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# FM 6-15

DEPARTMENT OF THE ARMY FIELD MANUAL

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*Supersedes by FM 6-15  
25 Mar 70*

# ARTILLERY METEOROLOGY

HEADQUARTERS OF  
DEPARTMENT OF THE ARMY  
FIELD SUPPORT AGENCY, 21 ST. ARMY  
FORT BELLE, VA.



HEADQUARTERS, DEPARTMENT OF THE ARMY  
JUNE 1962

FIELD MANUAL }  
 No. 6-15 }

HEADQUARTERS,  
 DEPARTMENT OF THE ARMY  
 WASHINGTON 25, D. C., 28 June 1962

## ARTILLERY METEOROLOGY

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**PART ONE**  
**GENERAL**  
**CHAPTER 1**  
**INTRODUCTION**

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### **1. Purpose and Scope**

*a. Purpose.* This manual is concerned with the meteorological needs of the artillery arm. It describes the sources of meteorological data within the field army and describes in detail how these data are developed. This manual also describes other meteorological data peculiar to the needs of the field army.

*b. Scope.* This manual covers the ballistic meteorological problem and the method of determining ballistic densities, temperatures, and winds. It presents the techniques of measuring and reporting high altitude winds for radiological fallout prediction measurement of low level winds and temperature for sound ranging, measurement of low level winds for rockets, and measurement of winds by radar. It describes the organization of the Air Weather Service within the field army and describes the manner in which artillery meteorological sections support the Air Weather Service. Operations of meteorological

units under extremes of weather are described. The method of measuring the Temperature-Humidity Index is described. It also describes maintenance, inspection, decontamination, necessary destruction of equipment, and safety precautions for meteorological sections and equipment. The material presented herein is applicable without modification to both nuclear and nonnuclear warfare.

### **2. Changes or Corrections**

Users of this manual are encouraged to submit recommended changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to Commandant, United States Army Artillery and Missile School, ATTN: AKPSITL, Fort Sill, Okla.



## CHAPTER 2

### ELEMENTARY METEOROLOGY

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#### Section I. GENERAL

### 3. Introduction

Meteorology of the weather-adage type is at least as old as the Bible; however, extensive knowledge of actual behavior of the atmosphere has been acquired rather slowly through the centuries. Meteorology as a science was actually founded about one hundred years ago by the French astronomer, Le Venier. The science of meteorology has advanced significantly since World War I. Some fundamentals of meteorology are discussed in this chapter to provide the artillery meteorologist with a basic understanding of weather.

### 4. Definition

Meteorology is defined as the science dealing with the atmospheric phenomena. In addition to the physics, chemistry, and dynamics of the atmosphere, meteorology includes many of the direct effects of the atmosphere upon the earth's surface, the oceans, and life in general.

### 5. Significance of Meteorology to the Army

The employment of rockets and missiles, the necessary dispersion of ground forces, the rapid displacement of both men and materiel on the nuclear battlefield, and the efficient use of nuclear weapons are all affected by the weather. There is an urgent requirement for meteorological information within the field army, and accurate meteorological information must be obtained in more detail over increasing areas for dissemination to all commands. The accomplishment of this task is a joint responsibility of the Air Weather Service of the U.S. Air Force and the meteorological services organic to the field army. The discharge of this joint responsibility is directed by AR 115-10/AFR 105-3. The artillery meteorologist is not expected to make weather forecasts, since forecasting is an Air Weather Service responsibility. However, he should be able to distinguish major types and changes of weather which will affect the validity of a meteorological message.

### 6. The Sun and the Earth

The sun is the original source of heat energy for both the surface of the earth and the earth's atmosphere. All changes and motions in the atmosphere are caused directly or indirectly by the energy radiated from the sun. There are two motions of the earth which affect the weather. First, the rotation of the earth on its axis each 24 hours causes day and night and produces the major wind belts of the earth. Second, the earth revolves in an elliptical orbit about the sun at a velocity of 29.8 kilometers per second, making one complete revolution per year. The average distance between the sun and earth is approximately 148,993,400 kilometers, being less in December and greatest in June. The seasons result from the fact that the axis on which the earth rotates is tilted at an angle of  $23\frac{1}{2}^{\circ}$  from a perpendicular to the plane of the earth's orbit. During the northern hemispheric summer, the North Pole tilts toward the sun and days lengthen for all locations in the Northern Hemisphere. During the northern hemispheric winter, the North Pole points away from the sun and colder temperatures prevail owing to the shorter duration of sunshine and the effect of the sun's rays striking the earth at a more acute angle. Twice a year, during the fall and spring equinoxes, the sun's rays fall equally on both hemispheres with day and night of equal duration everywhere on the earth. During the year ( $365\frac{1}{4}$  days), the earth loses approximately the same amount of heat it receives from the sun. During the spring, the Northern Hemisphere gains more heat than it loses. This accumulation of heat continues until late July when maximum warmth is reached, then slowly diminishes until late August. During the fall, the northern hemisphere loses more heat than it receives and begins to cool. The entire process is like starting a fire in a stove. Initially the roaring fire heats the room rather slowly, but the room remains warm for a considerable time after the fire has died down. This heat lag phenomenon also accounts for the fact that the warmest time of day is usually about 1500 hours and not at noon when the sun's rays are most direct.

## Section II. THE EARTH'S ATMOSPHERE

### 7. Composition

a. The earth's atmosphere is a mixture of transparent gases extending from the surface of the earth upward. Its exact upper limit is not known but is estimated to be well above 1,000 kilometers. The composition of this sea of air, which clings to the earth's surface because of the force of gravity, is nearly uniform from place to place throughout the world, with the exception of its moisture content. This is to be expected, since continual mixing occurs as the wind blows, and the surface is heated by the sun then allowed to cool. Rather surprising though is the fact that this mixture is nearly constant up to 80 kilometers, the beginning of the thermosphere. The atmosphere thins out with elevation so rapidly that approximately one-half of its weight is packed into the lower 6 kilometers.

b. The two most abundant gases of dry air are nitrogen, which accounts for nearly four-fifths of the total, and oxygen, which accounts for the other one-fifth. Carbon dioxide, argon, ozone, and various other gases make up approximately 1 percent of the permanent gases of the atmosphere. The air encountered in nature also contains a variable amount of invisible water vapor which normally is concentrated in the lower part of the atmosphere. From the standpoint of weather, water vapor is the most important constituent of the atmosphere. Clouds, fog, rain, and snow can form only as a result of this vapor changing into water droplets or ice crystals. The atmosphere also contains literally billions of minute foreign particles, such as dust, combustion products, and salt from sea spray. These particles are referred to as condensation nuclei due to the condensation of water vapor upon them to form clouds and fog. The majority of these solid particles are microscopic salt crystals suspended in the lower layers of the atmosphere.

### 8. Vertical Structure of the Atmosphere

The atmosphere normally is depicted on charts as being divided into layers, each of which possesses certain distinctive characteristics. Thermal characteristics are used herein to divide the atmospheric model (fig. 1) into layers. The data above 20 kilometers, while not official are, taken from a Department of Commerce document known as the U.S. Extension to the ICAO Standard Atmosphere.

a. *Troposphere.* The turbulent layer nearest the surface of the earth, in which practically all storms and clouds occur, is called the troposphere. This layer contains most of the mass of the atmosphere (about three-fourths) and is characterized by an approximately linear decrease of temperature with height. The thickness of the troposphere varies with the season of the year, the latitude, and the current weather situation, the average thickness being about 18 kilometers in equatorial regions and 8 kilometers in polar regions. The rate of decrease of temperature with height is known as the lapse rate. The standard tropospheric lapse rate is about 6.5° Celsius (Centigrade) per kilometer, but, on a particular occasion, the lapse rate may differ considerably from the standard.

*Note.* This lapse rate was agreed upon at the Ninth General Conference on Weights and Measures in 1948 and under standard conditions is defined in the Glossary of Meteorology, 1959.

Strong vertical and horizontal movements of air are developed within the troposphere with wind speed generally increasing with height. The top of the troposphere is known as the tropopause, and it defines a boundary above which convective activity is restricted. The tropopause usually is identified by a temperature of about minus 56° Celsius and a significant change in lapse rate. The tropopause was once thought to be continuous from the equator to the poles but it is now known to have occasional breaks and overlaps resulting in a multiple tropopause in some instances. These breaks are important in connection with jet streams, paths of high velocity winds, which are usually located near these discontinuities in the tropopause. Jet streams, discovered during World War II, may contain winds of 220 knots or more at their core.

b. *Stratosphere.* The layer immediately above the tropopause is called the stratosphere and is characterized by an almost complete lack of clouds and by relatively little turbulence. There is sufficient mixing in the stratosphere, however, to prevent the heavier gases from concentrating near the bottom. The lower part of the stratosphere, from the tropopause up to about 25 kilometers, is characterized by a slight increase of temperature with height (inversion) or by an essentially isothermal lapse rate. Within the upper part of the stratosphere, the temperature rises about 5° Celsius per





kilometer and reaches a peak in the vicinity of 50 kilometers. This warm region lies near the top of a thick layer containing ozone and is the result of absorption of ultraviolet radiation from the sun by the ozone. The total ozone in the atmosphere at normal sea level temperature and pressure would form a layer only 3 centimeters thick. The temperature at the stratopause (or top of the stratosphere) is roughly equivalent to that at the earth's surface.

*c. Mesosphere.* The mesosphere lies above the stratosphere and is a turbulent layer in which the temperature decreases with height. The temperature at the top of the mesosphere, known as the mesopause, is colder than that at the tropopause, reaching a minimum of approximately minus 100° Celsius. Noctilucent clouds, the highest clouds known, are formed near the mesopause. The relentless bombardment of the thinly scattered air molecules by radiation from the sun causes noticeable ionization within this layer of the atmosphere. The lowest of these ionized regions is known as the D region and has the ability to reflect low frequency radio waves. The ion density of these regions generally increases with height above 60 kilometers and goes through a large diurnal variation.

*d. Thermosphere.* The layer immediately above the mesopause is called the thermosphere. Temperature again increases with height and may have a negative lapse rate (inversion) as great as 20° Celsius per kilometer. Rocket research vehicles indicate that the temperature may reach 2,300° Celsius at the thermopause. Oxygen molecules in the thermosphere are gradually dissociated into oxygen atoms by energy from the sun. Gases in this upper region are not well mixed and several bands of ionized air are known to exist in the thermosphere. The phenomenon in the northern hemisphere known as the aurora borealis, or northern lights, occurs in the thermosphere. The auroras are believed to be produced by an influx of charged particles from the sun which collide with oxygen and nitrogen molecules and the excitation causes them to emit light.

*e. Exosphere.* At greater and greater heights, the atmosphere is bombarded so intensely by cosmic rays that air exists only as atoms instead of molecules. This outermost layer of the earth's atmosphere, where the density of atoms is extremely low and collisions between particles are negligible, has been aptly named the exosphere. Between the

thermopause and whatever is determined to be the outer limits of the atmosphere is the exosphere. The temperature at the top of the exosphere is believed to be approximately 10,000° Celsius. It should be remembered that our conventional concept of temperature has little significance at the very low pressures existing above 100 kilometers.

## 9. Transfer of Heat in the Atmosphere

The source of the earth's energy is the sun, which emits both heat and light much the same as an electric radiant heater. This radiant energy from the sun travels with the speed of light for approximately 148,000,000 kilometers through space to the earth. The energy which reaches the earth is partially reflected back into space and partially absorbed. The absorbed energy is converted into heat which is used by the earth-atmosphere system. An important fact is that the sun's energy warms the earth's surface without appreciably heating the bulk of the earth's atmosphere through which it passes. The distribution of temperature in the troposphere is controlled primarily by the heating and cooling of the earth's surface together with the subsequent convective activity. The manner in which air temperature changes horizontally, vertically, and with time, largely governs both weather and upper winds. Since the role that heat plays in the production of weather is of vital importance, an understanding of the various ways by which heat is transferred from one place to another is necessary. The three physical processes of heat transfer are conduction, convection, and radiation.

*a. Conduction.* When the end of a poker is held in a fire, heat will travel toward the opposite end. This means of heat transfer through a substance without any mass motion of the substance itself is called conduction. The thermal conductivity of different substances varies widely. As a rule, metals are good conductors and gases are poor conductors. In the atmosphere, heat is transferred by conduction to and from air which comes in contact with the earth's surface. Since the atmosphere is a gas, it is a poor conductor and only the lower layers next to the surface are affected by conduction. The amount of heat transferred by conduction in the atmosphere is negligible when compared to that transferred by convection and radiation.

*b. Convection.* Transfer of heat by means of physical movement of the medium through which

the heat is transferred is known as convection. In meteorology, convection is a term used exclusively to denote vertical air motion, and the transfer of heat by horizontal movement of air is referred to as advection. Large quantities of heat are continually transferred through the atmosphere by means of convection and advection. The advection process is primarily responsible for the day-to-day changes in the weather. The motion of the atmosphere is quite complex and does not follow a consistent, steady pattern. The layer of air in contact with the surface is warmed by conduction during daylight, which causes it to expand and become less dense. The less dense air rises and is replaced by cooler air from above, thus creating a convective cell similar to that about an open fire. On a small scale, this vertical motion is generally called turbulence and is quite irregular due to unequal heating and cooling of various types of terrain. On a large scale, the vertical motion in conjunction with the horizontal motion carries excess heat from equatorial regions to the cooler areas at higher latitudes. This mass transfer of heat by means of large scale movement of the atmosphere is essential in the overall heat balance which produces the climates of the world.

*c. Radiation.* Radiation is the transfer of heat energy by wave-like motions, similar to radio or light waves, through space without the aid of a material medium. This process is practically instantaneous, since radiant energy travels at the speed of light (299,274 kilometers per second). Radiation is the process whereby heat is transferred from the sun to the earth. The primary method of describing radiation is by its wavelength. All radiation travels in a straight line. The earth and its atmosphere actually receive only a small fraction of the total energy radiated from the sun. The energy that reaches the earth's atmosphere is partially scattered or absorbed by the atmosphere and partially reflected and radiated back into space by clouds and the surface of the earth. The fraction of the incoming radiation which is reflected back into space is called the albedo. The albedo for the earth-atmosphere system under average conditions of cloudiness is about 40 percent. All objects receive and emit radiation in varying amounts. The amount of heat energy emitted depends primarily on the temperature of the radiating body. The higher the temperature of any substance, the more radiation it sends out. The sun, having an estimated temperature of 6,000° Kelvin (par, 11a), emits most

of its energy in the form of a short-wave radiation (the higher the temperature of a substance, the shorter its wavelength of maximum energy emission). Approximately half of the sun's radiation is within the visible range of wavelengths; that is, it can be seen by the human eye. Visible light lies between the ultraviolet (shorter wavelengths) and the infrared (longer wavelengths) portions of the energy spectrum. The solar energy absorbed by the earth is reradiated from the earth in the form of long infrared waves, since the earth's average temperature is in the vicinity of 288° Kelvin. The earth's atmosphere is virtually transparent to the short wave solar radiation but readily absorbs most of the outgoing long wave terrestrial radiation. Thus, the atmosphere is similar to a greenhouse in that it allows a large amount of solar energy to pass through to the earth and holds the heat in by absorbing the outgoing terrestrial radiation. Water vapor in the air is primarily responsible for the absorption of the long wave terrestrial radiation. The atmosphere is heated by the processes of conduction and convection, and by its ability to absorb outgoing terrestrial radiation.

## 10. Atmospheric Pressure

Since the atmosphere is a mixture of gases, it is quite natural to think of air as being very light in weight; however, the total weight of the entire atmosphere is tremendous. If the entire weight of the atmosphere were replaced by an equal weight of water, the water would cover the entire surface of the globe to a depth of 10 meters. The weight of the air pressing down on itself, so to speak, produces atmospheric pressure. Atmospheric pressure is more specifically defined as the weight of a column of air of unit cross section which extends upward from the level of measurement to the top of the atmosphere. It is apparent from this definition that atmospheric pressure always decreases with an increase in altitude (fig. 2). Thus, surface pressure normally decreases as the altitude of the measuring station increases, since the length of the air column above the station becomes less. The rate of change of pressure with altitude is directly proportional to air density. This relationship is expressed mathematically by the hydrostatic equation. Pressure also varies in the horizontal. Pressure values are continuously changing (both in space and with time) primarily because of changes in air density brought about by the variations in temperature and moisture

content of the air. Atmospheric pressure is measured by means of either a mercurial or an aneroid barometer. Although less accurate than the mercurial barometer, the aneroid barometer normally is used in mobile weather stations because it is portable and durable. Pressure may be measured in terms of pounds per square inch (psi), millimeters (mm) of mercury, or millibars (mb.). The millibar unit of pressure is commonly used by the military and most countries of the world. Standard sea level pressure is assumed to be 1013.25 mb. or 760 mm of mercury. A useful conversion factor to remember is that 1 mb. is equal to 0.75 mm of mercury or 0.029 inches of mercury.

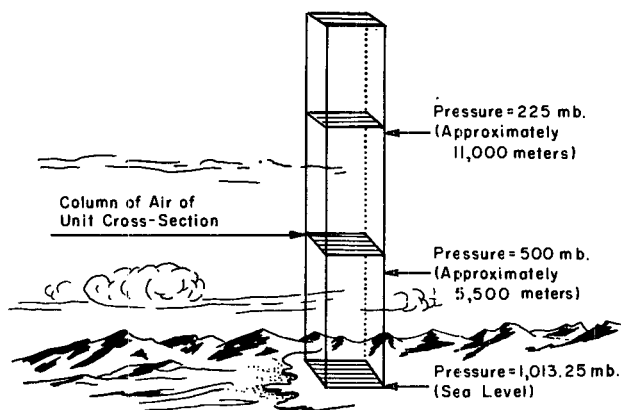


Figure 2. The decrease of atmospheric pressure with an increase in altitude.

## 11. Temperature

Air temperature is a measure of the internal energy which the air possesses. In the atmosphere, this energy causes the air to expand and become less dense. Thus, when a parcel of air is heated, it becomes lighter than the air surrounding it and rises. Air next to the ground tends to assume the temperature of the surface with which it is in contact. The temperature of the surface is mainly determined by the type of terrain and the amount of solar radiation available for heating purposes. The air temperature at any particular location also depends on the previous trajectory of the air. Generally speaking, surface air from high latitudes is cold and that from low latitudes is warm. Since the atmosphere receives most of its heat from terrestrial radiation, temperature normally decreases with height through the troposphere. This change of temperature with respect to height is called the lapse rate. The

standard lapse rate within the troposphere is approximately 6.5° Celsius per kilometer. Under certain conditions, a layer of the atmosphere may have a temperature increase with height. This condition is known as an inversion and may occur at any height in the atmosphere. An inversion just above the ground is quite common during the early morning hours after a clear calm night. This is because the earth's surface has cooled during the night due to its loss of heat through terrestrial radiation with no compensating heat gain from the sun. The base of a well-developed inversion acts as a lid or deterrent to vertical air motion. The tropopause is an outstanding example of this phenomenon. Distinct layers of dust, fog, and smoke as well as low status type clouds are generally associated with inversions. Sometimes the temperature within a layer of air remains constant with height. The lapse rate in this case could be zero, and the layer is said to be isothermal.

a. There are three scales in general use for expressing air temperature. These scales may be distinguished by the values on each scale which are assigned to the melting point of pure ice and the boiling point of water at standard sea level pressure. On the Fahrenheit scale, 32°F. is the melting point and 212° is the boiling point. Another scale is the Celsius scale which has 0°C. as the melting point and 100°C. as the boiling point. The third scale, which was designed for use in scientific equations involving temperature (so that temperature values would be expressed on an absolute scale) is the Kelvin scale. To convert temperature to degrees Kelvin (K.), one simply needs to add the constant 273.16 to the Celsius reading. The melting point of ice on the Kelvin scale is 273.16°K. while the boiling point of water is 373.16° K. At 0° K., there is no molecular motion.

b. The temperature and pressure of the air are specifically involved in computing density. These three variables, temperature, pressure, and density, are related to each other by the equation of state (ideal gas law of physics). At constant pressure, an increase (decrease) in air temperature will cause a decrease (increase) in density. Air density is greater near the earth's surface and decreases steadily with height. The moisture content of air is quite variable, and an increase (decrease) in moisture content causes a decrease (increase) in air density. In determining air density, it would be extremely difficult and cumbersome to compute density changes

caused by moisture variations in the atmosphere. Therefore, another method has been devised for determining the effect of moisture on air density. This method consists of using a fictitious temperature, called the *virtual temperature*, instead of the actual air temperature. Virtual temperature is the temperature which dry air would have in order to be of the same density and pressure as the actual moist air. In determining virtual temperature, the pressure is assumed to be constant; therefore, an increase in either the water vapor (moisture content) or the temperature will lower the density. Thus, the virtual temperature of moist air is always higher than the actual temperature. The difference between these two temperatures becomes greater as the moisture content of the air increases but rarely exceeds 3.5° C.

## 12. Moisture

a. Water, in one or more of its three states, is always present in the atmosphere. The oceans, which cover approximately three-fourths of the earth's surface, provide the major source of moisture for the air. Every day the sun's energy transforms millions of tons of liquid water into water vapor by the evaporation process. This water vapor is then distributed within the atmosphere by air currents. Water vapor represents only a small percentage of the atmospheric gases—about 4 percent by volume in very moist air—and is concentrated in the lower part of the troposphere. Water vapor is, by far, the most important constituent of the atmosphere in relation to weather processes.

b. Experiment has shown that there is an upper limit to the amount of water vapor that can be contained in any given volume of air at a specified temperature. Warm air can hold more water vapor than cold air. Air is said to be saturated at a particular temperature when it contains this maximum amount of water vapor. This moisture content of air can be expressed by several different terms; however, the term understood by the majority of people is relative humidity. Relative humidity is the ratio of the amount of water vapor actually present in the air to the maximum possible amount of water vapor the air could hold at the existing pressure and temperature. Relative humidity is expressed as a percent. When the temperature of moist air increases and the moisture content remains constant, the relative humidity decreases, since the capacity of the air for holding moisture becomes

greater. Relative humidity may be determined by using a psychrometer and psychrometric tables. Another term frequently used to indicate the amount of water vapor in the air is the dewpoint temperature. The dewpoint temperature is the temperature to which air must be cooled, at constant pressure and constant water vapor content in order for saturation to occur.

## 13. Clouds

a. Most weather phenomena are associated either directly or indirectly with clouds. Therefore, an understanding of the significance of certain cloud types will enable observer personnel to make pertinent and timely decisions on the effect of weather on operations. Clouds are composed of millions of water droplets and/or ice crystals suspended in the atmosphere. Clouds are formed when water vapor in the air condenses. It is evident that if no water vapor were present, clouds could not exist.

b. When the air in contact with the earth's surface is not saturated, some of the water from the surface gradually diffuses into the air as gaseous water vapor. This evaporative process continues until a state of equilibrium exists between the vapor pressure of the liquid and the partial pressure exerted by the water vapor in the air. Energy is required to change water into water vapor and is primarily supplied by solar radiation. About 600 calories of heat are needed to evaporate 1 gram of water at 20° Celsius. It is estimated that approximately one-half of the sun's energy that strikes a water surface is used in the evaporation process. The rate of evaporation depends specifically on the dryness of the air above the surface, the speed of the wind, and the temperature of the moist surface (fig. 3).

c. Condensation, as the term is normally applied to the atmosphere, is the process whereby gaseous water (water vapor) is changed into small droplets of liquid water. In order for condensation to occur, there must be something present in the atmosphere upon which the water vapor can condense. Literally billions of minute particles exist in the atmosphere resulting from ordinary dust, combustion products, and sea salt crystals. Clouds and fog are formed by the condensation of water vapor upon these particles, which are known as condensation nuclei. Condensation may result from either lowering the temperature, or decreasing the pressure, or from the addition of more water vapor to the air. In the atmosphere,

condensation (fig. 3) normally occurs when warm moist air rises and cools by expansion. Frontal activity, terrain features, and unequal heating of land and sea surfaces cause the air to rise or to be lifted. During the process of condensation, the heat which was originally absorbed by the water vapor during evaporation is released. Hence, condensation by itself tends to increase the temperature of the surrounding air.

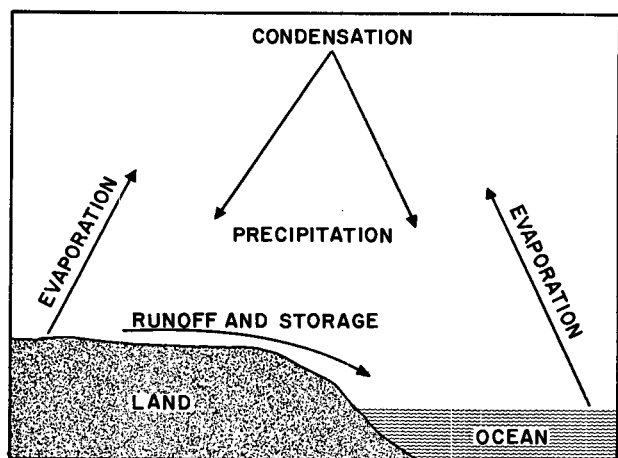


Figure 3. The water cycle.

*d.* Precipitation is visible moisture, either liquid or solid, which falls from a cloud to the surface. Clouds do not always produce precipitation, since the initial water droplets are extremely small and simply float in the atmosphere. Visible moisture may fall from clouds without reaching the earth's surface, because on many occasions it evaporates before reaching the surface. Precipitation occurs when the cloud particles become so large that the pull of gravity overcomes the buoyant force of the surrounding air in the cloud. The size of cloud droplets may be increased by collisions with other droplets, or the freezing of supercooled water droplets on ice crystals. Ice crystals grow quite rapidly as additional supercooled water freezes on them. The term "supercooled" is used to designate liquid moisture which exists in the atmosphere at temperatures below zero degrees Celsius. The cloud particles (liquid or ice) may continue to grow by colliding with smaller particles during their fall to the surface. When the temperature of the atmosphere between the cloud and the surface is above freezing, these falling particles will probably reach the ground as liquid precipitation although frozen precipitation

may occur at relatively high surface temperatures. If the temperature is at or below 0° C., the falling particles usually reach the ground as sleet or snow. If strong vertical currents are present within the cloud, the water droplets or ice crystals are carried to great heights. The particles involved in strong updrafts may become quite large before falling to the ground as large raindrops or hailstones.

*e.* Clouds are classified according to their appearance and by the physical processes which produce them. All clouds, according to their shape, fall into two general categories: cumuliform (cumulus) and stratiform (stratus). Cumulus means heaped or accumulated, and cumulus clouds are always formed by rising air currents. Local showers may be the only result of cumulus clouds; however, severe thunderstorms and extremely strong vertical air currents are usually associated with cumulonimbus clouds. The tops of cumulus clouds may rise or fall at a rate approaching 300 meters per minute. When a layer of air is cooled below its saturation point without pronounced vertical motion, stratiform or sheetlike clouds are formed. The vertical thickness of stratiform type clouds may range from several meters up to a few kilometers. Precipitation, if any, from stratiform clouds generally is continuous with only gradual changes in intensity and covers a relatively large area. These two general categories of clouds may be further classified by altitude into four families: high, middle, low, and towering clouds. Cloud bases of the towering family of clouds may be as low as the typical low clouds, but their tops may extend to, or even above, the tropopause. The mean heights of clouds shown in figure 4 are to be used as a guide only for land stations in temperate latitudes.

- (1) *Below 2,000 meters.* When clouds have their bases lower than 2,000 meters above the surface of the earth, they generally are designated as cumulus or stratus, unless they are producing precipitation, in which case the word "nimbo" is added as in nimbostratus and cumulonimbus. Another common low cloud, with some of the characteristics of both cumulus and stratus is the stratocumulus.
- (2) *Between 2,000 and 6,000 meters.* The word "alto" generally precedes the basic cloud name to designate clouds at intermediate heights. Altocumulus and altostratus clouds are in this category.

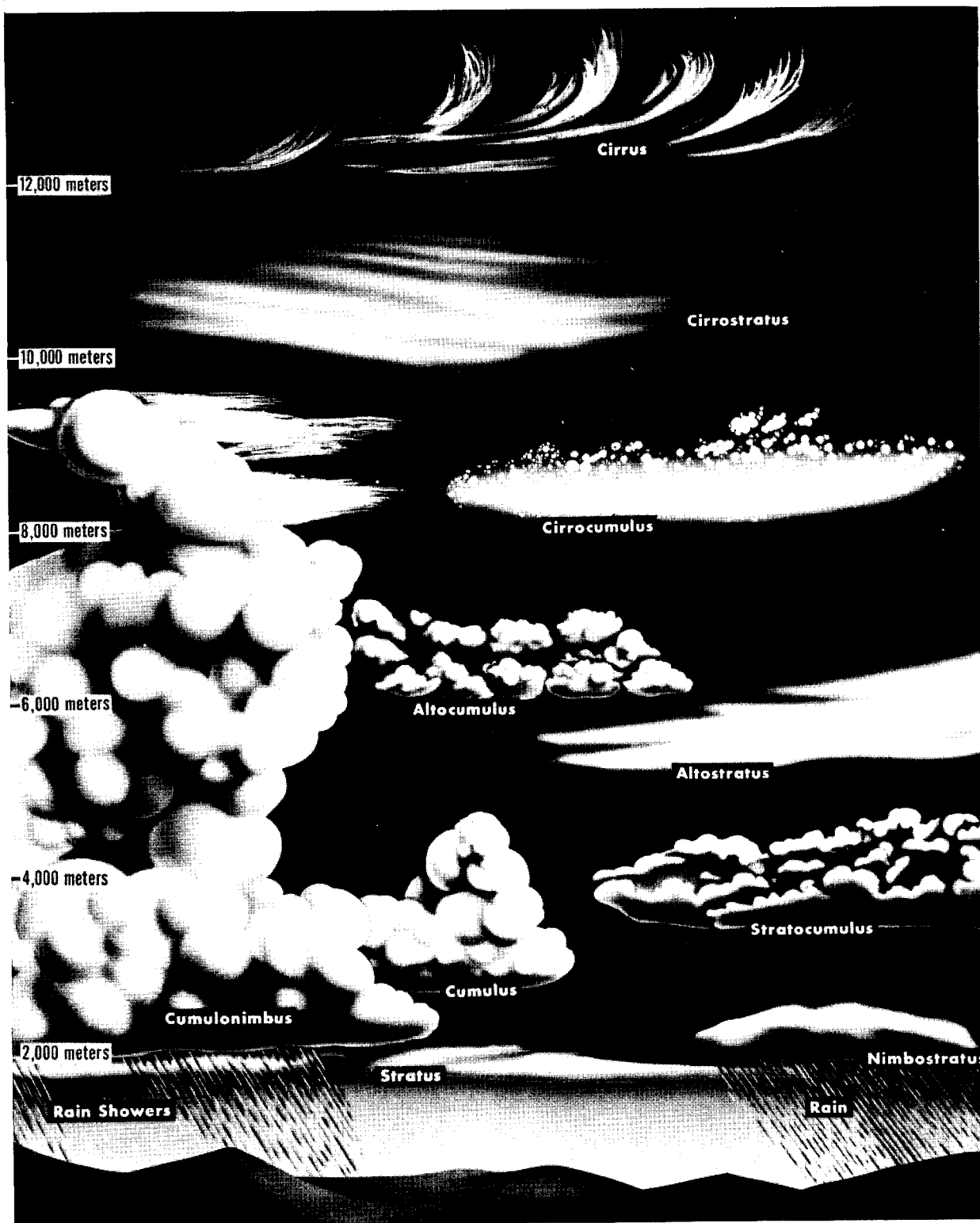


Figure 4. Cloud forms.

- (3) *Above 6,000 meters.* Clouds formed in the upper levels of the troposphere, that is, above 6,000 meters, are composed of ice crystals and generally have a delicate appearance. For these clouds, the word "cirro" is added, as in cirrocumulus and cirrostratus. At still greater altitudes, a fibrous type of cloud, which is given the name "cirrus," appears as curly wisps.

#### 14. General Circulation

*a.* The temperature differences which exist between various locations on the earth produce pressure changes which initiate all air motion in our atmosphere. When the wind blows, a definite set of forces are acting which cause the air to move with respect to the surface of the earth. The forces which are exerted on the atmosphere are gravity, the pressure gradient force, friction, and the apparent force (Coriolis force) due to the rotation of the earth. The pressure gradient force tends to move air from high to low pressure. Since pressure decreases with altitude, an upward force exists. This upward force caused by the vertical pressure gradient is counteracted by the force of gravity which is always directed toward the center of the earth. When these two forces are unbalanced, vertical air currents result. Vertical air motion may occur over large areas where the mean vertical velocities are generally less than 0.2 knots. Vertical air motion which is restricted to a small column, up draft, may have velocities greater than 20 knots. Pressure also varies in the horizontal, producing horizontal pressure gradients, which tend to displace the air in the direction of lower pressure. Although vertical air motion is important in cloud formation and weather, the large-scale wind systems throughout the world consist primarily of horizontal air motion. If the earth did not rotate, the air would always move directly toward lower pressures. The earth's rotation causes a deflective force, which acts at a right angle to the direction of the moving air and tends to balance the pressure gradient force. This deflective force (Coriolis force) causes moving air to deflect to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. The Coriolis force is proportional to the speed of the air and to the sine of the latitude at which the air movement is occurring. Thus, for the same wind speed the Coriolis effect on air motion increases with latitude, being a maximum at the poles and zero at the equator. The horizontal

wind is a result of quasi-balance between the pressure gradient force and the deflective force and will blow in a direction generally perpendicular to these forces (pressure gradient force acts to the left looking downwind, and the Coriolis force acts to the right). The direction of wind is defined as the direction from which the wind blows. When the pressure gradient and the Coriolis forces are exactly balanced for horizontal straight line flow, and friction is neglected, the resulting motion of the air is known as the geostrophic wind. The geostrophic wind blows in a straight line parallel to lines of constant pressure (isobars) with the spacing between the isobars inversely proportional to wind speed. Friction caused by air movement over the surface of the earth is effective in decreasing the wind velocity in approximately the lower 600 meters (the friction layer) of the troposphere. Above the friction layer, the actual wind (averaged over large areas) is very close to geostrophic. Within the friction layer, the decrease in wind speed reduces the Coriolis force, so that the pressure gradient force becomes dominant, and the wind will blow across isobars toward low pressure.

*b.* Around the earth near the equator lies a belt of hot air laden with moisture from the ocean surfaces. This equatorial air, being lighter (due to the high temperature and high water vapor content) than the surrounding air, expands and rises. The equatorial zone is known as the doldrums, since the predominant motion of air near the surface is vertical, and horizontal winds are weak and variable. The following relatively simple average atmospheric circulation pattern, caused by the sun, would exist if the earth did not rotate and its surface were uniform. The rising air of the doldrums flows poleward aloft and converges in the polar regions. As the air travels away from the equator, it becomes more dense due to adiabatic cooling, loss of moisture as it ascends, and loss of heat by radiation into space. The cold dry air sinks to the surface at higher latitudes and begins to travel toward the equator in the lower levels along the earth's surface. If this were the only circulation pattern, low pressures would exist in the vicinity of the equator and high pressures in polar regions.

*c.* Since the earth rotates from west to east, the Coriolis force causes the air to be deflected to the right in the Northern Hemisphere. The air that rises over the hot regions near the equator turns poleward and is deflected to the right becoming a

west wind near  $30^\circ$  north latitude (fig. 5). By the time the air reaches this latitude, it has become dense and some of it descends to the earth's surface and causes a high pressure belt known as the subtropical high. The descending air is compressed, heated, and spread out in both northerly and southerly directions near the surface. The southward flow of air is deflected to the right and becomes the northeast trade winds, and the northward flow of air is deflected to the right and becomes the prevailing westerlies. Only part of the air which flows away from the equator settles in the region of latitude  $30^\circ$  north. The remainder of the air continues to travel aloft toward the pole. This air is quite cold and dense by the time it reaches the polar region and sinks to the surface to spread out and start back toward the equator. The earth's rotation deflects this air to the right causing the polar easterlies. The air traveling north from latitude  $30^\circ$  north and the air traveling south from the north polar regions meet in the vicinity of latitude  $60^\circ$  north and form the polar front. The air from the polar region being much denser causes the warmer air to be lifted until it is caught in the poleward airflow aloft and carried on to the polar region. Thus the averaged circulation pattern has three vertical cells with three major wind belts at the surface of the earth (fig. 5). With this circulation pattern, low pressure belts exist at the equator and latitude  $60^\circ$  north, and high pressure belts exist at latitude  $30^\circ$  north and in the polar region. This general atmospheric circulation pattern is disturbed, however, by the distribution of land and sea masses over the earth and by topography. Water heats and cools much slower than land; therefore, in early winter the ocean is still relatively warm compared to the colder land temperatures. During the early part of the summer, the ocean is still cold compared to the warmer land temperatures. This differential heating results in organized pressure systems which create local circulation patterns which are superimposed on the general circulation system previously described for the rotating earth. High pressures form over land during winter and over oceans during summer, while the reverse is true for low pressures. One result of this unequal heating phenomenon is a large scale seasonal circulation known as the monsoon. The monsoon circulation is best illustrated in eastern Asia where a large land mass, India, extends into the Indian Ocean. The climate of India is actually controlled by the monsoon circulation. During the

summer months in India, the hot land causes low pressure to exist inland resulting in an on-shore wind which brings in moisture-laden air from the ocean. This moist air is mechanically lifted as it travels up the forward slopes of the Himalaya Mountains. Extremely heavy rainfall occurs in this region during the monsoon season, particularly in July. On a much smaller scale, this unequal heating causes a daily circulation pattern along any shoreline. During periods of fair weather, the land is warmed by the sun during the day and cooled by terrestrial radiation at night. This creates a "sea breeze" by day and a "land breeze" by night. Differential heating also causes local circulation patterns to develop in mountainous regions. The air motion is up the mountain slope during the day and down the slope toward the valley during the night. When horizontally moving air is forced to flow over mountains, the air cools as it rises and condensation may occur if sufficient moisture is present. Thus, cumulus clouds and large amounts of precipitation frequently occur on the windward side of mountain ranges (fig. 6). Thermal or convective turbulence often occurs over relatively smooth land on a clear day, as the sun warms the ground and the adjacent air is heated by conduction. The heated air will rise, resulting in small vertical air currents which disturb the horizontal flow of air.

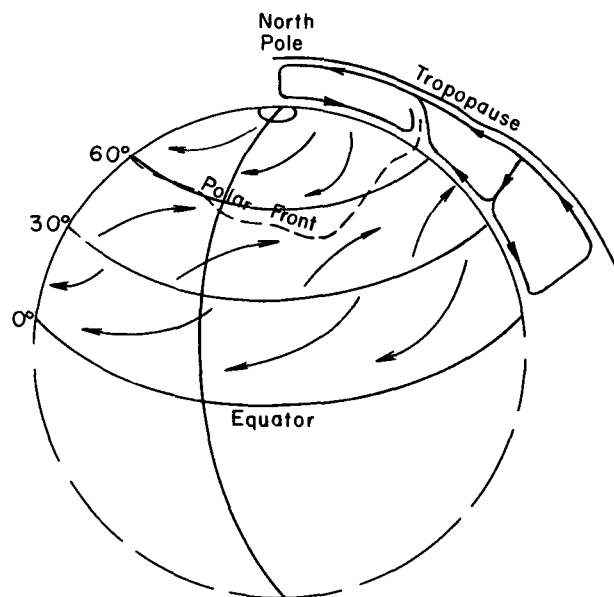


Figure 5. General circulation.





Figure 6. Orographic thunderstorm.

Convective turbulence also may occur when cold air passes over a warm land or water surface, and

becomes warm by contact with the surface and by radiation.

### Section III. AIR MASSES AND FRONTAL ACTIVITY

#### 15. General

The weather over a location at a given time depends on either the character of the prevailing air mass or the interaction of two or more air masses. A group of Norwegian meteorologists initiated the idea of describing weather systems by using the air mass concept. An air mass is a vast body of air whose physical properties, primarily temperature and moisture, are nearly uniform in the horizontal. The transition zone, which may be quite narrow, between two adjacent air masses is called a front or a frontal zone. Large, traveling storm systems are associated with fronts and greatly affect the weather in temperate latitudes. The basis of the air mass concept is that air masses retain their identity even

after they have moved a considerable distance from the region where they originally developed.

#### 16. Source Regions

The properties of an air mass are largely determined by the type of surface over which it forms. A source region for an air mass is an extensive portion of the earth's surface whose temperature and moisture properties are fairly uniform. In order to fulfill the requirements of a good source region, an area should be either all land or all water where the same air will remain near the surface and become stagnant. Many regions of the earth do not fulfill these requirements because of their distribution of land and water surfaces. On the other hand, large snow or ice

fields at high latitudes, large oceans, and large desert areas adequately meet the requirements and are called primary source regions. Secondary source regions exist but the air masses which form over them are rather small in extent and become modified quite rapidly upon leaving the source region. The time required for a mass of air to acquire the properties of an underlying surface varies greatly with the surface and in some cases may take a period of 2 weeks.

**17. Classification of Air Masses**

Air masses are classified according to the type of surface and the latitude of their source regions. The type of surface determines the basic moisture properties, while the latitude establishes the basic temperature characteristics of an air mass. The two types of surface are continental (land) and mari-

time (oceanic). The latitude at which the air becomes stagnant is either polar or tropical. Therefore, air masses originating in polar regions over the ocean are known as Maritime Polar (mP), and those forming over land are called Continental Polar (cP). Similarly, air masses originating in tropical regions are called Maritime Tropical (mT) and Continental Tropical (cT) (fig. 7). When an air mass leaves its source region, the state of equilibrium that existed with the underlying surface becomes disturbed, and the air mass undergoes a modification. The degree of modification depends upon the contrast with the underlying surface and the speed at which the air mass is traveling. The modification process is important, since it affects the stability of the air mass which, in turn, influences the type of weather that may be expected. Therefore, the four basic types of air masses are further identified as warm (w) or

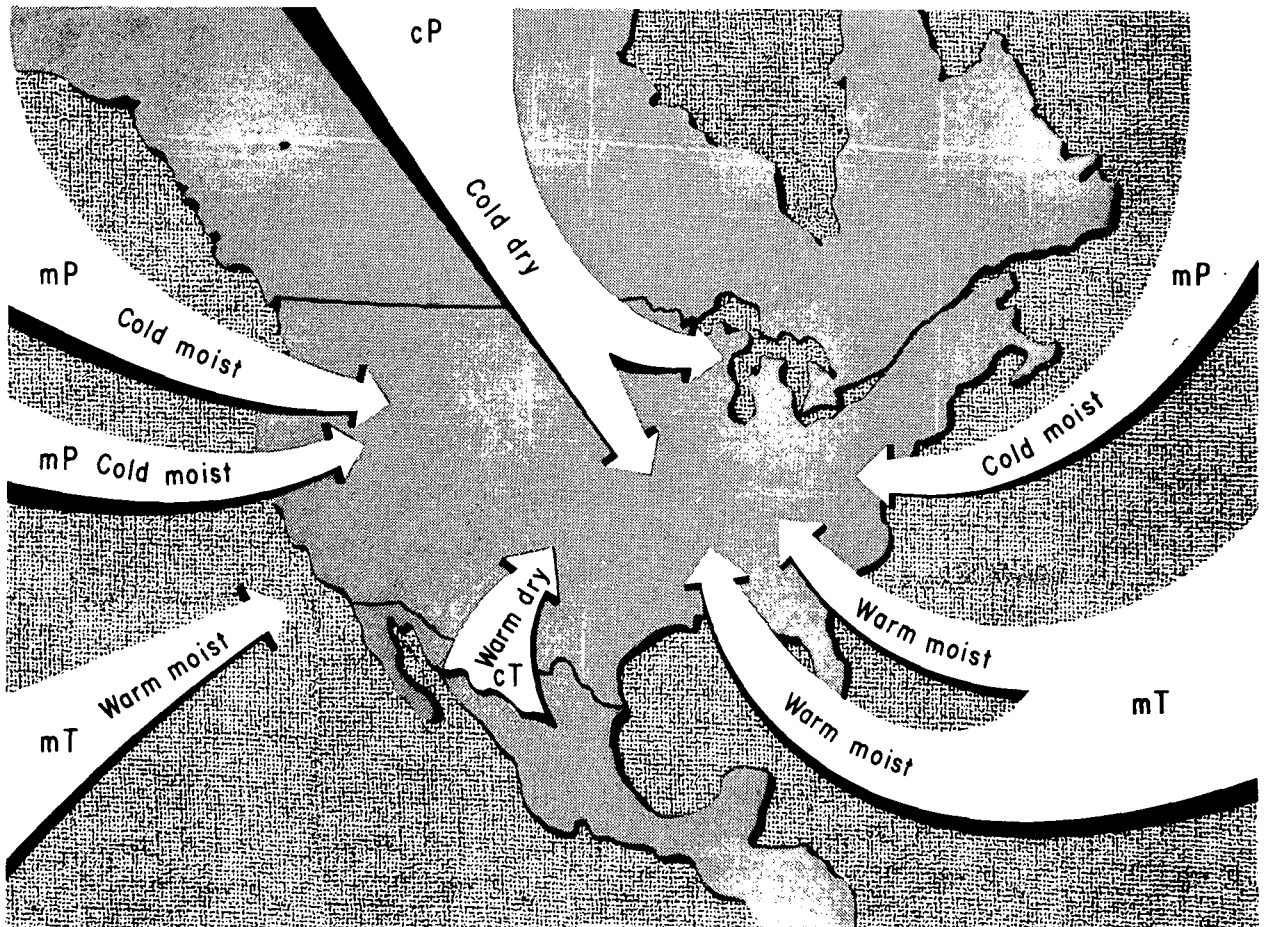


Figure 7. Trajectories of air masses into the United States.

cold (k). This third letter describes the temperature of the air mass in relation to the surface over which it is moving. For example, when a cP air mass moves over a warmer surface it is called a cPk air mass. This air mass will absorb heat from below and develop instability in its lower levels because cold air is lying on top of a warm surface. This unstable condition leads to convective activity and the formation of cumulus clouds which may provide showers or possibly thunderstorms.

## 18. Frontal Characteristics

*a. General.* At the surface, the transition zone (measured normal to the front) may vary from 5 to 80 kilometers and is created when air masses of different basic properties come in contact. This zone is referred to as a frontal surface and its intersection with the earth is shown as a front on weather maps. The frontal surface is not vertical due to the differing densities of the two air masses. The colder air, being more dense, will always wedge under the warmer air mass and cause the warmer air to be lifted. All true fronts actually separate distinct air masses of different densities. On a weather map, a frontal position is characterized by a distinct change in wind direction and a kink in the isobaric pattern, with the kink always pointing toward higher pressure. The weather associated with fronts is called frontal weather and is more complex and variable than air mass weather. The type and intensity of frontal weather is largely dependent on such factors as the slope of the frontal surface (which is propor-

tional to the amount of contrast between the two air masses), the amount of moisture, the stability of the air masses, and the speed of frontal movement. Because of the variability of these factors, frontal weather may range from a minor wind shift with no clouds to thunderstorms, hail, and severe turbulence. The passage of a front may cause rather abrupt changes in the meteorological elements observed at a given location. The magnitude and speed of these changes are factors in determining the frequency of observations by an army meteorological section.

*b. Cold Fronts.* Fronts are classified according to the relative motion of the warm and cold air masses. When cold air replaces warm air at the earth's surface, it is called a cold front (fig. 8). A slow moving cold front has a rather gentle slope, but as it accelerates, the slope becomes steeper (more vertical) near the surface due to the friction of the terrain. Cold fronts normally move faster and have steeper slopes than warm fronts. The advancing wedge of cold air lifts the lighter warm air mass and produces a relatively narrow band of clouds. The type of clouds will depend on the properties of the air masses involved and the speed of the frontal system. Fast moving cold fronts (fig. 9), when lifting moist unstable air, generate cumuliform clouds that are slightly ahead of the front. A line of thunderstorms (squall line) frequently develops parallel to and some distance ahead of rapidly moving cold fronts. The slow moving cold fronts (fig. 10) may have cloud systems

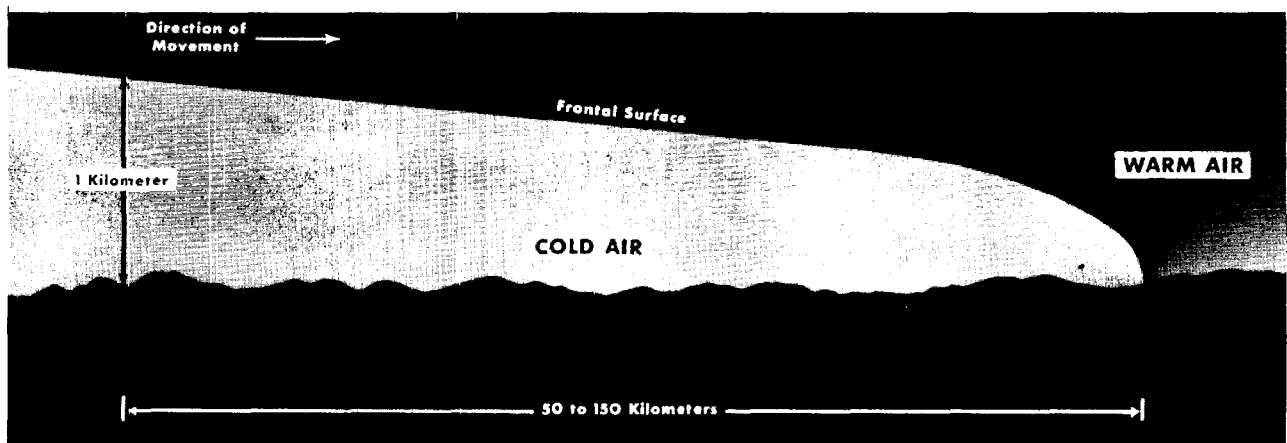


Figure 8. Cold front.

which extend to the rear of the surface position of the front. The clouds will be primarily stratiform when the warm air is moist and stable. When the warm air is quite dry, little or no cloudiness will occur with the passage of a cold front. At the

surface, the passage of a cold front is characterized by—

- (1) An abrupt decrease in temperature.
- (2) A marked shift of surface wind, usually greater than 90°.

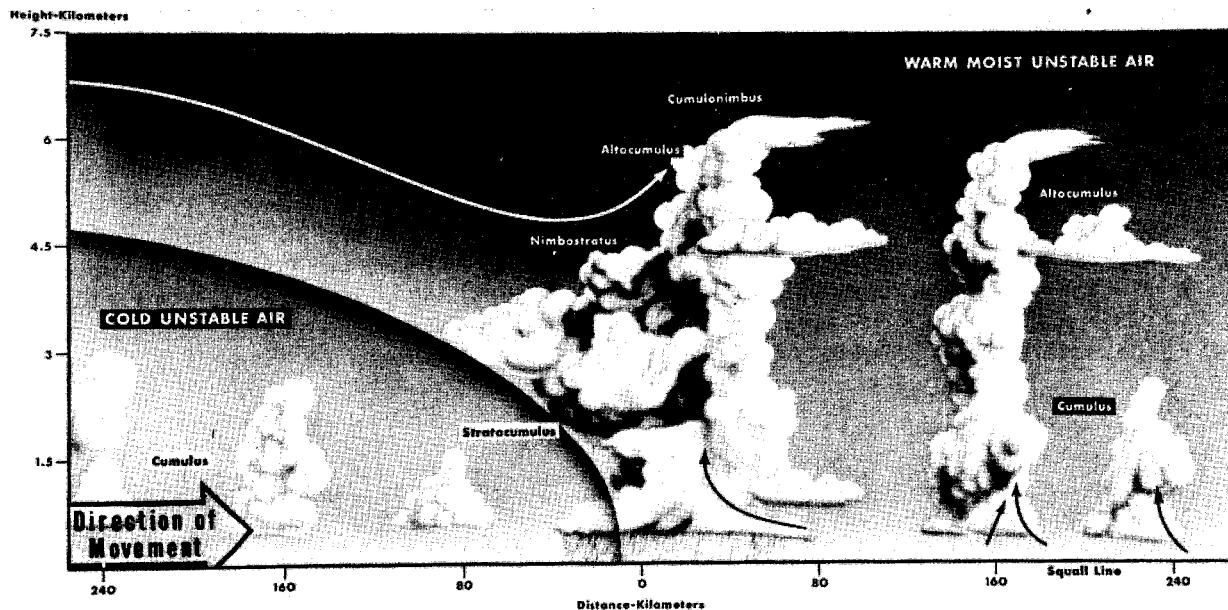


Figure 9. Fast moving cold front.

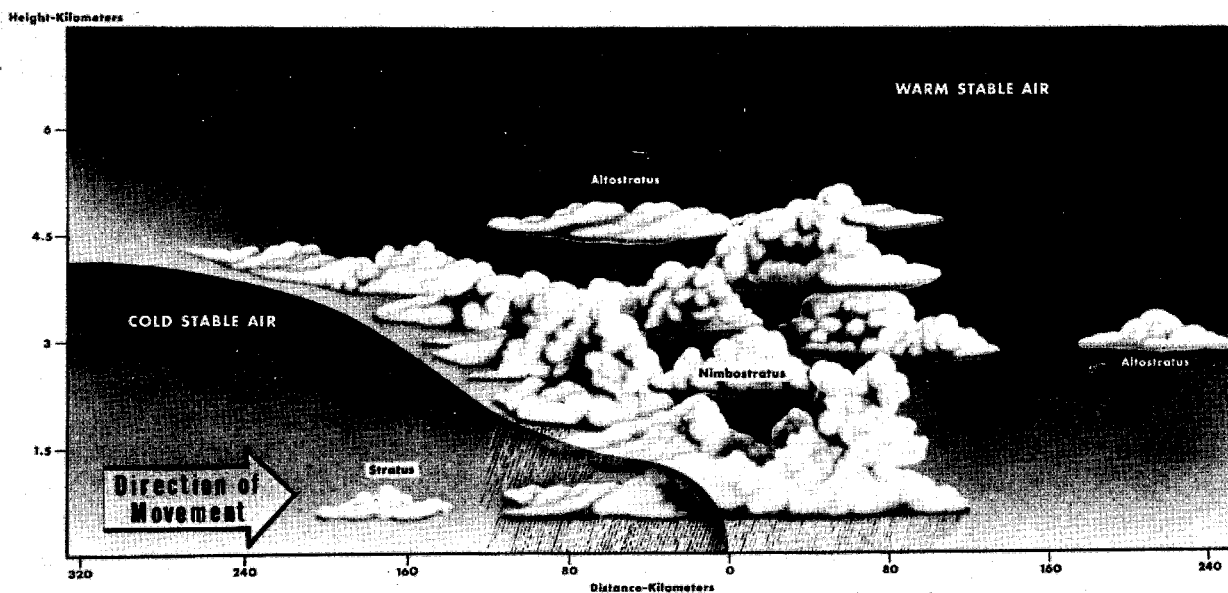


Figure 10. Slow moving cold front.

- (3) A decrease in moisture content of air.
- (4) A marked decrease in pressure as the front approaches and rising pressure after the front passes.

c. *Warm Fronts.* When warm air replaces cold air at the surface, it is called a warm front (fig. 11). The speed of the advancing warm air is greater than that of the retreating cold air; therefore, it flows upward over the sloping wedge of dense cold air.

The force of the rising warm air slowly pushes the cold air back. The friction effect of the earth's surface causes the slope of the warm front to be very flat. The slope of a warm frontal surface has an average value of about 1 to 200. With the same winds, the speed of a warm front is approximately one-half that of a cold front. The clouds associated with warm front weather are predominantly stratiform and extend well ahead of the surface position

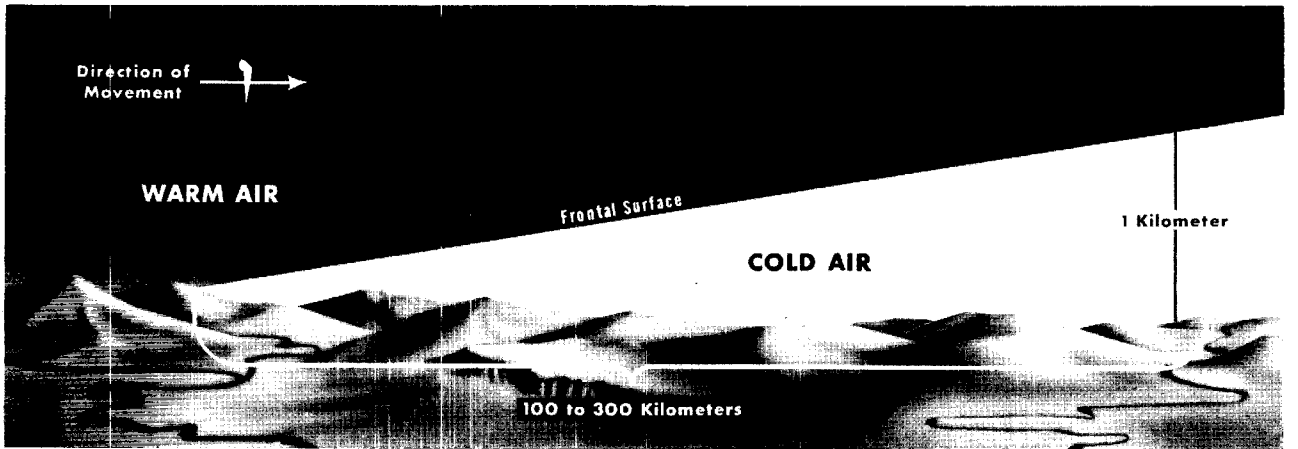


Figure 11. Warm front.

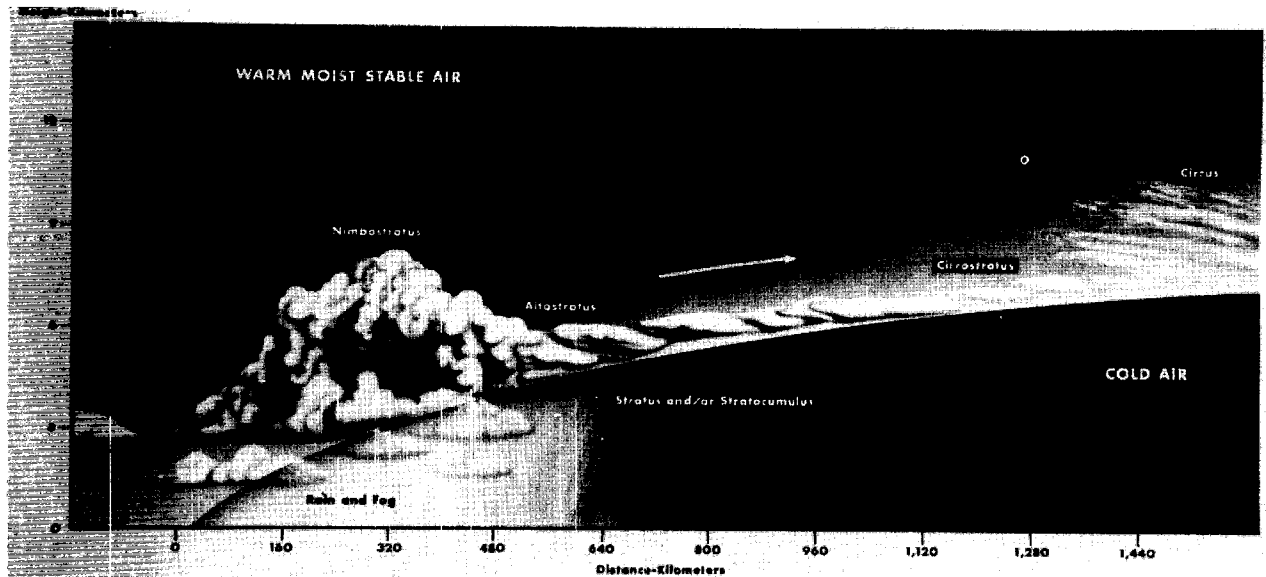


Figure 12. Stable air warm front.

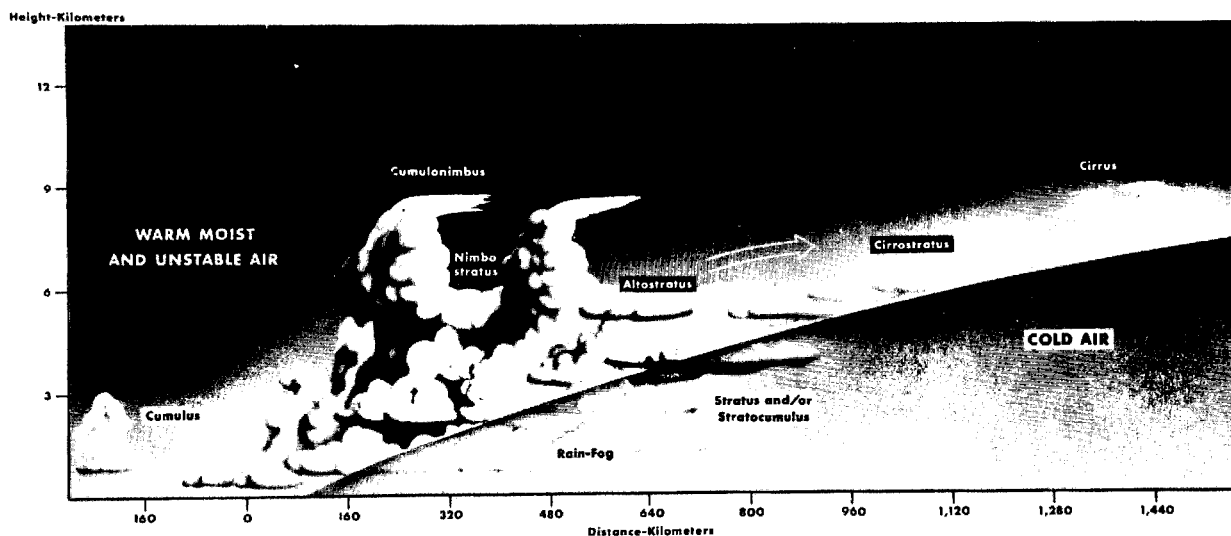


Figure 13. Unstable air warm front.

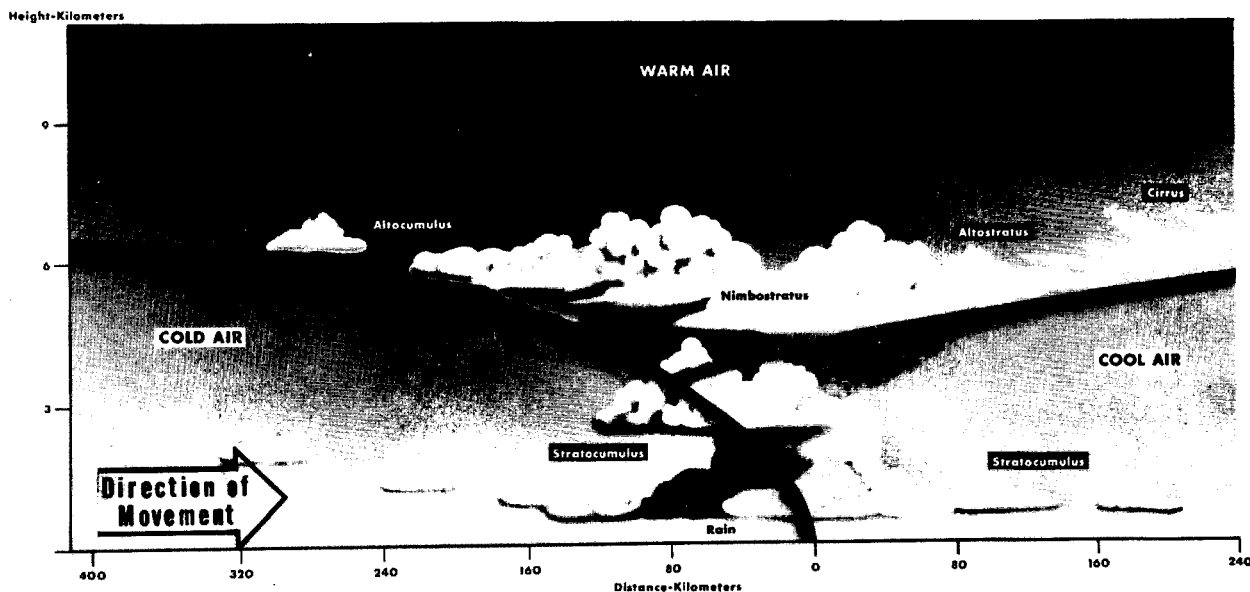


Figure 14. Cold front occlusion.

of the front. The weather depends largely on the stability and moisture content of the overrunning air (figs. 12 and 13). A steady type of precipitation with low ceilings and limited visibility is normal in advance of warm fronts. At the surface, the passage of a warm front is characterized by—

- (1) A marked increase in temperature.

- (2) A slight shift of surface wind, usually less than 90°
- (3) An increase in moisture content of air.
- (4) A decrease in pressure as the front approaches and a leveling off or slowly rising pressure after the front passes.

d. *Occluded and Stationary Fronts.* An occluded

front is formed when a cold front overtakes a warm front and forces aloft the warm air which originally occupied the space between the two fronts (fig. 14). There are two types of occlusions—the warm front occlusion and the cold front occlusion. The type which will occur depends on whether the cold air of the advancing cold front is colder or warmer than the retreating wedge of cold air in advance of the warm front. However, the essential point in both warm and cold front occlusions is that two cold air

masses meet and force the warm air aloft causing extensive cloudiness. The weather associated with an occlusion depends on the properties of the three air masses involved. On occasions, both warm and cold air masses contain almost equal amounts of energy and neither can move appreciably. During the period when little or no frontal movement takes place, the system is known as a stationary front. The weather associated with stationary fronts is quite similar to that accompanying a warm front.

## Section IV. SYNOPTIC WEATHER

### 19. General

Accurate weather forecasting depends on continual observations made by weather stations and military installations spread over a broad geographical region. These observations describe the condition of the atmosphere at specific times and locations to include upper air data. The raw meteorological data are collected and transmitted by teletypewriter to weather centrals. Weather data are transmitted in an international code so that the exchange of vital weather information can be accomplished expeditiously between countries. The observations must be furnished at regular and frequent intervals in order to provide an accurate and continuous weather picture. A large geographical network of stations is necessary, since the weather which may affect our area next week is being developed today in air masses over another region of the earth's surface. A worldwide network of observation stations operates under the World Meteorological Organization (WMO).

### 20. Synoptic Code

Four times a day (0600, 1200, 1800, 2400 hours Greenwich Mean Time (GMT)) each country transmits by teletypewriter the surface weather data gathered from a selected group of its observation stations. The synoptic code which is used to transmit these data always includes the station designator and six groups of five numbers each which commonly are referred to as the universal groups. The significance of each figure in each group is determined by the position of the figure within the group and by the position of the group within the format. Other groups of information and/or words in plain language may be transmitted to clarify the mandatory six groups. When any weather element in the universal groups cannot be

observed, an X is transmitted. The present code, revised in 1955, is international and completely describes most weather phenomena. An explanation of the letters within the universal groups may be obtained from code manuals available at synoptic observing stations.

### 21. The Station Model

The plotting of the surface weather map from the synoptic data is accomplished for each reporting station by use of a station model. This station model has all the meteorological elements of the universal groups arranged in a uniform shorthand system about the station circle (fig. 15). Plotting should always be in ink, preferably black, so that the data will not be obscured during the analysis. The data about the station circle must be legible and should be oriented by reference to the latitude and longitude grid and not by reference to the edges of the map. Each individual develops the order in which he plots the data; however, the wind group should always be plotted first to avoid running the wind shaft through other figures or symbols. When completed, the entire station plot should cover an area the size of a dime.

### 22. Synoptic Chart

The surface meteorological elements, which are observed simultaneously by the network of reporting stations, are plotted to form the surface synoptic chart or weather map (fig. 16). A meteorologist uses the current surface synoptic chart together with upper air charts and adiabatic diagrams to prepare a forecast. The first step in analyzing the plotted weather data is to place the past positions of both fronts and pressure centers on the map. Isobars, or lines of constant pressure, are then sketched at prescribed intervals. For most pur-

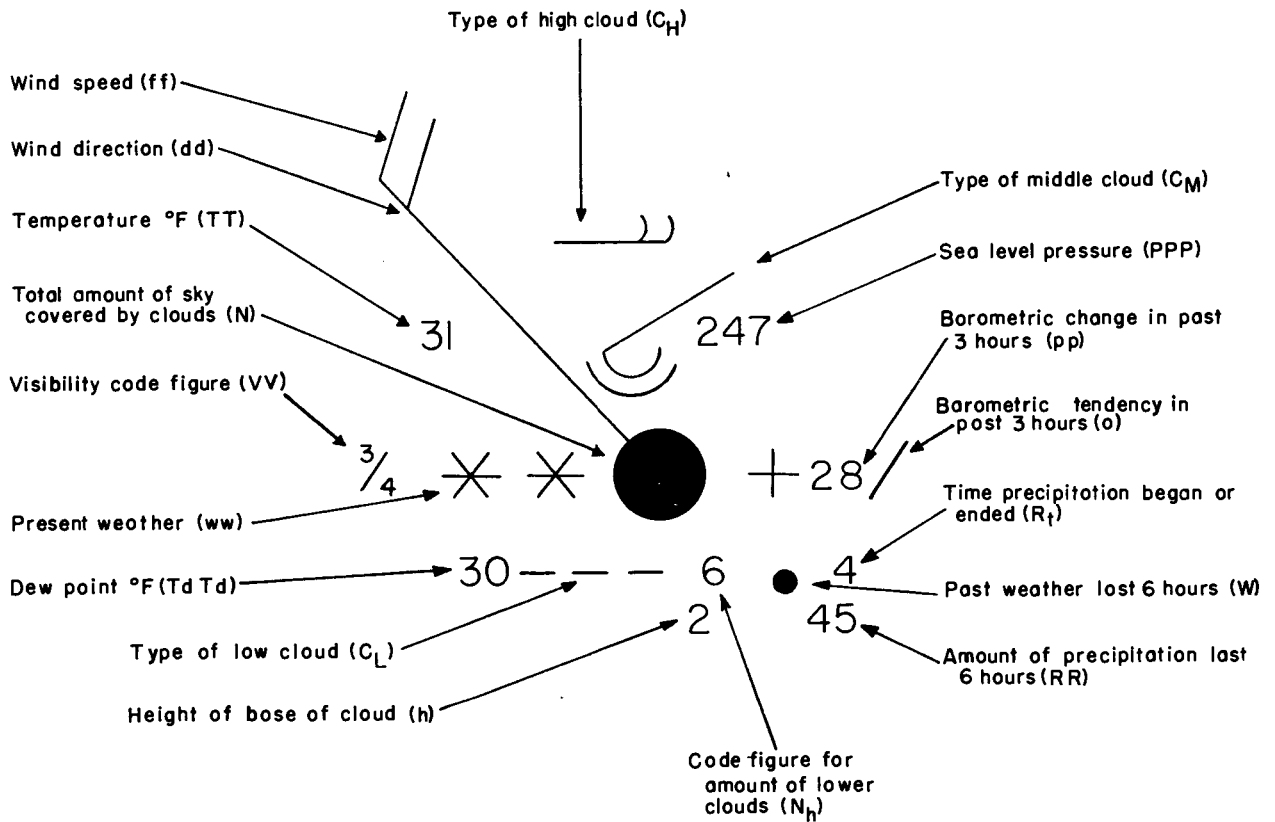


Figure 15. The station model.

poses, isobars are drawn at 3 or 4 millibar intervals; however, for a detailed analysis, this interval may be reduced to 1 millibar. Fronts, which always lie in low pressure troughs, may be temporarily located from the sketched isobars. An examination of wind shifts, temperatures, dewpoints, cloud patterns, and pressure tendencies will indicate the true surface position of the fronts and often will necessitate a slight change in the isobaric pattern. Other

features, such as fog and precipitation, are then placed on the synoptic chart in their respective colors so that the entire weather picture which existed at a particular hour can be seen at a glance. From the current chart, the forecaster prepares a prognostic chart, which indicates the expected weather picture for the next few hours. Generally speaking, the prognostic chart contains the same features as the current synoptic chart.



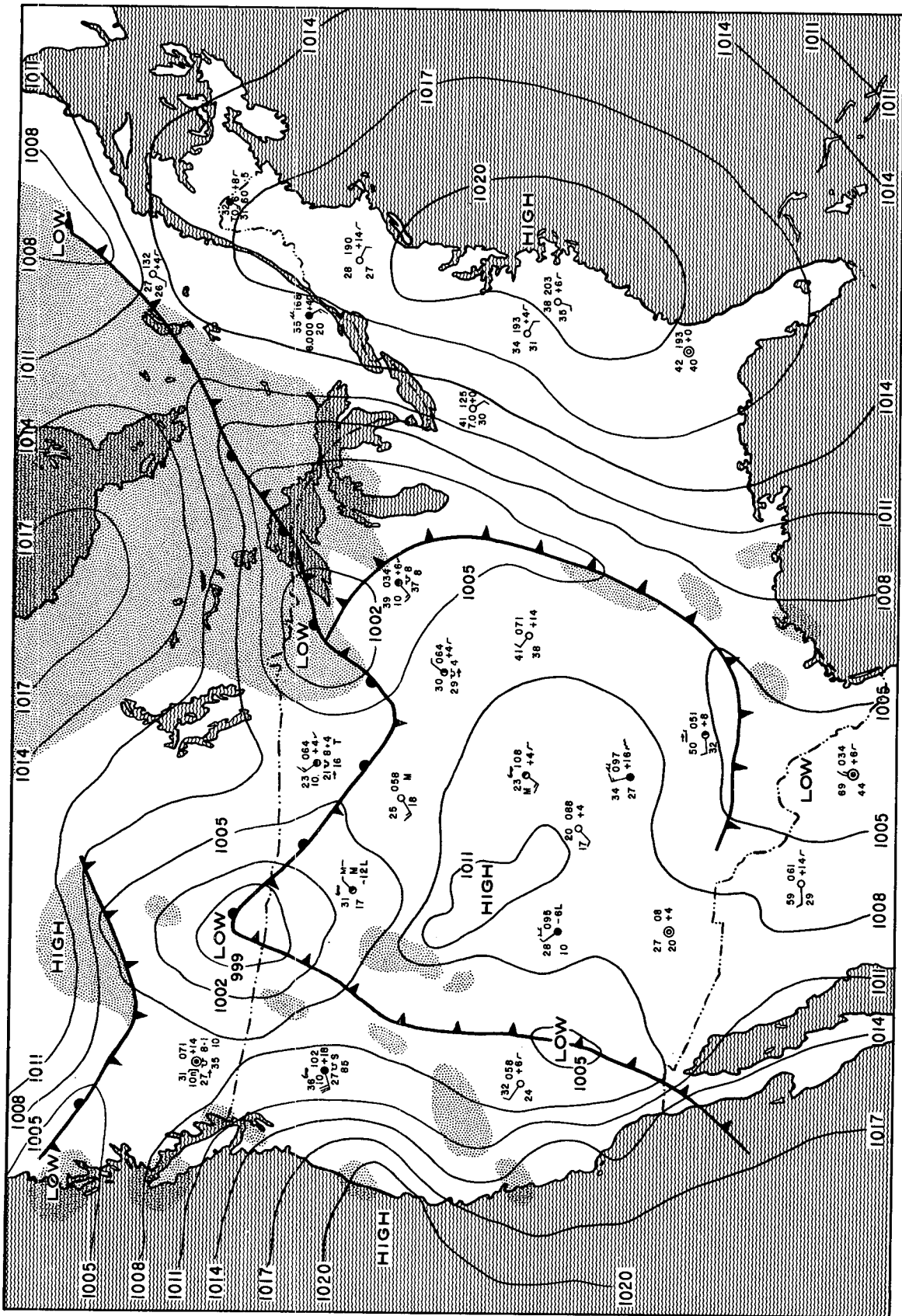


Figure 16. Synoptic weather map.

## CHAPTER 3

## METEOROLOGICAL REQUIREMENTS OF THE FIELD ARMY

**23. General**

There are five general meteorological requirements within the field army. They are climatological information, forecasts, surface meteorological observations, upper air meteorological observations, and weather summaries. Current metro data furnished by meteorological units of the field army may include ballistic meteorological messages, sound ranging messages, fallout prediction messages, upper air data for Air Weather Service, low level wind data for rockets, Temperature-Humidity (T-H) index reports, wind chill factor reports, and data required by the technical services. An explanation of these reports and the services of the Air Weather Service (AWS) are described in paragraphs 24 through 28.

**24. Ballistic Meteorology**

*a. Exterior Ballistics.* Exterior ballistics is the science which deals with the factors affecting the motion of a free projectile moving through the atmosphere. A projectile moving in the atmosphere is retarded according to the same physical laws regardless of whether it was put into motion by a gun tube or launcher or dropped from an aircraft. Generally, the forces acting on the projectile are gravity, aerodynamic drag, dynamic airfoil, and gyroscopic precession. Although these forces are few, they act and interact in an extremely complex manner. In fact, an exact mathematical solution to the motion of a projectile in space still defies mathematicians. Terrestrial gunnery does have a practical solution, however, by application of mathematical approximations. The application of mathematical approximations to the motions of projectiles is the responsibility of ordnance ballisticians. Their mathematical solutions are given to the artillery in the form of firing tables. In order to compute firing tables, ballisticians must assume certain conditions concerning the problem. These assumptions are known as standard conditions and include the projectile weight, projectile velocity, ballistic coefficient, air density, air temperature, and wind. After a ballisticians has computed a trajectory for standard conditions, he recomputes the trajectory by allowing one of the assumed conditions to

have a value different from its standard. The effect of allowing an element to be different from standard is known as a differential effect. Differential effects are presented in the firing tables as corrections and include corrections for range wind, cross wind, muzzle velocity, air temperature, air density, and projectile weight. To further illustrate how differential effects are computed, suppose that a ballisticians computes a trajectory for a 155-mm howitzer projectile for a range of 8,000 meters using standard conditions. He then recomputes the trajectory (using the same quadrant elevation) allowing only the air density to change from standard by +1.0 percent. The difference between 8,000 meters and the new computed range is the range differential effect for a 1.0 percent increase in air density. In this example, the computed range difference is -17.5 meters. The correction, or unit effect, published in the firing tables is +17.5 meters.

*b. Standard Atmosphere.* When computing trajectories, ordnance ballisticians use the ICAO (International Civil Aviation Organization) atmosphere in accordance with international agreement among the NATO (North Atlantic Treaty Organization) nations.

*Note.* The ICAO atmosphere was adopted as standard up to 20 kilometers by STANAG 4044 (NATO), August 1958. This ideal atmosphere is described fully in Report 1235, National Advisory Committee for Aeronautics and in "U.S. Extension to the ICAO Standard Atmosphere, Geophysics Research Directorate and Weather Bureau, U.S. Department of Commerce." The ICAO atmosphere is described as follows:

- (1) Dry atmosphere.
- (2) No wind.
- (3) Surface temperature 15° Celsius, with a 6.5° lapse rate per 1,000 meters up to a height of 11,000 meters, and a constant -56.5° Celsius between 11,000 and 25,000 meters.
- (4) Surface pressure of 1013.25 millibars, decreasing with height in accordance with the equation of hydrostatic equilibrium.
- (5) Surface density of 1,225 grams per cubic meter, decreasing with height according to

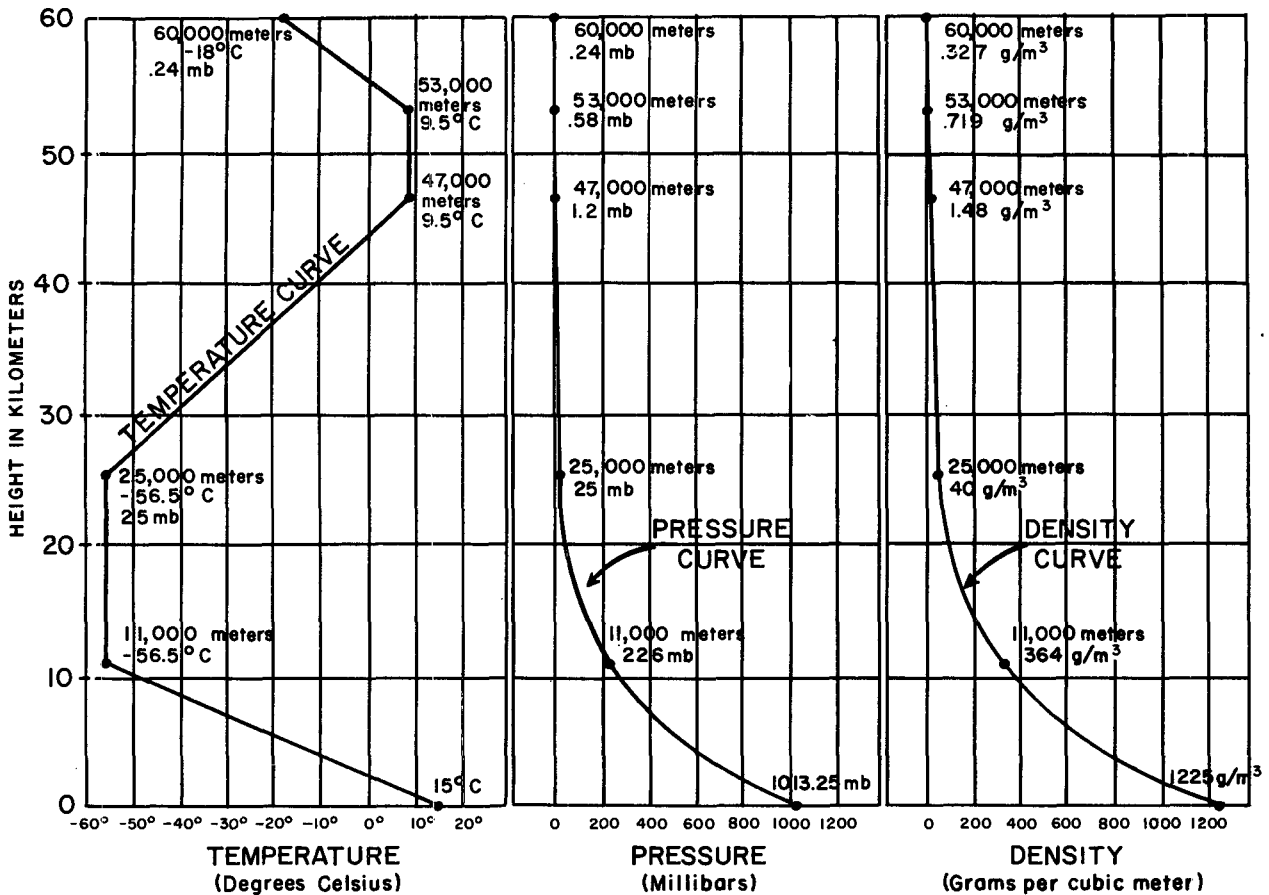


Figure 17. Standard atmosphere.

the density equation  $D = \frac{KP}{T_v}$ , wherein D is the density in grams per cubic meter, K is the constant to adjust units (348.4), P is the pressure in millibars, and  $T_v$  is the virtual temperature in degrees Kelvin, i.e., virtual temperature in degrees Celsius +273.16.

- (6) The pressure, temperature, and density variations with height are illustrated graphically in figure 17. For the convenience of computing, reporting, and applying corrections, the standard atmosphere is further identified by atmospheric zones. The atmospheric zones for the various meteorological messages are illustrated in figure 18.

c. *Ballistic Meteorological (Metro) Message.* The task of the ballistic meteorologist is to measure the parameters of the atmosphere, compare the current

conditions with standard conditions, and report the variations in terms of percents of standard. The measurement of upper air parameters is made by means of a balloon-borne radiosonde. As the radiosonde ascends, it measures pressure, temperature, and relative humidity. During ascent, the radiosonde is tracked by a rawin set AN/GMD-1(). The location of the balloon at each zone limit, as projected to the earth's surface, is plotted on a plotting board. From these plots, the average wind speed and direction for each of the atmospheric zones is determined. The computation of these zone winds is a preliminary step in the determination of ballistic winds. Upper air pressure and virtual temperature are plotted on the altitude-pressure-density chart ML-574/UM. This chart is constructed so that zone temperatures and zone densities may be obtained graphically from the sounding curve through the use of a small plastic scale (Scale ML-573). The general procedure is to

Zone structure of the NATO, computer, and fallout metro messages

Height meters	Line numbers		
	NATO	Computer	Fallout
Surface	0	0	0
200	1	1	1
500	2	2	
1000	3	3	
1500	4	4	
2000	5	5	
2500	6	6	2
3000		7	
3500		8	
4000	9		
4500	8	10	
5000		11	
6000	9	12	4
7000	10	13	
8000		14	
9000	11	15	5
10000		16	
11000	12	17	6
12000		18	
13000	13	19	7
14000		20	
15000	14	21	8
16000		22	
17000	15	23	9
18000		24	
19000		25	10
20000		26	
* * *			* * *
32000			16

Figure 18. Structure of atmospheric zones.

determine by plotting the mean zone density and temperature, then compare the results with the mean standard zone density and temperature. Since the standard atmosphere is assumed to be completely dry, any moisture in the actual atmosphere must be taken into account. This is accomplished by applying a humidity correction to the measured temperature. This corrected temperature is called the virtual temperature. The virtual temperature of moist air is the temperature which dry air at the

same pressure must have in order to have the same density as the moist air. The conversion of actual temperature to virtual temperature is accomplished graphically on chart ML-574/UM or by using tables in FM 6-16, Tables for Artillery Meteorology. The zone values of wind, density, and temperature are compared with the standard zone values and variations from standard are determined. The variations from standard are then weighted according to specified zone weighting factors, and mean weighted quantities are established. The mean weighted quantities are the ballistic values.

- (1) *Ballistic wind.* Ballistic wind is a wind of assumed constant speed and direction which would have the same total effect on a projectile during its flight as the varying winds actually encountered.
- (2) *Ballistic density.* Ballistic density is an assumed constant density, expressed as a percent of standard atmospheric density, which would have the same total effect on a projectile during its flight as the varying densities encountered.
- (3) *Ballistic temperature.* Ballistic temperature is that surface virtual temperature, expressed as a percent of 288.16° K., which, when associated with the standard lapse rate, produces a temperature structure that has the same effect on a projectile as the actual temperature structure encountered.

*d. Weighting Factors.* Weighting factors are used to establish the proportional effect of the meteorological conditions in each zone upon the total effect exerted by the atmosphere through which a projectile passes. These weighting factors are computed by the ballisticians and are based on empirical data. To reduce the number of weighting factors, two general categories of trajectories have been established—surface to surface and surface to air. A meteorological section may be required to produce both types of ballistic metro messages. In either case, the message would be based on the same sounding and the same zone values, but the ballistic quantities (except for surface and line 1 of the message) would not be the same because the difference in the type of trajectory necessitates a different set of weighting factors. Appropriate weighting factors are published in FM 6-16, Tables for Artillery Meteorology.

*e. Ballistic Quantities.* Ballistic quantities are reported to artillery units in the metro message. This message consists of a heading and a body. The heading identifies the location of the metro station, altitude of the metro station (MDP (Meteorological Datum Plane)), valid time period, and the station pressure reduced to mean sea level pressure (reported as a percent of standard sea level pressure). The body of the metro message reports the ballistic quantities for each standard altitude (top of zone), including the surface. Each line of the metro message reports ballistic data for that portion of the atmosphere extending from the surface to the top of the standard zone which corresponds to this line number. For example, line 5 of a ballistic message contains ballistic values which represent the atmospheric layer from the surface to the top of standard zone 5. These values would be applicable for all trajectories having a maximum ordinate between 1,500 and 2,000 meters. The zone values for zones 1, 2, 3, 4, and 5 are weighted and summed to arrive at the ballistic values for line 5. Coding of the metro message is further described in chapter 8, which also contains a sample message.

*f. Application of Metro Corrections.* The importance of metro corrections is sometimes minimized by artillerymen who prefer to "shoot in" these corrections by registrations. Although registration is the most accurate method of accounting for nonstandard conditions it is impossible when first round hits are required. First round hits are essential when nuclear weapons are employed. Registration is also time-consuming, expensive, and restricted only to that portion of the battlefield which can be observed. World War II statistics revealed that half of the artillery missions fired were on unobserved targets, and artillerymen in Korea encountered situations where the magnitude of the metro effect amounted to 25 percent of the range, making the application of metro corrections a necessity even for observed fire missions. The application of all nonstandard conditions to artillery fire are described in FM 6-40, Field Artillery Cannon Gunnery. To illustrate metro effects, a specific situation is presented: The weapon is a 155-mm howitzer firing at a target range of 8,000 meters on an azimuth of 1,600 mils with charge 5 (muzzle velocity, 1,220 feet per second). The altitude of the howitzer position is 310 meters and the altitude of the target is the same. The first consideration in the metro solution to this gunnery problem is: What

is the maximum ordinate of the trajectory? The answer is not given directly in the 155-mm howitzer firing tables FT 155-Q-3. However, based on the range and altitude of the target, the line number of the metro message to be used is indicated on the complementary range line of table B for FT 155-Q-3 for charge 5. In this special case, line 3 of the metro message will be used. Line 3 of the metro message indicates that the ballistic conditions are—

Ballistic wind..... Blowing from 2,400 mils  
at 19 knots  
Ballistic tempera- 103.9 percent of standard  
ture.  
Ballistic density.....95.4 percent of standard

The next consideration is the relative height of the howitzer position with respect to the altitude of the metro station (MDP). The metro station is 370 meters above sea level and the howitzer position is 60 meters below the MDP. The temperature and density values must be corrected to account for this difference. The correction of ballistic values for height of the howitzer position is made by reference to the firing tables. For this specific illustration, the correction for temperature is +0.1 percent, and the correction for density is +0.6 percent. The corrected ballistic values for the howitzer are now—

Winds..... 2,400 mils at 19 knots  
Temperature 103.9 +0.1 = 104.0 percent  
Density..... 95.4 percent +0.6 = 96.0 percent

It is important to realize that the ballistic zone structure of the atmosphere must be established at the firing position. No effort is made to adjust the ballistic winds for a difference in height between battery and MDP, because there is no specific relation between the speed and direction of the wind and this height difference.

*g. Computation.* The total effect of any one metro variable is obtained by multiplying the variation from standard by the unit corrections for this variable. Unit corrections corresponding to the charge and entry range under consideration are obtained from the firing tables (charge 5, entry range 8000). Figure 19 is an extract from the 155-mm howitzer firing tables appropriate to the illustration. The ballistic wind must be resolved into range wind and cross wind components. This is accomplished by subtracting the firing azimuth from the ballistic wind azimuth, after the ballistic wind azimuth has been referenced to the same azimuth as the firing azimuth (grid). The result of this subtraction is

known as a chart wind direction. Chart wind direction is resolved into range and cross wind components by referring to the firing tables. In this illustration, the chart wind direction is 800 mils (2,400-1,600) which resolves into a head wind of 13.5 knots (0.71 x 19 knots) and a left wind of 13.5 knots (0.71 x 19 knots). This illustration demonstrates the magnitude of errors, or corrections, which

may result from metro effects. In this illustration, the range wind correction is about the same as the combined temperature and density corrections and the resultant correction is +7 meters in range. The cross wind correction of 5 mils is equivalent to 40 meters on the ground. Computations of corrections for metro effects are made as follows:

<i>Metro effect</i>	<i>Unit Correction</i>	<i>Variation from standard conditions</i>	<i>Correction</i>
Temperature	-25.6 meters	increase of 4.0%	-102.4 meters
Density	-17.3 meters	decrease of 4.0%	-69.2 meters
Range Wind	+13.2 meters	head 13.5 knots	+178.2 meters
Cross Wind	0.38 mils	left 13.5 knots	R 5.1 mils

## 25. Meteorology for Sound Ranging

a. Sound ranging is a process employed in locating a sound source, such as the firing of a weapon or the burst of a projectile, by computations based on the speed and direction of sound waves from the source. Sound ranging is accomplished by the sound ranging section of the batteries of the corps target acquisition battalion. These sections establish bases of microphones which pick up sound impulses for transmission to a central recorder. The sound section personnel evaluate the recording and plot the location of the sound source. The solution is based on the differences in time at which the sound wave activates the individual microphones. The differences in time are related to the speed of sound and are resolved into a series of rays, the intersection of which is the location of the sound source. The variables in the system are the microphone locations, the wind displacement of the sound source, and the speed of sound. Speed of sound is determined by the equation  $V^2 = K \frac{P}{d}$ , wherein V is

the speed of sound in meters per second, K is a constant which is the ratio of specific heat at constant pressure to the specific heat at constant volume of the gas, P is the air pressure, and d is the air density. Density, however, is a function of pressure and virtual temperature as shown by the equation in paragraph 24b(5), and the speed of sound (meters per second) becomes a direct function of the square root of the virtual temperature:  $V = 20.06 \sqrt{T_v}$  (°K.). The meteorological data used to solve the sound ranging problem are wind speed, wind direction, and sonic temperature (virtual temperature corrected).

b. Each sound ranging section has a limited

capability of measuring the metro data required. Its equipment includes pilot balloon (pibal) observation equipment, wind plotting board and equipment, psychrometer, and meteorological tables. With this equipment, the sound ranging platoon can develop all metro data required. The methods of observation and computation are described in chapter 12. Artillery ballistic meteorological sections are capable of producing sound ranging metro data from electronic soundings. The electronic procedures are described in chapter 13. The general requirement is to determine the wind speed and direction in four layers from the surface to 800 meters and to determine the virtual temperature at a height of 200 meters.

c. Layer winds are not used directly in solving the sound ranging problem. Layer winds are weighted and averaged in the same manner as ballistic winds to compute an effective wind speed and direction. DA Form 6-48 is used for computing and reporting the sound ranging data. The winds measured with a pilot balloon by the sound ranging section may be more valid than the winds measured with the rawin set by the ballistic meteorological section because the rawin set may be farther from the sound base. However, the measurements of the pilot balloon are restricted by visibility, whereas the measurements made with the rawin set are not. When required, meteorological support for sound ranging can be obtained from an electronic ballistic meteorological section.

## 26. Meteorology for Radiological Fallout

a. Nuclear detonations at or near the surface are capable of contaminating large areas with radioactive material which falls from the cloud formed by the detonation. The area of fallout varies in size

PART 2-5 TABLE F

PART 2-5 TABLE F

Range	Muzzle Velocity		Range Wind		Air Temp		Air Density		Proj Wt of @	
	Decrease of 1%	Increase of 1%	Head Wind	Tail Wind	Decrease of 1%	Increase of 1%	Den	Dan	Decrease of	Increase of
R	F/S	m	W-R	W-R	Temp	Temp	m	m	m	m
7000	5.6	-5.3	17.2	-10.1	23.6	-27.0	-17.6	13.7	-4	16
7100	5.7	-5.4	17.4	-10.2	23.9	-27.3	-17.5	14.1	-4	16
7200	5.8	-5.5	17.6	-10.3	24.2	-27.6	-17.4	14.5	-4	16
7300	5.8	-5.5	17.8	-10.4	24.5	-27.9	-17.3	14.9	-4	16
7400	5.9	-5.6	18.0	-10.5	24.8	-28.1	-17.2	15.2	-4	16
7500	6.0	-5.6	18.2	-10.6	25.1	-28.4	-17.1	15.5	-4	16
7600	6.0	-5.7	18.4	-10.7	25.3	-28.7	-17.0	15.8	-4	16
7700	6.1	-5.8	18.6	-10.8	25.6	-28.9	-16.9	16.1	-4	16
7800	6.2	-5.8	18.8	-10.9	25.9	-29.1	-16.8	16.4	-4	16
7900	6.3	-5.9	19.0	-11.0	26.1	-29.4	-16.7	16.7	-4	16
8000	6.3	-5.9	19.2	-11.1	26.4	-29.6	-16.6	17.0	-4	16
8100	6.4	-6.0	19.4	-11.2	26.6	-29.8	-16.5	17.3	-4	16
8200	6.5	-6.1	19.6	-11.3	26.8	-30.1	-16.4	17.6	-4	16
8300	6.5	-6.1	19.7	-11.4	27.1	-30.3	-16.3	17.9	-4	16
8400	6.7	-6.2	19.9	-11.5	27.3	-30.5	-16.2	18.2	-4	16
8500	6.8	-6.3	20.1	-11.6	27.5	-30.7	-16.1	18.5	-4	16
8600	6.8	-6.3	20.3	-11.7	27.7	-30.9	-16.0	18.8	-4	16
8700	6.9	-6.4	20.5	-11.8	27.8	-31.1	-15.9	19.1	-4	16
8800	7.0	-6.4	20.6	-11.9	28.0	-31.3	-15.8	19.4	-4	16
8900	7.1	-6.5	20.8	-12.0	28.2	-31.5	-15.7	19.7	-4	16
9000	7.2	-6.6	21.1	-12.1	28.3	-31.6	-15.6	20.0	-4	16
9100	7.3	-6.7	21.3	-12.2	28.4	-31.8	-15.5	20.3	-4	16
9200	7.4	-6.7	21.5	-12.3	28.5	-32.0	-15.4	20.6	-4	16
9300	7.5	-6.8	21.7	-12.4	28.6	-32.1	-15.3	20.9	-4	16
9400	7.5	-6.9	21.8	-12.5	28.7	-32.2	-15.2	21.2	-4	16
9500	7.6	-6.9	22.0	-12.6	28.8	-32.4	-15.1	21.5	-4	16
9600	7.7	-7.0	22.2	-12.7	28.9	-32.5	-15.0	21.8	-4	16
9700	7.7	-7.0	22.3	-12.8	29.0	-32.6	-14.9	22.1	-4	16
9800	7.8	-7.1	22.5	-12.9	29.1	-32.7	-14.8	22.4	-4	16
9900	7.8	-7.1	22.6	-13.0	29.2	-32.8	-14.7	22.7	-4	16
10000	7.8	-7.1	22.7	-13.1	29.3	-32.9	-14.6	23.0	-4	16

Range	Change in Elevation		Change in Range		FS		Change in Range		Time of Flight		Azimuth Corrections	
	for 100 meters	for 100 meters	for 1 mil	for 1 mil	FS	FS	for 1 mil	for 1 mil	TF	TF	Drift (correct)	Drift (correct)
R	m	m	m	m	FS	FS	m	m	sec	sec	mil	mil
7000	378.0	7.8	1.6	1.6	25.3	25.3	1.6	1.6	24.7	24.7	8.9	0.33
7100	383.9	7.9	1.6	1.6	25.8	25.8	1.6	1.6	25.1	25.1	9.1	0.34
7200	391.9	8.1	1.6	1.6	26.3	26.3	1.6	1.6	25.6	25.6	9.3	0.34
7300	400.0	8.2	1.6	1.6	26.8	26.8	1.6	1.6	26.1	26.1	9.5	0.35
7400	408.4	8.4	1.6	1.6	27.3	27.3	1.6	1.6	26.6	26.6	9.7	0.35
7500	418.9	8.6	1.6	1.6	27.8	27.8	1.6	1.6	27.1	27.1	10.0	0.36
7600	428.6	8.8	1.6	1.6	28.3	28.3	1.6	1.6	27.6	27.6	10.2	0.36
7700	438.5	9.0	1.6	1.6	28.8	28.8	1.6	1.6	28.1	28.1	10.4	0.37
7800	448.6	9.2	1.6	1.6	29.4	29.4	1.6	1.6	28.7	28.7	10.7	0.37
7900	458.9	9.5	1.6	1.6	29.9	29.9	1.6	1.6	29.2	29.2	10.9	0.38
8000	462.5	9.7	1.6	1.6	30.5	30.5	1.6	1.6	29.7	29.7	11.2	0.38
8100	476.4	10.0	1.6	1.6	31.1	31.1	1.6	1.6	30.3	30.3	11.6	0.39
8200	488.5	10.3	1.6	1.6	31.7	31.7	1.6	1.6	30.9	30.9	11.8	0.39
8300	497.0	10.7	1.6	1.6	32.3	32.3	1.6	1.6	31.5	31.5	12.1	0.40
8400	508.9	11.1	1.6	1.6	32.9	32.9	1.6	1.6	32.1	32.1	12.4	0.40
8500	518.2	11.5	1.6	1.6	33.5	33.5	1.6	1.6	32.7	32.7	12.7	0.41
8600	528.9	12.0	1.6	1.6	34.2	34.2	1.6	1.6	33.4	33.4	13.1	0.41
8700	539.1	12.6	1.6	1.6	34.9	34.9	1.6	1.6	34.1	34.1	13.4	0.42
8800	550.0	13.2	1.6	1.6	35.6	35.6	1.6	1.6	34.8	34.8	13.8	0.43
8900	561.6	14.0	1.6	1.6	36.4	36.4	1.6	1.6	35.5	35.5	14.2	0.43
9000	580.0	14.9	1.6	1.6	37.2	37.2	1.6	1.6	36.3	36.3	14.7	0.44
9100	591.4	16.1	1.6	1.6	38.0	38.0	1.6	1.6	37.1	37.1	15.2	0.45
9200	611.1	17.5	1.6	1.6	38.9	38.9	1.6	1.6	38.0	38.0	15.7	0.46
9300	634.4	19.5	1.6	1.6	39.9	39.9	1.6	1.6	39.0	39.0	16.4	0.47
9400	651.1	22.5	1.6	1.6	41.0	41.0	1.6	1.6	40.1	40.1	17.1	0.48
9500	673.4	27.6	1.6	1.6	42.2	42.2	1.6	1.6	41.3	41.3	17.9	0.49
9600	706.2	41.5	1.6	1.6	43.8	43.8	1.6	1.6	42.8	42.8	19.1	0.50
9700	750.4	46.4	1.6	1.6	46.4	46.4	1.6	1.6	45.3	45.3	21.2	0.53
9800	821.6	46.4	1.6	1.6	46.4	46.4	1.6	1.6	48.3	48.3	24.0	0.57
9900	873.5	41.2	1.6	1.6	51.7	51.7	1.6	1.6	50.6	50.6	26.7	0.60
10000	908.9	27.1	1.6	1.6	53.0	53.0	1.6	1.6	51.8	51.8	28.3	0.62
9400	923.8	22.1	1.6	1.6	54.0	54.0	1.6	1.6	52.8	52.8	29.7	0.64
9500	930.1	19.2	1.6	1.6	54.8	54.8	1.6	1.6	53.6	53.6	31.0	0.65
9600	968.1	17.2	1.6	1.6	55.5	55.5	1.6	1.6	54.3	54.3	32.2	0.67
9700	984.4	15.7	1.6	1.6	56.1	56.1	1.6	1.6	54.9	54.9	33.3	0.68
9800	998.5	14.6	1.6	1.6	56.7	56.7	1.6	1.6	55.4	55.4	34.3	0.69

Figure 49. Extract from firing table.

depending upon the yield of the nuclear weapon, the height of burst, and the speed and direction of the wind. The area of fallout may further be modified by the presence of natural precipitation, such as rain, snow, and hail. The consideration of the area of fallout is essential in planning of operations in the field army area, and the prediction of the area of fallout from both friendly and enemy bursts is a requirement of the appropriate fire support agency. The predictions of fallout from both friendly and enemy nuclear bursts are a staff responsibility of the chemical officer and are prepared by the personnel of the chemical, biological, and radiological center or element. (CBRC at the division fire support coordination center, FSCC, and CBRE in corps or army tactical operations center, TOC.)

b. Meteorological data available for fallout prediction are the height of the tropopause and the average vector wind in each 2,000-meter zone from the surface to a height of 32,000 meters. These data are furnished by artillery ballistic meteorological sections on a fixed 2-hour schedule. Because high altitude winds are less variable than low altitude winds, the wind data above 18,000 meters are reported every 6 hours. The average wind for each 2,000-meter zone is reported to the nearest 1 knot and to the nearest 10 mils. The height of the tropopause, when required, is reported to the nearest 100 meters.

c. The measurements of the zone winds for fallout prediction are made in the same manner as for the artillery zones. The sounding is made by using a fast rising or high altitude balloon carrying the standard radiosonde. The location of the balloon at the time it reaches the limit of each fallout zone is plotted on a board. From the plots, the travel in each fallout zone is measured, and an average speed and direction are computed. Fallout winds are not weighted by the metro section. The height of the tropopause is determined by the procedure outlined in paragraph 200 utilizing the criteria set forth in paragraph 199.

d. Artillery meteorological sections report fallout data on DA Form 6-58, Fallout Metro Message. Artillery meteorological sections in the army service area forward fallout metro data to the Field Army Tactical Operations Center (FATOC) by the most expeditious means. Use of teletypewriter circuits is recommended. The detailed procedures for producing, encoding, and transmitting fallout data are described in part four of this manual.

## 27. Air Weather Service

a. The Air Weather Service (AWS) of the U.S. Air Force has the mission of providing weather forecasts, weather summaries, and climatological reports as outlined in AR 115-12. Climatological information, including both climatic summaries and climatic studies, are made by AWS for the Army, as required. Air Weather Service prepares forecasts for the Army on both a routine and special basis. Routine forecasts normally cover periods of 3 to 5 days, 48 hours, and 24 hours. Forecasts are based on the information forwarded to the field army by the worldwide weather service of the AWS and on metro data collected in the field army area by both AWS personnel and artillery meteorological sections.

b. The AWS support of the field army is accomplished through an Air Force Staff Weather Officer (SWO) at division, corps, and army headquarters. Each SWO is supported by an AWS detachment which includes both observers and forecasters. Detachments are linked by communication lines, installed and maintained by the signal corps, which include both teletypewriter and facsimile facilities. The SWO operates under the staff supervision of the G2, and at corps and division headquarters he is also the AWS detachment commander. The SWO advises the commander and his staff on matters related to weather. He arranges, through AWS channels, for climatological studies and summaries required, coordinates the delivery of routine and special weather forecasts and weather summaries, and is the liaison officer between the AWS detachment and the Army element.

c. The AWS detachments with the field army do not have an upper air sounding capability. Therefore, upper air data collected by the artillery meteorological sections are of great importance to the AWS forecaster. Artillery meteorological sections are trained to encode upper air data for transmission to the nearest AWS detachment. Part five of this manual describes the code used to transmit data to the AWS and the weather capability and limitations of the AWS system in the field army area.

## 28. Special Weather Requirements

a. Artillerymen have a requirement for measurement of the low level winds which affect the flight of a free rocket during the thrust period. The primary method of measuring these winds is by use of a wind measuring set which consists of an anemometer



mounted on a 15-meter mast near the launcher. The measurements of the component winds are transmitted to a remotely located indicator. Artillery meteorological sections are capable of assisting rocket launcher crews in measuring the low level winds by means of pilot balloon techniques. The capabilities and limitations of measuring low level winds by pilot balloon techniques are discussed in chapter 23.

*b.* For some missiles and rockets, special meteorological data are required. These data include the surface air pressure for rocket 762-mm (HJ), the surface winds for the LaCrosse missile, and certain zone winds for the LaCrosse and Corporal missiles. Additional data may be required for other missiles. It is the responsibility of missile units to make their requirements known to the nearest meteorological section. Meteorological data for missiles may require special considerations by the meteorological section.

*c.* All units within the field army may have a requirement for special reports, such as temperature-humidity or wind chill factor indexes. Units may require both forecasts and current reports. Fore-

casts are made by the Staff Weather Officer. The procedure for making current reports is described in chapters 27 and 28.

*d.* When automatic digital computers are used to compute ballistic trajectories, weighted ballistic data are not required. In this case, the requirement is for true zone data. The computer is used to solve the trajectory through the atmosphere reported by the artillery meteorological section. The manner of reporting the artillery atmosphere for computer use is described in detail in chapter 25.

*e.* Employment of CBR agents in the battle area requires a micrometeorological consideration of the area. The specific requirements may necessitate a great number of weather observations by all elements of the field army which have a capability to measure meteorological elements. Such measurements may include—

- (1) Surface wind speed and direction.
- (2) Air temperature from surface to 2 meters.
- (3) Humidity.
- (4) Precipitation.
- (5) Visibility.

CHAPTER 4

ORGANIZATION, MISSION, CAPABILITIES, AND LIMITATIONS OF THE ARTILLERY METEOROLOGICAL SECTION

29. Organization

a. The artillery meteorological (metro) section (fig. 20) is composed of 1 warrant officer and 14 enlisted personnel as follows:

Duty position	MOS	Grade
Metro officer	201A	WO
Metro section chief	103.7	E-7 (NCO)
Asst metro section chief	103.6	E-5 (NCO)
Chief metro computer	103.6	E-6 (NCO)
Metro equipment mechanic	205.1	E-6
Senior metro computer	103.1	E-5
Senior metro computer	103.1	E-5
Metro computer	103.1	E-4
Metro computer	103.1	E-4
Intermediate speed radio operator	051.1	E-4
Intermediate speed radio operator	051.1	E-4
Metro plotter	103.1	E-3
Metro plotter	103.1	E-3
Metro plotter	103.1	E-3
Metro plotter	103.1	E-3

b. Certain tables of organization and equipment (TOE) may modify this section organization to meet special requirements.

c. In some cases, tables of organization and equipment may authorize a four-man metro section. Such a section would not have an electronic sounding capability and would have to measure winds by observing pilot balloons and determine ballistic temperatures and densities from surface observations, using the departure method.

d. The standard artillery metro section is equipped to operate for a 30-day period without resupply.

e. The major items of equipment (fig. 21) in the operation of a metro section are listed below.

- 1 Generator set, gasoline engine, 10-kw, 60 cy, 1- and 3-phase, 4-wire reconnectable to 2-wire and 3-wire, ac, 120, 120/240, 120/208 v, skid mounted

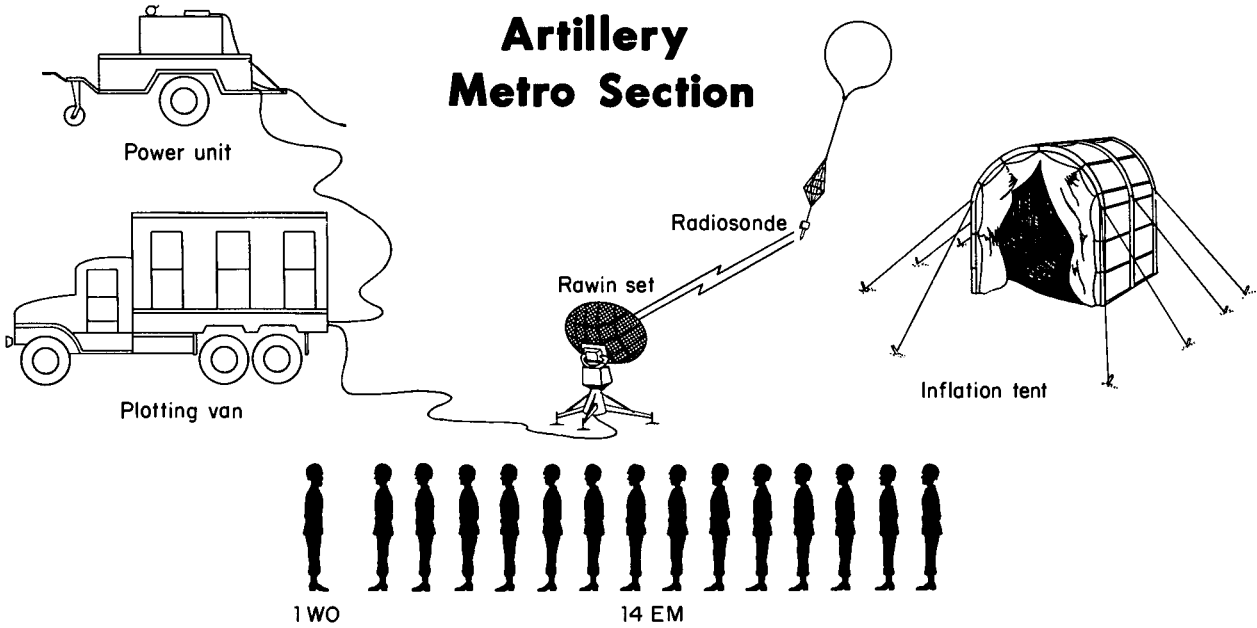


Figure 20. Artillery metro section.

- 1 Gun, machine, 7.62-mm, lightweight, general purpose, tripod mounted
- 1 Launcher, rocker 3.5 inch
- 2 Trailers, cargo, 1½-ton, 2-wheel
- 1 Trailer, tank, water, 1½-ton, 2-wheel
- 1 Truck, cargo, ¾-ton
- 2 Trucks, cargo, 2½-ton
- 1 Truck, van, shop, 2½-ton
- 2 Binocular, 7 x 50 mil reticle
- 1 Calculating machine, nonlisting, hand-electric, 10-digit
- 1 Clock, message center
- 2 Compass, mil graduations
- 1 Frequency standard TS-65/FMQ-1
- 1 Multimeter AN/URM-105 (replaces TS-352/U)
- 1 Power unit PE-75
- 1 Test set, electron tube TV-7/U
- 1 Support, radiosonde recorder, MT-1355/-TMQ-5
- 1 Radio set AN/GRC-19 and necessary operational accessories, mounted in truck shop van
- 1 Control set AN/GRA-6
- 1 Radiosonde baseline check set AN/GMM-1
- 1 Meteorological station, manual AN/TMQ-4

- 1 Radiosonde recorder AN/TMQ-5
- 1 Rawin set AN/GMD-1
- 1 Tool equipment TE-113

f. The component parts of these major items are described in the appropriate technical manuals. Most of the operating expendables are listed under meteorological station, manual AN/TMQ-4 and include approximately 5,400 pounds of materiel (fig. 22).

g. The equipment lists may be modified by tables of organization and equipment to meet specific requirements of various units. Airborne units are equipped with only two ¾-ton trucks for transportation, a command post tent in place of the shop van, and water cans in place of a water trailer.

h. When a four-man metro section is authorized, observation equipment is reduced to a minimum. Minimum equipment required for producing a ballistic message is listed in meteorological observation set SCM-12 (par. 96).

### 30. Mission

The mission of the artillery metro section is to fulfill the meteorological needs of the field army by providing—

- a. Ballistic messages.

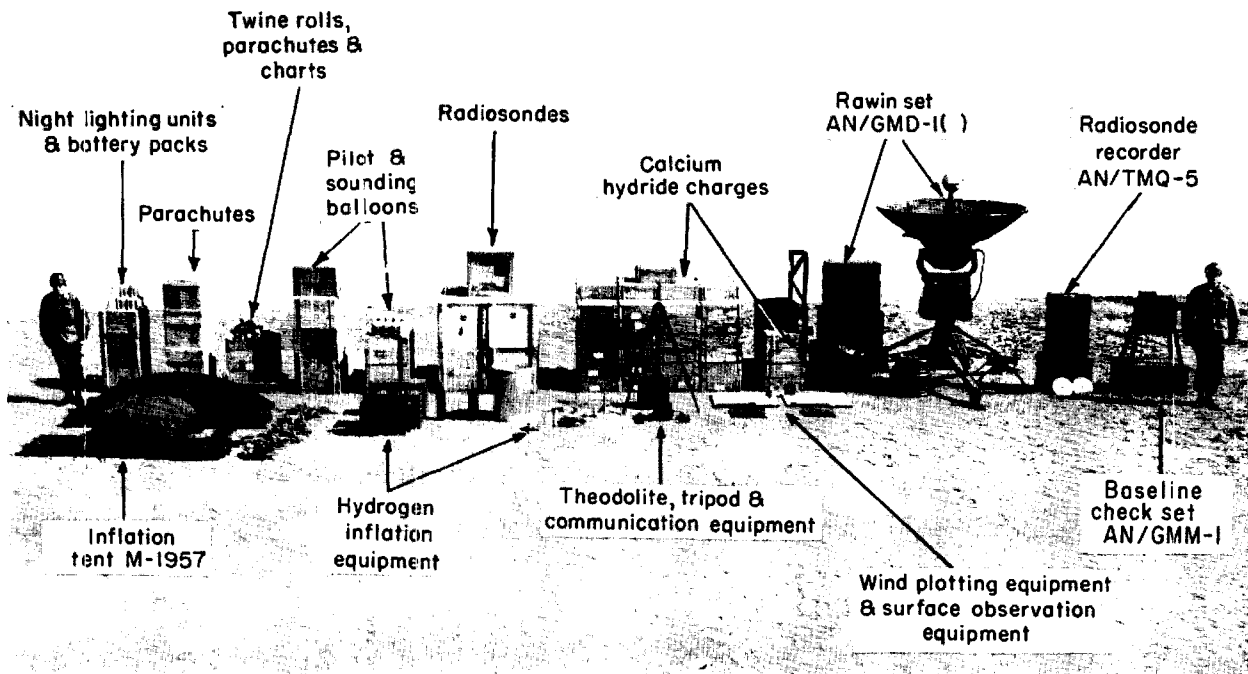


Figure 21. Major items of equipment, less vehicles.

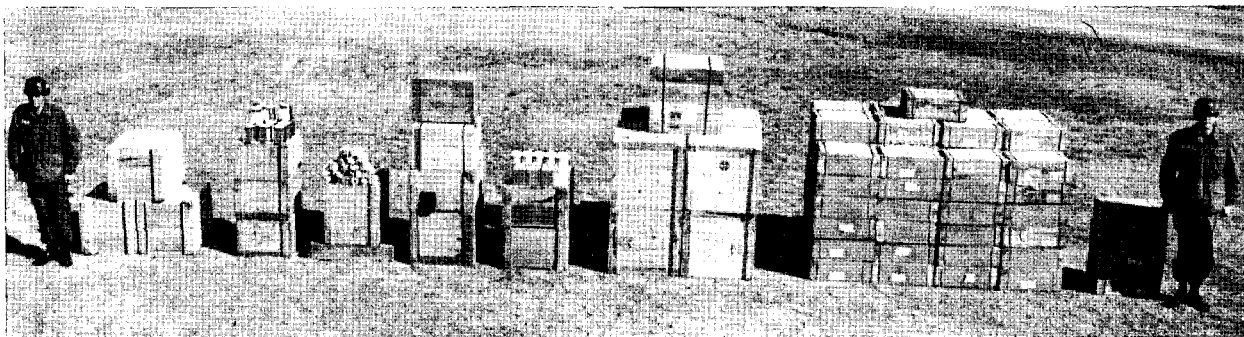


Figure 22. 30-day supply of operating expendables.

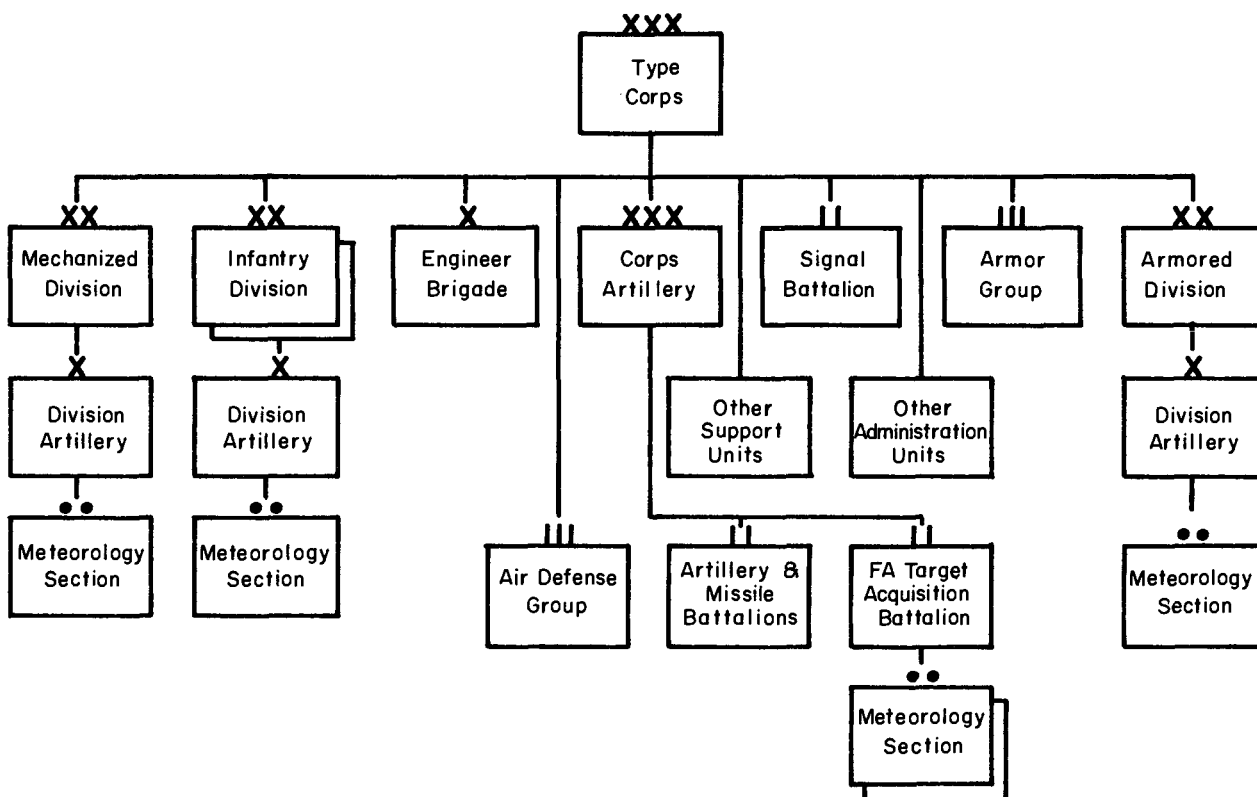


Figure 23. Type corps.

- b. Radiological fallout messages.
- c. Sound ranging messages.
- d. Metro data to the Air Weather Service with the field army.
- e. Metro data to missile units.

**31. Employment**

- a. Artillery metro sections are assigned as follows:
  - One to each infantry, mechanized, armored, and airborne division artillery.
  - Two to each corps target acquisition battalion.
  - One to each air defense group armed with guns.

One to each Honest John and/or Little John battalion when assigned to a missile command. Also, one to each Honest John battalion as an augmentation when the battalion is operating independently.

b. It is not expected that either air defense gun units or missile commands will be employed in the field army area. Therefore, within a typical corps consisting of four divisions (fig. 23), six artillery metro sections are deployed. Each division artillery metro section accompanies its own division artillery. The metro sections of the target acquisition battalion

are deployed where they can best support the overall meteorological requirement. Because of the requirement for fallout messages throughout the field army area, it is recommended that one metro section of the corps target acquisition battalion be employed near the corps rear boundary to produce fallout data for the rear area. It is recommended that the other target acquisition battalion section be employed in the division combat zone where it can best supplement the division artillery sections. Such a disposition of sections is shown in figure 24.

c. Division artillery metro sections are located in

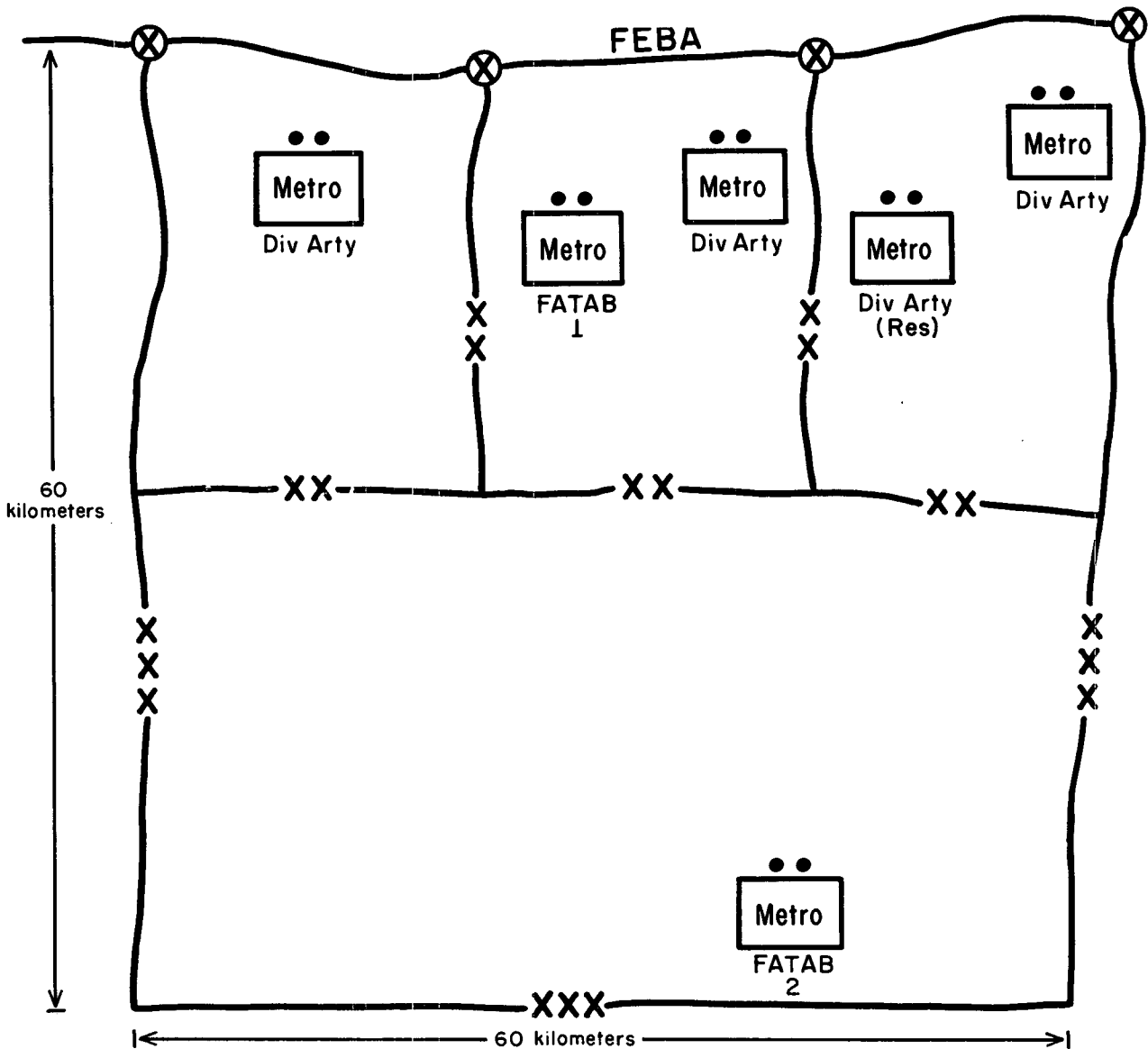


Figure 24. Disposition of metro sections.

the division artillery zone of action. Meteorological section locations are established where the sections can best sound the atmosphere through which the trajectories of the division artillery weapons will pass. The sections should be well forward and within a command post area where communication facilities are available. Prevailing winds, tactical location of artillery units, communication facilities and capabilities, administrative support, and local security are considered in selecting the position of a meteorological section.

