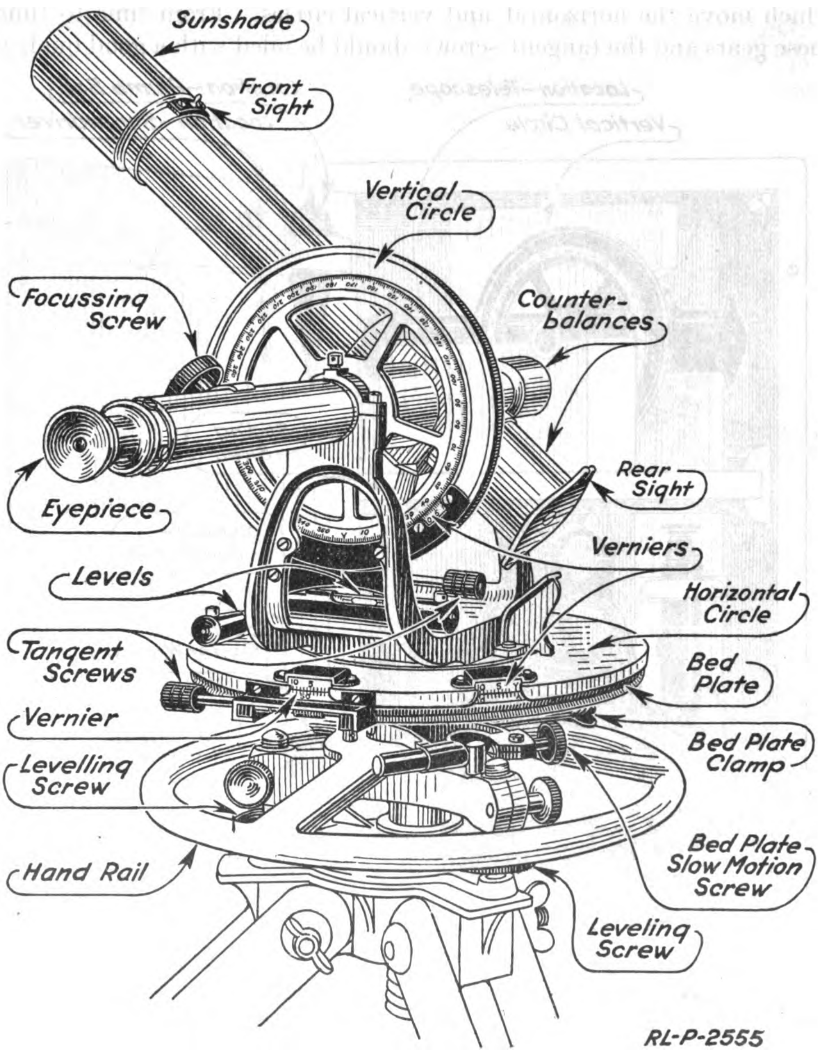


Fig. 45.—The theodolite

ability to handle the instruments before allowing the latter to use them. The damage resulting to the theodolite from a fall can hardly be repaired in less than three months. To insure against this occurrence, no theodolite should be left on its tripod without making certain it is firmly screwed to the tripod. Likewise, no theodolite should be moved without making certain that it is secured to the tripod. At the end of a day's work the metal parts of the theodolite should be carefully gone over with a soft cloth, and special attention should be paid to the removal of dust and grit from the worm gears which move the horizontal and vertical circles. From time to time these gears and the tangent screws should be oiled with a good quality

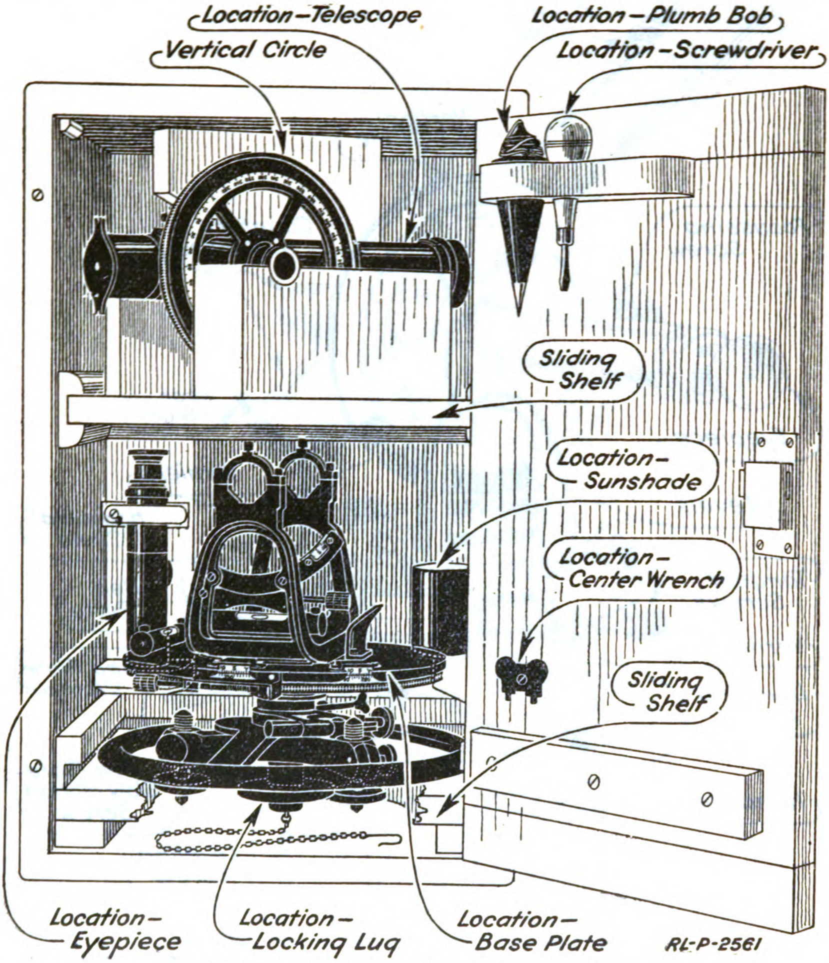


Fig. 46.—Theodolite in box (cover open)

of clock oil. No attempt should be made to take the instrument apart more than is necessary to pack it in its box. In case dust or moisture needs to be removed from the lenses, the exterior surface may be wiped off with a clean chamois; nothing else should be used for this purpose. If the instrument needs a thorough cleaning or repairs of any kind, notice to this effect should be sent at once to the office of the chief signal officer at Washington, D. C. When left standing for any length of time the instrument should be covered with a suitable cloth.

Directions.

1. Set the tripod firmly on the ground, with its plate approximately horizontal. Remove the theodolite from the packing box and place it on the plate of the tripod, with the leveling screws in their sockets.

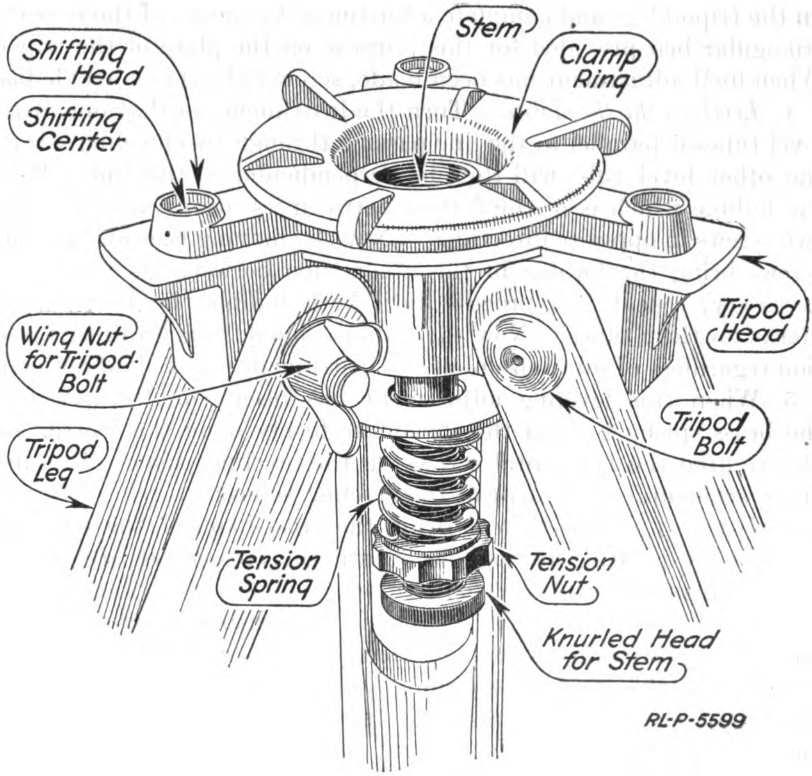


Fig. 47.—Theodolite tripod and shifting head

Screw the vertical pin into the tapped hole in the base of the instrument by means of the corrugated head below the plate of the tripod. By means of the knurled nut on the vertical pin, tighten the brass spring. Remove the protecting cap from the telescope barrel, screw on the eyepiece tube, and place the sunshade on the objective. Turn the telescope so that it points vertically upward, and engage the vertical motion tangent screw. Disengage the horizontal motion tangent screw. Bring the legs of the tripod together, carefully supporting the theodolite proper while so doing. The instrument is now ready to be carried.

2. The theodolite with tripod will be carried on the shoulders when out of doors; but indoors it must be carried under the right arm with the theodolite ahead.

3. *Setting up of the theodolite.*—Stand the tripod over the mark which has been placed to mark the exact point of observation. Attach the plumb bob and line. Adjust the tripod legs until the plumb bob hangs just above the nail in the stake when stationary. When the approximate position has been obtained, tighten the screws on the tripod legs and complete adjustment by means of the movable triangular bed provided for this purpose on the plate of the tripod. When final adjustment has been made, screw tight this movable bed.

4. *Leveling the theodolite.*—Turn the instrument so that one of the level tubes is parallel to the line passing through two leveling screws; the other level tube will then be perpendicular to this line. Bring the bubble which is in the former between its marks, moving these two screws in opposite directions. Now, by moving the third leveling screw, bring the bubble in the other tube between its marks. If necessary, repeat this process until both bubbles lie between the marks on their tubes. Now the bubbles should remain in this position regardless of rotation unless the instrument is out of adjustment.

5. When this leveling adjustment has been completed, tighten the brass spring to hold the theodolite firmly upon the tripod, and also tighten the horizontal screws on the leveling posts. This prevents accidental movement of the leveling screws.

6. *Focusing the theodolite.*—Bring the cross-hairs of the telescope in focus by rotating the eyepiece until the cross-hairs are seen at maximum sharpness.

7. Focus the telescope by means of the focusing screw until some image, at least 100 feet away, is perfectly clear and free from parallax. Parallax, as the word is here employed, denotes an apparent slight motion of cross hairs across the telescope field when the eye is moved from side to side or up and down in front of the eyepiece. When no parallax occurs the cross hairs appear to be stationary on the field. Focusing adjustments should be made in the order indicated; that is, cross hairs first and then telescope proper.

N. B.—Much eye strain can be avoided if these adjustments in focusing are made with both eyes open and in such a way that when the telescope is focused the naked eye is in clear focus at the same time.

Questions.

(6) *Why can not the theodolite always be carried on the shoulders?*

(7) *Why must the plumb bob hang directly over the nail?*

(8) *Why is it necessary to level the theodolite?*

(9) *Why is eye strain relieved by focusing the theodolite with both eyes?*

(10) *When the bubble of a level is in the middle, and the level parallel to two leveling screws, should the moving of the third leveling screw disturb the bubble of that level?*

(11) *If it does, what is the explanation?*

(12) *Why should only clean chamois skins be used in cleaning the lenses?*

(13) *Does the plumb bob point to the center of the earth?*

(14) *Can you devise a better way to mount the theodolite at a permanent position?*

(15) *If the theodolite is set up by the seashore and leveled, will the horizontal crosshair meet or coincide with the sea horizon?*

(16) *If one-half of the objective glass were covered or painted black, how would the image of the object look?*

(17) *What is the need of a counterbalance?*

Direction.

1. Study a theodolite, having Figures 45 and 46 at hand.
2. Compare all the parts of the theodolite with those named in the figures.
3. Examine each part and see how it works.
4. See which part of the instrument measures the azimuth and which the elevation angle.

Questions.

(18) *Explain each of the following words or phrases as used in this unit operation:*

a. The horizontal plane of the observer
b. Right angle prismatic telescope.
c. Milled heads of tangent screws.
d. Plumb bob.
e. Worm gears.
f. Clock oil.
g. Chamois.
h. Corrugated.
i. Tapped hole.

SUGGESTIONS FOR THE INSTRUCTOR

1. The following instruction test is provided for the use of the instructor, the same procedure and principles being involved as in preceding unit operations.

INSTRUCTION TEST NO. 10

PART I.—PERFORMANCE

PROBLEM No. 1

SETTING UP THE TRIPOD

Equipment.

One tripod for theodolite.

Directions to the student.

1. Take the tripod outside and set it up ready for the theodolite.
2. As soon as you have completed this operation report at once to the instructor.

Directions for scoring.

1. If tripod is correctly set up, credit student with 2 points.
2. Allow no partial score.

PROBLEM No. 2

REMOVING THE THEODOLITE FROM PACKING BOX

Equipment.

Theodolite in packing box.

Directions to the student.

1. Remove the theodolite from the packing box as carefully as you can, and after it has been removed and placed on the table, report at once to the instructor.
2. Return the theodolite to the packing box, and after this has been accomplished report again to the instructor.

Directions for scoring.

1. If he has exhibited care and properly handled the theodolite in its removal from and return to the packing box, credit student with 2 points.
2. Allow no partial score.

PROBLEM No. 3

SETTING THEODOLITE UPON THE TRIPOD AND LEVELING IT

Equipment.

Theodolite and tripod.

Direction to the student.

1. Place the theodolite upon the tripod.
2. Level the theodolite.
3. As soon as you have completed this operation report at once to the instructor.

Directions for scoring.

1. If theodolite has been properly placed upon the tripod and correctly leveled, credit student with 5 points.
2. Allow no partial score.

PROBLEM No. 4

FOCUSING THE THEODOLITE

Equipment.

Theodolite mounted on tripod.

Directions to the student.

1. Focus the theodolite properly and make observation.
2. As soon as you have completed this operation report at once to the instructor.

Directions for scoring.

1. If focusing has been correctly accomplished, credit student with 5 points.
2. Allow no partial score.

NOTE FOR THE INSTRUCTOR.—Part I of this instruction test may be repeated from time to time. It is suggested that the second time the test is administered the element of time be considered. Note and record to the nearest second the time the command "Begin" is given and note and record to the nearest second the time each individual student finishes.

	Points
1. The maximum possible score for Part I is	14
2. The minimum score required to pass Part I is	10

PART II. INFORMATION

Equipment and procedure for Part II, is identical with that in previous unit operations.

NOTE.—Fifteen minutes will be allowed for Part II of this test.

Directions to the student

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and if what it says is *true*, make a *plus* sign (+) on the line to the right. If what it says is *not true*, make a *minus* sign (−) on the line to the right of the statement.

1. Theodolites are instruments used to run levels. ------

2. The elevation angle is the angle between the horizontal plane and a line from the eye of the observer to the object. ------

3. Azimuth is a term used to express the angle between the north and south line and the vertical plane of the line of sight. ------

4. The plumb bob is not necessary in connection with the theodolite. ------

5. The two levels on the theodolite are necessary to level the instrument. ------

6. The eyepiece is always in focus. ------

7. The horizontal circle is larger than the vertical circle. The degrees on each have a different size. ------

8. The focus screw is the optical distance between the eyepiece and the object glass. ------

Directions to the student.

Below are a number of questions and unfinished statements, after each question or statement are several phrases or numbers each preceded by a *number*. Only *one* of these answers is correct. Write the *number* of the correct answer on the dotted line to the right.

9. The vertical and horizontal circles are usually read to what, by the the degrees? (1) 1.0; (2) 0.1; (3) .01; (4) .001. ------

10. The telescope is made right-angled for (1) convenience; (2) economy; (3) because of regulations. ------

11 To focus the theodolite turn the (1) focus screw; (2) the eyepiece; (3) the objective. ------

12. The plumb bob points (1) to the center of the earth; (2) to the axis; (3) plane of the ecliptic; (4) obliquely. ------

13. To take gun sight upon a balloon the observer should have the (1) vertical circular tangent screw free; (2) the horizontal circular tangent screw free; (3) both screws free. ------

Directions for scoring Part II.

	Points
1. The maximum possible score for Part II of this test is----	13
2. The minimum score required to pass Part II is----------	9
3. *a. True-false questions.* Score as directed on page 22.	
b. Recognition questions. For each question correctly answered.	1

NOTE FOR THE INSTRUCTOR.—In teaching this Unit Operation the instructor may be able to secure a transit and telescope and demonstrate to the students the difference between the two instruments. Students should be thoroughly drilled in the nomenclature of the theodolite before any attempt is made to instruct them in the use of the instrument.

ADJUSTMENT OF A THEODOLITE

Equipment.

Theodolite with tripod. (See figs. 44–45.)
Rule with scale.

Information.

It is quite impossible to manufacture an instrument such as a theodolite which will be accurate and also remain accurate when placed in use. It is therefore made adjustable, so that when adjusted the errors, while as small as possible, will be largely in proportion to the care used in adjusting.

Question.

(1) *Where and by whom are the theodolites manufactured which are used in the Signal Corps?*

Information.

The operations of adjusting in this case are independent of the operation of "setting up." To set up the instrument, the observer simply installs it so that the plumb bob is directly over the tack, nail, or other mark indicating the theodolite station, levels it, and orients the instrument, which is then ready for observation. It is assumed that the adjustments described below have been made.

Directions.

1. Set up the tripod at the spot desired, the base of the instrument being approximately horizontal. Care should be taken to plant the tripod so that the instrument is in as stable a position as possible; i. e., the legs should not be close together and should be pushed firmly into the ground. Tighten the screws which secure the legs to the base of the tripod. Slightly loosen the brass spring under the tripod plate so that the leveling screws may be moved readily.

Question.

(2) *Why should the base of the theodolite be set up approximately horizontal?*

Directions.

2. Verify the adjustments of the levels.

3. Disengage the tangent screws of the horizontal circle and turn the instrument so as to place one of the levels parallel to the line joining two of the leveling screws. Bring the bubble on this level between its marks by turning these screws in opposite directions. Rotate the instrument 180° about the vertical axis. If the bubble returns between its marks this level is adjusted. If not, bring the bubble halfway to its correct position by means of the leveling

screws, and complete the adjustment by raising or lowering one end of the bubble tube. This is done by means of the capstan screw which supports one end of the bubble tube. A small adjusting pin is provided in each theodolite box for turning all screws of this sort on the instrument. Repeat this operation until this level is completely in adjustment. By the same method adjust the other level.

Questions.

(3) *Can a theodolite be leveled if one of the levels is broken?*

(4) *Why have two levels?*

Directions.

4. Make the axis ot rotation of the theodolite veitical. Turn the instrument so that one of the levels is parallel to the line passing through two leveling screws; the other level will then be perpendicular to this line. Bring the bubble on the former between its marks, moving these two screws in opposite directions. Now by moving the third leveling screw bring the bubble in the other level between its marks. If necessary, repeat this process until both bubbles lie between the marks on their levels. Then, if the adjustment in "direction 3" has been correctly made, the bubbles should remain in this position no matter how the instrument is rotated. When these adjustments have been completed, tighten the brass spring in order to hold the theodolite firmly upon the tripod, and also tighten the horizontal screws on the leveling posts. This prevents accidental movement of the leveling screws. This operation or adjustment is also called "the leveling the theodolite."

Question.

(5) *Could four leveling screws be used instead of three?*

Directions.

To focus the theodolite.—5. When the telescope is horizontal (angle of elevations zero) the cross hairs should appear horizontal and vertical, although this is not necessary. Bring the cross-hairs in focus by rotating the eyepiece until the cross hairs are seen at maximum sharpness. Focus the telescope by means of the rack and pinion until an object 100 feet away can be seen perfectly clear and free from parallax. Parallax, as the word is here employed, denotes an apparently slight motion of crosshairs across the telescope field when the eye is moved from side to side or up and down in front of the eyepiece. When no parallax occurs the crosshairs appear to be stationary on the field. Focusing adjustments should be made in the order indicated.

N. B.—Much eye strain can be avoided if these adjustments in focusing are made with both eyes and in such a way that when the telescope is focused the naked eye is in clear focus at the same time.

6. Make the horizontal axis perpendicular to the vertical axis. Level the instrument carefully. Sight upon the top of a vertical corner of a building. Clamp the horizontal motions and revolve the telescope downward by means of the vertical circle and note a point at the bottom of the corner. Turn through 180° about both horizontal and vertical circles and again sight upon the top point. Lower the telescope as before to the bottom point. If the horizontal axis of rotation is truly horizontal, the second pointing at the base of the corner should coincide with the first. If not, adjust for one-half the difference between the lower sightings by raising or lowering one end of the horizontal axis. This is done by means of two screws on the stand at the counterweight end of the telescope axis, one screw above and the other below this axis, the process consisting in tightening one of these and loosening the other.

7. Check the zero of the vertical circle. The optical axis of the telescope must be made horizontal when the zero of the vertical circle coincides with the zero of the vernier. To check this, bring the zero of the vernier in coincidence with the zero of the vertical limb by turning the tangent screw. Then note on a target (a scale hanging vertically makes a good target in this case) the point which falls on the horizontal crosshair; turn the instrument 180° around its horizontal axis, and 180° around its vertical axis, so that it sights again in the same direction. If the point previously sighted falls on the horizontal crosshair the zero of the vernier of the vertical limb is well adjusted. If not, move the telescope so as to obtain this result, and note the difference. Correct the zero of the vernier by one-half the difference, using the adjusting screws of the vernier. Repeat the operation until the instrument is in adjustment.

NOTE.—In all of these adjustments the bubbles of both levels should stay between their marks. If they do not, repeat adjustments (3) and (4) above. The adjustments (6) and (7) need not be made frequently; it will be sufficient to check them from time to time. Adjustments (3) and (4) must be made before every observation with the theodolite.

Questions.

(6) *Why not adjust zero of horizontal circle?*

(7) *Why do not adjustments 6 and 7 need to be made frequently?*

(8) *When do adjustments for leveling need to be made?*

(9) *What is meant by "focusing the telescope"?*

(10) *Name the operations necessary to set up the theodolite, assuming that the instrument is in adjustment?*

(11) *Name the adjustments to be made upon receiving a new instrument?*

(12) *When should the theodolite be adjusted?*

(13) *What is the purpose of the cross-hairs in the theodolite?*

SUGGESTIONS TO THE INSTRUCTOR

1. The following instruction test is provided for use of the instructor, and the same general principles being involved as in preceding unit operations:

INSTRUCTION TEST NO. 11

PART I.—PERFORMANCE

Problem No. 1

ADJUSTMENT OF THE THEODOLITE

Equipment.

One theodolite and tripod in good working order.
One plumb bob.

Procedure.

1. Have the above listed equipment conveniently situated, with the theodolite removed from the tripod.
2. The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

Perform the following operation carefully and at the same time as quickly as you can:

1. Set up the tripod for the theodolite position, making the base approximately horizontal.
2. Verify the adjustments of the levels.
3. Make the axis of rotation of the theodolite vertical.
4. Focus the telescope.
5. Make the horizontal axis of the theodolite perpendicular with the vertical axis.
6. As soon as you have completed these operations report at once to the instructor.

Directions for scoring.

1. For each step correctly performed according to the above directions, credit each student with 2 points.
2. Allow no partial score.

PART II.—INFORMATION

The procedure for Part II is identical with that in previous unit operations.

Directions to the student.

Each of the following questions can be answered by a single word, phrase, or number. Write the answer on the short dotted line.

1. The theodolite is provided with how many levels? ....
2. How is the theodolite position designated? ....
3. Why is it necessary to tighten the screws which secure the legs to the base of the tripod? ....
4. When is a leveled theodolite said to be in adjustment? ....
5. Why is it necessary to verify the adjustment of the level on the theodolite? ....
6. If the theodolite were provided with only one level, could the adjustment which was described in unit operation No. 11 be made? ....
7. What is to be inferred when the telescope can not be focused by means of the rack or pinion; that is to say, when the image can not be made apparently clear? ....
8. If the horizontal axis can not be made perpendicular to the vertical axis, what would you say were the probable reasons? ....
9. If the zero of the vertical circle of an instrument, which has previously been checked, is found slightly in error when again set up, what has probably happened in the meantime? ....
10. Why is it not necessary to make the adjustments included in this operation every time the instrument is set up? ....
11. Why is there no zero adjustment to the horizontal circle? ....
12. In making the horizontal axis perpendicular to the vertical axis, which would lead to the greater accuracy, sliding from the top of a tall building or from a low building? ....
13. If the theodolite, after having been adjusted, were sent on to another station by express or by truck, would it be necessary to make these adjustments a second time? ....
14. If the theodolite has been at a station continuously how often should these adjustments be made? ....
15. What does the word parallax mean as employed in these instructions? ....

Directions for scoring.

	Points
1. The maximum possible score for Part II of this test is	15
2. The minimum score required to pass Part II	10
3. For each question correctly answered	1

SUGGESTIONS FOR CONDUCTING PROGRESS TEST

1. *a.* For convenience, this progress test is divided into two parts: Part I—Performance; Part II—Information. The test is designed to measure the progress that students have made in unit operations 6 to 11, inclusive.

b. It will not be necessary to administer this entire test at one time. If the instructor prefers to do so, Part I may be given on one day and Part II on another, whichever way best fits with the schedule of instruction.

c. The directions for the student in Part I may either be typewritten, mimeographed, or read aloud by the instructor. Allow the student sufficient time to read and understand the directions before giving the command, "Begin." Part II of the test may also either be typewritten, mimeographed, or placed on a blackboard.

General procedure.

2. The instructor should record to the nearest second, the time consumed by each student in the completion of each problem in Part I of this test. These records will provide the instructor with information which will show which students have fallen below the general average of the class and consequently require further practice. Emphasis should be placed more on the accuracy of the work than upon the rapidity with which it is performed.

General directions for scoring.

	Points
1. *a.* The maximum possible score for Part I of this test is	51
b. The maximum possible score for Part II of this test is	40
c. The maximum possible score for the entire test is	91
2. The minimum score required to pass the entire test is	50

3. *a.* A total score for Part I will be the total of the points obtained by each student.

b. The questions of Part II will be scored in the same manner as were similar questions in preceding instruction and progress tests.

PROGRESS TEST NO. 2

PART I—PERFORMANCE

PROBLEM NO. 1

CLASSIFICATION OF CLOUDS

Equipment.

Pencils.
Blank forms.

Procedure.

1. Prepare in advance blank forms as shown on page 6 of unit operation No. 6.

2. Record to the nearest second the time that the command "Begin" is given and the time that each individual student finishes his observation.

3. The instructor should, if possible, select a day for this problem in which a large variety of cloud formations is visible. He should also make an observation himself of the cloud formations prevailing at the time the problem is given, as a check against the observation reported by the students.

Time allowed for this problem, four minutes. At the end of four minutes give the command "Stop."

Directions to the student.

1. Go immediately outside and view the sky.

2. Mark down upon the blank form provided the amount, kind, and direction of as many different cloud formations prevailing in the sky at present as you can see.

3. Take the observation as quickly as possible after the instructor commands "Begin." Make no further observations after the instructor commands "Stop," but report immediately to the instructor and hand in the form as nearly as you have completed it.

Directions for scoring.

1. Determine the average amount, kind, and direction of cloud reported by the entire class and include the instructor's observation which should count 70 per cent of the total in computing the average.

2. If his record is within 5 per cent of this average, credit each student with 5 points.

3. Allow no partial score.

PROBLEM No. 2

MEASURING VISIBILITY

Equipment.

Pencils.
Blank forms.

Procedure.

1. If possible, select a day for this problem when the visibility is poor. The instructor should make an observation of the degree of visibility at the same time that the class is required to do so in this problem.

2. Time allowed for this problem, 2 minutes. The same procedure as outlined in problem No. 1 for giving the command "Begin" and "Stop" should be followed by the instructor.

Directions to the student.

1. Measure the visibility of the present condition of the atmosphere as you have previously been instructed and record the amount on the blank form provided.

2. Make no further record on the form after the instructor commands "Stop," but report to the instructor and hand in your paper.

Directions for scoring.

1. Credit each student with 5 points if his report of the degree of visibility is within 20 per cent of the average reported by the class, including that reported by the instructor. The instructor's observation to be counted as 70 per cent of the total in computing the average.

2. Allow no partial score.

PROBLEM No. 3

MAKING SURFACE OBSERVATIONS

Equipment.

One mercurial barometer.
One barograph.
One instrument shelter.
One thermograph.
One sling psychrometer, maximum and minimum thermometers.
One wind vane.
One anemometer.
One quadruple register.
Pencils.
Forms Nos. 1 and 2, Met'l.
Forms 79 and 80.
Psychrometic tables.

Procedure.

1. Prepare in advance all of the instruments listed above under equipment so that they are in perfect working order.

2. Time allowed for this problem, 15 minutes. The same procedure as outlined in the previous problems for giving the command "Begin" and "Stop" should be followed by the instructor.

Directions to the student.

(1) Go immediately to the instrument shelter and take observations of the weather in the following order:

a. Clouds.
b. Minimum temperature.
c. Maximum temperature.
d. Wet and dry bulb reading.
e. Wind direction.
f. Rainfall.

(2) Record the observations just taken on the form provided.

(3) Go immediately to the quadruple register and check the wind direction and record the velocity as shown by the register.

(4) Read the mercurial barometer and record.

(5) Check the barometrical readings and dry-bulb readings with the barograph and thermograph, respectively.

(6) Reduce the barometrical readings to—

a. Sea-level pressure.

b. Compute the relative humidity.

c. Dew point.

d. Vapor pressure.

(7) Make no further record after the instructor commands "Stop," but report to the instructor and hand in your paper.

Directions for scoring.

	Points
1. The maximum possible score for problem 3	18
2. The minimum score required to pass problem 3	13
3. No partial score allowed for the different operations.	
4. *a.* For each of the operations 1 and 6	5
b. For each of the operations 2, 3, 4, and 5	2

PROBLEM No. 4

CODING OBSERVATIONS

Equipment.

Pencil.

Paper.

Five surface observations to be coded.

Procedure.

1. Prepare in advance five surface observations to be coded.

2. Time allowed for this problem, 30 minutes. The same procedure as outlined in the previous problems for giving the command "Begin" and "Stop" should be followed by the instructor.

Directions to the student.

1. Code the five observations as quickly as you can.

2. Make no further record after the instructor commands "Stop," but report to the instructor and hand in your paper.

Directions for scoring.

1. Three points or three correctly coded observations is the minimum score required to pass problem 4.

2. Allow no partial score for any separate observation.

3. For each observation correctly coded, credit each student 1 point.

Problem No. 5

DECODING MESSAGES

Equipment.

Pencil.
Paper.
Five coded messages.

Procedure.

1. Prepare in advance five coded messages. These messages may be the same as those coded by the student in problem 4, above.

2. Time allowed for this problem, 30 minutes. The same procedure as outlined in the previous problems for giving the command "Begin" and "Stop" should be followed by the instructor.

Directions to the student.

1. Decode the five messages as quickly as you can, remembering that accuracy is more important than speed.

2. Make no further record after the instructor commands "Stop," but report to the instructor and hand in your paper.

Directions for scoring.

1. Three points or three correctly decoded messages is the minimum score required to pass problem 5.

2. Allow no partial score for any separate decoded message.

3. For each message correctly decoded credit each student 1 point.

Problem No. 6

SETTING UP THE THEODOLITE UPON THE TRIPOD AND LEVELING IT

Equipment.

One theodolite.
One tripod.

Procedure.

(1) Prepare in advance a theodolite in packing case and one tripod not set up.

(2) Time allowed for this problem, five minutes. The same procedure as outlined in the previous problems for giving the command "Begin" and "Stop" should be followed by the instructor.

Directions to the student.

(1) Set up the tripod.

(2) Remove the theodolite from the packing case.

(3) Place the theodolite upon the tripod.

(4) Level the theodolite.

(5) Proceed no further after the instructor commands "Stop," but face about and report to the instructor.

Directions for scoring.

(1) Maximum possible score for this problem is 8 points.
(2) Allow no partial score.
(3) Credit each student with 2 points for each step correctly done in accordance with the directions.
(4) If a student fails to complete the four directions within the time prescribed, require him to repeat the problem.

PROBLEM No. 7

FOCUSING THE THEODOLITE

Equipment.

Theodolite mounted on tripod.

PROCEDURE.

Prepare in advance a theodolite mounted on tripod with lenses out of focus.
Time allowed for this problem, one minute. The same procedure as outlined in the previous problems for giving the command "Begin" and "Stop" should be followed by the instructor.

Directions to the student.

(1) Go immediately to the theodolite when the instructor commands "Begin" and focus it properly as previously instructed.
(2) Proceed no further after the instructor commands "Stop," but face about and report to the instructor.

Directions for scoring.

(1) If focusing has been correctly accomplished, credit student with five points.
(2) Allow no partial score.
(3) If student fails to focus the theodolite properly within the prescribed length of time, require him to repeat the problem.

PART II.—INFORMATION

NOTE.—Forty-five minutes will be allowed for Part II of the test.

Directions to the Student.

Below are a number of unfinished statements and questions, After each question or statement there are several words, phrases. or symbols, each preceded by a number. Only *one* of these answers is correct. Write the *number* of the correct answer on the *dotted line* at the right of each question. Do not start until the instructor says "Begin."
1. Clouds are formed by (1) the sun drawing water; (2) electrical energy in the atmosphere; (3) the cooling of water vapor. ------

2. Cirrus is the name of (1) a type of cloud; (2) a planet; (3) a condition of a barometer; (4) snowflake ------

3. The lowest form of cloud is usually (1) alto-cumulus; (2) nimbus; (3) stratus; (4) cumulus. ------

4. The observation of clouds includes three elements—(1) density, height, color; (2) amount, kind, direction; (3) depth, spread, weight; (4) shape, thickness, humidity. ------

5. When a thunderstorm is occurring during an observation, it is recorded by use of the following symbol: (1)  ; (2)  ; (3)  ; (4)  . ------

6. When a light fog is observed and no clouds, the weather should be recorded as (1) clear; (2) slightly fogy; (3) hazy; (4) no clouds. ------

7. The direction of haze is (1) the way the wind is blowing; (2) has no direction; (3) its elevation; (4) has depth. ------

8. When no direction in a cloud is observed, record (1) minus; (2) negative; (3) zero; (4) O. K. ------

9. When the sky is totally obscured it is recorded as (1) total; (2) no record; (3) 10; (4) cloudy. ------

10. Visibility can best be measured in (1) north; (2) south; (3) east; (4) west. ------

11. Variation in the visibility is brought about by (1) amount of haze or fog in atmosphere; (2) density of humidity; (3) condition of sun; (4) altitude. ------

12. For computing relative humidity, dew point, and vapor pressure, use the (1) gonimetric tables, (2) psychrometric tables, (3) logarythmic tables, (4) wind tables. ------

13. Weather observations should be made (1) slowly; (2) quickly; (3) at night; (4) at sunrise only. ------

14. After reading the maximum and minimum thermometers they should be (1) wiped dry; (2) dipped in alcohol; (3) set; (4) shaken well. ------

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully, and if what it says is *true*, make a *plus* sign (+) on the line to the right. If what is says is *not true*, put a *minus* sign (−) on the line to the right of the statement.

15. The dry thermometer usually indicates a temperature higher than the maximum thermometer. ------

16. If the mercurial barometer is broken, the station reading may be taken from the barograph. ------

17. If the anemometer cups are still, the direction of the wind is not recorded. ------

18. The relative humidity may be over 102 per cent. ------

19. The dew point may be higher than the wet bulb. ------

20. In sending a meteorological code message, the date is omitted. ------

21. Meteorological data should not be transmitted in code form. ------

22. Ballistic wind direction data are furnished aviation organizations. ------

23. The same code form is used in transmitting data to the Weather Bureau as is used for aviation. ------

24. Time the message is sent is omitted from artillery and meteorological messages. ------

25. The plumb bob of the theodolite should hang directly over the nail. ------

26. It is not always necessary to level the theodolite. ------

27. If the theodolite is set up by the seashore and leveled, the horizontal cross-hairs will not coincide with the sea horizon. ------

28. Theodolites are instruments used to measure atmospheric pressure. ------

29. The eyepiece of the theodolite is always in focus. ------

30. The horizontal circle is larger than the vertical circle. ------

31. The focus screw is the optical distance between the eyepiece and the object glass. ------

32. Adjustment of the theodolite is the same as the process of setting it up. ------

33. The base of the theodolite should be set up approximately level. ------

34. Orienting the instrument is the same as leveling. ------

35. Parallax is caused by improper focusing. ------

36. When no parallax occurs the cross hairs appear to be stationary in the field. ------

37. Theodolites should constantly be focused. ------

38. A theodolite can not be leveled if one of the level tubes is broken. ------

39. Four leveling screws could be used instead of three on the theodolite. ------

40. It is necessary to verify the adjustment of the level on the theodolite. ------

TO DETERMINE TRUE NORTH

Equipment.

Geological Survey map of locality.
One theodolite.
One magnetic compass.
Three wooden stakes.
One watch.

Information.

True north is the direction from the point of observation to the earth's geographical North Pole.

The magnetic north is the direction as shown by the north pointing end of the magnetic needle. It is, in most cases, only approximately true north.

The angle formed by the direction of the magnetic north with that of true north is called the *magnetic variation or declination.*

True north may be determined in four ways: (1) By transferring a true north and south line from some point near by to the observation point; (2) by magnetic compass; (3) by the sun's shadow at true solar noon; (4) by observation of the stars.

ESTABLISHMENT OF OBSERVATION POINT

The location of a suitable position for the placement of the theodolite in making balloon observations should be selected with care. It should be in the open, and in level country or on the top of a slight rise, if possible, so that a clear vision with an elevation angle of 6° is obtainable in all directions. The ground should be firm; sandy or marshy spots are to be avoided. There should be no obstacles such as trees, buildings, etc., in the immediate neighborhood. When a tentative site has been chosen, set up and level the theodolite at the desired spot and sight at the top of each obstruction that may interfere with an observation. The elevation angles of these obstacles should be less than about 6°. When a satisfactory location is found, drive a stout stake at least 3 feet into the earth, at the point where the theodolite is to be set up, so as to project about 3 inches above the ground. Drive a small nail into the top of the stake to serve as an accurate mark. This nail indicates the theodolite observation point.

Directions.

(1) *To determine the longitude of a given place.*—Select any authentic map upon which the location of the station can be found and which contains the meridians of longitude.

(2) Measure with any scale the distance between the meridians on a line which goes through the station and which is perpendicular

to the meridian of the place. Let that distance be thirty-seven twentieths of an inch from the ninety-fifth to the one-hundredth meridian. Measure the distance on the same line from the ninety-fifth meridian to the station. Let that be fourteen-twentieths of an inch. The longitude of the station is therefore fourteen-thirty-sevenths times 5° west of the ninety-fifth meridian, or 96° 54′. This process is called "scaling from a map."

Questions.

(1) *Can the latitude of the station be found by the same method that the longitude is found?*

(2) *How many degrees around the earth at the forty-ninth parallel?*

(3) *How many degrees from the Equator to the North Pole?*

(4) *Find the approximate latitude and longitude of your station by scaling on some convenient map.*

(5) *How many miles in 1° of longitude at the Equator? How many miles in 1° of longitude at 45° latitude?*

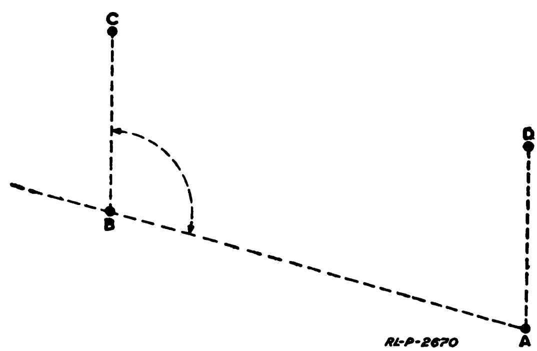


Fig. 48.—Method of determining north by transference

Directions

(3) *By transference.*—If it so happens that the true north and south line has been previously determined at a point not far from the point of observation selected for the theodolite, this line may be transferred with comparative ease. (See fig. 48.) Let A be the observation point and BC the true north and south line previously determined.

(*a*) Place theodolite carefully over point B and level it.

(*b*) Sight on C.

(*c*) Swing tube and sight on A, noting the angle ABC.

(*d*) Place theodolite over point A and level it.

(*e*) Sight on B.

(*f*) Then swing tube so that angle DAB equals 180° minus ABC.

Then AD is the true north and south line. If obstructions intervene, then a double transference will have to be made.

(4) *By magnetic compass.*—In cases of emergency only, the use of the compass may be made to determine the meridian. A compass may usually be obtained from the post engineer property officer. Plant a stake with the level top at the observation point and set the compass upon it in a horizontal position. Care should be taken to keep all iron and steel at a distance while the determination is being made. By careful sighting along the compass needle, plant a second stake north of the observation point at a distance of over 100 feet. This stake indicates the direction of the north magnetic declination at the station at which this operation is being performed in order to obtain the correct geographic north. The correction to be applied may be obtained from a map which gives the magnetic declination of the compass needle from true north at various places over the United States. In using the map find the correction for the station by reference to the line on the map passing nearest to the station; set up and level the theodolite over the observation point; and sight on the reference stake which indicates the magnetic north, with the azimuth circle set at zero. Rotate the azimuth circle by an angle equal to the correction obtained, to true north as found on the map, the motion being east of zero (the magnetic north) when the declination is west, and west when the declination is east of north. Plant a third stake at the final setting.

Question.

(6) *Which method is more accurate, by transference or by magnetic compass?*

(7) *What are the errors of the two methods?*

Directions.

(5) *By the sun.*—A method for determining the north-south meridian in the daytime depends upon an observation of the sun at true solar noon, which is only given by noon of the clock when the station is on a standard meridian and allowance is made for the equation of time. The principal difficulty in the method, therefore, consists in the determination of the correct time for the observation. Set up and adjust the theodolite at the spot chosen to be the observation point and attach a plumb bob and line. The shadow cast by this line on a horizontal surface at the true solar noon will be an exact north and south line. When established the line should be permanently marked by two stakes as in the above method.

(6) Before making the observation the observer must ascertain the exact difference between the standard time in use at the station and the true local time. This difference is found in the following manner: There is a difference in true local time of four minutes between points on the earth's surface differing in longitude by 1°.

Hence, the rule is: First find the correct longitude (to nearest minute) of the station—which may be determined from any reliable map. Subtract the meridian of standard time from the station longitude (in degrees). Multiply this difference by 4 and the result is the required time difference in minutes to be applied, taken as plus when the station is west of the standard meridian, and minus when east. The time correction, therefore, should be added to the local standard time when the station is west of the standard meridian, and subtracted from local standard time when the station is east of the standard meridian.

(7) The standard time meridians in the continental United States are the seventy-fifth, nintieth, one hundred and fifth, and one hundred and twentieth meridians. On these meridians a clock keeping standard time also keeps correct local sun time if proper correction for equation of time is made.

(8) *Example:* At what time by the clock will the sun cross the true meridian at a station located at longitude 83° 42′ west?

Standard of time for this region = ninetieth meridian.

$83° 42' = 83.7°$.

$83.7 - 90° = -6.3°$ distance of station from standard meridian.

$-6.3 \times 4 = -25$ minutes (to nearest minute).

Therefore (neglecting correction for the equation of time), true noon—i. e., when the sun is directly south—would occur at 25 minutes before 12 noon, or 11.35 a. m.

(9) To this difference between the standard time in use at the station and the true local time must then be added or subtracted, as the case may require, the so-called equation of time which is the number of minutes before or after mean local noon at which the sun passes the meridian. The equation of time is given approximately in the accompanying diagram (fig. 49), which is accurate enough for ordinary work. When the equation of time is plus, the sun is slower than the clock, and the specified number of minutes must be added to the true local noon to give the time at which the sun passes the meridian, and similarly when the sign is minus the number of minutes must be subtracted from local noon.

(10) *Example:* Suppose the north-south line is to be located at a station whose longitude is 79° 24′ west, the date being October 3.

Standard of time = seventy-fifth meridian.

$79° 24' = 79.4°$.

$79.4 - 75 = 4.4°$, distance of station from standard meridian.

$4.4 \times 4 = +18$ minutes.

(Plus sign taken because station is west of standard meridian. Hence +18 minutes equals time correction for station longitude. Correction for equation of time equals − 11 minutes (from fig. 49). Total correction equals 18 − 11, equals +7 minutes).

(11) Therefore the sun will be on the meridian at 12 o'clock plus 7 minutes, or 12.07 p. m., local standard time, and the shadow of the plumb line at this instant will be in a true north-south line.

(12) In order to mark this line accurately the procedure should be as follows: The theodolite has been set up and leveled for the observation with plumb bob suspended directly over a mark or a permanent stake, such as a pin driven into the head of a stake. At one minute before time for determination of north-south line drive another stake

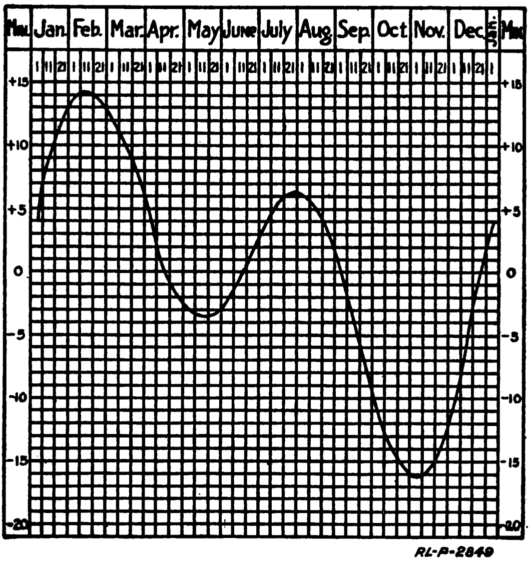


Fig. 49.—Equation of time chart

north of the first so that the shadow of the plumb line falls across the top of the stake. The instant that the sun is on the meridian, drive a pin in the second stake at exactly the center of the plumb line shadow. By carefully sighting along the line formed by the two pins this line may be extended to a stake properly placed at the distance of 100 feet or more due north of the observation point. This latter stake will then be used as a reference point for setting the theodolite in pilot balloon observations.

Questions.

(8) *What is solar noon?*

(9) *What is noon by standard time?*

(10) *What is meant by the "meridian of standard time?"*

(11) *What instrument in common use gives true solar time?*

(12) *At solar noon is the sun directly over one's meridian?*

Information.

A rough determination of the meridian may be made by sighting the theodolite on Polaris, the pole star. If, however, the proper time is chosen, true north may be determined at once by knowing when Polaris is at either its upper or lower culmination. Unless the proper time is chose for the observation, the determination of true north may be as much as 2° in error.

Question.

(13) *What is meant by "upper culmination"?*

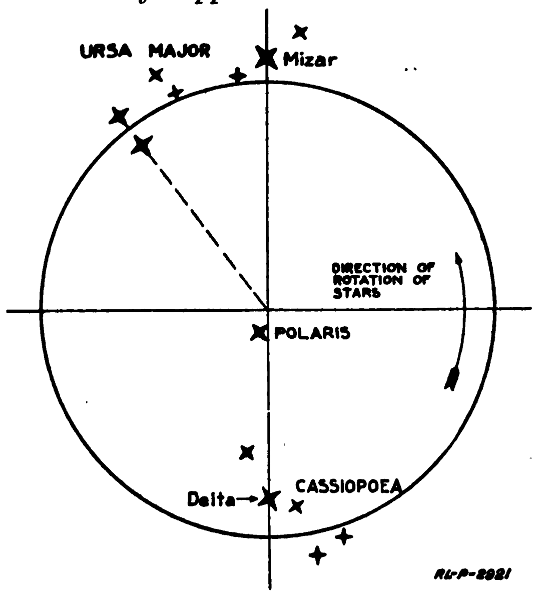


Fig. 50.—Relative position of stars.

Information.

The following is the method to be preferred: "Lazy W," Delta Cassiopeia is the lower left-hand star in the constellation Cassiopeia when this constellation is in the position of the letter W. This star crosses the meridian above the north point in the sky 10 minutes before Polaris; and at the same time Zeta Ursa Major (Mizar), the middle star in the handle of the Big Dipper, crosses the meridian below the north point. Cassiopeia and Ursa Major (a Great Bear, in which is located the Big Dipper) are on opposite sides of the North Star and about equidistant from it, apparently traveling in circles counterclockwise about the latter. The accompanying diagram (fig. 50) indicates the location of these stars.

NOTE.—Ursa Major means Great Bear and is the name of the constellation which contains the group of 7 stars commonly called the Big Dipper.

No computations and no tables are necessary in order to obtain the correct meridian if one acquaints oneself with the location of these stars.

If the theodolite is sighted on Delta Cassiopeia and Mizar as they near the meridian, at such a time that they may both be made to intersect the vertical crosshair as the telescope is depressed or raised to bring each successively into view, a determination will have been made of the true meridian. This may be checked by sighting on Polaris and noting the fact that it crosses the vertical crosshair just 10 minutes later.

It is essential that any instrument used in determining the true meridian should be in perfect adjustment throughout. The procedure then in establishing a correct reference point for setting the theodolite on the meridian is as follows:

Directions.

(13) Observe the approximate time when Delta Cassiopeia and Mizar cross the meridian, which happens twice in about 24 hours.

(14) Set up the theodolite over the observation point about one-half hour before the observation time and carefully level the instrument. Illuminate the cross hairs by means of a light reflected in through the objective end of the telescope.

(15) Clamp the base plate and engage the azimuth circle tangent screw and sight on the upper of the two stars mentioned. Depress the telescope by means of the vertical motion until the lower of the two stars is seen; it will at first lie to the left of the vertical cross hair. Again sight on the upper star at intervals and repeat the process until as the telescope is depressed both stars are seen to intersect the vertical cross hair. When this occurs do not again touch the azimuth setting, but raise the telescope to sight on Polaris and note that it crosses the vertical cross hair 10 minutes later.

(16) By means of the vertical motion, depress the telescope to sight upon the ground about 200 yards distant. Set a stake here and drive a tack or small nail into it coincident with the vertical cross hair. This stake is then the true north from the observation point and will serve as a reference point for setting the theodolite for balloon observations.

(17) *To orient the theodolite correctly preparatory to taking an observation.*—The determination of the north-south meridian as outlined above has resulted in the placing of a second stake at true north from the observation point. Set up and level the instrument as described. Set the horizontal circle at exactly zero degree and engage the tangent screw to insure that there will be no motion of this circle. Loosen the base-plate screw so as to allow the whole

instrument to rotate about a vertical axis, the azimuth circle remaining set at zero. By means of this motion and the use of the vertical circle, sight on the stake which indicates the true north. When approximately sighted, clamp the base plate and complete the adjustment in azimuth by means of the slow-motion screw under the base plate provided for that purpose.

Questions.

(14) *What stars in the constellation of "the Dipper" are called "the Pointers," and why?*

(15) *What means can you suggest for preserving the results of a good determination of true north?*

(16) *What is meant by finding true north by double transference?*

(17) *Why is the star method more accurate than the other methods?*

(18) *Can you suggest how to find true north by sighting a Polaris in a manner different than that described above?*

(19) *Is it necessary to have the cross hairs vertical and horizontal to do the above work?*

(20) *On what dates may true north be obtained by the sun method and the correction due to the "equation of time" be zero?*

(21) *What is meant by "orienting the theodolite"?*

SUGGESTIONS TO THE INSTRUCTOR

(1) In teaching unit operation No. 12, the instructor should always have in mind, field conditions where meteorological units may be changed in rotation quite often. This frequently happened during the late war while the meteorological unit was following up the advance of the First Army, and when for every succeeding position the true north had to be determined quickly. The method of procedure in this may be simulated by the instructor in class practice. Students should first find true north by the magnetic method and check it by the sun, or star method, as weather permits.

(2) The finding of true north by transference will seldom apply except when a meteorological unit is sent to hold a post, and even then the true north and south line as determined by the transference method should be checked by an observation of the stars.

(3) The following instruction test is provided for the use of the instructor, and the same general principles being involved as in preceding unit operations.

INSTRUCTION TEST NO. 12

PART I—PERFORMANCE

PROBLEM No. 1

DETERMINING TRUE NORTH WITH MAGNETIC COMPASS AND MAGNETIC DECLINATION CHART

Equipment.

One magnetic compass.
One magnetic declination chart.

Procedure.

(1) Designate the theodolite position where the students are required to work.

(2) The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

(1) Determine the true north, using the magnetic compass and the magnetic declination chart as you have been previously instructed.

(2) Report to the instructor as soon as you have completed this.

Directions for scoring.

Credit the student with 2 points if he has correctly determined the true north position.

Allow no partial score.

PROBLEM No. 2

DETERMINING THE DIRECTION OF TRUE NORTH OF A THEODOLITE POSITION BY THE USE OF CERTAIN STARS

Equipment.

One theodolite and tripod.
Pencil.
Paper.

Procedure.

(1) Select a clear night when the stars in the constellation of Cassiopeia and the Great Bear are distinctly visible. Assemble the class and designate the theodolite position and give the following directions.

(2) The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

(1) Erect the theodolite at the position indicated.

(2) Determine the direction of true north of your theodolite position by sighting upon certain stars in the constellation of Cassiopeia and the Great Bear.

(3) Report to the instructor as soon as you have completed this operation.

Directions for scoring.

(1) If the direction of true north has been properly determined, credit each student with 5 points.

(2) Allow no partial score.

PART II—INFORMATION

The administration of Part II is identical with that in previous unit operations.

Directions to the student.

Below are a number of statements, and just to the right of each one is a short dotted line. Read each statement carefully and if, what it says is *true*, make a *plus* sign (+) on the line to the right. If what it says is *not true*, put a *minus* sign (−) on the line to the right of the statement.

1. True north is at all times indicated by Polaris. ------
2. The accuracy of the transference made depends wholly upon how carefully the student does the work. ------
3. The magnetic method is more accurate than the star method. ------
4. The magnetic needle changes its direction slightly from time to time. ------
5. The sun method is more accurate than the magnetic method. ------
6. If true north were determined by the magnetic method at periods one year apart, and the same declinations were used, the same results would be obtained. ------
7. The magnetic compass does not give true north. ------
8. True north is the same as geographic north. ------
9. The meridians of longitude lie in a true north and south direction. ------
10. Of the four methods for finding true north, the star method is the most accurate. ------
11. The sun method is the quickest. ------
12. A means by which the true direction when determined may be best preserved is by stakes driven into the ground. ------
13. If two theodolite positions are used, two determinations of true north must be made. ------
14. If a determination is made for one position, it will be admissible to use the transference method to determine for true north the second position. ------
15. The true north should be determined at each balloon run. ------
16. The method of finding true north where it is necessary to know the longitude is called transference ------
17. Polaris is never at the true north. ------
18. There is a star in the southern heavens in a position so that the true south may be determined. ------
19. If there were a star in the southern heavens corresponding to Polaris it would be seen in the latitude of New York City. ------

Directions for scoring.

(1) The maximum possible score for Part II of this test is.... 19
(2). The minimum score required to pass Part II.......... 14
(3) The questions are to be scored as explained on page 22.

INFLATION OF THE BALLOON

Equipment.

Four balloons (assorted sizes and colors).
One cylinder of hydrogen.
One hose cock, type ML–56.
One tubing, rubber, 5 feet long by one-half inch inside diameter.
One hose coupling, type ML–49.
One additional weight 7.72 ounces, or 219 grams.
Six rubber bands, No. 16.
One Stillson wrench.
One paper lantern. }
One candle. } For soundings at night.
One wire and string. }

Information.

The balloons are of rubber, made in two sizes, 6 inches and 9 inches in diameter, uninflated, and having approximate diameters of 26 inches and 36 inches, respectively, when inflated. Uncolored and colored balloons are furnished; uncolored for soundings on clear, sunny days; red or black balloons for gray, cloudy days. The type numbers of these balloons are ML–50 for the smaller size, uncolored; ML–51 for the smaller size, colored; ML–52 for the larger size, uncolored; ML–53 for the larger size, colored.

Question.

(1) *Why is it necessary to have two sizes of balloons?*

Soundings at night.—For soundings at night a small lantern made of paper and illuminated by a piece of candle, three-fourths inch long, is suspended about 10 feet below the balloon by wire and string. (See fig. 53.) These lanterns are made up at stations from patterns furnished by O. C. S. O. (See figs. 51 and 52.)

Care of balloons.—Balloons should be stored in a dry, cool place, in a closed box. They are usually received, covered with powdered talc to prevent chafing and sticking together. If the rubber is cold the balloons are apt to burst during inflation, and for this reason they should be made soft and pliable by uniform warming. A balloon which has been carefully stretched by inflation is not injured, but rather improved. Do not expose an inflated balloon to the sun longer than is necessary before releasing it.

Question.

(2) *a. Why is it necessary to make the balloon soft and pliable before inflation?*

b. How should this be done?

Information.

Use of weights and cylinder.—The hose cock, weighing 4.66 ounces, is used alone when balloons of the smaller size are being inflated. When inflating balloons of the larger size an additional weight of 7.72 ounces is attached to the hose cock.

The hydrogen cylinders are made of steel and should be tested every five years at a pressure of 3,360 pounds per square inch.

The cylinders are charged to 2,000 pounds per square inch at 70° F., and have a capacity of 2,640 cubic inches. (One tank will fill from 15 to 20, 6-inch ballooons.)

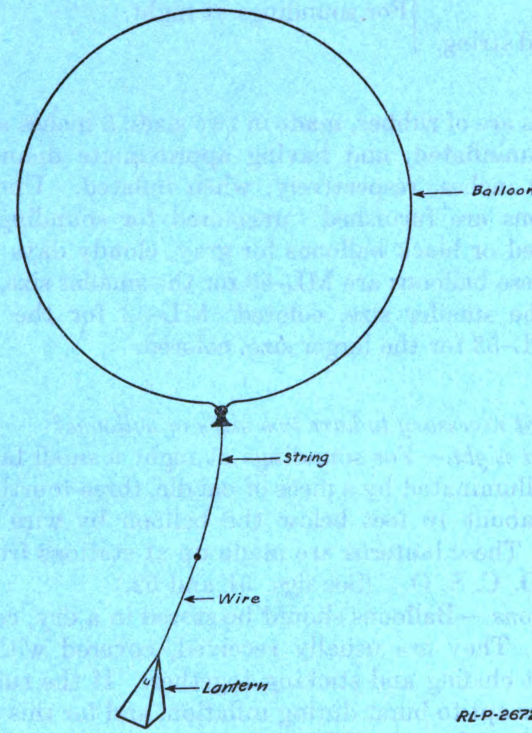


Fig. 51.—Sketch showing condition of paper lantern

Directions.

(1) To inflate the balloon, using hose cock, rubber hose, and special hose couplings (see figs. 53 and 54:) Attach the hose coupling and tubing to the hydrogen cylinder. Warm the balloon uniformly. (This precaution is especially necessary in cold weather.) This may be done by holding it near a stove or radiator, or, in the absence of these, by slipping it under one's blouse for a few minutes. When the rubber has become pliable, knead the balloon gently and fasten

the hose cock in the neck of the balloon. Roll the balloon up so as to expel any air from the balloon and the hose cock. Expel the air from the coupling and tubing by a slight rush of hydrogen from the cylinder. Slip the tubing cock into the end of the tube and inflate the balloon evenly until its ascensional force is slightly more than

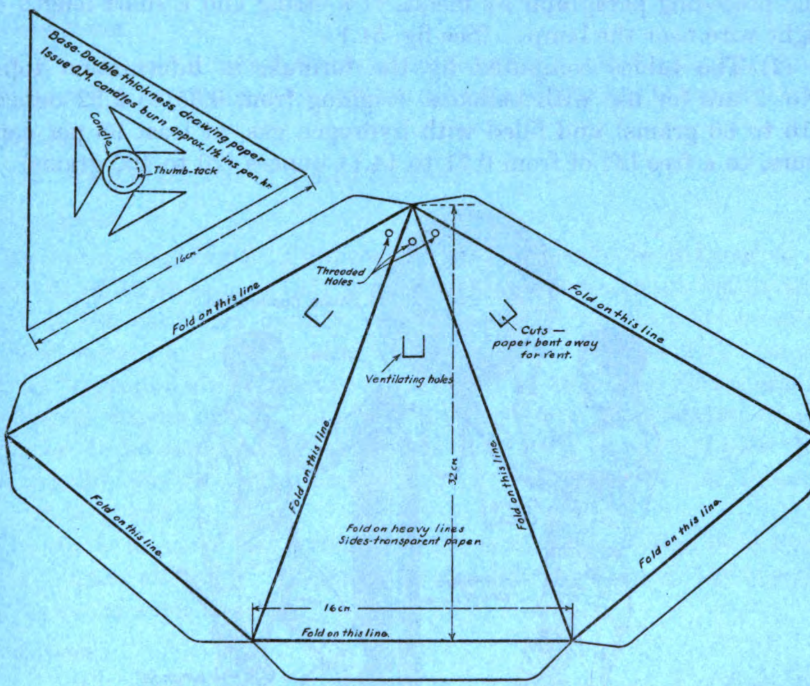


Fig. 52.—Sketch showing construction of paper lantern

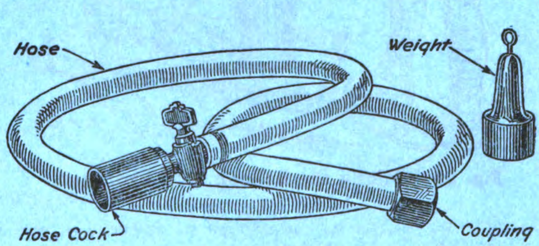


Fig. 53.—Rubber hose, hose cock, hose coupling, and weight

sufficient to lift the hose cock. Shut off the flow of hydrogen at the cylinder and then at the hose cock. Detach the hose cock from the tube. Let a little hydrogen out of the balloon by means of the hose cock until the weight of the latter just balances the ascensional force of the balloon. Now put two or three twists in the neck of the balloon just above the hose cock. Take this twisted part firmly in the thumb and forefinger, remove the hose cock, turn the lower part of the neck of the balloon over the twisted part, and secure by means of a rubber band stretched about the neck of the balloon thus twisted and folded. The balloon is now ready for a daylight sounding. In case the sounding is to be made at night, attach the lamp referred to in the preceding paragraph by means of a string and a short length of light wire near the lamp. (See fig. 51.)

(2) The tables computed by the formula in information topic No. 2 are for use with balloons weighing from 0.35 to 2.82 ounces (10 to 80 grams) and filled with hydrogen gas, at least 98 per cent pure, to a free lift of from 0.71 to 14.11 ounces (20 to 400 grams).

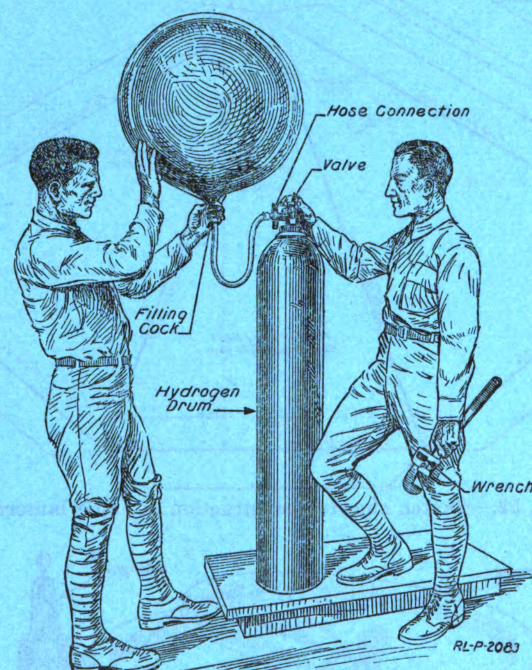


Fig. 54.—Filling the balloon with hydrogen

Question.

(3) *What is meant by a free lift?*

Information.

Pilot balloons 6 inches in diameter should be inflated to such free lift as will cause them to ascend at the rate of 200 yards per minute. Balloons weighing 1.06 ounces (30 grams) should be inflated to a free lift of 4.66 ounces (132 grams), to cause them to ascend at the rate of 200 yards per minute. In practice, the results will be sufficiently accurate if all balloons that weigh from 0.88 to 1.23 ounces (25 to

35 grams) are inflated to a free lift of 4.66 ounces (132 grams). A special hose cock weighing 4.66 ounces (132 grams) will be furnished all stations.

Question.

(4) *Why must the hose cock weigh only 132 grams?*

Information.

Pilot balloons 9 inches in diameter should be inflated to such free lift as will cause them to ascend at the rate of 250 yards per minute.

Question.

(5) *What is the size of a pilot balloon?*

Information.

Balloons weighing 2.12 ounces (60 grams) should be inflated to a free lift of 12.38 ounces (351 grams) to cause them to ascend at the rate of 250 yards per minute. In practice the results will be sufficiently accurate if all balloons that weigh from 1.76 to 2.47 ounces (50 to 70 grams) are inflated to a free lift of 12.38 ounces (351 grams). A special weight of 7.72 ounces (219 grams) will be furnished to all stations to be attached to the special hose cock which will give the proper lift for 9-inch balloons weighing from 1.76 to 2.47 ounces (50 to 70 grams).

In nearly all cases, balloons ascend faster near the ground than they do at higher altitudes. See table on ascensional rates of balloons in information topic No. 2.

Questions.

(6) *Why must balloons be inflated to ascend at a rate of 200 or 250 yards per minute?*

(7) *Why do balloons ascend faster near the ground than they do at higher altitudes?*

(8) *Would a balloon inflated to the same free lift, but made of inextensible material, answer as well as a pure rubber balloon?*

(9) *What kind of threads are in the hydrogen tank where the hose coupling is attached, right or left hand?*

(10) *If a small stream of hydrogen is escaping from the tank, what would happen if a flame were applied to it?*

(11) *How should hydrogen be stored?*

(12) *Is there any danger in having compressed hydrogen stored in a building?*

(13) *How can the danger be obviated?*

SUGGESTIONS FOR THE INSTRUCTOR

(1) It probably will be impracticable to have on hand enough material so that there may be instruction tests on the inflation of a balloon for the entire class at the same time. It is therefore suggested, as a means of saving material and at the same time of promoting instruction, that one member of the class go through the operations pertaining to the inflation of a balloon while the remainder of the class observe and write down their criticisms on the operations as performed by the man inflating the balloon.

(2) The sample test here given is designed for instructional purposes, and the instructor should accordingly use it with that end in view. As a result of the classroom work, the student should have learned how to prepare the balloon for inflation and how to get the material ready with the least possible work, how to select the balloon, how to make soundings at night, the use of the weights, and the care of balloons at all times.

(3) If the instructor finds it necessary to repeat the test, or if for any other reason he desires to vary the form of the instruction test for Part I, he may easily do so by recasting the questions in some of the other forms suggested in the introduction to Manuals Nos. 21 and 25 (revised editions) this guide. On account of the expense of balloon and gas, it is suggested that the instructor himself make a preliminary inflation, going through all the points and carefully calling the attention of the students to the various important features, and at the same time have the students take notes of the inflations. In all the range of meteorological observations there can be more waste in connection with the inflation of balloons than probably in any other operation. The instructor should, therefore, impress upon the students the value of these balloons and that economy is extremely important, as 6-inch balloons cost from 40 to 50 cents and 9-inch balloons cost $1.

(4) The following instruction test is provided for the use of the instructor, the same general principles being involved as in preceding unit operations.

INSTRUCTION TEST NO. 13

PART I.—PERFORMANCE

PROBLEM No. 1

INFLATION OF THE BALLOON

Equipment.

Four balloons (assorted sizes and colors).
One cylinder of hydrogen.
One hose cock, type ML–56.

One tubing, rubber, 5 feet long.
One hose coupling, type ML–49.
One additional weight, 219 grams.
Six rubber bands No. 16.
One Stillson wrench.

Procedure.

(1) Arrange the above equipment at some convenient location where the operation of inflation may be readily observed by the entire class. Provide pencil and paper for the remainder of the class who are to observe the experiment, and to record their criticisms of the student who inflates the balloon.

(2) The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time the student completes the problem. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

(1) Inflate one balloon, of a size and color agreeing with the conditions existing at the time of this inflation, so that it will have an ascentional rate of 200 yards per minute.

(2) As soon as you have completed this operation report to the instructor.

Directions for scoring.

	Points
(1) If the correct size and color of the balloon has been selected, credit	2
(2) If balloon has been correctly inflated, credit	5
(3) Allow no partial score.	

NOTE FOR THE INSTRUCTOR—Review the criticisms of the operation just performed as reported by the individual members of the class.

PART II.—INFORMATION

The administration of Part II is identical with that in previous unit operations.

Directions to the student.

Below are a number of statements and just of the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a *plus* sign (+) on the line to the right. If what it says is *not true*, put a *minus* sign (–) on the line to the right of the statement.

1. Hydrogen is heavier than helium. ------
2. If sufficient hydrogen is forced into a steel tank, the steel tank will finally rise into the air. ------

3. A rubber balloon is absolutely impervious to gases. ------
4. Cold balloons rupture more easily than warm balloons. ------
5. If a match is applied to a balloon an explosion occurs. ------
6. Inflation and deflation of a balloon impairs it. ------
7. Rubber bands are better than string to tie the neck of the balloon. ------
8. When a tank is charged with hydrogen gas to the pressure of 2,000 pounds at a filling, the pressure is greater at the end of the tank than in the middle. ------
9. If balloons are rapidly inflated the danger of bursting is overcome. ------
10. Balloons ascend faster near the ground than they do at higher altitudes. ------
11. Hydrogen should always be kept near a fire so as to increase its pressure. ------
12. The threads in the hydrogen tank where the hose coupling is attached are right-hand.
13. Balloons should be inflated to ascend at a rate of 50 feet per minute. ------
14. Hydrogen should be stored in a metal container. ------

Directions for scoring.

	Points
(1) The maximum score for Part II of this test is...........	14
(2) The minimum score required to pass Part II is..........	10

(3) The questions will be scored as explained on page 22.

MAKING A SOUNDING

Equipment.

The following equipment is supplied to each station for making and computing the results of air soundings:

1 theodolite, special aircraft, type ML–47.
1,000 cubic feet of hydrogen gas, compressed in steel cylinders.
100 balloons, rubber pilot, assorted sizes and colors, types ML–50, ML–51, ML–52, and ML–53.
1 tubing, rubber, one-half inch inside diameter, 5 feet long.
1 hose cock, special, type ML–56.
1 hose coupling, special, type ML–49.
1 box rubber bands, No. 16.
1 watch.
1 clipboard.
1 plotting board, special, type ML–55.
1 plotting board, special, type ML–57.
2 protractors and wind scales for use with plotting board, ML–55.
1 scale, for use with ML–57.
Pamphlets, instructions.
Forms, printed, meteorolgical.
Pencils.
Erasers, rubber.

Information.

The object of an air sounding is to determine the direction and speed of the wind at different altitudes. This information is obtained by determining at regular intervals of time the successive positions of the balloon floating freely in the air with a definite ascensional speed, and then plotting the horizontal projection of its path. Under certain conditions, instruments may be attached to those free balloons, and other meteorological elements such as air pressure, temperature, and humidity observed in addition to wind direction and speed. Experience has shown that the ascensional speed of the balloon may vary somewhat over or under the mean without introducing a serious error in the observation.

Question.

(1) *What conditions would be necessary to attach instruments for measuring air pressure to a free balloon, and how would it be possible to read them at a height of 3,000 feet?*

Directions.

(1) Two men, an observer and a recorder, are usually sufficient to do the necessary work in connection with a sounding, if there are no artillery computations to be made. Under unusual conditions more personnel may be required. If there is no automatic time buzzer the recorder must be provided with a stop watch.

Question.

(2) *What is the automatic time buzzer used for and how does it work?*

Directions.

(2) The recorder releases the balloon when all is ready; and immediately points the objective of the theodolite, taking a gun sight, at the rising balloon, the observer having previously disengaged the tangent screws. When the observer finds the balloon's image in the telescope he immediately pushes both tangent screws so that they engage with the horizontal and vertical circles, and by manipulating the screws follows the balloon as it ascends.

(3) The observer keeps the image of the balloon on the cross hairs of the telescope by means of the tangent screws.

(4) If there is telephonic connection with the plotting board the recorder then goes to the plotting board. If there is an automatic time buzzer in use, it buzzes at three seconds before the minute a warning and buzzes on the minute as a signal to read. The observer makes a reading every minute and calls the reading into the telephone connection to the recorder. If there is no telephone connection the recorder remains near the theodolite and at three seconds before each minute calls, "Warning." The observer then points the theodolite so the balloon is exactly at the intersection of the cross hairs and when the recorder says "Read" the observer reads, first, the elevation angle and then the azimuth angle, calling the results to the recorder as they are read. The observation should ordinarily continue as long as the balloon can be seen through the theodolite.

(5) During the pause necessary for making the first three or four readings, the balloon may leave the field of the telescope. In the first four minutes it will not be found difficult to relocate the balloon by means of the sights. After this, however, once lost the balloon is very hard to find, but since it stays longer in the field after each minute interval, there is no difficulty in following it after the first four minutes unless it bursts or is obscured by clouds or haze.

(6) All readings must be immediately entered on Form 201—Met'l as the readings are made. All the information called for on this form must be entered as near the actual time of the balloon ascension as possible. Too much emphasis can not be laid upon the manner of properly filling out the data sheet. This is all the more important since it is a feature which is easily neglected. A single error or omission on the data sheet will often render the entire data absolutely valueless, although the observation may have been in other respects perfect. A correct data sheet should be clear, complete, and accurate. To attain this result the requirements are: Completeness and accuracy in observation and care and promptness in recording. *Always record data immediately as taken; do not depend on memory.*

Question.

(3) *Why must data be entered immediately as taken?*

Directions.

(7) If any of the data called for is not obtained, the reason for such omission should be given.

(8) If any of the data appears to be questionable, the observation from which it was obtained should be repeated, if practicable, and a note entered regarding it.

(9) Complete notes will be made of all results which are unusual or call for comment of any kind, and of any data for which there is no regular place on the sheet. A space is provided on the data sheet for notes of this character. (Form No. 201—Met'l. "Field data sheet.")

Information.

Any rapid change in observed meteorological conditions should be noted, and also the following information, on Form 201—Met'l.:

a. Balloon data, including type of balloon (red, black, or uncolored, 6-inch or 9-inch); rate of ascent (yards per minute) as found from Table 1 or Chart A.

b. Observation data, including setting of theodolite. The readings of elevation and azimuth angles are to be taken and recorded when the instrument is sighted on the reference point for setting. This is to be done both at the beginning and at the end of every ascension. These readings will generally be the same, but there may sometimes occur variations and it is important that such be noted.

c. Starting time. The exact instant at which the balloon is released.

d. Times (from start) at which readings are taken. At each reading, record the time in minutes from the start of the flight, the latter being taken as zero. The first reading should be taken 15 seconds after the balloon was launched, the second 1 minute after launching, the third 2 minutes after launching, etc.

e. Angle readings (azimuth and elevation) at each reading. These should be read as nearly as possible to hundredths of a degree.

f. When the balloon is lost to sight the reason for its disappearance should be stated; e. g., balloon burst, obscured by clouds, lost in clouds, sun, haze, distance, etc. When lost in clouds the exact time (to the nearest second) at which the balloon disappeared and the readings of azimuth and elevation angles at this time should be recorded. This information should never be omitted.

g. In recording angles, a reading which for any reason is uncertain should be followed by a question mark.

Directions.

(10) Two or more men working together may take soundings.

(11) No. 1 man will inflate balloon as described in unit operation No. 13.

(12) No. 2 man will set up the theodolite as described in unit operation No. 10, and will connect up telephone head set.

(13) No. 2 man will then take an inflated balloon outside, where the theodolite is set up. No. 1 prepares the plotting board and gets necessary forms, pencils, and stop watch in readiness.

(14) Each man adjusts and tests head sets and determines if all is in readiness for sounding.

(15) No. 1 now tells No. 2 to release balloon. No. 2 then releases balloon and calls, "Gone," at the instant of release, at which signal No. 1 starts the stop watch.

(16) No. 1 warns No. 2, five seconds before expiration of each minute by calling, "Warning," and then says, "Read," at expiration of the minute.

(17) When No. 1 calls, "Read," No. 2 ceases to move the tangent screws on the theodolite until the readings of elevation and azimuth have been announced to No. 1 in the order named either by himself or one or more assistants.

(18) Readings will be announced as in the following example:

10.2 announced as one zero point two.
256.7 announced as two five six point seven.
100.6 announced as one zero zero point six.

(19) No. 1 enters the readings in spaces provided on Form 201—Met'l. *immeditaely as taken.*

(20) Readings are then taken each minute, on the minute, up to and including the fifteenth, unless a longer observation is desired or the balloon disappears sooner.

(21) When the balloon is lost to sight the reason for its disappearance, the exact time to the nearest second at which it disappeared, and the readings of the elevation and azimuth angles at this time should be recorded.

Questions.

(4) *If there are only two men taking a sounding, why is it necessary for No. 1 to take time with stop watch?*

(5) *In what ways may the balloon disappear before the end of fifteenth minute?*

(6) *Name the entries which may be made under "character of sun"?*

(7) *Why is it necessary to stop moving tangent screws when the command "Read" is given?*

(8) *Why are air soundings taken?*

(9) *Why must data be entered immediately as taken?*

SUGGESTIONS FOR THE INSTRUCTOR

(1) The following instruction test is provided for the use of the instructor, the same general principles being involved as in preceding unit operations.

(2) There probably will not be enough equipment to provide each member of the class with a complete set of equipment. However, the class may be divided into groups and members of each group so located that each student may have an opportunity to perform all the operations necessary in making a balloon sounding. The instructor should insist upon the observer "holding the balloon" as long as possible with the theodolite. It would be well for two groups to work together, at the same time competing with each other as to which group can follow the balloon the longest time.

INSTRUCTION TEST NO. 14

PART I.—PERFORMANCE

PROBLEM No. I

MAKING A BALLOON SOUNDING

Equipment.

One theodolite, special aircraft, type ML–47.
One balloon.
Hydrogen tank filled with hydrogen.
One rubber tubing.
One hose cock, special, type ML–56.
One hose, coupling, special type ML–49.
One rubber bands.
One watch.
One clipboard.
One form 201—Met'l.

Procedure.

(1) Prepare in advance the above equipment, conveniently situated where the instructor may observe the operation. Designate the men who are to perform this problem.

(2) The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

(1) Make balloon sounding beginning at ---- a. m., ---- p. m. (Time of sounding is to be designated by the instructor.) Assume

that the sounding is to begin at 8 a. m. The balloon must be inflated and theodolite in readiness before that time so that the balloon may be released at the time designated.

(2) Take the reading as instructed in unit operation No. 13, and continue until the balloon is lost to sight.

(3) Replace the instruments as you found them.

(4) After this has been completed report to the instructor.

Directions for scoring.

(1) Credit each student with 10 points if the general procedure has been correctly followed in making the sounding.

(2) Allow no partial score.

PART II.—INFORMATION

The administration of Part II is identical with that in previous unit operations.

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and if what it says is *true* make a plus sign (+) on the line to the right. If what it says is *not true,* place a *minus* sign (−) on the line to the right of the statement.

1. The object of a balloon sounding is to determine the direction and speed of the wind at different altitudes. ------
2. It is not necessary for the observer to keep the image of the balloon on the crosshairs of the theodolite. ------
3. The observer makes a reading every minute and calls the reading off to the recorder ------
4. The form used to record data for balloon sounding is known as 201–Met'l. ------
5. Observations should not continue longer than 3 minutes. ------
6. It is unnecessary to enter information at the exact time of the balloon ascension. ------
7. A single omission on the data sheet will often render the entire data valueless. ------
8. If any data are called for and not obtained, the reason for such omission need not be recorded. ------
9. If any data appear to be questionable, the observation from which it was obtained should be repeated if possible. ------
10. Any rapid change in observed meteorological conditions should be the subject of a special communication, but need not be noted on Form 201. ------
11. The type of balloon should be recorded. ------

12. The exact instant at which a balloon is released is known as the starting time. ------

13. Azimuth and elevation readings should be read as nearly as possible to hundredths of a degree. ------

14. When a balloon is lost to sight, the reason for its disappearance should not be stated unless it disappears within few minutes. ------

15. In recording an angle reading, if for any reason it is uncertain, it should be followed by a question mark. ------

16. If a theodolite is disturbed during the reading it should be refocused. ------

17. When a sounding is to begin at 8 a. m., this means that the balloon should be released 15 minutes later. ------

18. Accuracy of reading angles is unessential in balloon observations. ------

19. The purpose of a balloon observation is to determine the degree of temperature at various altitudes. ------

20. A balloon sounding should never be made at night. ------

Directions for scoring.

	Point
(1) The maximum passible score for Part II of this test is -------	20
(2) The minimum score required to pass Part II is ------------	15

(3) The questions will be scored as explained on page 22.

CHARTING BALLOON OBSERVATIONS AND REDUCING WIND DATA THEREFROM FOR USE IN AVIATION

Equipment.

One blotting board, type ML–55 (see fig. 55).
One rule, brass (see fig. 55).
One protractor and wind scale, for use with ML–55 (see. fig. 56).
One pencil (soft lead).
One eraser, rubber.
One slide rule, 10-inch or 16-inch (not essential).
One ruler, 12-inch (not essential).

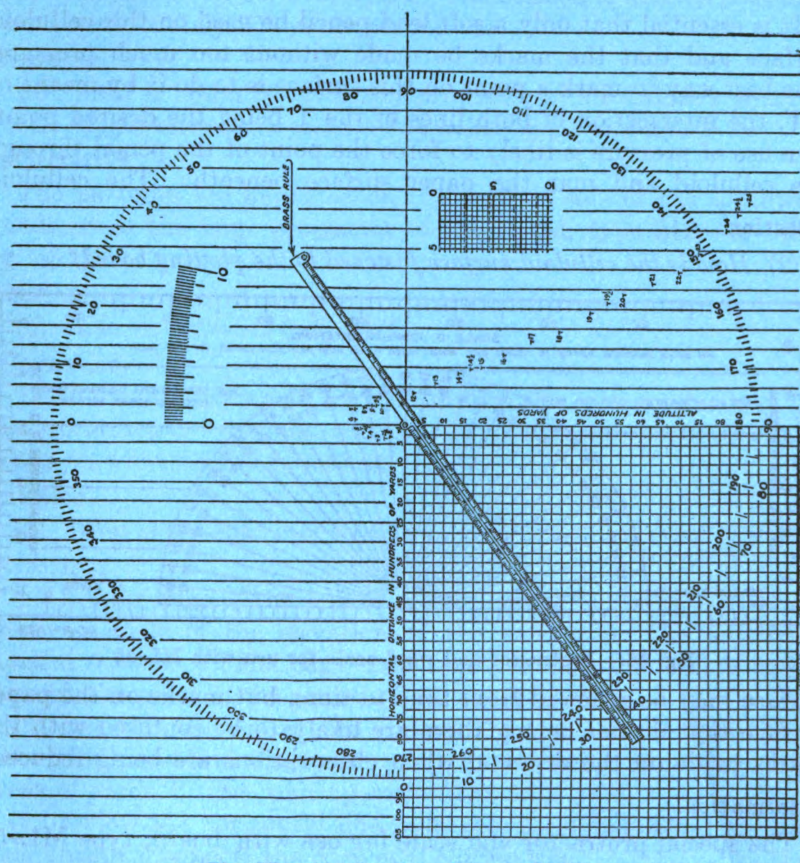


Fig. 55.—Plotting board, type ML–55

Information.

Material for reducing observations.—The special plotting board, type ML–55, consists of a chart, shown in Figure 55, on which are ruled a protractor and a system of north-south lines 1 inch apart.

The southwest quadrant of the large protractor circle is ruled in small squares. This chart is glued to a drafting board and covered with celluloid. The surface of the celluloid is slightly roughened by rubbing it with very fine emery cloth or sandpaper. This permits of its taking the mark of a soft lead pencil, which may afterwards be easily erased.

Question.

(1) *Why are the north and south lines only 1 inch apart on the plotting board?*

Information.

It is essential that only a soft lead pencil be used on this celluloid surface and that the marks be made without too much pressure. The best way to mark a point on this surface is to do it by means of a T, the intersection of both lines of the T being the desired point. The use of pressure is likely to force the point of the pencil through the celluloid and mar the paper surface beneath. The celluloid

Question.

(2) *How is the celluloid surface fastened to the plotting board?*

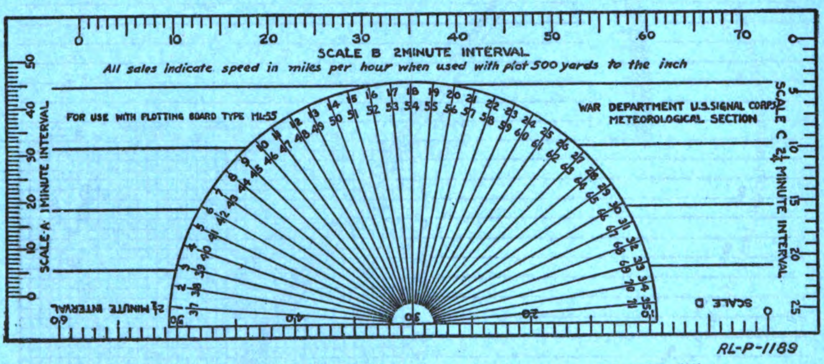


Fig. 56.—Protractor and wind scale for use with ML-55

surface may be renewed from time to time, but marks on the paper surface that do not belong there are likely to be confused with the marks made on the celluloid when observations are being reduced.

Information.

The special protractor and scale for use with board, type ML-55 is shown in Figure 56. It consists of a protractor callibrated in points, each point being equal to 5° of arc, four wind-speed scales, and a system of parallel lines. Wind-speed scale A is for use with intervals of one minute, scale B with intervals of two minutes, scale C with intervals of two and one-fourth minutes, and scale D with intervals of two and one-half minutes. The protractor is for use in determining wind directions. The system of parallel lines on the scale, three-fourths of an inch apart, enable the plotter to register the scale properly on the plotting board while the protractor is being read. The use of this protractor with scales in connection with board type ML–55 makes possible the plotting of the horizontal projection of the balloon's path and the determination of the wind speed and direction without computation. The radial lines of the protractor are numbered by an inner and outer series of numbers, the outer series running from 0 to 36, the inner from 36 to 72. Directions are indicated by the number of points, north being represented by 72, east by 18, south by 36, west by 54. The balloon is inflated so that it rises approximately 200 yards per minute.

Questions.

(3) *What is meant by horizontal projection of the balloon's path?*

(4) *Why are directions indicated by points on the protractor?*

Information.

The altitudes are indicated on the vertical side of the southwest quadrant of the large protractor in the board, type ML–55. (See fig. 55.)

Question.

(5) *How are altitudes indicated?*

Information.

The horizontal distances are indicated on the horizontal side of the same protractor. (See fig. 55; see also information topic No. 2 for tables on wind weighing factors.)

Question.

(6) *What is the difference between horizontal distances and altitudes?*

Directions.

(1) Set the edge of the brass rule on plotting board ML–55 at the observed angle of the elevation of the balloon on the protractor marked 0 to 90. (The edge used must be the edge which passes through the pivot in the center of the board.)

(2) Get the altitude at the end of the first minute from Form 201—Met'l, and find the point in the line marked "Altitude in hundreds of yards." (See unit operation No. 14.)

(3) Follow the horizontal line from this point indicating the altitude until it intersects the edge of the brass rule.

(4) From this intersection, follow the vertical line to the line marked "Horizontal distance in hundreds of yards." This is the horizontal distance of the balloon from the theodolite, at the instant the reading was taken.

(5) Enter this amount in the column on Form No. 201 marked "Distance from observation point, yards."

(6) Now set the brass arm at the angle of the azimuth of the balloon, using the circle 0 to 360°. The azimuth to be used is the azimuth at the end of the first minute taken from Form 201.

(7) Indicate the horizontal distance from the starting point of the balloon as just determined under directions 3 and 4 by a T made by a soft lead pencil, and mark this simply by the figure 1.

(8) Proceed as above to determine the position of the points indicating the azimuth and the horizontal distance of the balloon from the theodolite at each successive minute and indicate the T marks by the figures 2, 3, 4, etc. (See fig. 57.)

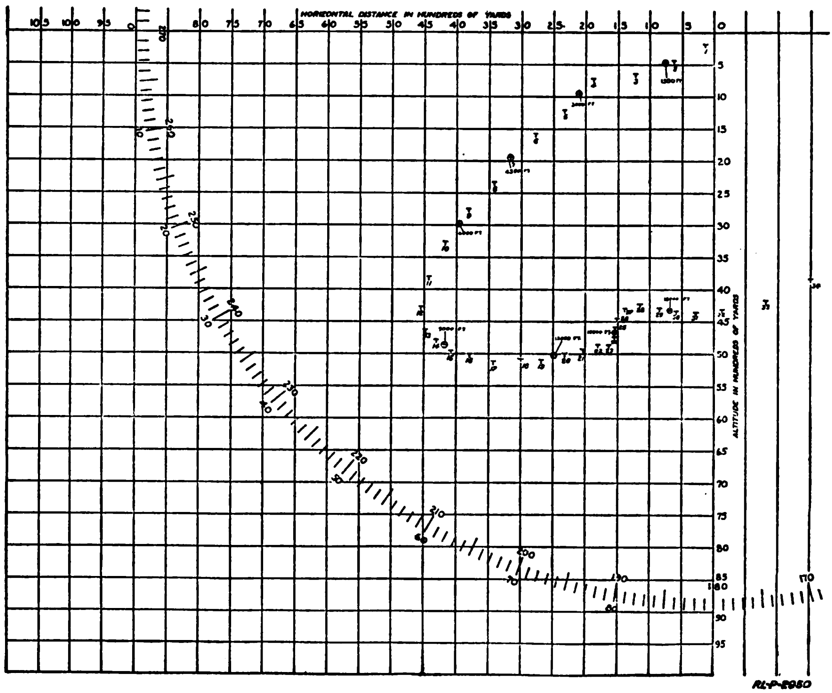


Fig. 57.—Sample balloon run plotted

Information.

If a smooth curve is drawn from the center of the circle through the T marks 1, 2, 3, 4, etc., that line will represent very nearly the true horizontal projection of the balloon's path. The T marks, if properly located, may be used to determine the air velocity; that is, wind speed and direction at these various levels. Since the balloon is free to travel in the direction and with the speed of the wind, it is evident that the direction at any time is determined by the line between any two successive points just located, and the speed is also determined by measuring the distance between the two points by a suitable speed scale.

Directions.

(9) Determine the wind speed at the 1,500-yard level as follows: Lay zero of the scale B at the 1,300-yard point and at the 1,700-yard point and read the speed in miles per hour. (See fig. 57.)

(10) Determine wind speed at 1,600-yard level as follows: Lay zero of the scale A at the 1,500-yard and at the 1,700-yard point and read the speed in miles per hour. (See fig. 57.)

Information.

There are four speed scales, A, B, C, and D, on the protractor, respectively, for 1, 2, 2¼, and 2½ minutes. Therefore to obtain the wind speed between any two points, use the speed scale which was designed to measure the speed between the points under consideration.

Directions.

(11) Determine wind direction between two points as follows: Place the special protractor for use with board type ML–55 on the board with the center of its semicircle on the point from which direction is to be measured; rotate the protractor about the point until the lines in its system of parallel lines are parallel with the north-south lines on the board. The second point will appear under the radial lines of the protractor. Read the direction on the inner series of numbers, if the second point lies east of the point at the center; read the direction on the outer series, if the second point is west of the point at the center. The direction thus determined is the direction from which the wind is blowing.

Questions.

(7) *Direction of the wind as shown by the protractor may always be checked mentally. How would you do it?*

(8) *The speed scales are made up to show the speed for various intervals. How would you make a scale for a 5-minute interval? For a 6½-minute interval?*

Information.

The wind speed and wind direction may be plotted on Form 204–Met'l. (See fig. 58.) The elevations are marked on the left in thousands of yards. The left half of the form is devoted to wind speed and right half to wind direction.

Directions.

(12) Plot the wind speed against the elevation. At the end of the first minute, when the balloon has attained an elevation of 240 yards, make a dot at the interesection corresponding to the 240-yard level and the wind speed at that level.

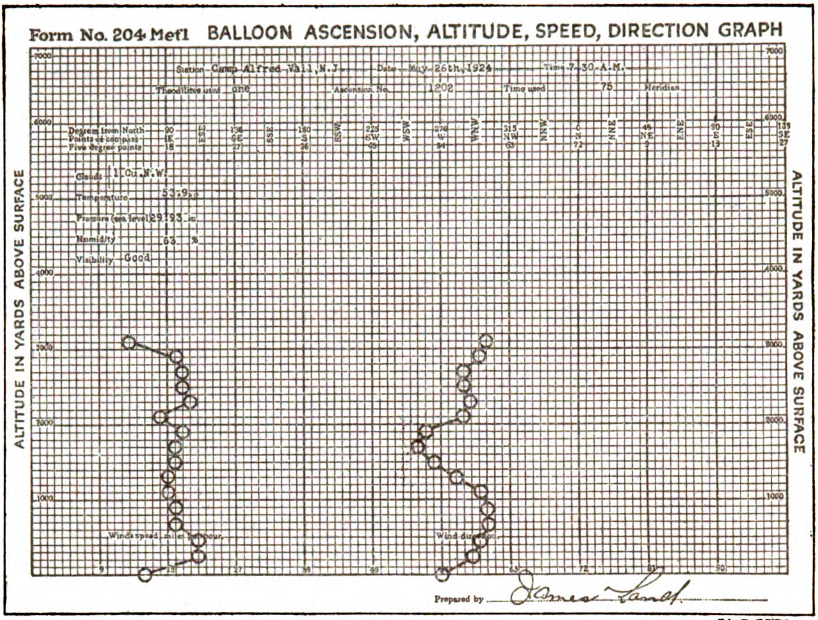


Fig. 58.—Form 204 Met'l.

(13) Do the same for the 460-yard level, and so on until the end of the run.

(14) Connect up the points as shown in Figure 58.

(15) Plot wind direction against the elevation. Make a dot at the intersection of the 240-yard level and the proper line representing the wind direction at that level.

(16) Do the same for the 460-yard level, and so on for the remainder of the run.

(17) Connect the points as shown in Figure 58.

Information.

The speed and direction may be picked out of the curves at any level desired.

Questions.

(9) *Can the units on this graph be changed—for instance, yards to feet, miles per hour to meters per second—and still have the curve represent the time conditions?*

(10) *On a 72-point scale, what number represents north?*

(11) *If the wind is from the northeast, what would be its scale number?*

(12) *How many degrees to 1 point on the 72-point scale?*

SUGGESTIONS FOR THE INSTRUCTOR

1. The following instruction test is provided for the use of the instructor, the same principles being involved as in preceding unit operations.

INSTRUCTION TEST NO. 15

PART I.—PERFORMANCE

Problem No. 1

CHARTING BALLOON OBSERVATIONS

Equipment.

One plotting board, special type ML–55.
One rule, brass.
One protractor and wind scale for use with ML–55.
One pencil (soft lead).
One eraser, rubber.
Form 201–Met'l, with observations thereon covering a period of 30 minutes and giving the elevation and azimuth angles.

Procedure.

(1) Prepare the above equipment in advance and give the following directions to the student.

(2) The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

Perform the following operation carefully and neatly and at the same time as quickly as you can.

(1) Clean the plotting board of all pencil marks and make the horizontal projection of the observation given you on Form 201.

(2) Report at once to the instructor as soon as you have completed this operation.

Directions for scoring.

	Points
(1) If the projection has been correctly done, credit each student with	10
(2) Allow no partial score.	

Note for the instructor.—In scoring this test the instructor should himself make a horizontal projection of the data presented to the student so as to facilitate the scoring.

PART II.—INFORMATION

The administration of Part II is identical with previous unit operations.

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a *plus* sign (+) on the line to the right. If what it says is *not true* put a *minus* sign (—) on the line to the right of the statement.

1. The southwest quadrant of the large protractor circle is ruled in small squares. ------
2. The surface of the celluloid on the plotting board is smooth so that the mark of a pencil can be easily erased. ------
3. The best way to mark a point on the plotting board is by means of a T. ------
4. The edge of the brass rule must be the edge that passes through the pivot in the center of the board. ------
5. The brass rule is used to determine the wind speed at various altitudes. ------
6. Wind directions can not be obtained from balloon observations. ------
7. To project the wind speed against the elevation it is necessary to use the protractor. ------
8. Miles per hour of wind speed may be changed to meters per second for convenience. ------
9. The 72-point scale contains 360°. If the wind were blowing from the northeast the scale number would be 72. ------
10. The plotting board used for charting balloon observations is known as type ML–55. ------
11. If the plotting board and schedules were lost, it would be impossible to make substitutions. ------
12. The protractor should be made of opaque material. ------
13. The direction of wind at the surface of the earth may be determine from the horizontal projection. ------
14. The value of wind velocities at various altitudes is important for aviators. ------
15. Balloon observations should always be charted. ------

Directions for scoring.

	Points
(1) The maximum possible score for Part II of this test is ----	15
(2) The minimum score required to pass Part II -------------	10

(3) The questions will be scored as explained on page 22.

CHARTING BALLOON OBSERVATIONS AND REDUCING WIND DATA THEREFROM FOR USE IN ARTILLERY

Equipment.

One plotting board, type ML–57 (see fig. 59).
One protractor for use on plotting board ML–57 (see fig. 60).
One pencil.
One ruler.
One parallel ruler (not essential).
One protractor, 64-point scale (see fig. 61).

Information.

Artillery and ordnance can not apply the actual wind direction and wind velocity directly to the laying of the gun; therefore the reduced wind data are furnished to these branches of the service. This is called the *ballistic wind.*

Question.

(1) *Why is reduced wind data called ballistic wind?*

Information.

The ballistic wind is defined as an assumed wind which would have the same effect upon the range and deflection of the projectile as do the actual winds through which the projectile passes.

For the purpose of this reduction the air is considered in layers or zones each having a depth of 1,500 feet, or some multiple of that depth. The line on board ML–55 connecting the horizontal projection of the balloon as it passes through the upper and lower boundaries of the same zone, indicates the resultant direction and speed of the wind in that zone. Beginning with the lowest zone, zones are numbered upward 1, 2, 3, etc.

The ballistic wind may be calculated by bearing in mind that the effect of wind direction and velocity upon a projectile is nearly proportional to the time that the projectile spends in the various layers of air. For example, about one-half the time of flight of the projectiles from the gun to the target is spent in the upper fourth of its maximum ordinate. Therefore, it is evident that the actual or true wind directions and velocities in the different zones must be weighted, or multiplied by a factor to obtain the ballistic wind. These factors are nearly in proportion to the time that the projectile spends in the various layers.

Question.

(2) *What determines an ordinate?*
(3) *How are different zones weighted?*
(4) *What is the difference between an ordinate and a zone?*

Information.

In order, therefore, that the meteorological section may give ballistic wind to the artillery, it must furnish such ballistic wind for the various ordinates used. The number and maximum height in feet in these ordinates are given velow:

Zone No.	Maximum ordinate feet	Rule
(1)	600	Use wind at first minute.
(2)	1,500	Use wind at second minute.
(3)	3,000	
(4)	4,500	
(5)	6,000	
(6)	9,000	
(7)	12,000	
(8)	15,000	
(9)	18,000	
(0)	24,000	
(1)	30,000	

In order to determine the ballistic wind for zone No. 1 or maximum ordinate 600 feet, using the wind speed and direction at two-thirds the height of the maximum ordinate, take the wind direction and speed during the first minute.