*d.* One of the metro sections of the target acquisition battalion normally is employed in the forward combat area. The second section may be employed either forward or in the corps rear area, depending on the meteorological requirements. Disposition of the sections is made by the corps artillery commander, who is advised by the corps artillery metro officer. The forward section should always be positioned where it can best supplement the division artillery sections. This position may be in the corps artillery command post area, the target acquisition battalion headquarters command post area, or the command post area of any subordinate unit. It is desirable that metro messages be delivered in written form. This may be accomplished by utilizing radio teletypewriter nets when possible. The forward section is the net control station for the corps metro radio net. When the second section is operating in the rear, it normally will have a fallout message requirement only. The rear section is positioned in any rear area command post which has communication with either the army artillery operations center or the army or corps tactical operations center.

### **32. Artillery Metro Staff Officer**

*a.* The operation of the artillery metro system requires that the artillery commanders at division artillery, corps artillery, and army artillery be continuously informed of the metro situation by the artillery metro staff officer. The artillery metro staff officer of the division artillery staff is the warrant officer of the division artillery metro section. The corps artillery metro staff officer is a commissioned officer of the S3 section. He may be assisted by one of the metro warrant officers of the corps target acquisition battalion. The army artillery metro staff officer is a member of the army artillery section. He may be assisted by the warrant officer of a metro section that has been attached to the

army artillery headquarters for fallout message support.

*b.* The duties of the division artillery metro staff officer are to—

- (1) Supervise the operation of the metro sections to include the production of—
  - (a) Ballistic metro messages.
  - (b) Fallout metro messages.
  - (c) Metro data for artillery computers.
  - (d) Metro data for Air Weather Service detachments.
- (2) Provide liaison on metro matters with higher headquarters, adjacent division artilleries, the corps target acquisition battalion, air defense artillery units in the corps sector, and Air Weather Service detachments.
- (3) Advise the commander and staff on all artillery metro matters.
- (4) Advise the headquarters battery commanding officer on the selection of positions for meteorological stations.
- (5) Supervise the maintenance on all meteorological equipment in the division artillery.
- (6) Advise and assist the S4 in the procurement of metro supplies.
- (7) Advise the commander concerning the allotment of radiosonde frequencies.
- (8) Advise and assist the S3 in organizing and supervising the metro training program.
- (9) Submit the necessary reports and keep pertinent records.

*c.* The duties of the corps artillery metro staff officer are to—

- (1) Supervise the operation of the corps metro sections to include the production of—
  - (a) Ballistic metro messages.
  - (b) Fallout metro messages.
  - (c) Metro data for artillery computers.
  - (d) Metro data for Air Weather Service detachments.
- (2) Coordinate metro matters with the division artillery metro sections within the corps.
- (3) Advise the corps artillery commander and staff on artillery metro matters.
- (4) Provide liaison on metro matters with the adjacent corps and with army artillery headquarters and the staff weather officer (SWO) at corps headquarters.
- (5) Supervise maintenance on all artillery metro equipment in the corps artillery.

- (6) Advise and assist the corps artillery S4 in the logistical support of the corps metro system.
- (7) Advise the corps artillery communications officer on the assignment of radiosonde frequencies.
- (8) Advise and assist the S3 in organizing and supervising the metro training program.
- (9) Advise the corps S3 as to the employment and operation of metro sections within the corps.

*d.* The duties of the army artillery metro staff officer are to—

- (1) Supervise the operation of the artillery metro sections in the army service area to include the production of—
  - (a) Ballistic metro messages.
  - (b) Fallout metro messages.
  - (c) Metro data for artillery computers.
  - (d) Metro data for Air Weather Service detachments.
- (2) Coordinate metro matters with the corps artilleries and their units in the army service area.
- (3) Advise the army artillery commander and his staff on matters concerning operation and employment of artillery metro sections.
- (4) Advise and assist the army artillery S4 in matters relating to the logistical support of the metro sections in the army service area.
- (5) Advise the army artillery communications officer on matters relating to assignment of radio nets and radiosonde frequencies.
- (6) Act as liaison officer between the army staff weather officer and the army artillery staff.

### 33. Capabilities of Artillery Metro Sections

*a.* Artillery metro sections have the capability of sounding the atmosphere to heights of 30,000 meters, day or night, and in all types of weather except severe surface winds. These sections are mobile and have a mobility compatible with that of a division artillery headquarters command post. The sections normally carry a 30-day supply of expendables and spare parts. Artillery metro sections in a corps area communicate with each other and exchange metro data on the corps metro net. Artillery units with the corps will ordinarily obtain

metro data by monitoring the corps metro net at specified times. They may also obtain metro data over the division artillery command/fire direction net, RATT, or the corps command/fire direction net, RATT.

*b.* Metro sections are capable of sounding the atmosphere approximately every 2 hours. A limiting factor is the period of time required for a sounding balloon to reach a required height. Where requirements for high altitude soundings exist and several types of messages are required, metro sections are capable of sounding the atmosphere only every 4 hours. A metro section in position is capable of producing a ballistic message for light artillery in a minimum time of 30 minutes after the release of the balloon. The maximum time required to produce a maximum height fallout message is about 2 hours. In the event of failure of electronic equipment, sections have an alternate but limited capability of measuring upper air winds by observing pilot balloons and of computing upper air densities and temperatures by using climatological tables in conjunction with the current surface values of each parameter.

*c.* All artillery metro sections are trained to produce the following types of messages and data:

- (1) Ballistic messages, types 2 and 3.
- (2) Computer messages.
- (3) Fallout messages.
- (4) Sound ranging messages.
- (5) Data for transmission to Air Weather Service.
- (6) Low level winds for rockets.

Sections are further capable of reporting a variety of special parameters, such as the temperature-humidity index, wind chill factor, and surface winds.

### 34. Scheduling of Metro Messages

The scheduling of metro messages should be geared to the needs of the using units. Requirements for fallout messages are scheduled by the corps artillery metro officer in coordination with the army artillery metro officer. The division artillery S3 publishes a schedule of metro requirements for the division artillery; this schedule is based on the schedule published by the corps artillery metro officer. If there are two or more metro sections in the same area, the corps metro officer coordinates and rotates the metro requirements between the sections.

### 35. Requests for Metro Support

*a.* In order to insure timely receipt of metro information, the unit requesting metro support should state specifically the information needed in the initial request. If a ballistic metro message is required, the requesting unit should state the type of message, the number of lines required, delivery time, and method of delivery. Ordinarily, the number of lines requested should be no greater than the number required for the maximum ordinate expected to be fired during the period of validity of the

metro message. Also, if the metro information is required for other than a ballistic metro message, the data needed should be clearly and completely explained in the initial request. All requests for metro support should state to whom the metro data are to be forwarded (ordinarily to the S3).

*b.* Units requesting metro support must realize that it is extremely difficult for a metro section to provide ballistic metro messages more frequently than every 2 hours. Metro messages are provided on time schedules based on Greenwich Mean Time (GMT).





## CHAPTER 5

## ADDITIONAL SOURCES OF METEOROLOGICAL INFORMATION

**36. General**

There are several additional sources of meteorological information available to artillery units. These additional sources include meteorological units from the various services of member countries of the North Atlantic Treaty Organization (NATO), the Air Weather Service (AWS) detachments of the United States Air Force, the meteorological agencies of the United States Navy, and the United States Weather Bureau. Data obtained from these sources may be ballistic, fallout, or computer messages in the standard format or raw unweighted data.

**37. Allied Nations Metro Message Service (NATO Messages)**

a. During the past several years, considerable effort has been expended by members of NATO in the area of standardization. One result has been the adoption, by NATO members, of the International Civil Aviation Organization (ICAO) standard atmosphere (STANAG 4044, 1958). The ICAO standard atmosphere is now used by all services (Army, Navy, and Air Force) of each member country. NATO member countries are—

Belgium	Luxembourg
Canada	Netherlands
Denmark	Norway
France	Portugal
German Federation Republic	Turkey
Greece	United Kingdom
Iceland	United States
Italy	

b. From a meteorological standpoint, this means that atmospheric data can be freely interchanged between NATO member countries, regardless of

which service obtained the data, with the assurance that the same atmospheric standards were used as a basis for obtaining and reporting such data.

**38. Air Weather Service Support**

Artillery units which do not have the service of an artillery metro section should request ballistic metro support from the Air Weather Service (AWS) through intelligence channels. Artillery metro sections which lose their capability of making upper air soundings may request upper air data from the Air Weather Service. Use of raw data obtained from AWS is described in chapter 22.

**39. U.S. Navy Support**

U.S. Marine artillery units have the same meteorological equipment as U.S. Army artillery units and produce ballistic data the same as Army artillery metro sections. When Army artillery units are operating with Marine artillery units, they will receive the standard NATO ballistic message. When operating with the U.S. Navy, as in a landing operation, Army artillery units may obtain ballistic metro support from Navy shipboard metro stations in the NATO format. Requests for meteorological support must be made well in advance of the time of need.

**40. U.S. Weather Bureau**

The U.S. Weather Bureau, as an agency of the Federal Government, may be called upon to assist the fulfillment of the metro requirements of the Army. Such a requirement would likely occur only in the continental United States. Requests for upper air data could quickly be met by any U.S. Weather Bureau station that normally sounds the atmosphere. U.S. Weather Bureau stations normally are not prepared to produce ballistic data.



**PART TWO**  
**BALLISTIC METEOROLOGY**  
**CHAPTER 6**  
**METEOROLOGICAL OBSERVATION EQUIPMENT**

**Section I. STATION, MANUAL AN/TMQ-4**

**41. General**

The meteorological station, manual AN/TMQ-4 (fig. 25) contains the various items of equipment required to measure and evaluate atmospheric conditions. Although the station manual is designed primarily for electronic soundings, it also contains the necessary equipment for the visual technique which may be used in event of an electronic equipment failure. The items of equipment and expendable supplies are packed in appropriate cases and carrying bags. Detailed information on the station manual is provided in TM 11-2426.

**42. Main Components**

The main components of meteorological station, manual AN/TMQ-4 and federal stock numbers are listed in succeeding paragraphs.

**43. Inflation Equipment**

The inflation equipment (fig. 26) consists of the following items.

<i>Item</i>	<i>Stock number</i>
Hydrogen generator set AN/TMQ-3	3655-408-4683
Shroud, balloon, ML-424/U	6660-356-5196
Nozzle ML-196	6660-663-7924
Nozzle ML-373/GM	6660-238-3044
Hydrogen regulator ML-193 (or ML-528/GM)	6685-407-4766
Tent, frame type, balloon inflation, M-1957	8340-543-7046
Rod, ground	5975-240-3864
Bracket assembly, antibuoyancy	6660-513-0090
Clamp, electrical	5975-248-5814
Coupling ML-49	4730-408-4628
Can, corrugated, galvanized iron, 32 gallon	7240-160-0440
Hose ML-81	4720-263-3308
Strap, ground assembly	6660-513-0109

**44. Wind Plotting Equipment**

The wind plotting equipment (fig. 27) consists of the following items:

<i>Item</i>	<i>Stock number</i>
Slide rule	7520-183-5695
Plotting scale ML-577/UM	6660-606-5835
Plotting board ML-122, with rule ML-126A	6660-663-4748

**45. Temperature and Density Computing Equipment**

The temperature and density computing equipment (fig. 28) consists of the following items:

<i>Item</i>	<i>Stock number</i>
Altitude-pressure density chart ML-574/UM	6660-606-8648
Zone-height scale ML-573/UM	6660-606-5834

**46. Surface Observation Equipment**

The surface observation equipment (fig. 29) consists of the following items:

<i>Item</i>	<i>Stock number</i>
Anemometer ML-433/PM (fig. 30)	6660-663-8090
Barometer ML-102-( ) (fig. 31)	6685-223-5073
Thermometer ML-352/UM (fig. 32)	6685-239-4019
Psychrometer ML-224 (fig. 33)	6660-223-5084
Theodolite ML-474/GM (fig. 34)	6675-498-9773
Timer FM-19 (fig. 35)	6645-568-4995
Tripod MT-1309/GM	6675-408-4846

**47. Wire Communication Equipment**

The wire communication equipment (fig. 36) consists of the following items:

<i>Item</i>	<i>Stock number</i>
Telephone TA-312/PT (replaces TA-43/PT)	5805-543-0012
Head and chest set HS-25-C	5965-162-8179
Reel RL-39-( ) with spool DR-8	3895-498-8343
Wire WD-1/TT, 200 meters	6145-226-8812
Jack JK-54	5935-199-2455

**48. Technical Manuals**

Detailed information on the equipment contained in station, manual AN/TMQ-4 is provided in the following manuals:

TM 11-2405, TM 11-2413, TM 11-2417, TM 11-2421, TM 11-2432A, TM 11-2442, TM 11-6660-218-15P, TM 11-6675-200-10, TM 11-6675-200-20.

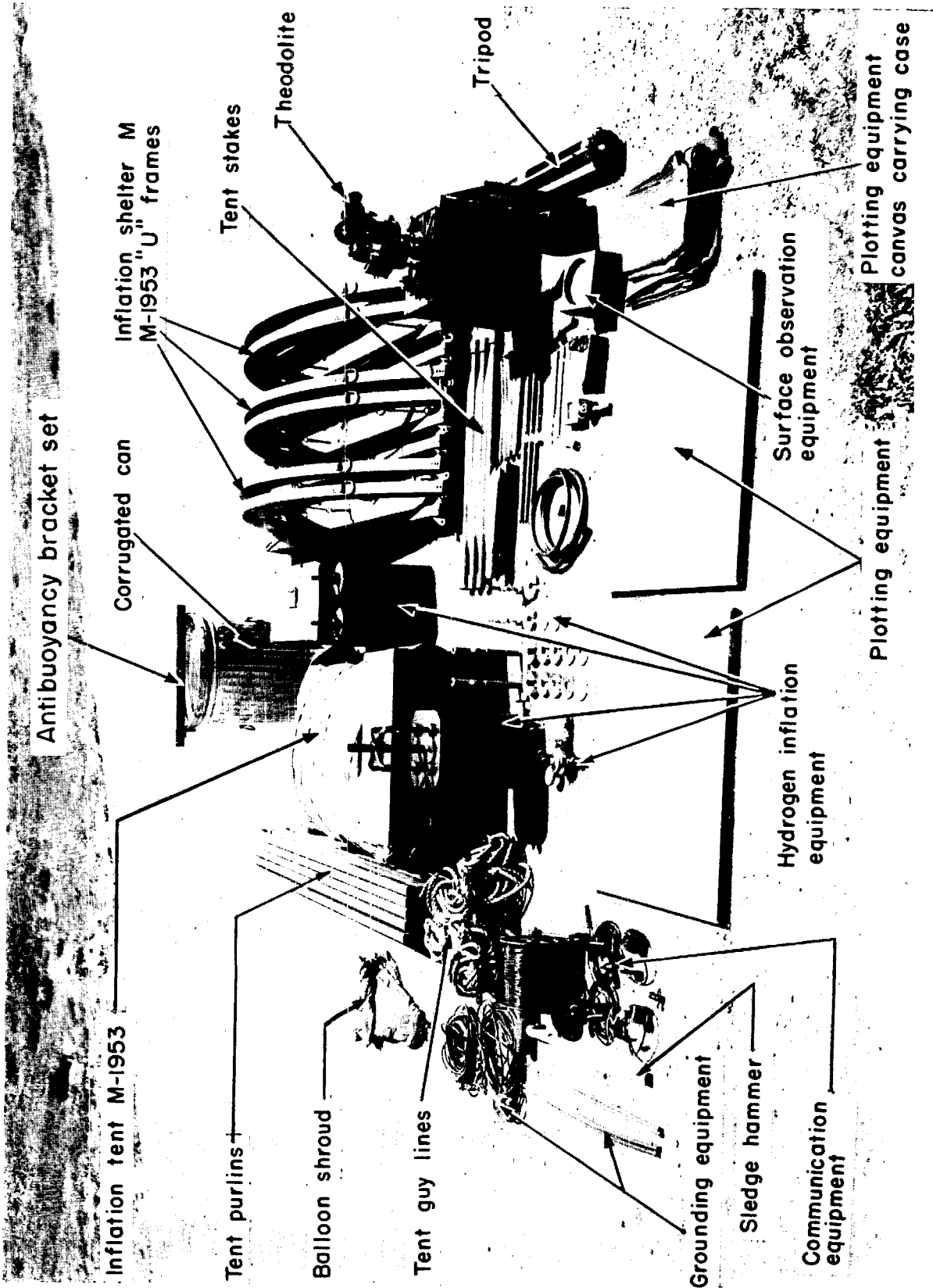


Figure 25. Station, manual AN/TMQ-4, less expendable items.

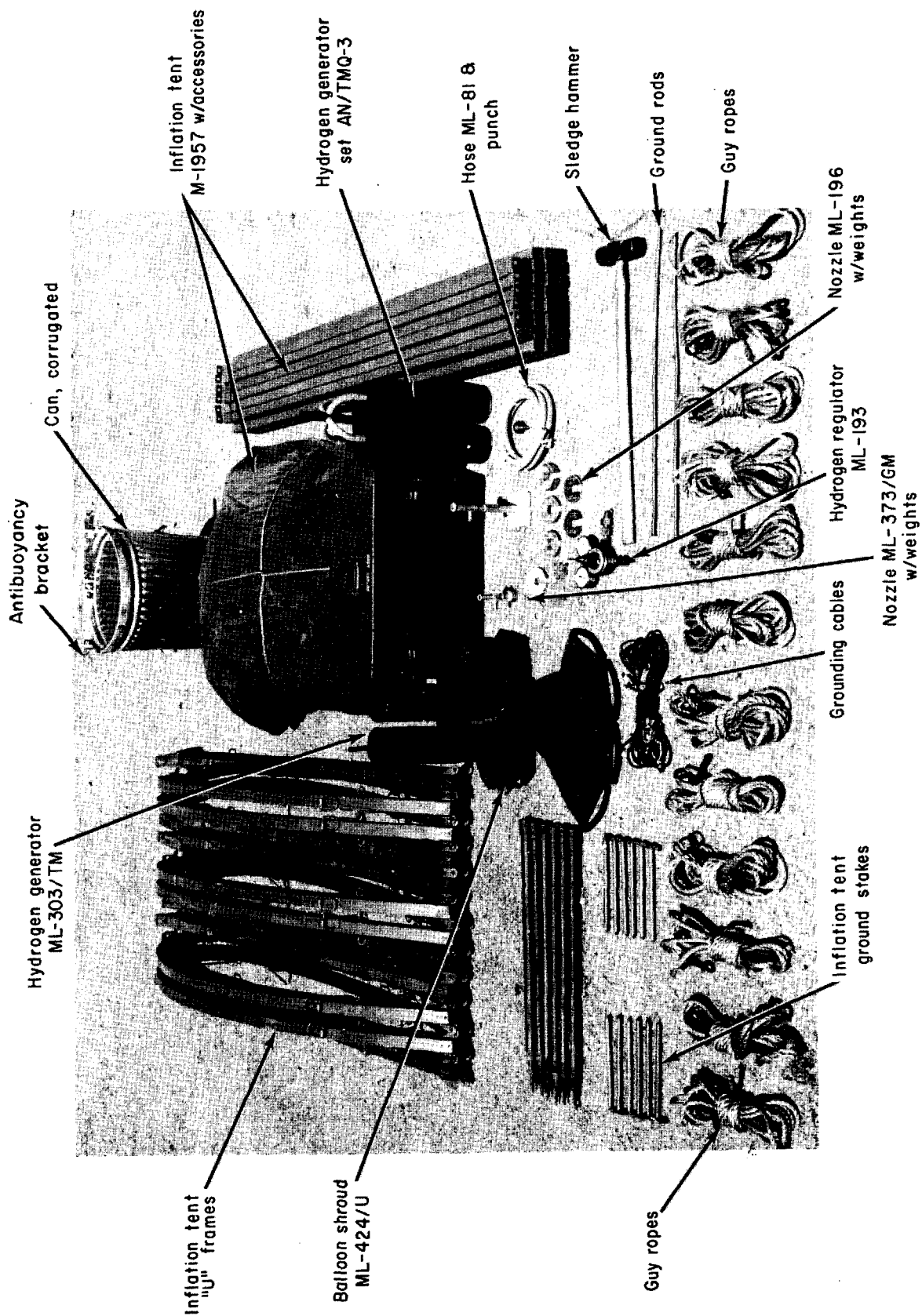


Figure 26. Inflation equipment.

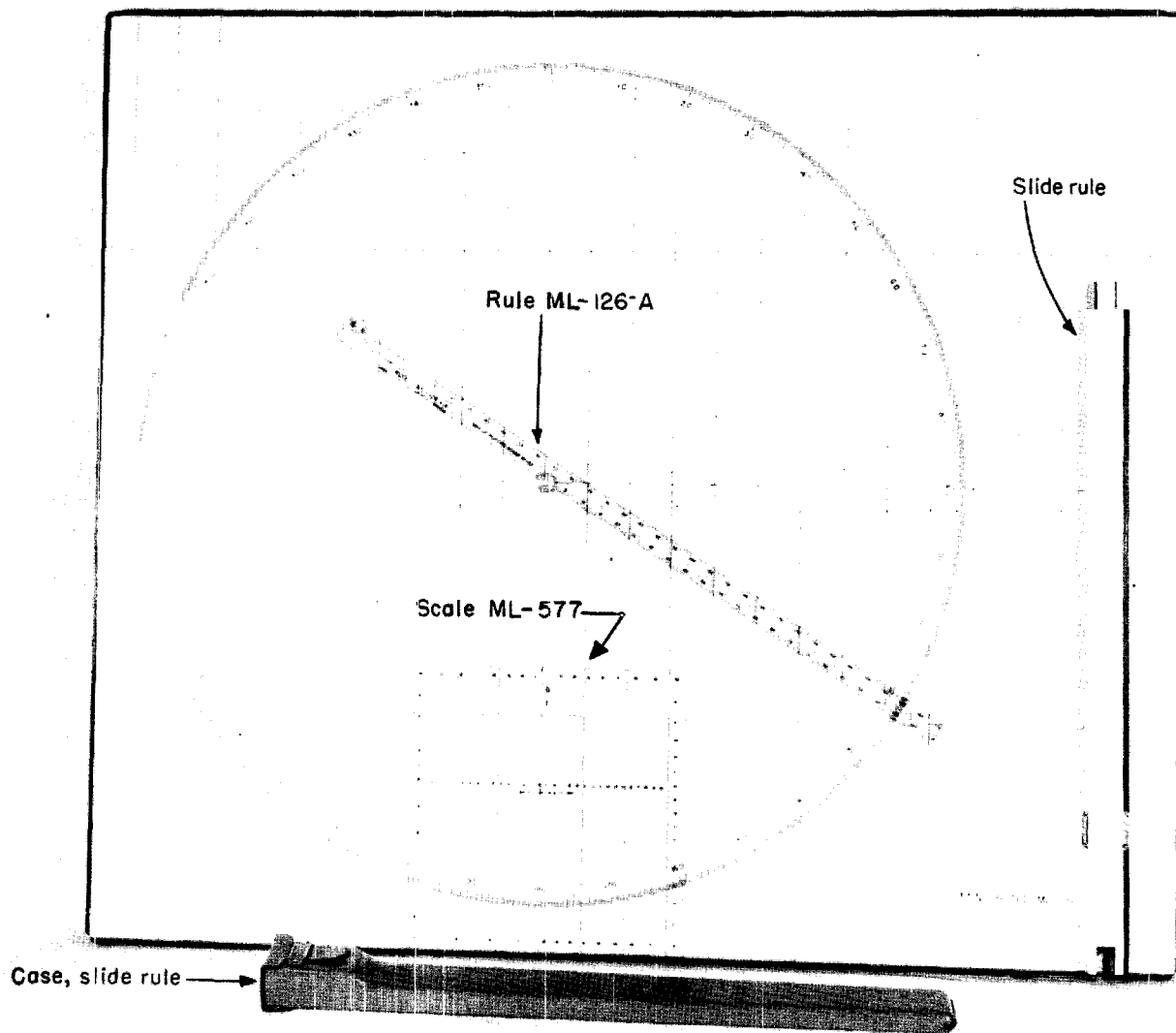
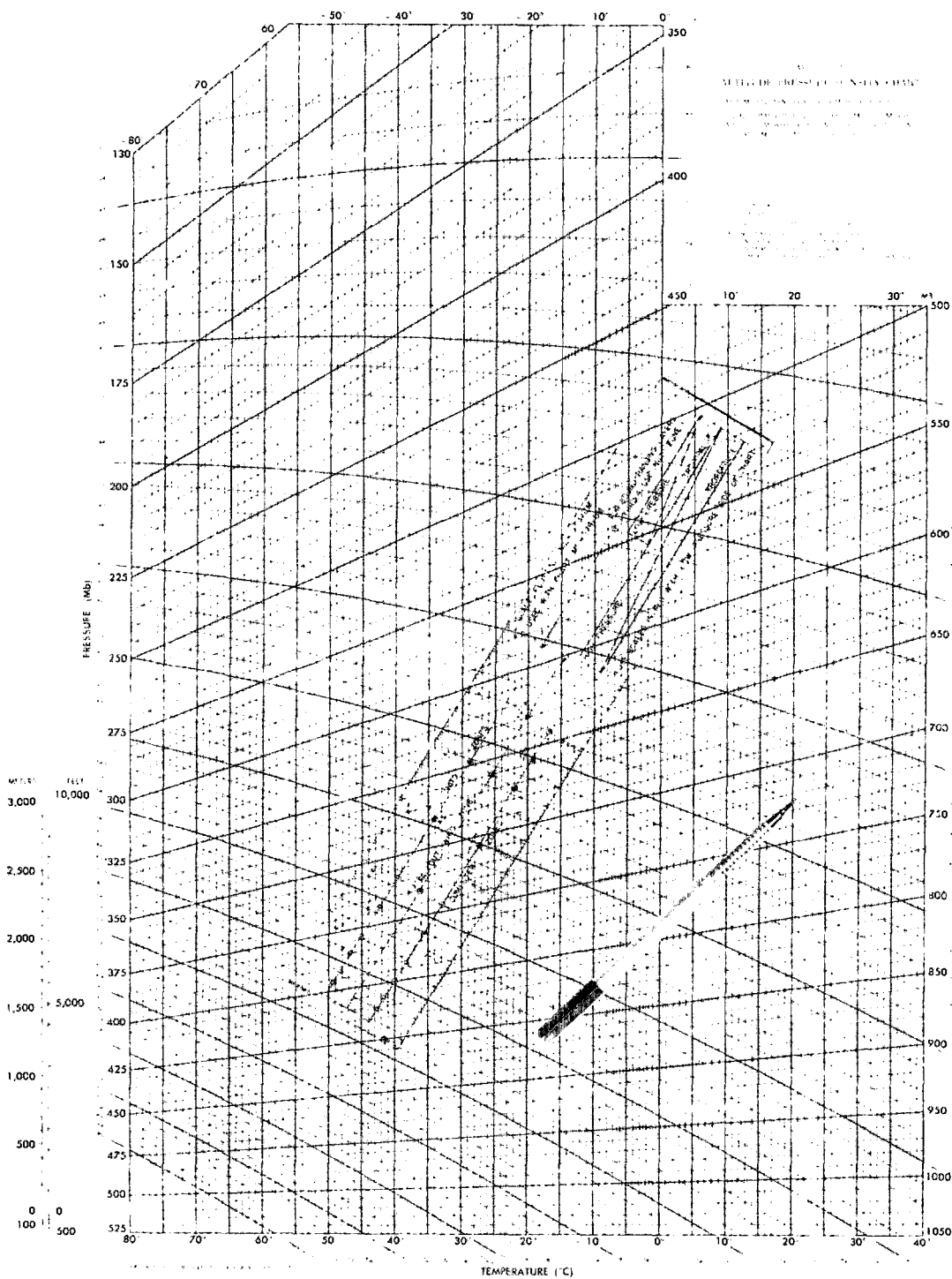


Figure 27. Wind plotting equipment.



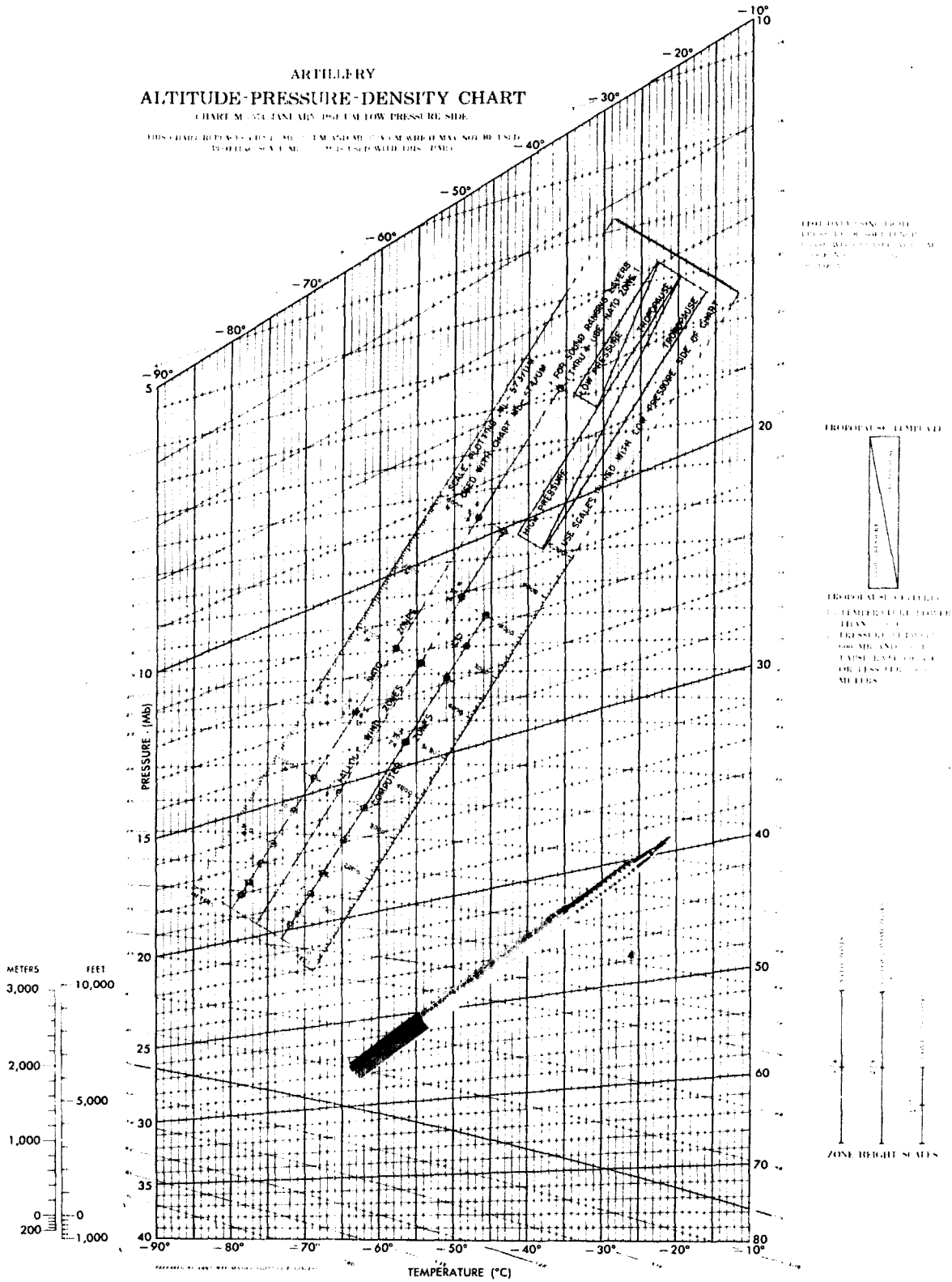
①

Figure 28. Temperature and density computing equipment.



ARTILLERY  
**ALTITUDE-PRESSURE-DENSITY CHART**  
 CHART MUST ALWAYS BE USED ON LOW PRESSURE SIDE

THIS CHART IS FOR USE ONLY ON THE LOW PRESSURE SIDE OF THE BAROMETER. IT MAY NOT BE USED ON THE HIGH PRESSURE SIDE OF THE BAROMETER.



②  
 Figure 28—Continued.

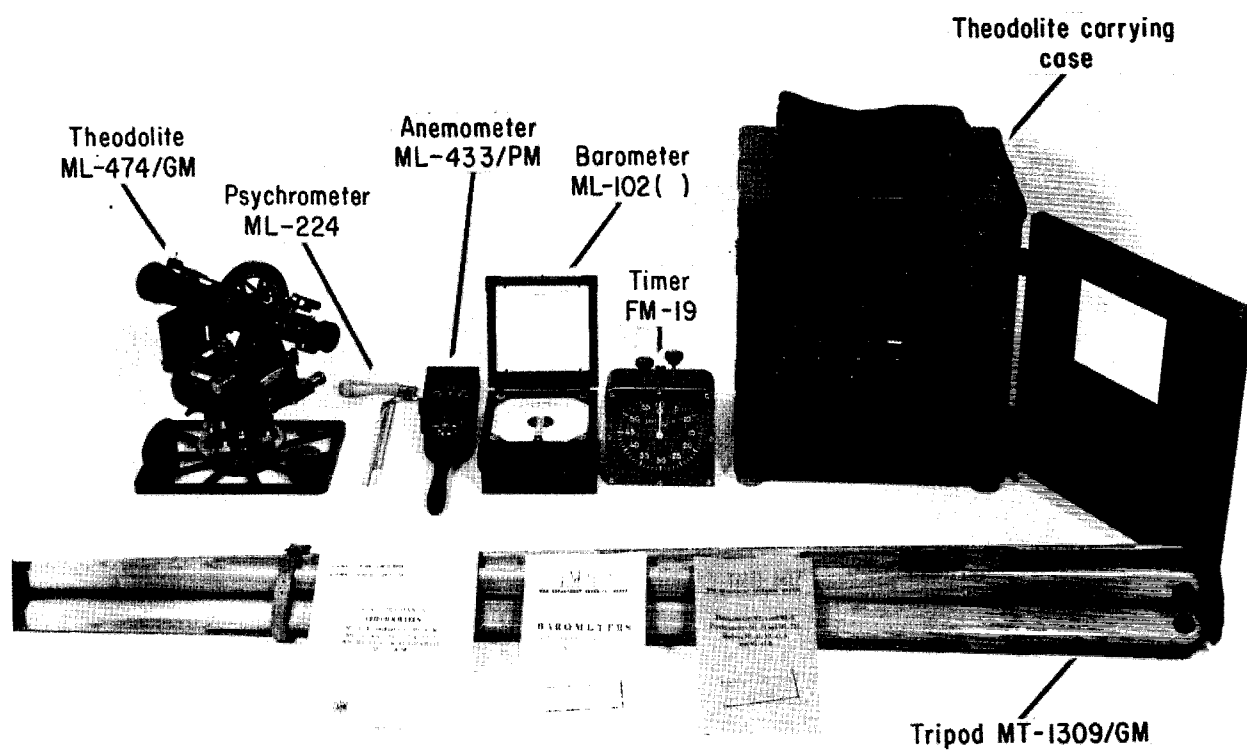


Figure 29. Surface observation equipment.

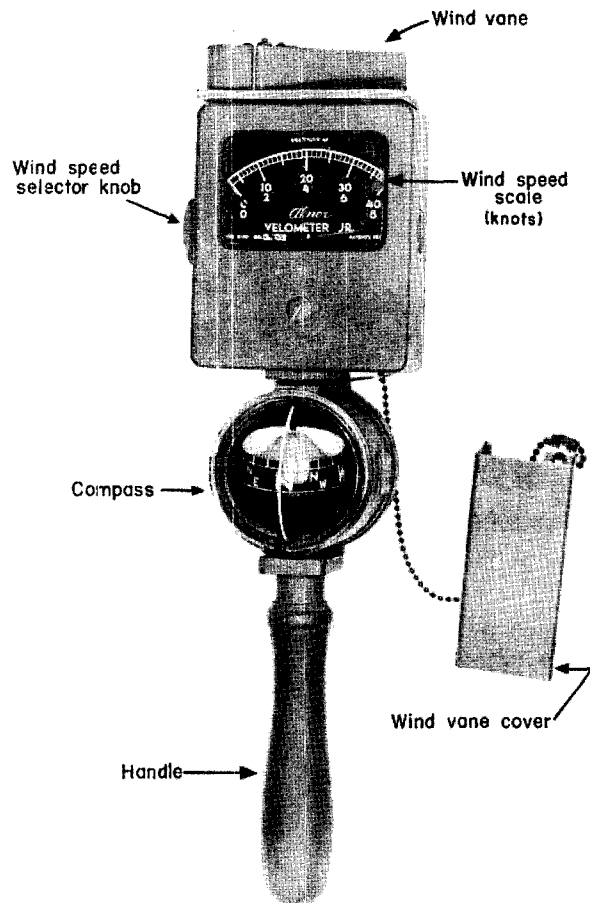
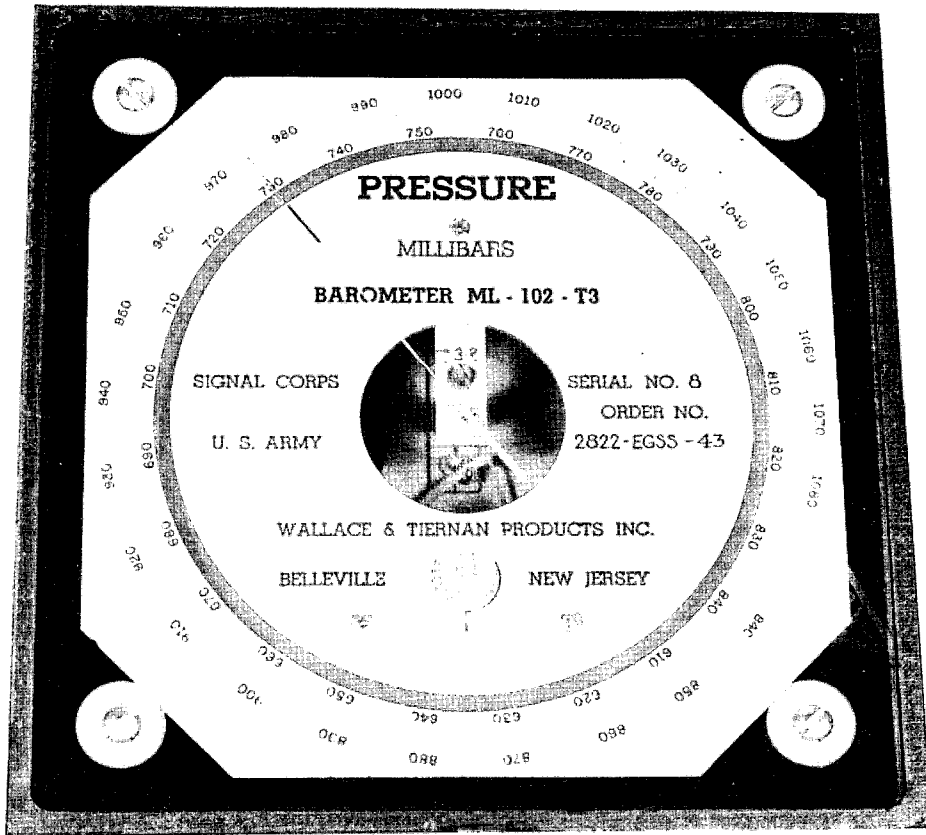
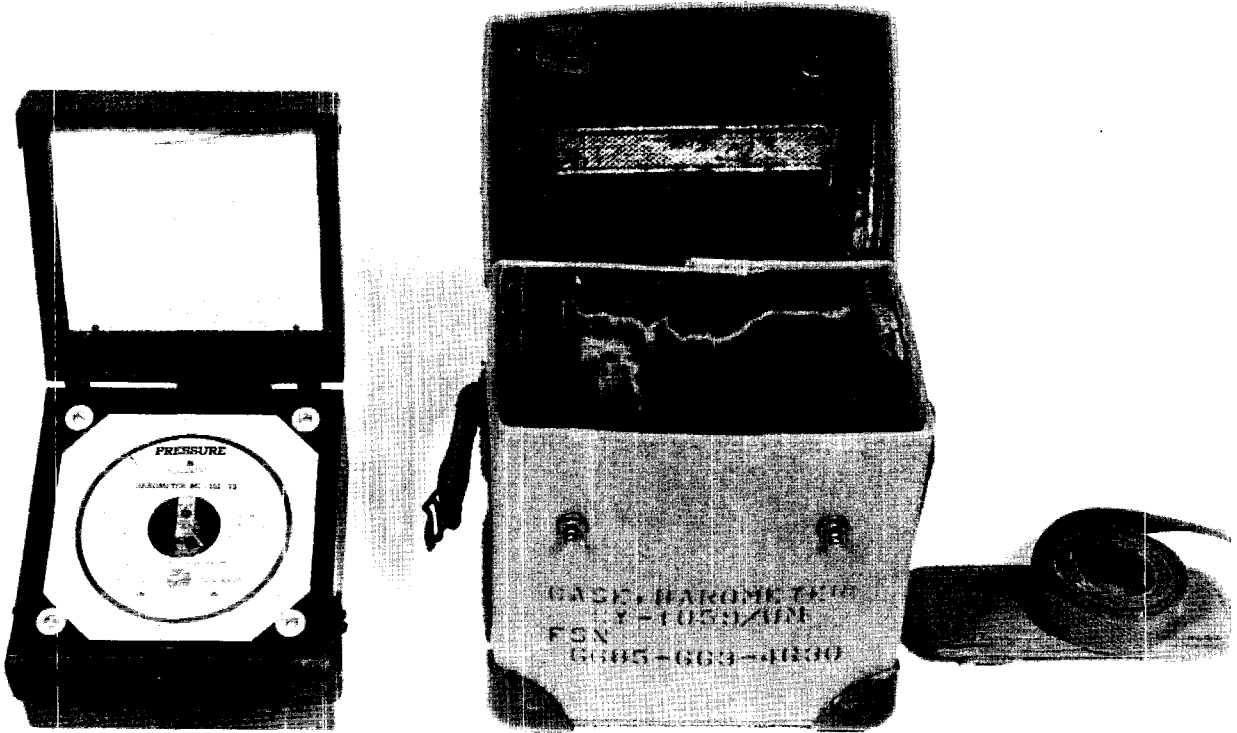


Figure 30. Anemometer ML-433/PM.

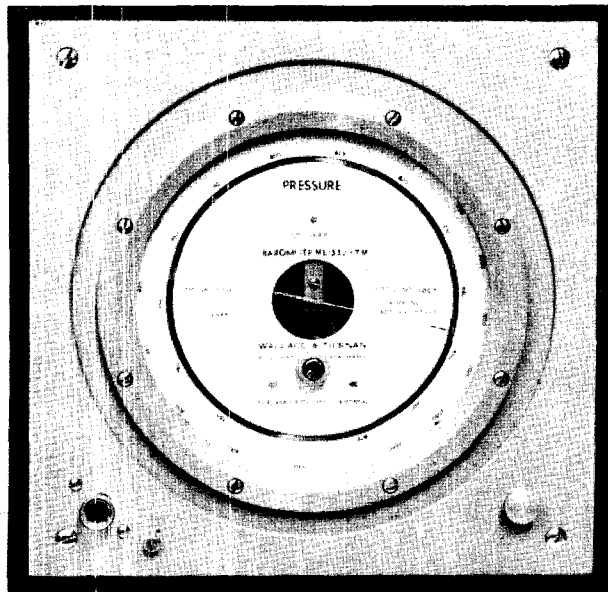


①  
Figure 31. Barometer ML-102-( ).



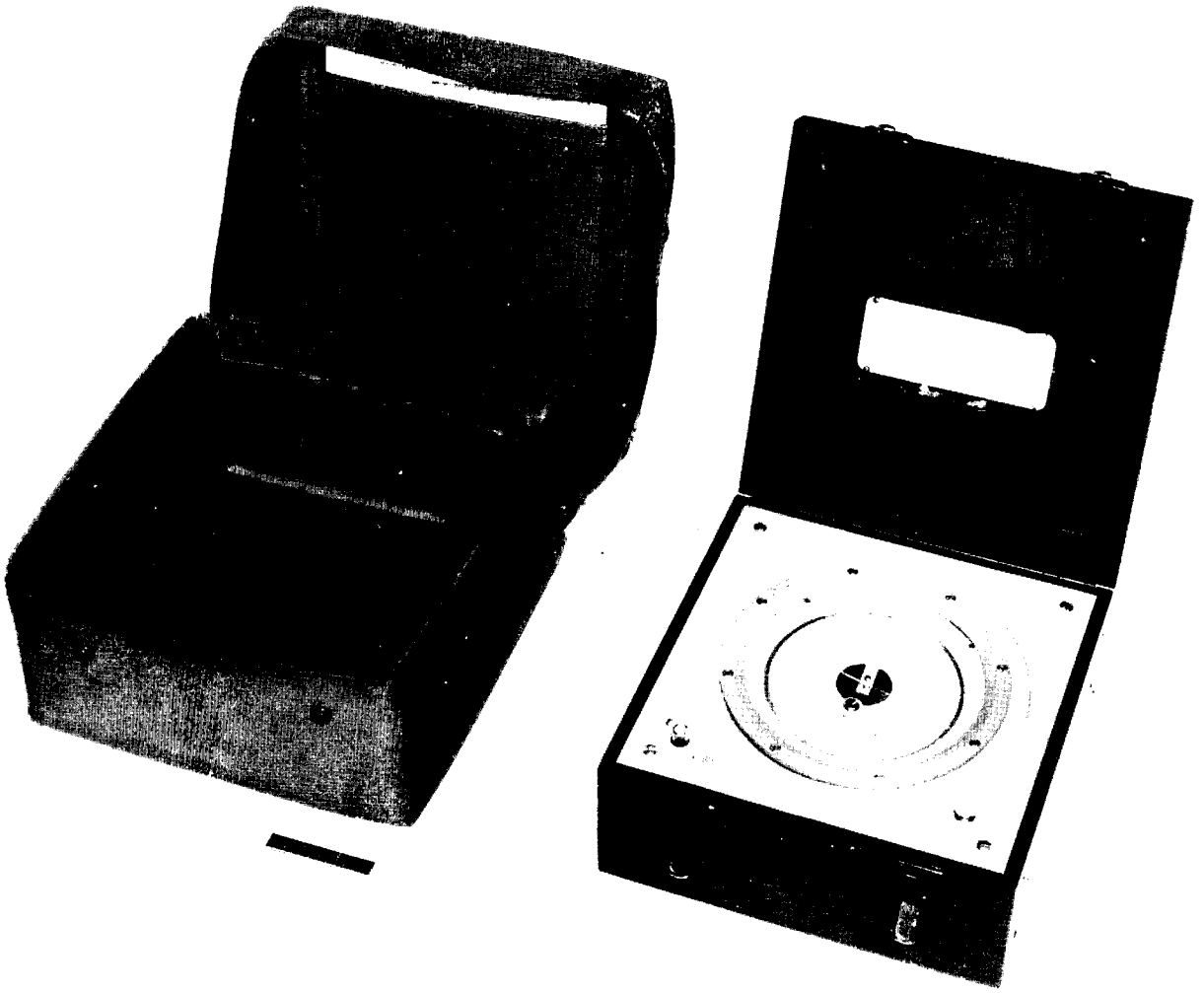
②

Figure 31. Barometer ML-102-( ).



③

Figure 31. Barometer ML-332/TM.



④  
Figure 31. Barometer ML-332/TM.

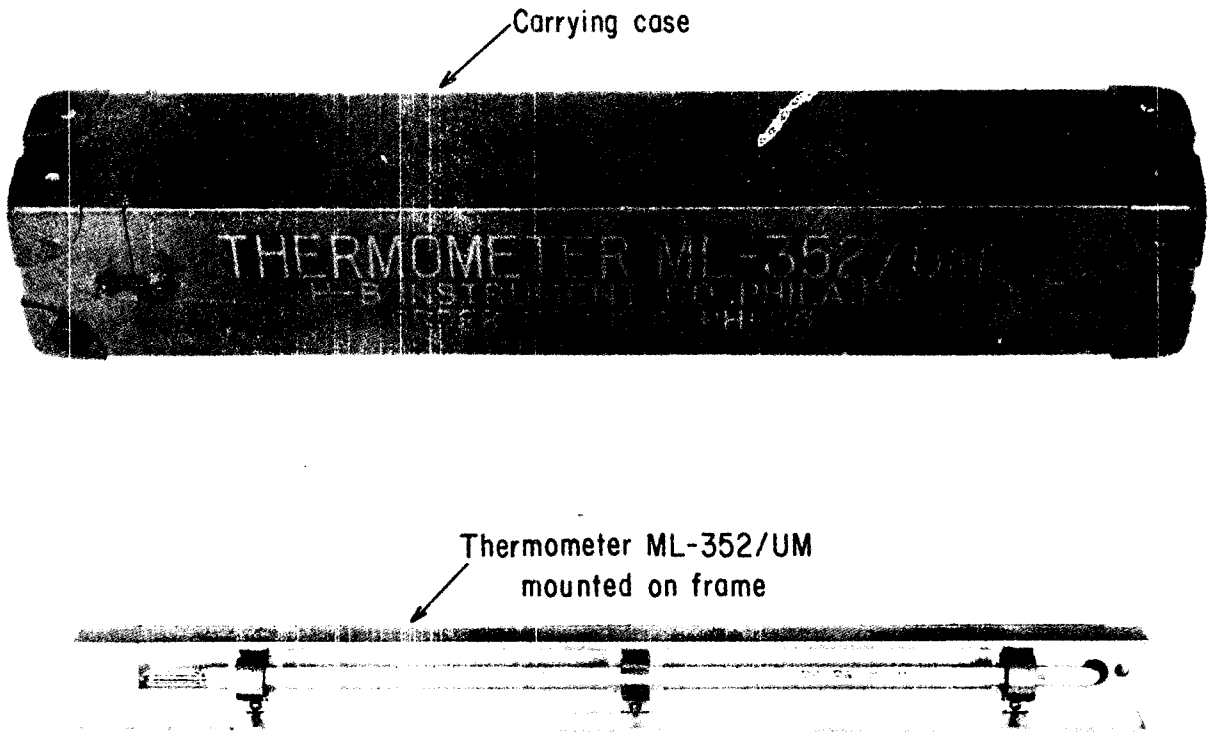


Figure 32. Thermometer ML-352/UM.

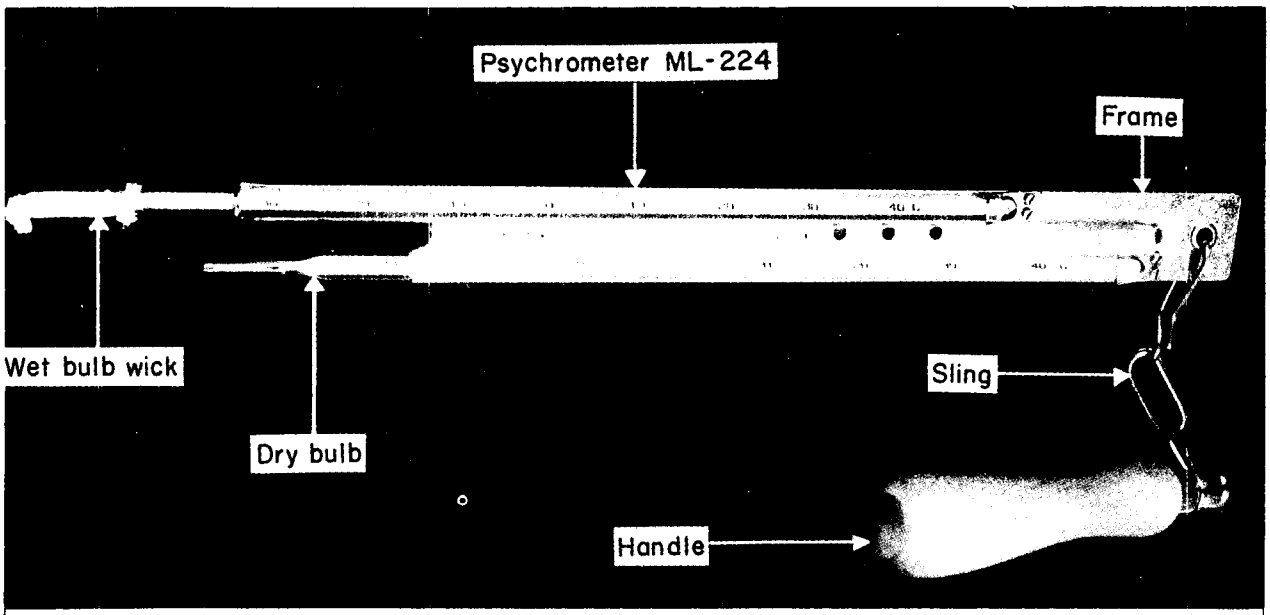


Figure 33. Psychrometer ML-224.

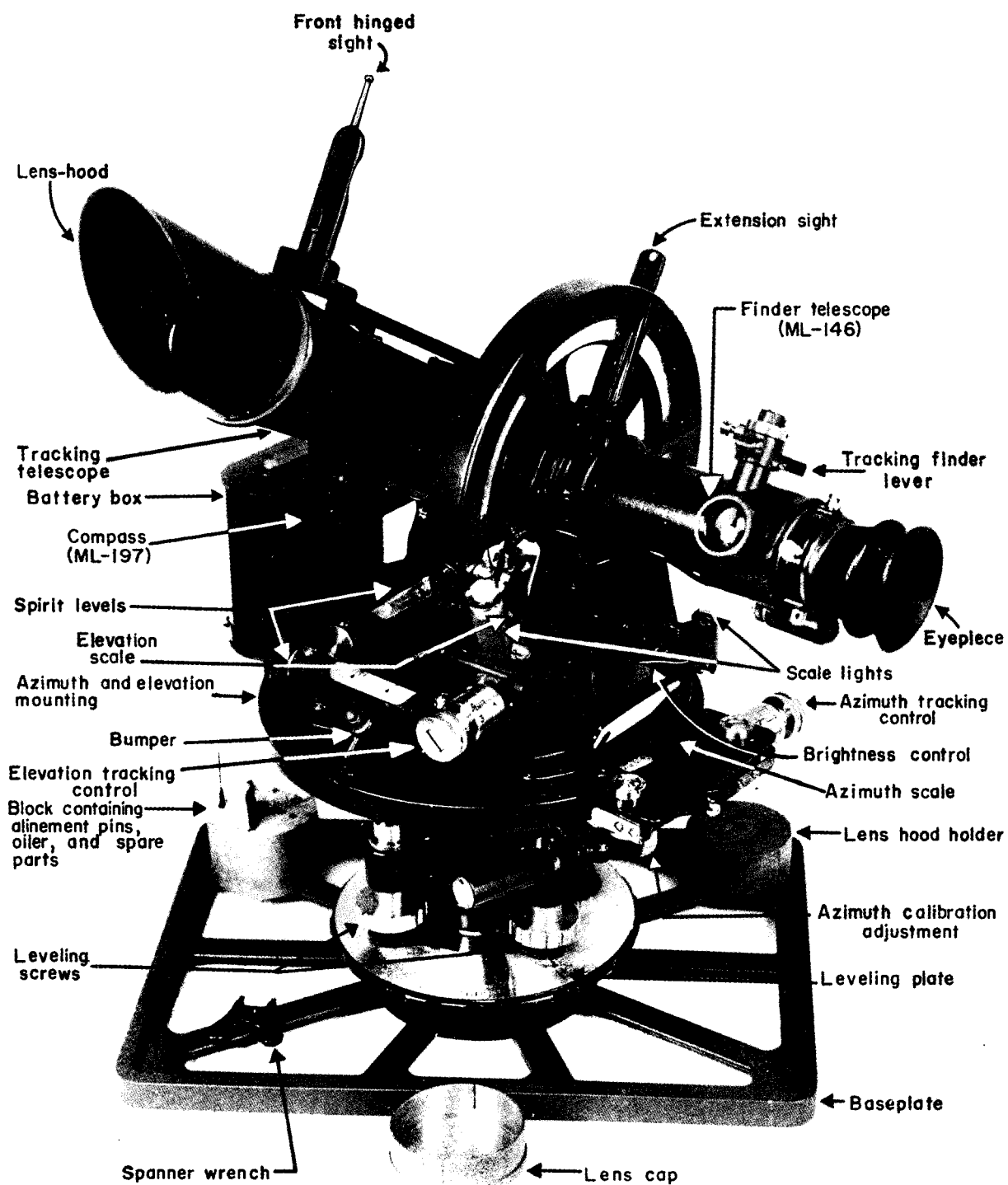


Figure 34. Theodolite ML-474/GM.



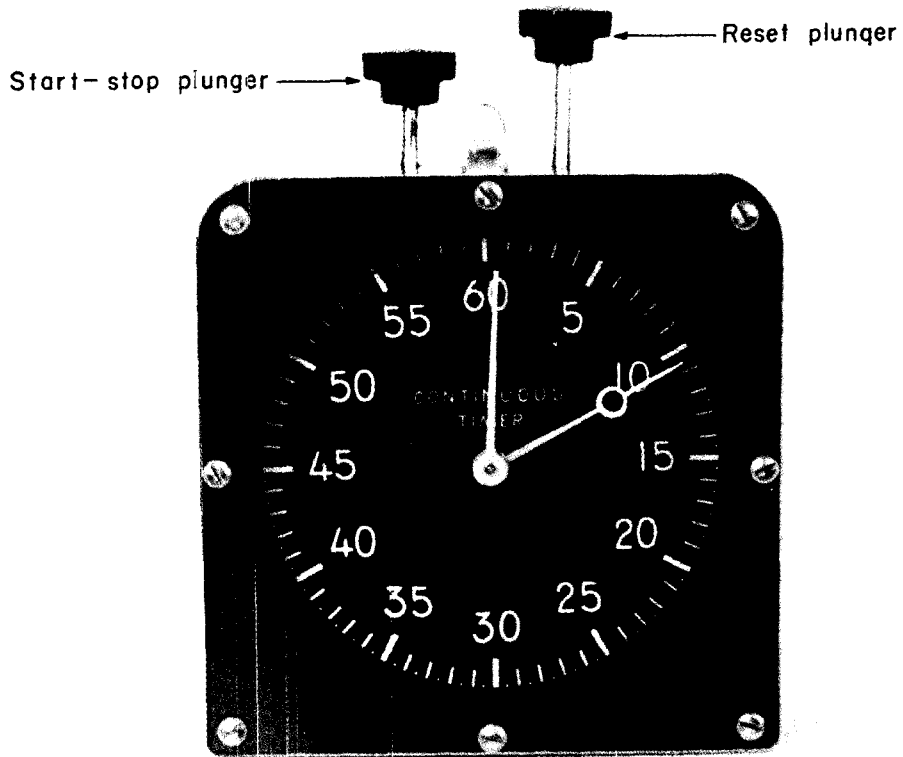


Figure 35. Timer FM-19.

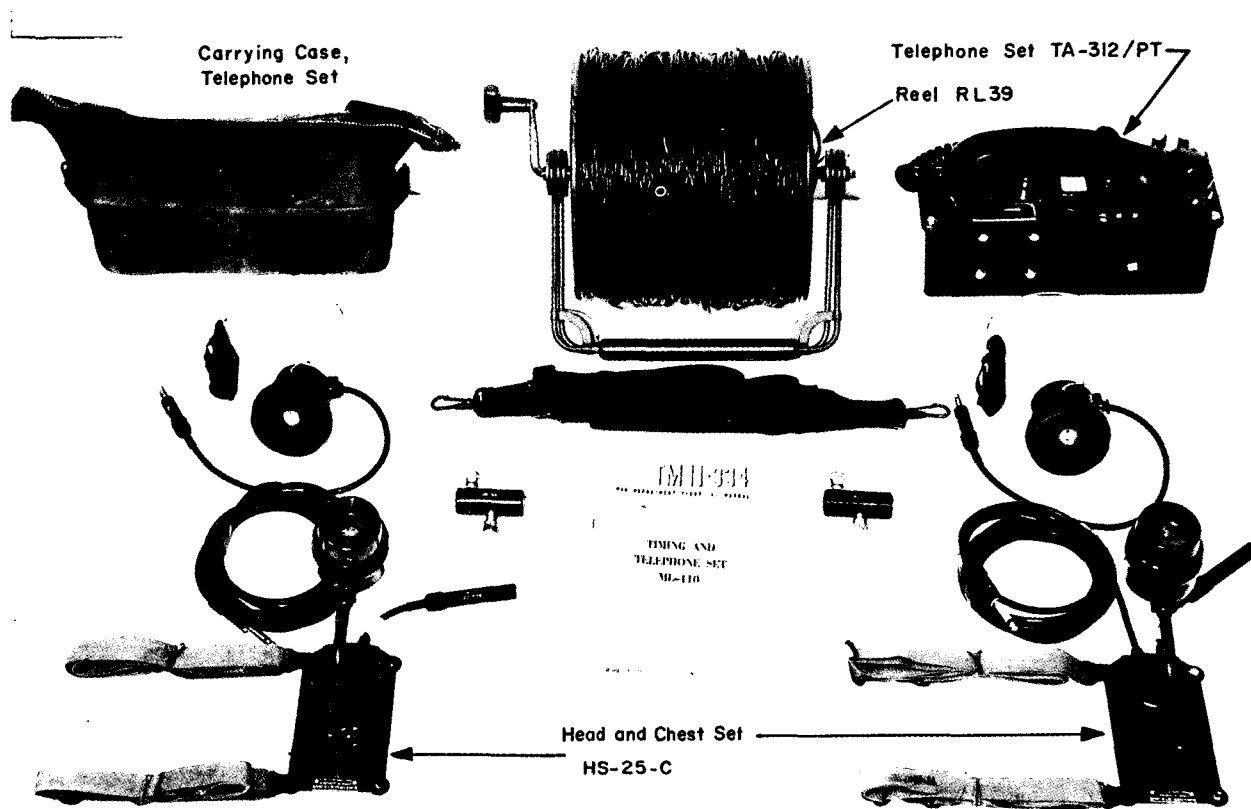


Figure 36. Wire communication equipment.

## Section II. SURFACE OBSERVATION EQUIPMENT

### 49. Anemometer ML-433/PM

*a. Purpose.* Anemometer ML-443/PM (fig. 30) is an instrument used for measuring surface winds. The anemometer provides the means for measuring both the direction and speed of the wind at the time the balloon is released.

*b. Description.* The anemometer consists of a wind vane with a removable cover, a velometer, a magnetic compass, and a removable handle. The velometer measures the wind speed in knots, and the 16-point compass measures the wind direction from magnetic north. An index pin adjacent to an index mark on the wind vane is used to align the vane with the wind direction. The velometer, on which the wind vane is mounted, has a knurled range-selector knob on the left side and a screened vent on the right side. Two wind-speed ranges, 0-8 and 0-40, are marked near the knob. The velometer scale is graduated in knots, the upper scale from 0 to 40 and the lower scale from 0 to 8. A pointer moves over

the scale to indicate wind speed. Under the velometer is a compass, which is mounted so that magnetic wind direction will be read directly when the observer faces the compass. For other features of the anemometer, see figure 30.

*c. Use.* To determine the wind *direction*, the anemometer is turned slowly clockwise and counterclockwise until the index mark on the vane is aligned with the index pin. Then the wind direction is read on the compass. The compass reading is the wind direction in relation to magnetic north and must be converted to direction in relation to true north by applying the local magnetic declination. The magnitude of the declination correction for a particular station should be determined by the section chief. If a shifting wind makes reading the compass difficult, two extreme compass readings are averaged. After reading the wind direction on the compass, it is converted to tens of degrees from true north, then the degrees are converted to mils (table II, FM

6-16). (Refer to fig. 136 for the relation between compass points and mils.) To determine the wind speed, the index mark on the range-selector knob is set to the appropriate windspeed range, 0-8 (gentle winds) or 0-40 (strong winds). Without changing the position in which the anemometer was held to read the wind direction, the wind speed is read on the velometer scale. The scale pointer must be viewed at a right angle to avoid parallax. Note that the wind speed is read in whole knots. If the pointer fluctuates considerably, the high and low points are read and the two readings are averaged. Then the windspeed reading is corrected for varying air density effect by using the windspeed correction factor chart furnished with the anemometer. Instructions for applying the correction are printed on the chart. The corrected wind speed is recorded.

*d. Preventive Maintenance.* The cover is kept on the wind vane when the anemometer is not in use. A dry brush is used to clean any dust and grit from the accessible parts or moving elements, and the surface of the anemometer is cleaned with a dry, lint-free cloth. Since the compass is magnetic, it should not be placed near any magnetized objects. Detailed instructions on the characteristics, maintenance, and adjustments are in a special booklet issued with the anemometer.

## 50. Barometer ML-102-( )

*a. Purpose.* The purpose of the barometer (1 and 2, fig. 31) is to measure the pressure of the atmosphere at the meteorological datum plane.

*b. Description and Theory of Operation.* Artillery meteorological sections are equipped with an aneroid barometer. In the aneroid barometer is a small metal cell, exhausted of all but a small amount of air and sealed so that changes in the external air pressure cause the cell to expand or contract. The movement of the cell, magnified through a gear and linkage system, is indicated on a dial calibrated in units of pressure, usually millibars (mb.). The accuracy of the pressure indicated is subject to irregularities in the elasticity of the cell, the effect of temperature variations, and other errors. The random error of the aneroid barometer is plus or minus 0.3 of a millibar. See TM 11-427 for details of the various models of barometer ML-102.

*c. Use.* The barometer usually is installed indoors. It should not be placed in the sun or near a draft or heat source but in a place where the temperature remains as constant as possible. The barom-

eter is read in either the horizontal or vertical position, as specified for the particular model. The plastic window of the dial scale is lightly tapped just before reading to insure that the pointer is free to move. The eye is alined over the pointer so that the pointer reflection in the mirror is obscured by the pointer itself. The pressure is read to the nearest 0.1 millibar and recorded to the nearest 1.0 millibar. When the temperature correction exceeds 0.1 mb., as determined from the temperature correction chart in the barometer cover, the correction must be applied.

**Caution:** If the barometer is transported by air or otherwise undergoes a rapid pressure change of 100 mb. or more, wait at least 24 hours before taking a reading. If a metro message must be determined shortly after movement by air, the barometer may be used if barometric data are not otherwise available. However, errors may exist in ballistic density values thus determined and a notation of this fact should be made on the metro message form.

*d. Preventive Maintenance.* The barometer dial face is cleaned with a damp cloth and occasionally polished with a thin coat of wax. The barometer instrument case should never be opened, and the parts never lubricated. Every 90 days, the aneroid barometer should be calibrated by comparing it with a standard mercurial or aneroid barometer of known accuracy. When the error is more than 0.3 mb., the position of the pointer is adjusted by turning the adjustment screw. An average of several pressure readings taken over a period of several hours will give a more accurate correction than a single pressure reading. Standard barometers are found at the Field Artillery Target Acquisition Battalion (FAT-AB) meteorological section and at most installations of the Air Weather Service, United States Air Force.

## 51. Standard Barometer ML-332/TM

*a. Purpose.* Barometer ML-332/TM (3 and 4, fig. 31) is issued to a metro section of the Field Artillery Target Acquisition Battalion for use in calibrating the barometers in the corps artillery.

*b. Description.* Barometer ML-332/TM consists of a metal case which contains the aneroid mechanism shock-mounted in a hardwood mounting case. A padded canvas carrying case is provided for hand carrying the barometer. The metal case containing the aneroid mechanism is kettle-shaped (8 inches in

diameter by 4 inches deep) and is made of aluminum alloy. A sealed plate glass cover protects the dial. An opening in the glass cover permits adjustment of the pointer without opening the case. This opening is plugged by means of a threaded metal sleeve with a flanged top cemented into the glass. The hardwood mounting case is 11 inches square by 5 inches deep. The metal case is held in the hardwood mounting case by a 10-inch square aluminum plate. A valve is mounted on the underside of the aluminum plate near the lower right-hand corner, and an air pump is similarly mounted near the lower left-hand corner of the plate. A pushbutton, which operates the valve, projects through to the top of the aluminum plate. The air pump consists of the barrel and plunger of a glass hypodermic syringe provided with a suitable valve to permit air to be pumped either into or out of the metal barometer case. The top of the plunger of this pump projects through the top of the aluminum plate, thus permitting operation of the pump when the lid of the wooden mounting case is raised. Two pieces of rubber tubing connect the valve and the pump to the barometer case. The purpose of the valve is to permit the metal barometer case to be sealed completely from the outside air or opened to the outside air so that the pressure in the case will be equal to that of the outside air. The purpose of the pump is to provide a means of controlling the air pressure within the metal barometer case when the valve is closed and the case is sealed from the outside air.

*c. Use and Preventive Maintenance.* For use and preventive maintenance, see TM 11-2421.

## 52. Psychrometer ML-224

*a. Purpose.* The purpose of the psychrometer ML-224 (fig. 33) is to provide a means for measuring the wet- and dry-bulb temperatures of the air. From these measurements, the water vapor content of the air may be determined.

*b. Description and Theory of Operation.* Psychrometer ML-224 consists of two 9-inch mercury-in-glass thermometers of the same type (general or tropical) mounted on a metal frame which is attached by means of a small chain to a wooden handle. The thermometers are graduated in degrees Celsius from  $-37^{\circ}$  to  $+46^{\circ}$ . One thermometer (wet-bulb), with the bulb covered by a small cotton wick to hold water, is mounted lower on the frame than the other. As water evaporates, it absorbs a fixed amount of heat energy. Thus, as the wetted wick of the wet-

bulb thermometer begins to dry, it absorbs heat from the bulb and causes the wet-bulb thermometer to register a lower temperature than the dry-bulb thermometer. This temperature difference is termed the depression. The rate of drying varies with the dryness of the surrounding air, i.e., the relative humidity (RH) of the air. Dry air (zero RH) causes the maximum evaporation to occur and likewise the maximum depression. The wet-bulb depression and the dry-bulb reading commonly are used as arguments to enter tables used to obtain the virtual temperature and relative humidity of the air. See TM 11-2417 for detailed information on psychrometer ML-224.

*c. Use.* The psychrometer is ventilated in the shade or an instrument shelter, when possible, to obtain the air temperature, since direct sunrays and precipitation cause erroneous readings. The operator ventilates the psychrometer (as pictured in fig. 37) to eliminate the effect of body heat. The thermometers are never handled because hand heat affects the readings. The operator wets the wick in clean water. When possible, distilled water is used or rainwater that is free of all mineral matter may be used. The operator whirls the psychrometer for about 15 seconds and reads the thermometers. He repeats this process until the wet-bulb thermometer changes less than  $1^{\circ}$  between readings; then he repeats the process at 5-second intervals until a minimum wet-bulb reading is reached. He records the lowest wet-bulb reading and the concurrent dry-bulb reading to the nearest  $0.1^{\circ}$  C. The dry-bulb temperature is the air temperature. When operating in high temperatures or very dry air, the wick is wetted thoroughly and a drop of water is allowed to stand on the bulb for several minutes to precool it. This precooling permits completion of the observation before the wick dries out completely. When operating at temperatures below freezing, the wick is wetted 10 to 15 minutes before use so that the heat of fusion of the ice will be dissipated before the observation is made. With the wick frozen in a thin coating of ice, the operator proceeds with the observation. After the observation, the wet-bulb depression is determined. This depression and the dry-bulb reading are used as arguments to enter the relative humidity chart (chart VIII, FM 6-16) to determine the percentage of relative humidity. The values of relative humidity given in chart VIII, FM 6-16, are with respect to water at all temperatures. If the air is saturated,



Figure 37. Ventilation of psychrometer.

no evaporation from the wet-bulb thermometer can occur, and the wet-bulb thermometer reading will be the same as the dry-bulb thermometer reading. If the air is not saturated, the wet-bulb thermometer reading will be lower than the dry-bulb thermometer reading and the relative humidity will be less than 100 percent.

*d. Preventive Maintenance.* The thermometer tubes are cleaned with a damp cloth and polished with a clean, dry cloth. The frames are cleaned by wiping with a solution of sodium bicarbonate; abrasives or acid cleaners are not used. Occasionally, the swivel bearing is oiled and the linkage is checked for free movement and good condition. The wet-bulb wick is changed weekly or more often in areas where there is excessive dust or other air pollution. To eliminate errors due to inaccuracies in thermometers, the thermometers should be compared when issued and the two which have the nearest readings at the same temperature should be mounted on the same psychrometer frame. If there is no standard thermometer available, the dry-bulb thermometer should be accepted as correct, and the reading of the wet-bulb thermometer should be corrected to that of the dry-bulb thermometer. If a standard thermometer is available, all thermometers should be compared by the method described in TM 11-2417 to determine the scale error. For detailed information on maintenance, see TM 11-2417.

### 53. Theodolite ML-247 or ML-474/GM

*a. Purpose.* The purpose of theodolite ML-247 or ML-474/GM (fig. 34) is to provide a means of visually tracking a pilot balloon in flight. The elevation and azimuth scales indicate the angles to the balloon. Changes in the position of the balloon observed at regular intervals are indicative of the wind speed and direction.

*b. Description.* Theodolites ML-247 and ML-474/GM are identical except for the manner in which the crosshair is illuminated. The theodolite is a precision-built optical instrument and usually is mounted on tripod ML-78 or MT-1309/GM. The main components of the theodolite are a tracking telescope, a finder telescope, and a set of open sites, arranged in conjunction with the azimuth and elevation scales. The tracking telescope of the theodolite has a 20-power magnification and a 2° field of view; it can be rotated 360° in azimuth and plunged in elevation. A finder telescope of 4-power magnification and 10° field of view is mounted parallel to

the tracking telescope in the eyepiece tube. The theodolite is equipped with a compass and, when properly declinated, can be oriented on true north. The elevation and azimuth scales are in  $1^\circ$  graduations. The drum micrometers of the azimuth and elevation tracking controls are in  $0.1^\circ$  graduations. By interpolation on the drum micrometer scale, readings may be made to the nearest  $0.01^\circ$ . See TM 11-6675-200-10 for details on operation of the theodolite.

*c. Use.* The theodolite should be located where there are no obstructions above an elevation angle of  $3^\circ$ . A windbreak is desirable, since wind gusts may upset the tripod. The operator must emplace the tripod firmly in the ground and level the instrument prior to use. Elevation and azimuth readings to a pilot balloon are determined by tracking the balloon with the theodolite and reporting the required readings at proper intervals.

*d. Orientation. Methods* The theodolite may be oriented by compass, survey data, the sun, Polaris, equal angles, datum lines, or transference. TM 11-6675-200-10 describes each of these methods. The two most common methods of orientation are by survey data and by compass.

- (1) *Orientation from survey data.* Orientation of the theodolite by using survey data is considered the primary method. When this method is used, the metro section chief coordinates with the survey personnel who provide the orientation data. Survey control, when available, consists of the correct grid azimuth from the theodolite position to a fixed reference point and the altitude of the theodolite to the nearest 10 meters. Orientation from survey data is more accurate than the magnetic orientation and should be used as soon as survey data are available. The theodolite operator first converts the grid azimuth to true azimuth, then sets the true azimuth on the instrument. With the azimuth calibration adjustment, he then sights through his main telescope on the reference point. The theodolite is accurately oriented on true north.
- (2) *Orientation by a compass.* When the theodolite is oriented by a compass, the local magnetic declination is obtained from the survey information center or from the marginal data of a map of the area. The

magnetic north pole of the earth (toward which the north seeking end of a compass needle points) does not coincide with the earth's geographical north pole (true north). Consequently, a compass seldom indicates the true north direction but deviates from it by varying amounts depending on its location and other factors. The extent of this deviation is known as magnetic declination, and must be known for a particular place before a theodolite can be oriented by a compass. The steps for orienting a theodolite by compass are as follows:

- (a) Disengage the azimuth tracking control and rotate the mounting until the fiducial marker of the azimuth scale is alined with the magnetic setting. Then engage the tracking control. This setting will be  $0^\circ$  plus the deviation for an East declination (magnetic direction arrow to the east of true north), or  $360^\circ$  minus the deviation for a West declination (magnetic direction arrow to the west of true north). For example, if the declination is  $5^\circ$  E, set the fiducial mark opposite the  $5^\circ$  graduation of the azimuth scale; if the declination is  $5^\circ$  W, set the mark opposite the  $355^\circ$  graduation.
- (b) Loosen the azimuth calibration clamp and lower the lock lever on the side of the compass.
- (c) Rotate the mounting until the compass needle is approximately over the **S** mark on the compass face.
- (d) Tighten the azimuth calibration clamp and turn the azimuth calibration adjustment until the needle is exactly over the **S** mark.
- (e) Raise the compass lock lever to its upper position to secure the internal mechanism.
- (f) The theodolite is now oriented on true north.

*e. Preventive Maintenance.* The theodolite is a delicate instrument and must be carefully protected from jarring, dirt, and unnecessary exposure to the weather. Extreme care should be exercised in removing it from or returning it to the carrying case. When mounted on the tripod, the theodolite should not be left unattended for an excessive period of

time. While on the tripod and not in use, it should be covered with the canvas hood. The magnetic needle requires declination at periodic intervals, especially under field conditions where movement is involved. (For detailed instructions, see FM 6-2, Artillery Survey.) The theodolite should be inspected daily for loose parts, which should be tightened if necessary. For specific instructions on organizational maintenance, see TM 11-6675-200-20. Details on operator's preventive maintenance are contained in TM 11-6675-200-10.

**Caution:** Care should be taken in adjusting brass screws which are soft and easily damaged.

#### 54. Timer FM-19

*a. Purpose.* The purpose of the timer FM-19 (fig. 35) is to time the flights of pilot balloons so that the azimuth and elevation angle readings will be taken at the proper times.

*b. Description.* The timer FM-19 is a conventional timer with a circular dial graduated from 0 to

60 minutes and marked at 5-minute intervals. It contains a large sweep second hand and a shorter minute hand. The start-stop and reset plungers are side by side on the top of the timer. A latch for rewinding is on the back. The timer is spring powered and should be wound before each balloon flight.

*c. Use.* After the timer is wound, the start-stop plunger is pressed to insure that the second hand is functioning properly. The start-stop plunger is pressed again to stop the hands, and the reset plunger is pressed. The timer is now ready for operation. The start-stop plunger is pressed at the instant the pilot balloon is released.

*d. Preventive Maintenance.* The face of the timer should be kept clean at all times to insure accurate readings. The timer should be handled with care in order to prevent jarring which might damage its operating mechanism. Regular checks and adjustments should be made by comparing the timer with an accurate watch.

### Section III. INFLATION EQUIPMENT AND BALLOONS

#### 55. Balloon Inflation Tent

*a. Purpose.* The balloon inflation tent M-1957 (fig. 38) is a portable inflation shelter designed for use by the metro section. During inflation, meteorological balloons must be protected from the wind. Under field conditions, it is difficult to find a suitable building for inflation; hence, a portable inflation shelter is provided.

*b. Description.* The tent is rectangular with an arched top. It is suspended beneath a wooden frame by webbing straps with buckles. The frame consists of 3 sectional arches and 22 aluminum purlins (a horizontal supporting brace). Each sectional arch consists of two lower arch segments (straight) and two upper arch segments (curved), which are hinged together when assembled. The tent is approximately 13 feet wide, 15 feet long, and 12 feet high. Each end of the tent opens to its full height by means of a slide fastener in the center, operated by ropes. Ropes threaded through D-rings on each side of the opening are attached to the slide fastener so that the entire end of the tent opens to allow removal of the inflated balloon. A heater duct is provided at the lower left corner of the front of the tent. The tent is issued with a cover for use when it is stored or is being transported.

*c. Assembly.* Using the procedure outlined below, the balloon inflation tent can be assembled by four men in approximately 30 minutes:

- (1) Designate the men as numbers 1, 2, 3, and 4.
- (2) Assemble all arches and attach a rope and pulley (not issued) at the top center of each end arch.
- (3) Numbers 1 and 2 raise the front end arch (fig. 39); number 1 holds the arch in an upright position.
- (4) Numbers 3 and 4 raise the center arch (fig. 39).
- (5) Number 2 procures six purlins and inserts three on each side (fig. 40). This will hold the first two arches upright. (Additional personnel may be utilized when available.)
- (6) Numbers 1 and 2 drive stakes through each foot plate.
- (7) Numbers 3 and 4 raise the third arch as number 1 inserts a purlin (fig. 40) to hold the third arch upright.
- (8) Numbers 1 and 2 drive stakes through the remaining foot plates and insert the remaining purlins; number 3 procures and installs the end braces while number 4 un-

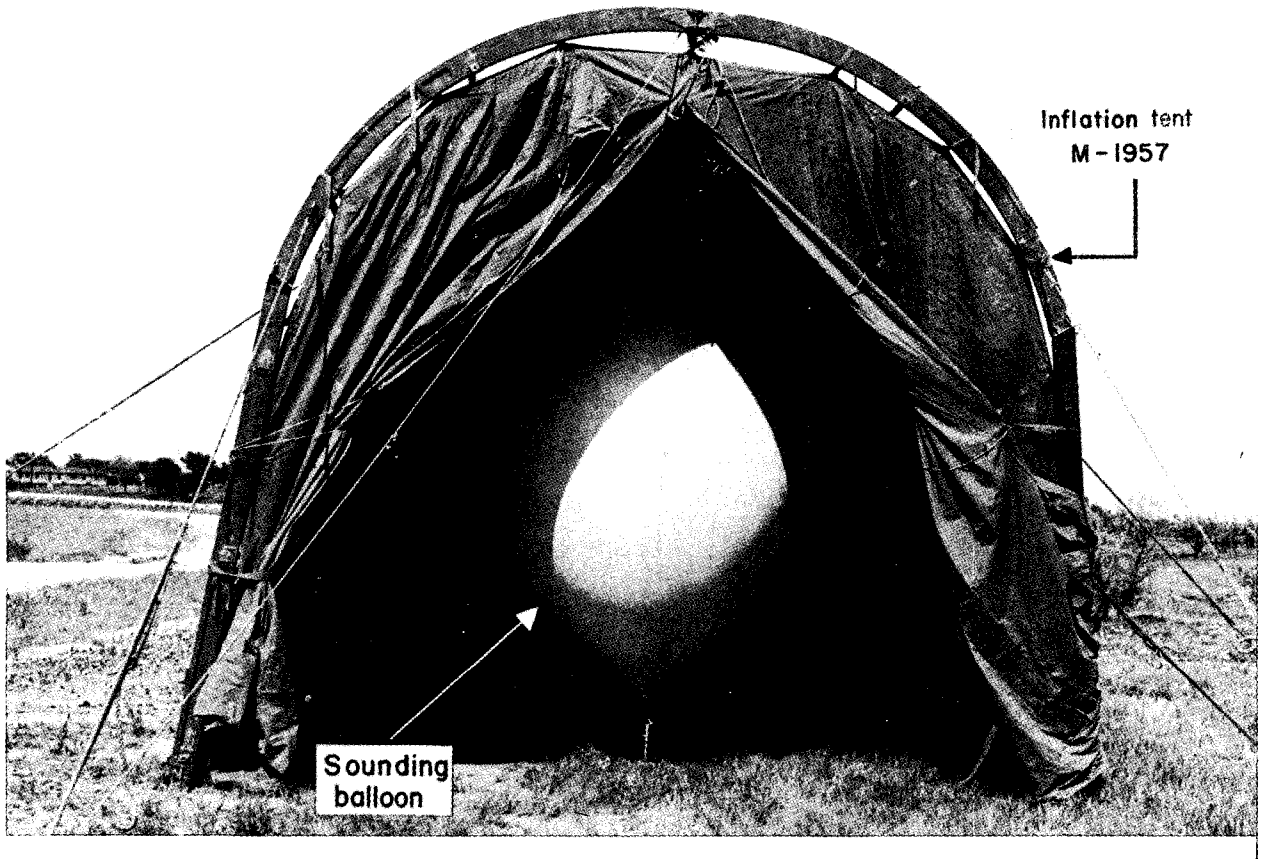


Figure 38. Balloon inflation tent, M-1957.

rolls the tent and ties a pulley rope to each end of the tent (fig. 41).

- (9) Numbers 1 and 2 on one side and numbers 3 and 4 on the other side install guy lines to the arches and secure them to the stakes (fig. 41).
- (10) Numbers 1 and 2 raise the tent by simultaneously drawing the pulley ropes on each end while numbers 3 and 4 (one on each side) tie the canvas to the arches (fig. 42).
- (11) Tighten and secure all guy lines and end support cables, roll up window covers, and install heater duct through the appropriate opening (if desired).

## 56. Gases Used for Inflation

Pilot and sounding balloons are inflated with either hydrogen or helium gas. The metro section

has the capability of producing hydrogen in the field by using calcium hydride charges (fig. 44). Calcium hydride reacts chemically with water to produce hydrogen gas. The calcium hydride method of preparing hydrogen for inflation of balloons is essential to self-sufficient operation of the metro section. However, commercial hydrogen or helium have many advantages and should be used if available. These gases are supplied commercially in high-pressure, steel cylinders which contain approximately 200 cubic feet of gas. Regulator ML-193 (ML-528/GM) (fig. 43), a component of meteorological station, manual AN/TMQ-4, is used to reduce the high pressure of the gas in the cylinder to a suitable pressure for balloon inflation. The use of commercial gases is more economical, reduces inflation time, requires no water, and is more convenient to handle. Commercial hydrogen (Federal stock number 6830-



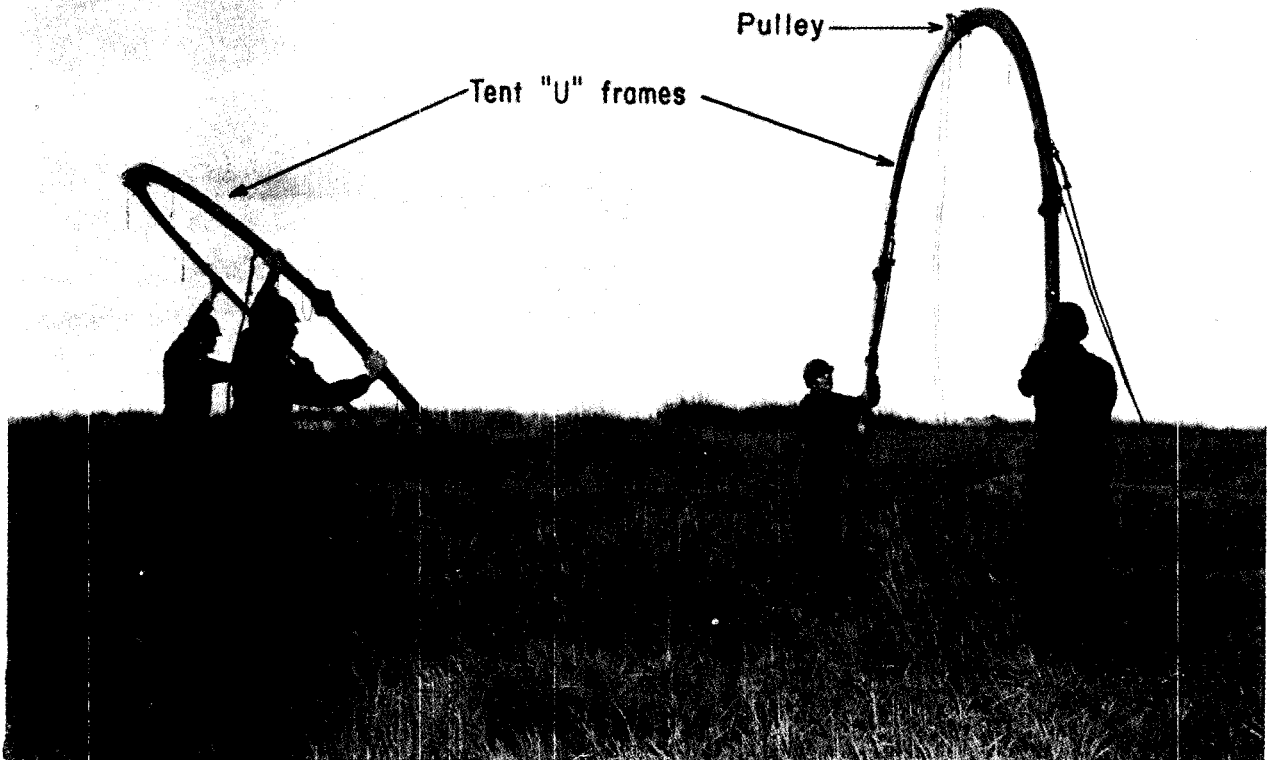


Figure 39. Erecting frames for balloon inflation tent, M-1957.

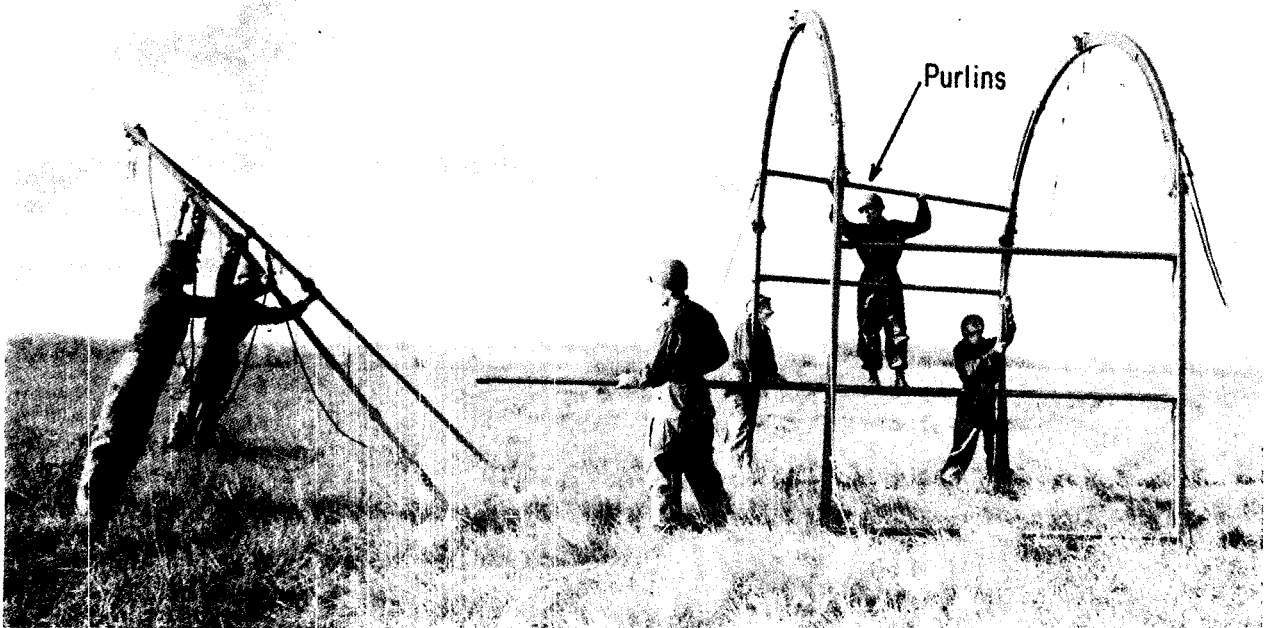


Figure 40. Inserting purlins.

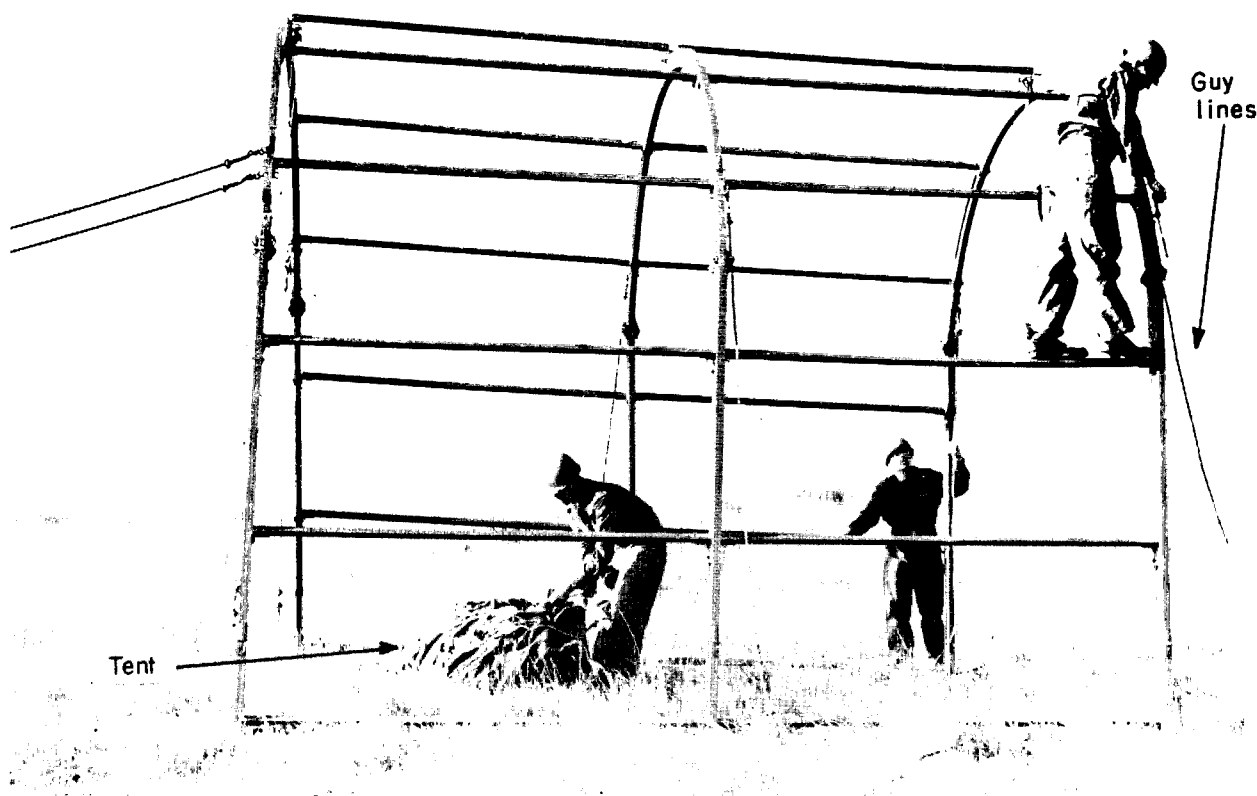


Figure 41. Framework assembled.

264-6748) or helium (Federal stock number 6830-660-0027) are procured through engineer supply channels. Commercial hydrogen has been economically used by metro sections in the continental United States, England, Germany, and Korea. Even though commercial hydrogen is used, the metro section should continue to stock calcium hydride charges at the authorized TOE level for use during emergencies. For training purposes, it is recommended that every tenth sounding balloon be inflated with hydrogen generated by the calcium hydride method. Because it is inert and not explosive, helium is often preferred to hydrogen. Unfortunately, helium is not available in many parts of the world and, when available, is supplied in cylinders only. Helium usually is cheaper than hydrogen prepared with calcium hydride and only slightly more expensive than commercial hydrogen. Because helium is heavier than hydrogen, more helium is required to attain the same rate of rise as hydrogen. Authority and procedures for requesting

commercial gases to be used for balloon inflation are contained in AR 725-5. Detailed information on commercial gases are contained in Engineer Supply Manual SM 5-1 and safety requirements for handling commercial gas cylinders are listed in AR 700-8120-1.

### 57. Safety Procedures

a. Both the generation and use of hydrogen are dangerous due to the highly flammable nature of the gas. Only by being extremely careful can the dangers of fire or explosion be minimized. Because of the hazards involved in handling hydrogen, helium (an inert gas) should be used to inflate balloons, when it is available. When hydrogen is used, the safety precautions outlined in chapter 34 must be carefully observed. Copper wire should be used to connect all metal parts of the equipment to each other and to a well-grounded object, such as a ground rod (1, fig. 45). Ground clamps or alligator clips are used to connect the wire to the metal. For

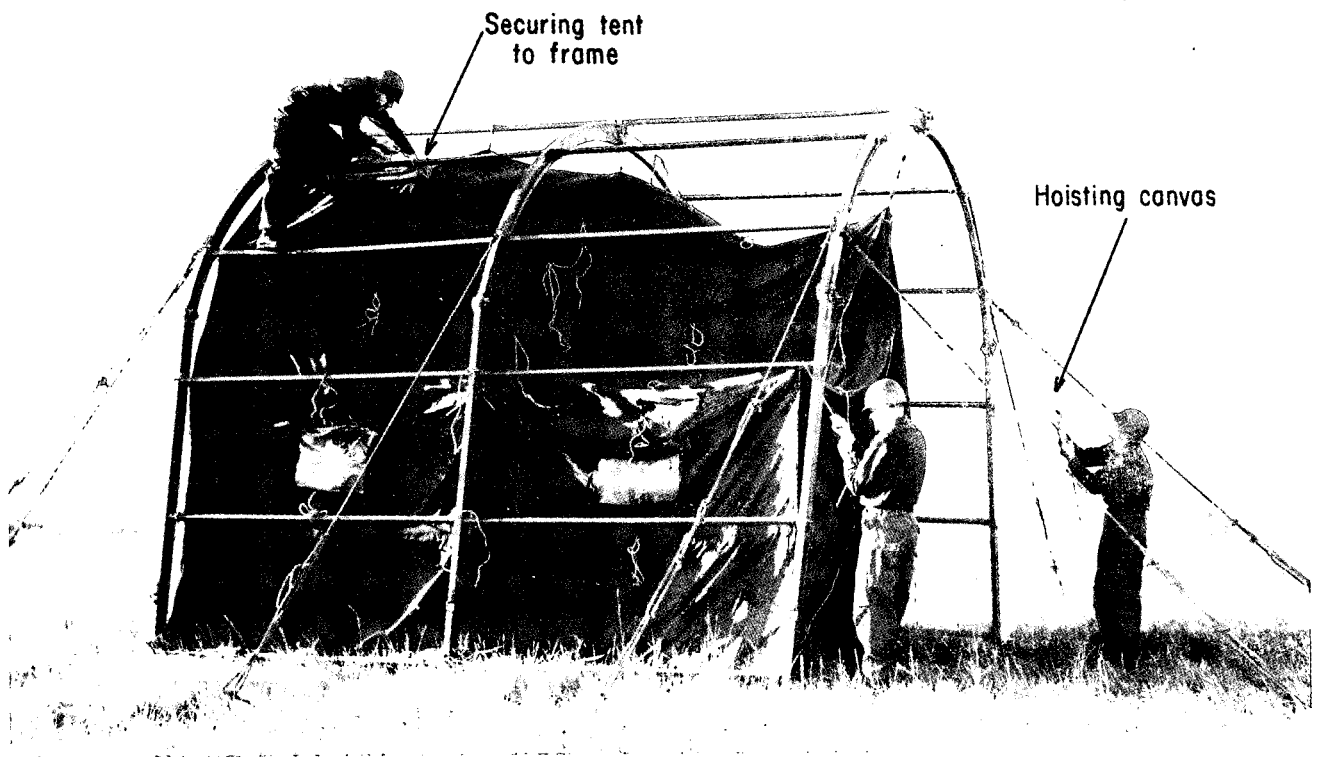


Figure 42. Hoisting canvas to framework.

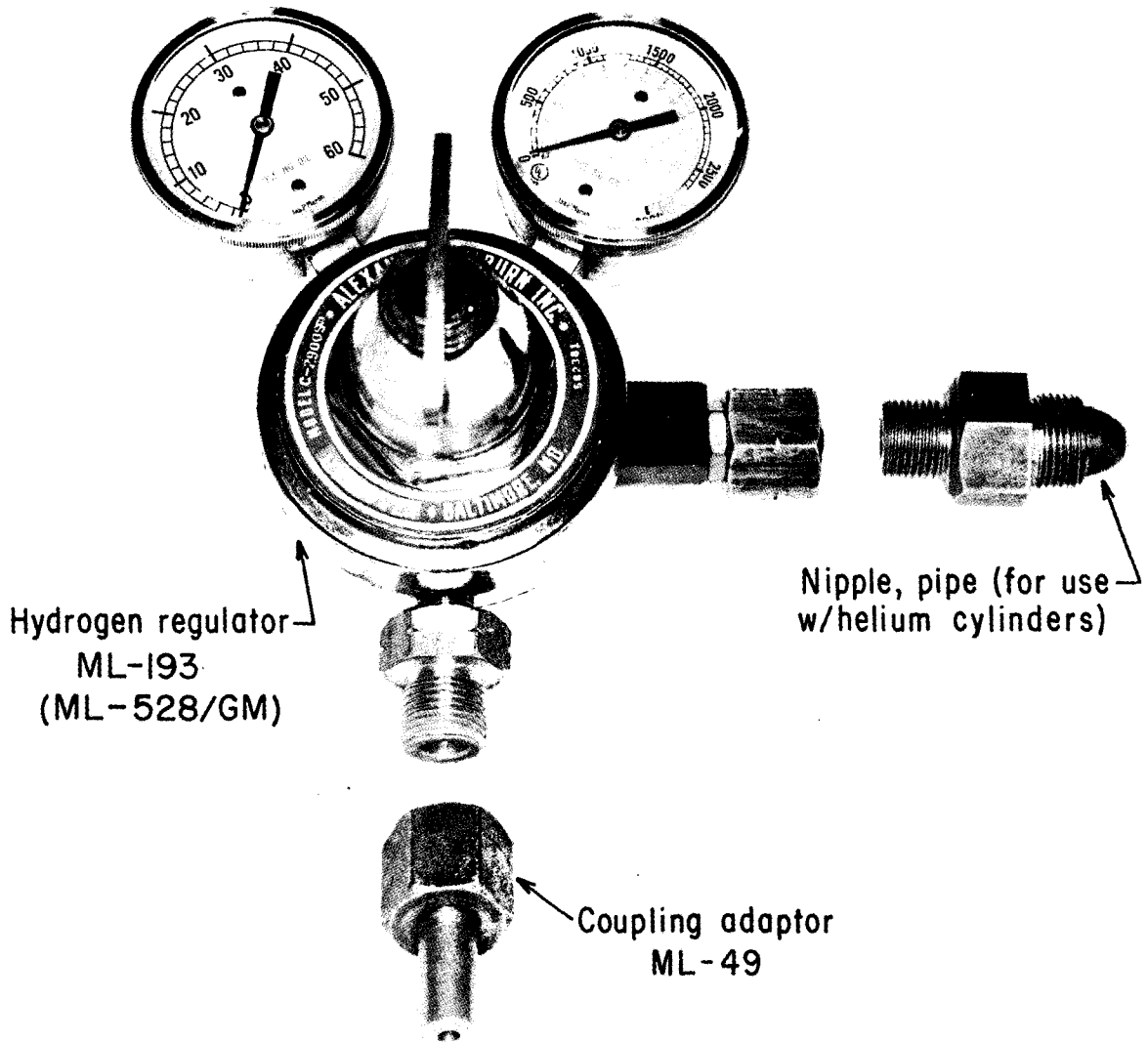


Figure 43. Regulator ML-193 with accessories.

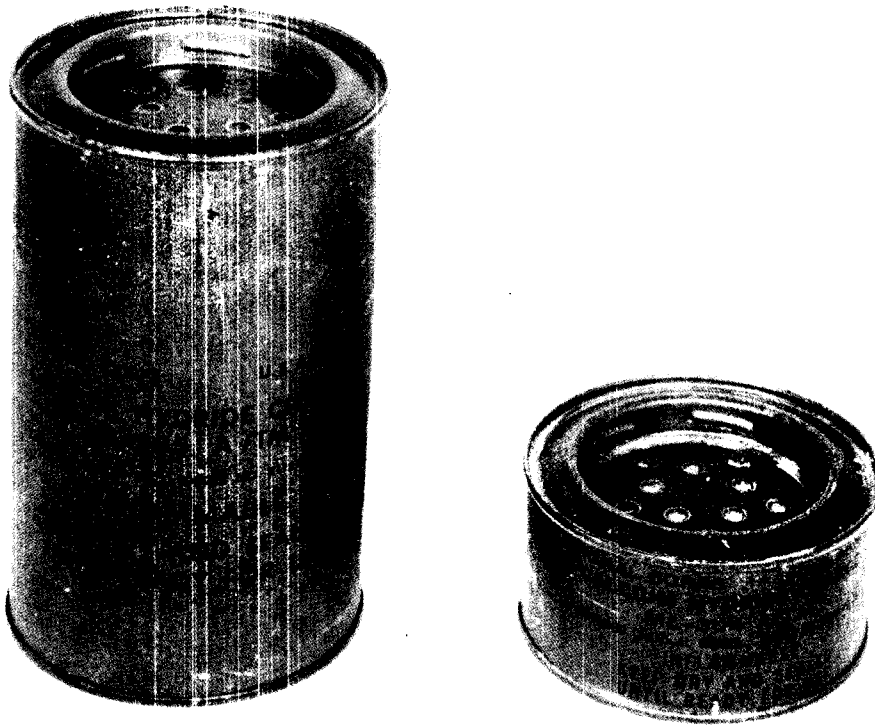


Figure 44. Calcium hydride charges.

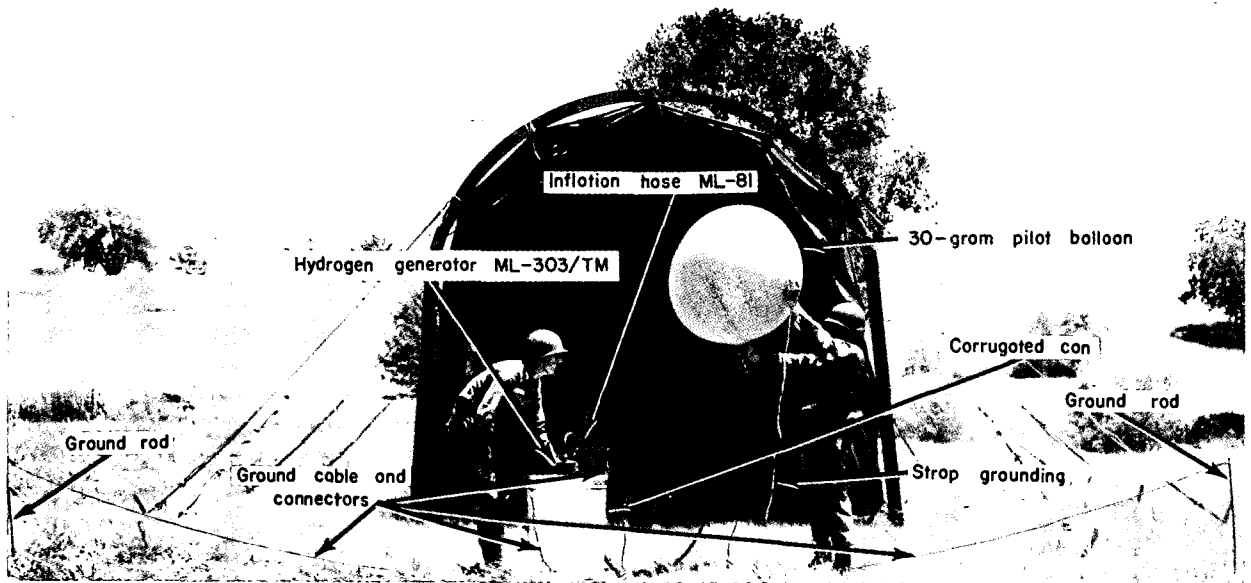
a good connection, the metal surfaces should first be cleaned with sandpaper. The following grounding procedure is used:

- (1) Two brass ground rods are spaced approximately 6 meters apart and driven into the ground to a depth of 1 meter.
- (2) The resistance is measured between the two rods with an ohmmeter by connecting the two rods electrically and using the pair as a ground to determine whether the resistance is 1,000 ohms or less.
- (3) If the resistance is greater than 1,000 ohms, another pair of rods is driven into the ground to form two rows of rods. The rows are 6 meters apart, and the distance between each rod in a row is approximately 1.5 meters.
- (4) The two rows are connected electrically and the combination is used as a ground to determine whether the resistance is 1,000 ohms or less. A rod is added to each row at 1.5 meter intervals until the resistance

between the rows is 1,000 ohms or less, and the final combination is used as a ground.

- (5) Personnel in the immediate area where hydrogen is being generated should be grounded by using the issued grounding strap assemblies. A path to ground for static electricity is particularly important for the individual actually handling the balloon (2, fig. 45).

b. When calcium hydride charges are used, each charge is inspected to insure that no corrosion exists along the sealed seams of the container. If any corrosion is present, *the charge is not used*. Corrosion indicates the possibility that moisture has leaked inside the container, and an explosion may result if a spark is caused by the hand punch used to open the charge. In most cases, but not always, the calcium hydride charge will bulge slightly if moisture has leaked inside and formed a small amount of hydrogen. Calcium hydride in powder form is highly subject to explosion from static electricity. If, while gently shaking an opened charge, it is observed



①  
Figure 45. Grounding of hydrogen generating equipment.

## 58. Hydrogen Generators

*a. Hydrogen Generator ML-303/TM.* The purpose of the hydrogen generator ML-303/TM (fig. 46) is to provide a means for producing hydrogen gas in the field for inflation of 30- and 100-gram pilot balloons. The hydrogen generator consists of an outlet tube for attaching hose ML-81, a punch to open the knockout holes in the calcium hydride charges, and a generator body which provides a pressure chamber for the generated gas. In the field, the calcium hydride charge fastened to the bottom of the generator body reacts chemically with water, in which the generator is immersed, to produce hydrogen gas. Water pressure at the base of the generator minimizes the loss of gas from back pressure, and the expanding gas passes through the outlet tube at the top. A baffle inside the top of the generator prevents water from being forced into the balloon along with the gas. (For detailed information, see TM 11-2413.) Hose ML-81 is used to conduct the gas from the generator to the inflation nozzle. The small calcium hydride charge will generate approximately 6 cubic feet of hydrogen, which will inflate the 30-gram pilot balloon. The large calcium hydride charge will generate approximately 24 cubic feet of hydrogen and will inflate the 100-gram pilot balloon. Care must be taken to



②  
Figure 45—Continued.

that the contents are not in a crystal or lump form, the charge is not used.

ground the hydrogen generator. To allow water to enter the can, the operator must punch out the knockout holes in the top of the calcium hydride charge can. Experience will show how many of the holes should be opened to give rapid, smooth generation. The operator then screws the charge to the bottom of the generator and places the assembly in the water so that the top of the generator is 2 inches above the water. The operator agitates the generator periodically so that the lime produced in the reaction will not clog the can containing the calcium hydride charge and the generator. No harmful byproducts are produced in this reaction; however, the water will decrease in efficiency as it becomes polluted. Therefore, it may become necessary to use fresh water for each balloon inflation. Any available water may be used. If any active material remains in the generator after inflation is complete, the operator should leave the generator in the water

until the charge is expended. This will prevent lime from clogging the holes and possibly causing an explosion. Care and maintenance of the hydrogen generator consists mainly of thorough cleaning. Best results are obtained if the equipment is cleaned immediately after use. The operator must check the perforations in the bottom of the generator and other parts, including hose ML-81, for clogging. The hose and connections must also be checked for leaks. If deposits of the chemicals in the water harden on the equipment, most of it can be removed with a wire brush.

b. *Hydrogen Generator Set AN/TMQ-3.* The purpose of hydrogen generator set AN/TMQ-3 (fig. 47) is to provide a means for producing hydrogen gas in the field for inflation of sounding balloons. The set consists of four generator bodies mounted on a common manifold, two spare generator bodies, a packing case, hoses, and a punch. The manifold

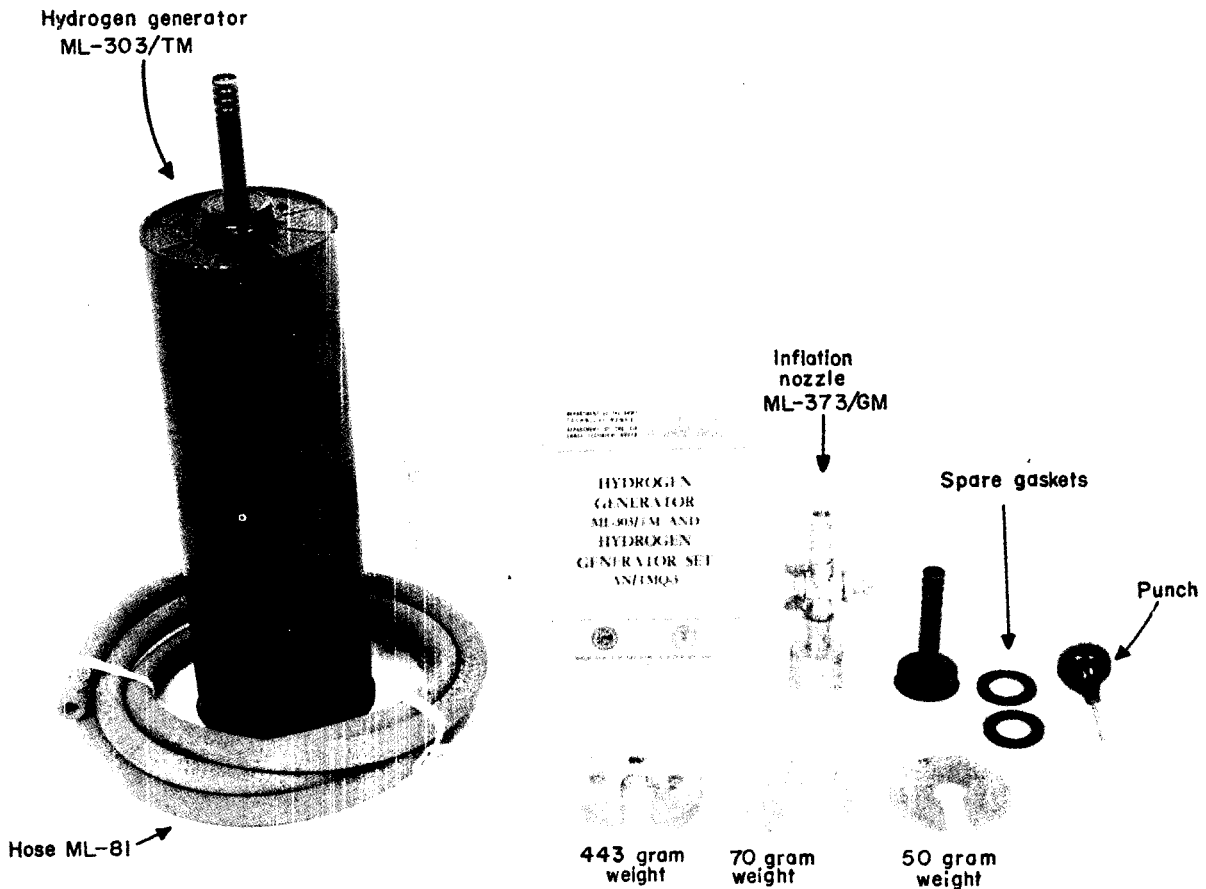


Figure 46. Hydrogen generator ML-303/TM.

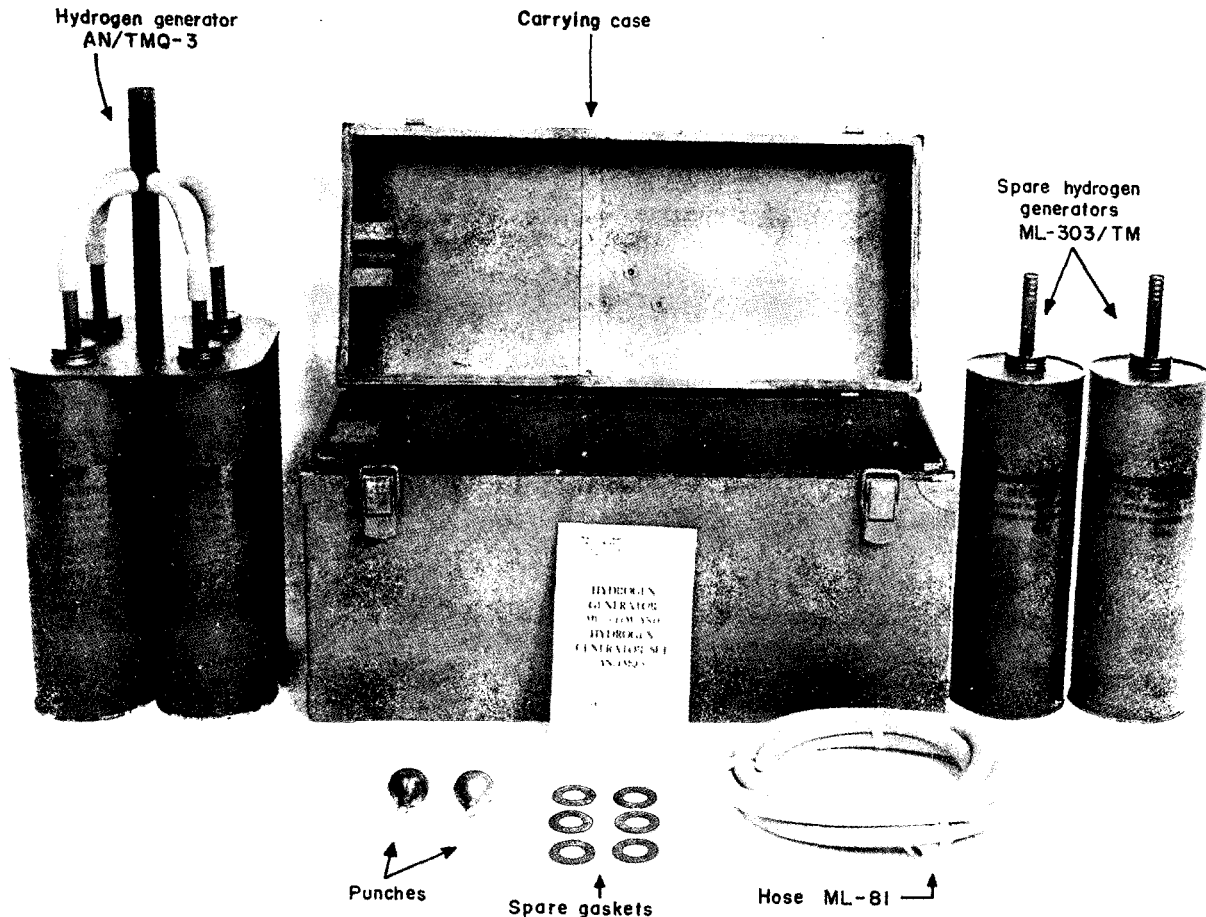


Figure 47. Hydrogen generator set AN/TMQ-3.

consists of a steel tube welded to a square sheet-iron plate. The plate has four holes for mounting four generators ML-303/TM, which are coupled together to permit the generation of hydrogen at four times the rate of a single generator ML-303/TM. Operator maintenance of hydrogen generator set AN/TMQ-3 consists of cleaning the equipment and replacing minor parts.

**59. Calcium Hydride Charges ML-304A/TM and ML-305A/TM**

Calcium hydride charge ML-304A/TM (fig. 44) is an airtight metal can containing approximately 6 ounces of 90-percent pure calcium hydride. The top of the can is recessed and has interrupted threads

for attaching the charge to the bottom of the generator body. On the top of the can, there are a number of knockouts which are opened to allow water to enter the can. The charge will produce approximately 6 cubic feet of hydrogen. Calcium hydride charge ML-305A/TM is the same as charge ML-304A/TM, except it is larger, and will produce approximately 24 cubic feet of hydrogen.

**60. Use of Water for Hydrogen Generator**

a. A water container, preferably of metal, is required unless a stream or lake is used. The metro section is issued a 32-gallon galvanized can for use in hydrogen generator.

b. It is desirable to change the water after each



generation because the waste chemical products retard the chemical action. The water should also be changed if it has become too hot. Cold water is much more efficient for hydrogen generation than hot water. If water is difficult to obtain, conservation can be accomplished by using more than one container as follows: When water is to be reused, allow it to stand for about 2 hours while using a second container of water. When the waste chemicals in the first container have settled, pour the clear water into a temporary container, clean the first container, and refill it with the water. When a second water container is not available or when it is expedient, the hydrogen generator may be operated in a stream, lake, or other suitable body of water.

### 61. Use of Condenser

When calcium hydride charges are used for balloon inflation, heat is generated during the chemical reaction, causing evaporation. Therefore, water vapor is carried along with the hydrogen. As the gas enters the balloon it cools, causing the water vapor to condense inside the balloon. In order to prevent this water from freezing at high altitudes and the balloon from being damaged, it is necessary to remove the water from the balloon before it is released. One method of doing this is to periodically "bleed" the water from the balloon by removing the inflation nozzle and allowing the water to drain out.

This procedure is acceptable; however, some hydrogen is wasted and the process may be time consuming and cumbersome. The local construction and use of an improvised condenser (fig. 48) is suggested as an efficient method of preventing water from accumulating in the balloon. A condenser may easily be constructed by using a metal container, such as a 1-gallon paint can or a 5-gallon oil drum, as follows: To each end of the can (at the bottom on one end and at the top of the other end), attach a pipe nipple over which hose ML-81 will fit. Place baffles on the inside of the can to prevent the gas from passing directly from one end of the can to the other. Attach the hose from the generator to the nipple at the bottom of the can. To the upper nipple at the opposite end of the can, attach a second hose to the inflation nozzle. Float the can in a large container of cold water. As the hot gases pass through the can, they are cooled and the water vapor condenses. Thus drier hydrogen gas is produced. When a condenser is used, smaller amounts of water collect in the neck of the balloon and the "bleeding" process will be unnecessary in most instances.

### 62. Bracket Assembly, Antibuoyancy

The purpose of the bracket assembly is to firmly hold the hydrogen generator set AM/TMQ-3 in position during inflation. The manifold gas outlet is fastened to an opening in the center of the bracket

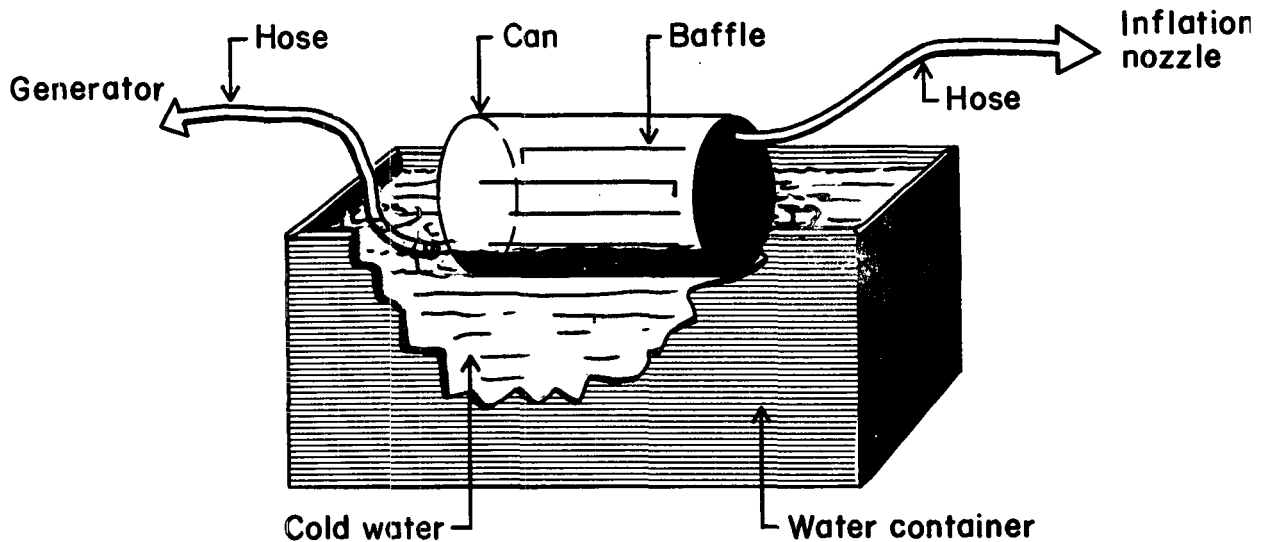


Figure 48. Condenser.

assembly. The bracket assembly has an adapter on each end so that it can be securely placed on the top of the corrugated can as shown in figure 49.

### 63. Balloons

#### a. Sounding Balloons.

- (1) *Purpose and description.* The purpose of sounding balloons is to carry aloft radiosondes and associated equipment, such as parachute, night lighting unit, and radar reflector. Sounding balloons are made of neoprene and are designed to lift radiosondes to certain minimum altitudes at specified rates of rise.
- (2) *Bursting altitude and rate of rise.* The bursting altitude of a sounding balloon depends on conditioning, inflation procedure, and the type of balloon. Low altitude training balloons, which weigh about 300 grams, have a rate of rise of approximately 300 meters per minute and burst at about 21,000 meters. High altitude balloons weigh 1,000 to 1,200 grams and burst near an altitude of 32,000 meters. The fast-rising balloon can rise to altitudes of 23,000 meters at an average rate of rise of approximately 500 meters per minute. At night, the balloons will normally burst at lower altitudes. Bursting altitudes are with respect to mean sea level (MSL).

#### b. Pilot Balloons.

- (1) *Purpose.* The purpose of pilot balloons is to provide a means of visually determining the speed and direction of winds aloft.
- (2) *Description.* Pilot balloons are issued in two sizes—30-gram and 100-gram (representing the weights of the deflated balloons). Under various sky conditions, some colors are more easily detected by the eye than others. For this reason, pilot balloons are issued in several colors, the most common being white, red, and black. The rate of rise of the 30-gram balloon is approximately 180 meters per minute, after a steady rate of rise is attained. The rate of rise of a 100-gram balloon is approximately 300 meters per minute, after a steady rate of rise is attained. Under conditions of good visibility and average winds, the 30-gram balloon can usually be observed to

a height of approximately 9,000 meters, and the 100-gram balloon can be observed to a height of approximately 14,000 meters. These altitudes represent the normal bursting altitudes of the 30- and 100-gram pilot balloon. For detailed information, see TM 11-2405, TM 11-2410, and TM 11-2411.

- (3) *Use.* When high winds prevail, the 100-gram balloon should be used, since it rises faster and will ascend through the desired zones before being blown out of sight. For economy, the 30-gram balloon should be used when the message required is for four lines or less. A general rule in selecting the color of the balloon is the darker the sky, the darker the balloon. For a night flight, the color of the balloon is immaterial.

*c. Care and Storage.* Balloons should be kept sealed in their original containers until just before use. They should be stored in a dry place and at moderate temperatures. All balloons deteriorate with age; therefore, the oldest balloons should be used first.

### 64. Inflation Procedure

Conditioning of sounding balloons prior to inflation is necessary to assure maximum bursting altitude.

#### a. Conditioning of Balloons.

- (1) *Purpose.* As a result of exposure to relatively low temperatures and of extended periods in storage, neoprene balloons lose some of their elasticity through the crystallization of the balloon film. Neoprene balloons used in this state will burst prematurely. Therefore, to insure maximum elasticity, the balloon must be conditioned before inflation. Conditioning is accomplished by heating the balloon.
- (2) *Methods of Conditioning.*
  - (a) Balloons less than a year old need no conditioning. Usually, exposure of the balloon to room temperature (21° C.) for 24 hours is all that is required.
  - (b) Balloons more than a year old should be conditioned by one of the methods explained in TM 11-2405. These methods are conditioning with boiling water and

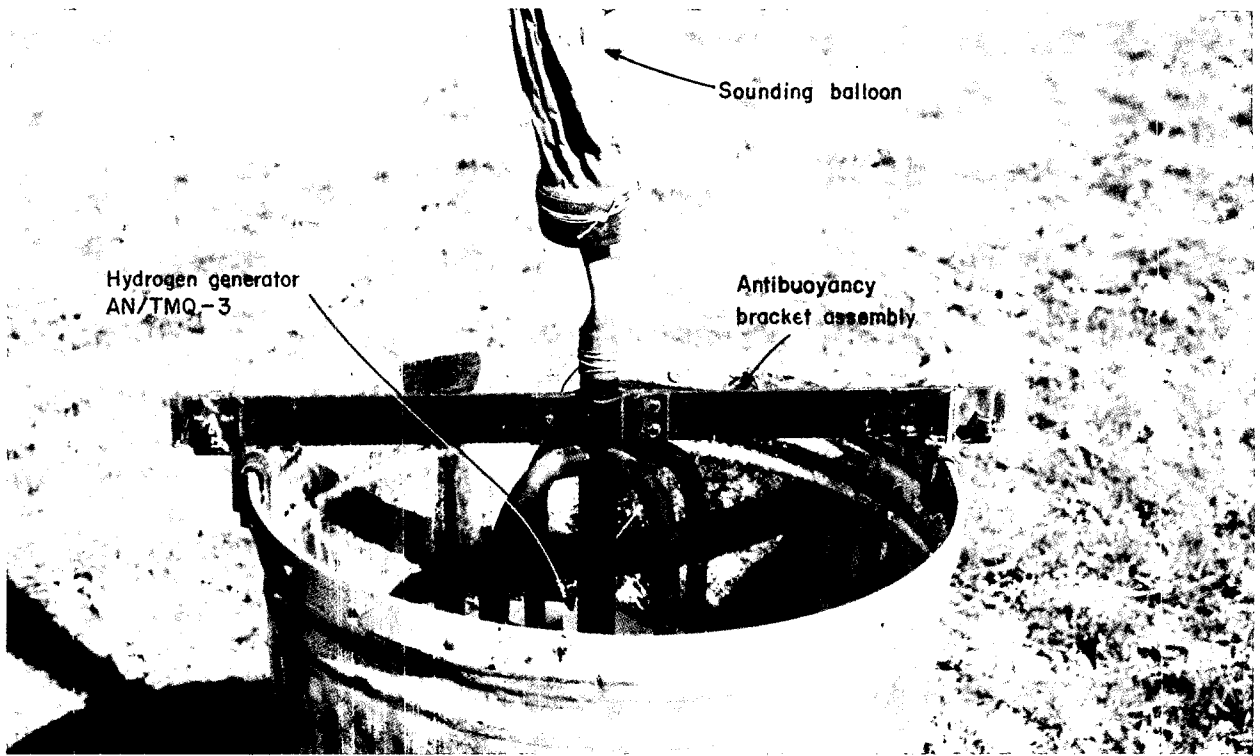


Figure 49. Bracket assembly, anti buoyancy.

conditioning in a locally made conditioning chamber.

- (c) Discoloration has no effect on the balloon film providing the balloon has not been exposed to direct sunlight for several hours. In direct sunlight and in most types of artificial illumination, discoloration is caused by the antioxidant included in the compounding. Antioxidants are used in compounding natural and synthetic rubber to prevent deterioration.
- (d) A balloon may be inflated immediately after conditioning, or it may be kept for a year *under normal storage conditions* (par. 63c) and then inflated. All balloons should be warmed before inflation.

b. *Use of Nozzles, Weights, Hoses, and Regulators.*

(1) *Nozzle ML-373/GM.*

- (a) *Purpose.* The purpose of nozzle ML-373/GM (fig. 50) is to connect hose ML-81 to the *pilot* balloon during inflation, to provide a valve for controlling the flow of gas, and to act as a calibrated

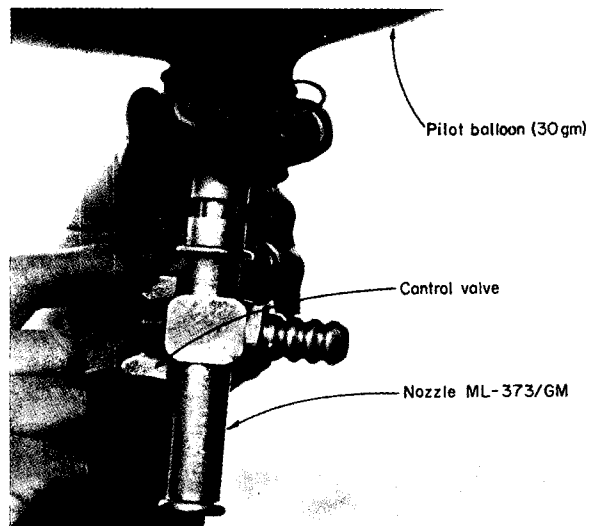


Figure 50. Nozzle ML-373/GM.

weight in determining the correct amount of inflation.

- (b) *Description.* The nozzle has two connections at opposite ends—a large con-

nection for the 30-gram pilot balloon and a small connection for the 100-gram balloon. Projecting from the middle of the nozzle is the fitting for hose ML-81. Opposite the hose fitting is a wingnut which controls the valve. The nozzle alone weighs 132 grams, which is the correct free lift weight for a 30-gram pilot balloon inflated with hydrogen for a daytime flight. (Free lift is defined as the net upward force which causes the balloon to rise.) Addition of the main collar weight, 443 grams, brings the complete nozzle weight, 575 grams, to the correct free lift for a 100-gram pilot balloon inflated with hydrogen for a daytime flight. When a night lighting device is attached to the balloon, additional weights are added to the nozzle to compensate for the greater air resistance caused by increased size of the balloon. The additional weights required are 70 grams for the 30-gram pilot balloon and 50 grams for the 100-gram pilot balloon. When helium is used, 14 grams for 30-gram balloons and 65 grams for 100-gram balloons are required to compensate for the larger size balloon due to the heavier gas. For detailed information, see TM 11-2405.

- (c) *Use.* In using the nozzle, the operator must first install the proper weights, when required, on the neck of the nozzle and stretch the neck of the balloon over the appropriate connection. In order to expel the air from the balloon and connections to the generator, the operator opens the valve on the nozzle and rolls up the balloon with his hands. He then repositions the valve to allow the hydrogen from the generator to escape into the air, thus clearing the hose and nozzle. The operator then turns the valve so the hydrogen will flow directly into the balloon. During the weighing off procedure, the valve is used to control the flow of gas. The balloon is weighed off properly when it will hang suspended in mid-air with appropriate weights attached.

- (d) *Care and maintenance.* The operator must keep the nozzle free of dirt, lime, or other foreign matter which will alter its weight or obstruct the gas passages. If the valve becomes sticky, it should be disassembled, cleaned, and lubricated with graphite.

(2) *Nozzle ML-196.*

- (a) *Purpose.* Nozzle ML-196 (fig. 51), with appropriate weights attached, is utilized during the inflation of sounding balloons.

- (b) *Description and use.* Nozzle ML-196 weighs 1,500 grams and is issued with five weights (100, 200, 400, 500, and 1,000 grams). The sounding balloon should be initially shaken to remove the powder inside of it and then rolled up to expel the air. Next, the balloon is attached to the nozzle and tied with a short length of twine. The weights required (in addition to the nozzle) to balance the desired total lift (par. 67c) are placed on the nozzle. Four of the large calcium hydride charges are attached to the hydrogen generator which has been grounded along with the nozzle and water can. The generator is placed in the water and sufficient hydrogen is allowed to escape through the hose to expel any air contained in the generator and hose. Then the hose from the generator is attached to the nozzle. Proper inflation is accomplished by allowing the hydrogen to enter the balloon until the balloon barely lifts off the ground and remains suspended (floats in balance) in midair with the nozzle, required weights, and hose attached. If the calcium hydride charges are expended before the required amount of lift is obtained, additional hydride charges are attached to the generator. When inflation is completed, the balloon neck is firmly sealed with twine and the hose is disconnected from the nozzle and placed outside of the shelter. The generator should remain in the water until the calcium hydride charges are completely expended.

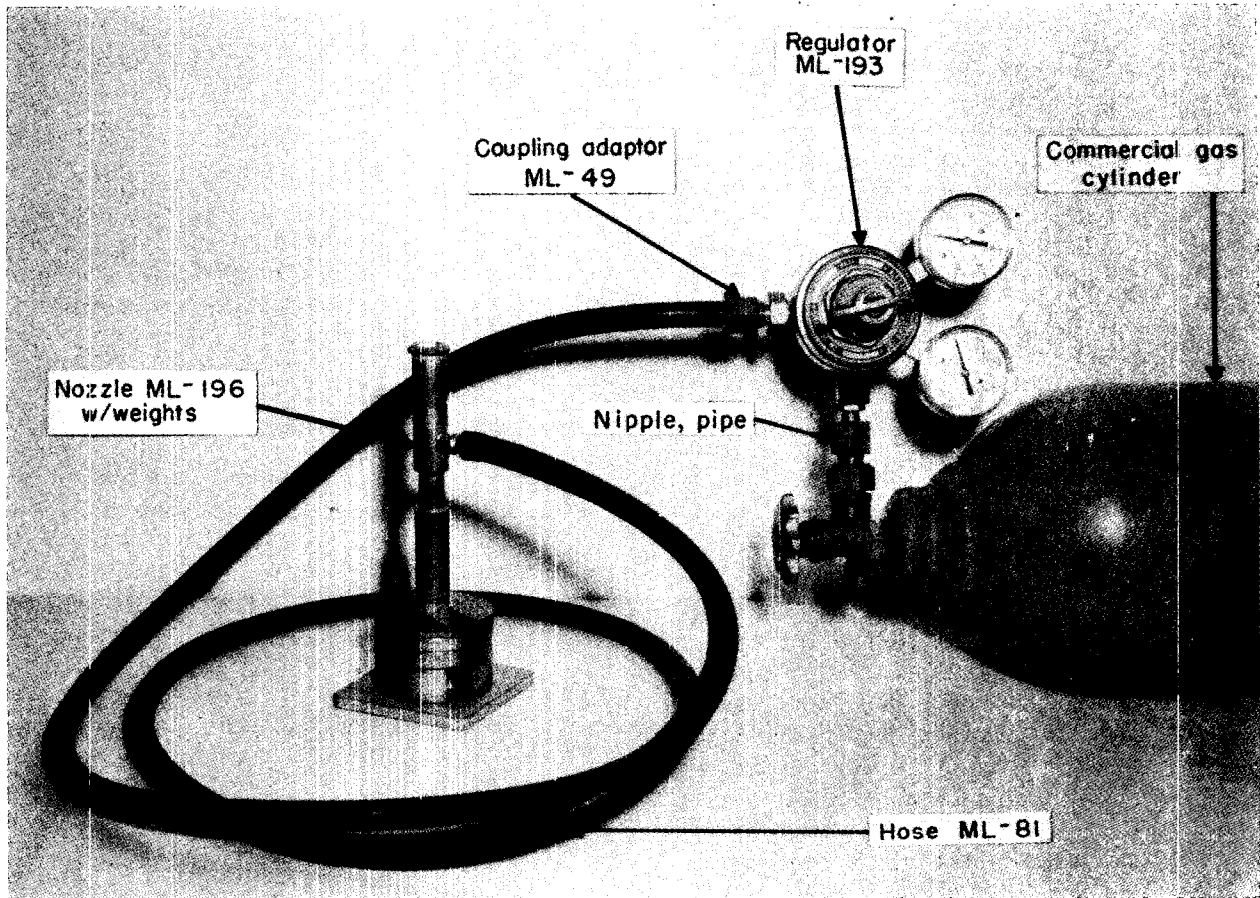


Figure 51. Hydrogen regulator ML-193 connected to gas cylinder.

## 65. Hydrogen Regulator ML-193

*a. Purpose.* Hydrogen regulator ML-193 (fig. 51) or regulator, pressure, compressed gas ML-528/GM is used with commercial hydrogen or helium cylinders to control the pressure of the gas being released for inflation of a balloon. The regulator also indicates the amount of gas remaining in the cylinder.

*b. Description.* Hydrogen regulators consist of a regulator valve, which controls the pressure of the gas being released from the cylinder, and two gages. One gage indicates the pressure of the gas being released from the cylinder. The other gage indicates the volume and pressure of the gas remaining in the cylinder. The regulator also has two connections. Hose ML-81 is attached to one connection. The other connection is attached to the

commercial gas cylinder with coupling ML-49 (fig. 51).

*c. Use.* Coupling ML-49 is connected to the gas outlet nipple on hydrogen regulator ML-193, and the connection is tightened with a wrench. The female connection of the hydrogen regulator is attached to the male connection of the commercial gas cylinder and tightened with a wrench. The cylinder valve is quickly opened and closed to expel any dirt in the valve opening. (The connections of coupling ML-49, hydrogen regulator ML-193, and the gas cylinder have left hand threads. Outlet nipples on helium and hydrogen cylinders are of a different size, and an adapter is required for coupling ML-49 when helium is used.) The small end of coupling ML-49 is inserted into one end of hose ML-81 (fig. 51). A hose clamp, cord, or wire is used to secure the hose to the coupling.

The free end of hose ML-81 is attached to nozzle ML-196. The gas regulator valve on the hydrogen regulator ML-193 is turned counterclockwise to the locked (off) position. The cylinder valve is opened by turning it clockwise. The regulator valve is opened by turning it clockwise to the desired position. The balloon is weighed off as described in paragraph 64b.

## 66. Night Lighting Units for Pilot Balloons

*a. Purpose.* The purpose of lighting unit ML-388/AM (fig. 52) is to provide a light source which will allow the tracking of pilot balloons at night.

*b. Description.* Lighting unit ML-388/AM consists of a 6-volt, water activated battery and a 6-volt bayonet base bulb. A miniature parachute (ML-430/U) and a ball of waxed twine are issued for use with the lighting unit. The parachute need not be used when it is evident that the falling battery will not be a hazard to personnel or property. For detailed information, see TM 11-2405.

*c. Use.* The lighting unit is activated by removing the battery from its insulating jacket and immersing it, with the bulb installed, in water.

Any type of water may be used. The battery should remain in the water for about 3 minutes, or until the bulb has reached full brilliance. The lighting device with accessories plus appropriate weights are attached to the nozzle for weighing off the pilot balloon. The weights for the 30-gram balloon consist of the nozzle, and a 70-gram weight. The weights for the 100-gram balloon consist of the nozzle, a 443-gram and a 50-gram weight. An additional weight is required to compensate for the greater air resistance caused by the increased size of the balloon. The larger additional weight is required for the 30-gram balloon because its size is increased proportionately more than that of the 100-gram balloon when the lighting device has been attached for weighing off.

## 67. Determination of Inflation Volume and Lift for Sounding Balloons

*a. General.* Free lift is the net upward force which causes the balloon train to rise. The amount of gas required for a sounding balloon should be determined before beginning the inflation process. The ascent rate of the balloon is primarily dependent

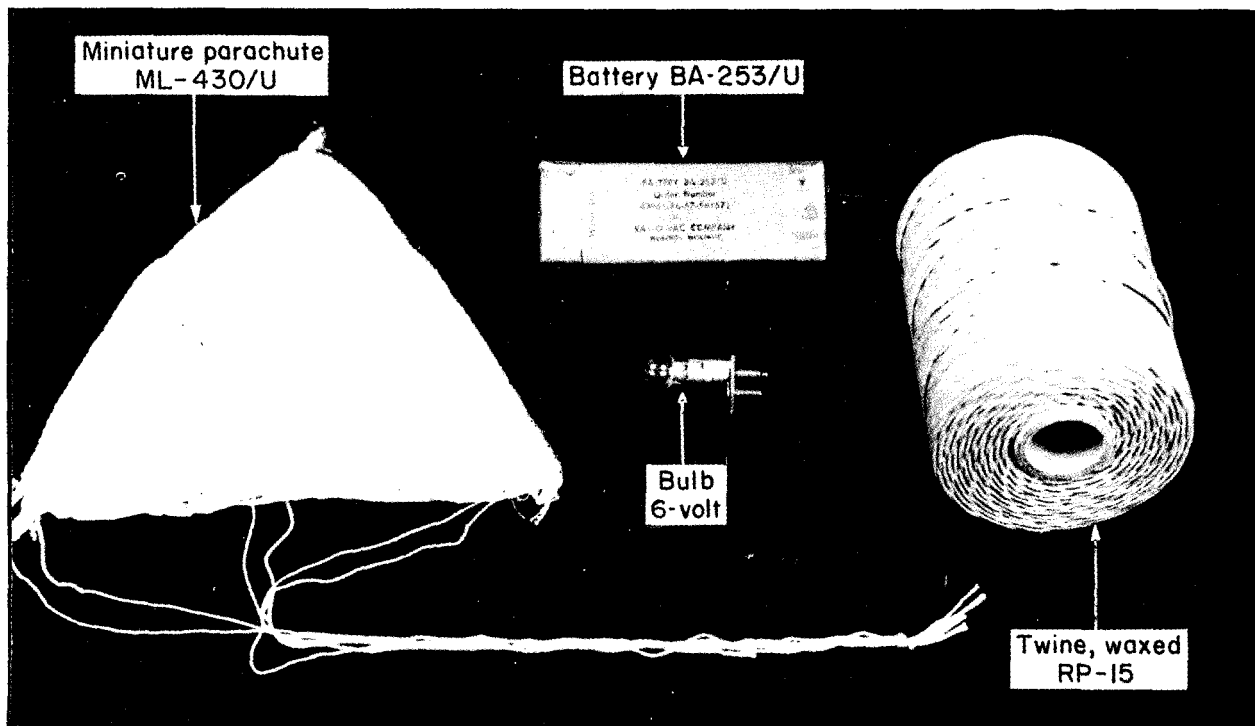


Figure 52. Lighting unit ML-388/AM, with accessories.

on the amount of gas. Other factors which affect its ascent rate are the balloon's shape, size, physical texture, and the state of the atmosphere through which the balloon travels. These latter factors are quite variable; therefore, considerable reliance must be placed on experience to obtain an ascent rate which will allow the flight to attain required height at least 15 minutes prior to prescribed message time. Table I is included as a guide for use in determining the amount of free lift for sounding balloons during fair weather and the number of charges normally required to produce that free lift. It is important for the gas temperature to be equal to the ambient air temperature. This condition is facilitated by use of a condenser with the generator AN/TMQ-3, or by valving gas slowly (up to 20 minutes) when using commercial gas.

Table I. Guide for Inflating Sounding Balloons

Balloon type	Use	Free lift (grams)	Number of charges using TMQ-3	
			ML-305A	ML-304A
1 ML-391( )/AM	Day	1600	4 and	2
2 ML-518( )/AM	Day	1600	4 and	2
3 ML-537( )/UM	Day	1600	4 and	2
4 ML-537( )/UM	Night	1900	5	0
5 ML-443( )/UM	Night	2000	5	0
6 ML-541( )/UM	Day	2500	8	0
7 ML-541( )/UM	Night	2700	8	0

Note. The first 5 balloons listed are one-piece, spherical type sounding balloons. The ML-541 is a streamlined, two-piece balloon.

b. *Computation of Required Nozzle Lift.* Nozzle lift is defined as the total weight, in grams, which must be balanced by the inflated balloon in order to lift the attachments and assure a desired rate of rise. As a convenient reference, the weights of the usual balloon train attachments are listed in table IIa, Table IIb indicates additional weights necessary to compensate for adverse weather conditions.

Table IIa. Weights of Balloon Attachments

Attachment	Weight (grams)
Radiosonde AN/AMT-4( ), with battery	1200
Lighting unit ML-338	85
Parachute ML-132	150
Launching reel ML-367	100

Table IIb. Additional Weights for Foul Weather

Weather	Weight (grams)
Precipitation of light intensity (all balloon types).	200
Heavy precipitation and/or icing (all balloon types).	400
Average zonal wind exceeding 60 knots (spherical balloons).	600 to 1200

Example: An example of the computation of the nozzle lift required for a typical daytime radiosonde flight using balloon type ML-537/UM is as follows:

Required free lift, from table I..... 1600 grams  
 Weight (radiosonde and parachute),  
 from table IIa..... 1350 grams

Nozzle lift required (highest 100 grams)..... 3000 grams

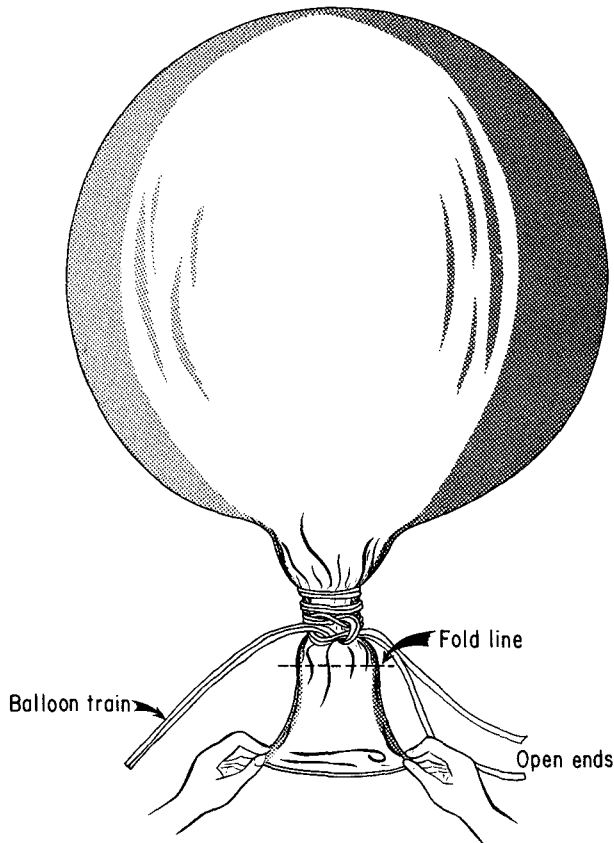
c. *Determining Weights Required.* Enough weight must be attached to nozzle ML-196 so that the total weight of the nozzle and the weights is equal to the weight of the balloon attachments plus the free lift required (nozzle lift). Assuming that the nozzle lift required is 3,000 grams (b above), the computation of weights required to obtain this lift is as follows:

Nozzle lift required..... 3000 grams  
 Minus weight of nozzle..... 1500 grams

Additional weight required..... 1500 grams

## 68. Preparation of Balloon Trains

When the balloon is properly inflated, it is sealed and tied. A 20-meter length of twine is doubled (i.e., 10-meter length, double strength) and the neck of the balloon is sealed and tied with the open end of the twine (1 and 2, fig. 53). Next, parachute ML-132 is secured to the closed end of the doubled twine. Another 20-meter length of twine is doubled, the open end is secured to the bottom of the parachute suspension lines, and the radiosonde is tied to the closed end. The overall length of the train is approximately 20 meters (fig. 54). The parachute is not normally used in an active theater of operations. The purpose of the 20-meter balloon train is to dampen the oscillation of the radiosonde during flight. Night lighting device ML-338/AM may be included in the train between the parachute and the radiosonde to aid in initial tracking.

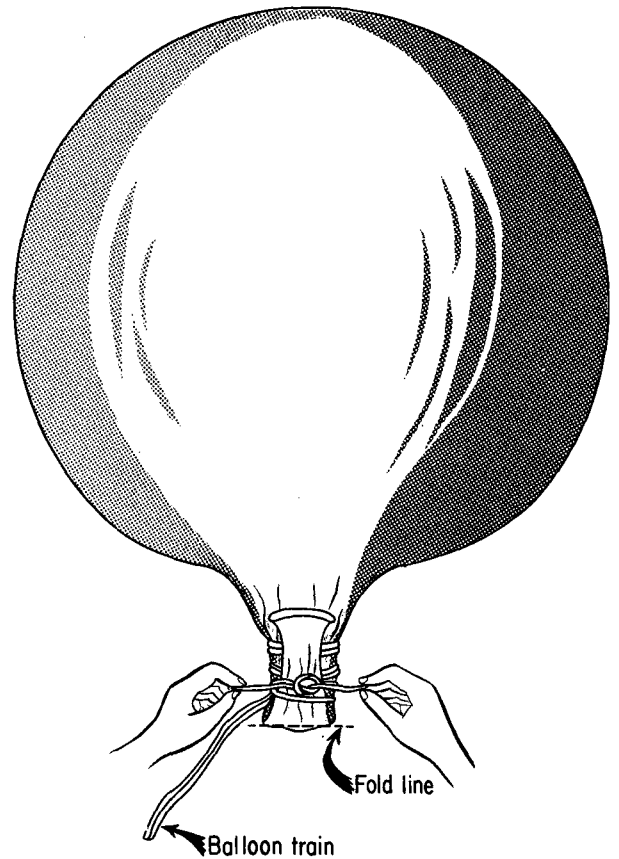


①  
Figure 53. Tying off the balloon.

## 69. Release Techniques

*a. Hand-Over-Hand Release.* During periods when the surface wind speed is low, the sounding balloon train is released 100 meters downwind from the rawin set. The balloon is sent aloft by paying out the twine in a hand-over-hand fashion. When the twine is taut, the balloon is anchored only by the person holding the radiosonde. The command **RELEASE**, by voice or hand signal, is given so that the control-recorder and radiosonde recorder may be started simultaneously with the release.

*b. Running (Two Man) Release.* It is difficult to release a balloon train during periods of high surface winds without damage to the balloon or radiosonde. However, a successful release during high surface



②  
Figure 53—Continued.

winds may be made by using a shorter train and the running release technique described below. No attempt should be made to carry the balloon downwind from the rawin set. The flight should be released as soon as possible after the balloon is removed from the inflation shelter. The procedure for a running release is as follows: The radiosonde is carried downwind from the balloon until the train is taut. At the signal to release, the man holding the radiosonde begins running downwind as soon as the balloon is released. The man runs until the balloon is overhead and the train is taut and then releases the radiosonde. At this time, the command **RELEASE** is given so that the control and radiosonde recorders may be started simultaneously with the release. Improper running releases invariably result in damage to the delicate radiosonde temperature element or destruction of the sounding balloon.



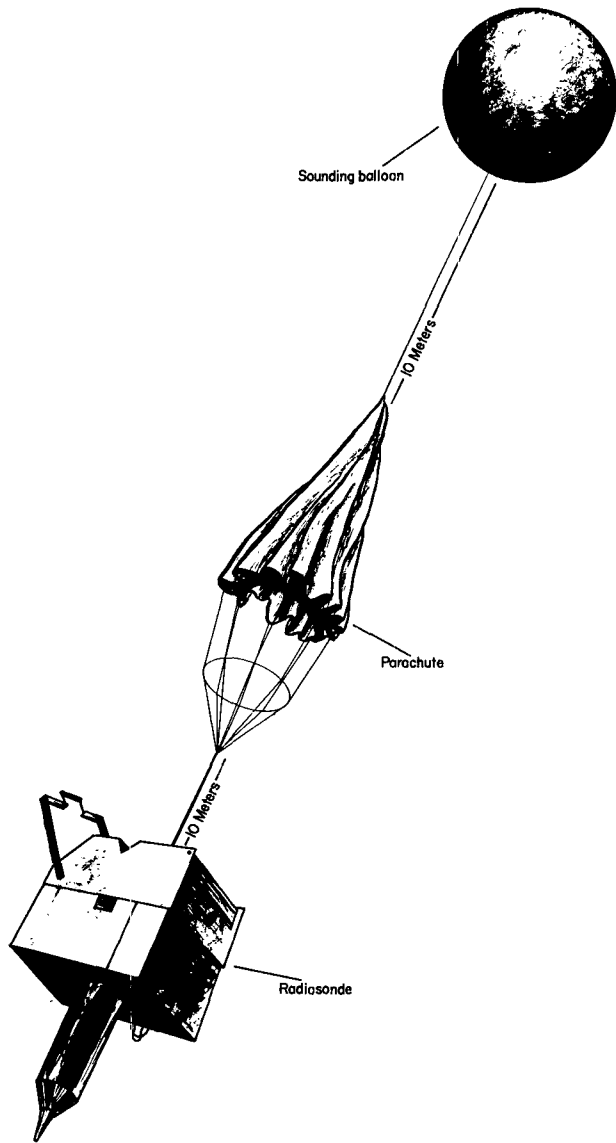


Figure 54. The balloon and train.

The proper method of handling the radiosonde during a running release is shown in figure 55.

c. *Release Using Launching Reel ML-367/AM.* When the area used for releasing balloons is limited, launching reel ML-367/AM (fig. 56) may be used. The launching reel is used as follows:

- (1) About  $1\frac{1}{2}$  meters of cord is unwound from the reel. The unwound cord is doubled and the end is tied securely to form a loop.
- (2) About  $\frac{1}{2}$  meter of the doubled cord is wound back onto the reel.

- (3) The unwound cord is placed across the spacer on the side opposite that from which it was unwound (fig. 56), and the end of the cord is secured to the top of the parachute.
- (4) One end of a double short length of twine is tied to the eyelet in the opposite end of the frame. This twine is used to tie the launching reel to the inflated balloon.
- (5) The launching reel is held in the left hand and the radiosonde is held in the right hand. The governor of the launching reel is held immobile. The balloon train is removed from the inflation shelter, and the launching reel and the radiosonde are released simultaneously at the earliest possible moment.

## 70. Release Using Balloon Shroud ML-424/U

Balloon shroud ML-424/U (fig. 57) is used when a sounding balloon is released in moderate or high winds. The shroud is placed over the balloon during inflation. Ordinarily, the balloon can be moved to the launching site by one operator, who grasps all the **D** handles with one hand and the top cord with the other hand, while the second man carries the radiosonde and parachute. In very high winds, two operators are needed to hold the balloon, one to hold the top cord and one to hold the **D** handles. When the balloon shroud is used for release, the procedure is as follows:

- a. Operators 1 and 2 hold the balloon train as shown in figure 57.
- b. Operator 1 releases the front **D** handles simultaneously and continues to hold the rear **D** handles and the top cord. The balloon will slide out from under the shroud.
- c. As the balloon ascends, operator 2 maintains a position directly beneath the drifting balloon until the radiosonde is lifted from his hands. He does not release the radiosonde until the balloon has risen sufficiently to carry it clear of adjacent obstructions.

**Warning:** When a shroud is used with a hydrogen inflated balloon, there is a possibility of producing static electricity by the rubbing together of the shroud and balloon surfaces. When temperatures are above freezing, the shroud should be sprinkled with water before use in order to minimize the danger of static electricity.

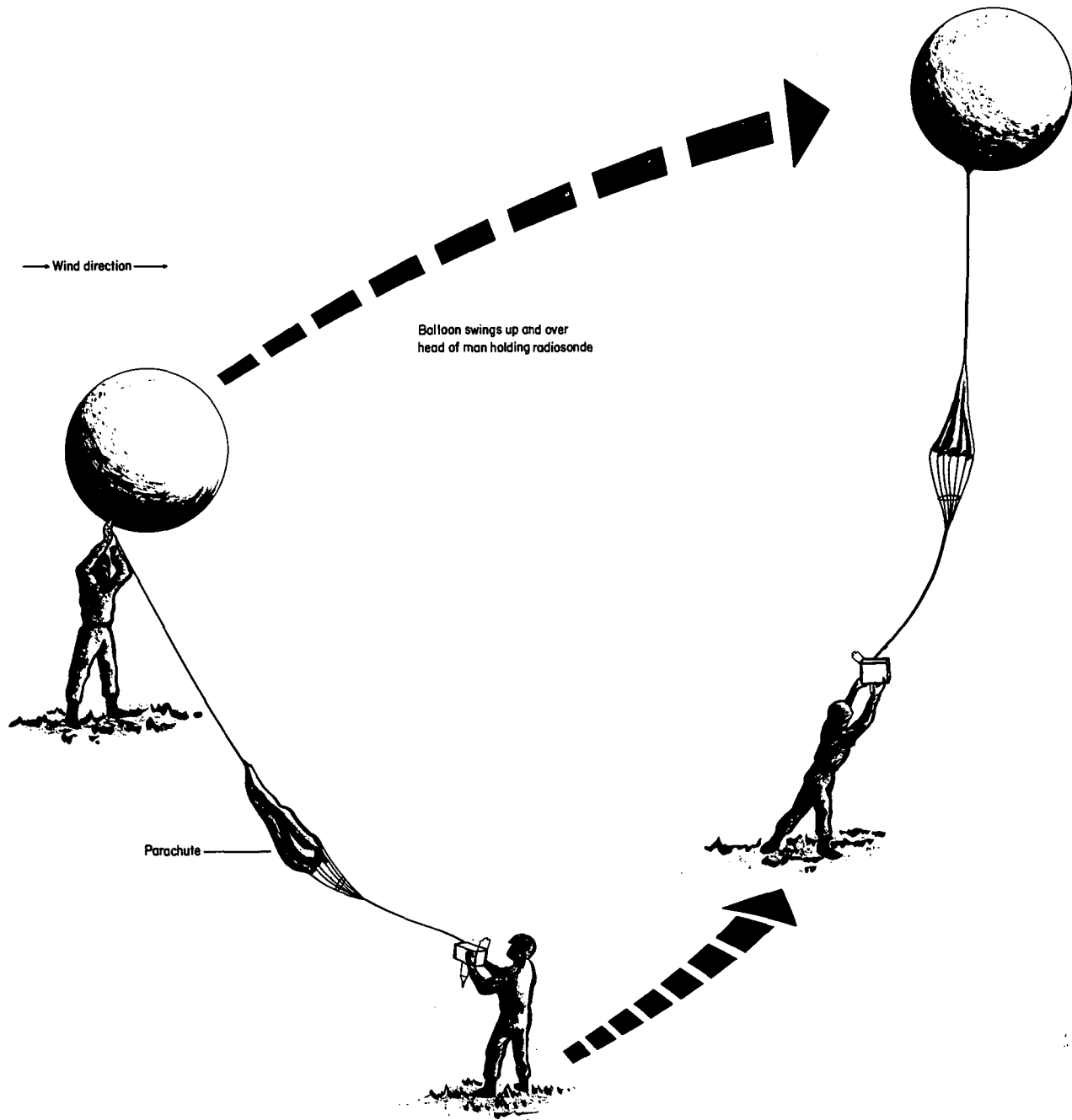


Figure 55. Running release of sounding balloon.

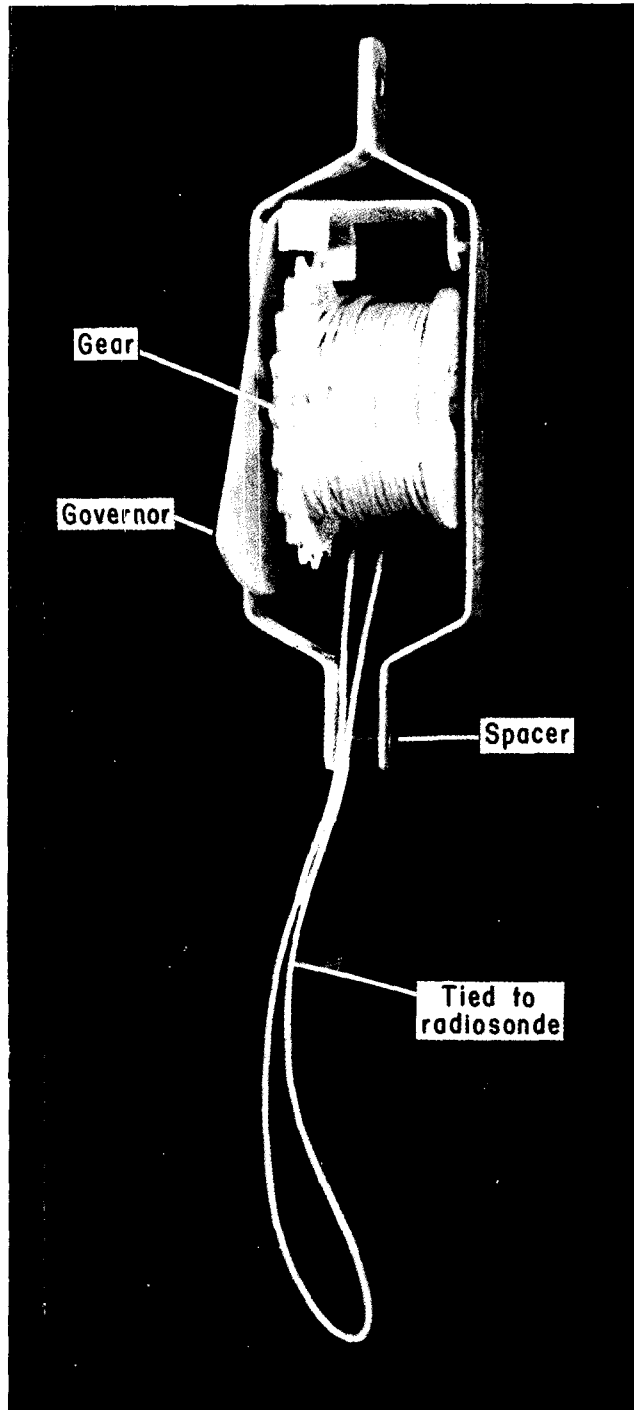


Figure 56. Launching reel ML-367/AM.

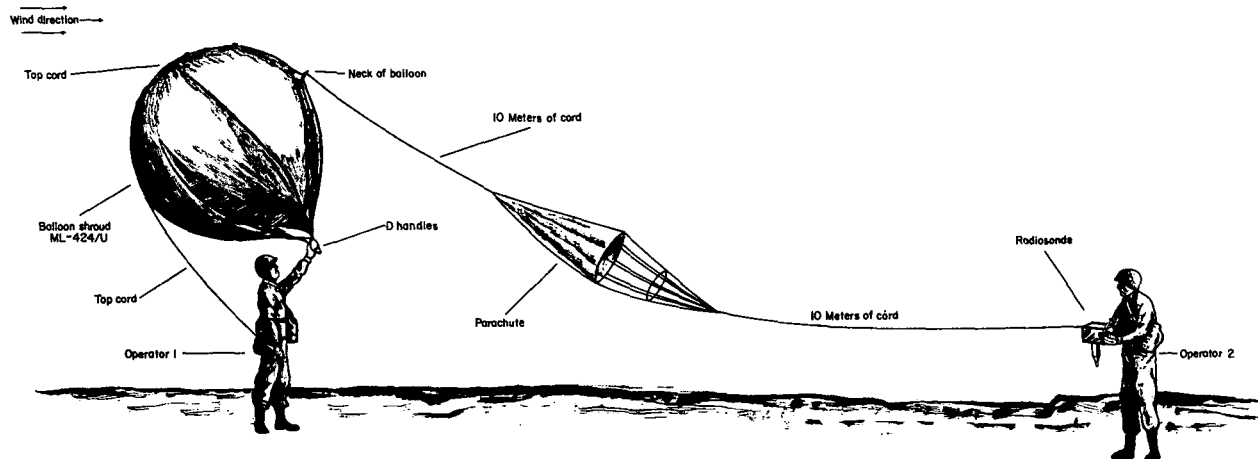


Figure 57. Release of balloon with balloon shroud ML-424/U.

## Section IV. PLOTTING AND COMMUNICATIONS EQUIPMENT

### 71. Wind Plotting Equipment

*a. Purpose.* The purpose of the wind plotting equipment (fig. 27) in meteorological station, Manual AN/TMQ-4 is to provide a means of determining the zone and ballistic winds.

*b. Description.* The wind plotting equipment includes two plotting boards ML-122. Two rules ML-126A are issued with each plotting board (each board has a spare rule). The plotting equipment also includes two scales ML-577 and one slide rule. By using plotting board ML-122 and rule ML-126A, the flight path of the balloon can be plotted as projected on the curved earth. These plots are made with rule ML-126A at a scale of 1 inch equals 750 meters. Zone wind speeds are computed from the measured distance between plots with rule ML-126A. These distances are measured in meters. A conventional 20-inch Mannheim slide rule is used to determine the wind speeds in knots. The zone wind directions are measured by using scale ML-577. Scale ML-577 also is used in plotting the ballistic winds on plotting board ML-122. By using this scale, the wind direction can be read to the nearest 10 mils.

*c. Use.* Plotting is done with a medium hard pencil (3H) to avoid pitting the plastic surface of the plotting board. After use, the plots are erased with an ordinary eraser. Detailed instructions on the use of wind plotting equipment in determining the zone and ballistic winds are contained in chapter 10.

*d. Preventive Maintenance.* After considerable

use, the plotting boards become smudged and should be washed with soap and water. Plotting equipment should never be cleaned with cleaning solvents or oils. Scale ML-577 should be wrapped in cloth to prevent fogging and scratching of the graduated surfaces. The slide rule may be dusted with talcum powder to reduce sticking. If the cursor glass on the slide rule is removed for cleaning, it should be remounted with care to insure that the crosshair is in alignment with the scales.

### 72. Communication Equipment

#### *a. Wire.*

(1) *Purpose.* The purpose of the wire communication equipment (fig. 36) is to provide the theodolite operator a means of reporting the angular data to the timer recorder. The metro section also has one field telephone for wire communication to a headquarters switchboard.

(2) *Description.* The communication equipment consists of two head and chest sets HS-25-C, one telephone TA-312/PT, one reel RL-39( ) with spool DR-8 and 200 meters of wire WD-1/TT, and two jacks JK-54. The head and chest sets are sound-powered; that is, the transmitter in each set generates a small electric current when activated by sound waves. With good connections, head and chest sets may be operated successfully over a distance of several kilometers. Jacks JK-54 facilitate

connection between the wire and the output cords of the chest sets.

- (3) *Use.* When the wire is installed, it is tied to some fixed object near the terminal so that accidental tripping over the wire will not destroy the connection.

**Caution: Do not tie the wire to the theodolite tripod.**

- (4) *Preventive maintenance.* The reel bearings should be oiled occasionally with heavy oil. The wire should be inspected frequently for wear and repaired or replaced where necessary. The connections should be kept clean and tight at all times.

*b. Radio Set AN/GRC-19.*

- (1) *General.* The metro section is equipped with radio set AN/GRC-19 (fig. 58). The section operates the radio set within the corps meteorological net (ch. 8). Radio communication in the corps metro net allows rapid dissemination of meteorological data and coordination of the meteorological activity throughout the corps sector.

- (2) *Description.* Radio set AN/GRC-19 is an amplitude modulated (AM) set and is made up of radio transmitter T-195/GRC-19, radio receiver R-392/URR, mounting MT-851/GRC-19, a whip antenna, and auxiliary items. This radio was initially designed for mobile service and can be operated on the move. It is capable of providing communication over moderate distances (up to approximately 80 kilometers). Transmission over distances of 240 to 2,400 kilometers is possible by means of sky waves. The frequency range is 1.5 to 20.0 megacycles (mc) for the transmitter and 0.5 to 32.0 mc for the receiver. The radio set operates from a 28-volt vehicular electrical system. The transmitter has a nominal output of 100 watts. With the cable furnished, the transmitter may be remotely controlled as far as 25 meters from the operating site. The receiver has a normal output of 200 milliwatts to a 600-ohm headset. The transmitter and the receiver are secured on mounting MT-851/GRC-19. The trans-

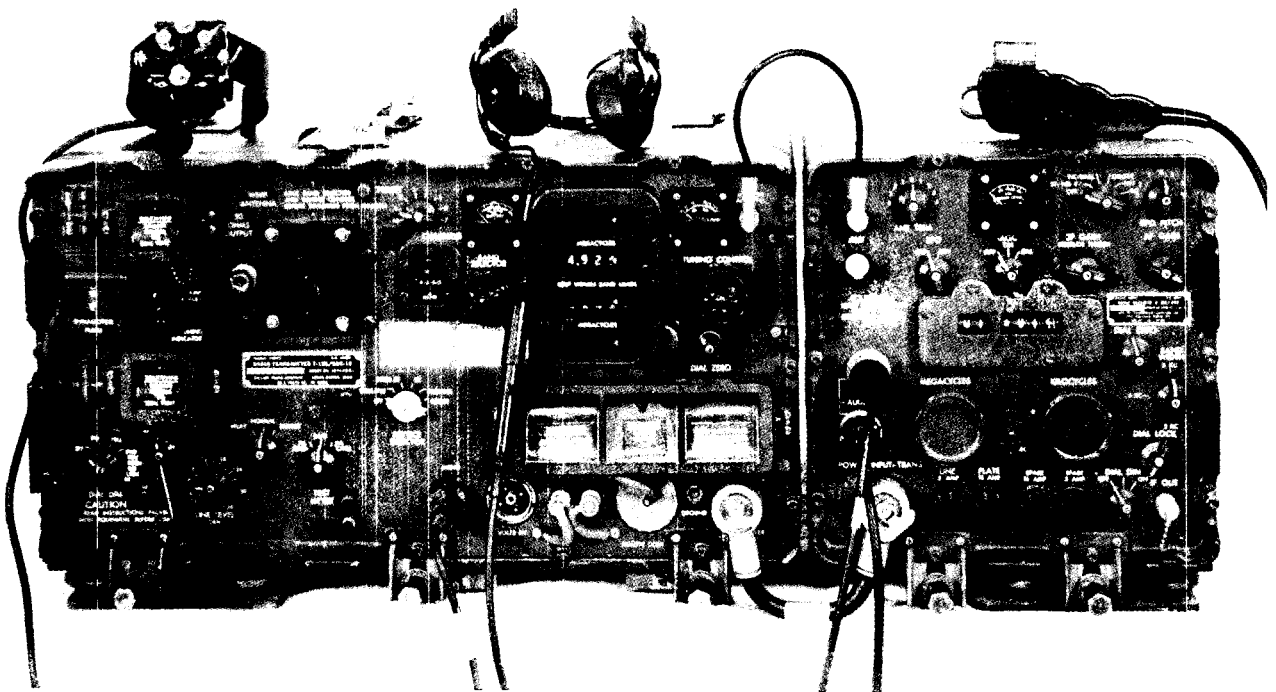


Figure 58. Radio set AN/GRC-19.

mitter can be operated in a drenching rain with the air-exhaust and air-intake vents open. With these vents closed, the transmitter is waterproof. The superheterodyne receiver is also waterproof and can be operated in a drenching rain. Spring-loaded metal handles are provided for carrying the radio set. For detailed information, see TM 11-5820-334-10 and TM 11-806.

- (3) *Use.* The location for radio equipment depends on the tactical situation and on local conditions, such as the need for camouflage, the type of vehicle in which it is mounted, possible installation in a shelter, and the terrain. The radio set will have a greater distance range if the antenna is high and clear of hills, buildings, cliffs, and wooded areas. Valleys and other low places are poor locations for radio reception and transmission, because the surrounding high terrain absorbs the radio frequency (RF) energy. Clear, strong signals cannot be expected if the radio set is operated near steel bridges, underpasses,

powerlines, hospitals, or power units. If possible, a site on a hilltop or other high place should be chosen. Generally, transmission and reception are better over water than over land. Detailed procedure for operation of radio set AN/GRC-19 is in TM 11-5820-295-10, TM 11-806, and TM 11-5820-334-10.

- (4) *Preventive maintenance.* A clean, dry, lint free cloth or a dry brush should be used for cleaning the radio equipment. Accessible parts should be cleaned with a cloth moistened with cleaning compound, then wiped dry with another cloth. If available, dry compressed air may be used at a line pressure not exceeding 30 pounds per square inch to remove dust from inaccessible mechanical components. Number 0000 sandpaper should be used to remove corrosion.

**Warning: Cleaning compound is flammable. Do not use steel wool: minute metallic particles can cause internal shorting and equipment failure.**

## Section V. RAWINSONDE SYSTEM

### 73. General

The rawinsonde system was designed for taking atmospheric soundings and thereby obtaining upper air meteorological data. This is accomplished by measuring the wind speed, wind direction, pressure, temperature, and humidity throughout the vertical extent of the sounding. Since the upper air meteorological variables are actually measured, data obtained from this system are more accurate than data provided by the visual technique.

### 74. Equipment

*a. Equipment of the Rawinsonde System.* The rawinsonde system consists of the following major items of equipment (fig. 59):

- (1) Radiosonde AN/AMT-4( ).
- (2) Rawin set AN/GMD-1( ).
- (3) Radiosonde recorder AN/TMQ-5( ).

*b. Associated Equipment.* The following associated equipment is also used with the rawinsonde system:

- (1) Frequency standard TS-65( )/FMQ-1.

- (2) Baseline check set AN/GMM-1( ).
- (3) Test set TS-538/U.
- (4) Power unit 10-KW; and/or power unit PE-75-( ).
- (5) Meteorological station, Manual AN/TMQ-5.

*c. Capabilities and Limitations of the Rawinsonde System.* The rawinsonde system provides an all-weather capability of obtaining atmospheric soundings to altitudes of 32,000 meters. The system affords a means of determining meteorological data within this region of the atmosphere to a high degree of accuracy. One major limitation of the present rawinsonde system is the relatively long time required to complete a sounding, which is due primarily to the slow rate of rise of the balloon. Various methods of decreasing the time required for a sounding are being tested in the field. At extreme altitudes, the accuracy of the pressure values obtained with current radiosonde equipment may result in errors in altitude. This problem may be reduced through the use of the hypsometer (par. 77). The electronic equipment of the rawinsonde system

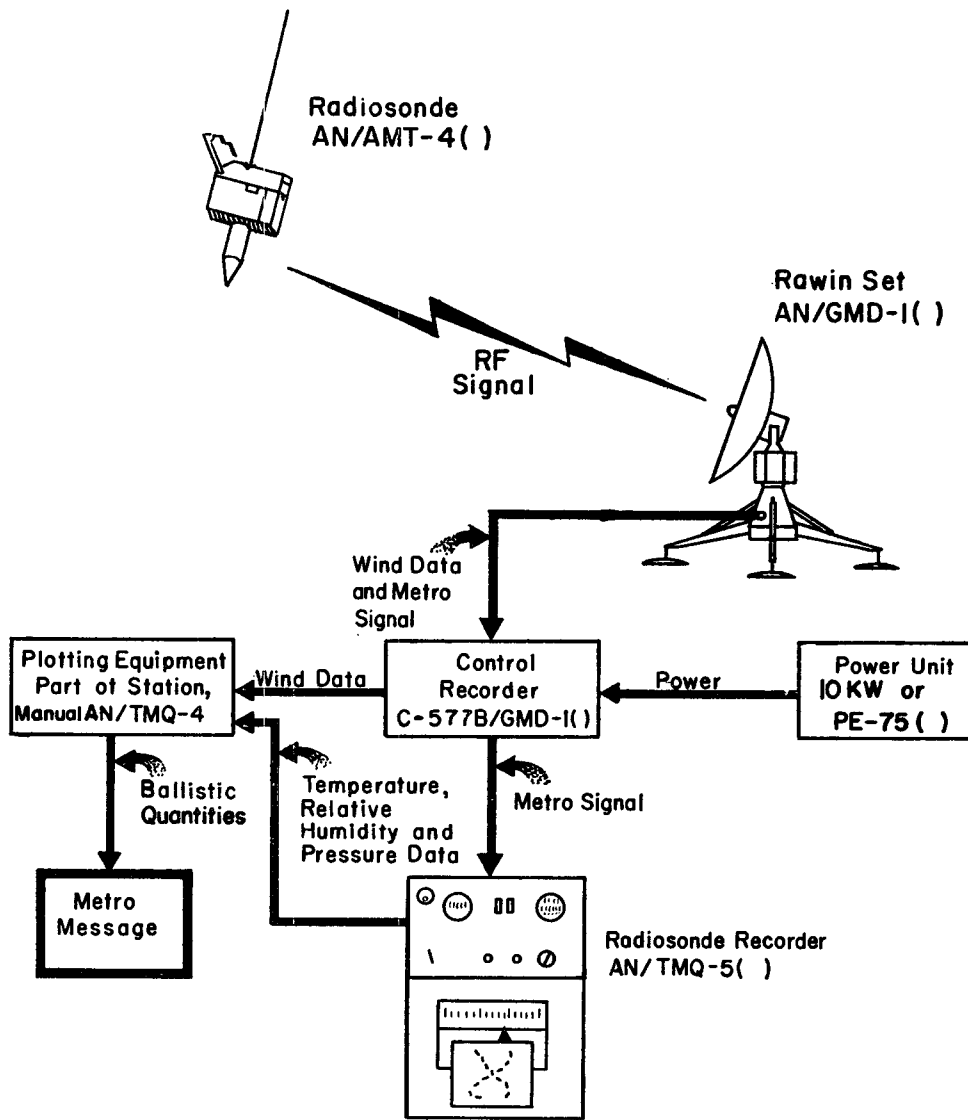


Figure 59. Equipment of the rawinsonde system.

is also subject to failure. Specially trained personnel are required to operate the equipment and

perform the necessary maintenance.

## Section VI. RADIOSONDES

### 75. General

Several models of the radiosonde are in use. All models are similar in appearance and operation. The model used by U.S. Army meteorological sections is the AN/AMT-4( ). For detailed

information concerning the differences, see TM 11-2432A.

### 76. Radiosonde AN/AMT-4( )

a. Purpose. The purpose of radiosonde AN/AMT-4( ) (fig. 60) is to provide a means of

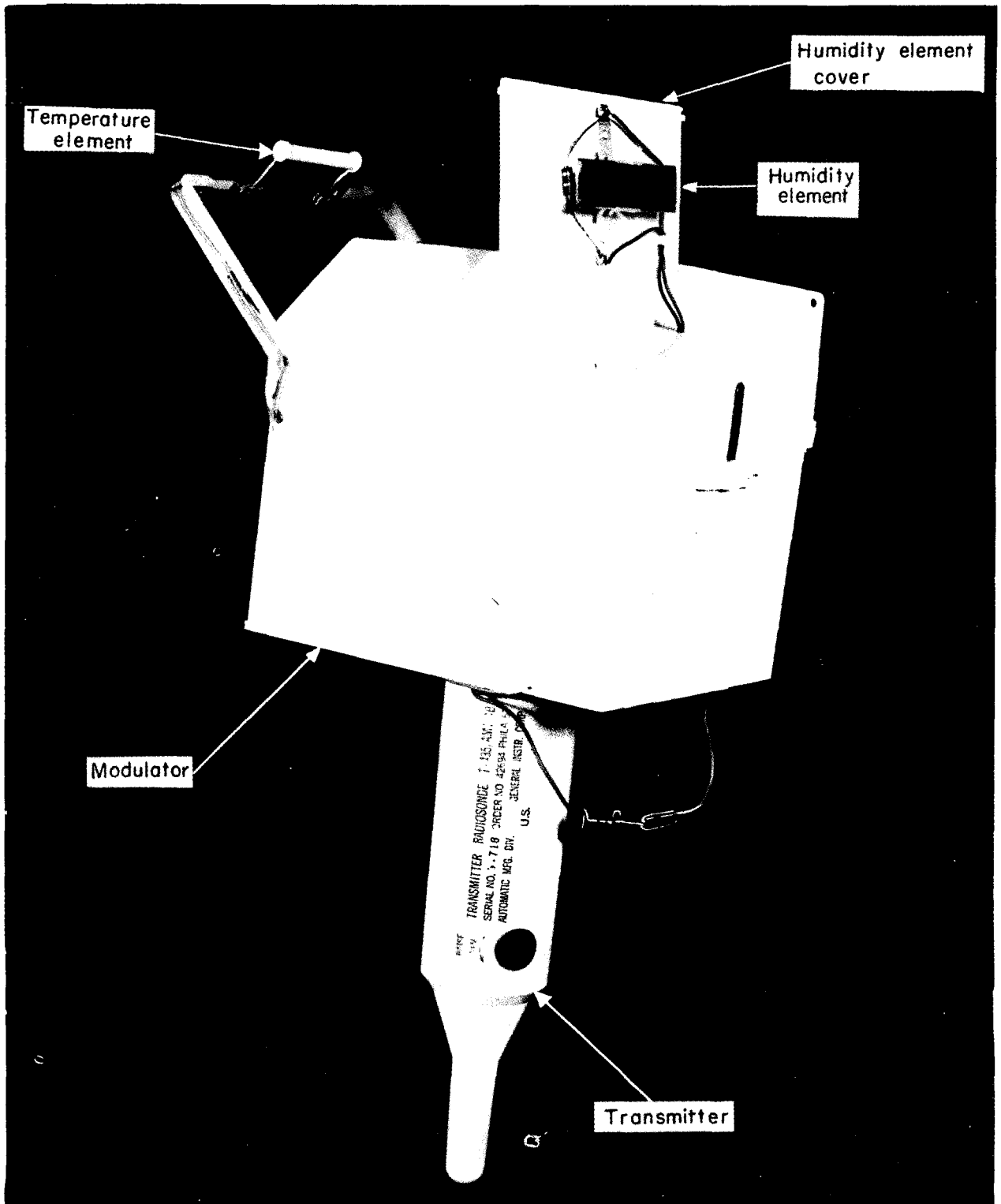


Figure 60. Radiosonde AN/AMT-4( ).



measuring the atmospheric pressure, temperature, and humidity to altitudes of 32,000 meters.

*b. Description and Operation.*

- (1) *Description.* Radiosonde AN/AMT-4( ) is a balloon-borne, battery-powered, meteorological instrument which automatically transmits pressure, temperature, and humidity information to a ground receiving station by means of radio waves. The radiosonde consists of a modulator and a transmitter. The modulator (fig. 61) is assembled in a white plastic container. The top of the container may be opened to permit access to the baroswitch mechanism. Temperature element clips are mounted on support arms attached to the sides of the modulator top. Humidity element clips are under a small removable lid on the top of the modulator. A hinged door on the bottom of the modulator provides access to the battery compartment. Clips on the outside of this door secure the transmitter to the modulator. The transmitter is enclosed in a plastic tube. One end of the tube is pointed and the other end is closed by a removable cover and rubber gasket. The leads used to interconnect the transmitter and the modulator are in either one or two plugs, depending on the model of the transmitter. The pressure unit is the heart of the modulator, since it activates all of the electrical weather measuring circuits. It consists of one or two aneroid pressure cells which expand as the atmospheric pressure decreases. By means of a linkage and lever system, this small expansion moves a thin pin arm, across a black bakelite plastic bar, the commutator bar, which is marked with 150 metal strips. The metal strips on the commutator bar conduct electricity, whereas, the bakelite material which separates these strips is a nonconductor. The end of the commutator bar is fitted with an adjusting screw so that the commutator bar may be moved laterally with respect to the pin arm. The pin arm may be raised from contact with the commutator bar by means of a lifting lever. An electrical relay acts as a switching device for the temperature and hu-

midity circuits. A radiosonde test plug or (in later models) three test leads are available for testing the electrical circuits and connecting the modulator to the baseline check set AN/GMM-1( ). The transmitter of the radiosonde is housed in a cylindrical plastic container. The transmitter consists of two subminiature electron tubes and the necessary circuit components to produce an ultrahigh frequency (UHF) radio signal of 1680 megacycles (mc). This frequency setting may be manually adjusted plus or minus 20 megacycles. The temperature element is a small ceramic resistor material which is coated with a white lead carbonate pigment to reflect the sun's rays. The electrical resistance of this element changes as the ambient temperature changes. Its range of measurement is from +60° to -90° Celsius. The temperature element is placed between the clips of two support arms. The humidity element is a strip of polystyrene plastic, fitted with two metal electrodes along the long edges and coated with a moisture sensitive film. The electrical resistance of the humidity element varies with both humidity and temperature. Its range of measurement is from 10 to 100 percent relative humidity. The humidity element is mounted between the clips on the top of the modulator. The temperature and humidity elements and a pressure calibration chart are packed in a cardboard box and stored in the battery compartment. The pressure unit calibration chart shows the relationship between the position of the pin arm on the commutator bar and the air pressure. This calibration chart is furnished by the manufacturer.

- (2) *Operation.*

- (a) *General.* As the aneroid pressure cell(s) expands, the pin arm of the modulator moves across the commutator bar and contacts, in turn, each of the 150 metal strips (fig. 62). Each silver strip (conducting segment) and the following bakelite strip (insulating segment) compose one contact of the commutator bar. Thus, the commutator bar is composed of

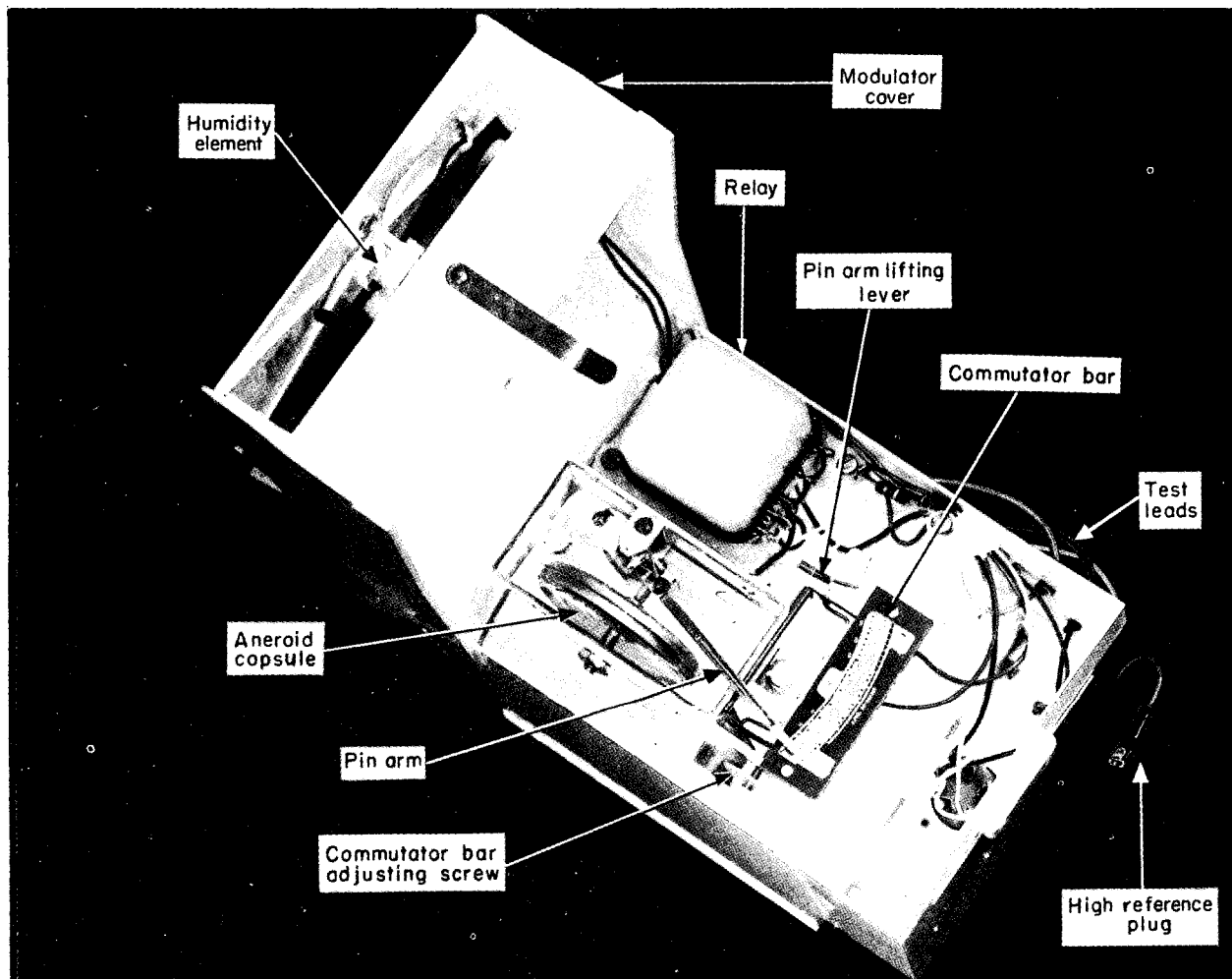


Figure 61. Radiosonde modulator MD-210/AMT-4B.

150 contacts in all. The temperature and humidity sensing elements are connected into the transmitter circuit at various positions of the pin arm along the bar. The electrical current conducted by the sensing elements operates the blocking oscillator tube of the transmitter. This electrical current causes the tube to turn itself off and on at an audio rate between 8 and 194 cycles per second (cps), depending on the particular value of resistance in the circuit. The amount of this resistance is determined by the position of the pin arm on the commutator bar and the existing

weather values. The blocking oscillator tube affects the carrier wave transmitter tube so that the 1680-mc. carrier wave is modulated at a rate dependent on existing weather values. Ground based equipment demodulates the wave and records the measured weather values on a printed chart for evaluation.

- (b) *Arrangement of the commutator bar.* There are four circuits which may be switched into the transmitting circuit by the movement of the pin arm over the 150 contacts on the commutator bar. The contacts are numbered from 0 to 150, beginning with the high pressure

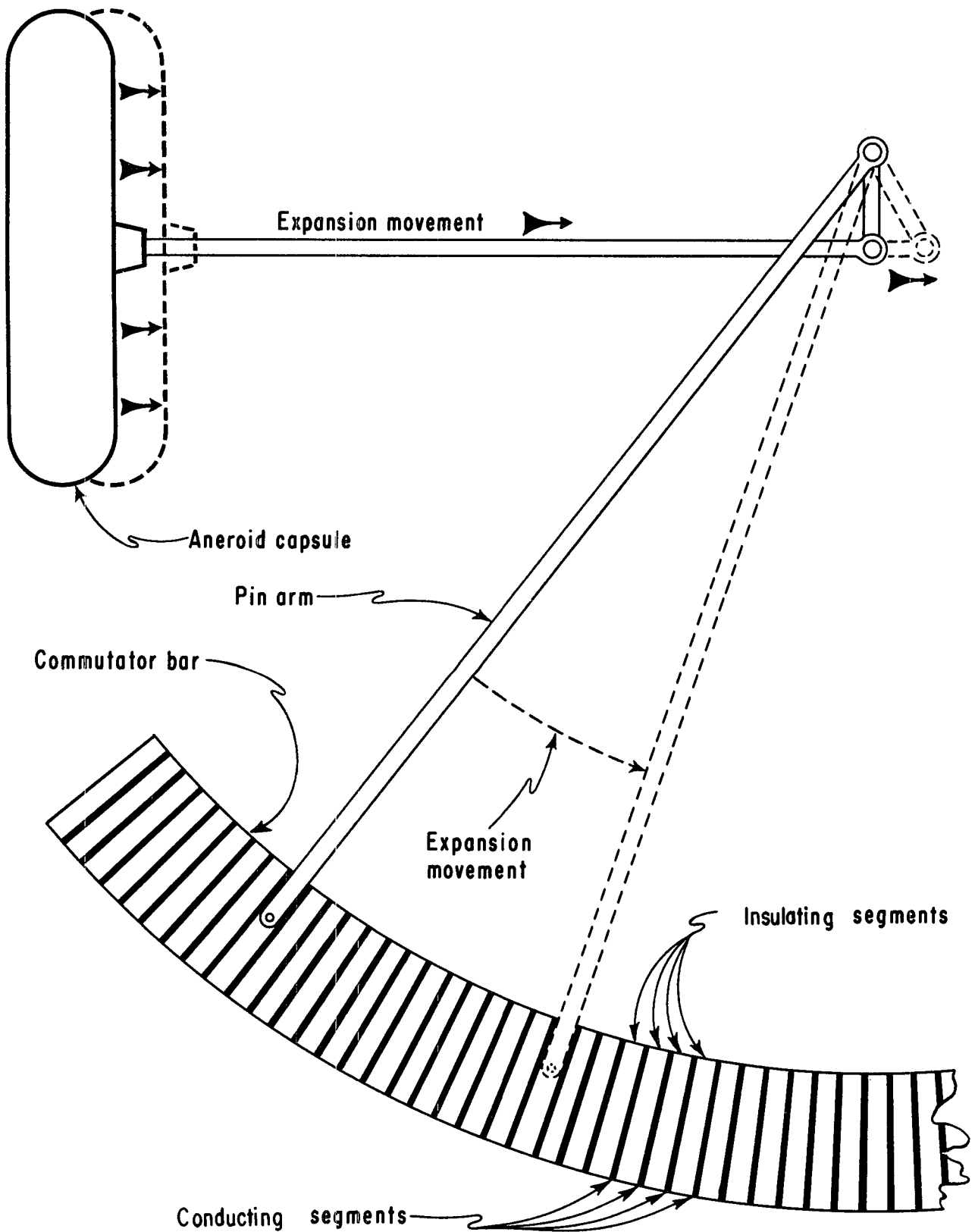


Figure 62. Action of baroswitch.

end. Starting with 0, the conducting segment of every fifth contact up to the 105th contact, except multiples of 15, connects the low reference circuit and causes the radiosonde to transmit a signal which is modulated at a rate of 190 cycles per second. Low reference signals are used to identify the contact pattern of the radiosonde data during flight and to adjust the temperature and humidity signals. The conducting segment of every 15th contact through the 105th contact connects the high reference circuit and causes the radiosonde to transmit a signal which is modulated at a rate of approximately 194 cycles per second. High reference signals are also used to identify the radiosonde contact pattern during flight.

*Note.* On some models, contact number 15 may be low reference. All other conducting segments up to the 105th contact, activate the relative humidity sensing circuit and cause the radiosonde to transmit a signal modulated at a rate of 8 to 185 cycles per second, depending on the ambient humidity. After the 105th contact, it is no longer necessary to measure the humidity, and each conducting segment that is not a multiple of 5 becomes low reference and each 5th conducting segment becomes high reference. When the pin arm is not on a conducting segment, the temperature sensing circuit is activated and the radiosonde transmits a signal modulated at a rate of 8 to 170 cycles per second, depending on the ambient temperature. The insulating segments between conducting segments are the temperature segments. The relative constructed width of all segments are shown in table III. A contact begins at the base of a relative humidity or reference segment and ends at the top of a temperature segment. Because of manufacturers tolerances and differences in widths of pins, contact values as recorded on the radiosonde record are different from the constructed values. When evaluating a radiosonde record to determine pressure-contact value, determine proportional parts of a contact with reference to the whole contact as it appears on the record. For example, the relative humidity portion of a contact is not necessarily 0.3 of the whole contact.

Table III. Contact Values of Segments as Constructed

Trace	Contact value
Humidity segment.....	0.3
Temperature segment following a humidity segment.....	0.7
Reference segment.....	0.4
Temperature segment following a reference segment.....	0.6
Low reference segment above the 105th contact.....	0.3

**77. Radiosonde Set AN/AMT-12 (Hypsometer)**

*a. General.* As stated in paragraph 74c, a disadvantage of the current rawinsonde equipment is the decrease in accuracy of the pressure values obtained at higher altitudes. This error can be reduced by the use of a hypsometer instead of an aneroid cell to measure the pressure at high altitudes. The hypsometer is a comparatively simple device which measures the boiling temperature of a liquid (carbon disulfide) (CS<sub>2</sub>) to determine pressure. The boiling point (temperature) of carbon disulfide is directly related to the atmospheric pressure. The hypsometer consists of an insulated container, a

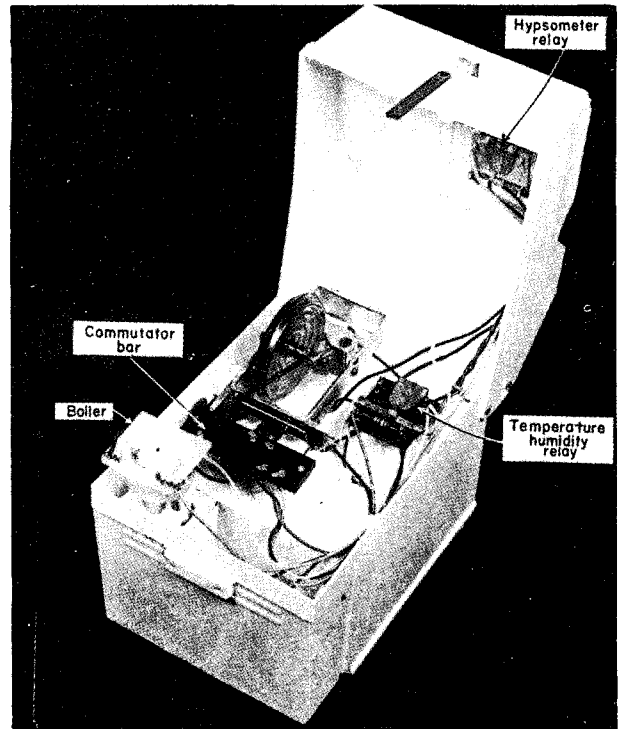


Figure 63. Radiosonde set AN/AMT-12 (hypsometer).

thermistor, and the liquid carbon disulfide. The hypsometric radiosonde AN/AMT-12 (fig. 63) has been developed for higher altitude soundings. This radiosonde can measure pressures down to 2 millibars with an accuracy of about 0.1 millibar. The hypsometric radiosonde is identical in physical appearance to radiosonde AN/AMT-4( ). Inside the modulator, however, is a hypsometric boiler. The boiler is a vacuum flask, about the size of a small radio tube; it is open at the top and mounted upright just in front of the commutator bar of the baroswitch. The temperature measuring element inside the flask is fishhook shaped and wrapped in cotton for protection. Just before flight, the small flask or boiler is charged with 5 cubic centimeters of carbon disulfide, using a hypodermic needle and syringe. For further description, see TM 11-6660-220-10.

b. *Function.* After release, radiosonde set AN/AMT-12 functions in exactly the same manner as radiosonde AN/AMT-4( ) until it reaches an

altitude corresponding to the 105th contact. At contact 106 and alternately every third and second contact thereafter (i.e., 106, 109, 111, 114, 116, etc.), the hypsometric circuit is activated. The temperature element measures the temperature of the boiling carbon disulfide. By using a special calibration chart, the metro section converts the hypsometric temperature ordinate value to a pressure reading. At pressures of approximately 40 millibars and lower, the hypsometric pressure is used in place of the aneroid pressure. See chapter 7 for details.

**Warning: Carbon disulfide is noxious and flammable and should be handled with care.**

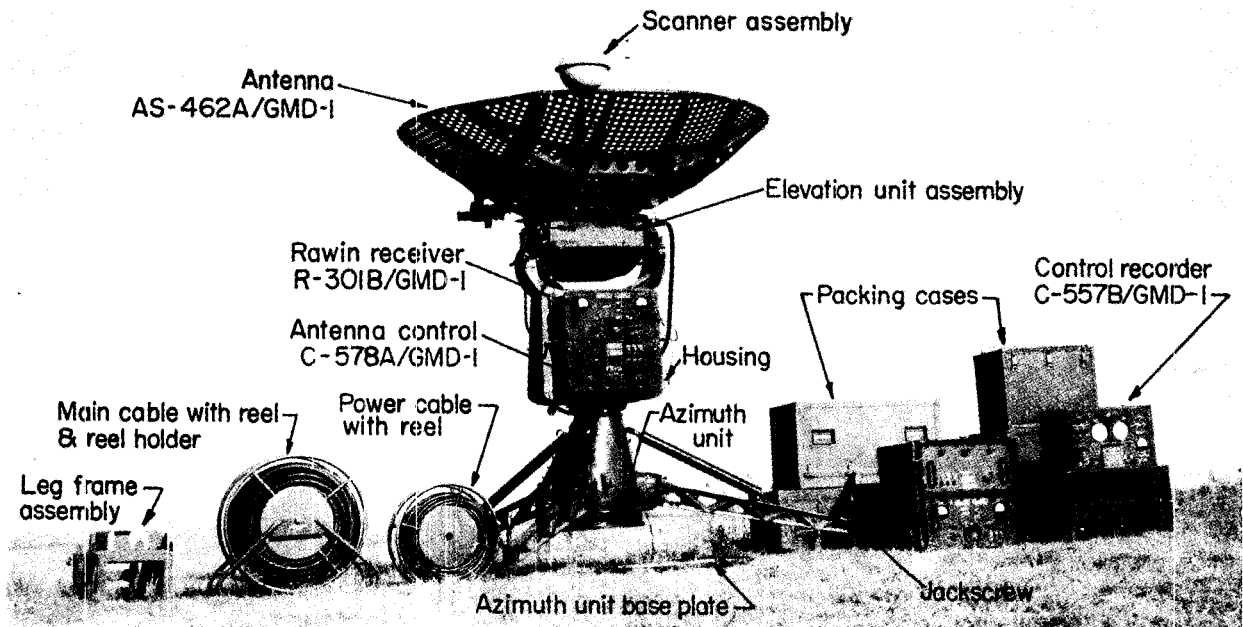
c. *Frequency Adjustment.* The frequency of the carrier wave of radiosonde set AN/AMT-12 is adjustable over a range of 1660 to 1700 megacycles by means of an adjusting screw on the transmitter. Test set TS-538/U is used to adjust the frequency. Procedure for adjusting the frequency is the same as for radiosonde AN/AMT-4( ) and is discussed in chapter 7.

## Section VII. RAWIN SET AN/GMD-1( )

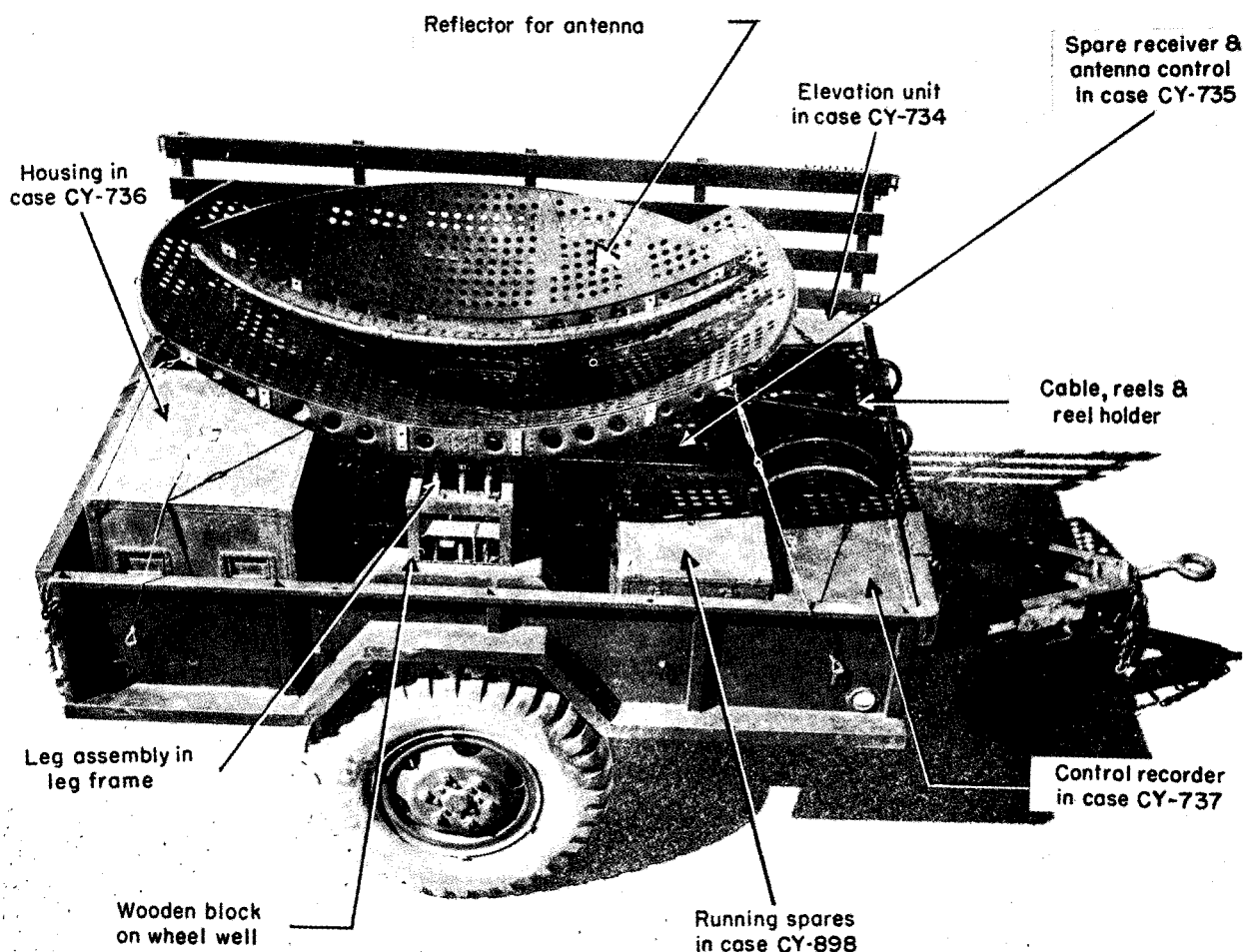
### 78. General

The purpose of rawin set (fig. 64) is to provide a means of tracking a balloon-borne radiosonde trans-

mitter throughout its flight, measuring elevation and azimuth angles to the radiosonde, and receiving radio signals from which values of temperature, pressure, and relative humidity may be determined.



①  
Figure 64. Rawin set AN/GMD-1( ).



②  
Figure 64—Continued.

## 79. Description

The rawin set AN/GMD-1 is a transportable radio direction finder. The set consists of a main assembly, a control recorder, and a trailer adapter kit. The main assembly consists of an antenna scanner assembly, the antenna control, a receiver, and a pedestal. The main assembly automatically tracks the radiosonde during flight. The azimuth and elevation angles to the radiosonde are measured along with the time since release and recorded on a paper tape. The receiver of the set is manually tunable over a frequency range of 1660 to 1700 megacycles and automatically tunes itself after it is locked on a particular radiosonde signal. The

radiosonde transmission signal which provides weather intelligence is demodulated by the receiver and sent to the radiosonde recorder AN/TMQ-5( ) (not a component of the rawin set). The control recorder, a combination remote control and recording device for the main assembly, is connected to the main assembly by a 65 meter cable. The control recorder also serves as a junction box for power distribution; it receives 105 to 129 volts of alternating current, 50 to 65 cycles per second, from the power source and relays it through cables to the main assembly and the radiosonde recorder. The rawin set will automatically track the radiosonde to altitudes of 32,000 meters, or more, and to horizontal

distances in excess of 200 kilometers, depending on the surrounding terrain. The set has four automatic features as follows:

- a. Receiving and demodulating the radiosonde weather signal.
- b. Tuning the receiver to receive the transmitted signal.
- c. Tracking the radiosonde throughout the flight.
- d. Recording angular data to the radiosonde during tracking.

## 80. Employment

a. *Selection of Site.* The ideal site for the operation of the rawin set is the center of a large plateau, with no natural or artificial objects within 200 meters and no obstructions, at any distance, extending  $3^\circ$  above the horizon. However, ideal conditions seldom exist and the selection of an operating site must often be a compromise. Several of the major considerations for siting the rawin set are listed below.

- (1) The distance from the operating location of the control-recorder to the main assembly must not exceed 65 meters.
- (2) The horizon from the main assembly should be unobstructed above  $3^\circ$  (at least in the direction toward which the balloon-borne radiosonde is carried by the prevailing winds). The prevailing winds, when known, must be considered.
- (3) The main assembly must be installed on a level and firm site so that accurate leveling and orientation may be obtained.
- (4) An adequate clear area must be available for the release of the balloons; the release position should be downwind from the rawin set main assembly (100 meters when possible) and adjacent to the balloon inflation shelter.
- (5) Nearby structures and elevated terrain must be avoided, since they may reflect the radio signal from the transmitter and give erroneous angular data.
- (6) Distant landmarks, suitable for orientation should be visible from the site.
- (7) The operating site should be conveniently accessible to operating personnel.

b. *Leveling.* Leveling of the rawin set is performed during the initial installation. The level of the set should be checked before and after each

flight and after any rain which might cause the set to settle out of level. Any error in the leveling of the horizontal plane of rotation of the rawin set will result in erroneous wind speed and direction values. For detailed leveling instructions, see TM 11-271A.

c. *Orientation.* Until all angle indicating dials and the recording mechanism of the control-recorder have been properly oriented, any angular data will be incorrect. Thus, the orientation of the rawin set becomes very important in the computation of accurate wind data. Several methods for accomplishing orientation are outlined in TM 11-271A, which covers the more usual installations found in the field. Orientation should be performed during initial installation of the rawin set and checked before and after each flight.

- (1) Survey control will generally be available for orientation purposes in the area where the metro section is located. The coordinates and altitude to the nearest ten (10) meters of the selected position and the angular data, grid azimuth, to reference points can be provided by unit survey personnel. Stationary objects, such as a pole, building, or tower should be selected as reference points. These objects should be at a considerable distance, never less than one kilometer, from the rawin site. Survey data to reference points are converted to true north by use of chart III, FM 6-16.
- (2) When survey data is not provided, the orientation of the rawin set will be accomplished by use of the theodolite. The theodolite is set up, centered, and leveled over the selected site (usually shown by a stake or other suitable marker) of the main assembly. The declination constant, true north, for the area of operation should be set on the azimuth scale before the theodolite is oriented utilizing the magnetic needle. The elevation and azimuth angles are then measured by sighting the theodolite on a well-defined portion of the object used as a reference point. These angles are read to the nearest one-tenth degree and recorded for future reference.
- (3) The main assembly should be centered over the point on the ground which was used to determine orientation data. After the rawin set is completely assembled, leveled,

and energized, the manual controls are used in sighting the GMD telescope on the reference point. When the telescope is on the point, the motors are turned to **STANDBY** position to prevent vibration during the orientation process. The local angle indicators on the azimuth and elevation units are set to the angular values furnished by survey, converted, or from the theodolite measurements. The remote angle indicators and printing mechanism on the control-recorder are set to indicate and record the same angular data that were set on the local angle indicators. This adjustment completes the orientation of the rawin set.

*d. March Order.* The metro section should become proficient in the unloading, assembly, disassembly, and loading of the rawin set so that rapid displacement will be possible. Procedures for assembly and disassembly of the set are a very important part in the operation of the rawinsonde system. The ability to assemble and disassemble the rawin set quickly and properly may mean the difference between timely or late delivery of the metro message to the using units. Damage due to improper procedure may cause a loss of valuable time while waiting for the maintenance technician

to repair the damaged components. The assembly and disassembly of the rawin set should progress from one component to the next in an orderly manner. When properly loaded in the 1½-ton, 2-wheel cargo trailer (models M104 or M105) using the trailer adapter kit, the rawin set can be transported from one position to another without being damaged. For detailed information on assembly, disassembly, and loading of the rawin set, see TM 11-6660-206-10.

### 81. Operation

*a. Controls.* The controls for operation of the rawin set are on the components of the main assembly and control-recorder. The rawin receiver panel (fig. 65) has six switches to operate, tune, and test the receiver. The antenna control panel (fig. 66) has four switches, an azimuth potentiometer and an elevation potentiometer. In addition, there is a separate set of manual positioning controls on the left side of the housing (not shown in fig. 66).

*b. Control-Recorder.* Power for the entire rawin set is supplied through the **MAIN FUZES** and the **MAIN POWER** switch of the control-recorder (fig. 67). The **MANUAL CONTROL ELEVATION** and **AZIMUTH** switches are employed to remotely control the positioning of the rawin set. A **MOTORS STANDBY** switch is available to operate the

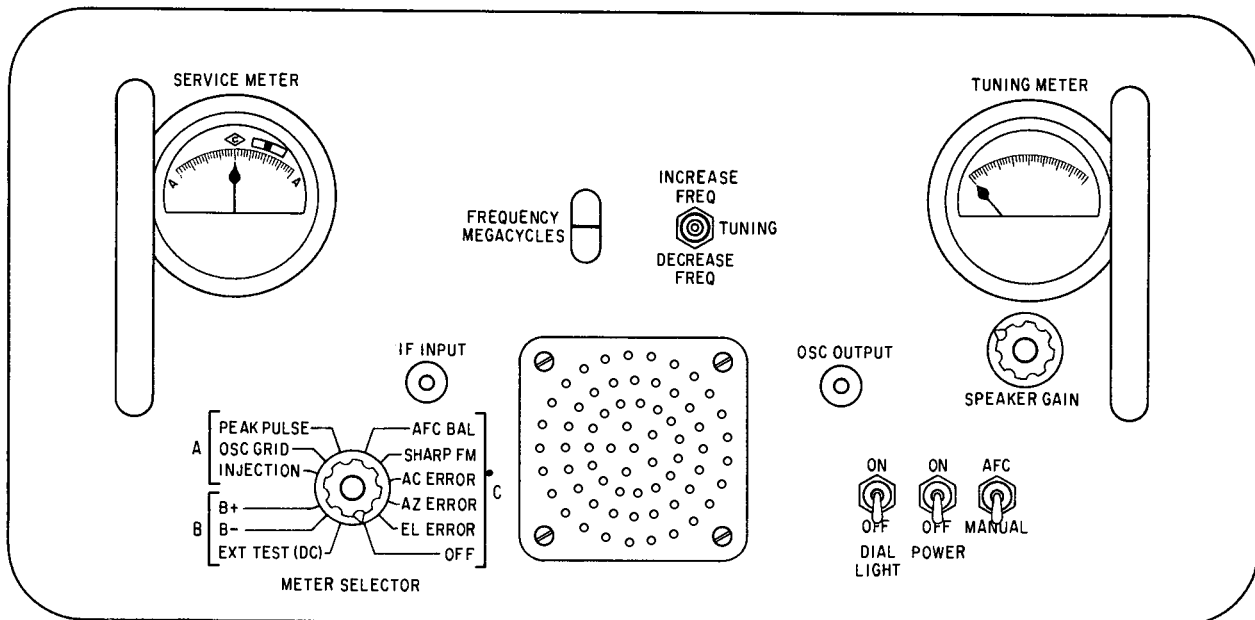


Figure 65. Rawin receiver, front panel.



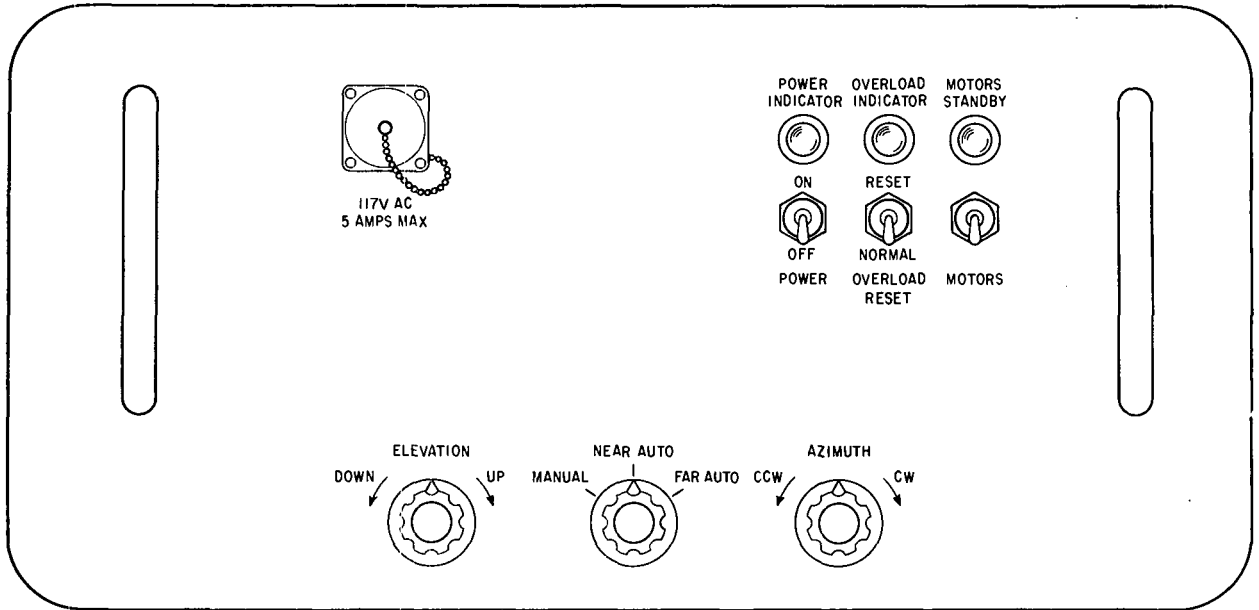


Figure 66. Antenna control, front panel.

antenna scanner motor and the tracking elements from the control-recorder position. ELEVATION and AZIMUTH RESET SELECTORS (mechanical clutches) and the RESET CONTROL knob are used to orient the elevation and azimuth indicator dials and the printing mechanism. The TIME RESET knob is used to reset the visual time indicator and time printing mechanism. The PRINTINGS-PER-MINUTE switch controls the number of prints per minute of the recording system. The RECORDS CONTROL switch insures coordination of the entire rawinsonde system at the release of a radiosonde. A set of lights indicates a power interruption and warns the operator that reorientation of the data recording system may be required.

*c. Starting Procedure.* The rawin set is placed in operation by placing the MAIN POWER switch on the control-recorder in the ON position. Normally, the power switches on the antenna control and rawin receiver are left in the ON position; the MOTORS STANDBY switch should be in the STANDBY position.

*d. Preflight Procedure.* The antenna reflector is positioned to face the radiosonde. On the receiver panel (fig. 65), the FREQUENCY MEGACYCLES

dial is set to the highest obtainable reading by pushing the TUNING switch to the INCREASE FREQ or DECREASE FREQ position. The AFC (automatic frequency control) -MANUAL control is switched from MANUAL to the AFC position. Normally, the automatic frequency control will lock on the radiosonde frequency and accurately tune the receiver. When the receiver is properly tuned, the TUNING METER should read 60 or more units, and the audio signal should be heard. If the TUNING METER reading is too high, the meteorological signal may be distorted during the baseline check. This distortion can be eliminated by positioning the antenna reflector off target. The automatic tracking system of the rawin set is checked by switching the MANUAL-NEAR AUTO-FAR AUTO switch to the NEAR AUTO position. The rawin set should position itself approximately on the radiosonde transmitter. The antenna reflector is repositioned to obtain 60 or more units on the receiver TUNING METER. The motors are turned off by switching the MOTORS switch to STANDBY (MOTORS STANDBY lamp lights). On the control-recorder, the RECORDS CONTROL switch is switched to the BASELINE CHECK position and the baseline

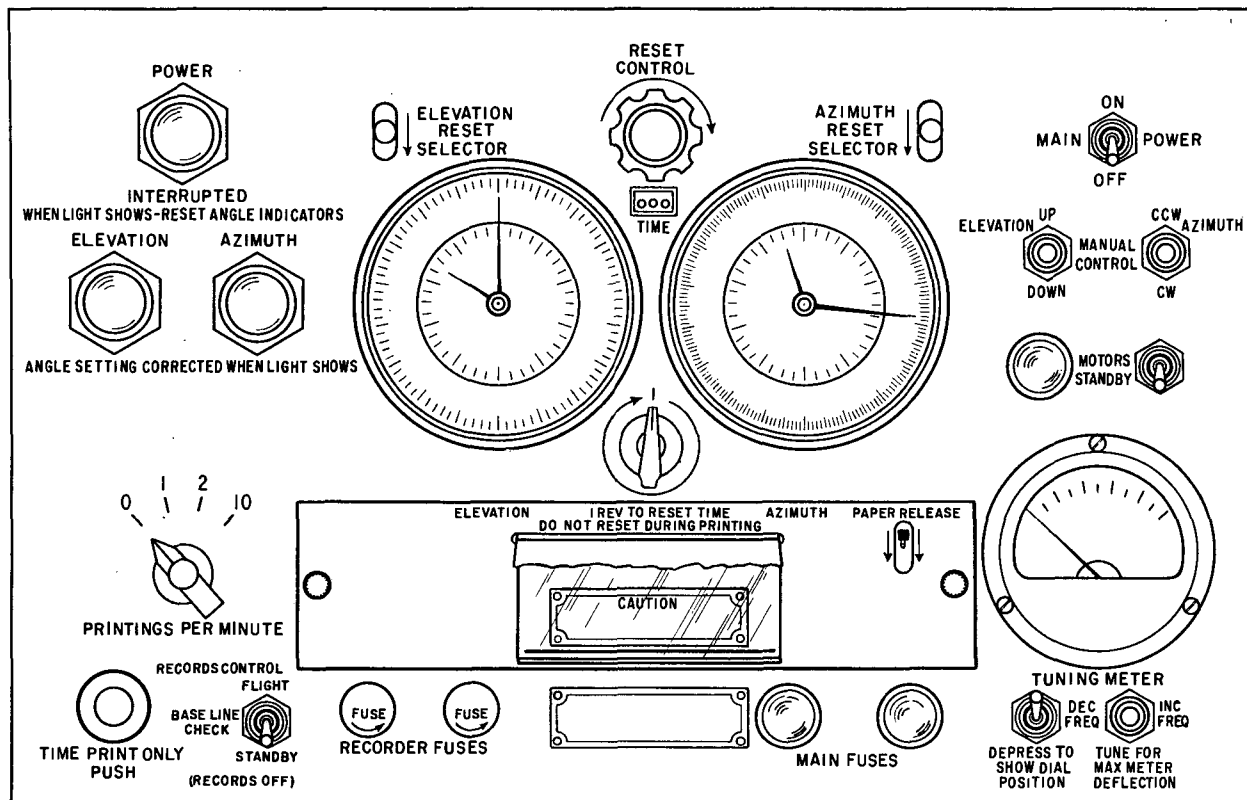


Figure 67. Control-recorder.

check is performed. When the baseline check is completed, the RECORDS CONTROL switch is positioned to STANDBY. After the baseline check has been verified, the motors are turned on. The radiosonde is prepared for release.

*e. Flight Procedure.* At the instant the radiosonde is released, the RECORDS CONTROL switch is switched to the FLIGHT POSITION. This causes simultaneous starting of the control-recorder, the radiosonde recorder, and the rawin set. The section chief stands by to insure that the rawin set is tracking on target. Normally, the rawin set will automatically track the radiosonde from release when the MANUAL-NEAR AUTO-FAR AUTO control on the antenna control (fig. 66) is in the NEAR AUTO position. To facilitate automatic tracking and thereby obtain valid data from the ground level upwards, the radiosonde should be released 100 meters or more downwind from the main assembly. Approximately 2 minutes after release of the radiosonde, the section chief switches the MANUAL-

NEAR AUTO-FAR AUTO switch to the FAR AUTO position.

*f. Stopping Procedure.* Generally, the flight should be terminated on the next reference after the required altitude has been attained, on the first high reference, after balloon burst, or when the critical angle has been reached. The critical angle is defined as an angle of  $6^\circ$  above or to the side of any object on the horizon. When the critical angle has been reached, wind data become invalid. However, the evaluation of temperature and density may continue so long as a requirement for these data exists. When the flight is terminated, the rawin set is stow locked in both azimuth and elevation. After the set is stow locked, the MAIN POWER switch on the control-recorder is placed in the OFF position. This procedure will prevent misorientation of the rawin set due to antenna movement while the remote control angle indicating and recording system is not energized.

## 82. Optical-Electrical Bearing Check

The optical-electrical bearing check is performed to insure that the optical axis of the telescope is parallel to the electrical axis of the rawin set.

*a. Performing the Bearing Check.* The telescope of the rawin set is used to perform the bearing check. No sooner than 5 minutes after release of the radiosonde (unless low clouds indicate a surface check), the radiosonde is viewed through the telescope. If the radiosonde is centered in the reticle, the optical and electrical axes are parallel and no further action is required. If the radiosonde is not centered in the reticle, the necessary angular corrections are determined on the reticle scales. The telescope is then adjusted to center the radiosonde in the reticle, thereby making the optical axis parallel to the electrical axis. The corrections noted are applied to all of the angular data extracted from the control-recorder paper tape. At the end of the flight, the rawin set is checked for orientation.

*b. Preflight Check of Telescope Alinement.* A preflight adjustment of the telescope can be made by using an optical-electrical bearing check board. This board may be used when poor visibility prevents a visual check of the radiosonde after its release.

- (1) The optical-electrical bearing check board (fig. 68) is used in a manner similar to the test target used in boresighting a howitzer.
- (2) To build the optical-electrical bearing check board, use a radiosonde and a sheet of plywood approximately 2 feet square. At the upper right corner, mount the radiosonde with the transmitter in a vertical position as shown in figure 68. Twenty inches to the left and 16 inches below the center of the transmitter antenna, drill a small hole on which to center a crosshair pattern. Paint in the crosshairs and then paint the first and third quadrants of the crosshair pattern so that the center will be plainly visible through the telescope of the rawin set. By placing a light behind the hole, the board can be used to check the bearing at night. To perform the bearing check, activate the radiosonde and place the board at least 50 meters from the rawin set and about 4 meters above the ground. With MANUAL-NEAR AUTO-FAR AUTO switch in the FAR AUTO position and the rawin set tracking the

target, adjust the telescope until the crosshairs on the reticle are alined with the crosshair pattern on the check board. After this adjustment, the transmitter should "jiggle" in the center of the reticle during an actual flight, and the correction for parallax does not have to be made. In a semipermanent position, a fixed upright can be constructed upon which to mount the test board. This upright can be surveyed in to serve as an azimuth reference point during orientation.

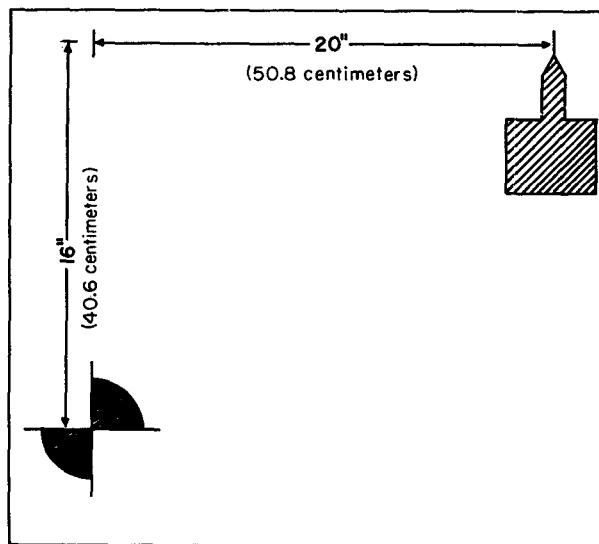


Figure 68. Optical-electrical bearing check board.

*c. Determination of Angular Corrections.* The angular corrections to be applied to the elevation and azimuth data extracted from the control-recorder tape are determined from the horizontal and vertical scales in the reticle of the telescope (fig. 69). The vertical scale is used to determine the correction for elevation angles, and the horizontal scale is used to determine the correction for azimuth angles. These scales divide the reticle of the telescope into four quadrants. The corrections are read directly from the scales to the nearest  $0.1^\circ$ . If the radiosonde appears in the upper half of the reticle, the elevation correction is added to each elevation angle extracted from the tape; if it appears in the lower half of the reticle, the elevation correction is subtracted from each elevation angle. If the radiosonde appears in

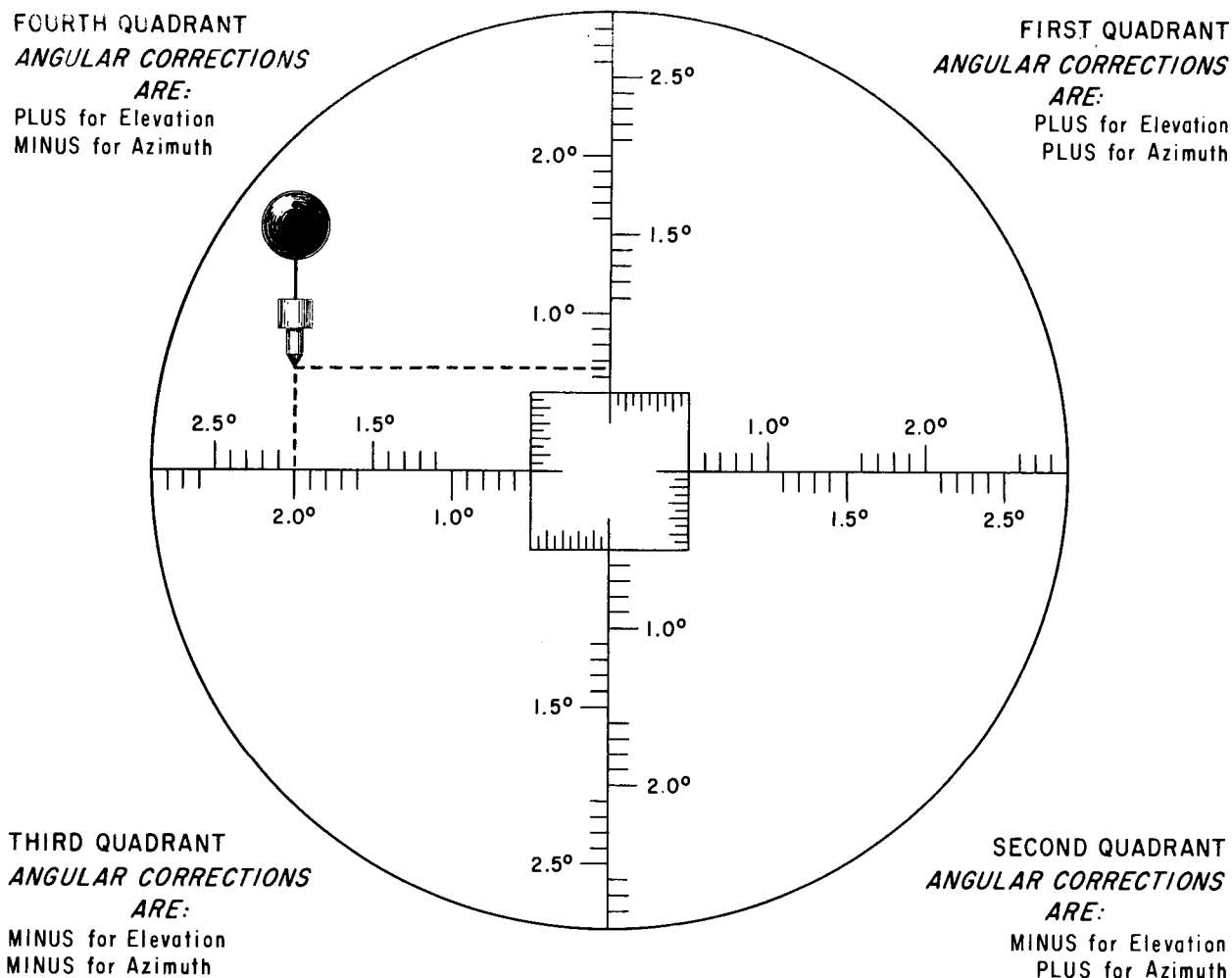


Figure 69. Determining angular corrections.

the right half of the reticle, the azimuth correction is added to each azimuth angle extracted from the tape; if it appears in the left half of the reticle, the azimuth correction is subtracted from each azimuth angle. The signs of the elevation and azimuth corrections for each quadrant are shown in figure 69. For the radiosonde illustrated in the figure, the elevation correction is  $+0.65^\circ$  and the azimuth correction is  $-2.0^\circ$ .

*d. Application of Angular Corrections.* The angular data printed by the control-recorder will be in error if the radiosonde is not centered in the reticle of the telescope. These data are corrected by adding or subtracting the angular corrections determined in *c* above. Only the angular data which are to be used in subsequent computations are corrected.

*e. Frequency of Performance.* The optical-electrical bearing check is performed during the first radiosonde flight after the rawin set is installed in a new location. The check also is performed at least once each day the rawin set is used or at any time the telescope alinement is disturbed. If the radiosonde does not appear initially in the reticle of the telescope, the procedures outlined in TM 11-6660-206-10 should be employed to obtain accurate angular data.

### 83. Preventive Maintenance

The preventive maintenance to be performed by the operator is specified in TM 11-6660-206-10. Troubleshooting by the operator is limited primarily to power troubles. The greatest single source of trouble is improper cable connections.

## Section VIII. RADIOSONDE RECORDER AN/TMQ-5( )

**84. General**

The purpose of radiosonde recorder AN/TMQ-5( ) (fig. 70) is to provide a means of recording the meteorological data, except winds, received by rawin set AN/GMD-1( ).

**85. Description and Use**

The radiosonde recorder converts the metro signal from the rawin set to a visual record. Circuits within the radiosonde recorder first convert the metro signal to a direct-current (d.c.) voltage proportional to the pulse frequency. This voltage is compared with another voltage which is representative of the recorder pen position. The difference between these voltages causes the pen to move to the proper recording position. In conjunction with a radiosonde and a rawin set, the radiosonde recorder produces an accurate record of the atmospheric sounding during a radiosonde flight. For detailed information, see TM 11-2436.

**86. Controls**

The controls required for operation of the radiosonde recorder are on the front panel of the recorder. These controls are used to regulate and adjust the sensitivity of the pen positioning circuits and the operation of the pen lifter circuits. The controls also are used to make compensations for drift of the radiosonde transmitter signal.

**87. Installation**

The radiosonde recorder is normally located in the metro van. It should be installed on mount MT-1355/TMQ-5 where it can be easily connected to the control recorder. Two cables are commonly used in the operation of the radiosonde recorder. Cable CX-1217/U provides a connection from the radiosonde recorder to the control-recorder of the rawin set. During operation of the rawinsonde system, this cable carries the necessary power to operate the radiosonde recorder, the metro signal, and provides the wires for the automatic rawin time print system. Cable CX-2337/TMQ-5 is a split cable which may be connected to a wall receptacle to supply power to the radiosonde recorder. Two leads are left free to provide for a signal input. This cable is used by the maintenance technician during the linearity calibration of the radiosonde recorder with frequency standard TS-65( )/FMQ-1.

**88. Operation**

*a. Preset Procedures.* The operator prepares the radiosonde recorder for operation by opening the cooling vent, erecting the desk, advancing the chart, and attaching the chart weight.

*b. Preliminary Starting Procedure.* Allow the set to warm up for 15 minutes. This should be done with the POWER ON-POWER OFF-STAND BY switch in the STAND BY position and the cooling fan operating. The power and frequency meters should be checked for correct values (105 to 125 volts and 50 to 65 cps). If necessary, the power source should be adjusted to obtain these values.

*c. Starting Procedure.* After the warmup period, the POWER ON-POWER OFF-STAND BY switch is placed in the POWER-ON position. With the SIGNAL SELECTOR switch still in the SC (short circuit) position, the pen should record at zero on the chart. If the pen does not print at zero, the maintenance technician should be informed. Check the chart alinement by manually advancing the chart and observing the relationship between the chart and the studs at the left edge of the roller. If, as the chart advances, the chart creeps to the right or left as shown by the left-hand holes in the chart and the chart roller studs, the chart must be realined. Next, hold the REC. TEST switch in its down position; the pen should move to 95 recorder divisions and mark the chart. This test insures that the pen will move freely to the right side of the chart. When the SIGNAL SELECTOR switch is set to 60 cps, the pen will move to 30 on the recorder chart. If not, adjust to 30 recorder divisions by rotating the REL. ADJUST handwheel. (This reading is one-half the line frequency.) After making the pen print at 30 recorder divisions on the chart, rotate the SIGNAL SELECTOR switch to the 120 cps. position. The pen should move to 60 recorder divisions. The pen can be positioned by rotating the RFE. ADJUST handwheel. After completing these tests, rotate the SIGNAL SELECTOR switch to SIG position. The recorder is now ready to receive and record signals.

**89. Calibration**

Linear calibration is performed with frequency standard TS-65( )/FMQ-1 by injecting selected groups of fixed frequencies that are accurate between 10 and 190 cycles per second. This calibration

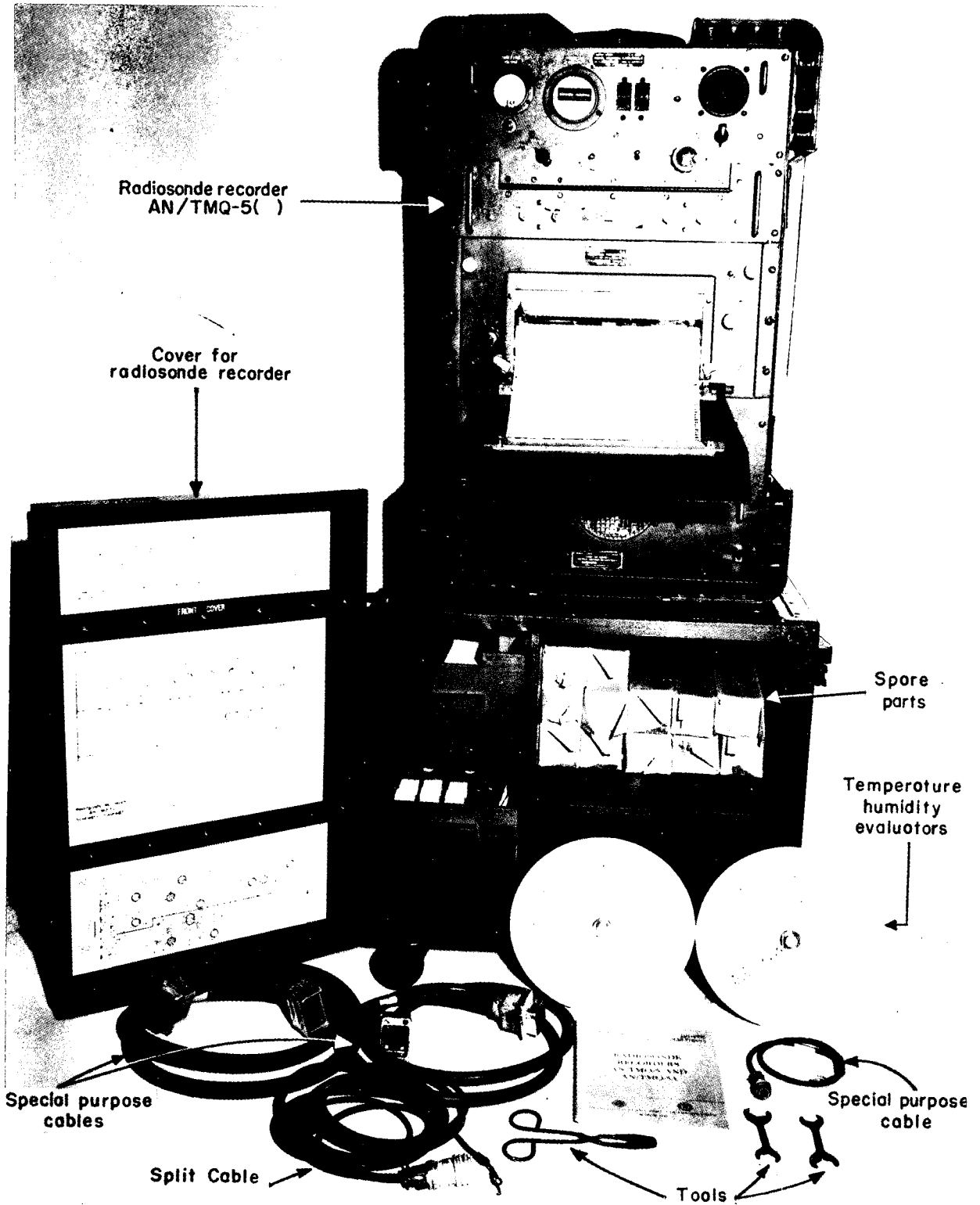


Figure 70. Radiosonde recorder AN/TMQ-5( ).

normally is performed by the maintenance technician as prescribed in TM 11-2436.

## 90. Preventive Maintenance

*a. Daily.* The recorder operator checks for completeness and general condition of the equipment; inspects for clean impression of printing and proper recorder paper feed; checks input voltage and frequency readings for proper values; and checks for normal operation by performing the preset, pre-

liminary, and starting procedures.

*b. Weekly.* The maintenance technician, assisted by the operator, tightens the mounting and the cam-lock fasteners on the cabinet; cleans and tightens the cable connectors; cleans the cabinet of rust, corrosion, and moisture; inspects the wires, cables, cord, and shock mounts for cuts, breaks, fraying, deterioration, kinks, and strain; cleans the meter windows; inspects the meters for damaged glass and cases; and checks the voltmeter for zero adjustment.

## Section IX. CALIBRATION EQUIPMENT

### 91. Frequency Standard TS-65( )/FMQ-1

*a. Purpose.* The purpose of frequency standard TS-65( )/FMQ-1 (fig. 71) is to provide a means for linear calibration of the radiosonde recorder AN/TMQ-5( ).

*b. Description and Use.* Frequency standard TS-65( )/FMQ-1 is a rugged electronic unit designed to provide accurate electrical signals of fixed frequency between 10 and 190 cycles per second. It is issued to meteorological sections for the linearity calibration of radiosonde recorder AN/TMQ-5( ). This calibration normally is performed by the maintenance technician as prescribed in TM 11-2436. The standard is a self-contained unit which operates on 110 volt alternating current at 50 to 60 cycles per second. For detailed information, see TM 11-2602B.

*c. Preventive Maintenance.* Since frequency standard TS-65( )/FMQ-1 is the only instrument available for performing a linearity calibration of the radiosonde recorder, the handling and operating instructions should be followed carefully. Always protect it from jarring, and report any evidence of improper functioning to the maintenance technician. Proper operation of the frequency standard can be determined by observing the light pattern through the SYNC (synchronization) hole on the front panel. A stationary pattern indicates proper operation.

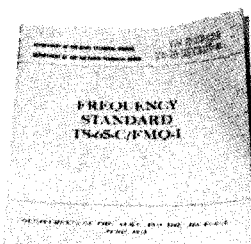
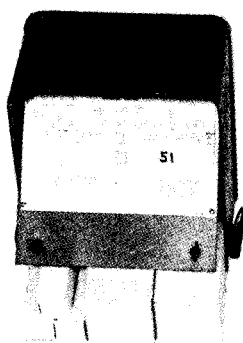
### 92. Radiosonde Baseline Check Set AN/GMM-1( )

*a. Purpose.* The purpose of radiosonde baseline check set AN/GMM-1( ) (fig. 72) is to provide a stable environment for the testing and preflight calibration of the radiosonde temperature and humidity sensing elements. In addition, the baseline check set is used to set the pin arm of the radiosonde.

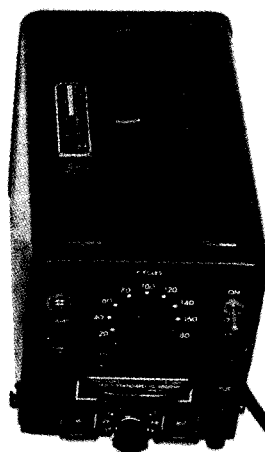
*b. Description and Use.* The set consists of a temperature-humidity chamber, a control unit, a psychrometer case, a 30-meter remote cable, and an 8-meter power cable. The chamber is provided with an air circulating fan, water tray, and heater. An electrical switch is installed to permit remote selection of the radiosonde circuits, either manually or automatically. An illuminated psychrometer is mounted inside the chamber and is visible through the door window so that chamber conditions can be measured without disturbing the chamber atmosphere. Connections are provided to power the radiosonde from a battery outside the chamber. When placed outside the battery heat and moisture will not affect the chamber conditions. The psychrometer case, which contains two psychrometers ML-224, spare tubes, and wicks, is mounted on top of the chamber. During operation, one psychrometer is installed in the check set chamber, and the other is used for local surface observations. The control unit for the baseline check set can be mounted on top of the chamber or at a remote location by use of the reel unit, which has 30 meters of interconnecting cable. For detailed information, see TM 11-6660-219-12.

*c. Installation.* The baseline check set should be placed in a shaded location where it is protected from the direct rays of the sun. The path between the check set and the rawin antenna must be free of any obstacles such as earth and large metallic objects that would block the transmitted signal. Radio transmitters, electrical machinery, high tension power lines and communication lines may cause interference and must be avoided in the selection of the site. Avoid movement of personnel in the vicinity of the check set, as such movement may cause interference with the transmitted signal. To facilitate baseline check procedure, the control unit

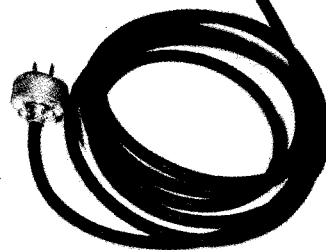
Cover w/spare parts



Frequency standard  
TS-65-C/FMQ-1



Test cable



Power cord

Figure 71. Frequency standard TS-65( )/FMQ-1.



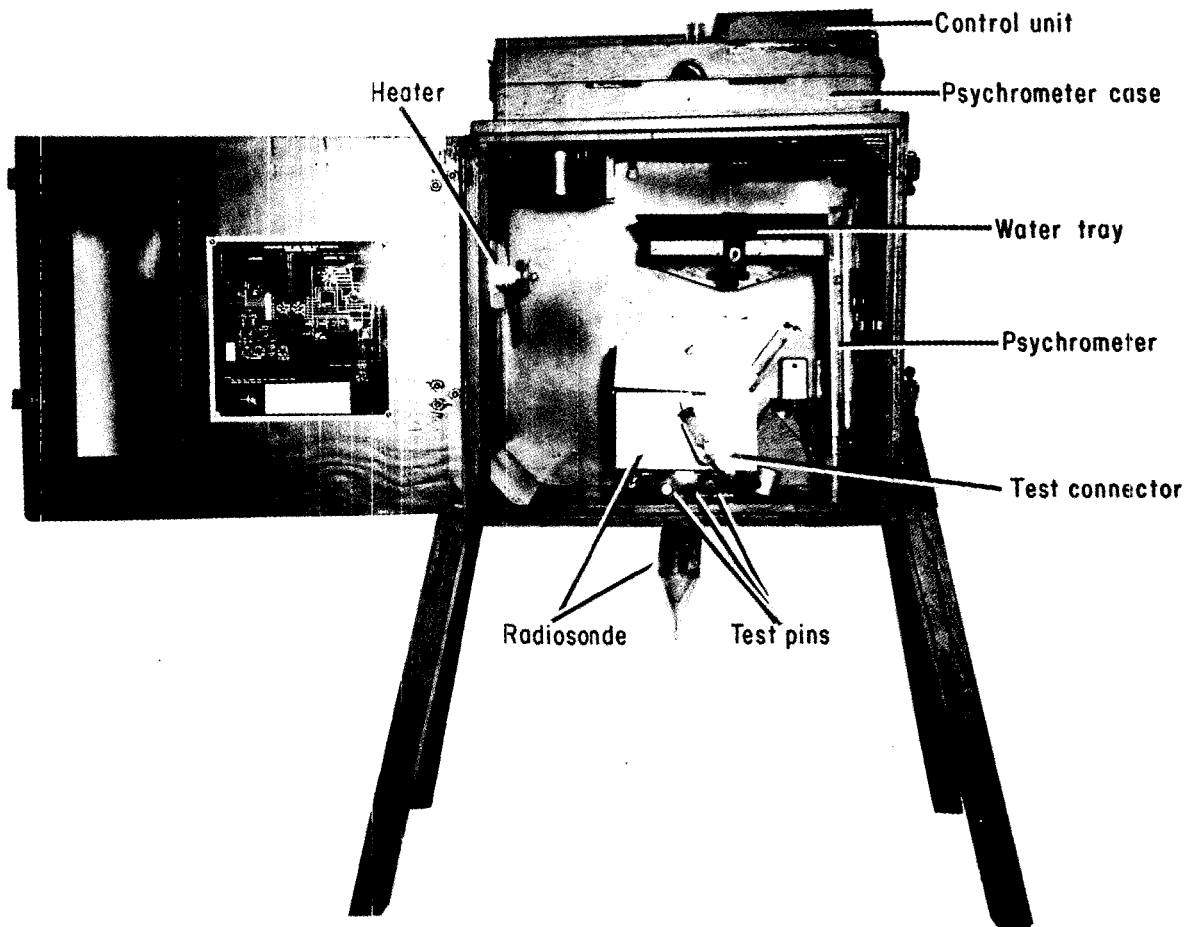


Figure 72. Radiosonde baseline check set AN/GMM-1( ).

is placed inside the shop van where it can be operated by the radiosonde recorder operator. Because of the length of the control unit cable, the check set must be installed within 30 meters of the shop van.

*d. Operation.* The control unit may be installed and operated either on the top of the atmospheric chamber or at a remote location. The POWER switch controls power to the FAN, HEATER, and LIGHT switches and to the pin arm adjustment circuit. When the main power is turned on, the FAN, HEATER, and LIGHT (chamber light) switches will operate, but the heater will not turn on unless the fan is on. For baseline check operations, the fan is always turned on. The heater is turned on when temperature is below freezing or when the humidity is above 90 percent within the chamber.

The selector switch takes the place of the radiosonde baroswitch by causing the radiosonde to transmit temperature, low reference, or humidity signals. The selector switch is turned manually to the TEMPERATURE, REFERENCE, or HUMIDITY position. When the selector switch is turned to its last position, AUTOMATIC, the radiosonde switching is controlled by a small motor which connects the low reference, temperature, low reference, humidity, in that order, at 15-second intervals. The high reference circuit is not tested by the baseline check set. As soon as the sensing elements are installed on the radiosonde, it is placed in the check set chamber, with the transmitter protruding through the aperture in the floor of the chamber and the temperature element toward the psychrometer.

Extreme care must be taken in handling the delicate temperature element, which is easily broken. The radiosonde test plug or test leads are connected to the mating plug in the baseline chamber. If the radiosonde modulator installed in the baseline chamber is not supplied with the test plug, the radiosonde test leads are connected to the test pins of the same colors. The pin arm of the modulator is left *off* (up). Then the door is closed. An interval of approximately 10 minutes is required to achieve stable conditions of temperature and humidity. After the radiosonde is installed in the atmospheric chamber and the door is closed, the baseline check is conducted as described in chapter 7.