To determine the ballistic wind for zone No. 2, or maximum ordinate 1,500 feet, use the wind speed and direction at two-thirds the height of the maximum ordinate. This is best obtained by taking the wind speed and direction during the second minute.

The direction may also be determined by using the protractor, 64 points to a circle. (This protractor is used only in the taking of the final ballistic direction, and at no other time.) This protractor is used the same way as directed in U. O. No. 15.

To compute the ballistic winds for maximum ordinate 3,000 feet, 4,500 feet, and higher, the average wind speeds and directions as obtained for each layer are weighted by certain factors and then used. The table for use in this connection is found in information topic No. 2. In the left-hand column are the actual wind speeds. The columns headed 31, 41, 51, 61, etc., contain the modified wind speeds that are used when ballistic winds are computed for trajectories having maximum ordinates of 3,000 feet, 4,500 feet, 6,000 feet, and 9,000 feet, etc., and are values of the modified wind speed in the first layer. Columns headed 32, 42, 52, 62, etc., contain values for the second layer of the corresponding trajectories.

Directions will now be given for computing the ballistic wind for an ordinate of 3,000 feet, which may represent the general case.

Directions.

(1) Determine ballistic wind for ordinate No. 3, or 3,000 feet. The man at board ML–55 calls out the wind direction and speed for first two and one-fourth minutes. The man at board ML–57 turns to the table (see information topic No. 2) and under 31, and opposite the actual speed or zone wind as called off to him by the man at board ML–55, finds the modified wind speed. He then lays off on board type ML–57 the reduced or modified wind speed, using special protractor for plotting board ML–57 and, with the direction as given,

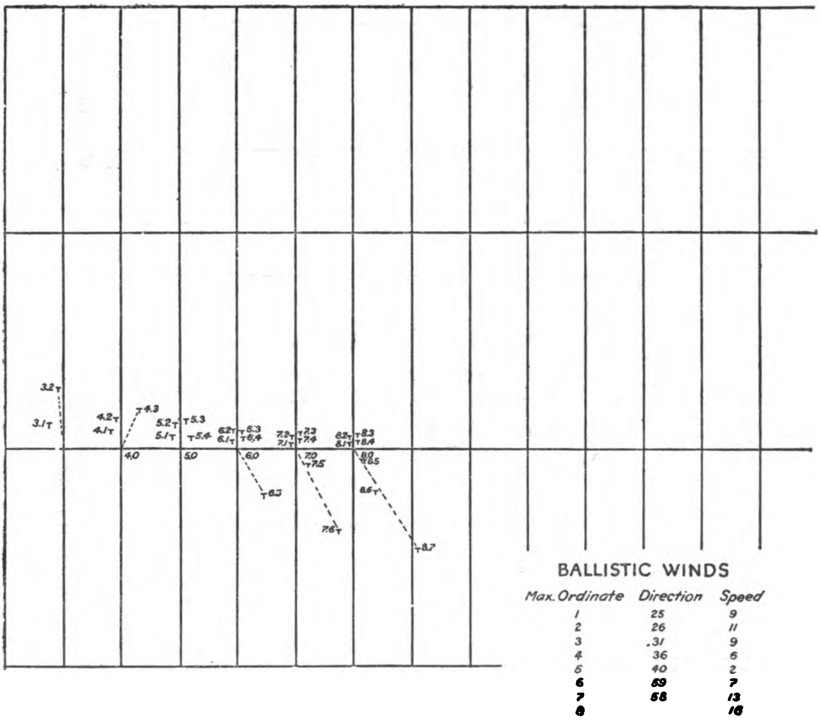


Fig. 59.—Plotting board, special type ML–57

beginning at the intersection of the east-west line and some north-south line, marks the point of the beginning of the plot 3.0 and the terminus of the first line 3.1.

(2) The man at board ML–55 then calls off the direction and the velocity in the second two and one-fourth minutes of the balloon's flight, and again the man at ML–57 turns to the table and finds the reduced wind speed opposite the actual wind speed and below 3–2.

(3) He then lays off, beginning with 3–1, a point having the direction and reduced wind speed as found in the table and marks it 3–2.

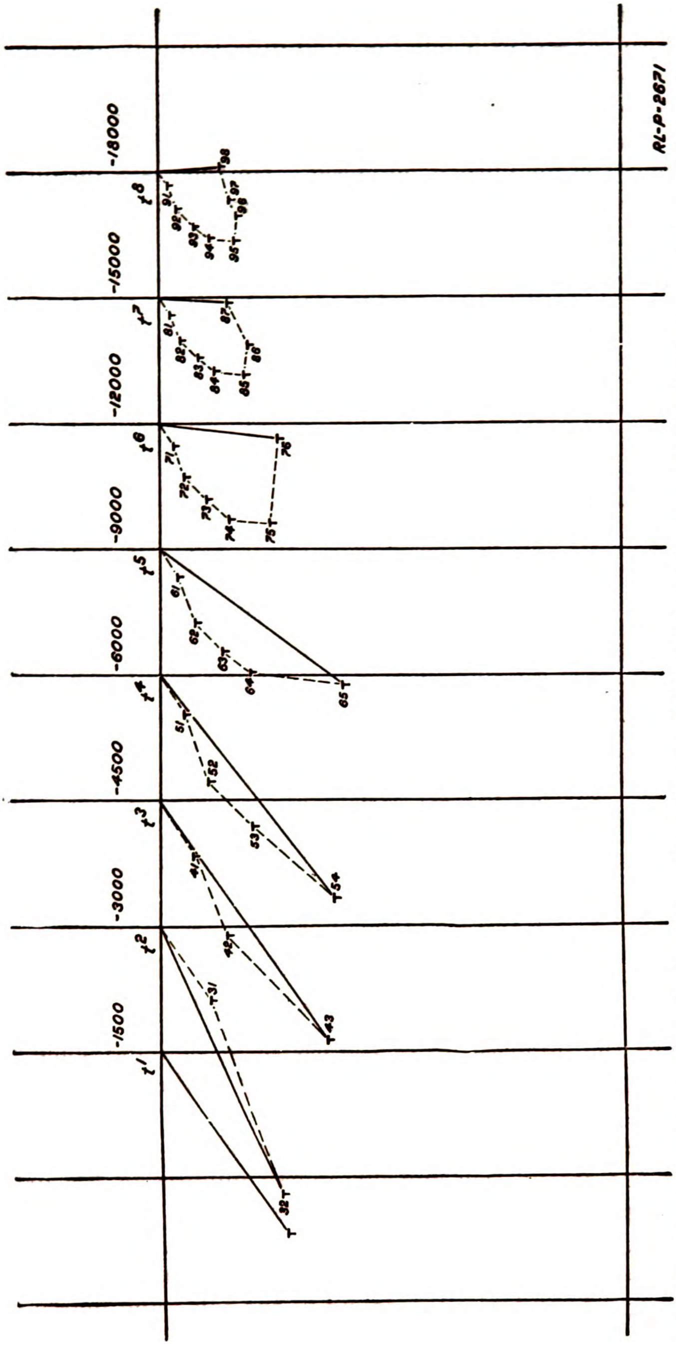


Fig. 60.—Section of board ML–57 showing polygons from which ballistic winds are determined for various maximum ordinates (based on data in Table I, I. T. No. 2)

(4) He then finds the ballistic wind speed by measuring from the starting point 3.0 or the intersection of the north-south and east-west line, to the point 3–2. This gives the ballistic wind speed.

(5) To find the ballistic direction: Use the protractor scaled to 64 points, and find the direction of the line representing ballistic wind speed as previously described.

Information.

The directions just given apply to the determination of ballistic wind direction and wind speed for a single ordinate, but the calculation of ballistic winds for all ordinates must be done simultaneously while the balloon is in its flight, and preceding directions will be modified as follows showing how this is accomplished.

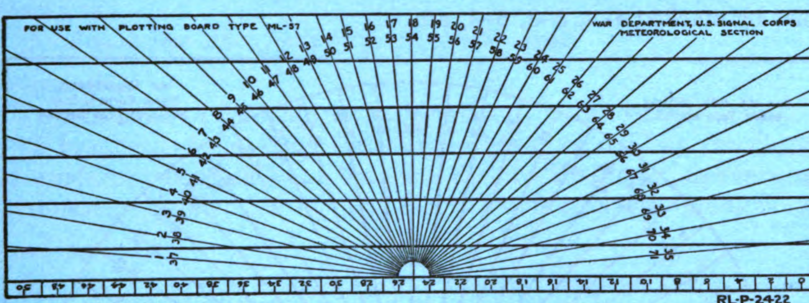


Fig. 61.—Special protractor for use on plotting board ML–57

Directions.

To compute ballistic wind speeds and directions for maximum ordinates, 3, 4, 5, 6, etc.—

(6) Man at board ML–55 calls off speed and direction for layer 0–1,500 feet, or for the first two and one-fourth minutes.

(7) Man at board ML–57 turns to the table, information topic No. 2, with the actual zone wind speed as called off, and finds this wind speed in the first column and the reduced wind speed opposite the actual wind speed and in columns headed 31, 41, 51, 61, etc.

(8) He then lays these wind speeds in the proper directions in succession on board ML–57. In laying off these points on board ML–57, he uses the special protractor (see fig. 61), and measures from the intersection of the east-west line with the north-south lines, as shown in Figure 60, and in the direction of the zone wind as called off.

(9) Points thus determined will be marked, 3–1, 4–1, 5–1, 6–1, etc.

(10) When the man at board ML–55 calls off the second zone, the man at board ML–57 will again turn to the table as before and ascertain the reduced wind speed under columns 32, 42, 52, 62, etc.

(11) He will then lay off points using the zone wind direction and beginning with points 3–1, 4–1, 5–1, 6–1, etc., and marking the new points 3–2, 4–2, 5–2, 6–2, etc.

(12) While waiting for the wind direction and speed in zone 3 the man at board ML–57 will now complete the first polygon and record the ballistic wind direction and speed for trajectories of 3,000 feet maximum ordinate. He will use protractor with 64 points to the circle for ascertaining the ballistic direction.

(13) When he hears the wind direction and speed for zone 3 he enters the table with the wind speed as before, and beginning with point 4–2, 5–2, 6–2, etc., lays off the reduced wind speeds found opposite the actual wind speed in columns 43, 53, 63, etc., using the direction of the wind in zone 3. The new points thus determined must be marked 4–3, 5–3, 6–3, etc.

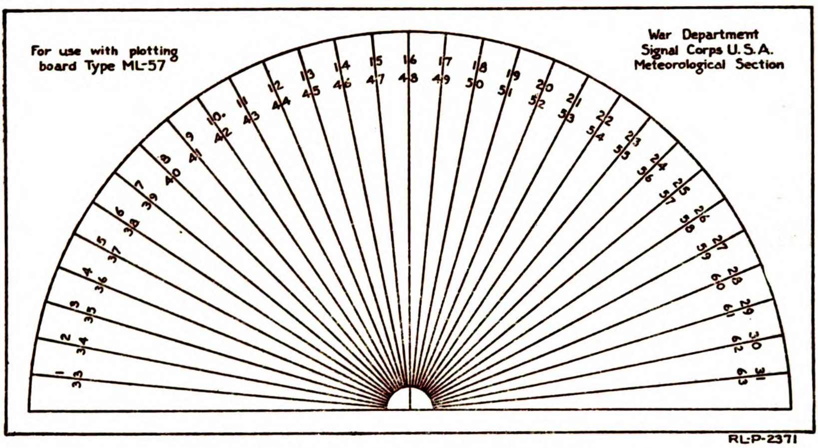


Fig. 62.—Protractor 64-point scale

(14) While waiting for wind direction and speed in zone 4, the polygon and ballistic wind for 4,500 feet will now be completed and the resultant wind direction and speed recorded.

(15) When the wind direction and speed for zone 4 is called off by the man at board type ML–55, the man at board type ML–57 enters the table of the zone speed and proceeds as he has done with the other zones.

Information.

When winds are being reduced for both artillery and antiaircraft artillery, as many as 12 polygons will be started when the wind direction and speed for zone 1 is called off. These polygons should be begun 8 or 10 inches from the left end of the board type ML–57. (See fig. 60.) Polygons may be started to the right of this initial polygon at each successive crossing of the north-south line with the east-west line from the middle of the board. The special protractor and scale for use with board ML–57 will be used in laying off these polygons. (See fig. 61.) This protractor is similar to that used on board ML–55 except that radial lines extend to the edge of the protractor. This is for convenience in marking directions on the board. The points are marked exactly as are the points on the protractor for use with board ML–55 and are used in a similar manner. The only difference in the two protractors is that one is designed for taking off wind directions from points already laid down on type ML–55, while the other is designed rather for laying down points in accord with direction called off to the man at board ML–57, although it may also be used in taking off wind directions.

Questions.

(5) *Could any other form of protractor be used?*

Information.

This method of recording wind directions meets the requirements of all branches of the Army with the exception of artillery and chemical warfare. These last two branches desire wind directions expressed in hundreds of mils; that is, in 64 points to the circle beginning north.

Question.

(6) *Why does the Artillery and Chemical Warfare Service require wind direction in hundreds of mils?*

Information.

To meet this need a protractor as shown in Figure 62 is furnished. All points laid down on board type ML–57 in the computation of ballistic winds will be laid down by using the protractor shown in Figure 61. Only ballistic wind direction—that is, direction of the full line shown in Figure 60—will be taken off with the protractor shown in Figure 62. The use of this protractor obviates the necessity of converting wind direction as expressed in the 72-point scale into the 64-point scale.

Figure 60 shows a series of polygons built up as described above. The resultants shown by the full lines are the ballistic winds for and ordinate ranging from 600 to 18,000 feet.

NOTE.—Observers should satisfy themselves that the instructions given above always give the direction of the wind as the direction from which it is blowing. It should be noted that the directions of the resultant lines from zero to the points located from azimuth angles given by the theodolite, show the direction toward which the wind is moving, since the theodolite points toward the moving balloon.

Question.

(7) *What do the polygons on the plotting board indicate?*

SUGGESTIONS FOR THE INSTRUCTOR

The following instruction test is provided for the use of the instructor, the same principles being involved as in preceding unit operations.

INSTRUCTION TEST NO. 16

PART I.—PERFORMANCE

PROBLEM No. 1

REDUCING WIND DATA FROM BALLOON OBSERVATION FOR USE IN ARTILLERY

Equipment.

One plotting board, special type ML–57.
One special protractor for use with ML–57.
One pencil (soft lead).
One protractor, 64-point scale.
One ruler.

Procedure.

1. On a table conveniently located, place the equipment listed above. The instructor should use, if possible, the basic data for plotting balloon runs as furnished by actual observations upon balloons. In the event that these are not available, the instructor should prepare fictitious data. It is suggested that data sufficient for only four or five ordinates be given and that later these data be increased so that the ballistic winds for projectiles having a maximum ordinate of 30,000 feet may be calculated.

The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions for student.

1. Determine the ballistic winds for as many ordinates as data are provided.
2. Report to the instructor as soon as you have completed this operation.

Directions for scoring.

1. If the ballistic wind data has been correctly recorded, credit each student with 10 points.
2. Allow no partial score.

PART II.—INFORMATION

Administration of Part II is identical with that in previous unit operations.

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a plus sign (+) on the line to the right. If what is says is *not true*, put a minus sign (–) on the line to the right of the statement.

1. The velocity and direction of the wind at the surface is a good indication of the velocity and direction of the wind at higher altitudes ------
2. As a general rule the velocity of the wind decreases in the higher altitudes. ------
3. The ballistic wind for the 600-foot ordinate is the true wind for the second minute. ------
4. The 64-point protractor is used for determining the direction of the ballistic wind. ------
5. Reduced wind data for use of artillery is called ballistic wind. ------
6. Ordinates are the same as zones. ------
7. A projectile fired from a gun spends about three-fourths of its time in flight in the upper fourth of its maximum ordinate. ------
8. Wind direction and velocity for different zones must be weighted. ------
9. The calculation of ballistic winds for all ordinates must be done simultaneously while the balloon is in its flight. ------
10. The wind data for use in artillery are identical with those for use in aviation. ------
11. Zones are numbered from the surface upward beginning with 1. ------
12. The depth of a zone is 20,000 feet, or some multiple of that depth. ------
13. The ordnance uses the same ballistic wind data as the artillery. ------
14. A parallel ruler is the most essential instrument in determining ballistic wind. ------
15. The plotting board used in determining ballistic wind is known as special type ML–59. ------

Directions for scoring.

	Pionts
1. The maximum possible score for Part II of this test is....	15
2. The minimum score required to pass Part II is...........	10

3. The question will be scored as directed on page 22.

BALLISTIC DENSITY

Equipment.

Tables A, B, and C. (See information topic No. 3.)
Pencil.
Paper.

Information.

In making up range tables the Ordnance Department assumes that the standard atmospheric conditions at the battery are:

Temperature, 59° F.
Barometric pressure, 29.528 inches.
Relative humidity, 78 per cent.
Air density, 1,203.4 grams per cubic meter.

It is also assumed that the temperature, pressure, and density decrease at definite rates with altitude. The actual atmospheric conditions are seldom, if ever, those that have been assumed as standard, and the Ordnance Department has, therefore, provided corrections to be applied to the laying of guns for variations from standard atmospheric conditions.

A ballistic density is a single computed air density that is used to express the density of the air for artillery purposes between the battery and a specified maximum altitude or ordinate which it is expected that projectiles will reach in traveling from the gun to the target. A separate ballistic density is determined for each maximum ordinate. For artillery purposes a ballistic air density is expressed as a percentage of the standard.

Question.

(1) *What is the difference between ballistic density and humidity?*

Information.

Ballistic winds and densities will be determined for the following maximum ordinate or zones: Surface, 600, 1,500, 3,000, 4,500, 6,000, 12,000, 15,000, 18,000, 24,000, and 30,000 feet above the meteorological station. It is impracticable to make upper air observations and compute ballistic densities therefrom in time for the data to be of use to artillery. It is therefore necessary to devise a method whereby ballistic densities can be closely approximated from observations at the ground. Tables have been prepared, therefore, for use with surface observations. Table IV, information topic No. 2, gives the ballistic densities. These are based on the average of the results of a large number of observations made in the United States under various atmospheric conditions.

Question.

(2) *What effect would great ballistic density have on a projectile?*

Information.

The air density at the ground may be determined from Table III (see information topic No. 2), using surface temperature and the barometric pressure as argument.

Question.

(3) *What is meant by an argument?*

Information.

This table is computed for relative humidity of 78 per cent. If the observed relative humidity is materially different from 78 per cent, the corrections indicated in Table IIIa should be applied to the results obtained from Table III. Table IV gives the ballistic densities for various maximum ordinates, using the air density at the surface as an argument. Actual air density decreases with altitude.

Question.

(4) *What causes air density to decrease with altitudes?*

Information.

Air density decreases on the average more rapidly if the surface density is above normal. It also decreases more rapidly near sea level than at higher altitudes. Table IV has been constructed to take these factors into account. If, for example, the ballistic densities are desired for use at a station 1,500 feet above sea level, interpolation should be made between the columns giving ballistic densities for use at stations 1,000 feet above sea level and 2,000 feet above sea level, respectively.

Directions.

The following example will illustrate the use of the tables:

Suppose the following data are given from which to determine the ballistic densities for the standard maximum ordinates up to 30,000 feet above the station.

Altitude of station above sea level	feet	1, 625
Temperature at station	°F	74
Barometric pressure at station	inches	29. 94
Relative humidity at station	per cent	42

1. Turning to Table III, the air density will be found to be 98.3 per cent of standard. As the humidity is 42 per cent and the table is computed for 78 per cent, Table IIIa shows that a correction of +0.4 per cent must be applied to the values determined from Table III, which gives a correct surface density of 98.7 per cent. With this value we enter Table IV.

2. Turn to Table IV. In using Table IV, the results will be sufficiently accurate if the ballistic densities and temperatures are determined, assuming the station to be 1,600 feet above sea level and the surface air density 99 per cent; that is, use the station elevation to the nearest 100 feet and the surface air density to the nearest whole per cent. The following values for ballistic density are then found from Table IV:

Maximum ordinate	Ballistic density
	Per cent
Surface	99.0
600 feet	98.9
1,500 feet	98.8
3,000 feet	98.6
4,500 feet	98.4
6,000 feet	98.3
9,000 feet	98.1
12,000 feet	98.0
15,000 feet	97.9
18,000 feet	97.7
24,000 feet	97.4
30,000 feet	96.7

Questions.

(5) *Is ballistic density more important to the artillery than ballistic wind data?*

(6) *Would it be possible to compute ballistic density without the use of Tables III and IIIa?*

(7) *How would this be done?*

SUGGESTIONS FOR THE INSTRUCTOR

1. The following test is provided for the use of the instructor, the same principles being involved as in preceding unit operations.
2. This is valuable in increasing the student's facility in the use of tables. Tests similar to the one provided here may be given frequently until sufficient accuracy has been acquired by the student in this respect.

INSTRUCTION TEST NO. 17

PART I.—PERFORMANCE

Problem No. 1

DETERMINING BALLISTIC DENSITY

Equipment.

Pencil.
Paper.
Atmospheric data.
Tables III, IIIa, and IV (see information topic No. 2).

Procedure.

1. Prepare in advance sufficient atmospheric data for maximum ordinates bearing from the surface to 30,000 feet. This data may be hypothetical or taken from actual conditions existing at the time.
2. The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

1. Find from each case given you below the ballistic densities for the maximum ordinates of projectiles varying from surface to 30,000 feet. Do this as quickly and accurately as possible.
2. As soon as you have completed this record hand your paper to the instructor.

Directions for scoring.

1. If the work has been satisfactorily accomplished, credit each student with 10 points.
2. Allow no partial score.

PART II.—INFORMATION

The administration of Part II is identical with that in previous unit operations.

Directions to the Student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a *plus* sign (+) on the line to the right. If what it says is *not true*, put a *minus* sign (−) on the line to the right of the statement.

1. In making up tables the Ordnance Department assumes that the standard atmospheric condition at the battery for temperature is 59° F. ------
2. Ballistic density and humidity are identical. ------
3. A separate ballistic density is determined for each maximum ordinate. ------
4. For artillery purposes a ballistic air density is expressed in degrees. ------
5. The standard relative humidity assumed by the Ordnance Department is 78 per cent. ------
6. High ballistic density will have a tendency to retard the flight of a projectile. ------
7. Air density at the surface is the same as at higher altitudes. ------
8. In determining the ballistic density, the altitude of the station above sea level must be considered. ------
9. The temperature at a station has no effect upon the surface density. ------
10. Ballistic density and ballistic wind data are of equal importance to the artillery. ------
11. Ballistic density for a certain ordinate may be the same as the relative humidity of that ordinate. ------
12. In computing ballistic density the observer need have only the following information:
    1. Relative humidity at station.
    2. Barometric pressure at station. ------
13. The highest maximum ordinates considered is 30,000 feet above the station. ------
14. Ninety per cent (90 per cent) is considered extremely high ballistic density. ------
15. Results will be sufficiently accurate if ballistic densities and temperature are determined assuming the station to be 1,600 feet above sea level and surface air density 99 per cent. ------

Directions for scoring.

	Points
1. The maximum possible score for Part II of this test is----	15
2. The minimum score required to pass Part II is-----------	10

3. The questions will be scored as directed on page 22.

MODEL AIRWAY BULLETIN BOARD

Equipment.

One model airway bulletin board (see fig. 63).
Chalk.
Data from stations on the model airway.

Information.

The "model airway" is a name given to certain routes of travel between Air Service fields. When the model airway was first formed the route started from Mitchel Field to Bolling Field, Langley Field, McCook Field, and Chanute Field. The object of laying out this airway was to establish routes of travel which would give pilots definite flight objectives. In addition, by flying over these routes, it is possible to teach the personnel how the fields should be manned and equipped to give the best meteorological service to the pilots. A part of this service consists in giving meteorological information so that the trips can be made more safely and economically than they could be without this information. In order that a pilot may know the condition of the ground at the field to which he is going and the weather conditions existing between two places, the model airway bulletin board was designed so that meteorological data could be presented in a compact and useful manner. (See fig. 63.)

The upper portion of the board gives a list of stations for which meteorological data are inserted in the proper places; this list of stations may be changed according to the location of the field at which the board is located. The list as printed shows the stations in which Bolling Field is interested, whereas the same bulletin board posted at Kelly Field should have a different list of stations. The lower part of the board shows how the flying forecast of the weather for the model airway is exhibited.

Directions.

1. Clean the board thoroughly with a damp cloth before the data for the day are received.
2. Write the data in the space allotted as quickly as they are received at the station.
3. Write the forecast of flying weather of the model airway as soon as it is received, or as soon as it is formulated at the station.

Questions.

(1) *Why is it necessary for the data to be entered immediately upon the board?*

(2) *Why is it necessary for the time to be entered at the head of every observation?*

METEOROLOGICAL DATA FOR THE MODEL AIRWAY

DATE March 1, 1924

	MITCHEL FIELD	CAMP VAIL	ABERDEEN PRO. GRD.	BOLLING FIELD	LANGLEY FIELD	DAHLGREN	LANGIN FIELD	McCOOK FIELD	SELFRIDGE FIELD	CHANUTE FIELD	SCOTT FIELD
TIME	9 a.m.	9 a.m.	9 a.m.	9 a.m.	9 a.m.		9 a.m.	9 a.m.	9 a.m.	9 a.m.	9 a.m.
WEATHER	Clear	Clear	Cloudy	Cloudy	Partly Cloudy		Clear Light Fog	Partly Cloudy	Clear	Drizzling	Cloudy
VISIBILITY	Fair	Fair	Poor	Poor	Poor		Poor	Fair	Good	Fair	Poor
SURFACE PRESSURE	29.84	29.84	29.89	29.83	29.89		29.88	29.87	29.98	29.84	29.82
PRESSURE TENDENCY	Steady	Rising	Falling	Falling	Steady		Falling	Rising	Rising	Rising	Rising
CLOUDS	None	None	9 A. Cu	9 A. Cu	6 A. St.		2 A. Cu	6 St	3 A. St	5 A St.	10 St.
HEIGHT OF LOW CLOUDS											3300
TEMPERATURE	30	30	32	34	41		30	36	15	40	49
RELATIVE HUMIDITY	80	60	90	85	80		80	60	80	90	85
STATE OF GROUND	Solid	Solid	Solid	Solid	Solid		Solid	Solid	Solid, Snow in Path	Solid	Soft
WIND AT SURFACE	WNW-12	WNW-8	SW-6	Calm	SW-24		N-1	NW-5	NW-2	NE-16	W-12
WIND AT 1500 FEET	WNW-25		W-11	SSW-3	W-27		ENE-3	SW-4	N-12		NW-25
WIND AT 3000 FEET	WNW-21		W-19	W-9	W-26		WSW-5	SW-8	NW-16		NW-32
WIND AT 4500 FEET	WNW-28		W-27	WSW-19	W-33		W-1	W-9	NW-11		
WIND AT 6000 FEET	WNW-36		W-29	W-23					WNW-27		
WIND AT 9000 FEET				WW-40							

FOR WEATHER FORECAST SEE OTHER BOARD

BULLETIN BOARD No. 1 – SCALE ½ in. = 1 ft.

FORECAST OF FLYING WEATHER ON THE MODEL AIRWAY

DATE March 1, 1924

WASHINGTON TO LONG ISLAND AND NORFOLK

Partly cloudy sky. Moderate to fresh westernly winds at 5000 feet.
Sunday clear weather with moderate winds mostly north and northwest.

WASHINGTON TO DETROIT

Partly cloudy sky. Moderate winds, mostly westernly at 5000 feet.
Sunday, clear weather with winds, mostly north and northwest.

SELFRIDGE FIELD TO CHANUTE FIELD

Generally clear sky. Moderate northernly winds near surface and moderate.
north and northwest winds about 2000 feet.
Sunday, cloudy weather with moderate north and northwest winds.

BEST FLYING ALTITUDE
- Washington to Mitchell Field. Low altitutude.
- Washington to Langley Field. 3000 to 5000 feet.

FOR REPORT OF PRESENT WEATHER ON MODEL-AIRWAY SEE OTHER BOARD

BULLETIN BOARD No. 2 - SCALE ½ in. = 1 ft.

RL-P-1035

Fig. 63.—Plan of model airway bulletin board

(3) *In case the observer writing the data upon the board has reason to question a particular element in the message, what should he do?*

NOTE.—The observer posting the data on the bulletin board should not perform this duty in a perfunctory manner. He should endeavor to visualize the condition at the field, and oftentimes by comparing the data of one field with another the mistakes in the message may be perceived, and either the data questioned as they are put on the board or a repeat message called for.

(4) *What is meant by a repeat message?*

(5) *What errors would you expect to find comparing data of one field with another?*

Information.

Stations at which model airway bulletin boards are located:

Aberdeen Proving Ground.	Langin Field.
Langley Field.	McCook Field.
Bolling Field.	Chanute Field.
Mitchel Field.	Scott Field.
Camp Alfred Vail.	Selfridge Field.

SUGGESTIONS FOR THE INSTRUCTOR

1. It is suggested in teaching unit operation No. 18 that the instructor prepare data to be used on the blackboard which will contain inconsistencies of the elements at various stations so that the student may get sufficient practice in detecting these errors.

2. If the station is not provided with a model airway bulletin board, the instructor may have the class construct one as a part of the work in connection with the unit operation, provided material is available. If no bulletin board can be procured, miniature copies of a bulletin board made of cardboard or heavy paper may be prepared. It is suggested that the instructor have the students construct these themselves.

3. The following sample instruction test is provided for the use of the instructor, the same principles being involved in its administration as in preceding unit operations.

INSTRUCTION TEST NO. 18

PART I.—PERFORMANCE

PROBLEM No. 1

PREPARATION OF A MINIATURE MODEL AIRWAY BULLETIN BOARD

Equipment.

Pencil
Cardboard.
Ruler.

Procedure.

The instructor will place on the blackboard or pin to the wall a drawing of the model airway bulletin board where all the students can see it. The size of the cardboard may be left to the discretion of the instructor. However, a size large enough to permit the student to enter data on the spaces made will be sufficient.

Directions to the student.

There is placed before you a drawing of a model airway bulletin board. With the equipment given you prepare a model bulletin board, following the plan as shown. Do the work neatly and at the same time as quickly as you can. As soon as you have completed the work hand it to the instructor.

Directions for scoring.

	Points
1. The maximum possible score for problem No. 1 is	5
2. *a.* If work has been neatly done, credit student with	2
b. If the drawing has been correctly copied, credit student with	3

3. Allow no partial score.

PROBLEM No. 2

ENTERING DATA ON BULLETIN BOARD

Equipment.

Model airway bulletin board.
Chalk.
Meteorological data from various flying fields.

Procedure.

1. Prepare in advance either actual data obtained from flying fields or hypothetical data.

2. Furnish each student with a copy of these data. It is suggested that the data be not arranged in the order that they are to be placed upon the bulletin board. This is done so that the student will be required to select from the information given him correct data and decide where they are to be placed.

Directions to the student.

1. Go to the model airway bulletin board and, with the data given you, record them in the proper places upon the board.

2. Do the work as quickly as you can. As soon as you have completed it, report to the instructor.

Directions for scoring.

1. *a.* Credit student with 5 points if the entries have been correctly made.

b. Credit student with additional 5 points if he has detected any inconsistencies in the data presented. This is providing inconsistencies actually appear in the data furnished by the instructor.

2. Allow no partial score.

PART II.—INFORMATION

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a *plus* sign (+) on the line to the right. If what it says is *not true*, put a *minus* sign (−) on the line to the right of the statement.

1. The model airway bulletin board is located at every aviation field in the Army. ------

2. The model airway bulletin board is used to display meteorological data for the use of aviation. ------

3. The condition of the ground at the aviation field need not be reported for entry on the bulletin board. ------

4. The bulletin board located at Bolling Field contains the same list of stations as one posted at Ross Field. ------

5. The lower part of the board shows the names of the stations from which data are received. ------

6. The upper portion of the board contains data on the forecasts of the weather for the model airway. ------

7. The bulletin board is made of slate. ------

8. The date the message is received at a station need not be entered on the bulletin board. ------

9. In comparing data from one station with another, inconsistencies in the report need not be checked, but should be entered as received. ------

10. The data should be printed when entered on the bulletin board. ------

Directions for scoring.

	Points
1. The maximum possible score for Part II of this test is.....	10
2. The minimum score required to pass Part II is..........	8

3. The questions should be scored as directed on page —.

METEOROLOGICAL OBSERVERS—RECORDS AND REPORTS

Equipment.

Pencil.

Paper.

Copies of all meteorological forms and records in current use.

Information.

LIST OF FORMS USED IN THE METEOROLOGICAL SECTION, SIGNAL CORPS

Form No.

1. Monthly record of observations.
2. Daily observation sheet.
13. Cloud chart.
52. Sunshine tables (blank).
79. Barometer card, for correction.
80. Correction for mercurial barometers for temperatures.
101. Single register form, anemometer record.
102. Quadruple register sheet, wind, sunshine, and rain.
104. Sheet for Dines's pressure tube anemometer.
110. Barograph sheet.
120. Thermograph sheet, 5 to 100 degrees.
130. Hygrograph sheet.
201. Pilot balloon ascension report.
202. Wind aloft report, for single flights.
203. Weekly summary of pilot balloon observations.
204. Altitude-speed-direction graph.
205. Pilot balloon telegraphic summary.
302. Model airway meteorological data.

In all meteorological work the prime factor of importance is accurate observations. Second to that is a careful recording of the same and the proper making out of reports. The reports of the meteorological stations consist of the observations made by the observer, together with the records made by the recording instruments.

In addition to the records of purely meteorological phenomena, there are other records of considerable importance that are often used in interpreting the records of any particular station. These records refer to the latitude, longitude, and elevation of the station, and standard time in use. Other records, while not always matters of observation, are often found of value as items of information and are also found necessary in working up reports. These include the times of sunrise and sunset and the times of moonrise and moonset.

Directions.

1. Assume that a meteorological station has just been established, and prepare a special report to be sent to the meteorological section

of the office of the Chief Signal Officer, Washington, D. C., containing the following information:

a. Name and rank of man in charge of station.
b. Name and rank of each man on duty at the station.
c. Latitude and longitude of the station to the nearest minute.
d. Standard of time in use, as seventy-fifth or ninetieth meridian.
e. The altitude of observation point for balloon ascension.
f. The altitude of station barometer.
g. General description of the location of station and observation point, accompanied, if possible, by photographs.
h. Inventory of the equipment on hand.
i. A schedule of the work, if this is different from the schedule sent out by the central office.

Questions.

(1) *Of what value in the report above are paragraphs e and f?*

(2) *Should meteorological reports contain information regarding tides if the station is situated near the ocean?*

(3) *What would be considered a meteorological phenomenon?*

(4) *What is the minimum equipment necessary to operate an Army meteorological station?*

Information.

Forms Nos. 1, 2, 101 or 102, 104, 110, 111 or 112, 120, 121 or 122 and 130 will be mailed monthly to the office of the Chief Signal Officer not later than the 10th of the month succeeding that of which they are a record.

The barograph, thermograph, and hygrograph traces, and Forms Nos. 101, 102, and 104 will include the record for the last day of the month.

In preparing Forms No. 1, 2, 101, 102, and 104, and barograph, thermograph, and hygrograph trace sheets for mailing, the sheets will be arranged chronologically with the earliest date on top, and fastened together with a Dennison or similar paper fastener.

Care should be taken to supply all the data called for on each form, and to make all entries in a neat, legible hand. Ditto marks (")will not be used in any form.

All instruments will be operated on the standard time in local use.

Questions.

(5) *Why not use ditto marks?*

(6) *What is standard time?*

Information.

Changes in the number or kinds of observations will be made only upon the approval of the Chief Signal Officer of the Army.

If an observation has been taken late it will be recorded in brackets, with the exact time at which it was taken, entered on the margin of the form. This will be used in computing all means and averages the same as if taken on schedule time, unless the conditions have changed since the time for the observation. In that case the probable conditions at the proper time of observation will be determined from the recording instruments by interpolation. These interpolated values will be entered in red ink above the late readings and used in all means and deductions.

Whenever an observation is taken late, or omitted, a full report of the facts will be made at once.

Anyone guilty of falsifying the record by reporting observations as taken at the prescribed hours which were not actually so taken, or in any other manner whatever, will be summarily and severely dealt with, regardless of previous record or length of service.

Directions.

PREPARATION OF FORM NO. 1—MET'L.

2. All observations entered on Form No. 2 will be immediately copied in the proper spaces on pages 2 and 3 of Form No. 1. Take observations already entered on Form No. 2 for the successive days and enter the data in Form No. 1, following the directions given below.

PAGE NO. 1, FORM NO. 1.—MET'L.

3. All entries on Form No. 1 will be printed in black record ink except when otherwise directed. Red ink will be used in underscoring. If an error is made in an entry, a line will be drawn through it and the correct entry made above it in black ink.

4. Entries of direction of wind and cloud movement will be printed thus: N., NE., E., etc.

5. Explanatory notes will be made in the margins of all sheets.

6. All meteorological observations will be checked before the next succeeding observation is taken.

Question.

(7) *Why should all entries be printed and not written on meteorological forms?*

Directions.

7. The *station elevation* is the elevation above sea level adopted for a station as a basis to which all pressure observations at the sta-

tion are correlated. Unless otherwise instructed, the actual elevation will be used as the station elevation.

8. When the position of a barometer is changed, a report of the facts, together with a request for barometer tables for the new elevation, will be made to the office of the Chief Signal Officer.

9. Underscore in red ink maximum and minimum of the column.

Questions.

(8) *What are barometer tables?*

(9) *What is the difference between actual elevation and station elevation?*

Directions.

PAGES NOS. 2 AND 3

In preparing pages 2 and 3 the following rules should be observed in disposing of decimals and in making corrections.

10. *Rule for disposing of decimals.*—In dropping decimals, if the figure to be dropped is greater than 5 (or 5 with a remainder), the preceding figure will be increased by 1. If the decimal figure to be dropped is exactly 5, the preceding figure when odd will be increased by 1, and when even it will remain unchanged. If the figure to be dropped is less than 5, retain the preceding figure unchanged.

11. The *sum of corrections* embraces all the corrections that are practically constant for a particular instrument in a particular location, namely, the correction for scale errors, capillarity, and gravity.

12. The *total correction* is the *sum of corrections* plus the temperature correction.

13. In computing the monthly means of barometer and vapor pressure the division will be carried to four decimal places, and the fourth decimal dropped in accordance with the preceding rule. In computing all means (except for barometer and vapor pressure) carry the division to two decimal places only, and dispose of the last figure (decimal) according to the preceding rule.

PAGE NO. 4

14. Page 4 will be prepared at stations where an automatic record of sunshine is made.

15. With the exception of the first and last fractional proportions of the "twilight correction," which will be recorded each day to the nearest hundredth of an hour, provided the sun when at the horizon was not obscured, the actual time of sunshine as recorded during each hour will be entered to the nearest tenth of an hour in the appropriate columns.

16. If at any time the amount of sunshine recorded by the instrument is known to be incorrect, either because the instrument fails to record when the sun is faintly obscured by thin haze, cloud, light fog, or light smoke, or because it continues to record for moderate cloudiness which obscures the disk of the sun, the true amount, as determined by eye observations, will be entered in the proper hour spaces in black ink and an explanatory note made on the margin of the form and on the original record sheets.

17. No twilight corrections for the first and last hours will be entered under the conditions given in the preceding paragraph, but the record for the entire time will be in black ink, and the entries for the fractional hours will be recorded to hundredths.

18. In the column "average cloudiness," page 4, observers will record in whole numbers the average amount of clouds during the day (sunrise to sunset) on a scale of zero (0) to ten (10).

19. The "character of day" will be determined from data in column headed "average cloudiness"; zero to three, inclusive, record "Clear"; four to seven, "Partly cloudy"; eight to ten, "Cloudy."

Question.

(10) *How are twilight corrections obtained?*

Directions.

PAGE NO. 5

20. Hourly thermograph readings, at the exact hour, taken from the corrected thermograph trace, will be entered on this page, except for the hours at which regular surface observations are taken, in which case the readings of the dry thermometer will be entered in the proper spaces. All entries, except the means, on this page will be in whole degrees.

21. When a recording instrument fails to record for a portion of the day, the missing data will be supplied by interpolation; the data thus obtained will be connected by an asterisk to an explanatory note on the margin.

22. Only data for whole days will be used in obtaining sums and means.

23. The means on this page will be recorded to tenths.

Question.

(11) *What is meant by sums and means?*

Directions.

PAGE NO. 6

24. On page 6 enter the prevailing direction of the wind for each hour in the proper spaces. Only one entry will be made as the

prevailing direction for any single hour. If two or more directions are recorded an equal number of times on Form No. 102, consider the directions adjacent to the hour, in determining the direction to be entered, as prevailing. When the wind movement for any hour is entered as "0," the direction for that hour will also be "0."

25. The prevailing direction for the day, and for the hour as recorded at the foot of page 6, is the direction or directions which appear most frequently in the respective line and column.

26. The direction recorded the greatest number of times during the month will be considered and entered as the prevailing direction for that period. If two or more directions occur an equal number of times, consider the adjacent directions in determining the prevailing directions for the month. Only one direction will be entered.

PAGE NO. 7

27. The average hourly velocity will be obtained by dividing the total movement by the number of hours in the month.

PAGE NO. 8

28. *Precipitation.*—The time of each beginning and ending of precipitation will be recorded; intervals of 15 minutes or less between the time of ending and recommencement not being considered, except near the time of an observation.

29. When a thunderstorm occurs the international symbol for thunderstorm (ꝁ) will be entered on the right-hand margin of page 8 on each day, midnight to midnight, standard of time in local use on which thunder was heard.

30. Precipitation from fog, dew, or frost will not be recorded in this form. Absence of precipitation will be indicated by the figure zero (0).

31. All beginnings and endings of precipitation will be entered in chronological order on the dates on which they occur, beginning at the left-hand column. Only one entry will be made in each column when there are not more than four showers. A. m. and p. m. will be entered as "a" and "p," respectively. When time of beginning and ending is unknown it will be recorded as D. N. a. or D. N. p. (during night).

32. The depth of snowfall (maximum depth, less amount, if any, on ground before the period) during the preceding 24 hours, will be entered each day in the column headed "Unmelted 4 p. m. to 4 p. m." on page 8. If any portion or all of the snow falling within the 24-hour period melts before the expiration of the period, the total fall for the 24-hour period will be the sum of the maximum depth for each fall.

33. Less than 0.05 inch of unmelted snow, and all snow which melts as it falls, will be recorded as "T," and in the case of the latter a marginal note, "Melted as it fell," will be entered.

Question.

(12) *What else in addition to melted snow is indicated by T in meteorology?*

Directions.

34. The total depth of unmelted snow on the ground each day at 4 p. m., by actual measurement (the means of three measurements when the snow is drifted), will be entered in the column headed "On the ground at 4 p. m.," page 8.

PAGE NO. 9

35. In entering records on page 9, the number of days with the maximum temperature 90° or above, 32° or below, and minimum temperature 32° or below, and zero or below, will be determined from the maximum and minimum thermometer readings as recorded to tenths. When the maximum or minimum temperature is taken from the thermograph it will be considered as whole degrees.

36. When on more than one date, both dates will be given.

37. Precipitation will be considered excessive when it equals or exceeds 2.50 inches in 24 consecutive hours, or 1 inch in 1 hour.

38. In computing the maximum precipitation in 24 hours and excessive precipitation data, the division of the months will be disregarded. The same data will not be included in the compilations for two months. When the record for the 1st of a month has been included in that for the preceding month, a note to that effect will be entered on page 9.

39. A day with hail is one on which a trace or more of hail fell.

40. Enter but one maximum wind velocity, direction, and date.

41. The "Monthly mean cloudiness" will be the mean of the column "Average daily cloudiness."

42. This is to include only days on which 0.01 inch or more of rain, melted snow, sleet, or hail has fallen.

43. A day with thunderstorm is one on which thunder is distinctly heard at the station, whether or not lightning is seen or rain falls at the station.

44. *Frosts.*—The date of occurrence of each frost will be recorded throughout the year in California and Florida and along the immediate coast of the Gulf of Mexico. In the spring all frosts will be recorded, beginning March 1, in the portions of Washington and Oregon west of the Cascade Mountains.

45. In the spring in all sections the date of occurrence of each frost will be recorded on and after March 21.

46. All frosts occurring at any station between May 1 and August 31 will be recorded.

47. During the autumn and winter, frosts will not be recorded subsequent to the date on which the first killing frost occurs.

48. Frosts will be designated as "light," "heavy," or "killing." The term "light" signifies no destructive effect except to tender plants and vines; "heavy," a copious deposit of frost, but which does not kill the staple products of the locality, and "killing," frost that is destructive to vegetation and staple products.

49. The character of frost, whether light, heavy, or killing, must sometimes be determined by the phenomenon itself, rather than by its effect on vegetation and the staple crops, since the latter may have passed the stage where injury was possible.

PAGE NO. 10

50. The directions for preparing this page are identical with pages 2 and 3. This page is only used in reporting special observations that may be requested from time to time by station commanders when special military problems are being planned.

PAGE NO. 11

51. The usual manner of recording kinds and amount of clouds will be followed as in unit operation No. 6.

52. When dense haze, dense smoke, or dense fog obscures eight-tenths or more of the sky, the state of the weather will be recorded as "Hazy," "Smoky," or "Foggy." Otherwise the state of the weather will be determined by the proportion of visible sky covered with clouds.

PAGE NO. 12

53. *Monthly meteorological notes.*—Page 12 will contain an account of important atmospheric phenomena, not easily susceptible of tabulation, occurring at or in the vicinity of the station. Events will be described after the manner of a narrative, covering the entire period of occurrence, whether consisting of a fraction of a day or of a number of days.

54. In the reporting of meteorological phenomena, too much care can not be exercised to make the account explicit and to state accurately the time of occurrence. Very often the omission of a single detail detracts materially from the value of the report.

55. In describing weather conditions and phenomena, midnight will be understood to refer to the end of the day and will receive the date thereof. Twelve o'clock midnight and 12 o'clock noon will be written thus, respectively, 12 midnight; 12 noon. Night will be referred to thus: "Night of the 3d–4th," and will cover the time from dark to daylight.

Information.

Forms Nos. 101 and 102.—There is entered on each sheet the meridian of time on which the record is made, as seventy-fifth meridian time, ninetieth meridian time.

Observers will examine the registers each morning immediately upon arriving at the office to see whether or not they are working properly. If the anemometer is out of order, a dial reading will be made at once and entered on the sheet, together with the time at which it was made.

Dial readings will also be made at each regular observation and at each noon during the incomplete record and when the record is started and entered, on Form No. 101 or No. 102. The data will be interpolated when the loss of record is less than 24 hours. Short breaks in the record when the self-register fails to work may be estimated when the observer believes he can approximate what the record should have been. In all such cases an explanatory note will be entered on all forms where the data are used.

In case of loss of record for a period of 24 hours or more, blank sheets for the period, containing the name of the station, dates, and such data as can be obtained, will be prepared and forwarded with the regular monthly package to the Chief Signal Officer.

Question.

(13) *What is meant by dial readings?*

Information.

Form No. 2 will be carried when taking a surface observation, and the data entered immediately thereon. The use of this form has already been described in previous unit operations.

Under "Notes" will be entered the character and beginnings and endings of precipitation, fog, haze, and smoke. Other meteorological phenomena, such as frost, thunderstorms, etc., will be described also under this heading, using the reverse side of Form No. 2 when necessary.

Records from barographs and thermographs.—Barograph and thermograph sheets will each be clearly marked on the face of the sheet with the name of the station, time on which the records are made (as seventy-fifth meridian, ninetieth meridian, local time, etc.), and date, each day's record being dated as near the noon line for that day as practicable. Whenever an instrument has not been running on correct time a note should be made to indicate the true time of the record.

Question.

(14) *How does the barograph record differ from the thermograph record?*

SUGGESTIONS TO THE INSTRUCTOR

1. *a.* It will be noted in unit operation No. 19 that particular emphasis has been placed upon the proper completion of Form No. 1—Met'l. This is the most important form used in the meteorological work, and the instructor should give the student as much drill as possible in the preparation of this form.

b. Students may be given this unit operation earlier in the course even though it appears as the last unit operation. The instructor should insist upon neat and accurate work in making up records and reports. The permanent records should be made with ink, but the temporary records, especially those which are made outside, may be made with pencil.

2. It may be found that a brief course in lettering is necessary for some students in order that neatness and uniformity may be obtained in the preparation of records.

3. *a.* The following sample of instruction test is provided as a guide for the instructor to determine which students are in need of special instruction in this work. The instructor should prepare tests of this nature for all records and forms used in the meteorological section.

b. The principles for this test should be the same as those involved in preceding unit operations.

INSTRUCTION TEST NO. 19

PART I.—PERFORMANCE

Problem No. 1

PREPARATION OF FORM NO. 1

Equipment.

Form No. 1—Met'l.
Pencil.
Paper.
Data to be recorded.

Procedure.

Furnish the student with meteorological data to be recorded on Form 1 for three successive days.

Directions to the student.

1. Take the data furnished you and record it neatly and accurately on Form No. 1—Met'l.
2. As soon as you have completed this, report to the instructor.

Directions for scoring.

1. If the form has been properly filled out and accurately recorded, credit each student with 10 points.
2. Allow no partial score, as the instructor must insist upon absolute accuracy in the preparation of this form.

PART II.—INFORMATION

Procedure for Part II is identical with that in previous unit operations.

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true*, make a *plus* sign (+) on the line to the right. If what it says is *not true*, put a *minus* sign (−) on the line to the right of the statement.

1. The altitude of the station barometer is not recorded on Form 2. ------
2. Form No. 1 is composed of 14 pages. ------
3. Latitude and longitude of a station are recorded on Form No. 1. ------
4. The decimal fraction is 5 or less; it should be dropped when entering data on Form No. 1. ------
5. To obtain the average number of observations for a month, the total number is added and divided by the number of days in the month. ------
6. Form No. 102 is used in recording wind observations. ------
7. Form No. 3 is not a meteorological form. ------
8. Page 10 of Form No. 1 is only used for reporting special observations. ------
9. All permanent forms should be filled out with red ink. ------
10. All temporary forms should be filled out with pencil. ------

Directions for scoring.