*e. Preventive Maintenance.* Detailed maintenance instructions for the radiosonde baseline check set are contained in TM 11-6660-219-12.

### 93. Test Set TS-538/U

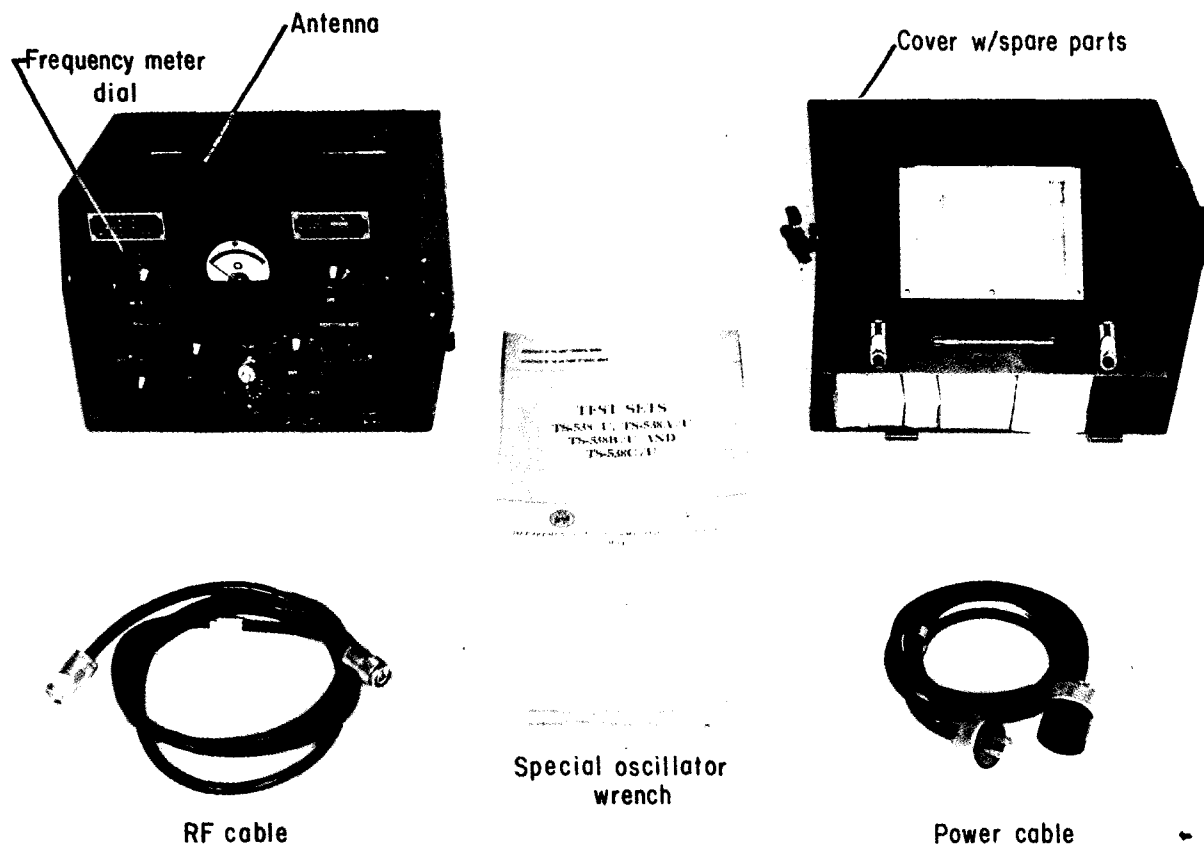
*a. Purpose.* Test set TS-538/U (fig. 73) provides a means for checking the frequency and signal

strength of the radiosonde transmitter. It also may be used as a signal generator.

*b. Description and Use.* Test set TS-538/U is a component part of the rawin set. The test set is contained in a metal case with a hinged cover. The power cable and antenna are stored inside the cover. When used as a signal generator, the test set requires 60-cycle, 110-volt power. When used to check the frequency and the signal strength, external power is not required. Only the FREQUENCY METER dial and the FREQUENCY METER are used to check the frequency and the signal strength. For a detailed description, see TM 11-5014.

*c. Operation.* The test set is used to measure the frequency and the power output of the radiosonde transmitter. The operation of the test set in performing these functions is described in chapter 7.

*d. Preventive Maintenance.* Detailed procedures for maintenance of the test set are outlined in TM 11-5014.



①  
Figure 73. Test set TS-538/U.



②  
Figure 73.—Continued.

## Section X. POWER UNITS

### 94. Power Unit 10 KW

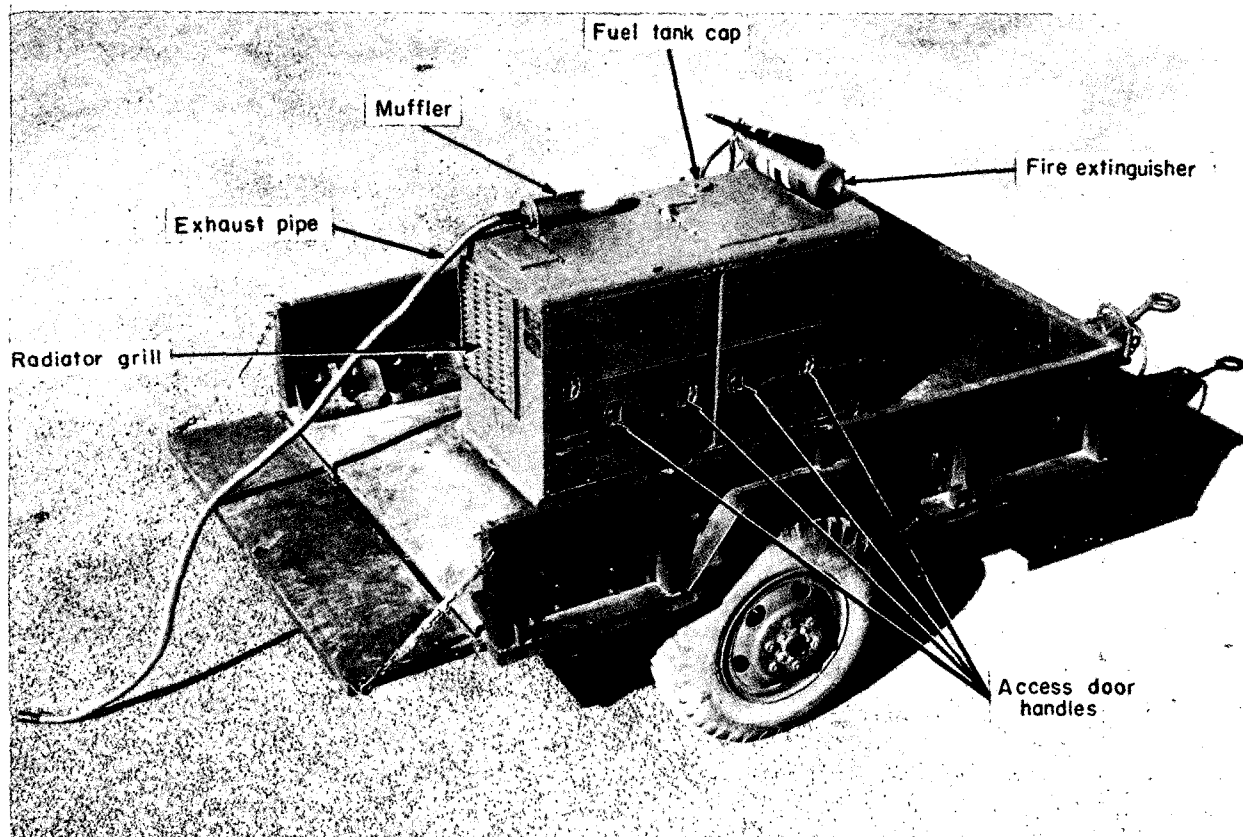
a. *Purpose.* The purpose of the 10-kw power unit (fig. 74) is to provide a power source for operation of the meteorological station.

b. *Description and Use.* The complete electronic meteorological section operating in the field requires approximately 2,300 watts of electric power for the equipment alone. Electric lights, soldering irons, and electrical test equipment require additional power. The rawinsonde system makes many meas-

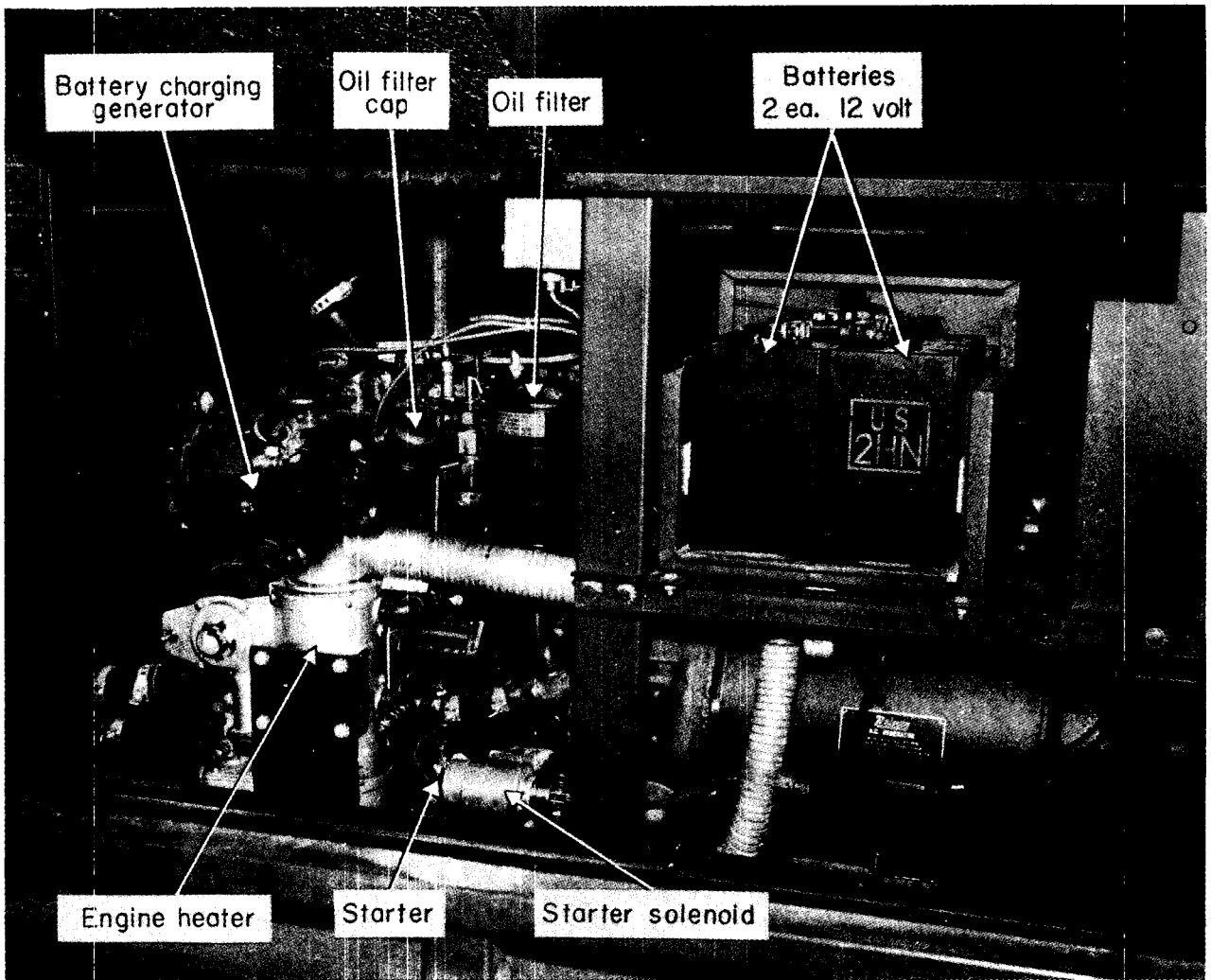
urements of minute electrical quantities in its automatic recording of radiosonde data, therefore, the system must be provided with an adequate and stable power source. The power unit must provide stable voltage and deliver power at a fixed frequency, regardless of the load. For more detailed information, see TM 5-6115-204-10 or TM 5-6115-232-10.

c. *Starting and Stopping Procedures.*

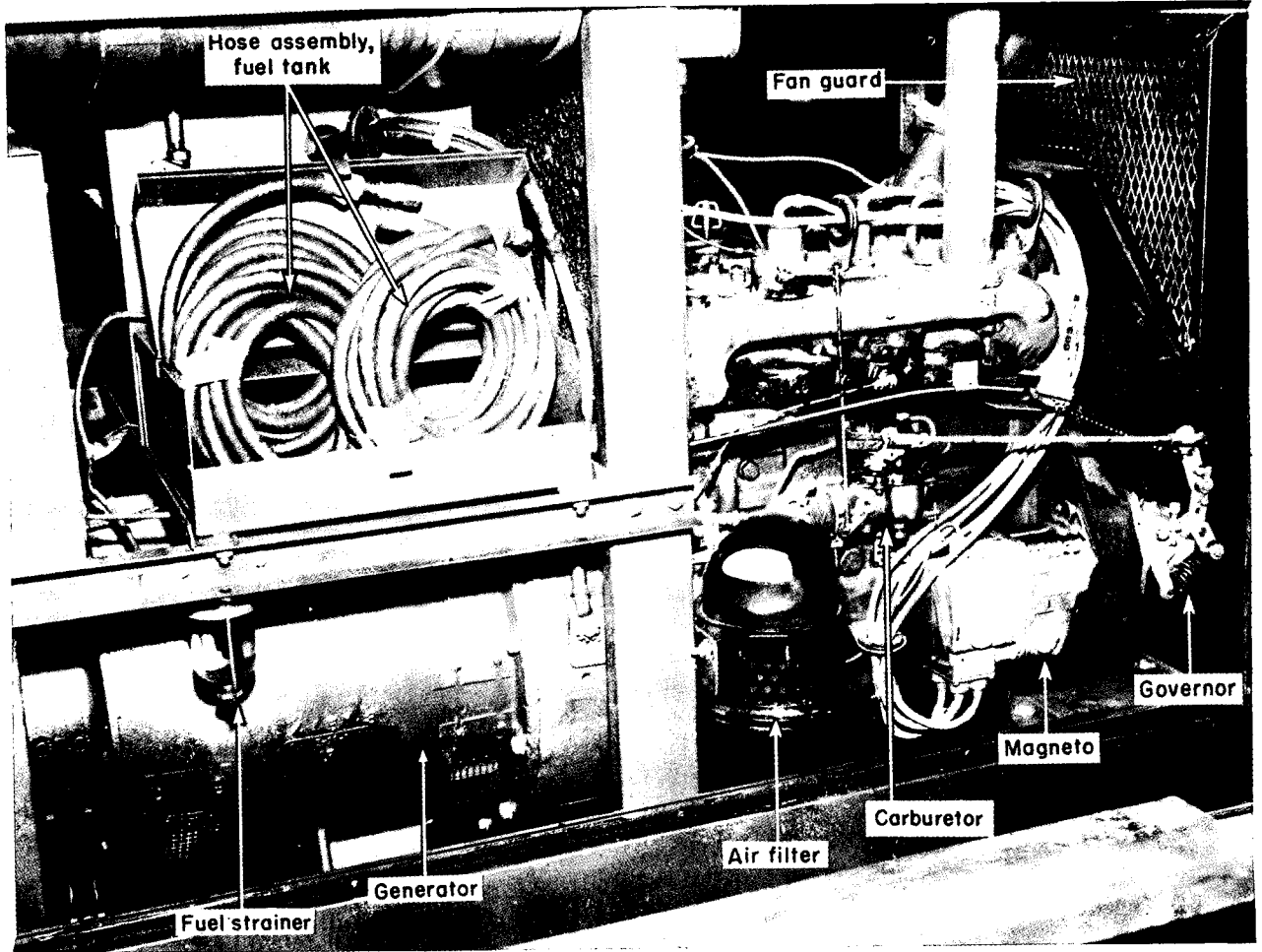
(1) *Starting.* The initial procedure for starting



①  
Figure 74. Power unit, 10-kw.



②  
Figure 74—Continued.



③  
Figure 74—Continued.

the 10-kw power unit is the same as that for a motor vehicle. The operator checks the lubrication, coolant, batteries, and fuel. The following steps are then performed:

- (a) Place the **VOLTAGE REGULATOR** switch in the **MANUAL** position.
  - (b) Set the **EXCITER FIELD RHEO-STAT** in low voltage position by turning the knob counterclockwise as far as it will go.
  - (c) Place the **MAGNETIC-CONTRACTOR-LOCAL-REMOTE** switch in the **LOCAL** position.
  - (d) Pull the engine idle control out.
  - (e) Press the **START** button until the engine starts. If the engine fails to start within 10 seconds, release the button. After waiting 10 seconds, repeat the procedure. If the unit does not start after a few attempts, check the fuel supply and ignition wiring and repeat the operation.
- (2) *Stopping.* To stop the engine—
- (a) Disconnect the load by pressing the **OFF** button of the **MAGNETIC CONTRACTOR**.
  - (b) Pull the throttle out to idle the engine. Allow the engine to idle for 5 minutes to cool the valves and pistons, then push the **STOP** switch.

*d. Operation.* The power unit operates in the same manner as the engine of a motor vehicle. Motor vehicle maintenance forms provided by the unit motor officer are used as a guide for before-, during-, and after-operation checks of the 10-kw power unit.

*e. Adjustments.* The speed of the engine, and therefore the frequency of the generated electric current, is automatically controlled by an engine governor. The output frequency should be approximately 60 cycles per second and must be stable. If the frequency is unstable when the generator is under a load, the condition must be corrected before the electronic equipment will operate in an acceptable manner.

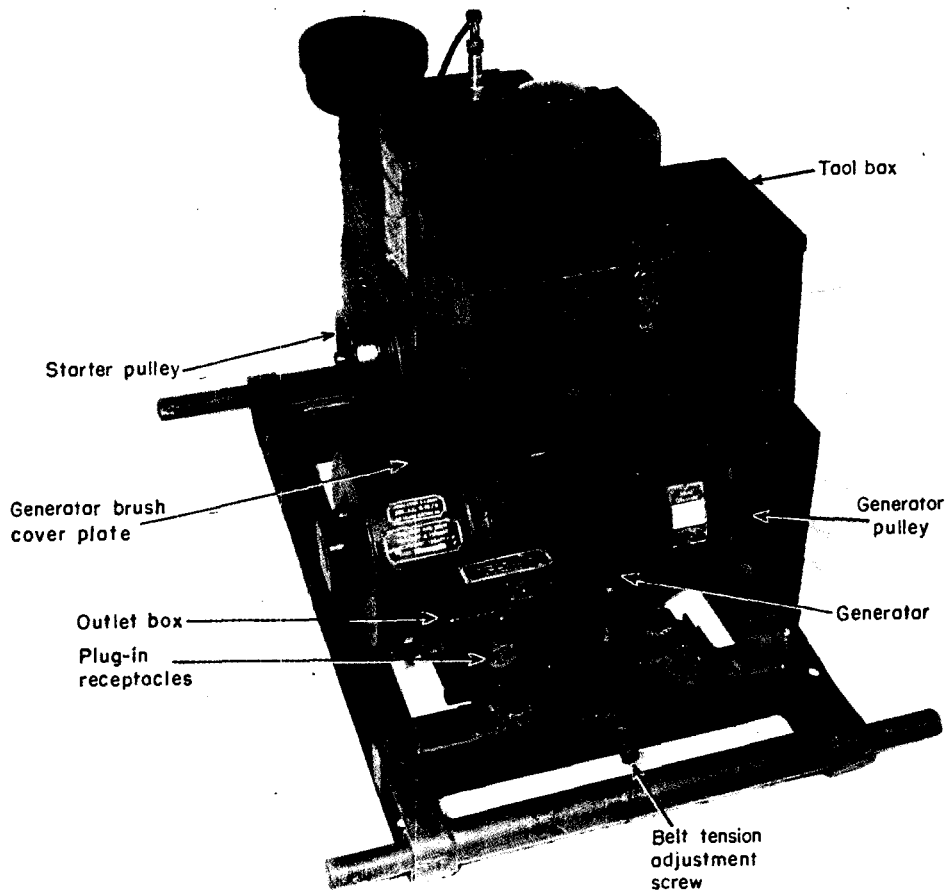
*f. Preventive Maintenance.* Daily preventive maintenance by personnel of the metro section and regular inspections by unit motor mechanics are

essential for dependable service. Detailed operational checks and services are prescribed in TM 5-6115-204-20P.

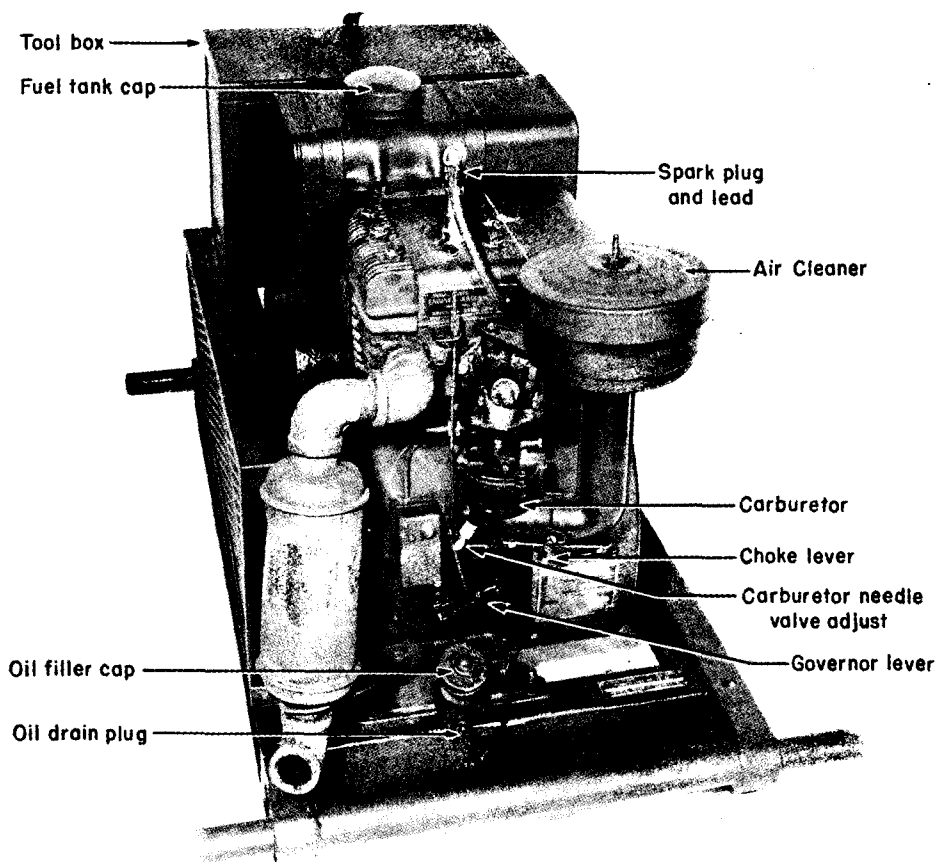
### 95. Power Unit PE-75-( )

*a. Purpose.* Power unit PE-75-( ) (1 and 2, fig. 75) is provided for use by the electronic meteorological section in case of failure of, and during periods of routine maintenance on the 10-kw power unit.

*b. Description and Use.* Power unit PE-75-( ) is a small, portable, field generator weighing approximately 319 pounds and powered by a single cylinder, 4-cycle, gasoline engine. Power unit PE-75-( ) is capable of providing 2,500 watts of electric power continuously at 120 volts and 60 cycles per second. It is started with a flywheel pull cord and stopped with a magneto disconnect button



①  
Figure 75. Power unit PE-75-( ).



②

Figure 75—Continued.

located at the top of the flywheel housing. The unit will satisfactorily operate the rawinsonde system, but care must be exercised not to overload the generator with accessories. This generator is not protected against electrical overload. Means are provided to adjust the frequency of the electrical generator power. This adjustment should be made while the generator is under normal load. The frequency can be measured on the POWER LINE FREQUENCY meter on the radiosonde recorder. For detailed information on power unit PE-75-( ), see TM 11-900.

*c. Starting and Stopping Procedures.*

- (1) *Starting.* The first step in starting the power unit is to wind the starting rope around the crankshaft pulley wheel on the flywheel housing side of the engine. Open the gasoline shutoff valve. The starting

rope is pulled slowly to determine if all internal parts of the power unit will move freely without abnormal drag or friction. To start the engine, the starter rope must be wound on the starter pulley and pulled with a quick steady motion. If the engine does not start after it has been cranked three or four times with the choke closed, it should be cranked several times with the choke partially open and then with the choke wide open. Do not race a cold engine. If the engine does not start, the metro maintenance technician should be consulted.

- (2) *Stopping.* The following procedure is used to stop the power unit PE-75-( ): The STOP button on the flywheel blower housing is depressed and held down until the



engine stops. If the engine has been operating for several hours, it may be necessary to depress the stop button for 30 seconds or more. If the engine is not to be used again for a period of 4 hours or more, it should be stopped by closing the shutoff valve on the fuel filter under the fuel tank.

*d. Operation.* The power unit operates in the same manner as the engine of a motor vehicle. During operation, the operator should listen for any unusual noises, such as backfiring, missing, or rattling. If any unusual noises are heard, corrective action should be taken as soon as possible.

*e. Adjustments.* After the engine starts running,

the choke should be gradually opened by moving it counterclockwise until the engine runs smoothly with the choke fully open. If the engine does not run smoothly with the choke fully open, the needle valve is turned counterclockwise. If the engine continues to run abnormally (missing, backfire, etc.), the needle valve is turned clockwise until the engine runs smoothly. A load should not be placed on the engine until it has reached normal operating temperature, which will occur approximately 15 minutes after starting.

*f. Preventive Maintenance.* The principles of operation, care, and maintenance for the 10-kw power unit apply to power unit PE-75-( ) with few exceptions. See TM 11-900.

## Section XI. METEOROLOGICAL OBSERVATION SET SCM-12

### 96. General

Meteorological observation set SCM-12 (fig. 76) contains all of the equipment necessary to obtain and evaluate ballistic meteorological data from surface and pilot balloon observations.

### 97. Components

The major components of meteorological observation set SCM-12 are as follows:

#### *a. Inflation Equipment.*

- (1) Hydrogen generator ML-303/TM.
- (2) Hose ML-81.
- (3) Balloon nozzle ML-373/GM, complete with weights.

*b. Maintenance Parts Kit.* In general, the maintenance parts kit contains forms, balloons, calcium hydride charges, twine, technical manuals, rubber

bands, night lighting devices, clock oil, and spare thermometer tubes and wicks for the psychrometer.

#### *c. Observation Equipment.*

- (1) Theodolite ML-474/GM.
- (2) Tripod MT-1309/GM.
- (3) Timer FM-19.
- (4) Psychrometer ML-224.
- (5) Barometer ML-102-( ).

#### *d. Wind Plotting Equipment.*

- (1) Plotting board ML-122.
- (2) Rule, plotting ML-126A.
- (3) Slide rule.
- (4) Scale ML-577/GM.

#### *e. Communication Equipment.*

- (1) Two head and chest sets HS-25-C.
- (2) Reel RL-39-( ) with spool DR-8 and wire WD-1/TT.
- (3) Two jacks JK-54.

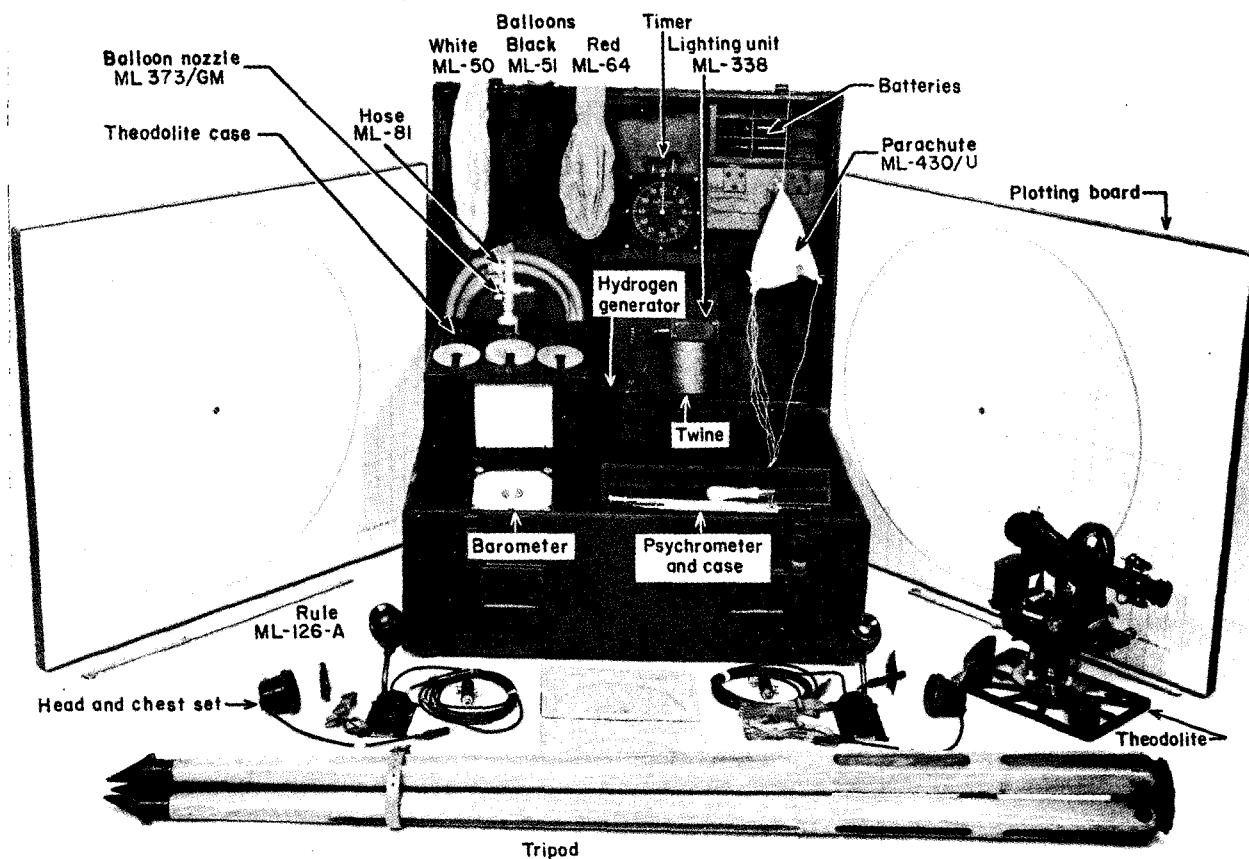


Figure 76. Meteorological observation set SCM-12.



## CHAPTER 7

### OBSERVATION TECHNIQUES

#### Section I. ORGANIZATION OF TEAMS

##### 98. General

In this chapter, the organization and operations of a ballistic meteorological section are explained in detail. The training of meteorological teams is related to the step-by-step procedures involved in obtaining and computing the various meteorological elements for a completed NATO meteorological message. All artillery meteorological sections operate in a similar manner, regardless of personnel and equipment available. The infantry division artillery meteorological section is used in describing team operations.

##### 99. Organization of Six-Man Teams

The tables of organization and equipment for the headquarters and headquarters battery of the infantry division artillery authorize 1 warrant officer (meteorological officer) and 14 enlisted men in the metro section. The chief of section, as the senior enlisted member of the metro section (E-7), must have a thorough knowledge of artillery ballistic meteorology. He must know the requirements of the various types of artillery units for ballistic meteorological data. He must be able to coordinate and supervise the operations of the section. He must be able to conduct instruction on all phases of the metro section's operations. To intelligently interpret radiosonde soundings, he must be familiar with synoptic weather maps and recognize significant weather changes. As a noncommissioned officer, he is responsible for the state of training and general welfare of the enlisted men under his supervision. He is further responsible to the metro warrant officer for the supervision of maintenance of all equipment and its proper performance as outlined in the appropriate technical manuals. For continuous operation, the metro section may be divided into 6-man teams; each team operates 12 hours a day. The chief of section assists the metro officer (warrant officer) in supervising the 24-hour operations. The radio operator is primarily responsible for transmitting messages. Each six-man team includes personnel to prepare and release the radiosonde and

compute a ballistic metro message. However, during the occupation of a new position, the entire section is required. The assignments of specific duties in the six-man team are made by the metro warrant officer. When more or fewer men are authorized by the table of organization and equipment, the number of men in the teams is altered, and the duty assignments are changed to meet the meteorological requirements.

##### 100. Organization of the Metro Section Into Teams

There will be occasions when one six-man team will have to be augmented with personnel from the other team in order to furnish special metro data, such as fallout metro messages and Air Weather Service messages, in addition to the usual ballistic metro messages. In normal operations, the two six-man teams are further divided into smaller teams (pars. 101-103). The organization of the metro section into teams will vary with the state of training of individual members of the section, the time schedule, and the number and type of metro requirements. (The listing of duty positions in paragraph 29a does not imply any team organization.) The metro warrant officer organizes the section personnel in the manner which best accomplishes the mission.

##### 101. Temperature-Density Team

In general, the temperature-density team is responsible for assembling the rawin set, preparing the radiosonde, taking temperature and relative humidity surface observations, and evaluating of the recorded data to determine the temperature and density for the metro message. The team is composed of a—

- a. Radiosonde recorder operator (RO), the team leader.
- b. Temperature-density plotter (TDP).
- c. Temperature-density computer (TDC).

## 102. Winds Team

The winds team is responsible for erecting the inflation tent, inflating the balloon, preparing the balloon train, making surface wind observations, and evaluating the recorded data to determine the ballistic wind direction and speed for the metro message. The team is composed of a—

- a. Zone-wind computer (ZWC), the team leader.
- b. Zone-wind plotter (ZWP).
- c. Ballistic-wind plotter (BWP).

## 103. Pilot Balloon Observation Team

There may be instances in which a continuous flow

of metro data is required which cannot be furnished by electronic means; such as during occupation of a new position area or failure of ground electronic equipment. Under these circumstances, a four-man pilot balloon observation team can be organized with personnel and equipment organic to the electronic metro section. Personnel of the four-man team are assigned duties as—

- a. Theodolite operator.
- b. Timer-recorder.
- c. Zone-wind plotter and surface observer.
- d. Ballistic-wind plotter.

## Section II. SELECTION AND OCCUPATION OF POSITION

### 104. Tactical and Technical Considerations in Selecting the Position Area

Since the primary mission of the artillery metro section is to provide ballistic data to the artillery firing units in the command, the section must be sited where it can best sound the atmosphere through which the trajectories of the artillery will pass. The section must be located in the perimeter of the command post of an artillery unit, preferably the parent unit, providing this position does not violate the principle cited above. The position must be coordinated with the area unit commander, the staff, and the next higher headquarters. Such administrative details as messing facilities, local security, and message transmission must be considered. When possible, the following minimum requirements should be met: a level area of cleared land for the main assembly and the launching site, no obstructions within a distance of 200 meters, and no objects on the horizon above an angle of 3°. In most instances, the position selected for the metro section will be one which is a compromise between this ideal location and the tactical requirements (area, cover, and camouflage). The requirements for emplacing the main components of the metro section are discussed in paragraph 105.

### 105. Emplacement of Equipment

(Fig. 77)

a. *Rawin Set AN/GMD-1* ( ). The location of the rawin set main assembly will control the locations of the remaining components of the station. The set must be mounted on firm, level, well-drained ground to insure continuous operation with suitable angular accuracy. Downwind, there must be an

area cleared of brush, shrubs, or obstructions and sufficient in size for the release of balloons. Ideally, there should be no obstructions over 3° elevation above the horizontal in any direction. The length of the main cable (65 meters) to the van limits the distance the set can be removed from the van area.

b. *Inflation Tent*. The inflation tent should be some distance downwind from the rawin set main assembly to facilitate automatic tracking of the radiosonde at release. The opening of the tent should be downwind, so that a balloon will not be blown back into the tent when it is removed for release. The location of a source of water and concealment are considered in selecting the general location. If water is available, it is desirable that the inflation tent be erected close by.

c. *Computing Van*. Concealment and a view of the balloon launching site are the major requirements for the van. Comfort of personnel operating inside the van may be increased by considering shade and the direction of prevailing winds when the location of the truck is selected.

d. *Power Units*. The trailer containing the power units must be placed under concealment; it should be positioned where the noise of the generator will not interfere with the work of personnel in the van. The length of the power cable (46 meters) limits the distance that the power unit may be separated from the van. Access to the power unit for fueling, lubrication, and maintenance is another consideration.

e. *Baseline Check Set AN/GMM-1* ( ). The baseline check set is placed in a shaded location near the van and convenient for radiosonde test activities.

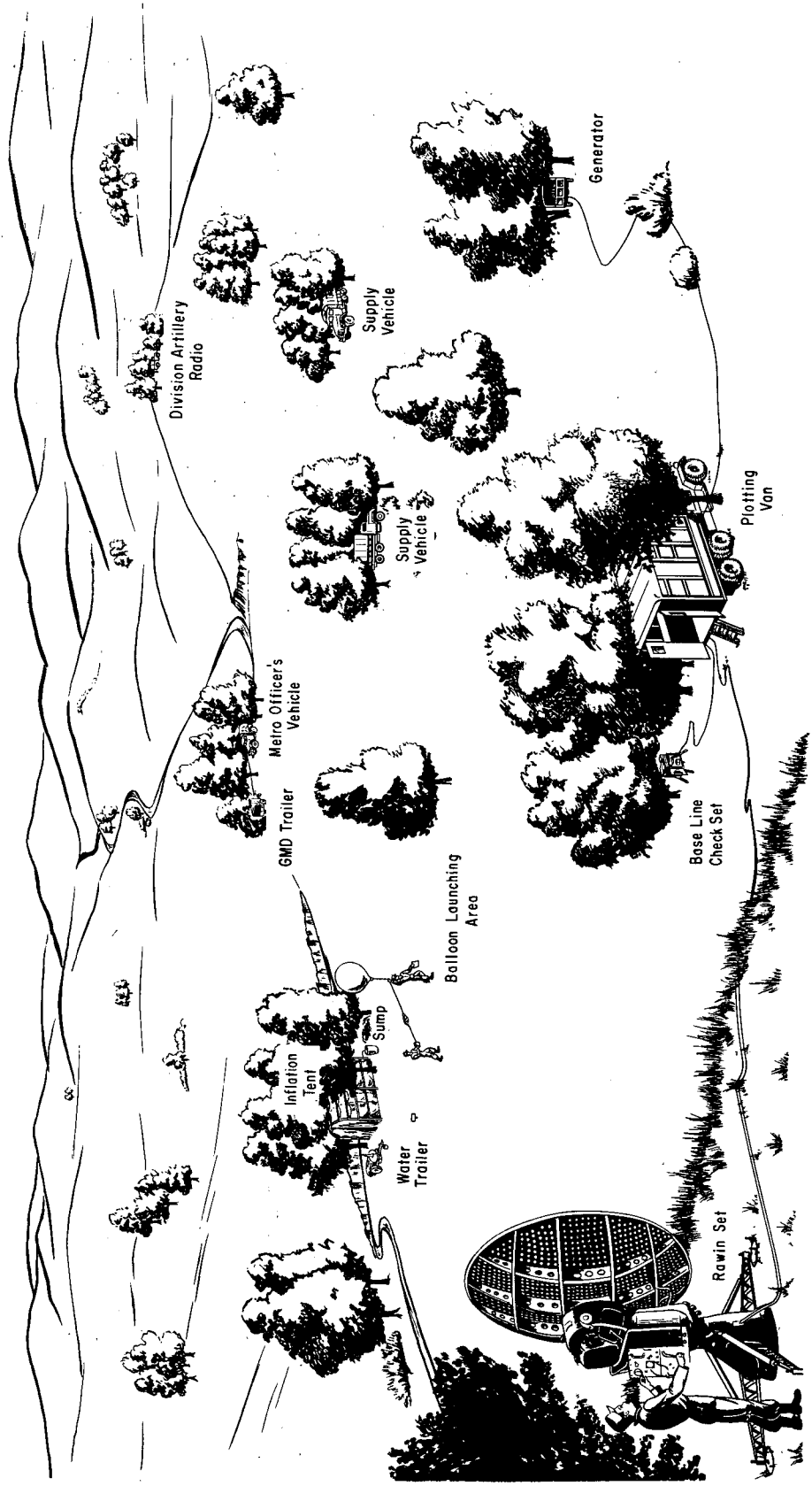


Figure 77. Metro equipment in position.

Although local conditions will necessarily determine the site, a location near electrical machinery, high tension power lines, and commercial telephone wires should be avoided. The conditioning chamber must be located so that it is shielded from direct or reflected rays of the sun. There should be no obstacles, such as earth or metallic objects, which would block the transmitted signal between the baseline check set and the rawin set main assembly. To facilitate baseline check procedures, the control unit is normally placed inside the van, where it can be operated by the radiosonde recorder operator (RO). For more detailed information, refer to TM 11-6660-219-12.

*f. Radio Antennas.* Successful radio communications depend on the proper location of the antenna. Generally, the antenna should be located on high ground away from metal objects, such as steel poles, bridges, and power lines and steel frame buildings and away from the foliage of trees. The proper location of the antenna is, however, that location from which radio communication is successfully established. Artillery command post areas, from which a metro section will operate, will usually be located on terrain which is favorable to radio communications. However, one spot on a favorable terrain feature may be better than another for the radio. A metro section may have to relocate their antenna within the command post area to obtain the best results. For further information concerning antenna sitings, see TM 11-806 and TM 11-5820-334-10.

## 106. Survey Control

*a.* The area occupied by the metro section must be identified, and a line of direction must be established therein. This is necessary because the location and altitude of the metro station are part of the information transmitted with the metro data, and wind direction must be computed with respect to true north. The specific requirements are—

- (1) The location of the rawin set to within 6 minutes longitude and latitude (grid coordinates are acceptable).
- (2) The height of the metro datum plane (MDP) to the nearest 10 meters.
- (3) A line of known direction, accurate to 5 mils.

*b.* The location and altitude of the metro station may be established from a large scale map by spot inspection. If a large-scale map is not available,

the location must be established by survey. Requests for survey control are sent to the corps or division artillery survey officer.

*c.* Direction may be established by use of the compass on the theodolite, provided the theodolite has been declinated for the area. A theodolite is declinated when the 360-degree line points to true north when the compass needle is centered. The preferred method of direction control is by survey. Direction control furnished by the survey officer is a grid azimuth reference and must be converted to a true azimuth reference. This conversion is accomplished by means of the grid azimuth conversion chart in FM 6-16. This chart gives the mil correction to be applied to the grid azimuth, based on the location of the grid coordinates, to obtain true azimuth.

*d.* Requests for survey control must be coordinated so that control will be brought to a stake in the ground at the rawin set, and direction will be provided from that stake to a distant, clearly identified, reference point. Requests should specify whether geographic or grid coordinates are desired.

## 107. Movement to Position

Movement of the metro section must be planned and organized to provide an uninterrupted flow of ballistic data required by the artillery firing units. The unit (battalion, group, brigade) commander is responsible for directing the movement of the metro section according to the tactical situation.

## 108. Personnel and Equipment Loading Plan

*a. Recommended Loading Plan for Artillery Metro Sections (fig. 78).*

- (1) Truck  $\frac{3}{4}$ -ton, 4x4.

### *Personnel*

Metro officer (WO)  
 Metro plotter (E-3), driver  
 Chief radiosonde operator  
 Radiosonde operator  
 Senior metro computer  
 Intermediate speed radio operator  
 Two metro computers  
 Radio direction finder operator

### *Equipment*

Ax, single bit, 4-lb,  $4\frac{3}{4}$ -in. cut, 36-in. handle  
 Mattock, pick, 5-lb, nominal size, with 36-in. long handle  
 Shovel, hand, round point, open back, D-handle,  $11\frac{1}{2}$ - to  $12\frac{1}{2}$ -in. blade  
 Binocular, 6x30 (carried by WO)  
 Compass, mil graduations (carried by WO)

Gun, machine, 7.62-mm  
 Mount, tripod, machinegun, 7.62-mm  
 Goggles, M-1944 (driver)

- (2) *Truck, cargo, 2½-ton, 6x6, with trailer, cargo, 1½-ton.*

*Personnel*

Metro plotter (E-3) driver  
 Metro equipment mechanic

*Equipment*

Ax, single bit, 4-lb, 4¾ in. cut, 36-in. handle  
 Mattock, pick, 5-lb, nominal size with 36-in. long handle  
 Shovel, hand, round point, open back, D-handle, 11½- to 12½-in. blade  
 Compass, magnetic lensatic (carried by mechanic)  
 Generator set, gasoline engine, 10 kw (mtd in trailer)  
 Goggles, M-1944 (driver)  
 Power unit PE-75 (mtd in trailer)  
 Chain, assembly, single leg with pear links and grab hook

*Meteorological station, manual AN/TMQ-4 components*

Can, corrugated, galvanized iron, 32-gallon (in trailer)  
 Tent, frame type, balloon inflation, M-1957  
 Charge, calcium hydride, ML-304A/TM (2 cases, 54 ea)  
 Battery pack BA-259 (1 case, 48 ea)  
 Charge, calcium hydride, ML-305A/TM (40 cases, 20 ea)  
 Lighting unit ML-338/AM (10 cans)  
 Parachute, ML-132 (2 cases, 100 ea)  
 Balloon ML-391/AM or ML-537 (2 cases, 48 ea)  
 Balloon ML-443A/UM or ML-541 (1 case, 48 ea)  
 Radiosonde AN/AMT-4( ) (4 cases, 24 ea)

- (3) *Truck, 2½-ton, cargo, 6x6, with trailer, water 1½-ton.*

*Personnel*

Metro computer (E-4), driver  
 Assistant metro section chief

*Equipment*

Ax, single bit, 4-lb, 4¾-in. cut, 36-in. handle  
 Mattock, pick, 5-lb, nominal size with 36-in. long handle  
 Shovel, hand, round point, open back, D-handle, 11½- to 12½-in. blade  
 Compass, magnetic lensatic (carried by chief metro computer)  
 Gun, machine, 7.62-mm  
 Mount, tripod, machinegun, 7.62-mm  
 Goggles, M-1944 (driver)  
 Heater, water, immersion, gas operated  
 Chain, assembly, single leg, with pear links and grab hook

*Meteorological station, manual AN/TMQ-4 components*

Hydrogen generator set AN/TMQ-3 (2 ea)  
 Hammer HM-3 (1 ea)  
 Ground rod (2 ea)

Clamp, electrical (6 ea)  
 Bracket assembly, antibuoyancy (1 ea)  
 Charge, calcium hydride, ML-305A/TM (40 cases, 20 ea)  
 Battery pack BA-259 (1 case, 48 ea)  
 Charge, calcium hydride, ML-304A/TM (2 cases, 54 ea)  
 Launching reel ML-367/AM (1 case, 48 ea)  
 Parachute ML-132 (2 cases, 100 ea)  
 Balloon ML-391/AM or ML-537 (1 case, 48 ea)  
 Balloon ML-443A/UM or ML-541 (1 case, 48 ea)  
 Radiosonde AN/AMT-4( ) (3 cases, 24 ea)

- (4) *Truck, van shop, 2½-ton, 6x6, with trailer, cargo, 1½-ton.*

*Personnel*

Metro computer (E-4), driver  
 Metro section chief

*Equipment*

Ax, single bit, 4-lb, 4¾-in. cut, 36-in. handle  
 Mattock, pick, 5-lb, nominal size with 36-in. long handle  
 Shovel, hand, round point, open back, D-handle, 11½- to 12½-in. blade  
 Book, logarithmic tables  
 Binocular, 7x30 (carried by metro section chief)  
 Compass, mil graduations (carried by metro section chief)  
 Watch, stop, type B  
 Machine, calculating  
 Case, field, office machine  
 Chair, folding (2)  
 Cook set, field  
 Clock, message center  
 Goggles, M-1944 (driver)  
 Stove, gasoline, 1-burner  
 Table, folding legs, wood (2)  
 Typewriter, portable, elite with case  
 Dynamic loudspeaker LS-166/U  
 Frequency standard TS-65/FMQ-1  
 Handset-headset H-144/U (2)  
 Multimeter AN/URM-105 (TS-352/U)  
 Radio set AN/GRC-19  
 Radiosonde baseline check set AN/GMM-1  
 Radiosonde recorder AN/TMQ-5  
 Rawin set AN/GMD-1 (trailer loaded)  
 Support, radiosonde recorder, MT-1355/TMQ-5  
 Test set, electron tube, TV-7/U  
 Thermometer ML-352/UM  
 Chain, assembly, single leg, with pear links and grab hook

*Meteorological station, manual AN/TMQ-4 components*

Reel RL-39 ( )  
 Coupling ML-49  
 Wrench TL-112  
 Tool equipment TE-33  
 Telephone set TA-312/PT  
 Head and chest set HS-25C (2)  
 Wire, WD-1/TT, 200 meters  
 Nozzle ML-373/GM (2)



- Pressure-time chart, DA Form 6-49
- Chart ML-574/UM (4)
- Thermometer and tubes (4)
- Scale ML-573/UM (2)
- Board, plotting, ML-122 (2)
- Anemometer ML-433/PM
- Nozzle, balloon, ML-196 (2)
- Straightedge ML-357/GM (2)
- Tripod ML-1309/GM (1)
- Theodolite ML-474/GM, with case
- Scale, plotting, ML-577/UM (2)
- Barometer ML-102-( )
- Thermometer ML-352/UM (2)
- Hydrogen regulator ML-193 (ML-528/GM)
- Sharpener, pencil
- Rule, slide, (2)
- Timer, clock, FM-19
- Twine, RP-15 (20 rolls)
- Battery pack BA-259 (1 case, 48 ea)
- Balloon ML-51A (2 boxes, 40 ea)
- Shroud, balloon, ML-424/U
- Parachute ML-430/U (150)
- Balloon ML-161A (1 box, 10 ea)
- Battery pack BA-259 (1 case, 48 ea)
- Lighting unit ML-338/AM (10 cans, 6 ea)
- Balloon ML-391/AM or ML-537 (1 case, 48 ea)
- Radiosonde AN/AMT-4( ) (1 case, 24 ea)
- Balloon ML-159A (4 boxes, 10 ea)
- Balloon ML-160A (1 box, 10 ea)
- Balloon ML-50A (6 boxes, 20 ea)
- Balloon ML-64A (2 boxes, 20 ea)
- Blank form
- Necessary plotting and supply manuals

*b. Modifications.* Often it is expedient for the artillery metro section to modify the loading plan by

loading the control-recorder and power cable for the rawin set in the van, since these items are used in the van area. Fragile items of equipment must be protected from possible damage which may be caused by road shock or the falling or the crushing action of other equipment. A detailed loading plan should be prepared for each vehicle and kept with the vehicle, so that loading will be uniform and complete from day to day. The entire loading arrangement should be inspected periodically by the meteorological officer or chief of section.

**109. Duties of Personnel During Occupation of Position**

*a. Meteorological Officer.* The meteorological officer (WO) is charged with the responsibility of detailed reconnaissance of the area and supervision of the occupation of position and installation and checking of the equipment. He will lead his section to the area assigned by the unit commander. With his chief of section, he will conduct a detailed ground reconnaissance and select positions for the main items of equipment, sanitation facilities, and local security. He will select a reference point and determine the metro station location and altitude from map or survey data. After the electronic equipment is installed, he checks the orientation of the rawin set, inspects the grounding of the inflation equipment, verifies the voltage and frequency output of the generator, and checks the linear calibration of



Figure 78. Metro section, loaded.

the radiosonde recorder AN/TMQ-5. As soon as practicable, he contacts the supported units, reports his location, and ascertains meteorological requirements (if not previously known).

*b. Duties of the Metro Section Chief.* The metro section chief assists the metro officer during the occupation of position. In the absence of survey data, the metro section chief sets up the theodolite and measures the significant angular data to the reference point for orientation of the rawin set.

*c. Duties of the Temperature-Density Team.* After the metro section chief has located the survey stake or oriented the theodolite in the new position, the rawin trailer is towed to the desired location and uncoupled. (The trailer may affect the magnetic field if it is moved into position before the theodolite is oriented.) The van should immediately be moved to its location by the temperature-density team leader. The van should be connected to the power source as soon as possible so that operation of the electronic equipment can begin. Assembly, cabling, and orientation of the rawin set is performed immediately by members of the temperature-density team. Immediately after installation of the rawin set, the trailer is moved to an area of concealment. When power is available, the metro equipment mechanic should connect the radiosonde recorder and perform the preliminary checks and calibration.

The baseline check set is then assembled and cabled in preparation for the preflight calibration of the radiosonde. The equipment is camouflaged as outlined in chapter 31 and FM 5-20. The team on duty then moves to the van area to organize the working positions and lay out the forms, tables, and required equipment.

*d. Duties of the Winds Team.* While the temperature-density team performs its work, the winds team works independently on its portion of the occupation. The inflation equipment is unloaded, and the water trailer is uncoupled at the inflation site. At the same time the metro equipment mechanic leads the truck towing the power generator to its selected site. The area around the power generator should be cleared as a firebreak. A gasoline storage pit is dug. The generator is then grounded, started, and the cables are connected. The inflation tent is erected and all hydrogen generating equipment is installed and grounded. The team chief, the zone wind computer, personally inspects and tests the installation of the grounding equipment. The final steps are the storage of expendable inflation supplies and the camouflage of the installation as outlined in FM 5-20. The winds team on duty then moves to the van area to lay out the necessary forms, tables, and plotting equipment.

### Section III. TEAM DUTIES BEFORE BALLOON RELEASE

#### 110. Duties of the Chief of Section

The metro section chief insures that all equipment is in good operating condition and adequately serviced. Special attention must be paid to the power units to insure continuous power during a flight. He determines the amount of nozzle lift of the balloon (par. 67). The section chief should personally verify the validity of the baseline check of the radiosonde. He positions the rawin set before making the baseline check and verifies orientation. A standing operating procedure which lists in detail the specific duties of each team member during all stages of the flight will enable the section chief to spend more time supervising the section.

#### 111. Duties of the Temperature-Density Team

*a. Unpacking Radiosondes.* When possible, radiosondes should be stored indoors in their original cartons. The storage space should be dry and not

subject to extreme temperatures. The cartons are dated and should be arranged so that the older radiosondes are used first. Individual radiosonde packages should not be opened more than 12 hours before use. Temperature and humidity elements should never be opened until time for final assembly of the radiosonde. The water and vapor proof containers and wrappings must be removed carefully to avoid damage to delicate parts. For further information regarding storage, assembly, and use, see TM 11-2432A and TM 11-6660-220-10.

*b. Visual Inspection of Radiosondes.* The element container is removed from the battery compartment. The serial number on the calibration chart is checked to insure that it agrees with the serial number on the baroswitch or hypsometer or modulator. (Examples of calibration charts are shown in figure 79.) The instrument is rejected if the serial numbers do not agree. Each baroswitch and hypsometer is individually calibrated, and the correct chart must be used.

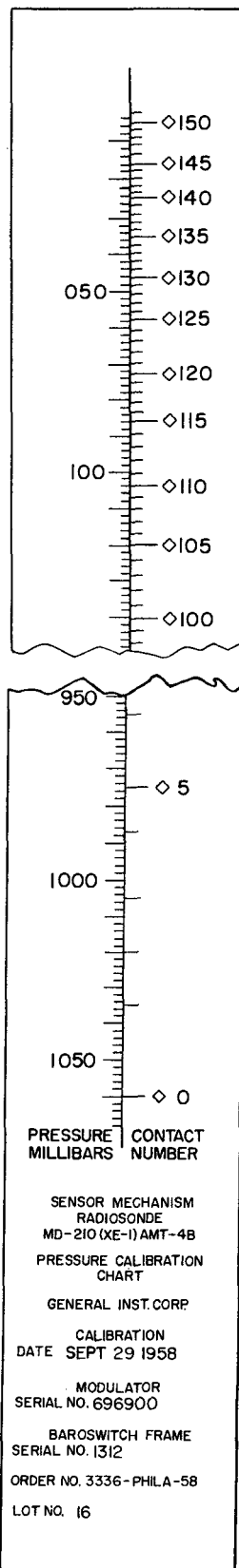
The elements are inspected to insure that they are present and in usable condition. The overall condition of the modulator and wiring is inspected, and defective units are rejected. The transmitter is inspected for damage to the case, wire, and plug. The following eight points should be checked:

- (1) The linkage connecting the aneroid cell(s) to the pin arm is checked for the presence of corrosion. The modulator is rejected if corrosion exists.
- (2) The commutator bar is examined for corrosion. If the bar is corroded, it should be rubbed with lens tissue.

**Caution:** Be sure to rub the bar in a direction parallel to the conducting segments.

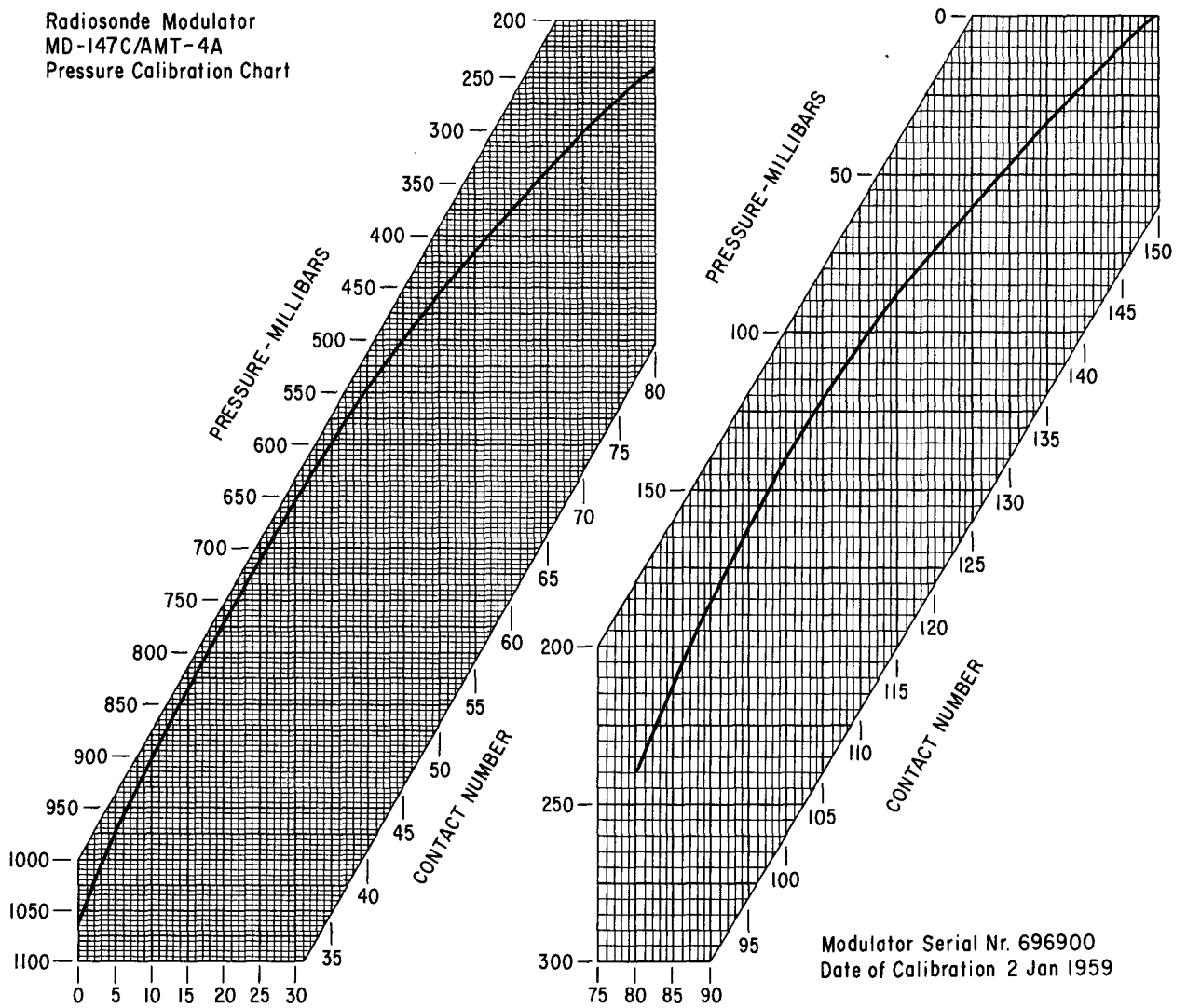
- (3) After the battery has been installed and has reached operating power, short the humidity (yellow) lead to the ground (black) lead. The relay can be heard opening and closing when it is operating properly. The modulator should be discarded if the relay fails to operate properly.
- (4) The element clips are cleaned of corrosion with abrasive paper.
- (5) The hypsometer is visually inspected, without removing it from the modulator.
- (6) With the pin arm on the commutator bar, the radiosonde is inverted. If the pin arm falls away from the commutator bar, the modulator is rejected.
- (7) The pin arm is moved, with the finger, one contact in the direction of decreasing pressure and released. If it does not spring back to its original position, the modulator is rejected.
- (8) The correct setting of the pin arm is determined from a barometric reading and the modulator calibration chart. If the pin arm position is not within 2.0 contacts of the correct setting, the modulator is rejected.

c. *Commutator Bar and Pin Arm Setting.* The pressure calibration chart packed with each radiosonde modulator reflects the relationship between air pressure and the position of the pin arm on the commutator bar. This calibration chart is prepared by the manufacturer for each individual modulator and is based on the movement of the pin

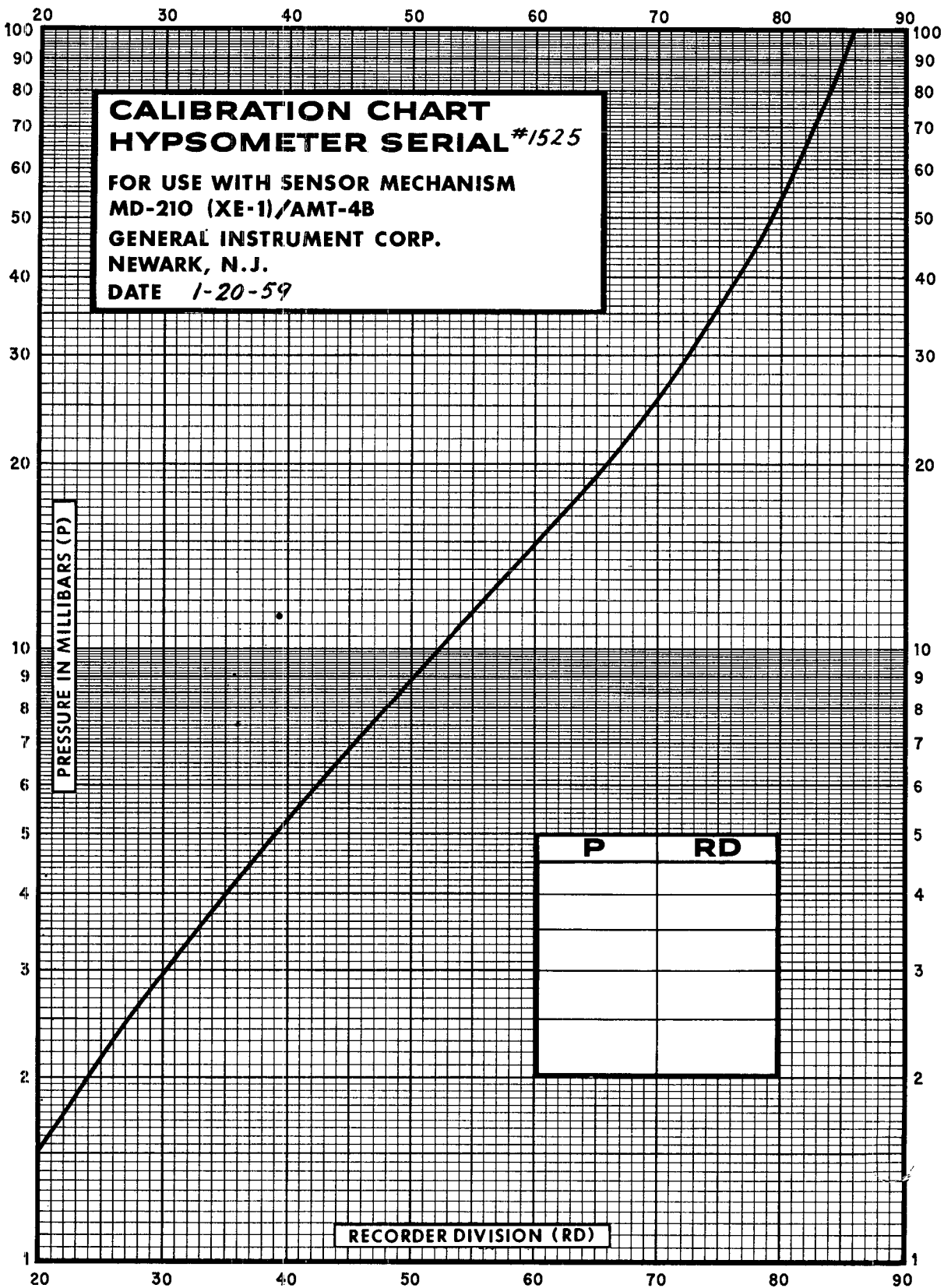


①  
Figure 79. Pressure calibration charts.

Radiosonde Modulator  
MD-147C/AMT-4A  
Pressure Calibration Chart



②  
Figure 79—Continued.



arm across the commutator bar as the air pressure is decreased inside a vacuum chamber. However, the position of the pin arm relative to the commutator bar may be changed during transit and storage. For this reason, the metro section must adjust the pin arm to the position that corresponds to the ambient air pressure. The adjustment is performed after baseline check. The procedure for positioning the commutator bar relative to the pin arm is as follows:

- (1) The station pressure, in millibars, is determined from the barometer.
- (2) The station pressure is used as the argument for entering the pressure calibration chart. In using the chart, the correct position of the pin arm is determined to the nearest 0.1 contact number. This contact number refers to the relative position of the pin arm on the commutator bar.
- (3) The pin arm is lowered onto the commutator bar.
- (4) The position of the pin arm on the commutator bar is visually checked by the operator. If the pin arm is not located at some point within the correct contact of the commutator bar, it is positioned to a point within this contact. For example, if the correct contact number is 5.4, the pin arm must be positioned between 5.0 and 6.0 contacts. Positioning of the pin arm is accomplished by turning the commutator bar adjusting screw (fig. 80). As the screw is turned, the commutator bar moves, causing the point of contact with the pin arm to change.
- (5) The modulator is connected to the control unit of the baseline check set (fig. 80). When this connection has been made, the lamp on the control unit will light any time the pin arm is in contact with a conducting segment of the commutator bar. When the pin arm is in contact with an insulating segment, the lamp will be off.
- (6) The commutator bar adjusting screw is turned to position the commutator so that the pin arm is on the beginning of the contact (toward higher pressure). Since a contact, by definition, begins with a conducting segment, the lamp on the control unit of the baseline check set will light just as this position is attained (5.0).

- (7) The commutator bar adjusting screw is turned to position the commutator toward lower pressure so that the pin arm is on the beginning of the next higher contact number (6.0). The operator counts the number of clicks as the adjusting screw is turned. The lamp goes on as the movement of the commutator bar begins (5.0), and goes off as the pin arm position leaves the conducting segment, and the lamp goes on again when the pin arm is on the exact point of the beginning of the next contact (6.0). The total number of clicks counted during this movement represents the width of the correct contact, the fifth contact in this example.
- (8) The position of the pin arm within the correct contact is determined by multiplying the number of clicks in the width of the contact by the decimal portion of the correct contact number. The commutator bar is then returned to the beginning of the contact just counted and advanced, toward lower pressure, the number of clicks computed.
- (9) For example, the calibration chart in 1, figure 79 shows that the correct position of the pin arm of the modulator is 5.4 contacts for a pressure of 967 millibars. The operator's visual inspection shows the pin arm to be about halfway between the fifth and sixth contacts. The pin arm position is moved to the beginning of the fifth contact by turning the commutator bar adjusting screw. When the lamp goes off, the pin arm is positioned at 5.0 contacts. The adjusting screw is then turned counterclockwise, moving the pin arm position across the fifth contact. The lamp goes on as the pin arm position moves toward 6.0, then goes off as the pin arm reaches an insulating segment, then on again at 6.0 contacts. The number of clicks from 5.0 to 6.0 contacts is 24. Four-tenths of 24 clicks is 10 clicks. The operator then returns the pin arm to 5.0 and advances the pin arm position ten clicks into the fifth contact. The pin arm is now positioned at 5.4 contacts.
- (10) Meteorological teams may find that it is more convenient to make the pin arm set-

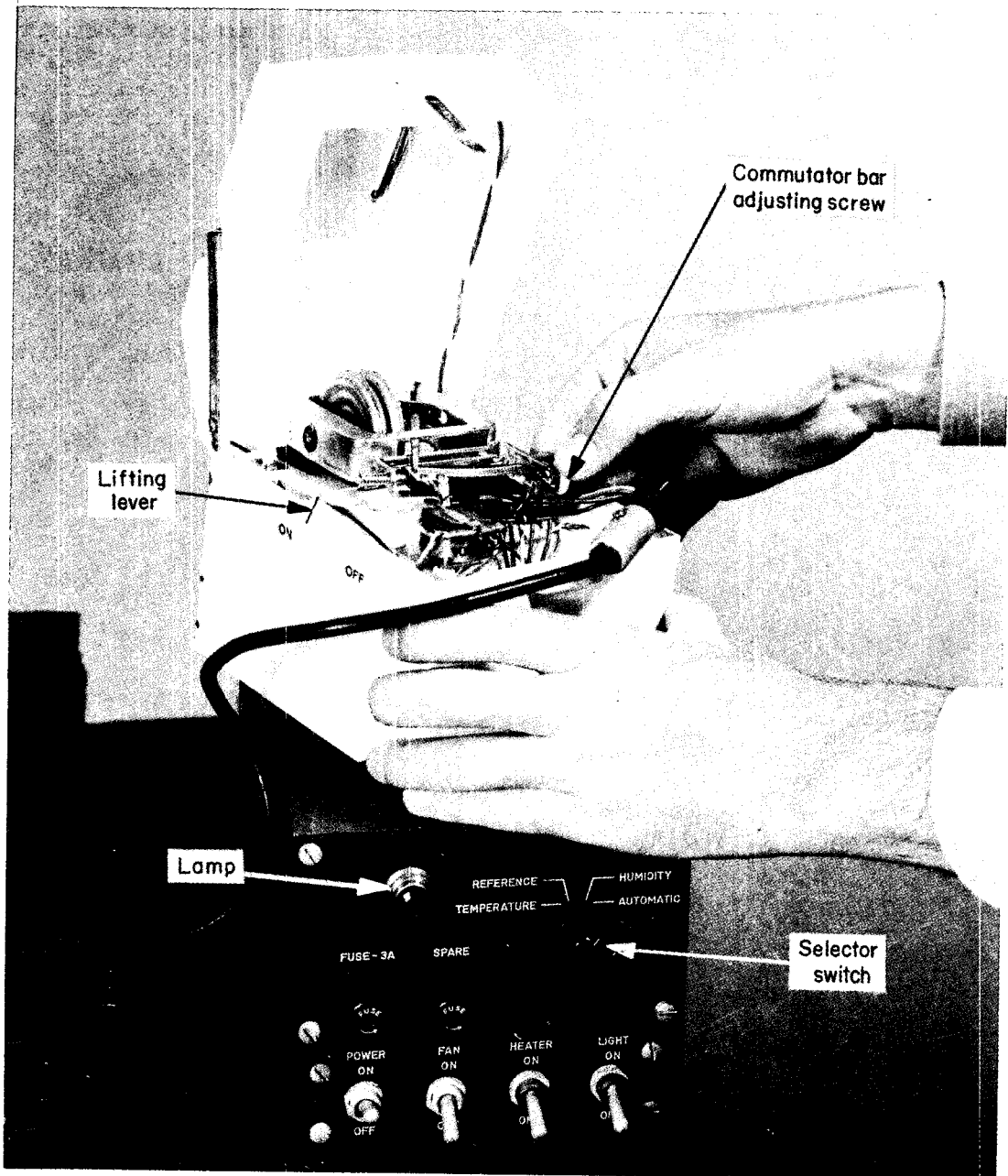


Figure 80. Use of the control unit in adjusting the pin arm.

ting by using the audio signal instead of the lamp on the baseline check set. The pin arm is set after the baseline check is completed. This method has the advantage of overcoming the possibility of missing the proper contact setting by one full contact and insures that the pin arm is down just before the balloon is released.

- (11) Other methods of setting the pin arm are discussed in TM 11-2432A.

## 112. Preparation of Battery Pack BA-259/AM

*a. Description.* Battery pack BA-259/AM is a water activated battery which supplies the power required to operate the radiosonde. The average time required for the battery to be activated and achieve full power is 20 minutes. The life of the battery is about 4 hours.

*b. Preparation.* Instructions for activating the battery are printed on the battery cover. Different manufacturers prescribe slightly different procedures for activating the battery.

## 113. Assembly of the Radiosonde

*a. General.* The assembly of the radiosonde should be scheduled according to the required time of release. Assembly far in advance of the time of release is to be avoided. A time interval of 20 minutes is allowed for activation of the battery and production of full power. Another time interval of 15 minutes is allowed for performance of the baseline check. These time intervals are approximate. Experience will indicate the amount of time required to assemble the radiosonde under varying conditions encountered in the field.

*b. Procedure.* After activation, the battery is placed on the battery shelf of the baseline check set and connected to the plug provided. The battery should always be placed with the top of the battery up. When using humidity element ML-418, the battery may be placed inside the modulator before the baseline check. Next, the transmitter is attached to the modulator and the electrical connection is made. A minimum of 10 minutes is required for the battery to attain sufficient operating power. (See instructions on the top of the battery for time specified by manufacturer.) In the meantime, the sensing elements are carefully installed; first, the humidity element, then, the temperature element.

To install the humidity element, the humidity element cover is raised and the element is inserted into the element clips. To install the temperature element, the temperature element arms are raised and locked in an extended position. The element leads should be clamped in the rough portion of the clips, with the element centered between the clips. About half the lead wires are left free of the clips and twisted around the element clips to further secure the temperature element. The leads are bent so that the temperature element extends away from the modulator. At release, the temperature element should be in the opposite direction from the balloon train so that it will not be broken. Immediately after the installation of the elements, the radiosonde is placed in the baseline check set which has previously been prepared as described in paragraph 92*b* and *c*. Then the chamber door is closed and the POWER and FAN switches on the baseline control unit are turned to the ON position. During the entire assembly of the radiosonde, the pin arm should be in the OFF position. While the conditions inside the baseline check set are stabilizing, the power output check and the frequency check are performed.

**Caution:** Be careful to handle the elements by the edges (humidity) or lead wires (temperature) when installing them in the modulator. Reject broken, chipped, scratched, or fingerprinted elements.

## 114. Power Output Check and Frequency Setting using Test Set TS-538/U

*a. Use of Test Set TS-538/U in Checking Radiosonde Power Output.* A small antenna is carried under the removable cover of test set TS-538/U. For use, it is firmly screwed in place in the socket on top of the set. The test set is oriented so that the antenna is parallel to the radiosonde transmitter antenna. Ordinarily the test set is positioned as shown in figure 81. As the test set is moved close to the radiosonde transmitter, the meter needle will deflect. The power output is satisfactory if the needle deflects into the GOOD (green) portion of the dial, while the antenna and the transmitter are 8 to 12 inches apart. If the antenna and transmitter are too close, excess power may cause the meter needle to deflect off the scale and possibly damage the test set.

*b. Use of the Test Set in Adjusting Radiosonde Frequency.* After the power output of the radiosonde is determined to be satisfactory, the test set is



positioned so that the meter needle indicates about two-thirds of the scale. The FREQUENCY METER dial (MC/S) is then rotated until the meter needle dips to the left and quickly returns to its previous position. This dip is sometimes very slight and difficult to detect, since the slightest movement of the test set or the radiosonde transmitter will also cause the needle to deflect. After the dip is observed, the FREQUENCY METER dial is adjusted until the meter needle indicates the lowest point of the dip. At this point, the reading on the FREQUENCY METER dial indicates the frequency of the carrier wave being transmitted. If this fre-

quency is not the desired carrier frequency, an appropriate adjustment is made using the frequency adjusting screw(s) on the radiosonde transmitter. An arrow on the transmitter case indicates the direction in which the frequency adjusting screw(s) must be turned to raise the frequency. The screw(s) is adjusted until the desired frequency is read on the frequency meter dial. The radiosonde recorder operator may now proceed with the baseline check.

*Note.* After the baseline check is completed and before the radiosonde is removed from the baseline check set, another frequency check is made with the test set to insure that the radiosonde transmitter is properly set on the desired frequency.

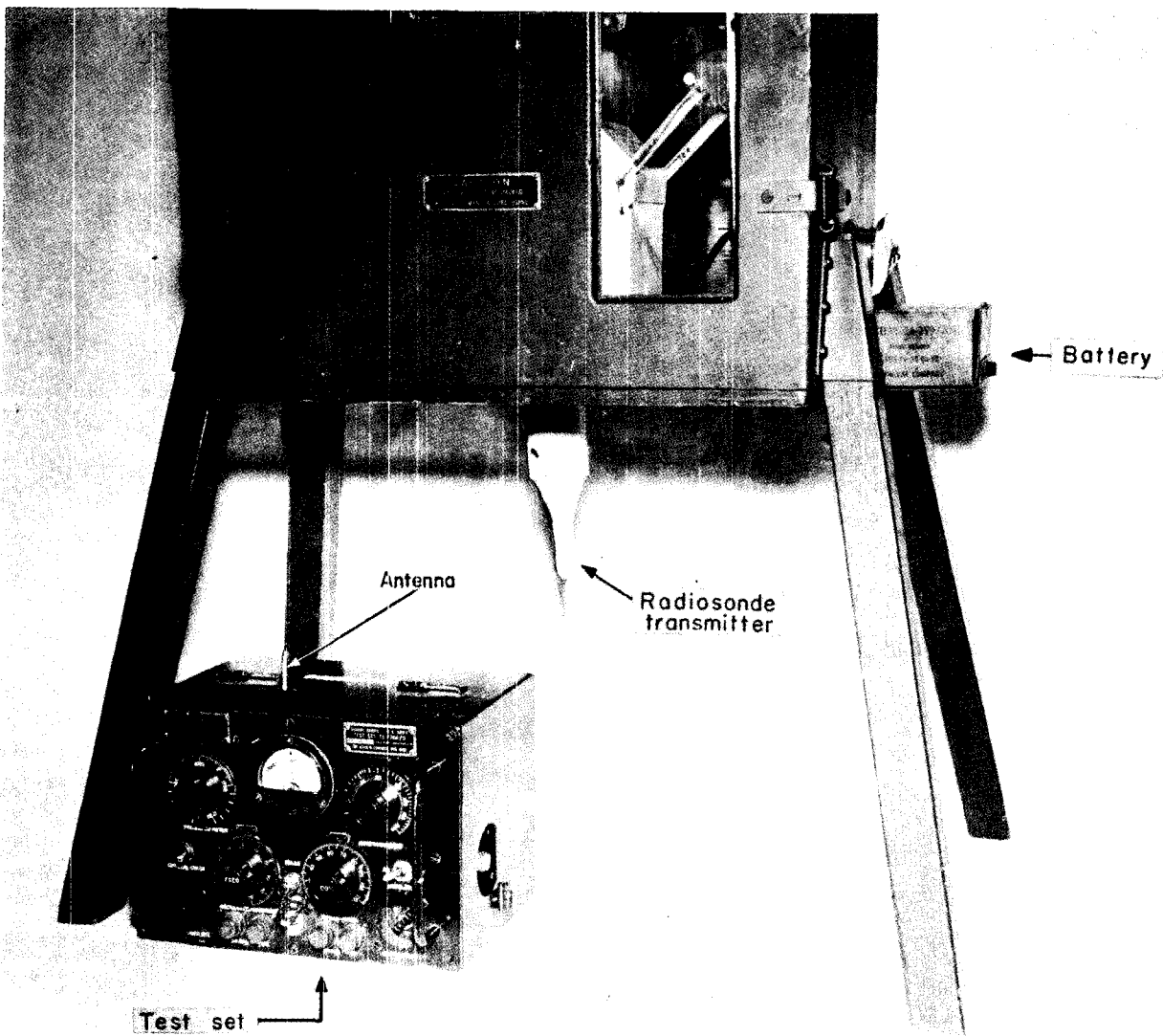


Figure 81. Position of test set for frequency setting and power check.

## 115. Baseline Check of Radiosonde and Sensing Elements

The radiosonde recorder record consists of a series of traces representing the values of temperature, relative humidity, and pressure at selected points in the atmosphere. Values of temperature and relative humidity are represented by the positions of the respective traces across the record as measured in recorder divisions. Thus, in order to obtain the temperatures in degrees Celsius and the relative humidities in percent, the value of the relationship between the recorder record divisions and each of these elements must be established. The two relationships are determined by the baseline check set AN/GMM-1( ) and computer, humidity-temperature check set, the known conditions of temperature and relative humidity are measured by the radiosonde. These radiosonde measurements are printed as recorder divisions on the recorder record. These record divisions are then compared with the measured values of temperature and relative humidity by means of the humidity-temperature computer. The measured values are obtained from the psychrometer within the baseline check set. Before any comparisons are made, the characteristics of the air inside the check set must be stable (i.e., the radiosonde elements must be sensing the same air sample as the psychrometer). (The requirements for obtaining stable air inside the check set are listed in *i* below.) The baseline check is performed as follows:

*a.* While the power output and the frequency of the radiosonde transmitter are being checked, the rawin set is pointed in the general direction of the radiosonde. Then the rawin set is tuned to the radiosonde carrier frequency so that the received signal indicates a strength of 60 or more microamperes on the TUNING METER. Values lower than this will be obtained until the power output of the battery reaches its operational level.

*b.* After the rawin set is tuned, the automatic tracking feature of the rawin set is checked. The antenna assembly is manually positioned to a point a few degrees above and to the side of the radiosonde. Then the MANUAL-NEAR AUTO-FAR AUTO control on the antenna control panel (fig. 66) is turned to the NEAR AUTO position. If the rawin set is tracking properly, it will automatically position itself on the radiosonde. This check is repeated several times to insure that the set is

tracking automatically in both azimuth and elevation. If the set will not track automatically, the fault must be corrected before the radiosonde is released.

*c.* When the automatic tracking check has been performed, the rawin set antenna is manually positioned toward the baseline check set. Normally in this position the antenna is directed about 20° above the radiosonde in order to minimize the effect of ground-reflected waves and to lessen the signal strength. Either ground-reflected waves or an excessive signal strength may cause an erratic tracing by the radiosonde recorder pen. Erratic pen tracing also may be caused by motor ignition, radio transmitters, or movement of personnel in the area of the rawin set and the radiosonde.

*d.* After the rawin set is directed toward the baseline check set, the MOTORS-STANDBY switch is placed in the STANDBY position. The switch is left in this position throughout the baseline check, as operation of the motors may result in fluctuation of the recorder pen.

*e.* The metro signal is received at the radiosonde recorder by placing the SIGNAL SELECTOR switch on the radiosonde recorder in the SIG position and placing the RECORDS CONTROL switch on the control-recorder (fig. 67) in the BASELINE CHECK position. Prior to this, the radiosonde recorder should have been calibrated and prepared for operation as described in chapter 6.

*f.* Prior to performing the baseline check, the following test should be performed as a partial check for poor electrical contact at the terminal strip of the baseline check set:

- (1) Cause the radiosonde to transmit low reference signal by shorting the black and the blue test leads. Adjust the low reference printed by the radiosonde recorder to 95.0 recorder divisions.
- (2) Place the test leads into the baseline check set terminal strip and set the SELECTOR switch of the baseline check set control unit to REFERENCE. The radiosonde recorder pen should print within 0.5 recorder divisions of the 95th recorder division. If this condition exists, the baseline check may be performed; otherwise, clean the terminals on the terminal strip and the radiosonde test leads and repeat the test.

g. Recommended limits within the temperature-humidity chamber for baseline check are 28 to 90 percent relative humidity and a temperature above 0° C. Every reasonable effort should be made to obtain baseline check conditions within these limits. The battery should always be installed on the pullout shelf on the right side of the conditioning chamber when using Humidity Element ML-476/AMT; power is connected to the radiosonde through the socket on the chamber wall. The heater should be used if the temperature is 0° C. or below. If the relative humidity is near 90 percent, approximately 4 ounces of dry calcium chloride should be placed in the tray inside the atmospheric chamber to reduce the humidity. Additional calcium chloride should be used if necessary to bring the relative humidity within the chamber below 90 percent. If the relative humidity is less than 28 percent, the tray inside the conditioning chamber should be filled about three-quarters full with water to raise the humidity.

h. The temperature and humidity reference traces are identified and marked (6, fig. 82) on the recorder record by switching the baseline check set SELECTOR switch to the TEMPERATURE and HUMIDITY positions. After the traces are located on the record, the SELECTOR switch is turned to AUTOMATIC. In this position, the baseline check set will continuously switch the transmitted signal through the following cycle of traces, each trace being 15 seconds in duration: reference, temperature, reference, humidity. Each reference trace that is printed is adjusted to exactly 95.0 recorder divisions with the REF ADJUST knob, if necessary (1, fig. 82).

i. The recorder operator observes the position of each trace until two successive identical traces of reference, temperature, and humidity are recorded without adjusting the reference traces. Note that the baseline check is terminated with a low reference trace, following a humidity trace.

j. After 10 minutes, if the successive traces of

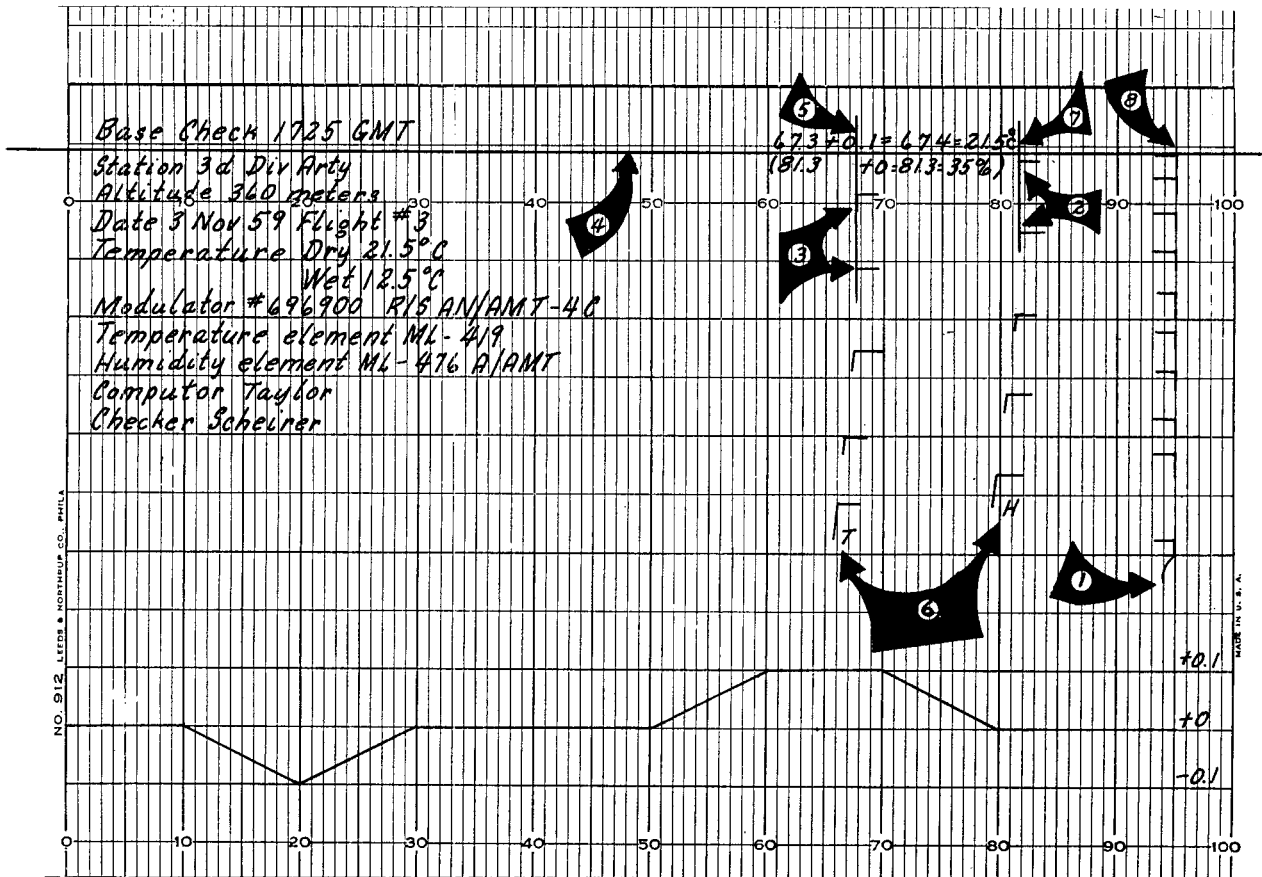


Figure 82. An evaluated baseline check.

temperature and humidity are not being printed within the prescribed criteria, the conditions in the baseline check set chamber may not be stable. To obtain stability, the following actions may be taken: Make certain that the fan is operating. For temperatures below freezing, turn on the heater. Be sure the baseline check set is out of the direct rays of the sun. If the battery has been installed in the radiosonde, remove it from the radiosonde and place it on the pullout shelf on the right side of the chamber (see TM 11-6660-219-12); continue with the baseline check. If the temperature and humidity traces still are not being printed within the prescribed criteria, new temperature and humidity elements are installed and a new baseline check is performed.

*k.* When the requirements for a baseline check are met, the check is terminated on a low reference trace. The SIGNAL SELECTOR switch is placed in the S.C. position. At this same time, the psychrometer inside the check set atmosphere chamber is read—first, the wet-bulb temperature, and then the dry-bulb temperature. These temperatures are read carefully to the nearest 0.1° C. and entered on the radiosonde recorder record and the radiosonde data sheet. After the baseline check is evaluated and verified as correct, the SIGNAL SELECTOR switch remains in the S.C. position until the zero print has recorded for a minimum of 1 inch to insure that no chart drift exists. The POWER ON-POWER OFF STANDBY switch is placed in STAND BY position, and the chart is advanced manually to the evaluation desk.

*l.* The radiosonde is left in the baseline check set atmosphere chamber until the validity of the baseline check is determined. The baseline check is verified as quickly as possible by the section chief and the radiosonde recorder operator. If the baseline check is valid, the baseline check set SELECTOR switch is set to the TEMPERATURE position and the POWER, FAN, HEATER, and LIGHT switches are turned off. If the baseline check is not verified, new temperature and/or humidity elements are installed and a new baseline check is performed.

*m.* Baseline check of radiosondes utilizing a lithium chloride humidity element ML-418 is performed as outlined above, with the following exceptions:

- (1) These radiosondes normally have a test plug rather than test leads. In this case, the electrical test in *f* above, is performed

by shorting between appropriate prongs of the test plug.

- (2) Recommended conditions for baseline check temperature and humidity within the conditioning chamber are 0° C. or higher and 40 percent relative humidity or higher. The battery is normally placed inside the radiosonde for baseline check. Water is placed in the tray inside the conditioning chamber, and the heater is used only when necessary to establish a stable environment or to keep the water inside the chamber from freezing.
- (3) Temperature-humidity evaluator, ML-420A/AMT-4A is used instead of humidity-temperature computer, CP-223A/UM.

## 116. Evaluation of the Baseline Check

In figure 82, low reference traces 1, relative humidity traces 2, and temperature traces 3 are shown. To evaluate the baseline check, the first step is to establish a baseline 4. The baseline 4 is a horizontal line drawn across the record through the top of the last reference trace. The next step is to evaluate the temperature trace. A thin straight line 5 is drawn through the top left corners of the last two temperature traces and extended about one-fourth inch above the baseline. The recorder record division value corresponding to the point of intersection of the line drawn through the temperature traces and the baseline is evaluated to the nearest 0.1 recorder division. The ordinate value of temperature, the calibration correction (par. 139), the algebraic sum of the temperature ordinate and the calibration correction, and the dry-bulb temperature inside the baseline check set are recorded above the baseline as shown by 7 in figure 82. Humidity is evaluated the same as temperature, but the values are entered below the baseline and inclosed in parentheses. In addition, the corrected recorder divisions for humidity are equated to the percentage of relative humidity determined from the wet- and dry-bulb temperatures and the relative humidity chart in FM 6-16. The last step in evaluating the baseline check is to record the baseline check items on the left-hand side of the record with the first item above the baseline and the others below it. The ten items, in sequence, are—

- a.* The words BASELINE CHECK and the time (GMT) of the last trace (above the baseline).

- b. The designation of the station (just below the baseline).
- c. The station altitude in meters.
- d. The date of the flight (GMT) and the flight number.
- e. The dry-bulb temperature to the nearest 0.1° C., as read inside the baseline check set at the time the baseline check is terminated.
- f. The wet-bulb temperature determined at the same time as the dry-bulb temperature (e above).

- g. The modulator serial number(s) and the type of radiosonde.
- h. The type of temperature element installed in the radiosonde.
- i. The type of humidity element installed in the radiosonde.
- j. The name of the computer (radiosonde recorder operator).
- k. The name of the checker (temperature-density plotter).

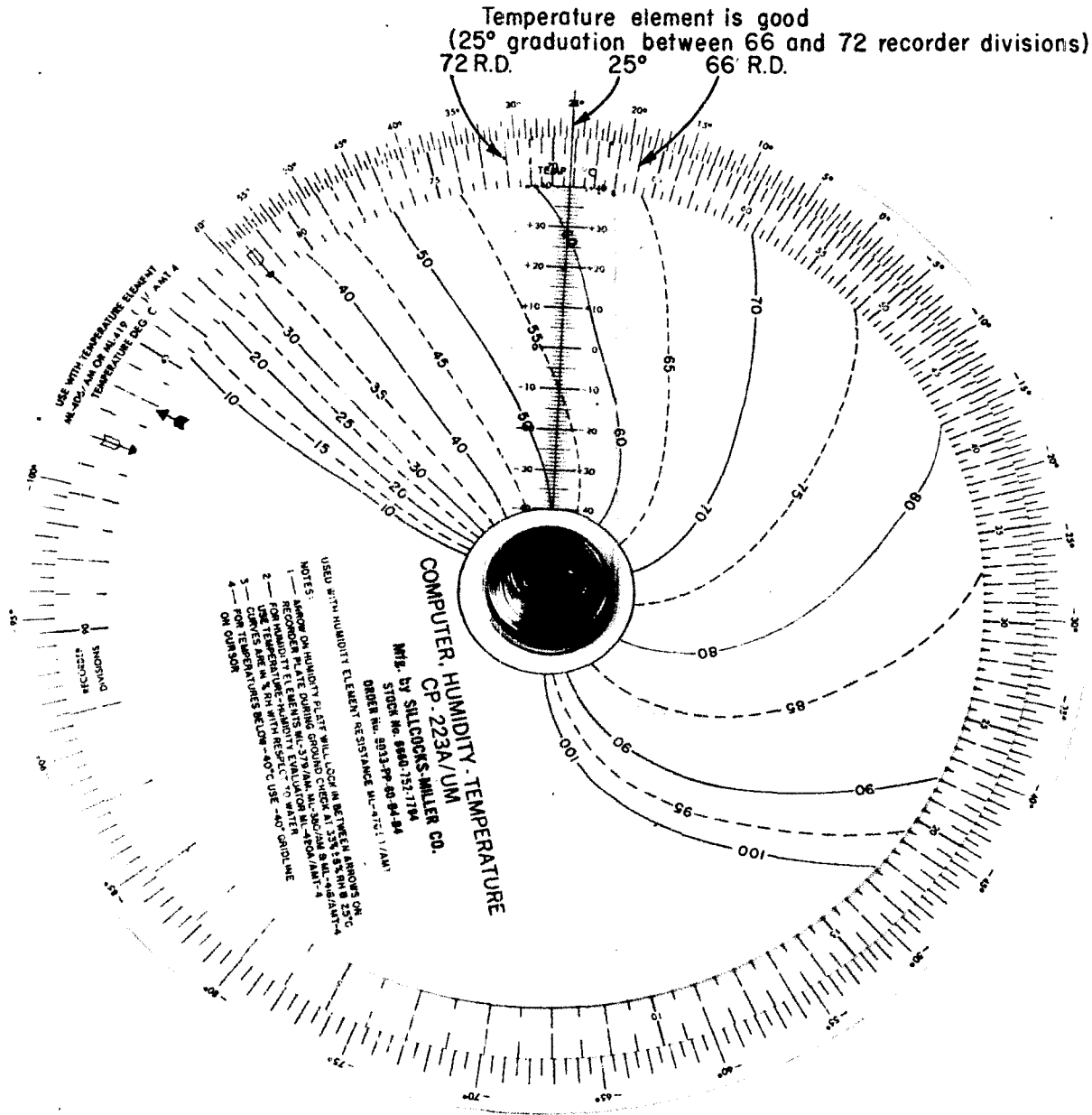


Figure 88. Computer, humidity-temperature CP-223A/UM, set with baseline check data.

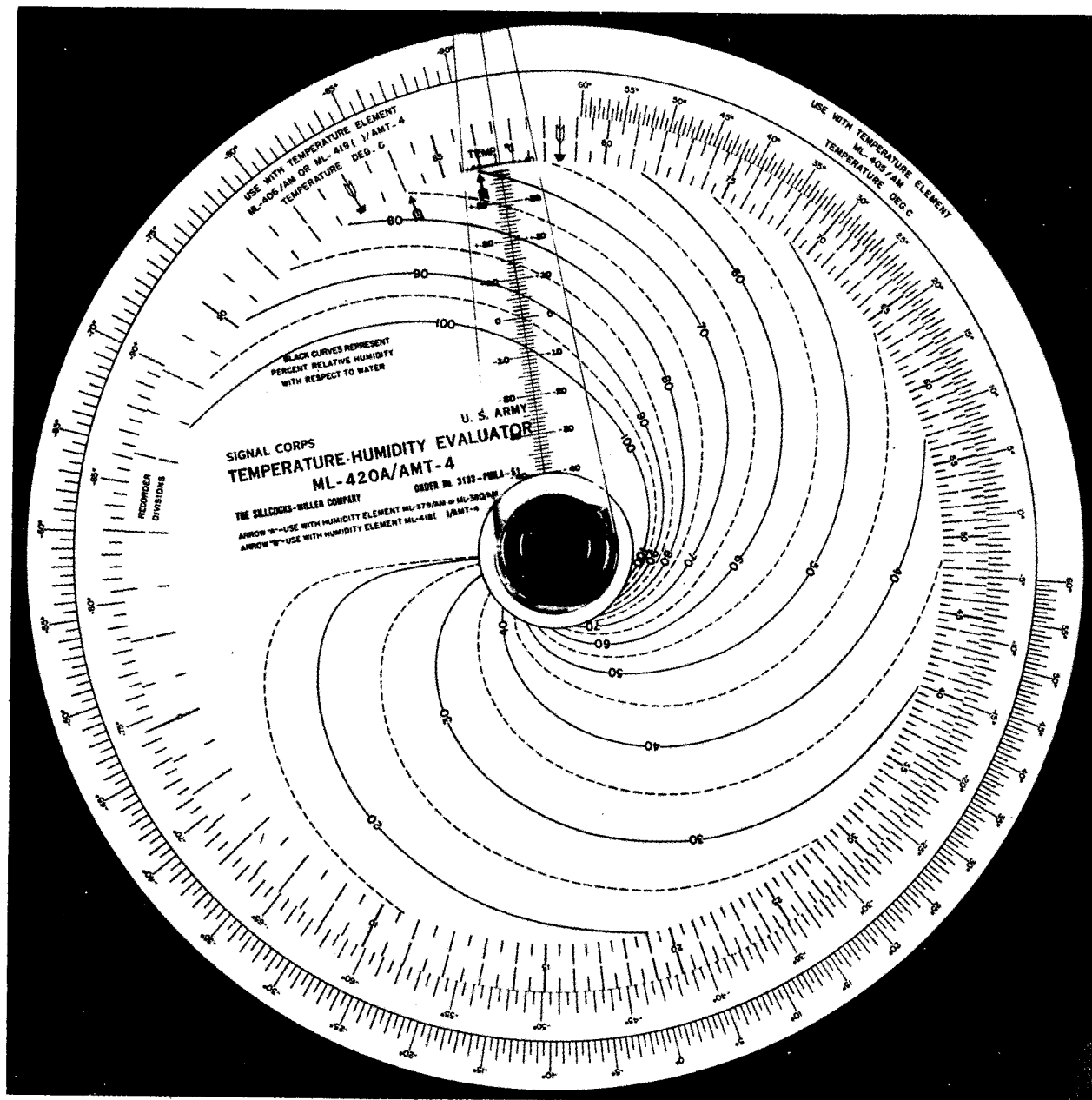


Figure 84. Temperature-humidity evaluator.

## 117. Humidity-Temperature Computer

*a. Functions.* The humidity-temperature computer is used to determine the validity of the baseline check and to convert the recorder divisions of temperature into degrees Celsius and the recorder divisions of relative humidity into percentages. There are two types of evaluators, the computer, humidity-temperature CP-223A/UM (fig. 83) which is used with humidity element ML-476 and temperature-humidity evaluator ML-420A/AMT-4 (fig. 84), which is used with humidity element ML-418. These two evaluators differ only in their scales.

*b. Description.* The evaluator is a circular slide rule consisting of three concentric plastic disks fastened together at their centers with a common screw and two knurled knobs, so that each disk rotates independently. Also, on the same center is a transparent arm (cursor) with a hairline engraved on its long axis. The hairline is used to align the graduations of one disk with those of another. The cursor is graduated in °C. The largest disk (base plate) is inscribed with the temperature scale. The middle disk is graduated in units representing frequency in recorder divisions. The smallest disk (humidity plate) consists of a family of curves representing the percent of relative humidity.

*c. Establishing the Temperature-Recorder Division Equivalency.* In order to set the evaluator, the temperature-recorder division equivalency is first established. The hairline of the cursor is positioned over the baseline check set dry-bulb temperature to the nearest 0.1° C. on the temperature scale (base plate). With the cursor held firmly in place, the frequency plate is rotated until the correct recorder division value of the baseline temperature, to the nearest 0.1 recorder division, falls under the hairline. The smaller knurled knob is firmly tightened and the larger knurled knob is loosened one-half turn. These steps complete the setting of the temperature equivalency.

*d. Establishing the Humidity-Recorder Division Equivalency.* To set up the humidity-recorder division equivalency, the cursor is rotated to position the hairline directly over the corrected baseline check value of humidity recorder divisions on the recorder division plate. The humidity plate is then rotated with the cursor held in place until the baseline check percentage of relative humidity is directly under the point corresponding to the dry-bulb

temperature. The baseline humidity should be visually interpolated to the nearest percent on the humidity plate. The larger knurled knob is tightened firmly.

*e. Conversion of Temperature-Recorder Division Value to Degrees Celsius.* To convert the temperature-recorder divisions to °C., the cursor hairline is positioned over the recorder division value on the recorder division plate and the temperature is read to the nearest 0.1° C. under the cursor hairline.

*f. Conversion of Humidity-Recorder Division Values to Percent of Relative Humidity.* To convert the humidity-recorder division value to percent of relative humidity, the cursor hairline is positioned over the recorder division, the temperature at which the humidity measurement took place, and is located on the cursor hairline. The percent of relative humidity is read under this point on the humidity plate. Humidity is read to the nearest whole percent by interpolating between the printed curves. A complete set of instructions is printed on the computer.

*g. Temperature-Humidity Evaluator ML-420A/AMT-4.* The temperature-humidity evaluator (fig. 84) is used for radiosondes which have lithium chloride humidity elements, ML-418. On this evaluation, there are two temperature scales on the base plate—one for element ML-405/AM and one for element ML-406 and ML-419. Otherwise, this evaluator appears the same as and is used in the same fashion as the humidity-temperature computer CP-223/UM.

## 118. Determining Validity of Baseline Check

The baseline will be considered valid if the requirements described below are met.

*a.* After the humidity-temperature computer CP-223A/UM has been set with the baseline check data, the 25° C. graduation on the base plate should be compared with the corresponding recorder division value on the recorder division plate. If the 25° C. graduation falls between 66.0 and 72.0 recorder divisions, the temperature element is good (fig. 83). If the 25° C. graduation is outside these limits, the temperature element should be replaced and another baseline check performed.

*b.* When using the Temperature-Humidity Evaluator ML-420A/AMT-4, if the arrow on the inner (humidity) plate of the computer falls between the two arrows on the recorder division scale, the humidity element is good; if the arrow is outside the

limits, the humidity element should be replaced and another baseline check performed. Figure 84 shows a humidity-temperature evaluator set with this condition existing. Both the temperature and the humidity elements are good since the above requirements have been met. This check is not performed using the Humidity-Temperature Computer CP-223A/UM.

c. Should either of checks above indicate that one or both of the elements are faulty, the following common sources of error should be checked: erroneous reading of baseline psychrometer or baseline recorder division values, muslin wick on psychrometer not properly wetted, and slippage of the temperature setting on the computer while the humidity equivalency is being established. If no error can be found, the faulty element should be replaced and another baseline check initiated.

d. Baseline check of radiosondes using lithium chloride humidity elements is verified as above, except that temperature-humidity evaluator, ML-420A/AMT-4 is used in place of humidity-temperature computer, CP-223A/UM.

### 119. Final Check of Radiosonde and Receiving Equipment

After determining the validity of the baseline check and rechecking the radio frequency of the radiosonde with the test set TS-538/U, the radiosonde is removed from the conditioning chamber for final preparations.

a. *Pin Arm Setting.* The pin arm of the radiosonde is adjusted to the contact number corresponding to the surface pressure as described in paragraph 111c.

b. *Installation of Battery.* The battery is removed from the pullout shelf of the conditioning chamber and installed in the radiosonde. (If the audio signal of the radiosonde is used in setting the pin arm, the battery must be installed prior to setting the pin arm.)

c. *Check of Signal Strength.* After the battery has been installed, the radiosonde signal strength should be rechecked. The rawin set antenna assembly is pointed in the general direction of the radiosonde and the signal strength is noted at the rawin set. There should be a reading of 60 or more microamperes on the TUNING METER.

d. *Reference-Temperature Check.* After the signal strength check has been completed, a check of reference and temperature is made. There are two

purposes for performing this check. The first, to align the pen of the radiosonde recorder on 95 recorder divisions of the recorder record while a low reference signal is transmitted from the radiosonde. The second is to make a comparison of the measured temperature by the radiosonde and actual temperature at surface. These two checks are made just prior to release. To perform this check, the radiosonde is placed in the same proximity and at same level as the sling psychrometer. The low reference check is made by crossing the blue and black test leads on the outside of the modulator (pin-arm up), and a short trace is permitted to print on the radiosonde recorder record. With the REF-ADJUST handwheel, adjust the pen on the recorder so that low reference prints at 95.0 recorder division. This will reasonably assure that the first low reference trace after release will print at 95.0 recorder divisions and eliminate any frequency drift. The temperature check is made by opening the leads, that were crossed in the reference check, to obtain a temperature signal and allow a short temperature trace to print on the radiosonde recorder record. This trace is evaluated to the nearest  $0.1^{\circ}\text{C}$ . by use of the humidity-temperature computer at the same time the surface observation is being made. This temperature is then compared to the dry-bulb temperature obtained during the surface observation. If the check does not indicate the two temperatures to be within  $1^{\circ}\text{C}$ ., the temperature element is replaced and another baseline check performed.

e. *Clip Leads.* The bared portion of the radiosonde test leads should be clipped off to prevent shorting.

f. *Exposure of the Radiosonde.* Where the temperature within the baseline check set differs drastically from the actual surface temperature, a short exposure of the radiosonde to outside conditions may be necessary.

g. *Automatic Tracking.* As the radiosonde is carried to the inflation tent, the automatic tracking of the rawin set is checked.

### 120. Duties of the Wind Team

The preflight duties of the wind team require approximately 30 minutes. While the temperature-density team makes the baseline check, the zone-wind and ballistic-wind plotters complete the inflation of the sounding balloon and prepare the balloon train (pars. 55-70).

a. The zone-wind computer will prepare DA Form



6-49 (Pressure-Time Chart) after the temperature-density team has accepted and adjusted the radiosonde.

b. Upon completion and verification of the baseline check, the zone-wind computer assists the chief of section in verifying the orientation angles. The zone-wind computer resets the TIME indicator on the control-recorder indicator to zero.

**121. Preparation of the Pressure-Time Chart, DA Form 6-49**

A table (fig. 85) for recording pressure and time for each reference contact is located on the pressure-time chart.

a. The following information should be entered in the appropriate spaces of the table: station, location, flight number, data, release time, modulator serial number, computer, and checker.

b. The contact number corresponding to the surface pressure is entered in the bottom box of the left column and the surface pressure is entered in the center column.

c. In the left column, the numbered reference contacts lower than the contact number corresponding to the surface pressure are crossed out. For example, if the contact number corresponding to the surface pressure is 5.4, the contact number 5.0 is crossed out.

d. The pressure for each reference contact number listed in the left column is read from the appropriate radiosonde pressure calibration chart to the nearest whole millibar and recorded in the center column.

e. The right column is provided for recording the time each reference contact is reached. Times are obtained from the control-recorder tape and are entered as they become available during the flight.

**122. Offset Release**

The rawin set must begin automatic tracking immediately at release if low-level winds derived from the rawinsonde system are to be considered accurate. An offset release point of at least 100 meters is recommended in order to permit automatic tracking by the rawin set from the time of release. This offset distance is based on balloons with a rate of rise of approximately 300 meters per minute. For faster rising balloons, the offset distance must be increased proportionately with the rate of rise of the balloon, i.e., 100 meter offset for balloons with a rate of rise of 300 meters per minute; 170 meter offset for balloons with a rate of rise of 500 meters per minute.

STATION: <i>3rd Div Arty</i>		
LOCATION: <i>Ht Sill, Okla</i>		
FLIGHT NR: <i>3</i>		
DATE: <i>3 Nov 59</i>		
RELEASE TIME & TIME ZONE: <i>1730 GMT</i>		
CONTACT NUMBER *	CONTACT PRESSURE (Mb)	CONTACT TIME (Min & Tenths)
(1)	(2)	(3)
120	73	58.4
115	86	55.0
110	104	51.5
105	120	48.8
100	140	46.0
95	162	43.5
90	186	40.8
85	212	38.1
80	240	35.3
75	270	32.2
70	303	30.2
65	337	27.7
60	374	25.3
55	413	22.8
50	454	20.6
45	499	18.2
40	548	15.7
35	601	13.3
30	654	11.0
25	710	8.7
20	772	6.6
15	837	4.4
10	905	1.6
<del>5</del>		
Surface 5.4	967	0.0
MODULATOR NR: <i>696900</i>		
COMPUTER: <i>Moore</i>		
CHECKER: <i>Scheiner</i>		
* CROSS OUT LINES FOR CONTACT LESS THAN RELEASE CONTACT NR.		

Figure 85. Recording contact pressure and time on pressure-time chart.

## Section IV. TEAM DUTIES DURING BALLOON RELEASE

### 123. Duties of the Section Chief

The section chief is in charge of all operations at the moment of release and must coordinate the activities of all personnel to insure maximum speed and efficiency. He announces the type of release to be used and gives the command WARNING—RELEASE. Immediately after release, he insures that the rawin set is tracking and operating automatically. If necessary, he manually operates the rawin set until it is positioned on the radiosonde, then switches to automatic tracking. After 2 minutes, he sets the antenna control MANUAL-NEAR AUTO-FAR AUTO switch to the FAR AUTO position.

### 124. Duties of the Temperature-Density Team

Just before the command RELEASE, the radiosonde recorder operator turns the SIGNAL SELECTOR switch to SIG position, the POWER ON-POWER OFF-STAND BY switch from STAND BY to POWER ON, and the RAWIN TIME PRINT switch to AUTO position. At the command RELEASE, he turns the RECORDS CONTROL switch on the control-recorder from STAND BY to FLIGHT. He verifies that the data are being properly received and enters the time of

release. The temperature-density plotter reads the psychrometer, determines the relative humidity at the surface, and reads the barometer to obtain the atmospheric pressure at the surface.

### 125. Duties of the Winds Team

The zone wind plotter and ballistic wind plotter are responsible for performing the actual release in accordance with procedures given in paragraph 69. It is the responsibility of the man who releases the radiosonde to see that the pin arm is placed in the ON (down) position just before release and to determine the offset distance. After the release, the zone wind plotter measures the surface wind with the anemometer. Assisted by the ballistic wind plotter, he then polices the inflation area and prepares for the next flight. The balloon for the next flight is not inflated immediately after a release but the charges, twine, and parachute may be set out and the balloon may be conditioned if required. Just before release, the zone wind computer insures that the control-recorder is ready (i.e., the PRINTINGS-PER-MINUTE switch at 10 prints per minute, the TIME indicator at zero, and the RECORDS CONTROL switch in STANDBY). The zone wind computer records the time of release on the pressure-time chart.

## Section V. DUTIES OF TEMPERATURE-DENSITY TEAM DURING FLIGHT

### 126. General Duties

a. During the flight, the temperature-density team computes ballistic temperatures and densities. The duties performed by each team member and the computations involved are described in this section.

b. The data for determining ballistic density and temperature are used in turn by the recorder operator, the temperature-density plotter, and the temperature-density computer, who determines the final ballistic quantities. Each man on the team is responsible for checking the data received from the man before him. The chief of section checks the entire set of data for inconsistencies before he records the results on the metro message form.

### 127. Flight Duties of the Radiosonde Recorder Operator

During the flight, the primary duty of the recorder operator is to evaluate the radiosonde recorder

record. The record should be evaluated as it becomes available. When the requirement has been met (par. 81f), the recorder operator rotates the SIGNAL SELECTOR switch to the S.C. position for 10 seconds, turns off the recorder, and completes the evaluation of the record. He then checks the data prepared by the temperature-density computer before it is turned over to the chief of section. The recorder record is printed automatically, but the recorder operator adjusts the print of each incoming low reference to a recorder division value of 95.0 with the REF ADJUST knob. Before making the adjustment, the operator should allow the recorder to print for a moment so that the beginning of the trace can be easily identified.

### 128. Evaluation of the Radiosonde Recorder Record

a. The general design of the recorder record is

described in this paragraph and the evaluation of the record is described in subsequent paragraphs.

b. The radiosonde recorder record consists of a series of traces representing the values of temperature, relative humidity, and pressure; these traces are printed during a radiosonde flight on a chart containing a grid of vertical and horizontal reference lines. There are 101 vertical lines evenly spaced from one side of the record to the other. The space between two adjacent lines is defined as 1 recorder division. Each 10th vertical line is numbered across the record from 0 on the left to 100 on the right (fig. 86). Horizontal lines are spaced one-half inch apart on the recorder record (this spacing is consistent with normal paper feed speed of one-half inch per minute). As a radiosonde is carried aloft, the values of temperature, pressure, and relative humidity are transmitted in the form of a pulse-modulated ultra high frequency (UHF) signal which is received by

the rawin set. The order of transmission is predetermined by the construction of the commutator bar. Modulation occurs in the audio frequency range and this metro signal is printed on the record at a recorder division value equal to one-half of the frequency, i.e., a frequency of 120 cycles per second is printed at 60 recorder divisions. A discussion of how the values of temperature, relative humidity, and pressure are measured by the radiosonde and recorded on the chart by the radiosonde recorder is presented in paragraphs 129 through 131.

### 129. Temperatures

The electrical resistance of the temperature element is a function of its temperature. This principle is utilized in the radiosonde with the effect that a radio signal is transmitted which contains temperature information in the form of frequencies from 8 to 170 cps. These frequencies vary directly with

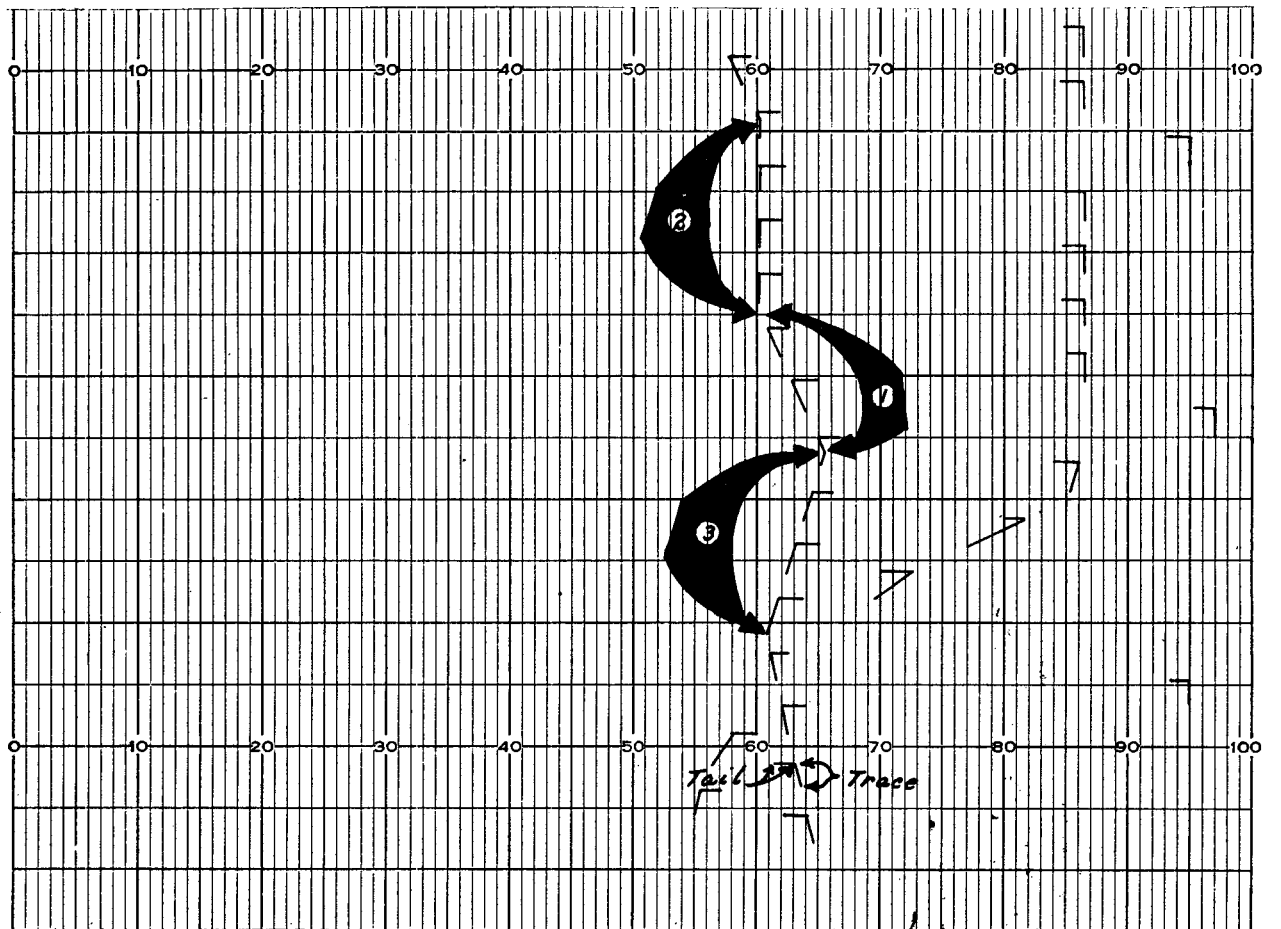


Figure 86. Recorder record showing a temperature trace pattern.

the temperature—the higher the temperature, the higher the frequency. Since recorder divisions are proportional to frequency, any temperature trace printed to the right of another represents a higher temperature. The horizontal portion of the print is the tail (which is always horizontal and at the top) (fig. 86). The portion that is vertical, or inclined from the vertical, is the trace. The trace terminates at its junction with the tail. The trace is the usable part of the print, as it reflects the temperature measurement. Since the temperature normally decreases with height, a series of temperature traces often appears on the recorder record as shown by 1 in figure 86. Sometimes the temperature does not change with an increase in height. Such a layer of atmosphere is known as an isothermal layer. The temperature traces would appear on the record as shown by 2 in figure 86. An inversion layer is a layer of the atmosphere in which the temperature *increases* with height. An inversion layer commonly is found near the surface during the night or early morning hours. The temperature traces of an inversion layer are shown by 3 in figure 86. The actual point at which the temperature lapse rate changes direction may occur while a temperature trace is being printed or while the humidity or reference signals are being received. In the former case, the point at which the change occurs is clearly portrayed by a distinct change in direction of the temperature trace (top of 2 in figure 86). Since the entire length of the temperature trace is valid, the point of change of direction is easily located. If the actual point of change in direction of the temperature lapse rate occurs during the print of a reference or humidity signal, the location becomes somewhat more difficult to determine. In this case, the point of change of direction is assumed to be at the point of intersection of two adjacent temperature traces (bottom of 2 in figure 86). Isothermal or inversional layers may occur completely within one temperature trace, a portion of a trace, or a series of traces.

### 130. Relative Humidity

a. The humidity elements are so constructed that their electrical resistance varies with the relative humidity. The resistance of the carbon element (ML-476/AMT) varies directly. Figure 87 shows a record made by a carbon humidity element. Higher relative humidities produce low recorder divisions on the record. Frequencies from 8 to 185 c.p.s. rep-

resenting humidity are transmitted by the radiosonde. The variation of humidity does not tend to follow any set pattern such as usually found with temperature. However, in the higher portions of the atmosphere, the moisture content is very low and may not be sufficient to be evaluated.

b. When the relative humidity is too low to be evaluated, it is said to be "motorboating." The term "motorboating" is used because of the "put-put-put" sound heard on the recorder speaker when a lithium chloride element is attempting to measure very low humidities. Lithium chloride elements motorboat at 5 recorder divisions and below, and the carbon elements motorboat at about 80 to 87 recorder divisions and above (1, fig. 87).

c. The relative humidity print is similar to the temperature print in that the horizontal portion is the tail and the portion that is vertical, or inclined from the vertical, is the trace. Humidity traces recorded from a radiosonde passing through a cloud layer are shown by 2 in figure 87.

### 131. Pressure

Contact numbers can be determined for any level on the recorder record and represent values of pressure. Contact numbers are converted to pressure using the radiosonde pressure calibration chart. The procedure for determining contact numbers is simplified by the use of easily identified reference traces. Two reference traces, high and low, are used (3, fig. 87). Low reference traces are transmitted at 190 c.p.s., and printed at 95.0 recorder divisions, and high reference traces are transmitted at 194 c.p.s. and printed at 97.0 recorder divisions. Below the 105th contact, each contact that is a multiple of 5, is a reference contact. Each reference contact that is a multiple of 15 is a high reference and the others are low references. On some modulators, the 15th contact is a low reference instead of a high reference. A note to this effect may be printed on the modulator case; if there is no note, the 15th contact can be identified by inspecting the commutator bar. Above the 105th contact, each contact that is a multiple of 5 is a high reference and a low reference signal replaces the relative humidity signal.

### 132. Rules for Selecting Significant Levels

The recorder record contains a series of temperature and humidity traces representing the values of these meteorological conditions at all heights from

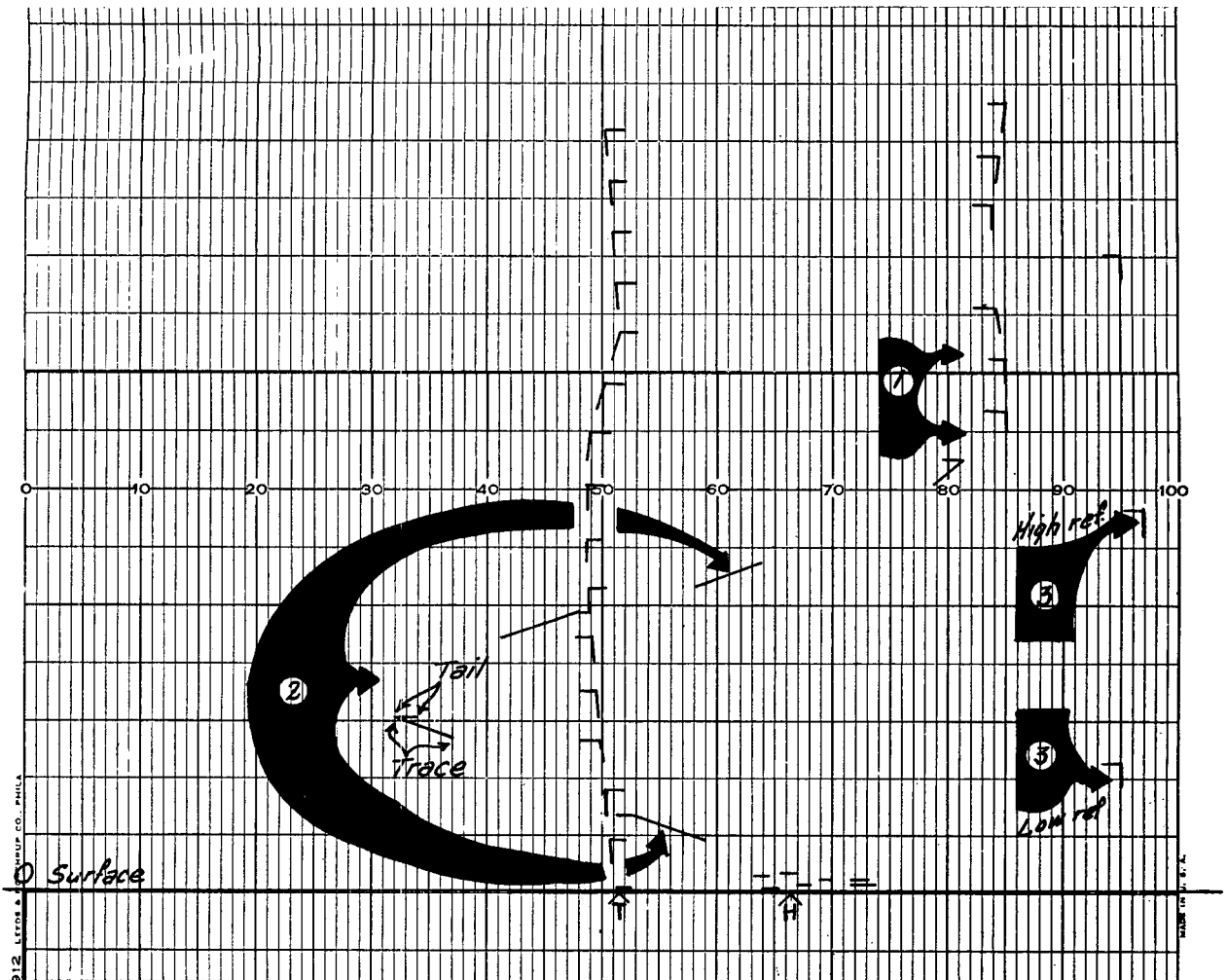


Figure 87. Typical humidity traces.

the surface to the top of the sounding (humidity traces stop at the 105th contact). The task of record evaluation is to reproduce the temperature sounding curve, corrected for humidity, on an altitude-pressure-density chart. One method would be to evaluate the top and bottom of each trace, thereby using all available data. This method would be acceptable if the accuracy of subsequent calculations warranted it and if sufficient time were available to perform such a detailed evaluation. However, these considerations have led to another method of evaluation. This method allows a tolerance up to certain predetermined amounts and

provides for evaluations to be made at certain critical points on the record. The method of evaluation is outlined in 10 rules for selecting significant levels. The application of these 10 rules insures that the requirements of the artillery are satisfied. On the recorder record, the significant levels take the form of horizontal lines located as specified by the rules. These lines or levels are the only points on the record that actually are evaluated. Levels are selected in accordance with the following rules:

- a. Rule 1. At the surface.