	Points
1. The maximum possible score for Part II of this test is....	10
2. The minimum score required to pass Part II is........	7

3. The questions will be scored as directed on page 22.

SUGGESTIONS FOR CONDUCTING PROGRESS TEST

Suggestions for conducting this progress test may be followed as in progress tests Nos. 1 and 2. It is suggested that the instructor familiarize himself with directions for preceding progress tests before administering this particular one.

General directions for scoring.

1. The total score for Part I of this test will be the sum total of the points obtained by each student for the various problems. Questions for Part II of the test will be scored in the same manner as similar questions were scored in the various instruction tests and progress tests Nos. 1 and 2.

	Points
2. *a.* The maximum possible score for Part I of this test is	37
b. The maximum possible score for Part II is	30
c. The maximum score for the entire test is	67
d. The minimum score required to pass is	50

PROGRESS TEST NO. 3

PART I.—PERFORMANCE

PROBLEM No. 1

INFLATION OF THE BALLOON

Equipment.

Assortment of different sizes and colors of balloons.
One tank of hydrogen.
One hose cock and weight.
Rubber bands.
Hose coupling.

Procedure.

1. Prepare the above equipment in advance, conveniently situated near the tank of hydrogen. In the assortment of balloons the instructor should give the student as many varieties as he is able to procure so that the student may have practice in distinguishing the various sizes and colors to be used for different occasions.

2. The instructor should note carefully the amount of time required to complete this problem.

Directions to the student.

1. When the instructor commands "Begin," select a balloon from the assortment before you and inflate it for an upper air sounding for present weather conditions.

2. As soon as you have completed, report to the instructor.

Directions for scoring. Points

1. The total possible score for this problem is 7
2. *a.* If he has selected the right color and size of balloon, credit each student with 2

b. If the balloon has been correctly inflated, credit each student with 5

3. No partial score allowed.

PROBLEM NO. 2

PLOTTING BALLOON RUN

Equipment.

One plotting board, type ML–55.
Pencil.
Paper.
Eraser.
Protractor.
Data for a hypothetical balloon run.
Slide rule (not essential).

Procedure.

Prepare in advance hypothetical data for a balloon run, or take actual data procured by the student in previous theodolite observations. By use of hypothetical data the instructor may bring out in the plotting of the balloon run such features as may not occur in reports made by the student.

Directions to the student.

1. Go to the plotting board and with the equipment provided for you, plot the balloon run from the data at hand.
2. As soon as you have completed, report at once to the instructor.

Directions for scoring.

1. If the balloon run has been correctly plotted, credit each student with 5 points.
2. Allow no partial score.
3. The instructor may more rapidly score this problem if he has prepared in advance the plotting of the balloon run on a sheet of tracing paper, which may be laid over the student's work to determine any errors.

PROBLEM NO. 3

CODING AND DECODING SURFACE OBSERVATIONS

Equipment.

Pencil.
Paper.
Two coded surface observations.
Two data or surface observations to be coded.

Procedure.

In preparing the data for coding, the instructor may use a hypothetical record to illustrate various forms of coding, or may direct the student to code the observations in two or more different code forms.

Directions to the student.

1. Decode the two coded messages furnished you.
2. Code the two surface observations furnished you.
3. As soon as you have completed this problem, report to the instructor.

Directions for scoring.

	Points
1. Maximum possible score for Problem No. 3	8
2. *a*. For each message correctly decoded as in directions 1, above, credit each student	2
b. For each observation correctly coded as directed in 2, above	2

3. The student will be required to make perfect coding and decoding of the four messages.

No partial score allowed.

PROBLEM No. 4

PREPARING THE QUADRUPLE REGISTER FOR OPERATION

Equipment.

One quadruple register.
Recording sheet.
Bottle of recording ink.

Procedure.

1. Prepare the above equipment in advance. Disconnect several wires from the binding post of the quadruple register and clean the pen so that it is free of ink.
2. The instructor should note and record the exact time of beginning and ending of this problem so as to determine which students can most quickly prepare the register for operation.

Directions to the student.

1. With the equipment set before you, prepare the quadruple register for immediate use.
2. Do the work as quickly as you can.
3. As soon as you have finished report to the instructor.

Directions for scoring.

1. Credit student with 10 points if he has successfully completed the following operations:

a. Properly connected the wires to the binding post of the quadruple register.

b. If new record sheet has been properly attached.

c. If pen has been properly inked.

d. If the clock has been wound and the gears set in motion.

2. Allow no partial score. If student does not satisfactorily perform each of the above steps the work will be repeated.

PROBLEM No. 5

PREPARATION OF FORMS 1, 2, 201, 203, 204

Equipment.

Copies of Forms 1, 2, 201, 203, 204.
Pencil.
Paper.
Hypothetical data for each form.

Procedure.

1. In the preparation of the data for recording on the above forms it is suggested that the instructor furnish the student with a variety of meteorological data such as he would be apt to find at different meteorological stations throughout the Army, climatic conditions being considered.

2. The student should first be required to fill out Forms 2, 201, 203, 204. As soon as this has been completed he will be given Form 1 to complete, using the data furnished him.

Directions to the student.

1. With the data furnished you fill out Forms 2, 201, 203, 204, recording the proper data on the forms provided.

2. As soon as you have completed this, turn in the forms to the instructor, who will then issue Form No. 1, with data to be entered on it. Fill our this form for the first three days only.

3. As soon as you have completed, report to the instructor.

Directions for scoring.

	Points
1. Maximum possible score for Problem No. 5	7
2. *a*. If Forms 2, 201, 203, 204, have been properly filled out, credit student with	2
b. If Form 1 has been properly filled out, credit student with	5

3. No partial score allowed.

PART II.—INFORMATION

Directions to the student.

Below are a number of questions which can be answered by a single word, phrase, or number. Write the correct answer to the question on the dotted line to the right of each question.

1. Except when otherwise directed what color record ink must be used on Form No. 1? ------------------
2. Are wind directions written or printed? ------------------
3. How many days are included in Form 203?
----
4. How many figures per code group in a meteorological message for the artillery? ------------------
5. What is the first figure of the first group of figures in a meteorological message for the artillery? ------------------
6. When are meteorological messages not coded? ----------------
7. The balloon is usually inflated so that it will rise how many yards per minute? ------
8. Should a hard or a soft pencil be used in charting balloon runs on a plotting board? ------
9. What is the diameter uninflated of an ML–52? ------
10. What is the color of an ML–51? ------

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and if what it says is *true*, make a plus sign (+) on the line to the right. If what it says is *not true*, put a *minus* sign (–) on the line to the right of the statement.

11. In charting balloon runs a heavy point should be made on the plotting board to show position of balloon. ------
12. In theodolite observations the angle of elevation can never be greater than 70°. ------
13. In determining a true north and south line, the magnetic compass method is the most accurate. ------
14. Smoking should never be allowed around hydrogen tanks because of danger of fire or explosion. ------
15. Both azimuth and elevation angles must be read to the nearest tenth of a degree. ------
16. Balloons should be kept in an open box at a temperature around 35° F. ------
17. The equation of time is used in determining the true north-south line by observation on the sun. ------
18. The easiest and surest way of getting a true north-south line is from a bench mark. ------
19. The magnetic compass method may be used for getting a north-south line if that method is most convenient. ------
20. The roof of a building is a poor place for a theodolite observation point because of the wind. ------

Directions to the student.

Below are a number of questions and unfinished statements. After each question or statement are several words, numbers, or phrases, preceded by a number. Only *one* of these answers is correct. Write the *number* of the correct answer on the dotted line at the right.

Sample: New York City is located in the State of (1) New Jersey; (2) Pennsylvania; (3) New York; (4) Massachusetts. ------

21. The protractor used with plotting board ML–55 has how many divisions to a circle? (1) 54; (2) 64; (3) 72; (4) 36. ------

22. The protractor used with plotting board ML–57 has how many divisions to a circle? (1) 70; (2) 74; (3) 64; (4) 72. ------

23. The Model Airway bulletin board is usually kept (1) near theodolite observation point; (2) indoors; (3) on the roof near instruments; (4) outdoors, just outside of station. ------

24. The best position for a theodolite observation point is (1) on a slight rise; (2) in a slight hollow; (3) in dry air; (4) near a wall to protect instrument from wind. ------

25. The time by the clock when the sun crosses the meridian is called (1) mean solar noon; (2) true sun meridian; (3) local standard noon; (4) true solar noon. ------

26. In cold weather, what should be done to a balloon before inflating it? (1) Heat it quickly; (2) stretch it by pulling; (3) warm it uniformly; (4) nothing. ------

27. In inflating balloon, how much hydrogen should be let in before shutting it off at the tank? (1) Enough to more than lift the hose cock; (2) until balloon is at least 30 inches in diameter; (3) only enough to make sure balloon will not burst; (4) depends on weather. ------

28. Pilot balloons should be inflated to make them rise (1) 240 yards per minute; (2) 230 yards per minute; (3) 250 yards per minute; (4) 300 yards per minute. ------

29. In plotting balloon runs on plotting board how are points marked? (1) By circle; (2) by an X; (3) by a T; (4) by a dot. ------

30. After a balloon run is plotted and the data coded, what should be done? (1) Erase everything from board; (2) connect points on board to make a graph; (3) nothing; (4) go over the points with a soft pencil. ------

SUGGESTIONS FOR CONDUCTING PROFICIENCY TEST NO. 1

The following proficiency test is designed to measure the student's proficiency as a meteorological observer. It is constructed so that it may be objectively scored and the results be nearly the same regardless of who scores the test. This is done in order that the test may be standardized and a proficiency mark for meteorological observers may be established just as for rifle marksmanship. This test is divided into two parts just as the progress tests were, throughout this manual: Part I—Performance; Part II—Information. The proficiency test should be given to the students as a conclusion to the course and should be considered in the light of a final examination on this subject.

For method of giving directions to students see progress test No. 1.

PROFICIENCY TEST NO. 1

PART I.—PERFORMANCE

PROBLEM NO. 1

PREPARATION OF THERMOGRAPH FOR OPERATION

Equipment.

One table.
One thermograph.
Supply of record sheets.
One bottle of recording ink.

Procedure.

1. Place the thermograph upon the table, with the supply of record sheets and recording ink.

2. The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

1. Perform the following operations carefully and neatly, but at the same time as quickly as you can.

a. Change the sheet on the thermograph.
b. See that the clock is properly wound.
c. Set the pen for 68°, 8.30 a. m. Monday.
d. Start the drum so as to avoid play in the gears.
e. Ink the pen.

2. As soon as these five operations have been completed report at once to the instructor.

Directions for scoring.

	Points
1. Maximum possible score for problem No. 1	10
2. Minimum score required to pass	8
3. For each one of the five operations performed correctly, credit each student with	2

4. Allow no partial score for single operations.

PROBLEM No. 2

READING BAROMETER AND MAKING ADJUSTMENTS

Equipment.

One standard mercurial barometer in its box.
Pencil and blanks for recording.

Procedure.

1. Prepare in advance the above equipment, conveniently situated.
2. The instructor should note and record to the nearest second the time that the command "Begin" is given and note and record the time each individual student completes the problem.
3. The command "Begin" should not be given until the student has indicated to the instructor that he understands the directions.

Directions to the student.

1. Perform the following operations carefully and neatly, but at the same time as quickly as you can.

a. Open the door of the box and take and record, as quickly and accurately as you can, the reading as indicated by the barometer.

b. Make all the necessary adjustments, including temperature corrections.

3. As soon as you have completed this record, report at once to the instructor.

Directions for scoring.

1. If reading has been correctly made and recorded, credit each student with 5 points.
2. If corrections have been properly made and recorded, credit student with an additional 5 points.
3. Allow no partial score.

PROBLEM No. 3

PREPARATION OF PSYCHROMETER FOR USE

Equipment.

One psychrometer with wet-bulb stripped of muslin wrapping.
One piece of thread.
One piece of new muslin.
One beaker of water at current temperature.

Procedure.

1. Prepare in advance the above equipment conveniently situated.
2. Read the directions to the student, and as soon as they understand the directions, give the command "Begin."
3. Note and record to the nearest second the time that command "Begin" was given, and when student finishes the task.

Directions to the student.

1. Prepare the wet-bulb of this psychrometer for immediate use.
2. As soon as you have completed this operation report to the instructor.

Directions for scoring.

1. If the psychrometer has been properly wrapped with muslin and properly immersed in the beaker of water, as prescribed in problem 3, credit student with 5 points.
2. Allow no partial score.

PROBLEM No. 4

THE QUADRUPLE REGISTER

Equipment.

One quadruple register with wires disconnected.
Supply of record ink.
Record sheets.

Procedure.

Prepare the quadruple register for this problem by removing the record sheet and disconnect two wires from the binding posts.

Directions to the student.

1. Perform the following operation carefully and at the same time as quickly as you can. Complete the necessary operations for the proper functioning of the quadruple register.
2. *a.* Connect the proper wires to the binding post of the quadruple register.
b. Place new record sheet upon the quadruple register, wind the clock, and start the drum.
c. Ink the pens.
3. As soon as you have completed these operations, report to the instructor.

Directions for scoring.

1. If pens have been properly inked, credit student with 2 points.
2. If record sheet has been properly placed on the register, clock properly wound, and the drum started, credit student with 4 points.
3. Allow no partial score for the different operations.

PROBLEM No. 5

MEASURING PRECIPITATION

Equipment.

One standard rain gauge containing quantity of water in excess of 2 inches.

One measuring stick.

Pencil and paper.

Procedure.

Prepare in advance the above equipment conveniently situated.

Directions to the student.

1. Perform the following operation carefully and neatly, but at the same time as quickly as you can.
2. The standard rain gauge is supposed to contain the precipitation for the past 24 hours.
3. Measure the amount and record it.
4. As soon as you have completed this operation report to the instructor.

Directions for scoring.

1. If student has correct measurement of precipitation, credit him with 5 points.
2. Allow no partial score.

PROBLEM No. 6

CODING SURFACE OBSERVATIONS

Equipment.

Pencil.

Paper.

Five surface observations to be coded.

Table.

Procedure.

Prepare in advance five surface observations to be coded, together with above equipment.

Directions to the student.

1. Code the five surface observations as quickly and as accurately as you can.
2. As soon as you have completed, report to the instructor.

Directions for scoring.

1. The minimum score required to pass problem No. 6 is 15 points.
2. For each observation correctly coded, credit each student with 5 points.
3. Allow no partial score for any separate observation.

PROBLEM No. 7

SETTING THEODOLITE UPON THE TRIPOD AND LEVELING IT

Equipment.

Theodolite and tripod.

Directions to the student.

1. Place the theodolite upon the tripod.
2. Level the theodolite.
3. As soon as you have completed this operation report to the instructor.

Directions for scoring.

1. If theodolite has been properly placed on the tripod and correctly leveled, credit student with 5 points.
2. Allow no partial score.

PROBLEM No. 8

INFLATION OF THE BALLOON

Equipment.

Four balloons uninflated (assortment of sizes and colors).
One cylinder of hydrogen.
One hose cock, ML–56.
One tubing, rubber, 4½-feet long.
One hose coupling ML–49.
One additional weight, 219 grams.
Four rubber bands, No. 16.
One Stillson wrench.

Procedure.

Prepare in advance the above equipment conveniently situated.

Directions to the student.

1. Inflate the balloon so that it will have an ascensional rate of 200 yards per minute, ready for immediate use.
2. As soon as completed, report at once to the instructor.

Directions for scoring.

1. If correct size of balloon has been selected, credit student with 2 points.
2. If inflation has been correctly made, credit student with 5 points.
3. Allow no partial score.

PROBLEM No. 9

CHARTING BALLOON OBSERVATION

Equipment.

One plotting board, special type ML–55.
One rule, brass.
One protractor and round scale for use with ML–55.
One pencil (soft lead).
One eraser, rubber.
Data on balloon observation, giving elevation and azimuth angles.

Procedure.

1. Lay out the equipment listed above in a convenient place. The data are to be prepared in advance and if possible to consist of actual readings made at some previous time and covering a period of 20 minutes.
2. Record time of beginning and finishing by each student.

Directions to the student.

1. Perform the following operation carefully and neatly and at the same time as rapidly as you can.
2. Clean the plotting board of all pencil marks and make the horizontal projection of the observation furnished you.
3. As soon as completed, report to the instructor, who will inspect your work.

Directions for scoring.

1. Having previously made a tracing of the horizontal projection on tracing paper, place it over the one made by the student and if it coincides credit student with 10 points for work correctly done.
2. Allow no partial score.

PROBLEM No. 10

MODEL AIRWAY BULLETIN BOARD

Equipment.

One model airway bulletin board (or miniature).
Complete list of observations and flying forecasts.

Procedure.

Prepare in advance the equipment listed above. Ruled paper with lines corresponding to the bulletin board may be used in lieu of the actual board itself.

Directions to the student.

1. Print upon the bulletin board, or paper copy, the data furnished you from the various stations.

2. As soon as you have completed the record report to the instructor.

Directions for scoring.

1. If data has been correctly entered, credit student with 10 points.
2. Allow no partial score.

NOTE FOR THE INSTRUCTOR:

	Points
1. The maximum possible score for Part I of this proficiency test is-----	96
2. The minimum score required to pass is----------------------------	70

PART II.—INFORMATION

Directions to the student.

Below are a number of statements and just to the right of each one is a short dotted line. Read each statement carefully and, if what it says is *true,* make a *plus* sign (+) on the line to the right. If what it says is *not true,* put a minus sign (−) on the line to the right of the statement.

1. The cause of sunrise and sunset colors is atmospheric dust. ------
2. The inert component in the atmosphere is nitrogen. ------
3. The earth is nearest to the sun on January 1. ------
4. The fluid ordinarily used in a barometer is alcohol. ------
5. The ground conducts heat very poorly. ------
6. When the sun's rays fall on a given surface obliquely they produce less heat on that given area than when they fall directly. ------
7. The direction from which the wind comes is called leeward. ------
8. Condensation is the opposite of evaporation. ------
9. Thermometers are exposed in a special shelter to protect them from extremes of heat and cold. ------
10. Temperature is measured by means of sling psychrometers and thermographs. ------
11. Temperature is recorded and read in degrees and tenth of a degree. ------
12. The maximum thermometer is set by whirling. ------
13. The flat metal tube of the thermograph is usually filled with water. ------
14. Mercury in the tube of a barometer raises and falls principally because it is acted upon by heat and cold. ------
15. Air in motion near the earth's surface and parallel with it is called surface air. ------
16. The vertical lines on the quadruple register record are 10 minutes apart. ------

17. As air becomes heated it expands. ------
18. The lower bulb of the sunshine recorder is covered with lamp-black. ------
19. In summer the sunshine recorder should be kept at a less steep angle than in winter. ------
20. When the sun goes under a cloud the sunshine recorder stops and the pen on the quadruple register draws a straight line. ------
21. Observations of precipitation include the time of beginning and ending. ------
22. Snow is usually formed by condensation at a temperature slightly above 32° F. ------
23. In very dry countries rain should be measured immediately after it has occurred. ------
24. The inner tube of the standard rain gauge is exactly 2 inches deep. ------
25. The smallest snow unit is the crystal, which is always formed upon the hexagonal pattern. ------
26. Hail usually occurs in connection with thunderstorms. ------
27. In the Signal Corps the humidity of the free air is usually measured. ------
28. The third factor which controls humidity in addition to a source of water vapor and temperature is density. ------
29. Absolute humidity is expressed by stating the weight of water vapor in grams per cubic meter. ------
30. The name of the instrument which makes a record of the changes in humidity is called the thermograph. ------
31. In the Signal Corps, measurements of the horizontal motions of the air are the only ones recorded. ------
32. The difference in temperature is a primary cause of motions of the air. ------
33. Another name for wind vane is anemometer. ------
34. The name of the instrument that measures the velocity of the wind is the heliometer. ------
35. Fog is similar in construction to a cloud. ------
36. Haze is said to move with the surface wind. ------
37. Rain falls from nimbus clouds. ------
38. Cirro-cumulus and cumulus clouds are alike in regard to elevation. ------
39. The state of the weather may be recorded as sleeting, sprinkling, or smoky. -----
40. The dew point may be higher than the wet-bulb. ------
41. The reading of the attached thermometer on the barometer is always the same as the dry-bulb. ------

42. The wet-bulb temperature may be higher than the dry-bulb. ------

43. The seven-figure code is used to transmit weather codes to the Weather Bureau. ------

44. The last three letters of a code indicate the name of the sending station. ------

45. The hours of the day for coding purposes are numbered from 1 to 24. ------

46. The wind code is used to transmit data to the artillery. ------

47. In a code of weather observations H indicates humidity. ------

48. The date is never sent in a meteorological coded message. ------

49. Theodolites are instruments used to measure wind velocity. ------

50. Azimuth is a term used to express the angle between the north and south line and the vertical plane of the line of sight. ------

51. A plumb bob is an essential part of a theodolite.

52. The eyepiece of a theodolite is always in focus. ------

53. The theodolite is provided with four levels. ------

54. The true north is indicated by Polaris. ------

55. Transference is a method of determining true north. ------

56. The magnetic compass gives the true north direction. ------

57. True north and geographic north are the same. ------

58. True north may be determined in only one way. ------

59. There is a star in the southern heavens in a position so that true south may be determined. ------

60. Balloons used in meteorological observations are usually inflated with air. ------

61. Balloons 6 inches in diameter should be inflated to ascend at a rate of 200 yards per minute. ------

62. Balloons ascend faster near the earth's surface than they do at higher altitudes. ------

63. A rubber balloon is practically impervious to gases. ------

64. If a match is applied to a balloon, an explosion occurs. ------

65. If balloons are rapidly inflated there is danger of bursting the balloon. ------

66. The purpose of a balloon observation is to determine the degree of temperature at various altitudes. ------

67. Accuracy of reading angles is essential in balloon observations. ------

68. A balloon sounding may sometimes be made at night. ------

69. In making a balloon observation, the type of balloon used need not be recorded. ------

70. When a balloon is lost to sight the reason for its disappearance should not be stated unless it disappears within a few minutes. ------

71. The theodolite is used in following an ascending balloon. ------

72. When a sounding is to begin at 8 a. m., this means that the balloon should be released 15 minutes later. ------

73. It is essential that the observer keep the image of the balloon on the cross hairs of the theodolite. ------

74. A single omission on the data sheet of a balloon run will often render the entire data valueless. ------

75. The plotting board is used for charting balloon observations and is known as type ML–55. ------

76. The brass rule on the plotting board is used to determine the wind velocity at various altitudes. --------

77. The protractor is an instrument used to measure the elevation of the balloon from the data on the plotting board. ------

78. Wind data are furnished the artillery and contain information regarding wind velocity at various altitudes. ------

79. It is necessary to compute ballistic winds for the artillery. ------

80. The term zone is used in plotting ballistic winds for use in the artillery. ------

81. The ballistic wind for the 600-foot ordinate is the true wind for the second minute. ------

82. Ballistic density is another term relative to humidity. ------

83. Air density varies with elevation. ------

84. The model airway bulletin board is designed to furnish aviators with meteorological information. ------

85. Date should not be entered on the bulletin board after it is 24 hours old. ------

86. The bulletin board need not be dated. ------

87. The bulletin board contains data on weather conditions at stations other than that where the board is located. ------

88. If the visibility at a particular station happens to be very bad and the barometric pressure is very high, the visibility report should be questioned. ------

89. In establishing a meteorological station the altitude of the station barometer should be determined. ------

90. Whenever a station observation is taken late or omitted, a full report of the facts will be made at once to the Chief Signal Officer. ------

91. Form No. 2—Met'l. is used in recording surface observations. ------

92. Maximum wind velocity for 24 hours is underlined in entering it on Form No. 1. ------

93. Whenever an instrument at a station has not been running on true time, a note should be made on the report to indicate the true time of the record. ------

94. Only one balloon run a day is necessary for a station observation. ------

95. All meteorological instruments at stations should be inspected weekly. ------

96. Form 204 is known as the altitude speed direction graph. ------

97. Form 120 is known as the thermograph sheet. ------

98. A meteorological company is usually assigned to an army. ------

99. A major is usually in charge of a meteorological company. ------

100. Meteorological equipment should be erected preferably on the top of a high building. ------

101. The value of meteorological observations is very important for aviation. ------

Directions for scoring.

	Points
1. The maximum possible score for Part II of this proficiency test	101
2. The minimum score required to pass Part II is	75

3. The questions will be scored as directed on page 22.

SUGGESTIONS FOR CONDUCTING PROFICIENCY TEST NO. 2

This proficiency test is for the same purpose as proficiency test No. 1 and is furnished the instructor as an additional sample. The instructor may combine parts of the two tests, or he may administer proficiency test No. 1 and No. 2 separately, according to whichever method he considers better. It will be noticed that while the two tests cover nearly the same subjects, the questions are recast in different forms. For the method of giving directions to the students, see progress test No. 1.

PROFICIENCY TEST NO. 2

PART I.—PERFORMANCE

PROBLEM No. 1

PREPARATION OF HYGROGRAPH

Equipment.

One hygrograph.
One recording sheet for hygrograph.
One bottle of recording ink.

Procedure.

Prepare the above equipment in advance by removing the record sheet and cleaning the recording pen. Lay out the equipment where the student may work conveniently. Time allowed for this problem, five minutes.

Directions to the student.

1. Prepare the hygrograph for immediate use, using the equipment given you.

Directions for scoring.

1. If the instrument has been correctly prepared for immediate use, credit student with 6 points, that is if—

	Points
a Clock is wound correctly	2
b Pen is inked correctly	2
c Recording sheet properly placed	2
Total	**6**

2. Allow no partial score for *a*, *b*, or *c*.

PROBLEM No. 2

MEASURING WIND VELOCITY BY USE OF HAND ANEMOMETER

Equipment.

One hand anemometer.
Pencil and paper for recording results.

Procedure

Provide the student with the above equipment. The purpose of this problem is to determine the student's ability to measure wind velocity with the above instrument. Prepare the recording paper as follows:

	Time	Wind velocity
First observation		
Second observation		
Third observation		

Directions to the student.

With the equipment provided, make three observations of the wind velocity at intervals of one minute. Record the time of each observation and the wind velocity on the sheet provided you.

Directions for scoring.

1. Maximum possible score for problem No. 2, 6 points.
2. Allow no partial score for single observations under the two points allowed.
3. The instructor should accompany the student and check each observation, crediting student with 2 points for each observation correctly made and recorded.

PROBLEM No. 3

PREPARATION OF BAROGRAPH

Equipment.

One barograph.
One record sheet.
One bottle of recording ink.

Procedure.

Prepare the above equipment by removing the record sheet and cleaning the recording pen of ink. Time allowed, 5 minutes.

Directions to the student.

Prepare the barograph for immediate use with the equipment furnished you.

Directions for scoring.

1. Credit student with following points if—

	Points
a. Record sheet is properly attached	2
b. Pens are properly inked	2
c. Clock is wound and drum started	2
Total	6

2. Allow no partial score for *a*, *b*, or *c*.

PROBLEM NO. 4

DECODING SURFACE OBSERVATION

Equipment.

Pencil and paper.
Five coded surface observations.

Procedure.

Prepare in advance five coded surface observations, together with pencil and paper, for student to decode the message. To facilitate scoring, the instructor may provide a form as follows:

First observation

Coded data	Decoded data

Time allowed for this problem, 10 minutes.

Directions to the student.

Decode the five surface observations furnished you. Do the work as quickly as you can.

Directions for scoring.

	Points
1. Maximum possible score for problem 4	10
2. Minimum score required to pass	8
3. Allow no partial score for separate observation.	
4. For each observation correctly decoded	2

PROBLEM NO. 5

PREPARATION OF PAPER LANTERN FOR BALLOON RUN

Equipment.

One large sheet of drawing paper.
One pattern for lantern.
One bottle of mucilage.
One small size spool of wire.
One pencil.
One ball cotton twine.
One pair of office shears.
One candle.
One box thumb tacks and paper fasteners.

Procedure.

Lay out the above equipment on a table where the student may be free to work.

Directions to the student.

1. Construct one paper lantern for use in making a night balloon observation. Do the work quickly and neatly.

2. As soon as completed report to the instructor.

Directions for scoring.

1. If a satisfactory lantern has been constructed according to the pattern furnished, credit student with 10 points.

2. Allow no partial score.

PROBLEM No. 6

DETERMINING BALLISTIC WIND DATA

Equipment.

Pencil and paper.
Wind data.
Ballistic wind tables.

Procedure.

Prepare in advance sufficient data for making ballistic wind determinations. Time allowed, 10 minutes.

Directions to the student.

1. Make the necessary ballistic wind determination from the data furnished you.

2. As soon as completed, report to the instructor with your paper. Do not start until the instructor commands "Begin." Do no additional work after the command "Stop."

Directions for scoring.

1. If correct ballistic wind determinations have been completed, credit student with 10 points.

2. Allow no partial score.

3. If student fails to complete the work within the time allotted, repeat the problem.

PROBLEM No. 7

DETERMINATION OF BALLISTIC DENSITY

Equipment.

Pencil and paper.
Tables A and B, Information Topic No. 3.
Density data.

Procedure.

Prepare in advance data from which ballistic density may be determined, along with the above equipment. Time allowed, 10 minutes.

Directions to the student.

1. Make the necessary ballistic density determinations from the data furnished you.
2. Wait for the instructor to say "Begin" before starting to work. Do no work after the command "Stop."

Directions for scoring.

1. If correct ballistic density has been determined within the time allowed, credit student with 10 points.
2. Allow no partial score.

PROBLEM No. 8

ADJUSTMENT OF SUNSHINE RECORDER

Equipment.

One sunshine recorder.

Procedure.

Loosen the inclination clamp so the sunshine recorder moves freely.

Directions to the student.

1. *a.* Adjust the sunshine recorder for winter use.
b. Report to the instructor when completed.
2. *a.* Adjust the recorder for summer use.
b. Report to the instructor when completed.

Directions for scoring.

	Points
1. Maximum possible score for Problem No. 8	4
2. For each operation credit student with	2

3. No partial score allowed.

PROBLEM No. 9

REBLACKENING GRADUATIONS OF A THERMOMETER

Equipment.

One unserviceable thermometer with graduations (unblackened).
One tube ivory black paint.
One wad of tissue paper.
One blotter.

Procedure.

Prepare the above equipment in advance. If no thermometer is at hand, an ordinary piece of glass tube, 10 inches long with graduations cut on it, may be substituted in place of a thermometer.

Directions to the student.

1. With the equipment furnished you, blacken the graduations of the thermometer.
2. When completed report to the instructor.

Directions for scoring.

1. If thermometer has been correctly blackened, credit student with 4 points.
2. Allow no partial score.

PROBLEM No. 10

PREPARATION OF FORM NO. 1—MET'L

Equipment.

Form No. 1—Met'l.
Data to be recorded.
Pencil.

Procedure.

Prepare data for student to enter on the various pages of Form No. 1, in order that all steps in the form may be considered.

Directions to the student.

From the data furnished you, enter it on Form No. 1 in the correct columns and prepare the form for forwarding to Washington.

Directions for scoring.

1. If student completes form correctly in all respects, credit with 20 points.
2. Allow no partial score.

NOTE FOR THE INSTRUCTOR:

	Points
1. The maximum possible score for Part I is	86
2. The minimum score required to pass is	65

PART II.—INFORMATION

Directions to the student.

Below are a number of questions and unfinished statements. Following each question or statement are several words, numbers, or phrases, each preceded by a number. Only *one* of these answers is correct. Write the *number* of the correct answer on the dotted line at the right.

Sample:

Twenty-five cents is what part of a dollar? (1) one-thirtieth; (2) one-half; (3) one-fourth; (4) twenty-five twenty-fifths. ------

Begin here.

1. The cause of sunrise and sunset colors is (1) rain drops; (2) parallax; (3) atmospheric dust; (4) humidity. ------
2. The inert component of the atmosphere is (1) carbon; (2) nitrogen; (3) hydrogen; (4) oxygen. ------
3. The fluid most commonly used in a barometer is (1) water; (2) alcohol; (3) sulphuric acid; (4) mercury. ------

4. Temperature is measured by means of a (1) barometer; (2) thermometer; (3) heliometer; (4) anemometer. ------

5. Temperature is read and recorded in (1) calories; (2) degrees and tenths of degrees; (3) watts; (4) amperes. ------

6. A maximum thermometer is set by (1) whirling; (2) immersing the end in cold water; (3) tapping the stem. ------

7. The barometer records (1) intensity of heat; (2) atmospheric pressure; (3) amount of carbon in air; (4) speed of the barograph. ------

8. As air becomes heated, it (1) expands; (2) evaporates; (3) condenses; (4) stagnates. ------

9. The lower bulb of the sunshine recorder is covered with (1) lead; (2) white paint; (3) lampblack; (4) mercury. ------

10. The sling psychrometer is composed of (1) two thermometers; (2) a psychrograph; (3 two maximum thermostats. ------

11. The drum of the thermograph is driven by (1) storage battery; (2) dry battery; (3) clock mechanism; (4) motor. ------

12. An instrument shelter should be painted (1) white; (2) green; (3) unpainted; (4) red. ------

13. The name of the most common type of thermometer used in meteorology is (1) Dewey Hall; (2) Fahrenheit; (3) centigrade; (4) Black & Black. ------

14. The vernier is used in reading the (1) mercurial barometer; (2) hygrograph; (3) thermometer; (4) thermograph. ------

15. The barograph is an instrument made to measure (1) dew point; (2) atmospheric pressure; (3) sunshine; (4) rainfall. ------

16. Hygrometry is the science of measuring the airs (1) temperature; (2) molecular content; (3) humidity; (4) gaseous content. ------

17. The sensitive material used in a hygrograph is (1) an alcohol column; (2) a strand of human hair; (3) a platinum wire; (4) a silk fiber. ------

18. The wet bulb of the whirling psychrometer should be wrapped with (1) silk; (2) paper; (3) rubber; (4) muslin cloth. ------

19. To set the hygrograph the pen should be adjusted to correspond to the reading at that time of the (1) thermograph; (2) whirling psychrometer; (3) hygroscope. ------

20. The wind vane is called (1) an astroscope; (2) a wind meter; (3) an anemoscope; (4) a vaneometer. ------

21. The wind vane is used to indicate (1) wind direction; (2) wind pressure; (3) wind tension; (4) wind inertia. ------

22. The Dines anemobiograph indicates (1) wind direction changes for eight points only; (2) all changes of wind direction; (3) the same as cup anemometer; (4) pressure at sea level. ------

23. The cup anemometer measures (1) rainfall; (2) general precipitation; (3) wind velocity; (4) wind direction. ------

24. The quadruple register records (1) the four cardinal points only; (2) four elements; (3) barometric pressure in quarter points; (4) sunshine only. ------

25. Precipitation includes all forms of (1) evaporation; (2) falling moisture; (3) heat ascension. ------

26. The instrument used to measure precipitation is the (1) tipping bucket rain gauge; (2) dropping cup; (3) rain kettle; (4) sponge cup. ------

27. Snow is a form of (1) crystallization or hail; (2) precipitation; (3) energy; (4) octagon. ------

28. Clouds are formed by the (1) gravity of the air; (2) electrical energy in the air; (3) cooling of water vapor; (4) ebb and flow of the tides. ------

29. Strato-cumulus is the name of a (1) windstorm; (2) cloud; (3) snowflake; (4) instrument for measuring clouds. ------

30. The name of the highest cloud observed is called the (1) nimbus; (2) stratus; (3) streamer; (4) cirrus. ------

31. Observation of clouds includes the following elements: (1) height, color; (2) amount, kind, direction; (3) speed; (4) penetrability, temperature, humidity. ------

32. The condition of the sky is called the (1) state of the weather; (2) datum plane; (3) meteorological condition. ------

33. Visibility is measured by using (1) the visiograph; (2) a colored prism; (3) the estimate of the observer; (4) the meteorometer. ------

34. A surface observation consists in making measurements of (1) temperature and wind; (2) precipitation and clouds; (3) wind and pressure; (4) temperature, pressure, wind, precipitation, clouds. ------

35. The observer should begin the surface observation (1) 8 minutes before the time at which it is dated; (2) 20 minutes before the time at which it is dated; (3) 15 minutes before the time at which it is dated; (4) should not begin before the time it is dated. ------

36. How many codes are used in sending weather information? (1) One; (2) four; (3) seven; (4) two. ------

37. The five-figure code is called the (1) artillery code; (2) meteorological code; (3) United States Weather Bureau code; (4) no such code exists. ------

38. The theodolite measures (1) angles; (2) depth of earth's surface, (3) balloon weights; (4) specific gravity of air. ------

39. The theodolite rests on a (1) box; (2) table; (3) tripod; (4) is suspended from the ceiling. ------

40. The telescope of the theodolite is provided with (1) cross hairs; (2) a gyroscope control; (3) wind indicator; (4) range finder. ------

41. The plumb bob of the theodolite is hung from the (1) adjusting screw; (2) base of the tripod; (3) observation screw; (4) right leg of instrument finder. ------

42. Adjusting the theodolite is only necessary (1) when making an observation; (2) is never necessary; (3) when the instrument has been roughly used. ------

43. The number of leveling screws on the theodolite is (1) three; (2) four; (3) one; (4) none. ------

44. The term azimuth refers to (1) an angle; (2) degree of heat; (3) water viscosity; (4) humidity. ------

45. The tripod legs of the theodolite are made of (1) aluminum; (2) steel; (3) wood; (4) laminated copper. ------

46. Adjustments in focusing the theodolite should be made (1) with one eye open; (2) with both eyes open; (3) with a reading glass; (4) with a compass. ------

47. The glass tube or the level of the theodolite is filled with (1) oil; (2) water; (3) liquid oxygen; (4) alcohol. ------

48. To determine dew point the observer must use (1) Form No. 80–Met'l; (2) psychrometric tables; (3) ballistic tables; (4) slide rule or vernier. ------

49. Frosts are designated as (1) mild and severe; (2) light, heavy, killing; (3) blighting, dull; (4) moist, still, saturated. ------

50. The number of sections in a meteorological company with an army is (1) four; (2) two; (3) five; (4) three. ------

51. The equatorial belt of calms is called the (1) doldrums; (2) air pockets; (3) dead space; (4) equinox. ------

52. The direction from which the wind comes is called (1) starboard; (2) lee; (3) windward; (4) windlass. ------

53. The earth is nearest the sun on (1) January 1; (2) February 22; (3) always same distance; (4) June 21. ------

54. The protractor used with plotting board ML 55 has how many divisions? (1) 54; (2) 64; (3) 72; (4) 36. ------

55. The protractor used with plotting board ML–57 has how many divisions to a circle? (1) 70; (2) 74; (3) 64; (4) 72. ------

56. The best position for a theodolite observation point is (1) on a slight rise; (2) in a hollow; (3) in dry air; (4) near a wall to protect it from wind. ------

57. In cold weather what should be done to a balloon before inflation? (1) Heat it quickly; (2) stretch it; (3) warm it uniformly; (4) nothing. ------

58. The time by the clock when the sun crosses the meridian is called (1) mean solar noon; (2) true sun meridian; (3) local standard noon; (4) true solar noon. ------

59. When inflating a balloon, how much hydrogen should be let in before shutting it off at the tank? (1) Depends on the weather; (2) enough to more than lift the hose cock; (3) until balloon is at least 30 mm. diameter; (4) only enough to make sure it will not burst. ------

60. In plotting balloon runs on plotting board the points are marked as follows: (1) By circles; (2) by a T; (3) by a dot; (4) ✓. ------

61. After a balloon run is plotted and the data coded, what should be done? (1) Erase everything on board; (2) connect points on board to make a graph; (3) go over with soft pencil. ------

Directions for scoring.

	Points
1. The maximum possible score for Part II of this test is--------------	61
2. The minimum score to pass Part II is----------------------------	40

NOTE.—In determining the total proficiency of the student in the entire test, which includes Part I, performance, and Part II, information, add the scores made by the student in the two parts. The total possible score for the entire test is 147 points; 105 points is the lowest possible score required to pass for the entire proficiency test.

INFORMATION TOPICS

DEFINITIONS

NOTE.—The definitions given below are the common meanings of words *as used in this manual.*

Acoustic. Refers to sound or hearing, or to the science of sound.

Adiabatic. The ratio of change in temperature to change in elevation of a mass of air as it rises or falls, without addition or subtraction of heat.

Adjustment. The regulation of meteorological instruments to meet certain conditions; for example, the adjustment of the theodolite consists of truing up the levels which may have been thrown out by an accident. It does not usually include leveling or focusing the instrument.

Anemometer. An instrument which measures the velocity of the wind.

Anemoscope. Another name given to a wind vane, which indicates wind direction.

Aneroid barometer. An instrument similar to the barograph except that it does not record, but merely indicates, the air pressure at the place at which it is installed.

Atmospheric pressure. The phenomenon of the air pressing down upon the earth's surface.

Azimuth. The term applied to the angle, expressed in degrees and tenths of a degree, between the vertical plane of the line of sight and the vertical plane on the north and south line, measured in a clockwise direction from the north.

Ballistic. Refers to the study of meterological temperature, wind pressure, and air density in so far as they assist in securing precision in firing projectiles for artillery and ordnance.

Barograph. An instrument that records continuously the air pressure at the place at which it is installed.

Climatology. Is the study of the average conditions respecting temperature, rainfall, humidity, clouds, velocity and direction of wind, and barometric pressure, etc.

Condensation. The reduction of a vapor or gas such as air to a liquid.

Convection. A way in which heat passes from one atmospheric region to another by the actual movement of air.

Elevation. The angle expressed in degrees and tenths of a degree between the line of sight and the horizontal plane of the observer.

Equilibrium. The state of a body so acted upon by counter-acting forces that it has no tendency to move.

Evaporation. The act or process by which a substance is changed into a vapor.

Free lift. The upward force in grams or ounces, which a balloon exerts after it is filled with hydrogen.

Halos. A luminous circle around the sun or moon caused by the refraction of light passing through the ice crystals floating in the air.

Hygrograph. An instrument similar in appearance to a barograph or a thermograph which makes a continuous record of the changing humidity.

Hygrometry. The science of measuring the humidity of the air.

Hygroscopic. Ability of a substance to absorb or condense moisture from the atmosphere.

Infinite. A limitless quantity or value or unmeasurable quantity.

Interpolation. Insertion of intermediate term or terms into a series of given values such as are found in a psychrometric table.

Intrinsic equation. The equation that gives the relation between the length of a curve to any point and the angle made with a fixed line by the tangent at that point.

Latitude. Distance on the earth's surface from the equator measured in degrees of the meridian.

Longitude. Distance east or west on the earth's surface measured by the angle which the meridian makes with some standard meridian such as Greenwich or Paris.

Magnetic declination. The angle formed by the direction of the magnetic north with that of true north.

Meteorology. The science which treats of the phenomena of the atmosphere, especially those that relate to weather and climate. This manual deals principally with military meteorology.

Meniscus. The surface or upper portion of a column of mercury made convex by capillarity.

Off Wind. Away from the wind.

Ordinate. An imaginary line perpendicular to the earth's surface which marks a layer of atmosphere or the distance of any given point above the surface of the earth.

Orientate. To place a meteorological instrument in a position with reference to the points of the compass.

Parallax. Such displacement of an object's actual position as would appear if viewed from some other than the standard position.

Plotting. Laying off on a board the movements of a balloon showing its position during flight with reference to the starting point.

Precipitation. A term usually meaning rainfall, but which includes all forms of falling moisture, such as rain, snow, hail, and sleet.

Projection. The course of the balloon flight as shown on the plotting board.

Protractor. A scale with certain graduations in points thereon for determining wind speed and wind direction from a balloon projection on a plotting board.

Quadruple register. Sometimes called a triple register. An instrument which records continuously the following four elements of the atmosphere: (*a*) Wind direction, (*b*) wind velocity, (*c*) sunshine, (*d*) rainfall.

Refraction. The change in direction of a ray of light or heat in passing through different densities of atmosphere or through water or ice particles.

Setting up. The erection of the theodolite including the placing of the tripod.

Silver thaw. Rain falling on the ground and the surfaces of objects, and forming a coating of ice as it falls; also known as a "sleet storm."

Surface tension. A phenomenon where the molecules at the surface of a liquid have greater attraction for each other than do those in the interior of the liquid.

Theodolite. An instrument in the form of a telescope by which an observer may follow moving objects such as balloons and read their elevation and azimuth at any instant.

Thermograph. An instrument which makes a continuous record of the temperature. It consists of a thermometer in the form of a curved metallic tube filled with alcohol.

Thermometry. The science or art of measuring the temperature of substances such as air.

Traces. The inscription made on a recording sheet of a meteorological instrument by the recording pen.

Trajectory. The path described by a projectile through the air in its flight from the muzzle of a gun to the target.

Transparency. A condition of the atmosphere similar to visibility, and expressed in degree according to the clearness with which objects can be distinguished.

Vernier. A small movable auxiliary scale on a barometer used to obtain fractional parts on the fixed scale.

Viscosity. The property of fluids by reason of which they resist an instantaneous change of their shape. For example, water when poured from the rain gauge will have particles cling to the sides of the gauge thus momentarily resisting the sudden change.

Visibility. The state of the atmosphere by reason of which objects are seen with greater or less distinctness.

Zones. Term applied to different layers of air for purposes of reducing air data to determine ballistic wind.

METEOROLOGICAL TABLES

The following tables are furnished the student in order to assist him in the preparation of meteorological data. They consist of:

Table I.—Wind weighting factors.
Table II.—Ascensional rates of balloons.
Tables III and IIIa.—Temperature and air density.
Tables IV and IVa.—Ballistic density.
Table V.—Air density weighting factors. Forms 79 and 80.

TABLE I.—*Wind weighting factors*

No.	Maximum ordinate	Zones									
		0–1,500 (t_1)	1,500–3,000 (t_2)	3,000–4,500 (t_3)	4,500–6,000 (t_4)	6,000–9,000 (t_5)	9,000–12,000 (t_6)	12,000–15,000 (t_7)	15,000–18,000 (t_8)	18,000–24,000 (t_9)	24,000–30,000 (t_{10})
(1)	600	Use wind during first minute.						--------	--------	--------	--------
(2)	1,500	Use wind during second minute.						--------	--------	--------	--------
(3)	3,000	0.41	0.59	--------	--------	--------	--------	--------	--------	--------	--------
(4)	4,500	.28	.26	0.46	--------	--------	--------	--------	--------	--------	--------
(5)	6,000	.21	.20	.20	0.39	--------	--------	--------	--------	--------	--------
(6)	9,000	.14	1.4	.13	.13	0.46	--------	--------	--------	--------	--------
(7)	12,000	.11	.10	.10	.10	.20	0.39	--------	--------	--------	--------
(8)	15,000	.09	.08	.08	.08	.16	.16	0.35	--------	--------	--------
(9)	18,000	.07	.07	.07	.07	.18	.13	.14	0.32	--------	--------
(0)	24,000	.06	.05	.05	.05	.10	.10	.10	.10	0.39	--------
(1)	30,000	.05	.04	.04	.04	.08	.08	.08	.08	.16	0.35

TABLE I.—*Wind weighting factors*—Continued

FACTORS FOR STRATA 0-1,500 FEET (t_1)

Speed	Point								
	31	41	51	61	71	81	91	01	11
2	0.8	0.6	0.4	0.3	0.2	0.2	0.1	0.1	0.1
4	1.6	1.1	.8	.6	.4	.4	.3	.2	.2
6	2.5	1.7	1.3	.8	.7	.5	.4	.4	.3
8	3.3	2.2	1.7	1.1	.9	.7	.6	.5	.4
10	4.1	2.8	2.1	1.4	1.1	.9	.7	.6	.5
12	4.9	3.4	2.5	1.7	1.3	1.1	.8	.7	.6
14	5.7	3.9	2.9	2.0	1.5	1.3	1.0	.8	.7
16	6.6	4.5	3.4	2.2	1.8	1.4	1.1	1.0	.8
18	7.4	5.0	3.8	2.6	2.0	1.6	1.3	1.1	.9
20	8.2	5.6	4.2	2.8	2.2	1.8	1.4	1.2	1.0
22	9.0	6.2	4.6	3.1	2.4	2.0	1.5	1.3	1.1
24	9.8	6.7	5.0	3.4	2.6	2.2	1.7	1.4	1.2
26	10.7	7.3	5.5	3.6	2.9	2.3	1.8	1.6	1.3
28	11.5	7.8	5.9	4.0	3.1	2.5	2.0	1.7	1.4
30	12.3	8.4	6.3	4.2	3.3	2.7	2.1	1.8	1.5
32	13.1	9.0	6.7	4.5	3.5	2.9	2.2	1.9	1.6
34	13.9	9.5	7.1	4.8	3.7	3.1	2.4	2.0	1.7
36	14.8	10.1	7.6	5.0	4.0	3.2	2.5	2.2	1.8
38	15.6	10.6	8.0	5.4	4.2	3.4	2.7	2.3	1.9
40	16.4	11.2	8.4	5.6	4.4	3.6	2.8	2.4	2.0
42	17.2	11.8	8.8	5.9	4.6	3.8	2.9	2.5	2.1
44	18.0	12.3	9.2	6.2	4.8	4.0	3.1	2.6	2.2
46	18.9	12.9	9.7	6.4	5.1	4.1	3.2	2.8	2.3
48	19.7	13.4	10.1	6.8	5.3	4.3	3.4	2.9	2.4
50	20.5	14.0	10.5	7.0	5.5	4.5	3.5	3.0	2.5
52	21.3	14.6	10.9	7.3	5.7	4.7	3.6	3.1	2.6
54	22.1	15.1	11.3	7.6	5.9	4.9	3.8	3.2	2.7
56	23.0	15.7	11.8	7.8	6.2	5.0	3.9	3.4	2.8
58	23.8	16.2	12.2	8.2	6.4	5.2	4.1	3.5	2.9
60	24.6	16.8	12.6	8.4	6.6	5.4	4.2	3.6	3.0
62	25.4	17.4	13.0	8.7	6.8	5.6	4.3	3.7	3.1
64	26.2	17.9	13.4	9.0	7.0	5.8	4.5	3.8	3.2
66	27.1	18.5	13.9	9.2	7.3	5.9	4.6	4.0	3.3
68	27.9	19.0	14.3	9.5	7.5	6.1	4.8	4.1	3.4
70	28.7	19.6	14.7	9.8	7.7	6.3	4.9	4.2	3.5
72	29.5	20.2	15.1	10.1	7.9	6.5	5.0	4.3	3.6
74	30.3	20.7	15.5	10.4	8.1	6.7	5.2	4.4	3.7
76	31.2	21.2	16.0	10.6	8.4	6.8	5.3	4.6	3.8
78	32.0	21.8	16.4	11.0	8.6	7.0	5.5	4.7	3.9
80	32.8	22.4	16.8	11.2	8.8	7.2	5.6	4.8	4.0
82	33.6	23.0	17.2	11.5	9.0	7.4	5.7	4.9	4.1
84	34.4	23.5	17.6	11.8	9.2	7.6	5.9	5.0	4.2
86	35.3	24.1	18.1	12.0	9.5	7.7	6.0	5.2	4.3
88	36.1	24.6	18.5	12.4	9.7	7.9	6.2	5.3	4.4
90	36.9	25.2	18.9	12.6	9.9	8.1	6.3	5.4	4.5
92	37.7	25.8	19.3	12.9	10.1	8.3	6.4	5.5	4.6
94	38.5	26.3	19.7	13.2	10.3	8.5	6.6	5.6	4.7
96	39.4	26.9	20.2	13.4	10.6	8.6	6.7	5.8	4.8
98	40.2	27.4	20.6	13.8	10.8	8.8	6.9	5.9	4.9
100	41.0	28.0	21.0	14.0	11.0	9.0	7.0	6.0	5.0

TABLE I.—*Wind weighting factors*—Continued

FACTORS FOR STRATA 1,500–3,000 FEET (t_2)

Speed	Point								
	32	42	52	62	72	82	92	02	12
2	1.2	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1
4	2.4	1.1	.8	.6	.4	.3	.3	.2	.2
6	3.5	1.6	1.2	.8	.6	.5	.4	.3	.2
8	4.7	2.1	1.6	1.1	.8	.6	.6	.4	.3
10	5.9	2.6	2.0	1.4	1.0	.8	.7	.5	.4
12	7.1	3.1	2.4	1.7	1.2	1.0	.8	.6	.5
14	8.3	3.7	2.8	2.0	1.4	1.1	1.0	.7	.6
16	9.4	4.2	3.2	2.2	1.6	1.3	1.1	.8	.6
18	10.6	4.7	3.6	2.5	1.8	1.4	1.3	.9	.7
20	11.8	5.2	4.0	2.8	2.0	1.6	1.4	1.0	.8
22	13.0	5.7	4.4	3.1	2.2	1.8	1.5	1.1	.9
24	14.2	6.3	4.8	3.4	2.4	1.9	1.7	1.2	1.0
26	15.3	6.9	5.2	3.6	2.6	2.0	1.8	1.3	1.0
28	16.5	7.3	5.6	3.9	2.8	2.2	2.0	1.4	1.1
30	17.7	7.8	6.0	4.2	3.0	2.4	2.1	1.5	1.2
32	18.9	8.3	6.4	4.5	3.2	2.6	2.2	1.6	1.3
34	20.1	8.9	6.8	4.8	3.4	2.7	2.4	1.7	1.4
36	21.2	9.4	7.2	5.0	3.6	2.9	2.5	1.8	1.4
38	22.4	9.9	7.6	5.3	3.8	3.0	2.7	1.9	1.5
40	23.6	10.4	8.0	5.6	4.0	3.2	2.8	2.0	1.6
42	24.8	10.9	8.4	5.9	4.2	3.4	2.9	2.1	1.7
44	26.0	11.5	8.8	6.2	4.4	3.5	3.1	2.2	1.8
46	27.1	12.0	9.2	6.4	4.6	3.7	3.2	2.3	1.8
48	28.3	12.5	9.6	6.7	4.8	3.8	3.4	2.4	1.9
50	29.5	13.0	10.0	7.0	5.0	4.0	3.5	2.5	2.0
52	30.7	13.5	10.4	7.3	5.2	4.2	3.6	2.6	2.1
54	31.9	14.1	10.8	7.6	5.4	4.3	3.8	2.7	2.2
56	33.0	14.6	11.2	7.8	5.6	4.5	3.9	2.8	2.2
58	34.2	15.1	11.6	8.1	5.8	4.6	4.1	2.9	2.3
60	35.4	15.6	12.0	8.4	6.0	4.8	4.2	3.0	2.4
62	36.6	16.1	12.4	8.7	6.2	5.0	4.3	3.1	2.5
64	37.8	16.7	12.8	9.0	6.4	5.1	4.5	3.2	2.6
66	38.9	17.2	13.2	9.2	6.6	5.3	4.6	3.3	2.6
68	40.1	17.7	13.6	9.5	6.8	5.4	4.8	3.4	2.7
70	41.3	18.2	14.0	9.8	7.0	5.6	4.9	3.5	2.8
72	42.5	18.7	14.4	10.1	7.2	5.8	5.0	3.6	2.9
74	43.7	19.3	14.8	10.4	7.4	5.9	5.2	3.7	3.0
76	44.8	19.8	15.2	10.6	7.6	6.1	5.3	3.8	3.0
78	46.0	20.3	15.6	10.9	7.8	6.2	5.5	3.9	3.1
80	47.2	20.8	16.0	11.2	8.0	6.4	5.6	4.0	3.2
82	48.4	21.3	16.4	11.5	8.2	6.6	5.7	4.1	3.3
84	49.6	21.9	16.8	11.8	8.4	6.7	5.9	4.2	3.4
86	50.7	22.4	17.2	12.0	8.6	6.9	6.0	4.3	3.4
88	51.9	22.9	17.6	12.3	8.8	7.0	6.2	4.4	3.5
90	53.1	23.4	18.0	12.6	9.0	7.2	6.3	4.5	3.6
92	54.3	23.9	18.4	12.9	9.2	7.4	6.4	4.6	3.7
94	55.5	24.5	18.8	13.2	9.4	7.5	6.6	4.7	3.8
96	56.6	25.0	19.2	13.4	9.6	7.7	6.7	4.8	3.8
98	57.8	25.5	19.6	13.7	9.8	7.8	6.9	4.9	3.9
100	59.0	26.0	20.0	14.0	10.0	8.0	7.0	5.0	4.0

TABLE I.—*Wind weighting factors*—Continued

FACTORS FOR STRATA 3,000–4,500 FEET (t_3)

Speed	Point							
	43	53	63	73	83	93	03	13
2	0.9	0.4	0.2	0.2	0.2	0.1	0.1	0.1
4	1.8	.8	.5	.4	.3	.3	.2	.2
6	2.7	1.2	.8	.6	.5	.4	.3	.2
8	3.7	1.6	1.0	.8	.6	.6	.4	.3
10	4.6	2.0	1.3	1.0	.8	.7	.5	.4
12	5.5	2.4	1.6	1.2	1.0	.8	.6	.5
14	6.4	2.8	1.8	1.4	1.1	1.0	.7	.6
16	7.3	3.2	2.1	1.6	1.3	1.1	.8	.6
18	8.3	3.6	2.3	1.8	1.4	1.3	.9	.7
20	9.2	4.0	2.6	2.0	1.6	1.4	1.0	.8
22	10.1	4.4	2.9	2.2	1.8	1.5	1.1	.9
24	11.0	4.8	3.1	2.4	1.9	1.7	1.2	1.0
26	12.0	5.2	3.4	2.6	2.1	1.8	1.3	1.0
28	12.9	5.6	3.6	2.8	2.2	2.0	1.4	1.1
30	13.8	6.0	3.9	3.0	2.4	2.1	1.5	1.2
32	14.7	6.4	4.2	3.2	2.6	2.2	1.6	1.3
34	15.6	6.8	4.4	3.4	2.7	2.4	1.7	1.4
36	16.5	7.2	4.7	3.6	2.9	2.5	1.8	1.4
38	17.5	7.6	4.9	3.8	3.0	2.7	1.9	1.5
40	18.4	8.0	5.2	4.0	3.2	2.8	2.0	1.6
42	19.3	8.4	5.5	4.2	3.4	2.9	2.1	1.7
44	20.2	8.8	5.7	4.4	3.5	3.1	2.2	1.8
46	21.1	9.2	6.0	4.7	3.7	3.2	2.3	1.8
48	22.1	9.6	6.2	4.8	3.8	3.4	2.4	1.9
50	23.0	10.0	6.5	5.0	4.0	3.5	2.5	2.0
52	23.9	10.4	6.8	5.2	4.2	3.6	2.6	2.1
54	24.8	10.8	7.0	5.4	4.3	3.8	2.7	2.2
56	25.7	11.2	7.3	5.6	4.5	3.9	2.8	2.2
58	26.7	11.6	7.5	5.8	4.6	4.1	2.9	2.3
60	27.6	12.0	7.8	6.0	4.8	4.2	3.0	2.4
62	28.5	12.4	8.1	6.2	5.0	4.3	3.1	2.5
64	29.4	12.8	8.3	6.4	5.1	4.5	3.2	2.6
66	30.3	13.2	8.6	6.6	5.3	4.6	3.3	2.6
68	31.3	13.6	8.8	6.8	5.4	4.8	3.4	2.7
70	32.2	14.0	9.1	7.0	5.6	4.9	3.5	2.8
72	33.1	14.4	9.4	7.2	5.8	5.0	3.6	2.9
74	34.0	14.8	9.6	7.4	5.9	5.2	3.7	3.0
76	35.0	15.2	9.9	7.6	6.1	5.3	3.8	3.0
78	35.9	15.6	10.1	7.8	6.2	5.5	3.9	3.1
80	36.8	16.0	10.4	8.0	6.4	5.6	4.0	3.2
82	37.7	16.4	10.7	8.2	6.6	5.7	4.1	3.3
84	38.6	16.8	10.9	8.4	6.7	5.9	4.2	3.4
86	39.5	17.2	11.2	8.6	6.9	6.0	4.3	3.4
88	40.5	17.6	11.4	8.8	7.0	6.2	4.4	3.5
90	41.4	18.0	11.7	9.0	7.2	6.3	4.5	3.6
92	42.3	18.4	12.0	9.2	7.4	6.4	4.6	3.7
94	43.2	18.8	12.2	9.4	7.5	6.6	4.7	3.8
96	44.1	19.2	12.5	9.6	7.7	6.7	4.8	3.8
98	45.1	19.6	12.7	9.8	7.8	6.9	4.9	3.9
100	46.0	20.0	13.0	10.0	8.0	7.0	5.0	4.0

TABLE I.—*Wind weighting factors*—Continued

FACTORS FOR STRATA 4,500–6,000 FEET (t_4)

Speed	Point							Speed	Point						
	54	64	74	84	94	04	14		54	64	74	84	94	04	14
2	0.8	0.3	0.2	0.2	0.1	0.1	0.1	52	20.3	6.8	5.2	4.2	3.6	2.6	2.1
4	1.6	.5	.4	.3	.3	.2	.2	54	21.1	7.0	5.4	4.3	3.8	2.7	2.2
6	2.3	.8	.6	.5	.4	.3	.2	56	21.8	7.3	5.6	4.5	3.9	2.8	2.2
8	3.1	1.1	.8	.6	.6	.4	.3	58	22.6	7.5	5.8	4.6	4.1	2.9	2.3
10	3.9	1.3	1.0	.8	.7	.5	.4	60	23.4	7.8	6.0	4.8	4.2	3.0	2.4
12	4.7	1.6	1.2	1.0	.8	.6	.5	62	24.2	8.1	6.2	5.0	4.3	3.1	2.5
14	5.5	1.8	1.4	1.1	1.0	.7	.6	64	25.0	8.3	6.4	5.1	4.5	3.2	2.6
16	6.2	2.1	1.6	1.3	1.1	.8	.6	66	25.7	8.6	6.6	5.3	4.6	3.3	2.6
18	7.0	2.3	1.8	1.4	1.3	.9	.7	68	26.5	8.8	6.8	5.4	4.8	3.4	2.7
20	7.8	2.6	2.0	1.6	1.4	1.0	.8	70	27.3	9.1	7.0	5.6	4.9	3.5	2.8
22	8.6	2.9	2.2	1.8	1.5	1.1	.9	72	28.1	9.4	7.2	5.8	5.0	3.6	2.9
24	9.4	3.1	2.4	1.9	1.7	1.2	1.0	74	28.9	9.6	7.4	5.9	5.2	3.7	3.0
26	10.1	3.4	2.6	2.1	1.8	1.3	1.0	76	29.6	9.9	7.6	6.1	5.3	3.8	3.0
28	10.9	3.6	2.8	2.2	2.0	1.4	1.1	78	30.4	10.1	7.8	6.2	5.5	3.9	3.1
30	11.7	3.9	3.0	2.4	2.1	1.5	1.2	80	31.2	10.4	8.0	6.4	5.6	4.0	3.2
32	12.5	4.2	3.2	2.6	2.2	1.6	1.3	82	32.0	10.7	8.2	6.6	5.7	4.1	3.3
34	13.3	4.4	3.4	2.7	2.4	1.7	1.4	84	32.8	10.9	8.4	6.7	5.9	4.2	3.4
36	14.0	4.7	3.6	2.9	2.5	1.8	1.4	86	33.5	11.2	8.6	6.9	6.0	4.3	3.4
38	14.8	4.9	3.8	3.0	2.7	1.9	1.5	88	34.3	11.4	8.8	7.0	6.2	4.4	3.5
40	15.6	5.2	4.0	3.2	2.8	2.0	1.6	90	35.1	11.7	9.0	7.2	6.3	4.5	3.6
42	16.4	5.5	4.2	3.4	2.9	2.1	1.7	92	35.9	12.0	9.2	7.4	6.4	4.6	3.7
44	17.2	5.7	4.4	3.5	3.1	2.2	1.8	94	36.7	12.2	9.4	7.5	6.6	4.7	3.8
46	17.9	6.0	4.6	3.7	3.2	2.3	1.8	96	37.4	12.5	9.6	7.7	6.7	4.8	3.8
48	18.7	6.2	4.8	3.8	3.4	2.4	1.9	98	38.2	12.7	9.8	7.8	6.9	4.9	3.9
50	19.5	6.5	5.0	4.0	3.5	2.5	2.0	100	39.0	13.0	10.0	8.0	7.0	5.0	4.0

FACTORS FOR STRATA 6,000–9,000 FEET (t_5)

Speed	Point						Speed	Point					
	65	75	85	95	05	15		65	75	85	95	05	15
2	0.9	0.4	0.3	0.3	0.2	0.2	52	23.8	10.4	8.3	6.8	5.2	4.2
4	1.8	.8	.6	.5	.4	.3	54	24.8	10.8	8.6	7.0	5.4	4.3
6	2.8	1.2	1.0	.8	.6	.5	56	25.8	11.2	9.0	7.3	5.6	4.5
8	3.7	1.6	1.3	1.0	.8	.6	58	26.7	11.6	9.3	7.5	5.8	4.6
10	4.6	2.0	1.6	1.3	1.0	.8	60	27.6	12.0	9.6	7.8	6.0	4.8
12	5.4	2.4	1.9	1.6	1.2	1.0	62	28.4	12.4	9.9	8.1	6.2	5.0
14	6.4	2.8	2.2	1.8	1.4	1.1	64	29.4	12.8	10.2	8.3	6.4	5.1
16	7.4	3.2	2.6	2.1	1.6	1.3	66	30.4	13.2	10.6	8.6	6.6	5.3
18	8.3	3.6	2.9	2.3	1.8	1.4	68	31.3	13.6	10.9	8.8	6.8	5.4
20	9.2	4.0	3.2	2.6	2.0	1.6	70	32.2	14.0	11.2	9.1	7.0	5.6
22	10.0	4.4	3.5	2.9	2.2	1.8	72	33.0	14.4	11.5	9.4	7.2	5.8
24	11.0	4.8	3.8	3.1	2.4	1.9	74	34.0	14.8	11.8	9.6	7.4	5.9
26	12.0	5.2	4.2	3.4	2.6	2.1	76	35.0	15.2	12.2	9.9	7.6	6.1
28	12.9	5.6	4.5	3.6	2.8	2.2	78	35.9	15.6	12.5	10.1	7.8	6.2
30	13.8	6.0	4.8	3.9	3.0	2.4	80	36.8	16.0	12.8	10.4	8.0	6.4
32	14.6	6.4	5.1	4.2	3.2	2.6	82	37.6	16.4	13.1	10.7	8.2	6.6
34	15.6	6.8	5.4	4.4	3.4	2.7	84	38.6	16.8	13.4	10.9	8.4	6.7
36	16.6	7.2	5.8	4.7	3.6	2.9	86	39.6	17.2	13.8	11.2	8.6	6.9
38	17.5	7.6	6.1	4.9	3.8	3.0	88	40.5	17.6	14.1	11.4	8.8	7.0
40	18.4	8.0	6.4	5.2	4.0	3.2	90	41.4	18.0	14.4	11.7	9.0	7.2
42	19.2	8.4	6.7	5.5	4.2	3.4	92	42.2	18.4	14.7	12.0	9.2	7.4
44	20.2	8.8	7.0	5.7	4.4	3.5	94	43.2	18.8	15.0	12.2	9.4	7.5
46	21.2	9.2	7.4	6.0	4.6	3.7	96	44.2	19.2	15.4	12.5	9.6	7.7
48	22.1	9.6	7.7	6.2	4.8	3.8	98	45.1	19.6	15.7	12.7	9.8	7.8
50	23.0	10.0	8.0	6.5	5.0	4.0	100	46.0	20.0	16.0	13.0	10.0	8.0

TABLE I.—*Wind weighting factors*—Continued

FACTORS FOR STRATA 9,000–12,000 FEET (t_6)

Speed	Point					Speed	Point				
	76	86	96	06	16		76	86	96	06	16
2	0.8	0.3	0.3	0.2	0.2	52	20.3	8.3	6.8	5.2	4.2
4	1.6	.6	.5	.4	.3	54	21.1	8.6	7.0	5.4	4.3
6	2.3	1.0	.8	.6	.5	56	21.8	9.0	7.3	5.6	4.5
8	3.1	1.3	1.0	.8	.6	58	22.6	9.3	7.5	5.8	4.6
10	3.9	1.6	1.3	1.0	.8	60	23.4	9.6	7.8	6.0	4.8
12	4.7	1.9	1.6	1.2	1.0	62	24.2	9.9	8.1	6.2	5.0
14	5.5	2.2	1.8	1.4	1.1	64	25.0	10.2	8.3	6.4	5.1
16	6.2	2.6	2.1	1.6	1.3	66	25.7	10.6	8.6	6.6	5.3
18	7.0	2.9	2.3	1.8	1.4	68	26.5	10.9	8.8	6.8	5.4
20	7.8	3.2	2.6	2.0	1.6	70	27.3	11.2	9.1	7.0	5.6
22	8.6	3.5	2.9	2.2	1.8	72	28.1	11.5	9.4	7.2	5.8
24	9.4	3.8	3.1	2.4	1.9	74	28.9	11.8	9.6	7.4	5.9
26	10.1	4.2	3.4	2.6	2.1	76	29.6	12.2	9.9	7.6	6.1
28	10.9	4.5	3.6	2.8	2.2	78	30.4	12.5	10.1	7.8	6.2
30	11.7	4.8	3.9	3.0	2.4	80	31.2	12.8	10.4	8.0	6.4
32	12.5	5.1	4.2	3.2	2.6	82	32.0	13.1	10.7	8.2	6.6
34	13.3	5.4	4.4	3.4	2.7	84	32.8	13.4	10.9	8.4	6.7
36	14.0	5.8	4.7	3.6	2.9	86	33.5	13.8	11.2	8.6	6.9
38	14.8	6.1	4.9	3.8	3.0	88	34.3	14.1	11.4	8.8	7.0
40	15.6	6.4	5.2	4.0	3.2	90	35.1	14.4	11.7	9.0	7.2
42	16.4	6.7	5.5	4.2	3.4	92	35.9	14.7	12.0	9.2	7.4
44	17.2	7.0	5.7	4.4	3.5	94	36.7	15.0	12.2	9.4	7.5
46	17.9	7.4	6.0	4.6	3.7	96	37.4	15.4	12.5	9.6	7.7
48	18.7	7.7	6.2	4.8	3.8	98	38.2	15.7	12.7	9.8	7.8
50	19.5	8.0	6.5	5.0	4.0	100	39.0	16.0	13.0	10.0	8.0

FACTORS FOR STRATA 12,000–15,000 FEET (t_7)

Speed	Point				Speed	Point				Speed	Point			
	87	97	07	17		87	97	07	17		87	97	07	17
2	0.6	0.3	0.2	0.2	42	14.6	5.9	4.2	3.4	72	25.1	10.1	7.2	5.8
4	1.5	.5	.4	.3	44	15.5	6.2	4.4	3.5	74	26.0	10.4	7.4	5.9
6	2.0	.8	.6	.5	46	16.0	6.4	4.6	3.7	76	26.5	10.6	7.6	6.1
8	2.9	1.1	.8	.6	48	16.9	6.7	4.8	3.8	78	27.4	10.8	7.8	6.2
10	3.5	1.4	1.0	.8	50	17.5	7.0	5.0	4.0	80	28.0	11.2	8.0	6.4
12	4.1	1.7	1.2	1.0	52	18.1	7.3	5.2	4.2	82	28.6	11.5	8.2	6.6
14	5.0	2.0	1.4	1.1	54	19.0	7.6	5.4	4.3	84	29.5	11.8	8.4	6.7
16	5.5	2.2	1.6	1.3	56	19.5	7.8	5.6	4.5	86	30.0	12.0	8.6	6.9
18	6.4	2.5	1.8	1.4	58	20.4	8.1	5.8	4.6	88	30.9	12.3	8.8	7.0
20	7.0	2.8	2.0	1.6	60	21.0	8.4	6.0	4.8	90	31.5	12.6	9.0	7.2
22	7.6	3.1	2.2	1.8	62	21.6	8.7	6.2	5.0	92	32.1	12.9	9.2	7.4
24	8.5	3.4	2.4	1.9	64	22.5	9.0	6.4	5.1	94	33.0	13.2	9.4	7.5
26	9.1	3.6	2.6	2.1	66	23.0	9.2	6.6	5.3	96	33.5	13.4	9.6	7.7
28	9.9	3.9	2.8	2.2	68	23.9	9.5	6.8	5.4	98	34.4	13.7	9.8	7.8
30	10.5	4.2	3.0	2.4	70	24.5	9.8	7.0	5.6	100	35.0	14.0	10.0	8.0
32	11.1	4.5	3.2	2.6										
34	12.0	4.8	3.4	2.7										
36	12.5	5.0	3.6	2.9										
38	13.4	5.3	3.8	3.0										
40	14.0	5.6	4.0	3.2										

TABLE I.—*Wind weighting factors*—Continued

FACTORS FOR STRATA 15,000–18,000 FEET (t_8)

Speed	Point 98	Point 08	Point 18	Speed	Point 98	Point 08	Point 18	Speed	Point 98	Point 08	Point 18
2	0.7	0.2	0.2	42	13.5	4.2	3.4	72	23.1	7.2	5.8
4	1.3	.4	.3	44	14.0	4.4	3.5	74	23.6	7.4	5.9
6	2.0	.6	.5	46	14.8	4.6	3.7	76	24.4	7.6	6.1
8	2.5	.8	.6	48	15.3	4.8	3.8	78	25.0	7.8	6.2
10	3.2	1.0	.8	50	16.0	5.0	4.0	80	25.6	8.0	6.4
12	3.9	1.2	1.0	52	16.7	5.2	4.2	82	26.3	8.2	6.6
14	4.4	1.4	1.1	54	17.3	5.4	4.3	84	26.8	8.4	6.7
16	5.2	1.6	1.3	56	18.0	5.6	4.5	86	27.6	8.6	6.9
18	5.7	1.8	1.4	58	18.5	5.8	4.6	88	28.1	8.8	7.0
20	6.4	2.0	1.6	60	19.2	6.0	4.8	90	28.8	9.0	7.2
22	7.1	2.2	1.8	62	19.9	6.2	5.0	92	29.5	9.2	7.4
24	7.6	2.4	1.9	64	20.4	6.4	5.1	94	30.0	9.4	7.5
26	8.4	2.6	2.1	66	21.2	6.6	5.3	96	30.8	9.6	7.7
28	8.9	2.8	2.2	68	21.7	6.8	5.4	98	31.3	9.8	7.8
30	9.6	3.0	2.4	70	22.4	7.0	5.6	100	32.0	10.0	8.0
32	10.3	3.2	2.6								
34	10.8	3.4	2.7								
36	11.6	3.6	2.9								
38	12.1	3.8	3.0								
40	12.8	4.0	3.2								

FACTORS FOR STRATA 18,000–24,000 FEET (t_9)

Speed	Point 09	Point 19	Speed	Point 09	Point 19	Speed	Point 09	Point 19	Speed	Point 09	Point 19
2	0.8	0.2	32	12.5	5.0	62	24.2	9.8	82	32.0	13.0
4	1.6	.6	34	13.3	5.4	64	25.0	10.2	84	32.8	13.4
6	2.3	1.0	36	14.0	5.8	66	25.7	10.6	86	33.5	13.8
8	3.1	1.4	38	14.8	6.2	68	26.5	11.0	88	34.3	14.2
10	3.9	1.6	40	15.6	6.4	70	27.3	11.2	90	35.1	14.4
12	4.7	1.8	42	16.4	6.6	72	28.1	11.4	92	35.9	14.7
14	5.5	2.2	44	17.2	7.0	74	28.9	11.8	94	36.7	15.0
16	6.2	2.6	46	17.9	7.4	76	29.6	12.2	96	37.4	15.4
18	7.0	3.0	48	18.7	7.8	78	30.4	12.6	98	38.2	15.8
20	7.8	3.2	50	19.5	8.0	80	31.2	12.8	100	39.0	16.0
22	8.6	3.4	52	20.3	8.2						
24	9.4	3.8	54	21.1	8.6						
26	10.1	4.2	56	21.8	9.0						
28	10.9	4.6	58	22.6	9.4						
30	11.7	4.8	60	23.4	9.6						

FACTORS FOR STRATA 24,000–30,000 FEET (t_{10})

Speed	Point 10	Speed	Point 10	Speed	Point 10	Speed	Point 10	Speed	Point 10
2	0.6	22	7.6	42	14.6	62	21.6	82	28.6
4	1.4	24	8.4	44	15.4	64	22.4	84	29.4
6	2.1	26	9.1	46	16.1	66	23.1	86	30.1
8	2.9	28	9.9	48	16.9	68	23.9	88	30.9
10	3.5	30	10.5	50	17.5	70	24.5	90	31.5
12	4.1	32	11.1	52	18.1	72	25.1	92	32.2
14	4.9	34	11.9	54	18.9	74	25.9	94	32.9
16	5.6	36	12.6	56	19.6	76	26.6	96	33.6
18	6.4	38	13.4	58	20.4	78	27.4	98	34.4
20	7.0	40	14.0	60	21.0	80	28.0	100	35.0

ASCENSIONAL RATES OF BALLOONS

The following formula may be used to determine rates of ascent of balloons in all pilot balloon work of the Signal Corps:

$$V=158\left(\frac{l}{L^{\frac{1}{3}}}\right)^{\frac{5}{8}}$$

Where V is the rate of ascent of the balloon in yards per minute, l is the free lift of the balloon in ounces, and L is the total lift of the balloon in ounces.

The same formula in metric units is:

$$V=72\left(\frac{l}{L^{\frac{1}{3}}}\right)^{\frac{5}{8}}$$

Where V is the rate of ascent of the balloon in meters per minute, l is the free lift of the balloon in grams, and L is the total lift of the balloon in grams.

The following tables show the altitude balloons will reach in the time indicated when they are inflated to ascend at the rate of 200 and 250 yards per minute, respectively, and after allowance is made for the balloons ascending 20 per cent faster than the standard rate during the first minute, 10 per cent faster during the second and third minutes, and 5 per cent faster during the fourth and fifth minutes:

TABLE II

Minutes after release	Balloons inflated to ascend 200 yards per minute	Balloons inflated to ascend 250 yards per minute	Minutes after release	Balloons inflated to ascend 200 yards per minute	Balloons inflated to ascend 250 yards per minute
	Yards	*Yards*		*Yards*	*Yards*
1	240	300	21	4,300	5,375
2	460	575	22	4,500	5,625
3	680	850	23	4,700	5,875
4	890	1,112	24	4,900	6,125
5	1,100	1,375	25	5,100	6,375
6	1,300	1,625	26	5,300	6,625
7	1,500	1,875	27	5,500	6,875
8	1,700	2,125	28	5,700	7,125
9	1,900	2,375	29	5,900	7,375
10	2,100	2,625	30	6,100	7,625
11	2,300	2,875	31	6,300	7,875
12	2,500	3,125	32	6,500	8,125
13	2,700	3,375	33	6,700	8,375
14	2,900	3,625	34	6,900	8,625
15	3,100	3,875	35	7,100	8,875
16	3,300	4,125			
17	3,500	4,375			
18	3,700	4,625			
19	3,900	4,875			
20	4,100	5,125			

TABLE II—Continued

RATE OF ASCENT IN YARDS PER MINUTE OF PILOT BALLOONS OF VARIOUS WEIGHTS AND FREE LIFTS

Free lift, in ounces	Free lift, in grams	Weight of balloon, in ounces								
		0.35	0.42	0.49	0.56	0.63	0.71	0.78	0.85	0.92
		Weight of balloon, in grams								
		10	12	14	16	18	20	22	24	26
		Yards	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*
0.71	20	124.1	120.8	117.8	115.0	112.5	110.1	107.9	105.9	103.9
.88	25	133.9	130.8	128.0	125.3	122.8	120.8	118.3	116.4	114.4
1.06	30	141.8	139.0	136.4	133.9	131.5	129.3	127.2	125.2	123.4
1.23	35	148.7	146.1	143.6	141.2	138.9	136.8	134.7	132.9	131.0
1.41	40	154.7	152.2	149.8	147.6	145.5	143.4	141.5	139.7	137.8
1.59	45	160.1	157.7	155.4	153.3	151.2	149.3	147.4	145.7	143.9
1.76	50	164.9	162.6	160.5	158.5	156.5	154.6	152.8	151.0	149.4
1.94	55	169.3	167.1	165.1	163.2	161.3	159.4	157.7	156.1	154.4
2.12	60	173.2	171.3	169.3	167.4	165.7	163.9	162.2	160.7	159.0
2.29	65	177.1	175.1	173.2	171.4	169.7	168.0	166.3	164.8	163.3
2.47	70	180.4	178.6	176.8	175.1	173.4	171.8	170.3	168.7	167.2
2.65	75	183.7	182.0	180.2	178.6	176.9	175.4	173.9	172.5	171.0
2.82	80	186.8	185.0	183.4	181.9	180.3	178.8	177.3	175.9	174.4
3.00	85	189.6	188.0	186.5	184.9	183.4	182.0	180.6	179.1	177.8
3.17	90	192.5	190.8	189.3	187.8	186.4	184.9	183.8	182.2	180.9
3.35	95	195.0	193.5	192.0	190.6	189.2	187.8	186.5	185.0	183.8
3.53	100	197.5	196.1	194.6	193.2	191.8	190.5	189.2	187.9	186.7
3.70	105	--------	198.5	197.1	195.8	194.3	193.0	191.8	190.5	189.3
3.88	110	--------	--------	199.5	198.1	196.8	195.5	194.3	193.1	191.9
4.06	115	--------	--------	--------	200.3	199.1	197.9	196.7	195.5	194.3
4.23	120	--------	--------	--------	--------	201.4	200.2	199.0	197.8	196.7
4.41	125	--------	--------	--------	--------	--------	202.4	201.2	200.1	199.0
4.59	130	--------	--------	--------	--------	--------	204.5	203.4	202.3	201.2
4.76	135	--------	--------	--------	--------	--------	206.6	205.5	204.4	203.3
4.94	140	--------	--------	--------	--------	--------	208.6	207.5	206.4	205.4
5.11	145	--------	--------	--------	--------	--------	210.4	209.3	208.3	207.3
5.29	150	--------	--------	--------	--------	--------	212.3	211.3	210.2	209.2
5.47	155	--------	--------	--------	--------	--------	214.0	213.0	212.1	211.1
5.64	160	--------	--------	--------	--------	--------	215.8	214.8	213.8	212.9
5.82	165	--------	--------	--------	--------	--------	217.5	216.5	215.6	214.7
6.00	170	--------	--------	--------	--------	--------	219.2	218.2	217.3	216.3
6.17	175	--------	--------	--------	--------	--------	220.8	219.8	218.9	218.0
6.35	180	--------	--------	--------	--------	--------	222.3	221.3	220.5	219.6
6.53	185	--------	--------	--------	--------	--------	223.9	223.0	222.0	221.1
6.70	190	--------	--------	--------	--------	--------	225.3	224.4	223.5	222.7
6.88	195	--------	--------	--------	--------	--------	226.8	225.9	225.1	224.2
7.05	200	--------	--------	--------	--------	--------	228.2	227.4	226.5	225.6

TABLE II—Continued

RATE OF ASCENT IN YARDS PER MINUTE OF PILOT BALLOONS OF VARIOUS WEIGHTS AND FREE LIFTS—Continued

Free lift, in ounces	Free lift, in grams	Weight of balloon, in ounces								
		0.99	1.06	1.13	1.20	1.27	1.34	1.41	1.48	1.55
		Weight of balloon, in grams								
		28	30	32	34	36	38	40	42	44
		Yards	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*
0.71	20	102.0	100.3	98.8	97.2	95.7	94.3	93.0	91.8	90.6
.88	25	112.5	110.9	109.3	107.6	106.2	104.8	103.5	102.1	100.8
1.06	30	121.5	119.9	118.2	116.6	115.2	113.7	112.3	111.0	109.8
1.23	35	129.3	127.6	126.0	124.5	123.0	121.6	120.2	118.9	117.7
1.41	40	136.2	134.5	132.9	131.5	129.9	128.6	127.2	125.9	124.7
1.59	45	142.3	140.6	139.1	137.7	136.3	134.8	133.5	132.2	131.0
1.76	50	147.9	146.2	144.8	132.8	142.0	140.5	139.3	138.0	136.7
1.94	55	152.9	151.4	149.9	148.5	147.1	145.8	144.5	143.3	142.1
2.12	60	157.5	156.1	154.6	153.2	151.9	150.6	149.4	148.1	146.9
2.29	65	161.9	160.4	159.0	157.7	156.4	155.1	153.9	152.7	151.5
2.47	70	165.8	164.5	163.1	161.7	160.5	159.2	158.0	156.8	155.7
2.65	75	169.6	168.2	166.9	165.7	164.4	163.2	162.0	160.9	159.7
2.82	80	173.1	171.8	170.5	169.3	168.1	166.9	165.7	164.6	163.5
3.00	85	176.4	175.2	173.9	172.7	171.6	170.3	169.2	168.1	167.0
3.17	90	179.6	178.4	177.2	176.0	174.8	173.7	172.5	171.4	170.4
3.35	95	182.6	181.3	180.1	179.0	177.8	176.7	175.6	174.5	173.6
3.53	100	185.5	184.3	183.1	182.0	180.8	179.7	178.6	177.6	176.5
3.70	105	188.1	187.0	185.8	184.7	183.6	182.5	181.5	180.4	179.5
3.88	110	190.7	189.6	188.4	187.3	186.4	185.3	184.3	183.2	182.2
4.06	115	193.2	192.1	191.1	190.0	188.9	187.9	186.9	185.8	184.9
4.23	120	195.6	194.6	193.5	192.4	191.4	190.4	189.4	188.4	187.4
4.41	125	197.9	196.8	195.8	194.8	193.8	192.8	191.8	190.8	189.9
4.59	130	200.1	199.0	198.1	197.1	196.1	195.1	194.1	193.1	192.3
4.76	135	202.3	201.2	200.2	199.3	198.3	197.3	196.4	195.4	194.6
4.94	140	204.3	203.3	202.3	201.3	200.3	199.5	198.5	197.6	196.7
5.11	145	206.4	205.4	204.4	203.4	202.4	201.6	200.7	199.7	198.8
5.29	150	208.2	207.2	206.4	205.4	204.5	202.8	202.8	201.8	200.9
5.47	155	210.1	209.2	208.2	207.3	206.4	205.5	204.6	203.7	202.9
5.64	160	211.9	211.0	210.1	209.2	208.3	207.5	206.6	205.7	204.8
5.82	165	213.7	212.8	211.9	211.0	210.1	209.2	208.4	207.6	206.7
6.00	170	215.4	214.6	213.6	212.7	211.9	211.1	210.2	209.3	208.6
6.17	175	217.1	216.2	215.3	214.5	213.6	212.8	211.9	211.2	210.3
6.35	180	218.7	217.8	217.0	216.1	215.3	214.4	213.7	212.8	212.1
6.53	185	220.3	219.5	218.6	217.7	217.0	216.1	215.3	214.6	213.8
6.70	190	221.9	221.0	220.1	219.4	218.5	217.7	217.0	216.2	215.4
6.88	195	223.3	222.5	221.7	220.9	220.1	219.4	218.6	217.7	217.0
7.05	200	224.8	224.0	223.2	222.4	221.7	220.8	220.0	219.3	218.6

TABLE II—Continued

RATE OF ASCENT IN YARDS PER MINUTE OF PILOT BALLOONS OF VARIOUS WEIGHTS AND FREE LIFTS—Continued

Free lift, in ounces	Free lift, in grams	Weight of balloon, in ounces								
		1.62	1.69	1.76	1.83	1.90	1.98	2.0	2.12	2.19
		Weight of balloon, in grams								
		46	48	50	52	54	56	58	60	62
		Yards	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yares*	*Yards*	*Yards*
0.71	20	89.3	88.3	87.2	86.2	85.2	84.3	83.3	82.5	81.7
.88	25	99.6	98.5	97.4	96.3	95.4	94.4	93.4	92.5	91.5
1.06	30	108.6	107.4	106.3	105.2	104.1	103.1	102.1	101.2	100.3
1.23	35	116.5	115.3	114.1	113.0	112.0	110.9	109.9	108.9	108.0
1.41	40	123.5	122.3	121.2	120.0	119.0	117.9	116.9	115.9	114.9
1.59	45	129.8	128.6	127.5	126.3	125.3	124.2	123.2	122.3	121.3
1.76	50	135.5	134.4	133.3	132.2	131.1	130.0	129.0	128.1	127.1
1.94	55	140.9	139.8	138.3	137.5	136.5	135.4	134.4	133.3	132.4
2.12	60	145.8	144.7	143.6	142.5	141.4	140.4	139.4	138.5	137.5
2.29	65	150.4	149.2	148.1	147.1	146.0	145.0	144.0	143.0	142.2
2.47	70	154.6	153.5	152.4	151.4	150.4	149.4	148.4	147.4	146.5
2.65	75	158.6	157.5	156.5	155.4	154.4	153.4	152.4	151.6	150.6
2.82	80	162.4	161.3	160.2	159.2	158.2	157.3	156.3	155.4	154.4
3.00	85	165.9	164.9	163.8	162.8	161.9	160.9	160.0	159.0	158.1
3.17	90	169.3	168.3	167.2	166.2	165.4	164.4	163.4	162.5	161.6
3.35	95	172.5	171.5	170.5	169.5	168.5	167.7	166.7	165.8	164.9
3.53	100	175.5	174.5	173.6	172.6	171.7	170.7	169.8	169.0	168.1
3.70	105	178.5	177.5	176.5	175.6	174.6	173.8	172.9	172.0	171.2
3.88	110	181.2	180.2	179.4	178.4	177.5	176.6	175.7	174.9	174.9
4.06	115	183.9	183.0	182.1	181.1	180.2	179.4	178.5	177.0	176.8
4.23	120	186.5	185.6	184.6	183.7	182.9	182.0	181.1	180.3	179.5
4.41	125	189.0	188.0	187.1	186.2	185.4	184.5	183.7	182.9	182.1
4.59	130	191.3	190.4	189.5	188.6	187.8	187.0	186.1	185.4	184.5
4.76	135	193.6	192.7	191.8	191.1	190.2	189.3	188.5	187.7	186.9
4.94	140	195.9	195.0	194.1	193.2	192.5	191.6	190.8	190.0	189.2
5.11	145	197.9	197.1	196.3	195.4	194.7	193.8	193.0	192.3	191.5
5.29	150	200.0	199.2	198.4	197.5	196.7	196.0	195.1	194.3	193.6
5.47	155	202.1	201.2	200.5	199.6	198.8	198.0	197.3	196.4	195.8
5.64	160	204.0	203.2	202.4	201.6	200.8	200.0	199.3	198.5	197.7
5.82	165	205.9	205.0	204.3	203.5	202.8	202.0	201.2	200.5	199.7
6.00	170	207.8	206.9	206.1	205.4	204.6	203.8	203.1	202.4	201.7
6.17	175	209.5	208.8	208.0	207.2	206.5	205.7	204.9	204.3	203.5
6.35	180	211.3	210.5	209.8	209.0	208.2	207.5	206.8	206.0	205.4
6.53	185	212.9	212.2	211.5	210.7	210.0	209.2	208.6	207.8	207.1
6.70	190	214.7	213.9	213.1	212.4	211.7	211.0	210.2	209.5	208.9
6.88	195	216.2	215.6	214.8	214.0	213.4	212.6	211.9	211.2	210.5
7.05	200	217.8	217.1	216.3	215.7	214.9	214.2	213.6	212.8	212.2

TABLE II—Continued

RATE OF ASCENT IN YARDS PER MINUTE OF PILOT BALLOONS OF VARIOUS WEIGHTS AND FREE LIFTS—Continued

Free lift, in ounces	Free lift, in grams	Weight of balloon, in ounces								
		2.26	2.33	2.40	2.47	2.54	2.61	2.68	2.75	2.82
		Weight of balloon, in grams								
		64	66	68	70	72	74	76	78	80
		Yards	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*
0.71	20	80.8	80.1	79.3	78.5	77.9	77.1	76.4	75.8	75.1
.88	25	90.7	89.9	89.0	88.3	87.5	86.8	86.1	85.3	84.6
1.06	30	99.4	98.5	97.7	96.9	96.0	95.3	94.5	93.8	93.1
1.23	35	107.1	106.2	105.3	104.4	103.7	102.9	102.1	101.4	100.6
1.41	40	114.1	113.2	112.3	111.4	110.6	109.8	108.9	108.2	107.4
1.59	45	120.4	119.4	118.5	117.7	116.9	116.0	115.3	114.5	113.7
1.76	50	126.2	125.2	124.3	123.5	122.7	121.8	121.1	120.2	119.4
1.94	55	131.6	130.7	129.7	128.9	128.1	127.2	126.4	125.5	124.8
2.12	60	136.6	135.6	134.7	133.9	133.1	132.2	131.3	130.6	129.8
2.29	65	141.2	140.3	139.4	138.6	137.7	136.9	136.0	135.3	134.5
2.47	70	145.6	144.7	143.8	142.9	142.1	141.3	140.4	139.7	138.9
2.65	75	149.7	148.8	148.0	147.1	146.2	145.5	144.6	143.8	143.0
2.82	80	153.5	152.7	151.8	151.0	150.2	149.3	148.5	147.7	147.0
3.00	85	157.3	156.4	155.5	154.6	153.9	153.0	152.2	151.5	150.7
3.17	90	160.8	159.9	159.0	158.2	157.4	156.6	155.8	155.0	154.2
3.35	95	164.0	163.2	162.4	161.5	160.8	160.0	159.1	158.4	157.6
3.53	100	167.2	166.4	165.6	164.8	163.9	163.2	162.4	161.6	160.9
3.70	105	170.3	169.4	168.6	167.9	167.0	166.2	165.5	164.7	163.9
3.88	110	173.2	172.4	171.6	170.7	169.9	169.2	168.4	167.7	167.0
4.06	115	176.0	175.2	174.3	173.6	172.8	171.9	171.3	170.5	169.8
4.23	120	178.7	177.8	177.1	176.3	175.5	174.8	174.0	173.2	172.6
4.41	125	181.3	180.4	179.7	178.9	178.1	177.4	176.6	176.0	175.2
4.59	130	183.7	183.0	182.2	181.4	180.7	179.9	179.1	178.5	177.7
4.76	135	186.1	185.4	184.6	183.8	183.1	182.3	181.6	180.9	180.2
4.94	140	188.4	187.7	186.9	186.1	185.5	184.7	184.1	183.3	182.6
5.11	145	190.7	190.0	189.2	188.4	187.8	187.0	186.4	185.6	184.9
5.29	150	192.9	192.1	191.4	190.6	190.0	189.2	188.5	187.9	187.1
5.47	155	195.0	194.2	193.5	192.8	192.0	191.4	190.7	190.0	189.3
5.64	160	197.1	196.3	195.5	194.9	194.1	193.5	192.8	192.1	191.4
5.82	165	199.0	198.3	197.0	196.8	196.2	195.5	194.8	194.1	193.5
6.00	170	200.9	200.2	199.5	198.8	198.2	197.5	196.7	196.1	195.4
6.17	175	202.9	202.1	201.4	200.7	200.7	199.4	198.7	198.1	197.4
6.35	180	204.6	204.0	203.3	202.5	201.9	201.2	200.6	199.9	199.3
6.53	185	206.5	205.7	205.1	204.4	203.7	203.1	202.4	201.8	201.1
6.70	190	208.1	207.5	206.8	206.1	205.5	204.8	204.2	203.5	203.0
6.88	195	209.9	209.2	208.6	207.9	207.1	206.6	205.9	205.3	204.7
7.05	200	211.5	210.8	210.2	209.5	208.9	208.2	207.7	207.0	206.4

TABLE II—Continued

RATE OF ASCENT IN YARDS PER MINUTE OF PILOT BALLOONS OF VARIOUS WEIGHTS AND FREE LIFTS—Continued

Free lift, in ounces	Free lift, in grams	Weight of balloon, in ounces									
		0.78	0.85	0.92	0.99	1.06	1.13	1.20	1.27	1.34	1.41
		Weight of balloon, in grams									
		22	24	26	28	30	32	34	36	38	40
		Yards	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*
7.23	205	228.8	227.9	227.0	226.3	225.5	224.6	223.9	223.1	222.3	221.6
7.41	210	-----	229.3	228.5	227.7	226.9	226.2	225.3	224.5	223.9	223.1
7.58	215	-----	-----	229.9	229.1	228.2	227.5	226.7	226.0	225.3	224.5
7.76	220	-----	-----	-----	230.4	229.7	228.9	228.1	227.4	226.7	225.9
7.94	225	-----	-----	-----	-----	231.0	230.2	229.4	228.8	228.0	227.4
8.11	230	-----	-----	-----	-----	232.3	231.5	230.9	230.1	229.3	228.7
8.29	235	-----	-----	-----	-----	233.6	232.8	232.1	231.4	230.6	230.0
8.47	240	-----	-----	-----	-----	234.8	234.1	233.4	232.7	232.0	231.3
8.64	245	-----	-----	-----	-----	236.1	235.3	234.7	233.9	233.3	232.6
8.82	250	-----	-----	-----	-----	237.3	236.5	235.9	235.2	234.5	233.8
8.99	255	-----	-----	-----	-----	238.5	237.8	237.1	236.4	235.8	235.0
9.17	260	-----	-----	-----	-----	239.6	239.0	238.3	237.6	236.9	236.2
9.35	265	-----	-----	-----	-----	240.8	240.1	239.4	238.7	238.1	237.4
9.52	270	-----	-----	-----	-----	241.9	241.3	240.6	239.9	239.3	238.6
9.70	275	-----	-----	-----	-----	243.0	242.3	241.7	241.0	240.4	239.8
9.88	280	-----	-----	-----	-----	244.1	243.4	242.8	242.1	241.6	240.9
10.05	285	-----	-----	-----	-----	245.2	244.5	243.9	243.2	242.7	242.0
10.23	290	-----	-----	-----	-----	246.3	245.6	245.0	244.3	243.8	243.1
10.41	295	-----	-----	-----	-----	247.3	246.6	246.1	245.2	244.8	244.2
10.58	300	-----	-----	-----	-----	248.4	247.7	247.0	246.5	245.8	245.3
10.93	310	-----	-----	-----	-----	250.3	249.7	249.1	248.5	247.9	247.4
11.29	320	-----	-----	-----	-----	252.3	251.6	251.1	250.5	249.9	249.3
11.64	330	-----	-----	-----	-----	254.2	253.6	253.1	252.4	251.9	251.3
11.99	340	-----	-----	-----	-----	256.0	255.5	254.9	254.3	253.7	253.2
12.35	350	-----	-----	-----	-----	257.9	257.2	256.7	256.1	255.6	255.0