*b. Rule 2.* At the bottom and top of each significant isothermal layer.

*c. Rule 3.* At the bottom and top of each significant inversion layer.

*d. Rule 4.* At each point where the temperature traces vary from the temperature line of linearity by 1° C. or more.

*e. Rule 5.* At each cutoff point which precedes or follows a layer where the relative humidity traces motorboat (are too low to be evaluated).

*f. Rule 6.* Within any motorboating stratum of more than four contacts, provided nonmotorboating humidity traces are available above this stratum. When humidity traces continue to motorboat throughout the remainder of the sounding, only the cutoff level for the beginning of the motorboating is required.

*g. Rule 7.* At each point where a relative humidity trace deviates from the humidity line of linearity by 10 percent or more.

*h. Rule 8.* At the beginning, end, and within any layer in which the temperature or humidity data is missing.

*i. Rule 9.* At the bursting point of the balloon or at the highest required contact on the record.

*j. Rule 10.* At certain mandatory pressure levels.

### 133. Application of Rules for Selecting Significant Levels

A discussion of the application of each rule is given below. The significant levels and their evaluation are marked on the radiosonde recorder record (fig. 101). These levels are numbered, beginning with 0, immediately above the significant level lines on the left edge of the record. The numbers in parentheses below the significant level lines indicate the order in which the operator established the levels during the evaluation of the record.

*a. Surface Level (Rule 1).* At surface or release level, a line is drawn across the record from the point where the pen left zero recorder divisions and is labeled SURFACE and numbered 0, as shown in figure 87. This level is not necessarily drawn through the bottom of the first trace printed on the record, since the first trace may be scattered or missing (fig. 87). Poor manual positioning of the radio direction finder just subsequent to release may result in the loss of the first signals transmitted. The

offset release usually precludes the need for manual positioning.

*b. Isothermal Layers (Rule 2).* Levels are drawn at the bases and tops of all significant isothermal layers. The significance of isotherms will be determined in accordance with rule 4 (*d* below). That is, if a point within an isotherm deviates from the temperature line of linearity by 1° C. or more, the isotherm is considered significant. If there is doubt whether a particular isotherm is significant, it may be temporarily passed in the record evaluation and then checked for linearity according to rule 4. Levels 1 and 2 in figure 88 are placed at the base and top of a significant isothermal layer. At 1 the isotherm clearly begins within a temperature trace; therefore the level is placed at the exact beginning of the isotherm within the trace. However, when the significant change in the temperature lapse rate occurs between two temperature traces, the exact point of the change is determined by "trending," i.e., extending the temperature traces bracketing the point of change as shown by 2 in figure 88. The significant level is drawn at the intersection of the trend lines.

*c. Inversion Layers (Rule 3).* Levels are drawn at the bases and tops of all significant inversions. The significance of inversions will be determined in accordance with rule 4 (*d* below), and by using the same procedure as for isotherms (*b* above). Levels 3 and 4 in figure 88 are placed at the base and top of an inversion layer. The base of this inversion is recorded within a temperature trace (3, fig. 88); thus, the point of change of direction of the temperature trace is clearly defined on the record. The change in direction between the top of the inversion and the normal lapse rate following it occurs between two temperature traces (4, fig. 88). The exact point of this change is determined by trending these two temperature traces.

*d. One Degree Celsius Deviation (Rule 4).* A temperature line of linearity is drawn between two consecutive levels selected previously according to any of the 10 rules except that no linearity line is drawn within missing data. The line of linearity is drawn between the point where the lower level intersects the temperature trace (or extension thereof) and the point where the upper level intersects the temperature trace (or extension thereof). An example of a temperature line of linearity is shown by 1 in figure 89. This line of linearity represents the temperature lapse rate between the levels at 2 and 3

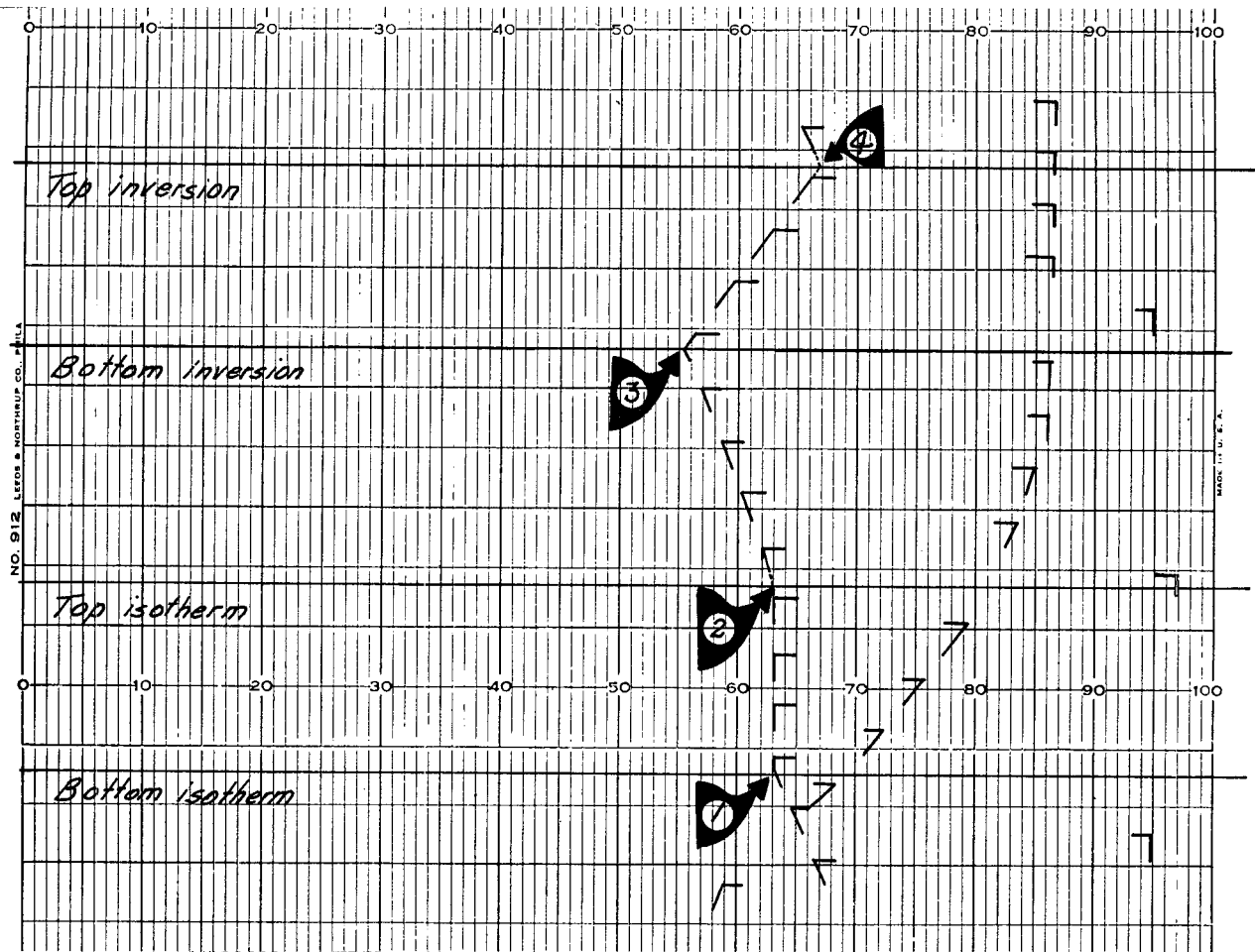


Figure 88. Isothermal and inversion traces.

in figure 89 that the temperature density plotter would plot on chart ML-574, if no further levels were selected. Since the accuracy required for temperature to be used in this plot is  $1^{\circ}\text{C}$ ., the temperature traces must not deviate from the line of linearity by  $1^{\circ}\text{C}$ . or more. The deviation of the traces from the line of linearity is measured on a horizontal line. In order to determine whether or not the traces deviate by  $1^{\circ}\text{C}$ . or more from the line of linearity, the point of greatest deviation (4, fig. 89) is investigated first. A horizontal line or trial line is drawn at the point of greatest deviation. The temperature is evaluated for the two points where this line intersects with the line of linearity and the temperature trace (4 and 5, fig. 89). First, the recorder divisions corresponding to each point are read from the record. Then, the

humidity-temperature computer, set with the baseline data (fig. 83), is used to convert the recorder division values to  $^{\circ}\text{C}$ .. If the greatest deviation is less than  $1^{\circ}\text{C}$ ., no level is drawn at this point. If the deviation is  $1^{\circ}\text{C}$ . or more, a level must be drawn at this point and the two lines of linearity which are drawn to the level above and below this level (1 and 2, fig. 90) must be checked again for an accuracy of  $1^{\circ}\text{C}$ .. In figure 90, level at 3 was selected because the temperature traces deviate more than  $1^{\circ}\text{C}$ . from the line of linearity. An additional level for a  $1^{\circ}\text{C}$ . deviation must be placed at 4.

*e. Relative Humidity Motorboating Cutoff Point (Rule 5).* When the amount of moisture in the air becomes so low that the relative humidity cannot be evaluated, i.e., is less than 10 percent, the situation

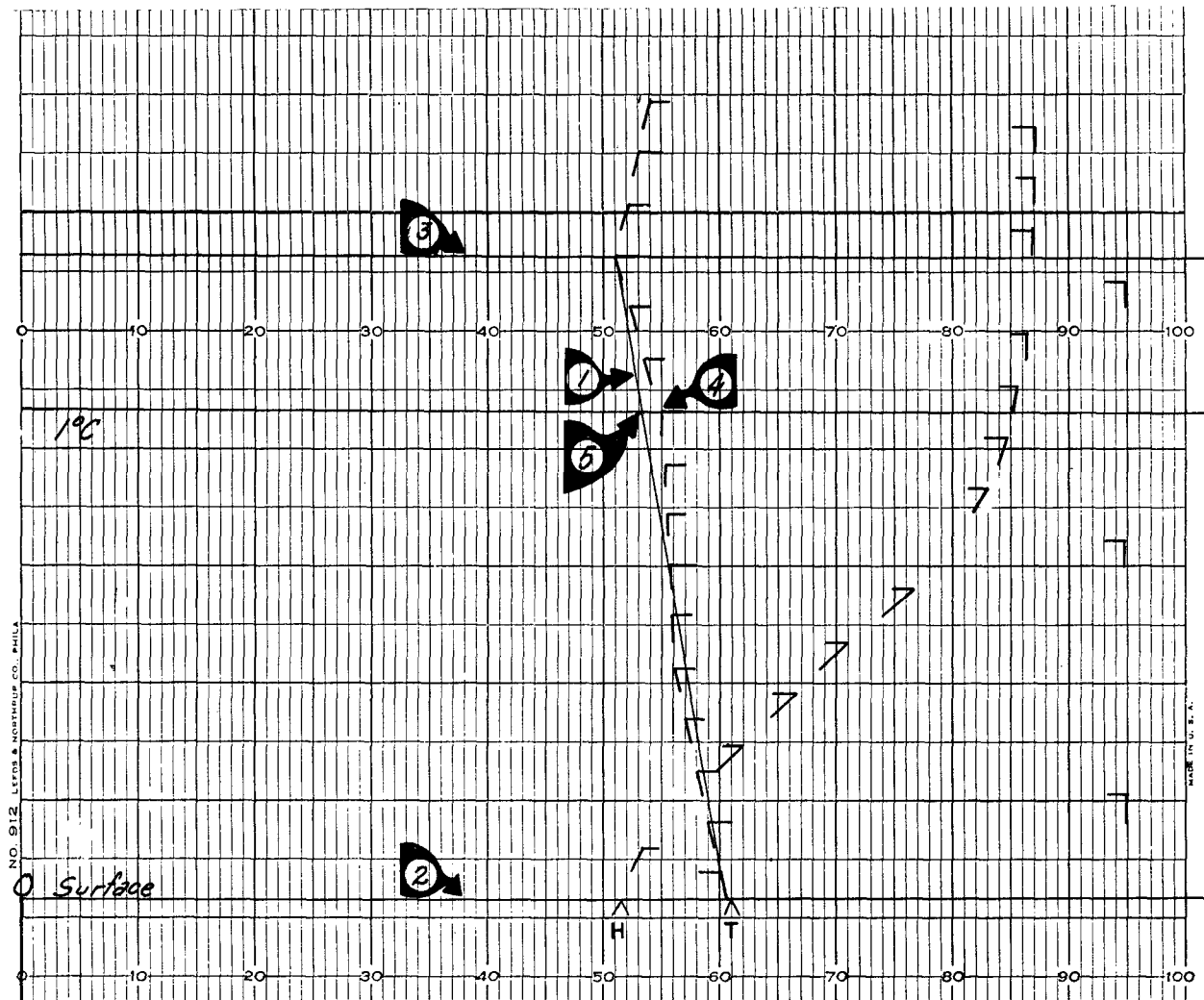


Figure 89. Test for 1°C deviation from a line of linearity.



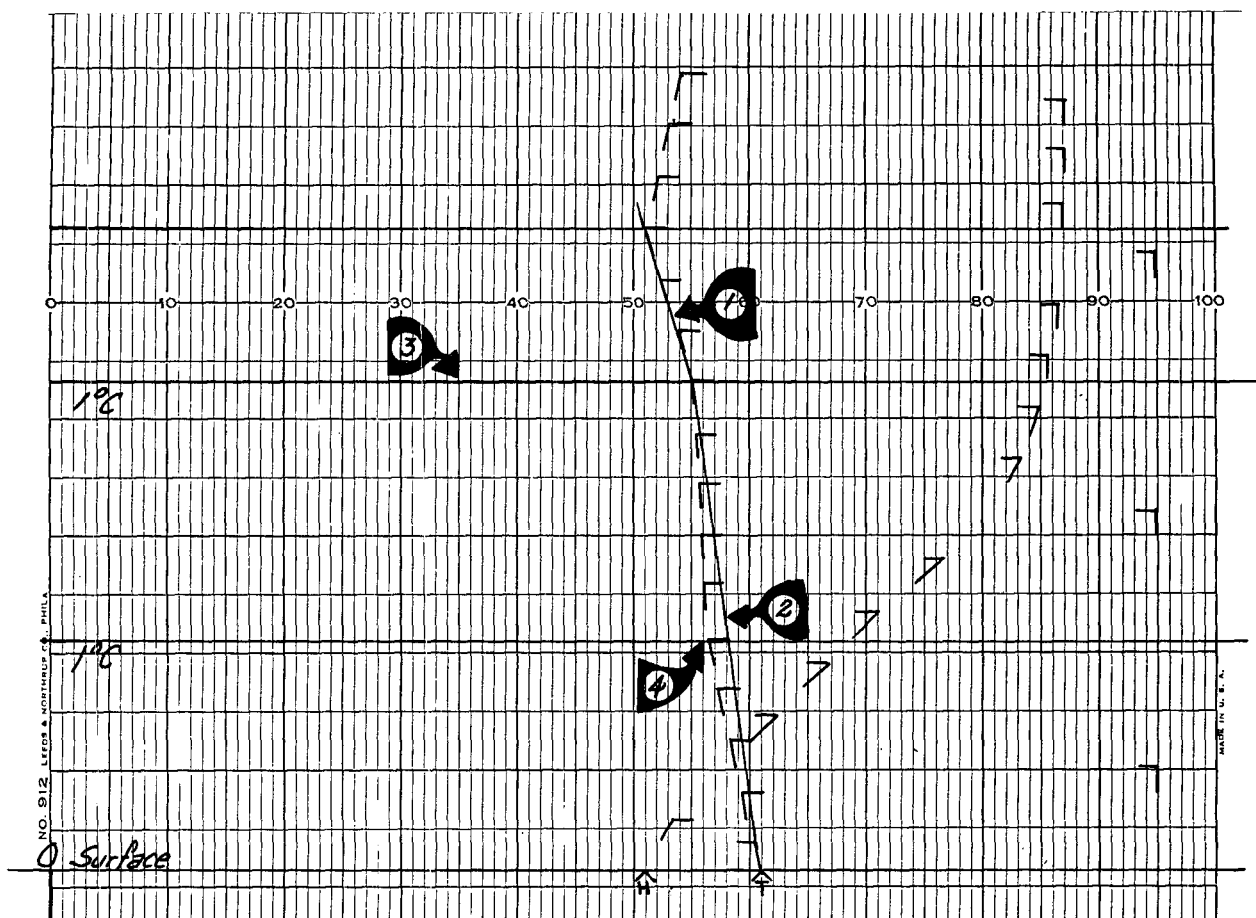


Figure 90. Determination of temperature deviation from line of linearity.

is known as motorboating. In this situation, the humidity trace will have a relatively constant value between approximately 80 and 87 recorder divisions. The points on the record where humidity traces enter or depart from the motorboating position are known as cutoff points. The fifth rule for level selection states that levels are selected at all cutoff points (as qualified below) which either precede or follow a layer where humidity traces motorboat. The location of cutoff points is made as follows:

- (1) After the humidity-temperature computer has been set with baseline check data, the computer is used to establish the recorder division values where 10 percent relative humidity and 20 percent relative humidity occur. This is done by placing the 0° C. graduation of the cursor over the 10 percent relative humidity curve and reading the

corresponding recorder division value. This value is the cutoff value, and for the baseline data shown in figure 82, it is 85.4 recorder divisions. Next, the 0° C. graduation of the cursor is placed over the 20 percent relative humidity curve and the corresponding recorder division value is read. This value is the 20 percent relative humidity value, and for the baseline data shown in figure 82, it is 84.0 recorder divisions. Both of these values are entered on the radiosonde recorder record as illustrated at 1, figure 91.

- (2) A significant level is required to be drawn in at the level at which the humidity trace (or the trend line between traces) crosses the cutoff recorder division value obtained above as shown at 2, 4, 5, and 6 in figure 91.

The exception to this is that a cutoff level is not entered on the record when the humidity curve comes out of motorboating but does not cross or touch the 20 percent recorder division value obtained in (1) above. Also, no level is required where the humidity curve returns to motorboating from such a region. This is illustrated at 3 in figure 91.

- (3) The procedure described in (1) above, for selecting the cutoff recorder division value and the 20 percent recorder division value introduces a slight error at extreme temperature ranges. However, in no case does this error exceed the stated tolerances of the humidity element ML-476/AMT or of the procedures contained in this manual.

f. Within Any Motorboating Stratum of More Than

Four Contacts (Rule 6). The sixth rule for level selection requires that a level be placed within any motorboating layer of more than four contacts, when there is no reason for any other level to be placed anywhere within the layer. Generally, the level satisfying this requirement is placed in the middle of the motorboating stratum. (In fig. 101, level 8 satisfies this rule.) This rule is always the last one applied to a given motorboating layer, since the placement of a level within the layer for any other reason will satisfy this rule. A layer is entirely in motorboating when all the humidity traces throughout the layer are to the right of the cutoff division value.

g. Ten Percent Humidity Deviation (Rule 7). A humidity line of linearity is drawn between two consecutive levels selected previously according to any of the ten rules (except that no line is drawn within

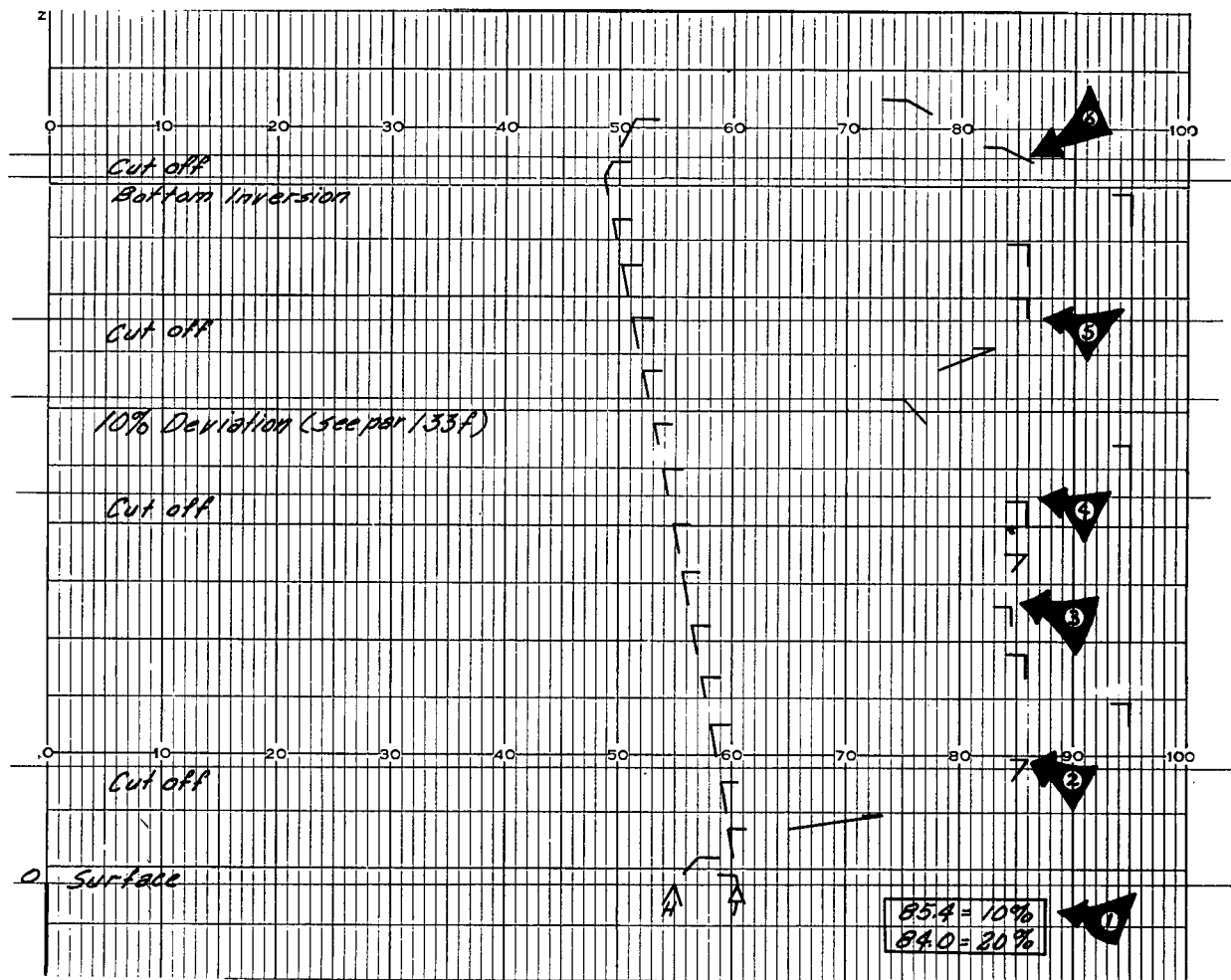


Figure 91. Determination of humidity cutoffs.

missing data) and the region between these levels is analyzed to determine if the humidity curve deviates from the line of linearity by ten percent relative humidity or more. This is accomplished as follows:

- (1) After the surface level has been placed, the recorder division values corresponding to the psychrometric values for surface temperature and humidity are plotted and marked as in 1 and 2, figure 92. In the example in figure 92, the first level selected above the surface is the cutoff level at 3, figure 92. Therefore a line of linearity (7, fig. 92) is drawn from the humidity recorder division value at the surface level (2, fig. 92) to the point of cutoff (3, fig. 92). This line of linearity represents the humidity in this area which would be plotted by the temperature-density plotter if no further levels were selected. Since the accuracy required for the humidity used in this plot is 10 percent, the humidity traces must not deviate from the humidity line of linearity by 10 percent or more.
- (2) As with temperature deviations, the point of greatest deviation (4, fig. 92) is investigated first. A trial level is drawn at this point. If the humidity corresponding to the intersection of the trial level and the humidity line of linearity (5, fig. 92) deviates from the humidity corresponding to the intersection of the trial level and the humidity trace (4, fig. 92) by 10 percent or more, the trial level must be evaluated as a significant level.
- (3) The humidity values for the two points (4 and 5, fig. 92) on the trial level are determined with the humidity-temperature computer. The first step is to determine the temperature measured at the trial level. This temperature is the temperature corresponding to the intersection of the trial level with a temperature trace or extension thereof (6, fig. 92). The recorder division value for this point is converted to degrees Celsius with the computer. This temperature is used with the recorder division values for the two points being checked (4, and 5, fig. 92) to determine the corresponding humidities. In this case, the deviation is greater than ten percent and a significant level is entered at 4 in figure 92. Next, this procedure is repeated between the surface and level 4 by drawing a line of linearity (8, fig. 92) and checking the point of maximum deviation (9, fig. 92) from the line of linearity.
- (4) If the two relative humidities differ by less than 10 percent, no significant level is required at the trial level (9, fig. 92). In which case, the record is checked for ten percent deviation between level 4 and the cutoff level 3. Another line of linearity (10, fig. 92) is drawn and the above procedure is repeated for the region between 4 and 3. In figure 92, the deviation at 9 was checked with a humidity temperature computer and it was found that no significant level was required at 9.
- (5) If the two relative humidities differ by ten percent or more, the trial level is entered as a significant level. The areas above and below this new level must then be checked for more ten percent deviations.
- (6) This same procedure is followed between all consecutive levels (with the exception of within missing data) regardless of the reasons for selecting the levels; i.e., the identical procedure that was followed in analyzing figure 92 would have been used had the cutoff level 3 been entered because it occurred at the bottom of an inversion or had the surface level been the top of a missing data region.
- (7) During the application of the procedure in (1) through (6) above, whenever the trial level crosses the line of linearity in the region between the cutoff recorder division value and the 20 percent relative humidity recorder division value, the point is evaluated as 10 percent relative humidity; and a significant level is entered if the humidity value on the humidity curve at this level is 20 percent or greater.

*h. Missing Data Levels (Rule 8).* Levels at the beginning and end of missing data are selected to define the limits of usable information. The levels at 1 and 2 in figure 93 were selected by this rule. The lower level is drawn through the top of the last usable temperature trace printed before the area of missing data, and the upper level is drawn at the

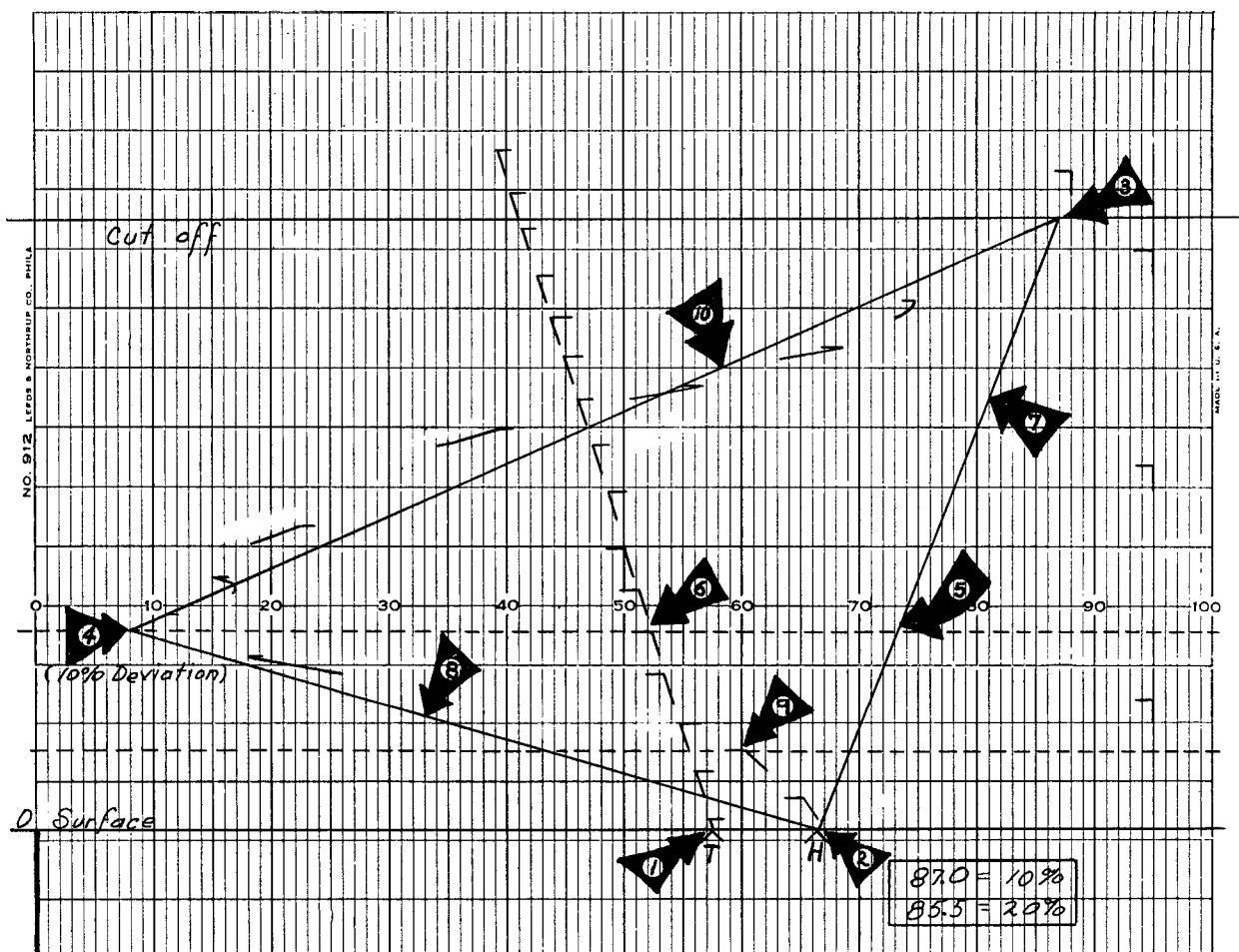


Figure 92. Humidity deviation from linearity.

base of the first usable temperature trace (or portion thereof) printed after the missing data. In addition, a level must be selected within the area of missing data, so the level at 3 in figure 93 was selected. To determine the contact number above the missing data, the vertical distance between the last two usable reference traces below the missing data (4, fig. 93) is measured. This distance is divided into the total distance (6, fig. 93) between the last usable reference trace before the missing data level and the first reference trace above the missing data level. The result is used to determine the reference contact number above the layer of missing data. For example, in figure 93, the vertical distance between reference contacts 25 and 30 (below missing data) is measured as 2 inches. This 2 inches is graphically

divided into the total distance (4 inches) by laying it off on the record two times, from the last reference trace below the missing data (reference 30) to the first reference trace (5, fig. 93) above the missing data. Therefore, the first reference trace above the missing data is 40 (two reference contacts above 30). When fast-rising balloons are used, the determination of references may be more difficult.

i. *Terminal Level (Rule 9)*. When the maximum altitude requirement for radiosonde data is obtained prior to balloon burst, a terminal level is drawn at the appropriate contact. Otherwise, a terminal level is drawn at the level corresponding to the bursting point of the balloon. The point of the balloon burst on the recorder record is determined by the following characteristics: the traces printed after the

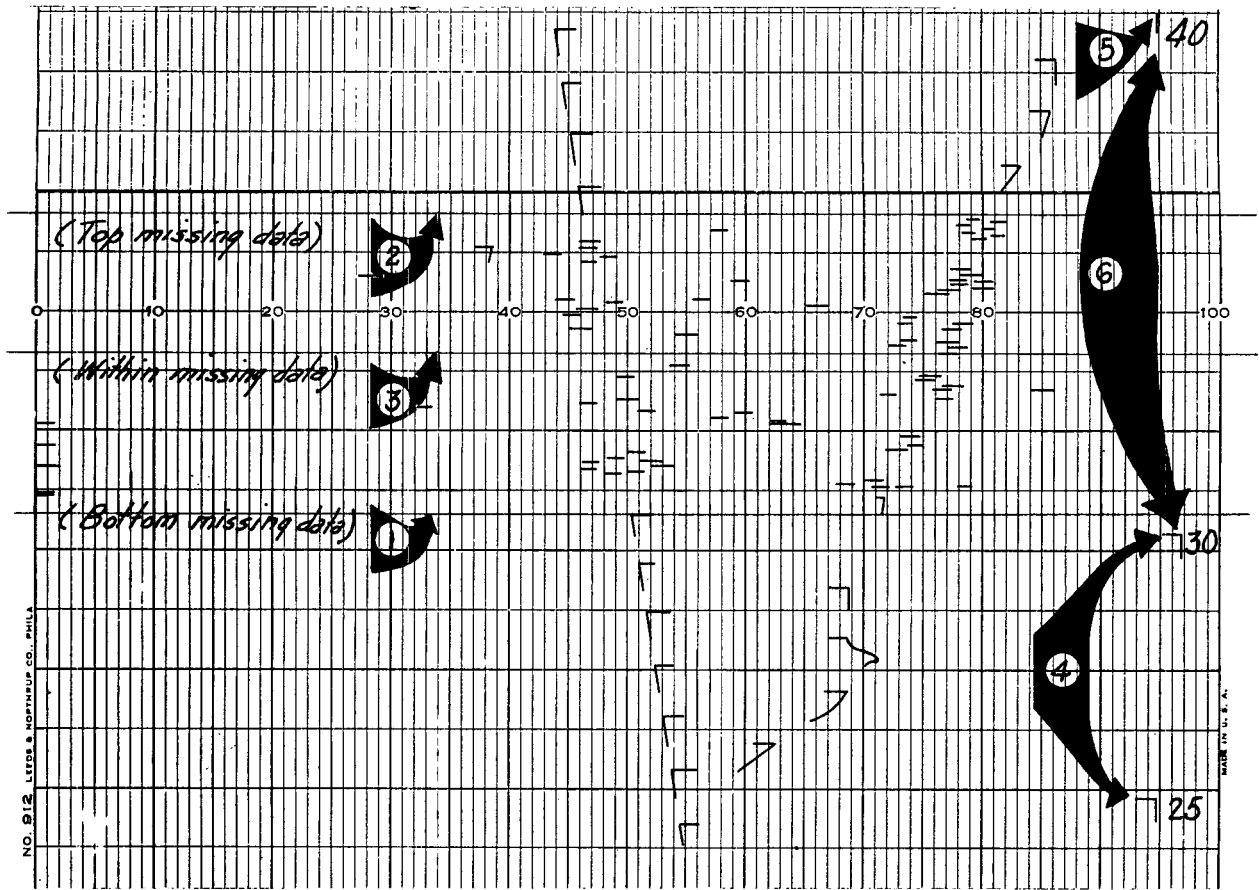


Figure 93. Missing data.

balloon burst are shorter than those before the burst, since the radiosonde descends faster than it ascends; the temperature and humidity traces printed after the burst correspond in reverse order to the temperature and humidity traces printed before the burst; and the reference traces are printed in reverse order of their original printing. The point of burst is fixed by determining the contact numbers of the traces printed between the last reference trace during the ascent and the same reference trace after the burst. In figure 94, the burst occurred at 1, during a temperature trace. This trace was located by inspecting the temperature traces and by assigning contact numbers to the temperature traces immediately above and below the burst. The position of the burst point within the trace is determined by comparing the lengths of the traces before balloon burst with the length of the traces after burst. In figure 94, the traces printed after the burst are about

one-half as long as the traces printed before the burst. In determining the contact number of the level of balloon burst, the last full contact below this level is used as a measure. Thus the operator lays off the vertical distance of the last full contact on the straight edge of a piece of paper by use of tick marks, places it vertically on the chart with the lower tick mark coinciding with the top of the last full temperature trace. He then visually interpolates the level of balloon burst to the nearest tenth of a contact. In this case, the correct contact is determined to be 90.8. The radiosonde should be tracked until it is certain the balloon has burst.

*j. Mandatory Levels (Rule 10).* Levels will be placed at 400 mb, 80 mb, and 10 mb to provide common levels for air weather service plotting charts and will be routinely entered even when the metro section is not furnishing data to the Air Weather Service. This is not illustrated in figures 101 and 110.

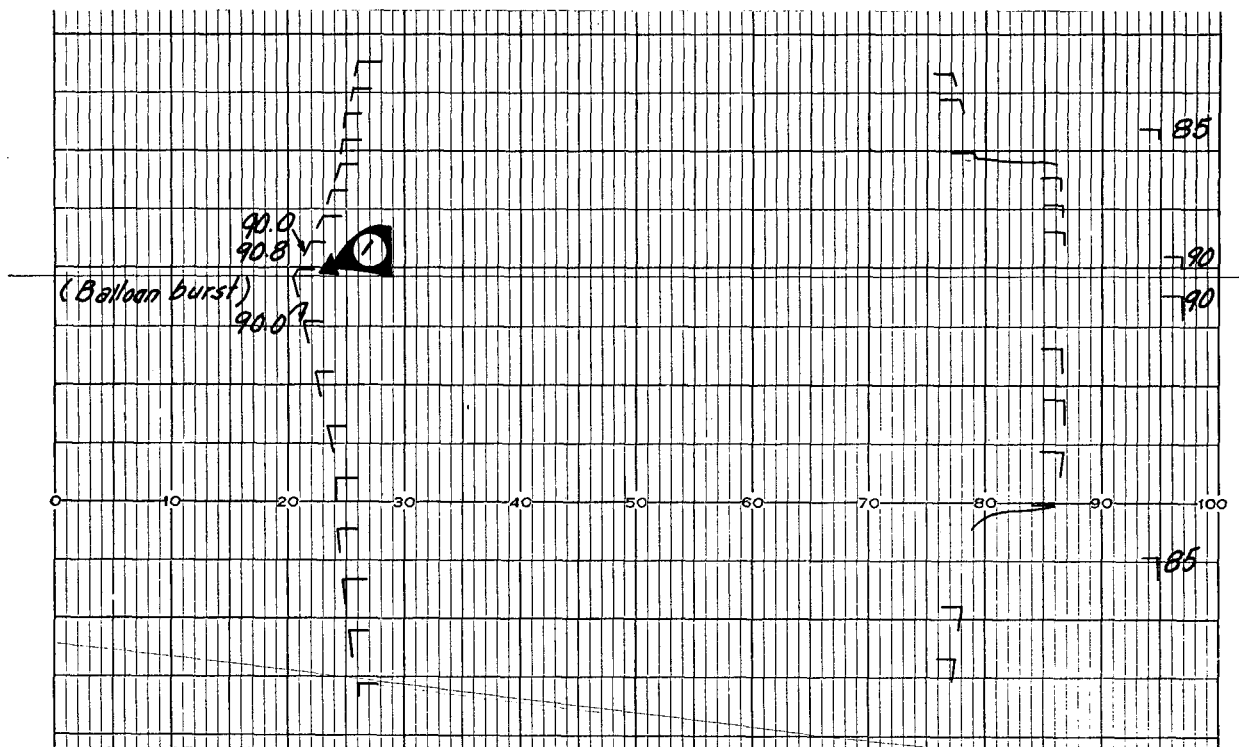


Figure 94. Terminal layer.

### 134. General Procedure for Selecting Significant Levels

The first significant level selected on a recorder record is the surface. Above the surface, no specific procedure can be established for the selection of significant levels, since the rules for selecting significant levels apply to the temperature, humidity, and pressure of the atmosphere—meteorological conditions which are extremely variable. However, a general procedure has been established for selecting significant levels. This general procedure encompasses all of the rules for selecting significant levels and is still flexible enough to apply to any given set of atmospheric conditions recorded on the radiosonde recorder record.

*a. Procedure in Making Selection.* The general procedure for selecting significant levels is as follows:

- (1) Scan the record from the surface level upward for the presence of either an isotherm, an inversion, a layer of missing data, or a humidity cutoff point.
- (2) Draw a level through the bottom and top of an isotherm, an inversion, and a layer of missing data and through a humidity cut-

off point, whichever is encountered first (rules 2, 3, 5, and 8.)

*b. Linearity Requirements.* Between adjacent levels established in *a* above (including the surface level), the temperature and humidity linearity requirements are investigated and a level is drawn where required (rules 4 and 7).

*c. Provisional Rules.* Between adjacent levels established in *a* and *b* above (including the surface level), the rule for humidity traces motorboating for more than four contacts is applied and levels are drawn where required (rule 6).

*d. Evaluation.* All of the levels selected in *a*, *b*, and *c* above, are evaluated and recorded on DA Form 6-43 (Radiosonde Data).

*e. Continuation of Selection of Significant Levels.* After the procedures outlined in *a* through *d* above, have been applied, the selection of significant levels is continued upward. When the next level has been selected, the temperature and humidity linearity requirements (*b* above) are checked, the provisional rules (*c* above) are applied, and the selected levels are evaluated (*d* above). Successive applications of this procedure are made until the recorder operator

encounters the terminal level. When the terminal level is reached, the recorder operator draws a level through this final point (rule 9), checks the linearity requirements, and applies the provisional rules to the last unevaluated stratum of the record. All established levels are evaluated and recorded on the radio-sonde data sheet.

*f. Expediting the Selection of Significant Levels.*  
 If no definite reason can be found for selecting a level within a sizeable area of the record (according to the judgment of the recorder operator), the process of evaluation is speeded up by selecting a new level at a point representing significant changes in the curves of temperature and humidity. In general, points of significant change are points through which levels would have been selected to satisfy the linearity requirements, if there were levels available for constructing the lines of linearity. The selection of a level through a point of significant change in temperature traces is illustrated at 2 in figure 95. There

is no definite reason for selecting a significant level from contact number 25 (1, fig. 95) up to contact number 36.5 (3, fig. 95). If the recorder record is advancing at a speed of one-half inch per minute, this point is not available to the recorder operator for about 5 minutes after the point of significant change. By immediately selecting a level at the point of significant change (2, fig. 95) instead of waiting for a definite reason for selecting a level, the recorder operator is able to evaluate the temperature, humidity, and pressure data earlier. Also, the other members of the temperature-density team, the plotter and the computer, can begin their duties sooner. This same procedure can be applied to significant changes in relative humidity. The selection of levels through points of significant change requires a thorough knowledge of the rules for recorder record evaluation. This procedure should not be adopted by anyone who has not had considerable practice and experience in applying the rules.

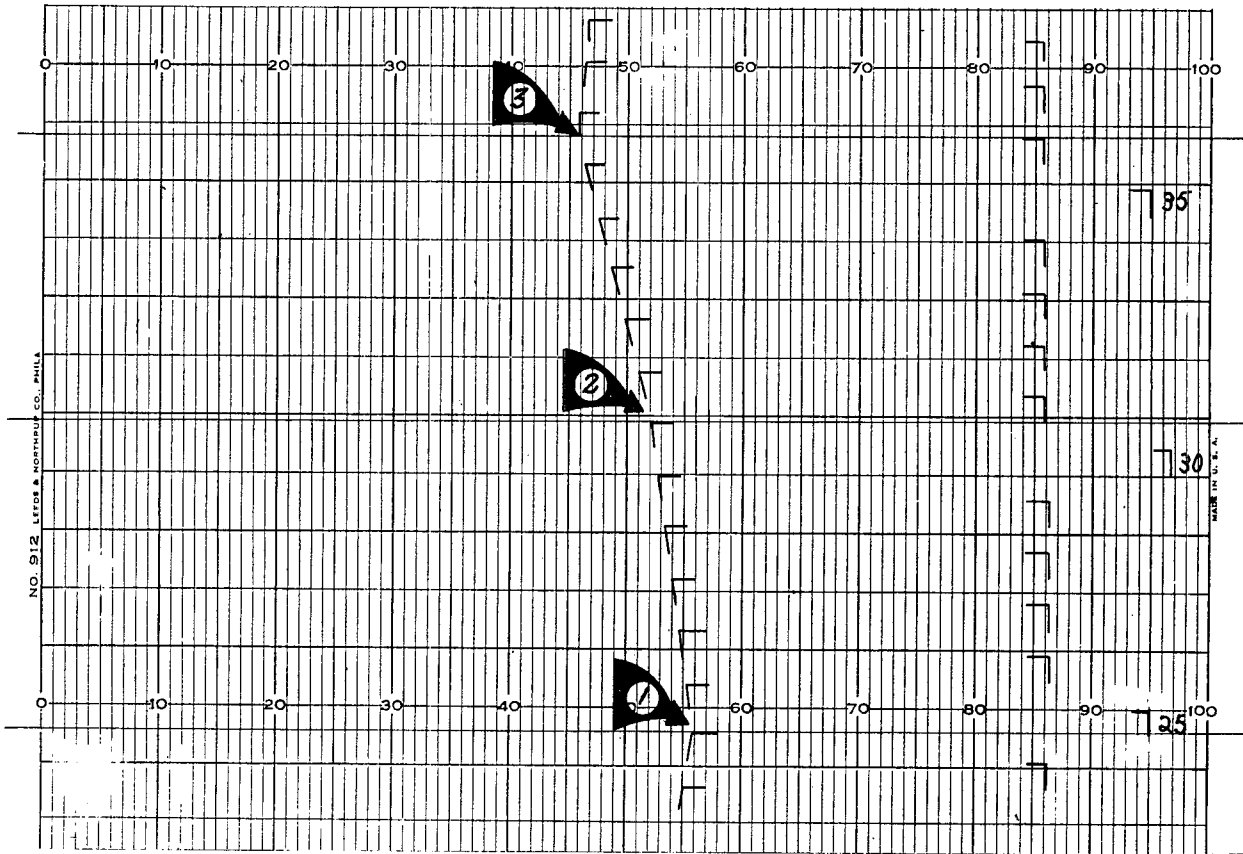


Figure 95. Significant change in temperature traces.

*g. Illustration.* The radiosonde recorder record (fig. 101) is evaluated in accordance with the general procedure in *a* through *f* above. The order in which each significant level was selected is entered in parentheses below the level line in the left margin of the record. The selection rule is also entered below the level line on the record. These numbers and rules normally are not entered on the record but are shown here for identification purposes only.

### 135. Evaluation of Significant Levels

The evaluation of significant levels selected on the recorder record is performed in several steps. First, the surface observations at the time of release are recorded on the record, and the surface level is evaluated for the release contact number. Then, the level contact number, the temperature recorder divisions, the humidity trace recorder divisions, and the sequence number of the level are evaluated from the record for each significant level aloft. Next, certain pertinent corrections are applied to these values. Finally, the corrected values are recorded on DA Form 6-43.

### 136. Recording Surface Observations at Release

At the time of release of the radiosonde, surface observations of temperature, relative humidity, and pressure are made. This information plus certain other necessary facts are entered on the recorder record. After the surface level has been drawn on the recorder record, certain items of information are entered on the record as shown in figure 96. These items are listed below.

*a.* The words SURFACE RELEASE and the Greenwich Mean Time (GMT) of release, immediately above the surface level.

*b.* The words SURFACE OBSERVATIONS AT RELEASE, immediately below the surface level.

*c.* The surface pressure in millibars and the contact number corresponding to this pressure on the radiosonde calibration chart.

*d.* The dry-bulb temperature of the outside air to the nearest  $0.1^{\circ}$  C.

*e.* The wet-bulb temperature to the nearest  $0.1^{\circ}$  C.

*f.* The relative humidity in percent determined from chart VIII, FM 6-16, with the wet-bulb and dry-bulb temperatures in *d* and *e* above.

*g.* The actual release contact number determined from the traces on the record. This release contact

number is also entered above the surface level to the left of the first temperature trace (1, fig. 96).

*h.* The contact error which is obtained by algebraically subtracting the contact number corresponding to the surface pressure (*c* above) from the actual release contact number (*g* above). The pressure contact number (*c* above) is considered the correct value.

*i.* The contact correction which has the sign opposite to that of the contact error in *h* above. For magnitude of correction, see paragraph 139*a*.

*j.* The cutoff recorder division value and the 20 percent relative humidity recorder value (2, fig. 96). For determination of these limits, see paragraph 133*e*.

### 137. Evaluation of Release Level

*a.* The first step in evaluating the surface contact number is to identify and label the first reference trace printed after release of the radiosonde. The normal method of determining the contact number of the first reference trace is based on the fact that the recorder operator must know the contact setting of the pin arm corresponding to the surface pressure (par. 111). He, therefore, can determine the contact number of the first reference trace printed. A contact begins at the top of a temperature trace and includes the following humidity or reference trace and the following temperature trace. Thus, the top of each temperature trace corresponds to a whole numbered contact. With the contact number of the first reference trace printed after release as a starting point, the operator counts whole contacts down the temperature traces to the top of the first temperature trace printed after release. He then compares the distance from the release level to the top of the first temperature trace with the distance occupied by the first whole contact to determine the fractional part of the contact printed before the top of the first temperature trace. This fractional part is subtracted from the first whole numbered contact to determine the release contact number to the nearest tenth. This contact number is recorded just above the surface level and to the left of the temperature traces (1, fig. 96). In figure 96, release occurred within contact number 5, i.e., the first reference. In order to determine the release contact number within the 5th contact, the contact beginning at 6.0 (5, fig. 96) and ending at 7.0 (6, fig. 96) is inspected. The distance from 6.0 to 7.0 contact is measured by laying a strip of paper along the traces and marking



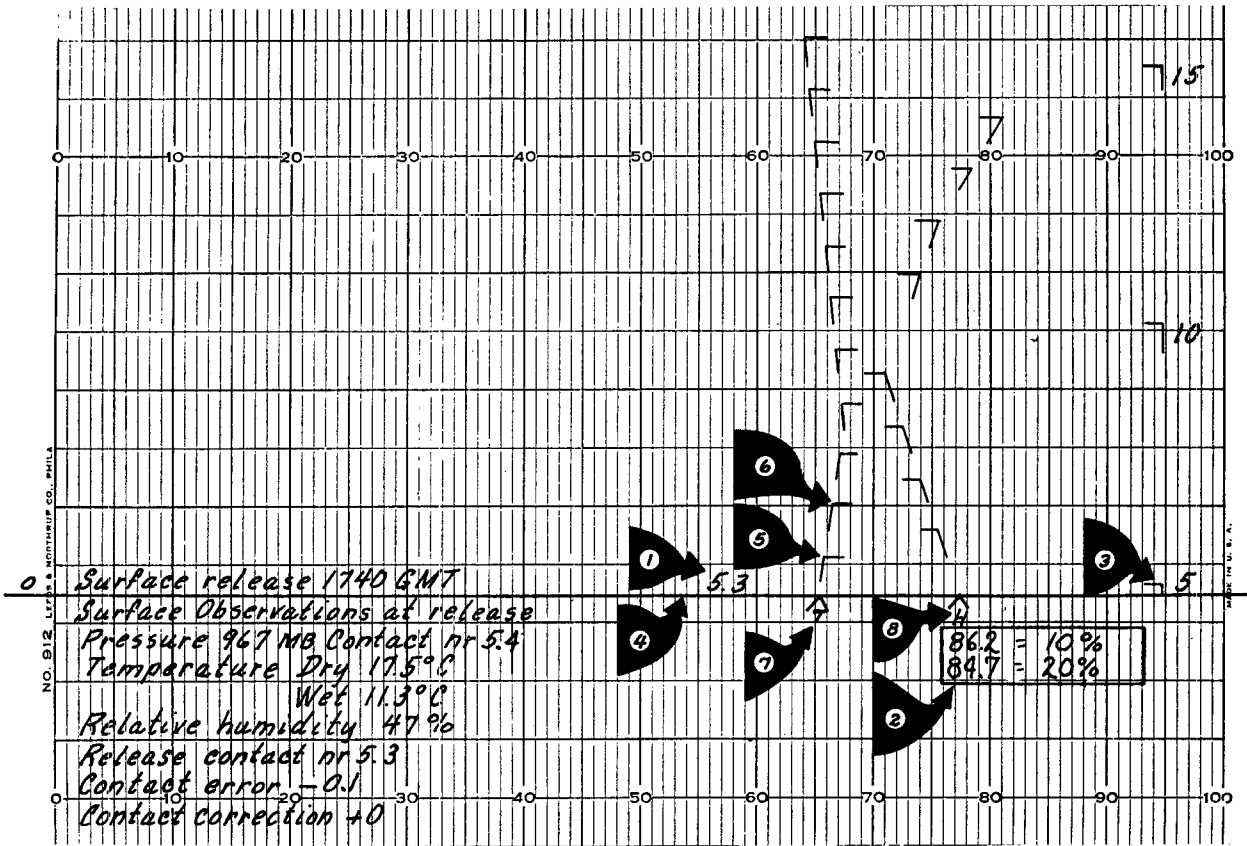


Figure 96. Surface observations and release level evaluation.

off the contact distance. The portion of the 5th contact printed after release is determined by comparing the distance from surface level to 5 with the contact length marked on the strip of paper. In figure 96, the portion of the 5th contact printed after release is 0.7 contact. This portion is subtracted from the first whole-numbered contact (6.0) to determine the contact number at release (6.0 - 0.7 = 5.3).

b. Surface observations are based on psychrometric values whereas levels aloft are selected according to radiosonde data. In order to keep the stratum between the release level and the first significant level aloft within the required 1° C. and 10 percent humidity linearity, the psychrometric surface values must be plotted and used in determining linearity. The psychrometric temperature and humidity at surface are converted to recorder divisions with the humidity-temperature computer. Each value is then plotted on the release level with

a “^”, and the temperature and humidity are marked with a “T” and “H,” respectively (7 and 8, fig. 96).

### 138. Significant Levels Aloft

a. Contact Number. Contact numbers for levels aloft are determined in a manner similar to that for determining the contact number of the surface level (par. 137). The determination of the contact number of a level aloft normally is begun at one of the reference traces which bracket the level, and the count from the reference trace to the level may go either up or down. Since the relative lengths of the traces will vary, it is important that contact numbers for significant levels be determined with reference to the whole contact in which the level is drawn, rather than by assigning fractional contact values to the various traces. That is, a temperature trace, for example, will not necessarily be 0.7 of a contact. Each significant level is assigned a contact number

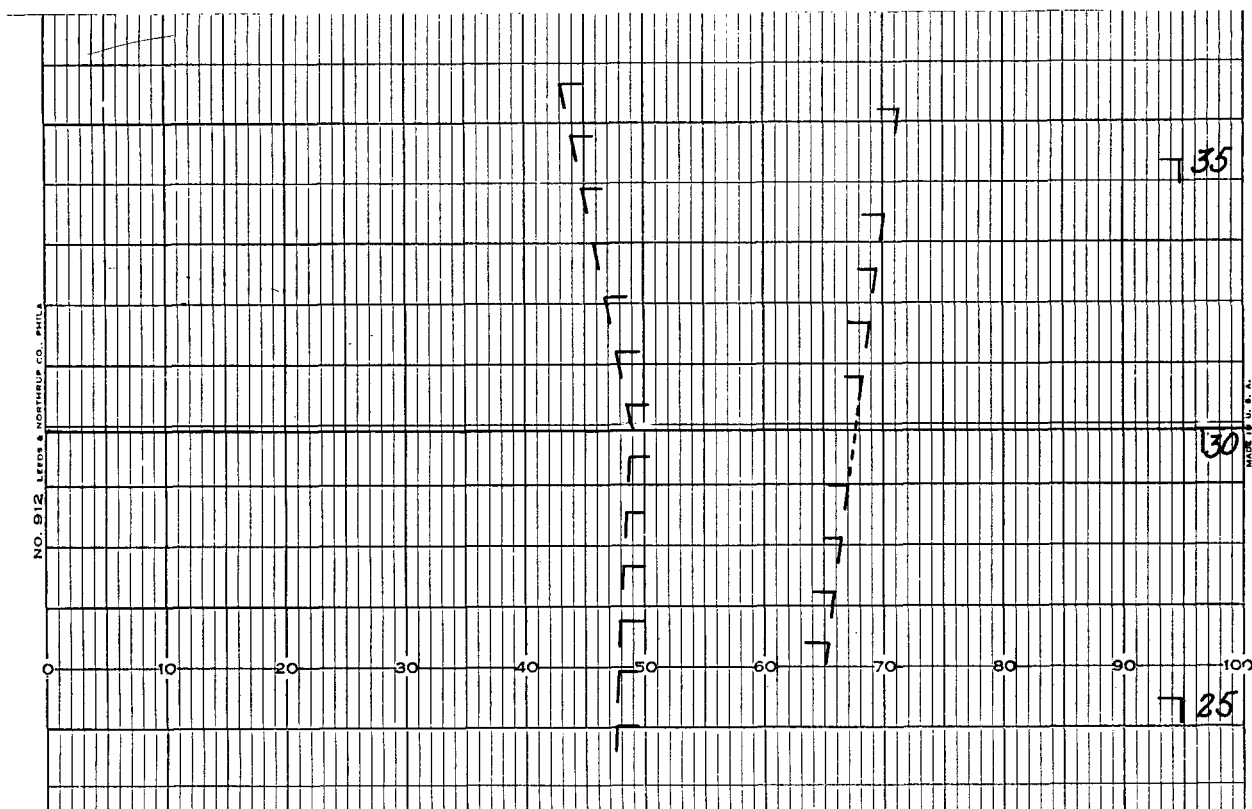


Figure 97. Humidity traces aligned.

based on the location of the level within the whole contact. In order to facilitate the evaluation of level contact numbers, all reference traces should be numbered (fig. 96).

*b. Temperature Recorder Divisions.* The uncorrected value of temperature recorder divisions for each level is read at the point of intersection of the level with the left edge of the temperature trace. When the significant level line does not intersect a temperature trace, the value of the recorder divisions is established at the point of intersection of the significant level line and a line drawn from the top left edge of the lower trace and the bottom left edge of the upper trace. The value of temperature ordinate is read and recorded to the nearest 0.1 recorder division.

*c. Humidity Recorder Divisions.* The uncorrected value of humidity for each level is read at the point of intersection of the significant level line and the humidity trace. When the significant level does not intersect a humidity trace, the uncorrected value of humidity is established at the intersection of the

significant level and a humidity trend line according to the following:

- (1) When the humidity traces immediately above and below the level follow the same general trend, a straight line is drawn connecting the traces immediately above and below the level (fig. 97).
- (2) When a humidity trace reverses direction or is displaced at the level, the temperature traces are examined. If the temperature traces above the level trend more to the right than they do below the level, a straight vertical line is drawn to extend, to the level line, that part of the adjacent humidity trace which has the higher value of relative humidity (1, fig. 99). If the temperature traces above the level trend more to the left, than those below the level, a straight vertical line is drawn to extend that part of the adjacent humidity trace which has the lower value of relative humidity (2, fig. 99).

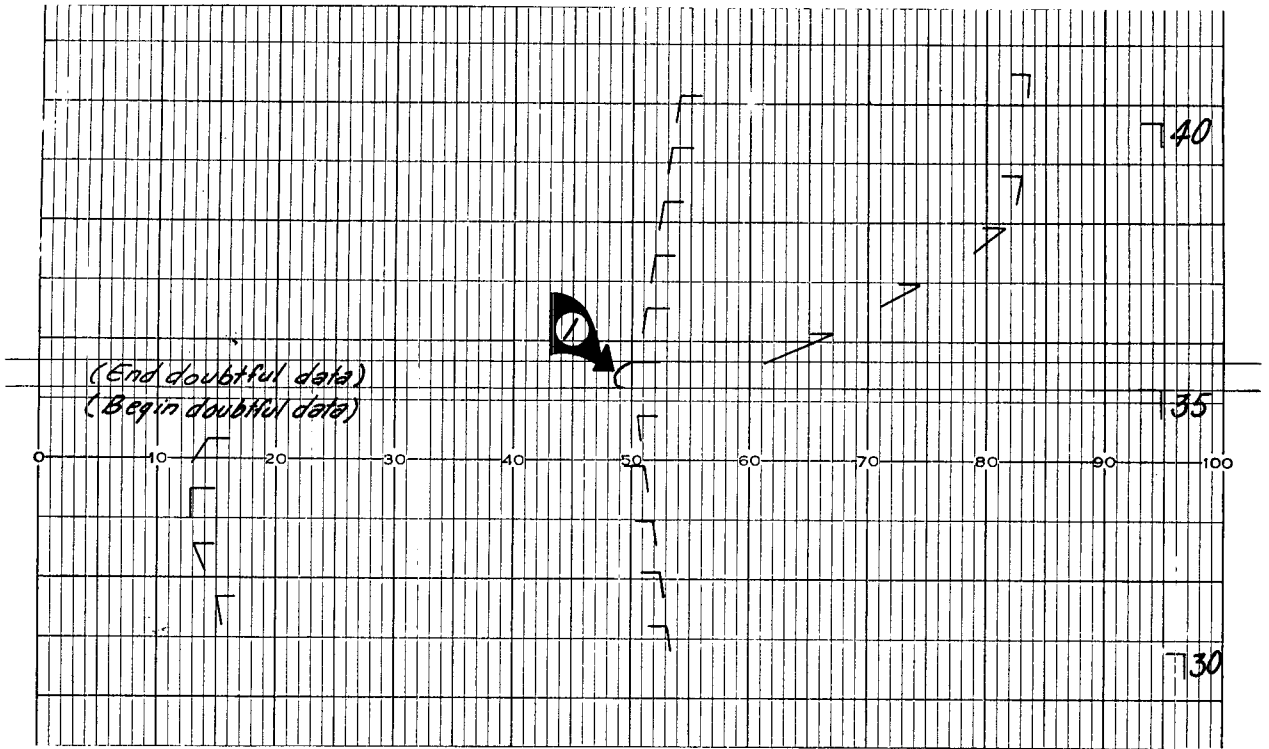


Figure 98. Evaluation of humidity at level of change and "wet-bulb" effect.

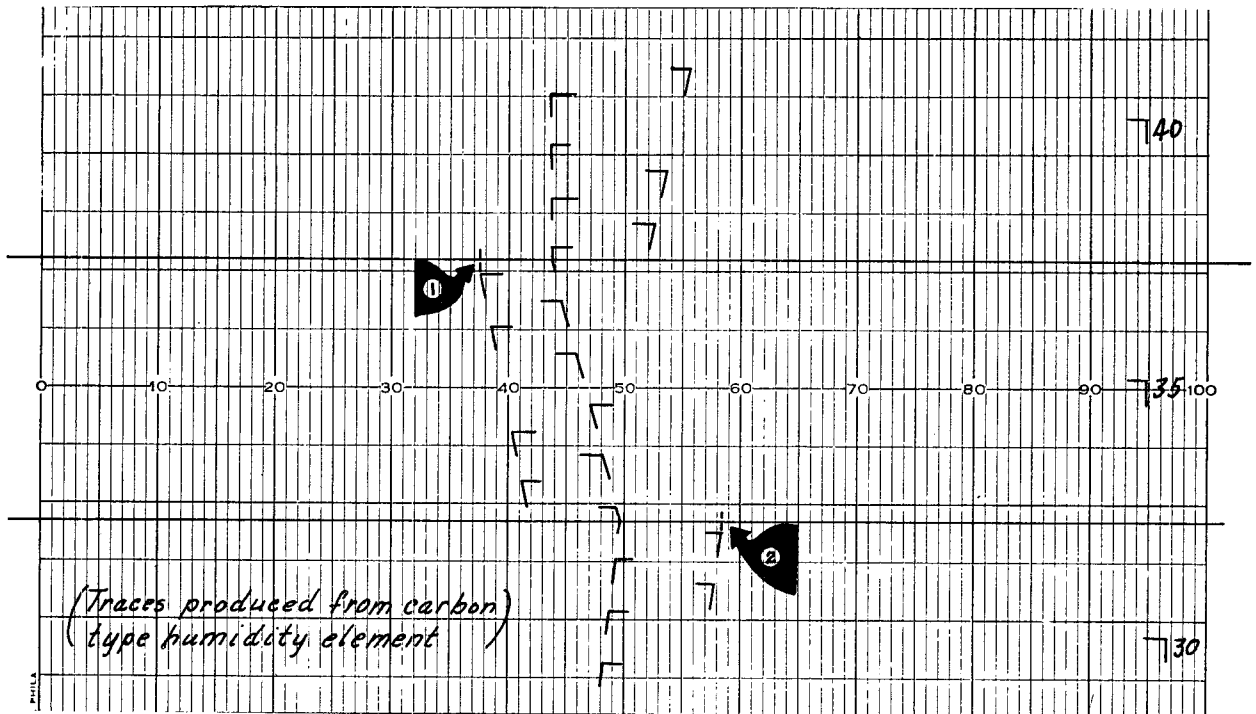


Figure 99. Humidity traces displaced.

- (3) The value of recorder divisions for humidity at levels selected to fulfill cutoff requirements is the cutoff value determined as outlined in paragraph 133e and is recorded below the significant level and followed by “=10%” (fig. 100). The whole entry is inclosed in parentheses. Humidity at a level within a stratum where humidity motorboats is evaluated as “motorboating.” The letters “MB” are placed below the level and are enclosed in parentheses (MB) (fig. 100).
- (4) When a level occurs (for any reason) where the humidity trace is between the cutoff value and the 20 percent value, the humidity is evaluated as 10 percent and the same entry is made as for cutoff in (3) above. In fact, as a result of this and paragraph 133g(7), it suffices to state that

the relative humidity is always considered to be 10 percent anywhere in this region of the chart.

d. *Level Number.* The levels are numbered in sequence, starting with the surface level as zero and ending with the terminal level. The level is numbered after all the rules for selecting levels have been applied to the area below it. Levels selected within areas of missing data are assigned a level number and evaluated as missing data (MD).

e. *Wet-Bulb Effect on Temperature.* When the radiosonde passes through a cloud, moisture may condense on the temperature element. After emerging from the cloud into dry air, the moisture evaporates and cools the temperature element. This cooling may cause the temperature trace to slope sharply to the left on the recorder record for a shallow stratum until all the moisture has evaporated from the element. This effect is known as the

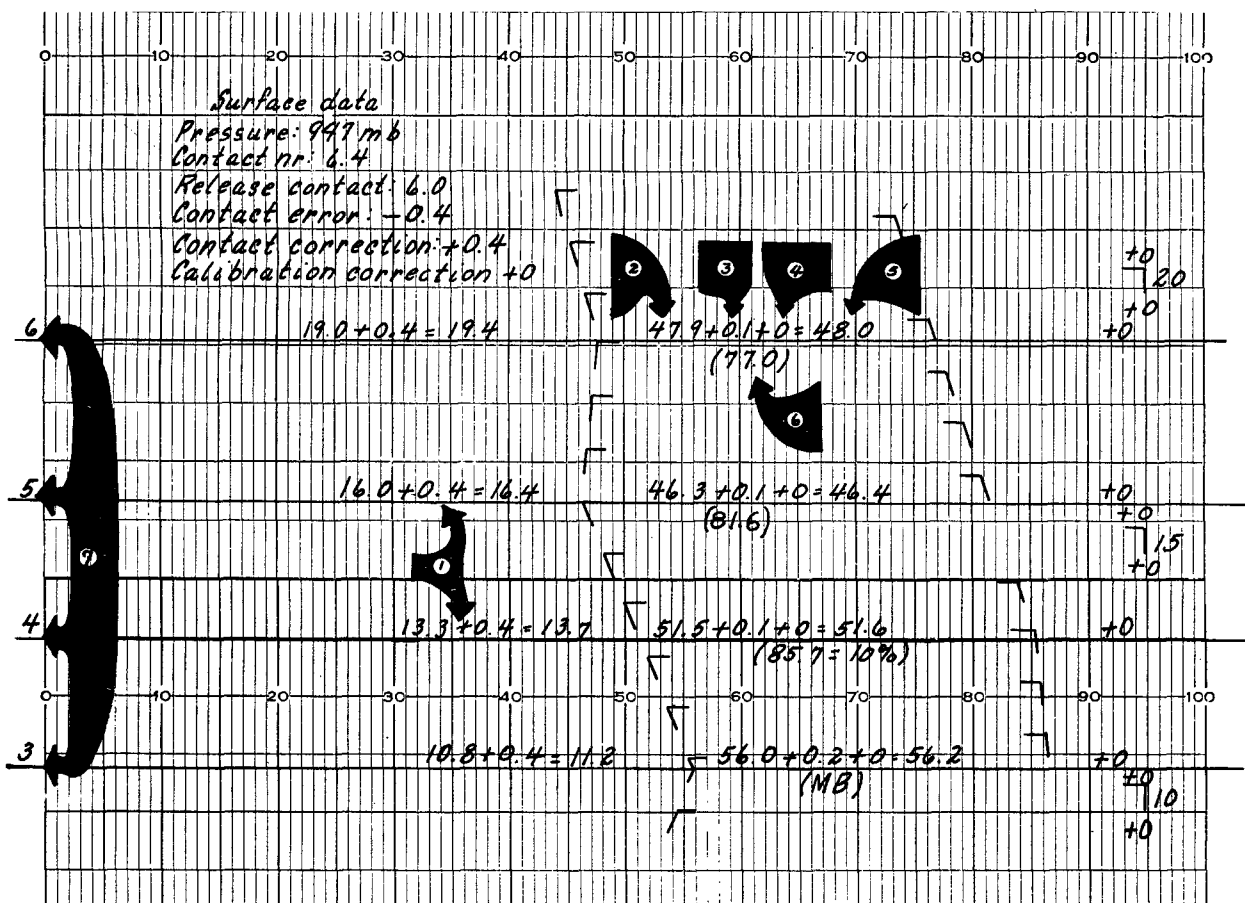


Figure 100. Evaluating significant levels and applying contact and calibration corrections.

*wet-bulb effect*, and the temperature is evaluated as doubtful from the cloud top to the level at which the temperature trace resumes normal lapse, inversion or isothermal (1, fig. 98).

*f. Multiple Ascents.* When multiple ascents occur due to icing, heavy rain, or turbulence, the highest altitude (lowest pressure) on the initial ascent is evaluated. When the balloon resumes its ascent, the same pressure level is evaluated on the final ascent.

*g. Recording Evaluated Data on Significant Levels.* The uncorrected contact number, the uncorrected values of temperature and humidity recorder divisions, and the number for each level evaluated are entered directly on the recorder record. Corrections to these values, where applicable, also are entered on the record. Contact numbers are entered above each level and to the left of the temperature trace. If a contact number correction is required, the correction is algebraically added to the contact number on the record as shown at 1 in figure 100. If no contact number correction is required, the value read from the record is the only value recorded (fig. 101). Uncorrected temperature recorder divisions are entered above each level line and just to the right of the temperature trace (where space permits) (2, fig. 100). After the uncorrected recorder division value, a recorder calibration correction (3, fig. 100) is entered, followed by either a frequency drift correction or a combined frequency shift plus drift correction (4, fig. 100). These values are added algebraically and the sum, the corrected recorder division value (5, fig. 100), is entered after the drift correction. The methods of determining the corrections for the recorder calibration, the frequency drift, and the frequency shift plus drift are explained in paragraph 139*b* through *g*. Uncorrected humidity recorder divisions are entered beneath each level and to the right of the temperature trace (6, fig. 100). Humidity evaluations of (MB) and for cutoff also are entered in this location. No corrections are made to humidity evaluations of (MB) or cutoff. Humidity recorder division values are corrected only under certain circumstances as described in paragraph 139*i*. If a calibration correction and a drift correction or a shift plus drift correction are required, they are recorded in the same manner and sequence as the corrections for temperature recorder division values. All humidity evaluations are inclosed in parentheses to aid in their identification. The level number is entered above

each level in the left-hand margin of the chart (7, fig. 100).

*Figure 101. Radiosonde recorder record.*

(Located in back of manual)

### 139. Corrections to Significant Level Evaluations

Several types of corrections are applied to the data evaluated from the significant levels. Level contact numbers are subject to a correction for erroneous pin arm setting. Recorder division values of temperature must be corrected for errors introduced by recorder misalignment and by drift or shift of the radiosonde pulse frequency. These values also are subject to corrections for inadvertent high reference adjustment and paper drift which results from faulty operation of the radiosonde recorder. Humidity recorder division values also must be corrected for these errors, when the total correction exceeds a certain limit (*i* below).

*a. Contact Correction.* The contact correction is determined by comparing the release contact number obtained from the radiosonde pressure calibration chart with the surface pressure reading taken at release. If the contact correction is 0 or  $\pm 0.1$  contact, it is disregarded. If the contact correction is greater than  $\pm 0.1$  contact, the contact numbers evaluated on the recorder record are corrected by the amount of the contact correction. The correction is applied to each significant level (1, fig. 100). In addition, the pressures corresponding to the corrected contact numbers must be read correctly from the radiosonde pressure calibration chart. (When discrepancies occur, the pressure-time plot data must be adjusted accordingly.) Contact discrepancies of 0.5 contact or more cannot be adequately corrected. When this situation exists, the flight should be disregarded and a new release initiated immediately.

*b. Calibration Correction.* The linearity calibration correction is applied by the recorder operator during the flight. This chart is constructed by the maintenance technician during the linearity calibration test, as described in TM 11-2436. A linearity calibration chart is shown at 1 in figure 102. The calibration chart is used to construct a calibration correction chart which is shown at 2 in figure 102. This correction chart is posted at the radiosonde recorder as a convenient reference for the radiosonde recorder operator during the evaluation of the record.

At the completion of the evaluation of the record, the linearity calibration chart (1, fig. 102), is inscribed at the bottom of each recorder record, during the period of its validity, for historical purposes. The calibration corrections are applied to all temperature recorder division values. Humidity recorder division values are corrected as specified in *i* below. To determine the correction for a particular recorder division value, the calibration correction chart is entered directly and read to the nearest 0.1 recorder division. For example, for an uncorrected recorder division value of 37.0 (fig. 102), the correction is +0.1 recorder division. This correction is applied to the recorder division value as described in paragraph 138g and as shown at 3 in figure 100.

*c. Drift Correction.* As a result of changes in battery voltages and resistances of the electrical components of the radiosonde, pulse frequency tends to drift. To compensate for this drift, the radiosonde recorder operator adjusts each low reference trace to 95 recorder divisions, as it is printed on the recorder record. Then corrections for the humidity

and temperature recorder division values are determined according to the amount of the drift at the corrected low reference. The determination of the drift correction at any level is based on the assumption that the drift is linear between low reference traces except at the surface (*e* below). (Figure 103 illustrates the procedure for determining drift corrections.) The amount of drift from 95 recorder divisions is first determined at the top and bottom of each low reference trace (1, fig. 103). A drift correction line (2, fig. 103) is drawn from the bottom of the drifted low reference trace to the top of the previous low reference trace. The amount of drift between the two low reference traces is determined at the intersection of the significant level and the drift line. The difference between the recorder division value of the point of intersection and 95.0 recorder divisions represents the drift at 95.0. The drift correction (to the nearest 0.1 recorder division) is entered immediately above the level and left of the drift line (3, fig. 103). Any recorder division value which is to be corrected at the level must be corrected by a proportionate part of the drift at 95.0

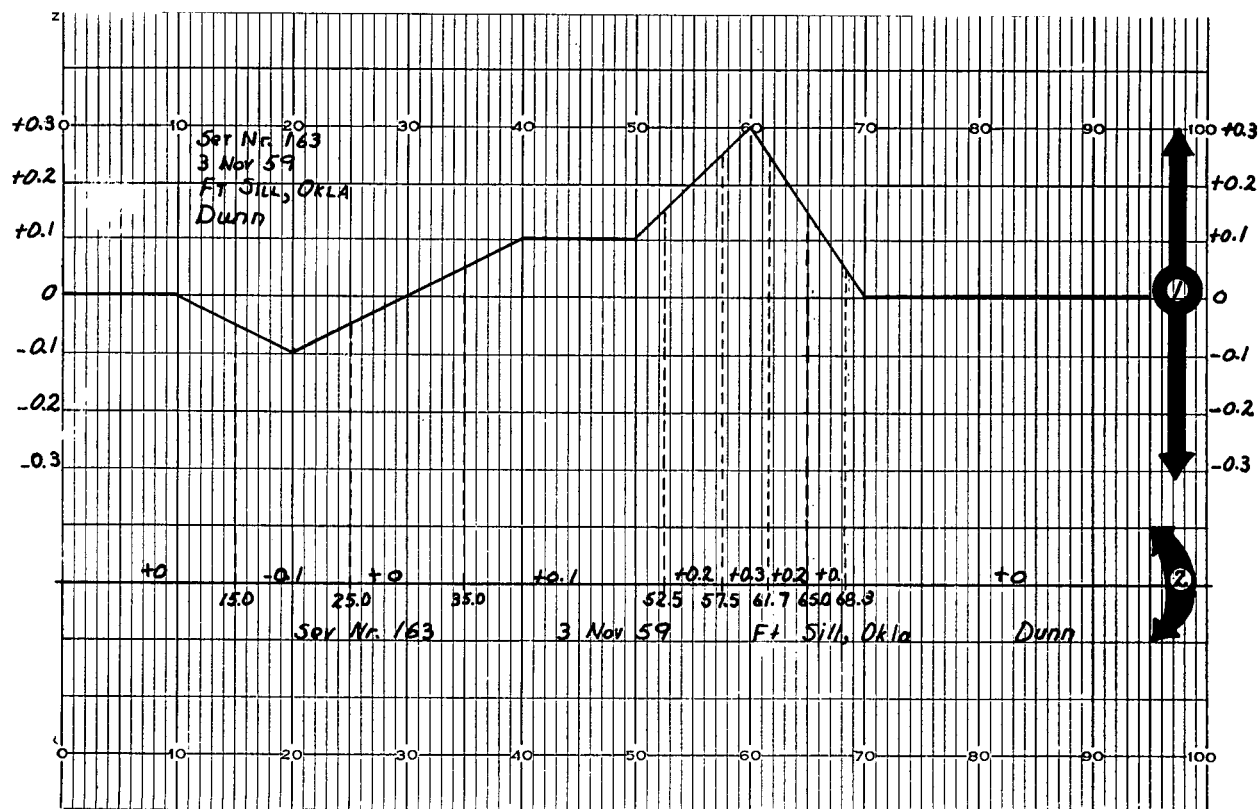


Figure 102. Recorder linearity calibration chart.

recorder divisions, since frequency drift is proportional to the frequency of the signal. This correction equals the recorder division value of temperature or humidity multiplied by the drift at 95.0 recorder divisions and divided by 95, the value of low reference. Determination of this correction is facilitated by use of the drift chart in figure 104. The radiosonde recorder operator may construct a drift chart on a section of the recorder record. A horizontal line is selected as the base of the chart. Straight lines are drawn from the 0 recorder division point on the base to the points where the horizontal lines intersect the vertical line representing 95.0 recorder divisions. To the right of these points, the horizontal lines above the base are numbered in tenths from 0.1 to 1.0. To determine the drift

correction, the chart is entered with the uncorrected recorder division value. This value is projected vertically to the diagonal line representing the amount of drift at 95.0 recorder divisions. From this point, a line is projected horizontally to the correction scale on the right edge of the drift chart, and the drift correction is read to the nearest 0.1. As an example, for an uncorrected recorder division value of 60.8, the drift at 95.0 recorder divisions is determined to be +0.4. The drift chart (fig. 104) is entered at the recorder division value of 60.8. This value is projected vertically to intersect the diagonal line labeled 0.4. From this point a line is projected horizontally to the correction scale which indicates a correction of +0.3. The correction (+0.3) is the drift correction. The drift correction

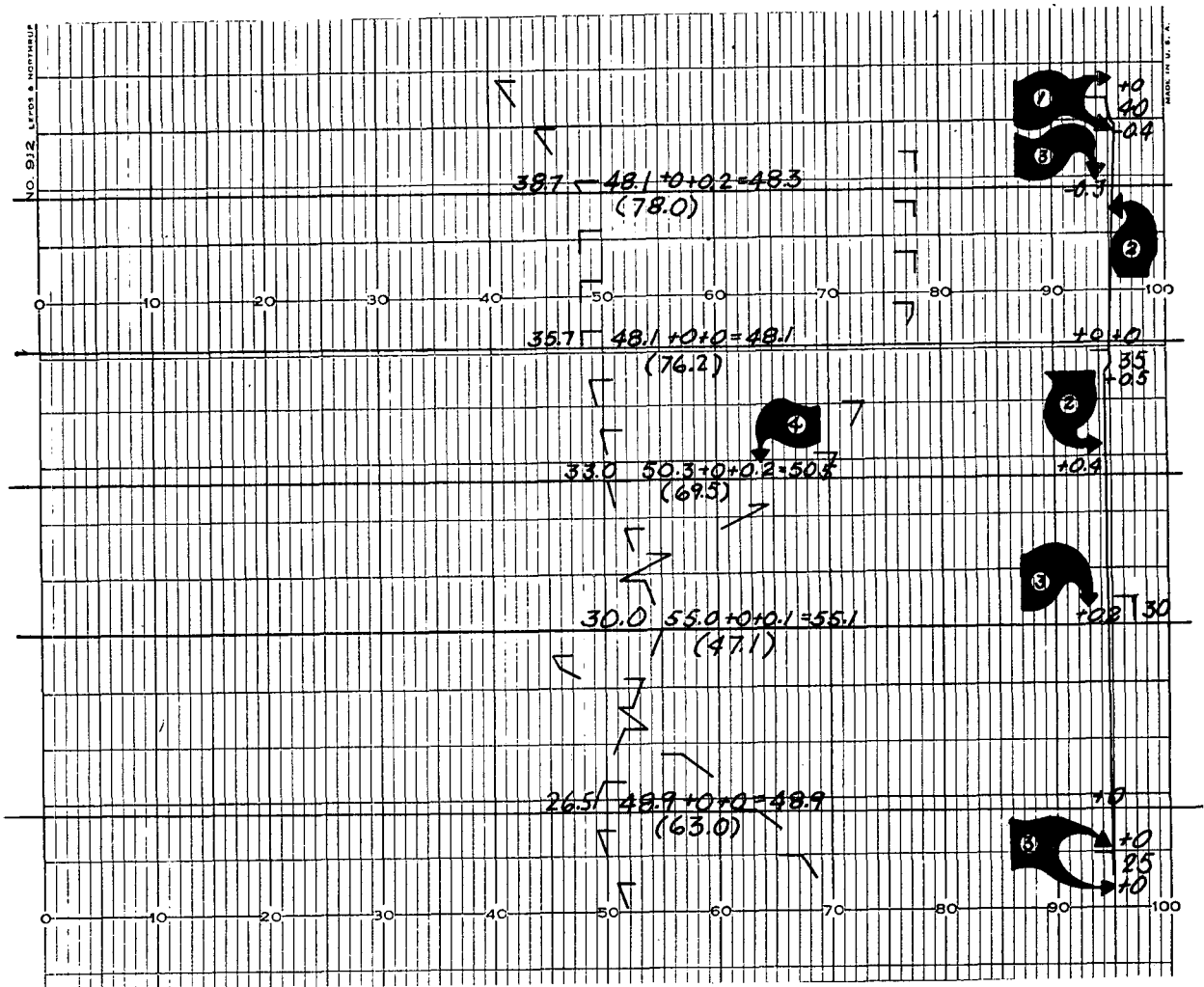


Figure 103. Frequency drift correction.

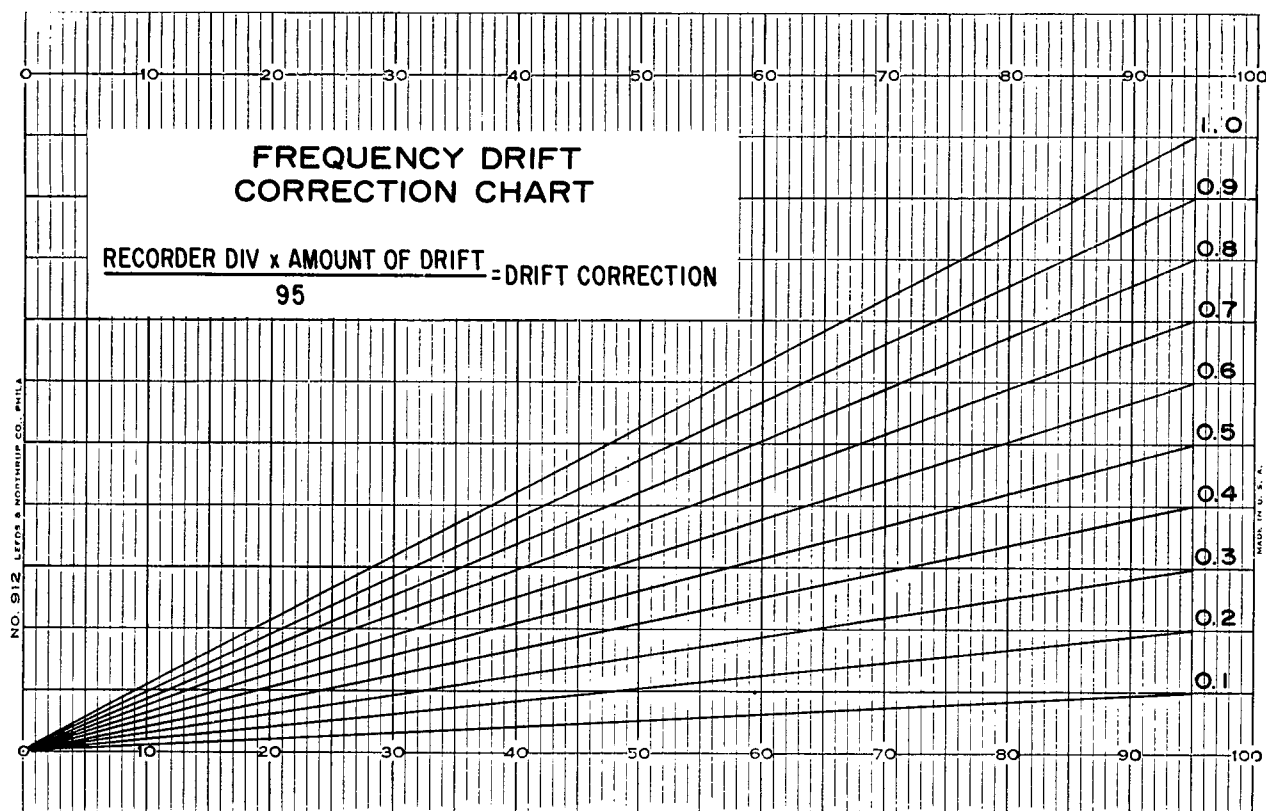


Figure 104. Use of the frequency drift chart.

is applied to the recorder division value as described in paragraph 138g.

d. *Frequency Shift Corrections.* An instantaneous change of electrical response in the components of the radiosonde may create a frequency shift. A shift is apparent when there is an abrupt change in the recorder division value of a temperature, relative humidity, or reference trace. (Note that changes in the positions of temperature and humidity traces resulting from the adjustment of a low reference trace to compensate for drift are not shifts.) Usually a shift will affect the frequency of all the recorded signals. When a shift occurs (1, fig. 105), the radiosonde recorder operator *should not* make a correction with the reference adjust handwheel until a low reference trace is being printed. The low reference trace is adjusted to 95.0 recorder divisions (2, fig. 105). This adjustment may compensate for drift (c above) in addition to the shift. A horizontal line is drawn to the right edge of the record. If the shift occurs during a temperature or humidity trace, the amount of shift at 95.0 recorder divisions must be computed based on the amount of shift occurring

within the trace. The amount of shift is multiplied by 95 and the answer is divided by the recorder division value at which the shift occurred. The computations necessary to determine the amount of shift at 95.0 recorder divisions are shown at 3, figure 105. When the adjustment of the low reference trace is greater or less than the shift computed for 95.0 recorder divisions, drift also has occurred. This condition exists at 4, figure 105; in this case, a drift correction line is constructed between the adjusted low reference trace and the preceding low reference trace. The computed shift at 95.0 recorder divisions is marked off at the beginning of the adjusted reference trace in the opposite direction of the shift (4, fig. 105). The drift line is drawn between this point and the top of the preceding low reference trace. The line at 5, figure 105 that is broken above the shift and solid below the shift represents the drift that occurred between the two low reference traces. Only the drift correction (determined from the solid portion of the drift line) is applied to significant levels below the shift. Levels between the shift and the corrected



low reference must be corrected for both drift and shift. A shift plus drift correction line is constructed in this area. The computed shift at 95.0 recorder divisions is marked off in the direction of the shift, beginning at the intersection of the level of the shift and the drift line (6, fig. 105). The shift plus drift line is a solid line drawn from this point to the point where the corrected reference trace began. The intersection of this line with any significant level represents the shift plus drift correction at 95.0 recorder divisions for the level. The drift chart (fig. 104) is used to determine the proportional part of the shift plus drift correction which is applicable to any particular value of recorder divisions. The traces evaluated at level 3 in figure 105 are affected only by the drift measured at the intersection of the level and the drift line. The traces evaluated at level 4 are affected by both the shift and the drift

measured at the intersection of the level with the shift plus drift corrections to recorder division values as described in paragraph 138g.

e. *Drift of First Low Reference Trace.* If a drift occurs in the first low reference trace after release, it is corrected in the same manner as explained in paragraph 139c. In the case of the first low reference trace after release, the drift line is drawn from the bottom of this trace to the top of the reference trace obtained during the reference temperature check (par. 119d). This is illustrated in figure 101.

f. *Singular Shifts.* When a shift occurs only in the temperature trace and is 1° C. or less as computed on the temperature-humidity evaluator, no correction is applied. If the temperature shift is more than 1° C. but not more than 3° C., a proportionate part of this shift must be applied to the recorder division values of temperatures at signifi-

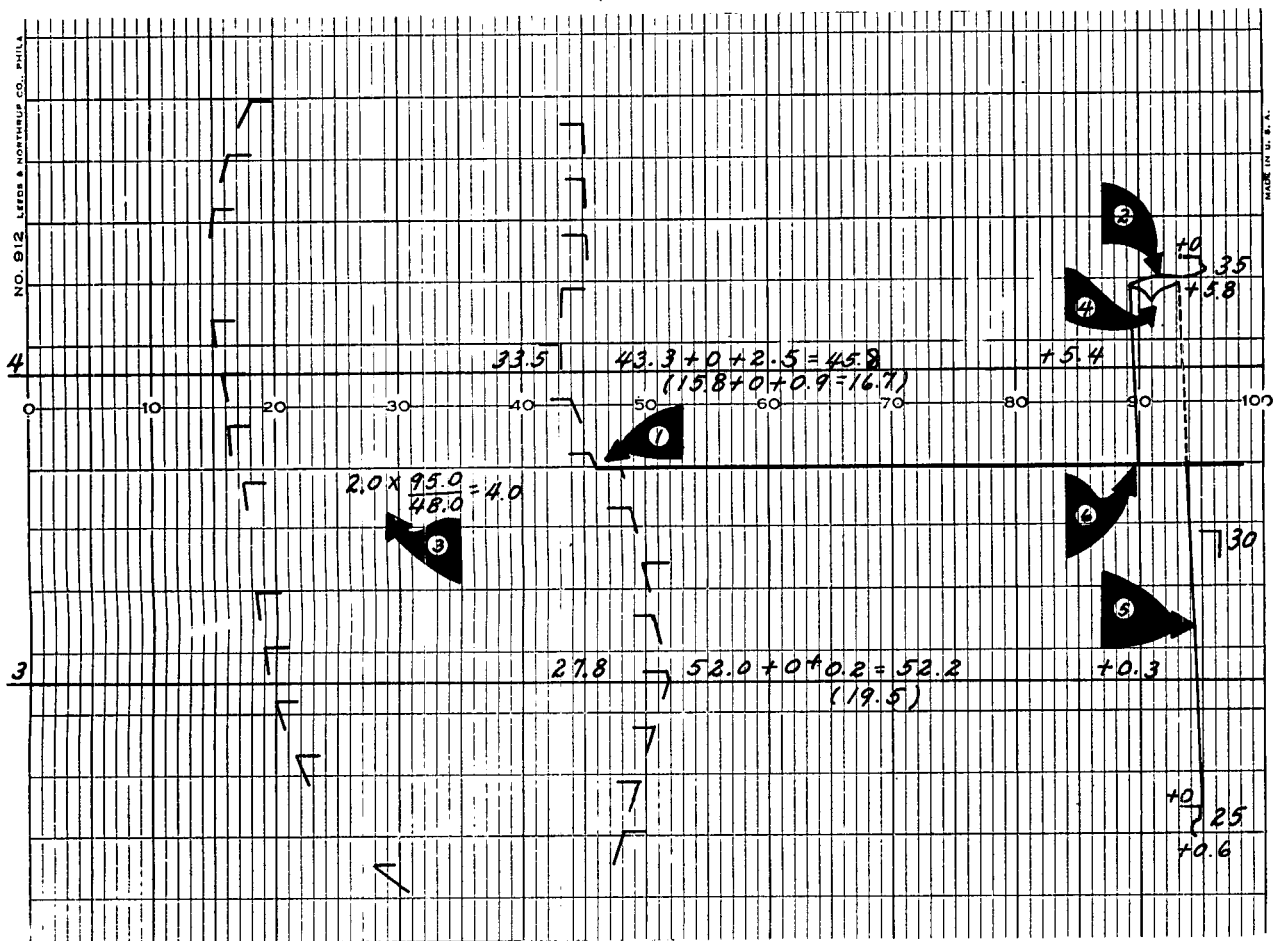


Figure 105. Determining shift or shift plus drift corrections.

cant levels which follow. Temperatures which fall in this category will be classified as doubtful. If the shift occurs in temperature only and is more than 3° C., the temperatures are not evaluated beyond the shift and are classified as missing. When a shift occurs in relative humidity only and is 10 percent or less, no correction is applied. However, if the relative humidity shift is greater than 10 percent, succeeding relative humidity values which are not in the motorboating position, as previously described, are classified as missing. Doubtful data may be used in the computation of a ballistic metro message, but are transmitted to the Air Weather Service (USAF) as missing. The accuracy of doubtful temperatures may be determined by comparing the current sounding with a recent scheduled flight no more than 6 hours old. The temperatures for several significant levels should reflect a high degree of consistency.

*g. Correction for High Reference Trace Adjustment.* Occasionally, the recorder operator may mistake a high reference trace for a low reference trace and adjust it to a value of 95.0 recorder divisions (1, fig. 106). This action causes a shift in the traces after adjustment. Any levels selected in this area (level 5, fig. 106) must be corrected for shift as well as any drift that may have occurred. Levels selected in the area between the adjusted high reference and the preceding low reference (level 4, fig. 106) are not affected by the shift, but may be affected by the drift. The amount of drift must be determined. The first step in drawing the correction lines for these areas is to measure the amount of shift resulting from the adjustment of the high reference trace to 95.0 recorder divisions. (As measured at 1 in fig. 106, the shift is 1.8 recorder divisions.) The amount of this shift is marked off in the opposite direction of the shift at the beginning of the following low reference (2, fig. 106). If the mark is not at 95.0 recorder divisions, drift (3, fig. 106) has occurred in addition to the shift between the two low reference traces. A drift correction line is drawn from the mark to the top of the preceding low reference trace. This line is drawn as a broken line in the area above the shift and as a solid line in the area below the shift (4, fig. 106). In the area where the drift line is broken, the correction for the shift which affects the traces in this area must be added to the drift line to obtain the final shift plus drift correction line. To draw the shift plus drift correction line, the amount of the shift (1.8 ordinates, from 95.0 recorder

divisions at 1 in fig. 106) is marked off in the direction of the adjustment, beginning at the intersection of the level of the shift and the drift line (5, fig. 106). The shift plus drift correction line (6, fig. 106) is drawn between this mark and the beginning of the corrected low reference trace. Temperature recorder division values for levels which intersect either of the solid correction lines are corrected with the drift chart (fig. 104) as described in *c* above. Humidity recorder division values are corrected in the same manner as temperature values, but corrections to humidity values are applied only under the conditions specified in *i* below.

*h. Chart Drift Correction.* If the chart feed system of the radiosonde recorder is not properly alined, the recorder chart may drift (fig. 107). Drift is evident when the chart rides off the cogs of the chart roller. To avoid inaccuracies caused by chart drift and the difficulties of correction, the recorder operator should carefully aline the chart during the starting procedure. Procedures for alining the chart with the chart feed mechanism are outlined in TM 11-2436. If it appears that the chart is drifting while a flight is being recorded, the SIGNAL SELECTOR switch is rotated to the S.C. position for about 10 seconds to obtain a zero print (1, fig. 107). This check is made at a point in the record where no significant data will be lost, e.g., during a high reference trace or a long temperature trace. During the remainder of the flight (or as long as the record continues to drift), a zero print may be obtained each time a high reference trace is transmitted by the radiosonde (2 and 3, fig. 107). Successive zero prints are connected with a thin straight line (4, fig. 107). The difference between the position of this chart drift line and the 0 recorder division line is the amount of the chart drift. After the chart drift lines are drawn, the chart drift correction at the 0 recorder division line is determined for any level selected during the period of chart drift, and the amount of the correction is entered at the intersection of the level and the chart drift line (5, 6, and 7, fig. 107). The corrections for chart drift to be applied to ordinate values are computed as follows: Subtract from 95 (low reference ordinate value) the uncorrected temperature ordinate value. Multiply the remainder by the chart drift correction at the given significant level and divide the product by 95. The quotient is the required correction for that temperature ordinate. For example, if the temperature ordinate at a given level is 39.8 (8, fig. 107) and

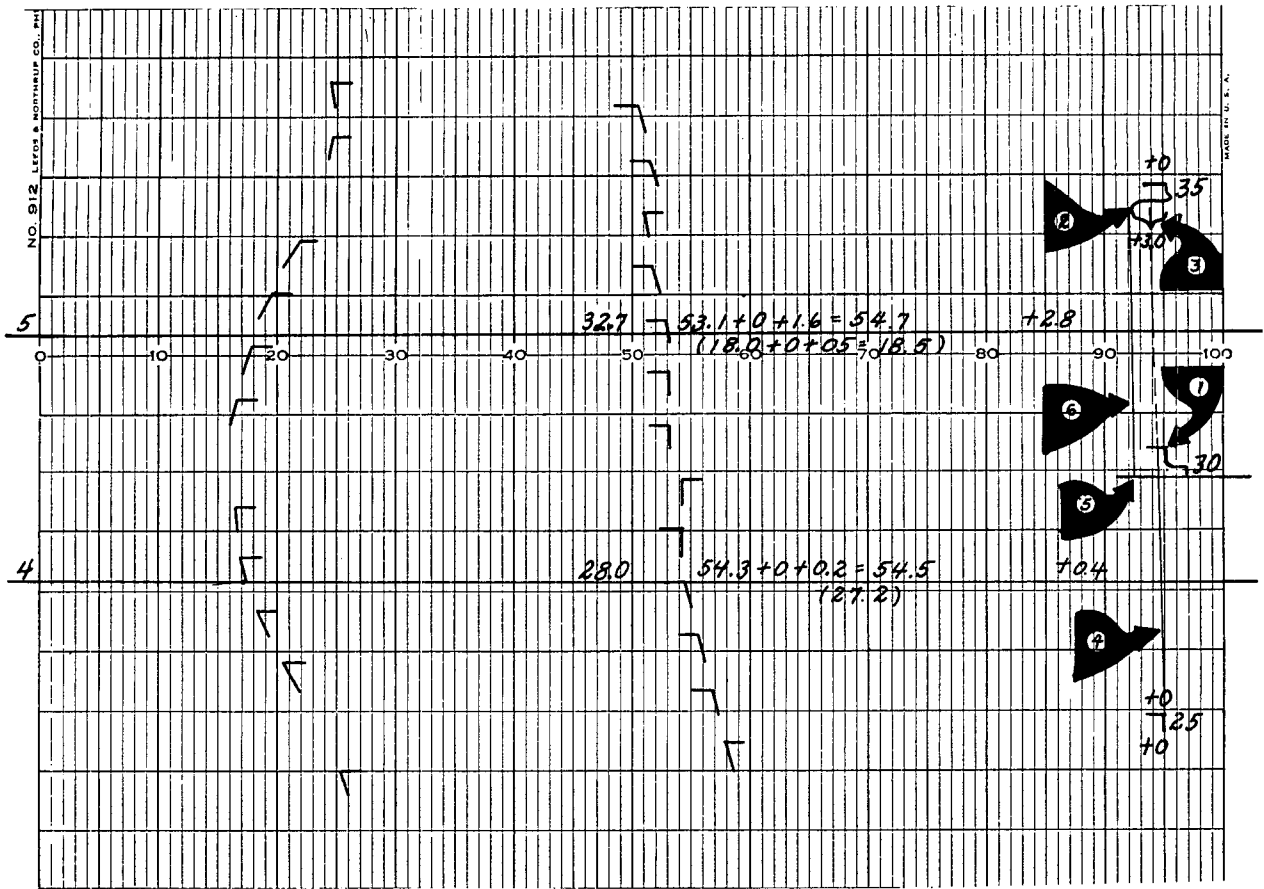


Figure 106. Determining corrections for high reference adjustment.

the chart drift is +0.8 ordinates (6, fig. 107), the correction is computed as follows:

$$95 - 39.8 = 55.2.$$

$$\text{Therefore } \frac{55.2 \times 0.8}{95} = +0.465$$

= +0.5 (rounded off to

the nearest tenth), which is the required chart drift correction for the ordinate 39.8. This correction of +0.5 is entered at 9 in figure 107. The chart drift correction is read to the nearest 0.1 recorded division (0.5). A chart drift correction is applied to the temperature recorder division values, when the chart drift is evaluated as 0.3 recorder divisions or more. The humidity recorder division value is corrected in the same manner as the temperature value, but the correction to a humidity value is applied only under the conditions specified in *i* below.

*i. Correcting Humidity Recorder Division Values.* Humidity recorder division values for any level, except levels selected in an area of chart drift, are

corrected only when the total shift plus drift correction at 95.0 recorder divisions exceeds 1.0 recorder division\* for that level. The humidity recorder division value for a level selected in an area where chart drift has occurred is corrected when the algebraic sum of chart drift at the 0 recorder division and the shift plus drift correction at 95.0 recorder divisions exceeds 1.0 recorder division\*. The shift plus drift correction at 95.0 recorder divisions includes the effects (if any) of drift (*c* above), shift (*d* above), and high reference adjustments (*g* above). This correction is computed by determining the difference between the approximately constructed correction line (drift or shift line, or combination thereof) and 95.0 ordinates at the levels in question. The appropriate sign for the correction must also be determined as described for temperature in *c*, *d*, and *g* above. When the shift plus drift correction at 95.0 recorder divisions plus chart drift at 0 is 1.0\* or

\* When the humidity element is ML-418, this may be 2.0 recorder divisions.

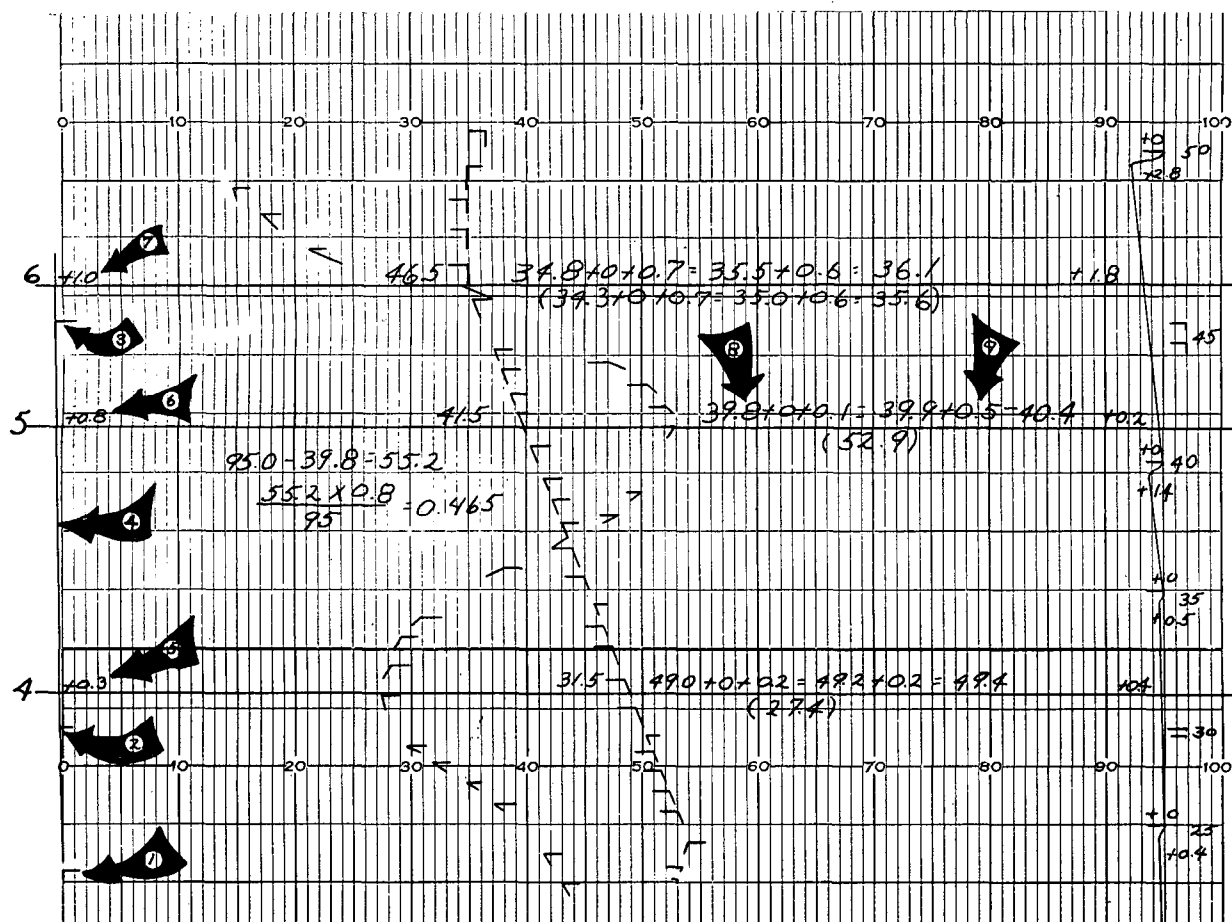


Figure 107. Determining chart drift corrections.

less, the uncorrected humidity recorder division value is entered in parentheses beneath the level (fig. 107, level 4). If the shift plus drift correction at 95.0 recorder divisions plus chart drift at 0 exceeds 1.0\*, a recorder calibration correction (*b* above) and a shift plus drift correction (*c*, *d*, and *g* above) are applied to the uncorrected humidity recorder division value followed by application (if required) of a chart drift correction (*h* above) (fig. 107, level 6).

#### 140. Special Considerations

*a. Leaking Aneroid Pressure Cell.* Evidence that the aneroid pressure cell in the radiosonde is leaking may be noted at pressures less than 100 mb. The traces will be unusually short and it will appear that an abnormally rapid ascension rate has developed. This condition will persist until the balloon bursts or until the pin arm leaves the commutator bar and

a continuous temperature trace begins. In such cases, it is difficult to determine exactly where the pressure cell began to leak. Therefore, all data may be in error, and a second flight should be made. At pressures greater than 100 mb., short traces may result from an actual increase in the rate of ascension due to updrafts. In this instance, the traces will return to normal length when the balloon moves out of the area of ascending air currents. When balloon ML-541 is being used, unusually short traces may occur when the balloon attains high rates of rise due to the design character. In this instance, traces will return to normal at high altitudes.

*b. Termination Due to Doubtful or Missing Data.*

- (1) When a stratum of missing temperature data is followed by a satisfactory record, the computations are continued, if the missing data do not exceed—

- (a) From the surface to 700 mb., 100 mb. of missing data.
  - (b) From the surface to 400 mb., 250 mb. of cumulative missing data, with (a) above satisfied.
  - (c) From the surface to 100 mb., 4 kilometers of cumulative missing data, with (a) and (b) above satisfied.
  - (d) From the surface to the termination of the flight, 5 kilometers of cumulative missing data, with (a), (b), and (c) above satisfied.
- (2) When the tropopause occurs within a stratum of missing temperature data that is more than 1,500 meters thick, the flight will be terminated.
  - (3) When the missing data in one stratum exceed the limits in (1) above, computations are terminated at the base of the stratum. When the sum of the missing data through several layers exceeds the limits in (1) above, the computations are terminated at the base of the stratum in which the limit is exceeded (last usable trace). If the termination level does not meet the desired altitude, another release will be made with the least possible delay.
  - (4) When any portion of the temperature record cannot be clearly evaluated, the computations are continued in the normal manner, except that more than 100 mb. of doubtful temperature data below 700 mb.

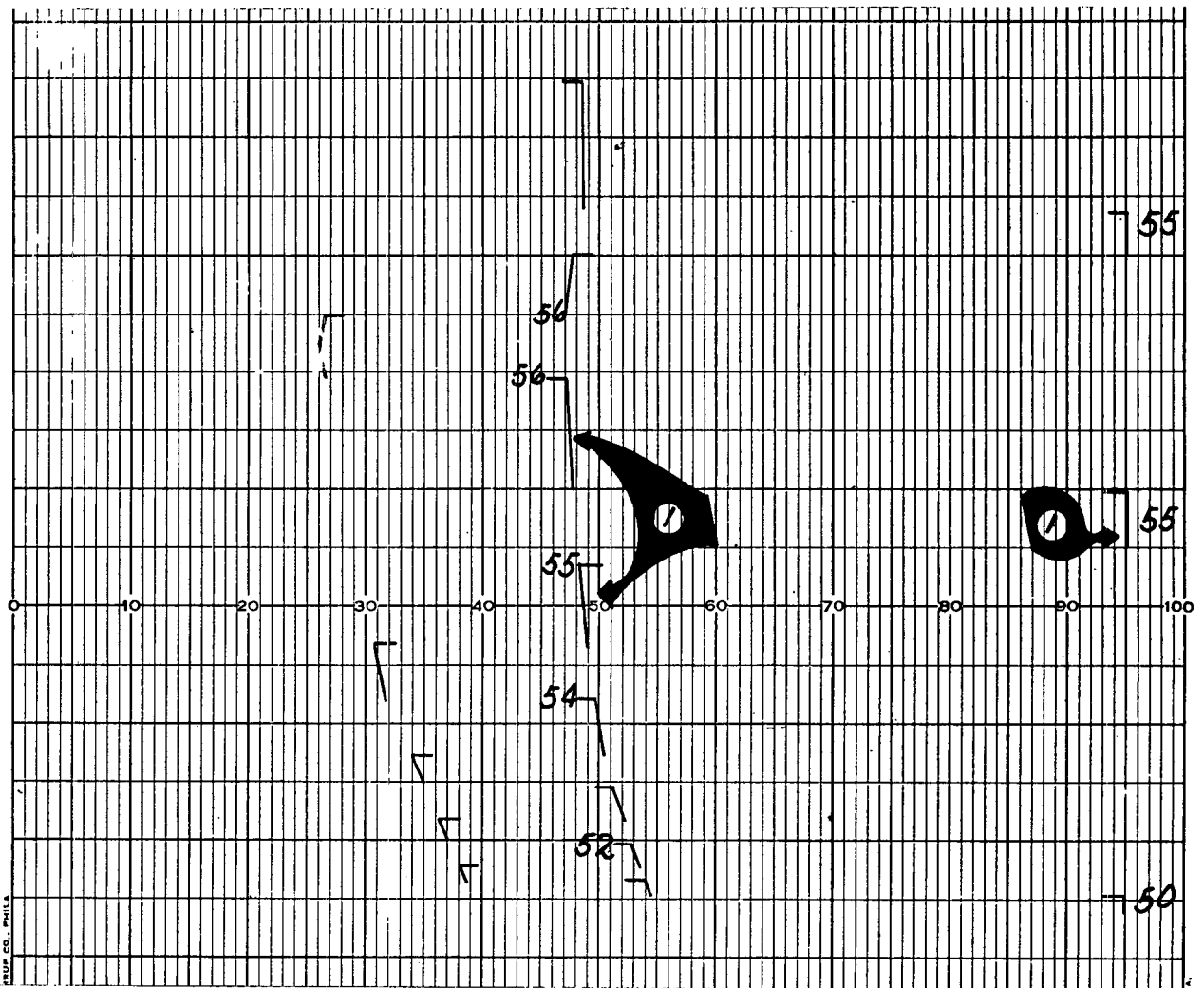


Figure 108. Icing.

necessitates another release.

- (5) As long as a stratum or strata of missing data does not exceed the above limits, the valid data are plotted on chart ML-574 and extrapolation is used in areas of missing data.

*c. Icing.* Icing causes a decrease in the ascension rate of the radiosonde balloon and is indicated by longer traces on the recorder record (1, fig. 108). Since the ascension rate can be decreased by turbulence as well as icing, the temperature and relative humidity traces must be examined critically before assuming that icing occurred. When icing occurs, the length of the traces will increase as more and more ice accumulates on the balloon. Usually, these longer traces will not be apparent in less than four contacts. Before assuming that icing has occurred, the temperature should be below freezing and the relative humidity near 100 percent.

*d. Floater.* A floater is a radiosonde flight in which the balloon reaches an altitude and seems to maintain a fairly constant altitude. This floating may be caused by icing, turbulence, or a leaky balloon. A second release may be necessary. When it becomes apparent from the length of time the balloon stays in a floating state that it will not assume a normal rate of rise, preparations for a second release should be started.

*e. Evaluation of Special and Significant Levels with the Hypsometer Radiosonde.*

- (1) *When to use the hypsometer pressure calibration chart.* The hypsometric pressure readings should be checked against the pressure capsule calibration chart readings between 50 and 20 millibars. When the criteria set forth in paragraph 143i(4)(a) are obtained, the hypsometer readings are used to evaluate pressure, utilizing a hypsometer pressure calibration chart such as shown on 3, figure 79.
- (2) *Significant level evaluation.* When the hypsometer calibration chart is used to evaluate the pressures at significant levels, the recorder division value of the hypsometer line of linearity is evaluated at the point where the hypsometer trace (or extension thereof) intersects the significant level. The recorder division value is entered on the record to the left of the hypsometer trace (or extension thereof) and above the significant level (par. 143).

#### 141. Evaluation of Radiosonde Recorder Records Produced by Radiosondes Using Lithium Chloride (ML-418) Humidity Elements

The same procedures as described above will be used in the evaluation of these recorder records, except as indicated below.

*a.* The ML-418 humidity element is constructed so that its electrical resistance varies *inversely* with the moisture content of the air. Therefore, lower humidity values are located on the left of the radiosonde recorder record. When the relative humidity is very low, the resistance of the humidity element becomes so high that the current in the measuring circuit bypasses the element through the "motorboating" resistor. This situation produces a motorboating trace on the recorder record at a fairly constant 5.0 recorder divisions or less. The points where humidity traces assume this value and the points where they depart from this value are known as cutoff points. Levels are selected at these cutoff points and within motorboating strata according to the rules in paragraph 133e and f. Any significant level which satisfies a cutoff requirement is evaluated as 5.0 recorder divisions for humidity. This value is recorded under the significant level and is inclosed in parentheses.

*b.* When an ML-418 humidity element is used, the full length of relative humidity traces, unlike temperature traces, cannot always be regarded as representing valid data. This humidity element is subject to an electrochemical phenomenon known as polarization. This condition is indicated on the recorder record by a decrease in the ordinate value of a humidity trace, over and above any apparent change in humidity, as indicated by successive traces. The traces appear to have "tails" (1, fig. 109). The effects of polarization may be masked when the humidity is changing rapidly (3, fig. 109).

*c.* When a significant level intersects a relative humidity trace, the relative humidity is evaluated at the point where the significant level intersects the trace, unless that point of the trace is affected by polarization to the extent of 0.5 or more ordinates. In that case, trend lines (2, fig. 109) are drawn between the top left edges of the humidity traces and the humidity is evaluated at the point where the significant level intersects the trend line.

*d.* When a significant level does not intersect a humidity trace, the humidity is evaluated in accord-

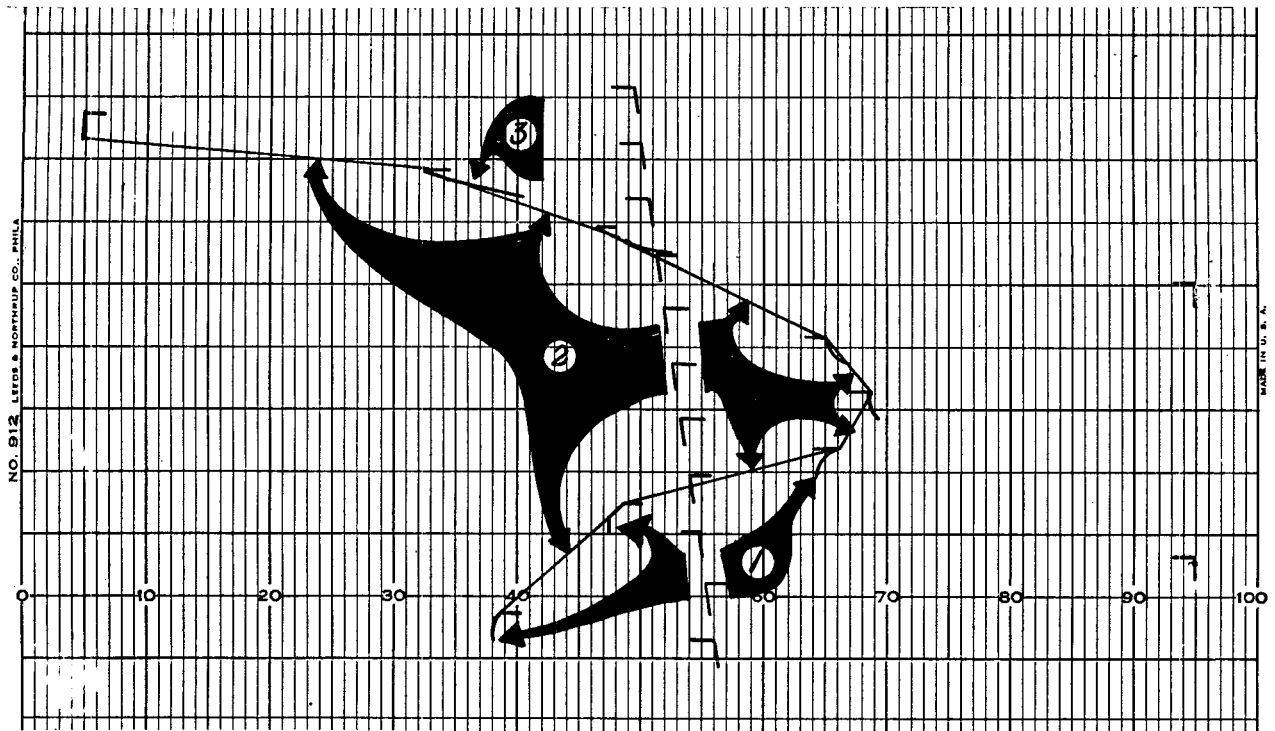


Figure 109. Polarized humidity traces.

ance with the instructions in paragraph 138. If polarization is evident, the top left edges of the traces are used when extrapolation is specified by the instructions in paragraph 138.

e. Figure 110 illustrates the selection and evaluation of significant levels on a recorder record which was produced by a radiosonde utilizing a ML-418 humidity element.

Figure 110. Evaluated radiosonde recorder record using humidity element ML-418.

(Located in back of manual)

### 142. Flight Duties of the Temperature-Density Plotter

The general duties of the temperature-density plotter during the radiosonde flight are to—

- a. Complete the surface observations and enter the results on DA Form 6-43, Radiosonde Data.
- b. Obtain and record on the radiosonde data form the corrected contact numbers and corrected recorder division values of relative humidity and temperature at significant levels.
- c. Convert the data in b above to pressure (in millibars), temperature (in °C.), and relative humid-

ity (in percent) by using the pressure calibration chart and the temperature-humidity evaluator and plot the virtual temperatures on chart ML-574.

d. Determine the mean zone densities and temperatures.

e. Assist and check the work of the radiosonde recorder operator.

### 143. Completion of DA Form 6-43 (Radiosonde Data)

The final step in evaluating a radiosonde recorder record is to complete the radiosonde data form (1 and 2, fig. 111). On this form are recorded the baseline check data, the release data, and the values of pressure, temperature, and relative humidity aloft. In completing the form, the station, location, date, release time, flight number, modulator serial number, name of computer, and name of checker are entered. Data for 1 and 2, figure 111, are obtained from figure 101.

a. *Baseline Check Data.* The following data from the baseline check observations are entered on DA Form 6-43 (1, fig. 111) in the spaces opposite the words BASELINE CHECK DATA:

- (1) *Column 1.* The contact setting (5.4) for





RADIOSONDE DATA (Continued)						
LEVEL NUMBER	PRESSURE		TEMPERATURE		RELATIVE HUMIDITY	
	CONTACT (1)	MILLIBARS (2)	RECORDER DIVISION (3)	°C (4)	RECORDER DIVISION (5)	% (6)
27	142.4	21	18.9	-45.8		
28	144.0	18	15.3	-51.8		
29	144.8	16	18.0	-47.3		
30	147.5	10	18.0	-47.3		
31	149.0	7	23.8	-38.5		
32	150.5	4	20.1	-44.0		
33						
34						
35						
36						
37						
38						
39						
40						
41						
42						
43						
44						
45						
46						
47						
48						
49						
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54						
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56						
57						
58						
59						

MODULATOR SERIAL NR. (7) <b>696900</b>	BASELINE CHECK TIME (LST) <b>1125</b> (GMT) <b>1725</b>	RECORDER OPERATOR <b>Jayson</b>	CHECKER <b>Schewer</b>
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②  
Figure 111—Continued.

the barometric pressure of the station, as determined from the radiosonde pressure calibration chart.

- (2) *Column 2.* The barometric pressure in millibars (967) used to determine the correct pin arm setting.
- (3) *Column 3.* The recorder division value of temperature (67.4) as evaluated from the baseline check.
- (4) *Column 4.* The dry-bulb temperature in degrees Celsius (21.5) observed inside the baseline check set; the wet-bulb temperature (12.7) in degrees Celsius observed inside the baseline check set; and the wet-bulb depression in degrees Celsius (8.8).
- (5) *Column 5.* The recorder division value of humidity (81.3) traces as evaluated from the baseline check.
- (6) *Column 6.* The percent of relative humidity (35) inside the baseline check set chamber as determined by entering chart VIII, FM 6-16, with the dry-bulb temperature and the wet-bulb depression to the nearest 0.1° C. (in column 4) as arguments.

*b. Release Data.* The following data from the surface observations at release are entered on DA Form 6-43 (1, fig. 111) in the spaces opposite the words RELEASE DATA:

- (1) *Column 1.* The release contact number evaluated for the surface level on the radiosonde recorder record.
- (2) *Column 2.* The barometric pressure in millibars (967) at the time of release.
- (3) *Column 4.* The atmospheric dry-bulb temperature in degrees Celsius (29.4) at the release time; the atmospheric wet-bulb temperature in degrees Celsius (12.7) at release time; and the wet-bulb depression in degrees Celsius (16.7).
- (4) *Column 6.* The percent of relative humidity (09) in the atmosphere as determined from chart VIII, FM 6-16.

*c. Surface Level.* The pressure dry-bulb temperature and relative humidity values entered opposite the word SUR are the same as those entered opposite RELEASE DATA. The recorder division values corresponding to the surface temperature and humidity are recorded in the appropriate blocks.

*d. Pressures Aloft.* In column 1 (1 and 2, fig. 111), the corrected contact number for each signifi-

cant level on the recorder record is entered opposite the level number. In column 2, the pressure in millibars is entered. The pressures for each level is obtained from appropriate pressure calibration chart with the correct number (column 1).

*e. Temperatures Aloft.* In column 3, the corrected recorder division value of temperature, for each level on the recorder record, is entered opposite the corresponding level number. The humidity-temperature computer is used to convert the recorder division values to temperatures to the nearest 0.1° C. These temperatures are entered in column 4 for the corresponding recorder division values.

*f. Relative Humidities Aloft.* In column 5, the recorder division values of humidity (corrected if necessary) are entered opposite the corresponding level numbers. The humidity-temperature computer is used to convert the recorder division values to percent of relative humidity. The temperatures in column 4 for each level are used to determine the values of relative humidity which are entered in column 6, opposite the corresponding recorder divisions. Humidities for levels aloft should be read from the computer to the nearest whole percent. When the humidity is evaluated as motorboating (MB), it cannot be converted into percent and a dash is entered in column 6. A dash is interpreted as zero percent relative humidity.

*g. Doubtful Data.* Doubtful data are indicated with an asterisk on the data sheet.

*h. Missing Data.* Missing data are indicated with an "X" on the data sheet (level 13, fig. 111).

*i. Hypsometer Pressure Evaluation.*

- (1) Pressure-contact values for radiosonde AN/AMT-12 are evaluated in the same manner as those for radiosonde AN/AMT-4( ) up to the level where the hypsometer becomes usable. The hypsometer circuit starts with contact 106 and replaces the low reference contact before and after each high reference contact above 105. For example, contact 106, 109, 111, 114, and 116 are hypsometer contacts. In addition, contact 148 is used because of the small pressure change.

*Note.* The hypsometer will trace out a continuous curve (when individual traces are connected) which trends toward the left. Therefore, pressures can be evaluated at any level; not merely at the top or bottom of a trace. When the flight ends on a temperature trace, the trend of the

hypsoneter trace will be extrapolated upward to the terminal level. It should also be noted that after the balloon bursts, the hypsoneter trace will change direction and trend toward the right; however, pressure values are not valid during the descending portion.