TABLE II—Continued

RATE OF ASCENT IN YARDS PER MINUTE OF PILOT BALLOONS OF VARIOUS WEIGHTS AND FREE LIFTS—Continued

Free lift, in ounces	Free lift, in grams	Weight of balloon, in ounces									
		1.48	1.55	1.62	1.69	1.76	1.83	1.90	1.98	2.05	2.12
		Weight of balloon, in grams									
		43	44	46	48	50	52	54	56	58	60
		Yards	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*
7.23	205	220.8	220.1	219.4	218.6	218.0	217.2	216.5	215.9	215.1	214.5
7.41	210	222.3	221.6	220.9	220.1	219.5	218.7	218.1	217.4	216.8	216.0
7.58	215	223.8	223.1	222.3	221.1	220.9	220.3	219.6	218.9	218.2	217.5
7.76	220	225.2	224.5	223.8	223.1	222.4	221.7	221.0	220.4	219.7	219.1
7.94	225	226.6	225.9	225.2	224.5	223.9	223.2	222.4	221.8	221.1	220.5
8.11	230	227.9	227.3	226.6	225.9	225.2	224.5	223.9	223.2	222.5	222.0
8.29	235	229.3	228.6	227.9	227.3	226.6	225.9	225.3	224.6	224.0	223.3
8.47	240	230.6	230.0	229.2	228.6	227.9	227.3	226.6	226.0	225.4	224.7
8.64	245	231.8	231.2	230.5	229.9	229.2	228.6	228.0	227.4	226.7	226.0
8.82	250	233.2	232.5	231.8	231.2	230.5	229.9	229.3	228.7	228.0	227.5
8.99	255	234.4	233.7	233.0	232.5	231.8	231.2	230.5	230.0	229.3	225.7
9.17	260	235.6	235.0	234.4	233.7	233.0	232.4	231.8	231.2	230.6	230.0
9.35	265	236.9	236.2	235.6	234.9	234.8	233.7	233.0	232.5	231.8	231.2
9.52	270	238.0	237.3	236.8	236.1	235.5	234.9	234.3	233.7	233.0	232.5
9.70	275	239.2	238.5	237.9	237.3	236.7	236.1	235.5	234.9	234.3	233.7
9.88	280	240.3	239.6	239.1	238.4	237.9	237.2	236.7	236.1	235.5	234.9
10.05	285	241.4	240.8	240.2	239.6	239.0	238.4	237.8	237.2	236.7	236.1
10.23	290	242.5	241.9	241.3	240.7	240.2	239.5	239.0	238.4	237.8	237.2
10.41	295	243.5	243.0	242.3	241.8	241.3	240.6	240.0	239.5	239.0	238.4
10.58	300	244.6	244.1	243.4	242.9	242.3	241.7	241.1	240.6	240.0	239.5
10.93	310	246.7	246.2	245.6	245.0	244.4	243.9	243.3	242.8	242.2	241.7
11.29	320	248.8	248.1	247.6	247.0	246.5	246.0	245.4	244.9	244.3	243.8
11.64	330	250.8	250.2	249.6	249.0	248.5	247.9	247.5	246.9	246.4	245.8
11.99	340	252.6	252.1	251.5	251.0	250.4	249.9	249.5	248.9	248.4	247.8
12.35	350	254.5	253.9	253.4	253.0	252.4	251.9	251.3	250.9	250.3	249.8
12.70	360	256.3	255.8	255.2	254.7	254.3	253.7	253.2	252.7	252.2	251.6
13.06	370	258.1	257.5	257.1	256.6	256.0	255.6	255.0	254.5	254.0	255.5
13.41	380	259.9	259.3	258.7	258.3	257.8	257.3	256.8	256.3	255.8	255.4
13.76	390	261.5	261.0	260.5	260.1	259.5	259.1	258.5	258.1	257.5	257.1
14.11	400	263.1	262.7	262.1	261.7	261.1	260.7	260.3	259.7	259.3	258.9

TABLE II—Continued

RATE OF ASCENT IN YARDS PER MINUTE OF PILOT BALLOONS OF VARIOUS WEIGHTS AND FREE LIFTS—Continued

Free lift, in ounces	Free lift, in grams	Weight of balloon, in ounces									
		2.19	2.26	2.33	2.40	2.47	2.54	2.61	2.68	2.75	2.82
		Weight of balloon, in grams									
		62	64	66	68	70	72	74	76	78	80
		Yards	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*
7.23	205	213.8	213.1	212.5	211.8	211.2	210.5	209.9	209.3	208.7	208.0
7.41	210	215.3	214.7	214.0	213.4	212.3	212.2	211.5	211.0	210.3	209.6
7.58	215	216.9	216.2	215.7	215.0	214.3	213.7	213.1	212.5	211.9	211.3
7.76	220	218.4	217.7	217.1	216.5	215.9	215.2	214.7	214.0	213.5	212.8
7.94	225	219.9	219.3	218.6	218.0	217.4	216.8	216.2	215.6	215.0	214.3
8.11	230	221.3	220.7	220.0	219.5	218.8	218.3	217.6	217.1	216.4	215.9
8.29	235	222.8	222.1	221.5	220.9	220.3	219.7	219.1	218.5	218.0	217.3
8.47	240	224.1	223.5	222.9	222.3	221.7	221.1	220.5	219.9	219.4	218.8
8.64	245	225.5	224.8	224.3	223.6	223.1	222.4	221.9	221.3	220.8	220.1
8.82	250	226.8	226.2	225.6	225.1	224.4	223.9	223.3	222.7	222.1	221.6
8.99	225	228.1	227.6	226.9	226.4	225.7	225.2	224.6	224.1	223.5	223.0
9.17	260	229.4	228.8	228.2	227.7	227.0	226.5	225.9	225.4	225.0	224.3
9.35	265	230.6	230.1	229.5	228.9	228.3	227.8	227.3	226.7	226.2	225.6
9.52	270	232.0	231.3	230.8	230.2	229.7	229.1	228.5	227.9	227.4	226.8
9.70	275	233.2	232.5	232.0	231.4	230.9	230.3	229.8	229.2	228.7	228.1
9.88	280	234.4	233.6	233.2	232.6	232.1	231.5	231.0	230.4	229.9	229.3
10.05	285	235.5	234.9	234.4	233.8	233.3	232.7	232.2	231.6	231.1	230.6
10.23	290	236.7	236.1	235.6	235.0	234.5	233.9	233.4	232.8	232.3	231.8
10.41	295	237.8	237.2	236.7	236.1	235.6	235.1	234.6	234.0	233.5	232.9
10.58	300	239.0	238.4	237.9	237.3	236.8	236.2	235.7	235.1	234.7	234.1
10.93	310	241.1	240.6	240.0	239.5	239.0	238.5	238.0	237.4	236.9	236.4
11.29	320	243.2	242.7	242.2	241.7	241.1	240.6	240.2	239.6	239.2	238.6
11.64	330	245.3	244.8	244.3	243.8	243.2	242.8	242.2	241.8	241.3	240.8
11.99	340	247.4	246.8	246.3	245.8	245.3	244.9	244.3	243.9	243.3	242.9
12.35	350	249.2	248.8	248.2	247.8	247.3	246.8	246.3	245.8	245.4	244.9
12.70	360	251.2	250.7	250.2	249.7	249.2	248.8	248.2	247.8	247.4	246.8
13.05	370	253.1	252.5	252.1	251.6	251.1	250.7	250.2	249.7	249.2	248.8
13.41	380	254.8	254.4	253.9	253.4	253.0	252.3	252.1	251.5	251.1	250.7
13.76	390	256.7	256.1	255.7	255.2	254.7	254.3	253.8	253.4	253.0	252.5
14.10	400	258.3	257.9	257.4	257.0	256.6	256.0	255.6	255.1	254.7	254.3

TABLE III.—*For determining air density in percentage of standard*

[Standard air density at battery, 1,203.4 grams per cu. m.; temperature, 59° F.; pressure, 29.528 inches; relative humidity, 78 per cent. Relative humidity of 78 per cent for all pressures and temperatures. To obtain corrections to be applied to results obtained from this table, when relative humidity is other than 78 per cent, see Table IIIa]

Pressure	Temperature										
	−20°	−16°	−12°	−8°	−4°	0°	4°	8°	12°	16°	20°
	Air density in percentage of standard										
27.00	108.3	107.4	106.5	105.5	104.6	103.7	102.8	102.0	101.1	100.2	99.3
27.10	107.8	107.8	106.9	105.9	105.0	104.1	103.2	102.3	101.4	100.6	99.7
27.20	109.2	108.2	107.3	106.3	105.4	104.5	103.6	102.7	101.8	100.9	100.0
27.30	109.6	108.6	107.7	106.7	105.8	104.9	104.0	103.1	102.2	101.3	100.4
27.40	110.0	109.0	108.1	107.1	106.2	105.3	104.4	103.5	102.5	101.7	100.8
27.50	110.4	109.4	108.5	107.5	106.6	105.6	104.7	103.8	102.9	102.0	101.2
27.60	110.8	109.8	108.9	107.9	107.0	106.0	105.1	104.2	103.3	102.4	101.5
27.70	111.2	110.2	109.2	108.3	107.3	106.4	105.5	104.6	103.7	102.8	101.9
27.80	111.6	110.6	109.6	108.7	107.7	106.8	105.9	105.0	104.1	103.1	102.3
27.90	112.0	111.0	110.0	109.1	108.1	107.2	106.3	105.4	104.4	103.5	102.6
28.00	112.4	111.4	110.4	109.5	108.5	107.6	106.7	105.7	104.8	103.9	103.0
28.10	112.8	111.8	110.8	109.8	108.9	108.0	107.0	106.1	105.2	104.3	103.4
28.20	113.2	112.2	111.2	110.2	109.3	108.4	107.4	106.5	105.6	104.6	103.7
28.30	113.6	112.6	111.6	110.6	109.6	108.7	107.8	106.8	105.9	105.0	104.1
28.40	114.0	113.0	112.0	111.0	110.0	109.1	108.2	107.2	106.3	105.4	104.4
28.50	114.4	113.4	112.4	111.4	110.4	109.5	108.6	107.6	106.7	105.8	104.9
28.60	114.8	113.8	112.8	111.8	110.8	109.9	108.9	108.0	107.0	106.1	105.2
28.70	115.2	114.2	113.2	112.2	111.2	110.3	109.3	108.4	107.4	106.5	105.6
28.80	115.6	114.6	113.6	112.6	111.6	110.6	109.7	108.8	107.8	106.9	106.0
28.90	116.0	116.0	114.0	113.0	112.0	111.0	110.1	109.1	108.2	107.3	106.4
29.00	116.4	115.4	114.4	113.4	112.4	111.4	110.5	109.5	108.6	107.6	106.7
29.10	116.8	115.8	114.8	113.8	112.8	111.8	110.9	109.9	109.0	108.0	107.1
29.20	117.2	116.2	115.2	114.1	113.2	112.2	111.2	110.3	109.3	108.4	107.4
29.30	117.6	116.6	115.6	114.5	113.6	112.6	111.6	110.7	109.7	108.7	107.8
29.40	118.0	117.0	116.0	114.9	113.9	113.0	112.0	111.0	110.1	109.1	108.2
29.50	118.4	117.4	116.4	115.3	114.3	113.4	112.4	111.4	110.4	109.5	108.5
29.60	118.8	117.8	116.7	115.7	114.7	113.7	112.8	111.8	110.8	109.9	108.9
29.70	119.2	118.2	117.1	116.1	115.1	114.1	113.1	112.1	111.2	110.2	109.3
29.80	119.6	118.6	117.5	116.5	115.5	114.5	113.5	112.5	111.6	110.6	109.6
29.90	120.0	119.0	117.9	116.9	115.9	114.9	113.9	112.9	112.0	111.0	110.0
30.00	120.4	119.4	118.3	117.3	116.2	115.3	114.3	113.3	112.3	111.4	110.4
30.10	120.8	119.8	118.7	117.6	116.6	115.6	114.6	113.7	112.7	111.7	110.7
30.20	121.2	120.2	119.1	118.0	117.0	116.0	115.0	114.0	113.0	112.1	111.1
30.30	121.6	120.6	119.5	118.4	117.4	116.4	115.4	114.4	113.4	112.5	111.4
30.40	122.0	121.0	119.9	118.8	117.8	116.8	115.8	114.8	113.8	112.8	111.8
30.50	122.4	121.4	120.3	119.2	118.2	117.2	116.2	115.2	114.2	113.2	112.2
30.60	122.8	121.8	120.7	119.6	118.6	117.5	116.5	115.5	114.5	113.5	112.6
30.70	123.2	122.2	121.0	120.0	119.0	117.9	116.9	115.9	114.9	113.9	112.9
30.80	123.6	122.6	121.4	120.4	119.3	118.3	117.3	116.3	115.3	114.3	113.3
30.90	124.0	123.0	121.8	120.7	119.7	118.7	117.7	116.7	115.6	114.6	113.6
31.00	124.4	123.4	122.2	121.1	120.1	119.1	118.0	117.0	116.0	115.0	114.0

TABLE III.—*For determining air density in percentage of standard*—Continued

Pressure	Temperature										
	20°	24°	28°	32°	36°	40°	44°	48°	52°	56°	60°
	Air density in percentage of standard										
27.00	99.3	98.5	97.6	96.8	96.0	95.2	94.4	93.6	92.8	92.0	91.2
27.10	99.7	98.9	98.0	97.2	96.4	95.6	94.8	94.0	93.1	92.3	91.6
27.20	100.0	99.2	98.4	97.5	96.7	95.9	95.1	94.3	93.5	92.7	91.9
27.30	100.4	99.6	98.7	97.9	97.1	96.3	95.5	94.7	93.8	93.0	92.2
27.40	100.8	100.0	99.1	98.2	97.4	96.6	95.8	95.0	94.2	93.4	92.6
27.50	101.2	100.3	99.4	98.6	97.8	96.9	96.1	95.3	94.5	93.7	92.9
27.60	101.5	100.7	99.8	99.0	98.2	97.3	96.5	95.7	94.9	94.1	93.3
27.70	101.9	101.0	100.2	99.3	98.5	97.7	96.9	96.0	95.2	94.4	93.6
27.80	102.3	101.4	100.5	99.7	98.9	98.0	97.2	96.4	95.6	94.8	93.9
27.90	102.6	101.8	100.9	100.0	99.2	98.4	97.6	96.7	95.9	95.1	94.3
28.00	103.0	102.2	101.3	100.4	99.6	98.7	97.9	97.1	96.3	95.4	94.6
28.10	103.4	102.5	101.6	100.7	99.9	99.1	98.3	97.4	96.6	95.8	95.0
28.20	103.7	102.9	102.0	101.1	100.3	99.4	98.6	97.8	97.0	96.1	95.3
28.30	104.1	103.3	102.4	101.5	100.7	99.8	99.0	98.1	97.3	96.5	95.7
28.40	104.4	103.6	102.7	101.8	101.0	100.1	99.3	98.5	97.6	96.8	96.0
28.50	104.9	104.0	103.1	102.2	101.4	100.5	99.7	98.8	98.0	97.1	96.3
28.60	105.2	104.3	103.4	102.5	101.7	100.8	100.0	99.2	98.3	97.5	96.7
28.70	105.6	104.7	103.8	102.9	102.1	101.2	100.3	99.5	98.7	97.8	97.0
28.80	106.0	105.1	104.2	103.3	102.4	101.6	100.7	99.9	99.0	98.2	97.4
28.90	106.4	105.5	104.5	103.6	102.8	101.9	101.1	100.2	99.4	98.5	97.7
29.00	106.7	105.8	104.9	104.0	103.2	102.3	101.4	100.6	99.7	98.9	98.1
29.10	107.1	106.2	105.2	104.3	103.5	102.6	101.8	100.9	100.1	99.2	98.4
29.20	107.4	106.6	105.6	104.7	103.9	103.0	102.1	101.3	100.4	99.5	98.7
29.30	107.8	106.9	106.0	105.1	104.2	103.3	102.5	101.6	100.8	99.9	99.1
29.40	108.2	107.3	106.3	105.4	104.6	103.7	102.8	102.0	101.1	100.2	99.4
29.50	108.5	107.6	106.7	105.8	104.9	104.0	103.2	102.3	101.4	100.6	99.7
29.60	108.9	108.0	107.0	106.2	105.3	104.4	103.5	102.6	101.8	100.9	100.1
29.70	109.3	108.4	107.4	106.5	105.6	104.7	103.9	103.0	102.1	101.2	100.4
29.80	109.6	108.7	107.8	106.9	106.0	105.1	104.2	103.3	102.5	101.6	100.8
29.90	110.0	109.1	108.2	107.3	106.4	105.5	104.6	103.7	102.8	102.0	101.1
30.00	110.4	109.5	108.5	107.6	106.7	105.8	104.9	104.0	103.2	102.3	101.4
30.10	110.7	109.8	108.8	107.9	107.1	106.2	105.3	104.4	103.5	102.6	101.8
30.20	111.1	110.2	109.2	108.3	107.4	106.5	105.6	104.7	103.8	103.0	102.1
30.30	111.4	110.6	109.6	108.7	107.8	106.9	106.0	105.1	104.2	103.3	102.4
30.40	111.8	110.9	109.9	109.0	108.1	107.2	106.3	105.4	104.5	103.6	102.8
30.50	112.2	111.3	110.3	109.4	108.5	107.6	106.6	105.7	104.8	104.0	103.1
30.60	112.6	111.6	110.6	109.7	108.8	107.9	107.0	106.1	105.2	104.3	103.4
30.70	112.9	112.0	111.0	110.1	109.2	108.2	107.3	106.4	105.5	104.6	103.8
30.80	113.3	112.4	111.4	110.4	109.5	108.6	107.7	106.8	105.9	105.0	104.1
30.90	113.6	112.7	111.7	110.8	109.9	108.9	108.0	107.1	106.2	105.3	104.4
31.00	114.0	113.1	112.1	111.2	110.2	109.3	108.4	107.5	106.6	105.7	104.8

TABLE III.—*For determining air density in percentage of standard*—Continued

Pressure	Temperature										
	60°	64°	68°	72°	76°	80°	84°	88°	92°	96°	100°
	Air density in percentage of standard										
27.00	91.2	90.5	89.7	88.9	88.1	87.3	86.5	85.7	84.9	84.1	83.3
27.10	91.6	80.9	90.0	89.2	88.4	87.6	86.8	86.0	85.2	84.4	83.6
27.20	91.9	91.1	90.3	89.6	88.8	87.9	87.1	86.3	85.5	84.7	83.9
27.30	92.2	91.5	90.7	89.9	89.1	88.3	87.5	86.7	85.9	85.1	84.2
27.40	92.6	91.8	91.0	90.2	89.4	88.6	87.8	87.0	86.2	85.4	84.5
27.50	92.9	92.1	91.3	90.6	89.8	88.9	88.1	87.3	86.5	85.7	84.9
27.60	93.3	92.5	91.7	90.9	90.1	89.3	88.5	87.7	86.8	86.0	85.2
27.70	93.6	92.8	92.0	91.2	90.4	89.6	88.8	88.0	87.2	86.3	85.5
27.80	93.9	93.1	92.3	91.5	90.7	89.9	89.1	88.3	87.5	86.7	85.8
27.90	94.3	93.5	92.7	91.9	91.1	90.3	89.5	88.6	87.8	87.0	86.1
28.00	94.6	93.8	93.0	92.2	91.4	90.6	89.8	89.0	88.1	87.3	86.4
28.10	95.0	94.2	93.3	92.5	91.7	90.9	90.1	89.3	88.4	87.6	86.7
28.20	95.3	94.5	93.7	92.9	92.1	91.2	90.4	89.6	88.8	87.9	87.1
28.30	95.7	94.9	94.0	93.2	92.4	91.6	90.8	89.9	89.1	88.3	87.4
28.40	96.0	95.2	94.4	93.6	92.7	91.9	91.1	90.3	89.4	88.6	87.7
28.50	96.3	95.5	94.7	93.9	93.1	92.2	91.4	90.6	89.7	88.9	88.0
28.60	96.7	95.9	95.0	94.2	93.4	92.6	91.8	90.9	90.1	89.2	88.3
28.70	97.0	96.2	95.4	94.6	93.7	92.9	92.1	91.2	90.4	89.5	88.6
28.80	97.4	96.5	95.7	94.9	94.1	93.2	92.4	91.5	90.7	89.9	89.0
28.90	97.7	96.9	96.1	95.2	94.4	93.5	92.7	91.9	91.0	90.2	89.3
29.00	98.1	97.2	96.4	95.6	94.7	93.9	93.1	92.2	91.4	90.5	89.6
29.10	98.4	97.6	96.7	95.9	95.1	94.2	93.4	92.5	91.7	90.8	90.0
29.20	98.7	97.9	97.0	96.2	95.4	94.5	93.7	92.9	92.0	91.1	90.3
29.30	99.1	98.2	97.4	96.6	95.7	94.8	94.0	93.2	92.3	91.5	90.6
29.40	99.4	98.6	97.7	96.9	96.1	95.2	94.4	93.5	92.6	91.8	90.9
29.50	99.7	98.9	98.1	97.2	96.4	95.5	94.7	93.8	92.9	92.1	91.2
29.60	100.1	99.2	98.4	97.6	96.7	95.8	95.0	94.1	93.3	92.4	91.5
29.70	100.4	99.6	98.7	97.9	97.0	96.2	95.3	94.5	93.6	92.7	91.8
29.80	100.8	99.9	99.0	98.2	97.4	96.5	95.7	94.8	93.9	93.0	92.2
29.90	101.1	100.3	99.4	98.6	97.7	95.8	96.0	95.1	94.3	93.4	92.5
30.00	101.4	100.6	99.7	98.9	98.0	97.1	96.3	95.5	94.6	93.7	92.8
30.10	101,8	100.9	100.0	99.2	98.4	97.5	96.7	95.8	94.9	94.0	93.1
30.20	102.1	101.3	100.4	99.6	98.7	97.8	97.0	96.1	95.2	94.3	93.4
30.30	102.4	101.6	100.7	99.9	99.0	98.1	97.3	96.4	95.5	94.6	93.7
30.40	102.8	101.9	101.1	100.2	99.3	98.4	97.6	96.7	95.8	94.9	94.0
30.50	103.1	102.3	101.4	100.5	99.7	98.8	97.9	97.0	96.2	95.3	94.3
30.60	103.4	102.6	101.7	100.9	100.0	99.1	98.3	97.4	96.5	95.6	94.6
30.70	103.8	102.9	102.0	101.2	100.3	99.4	98.6	97.7	96.8	95.9	94.9
30.80	104.1	103.3	102.4	101.5	100.6	99.7	98.9	98.0	97.1	96.2	95.3
30.90	104.4	103.6	102.7	101.9	101.0	100.1	99.2	98.3	97.4	96.5	95.6
31.00	104.8	103.9	103.0	102.2	101.3	100.4	99.5	98.6	97.7	96.8	95.9

TABLE IIIA.—*Corrections to be applied to results obtained from Table III when relative humidity is other than 78 per cent*

Relative humidity	Temperature						
	−20°	0°	20°	40°	60°	80°	100°
	Correction in percentage of standard density						
0	0	0	+0.1	+0.3	+0.5	+1.0	+1.8
10	0	0	+ .1	+ .2	+ .4	+ .9	+1.6
20	0	0	+ .1	+ .2	+ .4	+ .7	+1.3
30	0	0	+ .1	+ .2	+ .3	+ .6	+1.1
40	0	0	0	+ .1	+ .2	+ .5	+ .9
50	0	0	0	+ .1	+ .2	+ .3	+ .6
60	0	0	0	+ .1	+ .1	+ .2	+ .4
70	0	0	0	0		+ .1	+ .2
80	0	0	0	0	0	0	0
90	0	0	0	0	− .1	− .2	− .3
100	0	0	0	0	− .2	− .3	− .5

TABLE IV.—*Ballistic density, in percentage of standard used by the artillery, for various maximum ordinates. The arguments are the corrected surface density and the altitude of the meteorological station above sea level*

Maximum ordinate	Station elevation, in feet, above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
	Ballistic density in percentage of standard								
30,000	-------	-------	91.6	-------	94.1	91.6	96.5	94.4	92.2
24,000	-------	-------	90.8	-------	93.2	91.2	95.5	93.5	91.5
18,000	-------	-------	89.7	-------	91.9	90.4	94.0	92.3	90.7
15,000	-------	-------	89.1	-------	91.1	89.6	93.1	91.6	90.1
12,000	-------	-------	88.4	-------	90.2	88.9	92.0	90.7	89.4
9,000	-------	-------	87.2	-------	89.2	87.9	90.4	89.6	88.5
6,000	-------	-------	85.8	-------	87.2	86.6	88.6	87.9	87.3
4,500	-------	-------	85.0	-------	86.2	85.8	87.5	87.0	86.6
3,000	-------	-------	84.1	-------	85.3	85.0	86.3	86.1	85.8
1,500	-------	-------	83.1	-------	84.1	84.1	85.1	85.0	84.9
600	-------	-------	82.4	-------	83.4	83.4	84.5	84.4	84.4
Surface	-------	-------	82.0	-------	83.0	83.0	84.0	84.0	84.0
30,000	96.8	94.6	92.4	97.0	94.7	92.6	97.3	95.1	92.9
24,000	95.8	93.9	91.9	96.2	94.2	92.2	96.6	94.6	92.6
18,000	94.5	92.8	91.1	94.9	93.2	91.5	95.4	93.7	92.0
15,000	93.6	92.0	90.6	94.1	92.5	91.1	94.6	93.2	91.5
12,000	92.5	91.2	89.9	93.0	91.8	90.4	93.6	92.3	91.0
9,000	91.0	90.0	89.1	91.6	90.6	89.6	92.3	91.3	90.3
6,000	89.2	88.6	88.0	90.0	89.3	88.7	90.8	90.0	89.4
4,500	88.2	87.7	87.3	89.0	88.5	88.0	89.8	89.2	88.9
3,000	87.1	86.9	86.6	88.0	87.9	87.4	88.8	88.6	88.3
1,500	86.0	85.9	85.9	86.9	86.8	86.8	87.8	87.8	87.7
600	85.4	85.3	85.4	86.4	86.3	86.2	87.3	87.2	87.3
Surface	85.0	85.0	85.0	86.0	86.0	86.0	87.0	87.0	87.0
30,000	97.6	95.4	93.1	97.9	95.6	93.3	98.2	95.9	93.5
24,000	97.0	94.9	92.9	97.3	95.2	93.2	97.6	95.6	93.3
18,000	95.8	94.1	92.4	96.2	94.5	92.8	96.7	94.9	93.2
15,000	95.0	93.5	92.1	95.6	94.0	92.5	96.1	94.5	93.0
12,000	94.1	92.8	91.6	94.8	93.4	92.2	95.3	94.0	92.7
9,000	92.8	92.0	90.9	93.6	92.6	91.6	94.2	93.2	92.2
6,000	91.4	90.9	90.1	92.3	91.5	90.8	93.1	92.2	91.6
4,500	90.6	90.1	89.6	91.5	90.9	90.4	92.3	91.6	91.3
3,000	89.7	89.6	89.1	90.4	90.4	90.0	91.5	91.2	90.9
1,500	88.0	88.8	88.5	89.8	89.7	89.6	90.7	90.6	90.5
600	88.3	88.3	88.2	89.4	89.3	89.2	90.2	90.2	90.2
Surface	88.0	88.0	88.0	89.0	89.0	89.0	90.0	90.0	90.0

TABLE IV.—*Ballistic density, in percentage of standard used by the artillery, for various maximum ordinates. The arguments are the corrected surface density and the altitude of the meteorological station above sea level*—Continued

Maximum ordinate	Station elevation, in feet, above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
	Ballistic density in percentage of standard								
30,000	98.5	96.1	93.8	98.8	96.4	93.9	99.0	96.7	94.3
24,000	98.0	95.9	93.7	98.3	96.4	94.2	98.7	96.7	94.6
18,000	97.1	95.4	93.6	97.6	95.8	94.0	98.1	96.3	94.5
15,000	96.6	95.0	93.5	97.0	95.5	93.9	97.5	96.0	94.4
12,000	95.8	94.5	93.2	96.4	95.1	93.8	96.9	95.6	94.3
9,000	94.8	93.8	92.8	95.5	94.4	93.4	96.1	95.0	93.9
6,000	93.6	93.0	92.3	94.4	93.8	93.1	95.2	94.5	93.7
4,500	93.1	92.5	92.0	93.8	93.4	92.8	94.7	94.1	93.6
3,000	92.4	92.1	91.7	93.2	92.9	92.6	94.1	93.8	93.3
1,500	91.7	91.6	91.4	92.6	92.4	92.4	93.5	93.3	93.3
600	91.2	91.3	91.2	92.2	92.2	92.2	93.2	93.1	93.0
Surface	91.0	91.0	91.0	92.0	92.0	92.0	93.0	93.0	93.0
30,000	99.2	96.9	94.4	99.5	97.2	94.7	99.8	97.4	94.9
24,000	99.0	97.0	94.8	99.3	97.4	95.2	99.6	97.7	95.6
18,000	98.5	96.7	94.9	99.0	97.2	95.3	99.3	97.6	95.8
15,000	98.0	96.4	94.9	98.5	96.9	95.4	99.0	97.4	95.8
12,000	97.6	96.2	94.8	98.1	96.8	95.4	98.6	97.2	95.9
9,000	96.9	95.7	94.6	97.5	96.4	95.3	98.0	97.0	95.9
6,000	96.0	95.2	94.5	96.7	95.9	95.2	97.5	96.6	95.9
4,500	95.5	94.9	94.4	96.3	95.7	95.1	97.2	96.5	95.9
3,000	95.0	94.6	94.3	95.8	95.5	95.1	96.6	96.3	96.0
1,500	94.5	94.3	94.5	95.4	95.2	95.1	96.4	96.2	96.0
600	94.2	94.1	94.1	95.1	95.1	95.0	96.2	96.0	96.0
Surface	94.0	94.0	94.0	95.0	95.0	95.0	96.0	96.0	96.0
30,000	100.0	97.6	95.2	100.3	97.9	95.4	100.6	98.1	95.7
24,000	100.0	98.0	95.9	100.6	98.3	96.2	100.8	98.7	96.6
18,000	99.7	98.0	96.2	100.2	98.4	96.5	100.6	98.8	97.0
15,000	99.5	98.0	96.3	100.0	98.4	96.7	100.5	98.9	97.3
12,000	99.2	97.8	96.4	99.8	98.3	96.8	100.4	98.8	97.5
9,000	98.8	97.6	96.5	99.4	98.2	97.0	100.1	98.8	97.7
6,000	98.2	97.4	96.6	99.0	98.1	97.2	99.7	98.8	98.0
4,500	98.0	97.4	96.7	99.0	98.1	97.3	99.6	98.8	98.2
3,000	97.6	97.2	96.8	98.5	98.0	97.5	99.4	98.8	98.4
1,500	97.3	97.2	96.9	98.3	98.0	97.8	99.2	98.9	98.7
600	97.1	97.1	96.9	98.1	98.0	97.8	99.1	98.8	98.9
Surface	97.0	97.0	97.0	98.0	98.0	98.0	99.0	99.0	99.0
30,000	100.9	98.4	96.0	101.2	98.7	96.2	101.4	99.0	96.4
24,000	101.1	99.1	97.0	101.6	99.4	97.3	101.8	99.8	97.7
18,000	101.1	99.3	97.4	101.6	99.6	97.8	102.0	100.1	98.3
15,000	101.0	99.4	97.7	101.3	99.8	98.2	102.0	100.4	98.7
12,000	100.9	99.4	98.2	101.4	99.9	98.5	102.0	100.5	99.1
9,000	100.7	99.4	98.3	101.2	100.1	98.9	102.0	100.8	99.5
6,000	100.5	99.5	98.7	101.2	100.3	99.5	102.0	100.9	100.1
4,500	100.4	99.6	99.0	101.1	100.4	99.7	102.0	101.2	100.5
3,000	100.3	99.7	99.2	101.0	100.6	100.0	172.0	101.5	101.0
1,500	100.1	99.9	99.6	101.0	100.8	100.5	102.0	101.8	101.4
600	100.1	99.8	99.9	101.0	100.9	100.8	102.1	101.9	101.8
Surface	100.0	100.0	100.0	101.0	101.0	101.0	102.0	102.0	102.0
30,000	101.7	99.2	96.8	101.9	99.4	96.9	102.2	99.7	97.1
24,000	102.2	100.2	98.0	102.5	100.4	98.4	102.9	100.8	98.6
18,000	102.4	100.6	98.8	102.8	101.0	99.2	103.2	101.4	99.5
15,000	102.5	100.8	99.2	103.0	101.4	99.7	103.4	101.8	100.1
12,000	102.6	101.1	99.7	103.1	101.6	100.2	103.6	102.1	100.7
9,000	102.6	101.4	100.3	103.3	102.0	100.8	103.9	102.5	101.4
6,000	102.7	101.7	100.8	103.5	102.5	101.6	104.2	103.1	102.2
4,500	102.8	102.0	101.3	103.6	102.8	102.1	104.4	103.5	102.8
3,000	102.9	102.2	101.9	103.7	103.1	102.7	104.7	104.0	103.4
1,500	103.0	102.7	102.4	103.9	103.5	103.3	104.9	104.6	104.1
600	103.0	102.9	102.8	103.9	103.8	103.7	105.0	104.9	104.6
Surface	103.0	103.0	103.0	104.0	104.0	104.0	105.0	105.0	105.0

TABLE IV.—*Ballistic density, in percentage of standard used by the artillery, for various maximum ordinates. The arguments are the corrected surface density and the altitude of the meteorological station above sea level*—Continued

Maximum ordinate	Station elevation, in feet, above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
	Ballistic density in percentage of standard								
30,000	102.5	100.0	97.4	102.8	100.2	97.5	103.1	100.4	97.8
24,000	103.3	101.1	99.0	103.7	101.4	99.3	104.0	101.9	99.6
18,000	103.7	101.8	100.0	104.1	102.2	100.4	104.6	102.8	100.8
15,000	104.0	102.2	100.6	104.4	102.8	101.1	105.0	103.3	101.6
12,000	104.2	102.7	101.2	104.8	103.2	101.8	105.4	103.9	102.3
9,000	104.5	103.2	102.0	105.2	103.8	102.6	105.9	104.6	103.2
6,000	104.9	103.9	103.0	105.7	104.6	103.7	106.5	105.5	104.4
4,500	105.2	104.3	103.6	106.0	105.1	104.6	106.9	106.1	105.2
3,000	105.5	104.7	104.4	106.4	105.6	105.2	107.3	106.6	106.0
1,500	105.8	105.5	105.2	106.7	106.3	106.1	107.7	107.4	106.9
600	105.9	105.8	105.7	106.9	106.7	106.7	107.9	107.8	107.6
Surface	106.0	106.0	106.0	107.0	107.0	107.0	108.0	108.0	108.0
30,000	103.3	100.7	98.1	103.6	101.0	98.3	103.9	101.2	98.5
24,000	104.3	102.2	99.9	104.6	102.5	100.3	104.9	102.8	100.6
18,000	105.0	103.1	101.2	105.4	103.6	101.6	105.8	104.0	102.0
15,000	105.4	103.7	102.0	106.0	104.2	102.5	106.4	104.6	103.0
12,000	105.9	104.4	102.8	106.4	104.9	103.3	107.0	105.4	103.8
9,000	106.4	105.1	103.8	107.1	105.8	104.4	107.7	106.4	105.0
6,000	107.1	106.1	105.1	107.9	106.9	105.8	108.7	107.6	106.5
4,500	107.6	106.8	105.9	108.5	107.6	106.6	109.3	108.4	107.5
3,000	108.1	107.5	106.8	109.0	108.4	107.7	109.9	109.2	108.5
1,500	108.5	108.3	107.8	109.6	109.3	108.8	110.5	110.2	109.6
600	108.8	108.8	108.5	109.9	109.8	109.6	110.8	110.8	110.4
Surface	109.0	109.9	109.9	110.0	110.0	110.0	111.0	111.0	111.0
30,000	104.1	101.5	98.8	104.4	101.8	--------	104.7	102.0	--------
24,000	105.4	103.2	100.9	105.7	103.5	--------	106.2	103.7	--------
18,000	106.3	104.4	102.5	106.8	104.8	--------	107.3	105.3	--------
15,000	106.9	105.2	103.5	107.4	105.7	--------	108.0	106.2	--------
12,000	107.5	106.0	104.4	108.1	106.5	--------	108.7	107.0	--------
9,000	108.4	107.1	105.6	109.1	107.7	--------	109.7	108.2	--------
6,000	109.4	108.3	107.3	110.2	109.0	--------	111.0	109.7	--------
4,500	110.0	109.2	108.2	110.9	110.0	--------	111.8	110.6	--------
3,000	110.8	110.1	109.4	111.7	110.8	--------	112.6	111.6	--------
1,500	111.4	111.1	110.6	112.4	112.0	--------	113.4	112.8	--------
600	111.8	111.7	111.5	112.7	112.8	--------	113.8	113.7	--------
Surface	112.0	112.0	112.0	113.0	113.0	--------	114.0	114.0	--------
30,000	105.0	102.2	--------	105.2	102.4	--------	105.4	102.7	--------
24,000	106.5	104.2	--------	106.8	104.5	--------	107.1	104.9	--------
18,000	107.7	105.7	--------	108.2	106.1	--------	108.5	106.6	--------
15,000	108.4	106.6	--------	109.0	107.1	--------	109.4	107.6	--------
12,000	109.2	107.5	--------	109.8	108.1	--------	110.3	108.6	--------
9,000	110.3	108.8	--------	111.0	109.4	--------	111.7	110.2	--------
6,000	111.7	110.4	--------	112.5	111.1	--------	113.2	111.9	--------
4,500	112.5	111.4	--------	113.3	112.2	--------	114.1	113.1	--------
3,000	113.4	112.5	--------	114.3	113.4	--------	115.1	114.3	--------
1,500	114.3	113.8	--------	115.0	114.7	--------	116.1	115.7	--------
600	114.7	114.7	--------	115.7	115.7	--------	116.6	116.7	--------
Surface	115.0	115.0	--------	116.0	116.0	--------	117.0	117.0	--------

TABLE IV.—*Ballistic density, in percentage of standard used by the artillery, for various maximum ordinates. The arguments are the corrected surface density and the altitude of the meteorological station above sea level*—Continued

Maximum ordinate	Station elevation in feet above sea level		
	0	0	0
	Ballistic density in percentage of standard		
30,000	105.8	106.1	106.4
24,000	107.5	107.9	108.2
18,000	109.0	109.5	109.8
15,000	109.8	110.4	110.9
12,000	110.9	111.5	112.0
9,000	112.3	112.9	113.6
6,000	113.9	114.7	115.4
4,500	115.0	115.8	116.5
3,000	116.1	116.9	117.8
1,500	117.1	118.0	119.0
600	117.7	118.6	119.6
Surface	118.0	119.0	120.0
30,000	106.6	106.8	107.1
24,000	108.6	108.9	109.3
18,000	110.4	110.8	111.2
15,000	111.4	111.9	112.4
12,000	112.6	113.2	113.7
9,000	114.3	114.9	115.6
6,000	116.3	116.9	117.7
4,500	117.3	118.1	119.0
3,000	118.7	119.5	120.5
1,500	119.9	120.8	121.8
600	120.6	121.5	122.6
Surface	121.0	122.0	123.0

To compute ballistic air density from upper air observations it is first necessary to determine the actual density at certain levels above the meteorological station, namely, 300 feet, 1,050 feet, 2,250 feet, 3,750 feet, etc., up to the highest altitude for which ballistic density is desired. The actual density at the levels named may be taken as the mean density for the zones, 0–600 feet, 600–1,050 feet, 1,500–3,000 feet, 3,000–4,500 feet, etc., respectively. If observations have been made of the temperature, barometric pressure, and vapor pressure at the levels specified the air density may be computed with the following formula:

$$D=\frac{b-.378e}{459+t}\times 21218$$

Where D is air density in grams per cubic meter.
b is station barometer reading in inches.
e is vapor pressure in inches of mercury.
t is temperature on Fahrenheit scale.

After the actual air density has been computed for each of the levels named, these densities must each be reduced to the percentage of standard density for the level at which each particular density was observed. This is done by dividing the observed density at a par-

TABLE II—Continued

RATE OF ASCENT IN YARDS PER MINUTE OF PILOT BALLOONS OF VARIOUS WEIGHTS AND FREE LIFTS—Continued

Free lift, in ounces	Free lift, in grams	Weight of balloon, in ounces									
		0.78	0.85	0.92	0.99	1.06	1.13	1.20	1.27	1.34	1.41
		Weight of balloon, in grams									
		22	24	26	28	30	32	34	36	38	40
		Yards	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*
7.23	205	228.8	227.9	227.0	226.3	225.5	224.6	223.9	223.1	222.3	221.6
7.41	210	--------	229.3	228.5	227.7	226.9	226.2	225.3	224.5	223.9	223.1
7.58	215	--------	--------	229.9	229.1	228.2	227.5	226.7	226.0	225.3	224.5
7.76	220	--------	--------	--------	230.4	229.7	228.9	228.1	227.4	226.7	225.9
7.94	225	--------	--------	--------	--------	231.0	230.2	229.4	228.8	228.0	227.4
8.11	230	--------	--------	--------	--------	232.3	231.5	230.9	230.1	229.3	228.7
8.29	235	--------	--------	--------	--------	233.6	232.8	232.1	231.4	230.6	230.0
8.47	240	--------	--------	--------	--------	234.8	234.1	233.4	232.7	232.0	231.3
8.64	245	--------	--------	--------	--------	236.1	235.3	234.7	233.9	233.3	232.6
8.82	250	--------	--------	--------	--------	237.3	236.5	235.9	235.2	234.5	233.8
8.99	255	--------	--------	--------	--------	238.5	237.8	237.1	236.4	235.8	235.0
9.17	260	--------	--------	--------	--------	239.6	239.0	238.3	237.6	236.9	236.2
9.35	265	--------	--------	--------	--------	240.8	240.1	239.4	238.7	238.1	237.4
9.52	270	--------	--------	--------	--------	241.9	241.3	240.6	239.9	239.3	238.6
9.70	275	--------	--------	--------	--------	243.0	242.3	241.7	241.0	240.4	239.8
9.88	280	--------	--------	--------	--------	244.1	243.4	242.8	242.1	241.6	240.9
10.05	285	--------	--------	--------	--------	245.2	244.5	243.9	243.2	242.7	242.0
10.23	290	--------	--------	--------	--------	246.3	245.6	245.0	244.3	243.8	243.1
10.41	295	--------	--------	--------	--------	247.3	246.6	246.1	245.2	244.8	244.2
10.58	300	--------	--------	--------	--------	248.4	247.7	247.0	246.5	245.8	245.3
10.93	310	--------	--------	--------	--------	250.3	249.7	249.1	248.5	247.9	247.4
11.29	320	--------	--------	--------	--------	252.3	251.6	251.1	250.5	249.9	249.3
11.64	330	--------	--------	--------	--------	254.2	253.6	253.1	252.4	251.9	251.3
11.99	340	--------	--------	--------	--------	256.0	255.5	254.9	254.3	253.7	253.2
12.35	350	--------	--------	--------	--------	257.9	257.2	256.7	256.1	255.6	255.0

TABLE II—Continued

RATE OF ASCENT IN YARDS PER MINUTE OF PILOT BALLOONS OF VARIOUS WEIGHTS AND FREE LIFTS—Continued

Free lift, in ounces	Free lift, in grams	Weight of balloon, in ounces									
		1.48	1.55	1.62	1.69	1.76	1.83	1.90	1.98	2.05	2.12
		Weight of balloon, in grams									
		42	44	46	48	50	52	54	56	58	60
		Yards	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*
7.23	205	220.8	220.1	219.4	218.6	218.0	217.2	216.5	215.9	215.1	214.5
7.41	210	222.3	221.6	220.9	220.1	219.5	218.7	218.1	217.4	216.8	216.0
7.58	215	223.8	223.1	222.3	221.1	220.9	220.3	219.6	218.9	218.2	217.5
7.76	220	225.2	224.5	223.8	223.1	222.4	221.7	221.0	220.4	219.7	219.1
7.94	225	226.6	225.9	225.2	224.5	223.9	223.2	222.4	221.8	221.1	220.5
8.11	230	227.9	227.3	226.6	225.9	225.2	224.5	223.9	223.2	222.5	222.0
8.29	235	229.3	228.6	227.9	227.3	226.6	225.9	225.3	224.6	224.0	223.3
8.47	240	230.6	230.0	229.2	228.6	227.9	227.3	226.6	226.0	225.4	224.7
8.64	245	231.8	231.2	230.5	229.9	229.2	228.6	228.0	227.4	226.7	226.0
8.82	250	233.2	232.5	231.8	231.2	230.5	229.9	229.3	228.7	228.0	227.5
8.99	255	234.4	233.7	233.0	232.5	231.8	231.2	230.5	230.0	229.3	225.7
9.17	260	235.6	235.0	234.4	233.7	233.0	232.4	231.8	231.2	230.6	230.0
9.35	265	236.9	236.2	235.6	234.9	234.3	233.7	233.0	232.5	231.8	231.2
9.52	270	238.0	237.3	236.8	236.1	235.5	234.9	234.3	233.7	233.0	232.5
9.70	275	239.2	238.5	237.9	237.3	236.7	236.1	235.5	234.9	234.3	233.7
9.88	280	240.3	239.6	239.1	238.4	237.9	237.2	236.7	236.1	235.5	234.9
10.05	285	241.4	240.8	240.2	239.6	239.0	238.4	237.8	237.2	236.7	236.1
10.23	290	242.5	241.9	241.3	240.7	240.2	239.5	239.0	238.4	237.8	237.2
10.41	295	243.5	243.0	242.3	241.8	241.3	240.6	240.0	239.5	239.0	238.4
10.58	300	244.6	244.1	243.4	242.9	242.3	241.7	241.1	240.6	240.0	239.5
10.93	310	246.7	246.2	245.6	245.0	244.4	243.9	243.3	242.8	242.2	241.7
11.29	320	248.8	248.1	247.6	247.0	246.5	246.0	245.4	244.9	244.3	243.8
11.64	330	250.8	250.2	249.6	249.0	248.5	247.9	247.5	246.9	246.4	245.8
11.99	340	252.6	252.1	251.5	251.0	250.4	249.9	249.5	248.9	248.4	247.8
12.35	350	254.5	253.9	253.4	253.0	252.4	251.9	251.3	250.9	250.3	249.8
12.70	360	256.3	255.8	255.2	254.7	254.3	253.7	253.2	252.7	252.2	251.6
13.06	370	258.1	257.5	257.1	256.6	256.0	255.6	255.0	254.5	254.0	255.5
13.41	380	259.9	259.3	258.7	258.3	257.8	257.3	256.8	256.3	255.8	255.4
13.76	390	261.5	261.0	260.5	260.1	259.5	259.1	258.5	258.1	257.5	257.1
14.11	400	263.1	262.7	262.1	261.7	261.1	260.7	260.3	259.7	259.3	258.9

TABLE II—Continued

RATE OF ASCENT IN YARDS PER MINUTE OF PILOT BALLOONS OF VARIOUS WEIGHTS AND FREE LIFTS—Continued

Free lift, in ounces	Free lift, in grams	Weight of balloon, in ounces									
		2.19	2.26	2.33	2.40	2.47	2.54	2.61	2.68	2.75	2.82
		Weight of balloon, in grams									
		62	64	66	68	70	72	74	76	78	80
		Yards	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*	*Yards*
7.23	205	213.8	213.1	212.5	211.8	211.2	210.5	209.9	209.3	208.7	208.0
7.41	210	215.3	214.7	214.0	213.4	212.3	212.2	211.5	211.0	210.3	209.6
7.58	215	216.9	216.2	215.7	215.0	211.3	213.7	213.1	212.5	211.9	211.3
7.76	220	218.4	217.7	217.1	216.5	215.9	215.2	214.7	214.0	213.5	212.8
7.94	225	219.9	219.3	218.6	218.0	217.4	216.8	216.2	215.6	215.0	214.3
8.11	230	221.3	220.7	220.0	219.5	218.8	218.3	217.6	217.1	216.4	215.9
8.29	235	222.8	222.1	221.5	220.9	220.3	219.7	219.1	218.5	218.0	217.3
8.47	240	224.1	223.5	222.9	222.3	221.7	221.1	220.5	219.9	219.4	218.8
8.64	245	225.5	224.8	224.3	223.6	223.1	222.4	221.9	221.3	220.8	220.1
8.82	250	226.8	226.2	225.6	225.1	224.4	223.9	223.3	222.7	222.1	221.6
8.99	225	228.1	227.6	226.9	226.4	225.7	225.2	224.6	224.1	223.5	223.0
9.17	260	229.4	228.8	228.2	227.7	227.0	226.5	225.9	225.4	225.0	224.3
9.35	265	230.6	230.1	229.5	228.9	228.3	227.8	227.3	226.7	226.2	225.6
9.52	270	232.0	231.3	230.8	230.2	229.7	229.1	228.5	227.9	227.4	226.8
9.70	275	233.2	232.5	232.0	231.4	230.9	230.3	229.8	229.2	228.7	228.1
9.88	280	234.4	233.6	233.2	232.6	232.1	231.5	231.0	230.4	229.9	229.3
10.05	285	235.5	234.9	234.4	233.8	233.3	232.7	232.2	231.6	231.1	230.6
10.23	290	236.7	236.1	235.6	235.0	234.5	233.9	233.4	232.8	232.3	231.8
10.41	295	237.8	237.2	236.7	236.1	235.6	235.1	234.6	234.0	233.5	232.9
10.58	300	239.0	238.4	237.9	237.3	236.8	236.2	235.7	235.1	234.7	234.1
10.93	310	241.1	240.6	240.0	239.5	239.0	238.5	238.0	237.4	236.9	236.4
11.29	320	243.2	242.7	242.2	241.7	241.1	240.6	240.2	239.6	239.2	238.6
11.64	330	245.3	244.8	244.3	243.8	243.2	242.8	242.2	241.8	241.3	240.8
11.99	340	247.4	246.8	246.3	245.8	245.3	244.9	244.3	243.9	243.3	242.9
12.35	350	249.2	248.8	248.2	247.8	247.3	246.8	246.3	245.8	245.4	244.9
12.70	360	251.2	250.7	250.2	249.7	249.2	248.8	248.2	247.8	247.4	246.8
13.05	370	253.1	252.5	252.1	251.6	251.1	250.7	250.2	249.7	249.2	248.8
13.41	380	254.8	254.4	253.9	253.4	253.0	252.3	252.1	251.5	251.1	250.7
13.76	390	256.7	256.1	255.7	255.2	254.7	254.3	253.8	253.4	253.0	252.5
14.10	400	258.3	257.9	257.[illegible]	257.0	256.6	256.0	255.6	255.1	254.7	254.3

TABLE III.—*For determining air density in percentage of standard*

[Standard air density at battery, 1,203.4 grams per cu. m.; temperature, 59° F.; pressure, 29.528 inches; relative humidity, 78 per cent. Relative humidity of 78 per cent for all pressures and temperatures. To obtain corrections to be applied to results obtained from this table, when relative humidity is other than 78 per cent, see Table IIIa]