- (2) After the baseline check of the radiosonde AN/AMT-12 has been computed, the radiosonde is removed from the baseline check set and the pin arm is raised off the commutator. The black test lead protruding from the right side of the case is touched to the eyelet on the extreme right of the commutator. This contact should energize the hypsoneter relay and connect the hypsoneter into the circuit. On grounding the contact, the reading on the recorder should be about 93 ordinates. If the reading is 95 ordinates or more, the hypsoneter circuit is shorted and the modulator should be replaced. A new baseline check is performed. Modulators rejected because of defective hypsoneters may still be used for soundings in which high-altitude data are not required. To disable the hypsoneter, the leads to the capsule are disconnected and soldered together, then the pressure information obtained will be the same as that obtained with a radiosonde AN/TMQ-4.
- (3) After the baseline and hypsoneter are checked, and the pin arm has been set, 5 cc. of carbon disulfide ( $CS_2$ , reagent grade) are inserted in the hypsoneter boiler. The radiosonde should be held upright until it is launched to prevent the fluid from spilling.
 

**Warning: Carbon disulfide is flammable and toxic. Do not smoke while filling the hypsoneter. Do not inhale the toxic fumes. Keep the bottle closed when not in use.**
- (4) The hypsoneter calibration chart is a curve of pressure versus hypsoneter ordinate divisions as traced on the recorder record. The hypsoneter trace for the AN/AMT-12 Radiosonde first appears on the recorder record during flight at about 90 ordinates and moves towards lower ordinate values with decreasing pressure. When the AN/AMT-12 Radiosonde is used, pressures will

be determined from the pressure capsule calibration chart until the difference between the pressures thus obtained and the pressures obtained from the hypsoneter calibration chart reach a point of least difference in the 50 to 20 millibar range. When the least pressure difference exceeds four millibars, computations will be terminated at 50 millibars as this magnitude of difference indicates a pressure error which is unacceptable at pressures below 50 millibars. When computations are terminated at 50 millibars, a second release will be made if the minimum height requirement has not been attained. When the least pressure difference is four millibars or less, the pressures for each significant level will be determined from the hypsoneter calibration chart using the hypsoneter ordinate values to the nearest tenth of a division. Pressures obtained from the hypsoneter calibration chart will be read to the nearest millibar at pressure equal to or greater than 20 millibars and to the nearest tenth of a millibar at pressures lower than 20 millibars as 9.6, 5.4, etc. Significant errors in radiosonde and rawin data can result in the area where switchover from aneroid to hypsoneter pressure values occurs. Consequently, to minimize these errors, the procedures will be used as follows:

- (a) Select the point between 50 and 20 millibars on the hypsoneter trace where the pressure difference between hypsoneter and aneroid is smallest and 4 millibars or less. Label this point A (1, fig. 112). If the pressure difference is less than 1 millibar, use the hypsoneter pressures (as shown at 5, fig. 112) from point A on, and disregard the following subparagraphs. An illustration where this occurs is shown at A in figure 110.
- (b) Locate and draw a horizontal line at the level where the number of minutes below point A is equal to two times the pressure difference at point A. The point of intersection of this line with the 95th recorder division is labeled "B" (2, fig. 112).
- (c) Use the aneroid calibration chart to

obtain the pressure corresponding to the aneroid pressure contact value at point B. Convert the millibars of pressure obtained to recorder divisions by using the hypsometer calibration chart.

- (d) On the recorder record, plot the recorder divisions derived in (c) above, on the horizontal line through point B. Label this plot as point C (3, fig. 112). Connect points A and C with a straight line (4, fig. 112).
- (e) Compute and use the hypsometer pressures for all significant levels falling between points A and C by using line AC as the hypsometer pressure curve.

**144. Determining Mean Zone Densities and Temperatures From Radiosonde Data**

a. *Plotting Data on Chart ML-574.* The radiosonde data recorded on DA Form 6-43 (1 and 2, fig. 111) are used to plot points on chart ML-574 (fig. 113) so that the upper air densities and tempera-

tures may be determined graphically from a sounding curve. Chart ML-574 is constructed so that, in any part of the chart, the difference in height between two pressure values is proportional to the distance between the isobars representing those pressure values, provided the distance is measured along the isotherm representing the mean virtual temperature of the layer of air. This distance is measured with a zone height scale ML-573 (fig. 114), which is graduated in meters and which also indicates the thickness of artillery standard zones. Artillery metro sections ordinarily use only the zone portion of the scale. On this scale, the distance between the unnumbered graduations is equal to the thickness of the zone. The number of the zone appears opposite the intermediate graduation at the midpoint of the zone. The intermediate graduations are labeled with the numbers of all the zones to which they apply.

b. *Description of Chart ML-574.*

- (1) Chart ML-574 (fig. 113) contains four sets of lines which are—

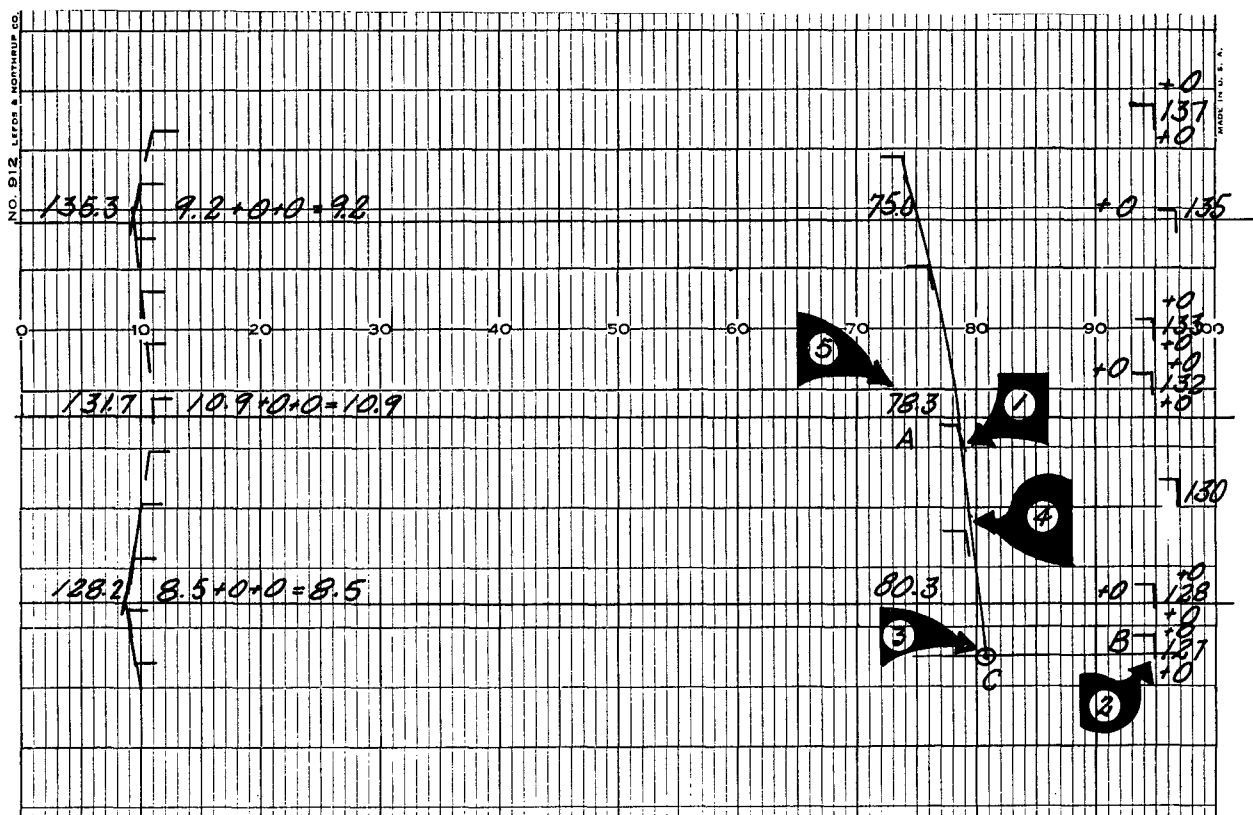


Figure 112. Hypsometer pressure evaluation.

- (a) Orange vertical lines of constant temperature (isotherms) graduated in degrees Celsius ( $^{\circ}\text{C}$ ).
  - (b) Orange constant pressure lines (isobars) sloping slightly upward from left to right.
  - (c) Short, blue, vertical lines, or hatchings, along certain isobars. The difference in temperature between successive hatchings on a given isobar indicates how much the virtual temperature exceeds the observed temperature at that pressure and temperature, if the relative humidity were 100 percent. These hatchings pertain only to the pressure scale on the right-hand edge of the chart.
  - (d) Blue lines of constant density, curving downward from left to right, labeled in grams per cubic meter ( $\text{gm}/\text{m}^3$ ).
- (2) The chart is presented in two parts—a high pressure part on the front side (1, fig. 113) and a low pressure part on the reverse side (2, fig. 113).
  - (3) The chart is a graphical solution of the hydrostatic equation and the equation of state.

①

Figure 113. Chart ML-574.

(Located in back of manual)

*c. Plotting Significant Data on Chart ML-574.*

The radiosonde data recorded on the DA Form 6-43 (temperature, pressure, and relative humidity) for each significant level are used to plot significant points on the sounding curve. Successive significant points are then connected with straight lines to produce the virtual temperature sounding curve. The size of the chart permits the plotting of the sounding curve in successive legs in order to obtain the data for a 15-line ballistic metro message. Each significant point used to construct the sounding curve is located by a value of pressure and a value of virtual temperature. (The virtual temperature of moist air is the temperature which dry air at the same pressure must have in order to have the same density as the moist air.) Vertical hatchings along the various isobars indicate how much greater the virtual temperature is than the observed temperature in that region of the chart, when the relative humidity is 100 percent. Thus, if the relative humidity is 50 percent, the location of the point is

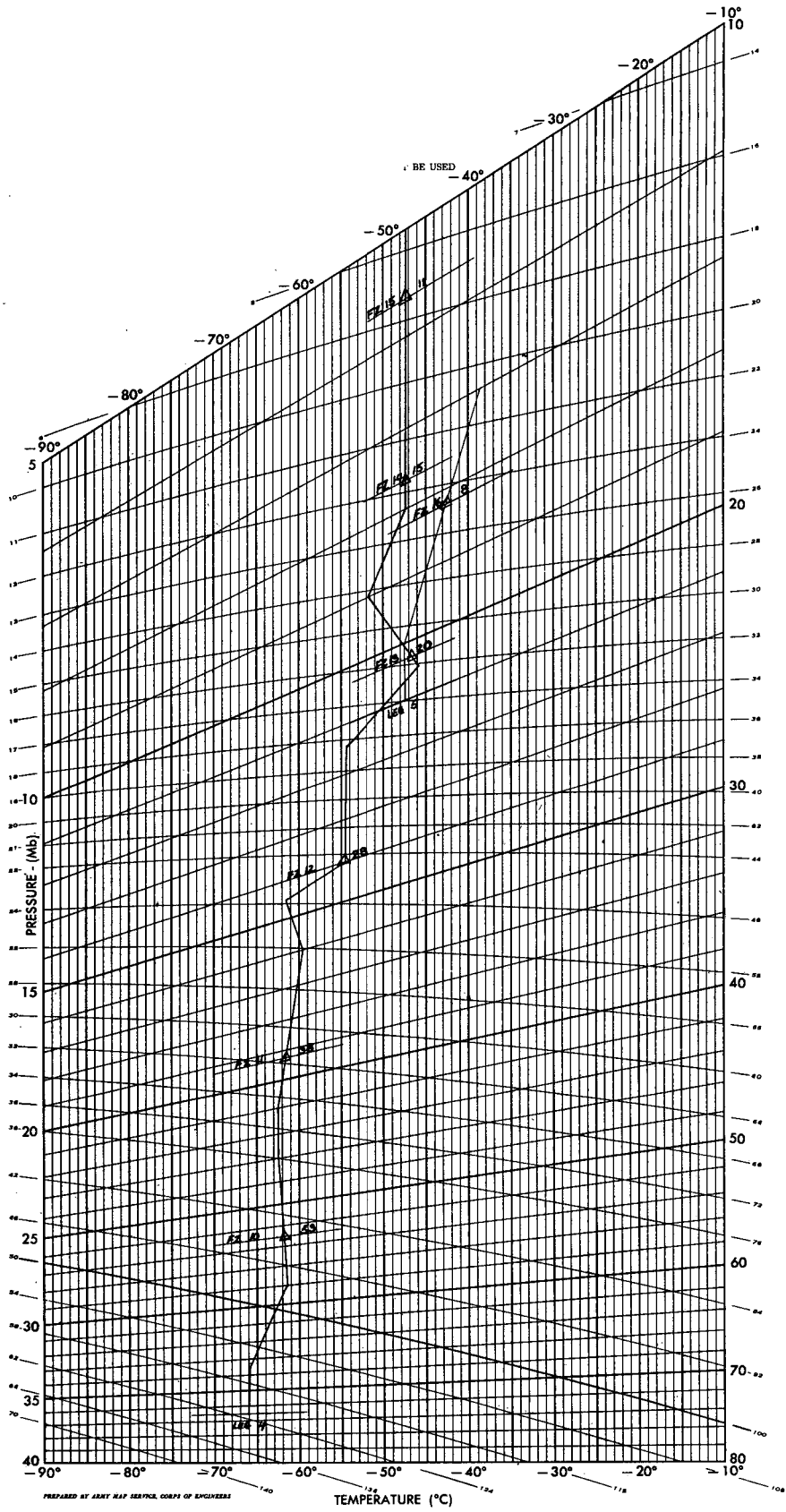
shifted toward higher temperature (to the right) along a constant pressure line by the amount which is one-half the spacing of the nearest set of hatch marks which bracket the point. The row of hatchings nearest the plotted point is used. For instance, if the pressure of the plotted point is 599 mb., the row of hatchings on the 550-mb. isobar is used (1, fig. 113). If the pressure is 601 mb., the row of hatchings at 650 mb. is used. If the pressure is 600 mb. or exactly halfway between two rows of hatchings, the row of hatchings toward the top of the chart (550 mb.) is used. After the nearest row of hatchings is determined, the two consecutive hatch marks that bracket the temperature of the plotted point are located. The space between those two hatch marks represents the effect of 100 percent humidity on the plotted point. If the temperature falls directly on a hatch mark, the space between that hatch mark and the one immediately on the right represents the effect of 100 percent humidity. Figure 115 shows a virtual temperature plot of a significant point based on the following data evaluated from level 6 of the radiosonde data form (1, fig. 111):

Pressure 557 millibars

Temperature  $-5.7^{\circ}\text{C}$ 

Relative humidity 48 percent

*d. Procedure.* First, the point is plotted at the pressure of 557 mb. and the actual temperature of  $-5.7^{\circ}\text{C}$ . The nearest row of hatch marks is found at the 550-mb. isobar, and the temperature of  $-5.7^{\circ}\text{C}$  is bracketed on the isobar by hatch marks that are  $0.8^{\circ}\text{C}$  apart. Since the relative humidity is 48 percent, the correction to be applied to the actual temperature of the point is  $0.48 \times 0.8 = 0.4^{\circ}\text{C}$ . (rounded off the nearest  $0.1^{\circ}\text{C}$ .) The virtual temperature plot is then located at a temperature of  $-5.3^{\circ}\text{C}$ . ( $-5.7 + 0.4 = -5.3$ ) and a pressure of 557 mb. It is this final point, corrected for the relative humidity, which is used in constructing the sounding curve. In the process of plotting these points, it is often expedient to perform a simple graphical estimation of the effect of humidity. After the original point is plotted and the nearest set of bracketing hatch marks is ascertained, the edge of a piece of paper is placed against the hatch marks. Two tick marks are made on the edge of the paper directly below the bracketing hatch marks. The distance between the two tick marks represents the effect of 100 percent humidity on the temperature of



②  
Figure 113—Continued.



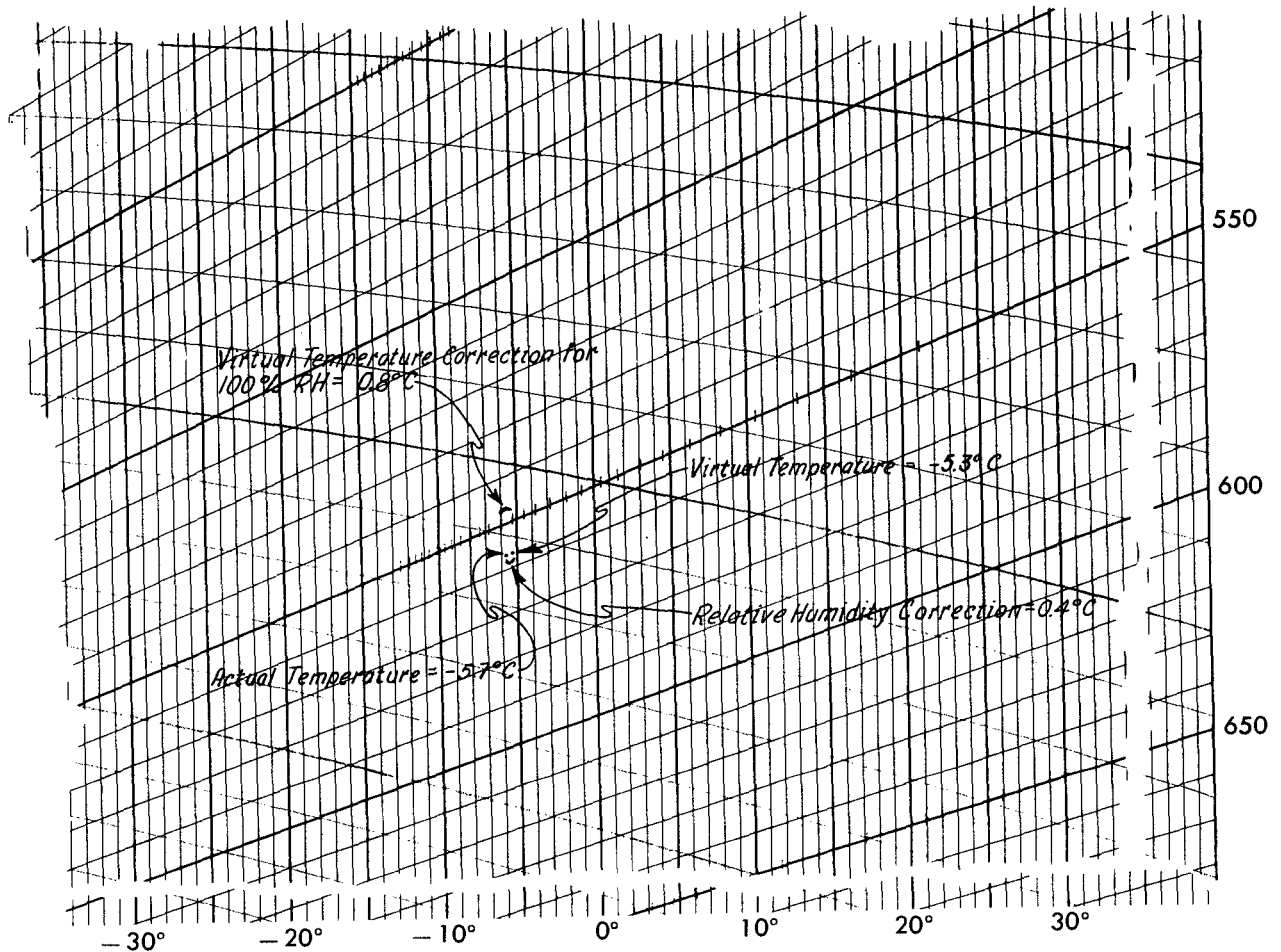


Figure 115. Virtual temperature plot of a significant point.

intersection are read on the temperature scale and the pressure scale on the left edge of the chart. The pressure (142 mb.) is multiplied by 2 (284 mb.). By using the original temperature and the doubled pressure, the point is replotted on the chart by using the same temperature and pressure scales. This replotted point is the first plot for the third leg. The pressures of all significant points between the pressure corresponding to the replotted pressure (145 mb. before it is doubled) and approximately 65 mb. are multiplied by 2, plotted, and connected by straight lines. The third leg includes those points plotted above the top of the last zone evaluated on the second leg. Actual pressures along the third leg are obtained by dividing by 2 the pressure reading along the left hand edge.

*h. Plotting the Fourth Leg of the Sounding Curve.* When a fourth leg of the sounding curve is required to complete the requirement for 15 artillery zones

because of very low surface pressure (high altitude) or when fallout winds are required, the plotting is continued on the low pressure side of chart ML-574 (2, fig. 113). The procedure is the same as that outlined for the first leg on the high pressure side. Additional legs may be plotted as required on the low pressure side of chart ML-574 by using the same procedures outlined for the corresponding legs on the high pressure side.

#### 145. Balancing Areas on Chart ML-574

*a. General.* After plotting the virtual temperature sounding curve, the next step is to scale off the 15 zones on the sounding curve. The zoning is accomplished by using the NATO zones on scale ML-573. In scaling zones on the chart, it is necessary that the scaling be done on an isothermal line that is the average virtual temperature of the zone being scaled. The determination of the



average temperature in a zone is accomplished graphically and visually with scale ML-573. The procedure is to balance the areas delineated by the sounding curve, the isobars bounding the zone and the vertical line of the NATO zone scale. The procedure is described in detail in *b* below.

*b. Straight Line Curve.* Scale ML-573 is oriented so that the point on the scale representing the base of NATO zone 1 lies on the surface isobar and the vertical line of the scale is parallel to the isotherms. Then the scale is shifted laterally along the isobars, maintaining the proper isotherm orientation, until the area to the left of the vertical line on the scale equals the area to the right of the vertical line. For example, the shaded area (1, fig. 116) which is bounded by the vertical line of the scale (2, fig. 116), the sounding curve (3, fig. 116), and the isobar passing through the top of zone 1 (4, fig. 116) equals the shaded area (5, fig. 116) which is bounded by the vertical line of the scale, the sounding curve, and the isobar passing through the bottom of zone 1 (6, fig. 116). When the areas are balanced, the vertical line of the scale lies along an isotherm, which is the mean (average) virtual temperature of the zone, and the mean density of the zone is at the zone midpoint. If the sounding curve appears as one straight line between the top and bottom of any zone, as shown in figure 116, the areas are balanced when the zone midpoint graduation on the scale falls directly on the sounding curve. After the areas are balanced, the zone midpoint (7, fig. 116) and the top of zone 1 (8, fig. 116) are marked on the chart at the appropriate graduations on the scale. The midpoint of zone 1 is circled and evaluated for temperature and density, and the zone number is entered just to the left of the circle. A solid line is drawn through the point at the top of zone 1 and parallel to the isobar nearest the point. This line represents the pressure at the top of zone 1 and the pressure at the bottom of zone 2. Zone 2 is balanced in the same manner as zone 1. The scale is oriented so that the graduation representing the base of zone 2 lies on the isobar drawn through the top of zone 1 (which represents the base of zone 2 on the chart) and the vertical line of the scale is parallel to the printed isotherms. The pertinent areas are balanced by laterally shifting the scale as described above. (Balancing of areas other than the straight line type is covered in *c* below.) When the zone areas are balanced, the midpoint and top of zone 2 are marked on the chart. As before, the top of the

zone is indicated by a line parallel to the isobar nearest the top of the zone. The midpoint is circled and numbered (to the left) and evaluated for temperature and density. The same procedure is carried out for the remaining zones. When the upper limit of a zone lies above the top of the first leg, this zone is evaluated starting at the bottom of the second leg.

*c. Balancing Irregular Areas.* The most simple case of balancing areas is shown in figure 116, where the curve appears as one straight line between the top and bottom of the zone. When the sounding curve does not follow a straight line, irregular areas are formed, and in certain instances three or more areas will have to be balanced. In all situations, all of the areas which appear to the left of the vertical line of the scale must balance all the areas that appear to the right of the vertical line. When the areas are properly balanced (area 1 equals area 2, as shown in illustration 1 of fig. 117), the midpoint of the zone (3, illustration 1 of fig. 117) may not fall on the curve (4, illustration 1 of fig. 117). Illustration 2 of figure 117 shows three areas to be balanced. The sum of the two shaded areas which fall to the right (1 and 2, illustration 2 of fig. 117) is balanced against the shaded area which falls to the left (3, illustration 2 of fig. 117). Although in this example the midpoint of the zone (4, illustration 2 of fig. 117) does not fall on the curve (5, illustration 2 of fig. 117), it is possible for it to do so. On this type curve the point normally will fall to the left or right, depending on the configuration of the sounding curve. Two important requirements must be fulfilled in moving the scale laterally across the chart to balance the areas for any zone: First, the graduation of the scale representing the bottom of the zone must be kept on the line of constant pressure which represents the bottom of the zone and, second, the vertical line of the scale must be kept parallel to the printed isotherms.

#### 146. Evaluation of Temperature, Density, and Pressure on Chart ML-574

*a. Evaluation of the First Leg of the Sounding Curve.* The evaluation of the sounding curve is begun at the surface level. Surface virtual temperature and surface density are read directly from the chart at the significant point representing the surface. The surface significant point is inclosed in a square (1, fig. 111) on the isobar drawn through this point. The words SURFACE DENSITY

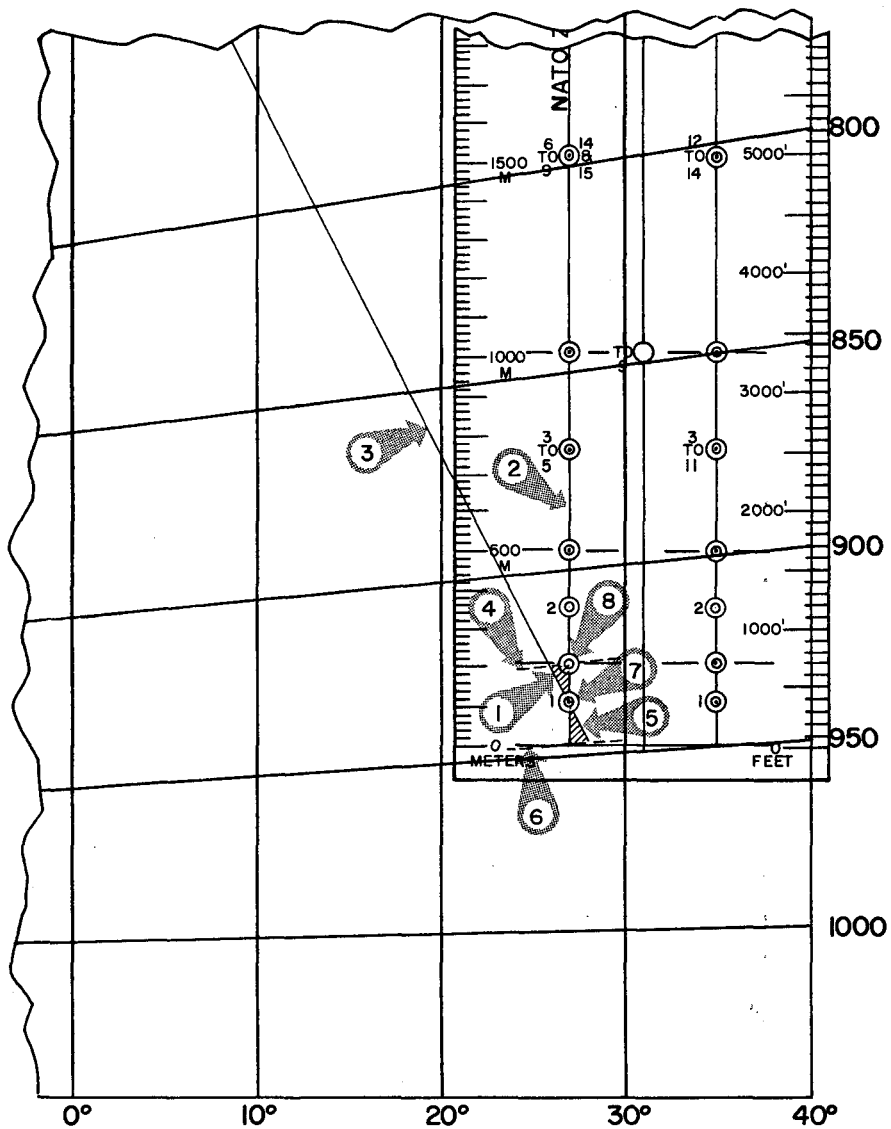
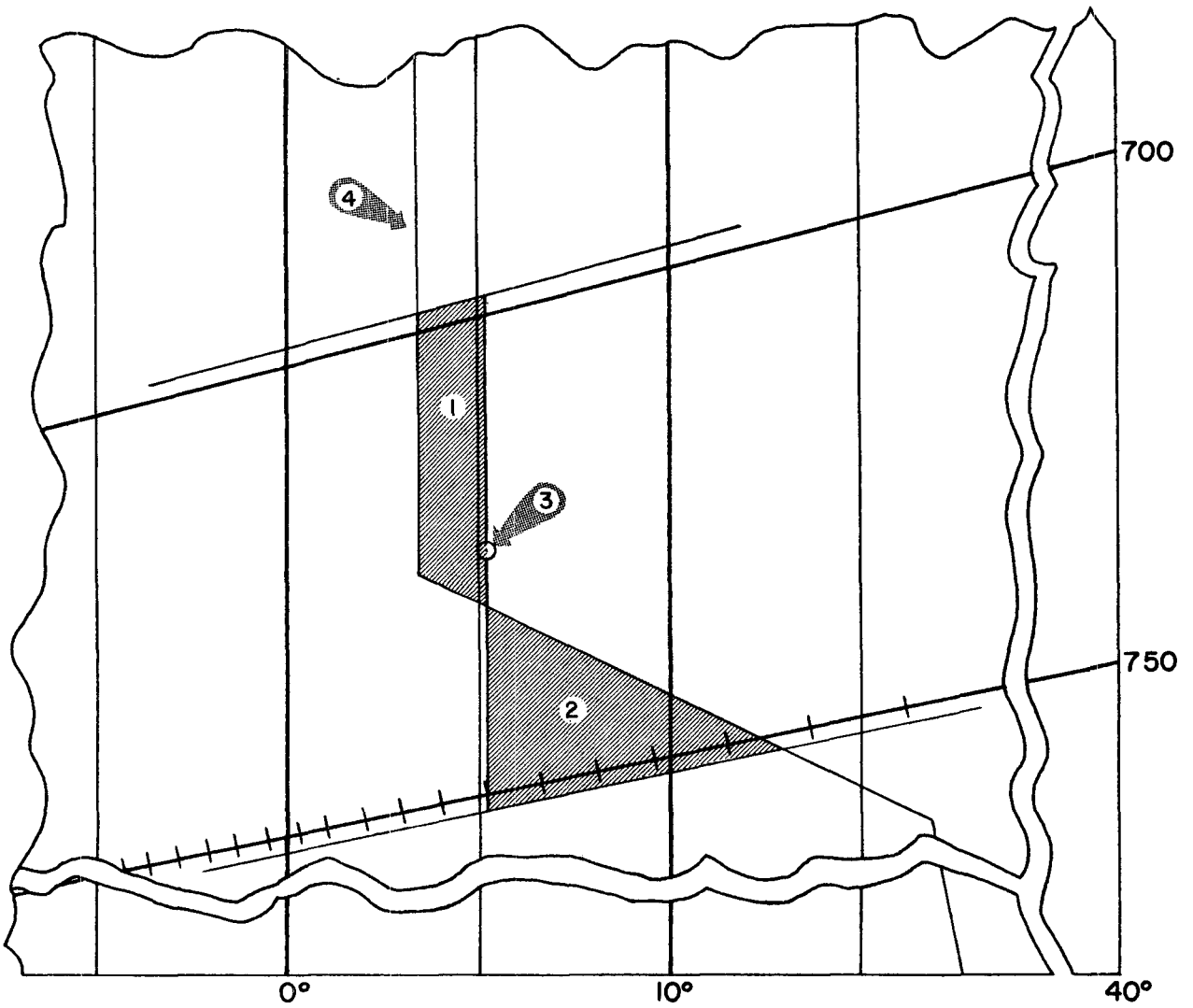
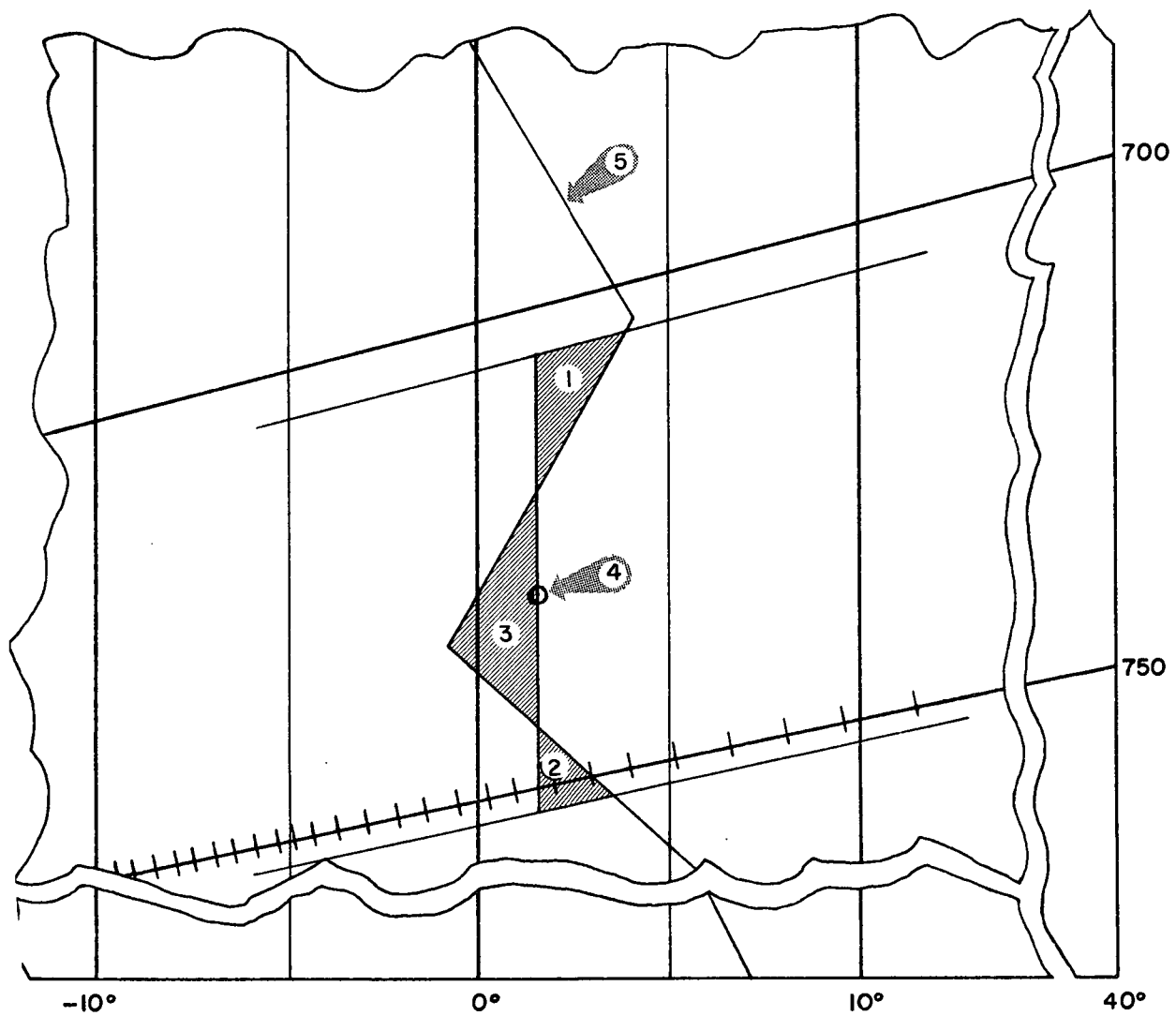


Figure 116. Balancing straight line sounding curve.



①  
Figure 117. Balancing irregular areas.



②  
Figure 117—Continued.

AND SURFACE VIRTUAL TEMPERATURE are entered on the chart immediately below the surface isobar (1, fig. 113). The midpoint of each zone (previously identified, circled, and numbered) is evaluated for temperature to the nearest  $0.1^{\circ}\text{C}$ . and for density to the nearest whole gram per cubic meter. Density is evaluated by either an accurate visual interpolation between the constant density lines or an accurate measurement. Scale ML-573 may be oriented so that an even number (preferably 10 or 20) of graduations on the meter scale are between the density lines bracketing the zone midpoint. With the scale so oriented, the mean density of the midpoint may be read to the nearest whole gram per cubic meter. All zone midpoint values are entered to the right of the midpoint, with the density above the temperature (1, fig. 113). The pressure at the top of each artillery zone is evaluated to the nearest whole millibar and entered on the isobar drawn at the top of the zone and to the right of the sounding curve (1, fig. 113). Also, the pressure is evaluated to the nearest whole millibar at the top of each artillery zone corresponding in altitude to the fallout zones, e.g., the top of artillery zone 5 is the top of fallout zone 1. The top of each fallout zone is identified by inclosing in a triangle the point where the sounding curve intersects the isobar drawn at the pressure at the top of the zone. This fallout zone pressure is entered on the isobar signifying the top of each fallout zone, to the right of the sounding curve. In 1, figure 113, the pressure for the top of zone 5 is 762 mb., and the pressure for the top of fallout zone 1 is 762 millibars.

*b. Evaluation of the Second Leg of the Sounding Curve.* The second leg of the sounding curve is evaluated in exactly the same manner as the first leg, except that density and pressure values are read from the left edge of the chart.

*c. Evaluation of the Third Leg of the Sounding Curve.* The third leg of the sounding curve is evaluated in the same manner as the second leg, except the values of density and pressure read from the left edge of the chart are divided by 2.

*d. Evaluation of the Fourth Leg of the Sounding Curve.* The fourth leg of the sounding curve is plotted on the low pressure side of chart ML-574 and is evaluated in the same manner as the first leg.

*e. Completing the Evaluation of the Sounding Curve.* The judicious selection of levels during the initial evaluation of the radiosonde recorder record often facilitates the evaluation of zone data on chart

ML-574. The selection of levels requires close cooperation between the temperature-density plotter and the radiosonde recorder operator.

- (1) In some cases, the graduation on scale ML-573, which represents the top of the next zone to be evaluated, falls on the chart, but above the plotted portion of the leg. Normally, it is necessary to extend the plot of this leg to evaluate the next artillery zone. In this case, an additional level must be selected and plotted to correspond to a pressure that falls above the top of the zone to be balanced and evaluated. For example, suppose the top of artillery zone 12 were evaluated for a pressure of 225 mb. and that the last significant point plotted on the second leg were evaluated for a pressure of 171 mb. This would allow the top of zone 13 to fall on the chart, but above the top of the plotted sounding curve. An additional level at 160 mb. would allow the temperature-density plotter to plot zone 13 on the second leg of the sounding curve.
- (2) Under circumstances similar to those in (1) above, but when the last significant point is not replottable on the succeeding leg, additional pressure and temperature data must be obtained from the radiosonde recorder record as in (1) above. These data are used to extend the leg.

#### 147. Flight Duties of the Temperature-Density Computer

During the radiosonde flight, the general duties of the temperature-density computer are to—

- a. Determine the surface density and temperature in percent of standard.
- b. Obtain the zone temperatures and densities from chart ML-574 and compute the ballistic temperatures and densities.
- c. Assist and check the work of the temperature-density plotter.

#### 148. Computation of Ballistic Temperature

Ballistic temperatures are computed on DA Form 6-44 (fig. 118). The type of message being prepared is checked in the lower left corner. Ballistic temperatures, reported as percents of standard, are obtained by applying weighting factors to the zone values.

BALLISTIC DENSITY OR TEMPERATURE (FM 6-15)																	
STATION			LOCATION			RE-LEASE TIME		DATE		HOUR		FLIGHT NR.					
3d DIV ARTY			FORT SILL, OKLA					3 NOV 59		1130		3					
Zone Nr.	(CHECK ONE)		PERCENT OF STANDARD (2)	WEIGHTED VALUES (3)													
	<input type="checkbox"/> DENSITY Gm/M <sup>3</sup>	<input checked="" type="checkbox"/> TEMPERATURE (C°)		1	2	3	4	5	6	7	8	9	10	11	12	13	14
SUR 0	29.8	105.1															
1	27.4	104.6	104.6	28.2	13.6	8.9	5.2	4.2	2.1	1.0	1.0	0.0					
2	23.3	103.7		75.7	20.8	12.5	10.4	4.2	4.2	3.1	1.0	1.0					
3	16.5	102.2			68.5	25.6	20.4	9.2	7.2	5.1	2.0	2.0					
4	15.8	103.2				56.9	21.7	11.4	9.3	4.1	3.1	2.1					
5	11.8	102.9					45.4	13.9	11.4	10.3	3.1	3.1					
6	3.5	101.8						60.1	26.4	19.9	9.2	7.1					
7	0.2	103.0							42.3	23.7	13.4	13.4					
8	-5.7	103.3								36.2	24.8	22.7					
9	-11.4	103.7									45.7	23.9					
10	-20.2	104.2										28.2					
11	-31.6																
12	-43.5																
13	-57.0																
14	-65.8																
15	-66.8																
BALLISTIC VALUES			104.6	103.9	102.9	103.9	103.1	102.5	102.9	102.9	103.3	103.5					
MESSAGE TYPE (CHECK ONE)			COMPUTER			CHECKER											
<input checked="" type="checkbox"/> B			Bailey			Howe											

DA FORM 6-44, 1 MAR 62

REPLACES DA FORM 6-44, 1 JUL 56 AND DA FORM 6-45, 1 JUL 56, WHICH ARE OBSOLETE.

Figure 118. Computed ballistic temperatures.

a. *Surface (Line 0) Ballistic Temperature.* To obtain the surface ballistic temperature, the surface virtual temperature is read to the nearest 0.1° C. (29.8° C.) from chart ML-574 (1, fig. 113) and converted to the nearest 0.1 percent of standard by using chart XII, FM 6-16. After checking the appropriate words in the heading of column (1), the surface virtual temperature is entered in column (1) and the percent of standard is entered in column (2), on the form.

b. *Ballistic Temperatures for Lines 1 Through 15.* Ballistic temperatures for lines 1 through 15 are computed by weighting the individual zone temperatures. Each zone temperature is read to the nearest 0.1° C. from chart ML-574 and recorded in

column (1) on the form (fig. 118). Next, percent of standard for each zone temperature and the zone weighted temperature (percent) for each line are obtained from the appropriate weighted temperature table in FM 6-16. Zone 1 temperature (27.4° C.) is weighted first. Enter table IIIg, FM 6-16, weighted temperatures (percent), zone 1 (Type-3 Message (surface to surface)). The zone 1 temperature (27.4° C.) is used as the argument to enter the °C. column. The percent of standard temperature (104.6) to the nearest 0.1 percent is read opposite the zone temperature, interpolating where necessary, and recorded on the form in column (2) opposite the zone 1 temperature. The weighted temperature (percent) for each line of zone 1 is opposite the zone

temperature in the table. These weighted temperatures (percents) are read to the nearest 0.1 percent, interpolating where necessary, and recorded on the form under the appropriate line numbers for zone 1. The weighted temperature (percent) for a particular line of zone 1 represents the proportional part of the total temperature effect of the zone 1 temperature for that line. The weighted temperatures (percents) for zones 2 through 15 are obtained and recorded in the same manner as the zone 1 values. After the required weighted temperatures (percents) have been determined and recorded, the weighted values for each line are added, and the sums are the ballistic values entered on the form. Each of these sums is a ballistic temperature in percent of ICAO standard atmosphere. These ballistic temperatures

are encoded as a percent of standard on the NATO message. Encoding is described in paragraph 160.

**149. Computation of Ballistic Density**

Ballistic densities for all types of meteorological messages are computed on DA Form 6-44 (fig. 119). The densities read from chart ML-574 are recorded on this form. The surface density is entered on the appropriate line in column (1), after checking the block marked DENSITY Gm/M<sup>3</sup> in the heading of the column to indicate that the form is being used to compute density. The densities for the remaining zones are read from chart ML-574 and entered in column (1) opposite the appropriate zone number on the form. The type of message being prepared is checked in the lower left corner of the form.

BALLISTIC DENSITY OR TEMPERATURE (FM 6-15)																			
STATION			LOCATION			RE-LEASE TIME		DATE		HOUR		FLIGHT NR.							
3d DIV ARTY			FORT SILL, OKLA			LST GMT		3 NOV 59 3 NOV 59		1130 1730		3							
Zone Nr.	(CHECK ONE)		WEIGHTED VALUES																
	<input checked="" type="checkbox"/> DENSITY Gm/M <sup>3</sup>	<input type="checkbox"/> TEMPERATURE (C°)	PERCENT OF STANDARD (2)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
SUR 0	1117		91.2	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
1	1106		91.2	91.2	39.2	20.0	13.7	10.1	7.3	5.5	4.6	3.7	2.7	0.9	1.8	1.8	1.8	1.8	
2	1091		92.1	/	52.5	28.5	19.3	15.6	10.1	7.4	5.5	5.5	3.7	2.8	2.8	1.8	2.8	3.7	
3	1064		93.4	/	/	43.9	29.9	23.4	15.9	13.1	10.2	8.4	6.5	4.7	4.7	3.7	4.7	4.7	
4	1004		92.6	/	/	/	29.6	20.4	15.7	12.0	10.1	8.3	6.5	4.6	4.6	4.6	4.6	4.6	
5	959		92.9	/	/	/	/	23.3	14.0	11.2	9.3	7.4	6.5	5.6	4.7	4.7	4.7	4.7	
6	901		94.1	/	/	/	/	/	30.1	20.7	17.9	16.0	12.2	11.3	10.3	10.3	9.4	9.4	
7	805		93.2	/	/	/	/	/	/	23.9	15.8	14.0	11.2	10.2	9.4	8.4	8.4	8.4	
8	725		93.4	/	/	/	/	/	/	/	19.6	13.1	10.2	8.4	8.4	8.4	7.4	7.4	
9	651		93.3	/	/	/	/	/	/	/	/	16.8	10.3	8.4	7.5	7.5	6.5	6.5	
10	551		93.4	/	/	/	/	/	/	/	/	/	23.3	14.9	13.1	13.1	12.1	11.2	
11	437		93.5	/	/	/	/	/	/	/	/	/	/	21.6	11.2	9.3	10.3	8.4	
12	343		94.0	/	/	/	/	/	/	/	/	/	/	/	15.1	8.5	7.6	7.6	
13	268		100.5	/	/	/	/	/	/	/	/	/	/	/	/	/	12.1	6.1	5.1
14	202		103.7	/	/	/	/	/	/	/	/	/	/	/	/	/	/	8.3	5.2
15	146		102.6	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	6.1
BALLISTIC VALUES				91.2	91.7	92.4	92.5	92.8	93.1	93.3	93.0	93.2	93.1	93.4	93.6	94.2	94.7	94.8	
MESSAGE TYPE (CHECK ONE)			COMPUTER			CHECKER													
3			A			Howe													
						Boiler													

DA FORM 6-44, 1 MAR 62

REPLACES DA FORM 6-44, 1 JUL 56 AND DA FORM 6-45, 1 JUL 56, WHICH ARE OBSOLETE.

Figure 119. Computed ballistic densities.

a. *Surface (Line 0) Ballistic Density.* The surface ballistic density is determined by converting the surface density to the nearest 0.1 percent of standard surface density. By using the surface density (1117 Gm/M<sup>3</sup>) in column (1) of the form as the argument for entering chart IX, FM 6-16, the surface ballistic density (91.2) is obtained to the nearest 0.1 percent. This value is entered in column (2).

b. *Ballistic Densities for Lines 1 Through 15.* Ballistic densities for lines 1 through 15 are computed by weighting the density for each zone. Each zone density is read to the nearest whole gram per cubic meter from chart ML-574 and entered in column (1) on DA Form 6-44. Next, the percent of standard of each zone density is obtained from the appropriate weighted densities table in FM 6-16. The example shown in figure 119 is a type-3 message (surface to surface); therefore, table IIIb of FM 6-16 is used. The zone 1 density (1106) is used as the argument for entering the table. The weighted density for zone 1 is determined to the nearest 0.1 percent of standard (91.2) by interpolating between 1100 and 1110 Gm/M<sup>3</sup>. This value is entered in column (2) opposite the density for zone 1 (1106, fig. 119).

After the zone percent of standard for each density has been determined and entered in column (2) on the form, the weighted zone densities for each line are obtained from the weighted densities table in FM 6-16 that corresponds to the message type. These weighted values are entered under the appropriate line numbers of the zone. For example, line-zone number 71 indicates that the weighted value (5.5) is entered under the column for line 7 on the row for zone 1. The weighted density is that portion of the total density effect that the density in zone 1 exerts. The percents of standard and the weighted densities for zones 1 through 15 are obtained and entered on the form in the same manner. The percents of standard densities are used only for checking purposes. After the required weighted densities have been determined and recorded, the ballistic density values for each line are obtained by adding the weighted densities of each column, 1 through 15. These sums are recorded in the appropriate space under the line number. These ballistic densities are now ready for encoding on the metro message form. See chapter 8 for encoding procedure.

## Section VI. DUTIES OF BALLISTIC WINDS TEAM AFTER BALLOON RELEASE

### 150. General

The rawin set, used in conjunction with a balloon-borne radiosonde and the radiosonde recorder, provides a method of determining winds aloft during all kinds of weather. The determination of winds aloft involves tracking the radiosonde in elevation and azimuth and determining the height of the radiosonde by pressure-temperature measurements. The determination of zone wind directions and zone wind speeds from the rawin data requires both plotting and computations. Zone winds must be weighted, according to the type of message and line number, and summed in order to compute a ballistic wind.

### 151. Duties of the Zone-Wind Computer and Zone-Wind Plotter

a. During the flight, the zone-wind computer—

- (1) Marks each reference time on the control-recorder tape with the contact number it represents.
- (2) Constructs a pressure-time plot on the pressure-time chart.

- (3) Records in column (2) on DA Form 6-46 (Rawin Computation) (fig. 120), the pressure evaluated at the top of each zone on chart ML-574 by the temperature-density plotter.
- (4) Reads from the pressure-time chart the time of arrival of the balloon-borne radiosonde at each standard height (pressure) and enters these times in column (3) on the rawin computation form.
- (5) Determines from the control-recorder tape the values of the elevation and azimuth angles at the times the radiosonde reached each standard height. Applies to the angular data the corrections obtained by the optical-electrical bearing check. Enters the corrected angular data in columns (4) and (5) on the rawin computation form.
- (6) Determines from table Ig, FM 6-16, and enters in column (6) of the rawin computation form the values of horizontal distance corresponding to the elevation angle for each standard height.



STATION		LOCATION		RE-LEASE TIME		DATE		FLIGHT NR.				
3d Div Arty		Fort Sill, Oklahoma		LST	HOUR	3 NOV 59		3				
				GMT	HOUR	3 NOV 59		1730				
Zone ar.	(1) Zone height (meters)	(2) Pressure at top of zone	(3) Time at top of zone	(4) Elevation angle (degrees & tenths)	(5) Azimuth angle (degrees & tenths)	(6) Horizontal distance (meters)	(7) Horizontal travel in zone (meters)	(8) Time in zone (min & tenths)	ZONE WIND DATA		BALLISTIC DATA	
									(9) Azimuth (10 miles)	(10) Speed (knots)	(11) Azimuth (100 miles)	(12) Speed (knots)
Offset	SUR								SUR	SUR	SUR	SUR
1	200	944	0.6	33.2	12.6	100	240	0.6	310	04	31	004
2	500	912	1.4	38.1	335.2	310	390	0.8	250	13	25	13
3	1000	858	3.5	33.8	344.1	640	940	2.1	306	14	30	13
4	1500	809	5.3	39.4	05.6	1490	390	1.8	357	14	34	13
5	2000	762	6.9	47.0	12.8	1820	380	1.6	396	07	36	09
6	3000	673	10.1	46.1	24.6	1860	1390	3.2	602	08	42	06
7	4000	594	13.6	49.4	48.0	2880	1390	3.2	464	14	44	11
8	5000	522	17.0	47.8	75.1	3420	1570	3.5	556	15	51	10
9	6000	458	20.4	46.2	97.8	4530	1890	3.4	573	18	54	12
10	8000	349	26.9	48.1	108.4	5750	1530	3.4	571	15	54	11
11	10000	263	33.1	52.5	120.4	7160	1960	6.5	600	10	57	09
12	12000	195	39.7	50.0	100.8	7660	2560	6.2	377	13	48	08
13	14000	142	45.7	46.8	78.1	10040	4180	6.6	381	21	44	10
14	16000	102	51.9	51.6	71.6	13100	3350	5.9	412	18	46	11
15	18000	73	58.4	57.0	86.3	12640	3310	6.2	635	19	50	08
16					107.2	11650	4480	6.5	034	22	52	07
(13)	MESSAGE TYPE (CHECK ONE)		ZONE WIND COMPUTER		ZONE WIND PLOTTER		ZONE WIND PLOTTER		BALLISTIC WIND PLOTTER			
	BALLISTIC	Moore		Dunn		Kelaey						
	FALLOUT											
	COMPUTER											

DA FORM 6-46, 1 MAR 62  
 PREVIOUS EDITION OF THIS FORM IS OBSOLETE.  
 Figure 120. Rawin computation form.

- (7) Enters the surface wind values and appropriate heights on the rawin computation form.
  - (8) Assists and checks the ballistic wind plotter.
- b. During the flight, the zone-wind plotter—
- (1) Plots the zone winds.
  - (2) Determines the wind direction and the distance traveled by the radiosonde in each zone.
  - (3) Computes the wind speed in each zone.
  - (4) Assists and checks the work of the zone-wind computer.

## 152. Determining Zone Wind Data

a. *Correcting for Erroneous Release Contact.* When the actual release contact number differs from the correct surface contact number by 0.2 contact or more, a contact correction must be applied to each contact evaluated on the recorder record. This correction also must be applied to each reference contact number shown on the pressure-time chart (DA Form 6-49 (fig. 121)). If, for example, the contact number corresponding to a surface pressure of 967 mb. is 5.3 and the actual release contact number is 4.9, the subsequent contact numbers must be corrected to obtain correct pressure values from the pressure calibration chart. In this example, the contact numbers on the recorder record are corrected for use with the pressure calibration chart by adding a contact correction of +0.4 contact. When a reference trace is printed on the recorder record, a time print (marked with an asterisk) is printed automatically on the control-recorder tape and represents the time the radiosonde reached the pressure at the beginning of the reference trace. (No elevation or azimuth angles are printed on the tape with this time print.) Thus, if the contact numbers differ, the time printed on the control-recorder tape represents the time the radiosonde reached the pressure corresponding to the correct contact number at the beginning of the reference trace. Since the preflight plot on the pressure-time chart is prepared with the uncorrected reference contact numbers, the preflight phase must be corrected when a contact error exists. The procedure is to cross out the uncorrected reference contact numbers printed on the chart and enter the corrected contact numbers. Then the pressures corresponding to the corrected contact numbers are read from the pressure calibra-

tion chart and recorded. The corrected reference contact pressures are used to plot the pressure-time curve.

b. *Pressure-Time Curve.* The pressure-time chart (fig. 121) is a semilog graph used to plot a pressure-time chart. This curve is used to determine the times at which the radiosonde reached standard heights. The vertical axis is a log scale of pressure in millibars, and the horizontal axis is a linear scale of time in minutes. The front side of the pressure-time chart (1, fig. 121) is divided into two segments and is used to plot the pressure-time curve from the surface to 100 millibars. The back side of the chart (2, fig. 121) is used for plotting the upper segments of the pressure-time curve and extends to 1 millibar. Each side of the chart has a block for recording the data used to plot the pressure-time curve. Column (1) of the block lists reference contact numbers. Column (2) provides a space for recording the pressures which correspond to the reference contact numbers. These pressures are obtained from the pressure calibration chart. Column (3) provides a space for recording the time corresponding to each reference contact number. These times are read directly from the control-recorder tape, where they are identified by asterisks. The pressures in column (2) and their corresponding times in column (3) are used to plot a pressure-time curve.

c. *Plotting the First Leg of the Pressure-Time Curve.* As each reference time is printed by the control-recorder, it is entered in column (3) on the pressure-time form. Each reference time and the corresponding pressure in column (2) are used to plot a point on the pressure-time chart. The surface pressure is plotted at zero time. The plotted points are circled and connected with straight lines to construct the pressure-time curve. The first segment of the pressure-time chart is used to plot the first leg of the pressure-time curve which is that portion of the curve with pressures less than 400 millibars and less than 32 minutes after release.

d. *Plotting the Second and Subsequent Legs of the Pressure-Time Curve.*

- (1) The second segment of the pressure-time chart extends from 450 to 100 millibars. The overlap in pressure with the first segment facilitates the transfer of the first leg of the curve to the second segment of the chart, on which the second leg of the curve is plotted. The times are not printed on the second and subsequent



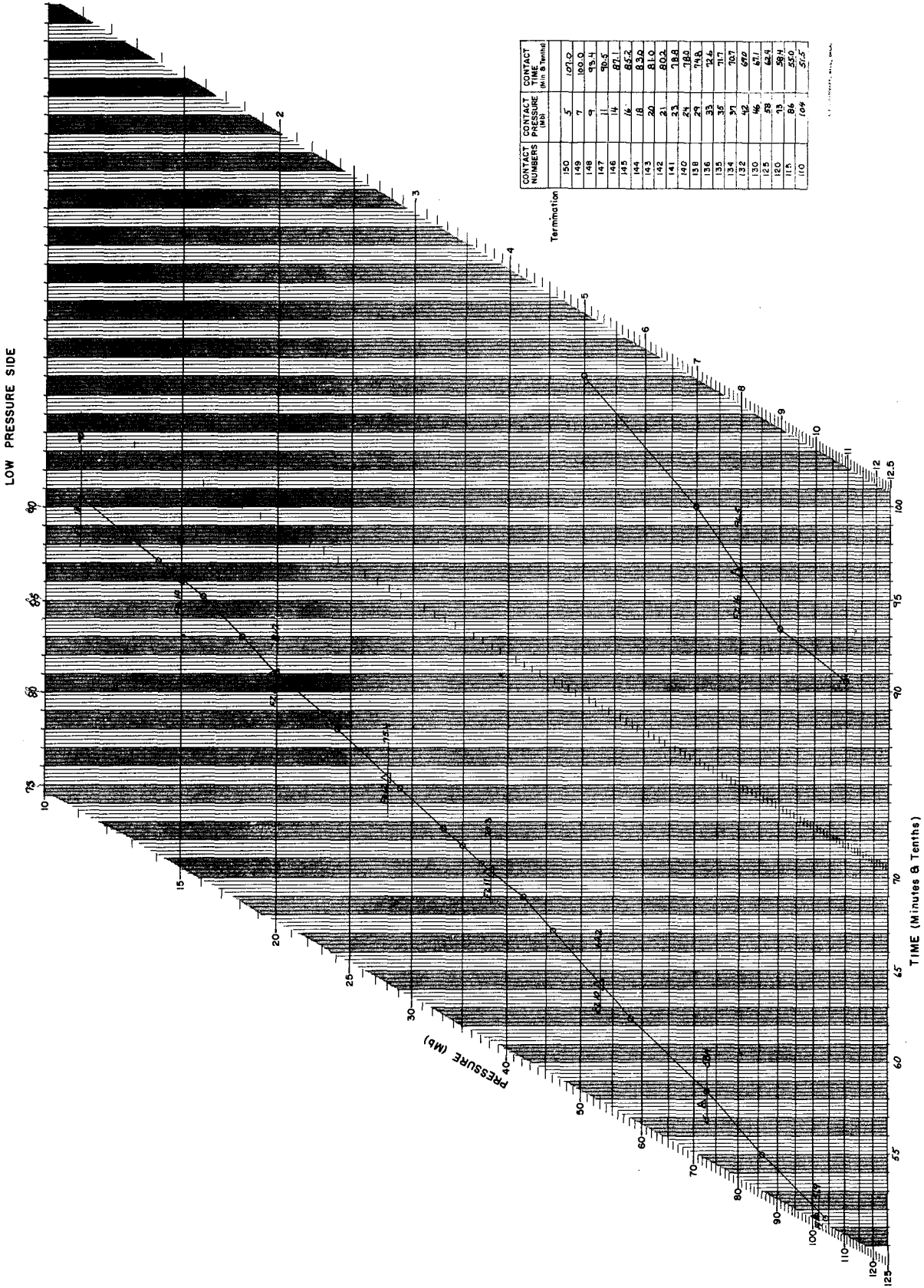


Figure 121—Continued.

segments of the chart and must be written in by the plotter. This procedure allows flexibility in plotting the second and subsequent legs of the curve because of the varying times at which different flights reach the 400-mb. level, (i.e., the top of the first leg). For example, the first leg of the pressure-time curve illustrated in 1, figure 121, ended at a pressure of 413 mb. and a time of 22.8 minutes. The times on the second segment were then written in, beginning with 22 minutes and ending with 65 minutes, to plot the pressure-time curve in the same manner as the first segment of the graph.

- (2) The low pressure side of the pressure-time chart extends from 125 to 10 millibars on the left scale and from 12.5 to 1 millibar on the right scale. This side of the chart is used to plot the final leg(s) of the pressure-time curve. The pressure and time values at the top of the second leg of the curve are transferred to the low pressure side of the chart in the same manner as they were transferred from the first to the second leg. Appropriate times must be entered on the horizontal scale of the low pressure side of the chart by the plotter (2, fig. 121). The low pressure side of the chart contains a block for recording the pressures and times of the reference contact numbers to be used in plotting the upper portion of the pressure-time curve. These values are determined in the same manner as those used on the front side. After the third leg of the curve is plotted, a fourth leg, if necessary, may be plotted by using the pressure scale on the right edge of the graph.
- (3) The completed pressure-time curve is used to determine the times at which the standard heights were reached by the radiosonde. These times are determined by the point of intersection of the pressure-time curve and the isobars whose values are the same as the pressure at each standard height. The pressure at each standard height is read from the altitude-pressure-density chart ML-574.

*e. Determining Time at Standard Height.* The zone-wind plotter obtains the pressure at the top of

each zone from chart ML-574 and enters these pressures in column (2) on the rawin computation form (fig. 120). The pressure at the top of each zone is used as the argument for entering the pressure-time chart. The zone-wind plotter moves horizontally along an isobar equal to the pressure at the top of each zone until the isobar intersects the pressure-time curve, then reads the time on the time scale (at the top or bottom of the chart, as applicable). The values of time are read directly from the scale to the nearest 0.1 minute. For example, the pressure corresponding to the top of zone 8 (standard height) is 522 mb. and the time is 17.0 minutes. This time is entered in column (3) opposite zone number 8 on the rawin computation form (fig. 120).

*f. Determining Angular Data.* Construction of the zone-wind plot requires the elevation and azimuth angles to the radiosonde at zone limits. The elevation and azimuth angles corresponding to the times at standard heights (*e* above) are obtained from the control-recorder tape, rounded off to the nearest 0.1 degree, and entered in columns (4) and (5) respectively on the rawin computation form. For example, the elevation angle corresponding to the time of 17.0 minutes (at standard height of zone 8) on the control-recorder tape in figure 122 is 47.8 degrees and the azimuth angle is 97.8 degrees (elevation angles are printed left of the time print). These data are entered opposite zone 8 in columns (4) and (5) on the rawin computation form (fig. 120). If corrections are applied to the angular data for nonalignment of the optical and electrical axes of the rawin set, the printed values of the angles are crossed out, and the corrected values are entered adjacent to the crossed out values on the control-recorder tape. The determination of angular corrections is described in paragraph 82c.

*g. Determining Distance Traveled.* Distances are obtained from table Ig, FM 6-16. The distance table for each zone is entered with the elevation angle for that zone as the argument, and the distance is read to the nearest 10 meters and recorded in column (6) on the rawin computation form (fig. 120). For example, the distance corresponding to the elevation angle of 47.8 degrees for zone 8 is 4,530 meters, as determined from table Ig, FM 6-16. The distances in table Ig are the arc distances or the distances projected to the earth's curved surface.

34	50	0 2.2	355	25	46	70	1 8.5	101	70
34	75	0 2.1	353	65	46	65	1 8.4	101	45
35	50	0 2.0	351	10	46	50	1 8.3	101	10
36	20	0 1.9	350	45	46	85	1 8.2	100	50
36	40	0 1.8	348	20			1 8.2*45		
37	20	0 1.7	346	65	47	30	1 8.1	100	65
37	05	0 1.6	347	50	47	15	1 8.0	100	45
		0 1.6*10			47	15	1 7.9	100	20
36	25	0 1.5	344	75	47	15	1 7.8	99	50
36	05	0 1.4	344	10	47	20	1 7.7	99	70
36	35	0 1.3	342	30	47	25	1 7.6	99	55
36	55	0 1.2	339	70	47	40	1 7.5	99	15
36	75	0 1.1	339	40	47	55	1 7.4	99	05
36	55	0 1.0	337	95	47	70	1 7.3	98	90
37	10	0 0.9	335	80	47	30	1 7.2	98	50
37	30	0 0.8	334	50	47	85	1 7.1	98	20
35	05	0 0.7	338	10	47	50	1 7.0	97	80
33	15	0 0.6	335	20	47	35	1 6.9	97	60
29	00	0 0.5	336	15	48	15	1 6.8	97	40
26	75	0 0.4	339	45	48	20	1 6.7	97	15
22	55	0 0.3	339	60	48	05	1 6.6	96	50
18	35	0 0.2	339	95	48	16	1 6.5	96	10
10	10	0 0.1	354	35	48	11	1 6.4	95	65
00	00	0 0.0	12	30	48	50	1 6.3	95	30

Figure 122. Control-recorder tape.

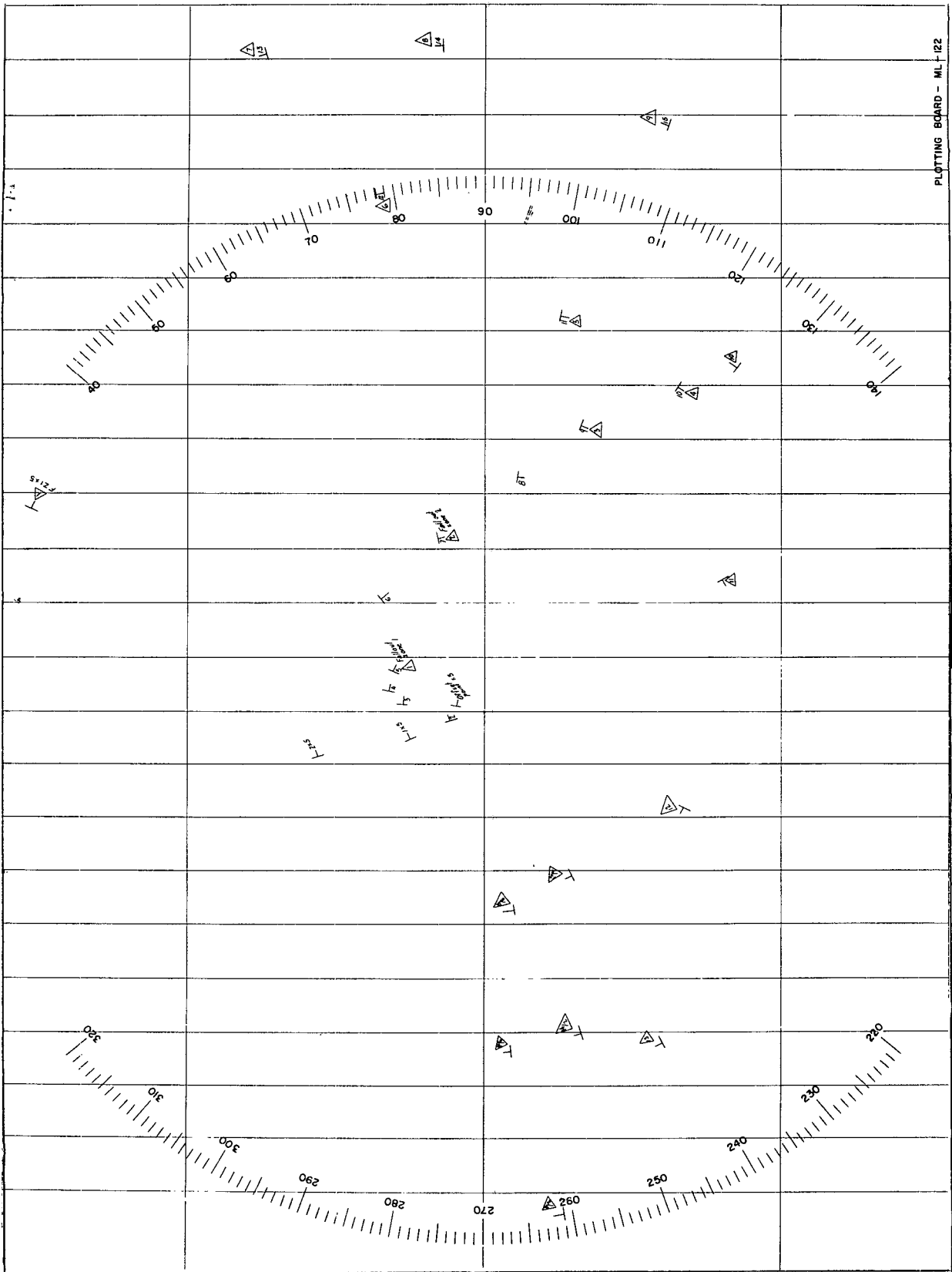


Figure 123. Completed zone wind plots.

*h. The Zone Wind Plot.* The zone wind plot is made by plotting each distance (column 6) at the indicated azimuth (column 5) obtained from DA Form 6-46 (Rawin Computation). The plot is made on plotting board ML-122 with rule ML-126 (fig. 27). The center of the plotting board represents the location of the rawin set and the distances are plotted from the center. Rule ML-126 is fitted to the center of the plotting board and oriented on the azimuth ring which is printed on the plotting board. Each plot is made by first drawing a fine line along the scale on plotting board ML-122, extending one-fourth inch on either side of the distance to be plotted. At the distance to be plotted, a  $\frac{1}{2}$ -inch fine line is drawn perpendicular to the rule, so that an inverted T (⊥) is formed. The plot is numbered the same as the zone number being plotted. As the distances increase, the scale of rule ML-126 must be reduced. In order to plot accurately, the scale is not reduced until the plots fall off the plotting surface or beyond the limits of rule ML-126. The scale is first reduced by dividing the distance by 2, and, if further reductions are required, the scale is reduced by dividing by 5 and then by 10. If the zone wind plots fall very close to the origin of the board (center), the scale is expanded by multiplying the distance by 10, 5, or 2 as deemed advisable. A complete zone wind plot is shown in figure 123.

*i. Plotting the Offset Release Point.* If the release point is more than 50 meters from the rawin set, a plot of the release point must be made on the wind plotting board ML-122. This point is known as the offset release point. The distance and the azimuth from the rawin set to the release point are used to plot the offset release point. The distance may be determined by pacing, and the azimuth used is the first azimuth angle printed on the control-recorder tape. The plot of the offset release point is used as the origin for determining the travel and direction for zone 1 winds.

*j. Measuring Travel in Zone.* Travel in zone is the net distance in meters in a given zone that the balloon-borne radiosonde moves in the horizontal direction. When the amount of time in zone is known, the zone wind speed is obtained by dividing the distance traveled by the time in zone and converting the result to knots. The distance traveled in each zone is measured in meters with rule ML-126. For example, to measure the distance traveled in

zone 7, the rule is alined between the plotted points representing zones 6 and 7. A fine line is drawn along the edge of the rule from 6 to 7 and extended, if necessary, to make a line at least 5 inches long. This line is the zone wind direction line. The distance traveled (1,570 meters) is read between the two points on the rule to the nearest 10 meters. The travel is measured for each zone required. If the scale of the zone wind plot is expanded or reduced by a given factor, the value of distance traveled as read on the rule must be multiplied or divided by the same factor. The values of distances traveled in zone are entered in column (7) on the rawin computation form (fig. 120).

*k. Computing Time in Zone.* Column (3) of the rawin computation form lists the time of arrival of the radiosonde at each standard height. Time in zone 1 begins at surface (zero time) and ends at standard height 1. The time in zone 2 is equal to the time at standard height 2 minus the time at standard height 1. The time in zone for each succeeding zone is determined in a similar manner. These values are entered in column (8) of the rawin computation form.

*l. Measuring Zone Wind Direction.* The zone wind direction is measured for each zone by using scale ML-577. To measure the direction, the center reference mark is placed over the zone lower limit plot and the scale is oriented so that the north-south reference line is parallel to the north-south reference lines on the plotting board and the arrow pointed toward the top of the board. The zone wind direction line is read to the nearest 10 mils. The zone wind directions are entered in column (9) on the rawin computation form (fig. 120).

*m. Computing Zone Wind Speed.*

(1) *Zone wind speed.* Each zone wind speed is computed by the formula:  $D/T \times 0.0324 = S$ ; where D is the horizontal travel in meters, T is the time in zone in minutes and tenths, and S is the zone wind speed in knots. The factor 0.0324 is used to convert meters per minute to knots. *Each zone wind speed in knots is entered in column (10) on the rawin computation form. The computations are performed with a slide rule as follows:*

- (a) The hairline on the indicator is set over the horizontal distance on the D scale.
- (b) The time in zone on the C scale is moved under the hairline.



- (c) The hairline is moved to 0.0324 on the C scale. If then value 0.0324 on the C scale is on the portion of the slide which extends from the body of the slide rule, the hairline is set over the index on the C scale. The the other index on the C scale is moved under the hairline, and the hairline is set on the value of 0.0324 on the C scale.
  - (d) The zone wind speed is read under the hairline on the D scale.
- (2) *Approximation of zone wind speed.* When the slide rule is used to calculate this speed (as described in (1) above), the position of the decimal point must be determined. For example, a slide rule reading of 2779 may be a wind speed (to the nearest knot) of 3 (2.8), 28 (27.8), or 278 (277.9). In order to place the decimal point in the number read from the slide rule, a mental calculation may be made of the approximate wind speed. In making this calculation, 30 meters per minute is used as the approximate equivalent of 1 knot. For example, the approximation may be made as follows:

$$\begin{aligned}
 2770 \text{ meters} &= \text{horizontal travel in zone} \\
 2700 \text{ meters} &= \text{approximate horizontal} \\
 &\quad \text{travel in zone} \\
 3.4 \text{ minutes} &= \text{time in zone} \\
 3.0 \text{ minutes} &= \text{approximate time in zone} \\
 30 \text{ meters} &= \text{approximate meters per} \\
 &\quad \text{minute for 1 knot} \\
 \text{Then } \frac{2700}{3.0} &= 900 \text{ meters per minute} \\
 \frac{900}{30} &= 30 \text{ knots, the approximate} \\
 &\quad \text{wind speed.}
 \end{aligned}$$

Since the approximate wind speed has been calculated as 30 knots, it becomes obvious that the decimal point is placed between the second and third digits in the number, of 2779, read from the slide rule. Hence, the answer is 27.79 which is rounded off to 28 knots.

### 153. Surface Wind Measurement

The surface wind speed and direction are measured with an anemometer at the time of release. Since the

surface wind direction and speed are ballistic data, they are entered in columns (11) and (12), respectively, on the rawin computation form.

### 154. Special Considerations

Ballistic meteorologists must have a general knowledge of meteorological conditions in order to interpret and evaluate an upper air sounding. When special weather phenomena are identified during a sounding, they should be considered valid meteorological data, so long as the ballistic meteorologist knows that his equipment is in proper working order. If the computations are correct, the weather measurements are also correct. Icing and floating of the sounding balloon ascensions are discussed in paragraph 140c and d.

*a. Frontal Wind.* Wind is simply air in motion and is the result of differences in atmospheric pressure between geographic locations. The flow of air is from high to low pressure areas, with a clockwise flow about the highs and a counterclockwise flow about the lows in the Northern Hemisphere. Pressure centers may be caused by differential heating; therefore, wind is a byproduct of the changes in temperature and pressure. Both the speed and direction of the wind can change rather abruptly with a frontal passage. The location of pressure systems on a weather map are important in the final evaluation of the validity of ballistic winds.

*b. Wind Shear.* A wind shear is an abrupt change in either speed or direction within a small change in altitude. For example, the wind at an altitude of 500 meters is blowing from 3,200 mils at 14 knots; at an altitude of 625 meters, the wind is from a direction of 5,500 mils at 37 knots. This wind phenomenon is not uncommon during soundings through fronts and should be recognized by metro personnel.

*c. Jet Stream.* A jet stream is a narrow belt of high velocity wind that occurs at upper levels in the troposphere. These meandering streams of winds normally occur at or near the tropopause height (par. 8a). The tropopause usually is broken near the jet stream and reforms at a lower level causing a folded or "leaf-like pattern."

*d. Local Storms.* Thunderstorms are associated with meteorological conditions which are extremely variable in both space and time. Therefore, any sounding made through a thunderstorm will not likely be representative of the meteorological conditions along the trajectory of an artillery projectile. For this reason, an effort should be made to adjust

the schedule release times when it is evident that the radiosonde will be influenced by a local thunderstorm.

**155. Duties of the Ballistic Wind Plotter**

During the flight, the general duties of the ballistic wind plotter are to—

- a. Plot the ballistic winds.
- b. Measure the ballistic wind speeds and directions.
- c. Record the ballistic wind quantities on the rawin computation form.

- d. Check the work of the zone wind plotter.

**156. Obtaining Ballistic Winds**

a. *General.* Zone winds are weighted and plotted to obtain ballistic winds by using the techniques described in e through h below. Since the ballistic wind data are generally the last items completed for the metro message, the ballistic wind plot (fig. 124) is begun as soon as the zone 1 wind data are determined. Ballistic wind data are entered in columns (11) and (12) on the rawin computation form.

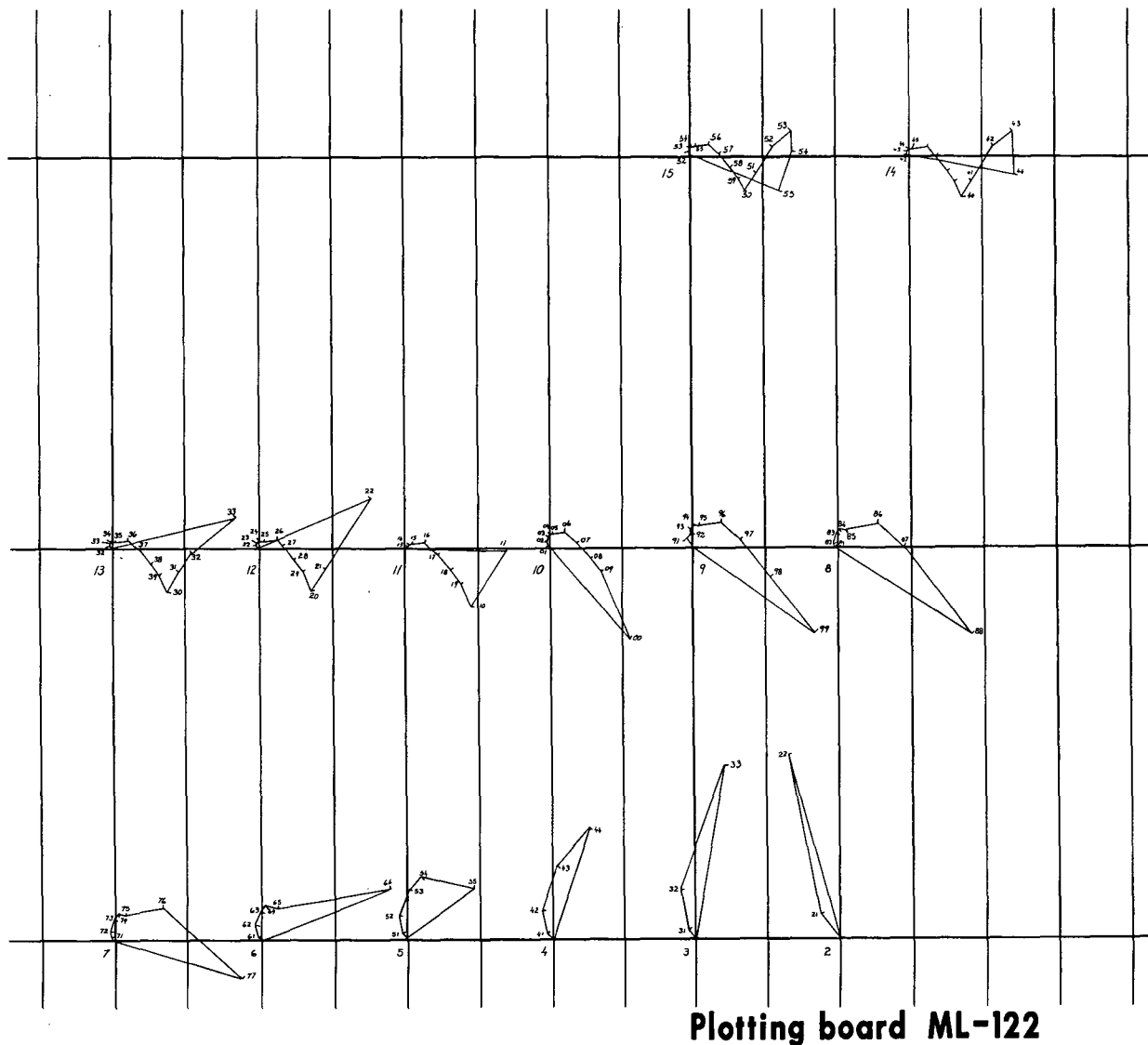


Figure 124. Completed ballistic wind plot.

b. *Ballistic Winds for Lines 0 and 1.* At the surface, only the surface wind is effective; hence, the wind values measured at the surface with the anemometer are entered in the ballistic wind data columns (columns 11 and 12) on the rawin computation form. The zone wind for zone 1 is the mean wind from the surface to an altitude of 200 meters, the top of zone 1. A projectile with a trajectory entirely in zone 1 is acted on only by the wind in zone 1; therefore, the zone wind for zone 1 is also the ballistic wind for line 1. Zone 1 wind speed and direction are entered in columns (11) and (12) of the rawin computation form.

c. *Plotting Lines 2 through 15.* A projectile is affected by the winds in all the zones through which it passes; therefore, the ballistic wind for any given line of the metro message is determined by weighting the wind in each of the zones below the standard height for that line. To obtain the ballistic wind for any line above line 1, a plot is made of the weighted wind of each zone which contributes to that ballistic wind value. These plots are vector plots. The direction is the zone wind direction and the magnitude is the weighted zone wind speed. The vector sum of the zone wind vectors is the ballistic wind (fig. 124).

d. *Selecting Starting Points.* The origin point for each line to be plotted is selected at the intersection of a horizontal line and a vertical line on plotting board ML-122. Each origin point is selected according to the direction and velocity of the winds aloft and to afford sufficient plotting space. The first origin point is selected for line 2. It is selected on the horizontal line that affords sufficient plotting space in the direction that the plot is expected to extend.

e. *Plotting Wind Directions.* The center point of plotting scale ML-577 is centered over the point of origin selected for the line being plotted, and the scale is oriented so that the arrow on the fan is pointing toward the top of the board and is parallel to the north-south lines on the plotting board (vertical lines). For example, suppose a zone wind direction (column 9 of the rawin computation form) is 600 mils. After the plotting fan is oriented at a point of origin, the direction of 600 mils is found and marked with a "T," the top of the "T" being a line drawn along the edge of the fan.

f. *Determining Weighted Wind Speeds.* To determine the weighted wind speed, the weighted wind tables in FM 6-16 are used. The table to be used depends on the type of message. The problem

illustrated in this chapter is a type-3 message (surface to surface). Therefore, table IIIe, the weighted wind speed table for message type-3 is used. The arguments for entering the table are the zone number, the zone wind speed, and the line-zone number.

g. *Plotting Zone Wind Speeds.* In order to plot the weighted values, the ballistic wind speed scale (center of the scale ML-577) is oriented so that the zero falls at the origin point and the speed scale is aligned on the "T" plotted for the wind direction. Weighted wind speeds must be plotted to the nearest 0.1 knot. At the indicated wind speed, a small tick mark is made perpendicular to the edge of the scale. For identification, the first plot is marked "21." The number "21" indicates line 2, zone 1, and is called the line-zone number. This point (marked by the perpendicular tick mark) is the point of origin for the next ballistic wind direction and weighted wind speed plots.

h. *Determining Ballistic Winds for Lines 2 Through 15.*

- (1) *Closing out plots.* The plot for a line number is closed out when all of the weighted zone winds for that line have been plotted. The plot is complete when the line-zone number of the point plotted contains two identical digits, i.e., when the line-zone number reaches 33 for the line 3 plot; 66 for the line 6 plot, etc. Closing out is done by drawing a straight line from the origin of the plot to the final plotted point.
- (2) *Ballistic winds for lines 2 through 15.* The direction and speed of the ballistic wind for a given line is determined by the direction and length of the straight line which closed the plot. The ballistic wind direction is measured by placing the center point of scale ML-577 over the point of origin, and orienting the arrow toward the top of the board and parallel to the north-south lines on the plotting board. Read the direction of the closeout line to the nearest 100 mils. The ballistic wind speed is measured by placing the zero of the ballistic wind speed scale over the point of origin, and aligning the edge of the scale along the vector which closes the plot. Read the wind speed at the end of the vector to the nearest knot. These ballistic wind data are entered in columns (11) and (12) of the rawin computation form (fig. 120).

## CHAPTER 8

## ENCODING AND TRANSMISSION OF BALLISTIC MESSAGES

**157. General**

Prior to 1961, several types of ballistic meteorological messages were used by the countries of the North Atlantic Treaty Organization (NATO). It was realized that a standard ballistic message was needed during joint combat operations for the common use and exchange of ballistic meteorological data among the allied countries. At a meeting in Paris, France, 7 to 11 November 1960; the External Ballistic Group of the Armaments Committee, NATO, adopted a standard ballistic message to be used by all the NATO member nations. As a member of NATO, the United States must fulfill its commitment with regard to specific coding procedures associated with the NATO ballistic message. DA Form 6-57, NATO Metro Message (fig. 125) is issued to all U.S. Army artillery metro sections for encoding the NATO message. The use of this form is discussed in paragraph 160. The data in 1, figure 125, are the results of the sample problem computed in chapter 7.

**158. The NATO Message Code**

*a. Symbolic Form.* The symbolic form of the NATO ballistic message code is—

METSKQ XXXXXX YYG<sub>0</sub>G<sub>0</sub>G<sub>1</sub>G<sub>1</sub>  
 hhhPPP BBC  
 ZZddFF TTTΔΔΔ ZZddFF TTTΔΔΔ  
 ZZddFF (etc.)

In order that the message may be conveniently transmitted over radio and teletypewriter circuits, it is arranged in six-digit groups, with the exception of the fifth group, which has only three digits. The initial three letters "MET" of the code remain unchanged on each message and are used as a prefix to identify a meteorological message.

*b. Definitions of Symbols.* Symbols are defined below in the order in which they appear in the message. Detailed explanations and coding procedures for each symbol are given in paragraph 159.

MET—Identifying prefix for a meteorological message.

S or A—type of fire.

K—type of message.

Q—octant of the globe in which the metro station is located.

XXXXXX—location of the metro station by latitude and longitude.

YY—date of the observation (Greenwich mean time).

G<sub>0</sub>G<sub>0</sub>—GMT hour of the beginning of the valid time period.

G<sub>1</sub>G<sub>1</sub>—GMT hour of the end of the valid time period.

hhh—altitude (height) of metro station in tens of meters.

PPP—pressure at metro station reduced to mean sea level and expressed as a percent of standard (1013.25 millibars).

BB—country of the metro section preparing the message (see table IV).

C—service (Army, Navy, or Air Force) of the metro section preparing the message.

ZZ—line number (00 through 15) of the message.

dd—ballistic wind direction in hundreds of mils.

FF—ballistic wind speed in knots.

TTT—ballistic air temperature expressed to the nearest 0.1 percent of ICAO standard (Kelvin or absolute scale).

ΔΔΔ—ballistic air density to the nearest 0.1 percent of ICAO standard.

Each consecutive line number (00 through 15) is always in a ZZ position as shown in the symbolic form (a above). The 10 digits after a line number provide ballistic data representative of that portion of the atmosphere from the surface to the top of the standard zone corresponding to the line number (1, fig. 125). The line number 00 represents the surface; therefore, ballistic data following this number represent surface meteorological conditions.

NATO METRO MESSAGE (FM 6-15)										
IDENTIFICATION MET	TYPE S OF A	TYPE MSG K	OCTANT & LOCATION Q      xxx      xxx		DATE YY	VALID TIME (GMT) G <sub>0</sub> G <sub>0</sub> G <sub>1</sub> G <sub>1</sub>	STATION HEIGHT (10's M) hhh	MSL PRES. % of STD PPP	SOURCE	
									COUNTRY BE	SERVICE C
MET	S	3	1	344 982	03	1822	036	996	US	L
ZONE HEIGHT (METERS)	LINE NUMBER ZZ	BALLISTIC WINDS		BALLISTIC AIR						
		DIRECTION (100's MILS) dd	SPEED (KNOTS) FF	TEMPERATURE (% of STD) TTT	DENSITY (% of STD) ΔΔΔ					
SURFACE	00	31	04	051	912					
200	01	25	13	046	912					
300	02	30	13	039	917					
1000	03	34	13	029	924					
1500	04	36	09	034	925					
2000	05	42	06	031	928					
3000	06	44	11	025	931					
4000	07	51	10	029	933					
5000	08	54	12	029	930					
6000	09	54	11	033	932					
8000	10	57	09	035	931					
10000	11	48	08	035	934					
12000	12	44	10	035	936					
14000	13	46	11	035	942					
16000	14	50	08	035	947					
18000	15	52	07	035	948					
REMARKS										
DELIVERED TO: RECEIVED FROM: 3d DIV ARTY							TIME (GMT) 1835			
MESSAGE NUMBER 3					DATE 3 Nov 59					
RECORDER Taylor					CHECKED Kelsey					

DA FORM 6-57, 1 MAR 62

REPLACES DA FORM 11-210, 1 JUL 56, WHICH IS OBSOLETE.

①  
Figure 125. NATO Metro Message.

THE NATO METRO MESSAGE IS ENCODED AS FOLLOWS

1. The NATO Metro Message is arranged to be conveniently transmitted by radio or teletypewriter in groups of six digits or letters, with only one exception.

2. Information data: The first three letters denote that the message is a ballistic metro message. The next letter denotes the type of fire: S-surface to surface trajectories; A-surface to air trajectories; and the following digit denotes the message-type, type 2 or 3. The sixth digit is the "Q" code of the global octant location of the metro station and the following six digits denote the location of the metro station in degrees and 10's of minutes. When 9 of the "Q" code is used, the following six digits are a coded identification of the metro station. The third group of six digits denotes the day and the hours of validity (Greenwich Mean Time) of the observation. The fourth group of six digits denotes the station height and the station pressure reduced to mean sea level and expressed in percent of standard ICAO sea level pressure. The fifth group of letters is used to denote the country and service of the metro station which produced the message. This group consists of only three letters; the first two identify the country and the third identifies the service. All succeeding groups of six are ballistic data.

3. The following specimen message was transmitted by teletype-writer:

METS31 623465 290206 025031 USL 000701  
 860163 015510 863162 . . . . .

Source Country

BE - Belgium	GR - Greece	NO - Norway
CA - Canada	IC - Iceland	PO - Portugal
DA - Denmark	IT - Italy	TU - Turkey
FR - France	LU - Luxembourg	UK - United Kingdom
GE - German Fed R	NL - Netherlands	US - United States
	Service	
L - Army	N - Navy	A - Air Force

EXPLANATION:

- Group 1 Metro Msg for surface to surface fire, type 3 message. The Metro Station located in global octant Nr 1.
- Group 2 Center of the area of applicability of the message (station location) 62°30'N; 146°50'W.
- Group 3 29th day of the month. Valid time is from 0200 to 0600 hours GMT.
- Group 4 Metro station is 250 meters above mean sea level. Station pressure is, when reduced to mean sea level. 103.1% of standard ICAO pressure.
- Group 5 The metro station is a United States - Army station.
- Group 6 Line 00 (surface) ballistic wind direction is 700 miles and wind speed is 1 knot.
- Group 7 For line 00, the ballistic temperature is 86.0% of standard and the ballistic density is 116.3% of standard.
- Group 8 Line 01, (0-200 meters) ballistic wind direction 5500 miles and wind speed is 10 knots.
- Group 9 For line 01, the ballistic temperature is 86.3% of standard and ballistic density is 116.2% of standard.

Q Code for Octant of Globe

- 0 - North latitude 0 - 90 West longitude
- 1 - " " 90 - 180 West "
- 2 - " " 180 - 90 East "
- 3 - " " 90 - 0 East "
- 4 - Not used
- 5 - South latitude 0 - 90 West longitude
- 6 - " " 90 - 180 West "
- 7 - " " 180 - 90 East "
- 8 - " " 90 - 0 East "
- 9 - Coded identification

Table IV. Source Country

Code	Country
BE	Belgium
CA	Canada
DA	Denmark
FR	France
GE	German Federal Republic
GR	Greece
IC	Iceland
IT	Italy
LU	Luxemburg
NL	Netherlands
NO	Norway
PO	Portugal
TU	Turkey
UK	United Kingdom
US	United States

### 159. Encoding of Individual Elements and Groups

The NATO message is arranged in groups to be conveniently transmitted by radio or teletypewriter.

#### a. First Group METSKQ.

- (1) **MET**—The letters “MET” are placed at the beginning of each NATO ballistic message as an identifying prefix.
- (2) **S** or **A**—An “S” specifies that the message is appropriate for weapons employed in surface-to-surface fire. An “A” is used to specify that the message is appropriate for weapons employed in surface-to-air fire.
- (3) **K**—This symbol “K” may be either a 2 or 3 depending on the type of message. The type-2 message is prepared for surface-to-air and the type-3 message for surface-to-surface ballistic trajectories (i.e., if a type-2 message is prepared, a 2 is placed in this space).
- (4) **Q**—This digit represents the global octant in which the metro section is located. For convenience in determining the geographical location of the reporting metro section, the globe has been arbitrarily divided into octants numbered 0 through 8 (the number 4 is not used) as specified in table V. An octant number of 9 is used to indicate that the next group of six digits is a special coded location.

Table V. Q Code for Octant of Globe

Q Code	Octant Location
0	North Latitude 0 to 90° West longitude
1	North Latitude 90 to 180° West longitude
2	North Latitude 180 to 90° East longitude
3	North Latitude 90 to 0° East longitude
4	Not Used
5	South Latitude 0 to 90° West longitude
6	South Latitude 90 to 180° West longitude
7	South Latitude 180 to 90° East longitude
8	South Latitude 90 to 0° East longitude
9	To be used when the location of the metro station is identified by a special code instead of the latitude and longitude.

Note. When using the Q code, latitude is always given first.

#### (5) Examples.

- (a) **META21**—Type-2 NATO message for surface-to-air fire. The metro section preparing the message is located in octant 1 of the globe (i.e., at a longitude between 90° and 180° West in the Northern Hemisphere).
- (b) **METS33**—Type-3 NATO message for surface-to-surface fire. The metro section preparing the message is located in octant 3 of the globe (i.e., at a longitude between 0° and 90° East in the Northern Hemisphere).

b. **Second Group, XXXXXX**—The second group of six digits is used to specify the location (to the nearest 10 minutes) of the reporting metro station within any particular octant of the globe. The first three digits are used to encode the latitude and the last three digits are used to encode the longitude. Examples are explained below.

- (1) **405113**. For this example, it is assumed that octant 1 is specified in the last digit of the previous group. This group shows that the location of the reporting metro station within octant 1 is latitude 40°50' North, longitude 111°30' West. If the longitude is 100 or over, the first number is dropped. The location in this case cannot be mistaken for longitude 11°30' West because this longitude is not in octant 1.
- (2) **512095**. For this example, it is assumed that the octant of the globe is 3. The location of the reporting metro station within this octant is latitude 51°20' North,

longitude 9°50' East. Again, the location cannot be mistaken for longitude 109°50' East because this longitude is not in octant 3.

c. *Third Group, YYG<sub>0</sub>G<sub>1</sub>G<sub>1</sub>.*

- (1) *YY*—These two symbols are used for the Greenwich date (i.e., the day of the current month, 01 through 31) of the observation on which the message is based. The Greenwich date may differ from the local date, depending on the location and the hour. Chart I, FM 6-16, contains the necessary information for conversion from local standard time to Greenwich mean time (GMT).
- (2) *G<sub>0</sub>G<sub>0</sub>*—These two symbols are used for the Greenwich hour (00 through 24) which represents the beginning of the valid time period. This time corresponds to the time of release of the radiosonde flight.
- (3) *G<sub>1</sub>G<sub>1</sub>*—The Greenwich hour (01 through 24) which represents the end of the valid time period is reported in these two spaces. The valid time for most messages is considered to be 2 hours. This period of time may be extended if justified by the presence of a prevailing synoptic weather situation which is stable. The valid time interval should not be extended for more than 4 hours and should not be extended at all during the period immediately before or after sunrise or sunset.
- (4) *Examples.*
  - (a) *150911*—The observation in which the message is based was taken on the 15th day of the current month. The valid time interval for this message is from 0900 hours to 1100 hours (GMT).
  - (b) *271517*—The observation was taken on the 27th day of the current month. The valid time interval is from 1500 hours to 1700 hours (GMT).

d. *Fourth Group, hhhPPP.*

- (1) *hhh*—These three spaces are used for entering the altitude of the metro station which prepared the message (i.e., the altitude of the meteorological datum plane (MDP)). The altitude is expressed in tens of meters above mean sea level.
- (2) *PPP*—The last three spaces of the fourth

group are used for encoding the station atmospheric pressure reduced to mean sea level (MSL) and expressed to the nearest 0.1 percent of ICAO standard (percent of 1013.25 millibars). The station pressure read in millibars on the barometer, is converted to percent of standard and mean sea level pressure in two steps. First, chart VI, FM 6-16, is used to convert the station pressure in millibars to a percent of standard (1013.25 mb.). Then table If, FM 6-16, is entered with the altitude of the metro station (MDP) to the nearest 10 meters to obtain the appropriate correction factor (also in percent) for reducing the converted station pressure to a mean sea level value. The correction factor is added to the converted station pressure to obtain the mean sea level value expressed as a percent of standard. In rare cases where the meteorological datum plane (MDP) is below sea level, the correction factor is subtracted from the station pressure to obtain the mean sea level value. The magnitude of the correction factor is directly proportional to the altitude of the meteorological datum plane. For example, the metro station is located at an elevation (altitude) of 480 meters, and the atmospheric pressure is 950 millibars. In chart VI, FM 6-16, 950 millibars is equivalent to 93.8 percent of standard. In table If, FM 6-16, the appropriate correction factor for a height of 480 meters is 5.8 percent. The correction factor (5.8 percent) added to the station pressure (93.8 percent) equals 99.6 percent, the mean sea level pressure used in the NATO message. The pressure reduction computation is recorded in the appropriate space on the lower right portion of DA Form 6-50 when ballistic values are determined from surface data (par. 164).

(3) *Examples.*

- (a) *033016*—The metro station is 330 meters above mean sea level. The station pressure, reduced to mean sea level, is 101.6 percent of 1013.25 mb. (the ICAO standard). The initial digit is dropped when the pressure exceeds 100 percent.
- (b) *071923*—The metro station is 710 meters above mean sea level. The station pres-



sure, reduced to mean sea level, is 92.3 percent of standard.

*e. Fifth Group, BBC.* The fifth group is the only three-letter group in the message.

- (1) *BB*—These two symbols are used to enter the code designation of the country represented by the metro section preparing the message. The code designation for each of the NATO countries is shown in table IV.
- (2) *C*—This symbol is used to reflect the service represented by the metro section preparing the message. The code designations to be used are—

L—Army (land forces)

N—Navy

A—Air Force

(3) *Examples.*

- (a) *CAA*—The message was prepared by a Canadian Air Force metro section.
- (b) *USL*—The message was prepared by a United States Army metro section.

*f. Sixth Group, ZZddFF.* The six-digit groups which follow the fifth group provide ballistic data.

- (1) *ZZ*—These two symbols are used to enter the line number which identifies the reported ballistic information with the appropriate atmospheric layer. The line numbers begin with 00 (surface) and are numbered consecutively through 15, in conjunction with the 15 standard altitude zones for a NATO message.
- (2) *dd*—The true direction from which the ballistic wind is blowing is reported by these two symbols. The direction is reported in hundreds of mils. This ballistic wind direction is representative of the atmosphere from the surface to the top of the standard zone corresponding to the line number for this group. The procedure for determining ballistic wind direction is described in detail in paragraph 156.
- (3) *FF*—These two symbols are used for encoding the ballistic wind speed in knots. This wind speed represents the atmospheric winds from the surface to the top of the standard zone corresponding to the line number for this group. The procedure for determining ballistic wind speed is described in paragraph 156.

(4) *Examples.*

- (a) *053117*—The ballistic wind direction for line number 5 is 3,100 mils. The ballistic wind speed for line number 5 is 17 knots. Thus, the ballistic wind representing the atmosphere from the surface to 2,000 meters (the top of zone 5) is blowing from 3,100 mils at a speed of 17 knots.
- (b) *104551*—The ballistic wind representing the atmosphere from the surface to 8,000 meters (the top of zone 10) is blowing from 4,500 mils at a speed of 51 knots.

*g. Seventh Group, TTTΔΔΔ.* The seventh group reports the ballistic air temperature (TTT) and ballistic air density (ΔΔΔ) for the line number shown in the sixth group. Each subsequent line of the message will furnish information in group ZZddFF and group TTTΔΔΔ for the altitude of that line number. Thus, each line number is followed by 10 digits which provide the ballistic wind, ballistic air temperature, and ballistic air density for the altitude indicated by that line number.

- (1) *TTT*—The ballistic air temperature is reported by these three spaces. This temperature is expressed to the nearest 0.1 percent of ICAO standard using the Kelvin scale. For temperature values over 100 percent, the first digit is dropped. The procedure for determining the ballistic temperatures is described in paragraph 148.
- (2) *ΔΔΔ*—The ballistic air density is reported by these three symbols. This density is expressed to the nearest 0.1 percent of ICAO standard. For density values over 100 percent, the first digit is dropped. The procedure for determining the ballistic air density is described in paragraph 149.
- (3) *Examples.*
  - (a) *973036*—For the line number of the previous six-digit group, the ballistic air temperature is 97.3 percent of standard, and the ballistic density is 103.6 percent of standard.
  - (b) *111899*—For the line number of the previous six-digit group, the ballistic air temperature is 111.1 percent of standard, and the ballistic density is 89.9 percent of standard. This temperature value cannot be mistaken for 11.1 percent because

that would obviously be too low to be realistic. Normally, ballistic temperature and density values will not depart radically from 100 percent.

### 160. DA Form 6-57, NATO Metro Message

a. DA Form 6-57 (1, fig. 125) is used by U.S. Army artillery metro sections for encoding the NATO ballistic message. This form is arranged so that the data appear in the sequence of the symbolic code for the NATO message. The first five groups of the message, METSKQ through BBC, are the introduction. As soon as these data are determined by the meteorological personnel, they are entered in the appropriate spaces across the top of DA Form 6-57. Below the introduction, the form is divided into six columns for zone height, line number, ballistic wind direction, ballistic wind speed, ballistic air temperature, and ballistic air density. As the ballistic data for each line number are determined, they are entered in the appropriate columns. Below the ballistic data columns a space is provided for any remarks deemed appropriate, such as a comment on any unusual data in the message. At the bottom of the form, a space is provided for entering the unit(s) to whom the message was sent or from whom the message was received. Also entered is the time of day the message was sent or received, the date, the message number (numbered consecutively each 24-hour period), the name of the person recording the message, and the name of the person who checked the data for accuracy.

b. On the back of DA Form 6-57 (2, fig. 125) a sample NATO message is shown and the encoding is explained. Also shown is the information for encoding the octant of the globe and the BBC group of the message.

### 161. Transmission of the Metro Message

a. *General.* Rapid distribution of the metro message is essential to furnish the firing units with the most current metro data. Any expeditious means may be used to transmit the message to the firing units. However, with the present communication system, certain means of transmission are especially suited for the distribution of meteorological data.

b. *Corps Artillery Metro Net.* Each metro section is presently equipped with radio set, AN/GRC-19. This radio is operated in the corps artillery metro net (fig. 126). The corps artillery metro net is used to coordinate radiosonde frequencies and to schedule soundings. This coordination is necessary because of the number of metro sections within a corps area, the limited number of radiosonde frequencies available, and the requirement for high altitude soundings for radiological fallout messages.

c. *The Monthly File.* DA Form 6-57 and all flight data collected for the computations of this message will be retained and kept in a monthly file. The monthly file is kept until the 15th day of the second month following, and then destroyed. For example: the January file will be destroyed on 15 March.

(1) The corps artillery metro net further pro-

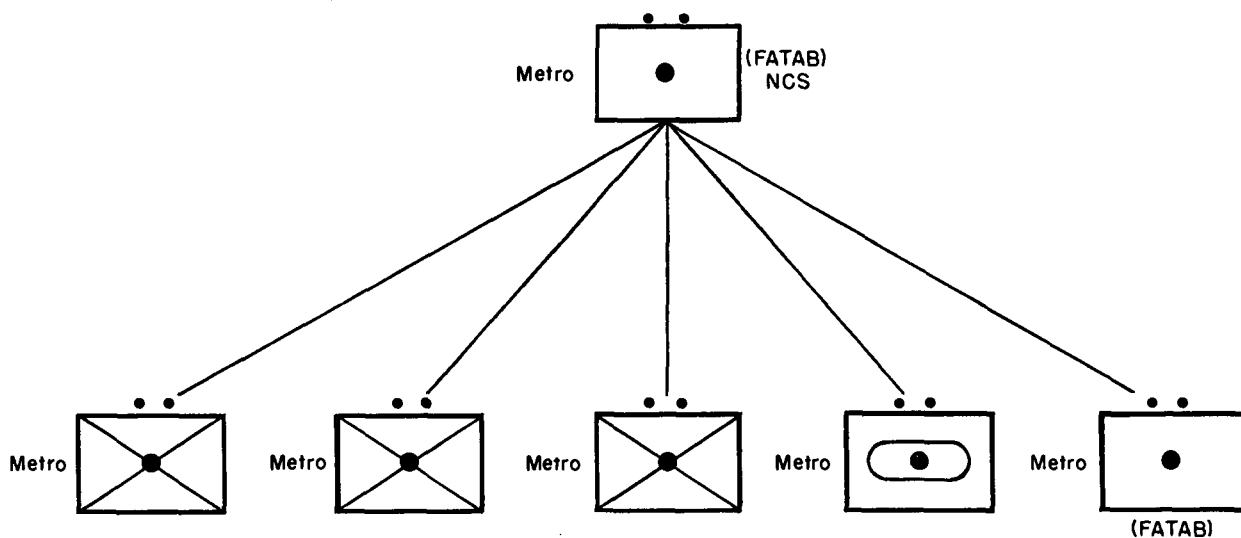


Figure 126. Corps metro net.

vides a means of "back up" to each metro section. Should a section not be able to make an observation due to displacement or equipment failure, valid data may be obtained from a neighboring section over this net.

- (2) The net control station is one of the FATAB metro sections as designated by the corps artillery communications officer.

*d. Dissemination of Metro Messages.* Wherever possible, radio teletypewriter is recommended for dissemination of metro messages. It is a rapid and efficient means of communications. In addition, the

recipient is provided with a typed copy of the metro message as well as providing him a means of acknowledging receipt.

- (1) Division artillery metro sections will deliver metro messages so the division artillery FDC, where it will be transmitted by radio teletypewriter over the division artillery command/fire direction net (RATT) to all battalions within the division artillery.
- (2) The forward FATAB metro section will deliver metro messages to the corps artillery FDC. The corps artillery FDC will transmit metro messages to the FDC's of

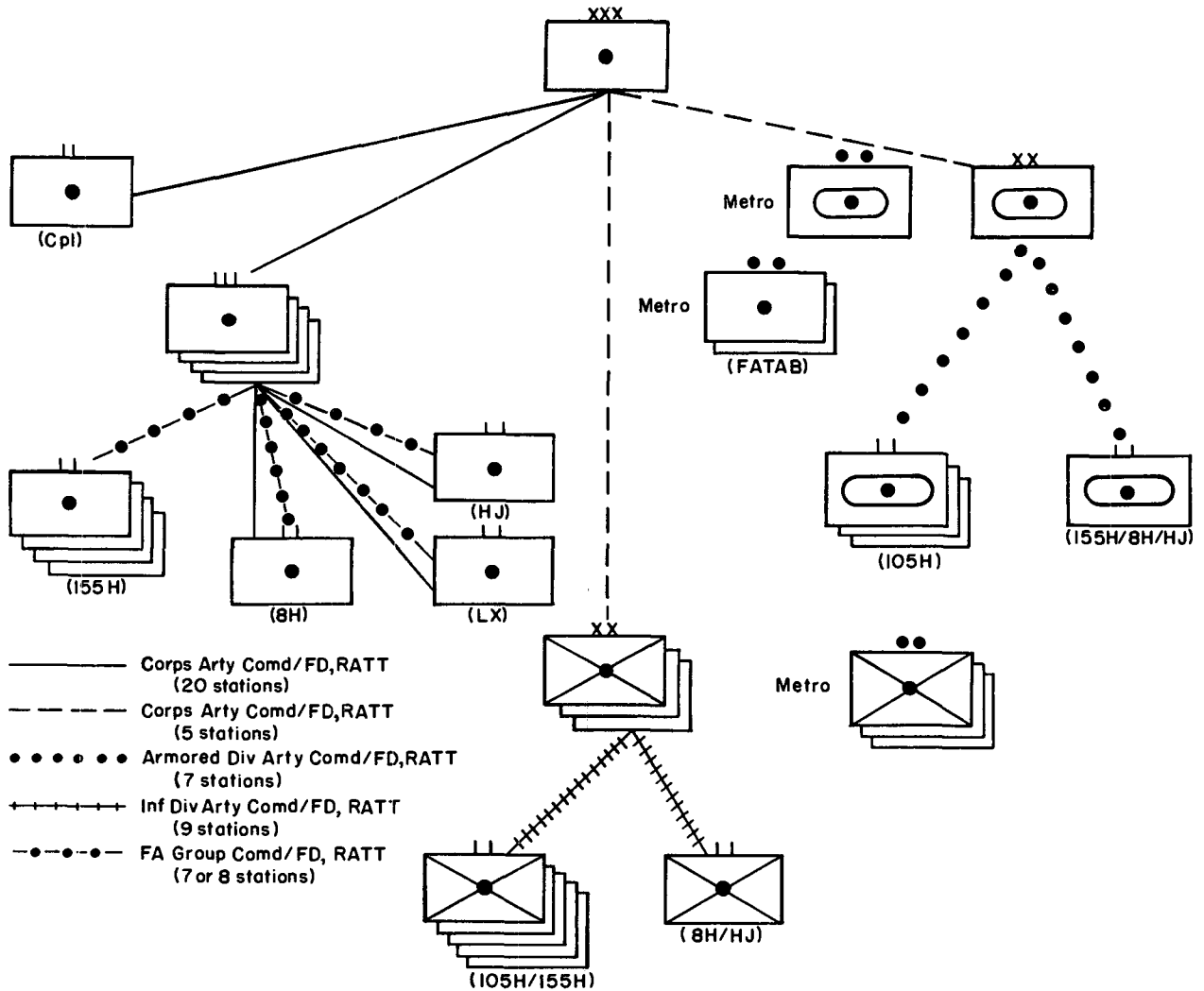


Figure 127. Corps artillery radio teletypewriter nets.

artillery battalions retained under corps artillery control and to artillery groups. The message may be transmitted over the corps artillery command/fire direction net (RATT) (fig. 127), over the corps artillery metro net or other voice communication means. Within groups, metro messages are disseminated to firing units over the group command/fire direction net (RATT). Corps and army units, firing from positions within a division combat zone, should take full advantage of metro data available from the nearest division artillery unit.

- (3) When a corps artillery unit is assigned the mission of reinforcing or general support-reinforcing a division artillery, the unit should receive metro data over the division artillery command/fire direction net (RATT). When a field artillery unit reinforces another artillery battalion, the rein-

forcing unit may obtain metro data directly from the reinforced battalion through the channel used for fire missions.

- (4) Each artillery battalion is authorized radio receiving set AN/GRR-5, with which it is capable of monitoring the corps artillery metro net. By this means, it is possible for metro data to be disseminated directly to the firing battalions. The battalions could obtain their required metro data by monitoring the corps artillery metro net at times specified by standard operating procedures. A disadvantage of this method is the inability of the firing units to acknowledge receipt of a message. Therefore, monitoring should be used only as an alternate means of obtaining metro data. When monitoring is utilized, it is essential that a definite time schedule be established for transmitting metro data.



## CHAPTER 9

## DETERMINATION OF BALLISTIC DENSITIES AND TEMPERATURES FROM SURFACE OBSERVATIONS

### 162. Surface Observations

*a. General.* The use of electronic equipment is the primary means of obtaining ballistic densities and temperatures. However, it may become necessary to use the departure method when the electronic equipment fails or a shortage of radiosondes exists and there is no other electronic metro section in the vicinity. In the departure method, the ballistic air densities and temperatures are determined from surface observations of pressure, air temperature, and wet-bulb depression, when the metro station height above sea level and the times of sunrise and sunset are known.

*b. Recording Observations.* The surface data initially recorded on DA Form 6-50, Ballistic Density from Surface Data (fig. 128), are used to determine ballistic density for each line of the message. Ballistic data are computed on DA Form 6-50 and transferred to DA Form 6-57 (NATO Metro Message).

*c. Pressure.* The station pressure at the station is recorded to the nearest millibar. If the station pressure is read in inches of mercury, it is read to the nearest 0.01 inch and converted to millibars by using chart X, FM 6-16. The station pressure in millibars is converted to percent of ICAO standard by using chart VI, FM 6-16. The percent of standard pressure at the station is reduced to pressure at sea level by applying the correction obtained by entering table If, FM 6-16, with the altitude of the station. In this table, the percent of pressure increases at the rate of 1.2 percent for each 100-meter decrease in altitude, which is the approximate change in pressure in the standard atmosphere near sea level.

*d. Temperature.* Both the wet-bulb and dry-bulb temperatures are measured to the nearest 0.1° Celsius with the psychrometer ML-224 (par. 52).

*e. Station Altitude.* The altitude of the station is determined to the nearest 10 meters above sea level from a contour map of the area or by survey (par. 106), and recorded in tens of meters.

*f. Time of Sunrise and Sunset.* Times of sunrise and sunset may be obtained from the Air Weather

Service detachment, the S2, or the division or corps survey information center (SIC).

### 163. Determining Ballistic Temperature

*a.* When the surface observation technique is used, the same ballistic air temperature is used for each line number of the message. This temperature value is also expressed to the nearest 0.1 percent of ICAO standard. After the surface temperature has been determined, this same value is entered in the appropriate spaces for the remaining lines of the message. Since the temperatures aloft are not actually measured, the assumption is made that the temperature changes with height in accordance with the standard ICAO atmosphere lapse rate. Thus, the ballistic temperature (as a percent of ICAO standard) will remain unchanged for successive line numbers.

*b.* The virtual temperature is recorded on DA Form 6-50 in degrees Celsius and percent of ICAO standard. To determine the ballistic temperature (surface virtual temperature), the wet-bulb temperature in block (3), DA Form 6-50 (fig. 129), is subtracted from the dry-bulb temperature in block (2) to nearest 0.1° C. The difference is the wet-bulb depression entered in block (4). Table Ia, FM 6-16, is entered with the dry-bulb temperature and the wet-bulb depression to determine the surface virtual temperature to the nearest 0.1° C. The virtual temperature is entered in block (5). The virtual temperature in degrees Celsius is converted to the nearest 0.1 percent of standard by using chart XII, FM 6-16.

### 164. Use of Departure Tables

*a. General.* Research in climatology has indicated that a correlation exists between the density at the surface and the densities aloft. The procedure for computing the ballistic densities is based on the use of climatological tables which contain the values of the upper air densities corresponding to specific regions of the world, time of day, and

BALLISTIC DENSITY FROM SURFACE DATA FM 6-15										
STATION <i>3d Div Arty</i>			LOCATION <i>Fort Sill, Okla</i>			RE- LEASE TIME	DATE	HOUR	FLIGHT NR. <i>3</i>	
							LST	1400		
						GMT		2000		
1	(8) TYPE MESSAGE					(1) SURFACE PRESSURE	INCHES		MSL % STD (ICAO) <i>100.8</i>	
	BALLISTIC		S	A			MILLIBARS <i>978</i>			
2	(9) REGION							(2) DRY <i>20.2</i> <sup>c</sup>		
	1	2	3	4	5	6	7			
3	(10) PERIOD							(3) WET <i>16.3</i> <sup>c</sup>		
	Night		Afternoon			Transition				
(11) TRUE SURFACE DENSITY						(1) TEMPERATURE				
(12) MEAN SURFACE DENSITY										
(13) DEPARTURE FROM MEAN SURFACE DENSITY						(7) SUNRISE <i>0611</i>			SUNSET <i>1901</i>	
Lines	DEPARTURE FROM MEAN BALLISTIC DENSITY (14)				BALLISTIC DENSITY % (15)		COMPUTATIONS			
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
OBSERVER					COMPUTER			CHECKER		

DA FORM 6-50, 1 MAR 62

PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

Figure 128. Recording initial data on DA Form 6-50.

BALLISTIC DENSITY FROM SURFACE DATA FM 6-15														
STATION				LOCATION				RE-LEASE TIME		DATE	HR	FLIGHT NR.		
<i>3d Div Arty</i>				<i>FORT SILL, OKLA</i>				LST		<i>8 APR 60</i>		<i>1400</i>		<i>3</i>
										GMT		<i>8 APR 60</i>		
1	(8) TYPE MESSAGE						(1) SURFACE PRESSURE	INCHES		MSL % STD (ICAO)				
	BALISTIC		S		A			MILLIBARS		<i>100.8</i>				
2	(9) REGION							TEMPERATURE	(2) DRY					
	1	2	3	4	5	6	7		<i>20.2 °C</i>					
(10) PERIOD							(3) WET							
Night		Afternoon			Transition		<i>16.3 °C</i>							
(11) TRUE SURFACE DENSITY							(4) DEPRESSION							
(12) MEAN SURFACE DENSITY							(5) VIRTUAL							
(13) DEPARTURE FROM MEAN SURFACE DENSITY							(6) STATION HEIGHT (10's METERS)							
(14) DEPARTURE FROM MEAN BALLISTIC DENSITY							(7) SUNRISE		SUNSET					
(15) BALLISTIC DENSITY %							COMPUTATIONS							
OBSERVER							COMPUTER			CHECKER				

DA FORM 6-50, 1 MAR 62

PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

Figure 129. Determining ballistic temperature.



BALLISTIC DENSITY FROM SURFACE DATA FM 6-15											
STATION			LOCATION			RE- LEASE TIME	DATE		FLIGHT NR.		
3d Div Arty			FORT SILL, OKLA				[Grid]	LST	1400	3	
						GMT		08 APR 60			
1	(8) TYPE MESSAGE					(1) SURFACE PRESSURE	INCHES		MSL % STD (ICAO)		
	BALLISTIC		S		<del>X</del>		MILLIBARS				
							978		100.8		
2	(9) REGION					TEMPERATURE	(2) DRY				
	1	<del>X</del>	3	4	5		6	7	20.2 °C		
(10) PERIOD					(3) WET			16.3 °C			
Night		<del>X</del> Afternoon		Transition			(1) DEPRESSION			3.9 °C	
(11) TRUE SURFACE DENSITY					(5) VIRTUAL						
					22.0 °C 102.9% STD						
(12) MEAN SURFACE DENSITY					(6) STATION HEIGHT (10's METERS)						
					036						
4	(13) DEPARTURE FROM MEAN SURFACE DENSITY					(7) SUNRISE		SUNSET			
						0611		1901			
Line #	DEPARTURE FROM MEAN BALLISTIC DENSITY (14)			BALLISTIC DENSITY % (15)			COMPUTATIONS				
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
OBSERVER				COMPUTER				CHECKER			

DA FORM 6.50, 1 MAR 62

PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

Figure 130. Data for selecting a table of departure from mean surface density.

measured surface conditions. Tables are provided for both surface-to-surface (type-3) and surface-to-air (type-2) ballistic messages. In the tables, the values of density are expressed as a percent of standard ICAO atmosphere.

*b. Recording Starting Data.* The data for selecting a table of departure from mean surface density are recorded in blocks (8) message type, (9) region, and (10) period, DA Form 6-50 (fig. 130).

*c. Type of Message.* An X is placed in the appropriate box in block (8), DA Form 6-50, indicating the type of message being prepared.

*d. Region.* The Northern Hemisphere is divided into seven climatic regions (chart I, FM 6-16). The number of the region in which the metro station is located is determined, and an X is placed in the appropriate box of block (9). If the metro station is in the Southern Hemisphere, the number of the climatic region of the Northern Hemisphere most nearly resembling the climate of this location is used. Assistance in selecting this region may be obtained from the weather staff officer at division, corps, or army headquarters.

*e. Periods.* A meteorological day is divided into three periods; night, afternoon, and transition (fig. 131). A separate set of data is provided for each period. If the sky is covered by opaque clouds, regardless of the time of day or night, the determination of densities by the departure method should

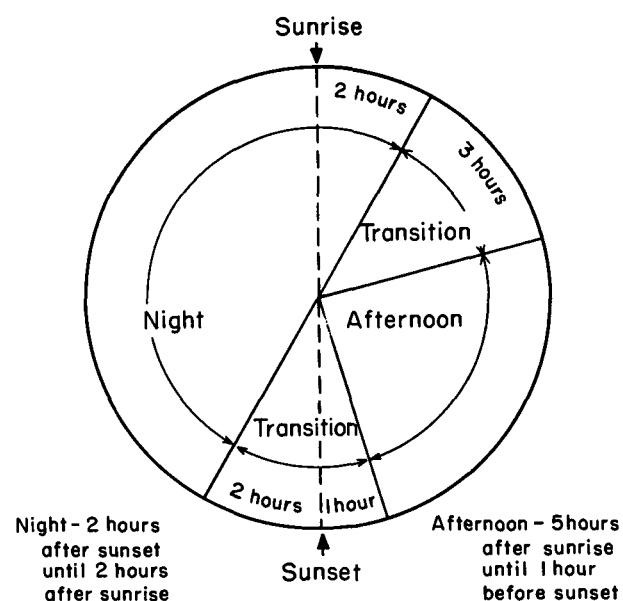


Figure 131. Meteorological day.

be based on the transition period. In determining the correct period, the times of sunrise, sunset, and release are used in conjunction with chart IV, FM 6-16. An X is placed in the appropriate box in block (10), DA Form 6-50. The periods are defined as follows:

- (1) *Night*—from 2 hours after sunset until 2 hours after sunrise.
- (2) *Afternoon*—from 5 hours after sunrise until 1 hour before sunset.
- (3) *Transition*—the two 3-hour periods between the night and afternoon periods.

## 165. Departure From Mean Surface Density

In order to determine the departure from mean surface density, the mean surface density in block (12) and the true surface density in block (11) must be known. The true surface density is determined to the nearest 0.1 percent by entering table Ib, FM 6-16, with the virtual temperature in block (5) to the nearest 0.1° Celsius and the surface pressure in block (1) to the nearest millibar and entered in block (11) (fig. 132). The mean surface density is determined to the nearest 0.1 percent by entering chart V, FM 6-16, with the station altitude to nearest 10 meters and entered in block (12). The mean surface density is the ICAO standard density at the altitude of the meteorological datum plane. The mean surface density in block (12) is algebraically subtracted from the true surface density in block (11), and the result to the nearest 0.1 percent is the departure from mean density. The departure from mean surface density, with the proper sign, is entered in block (13).

## 166. Ballistic Density

*a. Departure From Mean Ballistic Density.* The type of message, the region, and the period are used to select the appropriate table of departure from mean surface density (tables IIc and IIIc, FM 6-16). The table is entered with the line number and the value of the departure from mean surface density with the proper sign to the nearest whole percent. The departure from mean ballistic density is determined to the nearest 0.1 percent for each line number required and entered on the appropriate line in block (14), DA Form 6-50.

*b. Percent of Standard Ballistic Density.* The percent of standard ballistic density for each line is obtained by adding algebraically the departure from

BALLISTIC DENSITY FROM SURFACE DATA FM 6-15											
STATION			LOCATION				RE-LEASE TIME		DATE	HOUR	FLIGHT NR.
<i>3d Div Arty</i>			<i>FTSILL, OKLA</i>				<input type="checkbox"/> LST <input type="checkbox"/> GMT		<i>8 APR 60</i>	<i>1400</i> <i>2000</i>	<i>3</i>
1	(8) TYPE MESSAGE					(1) SURFACE PRESSURE	INCHES		MSL % STD (ICAO)		
	BALLISTIC		S	<input checked="" type="checkbox"/>			MILLIBARS				
2	(9) REGION							(2) DRY		<i>20.2 °C</i>	
	1	<input checked="" type="checkbox"/>		3	4	5	6				7
3	(10) PERIOD					TEMPERATURE		(3) WET		<i>16.3 °C</i>	
	Night		<input checked="" type="checkbox"/>		Afternoon						Transition
(11) TRUE SURFACE DENSITY						(4) DEPRESSION		(5) VIRTUAL		<i>22.0 °C 102.9%STD</i>	
<i>94.2</i>											
(12) MEAN SURFACE DENSITY						(6) STATION HEIGHT (10's METERS)					
<i>96.6</i>						<i>036</i>					
4	(13) DEPARTURE FROM MEAN SURFACE DENSITY					(7) SUNRISE		SUNSET			
<i>-2.4</i>						<i>0611</i>		<i>1901</i>			
Lines	DEPARTURE FROM MEAN BALLISTIC DENSITY (14)				BALLISTIC DENSITY % (15)			COMPUTATIONS			
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
OBSERVER				COMPUTER				CHECKER			

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PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

Figure 132. Determining departure from mean surface density.