Pressure	Temperature										
	−20°	−16°	−12°	−8°	−4°	0°	4°	8°	12°	16°	20°
	Air density in percentage of standard										
27.00	108.3	107.4	106.5	105.5	104.6	103.7	102.8	102.0	101.1	100.2	99.3
27.10	107.8	107.8	106.9	105.9	105.0	104.1	103.2	102.3	101.4	100.6	99.7
27.20	109.2	108.2	107.3	106.3	105.4	104.5	103.6	102.7	101.8	100.9	100.0
27.30	109.6	108.6	107.7	106.7	105.8	104.9	104.0	103.1	102.2	101.3	100.4
27.40	110.0	109.0	108.1	107.1	106.2	105.3	104.4	103.5	102.5	101.7	100.8
27.50	110.4	109.4	108.5	107.5	106.6	105.6	104.7	103.8	102.9	102.0	101.2
27.60	110.8	109.8	108.9	107.9	107.0	106.0	105.1	104.2	103.3	102.4	101.5
27.70	111.2	110.2	109.2	108.3	107.3	106.4	105.5	104.6	103.7	102.8	101.9
27.80	111.6	110.6	109.6	108.7	107.7	106.8	105.9	105.0	104.1	103.1	102.3
27.90	112.0	111.0	110.0	109.1	108.1	107.2	106.3	105.4	104.4	103.5	102.6
28.00	112.4	111.4	110.4	109.5	108.5	107.6	106.7	105.7	104.8	103.9	103.0
28.10	112.8	111.8	110.8	109.8	108.9	108.0	107.0	106.1	105.2	104.3	103.4
28.20	113.2	112.2	111.2	110.2	109.3	108.4	107.4	106.5	105.6	104.6	103.7
28.30	113.6	112.6	111.6	110.6	109.6	108.7	107.8	106.8	105.9	105.0	104.1
28.40	114.0	113.0	112.0	111.0	110.0	109.1	108.2	107.2	106.3	105.4	104.4
28.50	114.4	113.4	112.4	111.4	110.4	109.5	108.6	107.6	106.7	105.8	104.9
28.60	114.8	113.8	112.8	111.8	110.8	109.9	108.9	108.0	107.0	106.1	105.2
28.70	115.2	114.2	113.2	112.2	111.2	110.3	109.3	108.4	107.4	106.5	105.6
28.80	115.6	114.6	113.6	112.6	111.6	110.6	109.7	108.8	107.8	106.9	106.0
28.90	116.0	115.0	114.0	113.0	112.0	111.0	110.1	109.1	108.2	107.3	106.4
29.00	116.4	115.4	114.4	113.4	112.4	111.4	110.5	109.5	108.6	107.6	106.7
29.10	116.8	115.8	114.8	113.8	112.8	111.8	110.9	109.9	109.0	108.0	107.1
29.20	117.2	116.2	115.2	114.1	113.2	112.2	111.2	110.3	109.3	108.4	107.4
29.30	117.6	116.6	115.6	114.5	113.6	112.6	111.6	110.7	109.7	108.7	107.8
29.40	118.0	117.0	116.0	114.9	113.9	113.0	112.0	111.0	110.1	109.1	108.2
29.50	118.4	117.4	116.4	115.3	114.3	113.4	112.4	111.4	110.4	109.5	108.5
29.60	118.8	117.8	116.7	115.7	114.7	113.7	112.8	111.8	110.8	109.9	108.9
29.70	119.2	118.2	117.1	116.1	115.1	114.1	113.1	112.1	111.2	110.2	109.3
29.80	119.6	118.6	117.5	116.5	115.5	114.5	113.5	112.5	111.6	110.6	109.6
29.90	120.0	119.0	117.9	116.9	115.9	114.9	113.9	112.9	112.0	111.0	110.0
30.00	120.4	119.4	118.3	117.3	116.2	115.3	114.3	113.3	112.3	111.4	110.4
30.10	120.8	119.8	118.7	117.6	116.6	115.6	114.6	113.7	112.7	111.7	110.7
30.20	121.2	120.2	119.1	118.0	117.0	116.0	115.0	114.0	113.0	112.1	111.1
30.30	121.6	120.6	119.5	118.4	117.4	116.4	115.4	114.4	113.4	112.5	111.4
30.40	122.0	121.0	119.9	118.8	117.8	116.8	115.8	114.8	113.8	112.8	111.8
30.50	122.4	121.4	120.3	119.2	118.2	117.2	116.2	115.2	114.2	113.2	112.2
30.60	122.8	121.8	120.7	119.6	118.6	117.5	116.5	115.5	114.5	113.5	112.6
30.70	123.2	122.2	121.0	120.0	119.0	117.9	116.9	115.9	114.9	113.9	112.9
30.80	123.6	122.6	121.4	120.4	119.3	118.3	117.3	116.3	115.3	114.3	113.3
30.90	124.0	123.0	121.8	120.7	119.7	118.7	117.7	116.7	115.6	114.6	113.6
31.00	124.4	123.4	122.2	121.1	120.1	119.1	118.0	117.0	116.0	115.0	114.0

TABLE III.—*For determining air density in percentage of standard*—Continued

Pressure	Temperature										
	20°	24°	28°	32°	36°	40°	44°	48°	52°	56°	60°
	Air density in percentage of standard										
27.00	99.3	98.5	97.6	96.8	96.0	95.2	94.4	93.6	92.8	92.0	91.2
27.10	99.7	98.9	98.0	97.2	96.4	95.6	94.8	94.0	93.1	92.3	91.6
27.20	100.0	99.2	98.4	97.5	96.7	95.9	95.1	94.3	93.5	92.7	91.9
27.30	100.4	99.6	98.7	97.9	97.1	96.3	95.5	94.7	93.8	93.0	92.2
27.40	100.8	100.0	99.1	98.2	97.4	96.6	95.8	95.0	94.2	93.4	92.6
27.50	101.2	100.3	99.4	98.6	97.8	96.9	96.1	95.3	94.5	93.7	92.9
27.60	101.5	100.7	99.8	99.0	98.2	97.3	96.5	95.7	94.9	94.1	93.3
27.70	101.9	101.0	100.2	99.3	98.5	97.7	96.9	96.0	95.2	94.4	93.6
27.80	102.3	101.4	100.5	99.7	98.9	98.0	97.2	96.4	95.6	94.8	93.9
27.90	102.6	101.8	100.9	100.0	99.2	98.4	97.6	96.7	95.9	95.1	94.3
28.00	103.0	102.2	101.3	100.4	99.6	98.7	97.9	97.1	96.3	95.4	94.6
28.10	103.4	102.5	101.6	100.7	99.9	99.1	98.3	97.4	96.6	95.8	95.0
28.20	103.7	102.9	102.0	101.1	100.3	99.4	98.6	97.8	97.0	96.1	95.3
28.30	104.1	103.3	102.4	101.5	100.7	99.8	99.0	98.1	97.3	96.5	95.7
28.40	104.4	103.6	102.7	101.8	101.0	100.1	99.3	98.5	97.6	96.8	96.0
28.50	104.9	104.0	103.1	102.2	101.4	100.5	99.7	98.8	98.0	97.1	96.3
28.60	105.2	104.3	103.4	102.5	101.7	100.8	100.0	99.2	98.3	97.5	96.7
28.70	105.6	104.7	103.8	102.9	102.1	101.2	100.3	99.5	98.7	97.8	97.0
28.80	106.0	105.1	104.2	103.3	102.4	101.6	100.7	99.9	99.0	98.2	97.4
28.90	106.4	105.5	104.5	103.6	102.8	101.9	101.1	100.2	99.4	98.5	97.7
29.00	106.7	105.8	104.9	104.0	103.2	102.3	101.4	100.6	99.7	98.9	98.1
29.10	107.1	106.2	105.2	104.3	103.5	102.6	101.8	100.9	100.1	99.2	98.4
29.20	107.4	106.6	105.6	104.7	103.9	103.0	102.1	101.3	100.4	99.5	98.7
29.30	107.8	106.9	106.0	105.1	104.2	103.3	102.5	101.6	100.8	99.9	99.1
29.40	108.2	107.3	106.3	105.4	104.6	103.7	102.8	102.0	101.1	100.2	99.4
29.50	108.5	107.6	106.7	105.8	104.9	104.0	103.2	102.3	101.4	100.6	99.7
29.60	108.9	108.0	107.0	106.2	105.3	104.4	103.5	102.6	101.8	100.9	100.1
29.70	109.3	108.4	107.4	106.5	105.6	104.7	103.9	103.0	102.1	101.2	100.4
29.80	109.6	108.7	107.8	106.9	106.0	105.1	104.2	103.3	102.5	101.6	100.8
29.90	110.0	109.1	108.2	107.3	106.4	105.5	104.6	103.7	102.8	102.0	101.1
30.00	110.4	109.5	108.5	107.6	106.7	105.8	104.9	104.0	103.2	102.3	101.4
30.10	110.7	109.8	108.8	107.9	107.1	106.2	105.3	104.4	103.5	102.6	101.8
30.20	111.1	110.2	109.2	108.3	107.4	106.5	105.6	104.7	103.8	103.0	102.1
30.30	111.4	110.6	109.6	108.7	107.8	106.9	106.0	105.1	104.2	103.3	102.4
30.40	111.8	110.9	109.9	109.0	108.1	107.2	106.3	105.4	104.5	103.6	102.8
30.50	112.2	111.3	110.3	109.4	108.5	107.6	106.6	105.7	104.8	104.0	103.1
30.60	112.6	111.6	110.6	109.7	108.8	107.9	107.0	106.1	105.2	104.3	103.4
30.70	112.9	112.0	111.0	110.1	109.2	108.2	107.3	106.4	105.5	104.6	103.8
30.80	113.3	112.4	111.4	110.4	109.5	108.6	107.7	106.8	105.9	105.0	104.1
30.90	113.6	112.7	111.7	110.8	109.9	108.9	108.0	107.1	106.2	105.3	104.4
31.00	114.0	113.1	112.1	111.2	110.2	109.3	108.4	107.5	106.6	105.7	104.8

TABLE III.—*For determining air density in percentage of standard*—Continued

Pressure	Temperature 60°	64°	68°	72°	76°	80°	84°	88°	92°	96°	100°
	Air density in percentage of standard										
27.00	91.2	90.5	89.7	88.9	88.1	87.3	86.5	85.7	84.9	84.1	83.3
27.10	91.6	80.9	90.0	89.2	88.4	87.6	86.8	86.0	85.2	84.4	83.6
27.20	91.9	91.1	90.3	89.6	88.8	87.9	87.1	86.3	85.5	84.7	83.9
27.30	92.2	91.5	90.7	89.9	89.1	88.3	87.5	86.7	85.9	85.1	84.2
27.40	92.6	91.8	91.0	90.2	89.4	88.6	87.8	87.0	86.2	85.4	84.5
27.50	92.9	92.1	91.3	90.6	89.8	88.9	88.1	87.3	86.5	85.7	84.9
27.60	93.3	92.5	91.7	90.9	90.1	89.3	88.5	87.7	86.8	86.0	85.2
27.70	93.6	92.8	92.0	91.2	90.4	89.6	88.8	88.0	87.2	86.3	85.5
27.80	93.9	93.1	92.3	91.5	90.7	89.9	89.1	88.3	87.5	86.7	85.8
27.90	94.3	93.5	92.7	91.9	91.1	90.3	89.5	88.6	87.8	87.0	86.1
28.00	94.6	93.8	93.0	92.2	91.4	90.6	89.8	89.0	88.1	87.3	86.4
28.10	95.0	94.2	93.3	92.5	91.7	90.9	90.1	89.3	88.4	87.6	86.7
28.20	95.3	94.5	93.7	92.9	92.1	91.2	90.4	89.6	88.8	87.9	87.1
28.30	95.7	94.9	94.0	93.2	92.4	91.6	90.8	89.9	89.1	88.3	87.4
28.40	96.0	95.2	94.4	93.6	92.7	91.9	91.1	90.3	89.4	88.6	87.7
28.50	96.3	95.5	94.7	93.9	93.1	92.2	91.4	90.6	89.7	88.9	88.0
28.60	96.7	95.9	95.0	94.2	93.4	92.6	91.8	90.9	90.1	89.2	88.3
28.70	97.0	96.2	95.4	94.6	93.7	92.9	92.1	91.2	90.4	89.5	88.6
28.80	97.4	96.5	95.7	94.9	94.1	93.2	92.4	91.5	90.7	89.9	89.0
28.90	97.7	96.9	96.1	95.2	94.4	93.5	92.7	91.9	91.0	90.2	89.3
29.00	98.1	97.2	96.4	95.6	94.7	93.9	93.1	92.2	91.4	90.5	89.6
29.10	98.4	97.6	96.7	95.9	95.1	94.2	93.4	92.5	91.7	90.8	90.0
29.20	98.7	97.9	97.0	96.2	95.4	94.5	93.7	92.9	92.0	91.1	90.3
29.30	99.1	98.2	97.4	96.6	95.7	94.8	94.0	93.2	92.3	91.5	90.6
29.40	99.4	98.6	97.7	96.9	96.1	95.2	94.4	93.5	92.6	91.8	90.9
29.50	99.7	98.9	98.1	97.2	96.4	95.5	94.7	93.8	92.9	92.1	91.2
29.60	100.1	99.2	98.4	97.6	96.7	95.8	95.0	94.1	93.3	92.4	91.5
29.70	100.4	99.6	98.7	97.9	97.0	96.2	95.3	94.5	93.6	92.7	91.8
29.80	100.8	99.9	99.0	98.2	97.4	96.5	95.7	94.8	93.9	93.0	92.2
29.90	101.1	100.3	99.4	98.6	97.7	96.8	96.0	95.1	94.3	93.4	92.5
30.00	101.4	100.6	99.7	98.9	98.0	97.1	96.3	95.5	94.6	93.7	92.8
30.10	101,8	100.9	100.0	99.2	98.4	97.5	96.7	95.8	94.9	94.0	93.1
30.20	102.1	101.3	100.4	99.6	98.7	97.8	97.0	96.1	95.2	94.3	93.4
30.30	102.4	101.6	100.7	99.9	99.0	98.1	97.3	96.4	95.5	94.6	93.7
30.40	102.8	101.9	101.1	100.2	99.3	98.4	97.6	96.7	95.8	94.9	94.0
30.50	103.1	102.3	101.4	100.5	99.7	98.8	97.9	97.0	96.2	95.3	94.3
30.60	103.4	102.6	101.7	100.9	100.0	99.1	98.3	97.4	96.5	95.6	94.6
30.70	103.8	102.9	102.0	101.2	100.3	99.4	98.6	97.7	96.8	95.9	94.9
30.80	104.1	103.3	102.4	101.5	100.6	99.7	98.9	98.0	97.1	96.2	95.3
30.90	104.4	103.6	102.7	101.9	101.0	100.1	99.2	98.3	97.4	96.5	95.6
31.00	104.8	103.9	103.0	102.2	101.3	100.4	99.5	98.6	97.7	96.8	95.9

TABLE IIIA.—*Corrections to be applied to results obtained from Table III when relative humidity is other than 78 per cent*

Relative humidity	Temperature						
	−20°	0°	20°	40°	60°	80°	100°
	Correction in percentage of standard density						
0	0	0	+0.1	+0.3	+0.5	+1.0	+1.8
10	0	0	+ .1	+ .2	+ .4	+ .9	+1.6
20	0	0	+ .1	+ .2	+ .4	+ .7	+1.3
30	0	0	+ .1	+ .2	+ .3	+ .6	+1.1
40	0	0	0	+ .1	+ .2	+ .5	+ .9
50	0	0	0	+ .1	+ .2	+ .3	+ .6
60	0	0	0	+ .1	+ .1	+ .2	+ .4
70	0	0	0	0		+ .1	+ .2
80	0	0	0	0	0	0	0
90	0	0	0	0	− .1	− .2	− .3
100	0	0	0	0	− .2	− .3	− .5

TABLE IV.—*Ballistic density, in percentage of standard used by the artillery, for various maximum ordinates. The arguments are the corrected surface density and the altitude of the meteorological station above sea level*

Maximum ordinate	Station elevation, in feet, above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
	Ballistic density in percentage of standard								
30,000	-------	-------	91.6	-------	94.1	91.6	96.5	94.4	92.2
24,000	-------	-------	90.8	-------	93.2	91.2	95.5	93.5	91.5
18,000	-------	-------	89.7	-------	91.9	90.4	94.0	92.3	90.7
15,000	-------	-------	89.1	-------	91.1	89.6	93.1	91.6	90.1
12,000	-------	-------	88.4	-------	90.2	88.9	92.0	90.7	89.4
9,000	-------	-------	87.2	-------	89.2	87.9	90.4	89.6	88.5
6,000	-------	-------	85.8	-------	87.2	86.6	88.6	87.9	87.3
4,500	-------	-------	85.0	-------	86.2	85.8	87.5	87.0	86.6
3,000	-------	-------	84.1	-------	85.3	85.0	86.3	86.1	85.8
1,500	-------	-------	83.1	-------	84.1	84.1	85.1	85.0	84.9
600	-------	-------	82.4	-------	83.4	83.4	84.5	84.4	84.4
Surface	-------	-------	82.0	-------	83.0	83.0	84.0	84.0	84.0
30,000	96.8	94.6	92.4	97.0	94.7	92.6	97.3	95.1	92.9
24,000	95.8	93.9	91.9	96.2	94.2	92.2	96.6	94.6	92.6
18,000	94.5	92.8	91.1	94.9	93.2	91.5	95.4	93.7	92.0
15,000	93.6	92.0	90.6	94.1	92.5	91.1	94.6	93.2	91.5
12,000	92.5	91.2	89.9	93.0	91.8	90.4	93.6	92.3	91.0
9,000	91.0	90.0	89.1	91.6	90.6	89.6	92.3	91.3	90.3
6,000	89.2	88.6	88.0	90.0	89.3	88.7	90.8	90.0	89.4
4,500	88.2	87.7	87.3	89.0	88.5	88.0	89.8	89.2	88.9
3,000	87.1	86.9	86.6	88.0	87.9	87.4	88.8	88.6	88.3
1,500	86.0	85.9	85.9	86.9	86.8	86.8	87.8	87.8	87.7
600	85.4	85.3	85.4	86.4	86.3	86.2	87.3	87.2	87.3
Surface	85.0	85.0	85.0	86.0	86.0	86.0	87.0	87.0	87.0
30,000	97.6	95.4	93.1	97.9	95.6	93.3	98.2	95.9	93.5
24,000	97.0	94.9	92.9	97.3	95.2	93.2	97.6	95.6	93.3
18,000	95.8	94.1	92.4	96.2	94.5	92.8	96.7	94.9	93.2
15,000	95.0	93.5	92.1	95.6	94.0	92.5	96.1	94.5	93.0
12,000	94.1	92.8	91.6	94.8	93.4	92.2	95.3	94.0	92.7
9,000	92.8	92.0	90.9	93.6	92.6	91.6	94.2	93.2	92.2
6,000	91.4	90.9	90.1	92.3	91.5	90.8	93.1	92.2	91.6
4,500	90.6	90.1	89.6	91.5	90.9	90.4	92.3	91.6	91.3
3,000	89.7	89.6	89.1	90.4	90.4	90.0	91.5	91.2	90.9
1,500	88.0	88.8	88.5	89.8	89.7	89.6	90.7	90.6	90.5
600	88.3	88.3	88.2	89.4	89.3	89.2	90.2	90.2	90.2
Surface	88.0	88.0	88.0	89.0	89.0	89.0	90.0	90.0	90.0

TABLE IV.—*Ballistic density, in percentage of standard used by the artillery, for various maximum ordinates. The arguments are the corrected surface density and the altitude of the meteorological station above sea level*—Continued

Maximum ordinate	Station elevation, in feet, above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
	Ballistic density in percentage of standard								
30,000	98.5	96.1	93.8	98.8	96.4	93.9	99.0	96.7	94.3
24,000	98.0	95.9	93.7	98.3	96.4	94.2	98.7	96.7	94.6
18,000	97.1	95.4	93.6	97.6	95.8	94.0	98.1	96.3	94.5
15,000	96.6	95.0	93.5	97.0	95.5	93.9	97.5	96.0	94.4
12,000	95.8	94.5	93.2	96.4	95.1	93.8	96.9	95.6	94.3
9,000	94.8	93.8	92.8	95.5	94.4	93.4	96.1	95.0	93.9
6,000	93.6	93.0	92.3	94.4	93.8	93.1	95.2	94.5	93.7
4,500	93.1	92.5	92.0	93.8	93.4	92.8	94.7	94.1	93.6
3,000	92.4	92.1	91.7	93.2	92.9	92.6	94.1	93.8	93.3
1,500	91.7	91.6	91.4	92.6	92.4	92.4	93.5	93.3	93.3
600	91.2	91.3	91.2	92.2	92.2	92.2	93.2	93.1	93.0
Surface	91.0	91.0	91.0	92.0	92.0	92.0	93.0	93.0	93.0
30,000	99.2	96.9	94.4	99.5	97.2	94.7	99.8	97.4	94.9
24,000	99.0	97.0	94.8	99.3	97.4	95.2	99.6	97.7	95.6
18,000	98.5	96.7	94.9	99.0	97.2	95.3	99.3	97.6	95.8
15,000	98.0	96.4	94.9	98.5	96.9	95.4	99.0	97.4	95.8
12,000	97.6	96.2	94.8	98.1	96.8	95.4	98.6	97.2	95.9
9,000	96.9	95.7	94.6	97.5	96.4	95.3	98.0	97.0	95.9
6,000	96.0	95.2	94.5	96.7	95.9	95.2	97.5	96.6	95.9
4,500	95.5	94.9	94.4	96.3	95.7	95.1	97.2	96.5	95.9
3,000	95.0	94.6	94.3	95.8	95.5	95.1	96.6	96.3	96.0
1,500	94.5	94.3	94.5	95.4	95.2	95.1	96.4	96.2	96.0
600	94.2	94.1	94.1	95.1	95.1	95.0	96.2	96.0	96.0
Surface	94.0	94.0	94.0	95.0	95.0	95.0	96.0	96.0	96.0
30,000	100.0	97.6	95.2	100.3	97.9	95.4	100.6	98.1	95.7
24,000	100.0	98.0	95.9	100.6	98.3	96.2	100.8	98.7	96.6
18,000	99.7	98.0	96.2	100.2	98.4	96.5	100.6	98.8	97.0
15,000	99.5	98.0	96.3	100.0	98.4	96.7	100.5	98.9	97.3
12,000	99.2	97.8	96.4	99.8	98.3	96.8	100.4	98.8	97.5
9,000	98.8	97.6	96.5	99.4	98.2	97.0	100.1	98.8	97.7
6,000	98.2	97.4	96.6	99.0	98.1	97.2	99.7	98.8	98.0
4,500	98.0	97.4	96.7	99.0	98.1	97.3	99.6	98.8	98.2
3,000	97.6	97.2	96.8	98.5	98.0	97.5	99.4	98.8	98.4
1,500	97.3	97.2	96.9	98.3	98.0	97.8	99.2	98.9	98.7
600	97.1	97.1	96.9	98.1	98.0	97.8	99.1	98.8	98.9
Surface	97.0	97.0	97.0	98.0	98.0	98.0	99.0	99.0	99.0
30,000	100.9	98.4	96.0	101.2	98.7	96.2	101.4	99.0	96.4
24,000	101.1	99.1	97.0	101.6	99.4	97.3	101.8	99.8	97.7
18,000	101.1	99.3	97.4	101.6	99.6	97.8	102.0	100.1	98.3
15,000	101.0	99.4	97.7	101.3	99.8	98.2	102.0	100.4	98.7
12,000	100.9	99.4	98.2	101.4	99.9	98.5	102.0	100.5	99.1
9,000	100.7	99.4	98.3	101.2	100.1	98.9	102.0	100.8	99.5
6,000	100.5	99.5	98.7	101.2	100.3	99.5	102.0	100.9	100.1
4,500	100.4	99.6	99.0	101.1	100.4	99.7	102.0	101.2	100.5
3,000	100.3	99.7	99.2	101.0	100.6	100.0	172.0	101.5	101.0
1,500	100.1	99.9	99.6	101.0	100.8	100.5	102.0	101.8	101.4
600	100.1	99.8	99.9	101.0	100.9	100.8	102.1	101.9	101.8
Surface	100.0	100.0	100.0	101.0	101.0	101.0	102.0	102.0	102.0
30,000	101.7	99.2	96.8	101.9	99.4	96.9	102.2	99.7	97.1
24,000	102.2	100.2	98.0	102.5	100.4	98.4	102.9	100.8	98.6
18,000	102.4	100.6	98.8	102.8	101.0	99.2	103.2	101.4	99.5
15,000	102.5	100.8	99.2	103.0	101.4	99.7	103.4	101.8	100.1
12,000	102.6	101.1	99.7	103.1	101.6	100.2	103.6	102.1	100.7
9,000	102.6	101.4	100.3	103.3	102.0	100.8	103.9	102.5	101.4
6,000	102.7	101.7	100.8	103.5	102.5	101.6	104.2	103.1	102.2
4,500	102.8	102.0	101.3	103.6	102.8	102.1	104.4	103.5	102.8
3,000	102.9	102.2	101.9	103.7	103.1	102.7	104.7	104.0	103.4
1,500	103.0	102.7	102.4	103.9	103.5	103.3	104.9	104.6	104.1
600	103.0	102.9	102.8	103.9	103.8	103.7	105.0	104.9	104.6
Surface	103.0	103.0	103.0	104.0	104.0	104.0	105.0	105.0	105.0

TABLE IV.—*Ballistic density, in percentage of standard used by the artillery, for various maximum ordinates. The arguments are the corrected surface density and the altitude of the meteorological station above sea level*—Continued

Maximum ordinate	Station elevation, in feet, above sea level								
	0	1,000	2,000	0	1,000	2,000	0	1,000	2,000
	Ballistic density in percentage of standard								
30,000	102.5	100.0	97.4	102.8	100.2	97.5	103.1	100.4	97.8
24,000	103.3	101.1	99.0	103.7	101.4	99.3	104.0	101.9	99.6
18,000	103.7	101.8	100.0	104.1	102.2	100.4	104.6	102.8	100.8
15,000	104.0	102.2	100.6	104.4	102.8	101.1	105.0	103.3	101.6
12,000	104.2	102.7	101.2	104.8	103.2	101.8	105.4	103.9	102.3
9,000	104.5	103.2	102.0	105.2	103.8	102.6	105.9	104.6	103.2
6,000	104.9	103.9	103.0	105.7	104.6	103.7	106.5	105.5	104.4
4,500	105.2	104.3	103.6	106.0	105.1	104.6	106.9	106.1	105.2
3,000	105.5	104.7	104.4	106.4	105.6	105.2	107.3	106.6	106.0
1,500	105.8	105.5	105.2	106.7	106.3	106.1	107.7	107.4	106.9
600	105.9	105.8	105.7	106.9	106.7	106.7	107.9	107.8	107.6
Surface	106.0	106.0	106.0	107.0	107.0	107.0	108.0	108.0	108.0
30,000	103.3	100.7	98.1	103.6	101.0	98.3	103.9	101.2	98.5
24,000	104.3	102.2	99.9	104.6	102.5	100.3	104.9	102.8	100.6
18,000	105.0	103.1	101.2	105.4	103.6	101.6	105.8	104.0	102.0
15,000	105.4	103.7	102.0	106.0	104.2	102.5	106.4	104.6	103.0
12,000	105.9	104.4	102.8	106.4	104.9	103.3	107.0	105.4	103.8
9,000	106.4	105.1	103.8	107.1	105.8	104.4	107.7	106.4	105.0
6,000	107.1	106.1	105.1	107.9	106.9	105.8	108.7	107.6	106.5
4,500	107.6	106.8	105.9	108.5	107.6	106.6	109.3	108.4	107.5
3,000	108.1	107.5	106.8	109.0	108.4	107.7	109.9	109.2	108.5
1,500	108.5	108.3	107.8	109.6	109.3	108.8	110.5	110.2	109.6
600	108.8	108.8	108.5	109.9	109.8	109.6	110.8	110.8	110.4
Surface	109.0	109.9	109.9	110.0	110.0	110.0	111.0	111.0	111.0
30,000	104.1	101.5	98.8	104.4	101.8	-------	104.7	102.0	-------
24,000	105.4	103.2	100.9	105.7	103.5	-------	106.2	103.7	-------
18,000	106.3	104.4	102.5	106.8	104.8	-------	107.3	105.3	-------
15,000	106.9	105.2	103.5	107.4	105.7	-------	108.0	106.2	-------
12,000	107.5	106.0	104.4	108.1	106.5	-------	108.7	107.0	-------
9,000	108.4	107.1	105.6	109.1	107.7	-------	109.7	108.2	-------
6,000	109.4	108.3	107.3	110.2	109.0	-------	111.0	109.7	-------
4,500	110.0	109.2	108.2	110.9	110.0	-------	111.8	110.6	-------
3,000	110.8	110.1	109.4	111.7	110.8	-------	112.6	111.6	-------
1,500	111.4	111.1	110.6	112.4	112.0	-------	113.4	112.8	-------
600	111.8	111.7	111.5	112.7	112.8	-------	113.8	113.7	-------
Surface	112.0	112.0	112.0	113.0	113.0	-------	114.0	114.0	-------
30,000	105.0	102.2	-------	105.2	102.4	-------	105.4	102.7	-------
24,000	106.5	104.2	-------	106.8	104.5	-------	107.1	104.9	-------
18,000	107.7	105.7	-------	108.2	106.1	-------	108.5	106.6	-------
15,000	108.4	106.6	-------	109.0	107.1	-------	109.4	107.6	-------
12,000	109.2	107.5	-------	109.8	108.1	-------	110.3	108.6	-------
9,000	110.3	108.8	-------	111.0	109.4	-------	111.7	110.2	-------
6,000	111.7	110.4	-------	112.5	111.1	-------	113.2	111.9	-------
4,500	112.5	111.4	-------	113.3	112.2	-------	114.1	113.1	-------
3,000	113.4	112.5	-------	114.3	113.4	-------	115.1	114.3	-------
1,500	114.3	113.8	-------	115.0	114.7	-------	116.1	115.7	-------
600	114.7	114.7	-------	115.7	115.7	-------	116.6	116.7	-------
Surface	115.0	115.0	-------	116.0	116.0	-------	117.0	117.0	-------

TABLE IV.—*Ballistic density, in percentage of standard used by the artillery, for various maximum ordinates. The arguments are the corrected surface density and the altitude of the meteorological station above sea level*—Continued

Maximum ordinate	Station elevation in feet above sea level		
	0	0	0
	Ballistic density in percentage of standard		
30,000	105.8	106.1	106.4
24,000	107.5	107.9	108.2
18,000	109.0	109.5	109.8
15,000	109.8	110.4	110.9
12,000	110.9	111.5	112.0
9,000	112.3	112.9	113.6
6,000	113.9	114.7	115.4
4,500	115.0	115.8	116.5
3,000	116.1	116.9	117.8
1,500	117.1	118.0	119.0
600	117.7	118.6	119.6
Surface	118.0	119.0	120.0
30,000	106.6	106.8	107.1
24,000	108.6	108.9	109.3
18,000	110.4	110.8	111.2
15,000	111.4	111.9	112.4
12,000	112.6	113.2	113.7
9,000	114.3	114.9	115.6
6,000	116.3	116.9	117.7
4,500	117.3	118.1	119.0
3,000	118.7	119.5	120.5
1,500	119.9	120.8	121.8
600	120.6	121.5	122.6
Surface	121.0	122.0	123.0

To compute ballistic air density from upper air observations it is first necessary to determine the actual density at certain levels above the meteorological station, namely, 300 feet, 1,050 feet, 2,250 feet, 3,750 feet, etc., up to the highest altitude for which ballistic density is desired. The actual density at the levels named may be taken as the mean density for the zones, 0–600 feet, 600–1,050 feet, 1,500–3,000 feet, 3,000–4,500 feet, etc., respectively. If observations have been made of the temperature, barometric pressure, and vapor pressure at the levels specified the air density may be computed with the following formula:

$$D=\frac{b-.378e}{459+t}\times 21218$$

Where D is air density in grams per cubic meter.
b is station barometer reading in inches.
e is vapor pressure in inches of mercury.
t is temperature on Fahrenheit scale.

After the actual air density has been computed for each of the levels named, these densities must each be reduced to the percentage of standard density for the level at which each particular density was observed. This is done by dividing the observed density at a particular level by the standard density for that level. It is next necessary to compute the ballistic density from these percentage densities. This is done by multiplying the percentage densities found at the several levels by appropriate weighting factors, depending on the maximum ordinate for which the ballistic density is desired; the sum of the products thus obtained is the ballistic density. A table of weighting factors, together with the standard temperature and densities for each level above the meteorological station, has been supplied by the Ordnance Department. A copy of these density weighting factors and table of standard temperature, pressure, and density values for the levels used in computing ballistic density and temperature is given at the end of this paragraph. The following is an example of the computation of the ballistic density for a maximum ordinate of 4,500 feet:

Altitude above station, in feet	Observed density, grams per cubic meter	Standard density, grams per cubic meter	Observed density, in per cent of standard	Weighting factors	Observed density × weighting factors
3,750	1,097.0	1,069.0	102.6	0, 37	37.962
2,250	1,153.0	1,120.9	102.9	.31	31.899
1,050	1,199.0	1,164.2	103.0	.19	19.57
300	1,228.0	1,192.1	103.0	.13	13.39
Ballistic density for maximum ordinate of 4,500 feet					102.8

Ballistic densities are computed for the following maximum ordinates: 600, 1,500, 3,000, 4,500, 6,000, 9,000, 12,000, 15,000, 18,000, 24,000, and 30,000 feet.

Temperature weighting factors for use in computing ballistic temperatures under field conditions are not available. Therefore ballistic temperatures are obtained by resolving the ballistic densities, computed by the method outlined above, into pressures and temperatures. The method for doing this is similar to that indicated in a preceding paragraph. The only difference is that the ballistic densities computed from actual observation will be used when they are available instead of those determined from Table IV.

TABLE V

AIR DENSITY WEIGHTING FACTORS
[Furnished by the Ordnance Department]

Maximum ordinate	Zones										
	0–600	600–1,500	1,500–3,000	3,000–4,500	4,500–6,000	6,000–9,000	9,000–12,000	12,000–15,000	15,000–18,000	18,000–24,000	24,000–30,000
600	1.00										
1,500	.39	0.61									
3,000	.20	.28	0.52								
4,500	.13	.19	.31	0.37							
6,000	.10	.14	.24	.21	0.31						
9,000	.06	.10	.16	.16	.15	0.37					
12,000	.05	.07	.12	.12	.12	.21	0.31				
15,000	.04	.06	.10	.10	.09	.18	.16	0.27			
18,000	.04	.04	.08	.08	.08	.16	.15	.14	0.23		
24,000	.03	.03	.06	.06	.06	.12	.12	.11	.10	0.31	
30,000	.02	.03	.05	.05	.05	.10	.09	.09	.09	.16	0.27

STANDARD TEMPERATURE, PRESSURE AND DENSITY VALUES

[For levels used in computing ballistic density and temperature. From data furnished by the Ordnance Department]

Altitude (feet)	Density (kilograms per cubic meter)	Temperature (° F.)	Pressure (inches)
0	1.2034	59.0	29.528
300	1.1921	58.3	29.216
1,050	1.1642	56.8	28.449
2,250	1.1209	54.5	27.260
3,750	1.0690	51.1	25.831
5,250	1.0196	47.7	24.468
7,500	.9496	42.3	22.547
10,500	.8638	34.2	20.181
13,500	.7857	25.3	18.035
16,500	.7146	15.8	16.079
21,000	.6199	−.2	13.472
27,000	.5130	−25.8	10.528

FORM NO. 79—MET'L

Form No. 79 Met'l

WAR DEPARTMENT

SIGNAL CORPS, UNITED STATES ARMY

METEOROLOGICAL SECTION

BAROMETRIC CORRECTIONS

Signal Corps ________________
(Type)

Barometer No. ____________

In use at—

____________________________ { Long. ______
(Station) { Lat. ______

Station elevation ________________	_____	ft.
Mean annual temperature ________	_____	°F.
Mean pressure ________________	_____	in.
Correction for local gravity ________________ { Latitude	_____	in.
{ Altitude	_____	in.
Scale error and capillarity of instrument ________________	_____	in.
Sum of gravimetric and instrumental corrections ____________	_____	in.
Removal correction _____ ft. (Altitude) _____ (Date)	_____	in.
Sum of gravimetric and instrumental corrections ____________	_____	in.
Removal correction _____ ft. (Altitude) _____ (Date)	_____	in.
Sum of gravimetric and instrumental corrections ____________	_____	in.
Removal correction _____ ft. (Altitude) _____ (Date)	_____	in.
Sum of gravimetric and instrumental corrections ____________	_____	in.

SPECIAL REMOVAL CORRECTIONS

Temp. (dry bulb)	Elevation	Removal correction	Sum of corrections
−20			
−10			
0			
+10			
+20			
+30			
+40			
+50			
+60			
+70			
+80			
+90			
+100			

	ATTACHED THERMOMETER No. .... (Correction in degrees Fahrenheit to reduce to standard air thermometer)							
SCALE READING	32	42	52	62	72	82	92	100
CORRECTION	−0.	−0.	−0.	−0.	−0.	−0.	−0.	−0.

Corrections of 0.5 degree or more will be applied to the observed temperature and the reading thus corrected will be used in determining the correction for temperature of the barometer.

Form No. 80–Met'l.

WAR DEPARTMENT

SIGNAL CORPS, UNITED STATES ARMY

METEOROLOGICAL SERVICE

CORRECTION OF MERCURIAL BAROMETER FOR TEMPERATURE, ENGLISH MEASURES

HEIGHT OF BAROMETER IN INCHES

°F.	24.0	24.5	25.0	25.5	26.0	26.5	27.0	27.5	28.0	28.5	29.0	29.5	30.0	30.5	31.0
			Inches				ADD					*Inches*			
16	0.028	0.028	0.029	0.030	0.030	0.030	0.031	0.032	0.032	0.032	0.033	0.034	0.034	0.035	0.036
17	.025	.026	.026	.026	.027	.028	.029	.030	.030	.030	.031	.032	.032	.032	.033
18	.023	.024	.024	.024	.025	.026	.026	.026	.027	.028	.028	.028	.029	.030	.030
19	.021	.022	.022	.022	.023	.024	.024	.024	.025	.025	.025	.026	.026	.026	.027
20	.019	.020	.020	.020	.020	.020	.021	.022	.022	.022	.023	.024	.024	.024	.024
21	.017	.017	.017	.018	.018	.018	.019	.019	.019	.020	.020	.020	.021	.022	.022
22	.014	.014	.015	.016	.016	.016	.016	.016	.017	.017	.017	.018	.018	.018	.019
23	.012	.012	.013	.013	.013	.014	.014	.014	.014	.014	.015	.015	.015	.016	.016
24	.010	.010	.011	.011	.011	.011	.011	.012	.012	.012	.012	.012	.013	.013	.013
25	.008	.008	.008	.008	.009	.009	.009	.009	.009	.010	.010	.010	.010	.010	.010
26	.006	.006	.006	.006	.006	.006	.006	.006	.007	.007	.007	.007	.007	.007	.007
27	.004	.004	.004	.004	.004	.004	.004	.004	.004	.004	.004	.004	.004	.004	.005
28	.001	.001	.001	.001	.001	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002
			Inches				SUBTRACT					*Inches*			
29	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30	.003	.003	.003	.003	.003	.003	.003	.003	.003	.004	.004	.004	.004	.004	.004
31	.005	.005	.005	.005	.006	.006	.006	.006	.006	.006	.006	.006	.006	.007	.007
32	.007	.007	.008	.008	.008	.008	.008	.008	.009	.009	.009	.009	.009	.009	.009
33	.010	.010	.010	.010	.010	.011	.011	.011	.011	.011	.012	.012	.012	.012	.012
34	.012	.012	.012	.012	.013	.013	.013	.013	.014	.014	.014	.014	.015	.015	.015
35	.014	.014	.014	.015	.015	.015	.016	.016	.016	.016	.017	.017	.017	.018	.018
36	.016	.016	.017	.017	.017	.018	.018	.018	.019	.019	.019	.020	.020	.020	.021
37	.018	.019	.019	.019	.020	.020	.021	.021	.021	.022	.022	.022	.023	.023	.024
38	.020	.021	.021	.022	.022	.023	.023	.023	.024	.024	.025	.025	.026	.026	.026
39	.023	.023	.024	.024	.024	.025	.025	.026	.026	.027	.027	.028	.028	.029	.029
40	.025	.025	.026	.026	.027	.027	.028	.028	.029	.029	.030	.030	.031	.031	.032
41	.027	.027	.028	.029	.029	.030	.030	.031	.031	.032	.033	.033	.034	.034	.035
42	.029	.030	.030	.031	.032	.032	.033	.033	.034	.035	.035	.036	.036	.037	.038
43	.031	.032	.033	.033	.034	.035	.035	.036	.036	.037	.038	.038	.039	.040	.040
44	.033	.034	.035	.036	.036	.037	.038	.038	.039	.040	.040	.041	.042	.043	.043
45	.036	.036	.037	.038	.039	.039	.040	.041	.042	.042	.043	.044	.045	.045	.046
46	.038	.039	.039	.040	.041	.042	.043	.043	.044	.045	.046	.046	.047	.048	.049
47	.040	.041	.042	.042	.043	.044	.045	.046	.047	.047	.048	.049	.050	.051	.052
48	.042	.043	.044	.045	.046	.047	.047	.048	.049	.050	.051	.052	.053	.054	.054
49	.044	.045	.046	.047	.048	.049	.050	.051	.052	.053	.054	.054	.055	.056	.057
50	.046	.047	.048	.049	.050	.051	.052	.053	.054	.055	.056	.057	.058	.059	.060
51	.049	.050	.051	.052	.053	.054	.055	.056	.057	.058	.059	.060	.061	.062	.063
52	.051	.052	.053	.054	.055	.056	.057	.058	.059	.060	.061	.062	.064	.065	.066
53	.053	.054	.055	.056	.057	.059	.060	.061	.062	.063	.064	.065	.066	.067	.068
54	.055	.056	.057	.059	.060	.061	.062	.063	.064	.066	.067	.068	.069	.070	.071
55	.057	.059	.060	.061	.062	.063	.064	.066	.067	.068	.069	.070	.072	.073	.074
56	.060	.061	.062	.063	.064	.066	.067	.068	.069	.071	.072	.073	.074	.076	.077
57	.062	.063	.064	.066	.067	.068	.069	.071	.072	.073	.075	.076	.077	.078	.080
58	.064	.065	.066	.068	.069	.070	.072	.073	.074	.076	.077	.078	.080	.081	.082
59	.066	.067	.069	.070	.072	.073	.074	.076	.077	.078	.080	.081	.083	.084	.085
60	.068	.070	.071	.072	.074	.075	.077	.078	.080	.081	.082	.084	.085	.087	.088
60.5	.069	.071	.072	.074	.075	.076	.078	.079	.081	.082	.084	.085	.087	.088	.089
61	.070	.072	.073	.075	.076	.078	.079	.081	.082	.084	.085	.086	.088	.089	.091
61.5	.071	.073	.074	.076	.077	.079	.080	.082	.083	.085	.086	.088	.089	.091	.092
62	.073	.074	.076	.077	.079	.080	.082	.083	.085	.086	.088	.089	.091	.092	.094
62.5	.074	.075	.077	.078	.080	.081	.083	.084	.086	.087	.089	.090	.092	.094	.095
63	.075	.076	.078	.079	.081	.082	.084	.086	.087	.089	.090	.092	.093	.095	.096
63.5	.076	.077	.079	.080	.082	.084	.085	.087	.088	.090	.092	.093	.095	.096	.098
64	.077	.078	.080	.082	.083	.085	.086	.088	.090	.091	.093	.094	.096	.098	.099
64.5	.078	.080	.081	.083	.084	.086	.088	.089	.091	.093	.094	.096	.097	.099	.101
65	.079	.081	.082	.084	.086	.087	.089	.091	.092	.094	.095	.097	.099	.100	.102

Inches **SUBTRACT** *Inches*

°F.	24.0	24.5	25.0	25.5	26.0	26.5	27.0	27.5	28.0	28.5	29.0	29.5	30.0	30.5	31.0
65.5	0.080	0.082	0.083	0.085	0.087	0.088	0.090	0.092	0.093	0.095	0.097	0.098	0.100	0.102	0.103
66	.081	.083	.085	.086	.088	.090	.091	.093	.095	.096	.098	.100	.101	.103	.105
66.5	.082	.084	.086	.087	.089	.091	.093	.094	.096	.098	.099	.101	.103	.105	.106
67	.083	.085	.087	.089	.090	.092	.094	.095	.097	.099	.101	.102	.104	.106	.108
67.5	.084	.086	.088	.090	.092	.093	.095	.097	.098	.100	.102	.104	.106	.107	.109
67.5	.084	.086	.088	.090	.092	.093	.095	.097	.098	.100	.102	.104	.106	.107	.109
68	.085	.087	.089	.091	.093	.094	.096	.098	.100	.102	.103	.105	.107	.109	.110
68.5	.087	.088	.090	.092	.094	.096	.097	.099	.101	.103	.105	.106	.108	.110	.112
69	.088	.089	.091	.093	.095	.097	.099	.100	.102	.104	.106	.108	.110	.111	.113
69.5	.089	.091	.092	.094	.096	.098	.100	.102	.104	.105	.107	.109	.111	.113	.115
70	.090	.092	.094	.095	.097	.099	.101	.103	.105	.107	.109	.110	.112	.114	.116
70.5	.091	.093	.095	.097	.098	.100	.102	.104	.106	.108	.110	.112	.114	.116	.117
71	.092	.094	.096	.098	.100	.102	.103	.105	.107	.109	.111	.113	.115	.117	.119
71.5	.093	.095	.097	.099	.101	.103	.105	.107	.109	.110	.112	.114	.116	.118	.120
72	.094	.096	.098	.100	.102	.104	.106	.108	.110	.112	.114	.116	.118	.120	.122
72.5	.095	.097	.099	.101	.103	.105	.107	.109	.111	.113	.115	.117	.119	.121	.123
73	.096	.098	.100	.102	.104	.106	.108	.110	.112	.114	.116	.118	.120	.122	.124
73.5	.097	.099	.101	.103	.105	.108	.110	.112	.114	.116	.118	.120	.122	.124	.126
74	.098	.101	.103	.105	.107	.109	.111	.113	.115	.117	.119	.121	.123	.125	.127
74.5	.100	.102	.104	.106	.108	.110	.112	.114	.116	.118	.120	.122	.124	.126	.129
75	.101	.103	.105	.107	.109	.111	.113	.115	.117	.119	.122	.124	.126	.128	.130
75.5	.102	.104	.106	.108	.110	.112	.114	.117	.119	.121	.123	.125	.127	.129	.131
76	.103	.105	.107	.109	.111	.113	.116	.118	.120	.122	.124	.126	.128	.131	.133
76.5	.104	.106	.108	.111	.113	.115	.117	.119	.121	.123	.125	.128	.130	.132	.134
77	.105	.107	.109	.112	.114	.116	.118	.120	.122	.125	.127	.129	.131	.133	.136
77.5	.106	.108	.110	.113	.115	.117	.119	.121	.124	.126	.128	.130	.133	.135	.137
78	.107	.109	.112	.114	.116	.118	.120	.123	.125	.127	.129	.132	.134	.136	.138
78.5	.108	.110	.113	.115	.117	.119	.122	.124	.126	.128	.131	.133	.135	.137	.140
79	.109	.112	.114	.116	.118	.121	.123	.125	.127	.130	.132	.134	.137	.139	.141
79.5	.110	.113	.115	.117	.120	.122	.124	.126	.129	.131	.133	.136	.138	.140	.143
80	.111	.114	.116	.118	.121	.123	.125	.128	.130	.132	.135	.137	.139	.142	.144
80.5	.112	.115	.117	.120	.122	.124	.127	.129	.131	.134	.136	.138	.141	.143	.145
81	.114	.116	.118	.121	.123	.125	.128	.130	.132	.135	.137	.140	.142	.144	.147
81.5	.115	.117	.119	.122	.124	.127	.129	.131	.134	.136	.139	.141	.143	.146	.148
82	.116	.118	.121	.123	.125	.128	.130	.133	.135	.137	.140	.142	.145	.147	.149
82.5	.117	.119	.122	.124	.127	.129	.131	.134	.136	.139	.141	.144	.146	.148	.151
83	.118	.120	.123	.125	.128	.130	.133	.135	.138	.140	.142	.145	.147	.150	.152
83.5	.119	.121	.124	.126	.129	.131	.134	.136	.139	.141	.144	.146	.149	.151	.154
84	.120	.123	.125	.128	.130	.133	.135	.138	.140	.143	.145	.148	.150	.153	.155
84.5	.121	.124	.126	.129	.131	.134	.136	.139	.141	.144	.146	.149	.151	.154	.156
85	.122	.125	.127	.130	.132	.135	.137	.140	.143	.145	.148	.150	.153	.155	.158
85.5	.123	.126	.128	.131	.134	.136	.139	.141	.144	.146	.149	.152	.154	.157	.159
86	.124	.127	.130	.132	.135	.137	.140	.142	.145	.148	.150	.153	.155	.158	.161
86.5	.125	.128	.131	.133	.136	.138	.141	.144	.146	.149	.152	.154	.157	.159	.162
87	.126	.129	.132	.134	.137	.140	.142	.145	.148	.150	.153	.155	.158	.161	.163
87.5	.128	.130	.133	.136	.138	.141	.144	.146	.149	.151	.154	.157	.159	.162	.165
88	.129	.131	.134	.137	.139	.142	.145	.147	.150	.153	.155	.158	.161	.163	.166
88.5	.130	.132	.135	.138	.141	.143	.146	.149	.151	.154	.157	.159	.162	.165	.168
89	.131	.134	.136	.139	.142	.144	.147	.150	.153	.155	.158	.161	.164	.166	.169
89.5	.132	.135	.137	.140	.143	.146	.148	.151	.154	.157	.159	.162	.165	.168	.170
90	.133	.136	.138	.141	.144	.147	.150	.152	.155	.158	.161	.163	.166	.169	.172
90.5	.134	.137	.140	.142	.145	.148	.151	.154	.156	.159	.162	.165	.168	.170	.173
91	.135	.138	.141	.144	.146	.149	.152	.155	.158	.160	.163	.166	.169	.172	.175
91.5	.136	.139	.142	.145	.148	.150	.153	.156	.159	.162	.165	.167	.170	.173	.176
92	.137	.140	.143	.146	.149	.152	.154	.157	.160	.163	.166	.169	.172	.174	.177
92.5	.138	.141	.144	.147	.150	.153	.156	.159	.161	.164	.167	.170	.173	.176	.179
93	.139	.142	.145	.148	.151	.154	.157	.160	.163	.166	.168	.171	.174	.177	.180
93.5	.140	.143	.146	.149	.152	.155	.158	.161	.164	.167	.170	.173	.176	.179	.181
94	.142	.145	.147	.150	.153	.156	.159	.162	.165	.168	.171	.174	.177	.180	.183
94.5	.143	.146	.149	.152	.155	.158	.160	.163	.166	.169	.172	.175	.178	.181	.184
95	.144	.147	.150	.153	.156	.159	.162	.165	.168	.171	.174	.177	.180	.183	.186
96	.146	.149	.152	.155	.158	.161	.164	.167	.170	.173	.176	.179	.182	.185	.188
97	.148	.151	.154	.157	.160	.163	.167	.170	.173	.176	.179	.182	.185	.188	.191
98	.150	.153	.156	.160	.163	.166	.169	.172	.175	.178	.181	.185	.188	.191	.194
99	.152	.155	.159	.162	.165	.168	.171	.175	.178	.181	.184	.187	.190	.194	.197
100	.154	.158	.161	.164	.167	.171	.174	.177	.180	.183	.187	.190	.193	.196	.200
101	.157	.160	.163	.166	.170	.173	.176	.179	.183	.186	.189	.193	.196	.199	.202
102	.159	.162	.165	.169	.172	.175	.179	.182	.185	.189	.192	.195	.198	.202	.205
103	.161	.164	.168	.171	.174	.178	.181	.184	.188	.191	.194	.198	.201	.204	.208
104	.163	.166	.170	.173	.177	.180	.183	.187	.190	.194	.197	.200	.204	.207	.211
105	.165	.169	.172	.176	.179	.182	.186	.189	.193	.196	.200	.203	.207	.210	.213

REPAIRS TO INSTRUMENTS

While in general the repairs to meteorological instruments should be made by experts in the office of the Chief Signal Officer, this information topic is furnished to enable the student to see which instruments are capable of local repairs and which should be sent for repairs to the office of the Chief Signal Officer.