BALLISTIC DENSITY FROM SURFACE DATA FM 6-15											
STATION <i>3d Div Arty</i>			LOCATION <i>FT. SILL, OKLA</i>				RE-LEASE TIME		DATE	HOUR	FLIGHT NR.
		LST		8 APR 60		1400		3			
		GMT		8 APR 60		2000					
1	(8) TYPE MESSAGE					(1) SURFACE PRESSURE	INCHES		MSL % STD (ICAO) <i>100.8</i>		
	BALLISTIC		S		<input checked="" type="checkbox"/>		MILLIBARS <i>978</i>				
2	(9) REGION							TEMPERATURE		(2) DRY <i>20.2 °C</i>	
	1	<input checked="" type="checkbox"/>		3	4	5	6			7	(3) WET <i>16.3 °C</i>
3	(10) PERIOD							(1) DEPRESSION <i>3.9 °C</i>			
	Night		<input checked="" type="checkbox"/>		Afternoon		Transition				
(11) TRUE SURFACE DENSITY <i>94.2</i>						(5) VIRTUAL <i>22.0 °C 102.4% STD</i>					
(12) MEAN SURFACE DENSITY <i>96.6</i>						(6) STATION HEIGHT (10's METERS) <i>036</i>					
4	(13) DEPARTURE FROM MEAN SURFACE DENSITY <i>-2.4</i>					(7) SUNRISE <i>0611</i>		SUNSET <i>1901</i>			
Lines	DEPARTURE FROM MEAN BALLISTIC DENSITY (14)				BALLISTIC DENSITY % (15)			COMPUTATIONS			
1	<i>-1.7</i>				<i>94.9</i>						
2	<i>-1.8</i>				<i>94.8</i>						
3	<i>-1.9</i>				<i>94.7</i>						
4	<i>-2.2</i>				<i>94.4</i>						
5	<i>-2.5</i>				<i>94.1</i>						
6	<i>-2.7</i>				<i>93.9</i>						
7											
8											
9											
10											
11											
12											
13											
14											
15											
OBSERVER <i>Davis</i>				COMPUTER <i>Basham</i>				CHECKER <i>Buntyn</i>			

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PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

Figure 133. Completed ballistic density form.

**FM 6-15**

mean ballistic density for that line number and the mean surface density in block (12). The percent of standard ballistic density is entered to the nearest 0.1 percent for each line number in block 15 (fig.

133).

*c. Encoding Ballistic Density.* The ballistic densities in block (15) are transferred to the NATO Metro Message, DA Form 6-57.

## CHAPTER 10

## DETERMINATION OF BALLISTIC WINDS FROM OBSERVATION OF PILOT BALLONS

### 167. Tracking Pilot Balloon and Recording Angular Data

*a. General.* The primary means of obtaining ballistic winds is by radiosonde observation. When electronic equipment fails or is not available, ballistic winds may be determined from observation of pilot balloons. Winds determined from pilot balloon observation are not as accurate as winds determined from radiosonde observation, basically because the height of a pilot balloon is estimated by using an assumed rate of rise. Pilot balloons and observing equipment are described in paragraphs 53 through 66.

*b. Tracking.* When possible, the balloon should be released approximately 100 meters downwind from the theodolite. This will reduce the tracking error and increase the accuracy of low-level winds. Initially, the balloon is tracked with the open sights and with the tracking controls disengaged. The first elevation and azimuth angles measured are read to the nearest whole degree. After reporting the first readings, the observer tracks the balloon through the telescopic sight. To change to the telescopic sight, the observer alines the open sights on the balloon, then quickly moves to the eyepiece and engages the tracking controls. The wide-angle finder telescope may be used until the balloon steadies on its flight path. The balloon is tracked using the tracking controls for the remainder of the flight. When the timer-recorder commands WARNING, the observer adjusts the tracking controls so that the crosshairs are centered on the balloon. At the common READ, he ceases tracking, and reports to the timer-recorder the elevation angle and the azimuth angle to the balloon, in that order, to the nearest 0.1°. Individual numbers are reported. An elevation angle of 71.6° and an azimuth angle of 247.3° are reported as SEVEN ONE POINT SIX . . . TWO FOUR SEVEN POINT THREE. From time to time, the observer must refocus the main telescope to insure a sharply defined image. When angular values are changing rapidly, the observer may require assistance in positioning the sights on the balloon. An assistant also may be needed to

read one or both angles while the observer concentrates on tracking. When the elevation angle approaches 90°, the balloon must be tracked by rapid azimuth movement of the telescope so that the elevation angle does not exceed 90°.

*c. Recording Data.* Angular data are recorded on DA Form 6-42, Ballistic Winds from Observations of 30- and 100-Gram Balloons, which also is used to record the zone wind and ballistic wind values (fig. 134). The timer-recorder completes the marginal information on the form. In column (1), time at top of zone, the time data which is not appropriate for the balloon being used should be lined through. At release, the previously zeroed timer must be started. A reading must be taken at exactly the times indicated in column (1). To do this, the timer-recorder commands WARNING to the observer approximately 5 seconds before the time indicated. At the exact time of reading, the timer-recorder commands READ. The observer reports the elevation and azimuth angles (*b* above). The timer-recorder examines the angular readings carefully and calls for a recheck of angles which appear unreasonable or inconsistent with those previously reported.

*d. Interpolation of Missing Angular Data.* If for some reason the angular data for a given reading is lost or missed, these angles may be determined by interpolating between the adjacent readings. Interpolation is based on the proportional change in height of the balloon for the missing readings as compared with the total change between the adjacent readings. The angular values determined by interpolation are indicated on the form by circling, since they are not actual flight data. If angular data are missed for two or more consecutive zones, the flight is considered lost from the missing data upwards. If this occurs, another flight should be made.

### 168. Plotting Zone Winds

*a. General.* After the elevation and azimuth angles to the position of the balloon at the top of each zone have been determined and recorded, the horizontal distance in meters to each of these heights

BALLISTIC WINDS FROM OBSERVATIONS OF 30 AND 100 GRAM BALLOONS (FM 6-15)													
STATION			LOCATION				RE-LEASE TIME		DATE		HOOR	FLIGHT NR.	
<i>3d Div Arty</i>			<i>FT. SILL, OKLA.</i>						<i>8 APR 60</i>		<i>1400</i>	<i>2</i>	
								<i>8 APR 60</i>		<i>2000</i>			
Zone nr.	(1) Time at top of zone (min & sec)		(2) Elevation angle (degrees)	(3) Azimuth angle (degrees)	(4) Horizontal distance (meters)	(5) Horizontal travel in zone (meters)	(6) Time in zone (min & tenths)		ZONE WIND DATA		Line nr.	BALLISTIC WIND DATA	
	30 gram gallon	100 gram gallon					30 gram balloon	100 gram balloon	(7) Azimuth (10's mils)	(8) Speed (knots)		(9) Azimuth (100's mils)	(10) Speed (knots)
Off-set	/ / / / /		/ / / / /	<i>360.0</i>	<i>100</i>	/ / / / /	/ / / / /		<i>SUR 320</i>	<i>SUR 05</i>	<i>0</i>	<i>SUR 32</i>	<i>SUR 05</i>
<i>1</i>	<i>0:54</i>	<i>0:36</i>	<i>24.0</i>	<i>360.0</i>	<i>450</i>	<i>350</i>	<i>0.0</i>	<i>0.0</i>	<i>320</i>	<i>13</i>	<i>1</i>	<i>32</i>	<i>13</i>
<i>2</i>	<i>2:21</i>	<i>1:24</i>	<i>22.2</i>	<i>065.0</i>	<i>1220</i>	<i>1120</i>	<i>1.5</i>	<i>2.8</i>	<i>475</i>	<i>24</i>	<i>2</i>	<i>46</i>	<i>19</i>
<i>3</i>	<i>5:00</i>	<i>2:54</i>	<i>24.3</i>	<i>068.3</i>	<i>2210</i>	<i>1000</i>	<i>2.6</i>	<i>1.5</i>	<i>449</i>	<i>12</i>	<i>3</i>	<i>45</i>	<i>13</i>
<i>4</i>	<i>7:42</i>	<i>4:24</i>	<i>25.4</i>	<i>073.5</i>	<i>3160</i>	<i>980</i>	<i>2.7</i>	<i>1.0</i>	<i>471</i>	<i>12</i>	<i>4</i>	<i>46</i>	<i>13</i>
<i>5</i>	<i>10:24</i>	<i>5:48</i>					<i>2.7</i>	<i>1.5</i>			<i>5</i>		
<i>6</i>	<i>15:42</i>	<i>8:54</i>					<i>5.3</i>	<i>3.1</i>			<i>6</i>		
<i>7</i>	<i>21:00</i>	<i>12:00</i>					<i>5.3</i>	<i>3.1</i>			<i>7</i>		
<i>8</i>	<i>26:18</i>	<i>15:18</i>					<i>5.3</i>	<i>3.3</i>			<i>8</i>		
<i>9</i>	<i>31:36</i>	<i>19:48</i>					<i>5.3</i>	<i>2.5</i>			<i>9</i>		
<i>10</i>	<i>42:21</i>	<i>25:36</i>					<i>10.8</i>	<i>6.0</i>			<i>10</i>		
<i>11</i>	<i>53:12</i>	<i>32:24</i>					<i>10.8</i>	<i>4.8</i>			<i>11</i>		
<i>12</i>	<i>64:00</i>	<i>39:12</i>					<i>10.8</i>	<i>6.8</i>			<i>12</i>		
<i>13</i>	/ / / / /	<i>46:00</i>					/ / / / /	<i>6.0</i>			<i>13</i>		
<i>14</i>	/ / / / /	<i>52:48</i>					/ / / / /	<i>6.8</i>			<i>14</i>		
<i>15</i>	/ / / / /	<i>59:36</i>					/ / / / /	<i>6.8</i>			<i>15</i>		

(11) MESSAGE TYPE (CHECK ONE)		THEODOLITE OPERATOR		TIMER-RECORDER		ZONE WIND PLOTTER		BALLISTIC WIND PLOTTER	
<i>V</i>	<i>S</i>	<i>A</i>	<i>Carlstrom</i>	<i>Schierer</i>	<i>Taylor</i>	<i>Trout</i>			

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PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

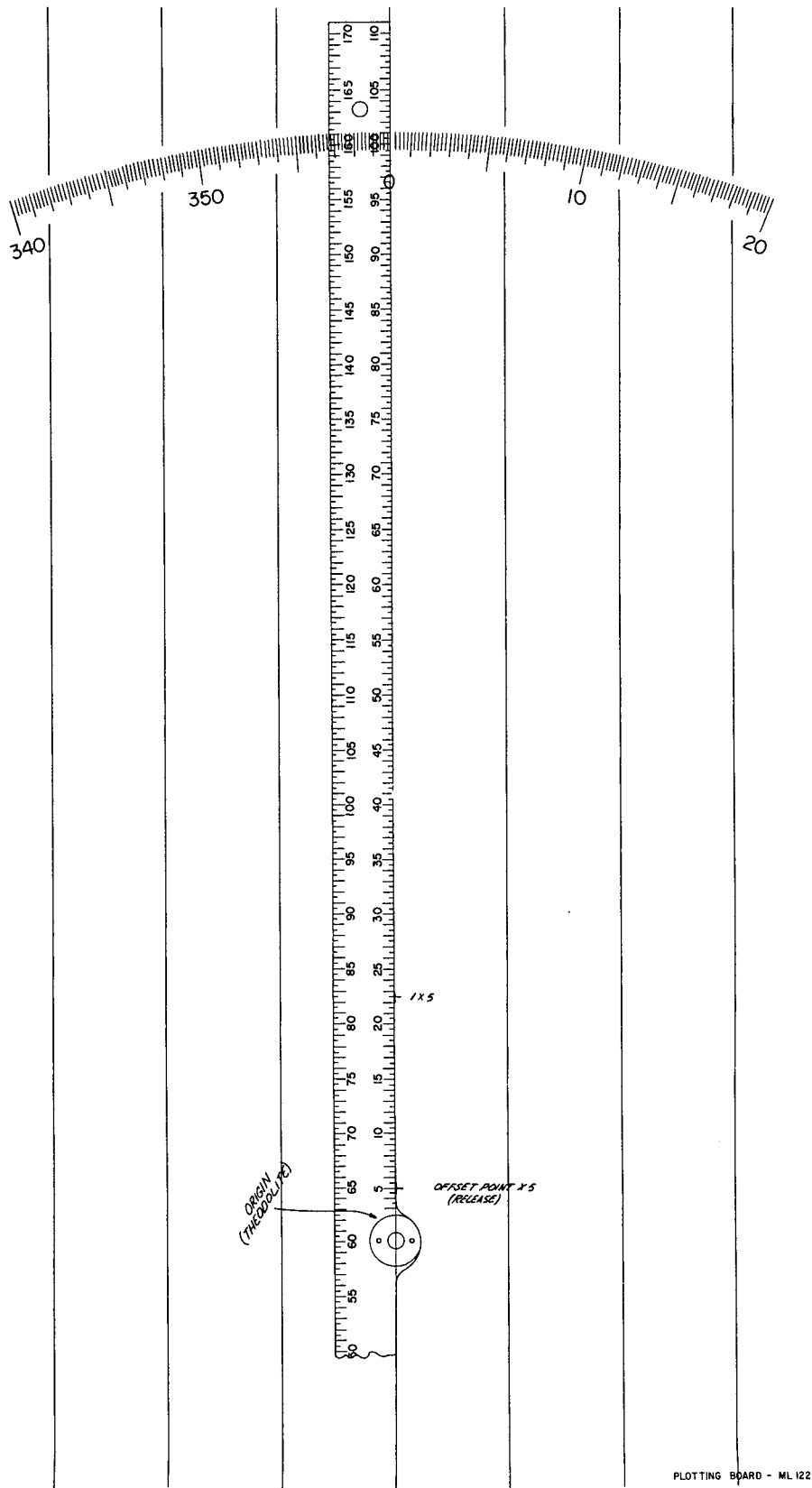
Figure 134. Ballistic wind data.

is determined from horizontal distance tables in FM 6-16. The hole in the center of the azimuth circle in plotting board ML-122 is used as the theodolite position (fig. 27). Beginning with zone 1, the position of the balloon at the top of each zone is polar plotted from the origin.

b. *Offset Release Point Data and Plotting Procedure.* When the pilot balloon is released from a point offset more than 50 meters from the theodolite, the actual point of release in relation to the theodolite must be plotted on the zone wind plotting board. The direction to the release point is determined from the theodolite just before release, and the distance is determined by pacing from the point of release to the theodolite. The direction and distance of the release point must be included in the zone wind plot.

Normal plotting procedure is followed. The release point is marked "offset point," and the zone 1 point is marked with the zone number (1) (fig. 135).

c. *Determination of Horizontal Distance.* The zone wind is a projection of the balloon flight path on a curved earth. Thus, it is necessary to know the distance from the theodolite to the point on the ground directly under the balloon. Table Ig, FM 6-16, provides the horizontal distance for each standard height and is entered with the elevation angle to the balloon as an argument. The table is entered with the elevation angle to the nearest 0.1°. The horizontal distance is read to the nearest 10 meters. Horizontal distance to the release point need not be determined, unless the release point is more than 50 meters from the theodolite (b above).



PLOTTING BOARD - ML 122

Figure 135. Zone wind plot.



These data are recorded in column (4), DA Form 6-42.

*d. Plotting Scale.* Rule ML-126A permits plotting at a scale of 1 inch equals 750 meters. The longer scale is graduated every 50 meters and marked in hundreds of meters at 500 meter intervals up to 17,000 meters. The smaller scale on this rule, which is similar in numbering and graduations, is used for plotting low wind speeds. However, at times it is necessary to expand or reduce the scale. To expand the scale, the distance is multiplied by a factor of 2, 5, or 10, and the magnified distance is plotted. When the horizontal distance to be plotted is less than 500 meters, it is necessary to expand the scale to a measurement of at least 500 meters to facilitate plotting. For example, if the distance is between 250 and 500 meters, a minimum factor of 2 is required so that the product is 500 or greater. If the distance is between 100 and 250 meters, a minimum factor of 5 is required; and, if the distance is less than 100 meters, a minimum factor of 10 is required. Normally, the largest of the factors 2, 5, or 10 that will permit plotting of at least two consecutive points is the best choice for expansion of the scale. When the horizontal distance is 500 meters or more, expansion is unnecessary. During the course of plotting, a point to be plotted may fall off the board. When this occurs, it will be necessary to reduce the plotting scale so that subsequent points will fall on the plotting board. When reducing the scale, the same factors of 2, 5, or 10 may be used (preferably the smallest factor possible). To measure actual distance, the plotted distance must be divided or multiplied by the same factor used in plotting.

*e. Plotting Zone Winds.* Plotting begins as soon as the horizontal distance to the top of zone 1 has been determined. Plotting board ML-122 is oriented by placing north directly away from the plotter. Then the pivot hole of plotting rule ML-126A is placed on the pin in the center of the azimuth circle on the plotting board (fig. 135). The pin can be raised by pushing forward on the lever beneath the board. The rule is then placed so that the edge in line with the pivot hole passes over the appropriate azimuth on the plotting board. Opposite the appropriate horizontal distance on the edge of the rule, the balloon position is marked with a small T-shaped index formed by a straight line (the top of the T) along the edge of the rule and a short tick mark (the stem of the T) perpendicular to the line.

Each point plotted is identified by the zone number at which the angular data was read. If the plot is made at other than the normal scale, the factor by which the distance is expanded or reduced is shown after the zone number by writing a multiplication or division sign and the factor used ( $1 \times 5$ ) (fig. 135). In this manner, the angular data for each of the required standard heights are plotted. A completed zone wind plot for a 30-gram pilot balloon would appear the same as the zone wind plot for a sounding balloon (fig. 123).

**169. Determining Zone Wind Speed and Direction**

*a. Surface.* The direction and speed of the surface wind are determined with anemometer ML-433/PM. The azimuth is obtained by converting the reading of the compass direction to the nearest 100 mils (fig. 136). The speed is read directly from the anemometer to the nearest whole knot. Surface wind direction and speed are recorded in columns (7) and (8) on DA Form 6-42. The procedure for using anemometer ML-433/PM is described in paragraph 49. An alternate means of measuring surface wind is observing the pilot balloon at 15 seconds for a 30-gram balloon or 10 seconds for a 100-gram balloon. The observed direction to the balloon is converted to a wind direction using table Ie, FM 6-16. The observed elevation angle is converted to a wind speed using table Ic or Id, FM 6-16.

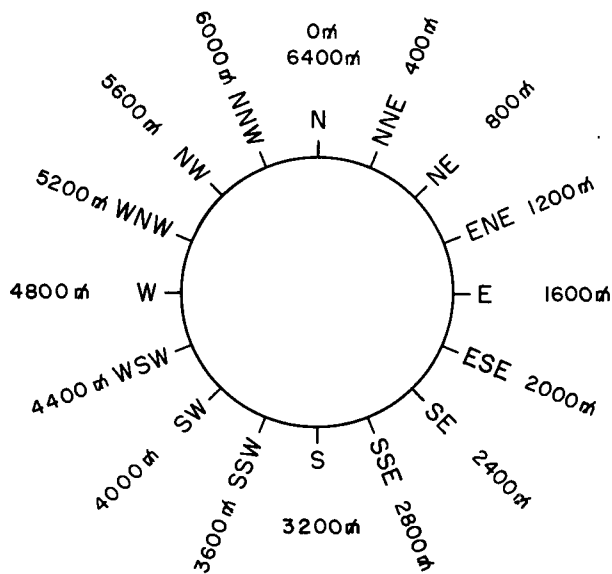
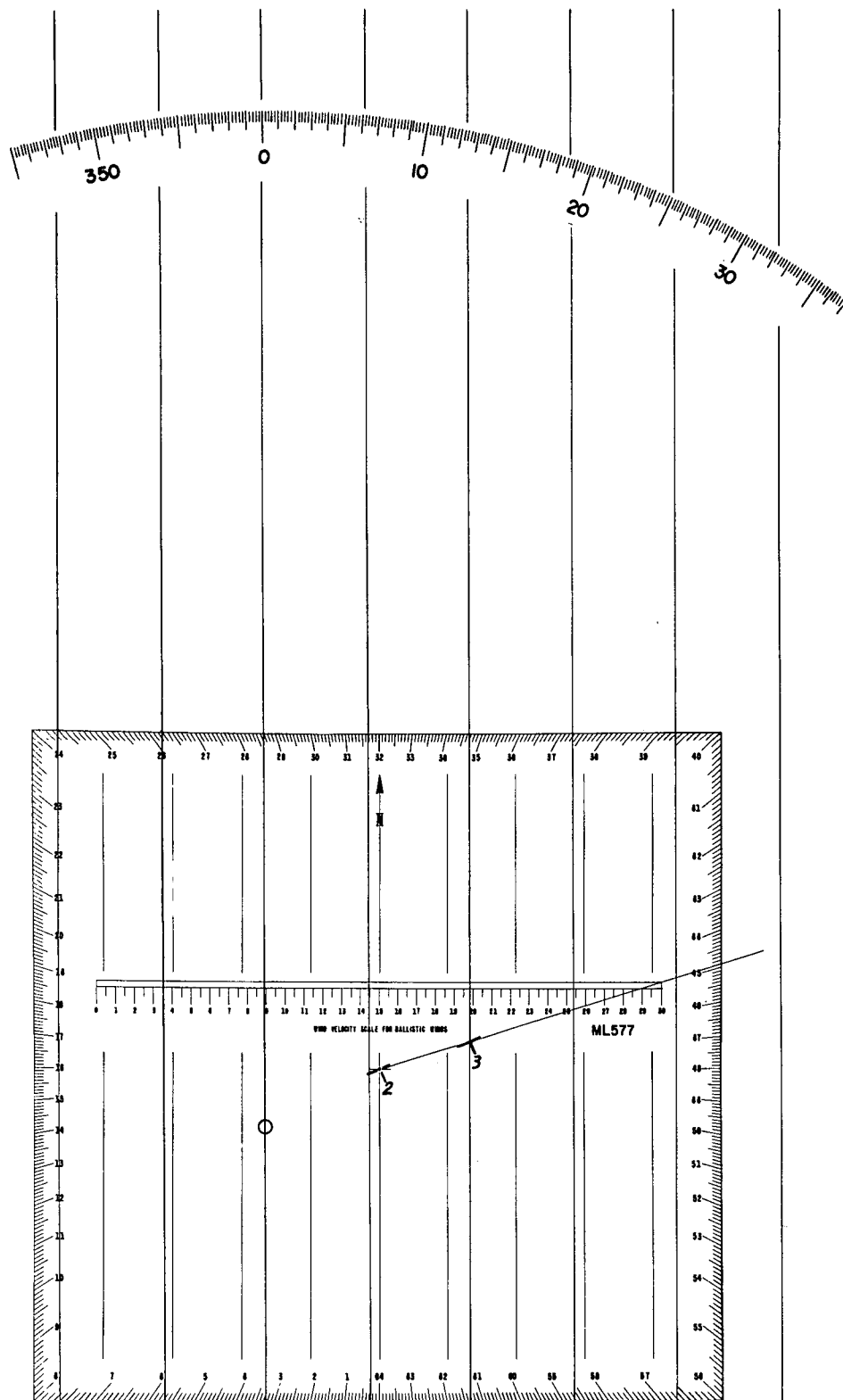


Figure 136. Conversion of points of compass to mils.



PLOTTING BOARD-ML122

Figure 137. Measuring zone wind direction with scale ML-577.

*b. Reading Zone Wind Direction.* The zone wind directions for zone 1 and higher are read directly from the plots by using wind plotting scale ML-577. A line is drawn from the point where the balloon entered the zone to a point over and sufficiently beyond the next point to enable the plotter to read the direction on scale ML-577. The center of the scale, identified by the short horizontal line intersecting the long vertical north line, is placed over the point of origin or the plotted point where the balloon entered the zone being considered. The scale is oriented with north by alining the vertical lines of the scale with those on the plotting board. The wind direction is read and recorded to the nearest 10 mils. This procedure is used for each succeeding plot. Since the wind direction is that direction from which the wind is blowing, back azimuths of the directions are measured. Scale ML-577 is constructed to allow the plotter to read these back azimuths directly. In figure 137, the zone wind direction for zone 3 is 4,490 mils. This azimuth is recorded as 4,490 in column (7), DA Form 6-42 (fig. 134). When an offset release point is used, the wind direction for zone 1 must be determined from the offset release point, because it is the point of origin and the wind direction for zone 1 is measured from the point of origin.

*c. Determining Zone Wind Speeds.*

- (1) *Measuring horizontal travel in zone.* Horizontal travel in zone is the net horizontal distance in meters that the balloon travels in a given zone. Since the amount of time in zone is known, the zone wind speed is obtained by dividing the horizontal travel by the time in zone and converting the result to knots. The time in each zone is always a fixed value predetermined by the assumed rate of rise of the balloon. These fixed time intervals are used in conjunction with horizontal travel in zone to determine the wind speed in knots. The horizontal travel in each zone is measured in meters with rule ML-126A. For example, to measure the horizontal travel in zone 2 (fig. 138), the rule is alined between the plotted points representing the tops of zone 1 and zone 2. The horizontal travel (5,560 meters) is read to the nearest 10 meters (in fig. 138, from 5 to 6.06 or 5.56). The measuring procedure is repeated for

each zone plotted. If the scale of the zone wind plot was expanded or reduced by a given factor, the horizontal travel measured with the rule must be divided or multiplied by the same factor. In this example,  $5560 \div 5 = 1112$  or 1110 meters. The values of horizontal travel in zone are entered in column (5) on DA Form 6-42.

- (2) *Time in zone.* Column (1) of DA Form 6-42 gives the time of arrival of the pilot balloon at each standard height. Since zone 1 begins at the surface (zero time), the time in zone 1 is equal to the time the balloon reaches standard height 1. Time in zone 2 is equal to the time the balloon reached standard height 2 minus the time at standard height 1. Similarly, time in zone 3 is equal to the time at standard height 3 minus the time at standard height 2. Time in zone for each succeeding zone is determined in the same manner. These values of time in zone are printed in column (6) of DA Form 6-42. Since the time at standard height for each artillery zone is a fixed time, the time the balloon spends in each respective zone is always the same.
- (3) *Computing zone wind speed.* Each zone wind speed is computed by using the formula:  $D/T \times 0.0324 = S$ ; wherein D is the horizontal travel in meters, T is the time in zone in minutes and tenths, and S is the zone wind speed in knots. The factor 0.0324 is used to convert meters per minute into knots. The values of zone wind speed obtained are recorded in column (8) on DA Form 6-42. The computations are performed with slide rule ML-59 as follows:
  - (a) The hairline on the indicator is set over the value of horizontal travel on the D scale.
  - (b) The time in zone on the C scale is moved under the hairline.
  - (c) The hairline is moved to 0.0324 on the C scale.
  - (d) The zone wind speed is read under the hairline on the D scale to the nearest whole knot.

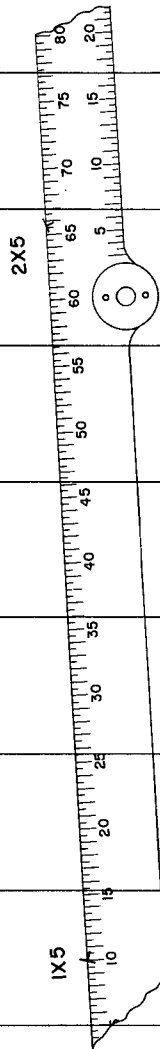


Figure 188. Measuring distance traveled in zone.

## 170. Determining Ballistic Winds

a. *Ballistic Winds for Line 0 and 1.* Line 0 (SUR) and line 1 ballistic winds are the same as the surface wind and zone 1 wind. Therefore, the zone wind data recorded in columns (7) and (8) for lines 0 and 1 are entered for the ballistic wind data in columns (9) and (10) on DA Form 6-42.

b. *Plotting Lines 2 through 15.*

- (1) *General.* A projectile with a trajectory that has a maximum ordinate in excess of 500 meters (2d standard height) is affected by the wind in both zones 1 and 2. A projectile that rises to 1,000 meters (3d standard height) is affected by the winds in zones 1, 2, and 3, and a projectile that rises to 3,000 meters (6th standard height) is affected by the winds in zones 1, 2, 3, 4, 5, and 6. In general, the value of the ballistic wind for any given line of the metro message is determined by considering the zone winds of all zones from the surface to the standard height of that line. To obtain the ballistic wind for any line above line 1, a plot is made of the weighted wind effect of each zone which contributes to the ballistic value for that line of the message. These plots take the form of vectors. The vector direction represents the zone wind direction, and the magnitude of the vector represents the weighted zone wind speed. The sum of the zone wind vectors is the ballistic wind.
- (2) *Selecting starting points.* The plotting board ML-122 is oriented so that the closely spaced parallel lines run from the top to the bottom of the board. The top of the board represents north. Origin points for the lines to be plotted are selected at the intersections of the horizontal and vertical lines. The proper selection of these origin points will depend on the direction and speed of the winds aloft and should afford maximum plotting space. The first origin selected is that for line 2. It usually is selected on the horizontal line that affords maximum plotting space in the direction that the plot is expected to extend. Its position along the line depends on the direction of the wind. If the wind is from the west, the origin is selected at one of the

intersections near the left edge of the board. If the wind is from the east, the origin is moved farther to the right so that subsequent plots will not fall off the board. The remaining origins are placed along the same line as the first until they fall too close to the edge of the board, then another line is used. Each origin is numbered to represent the line being plotted. Therefore, it is possible to have origins numbering from 2 to 15.

- (3) *Plotting zone 1 direction.* The center of scale ML-577 is centered over the origins for lines 2 through 15, and oriented so that the north-south lines of the scale are alined with the north-south lines on the board. Since the projectile must pass through zone 1 in order to reach the higher zones, the wind direction for zone 1 is first plotted at each of the origins. The direction for zone 1 is plotted by selecting the azimuth along the outer edge of the scale which corresponds to the wind direction for zone 1 (3,200 mils in fig. 134). The point of intersection is identified by a small T-shaped index formed by drawing a straight line (the top of the T) along the edge of the scale and a short tick mark (the stem of the T) perpendicular to the line (fig. 139).
- (4) *Determining zone 1 weighted wind speed.* To determine the weighted wind speed for zone 1, the weighted wind speed tables in FM 6-16 are used. The selection of the correct table depends on the type of message. In figure 134, a type-3 message(s) is checked. This means that the weighted wind speed table for a type-3 message (table IIIe) is used. The arguments for entering the table are the zone number, the zone wind speed, and the line-zone number. The numbers across the top of the table are the line-zone numbers. In table IIIe, Weighted Wind Speeds (Type-3 Message), Zone 1, the first line-zone number is 21. This is interpreted as meaning line 2, zone 1 (i.e., the effect of zone 1 on line 2). The next line-zone number is 31 (line 3, zone 1). The wind speed to the nearest knot for zone 1 is used to enter the table. In figure 134, the zone 1

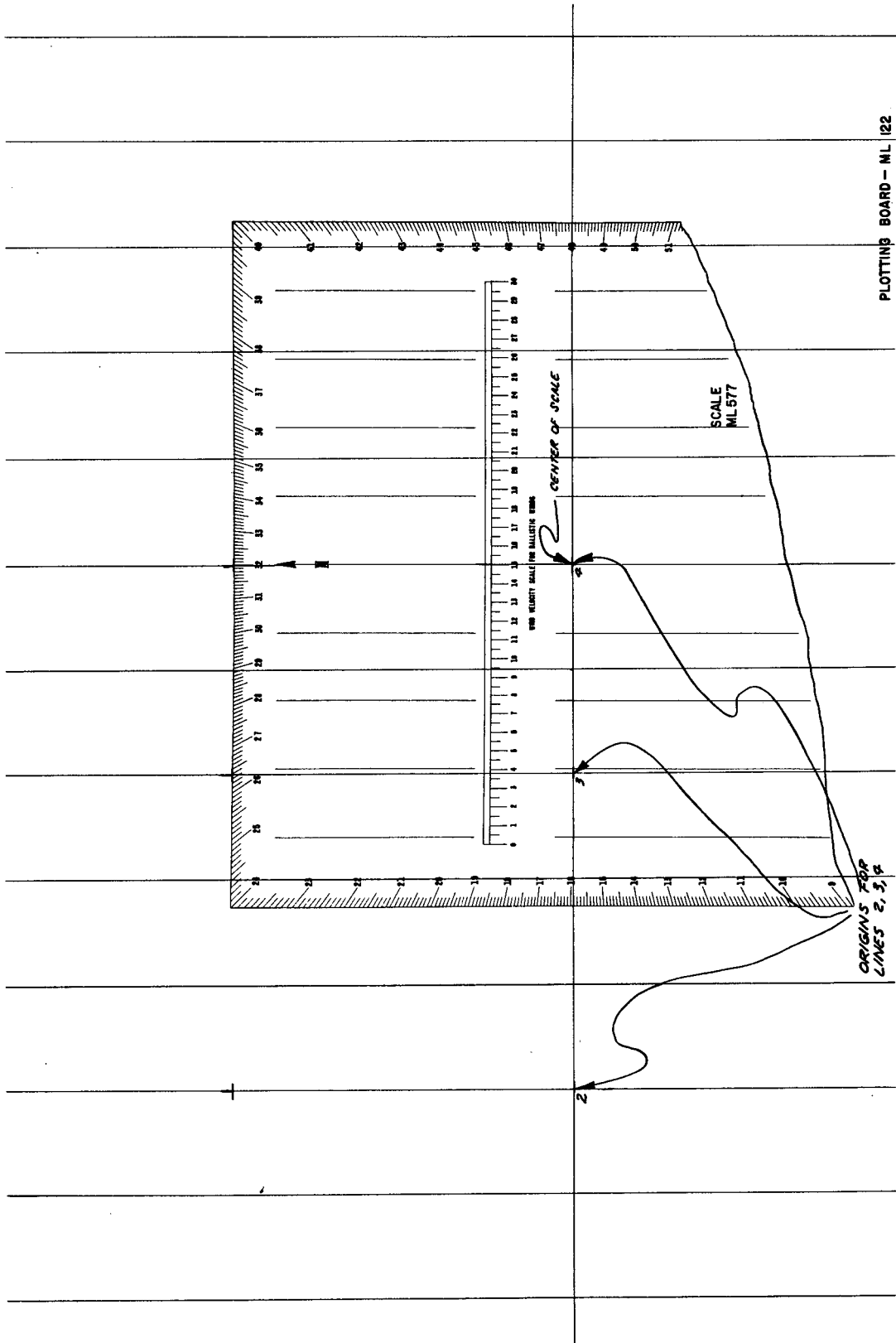


Figure 159. Ballistic wind plot.



wind speed is 13 knots. By entering the table at 13 knots, the weighted wind speed for line 2, zone 1, is found to be 2.6 knots. For line 3, zone 1, the weighted wind speed is 1.2 knots; and for line 4, zone 1, the weighted wind speed is 0.8 knots.

- (5) *Plotting zone 1 weighted wind speeds.* In order to plot the first weighted value, the ballistic wind velocity scale on scale ML-577 is oriented so that the zero falls at the origin of the plot and the edge indicating wind speeds extends through the point of intersection of the stem and top of the T-shaped index, or azimuth mark (fig. 140). The weighted wind speed is plotted to the nearest 0.1 knot by interpolating between the printed graduations when necessary. The weighted wind speed determined from the table for zone 1 for line-zone 21 is 2.6 knots. With the zero end of the scale at the origin point for line 2 and the scale oriented through the azimuth mark, a straight line is drawn from the origin to the 2.6 knot graduation on the scale where a small tick mark is made perpendicular to the scale. For identification, the plot is numbered 21. In order to indicate that this particular segment of the plot has been completed, a small "x" is drawn through the azimuth mark at the time the weighted speed is plotted. The scale is shifted to the next origin which is 3. The same procedure is used to plot the weighted wind speed of 1.2 knots for line-zone 31. The plot is drawn and identified with a 31 and a small "x" is placed through the azimuth mark. Next, the weighted wind speed is plotted from origin 4 and identified as 41, etc.
- (6) *Plotting zone 2 weighted wind speeds.* To plot the second segment, the same procedure is used for direction as before, except that the center of scale ML-577 is aligned over the last plot (21, 31, 41). This time the zone 2 wind direction of 4,740 mils is plotted. Again, a T-shaped azimuth mark is drawn to indicate direction. The weighted wind speeds are determined in the same manner as before except that the zone 2 wind speed is used to enter the zone 2 portion of table IIIe instead of the

zone 1 table. In figure 134, the zone 2 wind speed is 24 knots. To obtain the weighted wind speed for line 2, zone 2, the table is entered under the line-zone number 22 at the wind speed of 24 knots. This weighted value is 19.2 knots. For plot 32, the weighted value is 4.6 knots, and for plot 42, the weighted value is 2.9 knots. The weighted wind speeds are determined and plotted for the remaining lines by placing the zero mark of the ballistic wind velocity scale at the end of the first segment (21, 31, 41, etc.) instead of at the origin. An "x" is placed through the azimuth mark as before.

- (7) *Completing the ballistic wind plot.* After the zone 2 weighted wind speeds have been plotted, the effects of the zone 3 wind speed on line 3 and above are plotted. To plot these effects, the zone 3 wind direction is plotted in the same manner as the zone 2 wind direction, except that the center of the scale is oriented over the end of the segment for each line (32, 42, 52, etc.). Then the zone 3 weighted wind speeds are scaled off along the zone wind direction for each of the lines. Similarly, the wind directions and weighted wind speeds for succeeding zones are plotted for the lines they affect. Each plot for a given line originates from the last point plotted for that line. In this way, the weighted wind effects for each zone are combined as vectors to obtain the total effect (fig. 141). When the line and zone number for the plot for any given line coincide and before plotting is continued, the plot for this line is closed out and the ballistic wind direction and speed are measured and recorded in columns (9) and (10) on DA Form 6-42. The ballistic wind speed is measured first by placing the zero of the wind velocity scale on the point of origin and reading the ballistic wind speed at the end of the last plot for that line (fig. 141). The speed is read to the nearest 0.1 knot and rounded off to the nearest whole knot. The ballistic wind direction is determined last by extending a line from the point of origin through the last plot. The line must be of sufficient length so that it will extend



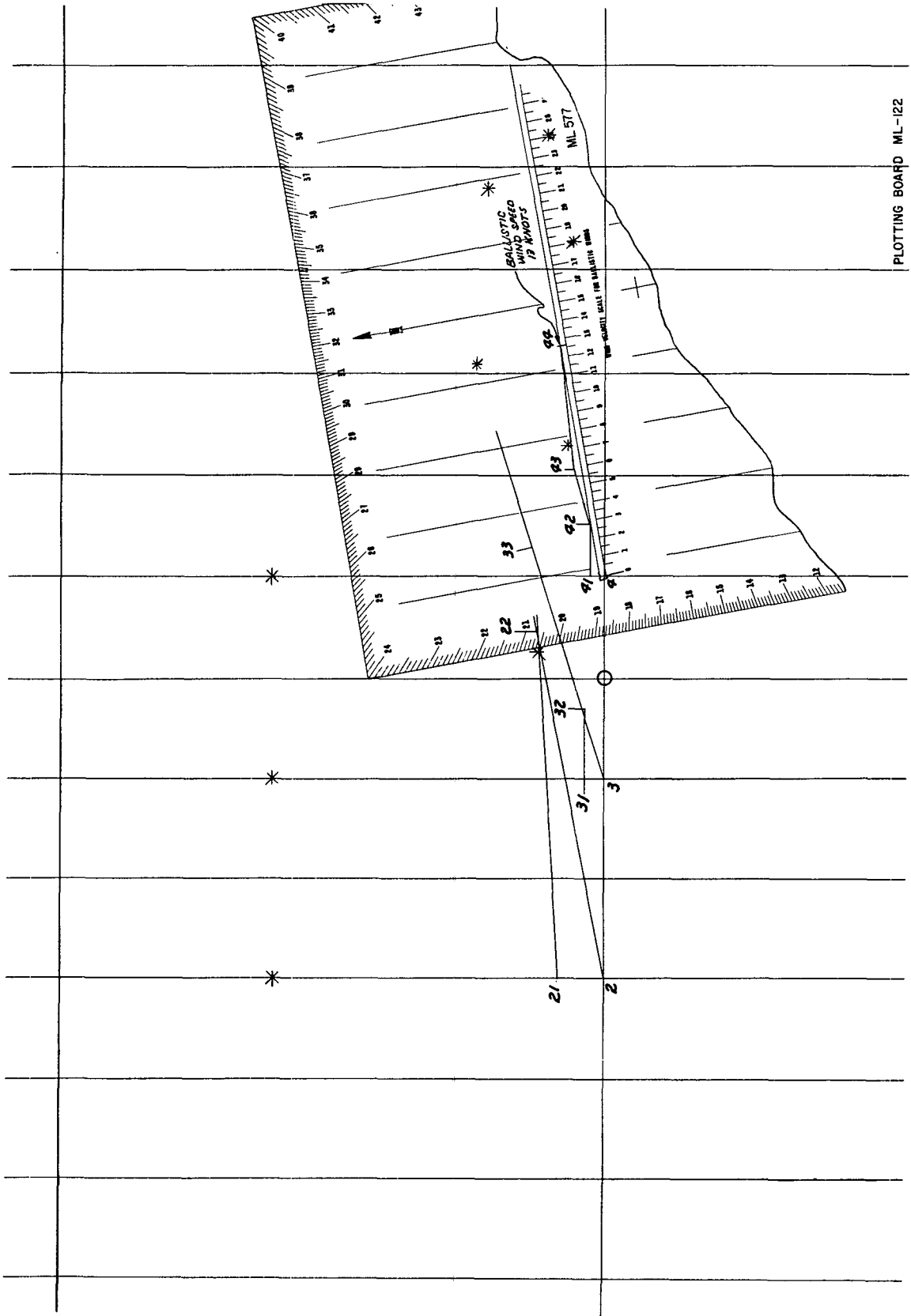


Figure 141. Measuring ballistic wind speed.

beyond the outer edge of scale ML-577. The midpoint of the scale is placed over the point of origin with the north-south lines on the scale parallel to the north-south lines on the plotting board. The direction is read at the point where the extended line passes underneath the outer edge of the azimuth scale. This azimuth is read and recorded to the nearest 100 mils.

- (8) *Plotting off the board.* When a point extends off the plotting board, the entire

plot is moved by changing the origin. The direction and speed of the last point plotted is read from the origin and replotted from the new origin; it is not necessary to replot intermediate points between the origin and the last point.

- (9) *Encoding data.* Ballistic winds (columns (9) and (10), DA Form 6-42) are encoded on the NATO Metro Message form as described in paragraph 159.



## CHAPTER 11

### VALIDITY OF BALLISTIC METEOROLOGICAL MESSAGES

#### 171. General

The validity of the meteorological message is extremely important to artillery commanders and staff officers. There are two broad factors which affect the validity of metro message data: the accuracy of the weather measuring system and the variability of the atmosphere. Artillery metro sections are capable of obtaining very accurate measurements of the atmosphere through which the radiosonde travels; however, in the true sense, these measurements pertain only to one location and one instant in time. The values of wind, air density, and air temperature continuously undergo complex and inconsistent variations in both time and space (distance). On occasion, these weather variables may change abruptly over a very short distance or over a brief interval of time. On other occasions and in other geographical areas, the change may be extremely gradual with respect to both distance and time. The trajectory of the artillery projectile will always be some distance from where the weather elements were actually measured. Also, some time will elapse between the measurement of atmospheric conditions and the firing of the weapon. This elapse of time is due to the time required for completion of the radiosonde flight, computation and transmission of the message, and the determination of appropriate meteorological corrections to be applied to the weapon. Thus, the validity question arises.

#### 172. Space Validity

*a.* In general, the validity of a message decreases as the distance increases from the meteorological sounding site. Local topography has a pronounced effect on the distance to which metro data may be reasonably extended. For instance, mountainous terrain particularly influences the wind, causing large variations over short distances. This orographic effect on wind frequently extends to heights much greater than the tops of the mountains. It would be impossible to compute a valid distance for every combination of weather and terrain which might exist; however, the following general rules may be used as a guide:

- (1) Over fairly level terrain, such as the Central States, a message is considered valid up to 32 kilometers.
- (2) In mountainous terrain, the valid distance should be reduced by approximately 50 percent.

*b.* The proximity of large bodies of water will have an effect on both the time and space validity of metro messages due to the existence of land and sea breezes and the effect of humidity on density (increased humidity decreases air density). Therefore, the space validity of a message should be reduced when operating along coastlines.

#### 173. Time Validity

Because of the changing nature of weather data, the validity of a message will decrease with the passage of time. With the present equipment, it is extremely difficult for the artillery metro section to provide ballistic metro messages more frequently than every 2 hours. Experience has shown that meteorological messages provided more often than once every 2 hours gives only marginal improvement to artillery fire. There are no specific rules by which the valid time may be specified. The valid time is a function of the characteristics of the atmosphere. When the weather pattern is variable, the valid time should not exceed a 2-hour period. If the passage of a weather front is forecast for the area, the valid time of the message should not extend beyond the time forecast for the arrival of the front in the area. When the weather pattern is stable, the valid time may be extended to 4 hours during the middle of the day or night.

#### 174. Validity of Density Departure Tables

The ballistic density departure tables in FM 6-16 are used when the pilot balloon and surface observation technique of obtaining atmospheric data is employed. The tables are based on climatological data; therefore, it is apparent that upper air density values obtained from these climatological data are not as accurate as density values based on actual upper air measurements with a radiosonde.

**175. Criterion for Selection of Meteorological Data**

*a.* In November 1959, the U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J., published the results of a study on the validity of ballistic density obtained from various sources. This study was based on a series of firings conducted in 1958 at Fort Sill, Okla. From that study, it was determined that the order of accuracy of the various sources is as follows:

- (1) Current metro message from local observation station.
- (2) Current metro message from any station within 32 kilometers of the local station.
- (3) A 2-hour old metro message from local station.

- (4) Current metro message from any station between 32 and 80 kilometers from the local station or a 2-hour old message from a station within a 32-kilometer radius.
- (5) Current metro message from a station 80 to 112 kilometers distant, or a 2-hour old message 32 to 48 kilometers distant, or a 4-hour old message from local station.
- (6) Ballistic density departure tables.

*b.* The list of sources in *a* above, indicates that more accurate ballistic density values can be obtained by using metro messages from other areas or older messages of the local observation station than by using the density departure tables. Ballistic density departure tables should be available, but they should be used only as a last resort when no better data are available.

**PART THREE**  
**METEOROLOGY FOR SOUND RANGING**  
**CHAPTER 12**  
**PRINCIPLES OF SOUND RANGING**

### 176. Sound Ranging Theory

*a.* Sound ranging is a method of locating a sound source (such as the firing of a weapon or the burst of a projectile) through computations which depend on the speed of the sound wave produced. The discharge of a gun or the burst of a shell causes a sound disturbance or pressure vibration in the air which lasts for only a fraction of a second. The sound wave travels outward through the air at speeds which vary with the atmospheric conditions. Sound ranging techniques locate the source of the sound wave by measuring the time intervals between the arrival of the sound wave at several accurately located microphones.

*b.* The speed of sound is not a fixed value but varies with existing meteorological conditions. In order to make the necessary computations, certain atmospheric conditions are designated as standard. Existing atmospheric conditions are measured, plotted, and weighted, and this information is disseminated to the sound ranging sections of the target acquisition battalion. Correction factors are applied to the measured sound ranging data to compensate for the variation of actual atmospheric conditions from standard.

*c.* The standard meteorological conditions on which all computations are based are a wind speed of zero and an effective temperature of ten degrees Celsius (10° C.) at a height of 200 meters above the surface. Under these standard conditions, the speed of sound is 337.6 meters per second. Standard conditions seldom, if ever, exist in the atmosphere.

### 177. Meteorological Effects on the Speed of Sound

The direction and speed of the wind and the temperature and humidity of the air affects the manner in which a sound wave travels through the atmosphere.

*a. Wind.* Wind may increase or decrease the speed of sound, depending on whether the wind moves with or against the direction of the sound

waves. Cross winds tend to displace the entire sound wave without distorting it, provided the entire volume of air moves at the same speed and in the same direction. In the atmosphere, the wind speeds are seldom uniform and tend to distort the sound waves. However, wind corrections are based on the assumption that the wind velocity is uniform. As an example of the effect of wind on locating a sound source, it is known that a cross wind of 9 knots at standard effective temperature (10° C.) and at a range of 9,144 meters results in a location which is 128 meters right or left of the true location. In addition to introducing errors in the location of sound sources, high winds create noise interference on the sound recording which makes evaluation extremely difficult. Sound ranging is ineffective when surface wind speeds exceed 45 knots.

*b. Temperature.* One formula for expressing the speed of sound is  $V = 20.06 \sqrt{T_s}$ , where  $V$  is the speed of sound in meters per second and  $T_s$  is the effective or sonic temperature in degrees Kelvin (sonic temperature in ° C. plus 273.2). Hence, it may be stated that speed of sound varies directly with the temperature. For example, a sound source located at a range of 7,315 meters, a sonic temperature of 21° C. (11° C. above standard) at a height of 200 meters above the surface, and with a calm atmosphere (no wind) will result in erroneously locating the source 155 meters over the true location.

*c. Relative Humidity.* The speed of sound also varies directly with the amount of moisture in the air. This effect is compensated for by adjusting the air temperature. Sonic temperature is air temperature adjusted for moisture. The adjustment is described in paragraph 178b.

*d. Pressure and Density.* Another formula for expressing the speed of sound is  $V^2 = \frac{KP}{\rho}$ , where  $V$

is the speed of sound in meters per second,  $K$  is a constant which is the ratio of specific heat at constant pressure to the specific heat at constant volume of the gas (for air,  $K = 1.4$ ),  $P$  is the pressure

in millibars, and  $\rho$  is the density in grams per cubic meter of the gas. From this equation, it can be seen that the speed of sound is a function of the ratio of pressure to density. Since pressure and density change in almost the same proportion in the atmosphere, the ratio remains fairly constant. Therefore, changes in pressure and density have slight effect on the speed of sound and are disregarded.

### 178. Meteorological Data for Sound Ranging

The meteorological data which are used for sound ranging consist of the sonic temperature in °C. at a height of 200 meters above the metro station and the effective wind direction and speed between the surface and a height of 800 meters. The effective wind direction is expressed to the nearest 10 mils. Effective wind speed is a weighted average of the wind speed in knots between the surface and a height of 800 meters.

*a. Source of Data.* Sound ranging data are available at the artillery metro section and the sound ranging sections.

- (1) Artillery metro sections use radiosondes to accurately measure wind and temperature.
- (2) Sound ranging sections observe pilot balloons to measure the winds. They measure temperature at the surface and estimate the sonic temperature at 200 meters.

*b. Data for the Sound Ranging Metro Message.*

- (1) *Steps in determination of data.*
  - (a) The sound ranging effective temperature or sonic temperature is determined from measurements of temperatures and relative humidity.
  - (b) The sound ranging effective wind direction and speed are determined from angular measurements to the position of a balloon at timed intervals. The wind directions and speeds computed from these measurements for certain layers of the atmosphere above the metro station are weighted, and these weighted values are totaled to obtain the effective wind direction and speed.
- (2) *Wind weighting factors.* Four sets of wind

weighting factors are available for computing the effective wind. The correct set is chosen by comparison of the measured layer wind speeds.

- (3) *Recording data.* Final data are recorded on DA Form 6-48, Weather Data for Sound Ranging, and reported to the sound ranging sections. The form provides spaces for recording the measurements, application of weighting factors, and the final data.

*c. Transmission of Data.* The sound ranging data are transmitted to the sound ranging section by the most expeditious means. The best means of transmission will depend on the relative location of the metro section furnishing the data. If the data are prepared by an electronic metro section, away from the sound base, wire communication normally will be used.

*d. Coordination Between Sound Ranging Officer and Meteorological Officer.* Close liaison between the sound ranging and metro sections is very important to insure that the meteorological data used to compute the sound ranging data are the best available. Usually the sound ranging section prepares its own data by using its visual equipment. However, it should be kept in mind that the metro section using electronic equipment is capable of providing these data. Also, the sound ranging section will not be able to use visual equipment during periods of poor visibility, and electronic data may be the only data available. The decision on whether to use electronic data or the sound ranging section data will depend on the location of the metro section in relation to the sound base and the topography of the area. Many times, the metro section can report to the sound ranging section the presence of abnormal temperature lapse rates off surface that will affect the evaluation of sound ranging effective temperature. Technical advice on methods of computing meteorological data and on maintenance of equipment common to both sections is available at the metro section. Therefore, the sound ranging officer should contact the nearest metro section in his area and make the presence of the sound ranging section and its requirements known.

## CHAPTER 13

## SOUND RANGING MESSAGE DEVELOPED FROM RADIOSONDE DATA

**179. General**

It is possible to determine the effective wind and temperature from the data obtained during any radiosonde sounding. A radiosonde is carried aloft by a sounding balloon and transmits meteorological data to a radiosonde recorder on the ground. The radio direction finder automatically tracks the radiosonde and records angular data used for determination of wind direction and speed. A sound ranging message can be prepared from the recorded data, and will not appreciably delay the ballistic metro message. The sound ranging message is forwarded to the sound ranging sections immediately upon completion of the necessary computations; it is not held until the flight is completed.

*a. Modifications to Weather Data for Sound Ranging Form.* When a sound ranging message is to be prepared from radiosonde data, DA Form 6-48 (Weather Data for Sound Ranging) (fig. 142) is used. In the WIND DATA section on the form, the column of 30-gram balloon data under the heading "Time at layer limit" is lined out. The Surface Observation block in the TEMPERATURE DATA section is not used, and the TIME OF SUNRISE and TIME OF SUNSET blocks are not required.

*b. Consideration in Selecting the Observation Site.* The location of the artillery metro section is normally dictated by the location of the artillery units using its data. Its location may or may not be centrally located either laterally or in altitude with respect to the sound base. However, its location relative to the sound base should be kept in mind so that the meteorological data provided the sound ranging unit will be valid.

**180. Procedure for Determining Effective Temperature**

The effective temperature is the sonic temperature at a height of 200 meters. The sonic temperature is computed from the formula  $T_s = \frac{3T_v + T}{4}$ ,

where  $T_s$  is the sonic temperature,  $T_v$  is the virtual temperature, and  $T$  is the thermistor temperature. The sonic temperature is computed in the Radiosonde Observation section of the TEMPERATURE

DATA block on DA Form 6-48 (fig. 142). The virtual temperature is read to the nearest  $0.1^\circ$  from the sounding curve on chart ML-574/UM at the point where it crosses the 200-meter zone height line and recorded on the data sheet. To determine the thermistor temperature value at 200 meters, the thermistor temperature is plotted at the significant level just below and just above the 200-meter line (1 and 2, fig. 143). A straight line is drawn between the two plots. The point at which this line crosses the 200-meter line (3, fig. 143) represents the thermistor temperature at 200 meters. The thermistor temperature to the nearest  $0.1^\circ$  C. is entered in the Radiosonde Observation section of the TEMPERATURE DATA block on DA Form 6-48. The sonic temperature is then computed and entered on the line for effective temperature in the DATA REPORTED TO SOUND RANGING SECTION block. The data in figure 143 normally will be reflected on chart ML-574/UM (1, fig. 113) used for the ballistic sounding; however, for instructional purposes the data are shown separately.

**181. Procedure for Determining Effective Wind Direction and Speed**

The sound ranging layer wind data are obtained from radiosonde data in the same manner as the artillery zone winds are obtained (par. 152). First, the pressure that the sounding balloon encountered at each sound ranging layer limit is read from chart ML-574/UM (fig. 143) and recorded on the sound ranging form, DA Form 6-48. The times at which the radiosonde transmitted these pressures are determined from the pressure-time chart (1, fig. 121) and entered on the sound ranging form. The azimuth and elevation angles corresponding to these times are read from the control-recorder tape and entered on the form. From these angular values and the times, the layer winds are determined by the wind plotting technique described in *d* below. For sound ranging, the effective wind speeds and directions are obtained from the sound ranging layer winds in the manner described in *e* below.

*a. Determining Time at Layer Limits.* The pressures at the sound ranging layer limits of 200,



WEATHER DATA FOR SOUND RANGING																			
STATION		LOCATION			RE-LEASE TIME		DATE		HOUR		FLIGHT NR								
3d Div Arty		FORT SILL, OKLA			LST GMT		3 NOV 59 3 NOV 59		1130 1730		3								
WIND DATA																			
Sound ranging layer limit (meters)	SUR	Time at layer limit (minutes & seconds)	Elevation angle (degrees & tenths)	Azimuth angle (degrees & tenths)	Horizontal distance (meters)	Horizontal layer (meters)	Time in layer (minutes & tenths)	LAYER WIND DATA		WEIGHTED WIND DATA									
								Direction (tens of mills)	Speed (Knots)	Direction (tens of mills)	Speed (Knots)								
200		0:54	33.2	335.2	310	240	0.6	310	04	0	0								
400		1:54	39.0	339.7	490	180	0.6	298	13	0	0								
600		2:54	36.4	348.2	810	330	0.6	321	10	298	10								
800		3:54	34.4	358.6	1170	400	0.8	356	18	0	0								
<p>WIND WEIGHING FACTORS</p> <p>400 meter layer wind speed is: (check one)</p> <p><input type="checkbox"/> 1 to 2 times 200 meter layer</p> <p><input type="checkbox"/> over 2 times 200 meter layer</p> <p><input checked="" type="checkbox"/> Less than 200 meter layer and not within 2 knots of surface</p> <p>Normal structure 2: 0.2, 0.4, 0.5, 0.15, 0.15, 0.075, 0.075</p> <p>Structure 3: 1.0, 1.0, 0, 0</p> <p>Structure 4: 0, 0, 1.0, 0</p>																			
<p>TEMPERATURE DATA</p> <p>Surface Observation</p> <p>Dry bulb <math>\text{---}^{\circ}\text{C}</math></p> <p>Wet bulb <math>\text{---}^{\circ}\text{C}</math></p> <p>Depression <math>\text{---}^{\circ}\text{C}</math></p> <p>Virtual <math>\text{---}^{\circ}\text{C}</math></p> <p>Time of day correction <math>\text{---}^{\circ}\text{C}</math></p> <p>Effective temperature <math>\text{---}^{\circ}\text{C}</math></p> <p>Period of day and temperature correction (Check one)</p> <p>Night <math>+1.3^{\circ}\text{C}</math> Transition</p> <p>Afternoon <math>-1.3^{\circ}\text{C}</math> <math>-0.6^{\circ}</math> <math>+0.0^{\circ}</math> <math>+0.6^{\circ}</math></p> <p>Radioonde Observation</p> <p>Virtual <math>26.5^{\circ}\text{C} \times 3 = 79.5^{\circ}\text{C}</math></p> <p>Thermister <math>\frac{25.8}{103.3} = 26.9^{\circ}\text{C}</math></p>																			
TIME OF SUNRISE				RECORDER				PLOTTER				CHECKER							
<del>TIME OF SUNRISE</del>				Langston				Samuels				Carleton				Barry			
<p>DELIVERY TO</p> <p>53 3/26</p> <p>RELEASE TIME</p> <p>1730 GMT</p> <p>DELIVERY TIME</p> <p>1750</p>																			

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

Figure 142. Sound ranging form completed from electronic data.

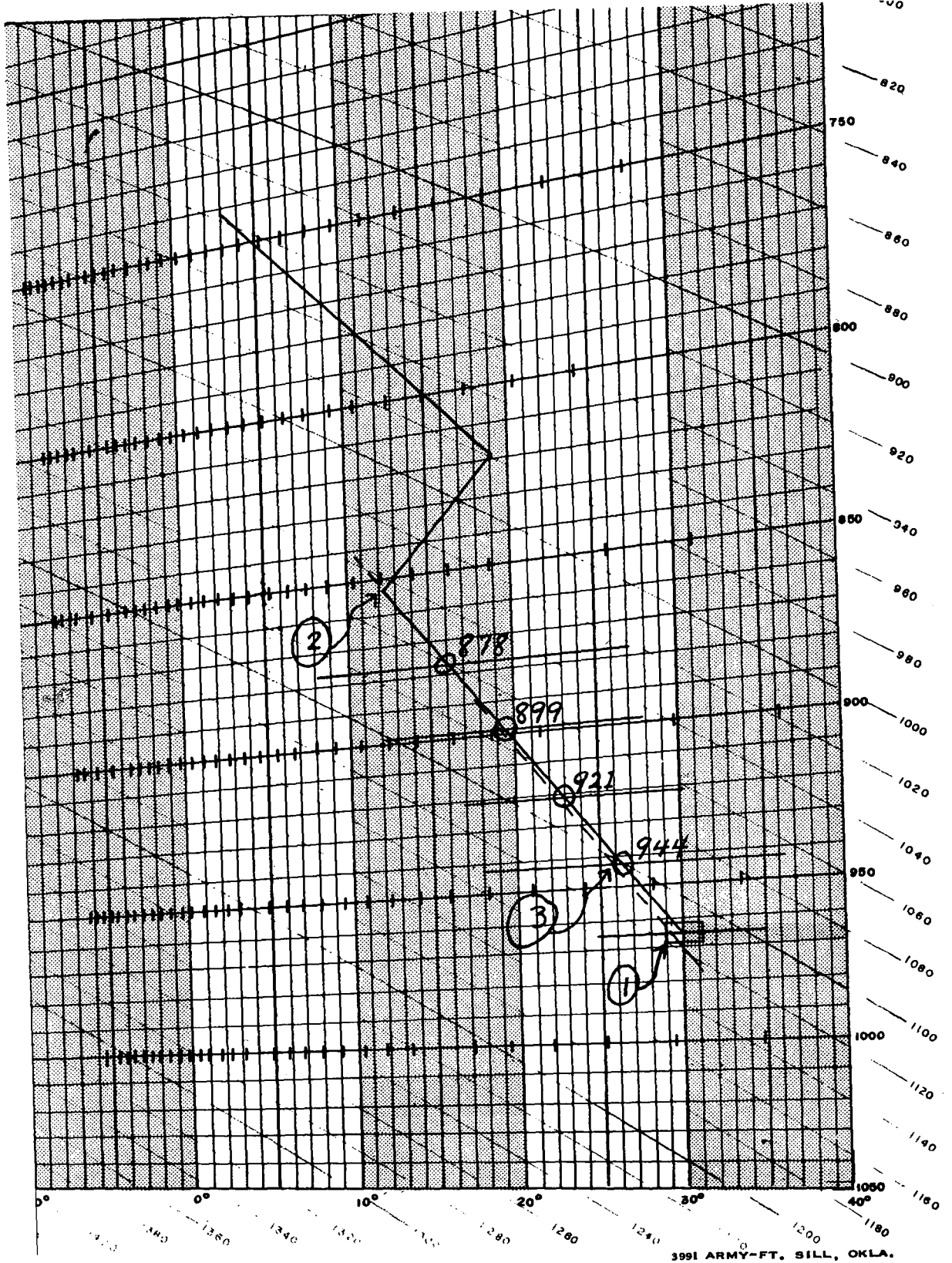


Figure 143. Sound ranging layers plotted on chart ML-574/UM.

400, 600, and 800 meters are determined from the sounding curve on chart ML-574/UM (fig. 143). The time at each layer limit is determined by entering the pressure-time chart (1, fig. 121) at the pressure value of the layer limit on the left side of the chart, moving horizontally to the right until the pressure-time curve is intersected, and reading the time on the time scale, vertically beneath this point. The time for each layer limit is read to the nearest 0.1 minute and entered in the WIND DATA section on the sound ranging form (fig. 142).

*b. Determining Angular Data.* The values of the elevation and azimuth angles corresponding to the time at each layer limit are obtained to the nearest 0.1° from the control-recorder tape (fig. 122). These angular data are entered in the WIND DATA section on the form.

*c. Determining Surface Wind Data.* The surface wind speed and direction are measured with an anemometer.

*d. Determining the 200-, 400-, 600-, and 800-Meter Layer Wind Data.* The distance traveled corresponding to the elevation angle of the balloon as it reaches each layer limit is obtained from table IVa, FM 6-16. These distances are plotted at the corresponding azimuth angles for each layer limit on plotting board ML-122. In addition, the offset release point data, when required, are plotted. The azimuth and horizontal distance to the offset release point are recorded on the surface line of the WIND DATA section of the sound ranging form as shown in figure 142. The completed layer wind plot is shown in figure 144. The layer wind directions are measured for each layer as described in paragraph 169 and recorded on the form. The distance traveled for the 200-meter layer is measured from the offset plot or from the origin of the plotting board when the offset plot is not required. The distance traveled for each subsequent layer is measured from the plot of the preceding layer limit. The time in each layer is determined by computing the difference in time between consecutive layer limits. Then, the layer wind speeds are computed on a slide rule by using the following formula: 
$$\frac{\text{distance traveled in layer (in meters)} \times 0.0324}{\text{time in layer (in minutes and tenths of minutes)}} = \text{layer wind speed (knots)}.$$

These layer wind speeds are entered in the appropriate spaces in the WIND DATA section on the sound ranging form.

*e. Effective Wind Direction and Speed.* The effective wind for sound ranging is a total of the weighted values of the surface and layer winds. There are four different wind structures (normal, 2, 3, and 4), each having a set of weighting factors. Thus, the set of weighting factors used to compute the effective wind is selected according to the structure of the measured winds. The wind structure is determined by comparing the 400- and 200-meter layer wind speeds and, when required, the surface wind speed. The four wind structures, the corresponding sets of weighting factors, and the basis for their selection are given in the WIND WEIGHTING FACTORS section of the sound ranging form. In figure 142, structure 4 is used, since the 400-meter layer wind speed (10 knots) is less than the 200-meter layer wind speed (13 knots) and not within 2 knots of the surface wind speed (4 knots). After the wind structure has been determined, the box is checked as shown, and the surface and layer wind speeds and directions are multiplied by the corresponding weighting factors. These computations are tabulated for normal structure and structure 2 winds in table IVd, FM 6-16, so that the actual multiplication is unnecessary. The resulting weighted wind speeds and directions are entered in the last two columns of the WIND DATA section on the sound ranging form and totaled. These totals are the effective wind speed (10 knots) and direction (2980 mils) and are recorded to the nearest knot and nearest 10 mils in the Effective Wind block in the section for DATA REPORTED TO SOUND RANGING SECTION.

*f. Layer Wind Direction Passing 6,400 Mils.* Close attention must be given to the direction of the layer winds and the manner in which they change from one zone to the next. When the wind direction between successive layers passes from the third (3,200 mils to 4,800 mils) or fourth (4,800 mils to 6,400 mils) quadrants to the first (0 to 1,600 mils) or second (1,600 mils to 3,200 mils) quadrants, or vice versa, and in so doing crosses the 6,400 mil direction, 6,400 must be added to the direction in the first or second quadrants before the application of weighting factors. For example, if the wind directions of 6,300 mils and 100 mils were averaged (added and divided by 2), the result would be 3,200 mils, an erroneous result. By adding 6,400 mils to the 100-mil value, the average result would be a correct direction of 6,400 mils. Before weighting, the layer wind directions must be adjusted by adding

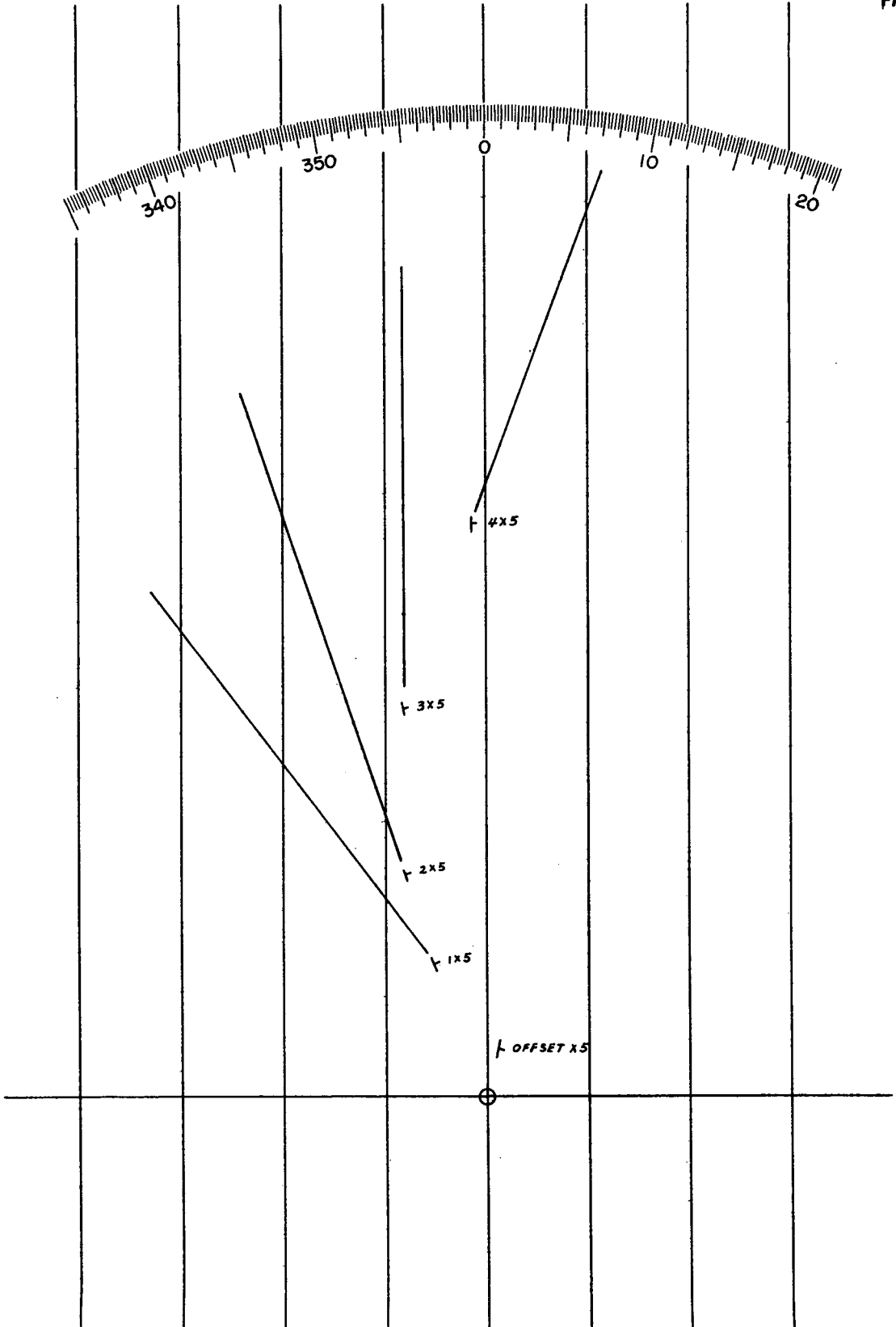


Figure 144. Completed layer wind plot for electronic data.

6,400 mils where needed. The tables in FM 6-16 (table IVd) are constructed to weight directions up to 7,900 mils. When the totaled wind direction (total of the weighted wind direction values) is greater than 6,400 mils, 6,400 must be subtracted from the answer to obtain the corrected effective wind direction.

### **182. The Completed Sound Ranging Message**

At the completion of all computations, the sound ranging message is transmitted to the using unit without delay. Only that information recorded in the block for DATA REPORTED TO SOUND RANGING SECTION is transmitted. This data

consists of the effective temperature, effective wind direction and speed, and time of release. After the sound ranging message has been transmitted, the designation of the receiving unit and the time the message was delivered are entered on the form.

### **183. Validity and Frequency**

The preparation of the sound ranging message by the ballistic metro section is completed before any other requirement. This will insure that the data are current. The data obtained by the electronic method are normally available for sound ranging every 2 hours.

## CHAPTER 14

SOUND RANGING MESSAGE DEVELOPED FROM  
SURFACE AND PILOT BALLOON OBSERVATIONS**184. General**

The data for the sound ranging message may be obtained by the sound ranging section using its TOE equipment. The description, use, care, and maintenance of this equipment are explained in chapter 6. As outlined in the previous chapter, the artillery metro sections provide the sound ranging messages from measurements of the atmosphere aloft. However, because of distance and topography, this data may not be as valid as that obtained by the sound ranging section. In this situation, the sound ranging section will measure the data used to prepare the message by using the pilot balloon observation technique.

**185. Observation Site Selection**

The primary consideration in the selection of an observation site should be as close as possible to a point centrally located, both laterally and in altitude, with respect to the sound base. However, an observation site near the command post of the sound ranging section will facilitate the dissemination and application of sound ranging weather data.

**186. Procedure for Determining Effective Temperature**

DA Form 6-48 (fig. 145) provides a step-by-step method for determining the effective temperature based on surface observations.

*a. Surface Observation.* Surface observations of dry- and wet-bulb temperatures are taken with psychrometer ML-224 as explained in paragraph 52. The temperatures are entered in the Surface Observation block of the TEMPERATURE DATA section. These surface temperatures are measured and recorded to the nearest 0.1° C. The dry-bulb temperature is entered in two positions. In figure 145 the wet-bulb depression (3.9° C.) is obtained by subtracting the wet-bulb temperature (16.3° C.) from the dry-bulb temperature (20.2° C.)

*b. Determining Surface Virtual Temperature.* The surface virtual temperature is determined from the surface temperature observation and the virtual temperature table. Table Ia, FM 6-16, is entered

with the air temperature (dry-bulb) and the wet-bulb depression to the nearest 0.1° C. as arguments. The virtual temperature (22.0° C.) is obtained from the table to the nearest 0.1° C. and recorded in the TEMPERATURE DATA section of the form. An example of determining surface virtual temperature is shown below:

Dry-bulb temperature.....	20.2° C.
Wet-bulb temperature.....	16.3° C.
Wet-bulb depression.....	3.9° C.
Virtual temperature from table.....	22.0° C.

*c. Determining Effective Temperature.* The effective sound ranging temperature is the sonic temperature in degrees Celsius at a height of 200 meters above the surface. Since there are no means available to the sound ranging section for measuring upper air temperatures, the effective temperature is determined by assuming a departure from the surface sonic temperature. At night, the effective temperature is obtained by adding 1.3° C. to the surface sonic temperature; in the afternoon, the effective temperature is obtained by subtracting 1.3° C. from the surface sonic temperature. The amount by which the surface sonic temperature must be corrected at any time of day or night is determined from chart XIII, FM 6-16, based on the flight release time, the weather conditions, and the times of sunrise and sunset. The times of sunrise and sunset are obtained from the survey information center (or from any other unit having access to an ephemeris or by estimation from the previous day) and entered in the lower left corner of the form. For the release time in figure 145, the period of the day is afternoon and the surface virtual temperature correction is -1.3° C. The temperature correction for the period of the day is checked on the form and the surface sonic temperature correction is entered on the line for time of day correction in the TEMPERATURE DATA section of the sound ranging form. The effective temperature (20.3° C.) is the algebraic sum of the surface sonic temperature (21.6° C.) and the time of day correction (-1.3° C.) and is entered on the last line of the TEMPERATURE DATA section. This temperature is

WEATHER DATA FOR SOUND RANGING

FM 6-15

STATION		LOCATION		DATE		FLIGHT NR		
3d Div Arty		Fort Sill, Okla		4 OCT 59		3		
RE-LEASE TIME		LST		GMT		HOUR		
		4 OCT 59		4 OCT 59		1130 1730		
WIND DATA								
Sound ranging layer limit (meters)	Time at layer limit (minutes & seconds)	Elevation angle (degrees & tenths)	Azimuth angle (degrees & tenths)	Horizontal distance (meters)	Horizontal travel in layer (meters)	Time in layer (minutes & tenths)	WEIGHTED WIND DATA	
							Direction (tens of miles)	Speed (Knots)
SUR 0:15		27.0	197.0	—	—	030	14	006
200	0:54	26.9	208.1	390	390	050	14	025
400	1:54	18.5	212.6	1200	810	062	26	009
600	2:54	17.2	216.8	1940	750	078	24	006
800	3:54	16.7	220.9	2670	750	090	24	007
TEMPERATURE DATA								
Surface Observation								
Dry bulb 20.2 °C								
Wet bulb 16.3 °C								
Depression 3.9 °C								
Virtual 28.0 °C x 3 = 66.0 °C								
Time of day correction 1.3 °C								
Effective temperature 20.3 °C								
WIND WEIGHING FACTORS								
+100 meter layer wind speed is: (check one)								
<input checked="" type="checkbox"/> 1 to 2 times 200 meter layer		<input type="checkbox"/> Over 2 times 200 meter layer		<input type="checkbox"/> Less than 200 meter layer		<input type="checkbox"/> Less than 200 meter layer and not within 2 knots of surface		
Surface	200 Meter	400 Meter	600 Meter	800 Meter	Normal structure	Structure 2	Structure 3	
0.2	0.5	0.15	0.075	0.075	0.4	0	0	
Sound ranging layer								
Effective temperature nearest 1/10 °C								
20.3 °C								
EFFECTIVE WIND								
Direction (tens of miles)								
053								
Speed (knots)								
17								
RELEASE TIME								
1730 GMT								
RECORDER				PLOTTER				
Donnelly				Jefferson				
OBSERVER				CHECKER				
Trout				Reed				
TIME OF SUNRISE		TIME OF SUNSET		DELIVERY TO		DELIVERY TIME		
0600		1800		S3 3/26		1800		

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

Figure 145. Sound ranging form completed for surface observation.

DA FORM 6-45, 1 MAR 62

reported to the sound ranging section and is entered in the Effective Temperature box in the section for DATA REPORTED TO SOUND RANGING SECTION.

### 187. Procedure for Determining Effective Wind Speed and Direction

The effective wind for sound ranging is determined from periodic observations of the angular position of a balloon. When the visual method is used, a 30-gram pilot balloon (weighted off during inflation as described in par. 67) is released. The elevation and azimuth angles to the balloon are read at 15 seconds, 54 seconds, 1 minute 54 seconds, 2 minutes 54 seconds, and 3 minutes 54 seconds after release. The 15-second angular reading is used to determine the surface wind conditions. At the end of 54 seconds and 1 minute 54 seconds, 2 minutes 54 seconds, and 3 minutes 54 seconds, the balloon has ascended to heights of 200, 400, 600, and 800 meters, respectively. For sound ranging purposes these heights represent the limits of sound ranging layers of the atmosphere. The 200-meter sound ranging layer limit represents the top of a layer of the atmosphere extending from the surface to a height of 200 meters. The 400-meter limit represents the top of the sound ranging layer extending from the top of the preceding layer (200 meters) to a height of 400 meters above the surface. Similarly, the heights of 600 and 800 meters represent the tops of successive layers of the atmosphere which extend from the preceding layer limit (400 and 600 meters, respectively). The direction and speed of the wind within each of these layers are determined by the techniques described in *a* through *f* below. Then the layer wind values of speed and direction are weighted, and the weighted values are added to obtain the effective wind speed and effective wind direction. The effective wind computations are recorded in the WIND DATA section on the sound ranging form (fig. 145).

*a. Modifications to DA Form 6-48, Weather Data for Sound Ranging.* When a sound ranging message is prepared from pilot balloon observation data, the Radiosonde column in the WIND DATA section of the form is lined out.

*b. Angular Data.* The elevation and azimuth angles are read to the nearest  $0.1^\circ$  and the values are entered in the appropriate columns of the WIND DATA section of the form.

*c. Determining Distance Traveled.* The distance to the balloon at each time is obtained from table IVa, FM 6-16, and entered on the sound ranging form. The values listed in the tables have been computed for the elevation angles at the time the balloon reaches each height (200, 400, 600, and 800 meters), thus eliminating the necessity of separate computations for each observation.

*d. Plotting the Layer Winds.* A plot of the horizontal projection of the path of the balloon is made on plotting board ML-122, by using the horizontal distances and corresponding azimuth angles read by the observer. The plot is labeled with the time that the balloon was observed for the data plotted and with any factor of scale expansion that was utilized. A completed layer wind plot is shown in figure 146. Since the equipment generally used for plotting the path of a pilot balloon is designed for plotting longer flight periods than that required in preparing data for sound ranging, normal scale plotting of the sound ranging data often results in all of the layer plots falling close to the origin. If wind speeds are low, it is advantageous to increase the scale of the plot. The horizontal distances may be plotted 10, 5, or 2 times the actual values entered on the sound ranging form.

*e. Surface Sound Ranging Layer Wind Speed and Direction.* The surface sound ranging wind speed is obtained from table IVb, FM 6-16, based on the 15-second reading of the elevation angle. The surface sound ranging wind direction for balloons released at the theodolite is obtained from table IVe, FM 6-16, based on the 15-second reading of the azimuth angle.

*f. Determination of Layer Wind Speeds.* The layer wind speeds are determined by entering table IVc, FM 6-16, with the argument of horizontal travel in layer.

*g. Determination of Layer Wind Directions.* The technique used in determining layer wind directions for sound ranging is similar to that used in determining zone wind directions. The layer wind directions for all layers are read directly from the plots on plotting board ML-122 by using scale ML-577. To facilitate the reading of layer wind direction, place a straight edge along the two plotted points representing the base and top of a given layer. Then draw a reasonably long line beyond the upper plotted point as shown in figure 146. The length of this line should permit direction to be read from the outside edge of scale ML-577



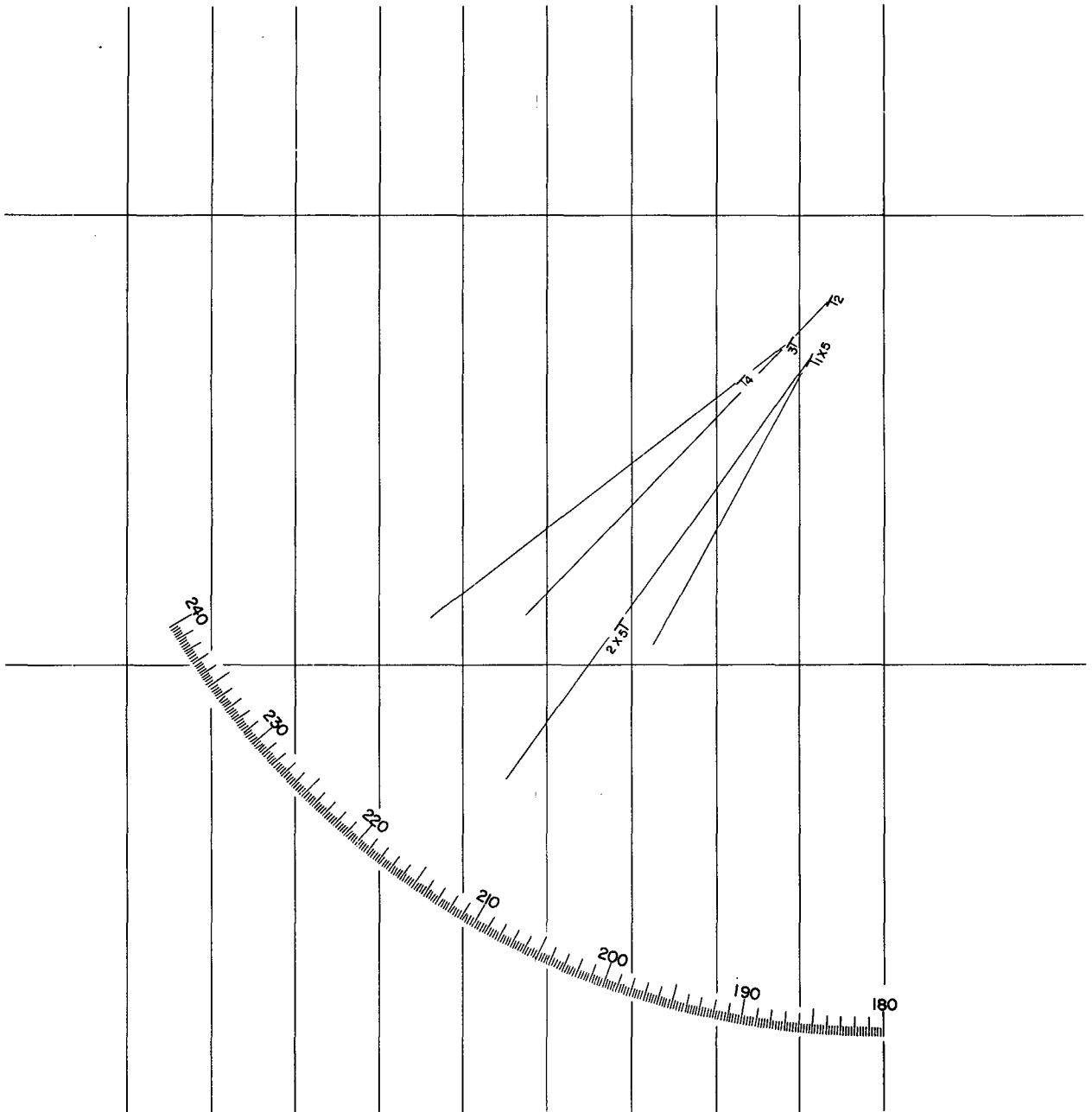


Figure 146. Completed layer wind plot for surface observation.

when its center is placed over the lower plotted point of any layer. The scale is oriented with the north line parallel to the vertical lines on the plotting board. (The north arrow of the scale points toward the top of the plotting board.) Each layer wind direction is read from the scale to the nearest 10 mils. These data are recorded in their respective blocks in the LAYER WIND DATA section of the form.

*h. Effective Wind Direction and Speed.* The effective wind for sound ranging is a total of the weighted values of the surface and layer winds. There are four wind structures (normal, 2, 3, and 4), each having a set of weighting factors. The set of weighting factors used to compute the effective wind is selected according to the structure of the measured winds. The wind structure is determined by comparing the 400- and 200-meter layer wind speeds and, when required, the surface wind speed. The four wind structures, the corresponding sets of weighting factors, and the basis of their selection are given in the WIND WEIGHTING FACTORS section of the sound ranging form. In the case of the data recorded on the form in figure 145, the layer wind speeds are within the normal structure, since the 400-meter layer wind speed (26 knots) is 1 to 2 times the 200-meter layer wind speed (14 knots). After the wind structure has been determined, the box is checked as shown, and the surface and layer wind speeds and directions are multiplied by the corresponding weighting factors for that structure. These computations are tabulated for normal structure and structure 2 in table IVd, FM 6-16. The

resulting weighted wind speeds and directions are entered in the last two columns of the WIND DATA section on the sound ranging form and totaled. These totals are the effective wind speed and direction and are entered to the nearest 1 knot and to the nearest 10 mils, respectively, in the Effective Wind block in the section for DATA REPORTED TO SOUND RANGING SECTION.

*i. Layer Wind Direction Passing 6,400 Mils.* Close attention must be given to the direction of the layer winds and the manner in which they change from one layer limit to the next. The same procedure outlined in paragraph 181f should be followed.

### 188. Comparison With Electronic Data

The sound ranging message prepared from the pilot balloon and surface observation method should be compared with the electronic data available at the metro section. This comparison is made primarily for temperature rather than wind direction and speed. The reason for this comparison is that the temperature is relatively constant over a large horizontal area, whereas the wind direction and speed are not. The presence of abnormal temperature lapse rates within the area from the surface to a height of 200 meters will invalidate the period of day correction. Therefore, the sound ranging section should check with the metro section for the presence of an abnormal temperature lapse rate. If present, the difference in temperature between the surface and 200 meters obtained by the electronic sounding should be used in place of the time of day correction.



**PART FOUR**  
**METEOROLOGY FOR RADIOLOGICAL FALLOUT PREDICTION**  
**CHAPTER 15**  
**GENERAL**

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**189. General**

The prediction of radiological fallout is accomplished by chemical corps personnel at division, corps, and field army levels. The chemical, biological, radiological center (CBRC) at division and the chemical, biological, radiological element (CBRE) of the tactical operations centers at field army, independent corps, and organic corps are responsible for the prediction of fallout from both friendly and enemy nuclear weapons. The division FSCC will incorporate the resulting fallout prediction plots for friendly delivered nuclear weapons in its target analysis. In order to make optimum meteorological support available to army elements engaged in the prediction of fallout, a supporting system has been devised. Primary responsibility for providing meteorological data has been assigned to artillery metro sections. The Air Weather Service (AWS) is

available to provide forecast data when army meteorological data are not available. In the communications zone, the AWS will be the primary source of metro data for the production of fallout predictions. However, the information contained in this part is confined to metro data furnished by artillery metro sections to units of the field army and the techniques and procedures employed by them in measuring and reporting data used in fallout predictions.

**190. Action Upon Receipt of Fallout Metro Message**

Upon receipt of the fallout metro message by the CBRC/CBRE, a fallout wind vector plot and a simplified or detailed fallout prediction are prepared in accordance with the procedures described in TM 3-( ), U.S. Army Fallout Prediction Method (when published).



## CHAPTER 16

## FALLOUT METEOROLOGICAL REQUIREMENTS

**191. General**

In order to furnish the required meteorological data for fallout prediction, the artillery metro section provides fallout metro messages on the following daily schedule:

Time (GMT)	Height required (meters above MDP)	Minimum acceptable height (meters above MDP)
0000	30,000	24,000
0200	18,000	14,000
0400	18,000	14,000
0600	30,000	24,000
0800	18,000	14,000
1000	18,000	14,000
1200	30,000	24,000
1400	18,000	14,000
1600	18,000	14,000
1800	30,000	24,000
2000	18,000	14,000
2200	18,000	14,000

*Note.* Actual time of release will be not more than 30 minutes earlier or 30 minutes later than the scheduled release time.

**192. Information Contained in the Fallout Metro Message**

The fallout metro message will contain the following information:

a. Wind speed and direction above the mean datum plane (MDP) in 2,000-meter zones.

(1) Wind direction is reported in tens of mils.

(2) Wind speed is reported to the nearest knot.

b. Where required, height(s) of the tropopause(s) in hundreds of meters is (are) selected according to the procedure outlined in paragraph 200.

c. If an observation is terminated before the desired height is reached, the following action will be taken:

(1) Obtain information from the adjacent unit as prescribed in paragraph 33.

(2) Make a second release as soon as possible, provided the release can be made before 1 hour after the scheduled release time.

(3) Compute and transmit data for both observations.

d. Other metro requirements, in addition to fallout requirements, normally will be met.

**193. Assignment of Flight Schedules**

Since all artillery metro sections have the capability of measuring and reporting high-altitude data, the fallout meteorological requirements should be rotated among the sections within the corps area to reduce the workload on any one section. Assignment of release schedules normally will be specified in the artillery and/or air defense support annex to the operations order. Coordination of fallout metro requirements must be accomplished by the corps artillery metro staff officer; overall supervision is coordinated at army artillery.



## CHAPTER 17

## DETERMINATION OF HIGH-ALTITUDE WINDS

**194. General**

a. Evaluation of soundings for a fallout metro message follows the procedure outlined in chapter 7 for a ballistic message.

b. A sounding for a fallout metro message may also be used to produce ballistic, computer, and sound ranging metro messages and significant level data for transmission to AWS (USAF). All or none of the extra requirements may exist; therefore, teams must be prepared to compute data for all messages from a single sounding.

**195. Requirements and Equipment for High-Altitude Soundings**

a. Installation of the metro station, organization of personnel, preflight checks, and baseline check procedures are the same as those for a ballistic sounding described in chapter 7.

b. Equipment includes—

- (1) High-altitude balloons.
- (2) Fast rising balloons.
- (3) Hypsometric radiosondes.

c. Special requirements include the following:

- (1) Equipment must be tuned for peak performance.
- (2) Because of the long period of time required for an observation—
  - (a) Generators must be serviced.
  - (b) Paper tape rolls must be checked for sufficient paper.
  - (c) Teams should be rotated just before high-altitude requirements, if practical.
- (3) During the high-altitude soundings, data for sound ranging, ballistic, or computer messages are transmitted immediately and not held until the completion of all requirements.
- (4) Balloons must receive special handling (pars. 63c and 64a).

**196. Determination of Fallout Zones on Chart ML-574/UM**

a. The sounding is plotted on chart ML-574/UM and zones are balanced in the same manner as artillery zones (par. 145).

b. Zone height scale ML-573 is graduated for fallout zones (fig. 114). Zones are measured by

balancing areas on the virtual temperature curve. When artillery zones are measured, the top of each artillery zone corresponding to a fallout zone is marked as a fallout zone (fig. 114), and the pressure is entered to the left of the sounding curve.

c. The pressure-time chart is plotted the same as that for a ballistic flight discussed in chapter 7.

**197. Completion of Fallout Wind Data**

a. *Modification of Rawin Computation Form, DA Form 6-46.* DA Form 6-46 (fig. 147) is used to record the data for fallout winds; however, some modifications are necessary.

- (1) The heights of the fallout zones are entered in column (1); each zone is 2,000 meters thick; therefore, the tops of the fallout zones would be at heights of 2,000, 4,000, 6,000, 8,000, 10,000, etc., up to 32,000 meters.
- (2) Columns (11) and (12) are lined out as ballistic winds are not plotted for a fallout message.
- (3) In the lower left corner, the message type "fallout" is checked.
- (4) The block for the ballistic wind plotter's signature is crossed out.

b. *Columns (2) through (6), DA Form 6-46.* Data are entered on DA Form 6-46 as follows:

- (1) *Column (2).* Pressure at top of each fallout zone is obtained from chart ML-574/UM and entered in column (2).
- (2) *Column (3).* Time at top of each zone is determined from the pressure-time chart using pressure from column (2) and is entered in column (3).
- (3) *Columns (4) and (5).* Elevation and azimuth angles are obtained from the control-recorder tape by using the time at top of each zone in column (3) and are entered in columns (4) and (5).
- (4) *Column (6).* Distances traveled are obtained from table Ig, FM 6-16, and entered to the nearest 10 meters in column (6).

c. *Wind Plots.* Azimuth angles (column 5) and distances traveled (column 6) are plotted on plotting board ML-122.



STATION		LOCATION		RAWIN COMPUTATION FM 6-15		DATE		FLIGHT NR.			
3d Div Arty		FORT SILL, OKLA				3 NOV 59		3			
				RE-LEASE TIME		LST		HOUR			
						3 NOV 59		1130			
						GMT		1730			
Zone nr.	(1) Zone height (meters)	(2) Pressure at top of zone	(3) Time at top of zone	(4) Elevation angle (degrees & tenths)	(5) Azimuth (degrees & tenths)	(6) Horizontal distance (meters)	(7) Horizontal distance (miles)	ZONE WIND DATA		BALLISTIC DATA	
Obs't	SUR							(9) Azimuth (10 mills)	(10) Speed (knots)	(11) Azimuth (100 mills)	(12) Speed (knots)
1	2000	762	6.9	47.0	12.6	100		310	004	SUR	SUR
2	4000	594	13.6	49.4	24.6	1860	1760	365	008		
3	6000	458	20.4	46.2	108.4	5750	2660	513	013		
4	8000	349	26.9	48.1	120.4	7160	3420	571	016		
5	10000	263	33.1	52.5	100.8	7660	1960	600	010		
6	12000	195	39.7	50.0	78.1	10040	2560	377	013		
7	14000	142	45.7	46.8	71.6	13100	4180	381	021		
8	16000	102	51.9	51.6	86.3	12640	3350	407	018		
9	18000	73	58.4	57.0	107.2	11650	3310	635	017		
10	20000	53	64.2	68.0	125.9	8050	4490	034	022		
11	22000	38	70.3	76.8	150.4	5140	4750	133	027		
12	24000	28	75.4	80.0	206.2	4220	4030	167	021		
13	26000	20	81.0	74.4	241.9	7230	4450	175	028		
14	28000	15	86.1	65.0	253.0	12990	4510	168	026		
15	30000	11	90.5	56.7	260.6	19590	6020	153	038		
16	32000	8	96.5	44.0	264.9	32880	6960	168	051		
(13)							13400	161	072		
		MESSAGE TYPE (CHECK ONE)		ZONE WIND COMPUTER		ZONE WIND PLOTTER		BALLISTIC WIND PLOTTER			
		BALLISTIC		Moore		Dunn					
		S		A		COMPUTER					

PREVIOUS EDITION OF THIS FORM IS OBSOLETE.  
Figure 147. Rawin computations for fallout metro message.

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*d. Columns (7) through (10), DA Form 6-46.*

- (1) *Column (7).* Distance traveled in zone is measured directly on the plotting board with rule ML-126A. Travel is measured between two successive zone wind plots. Travel for zone 1 is measured from the offset release point to zone 1 (0-2,000 meters), zone 2 is measured from zone 1 to zone 2 (2,000 to 4,000 meters), etc., and the values are entered in column (7) to the nearest 10 meters.
- (2) *Column (8).* Time in zone is determined from the information in column (3). The time in zone for zone 1 is carried over from column (3) (the time at top of zone 1). The time for zone 2 is determined by subtracting the time at top of zone 1 from the time at top of zone 2 and the difference is entered in column (8). For example, the time at top of zone 1 is 6.9, the time at top

of zone 2 is 13.6. The difference of 6.7 is entered in column (8).

- (3) *Column (9).* Wind directions are also measured from the zone wind plots with scale ML-577. Scale ML-577 is oriented over the offset release point and the azimuth is measured to the zone 1 plot; zone 2 azimuth is measured from zone 1 to zone 2, etc., and the azimuths are entered in column (9) to the nearest 10 mils. For a detailed explanation, see paragraphs 152 and 153.
- (4) *Column (10).* Wind speed in knots is determined in the same manner as artillery zone winds discussed in paragraph 152*m*. Wind speeds are recorded in three digits in column (10) of DA Form 6-46 (fig. 147).

*e. Checking.* The procedure for checking fallout message computations is the same as that for ballistic messages.



## CHAPTER 18

## DETERMINATION OF THE TROPOPAUSE

**198. Description and Significance of Tropopause**

*a.* The tropopause is the boundary between the lowest layer of the atmosphere, the troposphere, and the next higher layer, the stratosphere. Usually at the tropopause there is a relatively distinct change in the lapse rate of temperature. Above the tropopause, the temperature does not decrease as rapidly with an increase in altitude as it does below the tropopause. Because of this change in lapse rate, the atmosphere above the tropopause is relatively stable and any vertical air motion will tend to stop or slow down as it reaches the tropopause level.

*b.* When a nuclear detonation occurs, a column of extremely hot gases rises through the atmosphere and eventually assumes the form of a mushroom-shaped cloud. The spreading out of the mushroom top of the nuclear cloud from medium or higher yield weapons usually occurs at the tropopause level. Thus, the tropopause acts as a lid on the upward motion of the nuclear cloud. The height of the tropopause, which varies with the weather pattern, can be an extremely important consideration in determining the resultant fallout pattern of the nuclear burst. (Minute contaminated particles of dust, debris, etc., which are carried aloft and eventually fall back to earth are known as radiological fallout.) The nuclear cloud from a high yield detonation may be strong enough to penetrate through the tropopause and extend to even greater heights; however, the tropopause will still have an effect on the fallout pattern and its height must be considered. Wind speed and direction from the surface to the top of the nuclear cloud will also have a pronounced effect on the resulting fallout pattern.

**199. Criteria for Tropopause**

The following three criteria are used for locating the tropopause:

- a.* The tropopause lies between 600 and 30 millibars.
- b.* The tropopause level temperature is lower than  $-30^{\circ}\text{C}$ .
- c.* The tropopause is selected at the lowest level at which the lapse rate decreases to  $2^{\circ}\text{C}$ . per

kilometer, or less, and then averages  $2^{\circ}\text{C}$ . per kilometer, or less, in the 2 kilometer layer immediately above that level.

**200. Measurement of Height(s) of Tropopause(s)**

*a.* Where required, the height of the tropopause is evaluated on chart ML-574/UM at a significant level which meets the criteria in paragraph 199. A check must be made for the presence of more than one tropopause, since it is possible for several tropopauses to exist. In this case, all should be reported. The height of the lowest tropopause is reported in the Tropopause Height block and the heights of subsequent tropopauses are reported in the Remarks block, DA Form 6-58 (Fallout Metro Message).

*b.* A solid sloping line representing a lapse rate of  $4^{\circ}\text{C}$ . per 2,000 meters has been constructed on scale ML-573 and labeled "Tropopause Criteria" for use as a template for determining the height of the tropopause on chart ML-574/UM.

*c.* The template is placed on chart ML-574/UM with the guidelines parallel to the isotherms on the chart and to meet the criteria in paragraph 199*a* and *b*. The template is moved along the sounding curve (1, fig. 148) until the base of the solid sloping line is at some significant level point on the curve. When the sounding curve between this level and the next significant level is on or to the right of the lapse rate line on the template and when the sounding curve at 2,000 meters above this level is also on or to the right of the lapse rate line on the template, the level tested is the tropopause. This is true regardless of the configuration of the sounding curve within the 2,000-meter layer. If the above conditions are not met, the template is moved to succeeding significant levels until all criteria are met.

*d.* The height of the tropopause is the lowest significant level found on chart ML-574/UM which meets the criteria in paragraph 199 above.

*e.* To measure the height of the tropopause after the criteria have been met—

- (1) The height of the base of the tropopause above the preceding fallout zone is meas-

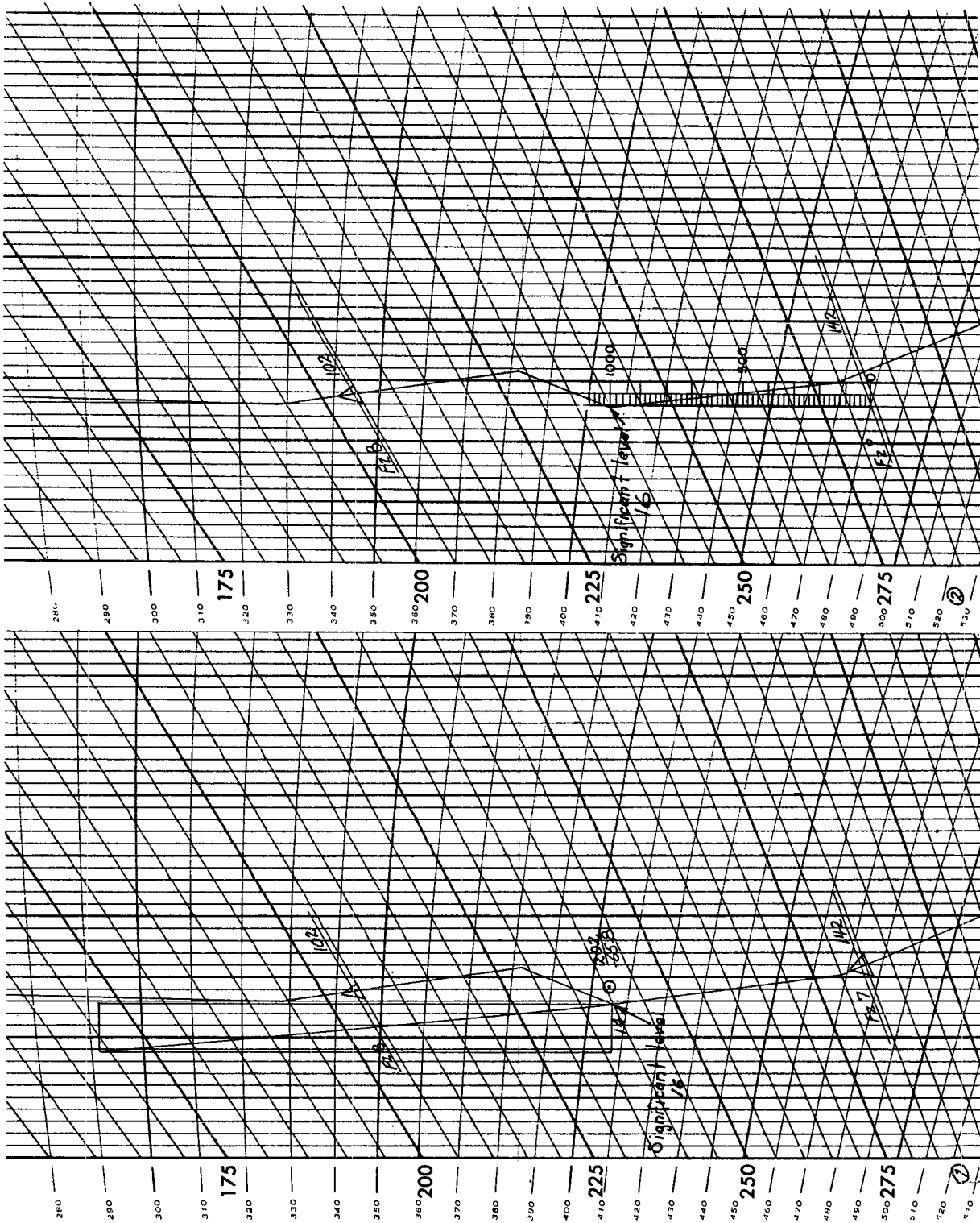


Figure 148. Determination of tropopause.

ured with the height scale in meters on scale ML-573 (2, fig. 148).

- (2) The height measured is added to the height of the preceding fallout zone.
- (3) This height is reported in hundreds of meters to the nearest hundred.

*Example:* The base of the tropopause is measured to be 1,000 meters above fallout zone 7 (14,000 meters). The height of the tropopause is 15,000 meters (14,000 meters + 1,000 meters) and reported as 150 in hundreds of meters.



CHAPTER 19

ENCODING AND TRANSMISSION OF FALLOUT METEOROLOGICAL MESSAGE

201. General

Metro data for fallout prediction are recorded on DA Form 6-58 (1, fig. 149). Use of this form is described on the back of the form (2, fig. 149). The data recorded on the form are encoded as follows:

a. Octant and Location. The area is identified by

either a geographic location or a coded location of the metro station. In either case, the location is preceded by a number (0, 1, 2, 3, 5, 6, 7, or 8) from the Q code which designates the octant of the globe in which the station is located. The geographic location of the metro station may be determined

FALLOUT METRO MESSAGE (FM 6-15)									
IDENTIFICATION METFM	OCTANT Q	LOCATION xxx xxx		DATE YY	VALID TIME (GMT) G <sub>0</sub> G <sub>0</sub> G <sub>1</sub> G <sub>1</sub>	STATION HEIGHT (10's M) hhh	TROPOPAUSE HEIGHT (100's M) TRO	SOURCE	
								COUNTRY BB	SERVICE C
METFM	9	WALNUT		03	1822	036	150	US	L
ZONE HEIGHT (METERS)	LINE NUMBER ZZ	TRUE WIND		ZONE HEIGHT (METERS)	LINE NUMBER ZZ	TRUE WIND			
		DIRECTION (10's Mils) ddd	SPEED (KNOTS) FFF			DIRECTION (10's Mils) ddd	SPEED (KNOTS) FFF		
SURFACE	00	310	004	2000	10	133	027		
2000	01	365	008	22000	11	167	021		
4000	02	513	013	24000	12	175	028		
6000	03	571	016	26000	13	168	026		
8000	04	600	010	28000	14	153	038		
10000	05	377	013	30000	15	168	051		
12000	06	381	021	32000	16	161	072		
14000	07	407	018	REMARKS					
16000	08	635	017						
18000	09	034	022						
Received From: Delivered To:						Date & Time (GMT)			
3d DIV FSCC						3 NOV 59 1912			
Recorder Langston					Checker Houck				

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①  
Figure 149. Fallout Metro Message.



THE FALLOUT METRO MESSAGE IS ENCODED AS FOLLOWS

1. The message is arranged in groups to be conveniently transmitted by radio or teletypewriter.

2. Information data: The first five letters denote that the message is a fallout message. The sixth digit denotes the "Q" code of the global octant of the metro station. The next group of six digits denotes the location of the metro station in degrees and 10's of minutes. When 9 of the "Q" code is used, the following six digits are a coded identification of the metro station. The third group of six digits denote the day of the month and the hours (Greenwich Mean Time) of validity of the observation. The first three digits of the fourth group denote the height of the metro station (Metro Datum Plane) in multiples of 10 meters above sea level. The other three digits of the fourth group denote the height of the tropopause above the MDP in multiples of 100 meters. The fifth group is a three-letter group only and identifies the country and service of the metro station. All succeeding groups of eight-digit groups are true zone wind data.

3. The following specimen message was transmitted by teletype-writer:

METFM1 623465 290206 025246 USL 00026015  
 01030021 02046023 .....

Source Country

BE - Belgium GR - Greece NO - Norway  
 CA - Canada IC - Iceland PO - Portugal  
 DA - Denmark IT - Italy TU - Turkey  
 FR - France LU - Luxembourg UK - United Kingdom  
 GE - German Fed R NL - Netherlands US - United States

Service

L - Army N - Navy A - Air Force

EXPLANATION:

- Group 1 Fallout message. Metro station located in global octant Nr 1. (N Lat 90°-180°W)
- Group 2 Center of area of applicability of the message (station location) is 62°30'N; 146°50'W.
- Group 3 29th day of the month. Valid time is from 0200 to 0600 hours GMT.
- Group 4 Metro station is 250 meters above mean sea level. The tropopause is 24,600 meters above the metro station.
- Group 5 The metro station is a United States - Army station.
- Group 6 For line 00 (surface) the true wind direction is 0260 mils, wind speed is 15 knots.
- Group 7 For line 01 (0-2000 meters) the true wind direction is 0300 mils, wind speed is 21 knots.
- Group 8 For line 02 (2000-4000 meters) the true wind direction is 0460 mils, wind speed is 23 knots.

Q Code for Octant of Globe

- 0 - North latitude 0 - 90 West longitude
- 1 - " " 90 - 180 West "
- 2 - " " 180 - 90 East "
- 3 - " " 90 - 0 East "
- 4 - Not used
- 5 - South latitude 0 - 90 West longitude
- 6 - " " 90 - 180 West "
- 7 - " " 180 - 90 East "
- 8 - " " 90 - 0 East "
- 9 - Coded identification

② Figure 149—Continued.

from a military map and is recorded in degrees and tens of minutes. If the longitude is equal to 100° or more, the first digit, 1, is dropped. For example, latitude 32° 30' North, longitude 146° 50' West would be encoded as 1 323 465. When operations require that the station be identified by a code word, the Q code number "9" is used to signify that the next six digits are a coded location of the metro station. For example, if the coded location is WALNUT, the OCTANT and LOCATION would be encoded as 9 WALNUT.

*b. Date.* The day of the month is entered in two digits, e.g., 03 indicates the message is for the third day of the month.

*c. Valid Time.* The valid time for U.S. messages is from release time, rounded off to the nearest whole hour, to the end of the valid period, reported to a whole hour. Releases made at the half hour are reported as the subsequent whole hour. The number 1822 indicates the message is valid from 1800 to 2200 hours GMT.

*d. Station Altitude.* The altitude of the metro station (MDP) above mean sea level is entered in tens of meters. The altitude of the station may be determined from a military map or from the survey section and is encoded in three digits; e.g., 036 indicates the station is 360 meters above mean sea level (MSL).

*e. Tropopause Height.* The height of the tropopause above the MDP is entered in hundreds of meters and encoded in three digits. The number 150 indicates the tropopause is located at 15,000 meters above the MDP.

*f. Source (Country and Service).* The country and service of the meteorological station preparing the message are encoded in a three letter group. The first two letters indicate the country and the third letter indicates the service. USL indicates the message was prepared by the United States Army. The source country code is printed on the back of the fallout metro message form (2, fig. 149).

*g. Line Number.* The line number is identified by two digits which correspond to the zone number. The first line number, 00, indicates surface; 01, surface to 2,000 meters; 02, 2,000 meters to 4,000 meters, etc.

*h. True (Zone) Wind Data.* Wind direction is encoded in three digits in tens of mils. Wind speed is encoded in three digits to the nearest knot. The number 310 indicates the wind direction is 3,100 mils, and the number 004 indicates a speed of 4 knots.

*i. Remarks.* The block for remarks is used to record double tropopause and other pertinent data.

*j. Message Format for Transmission.* The fallout metro message is transmitted in a certain code group format, e.g., METFMQ XXXXXX YYG<sub>0</sub>G<sub>0</sub>G<sub>1</sub>G<sub>1</sub> hhhTRO BBC ZZdddFFF ZZdddFFF ZZdddFFF ZZdddFFF, etc.

<i>Code group</i>	<i>Explanation</i>
METFM	Fallout metro message.
Q	Octant of globe in a numerical code.
XXXXXX	Location of metro station.
YY	GMT date of beginning of valid time period.
G <sub>0</sub> G <sub>0</sub>	GMT hour of beginning of valid time period.
G <sub>1</sub> G <sub>1</sub>	GMT hour of ending of valid time period.
hhh	Height of metro station (MDP) in tens of meters.
TRO	Height of tropopause in hundreds of meters.
BBC	Code of source for the country and service preparing the message.
ZZ	Line number of fallout message.
ddd	Wind direction expressed in tens of mils.
FFF	Wind speed expressed in knots.

## 202. Transmission of Data

Fallout metro messages are transmitted by the most expeditious means to fire support elements. It is the responsibility of the corps fire support element of the TOC to forward messages to the army tactical operations center. Artillery metro stations operating in the army service area will forward fallout messages through army artillery headquarters to army tactical operations center.



**PART FIVE**  
**AIR WEATHER SERVICE**  
**CHAPTER 20**  
**ORGANIZATION AND MISSION OF THE AIR WEATHER SERVICE WITH THE**  
**U.S. ARMY**

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**Section I. INTRODUCTION**

**203. Requirement for Weather Support**

Throughout history, weather conditions have played a large part in the success or failure of military operations. The complexity of present day weapons systems and surface combat forces, with their associated training requirements and employment tactics, and the continued necessity for the estimate of enemy capabilities require maximum consideration of weather conditions. The weather conditions must be a carefully considered part of any military plan or operation.

**204. Objective of Military Weather Service**

The primary objective of a military weather service is to provide meteorological and environmental information to insure the full and effective employment of military forces in their role of instruments of national policy. This weather service must maintain the same operational readiness as the unit or command it supports. It is necessary that this service be completely aware of the operational and planning factors; and it must have the technical and organizational capabilities to provide service to all echelons of the supported command.

**205. Functions of a Military Weather Service Unit**

A weather service unit has two basic functions.

*a.* It produces weather information including reports of current weather conditions, forecasts of future weather conditions, and studies of past weather conditions as applied to specific planning requirements. This is accomplished by the collection, analysis, and interpretation of meteorological data at all available altitudes in and around operational areas.

*b.* It advises commanders and staff officers on

meteorological factors that affect operations and plans being considered. This includes presenting, interpreting, and advising on forecasts and climatological probabilities of weather conditions.

**206. United States Meteorological Services**

*a.* In 1870, the U.S. Army Signal Corps established the first United States meteorological service. The National Weather Service of the United States was established in 1891. Known as the U.S. Weather Bureau, this organization assumed the meteorological service then performed by the Signal Corps.

*b.* Military weather service came into being when personnel of the U.S. Weather Bureau were assigned to the Signal Corps for the purpose of supplying military weather support for aircraft, artillery, chemical, and other operations.

*c.* When the importance of meteorological service to aviation was recognized in 1937, the responsibility for U.S. Army weather service was transferred from the Signal Corps to the Army Air Corps.

*d.* Provisions for the weather support organization of the United States Air Force, Air Weather Service, were established in the Unification Act of 1947. Additional interservice agreements have charged the Air Weather Service with the responsibility for providing weather support to the United States Army. The Army, however, has maintained the capability of meeting certain of its meteorological requirements, for example the upper air data used by artillery. The U.S. Navy, on the other hand, has complete meteorological activities. The Joint Meteorological Group (JMG) was formed within the Joint Chiefs of Staff organization to accomplish joint planning of interdepartmental concern to insure maximum effectiveness and economy of a military weather service.

## 207. Weather Service Data Requirements

Climatological studies and operational forecasts cannot be prepared without meteorological data. Meteorological data must be global in scope since military forces possess a worldwide capability and cannot be supported by a meteorological service that has a limited capability. To obtain a worldwide capability, weather data supplied by both friendly and unfriendly nations must be utilized. With this condition existing, it is absolutely necessary in peace-

time that the military weather service cooperate with all other meteorological services to insure full and free access to current data. To accomplish this, the military weather service must—

- a. Exchange data with other meteorological services.
- b. Conform to established practices of the World Meteorological Organization.
- c. Cooperate with national services with jurisdiction over areas of military interest.

## Section II. AIR WEATHER SERVICE SUPPORT FUNCTION AND ORGANIZATION WITH THE ARMY

### 208. General

a. Because of the complexity of modern warfare, many diverse military forces are created. These military forces require a wide variety of weather data to support their plans and operations. Operational requirements vary from reporting the current weather to making extended weather forecasts at any location in the world.

b. It is essential that the effect of weather conditions be carefully considered in any specific military operation. Winds aloft may limit the range of aircraft, temperature may limit the payload of aircraft, and cloud conditions over the target may determine the type of ordnance which will be used. Winds may affect the accuracy of the ordnance delivered. Weather factors affect the efficiency of nuclear weapon systems.

c. Weather support service can attain optimum effectiveness only when the weather personnel know the capabilities, doctrine, plans, and procedures of the command they serve. Similarly, the commanders and operational personnel must understand and appreciate the nature of meteorology and the capabilities and limitations of the weather support organization.

### 209. Character of Weather Services

a. Weather service support is tailored to meet the specialized capabilities of the command supported. The areas of responsibility and operational authority of commands are established to effect the most economical employment of available forces and weapons. While there is some fundamental similarity among all types of weather service, this similarity is of little consequence when the vastly different types of weather service required to support the

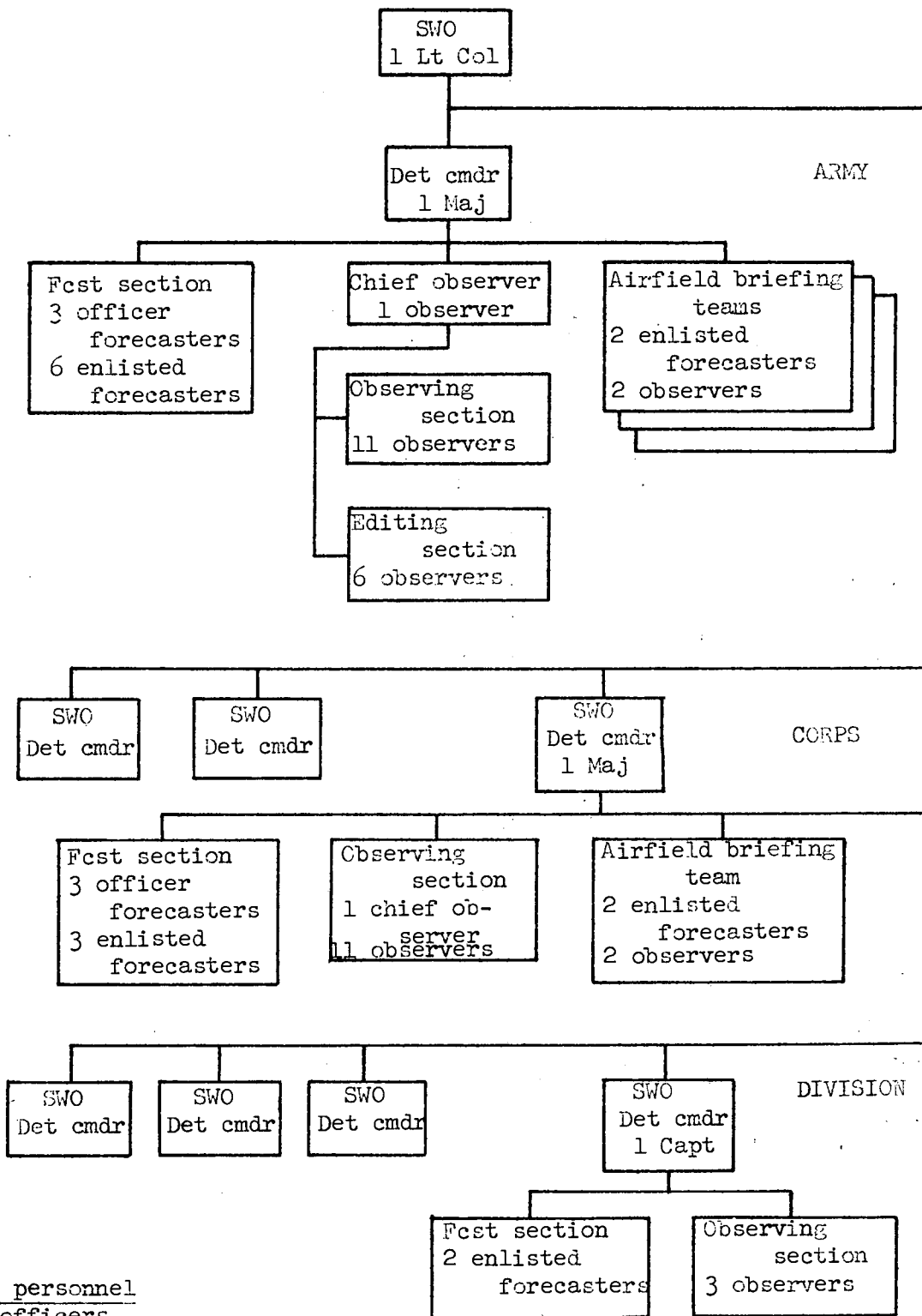
capabilities of the entire army are considered. Experience proves that the forecast capability is greatly improved by limiting the service to one specific task at a time. Economy and concentration of effort are achieved by the specialization of meteorological requirements peculiar to the command supported. Conversely, when forecasts are required for all places and all elements at all times, the forecast capability suffers accordingly.

b. The wide dispersion of Army forces on the nuclear battlefield and the sophisticated weapon systems increase the Army's requirements for weather service support. With the advent of the concept of vertical envelopment combined with lateral envelopment, the requirements have been greatly magnified. The area of weather interest of a field army extends 480 kilometers forward and 160 kilometers behind the forward edge of the battle area (FEBA). Although lateral distances may vary considerably, this distance is generally considered to be 480 kilometers. Within this relatively small volume of the atmosphere, specialized service is required for all elements of the field army.

### 210. Organization for Army Support

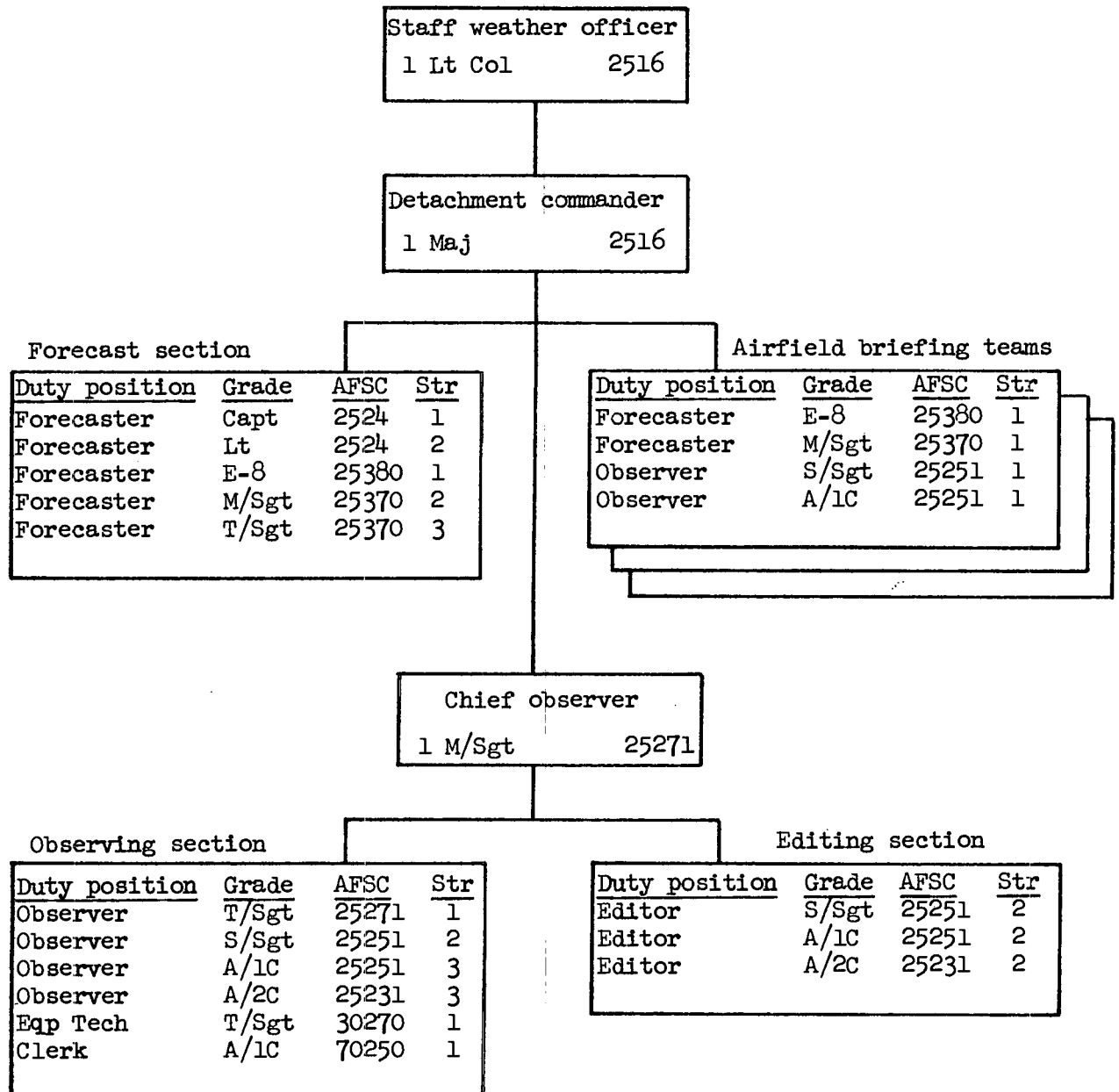
A part of the mission of the Air Weather Service is to provide weather support to the Army. Providing weather service for a field army is the responsibility of a single air weather service (AWS) organization, functionally aligned with the field army. All AWS personnel attached to army units within the field army organization are under the command of the senior AWS officer attached to the field army. This commander normally is assigned as staff weather officer to the army headquarters. The staff weather officer at each corps supervises all AWS activity

Chart I. Air Weather Service Support of a Type Field Army.



Total personnel  
 29 officers  
 153 airmen

Chart II. Army--Tactical Weather Station (Augmented).



Total personnel

5 officers

36 airmen

Chart III. Army--Additional Augmentation.

Additional augmentation for such time as forecast service from a higher level is not available to the tactical weather station at field army level.