Students should not attempt to repair any instruments unless they are thoroughly familiar and qualified to do the work, as the delicacy and expense of the instruments make it prohibitory to perform experimental work in this connection.

Thermometers.—When a thermometer is broken—that is, the glass tube—it can not be repaired and must be reported as entirely unserviceable. There are, however, certain repairs which apply to thermometers.

The black material in the etched graduations and figure markings may have fallen out or may be worn out, and those graduations should then be reblacked. Each station is supplied with a tube of ivory black, which is simply thick black paint. To reblack the graduations of a thermometer, first remove the thermometer tube from its aluminum back by taking out the small screws fastening the brass straps. It may be necessary to apply oil to the screws to soften the corroded substances. Then thoroughly clean all parts and dry them. Squeeze some ivory black on the thermometer tube and with a piece of paper smear it well over all the etched places. Then wrap a wad of tissue paper around the thermometer and wipe off the surplus black. Polish the thermometer tube clean by using the flat surface of a blotter. Carefully replace the thermometer tube by screwing it upon its aluminum back. All aluminum parts may be cleaned with washing soda, and rinsed with pure water afterwards.

It sometimes happens that the alcohol in the minimum thermometer is no longer continuous, and the column of alcohol appears as if there were many air bubbles in it. Remove the thermometer from its support and hold the bulb end in the right hand, striking it against the fleshy part of the left hand until the alcohol is entirely united. Another method is to attach the thermometer to the handle of a sling psychrometer and whirl it rapidly for a minute or so, or until the alcohol becomes united. The observer may be entirely baffled in his attempt to reunite the columns of some thermometers, and in this case he should report the matter to the O. C. S. O. and suitable instructions will be issued.

In mercurial thermometers, the column may also become disunited at times, and the defect may be remedied by whirling or tapping. If in some cases these methods fail to accomplish the purpose desired, the following method may be used with both alcohol and mercurial thermometers which have a considerable space at the top of the column. Heat the bulb of the instrument gently, forcing the liquid into the empty space at the top of the tube, until the entire column is united, then allow the thermometer to cool down, when all the mercury will be drawn back into the bore of the tube into a united column. *In this process, care must be taken that there shall always be a little space at the top of the bore,* otherwise the thermometer will *surely* be broken.

The thermometer supports sometimes become worn in such a way as to support the thermometer improperly; that is, the minimum will not be nearly level and the maximum will not have its bulb slightly elevated. The ingenuity of the observer will suggest a method to remedy this; or, if the support is very unserviceable, the fact must be reported and the station will be supplied with a new thermometer support.

Thermographs.—These instruments may develop defects along several lines.

a. The clock may not keep correct time. Each clock is provided with a means by which it can be regulated; this should be done by the observer as carefully as possible.

b. The clock may stop. This may be due to dirt or gummy oil in the works, in which case the observer must requistion a new clock and dispose of the unserviceable instrument in accordance with existing instructions.

c. The pen may be set to some correct temperature and may read incorrectly at higher or lower temperatures. In this case the thermograph must be exchanged for a good one if the correction at any part of the scale is over 5 degrees.

Barometer.—It is very seldom that a barometer which is hung up and in good working order develops defects, but in such a case the fact must be reported to the O. C. S. O., and a new barometer will be sent to the station. The observer may have some difficulty in reading the barometer, due to the surface of the mercury in the cistern becoming dirty, making it difficult for the observer to adjust the level of the mercury to the ivory point. This is not a serious defect, and the barometer should be cleaned by the inspector, or by some one having competent authority. In cleaning the outside of the barometer, care must be taken so that the scales will not move. It is unnecessary to polish these scales; simply wipe them off with a clean cloth, which will preserve them for a long time in good condition for reading.

Barograph.—This instrument, with care, will require very little in the way of repairs except that the clock movements may need cleaning occasionally, perhaps once a year, and preferably in the fall. Like all other meteorological instruments, it is delicate and extreme care must be taken with the so-called sylphon cell. The adjustment of the new type of barograph is on the top of the base plate and is very easily effected. A notable departure in the construction of this instrument from other barographs is that the link connecting the sylphon cell to the lever is detachable. When a barograph is received at a station it will be found that this link has been detached from the lever and must be hooked in place. This is done by so operating the adjustment screw that the pen drops, and the link can then easily be put in place. If for any reason, the barograph does not give a record comparable with the readings of a mercurial barometer, the fact should be reported to the O. C. S. O. In general, it should read within 0.05 of an inch of the barometer reading.

The sling psychrometer.—The sling psychrometer, being composed of two thermometers, may suffer injury by having one of the two thermometers broken. The broken thermometer may be replaced with the nearest type of thermometer available. The cloth or wick around the wet bulb must be clean, and therefore it should be cleaned when soiled, or changed at least once a week.

Hygrographs.—These instruments always require considerable adjustment and frequent cleaning, especially the hairs which make up the hygroscopic element. These hairs must be cleaned with a camel's-hair brush for the purpose of removing the dust which may accumulate from time to time. It will not always be found that agreement will be observed between the readings of the sling psychrometer and the hygrograph, but the instrument must be judged by its average operation.

Wind instruments.—When once properly installed the wind-vane instrument will rarely give trouble, if oiled regularly and kept clean. In the antifriction roller type, it is necessary to inspect these rollers to see that they are clean and are not worn out so much as to be inefficient. They should never be oiled. The contacts which are used in connection with the wind vane of this type are contained in the contact box in the bottom of the support. It is seldom that these contacts will cause any trouble, and if a record becomes broken it will probably be necessary to look elsewhere for trouble, such as an open wire, or some faulty operation in the quadruple register. The Robinson anemometer should be taken down and cleaned once each month. The central shaft should be taken out, cleaned, and oiled, and the large screw holding the two dials should be removed and the dials thoroughly cleaned. Afterwards, the instrument should be oiled with clock oil.

Dines anemo-biagraph.—In the Dines anemo-biagraph the wind vane is operated with roller bearings, which need occasional cleaning and oiling. The recording instrument should be carefully inspected to see that the proper records are being made and that all the moving parts work freely.

Hand anemometers.—These instruments are exceedingly delicate and must be handled carefully. Before being shipped to a station they are carefully adjusted and, unless very roughly treated en route, should arrive in working condition. The vanes of this anemometer are mounted very carefully and are always protected on the sides, but they may be displaced by heavy pieces hitting them, or otherwise, making erroneous records. The observer must not attempt to straighten out the vanes which have become bent, because the angle of the vanes has a very definite relation to the wind speed which they record, and all repairs to this instrument should be made at the O. C. S. O. When they become unserviceable, the fact should be reported at once.

Rain gauges.—The 8-inch rain gauge will not need attention if carefully handled. Sometimes it occurs, however, that the receiver, overflow attachment, or inner tube may become so deformed as to be unserviceable. When this occurs, the fact should be reported and an entirely new instrument, or the injured part, requested. The inner tube and overflow attachment should also be carefully inspected with the view of finding leaks, which may be repaired locally.

Tipping bucket rain gauge.—The tipping bucket rain gauge is a somewhat delicate instrument and needs careful adjusting; that is, when set up, a level should be used to make the receiver perfectly horizontal, so that the tipping of the bucket either way will record equal amounts of rain. In the event of this instrument giving a wrong record, the observer may look for a sticking of the bucket, open wires, breaks in the circuit, bad contact at any of the binding posts, or possibly a defective battery.

Sunshine recorder.—It will seldom happen that the observer will be able to make any repairs to this instrument, but adjustments may be necessary. If the sunshine recorder is broken, it is then in an unserviceable condition and can not be repaired. Faulty records may be made through the defect in some part of the circuit in the sunshine recorder with the appropriate pen on the triple register. This fault must be searched for in the usual manner and faults in the circuit corrected.

Quadruple register.—The clock of the quadruple register is very rugged and will seldom need repairs, but it should be cleaned once each year. Other parts of the instrument are also made in a rugged fashion, but of course accidents may happen so that some repairs may be necessary. After considerable use the contacts points of the direction arms should be replaced. This may be done by an inspector, or by an observer if he is proficient in repairs of this kind It will seldom be found that in searching for bad electrical contacts the observer need go any further than the binding posts. The internal parts of the machine are well made, but of course should not be overlooked when the trouble can not be found elsewhere. There are three types of batteries used with the quadruple register—storage batteries and wet or dry cells. Care must be taken that the storage battery is frequently charged. The best may to provide for this, however, is to install two batteries, one of which is being charged while the other is being used on the instrument. The change from charge to discharge is effected by a switch.

Clocks.—All the clocks used on the recording instruments are of an exceptionally good make and deserve the best of attention. The adjustment of the clock—that is, the method by which it is made to go faster or slower—is understood by all observers. Clocks should be carefully set to standard meridian time in local use. Attempts should be made to have all the parts cleaned once a year and the arrangements should be made so that the instruments will be idle only a very short time.

Recording pens.—No attempt should be made to sharpen the pens in order to get a finer record. Adjustment of the pen should be made, however, with the proper instruments so that the pens will read correctly that element which they are supposed to record. When a pen is inked it should last about one week, but in case of the quadruple register, the pad which inks the points giving the wind direction should be inked every day. Inspection of all instruments should be made regularly so that they will give correct values of that which they are supposed to give, and so that the slight repairs which may be necessary can be made at once, thus necessitating only short breaks in the record. The ink used in all the registering instruments is made with a glycerine base. This ink freezes at very low temperatures and evaporates very slowly, but it is somewhat hygroscopic; that is, it absorbs moisture. At times, when the trace becomes very light in color, the pen should be cleaned out with a piece of blotting paper and refilled with new ink.

Theodolite.—If the theodolite has been carried through all the points of adjustment, and is then carefully carried about and carefully cleaned, there is very little that can happen to this instrument of a nature that the observer need repair. If the instrument is accidently thrown to the ground or is leaned against the wall and falls to the floor, it will probably be damaged to such an extent that it will be necessary to send it in to the O. C. S. O. for thorough overhauling by an expert instrument maker. For this reason it is necessary that this instrument be handled with extreme care.

Due to jars and shocks which the theodolite may receive during the instruction period or while being transported, it may be necessary to readjust rather than to repair it. These readjustments should be performed as directed in unit operation No. 1.

In cleaning the instrument great care should be taken with the lens. Only a soft cloth should be used in wiping off the dust. No attempt should be made to polish the lens as one would a window pane. The observer's fingers should never come in contact with the lens, it is probable that the only kind of dirt settling on the lens will be dust from the atmosphere. This can be removed, as stated above, by a clean, soft cloth.

If the cross hairs are not level after the instrument has been leveled and the vernier of the vertical scale placed at zero, it will be impossible to make them so, unless the reticule, or little ring upon which the cross hairs are attached, is actually rotated. This should not be done by the observer, as it is quite possible that he will move the crossing of the hairs out of the optical center of the telescope by so doing. It is not necessary to have the cross hairs vertical and horizontal for balloon work.

Light oil should be used on all the moving parts, but in extremely small quantities, since too much oil will cause them to become gummy and interfere with the smooth working of the instrument.

General remarks.—All instruments sent to stations are packed in the best possible manner. The boxes containing them should be opened with care. Sometimes an instrument is broken while being removed from its wrappings. This can be avoided by using proper precautions in unpacking. In preparing a delicate instrument for shipment to the O. C. S. O., care should also be taken that it is packed so as to arrive in as good condition as it left the station. This means that the covers, if any, should be tied down well and all parts of the instrument which are likely to be injured by a railroad journey removed and wrapped separately or fastened in some manner so as to prevent injury. All meteorological instruments are repaired in the O. C. S. O., Washington, D. C.

MILITARY METEOROLOGY

A GENERAL DISCUSSION

1. Two kinds of meterological information are used in connection with military installations and operations. These are statistical and current.

STATISTICAL METEOROLOGY

2. By statistical meteorological information is meant the information that may be gathered from records of past observations for a period sufficiently long to warrant some faith being put in the conclusions that may be drawn. A period of 5 to 10 years is usually long enough, depending on the elements of which information is desired and the use to which the information is to be put.

3. In general, statistical meteorological information is of value in connection:

(1) With many military installations of more or less permanent character; and

(2) With the distribution of material and personnel whether it be among training stations or along a battle front.

4. If a field for training in chemical warfare is to be installed in a given locality it is apparent that site A, which has a great percentage of winds the speed of which is too high for the use of gas, is not so advantageous as site B, perhaps not more than 10 or 20 miles distant, with a much smaller percentage of high winds. The latter site may easily offer twice as many days in the year suitable for the use of gas, and consequently for training personnel, as the former. A variety of terrain is important when experimental work in the use of gas is contemplated.

5. An artillery training camp and range will be located where visibility is best and where the number of training days with opportunity for observation of fire is consequently large.

6. Probably the installation most dependent on statistical meteorological information is the airdrome. Considered as a harbor approached by aerial routes, it is possible to determine very approximately the number of days in a year, season, or month in which ingress and egress are comparatively easy and safe. In a given locality this number may be very different for sites at no great distance apart because it is dependent chiefly on surface conditions. After planes have got well into the air they can take care of themselves under conditions which would result in crashes if they were near the ground in the act of landing. The layout of the field and the orientation of buildings and hangars in any airdrome should be made with reference to the prevailing wind and the directions from which storm winds most frequently come.

7. In connection with the installation of refrigerating plants, a knowledge of the highest temperatures experienced and the usual duration of excessively hot spells is of fundamental importance. The mean monthly rainfall, the time of freezing up, and of spring thawing are of prime importance to engineers in connection with road building, control and bridging of streams, and water supply. Transportation and all supply services are thus directly affected.

8. Other illustrations might be given, but the above suffice to show that most military installations, even those of a temporary nature, are best made when account is taken, among other things, of the meteorological records of the localities concerned.

9. The distribution of material and personnel within any zone of military operations is controlled to a greater or less degree by the meteorological characteristics of the zone as shown in the records of its past weather. It is known to everyone that the distribution of clothing, food, shelter, heat, and light is so controlled.

10. The prevailing wind by months as shown by, say, a 10-year record is probably the best available guide for the concentrations on certain parts of a battle front of Chemical Warfare Service or artillery troops and material used in gas-offensive operations. It is also an aid in the distribution of material and personnel of whatever service for protection or defense against enemy gas and the care of gassed men and animals.

11. Light data, the times of moonrise, moon on meridian, and moonset, sunrise and sunset, and the duration of twilight have been found of value by the searchlight section of the Engineer Corps, by antiaircraft units, and by night bombing squadrons of the Air Service in the distribution of lookouts and other personnel and in the preparation and distribution of material. Incidentally these charts have been of interest to any troops or civilians occupying places marked for aerial attack by the enemy.

12. Without multiplying illustrations it may be stated that the work of all supply organizations, especially where considerable time is needed for preparation and concentration of material, depends on when and where operations are to take place, and these in turn are to an important degree dependent on seasonable weather.

CURRENT METEOROLOGY—FORECASTS

13. After installations, whether permanent or temporary, have been made, communications established, and personnel and material distributed—i. e., after preparations requiring a comparatively long time, say six months or one month, depending on the extent or intensity of the contemplated operations, have been made—a

carefully made short-time forecast of the weather based on current observations will often be found of value in determining the zero hour. This short-time forecast may be a very detailed one for the following five or six hours or it may be more general and cover the following two or three to five or six days, depending on the operation.

14. Such operations as the transfer of airplanes from one field to another at some hundreds of miles distant, night or day bombing expeditions, gas offensive with cloud gas or projectors, etc., are the type of operations needing detailed short-time forecasts.

15. A decided advantage may be obtained if in the case of a larger operation, say, a sustained attack on a considerable length of front, the attack may be started at the beginning of a spell of favorable weather that will last for two or three days or longer. Favorable weather for an operation does not necessarily mean what is commonly designated as fine weather. The element of surprise may more than outweigh the inconvenience of a fog cover, or winds favorable for the use of gas may be of sufficient advantage to offset the fact that such winds are accompanied by a cloudy sky. The nature of the operation determines these things. It follows that a capable meteorological officer, familiar with the plans for an operation of almost any sort or extent, can furnish information of decided value to those directing such operations.

16. The information required in a forecast of meteorological conditions depends on the use to be made of it. Air units want to know what the air movement will be both at the earth's surface and to heights including the highest flying levels, the amount and height of clouds, visibility, and precipitation. Horizontal visibility as affected by the presence of fog and haze, as well as vertical visibility as affected by these conditions and also by the presence of clouds, are of interest, the former for balloon units, or almost any "réglage" work, the latter for reconnaissance, including photographic work. A bombing unit leaving its airdrome for an operation of some hours' duration is not only concerned about the conditions to be encountered en route to and from its objective. It is especially concerned with whether or not it will have a clear field to land on when it returns. The clear nights usually chosen for such operations are frequently accompanied by early morning fogs. The forecaster's statement of the time the fog will begin may therefore determine which of several objectives will be chosen, since it determines the time available for the expedition. Squall and high-wind warnings are of especial interest to all Air Service units.

17. Gas operations, both offensive and defensive, especially when cloud gas or projectors are used, are dependent to a great extent on surface air movement and on surface air temperature, the former

because it has to do with the gas reaching its objective, the latter because it has to do with evaporation and consequently with the effectiveness of the gas or its concentration in the air mass carrying it. At the time of the advent of the American Expedition Forces on the front the element of surprise was of prime importance in any gas attack—this because of the development of protective measures against gas. Unless a new gas can be used against which no protective measures have been devised, expert meteorological advice becomes the all-important element in a surprise attack. Observation may indicate that the general air movement is favorable for an attack, but the enemy has this information as well. The effect of topography on the local air current at points so near the objective that observations can not be made must be deduced from a knowledge of the slope, of the air density, and of the adiabatic constants of the air mass contaminated with the poisonous or other gas being used. It is often quite possible to "pull off" safely effective local gas attacks when observations of the general air movement indicate conditions unfavorable for gas attack in the sector. This type of detailed short-time forecast is better done at or near the place of the attack, but may be based upon carefully prepared topographic charts and done at some point farther to the rear.

18. In the forecast or outlook for two, three or more days ahead the information desired by officers directing operations is of a more general nature. A statement in general terms of the air movement at the earth's surface and aloft, of cloud, fog, rain, or other precipitation, of the temperature, and of the visibility to be expected may be of considerable assistance in determining the zero hour or in operating after or in case zero hour has been determined. In the case of secondary operations, as a rule, zero hour can not be determined by meteorological conditions. Nevertheless the forecast is of value to officers conducting such operations because weather may affect the terrain over which they operate, rendering it more or less difficult. Supply trains, movement of guns to new positions, etc., may require additional personnel and material in places in order to keep up and function. Reduction of positions by artillery may be rendered uncertain in case of low cloud or fog and other means for their reduction, or perhaps an increased attacking force provided. Other illustrations might be given.

19. In every case an officer directing an operation must take chances with various elements entering into its success or failure. Where the weather has been an important factor these officers have expressed appreciation of the form in which the Meteorological Section, S. C., A. E. F., issued its forecast, a direct statement regarding future weather conditions accompanied by the forecaster's estimate expressed as odds in favor of its being right.

CURRENT METEOROLOGY—EXISTING CONDITIONS

20. Information of current meteorological conditions is also needed in order to correct for their effect on range and deflection of projectiles, on the drift of airplanes, and on the speed and direction of sound travel. It is also of immediate use in handling captive observation balloons.

21. The temperature, pressure, humidity, and movement of the air to the height reached by a projectile are needed in correcting for the effects of these elements on its travel. Air density is a function of the first three elements named. This and the speed and direction of air movement are the essential factors which must be taken into account. Air viscosity is rather directly related to air temperature.

22. Meteorological conditions begin to affect the projectile from the time it leaves the gun until it lands. The effect of the variation from standard of the conditions in any layer of air is proportional to the time the projectile spends in that layer provided the shell passes twice through the layer; i. e., when the target is at approximately the same level as the gun. When the target is to be reached before the projectile gets to the highest point of its trajectory, as is usually the case with antiaircraft targets, the effect in any layer is proportional to the time the projectile spends in the layer, and to the time of its travel from this layer to the target.

23. The importance of the upper layers of air is evident when it is considered that a projectile spends half its time in the upper one-fourth of the height of its trajectory. If the variations in meteorological conditions with height were linear or arithmetic an observation of these conditions at two-thirds the height of the trajectory would furnish the data needed to correct for atmospheric conditions. This is so nearly the case for low trajectories, say, under 500 yards, that this method of correcting them may be used. In general the variations with height in meteorological conditions are either logarithmic or, from a mathematical point of view, lawless. A different method must therefore be employed in getting corrections for trajectories of 500 yards or greater height. In practice the conditions observed in each 500-yard layer of air passed through by the projectile are considered separately, weighted with the proper time factor, and then combined for the total height of the trajectory. Thinner or thicker layers of air might be considered depending on whether greater or less accuracy is desired. In reducing meteorological data for the use of artillery, accuracy and speed are of prime importance. Various methods are employed. The Meteorological Section, Signal Corps, has developed a graphic method by means of which all reductions are accurately made and the message coded for transmission within

less than a minute after the last observation of the series had been made. Immediate transmission of the reduced data by radio enables artillery to use them while they are valid; i. e., before conditions have perceptibly changed.

24. The data required by the Air Service in determining the speed and drift of airplanes and in connection with the use of captive balloons consist in actual air movement at all levels concerned in these operations. These data were got out graphically and simultaneously with the artillery and antiaircraft data.

25. It has been found by experiment that the rate and direction of travel of sound coming from enemy guns is more affected by the air movement at about 100 yards above the earth's surface than by that at higher or lower levels. Especially careful observations of winds at this level are furnished.

ORGANIZATION FUNCTIONING

26. In the above discussion and illustration it appears that practically all branches of the military organization derive value in one way or another from suitable meteorological information and that certain information is essential to the proper functioning of air, artillery (including antiaircraft), gas, and sound ranging units. Statistical meteorological information may be obtained from Weather Bureau records, but these records should be handled by meteorologists if rational useful conclusions are to be drawn from them. All current meteorological information needed is readily classified, as shown by the above discussion, into (1) anything in the nature of a forecast and (2) information of existing conditions.

27. The furnishing of these three sorts of information—statistical, forecast, and existing conditions—determine the organization needed. Existing conditions are best furnished by a local station established at the place where the data are used and observing at sufficiently frequent intervals to keep up with the changing atmospheric conditions under observation. These local stations, reporting their observations from a sufficiently large area into a central station, enable the forecaster to state with a fair degree of accuracy the weather that may be expected in a given part of the area for a given period. The detail of such a forecast depends on the size of the area and on the length of time ahead for which the forecast is made. Forecasts for larger areas and for longer times ahead are the more general. When observations made at the local stations have been recorded and properly filed they become available for statistical use.

28. The idea that a special sort of local meteorological station should be created and maintained for air, another for artillery, and

still others for gas, sound ranging, and forecast is entirely erroneous, and its logical result is duplication of effort and inefficiency from any point of view. It is inconceivable that any one of these services will be isolated or operating independently on any sector of a modern battle front or even in a training area. An artillery range must have its air units for observation. It will doubtless occasionally shoot gas shells. A sound-ranging unit in training can find practice here in ranging either for the guns firing or for the shell bursts. It is the same air movement that influences the projectiles fired on this range, that drifts the airplanes observing the fire, that must be taken account of in handling observation balloons, that deflects or changes the rate of speed of sound, and that carries along the poisonous or asphyxiating gas. The same may be said of the other meteorological elements concerned. One observation station therefore is sufficient for the range. For the same reason one observing station is sufficient for a given sector of front and can serve every activity within that sector. The extent of a sector served by one meteorological station depends on how meteorological conditions change along the front. This in turn depends on a number of factors, such as latitude, proximity to oceans, lakes, or rivers, and on topography. The boundaries of such of such a sector should be left as much as possible to the meteorologist.

29. The distribution of observing meteorological stations is therefore a purely regional question. The personnel of these stations should be directly responsible to the headquarters station of the meteorological organization and should maintain their positions in the sector regardless of the combatant units holding it. Any military activity or activities within a region properly covered by such a station can most economically and efficiently be served by one such station. Any other arrangement means duplication of technical equipment, of personnel, and of communications. It often happens that remote stations serving no immediate local purpose must be established and maintained because of the value of their reports to the forecaster. The reports from the stations in Iceland, Valencia, or the Azores have frequently proved of the utmost importance to the Meteorological Section, Signal Corps, American Expeditionary Forces, in forecasting for the Argonne or for the Lorraine sector in the summer and autumn of 1918.

30. The distribution of stations of the Meteorological Section, Signal Corps, American Expeditionary Forces, was on the regional plan and practically ideal. Six stations served the entire front from the Moselle River to the Argonne forest. These stations each observed every 4 hours of the 24. Data obtained in each observation were immediately transmitted by radio to air, artillery, and sound

ranging units in the vicinity. Special observations were made when called for by any unit. Observations for gas units have been made as frequently as four times an hour during critical periods. Data were transmitted to gas units by telephone. These front-line stations were located from 8 to 13 kilometers back of the front trenches. They operated in pairs, the hours of observation being staggered, thus avoiding interference in sending by radio and making data available every two hours in the sector served by a pair of stations. The first pair observed in even hours, the second in odd, and the third in even hours again.

31. Eighteen stations of the type "Observation stations S. O. S." served all fields and ranges used for training. Their distribution, however, was such that no squall got through to the American sector undetected and for which due warning was not given all units concerned. These stations were also well placed from the forecasters' point of view.

32. A "field headquarters" and "forecast station Z of A" combined was located about one-half mile east of Colombey-les-Belles. This station was fully equipped for its work in every way, including a 24-hour telegraph and telephone service as well as a "listening" radio station by means of which the work of the front line stations could be followed and reports regularly received from German stations on the other side of the line. The 24 observing stations reported into the headquarters station by telegraph or telephone. These reports, together with reports from French and British sources received in exchange, formed the basis of the forecasts issued four times daily, and on special occasions as called for, by the headquarters station.

33. Following are tables of organization of meteorological company and of meteorological equipment:

TABLE 209 W.—*Meteorological Company, Signal Corps (war strength)*

July 5, 1921

	1	2	3	4	5	6	7
1	Units	Specialist rating	Symbol No.	Company head quarters and forecast section	Headquarters observation section	(3) Mobile observation sections	Total
2	Captain ([a])			1			1
3	First lieutenants				1	3	4
4	Total commissioned			1	1	3	5
5	Master sergeants (inclusive			2			2
6	Assistant forecasters			(2)			
7	Technical sergeant (inclusive).			1			1
8	Observer and computer.			(1)			
9	First sergeant			1			1
10	Staff sergeants (inclusive)				1	3	4
11	N. C. O. in charge station.				(1)	(3)	
12	Sergeants (inclusive)			5	1	3	9
13	Mess			(1)			
14	Observers [a] and computers.			(4)	(1)	(3)	
15	Privates, first class; and privates (inclusive).			13	9	30	[b]52
16	Chauffeurs	V		(2)			
17	Cooks, first	IV		(1)			
18	Cooks, assistant	V				(3)	
19	Motorcyclists	VI		(1)	(1)	(3)	
20	Observers and computers, meteorological.	I			(1)		
21	Observers and computers, meteorological.	II				(2)	
22	Observers and computers, meteorological.	III			(2)	(1)	
23	Observers and computers, meteorological.	IV			(1)	(3)	
24	Observers, meteorological.	V			(1)	(6)	
25	Observers, meteorological.	VI			(2)	(6)	
26	Unclassified			(9)	(1)	(6)	
27	Total enlisted			22	11	36	69
28	Aggregate			23	12	39	74
29	Cars, motor, 5-passenger			1			1
30	Motorcycles with side cars.			1	1	3	5
31	Trucks, cargo, 1½-2 ton			1			1
32	Pistols			23	12	39	74

8 — Remarks

[a] Commanding company and in direct charge of forecasting.

[b] Includes 17 privates 1st class, 35 privates.

Summary of specialist ratings:

First class	1
Second class	2
Third class	3
Fourth class	5
Fifth class	12
Sixth class	13
Total	36

BASIC ALLOWANCES OF EQUIPMENT SPECIAL FOR METEOROLOGICAL COMPANY, FIELD CONTROL SECTION, AND FIELD OBSERVATION SECTION, SIGNAL CORPS

Circular 169, W. D., 1921 (tables of basic allowances) is supplemented by adding to the tables enumerated therein the following tables prescribing the basic allowances of individual and organizational equipment special for meteorological company, and separate meteorological detachment, Signal Corps.

TABLE IV–H

Branch	Article	Company head-quarters and forecast section	Head-quarters obser vation section	Three mobile obser-vation sec-tions	Total war set for field and gar-rison service	Separate meteorological sections	
						Field control section	Field obser-vation section
	METEOROLOGICAL EQUIPMENT						
S	Anemometer, hand ML–62	--------	1	3	4	1	1
S	Anemometer, Robinson type, with cups and buzzer ML–58	--------	1	3	4	2	1
S	Bag, tool service, complete, RE–11	--------	1	3	4	1	1
S	Barometers, aneroid, type ML–9	--------	1	3	4	1	1
S	Barometers, mercurial, type ML–2	--------	2	3	5	2	1
S	Barograph, recording aneroid barometer, type ML–3	--------	1	3	4	1	1
S	Battery, BA–1	--------	4	6	10	2	2
S	Battery BB–28B	--------	2	6	8	2	2
	Books:						
S	Dictionary, English, medium size	--------	1	--------	1	1	--------
S	Instructions, meteorology	1	1	3	5	1	1
S	Meteorology, text	1	1	3	5	1	1
S	Meteorological Tables (Smithsonian)	1	1	3	5	1	1
S	Psychrometric Tables	2	2	6	10	4	2
S	Case, barometer, ML–48	--------	2	3	5	2	1
S	Case, for instrumental equipment, BC–30	--------	1	3	4	1	1
S	Case for plotting boards	--------	1	3	4	1	1
S	Clocks, alarm	--------	2	3	5	2	1
S	Cloth, black, 20-yard rolls	--------	2	3	5	1	1
E	Compass, prismatic, luminous dial with case	--------	1	3	4	1	1
S	Connectors, Fahenstock	--------	25	25	50	20	10
S	Cylinders, steel, filled with 200 cubic feet hydrogen	--------	30	30	60	15	15
E	Drafting equipment company	--------	5	--------	5	1	--------
Q	Flashlight complete, with extra battery and bulb, TL–95	--------	10	10	20	5	2
	Hydrogen gas, cubic feet	--------	3,000	9,000	12,000	3,000	3,000
S	Gauge, rain and snow, type ML–17	--------	1	3	4	1	1
S	Gauge, rain-tipping bucket, ML–30	--------	2	--------	2	1	--------
S	Hose cock, special type, ML–56	--------	4	6	10	2	1
S	Hose coupling, special type, ML–49	--------	3	3	6	1	1
S	Instrument shelter, type ML–41	--------	1	3	4	1	1
S	Hydrograph, type ML–16	--------	1	3	4	1	1
S	Interrupter, Western Electric Co., 151–A	--------	2	6	8	2	2
S	Kit, inspectors pocket, complete, TE–5	--------	2	3	5	1	1
S	Plotting boards, type ML–57	--------	1	3	4	1	1
S	Plotting boards, type ML–55	--------	1	3	4	1	1
S	Psychrometer, sling type ML–24	--------	5	10	15	4	3
S	Register, quadruple, type ML–27	--------	1	--------	1	1	--------
S	Register, single, type ML–28	--------	--------	--------	--------	--------	1
S	Rotor, psychrometer, ML–74	--------	1	3	4	1	1
S	Slide rule, 16-inch, K. & E	--------	1	3	4	2	1
S	Scales, celluloid (for use with plotting boards) ML–70, 71, 72	--------	5	15	20	5	5
S	Rule, brass, ML–63	--------	1	3	4	1	1
S	Sunshine recorder, type ML–20	--------	2	--------	2	2	--------
S	Support, anemometer, and wind vane, 20-foot, type ML–31	--------	1	--------	1	1	--------
S	Support, instrument shelter, wood, type ML–42	--------	1	3	4	1	1

TABLE IV–H—Continued

Branch	Article	Company head-quarters and forecast section	Head-quarters observation section	Three mobile observation sections	Total war set for field and garrison service	Separate meteorological sections: Field control section	Separate meteorological sections: Field observation section
	METEOROLOGICAL EQUIPMENT—continued						
S	Support, anemometer, and wind vane, 7-foot, type ML–29	--------	3	--------	3	1	--------
	Support, thermometer, Townsend, type ML–54	--------	1	3	4	1	1
S	Telephone, type EE4	1	--------	3	5	1	1
S	Headset, type EE–70 (connecting block is fitted with waterproof transmitter cut-out)	--------	2	6	8	2	2
S	Theodolite, with tripod, conplete, type ML–47	--------	2	4	6	2	1
S	Thermograph, type ML–18	--------	1	3	4	1	1
S	Thermometer, maximum, type ML–4	--------	4	6	10	4	3
S	Thermometer, minimum, type ML–5	--------	4	6	10	4	3
S	Thermometer, general service, type ML–7	--------	4	6	10	4	2
S	Tubing, rubber, heavy ½-inch inside diameter, 5-foot lenghts	--------	2	3	5	1	1
O	Watches, wrist, luminous dial, jewel, with wristlets	--------	2	6	8	2	2
S	Wind vane, tranch ML–73	--------	2	3	5	1	1
S	Wire, outpost, twisted pair, miles, W44	--------	1	--------	1	½	½
	TRANSPORTATION						
Q	Cars, motor, 5-passenger	1	--------	--------	1	1	--------
Q	Motorcycles, with side cars	1	1	3	5	1	1
Q	Trucks, cargo 1½–2 ton	1	--------	--------	1	--------	--------
	MISCELLANEOUS EQUIPMENT						
Q	Ax, with helve	--------	2	3	5	1	--------
S	Ax, hand, 5½-inch bit	--------	1	3	4	1	1
Q	Board, clip	--------	4	6	10	5	2
Q	File, flat, 8-inch, bastard	--------	2	3	5	1	1
Q	Lantern, complete with glove and wick	--------	4	6	10	2	1
Q	Padlocks	--------	10	20	30	5	5
Q	Mimeograph set, complete	--------	1	--------	1	1	--------
Q	Pens, special register	--------	5	15	20	5	5
Q	Pickax with helve	--------	2	3	5	--------	--------
O	Pistols, automatic, caliber .45	--------	--------	--------	[1] 74	--------	--------
Q	Ranges, field No. 2	--------	1	3	4	1	1
Q	Saws, hand, crosscut, 8 points, 26-inch	--------	5	--------	5	1	--------
Q	Saws, hand, rip, 6 points, 26-inch	--------	1	--------	1	1	--------
Q	Shovels, short handle	--------	5	--------	5	1	--------
Q	Tent, pyramidal, complete with poles, pins, hood, tripods, etc	--------	2	3	5	1	1
S	Typewriter	--------	2	4	6	2	1
	SUPPLIES, SIX MONTHS' ALLOWANCE						
S	Balloons, pilot, assorted, ML–50, ML–51, 52–53	--------	3,000	6,000	9,000	1,500	1,500
Q	Ink, special register, bottles	10	10	30	50	10	10
Q	Candles	--------	400	600	1,000	100	100
Q	Clips, paper	500	1,500	3,000	5,000	1,000	1,000
Q	Envelopes, franked	500	500	1,000	2,000	500	500
Q	Erasers, ink	10	10	30	50	10	10
Q	Erasers, pencil, hard	10	10	30	50	10	10
Q	Erasers, pencil, soft, "Art Gum"	25	25	50	100	20	20
Q	Ink, fountain-pen, bottles	5	5	10	20	10	10
Q	Ink, drawing, black, bottles	5	5	10	20	10	10
Q	Ink, drawing, red, bottles	--------	5	5	10	1	1
	METEOROLOGICAL BLANK FORMS						
	No. 1. Monthly record of observations	--------	40	60	100	20	20
	No. 2. Daily observation sheet	--------	300	900	1,200	300	300
	No. 20. Squall reports	--------	140	360	500	100	100
	No. 50. Elevation and position of instruments	--------	4	16	20	10	10
	No. 51. List of instruments on station	--------	4	16	20	10	10

[1] One for each officer and enlisted man.

TABLE IV-H—Continued

Branch	Article	Company headquarters and forecast section	Headquarters observation section	Three mobile observation sections	Total war set for field and garrison service	Separate meteorological sections: Field control section	Separate meteorological sections: Field observation section
	METEOROLOGICAL BLANK FORMS—continued						
	No. 60. Comparative barometer readings	--------	20	80	100	20	20
	No. 80. Correction of mercurial barometer for temperature	--------	8	12	20	10	10
	No. 101. Single register sheet	--------	600	--------	600	--------	200
	No. 102. Quadruple register sheet	--------	200	--------	200	200	--------
	No. 103. Wind scale for use on Form 102	--------	10	--------	10	10	--------
	No. 110. Barograph record sheet	--------	400	--------	400	100	100
	No. 120. Thermograph record sheet	--------	400	--------	400	100	100
	No. 130. Hygrograph record sheet	--------	400	--------	400	100	100
	No. 201. Pilot balloon ascension report	--------	2,000	4,000	6,000	1,200	1,200
	No. 203. Weekly summary of pilot balloon observations		100	100	200	100	100
	No. 202. Wind aloft report	--------	3,600	8,400	12,000	2,400	2,400
	No. 204. Altitude, speed direction graph	--------	1,000	4,000	5,000	1,000	1,000
	No. 205. Pilot balloon telegraphic summary	--------	1,000	1,000	2,000	500	500
	No. 300. Requisition blank forms for meteorological supplies	25	25	150	200	100	100
•	No. 301. List of Signal Corps meteorological forms	5	5	10	20	10	10
Q	Nails, 6d common wire, pounds	5	5	10	20	10	10
Q	Nails, 16d, common wire, pounds	5	5	10	20	10	10
Q	Oil, clock, ½-ounce bottles	2	2	6	10	5	5
Q	Paper, carbon, boxes, 8 by 10½ inch	2	2	6	10	10	10
Q	Paper, cross section, 20 inches wide, rolls 20 yards long	6	6	18	30	1	1
Q	Paper, drawing, rolls	6	6	18	30	1	1
Q	Paper, manifold, reams 8 by 10½ inch	25	25	50	100	10	1
Q	Paper, scratch, pads, 8 by 10½ inch	50	50	100	200	100	50
Q	Paper, transparent, for lanterns, yard, rolls, 20 yards	25	25	50	100	20	20
Q	Paper, typewriter, reams, 8 by 10½ inch	2	2	6	10	5	1
Q	Paste, bottles, quarts	2	2	6	10	5	1
Q	Pencils, drawing, soft	50	50	100	200	50	50
Q	Pencils, blue	20	--------	--------	20	20	--------
Q	Pencils, red	20	--------	--------	20	20	--------
Q	Rubber, bands, No. 14 boxes	5	5	10	20	5	2
Q	Twine, balls	10	10	20	40	10	10

E—Procured by Engineer Corps.
Q—Procured by Quartermaster Corps.
O—Procured by Ordnance Corps.

TABLE OF BASIC ALLOWANCES OF EQUIPMENT FOR COAST ARTILLERY METEOROLOGICAL STATIONS

Number required	Meteorological equipment
1	Anemometer, indicating, with buzzer and cups, type ML-58.
1	Barometer, aneroid, type ML-9.
1	Barometer, mercurial, type ML-2.
1	Case, barometer, wood ML-48.
E 1	Compass, prismatic I-24.
1	Instrument shelter, cotton region, type ML-41.
1	Plotting board, type ML-55.
1	Plotting board, type ML-57.
1	Support, 7-foot, type ML-29.
1	Support, instrument shelter, type ML-42.
1	Support, Townsend, type ML-54.
2	Telephones, head and breast sets, EE-70.
1	Theodolite, with tripod, complete, type ML-47.
2	Thermometers, type ML-7.
O 1	Watch, wrist.
1	Hose cock, ML-56.
6	Cylinders, steel, for hydrogen.
200	Wire, twisted pair, feet, W-40.
1	Hose coupling, type ML-49.
2	Scales, ML-70, ML-72.
4	Tubing, rubber, 4½ feet, ⅛-inch inside diameter.
1	Pattern for lantern.
,200	Hydrogen gas, cubic feet, compressed in steel cylinders.
300	Balloons, pilot, rubber, ML-50.
500	Balloons, pilot, rubber, ML-51.
1	Oil, clock, bottle.
1	Rubber bands, box.
800	forms, printed, meteorological, 201.
1	Paper, roll, transparent, for lantern.

WORKS ON METEOROLOGY

Book	Author	Publisher
Meteorology	A. E. M. Geddes	Blackie & Sons, London.
Meteorology [1]	W. I. Milham	McMillan Co., New York.
A popular Treatise on the Winds	Wm. Ferrel	Wiley & Co., New York.
Physics of the Air	W. J. Humphreys	J. P. Lippincott Co., Philadelphia.
Weather Forecasting in United States.	Professor Henry and others	Government Printing Office.
Weather Prediction	L. F. Richardson	Cambridge University Press, Cambridge, Mass.
Forecasting Weather	W. N. Shaw	Constable & Co., London.
Charts of the Atmosphere for Aeronauts and Aviators.	A. Lawrence Rotch and Andrew H. Palmer.	Wiley & Sons, New York.
Principles of Aërography	A. G. McAdie	Rand McNally Co.
Handbook of Climatology	J. Hann, translated by R. D. Ward.	McMillan Co., New York.
Climates of the Continents	W. G. Kendrew	Clarendon Press, Oxford, England.
Civilization and Climate	Ellsworth Huntington	Yale University Press.
Evolution of Climate	C. E. P. Brooks	Benn Bros., London.
Smithsonian Meteorological [1] Tables.		Government Printing Office.
Meteorology and Aeronautics, Report No. 13. [1]	W. R. Blair	Do.

[1] These books may be obtained from the Chief Signal Officer.

OUTLINE OF PROCEDURE FOR TAKING OBSERVATIONS

The object of the present information topic is to present a detailed procedure to meteorological personnel for the taking of observations and for doing the general work at a meteorological station.

At most stations the following outline of observations is followed:

SCHEDULE

7 a. m.	Wind aloft observation.
7.40 a. m.	Surface observation.
9.30 a. m.	Wind aloft observation.
10 a. m.	Cloud observation.
12 N.	Cloud observation.
1 p. m.	Wind aloft observation.
2 p. m.	Cloud observation.
3.40 p. m.	Surface observation.

The time of taking observations as given above is varied at some of the stations because of local needs. The general theory is that the first wind aloft observation should be taken as early as possible and the last surface observation should be taken as late as possible. In general, all work should be included between the time of reveille and retreat.

At all stations the observer who comes on duty first should examine the recording instruments in the office for the purpose of seeing that all are in good working order and that suitable records are being obtained. The instruments exposed either on the ground or on the roof should be examined carefully when the first surface observation is being taken for the same reasons. If it is found that there is insufficient time for correcting the faults of the instrument a note should be made and the instruments fixed as soon as practicable. If the fault of the instrument is serious, report of the fact should be made to the meteorological observer in charge or to the meteorological officer. Every effort should be made to make all minor repairs at the station, but if an instrument is out of order it should be surveyed, after which it may be sent to the office of the Chief Signal Officer for repairs, accompanied by the survey. In general, all instruments should be thoroughly cleaned once a week, except the anemometer, which should be cleaned and oiled once a month. The instruments in the meteorological office, however, should be dusted carefully once each day.

OUTLINE OF PROCEDURE AT AVIATION STATION

To make a sounding, chart a balloon observation, and reduce wind data for use in aviation requires the services of two or three men. If three men are employed, one man sets up the theodolite at the observation point, the second man inflates the balloon, and the third man prepares the plotting board and the forms for recording the observation and computing the data. These preparations should be begun in sufficient time to be completed by 7 a. m., when the balloon is released. The observer who releases the balloon then aims the theodolite on it by means of the gun sights, while the other observer follows the balloon with the theodolite. During this observation the second observer keeps the theodolite trained upon the balloon, and the first observer reads the angles and telephones them to the computer at the plotting board. The computer enters the data upon the forms, plots the balloon run, obtains wind data therefrom, and finally prepares the message for the Air Service.

After the balloon observation is finished the theodolite observer should then carefully carry the theodolite back to the office, dusting it, oiling the screws and joints if necessary, and in every way putting it into condition for the next observation.

As soon as this wind aloft observation is completed it will be nearly time for the first surface observation at 7.40 a. m. This observation should be taken by the observer who inflated the balloon and read the angles on the theodolite. Before 7.40 a. m. he should carefully prepare what materials he needs for this observation, and begin taking the various elements of the observation at exactly 7.40. Twenty minutes is thought sufficient for this observation; that is, to make all the readings, reduce them, enter the data on the proper forms, and prepare a message if necessary.

Observations during the remainder of the day will be done in the same manner as those just described. The observer last leaving the meteorological office should examine all instruments, making sure of a good record for the ensuing night.

It is advisable that the different duties be rotated weekly in order that each man may become familiar with all phases of the meteorological work. To keep an observer on one branch of the work defeats the object of training; and by teaching of the personnel all branches of the work, no observations are missed on account of the absence of any member of the detachment.

MAKING A BALLOON SOUNDING, CHARTING THE SAME, AND REDUCING WIND DATA THEREFROM FOR USE IN ARTILLERY

To do this work requires from three to four men. The first observer prepares the balloon for ascension; the second observer sets up the theodolite; the computer takes his position at plotting board, ML–55, and records data as they are called off to him, plots the horizontal projection of the balloon's path, and obtains the wind data therefrom. The fourth man takes his position at board ML–57, and as the data are called off to him by the observer at board ML–55 he plots the ballistic wind and prepares the message for artillery. If only three men are used at this observation, then it is more efficient for the observer at board ML–57 to prepare the balloon for ascension and as soon as it is released to take up his position at board ML–57 and catch up on his part of the work during the intervals.

GENERAL DUTIES

It will be the duty of the observer in charge to assign to himself and to his assistants equitable proportions of the work of the office; that is, the preparations of whatever forms and reports are necessary, the cleaning of the instruments, keeping them in adjustment, making whatever minor repairs seem necessary, and other jobs that come up from time to time.

The outside apparatus such as the instrument shelter and the supports for the wind vane and anemometer should be painted at least once each year.

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TRAINING MANUALS

(Corrected to January, 1925)

Manuals prepared by the Signal Corps, relating to signal communication specialists are titled as follows:

	Training Manual
Basic Signal Communication:	
*Students Manual	No. 20
*Instructors Guide	No. 21
Telephone Switchboard Operator:	
*Students Manual	No. 22
*Instructors Guide	No. 23
Message Center Specialist:	
*Students Manual	No. 24
*Instructors Guide	No. 25
Radio Operator:	
*Students Manual	No. 26
*Part I—Sets.	
**Part II, Vol. I—Code Practice.	
*Part II, Vol. II—Tactical Radio Procedure.	
*Instructors Guide	No. 27
*Part I—Sets.	
*Part II, Vol. I—Code Practice.	
*Part II, Vol. II—Tactical Radio Procedure.	
Telegraph Operator:	
*Students Manual	No. 28
Instructors Guide	No. 29
Meteorological Observer:	
*Students Manual	No. 30
Instructors Guide	No. 31
Pigeoneer:	
*Students Manual	No. 32
Instructors Guide	No. 33
Basic Electrician:	
Students Manual	No. 34
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Radio Electrician:	
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Instructors Guide	No. 37
Telephone Electrician:	
Students Manual	No. 38
Instructors Guide	No. 39
Telegraph Electrician:	
Students Manual	No. 40
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