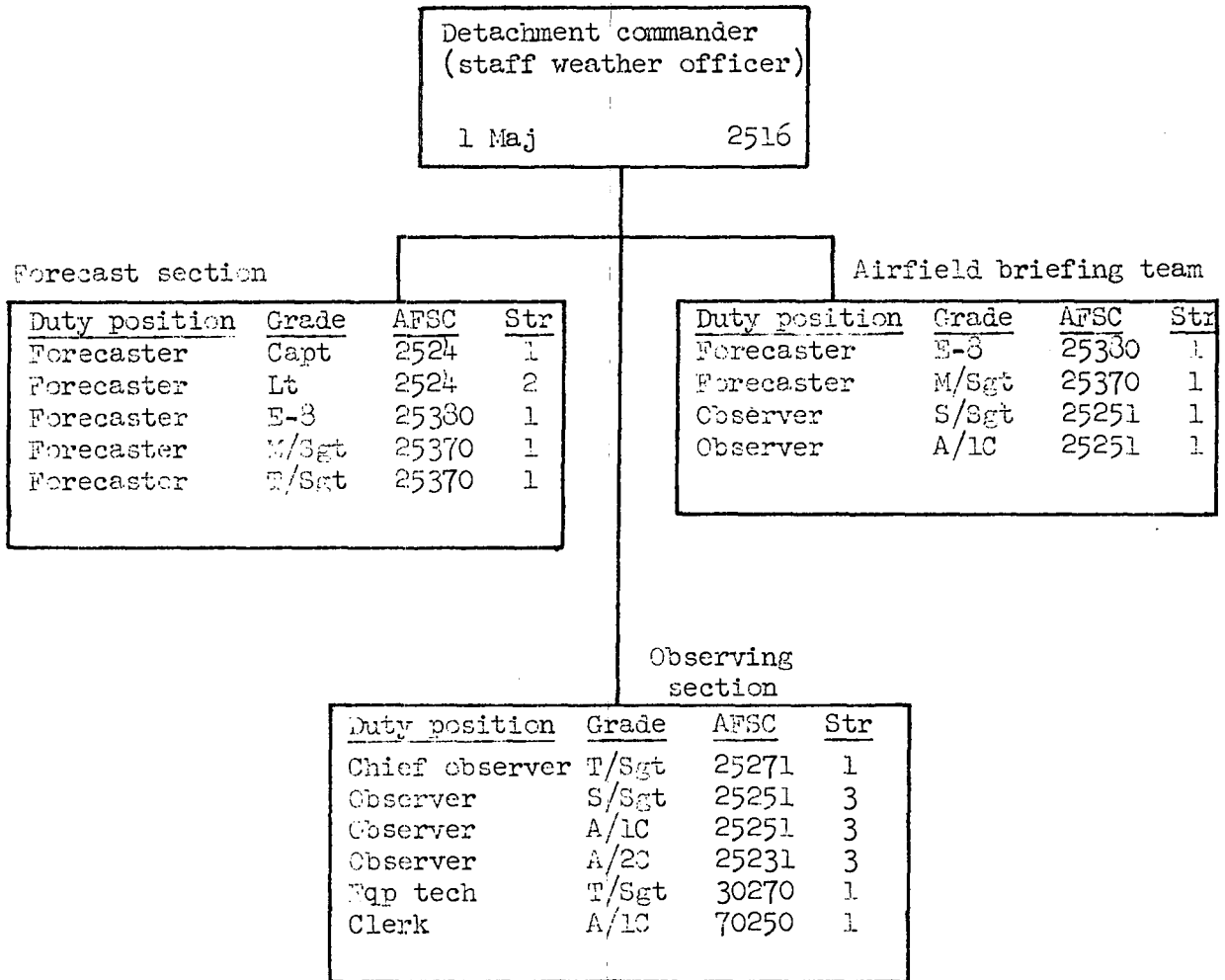
<u>Duty position</u>	<u>Grade</u>	<u>AFSC</u>	<u>Str</u>
Forecaster	Capt	2524	3
Observer	A/IC	25251	3
(Map plotter)			

Total personnel.

3 officers  
3 airmen



Chart IV. Corps--Tactical Weather Station.

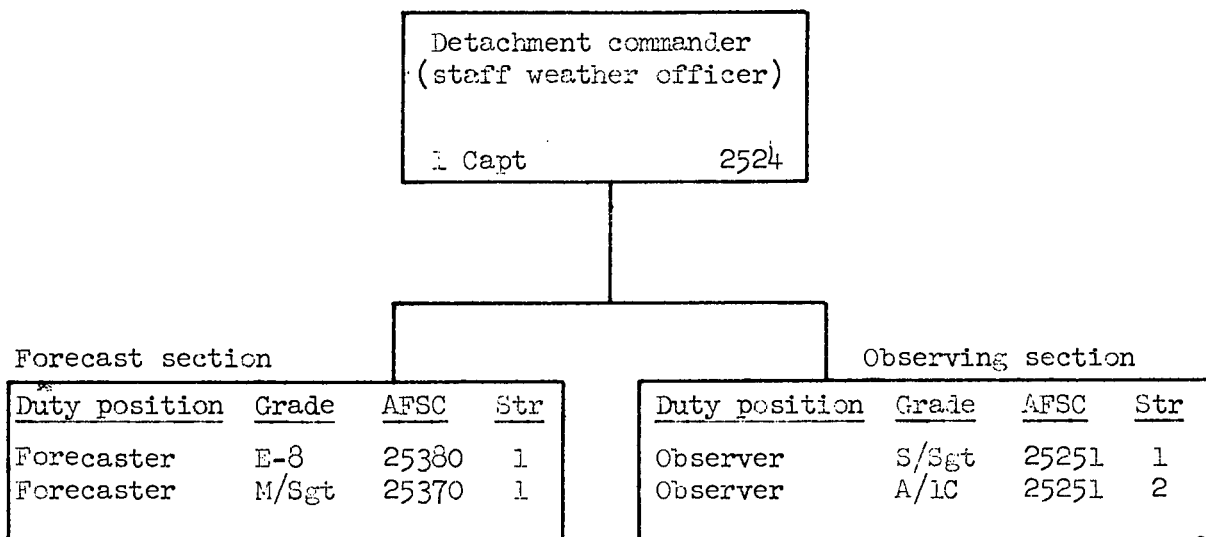


Total personnel

4 officer

19 airmen

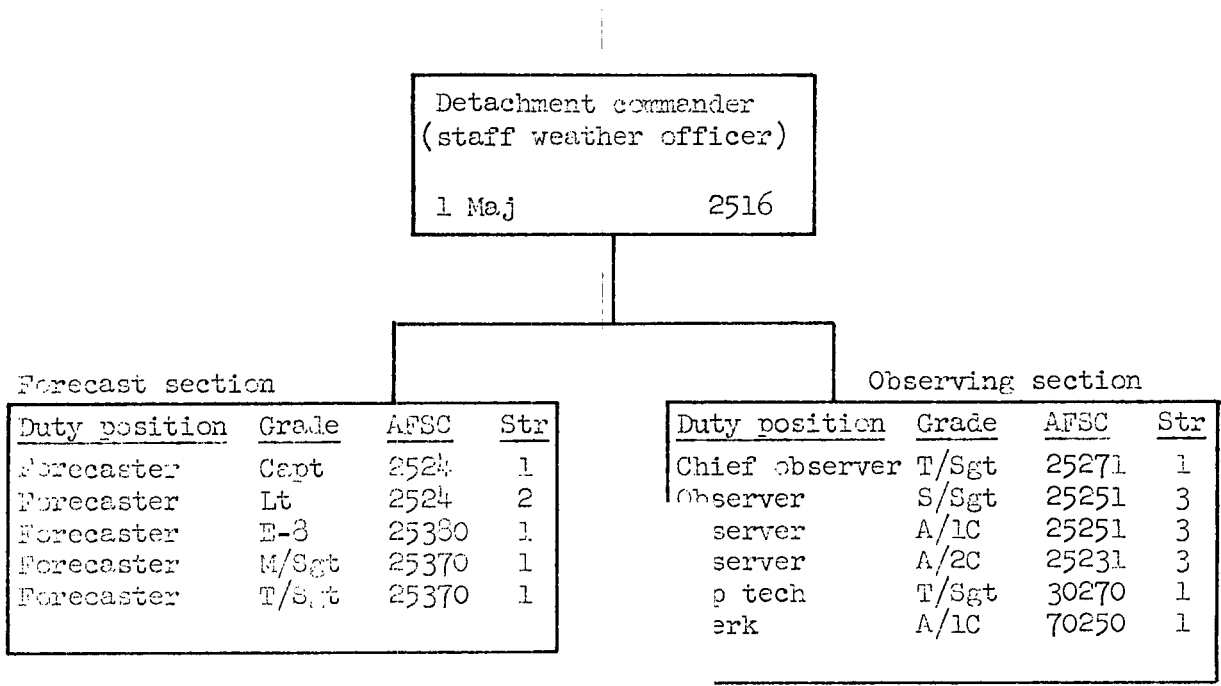
Chart V. Division--Tactical Weather Station (Reduced).



Total personnel

1 officer  
5 airmen

Chart VI. Missile Command (Medium)--Tactical Weather Station.



Total personnel

4 officers

15 airmen

within the corps and subordinate units. The staff weather officer at each division supervises all AWS activity within the division. In STRAC (United States Strategic Army Corps) units and missile commands, the senior AWS officer exercises command over all AWS personnel.

### **211. Manning**

*a.* Charts I through VI show the normal distribution of Air Weather Service personnel within the various echelons of a type field army and a missile command (medium).

*b.* The Air Weather Service support is functional and flexible and is capable of—

- (1) Rapid revision to meet temporary changes in weather service requirements.
- (2) More permanent revision to meet changing organizational and operational concepts of both the Army and the Air Weather Service.

*c.* One specific change to the manning charts that may be expected in the near future is the addition of a radar weather section (approximately three enlisted men) to the tactical weather station at field army or corps. This section may be organized when suitable weather radar becomes available.



## CHAPTER 21

WEATHER FORECAST CAPABILITIES AND LIMITATIONS OF THE AIR  
WEATHER SERVICE**212. Worldwide Weather Service Data**

The Air Weather Service operates on a global basis and has the mission of providing weather information for both the Army and the Air Force. The mission of the Air Weather Service includes both forecasting and climatological information. A wide variety of weather phenomena will be encountered by AWS personnel in performing their mission throughout the world; therefore, they have a continual need for both surface and upper air data. The necessary raw meteorological data to make a forecast must be furnished at specified intervals by hundreds of observing stations. Within the CONUS, there are relatively few fully equipped AWS stations, as the U.S. Weather Bureau has been assigned the responsibility of furnishing the bulk of the upper air data required by the other weather services. Overseas, the AWS has an increased capability for taking upper air observations, yet wherever possible, the weather service uses the data furnished by allied meteorological services. In tactical operations involving the Army, the AWS uses the data furnished by the artillery ballistic meteorological sections. A reliable forecast is dependent on an accurate description of the atmosphere over a large geographical region. Therefore, in certain parts of the world, many land areas are inaccessible and data is secured by aerial reconnaissance flights, while ships at sea provide data over ocean areas. Because of the temporary nature of weather information, a rapid and dependable means of acquiring and exchanging raw, analyzed, and forecast data must be available at all times. The volume of weather information traffic within a field army will vary with the composition and mission of the command. Communication means for weather information traffic is primarily in the form of radioteletype, continuous wave broadcasts, and radio facsimile. Adequate weather communications are a necessary prerequisite of satisfactory weather service.

**213. Definitions**

*a. Weather Information.* Information concerning the condition and behavior of the atmosphere at a

given place or over a given area and for a given instant of time or for any specified period of time.

*b. Climatological Information.* Information which deals with weather conditions and variations from normal for a particular place or area during a specified period of the year. Two types of climatological information are climatic summaries and climatic studies.

- (1) *Climatic summary.* A statistical expression of weather elements in terms of averages, extremes, and frequencies of occurrences over a given period of time. This summary highlights those features of the climate which may impose problems in military operations and is of value to the field commander in preparing to meet such problems.
- (2) *Climatic study.* The application of climatological information in a manner to reveal the probable effects of climate and weather elements on a specific operation or activity.

*c. Weather Forecast.* A prediction of expected weather conditions at a point, along a route, or within an area for a given time or specific period of time in the future.

- (1) *Short period forecast.* Predictions up to 48 hours in advance.
- (2) *Extended period forecast.* Predictions 3 to 5 days in advance.
- (3) *Long period forecast.* Predictions for more than 5 days in advance. A statement of expected variations of weather elements from climatological normals.

*d. Weather Summary.* A description of the weather elements that have occurred at a point, along a route, or within an area during a specified period of time.

**214. Forecast Available From AWS Detachments at Army, Corps, and Division Levels**

*a. General.* The use of various weather elements from a forecast or a climatic summary will vary

considerably between the levels of a command and even between units of the same level. Requests for assistance or services beyond the capabilities of air weather service personnel at any echelon are forwarded to higher echelons. All weather detachments depend on the next higher echelon for backup data and forecast assistance. Therefore, when this backup assistance is not available because of the tactical situation, the quality of weather support will deteriorate.

*b. Field Army.* On the nuclear battlefield, the field army may exert influence throughout an area as large as 480 kilometers square. A command of this extent will have numerous requirements for weather information to insure effective employment of its forces. The weather detachment at Army provides technical liaison with higher echelon weather agencies and provides planning guidance, coordination, and limited technical and logistical support for AWS detachments at lower echelons. This detachment furnishes daily forecasts for periods up to 48 hours, limited climatological information, flight forecasts, and facilities for editing observations made within the army area.

*c. Corps and Division.* The weather support required by corps and divisions differs from that required by an Army because of the reduced area of operations and reduced planning time for operations. Corps and divisions require climatic information and extended period forecasts and, in addition, require current weather observations and short period forecasts.

## 215. Special Forecast and Climatology

*a.* In addition to the regular forecasts that are issued on a recurring basis, the Air Weather Service

personnel are also responsible for special forecasts. One special forecast of considerable interest to any commander is the severe weather forecast. Severe weather is defined as any type of weather or any value of a weather element which a commander considers a potential hazard to his equipment or personnel or the fulfillment of his mission. These special forecasts must be timely and accurate so that local precautionary measures may be taken to minimize property damage and personnel injuries. Weather stations at Army level may be equipped with weather radar sets. These sets are capable of detecting and tracking thunderstorms and heavy precipitation areas within a radius of 160 kilometers of the station. Information concerning the location, shape, intensity, direction, and speed of severe weather movements can be determined and disseminated by the forecaster. A commander can normally plan on at least 2 hours' notification of severe weather situations. In the future, a new radar set, capable of presenting a three-dimensional picture of storms within a 400-kilometer radius of the station, will replace the present weather radar.

*b.* The climatic summaries and studies are used to supplement the information contained in intelligence surveys. The summaries should be available to a commander at least 6 months prior to the period covered by the report. Certain items of information that describe a region may be required by staff members or the technical services in planning for a military operation. Examples of such requirements are the relation between precipitation, snow cover, and thaw dates used by the engineers when they prepare charts on soil trafficability. The wind and cloud patterns that may be expected at the surface and aloft during a certain season, are needed by staff sections planning airborne operations.

## CHAPTER 22

## ENCODING AND EXCHANGE OF METEOROLOGICAL DATA BETWEEN AIR WEATHER SERVICE AND ARMY ARTILLERY

**216. Establishment of Liaison With Air Weather Service Detachments**

a. Many items of equipment and many methods employed by Air Weather Service (USAF) are identical to those in use by artillery metro sections. In certain cases, the data obtained by an artillery metro section will be of value to the weather forecaster. Similarly, data available from the Air Weather Service may assist the artillery metro section in performing its mission. Therefore, information should be exchanged when practicable. Liaison for the exchange of weather information is directed by higher headquarters. However, the artillery metro section should contact the nearest Air Weather Service installation as soon as possible after arrival in an area of operation. Personnel liaison should be used to the maximum to work out the details of rapid transmission of data and to affirm the codes authorized for use.

b. Weather information may be exchanged by means of wire, radio, or messenger. The most expeditious means possible should be utilized. The manner of transmission of data is a detail which should be worked out between the Air Weather Service installation and the artillery metro section.

**217. Encoding Meteorological Data for Exchange Between Army Artillery and Air Weather Service**

Meteorological support of the field army requires that metro data be exchanged between the army artillery metro sections and the Air Weather Service detachments assigned to the field army. In order that this exchange may be accomplished routinely and efficiently, a coded message format, compatible with the two meteorological services and the communications means, is necessary. This chapter specifies the standard code for use by artillery meteorological sections in support of an AWS unit.

a. *Message Format.* The data are encoded in five- and three-digit groups for convenience in radio-teletypewriter transmission. The encoded message consists of three parts; the heading, the significant

level data, and the rawin data. The format is as follows:

Heading	METWQ	L <sub>a</sub> L <sub>a</sub> L <sub>a</sub> GG	L <sub>o</sub> L <sub>o</sub> L <sub>o</sub> gg	YYhh
Significant level data	SSPPP	TTTUU	SSPPP	TTTUU
	SSPPP	TTTUU	***	***
	666666	PPPTT	PPPTT	***
Rawin data	RAWIN	HHddd	fff	HHddd fff
	HHddd	fff	HHddd	*** **

The data are recorded on DA Form 6-60 (Meteorological Data for Artillery-Air Weather Service Exchange) (fig. 150).

b. *Heading.* The heading consists of four five-digit groups which identify the sounding station and the time of the balloon release.

(1) *Group 1—METWQ.*

METW—is transmitted to indicate that the message is encoded for exchange between army artillery and the Air Weather Service.

Q—is the number for the Q code for octant of the observing station. See table V for Q code.

*Note.* When using the Q code, latitude is always given first.

- (a) When the Q code is 1, 2, 6, or 7, no value for longitude is encoded in more than three digits (99.9°). For a longitude equal to 100° or more, the first digit, 1, corresponding to one hundred, is dropped when encoding and added when decoding.
- (b) When codes are used, meteorological stations will report coordinate location by geographic or UTM grid coordinates, as required. Code names for station locations are specified by appropriate SSI's. Six-letter code words will be used. Number 9 of the Q code will be used when a station code name is used or when the location is given by UTM grid coordinates. When military grid coordinates are used to identify the station location, L<sub>a</sub>L<sub>a</sub>L<sub>a</sub> will be the X coordinate



METEOROLOGICAL DATA							
FOR ARTILLERY-AIR WEATHER SERVICE EXCHANGE							
(FM 6-15)							
IDENTIFICATION	OCTANT	LOCATION LATITUDE (degrees & tenths) LaLoLa	RELEASE TIME HR-GMT GG	LOCATION LONGITUDE (degrees & tenths) LoLoLo	RELEASE TIME MIN-GMT gg	DATE Z YY	STATION HEIGHT (10's meters) hh
METW	Q						
METW	/	347	17	983	30	03	36
SIGNIFICANT LEVEL DATA							
LEVEL NR	PRESSURE mb	TEMPERATURE 1/10°C	RELATIVE HUMIDITY % UU	LEVEL NR	PRESSURE mb	TEMPERATURE 1/10°C	RELATIVE HUMIDITY % UU
SS	PPP	TTT	UU	SS	PPP	TTT	UU
00	967	294	09		032	10	
01	856	121	MB		029	12	
02	818	189	MB		028	04	
03	742	030	MB		023	04	
04	660	030	MB		021	96	
05	621	505	10		018	02	
06	557	557	48		016	97	
07	527	577	10		010	97	
08	499	604	MB		007	88	
09	479	623	10		004	94	
10	458	643	43				
11	420	682	10				
12	334	774	MB				
13	XXX	XXY	XX				
66	666						
	198	98					
	140	15					
	120	17					
	144	14					
	097	17					
	067	16					
	058	11					
	046	12					
	042	12					
<p><b>NOTE:</b> Level numbers are numbered sequentially to the level where temperature is colder than -40°C. Then 66666 is transmitted to indicate that only a five-digit group will be transmitted for each level, 3 digits for pressure and 2 digits for temperature see Ch 22, FM 6-15.</p>							

DA FORM 6-60, 1 MAR 62

Figure 150. Meteorological data recorded for Air Weather Service message.

- and  $L_oL_oL_o$  the Y coordinate to the nearest 1,000 meters.
- (2) *Group 2— $L_aL_aL_aGG$ .*  
 $L_aL_aL_a$ —is the latitude of the observing station to the nearest  $0.1^\circ$ .  
 $GG$ —is the hour, GMT, during which the sounding balloon was released and may be any number from 00 through 24.
- (3) *Group 3— $L_oL_oL_oL_oL_o$ .*  
 $L_oL_oL_oL_oL_o$ —is the longitude of the observing station to the nearest  $0.1^\circ$ .  
 $gg$ —is the number of minutes past the hour at which the balloon was released and may be any number from 00 through 59.
- (4) *Group 4— $YYhhh$ .*  
 $YY$ —is the day of the month of the observation and may be any number from 01 through 31.  
 $hhh$ —is the altitude of the observing station to the nearest 10 meters. Altitudes below sea level are indicated by transmitting a 9 for the first digit. For example, an altitude of  $-30$  meters would be transmitted as 903.

## 218. Significant Level Data

Data for each significant level are encoded in two 5-digit groups. Because humidity is not computed below  $-40^\circ\text{C}$ . (normally at pressures around 300 mb.), the significant level code is modified to a single 5-digit group when temperatures below  $-40^\circ\text{C}$ . are reached (*b* and *c* below). Levels are selected on the radiosonde recorder record according to the criteria set forth in chapter 7.

### *a. Significant Level—SSPPP TTTUU.*

- (1) *SS*—is the number of the significant level. The first significant level is the surface level numbered 00. Levels are numbered consecutively from the surface up.
- (2) *PPP*—is the significant level pressure in millibars. For encoding pressures greater than 999 millibars, the first digit, 1, corresponding to one thousand, is dropped.
- (3) *TTT*—is the significant level temperature to the nearest  $0.1^\circ\text{C}$ . encoded as follows: Temperatures of  $0^\circ\text{C}$ . and

warmer are reported directly; for temperatures of  $-0.1^\circ\text{C}$ . through  $-49.9^\circ\text{C}$ ., the minus sign is disregarded and 50 is added; for temperatures of  $-50.0^\circ\text{C}$ . or below, the minus sign is disregarded and 50 is subtracted. For example,  $6.2^\circ\text{C}$ . is encoded 062,  $-8.7^\circ\text{C}$ . is encoded 587, and  $-59.2^\circ\text{C}$ . is encoded 092.

- (4) *UU*—is the significant level relative humidity reported in whole percent. Relative humidity is encoded MB for a motorboating level. One hundred percent relative humidity is encoded 00.

### *b. Indicator Group—66666.*

66666—is transmitted as an indicator that the significant level will be coded in a single 5-digit group and that the level number (SS) and the relative humidity (UU) will no longer be reported. The group 66666 further indicates that significant level temperatures are colder than  $-40^\circ\text{C}$ .

### *c. Significant Level—PPPTT.*

- (1) *PPP*—is the significant level pressure in millibars.
- (2) *TT*—is the significant level temperature, encoded as explained in *a* above but reported to the nearest whole  $^\circ\text{C}$ . For example,  $-53.2^\circ\text{C}$ . would be encoded 03 ( $53.2 - 50 = 03.2$ ).

## 219. Rawin Data

Rawin data are the wind directions and speeds at heights above the observing station (fig. 151). The code numbers of the standard heights are shown in table VI. The heights shown are the zone midpoint heights. The zone structure is the same as the zone structure for computer message winds and, to line 26, are the same winds as those prepared for a computer message (par. 232). Above 20,000 meters, lines 27-32, winds are the same as fallout zone winds.

*a. Indicator Group—RAWIN.* RAWIN is transmitted to indicate that wind data will follow.

### *b. Wind Groups—HHddd fff.*

- (1) *HH*—is the code for the height and may be any number from 00 (surface) through 32. See table VI.
- (2) *ddd*—is the wind direction to the nearest degree from geographic (true) north.
- (3) *fff*—is the wind speed to the nearest knot.

RAWIN DATA							
STANDARD HEIGHT (Meters)	HEIGHT CODE HH	WIND DIRECTION (Degrees) ddd	WIND SPEED (Knots) fff	STANDARD HEIGHT (Meters)	HEIGHT CODE HH	WIND DIRECTION (Degrees) ddd	WIND SPEED (Knots) fff
RAWIN				9500	16	222	016
SUR	00	174	004	10500	17	216	014
100	01	141	013	11500	18	213	028
350	02	172	014	12500	19	222	021
750	03	201	014	13500	20	238	017
1250	04	223	007	14500	21	352	016
1750	05	282	008	15500	22	002	019
2250	06	255	015	16500	23	357	025
2750	07	267	013	17500	24	042	023
3250	08	292	013	18500	25	060	026
3750	09	327	018	19500	26	088	029
4250	10	323	017	21000	27	094	021
4750	11	318	016	23000	28	098	028
5500	12	321	015	25000	29	094	026
6500	13	331	009	27000	30	086	038
7500	14	344	011	29000	31	094	051
8500	15	199	012	31000	32	091	072
Delivered to: SWO				Remarks:			
Received from: 3d Div Arty							
Date: 3 Nov 59		Time: 1912		Flight number: 3			
Recorder: Langston				Checker: Barry			

Figure 151. Rawin data recorded on back of AWS metro message form.

Table VI. Wind Height Code

HH code	Height (meters)	HH code	Height (meters)
00	Surface (MDP)	17	10500
01	100	18	11500
02	350	19	12500
03	750	20	13500
04	1250	21	14500
05	1750	22	15500
06	2250	23	16500
07	2750	24	17500
08	3250	25	18500
09	3750	26	19500
10	4250	27	21000
11	4750	28	23000
12	5500	29	25000
13	6500	30	27000
14	7500	31	29000
15	8500	32	31000
16	9500		

## 220. General Rules for Encoding Data

a. All data reported are relative to the altitude of the artillery observing station, the metro datum plane.

b. Missing data are encoded as X's.

c. The critical angle for wind data is 6°. This 6° angle is measured vertically above and/or horizontally from any terrestrial object. No wind data will be reported when the observed angles are smaller than the critical angle of 6°.

## 221. Artillery Metro Application of a Message From Air Weather Service (AWS)

When army artillery metro sections do not have the capability of upper air soundings, they will request upper air data from Air Weather Service. Data will be furnished in appropriate World Meteorological Organization (WMO) code. When proper codes are available, they will be published as a change to this manual. Pending this change, artillery metro sections, by close liaison with AWS detachments, may obtain an explanation of codes used.



**PART SIX**  
**SPECIAL APPLICATIONS AND MISCELLANEOUS OPERATIONS**  
**CHAPTER 23**  
**MEASUREMENT OF LOW-LEVEL WINDS FOR FREE ROCKETS**

### 222. General

Winds have two major effects on the flight of a free rocket. One effect is the ballistic wind effect and the other is the low-level wind effect. The ballistic wind effect is dominant only after burnout of the rocket when the rocket is in a true ballistic flight. The ballistic wind effect on a free rocket is the same as that on an artillery projectile. The low-level winds are those winds encountered by the rocket during its powered flight, that short period of time between firing and burnout. For the Honest John rocket, this time is approximately 4 seconds. The low-level winds turn or cock the rocket into the wind (fig. 152). This turning causes the thrust vector of the rocket to change and results in the rocket deviating from the intended path of flight. Corrections to rocket trajectories for ballistic winds are made in the same manner as corrections for artillery trajectories and are described in paragraph 24. The measurements of low-level winds and the corrections therefore are made by launcher crew personnel at the launcher position just prior to firing. Low-level winds are continuously changing; therefore, time is of primary importance in measuring low-level winds and applying the corrections. The various methods of measuring the low-level winds are described in paragraphs 223 and 224. Application of corrections is described in the appropriate firing tables.

### 223. Aerovane Anemometers

a. The accurate measurement of a representative low-level wind is a difficult problem which has not been completely solved. A practical method used is measurement by means of an Aerovane anemometer exposed 15 meters above the surface. The equipment currently issued for making this measurement is wind measuring set (windset) AN/MMQ-1 ( ) (fig. 153) or AN/PMQ-6 (fig. 154). These wind measuring sets are described in TM 11-6660-203-10. The essential components of the sets are a telescoping mast (15 meters), a wind transmitter, and an

indicator. The indicator is positioned remotely from the mast and usually at the fire control point from which the rocket is fired. Indicator ID-624 ( ) reads out range and crosswind corrections in miles per hour. The anemometer (fig. 155) is activated by a six-blade impeller which reacts to a wind speed greater than 2 or 3 knots. As the impeller rotates, it turns the armature of a small generator which develops a voltage proportional to the wind speed. The voltage generated is applied across a sine-cosine potentiometer from which two outputs are taken. One cosine-output, is a voltage proportional to range wind, that wind component parallel to the direction of the launcher. The other is the sine-output and is a voltage proportional to the crosswind, that wind component perpendicular to the direction of fire.

b. The wind measuring set is emplaced in an open area away from any obstructions that would interrupt the existing wind pattern. The set should be emplaced approximately 50 meters in front of the rocket launcher, and for safety, at least 25 meters to the side of the trajectory. The mast initially should be oriented parallel to the azimuth of fire. If the

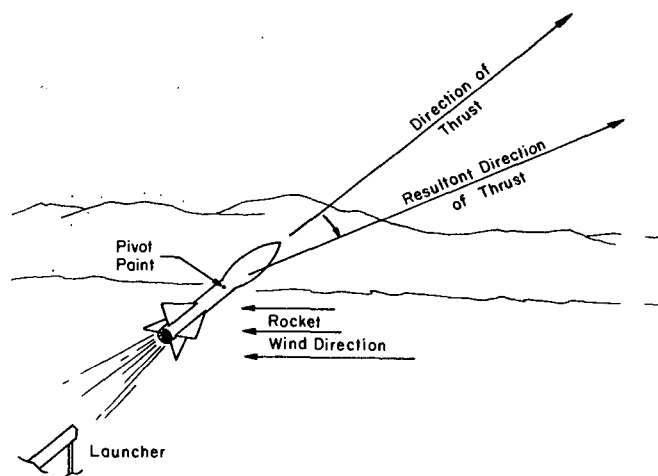
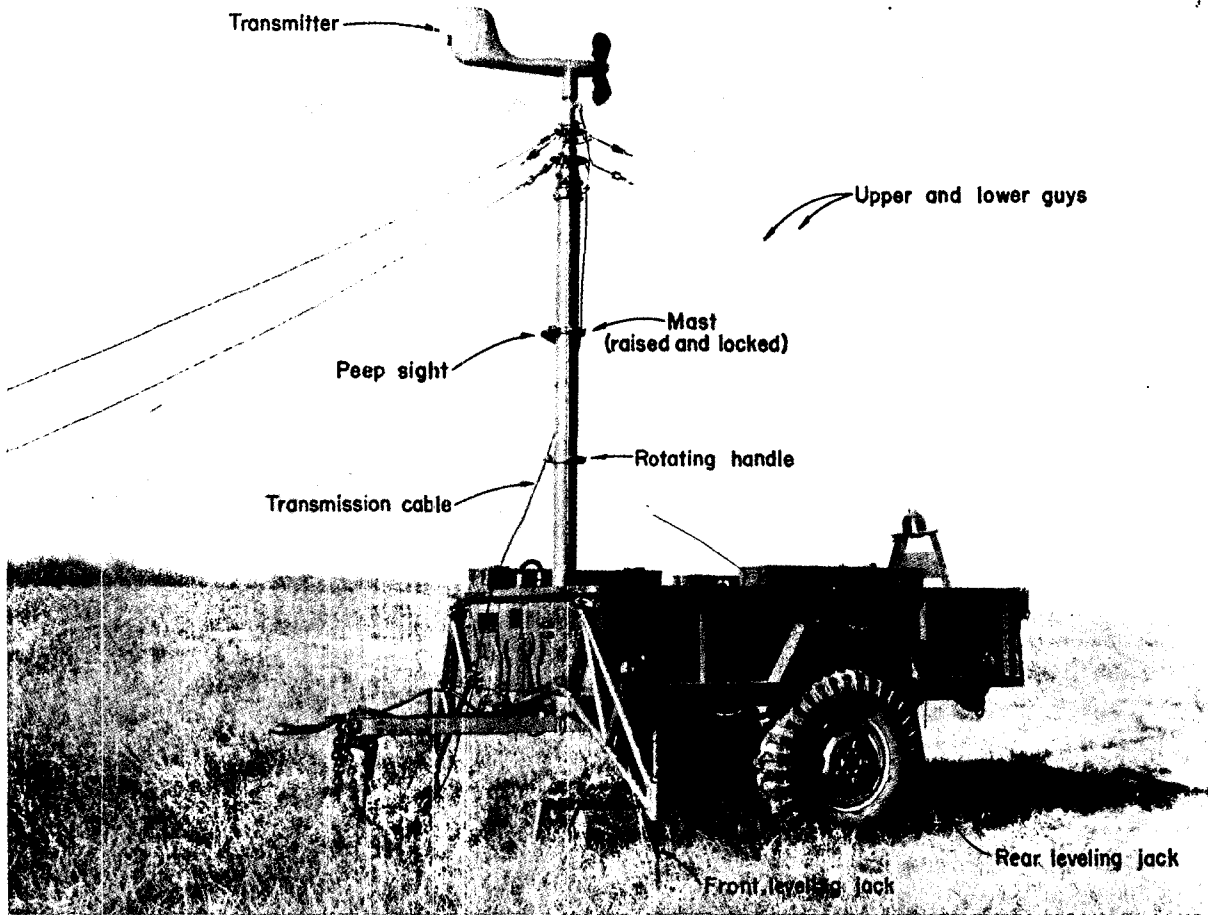
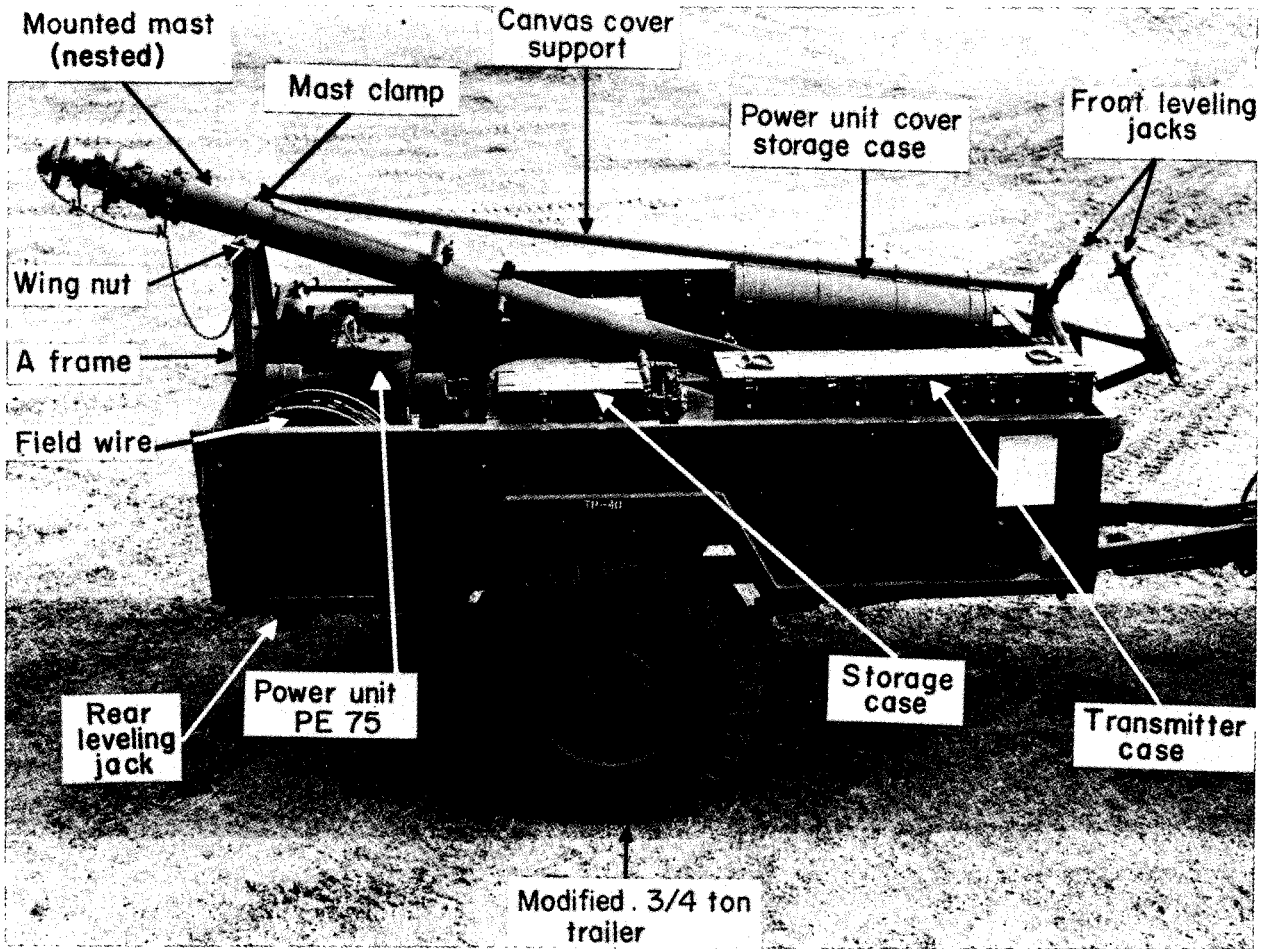


Figure 152. Low-level wind effect on rocket.



①

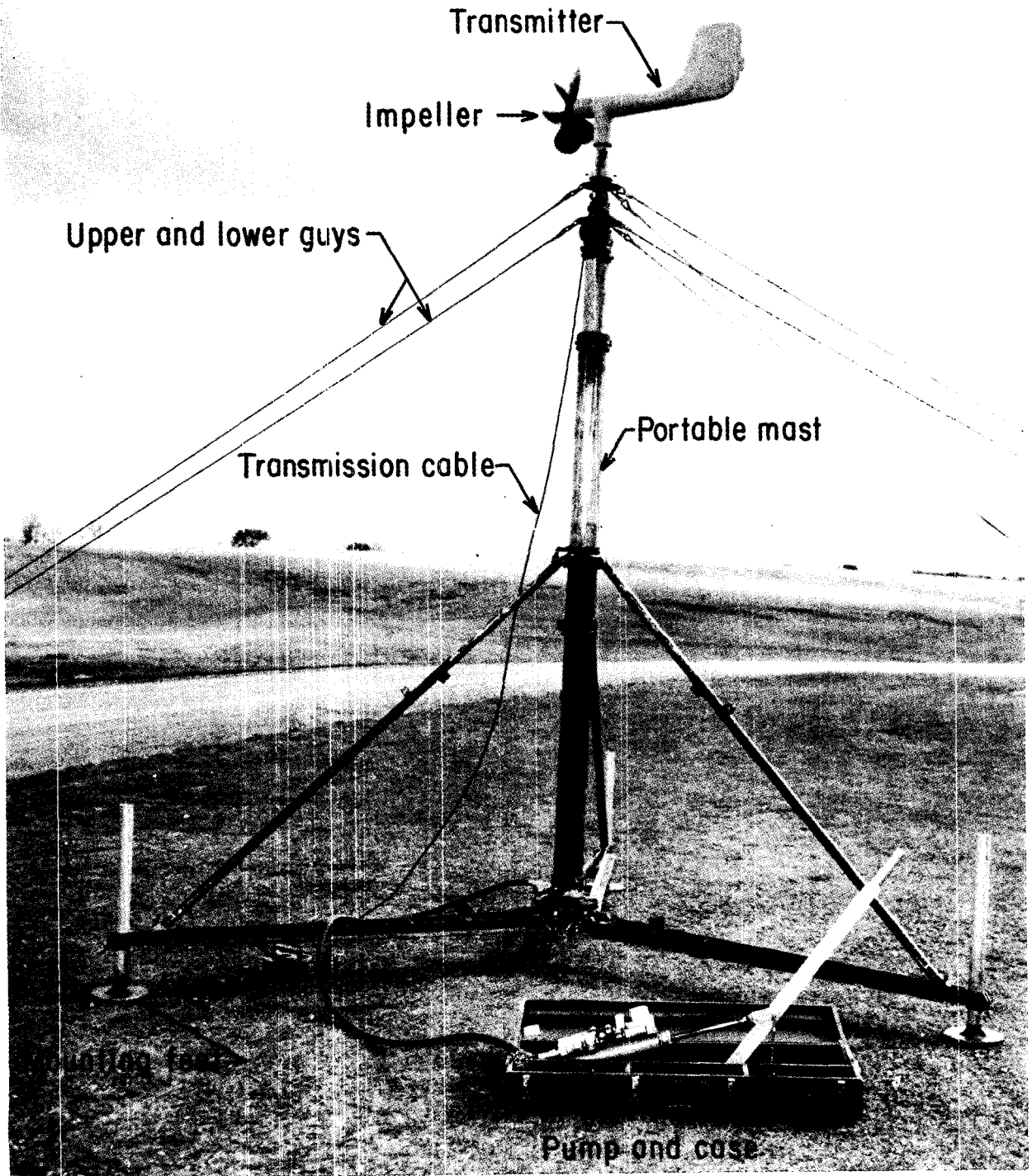
Figure 153. Wind measuring set AN/MMQ-1( ).



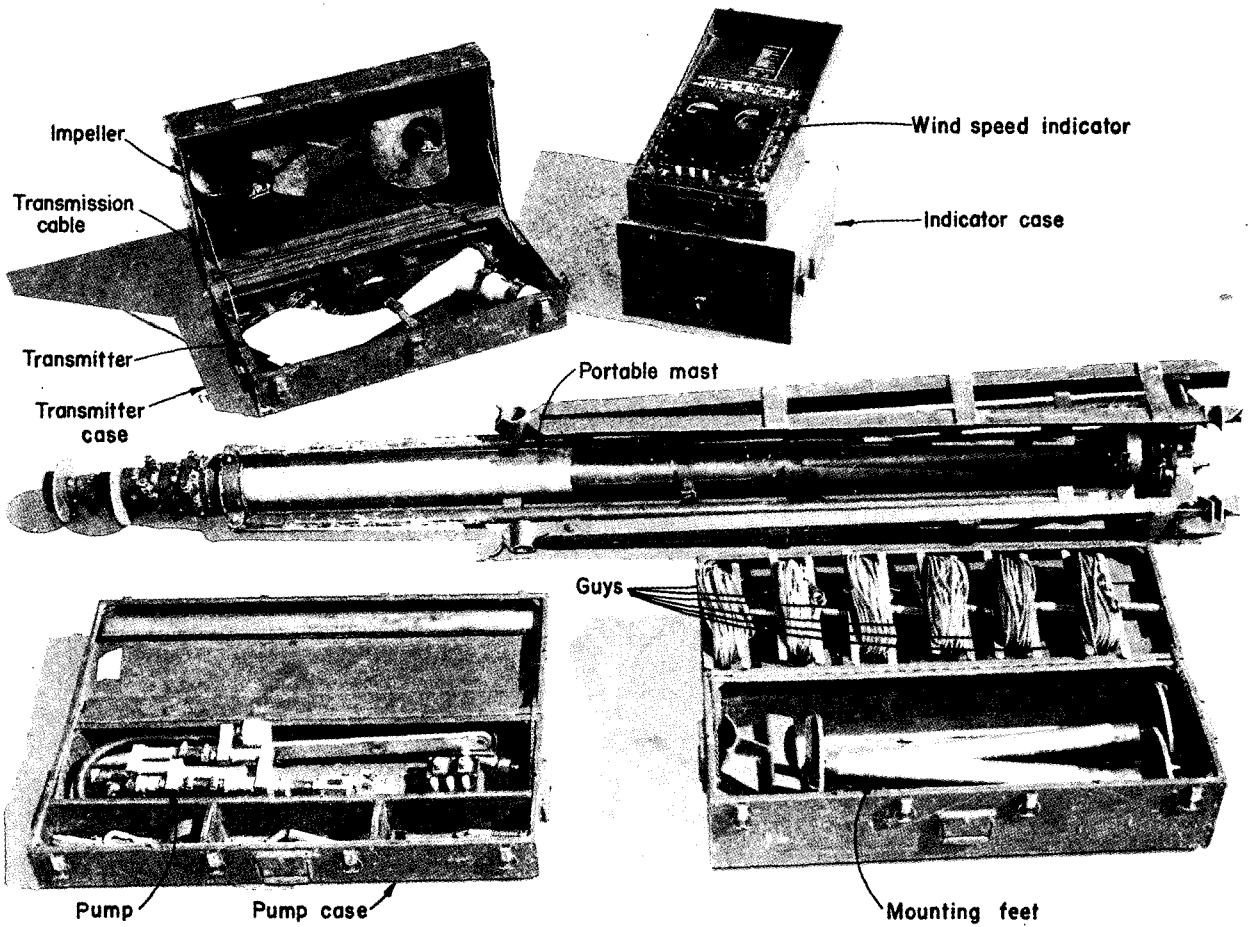
②

Figure 153—Continued.

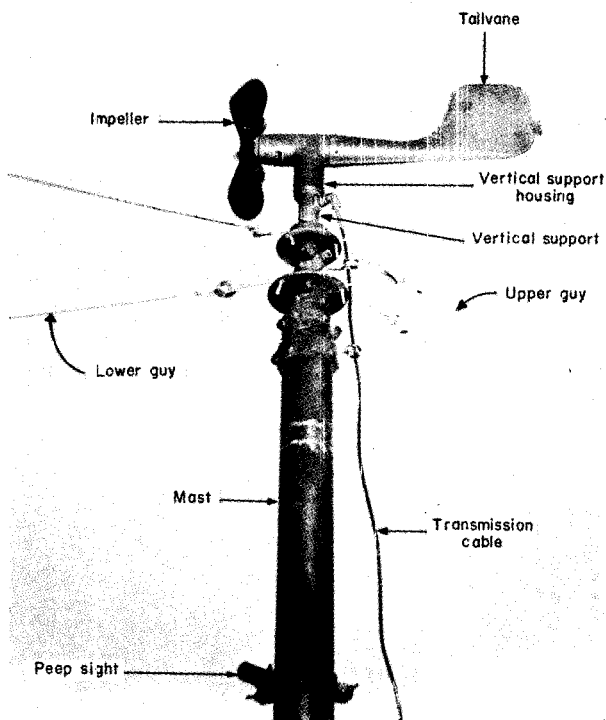




①  
Figure 154. Wind measuring set AN/PMQ-6.



②  
Figure 154—Continued.



①  
Figure 155. Anemometer.

deflection correction (metro and rotation) exceeds 25 mils, the mast should be reoriented to the corrected firing azimuth before correction for low-level winds are determined. The measurement must be corrected to account for the fact that wind speeds generally increase with height and to account for the fact that the wind used for corrections should be the mean wind encountered by the rocket from the surface to the height of burnout. Hence, wind measuring set readings must be corrected by weighting, to account for height of burnout and wind speed variance. The correction factors for the 762-mm rocket (Honest John) are described in FM 6-61, Field Artillery Missile Battalion, Honest John Rocket, Self-Propelled. The correction factors for the 318-mm rocket (Little John) are contained in FM 6-56, Field Artillery Missile Battalion (Battery), Little John Rocket.

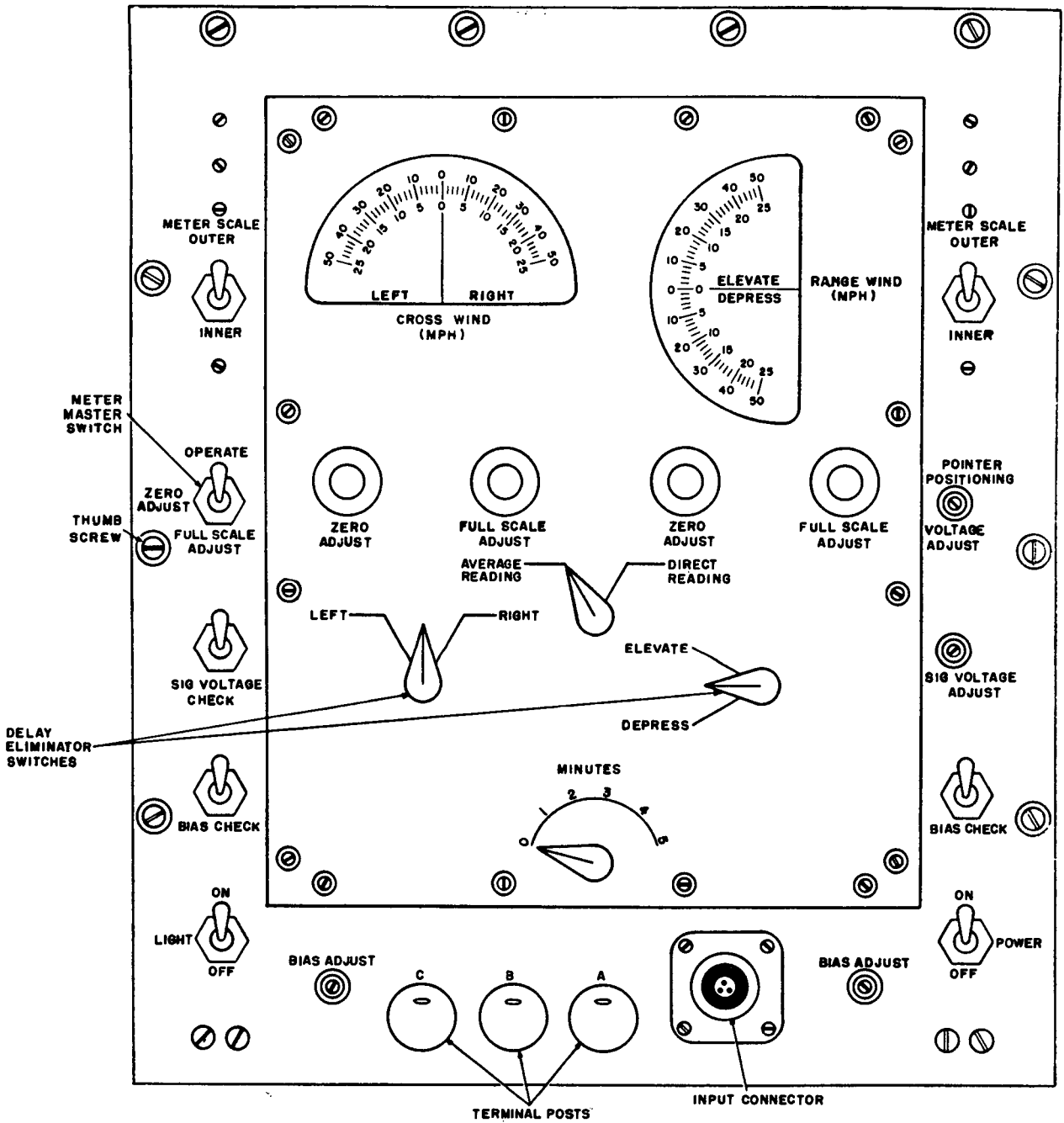
c. After a low-level wind has been measured and corrected, the launcher crew must apply the corrections to the settings on the launcher. The

computation and setting of corrections require time, possibly as much as 4 minutes. Because of the fluctuations of low-level winds, it is probable that the value of the measured wind will change by the time of firing. Two techniques may be used to overcome this deficiency. One system is the recurring wind technique, wherein a wind measurement is made and the rocket is fired when the same wind recurs within a tolerance of plus or minus 1 knot. The other system is the technique of predicting wind, wherein the measured wind is averaged for 5 minutes and it is assumed that the average wind will persist until the rocket is fired. The recurring wind will produce the most valid low-level wind corrections but this technique cannot be used if the rocket is to be fired at a specific instant, inasmuch as the measured wind may not occur again at the time required to fire. For detailed information on application of wind corrections, see FM 6-61 for Honest John rockets and FM 6-56 for Little John rockets.

## 224. Pilot Balloon Observation for Measurement of Low-Level Winds

a. Low-level winds may be measured by means of a single theodolite observation of a pilot balloon. Because of the erratic rate of rise of a pilot balloon, the wind computed from a single theodolite observation is not as valid as a measurement with a wind measuring set. The single theodolite balloon technique may be used as an alternate method. For this measurement, a theodolite is set up and oriented near the launcher, preferably upwind at a distance of approximately 50 meters. The distance is not critical. Installation and use of the theodolite are described in paragraph 53. *The theodolite must be oriented so that the zero direction of the theodolite is in the direction of fire and not in the direction of true north.* This orientation may be accomplished by one of the three methods outlined below:

- (1) *Panoramic telescope method.* The panoramic telescope is the optical instrument used to lay the launcher for direction. After the launcher has been laid, the following procedure may be used:
  - (a) Set up and level the theodolite.
  - (b) Obtain the deflection angle to the theodolite from the launcher by commanding DEFLECTION ANGLE, METRO THEODOLITE.



**NOTE:**

ON SOME MODELS OF THE INDICATOR THE **RANGE WIND (MPH)** METER IS MARKED **HEADWIND** **TAILWIND** INSTEAD OF **ELEVATE** **DEPRESS** THE RIGHT-HAND DELAY ELIMINATOR SWITCH IS MARKED **HEADWIND** INSTEAD OF **ELEVATE** AND **TAILWIND** INSTEAD OF **DEPRESS**

**WIND INDICATOR PANEL**

②  
Figure 155—Continued.

- (c) When facing the direction of fire, if the launcher is left of the theodolite, add 3,200 mils to the deflection angle. If the launcher is right of the theodolite use deflection angle directly.

*Note.* If the panoramic telescope has a 0-6,400 mil scale, subtract 3,200 mils when the launcher is right.

- (d) Convert the deflection angle to degrees and set it on the azimuth scale. Engage the azimuth tracking controls.
- (e) Loosen the azimuth calibration clamp on the theodolite.
- (f) Sight the theodolite on the panoramic telescope. Tighten the azimuth calibration clamp. Adjust precisely. The theodolite is now oriented.

- (2) *Orienting angle method.* The orienting angle method requires that the unit survey crew establish an orienting line in the firing position parallel to the launcher orienting line with a stake for the location of the theodolite and an identification of a distant aiming point of known direction. The following procedure is used:

- (a) Set up and level the theodolite over the stake.
- (b) Obtain the orienting angle from the launcher platoon leader and convert to degrees and tenths of degrees.
- (c) Disengage the azimuth tracking control on the theodolite and set the orienting angle on the azimuth scale.
- (d) Engage the azimuth tracking control and loosen the azimuth calibration clamp.
- (e) Orient the theodolite approximately by sighting on the distant aiming point using the fast motion.
- (f) Tighten the azimuth calibration clamp and precisely orient the theodolite by using the azimuth calibration adjust. The theodolite is now oriented.

- (3) *Compass method.* When the launcher is laid by the compass method the following procedure is used:

- (a) Obtain the azimuth of fire from the launcher platoon leader. Convert the direction to degrees and tenths of degrees.
- (b) Subtract the direction of fire from 360

degrees and then apply the correction for the declination constant. The value of the declination constant may be obtained from a map of the local area. An east declination is added, and a west declination is subtracted.

- (c) Disengage the azimuth tracking control and set the angle computed in (b) above on the azimuth scale of the theodolite. Subtract 360 degrees if necessary.
- (d) Engage the azimuth tracking control and loosen the azimuth calibration clamp.
- (e) Lower the lifter lever on the theodolite compass and allow the magnetic needle to rotate freely on its axis.
- (f) Center the compass needle by means of the nonrecording motion of the theodolite.
- (g) Tighten the azimuth calibration clamp. The theodolite is now oriented.

b. The wind measurement is made by means of observation of a 30-gram balloon. For inflation and release of a 30-gram pilot balloon, see paragraphs 58 and 64. A single observation of the balloon is read at a time dependent on the quadrant elevation setting of the rocket launcher and the predicted wind profile. A prediction of the wind profile is simplified to "nighttime" conditions and "other than nighttime" conditions. The quadrant elevation-time of observation relationship is dependent on the configuration of the rocket. This relationship for the Honest John rocket is shown in FM 6-61 and in FM 6-56 for Little John rockets.

c. The procedure for measuring the wind is as follows:

- (1) From the launcher crew, obtain the time of observation.
- (2) Release the balloon 5 minutes prior to firing (X-5) and track the balloon with the theodolite.
- (3) Read and record the vertical and azimuth angles of the balloon at the time obtained in (1) above.
- (4) To determine the effective rocket wind speed in knots, use the vertical angle recorded to enter table Ic, FM 6-16, Wind Speed for Zone 1 (Knots), 54-Second Reading, 30-Gram Balloon. This wind speed is the effective wind for the rocket and is not the mean wind for zone 1. Use





## CHAPTER 24

### RADAR WINDS

#### 225. General

a. Some artillery and air defense radars are capable of determining the data required for computation of zone winds. Winds computed from radar data are suitable for ballistic application. The primary mission of these radar sections is fire control, hostile weapon location, and aircraft location. The use of radar in determining artillery meteorological data will be limited to those times when the radar can be diverted from its primary mission. Therefore, the use of radar should not be requested when the required data can be obtained by other means.

b. Radar is used to determine zone winds by tracking a balloon-borne radar reflector. The height indicator on the radar is observed, and as the balloon reaches each zone limit, the values of time, horizontal range, and azimuth are read and recorded. A zone wind plot is then constructed, and the zone and ballistic winds are determined as in the rawin system.

#### 226. Special Considerations

a. *Release Point.* Each radar has a minimum tracking range. If the release point of a balloon is closer than the minimum range, the radar will not be able to track. A balloon released at the radar position must be tracked optically until it reaches the minimum tracking range. The radar may track the balloon from the surface if the release point is a sufficient distance from the radar site, i.e., at least two to three times the minimum tracking range.

b. *Ground Clutter.* Radar sets are affected by reflections from ground objects. This interference, called clutter, limits the tracking capability of the radar. It is, therefore, important for the metro chief to coordinate with the radar team chief in selecting the balloon release point.

c. *Communications.* Communications must be established between the offset release point and the radar crew. This requirement may limit the site selected for the offset release point.

#### 227. Preparation for Flight

a. *Radar Targets.* Radar sections are issued metal foil targets for use in collimating the radar

sets. When dismantled, one of these targets provides enough metal foil for the assembly of several streamer targets (fig. 157) which are suitable for tracking. When a streamer target is carried aloft by a 100-gram balloon, the rate of rise is sufficient for most winds likely to be encountered.

b. *Inflation Procedures.* The 100-gram balloon is inflated and weighed off with the foil train attached to the inflation nozzle. The weighing off is not critical and is performed only to insure that the balloon has a sufficient rate of rise.

c. *Communications.* Communications with the radar section are established prior to release in order that the necessary coordination may be accomplished. Communications should be maintained until the flight is completed; however, if necessary, the data may be recorded at the radar site and then delivered to the metro section.

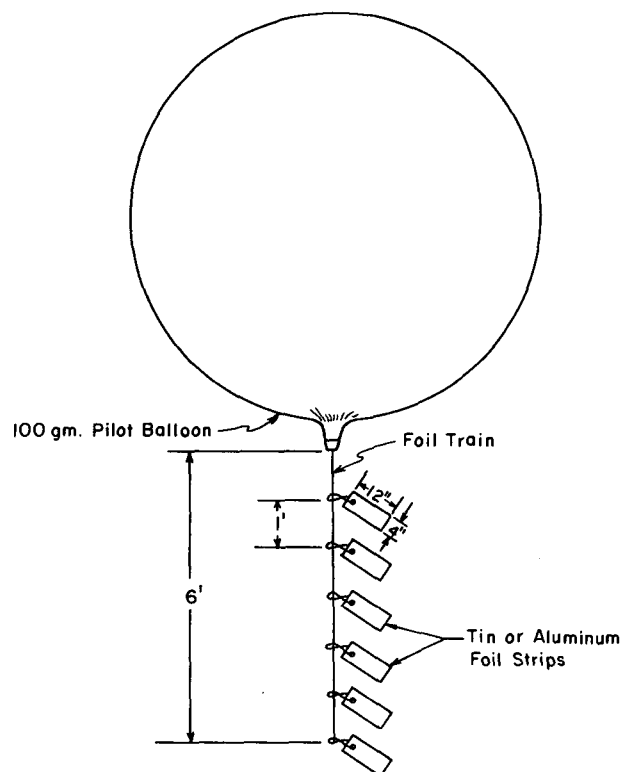


Figure 157. Streamer target.



RADAR FLIGHT DATA RECORD (FM 6-15)														
STATION				LOCATION				RE- LEASE TIME	DATE		HOURL	FLIGHT NUMBER		
<i>3d Div Arty</i>				<i>Fort Sill, Okla</i>					LST	<i>4 NOV 60</i>		<i>0530</i>	<i>2</i>	
									GMT	<i>4 NOV 60</i>		<i>1130</i>		
ZONE NR	STANDARD HEIGHT (Meters)	TIME AT STANDARD HEIGHT		HORIZONTAL DISTANCE (Meters)	AZIMUTH ANGLE		HORIZONTAL TRAVEL IN ZONE (Meters)	TIME IN ZONE (Minutes & Tenths)	ZONE WINDS		LINE NR	BALLISTIC WINDS		
		Minutes & Sec	Minutes & Tenths		Mils	Degrees & Tenths			Azimuth (10 Mils)	Speed (Knots)		Azimuth (100 Mils)	Speed (Knots)	
SUR 0	<i>0</i>			<i>600</i>	<i>435</i>			<i>-</i>	<i>363</i>	<i>21</i>	<i>0</i>	<i>36</i>	<i>21</i>	
<i>1</i>	<i>200</i>	<i>0:42</i>	<i>0.7</i>	<i>1100</i>	<i>627</i>	<i>35.6</i>	<i>530</i>	<i>0.7</i>	<i>406</i>	<i>25</i>	<i>1</i>	<i>47</i>	<i>25</i>	
<i>2</i>	<i>500</i>	<i>1:30</i>	<i>1.5</i>	<i>1900</i>	<i>760</i>	<i>42.8</i>	<i>840</i>	<i>0.8</i>	<i>412</i>	<i>34</i>	<i>2</i>	<i>41</i>	<i>32</i>	
<i>3</i>	<i>1000</i>	<i>3:30</i>	<i>3.5</i>	<i>3300</i>	<i>878</i>	<i>49.4</i>	<i>1440</i>	<i>2.0</i>	<i>424</i>	<i>23</i>	<i>3</i>	<i>42</i>	<i>25</i>	
<i>4</i>	<i>1500</i>	<i>5:36</i>	<i>5.6</i>	<i>4900</i>	<i>945</i>	<i>53.2</i>	<i>1630</i>	<i>2.1</i>	<i>428</i>	<i>25</i>	<i>4</i>	<i>42</i>	<i>26</i>	
<i>5</i>	<i>2000</i>	<i>7:24</i>	<i>7.4</i>	<i>6900</i>	<i>980</i>	<i>55.1</i>	<i>2010</i>	<i>1.8</i>	<i>426</i>	<i>36</i>	<i>5</i>	<i>43</i>	<i>31</i>	
<i>6</i>	<i>3000</i>										<i>6</i>			
<i>7</i>	<i>4000</i>										<i>7</i>			
<i>8</i>	<i>5000</i>										<i>8</i>			
<i>9</i>	<i>6000</i>										<i>9</i>			
<i>10</i>	<i>8000</i>										<i>10</i>			
<i>11</i>	<i>10000</i>										<i>11</i>			
<i>12</i>	<i>12000</i>										<i>12</i>			
<i>13</i>	<i>14000</i>										<i>13</i>			
<i>14</i>	<i>16000</i>										<i>14</i>			
<i>15</i>	<i>18000</i>										<i>15</i>			
<i>16</i>														
MESSAGE TYPE (Check one)		RADAR OPERATOR				TIMER-RECORDER				RECORDER OPERATOR				
BALLISTIC	FALLOUT	<i>Davis</i>				<i>Scheirer</i>				<i>Moore</i>				
<i>18</i>	COMPUTER													

DA FORM 6-47, 1 MAR 62

PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

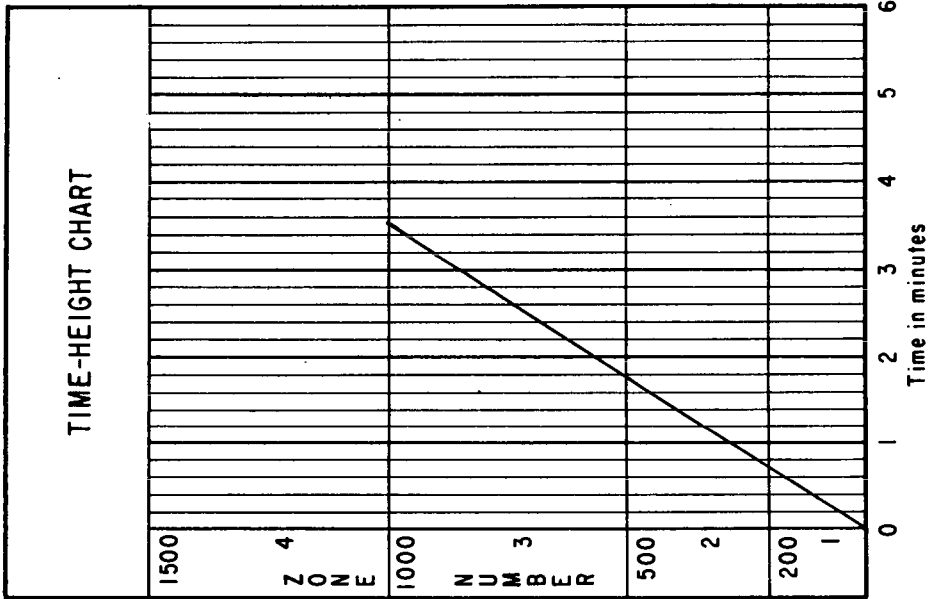
Figure 158. Radar flight data recorded on DA Form 6-47.

### 228. Ascension Technique

a. *Automatic Tracking.* The radar antenna is positioned in the direction of the offset release point. After the balloon is released, automatic tracking is commenced as soon as possible. A stopwatch or timer is started at the instant of release. While the streamer target is being tracked automatically, the values of time, azimuth angle, and horizontal distance are determined by the radar crew as the balloon reaches each standard height. Data are recorded on DA Form 6-47, Radar Flight Data Record (fig. 158). This procedure continues until the required line number (height) is reached.

b. *Visual Data.* If the radar does not automatically track the target from the surface, visual data must be used for the lower zones. The azimuth and elevation angles are read at half-minute intervals until the first radar reading is obtained. The theodolite is the preferred instrument for measuring these angles. However, the radar may be visually positioned on the target, and the azimuth and elevation angles may be read from the dials on the radar. Visual data are recorded in the VISUAL DATA block on the reverse side of DA Form 6-47 (fig. 159).

VISUAL ZONE DATA			
ZONE NR	TIME (min & tenths)	ELEVATION (mils)	AZIMUTH (mils)
4			
3			
2	1.8	262	760
1	0.7	183	633



TIME (Min)	ELEVATION ANGLE		AZIMUTH ANGLE	
	Mils	Degrees & tenths	Mils	Degrees & tenths
0.5	155	8.7	574	32.3
1.0	225	12.7	677	38.1
1.5	246	13.9	760	42.8
2.0	272	15.3	789	44.4
2.5	280	15.8	819	46.0
3.0	289	16.2	849	47.8
3.5	298	16.8	878	49.4
4.0				
4.5				
5.0				
5.5				
6.0				
6.5				

Figure 159. Visual data recorded on back of DA Form 6-47.

## 229. Computing Ballistic Winds

*a. Surface Winds.* It is impossible to determine surface wind direction or speed from radar data. If an anemometer is available, it is used to determine the surface wind values. If the anemometer is not available, the surface wind may be estimated or zone 1 data may be used for both zone 1 and the surface.

*b. Plotting the Release Point.* As in the rawin system, the release point offset is plotted in order to determine zone 1 wind. The azimuth and range from the radar site to the release point are determined by map or survey or from the radar. For determination by radar, the release point must be visible from the radar site. The radar antenna is positioned visually on the radar target. In the event a clear signal is not received from the target, the azimuth and range are measured to a vehicle or other large metallic object at or near the release point. In any case, the horizontal distance (horizontal range) and azimuth are recorded on the offset line of the radar flight data record. These values are used to plot the release point on the plotting board. If the azimuth angle is indicated in mils, it must be converted to degrees before plotting, and if the horizontal range is in yards, it must be converted to meters.

*c. Use of Recorded Data.* The values of time, azimuth angle, and horizontal distance noted during automatic tracking are recorded on a radar flight data sheet (fig. 158). Azimuth angles recorded in mils are converted to degrees and tenths by using table II, FM 6-16, and the horizontal distance in

yards may be converted to meters by using table Ij. The azimuth angles and horizontal distances are used to plot the zone winds on plotting board ML-122 as explained for the rawin system.

*d. Use of Visual Data.* If visual data are required, additional steps must be included in the computational procedure. The first step is to determine the time at each zone limit. The time at which the balloon reached the first zone limit after automatic tracking commenced (1,000 meters; 3.5 minutes) is plotted on the TIME-HEIGHT chart on DA Form 6-47 as illustrated in figure 159. A straight line is drawn from the plotted point to zero time-zero height point. The intersection of this line with each horizontal line representing the top of a lower zone determines the time at zone limits for the zones. By using these times, the azimuth and elevation angles at the zone limits are determined by interpolating between the recorded angular data. The azimuth and elevation angles are recorded in the VISUAL ZONE DATA block as illustrated in figure 159. The elevation angles are used to determine the horizontal distance (table Ig, FM 6-16). Then, the times, the azimuth angles, and the horizontal distances determined from the visual data are used in the same manner as the values obtained during automatic tracking (*c* above). If automatic tracking commenced before the balloon reached the top of zone 1, neither visual data nor a time-height curve is required.

*e. Ballistic Winds.* Once the zone winds have been obtained, ballistic winds are determined by making the normal ballistic wind plot as described for the rawin system.

CHAPTER 25

WEATHER DATA FOR USE WITH ARTILLERY COMPUTERS

**230. General**

a. The advent of nuclear artillery ammunition and the development of highly mobile army units has required that the artillery produce a first-round hit capability. The development of artillery fire direction computers has resulted from this requirement. Artillery batteries and battalions are being equipped with high-speed automatic digital computers which compute the flight trajectories of shells and rockets. Besides the gunnery problem, these computers also solve problems in fire planning, ammunition resupply, and survey.

b. When digital computers are used to solve the gunnery problem, a special meteorological message is required. The computer message differs from the usual ballistic (NATO) message in that the zoning structure is different, the zone values are not weighted, and the weather elements are reported as true values instead of a percent of standard. The form for the computer message is illustrated in figures 160 and 161. Fire direction center (FDC) personnel insert the metro data into the computer, either by a keyboard or punched tape. The computer solves the meteorological problem as it computes the ballistic trajectory.

c. The methods used to prepare the sounding balloon, radiosonde, and accessories are the same as those for the NATO metro message. There are no special or unusual procedures required in taking the sounding.

**231. Development of Zone Temperature and Density From Chart ML-574/UM**

a. Temperatures are reported to the nearest one-tenth of a degree Kelvin. This temperature is obtained from chart ML-574/UM in the manner described for NATO metro messages (zone midpoint virtual temperature °C.) and converted to °K. by adding algebraically 273.2°. This temperature is recorded in a four-digit group on the computer message, omitting the decimal point.

*Example.*    273.2°  
                   +18.1° C. (virtual temperature)  
                   291.3° K. = recorded as 2913 on computer message

b. The density is obtained for each zone from the zone midpoint on chart ML-574/UM and recorded to the nearest gram per cubic meter (Gm/M<sup>3</sup>) on the computer message in a four digit group.

c. The computer zone heights on scale ML-573 are used to determine the zone midpoints on chart ML-574/UM.

**232. Development of Zone Winds**

True values of wind direction and wind speed are required by the computer for each zone. Wind directions are reported, with reference to true north, to the nearest 10 mils and recorded in a three-digit group on the computer message (fig. 160). The method for determining wind direction and speed is the same as that for determining zone winds, for the NATO metro message, except for the difference in zone structure. The rawin computation form (fig. 162) is used in determining computer winds by entering the computer zone heights (meters) in column (1) of the form; checking the appropriate message type in block (13) for the computer; and crossing out the ballistic data portion, columns (11) and (12) (1 and 2, fig. 162).

**233. Encoding and Transmission of Data**

a. The computer meteorological data are encoded on DA Form 6-59 (Computer Metro Message).

(1) The identification line of the computer message includes the octant of the globe, source country and service, location, date, valid time period (GMT), station altitude (10's m), and meteorological datum plane pressure (% of std (1013.25 mb.)). The identification line is completed as follows (fig. 160):

- (a) *Octant (Q)*—indicates the octant of the globe of the metro station by a number of the Q code. In order to determine the geographic octant, refer to chart I, FM 6-16. The Q code for octant of the globe is on the back of DA Form 6-59.
- (b) *Source (BB) and (C)*—indicates the source country and service preparing the data, encoded in a three-digit group.

COMPUTER METRO MESSAGE (FM 6-15)									
IDENTIFICATION METCM	OCTANT Q	SOURCE		LOCATION		DATE YY	VALID TIME (GMT) G <sub>0</sub> G <sub>1</sub> G <sub>2</sub> G <sub>3</sub>	STATION HEIGHT (10's M) hhh	MDP PRESSURE % of STD P <sub>0</sub> P <sub>1</sub> P <sub>2</sub>
		COUNTRY BB	SERVICE C	xxx	xxx				
METCM	1	US	L	344	982	03	1822	036	954
ZONE HEIGHTS (METERS)		LINE NUMBER ZZ		TRUE VALUES					
				WIND DIRECTION (10's Mils) ddd	WIND SPEED (KNOTS) FFF	TEMPERATURE (1/10° K) TTTT	DENSITY (GMS/M <sup>3</sup> ) ΔΔΔΔ		
SURFACE		00		310	004	3030	1117		
200		01		250	013	3006	1106		
500		02		306	014	2965	1091		
1000		03		357	014	2897	1064		
1500		04		396	007	2890	1004		
2000		05		502	008	2850	0959		
2500		06		454	015	2777	0927		
3000		07		475	013	2762	0876		
3500		08		520	013	2752	0825		
4000		09		582	018	2721	0784		
4500		10		575	017	2692	0744		
5000		11		566	016	2664	0706		
6000		12		571	015	2618	0651		
7000		13		588	009	2557	0583		
8000		14		611	011	2502	0521		
9000		15		354	012	2446	0464		
10000		16		395	016	2386	0412		
11000		17		384	014	2330	0366		
12000		18		379	028	2274	0322		
13000		19		394	021	2202	0286		
14000		20		423	017	2115	0252		
15000		21		625	016	2074	0220		
16000		22		003	019	2082	0185		
17000		23		634	025	2064	0159		
18000		24		074	023	2068	0134		
19000		25		106	026	2079	0114		
20000		26		156	029	2112	0094		
FROM TO <i>3d Div Arty</i>			DATE & TIME (GMT) <i>03 Nov 59 1840</i>			RECORDER <i>Thomas</i>			

DA FORM 6-59, 1 MAR 62

COMPUTER METRO MESSAGE IS ENCODED AS FOLLOWS

1. The message is arranged in groups to be conveniently transmitted by radio or teletypewriter.

2. Information data: In the first group, the first five letters denote that the message is a computer message and the digit denotes the "Q" code of the global octant of the metro station. The second group is a three letter group only and identifies the country and service of the metro station. The next group of six digits denote the location of the metro station in degrees and 10's of minutes. When 9 of the "Q" code is used, the six digits are a coded identification of the metro station. The 4th group of digits denote the day of the month and the hours (Greenwich Mean Time) of validity of the observation. The first three digits of the 5th group denote the height of the metro station (Metro Datum Plane) above mean sea level in multiples of 10 meters. The other three digits of the group denote the station pressure (MDP) in percent of MSL standard to the nearest one tenth of a percent. The succeeding groups of eight digits are true zone values, two groups for each line of the message.

3. The following specimen message was transmitted by teletypewriter.

MEICM1 USL 344982 081416 123862  
 00451025 29311038 01454027 29201028 . . . . .

EXPLANATION:

- Group 1 Computer message. Metro Station located in global octant Nr 1. (N Lat 90°-180°W).
- Group 2 The metro station is a United States - Army station.
- Group 3 Center of area of applicability of the message (station location) is 34°40'N; 98°20'W.
- Group 4 8th day of the month. Valid time is from 1400 to 1600 hours GMT.
- Group 5 Metro station is 1230 meters above MSL. The MDP pressure is 86.2% of 1013.2 mb (Std MSL pressure)
- Group 6 & 7 At the surface (line 00) the true wind direction is 4510 mils, wind speed is 25 knots. The surface temperature is 293.1° Kelvin. Density is 1038 grams per cubic meter.
- Group 8 & 9 For line 01 (0-200 meters) the true wind direction is 4540 mils and wind speed is 27 knots. Zone temperature is 292.0° Kelvin and zone density is 1028 grams per cubic meter.

Source Country

BE - Belgium GR - Greece NO - Norway  
 CA - Canada IC - Iceland PO - Portugal  
 DA - Denmark IT - Italy TU - Turkey  
 FR - France LU - Luxembourg UK - United Kingdom  
 GE - German Fed R NL - Netherlands US - United States

Service

L - Army N - Navy A - Air Force

Q Code for Octant of Globe

0 - North latitude 0 - 90 West longitude  
 1 - " " 90 - 180 West "  
 2 - " " 180 - 90 East "  
 3 - " " 90 - 0 East "  
 4 - Not used  
 5 - South latitude 0 - 90 West longitude  
 6 - " " 90 - 180 West "  
 7 - " " 180 - 90 East "  
 8 - " " 90 - 0 East "  
 9 - Coded identification

Figure 161. Reverse side, Computer Metro Message form.

RAWIN COMPUTATION FM 6-15												
STATION				LOCATION				RE- LEASE TIME	DATE		HOURL	FLIGHT NR.
3d Div Arty				Fort Sill, Okla					LST	3 NOV 59	1730	
Zone nr.	(1) Zone height (meters)	(2) Pressure at top of zone	(3) Time at top of zone	(4) Elevation angle (degrees & tenths)	(5) Azimuth angle (degrees & tenths)	(6) Horizontal distance (meters)	(7) Horizontal travel in zone (meters)	(8) Time in zone (min & tenths)	ZONE WIND DATA		BALLISTIC DATA	
									(9) Azimuth (100 mils)	(10) Speed (knots)	(11) Azimuth* (100 mils)	(12) Speed (knots)
Offset:	SUR				12.6	100			SUR	310	SUR	004
1	200	944	0.6	33.2	335.2	310	240	0.6	250	013		
2	500	912	1.4	38.1	344.1	640	340	0.8	306	014		
3	1000	858	3.5	33.8	05.6	1490	940	2.1	357	014		
4	1500	809	5.3	39.4	12.8	1820	390	1.8	396	007		
5	2000	762	6.9	47.0	24.6	1860	380	1.6	502	008		
6	2500	716	8.4	46.4	37.8	2380	710	1.5	454	015		
7	3000	673	10.1	46.1	48.0	2880	680	1.7	475	013		
8	3500	632	11.9	47.1	59.4	3250	710	1.8	520	013		
9	4000	594	13.6	49.4	75.1	3420	940	1.7	582	018		
10	4500	558	15.2	49.2	88.8	3880	880	1.6	575	017		
11	5000	522	17.0	47.8	97.8	4530	930	1.8	566	016		
12	6000	458	20.4	46.2	108.4	5750	1530	3.4	571	015		
13	7000	401	23.6	47.4	113.8	6430	890	3.2	588	009		
14	8000	349	26.9	48.1	120.4	7160	1080	3.3	611	011		
15	9000	303	30.2	51.9	110.6	7040	1220	3.3	354	012		
16	10000	263	33.1	52.5	100.8	7660	1400	2.9	395	016		
(13) MESSAGE TYPE (CHECK ONE)				ZONE WIND COMPUTER				ZONE WIND PLOTTER				BALLISTIC WIND PLOTTER
BALLISTIC		FALLOUT		Moore				Dunn				
S	A	COMPUTER										

DA FORM 6-46, 1 MAR 62

PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

①

Figure 162. Rawin computations for computer message.

- The first two digits identify the country and the third digit identifies the service.
- (c) *Location (XXXXXX)*—indicates the location of the reporting station. In the example in figure 160, the station is located at 34° 38' N latitude, 98° 21' W longitude. The coded location is 344982. When the metro station is identified by a code word, number 9 of the Q code is used. When specified in the appropriate SOP, the location may be indicated to the nearest 1,000 meters by UTM grid coordinates.
  - (d) *Date (YY)*—indicates the day (GMT) of the month encoded in two digits. For example, 3 November is written 03.
  - (e) *Valid time (G<sub>0</sub>G<sub>0</sub>G<sub>1</sub>G<sub>1</sub>)*—indicates the beginning and end of the valid time

period of the message. The beginning is the time of release to the nearest hour, GMT. The valid period is usually from 2 to 4 hours. For this illustration, the balloon was released at 1730 hours GMT. To change local time to GMT, use chart I, FM 6-16.

- (f) *Station altitude (hhh)*—indicates the station altitude in tens of meters, encoded in three digits. Station altitude for this example is 360 meters, which is recorded as 036.
- (g) *MDP pressure (P<sub>0</sub>P<sub>0</sub>P<sub>0</sub>)*—indicates metro datum plane (MDP) pressure in percent of standard, encoded in three digits. When the MDP exceeds 100, the hundred digit is dropped. The percent of standard is computed by dividing the station

RAWIN COMPUTATION (FM 6-15)											
Zone nr.	(1) Zone height (meters)	(2) Pressure at top of zone	(3) Time at top of zone (min & tenths)	(4) Elevation angle (degrees & tenths)	(5) Azimuth angle (degrees & tenths)	(6) Horizontal distance (meters)	(7) Horizontal travel in zone (meters)	(8) Time in zone (min & tenths)	Zone Wind Data		
									(9) Azimuth (10 mils)	(10) Speed (knots)	
16	10000	263	33.1	52.5	100.8	7660	1400	2.9	395	016	
17	11000	227	36.5	52.7	71.8	8360	1450	3.4	384	014	
18	12000	195	39.7	50.0	78.1	10040	2750	3.2	379	028	
19	13000	166	43.0	47.8	72.2	11750	2060	3.2	394	021	
20	14000	142	45.7	46.8	71.6	13100	1400	2.7	423	017	
21	15000	120	48.8	49.2	78.2	12910	1510	3.1	625	016	
22	16000	102	51.9	51.6	86.3	12640	1830	3.1	003	019	
23	17000	86	55.0	52.8	97.1	12860	2410	3.1	634	025	
24	18000	73	58.4	57.0	107.2	11650	2460	3.4	074	023	
25	19000	62	61.2	61.5	116.7	10280	2240	2.8	106	026	
26	20000	53	64.2	68.0	125.9	8050	2650	3.0	156	029	
(13) MESSAGE TYPE (CHECK ONE)			ZONE WIND COMPUTER				ZONE WIND PLOTTER				
BALLISTIC		FALLOUT		<i>Moore</i>				<i>Dunn</i>			
S	A	COMPUTER									

Figure 162—Continued.

barometric pressure by standard pressure (1013.25) or is obtained from chart VI, FM 6-16. For this illustration, station pressure is 967 mb., standard surface pressure is 1013.25 mb. Therefore,

$$\frac{967}{1013.25} = 95.4 \text{ percent.}$$

- (2) The true values required for the computer message, discussed in paragraphs 230 and 231, are reported on the computer message as follows:
  - (a) *First column*—zone height in meters (printed on form).
  - (b) *Second column*—line number of computer message (printed on form) from surface to zone 26 (20,000 meters).
  - (c) *Third column*—wind direction in 10's of

mils obtained from column (9), DA Form 6-46.

- (d) *Fourth column*—wind speed to nearest knot obtained from column (10), DA Form 6-46.
- (e) *Fifth column*—temperature in 0.1° K. for midpoint of each computer zone obtained from chart ML-574/UM. Temperature is recorded in four digits by omitting the decimal point, i.e., 291.3 is recorded as 2913.
- (f) *Sixth column*—density to nearest gram per cubic meter for each zone midpoint as read from chart ML-574/UM is recorded in four digits.
  - b. The computer message must be transmitted by the most expeditious means to the using units. Use of teletypewriter or other similar electronic means is recommended.





## CHAPTER 26

## ARCTIC AND JUNGLE OPERATIONS

## Section I. ARCTIC OPERATIONS

**234. General**

*a.* No specific instructions can be given which will cover all arctic operations. Conditions will vary greatly from season to season and from one area to another. The types of surfaces over which operations are conducted will vary as greatly as the weather. During warm summer months, the surface may be one of tundra or muskeg. In winter, the surface normally will be covered with ice and/or snow of varying depths. The instructions in this section pertain to operations under conditions of extremely low temperatures. Before a unit or an individual moves into an arctic region, a reference on climatology should be checked to ascertain the meteorological conditions that may be expected in that area.

*b.* The general area in which the metro section operates will be determined by the area of operations of the unit to which it is assigned. The location of the metro section will be limited further by the mobility of its vehicle; therefore, it usually will be near cleared roads or trails. The rules for selecting the sites for the individual items of meteorological equipment are the same as those given in preceding chapters. In addition, the equipment should be located so that personnel making an observation or performing maintenance will be exposed for a minimum amount of time. An arrangement of guide ropes should be provided to assist the observers in moving from one installation to another during periods of extremely limited visibility.

**235. Operational Procedures and Maintenance**

*a.* Tests under conditions of extreme cold have proved that the mission of an artillery metro section can be accomplished with the equipment currently authorized. With proper maintenance and winterization, the metro equipment will generally function as well as in temperate climates. Hardships will be alleviated, to some extent, by the proper use of the clothing and equipment issued. The mobility of the section will decrease, the same as all units

equipped with wheeled vehicles for operation in extreme cold.

*b.* The rules for operational procedures and use of the equipment are generally the same as those given in preceding chapters. Installation of equipment requires more time under conditions of extremely low temperatures than under conditions of moderate temperatures. Also, it will be extremely difficult to maintain the rigid schedule of flights which is expected in Temperate Zones. Numerous difficulties will develop; their corrections will depend on the training and experience of personnel and on the facilities and supplies available in the area.

*c.* Maintenance of equipment must be a continuous process. Vehicular equipment and the power unit must receive more attention in low temperatures than in the Temperate Zones.

*d.* For information relating to permanent or semipermanent operation in the arctic, see FM 31-70.

*e.* Normal lubrication procedures for meteorological equipment are inadequate for operations in extremely low temperatures (below  $-35^{\circ}\text{C}$ .). This is because—

- (1) Congealing of lubricants increases the torque required to operate some equipment, causing erroneous meter readings or recordings.
- (2) Thickening of lubricants prevents capillary flow of oil through wicks and circulatory system; therefore, the oil fails to lubricate properly.
- (3) Certain lubricants have been developed for use in low temperatures to help combat these conditions. For information regarding lubricants for metro equipment in extremely low temperatures, refer to the appropriate technical manuals listed in appendix I.

*f.* When the temperature is  $-35^{\circ}\text{C}$ . or lower, care must be exercised in using equipment outside; for example, the theodolite. The material becomes extremely brittle and shatters easily in low tempera

tures. The instrument should be placed outside at least 1 hour prior to using, and care must be taken by the operator not to exert any unnecessary pressure in adjusting the instrument. The focusing knob should be preset before the instrument is taken outside to prevent possible breakage. Antifog compound should be used on lens.

g. Several other special precautions which must be observed when operating in cold weather are listed below.

- (1) *Cables.* Extra care must be taken in handling electrical cables. Cold temperatures cause the insulation to become extremely hard and brittle; bending will cause breakage.
- (2) *Safety precautions.* Personnel must ground themselves as well as the equipment when using hydrogen. Static electrical charges are severe and extreme care must be taken in grounding procedures. Winter woolen clothing must be kept from rubbing against the hydrogen-filled balloons. When operating in the Arctic, every effort should be made to obtain helium for balloon inflation.
- (3) *Inflation nozzles.* Extra nozzles should be requisitioned for inflating balloons, since they must be thawed between flights.
- (4) *Personnel.* Metal should not be handled with the bare hands, since the flesh will freeze and stick to the metal.
- (5) *Rawin set.* The rawin set must be warmed up at least one-half hour before any movement of the set for operation is attempted. The set should be moved by hand in

elevation and azimuth before applying electrical power. Care must be taken to insure that the equipment is leveled before each flight, since the thawing and freezing of the soil causes a constant movement of the equipment.

- (6) *Psychrometers.* Since temperatures are almost always below 0° C., the rule is to allow ice to form on the wet bulb before use, since the heat of fusion released in the freezing of the water saturated wick will cause erroneous readings. When temperatures are lower than -5° C., the wet-bulb reading is not necessary for ballistic or sound ranging computations. In this case, the arctic thermometer ML-352/UM should be used. The temperature scale on this thermometer is from 35° F. to -79° F.
- (7) *Vehicles and generators.* The technical manuals and bulletins for vehicles and generators are listed in DA Pamphlet 310-4 and issued by the area command. Vehicles and the plotting area inside the van should have at least one window open for ventilation to prevent carbon monoxide poisoning.
- (8) *Radiosondes.* When using the baseline check set, care should be taken not to spill any water on the plug that connects to the radiosonde, since the water may freeze. After completing the baseline check, the radiosonde should be allowed to weather outside, away from all buildings. A check should be made prior to release to insure that the correct surface temperature is being measured by the radiosonde.

## Section II. JUNGLE OPERATIONS

### 236. General

a. When military operations are conducted in jungle regions, equipment and supplies are subjected to climatic conditions far different from those of temperate regions. The heavy rainfall and the continuously high relative humidity of most jungle areas introduce numerous problems in the performance and serviceability of equipment that are of little concern in temperate regions. In jungle warfare, all items of materiel must be adequately protected against the effects of prolonged exposure to the high temperature and humidity of the air and the ravages of insects and fungi.

b. Microscopic plant life (fungi) form and grow on materials that remain wet for long periods of time. Well known forms of such growths are mold, mildew, and slime. These fungi secrete a corrosive fluid which is detrimental to wood, rubber, wax, paper, fabric, cork, leather, wool, and glass as well as to metals and insulation on electrical conductors.

c. A few general effects which result from inadequate protection against excessively high temperature, relative humidity, and/or fungi are listed below:

- (1) Corrosion of many materials is greatly accelerated.

- (2) Radio and electronic equipment become inoperable.
- (3) Fabric materials become unserviceable.
- (4) Etching of glass renders optical instruments unusable.

### 237. Treatment of Equipment

*a.* To protect equipment used in the jungles, the equipment is treated with a protective fungicidal, moisture-resistant coating, or the components are redesigned, or materials are substituted to reduce or eliminate the effects of moisture and fungi on the equipment. A moisture-resistant and fungi-resistant treatment has been adopted for signal corps equipment, which provides a reasonable degree of protection against fungus growth, insects, corrosion, salt spray, and moisture. This fungi-resistant varnish or lacquer is applied with either a spray gun or a brush. This treatment is generally performed at the factory or by field maintenance personnel.

*b.* Dust also is a formidable enemy in the tropics. It sticks to any object with which it comes in contact, forming a hard crust over the surface. In addition to being harmful to electrical switches, relays, and capacitors, dust acts as an excellent medium for airborne fungi spores, which attach themselves to the equipment and instantly begin to grow. For these reasons, every possible effort should be made to keep dust from settling on equipment.

*c.* Thorough application of a fungicidal varnish or

lacquer will protect the covered parts from the detrimental effects of both moisture and fungi for approximately 6 months. However, when the equipment is used under extreme weather conditions, it probably will be necessary to apply the treatment more often.

### 238. Special Operating Procedures

*a.* Special precautions must be taken when operating metro equipment in tropical climates. Great care must be taken to prevent the treated surfaces from becoming chipped, dented, scratched, or otherwise defaced; such conditions provide a vulnerable point for damage by moisture and/or fungi. The need for frequent and thorough inspection of all treated equipment is emphasized. Varnish that is cracking, peeling, or showing a whitish color, should be cleaned off, and a new coat should be applied. If any treated surface accidentally becomes marred, scratched, cut, dented, or otherwise defaced, that damaged portion should be repaired and covered immediately with the protective varnish.

*b.* If hydrogen is generated too rapidly, the chemical reaction of the calcium hydride charges may be controlled by the number of holes punched out in the top of each charge.

*c.* See appropriate technical manuals for special considerations in operation of specific pieces of equipment.



## CHAPTER 27

## DETERMINATION OF TEMPERATURE AND HUMIDITY INDEX

**239. Means and Purpose of an Index.**

For some time, there has been a need for a method of measuring the amount of discomfort to which the human body is subjected during hot and humid days. Generally speaking, when the air temperature is extremely high and the relative humidity is also high, the human body perspires more than usual, especially when performing heavy labor. The United States Weather Bureau has established a standard system to be used in their installations for determining a temperature and humidity index, sometimes called the discomfort index. This index was reported to the general public for the first time in 1959.

**240. Computation of Temperature and Humidity Index**

The temperature and humidity index (THI) is computed by applying a simple linear adjustment to the sum of the dry-bulb and wet-bulb readings obtained from the psychrometer. The formula is  $THI = (t_d + t_w) 0.4 + 15$ , where  $t_d$  is the dry-bulb temperature,  $t_w$  is the wet-bulb temperature, both in degrees Fahrenheit. The two temperatures are added, the sum multiplied by 0.4, and 15 added to the total. The figures 0.4 and 15 are arbitrary numerical constants determined by Weather Bureau mathematicians. The final result is the temperature and humidity index.

*Example.* Temperature and humidity index =  $(t_d) 91.4^\circ \text{F.} + (t_w) 85.6^\circ \text{F.} = 177.0 \times 0.4 = 70.8$  or 71 (rounded off) + 15 = 86.

*Note.* Although every person has a different reaction to the heat and humidity, the Weather Bureau has calculated the discomfort index based on averages. The wind effect is not considered in this index. When the temperature and humidity index is 70, 10 percent of the people in the area are uncomfortable; when the index is 75, 50 percent of the people are uncomfortable; when the index is 80 or higher, everyone is uncomfortable. An index above 85 is considered the danger zone.

**241. Wet-Bulb Globe Temperature Index**

*a.* A Wet-Bulb Globe Temperature Index (WBGT), as specified by the American Society of

Heating and Ventilating Engineers, has been used as a work discomfort index. This index is more realistic but is more difficult to compute. Generally, artillery metro sections do not have a capability of measuring a WBGT index. Artillery metro sections could be equipped to make the measurement at fixed installations.

*b.* The WBGT index is computed from readings of (1) a stationary wet-bulb thermometer exposed to the sun and to the prevailing wind, (2) a black globe thermometer similarly exposed, and (3) a dry-bulb thermometer shielded from the direct rays of the sun. All readings are taken at a location representative of the conditions to which men are exposed. The wet-bulb and black globe thermometers are suspended in the sun at a height of 4 feet above ground, as shown in figure 163. A period of 30 minutes should elapse before readings are taken.

*c.* The wet-bulb thermometer is a standard, laboratory, glass thermometer with its bulb covered with a wick (heavy white corset or shoe string). The wick extends into a flask of clean water, preferably distilled water. The mouth of the flask should be about three-fourths of an inch below the bulb of the thermometer. The water level in the flask should be high enough to insure thorough wetting of the wick. The water should be changed daily after rinsing the flask and washing the wick with soap and water. To avoid erroneous readings, the water and wick must be free of salt and soap.

*d.* The globe thermometer consists of a 6-inch hollow copper sphere painted a dull black color on the outside and containing a thermometer with its bulb in the sphere. The thermometer stem protrudes to the outside through a rubber stopper. The stopper is tightly fitted into a brass tube soldered to the sphere (fig. 163). The sphere has two small holes near the top used for suspending the sphere with piano wire. The globe must be kept dull black at all times and must be kept free of dust or rain streaks by dusting, washing, or repainting if necessary.

*e.* The WBGT index is computed by using the formula  $WBGT = [(WBT) \times 0.7] + [(BGT) \times 0.2] + [t_d \times 0.1]$ , where WBT is the wet-bulb tempera-

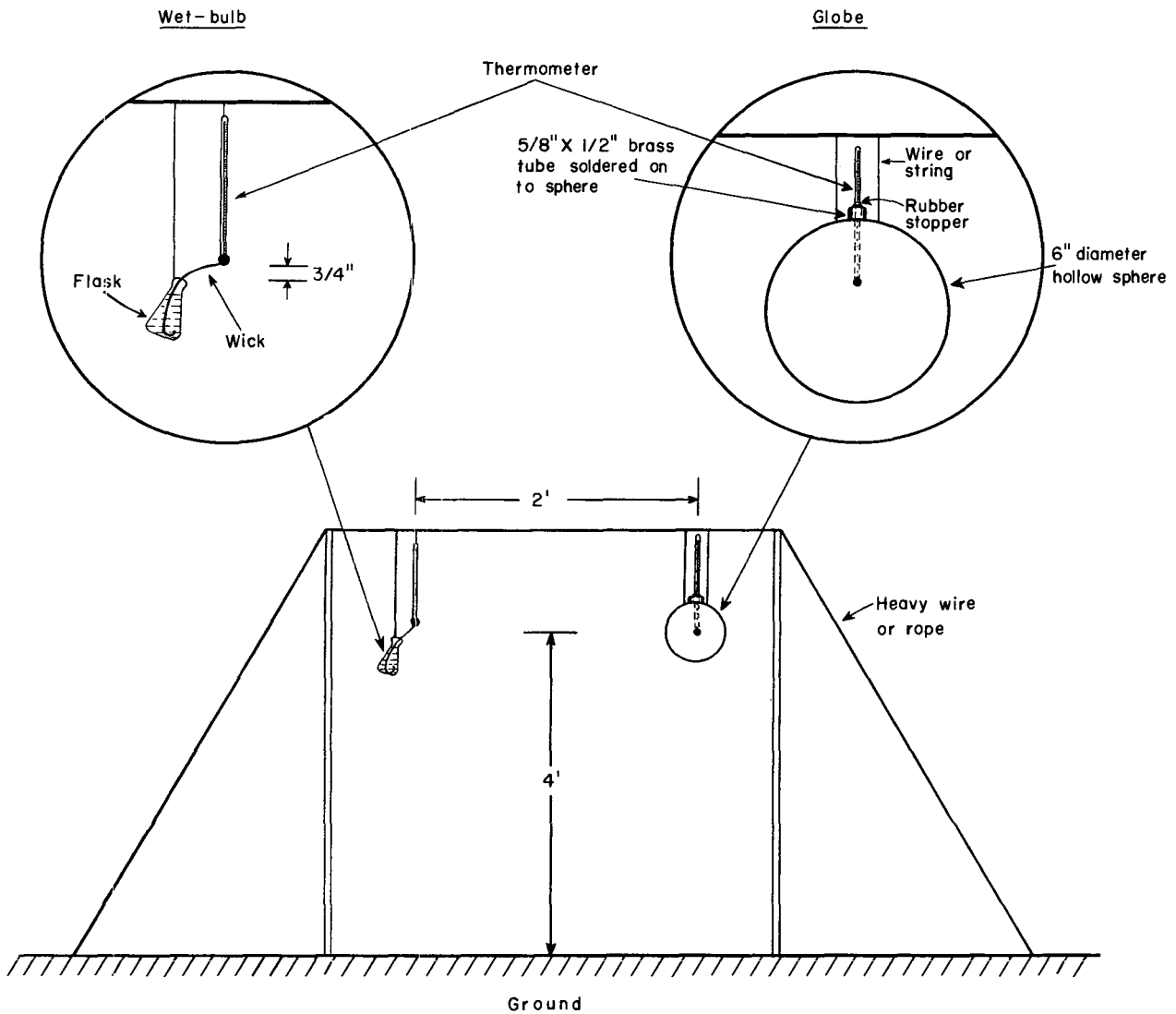


Figure 163. Equipment for measuring WBGT index.

ture, BGT is the black-globe temperature, and  $t_d$  is the dry-bulb temperature (shade).

Example:

$$\begin{aligned} \text{WBT} &= 80^\circ \text{ F.} \times 0.7 = 56^\circ \\ \text{BGT} &= 120^\circ \text{ F.} \times 0.2 = 24^\circ \\ t_d &= 90^\circ \text{ F.} \times 0.1 = 9^\circ \\ \hline \text{WBGT} &= 89^\circ \end{aligned}$$

### 242. Use of the WBGT Index in the Control of Physical Activity

The proponents of the WBGT index have proposed the standards for application of the index. It should be emphasized that the temperatures must be measured at a site which is the same or closely

approximates the environment to which personnel are exposed.

a. When the WBGT index exceeds  $80^\circ$ , discretion should be used in planning heavy exercise for unseasoned personnel.

b. When the WBGT index reaches  $85^\circ$ , strenuous exercises, such as marching at standard cadence, should be suspended for unseasoned personnel during their first 2 weeks of training. At this temperature, training activities may be continued on a reduced scale after the second week of training.

c. Outdoor classes in the sun should be avoided when the WBGT index exceeds  $85^\circ$ .

d. All physical training should be suspended when the WBGT index reaches 88°. Hardened personnel, after having been acclimated each season, can carry on limited activity at a WBGT index of 88° to 90° for periods not exceeding 6 hours a day (DA Technical Bulletin MED 175).

### **243. Wind Effect on Temperature**

Air movement has a great influence on the effect of temperature on personnel. A soldier working in a well-ventilated area can withstand a higher

temperature than a soldier working in a confined area. The temperature and humidity index or the WBGT index may be modified to some lower value when the air movement is known. At low temperatures, the effect of the wind is quite pronounced and is described in chapter 28 as Wind Chill. Wind-effective-temperature tables have not been computed for hot temperatures. An indication of wind on hot temperatures can be seen by examining the top line of Table VII, the Wind Chill Table.





CHAPTER 28

DETERMINATION OF WIND CHILL FACTOR

**244. Means and Purpose of a Wind Chill Factor**

a. The human body is greatly affected by wind which sets in motion the process of convective cooling. This cooling alters the human body's metabolism and greatly increases the danger of freezing any exposed tissue. The wind removes the layer of radiated heat which normally surrounds the human body, unless this heat is trapped between layers of clothing with a wind-resistant outer garment.

b. In any future campaign where dispersion and isolation will be the rule rather than the exception, commanders may not be able to obtain immediate advice from a medical officer for the prevention of cold injuries to troops. Thus, a commander must be able to recognize environmental conditions which are likely to cause cold injuries and must consider appropriate precautions in preparing and planning operations. Planning should include the timely requisitioning of supplies and equipment, the train-

ing of personnel to operate in the cold, and the provision for receipt, dissemination, and utilization of metro data.

**245. The Wind Chill Table**

a. A wind chill table (table VII), using the arguments of temperature in ° F. versus wind velocity in miles per hour, has been constructed by the U.S. Army Medical Service research staff, in order to establish a means of determining the effectiveness of military operations, primarily the troops involved, under extreme weather conditions. The wind chill table is used to determine the wind chill factor. Instructions for using this table are printed at the bottom of the table, with an example problem illustrated.

b. There may be instances when wind velocity will be given in knots and temperature given in ° C. The formulas for converting to miles per hour and ° F. are shown as a footnote to table VII. See also conversion tables, table Ii and chart XI, FM 6-16.

Table VII. Equivalent Temperatures on Exposed Flesh at Varying Wind Velocity (Wind Chill)

Temperature (degrees Fahrenheit)	Wind velocity (miles per hour)										Factor
	45	35	25	20	15	10	5	3	2	1	
90	89.5	89	88.5	88	88.75	87.5	87	86	84.5	83	83
82	81	80.5	80	79.5	78	76	74	72.5	70	60	60
72	71	69.5	68	67	65	60	57	53.5	47.5	23	23
63	61	59	57	55	52	44.5	39	34.5	20	-11	-11
51	49	47	45	42.5	38	28	18.5	11	0	-27	-27
41	39	36	34	30.5	25	11	0	-9	-23.5	-38	-38
30	28	25	23	18	11	-5	-16.5	-40	Below -40	Below -40	Below -40
20	18	14	11	6	-2	-19	-40	Below -40	do	Do.	Do.
10	7.5	3	0	-6	-15	-35	Below -40	do	do	Do.	Do.
0	-2.5	-8	-12	-18	-29	Below -40	do	do	do	Do.	Do.
-11	-14	-18	-23	-30	Below -40	do	do	do	do	Do.	Do.
-21	-24	-30	-35	Below -40	do	do	do	do	do	Do.	Do.
-32	-35	-40	-40	do	do	do	do	do	do	do	do

- (1) Obtain the temperature and wind velocity forecast.
- (2) Locate the wind velocity column corresponding to the expected wind speed (or the wind speed closest to this).
- (3) Read down this column to the temperature corre-

sponding to the expected temperature (or the temperature closest to this).

- (4) On the same line as the temperature, read the value in the column for 0 wind velocity. This value is the equivalent temperature.

Conversion formulas:

$$^{\circ}\text{F.} = 9/5. (^{\circ}\text{C.}) + 32$$

$$\text{MPH} = \text{Knots} (0.868)$$

*Example.* Weather information gives the expected temperature to be 35° F. and the expected wind velocity to be 20 miles per hour at midnight. Locate the 20 mph column and read down this column to the temperature nearest 35° F.

The nearest temperature is 34° F. From 34° F. move all the way to the right on the same line and find the factor of -38° F. The factor -38° F. means that with a temperature of 35° F. and a wind speed of 20 mph, the rate of cooling of all exposed flesh is the same as -38° F. with no wind.

$$^{\circ}\text{C.} = 5/9. (^{\circ}\text{F.} - 32)$$

$$\text{Knots} = \text{MPH} (1.152)$$

## CHAPTER 29

## INSPECTIONS AND INSPECTION CHECKLIST

## Section I. GENERAL

**246. General**

Inspections are essential to insure that the metro section is prepared to accomplish its assigned mission at all times. Systematic inspections provide the best insurance against unexpected breakdowns at a critical moment when maximum performance is essential. All inspections of equipment are conducted under command authority. They are the means by which commanders at all echelons ascertain the serviceability of equipment and the status of maintenance.

**247. Command Maintenance Inspections**

*a.* Command maintenance inspections insure the proper utilization of equipment, supply economy, compliance with the maintenance principles set forth in Department of the Army publications, and evaluated operational readiness. Command maintenance inspections are conducted as prescribed in AR 750-8. They are intended to make available to Commanding General, Continental Army Command; ZI Army Commanders; Commanding General, Military District of Washington, U.S. Army; overseas commanders; Commanding General, Air Defense Command; and heads of technical services a single inspection report on the following factors:

- (1) Serviceability, proper usage, and operational readiness of a unit's major items of equipment together with their applicable on-vehicle and on-carriage materiel.
- (2) The adequacy and effectiveness of organizational and/or field maintenance operations.
- (3) The efficiency of repair parts supply procedures directly supporting maintenance operations.
- (4) The proficiency of unit maintenance personnel.
- (5) Future maintenance and exchange requirements derived from shortcomings disclosed during the inspection.

*b.* The checklist for signal corps equipment in appendix II will be used to inspect organizational

maintenance and related supply facilities for command maintenance inspections. This checklist is normally used by major commanders and signal corps spot check inspection teams.

**248. Spot Check Inspections**

Spot check inspections are performed for the purpose of ascertaining the adequacy and effectiveness of organizational maintenance. Major commanders and the heads of Department of the Army agencies are responsible for insuring that spot check inspections are performed on equipment or organizations and activities under their command. Spot check inspections will be scheduled and accomplished in accordance with AR 750-625.

*a.* There are two types of spot check inspections—those ordered at division or higher level and conducted by technical service teams, and those ordered below division level and conducted by organizational maintenance personnel. Both types have the same basic characteristics and purposes. They may be accomplished with or without prior warning to the unit to be inspected. The purposes of the spot check inspection are to—

- (1) Detect incipient failures before equipment becomes unserviceable.
- (2) Insure the adequacy and effectiveness of organizational maintenance and supply procedures.
- (3) Ascertain the availability and use of technical manuals and lubrication orders.
- (4) Determine the accuracy of records.
- (5) Check authorized levels of equipment, repair parts, and supplies.
- (6) Check practice of supply economy and preservation and safekeeping of tools.
- (7) Check knowledge of proper procedures for requisitioning supplies and equipment.

*b.* The spot check inspection is conducted by qualified technical personnel under the direct supervision of qualified officers. Minimum frequency for spot check inspections is established by each technical service in the following Army Regulations:

Engineer—AR 750-525, Ordnance—AR 750-925, Quartermaster—AR 750-425, and Signal—AR 750-625.

c. These regulations also require that organizational maintenance facilities and at least 10 percent of each type of equipment in every unit will be spot check inspected at least once a year. This does not limit the authority of commanders to conduct spot

check inspections more frequently if they so desire.

d. The checklist found in appendix II will be used to determine minor shortcomings in signal corps equipment inspected. This checklist normally will be used by signal corps spot check inspection teams at division or higher level. Organizational maintenance personnel conducting spot check inspections below division level may use the same checklist.

## Section II. COMMAND INSPECTIONS

### 249. General

a. *Command Responsibility.* Commanders are required to insure that all equipment issued or assigned to their command is maintained in a serviceable condition and is used properly and that personnel under their command comply with technical instructions. The first requirement for attaining a high standard of maintenance is a program to keep the commander informed as to the state of maintenance within his command. This is best accomplished through maintenance inspections. The battalion is generally considered the largest unit in which a commander can be fully aware, by personnel observation and inspection, of the condition of all types of weapons and equipment for which he is responsible.

b. *Direct Responsibility.* Direct responsibility is defined as responsibility of individuals for equipment entrusted to them for their individual use or for use by subordinates.

### 250. Inspections

Strictly speaking, all inspections are a command function in that they are always conducted under command authority. However, the principal characteristic of the command inspection is that the commander personally participates. There are two types of command inspections, formal and informal.

a. *Formal Command Inspections.* The formal command inspection involves advance notice and a set procedure. It normally applies to all phases of unit activity, including personnel and all types of equipment. This thorough inspection of the unit requires considerable time and preparation. The advance notice should specify the units to be inspected and the manner in which the inspection will be conducted (including the specific way in which equipment is to be displayed).

(1) Although the commander personally par-

ticipates, he employs inspecting parties to assist him with the inspection. These inspecting parties include various members of his staff and technical assistants; specific composition of the party depends on the level at which the inspection is being conducted.

(2) Actually, the formal command inspection is only one element in the overall inspection system, and it has certain specific purposes and advantages. It gives the unit time to prepare and that is what is intended. Thus, subordinate unit commanders are given an opportunity and the incentive to evaluate their unit's preventive maintenance program and to correct shortcomings. However, it should be kept in mind that the ability of the unit to properly prepare to lay out its equipment in neat and orderly fashion and, in general, to be prepared to "meet the commander" is some indication of unit morale and efficiency.

b. *Informal Command Inspections.*

(1) The informal command inspection is again characterized by the commander's personal participation. However, the inspection can be made at any opportune time or place and is usually made without prior notice. The informal inspection differs from the formal inspection in another respect, it provides the commander with firsthand information on the actual day-to-day condition of his equipment and the maintenance proficiency of the personnel. Usually the informal inspection will involve no set procedure.

(2) The informal command inspection is the day-to-day life blood of the preventive maintenance program. It is a normal part of the commander's daily check of his units

or unit. Preventive maintenance is every soldier's job.

## 251. Inspection Procedure

This paragraph outlines a detailed inspection procedure and layout for each group of equipment in the metro section and lists the essential items and procedures to be inspected. Introductory remarks concerning each group of equipment describe a suggested method of inspection to best determine both the operating efficiency of the equipment and, where applicable, the proficiency of the personnel operating the equipment. In addition to the checks listed, the inspector should insure that preventive maintenance, as outlined in chapter 6 is being performed by the operating personnel.

*a. Checklist.* The checklist in appendix II may be used by commanders as an overall checklist to determine minor discrepancies in metro sections.

*b. Layout of equipment.* There are no regulations that state how the metro equipment will be displayed. However, it should be displayed in a neat, orderly and military manner to facilitate the inspection procedure. Equipment should be displayed in such a manner that all nomenclatures or numbers can be seen. If the equipment has a carrying or packing case, it should also be displayed. When tool sets are displayed, the tools should be displayed in the sequence shown on the parts list. This will save time for the inspector as well as the section personnel. Every item should be displayed.

*c. Surface Observation Equipment.* For the best results, surface observation equipment is inspected during normal operation. While the equipment is being used, the commander has an opportunity to check on the proficiency of the personnel as well as the physical condition and operating efficiency of the equipment. The following checklist emphasizes the essential items to be inspected.

- (1) Are all components present and clean?
- (2) Are authorized spare parts on hand?
- (3) From a brief visual inspection, are there any broken or missing parts or any parts that require maintenance and repair?
- (4) Does the theodolite track properly with the tracking controls engaged?
- (5) Can the theodolite be properly leveled?
- (6) Do the night lights on the theodolite work (brightness control on the crosshairs and scale lights)?

- (7) Is the wick of the psychrometer clean?
- (8) Do the two thermometers of the psychrometer indicate identical temperatures when the psychrometer is whirled with the wick removed? If not, is an appropriate temperature correction recorded?
- (9) Does the barometer pointer move when the barometer face is lightly tapped?
- (10) Does the anemometer function properly and is the density correction chart available?
- (11) If the surface observation equipment cannot be inspected during operation, figure 29 is a guide for the equipment layout for the inspection.

*Note.* For detailed information on equipment, see appropriate technical manuals.

*d. Inflation Equipment.* Inflation equipment should be inspected under the same conditions as the surface observation equipment, i.e., under normal operating conditions.

- (1) Are all components present and free from thick deposits of residue? (It is impossible to keep the inflation equipment, particularly the generator and 32-gallon water can, free from residue. However, vigorous cleaning of this equipment immediately after use will keep it operational.)
- (2) From a brief visual inspection, are there any broken or missing parts or any parts that require maintenance and repair?
- (3) Are authorized spare parts on hand?
- (4) Are all hoses and internal passages of the generator and nozzles free from clogging deposits of residue?
- (5) Do the generators, hoses, or connections leak gas?
- (6) Are all metal surfaces of the inflation setup properly grounded? (See par. 57a for proper grounding procedure.)
- (7) Is the inflation area free of debris (empty calcium hydride cans, packing cases, balloon cartons, etc.) and is the water used in the inflation generator properly disposed of? (This white residue must be disposed of to maintain camouflage discipline.)
- (8) Is the inflation tent relatively draftproof and oriented with the rear of the tent facing into the direction of the prevailing wind?

- (9) Is the inflation area clearly marked as a "No Smoking" area?
- (10) Are pilot balloons weighted off for proper rate of rise?
- (11) Are provisions made for conditioning pilot and sounding balloons (TM 11-2405)?
- (12) If the inflation equipment cannot be inspected during operation, figures 46 and 47 are guides for the equipment layout for the inspection. For detailed information on inflation equipment, see appropriate technical manuals—TM 11-2405, Meteorological Balloons and Inflation and Launching Accessories; TM 11-2413, Hydrogen Generator ML-303/TM and Hydrogen Generator Set AN/TMQ-3.

*c. Plotting Equipment.* All plotting equipment should be clean, with all lines, numbers, and writing thereon clearly legible. Plotting scales and rules should show no signs of warping or cracking. Plotting equipment should be cleaned with soap and water, never with cleaning solvents or oils. The slide rule is delicate and should show no signs of abusive use. It is important that all plotting equipment described in chapter 6, section IV is available to the metro section and is in a usable condition, since all of this equipment is required for normal operation. If the plotting equipment is not being used at the time of the inspection, figure 27 is a guide for the equipment layout for the inspection. For further information on plotting equipment, see TM 11-6660-218-15, TM 11-6660-218-15P, and TM 11-2442.

*f. Communication Equipment.* The communication equipment is observed most effectively while in operation. If all components are operating properly, a two-way conversation is possible. The communication wire should never be anchored to the theodolite tripod leg, as any sudden tension on the wire might result in upsetting and seriously damaging the theodolite. All splices in the wire should be securely covered with friction tape. Tools should be clean and in a usable condition. If the communication equipment cannot be inspected in the operating setup, figure 36 is a guide for the equipment layout for the inspection. For detailed information of equipment, see TM 11-334 and TM 11-2155.

*g. Rawin Set AN/GMD-1( ).* An overall evaluation of the condition of the rawin set is made best

from an observation of its operation during a radiosonde flight. Power operation of the rawin set is indicated by the continuous reception of the metro signal at the radiosonde recorder and the automatic printing of angular data at the control-recorder. Also, if the rawin set is operating properly, it will automatically track the balloon-borne radiosonde. A positive answer to each of the following questions indicates efficient operation and proper utilization of the rawin set by the operating personnel.

- (1) Does the antenna follow the radiosonde smoothly?
- (2) Does the AN/GMD-1( ) operate without harsh or clashing noises or excessive vibrations?
- (3) Is the position of the radiosonde centered in the reticle of the telescope? (If not, is there a correction being applied to the angular data extracted from the control-recorder tape?)
- (4) Are all cables connected securely?
- (5) Is the main cable entrenched at all points where vehicles are likely to run over it (6 inches or deeper if tracked vehicles are expected in the vicinity)?
- (6) Are there any sharp bends in the main cable and is there sufficient slack at each end to prevent damage to the cable or cable connectors?
- (7) Is the orientation and leveling of the rawin set checked before each flight?
- (8) Do the angles on the control-recorder tape read the same as the angles on the AN/GMD-1( )?
- (9) Is the rawin set grounded?
- (10) Is the angular data from the control-recorder tape legible?
- (11) Are preventive maintenance forms used? DA Form 11-238 is the appropriate maintenance checklist for rawin set AN/GMD-1( ). For further information on this maintenance and inspection checklist, see appropriate technical manuals.

*h. Radiosonde Recorder AN/TMQ-5( ).* An overall evaluation of the condition of the radiosonde recorder is made best from observation of its operation during a radiosonde flight. The operation of the radiosonde recorder depends on the proper reception of the metro signal by the rawin set. After the inspector has checked the rawin set, he

may apply the checks listed below to the radiosonde recorder. A positive answer to each question indicates efficient operation and proper utilization of the recorder by the operating personnel.

- (1) Does the recorder pen respond smoothly and rapidly to changes in the metro signal?
  - (2) Is the vent open at the top of the recorder and is the fan turned on?
  - (3) Does the pen print exactly at zero when the SIGNAL SELECTOR switch is in the SC position?
  - (4) Are the baseline check and release data entered on the recorder record?
  - (5) Has the response of the recorder been checked recently for linearity?
  - (6) If the response is not linear, has a correction chart been prepared?
  - (7) Are the cabinet and the accessories case free of rust, corrosion, and moisture?
  - (8) Are all controls free of binding, scraping, and excessive looseness? (Controls should not be checked while a flight is being recorded.)
  - (9) Are all external cables and shock mounts free of cuts, breaks, fraying, deterioration, kinks, and strains?
  - (10) Is the fan operating without overheating?
  - (11) Is the area behind the fan free of dust and dirt? (The radiosonde recorder AN/TMQ-5 should be displayed as in figure 70, if it is not in operation. For detailed information on the radiosonde recorder AN/TMQ-5, see the appropriate technical manual. References: TM 11-2436, for radiosonde recorder AN/TMQ-5( ) and DA Pamphlet 750-1.)
- (4) Does the plastic cup contain sufficient water to wet the wick of the psychrometer inside the set?
  - (5) Is the water fresh?
  - (6) Is the chamber door fastened?
  - (7) Is the baseline check continued until successive traces of temperature, humidity, and reference that are printed on the radiosonde recorder record repeat one another in an identical pattern?
  - (8) Are the baseline check set data checked (verified) by reference to the humidity-temperature computer *before* the radiosonde is removed from the baseline check set?
  - (9) Is the radiosonde removed from the chamber, weathered, and released without undue delay?
  - (10) An actual physical inspection of the baseline check set is made when the equipment is not in use. If the inspection is attempted while making a baseline check, interference will result. There should be no movement of personnel around the baseline check set while the baseline check is in progress. The control unit may be on top of the set or it may be remoted as far away as 30 meters using the cable for remote control. Figure 72 shows the baseline check set AN/GMM-1 with door open and radiosonde properly installed. When the set is not in operation, the packing case, reel, and cable are also displayed. For detailed information on the baseline check set, see TM 11-6660-219-12.

*i. Radiosonde Baseline Check Set AN/GMM-1( ).*

The inspector can best inspect the operation of the baseline check set during the performance of a baseline check. Positive answers to the following questions indicate efficient performance of the baseline check and satisfactory condition of the baseline check set.

- (1) Is the fan turned on while the check is being performed?
- (2) Is the radiosonde positioned so that the temperature element is on the right side of the baseline check set?
- (3) Are the test leads from the radiosonde properly connected?

*j. Frequency Standard TS-65( )/FMQ-1.* The inspector should check to see that all components of the test set are in the possession of the metro section and that they are in serviceable condition. The frequency standard is inspected with best results when the equipment is being used. Figure 71 shows the equipment layout for inspection. Cable CX-2337/TMQ-5 should be displayed with the frequency standard. For detailed information on the equipment, see TM 11-2602B.

*k. Test Set TS-538/U.* The inspector should insure that the test set is in the possession of the metro section and is being used properly. Test set TS-538/U is inspected with best results when the set is being used. Figure 73 shows the layout for inspection. For detailed information on the test set, see TM 11-5014.



*l. Power Units.* A thorough operational check of the power units may be made by using DD Form 110 (Vehicle and Equipment Operational Record). The inspector should insure that the personnel of the section are performing preventive maintenance on these power units and that DD Form 110 is completed daily, when applicable. DD Form 110 may

also be used for a command maintenance or a spot checklist for both signal corps and engineer power units. For detailed information on the 10 kw power units, see TM 5-6115-204-10 or TM 5-6115-232-10. For information concerning the PE-75 power unit, see TM 11-900A.



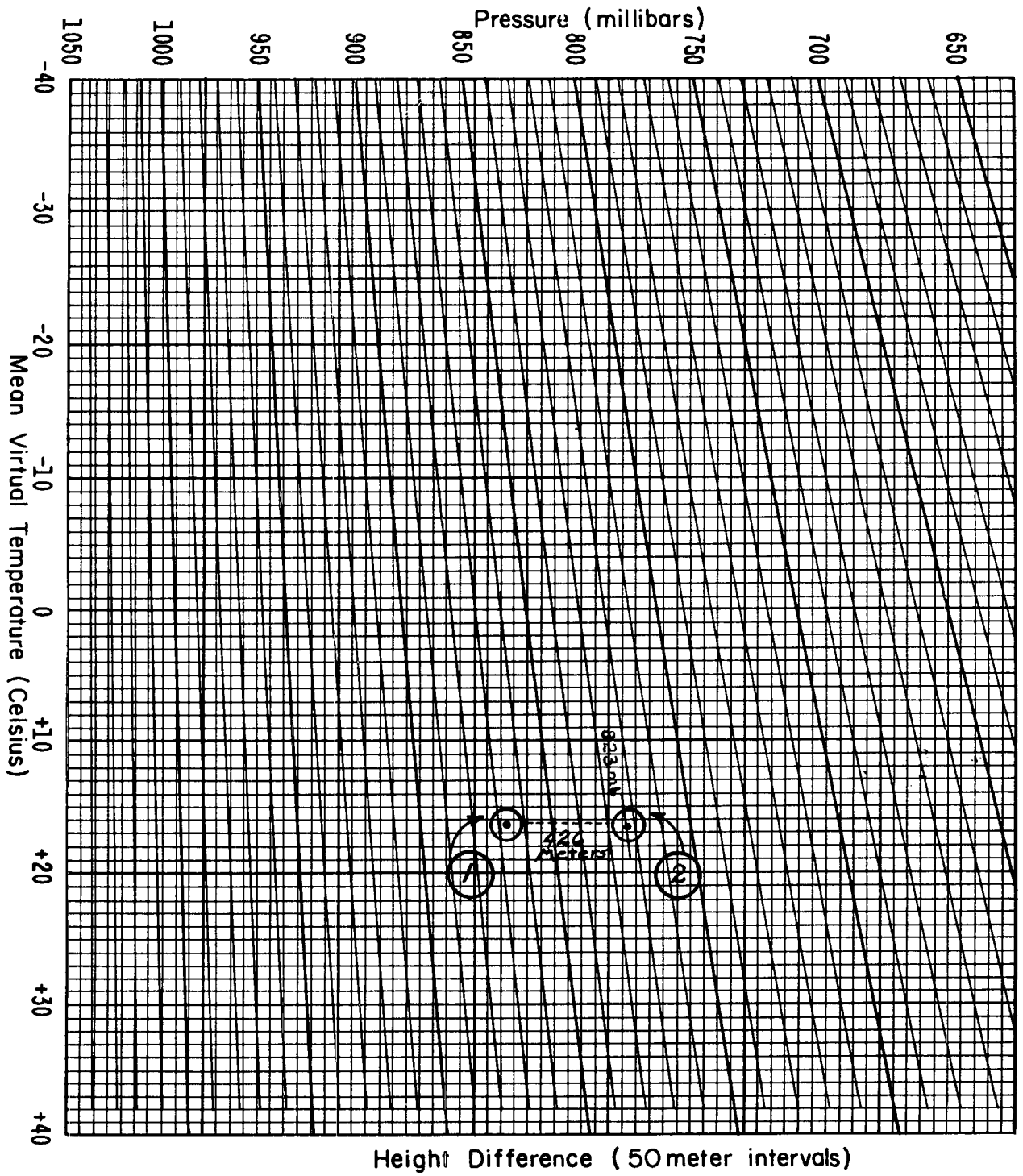


Figure 164. Pressure-height chart.

- (2) *Computation of altitude difference.*  
 Pressure altitude = 1,050 meters  
 Surface altitude =  $\frac{624 \text{ meters}}{}$   
 Altitude difference = 426 meters
- (3) *Computation of mean virtual temperature.*  
 $6.5^{\circ} \text{ C.} \times \frac{1}{2}(0.426 \text{ km}) = 1.4^{\circ} \text{ C.}$   
 Surface virtual temperature =  $17.8^{\circ} \text{ C.}$   
 Less altitude diff correction =  $\frac{1.4}{}$   
 Mean virtual temperature =  $16.4^{\circ} \text{ C.}$
- (4) *Surface plot (1, fig. 164).* A point is plotted on the pressure-height chart at a surface pressure of 866 mb. and a mean virtual temperature of  $16.4^{\circ} \text{ C.}$
- (5) *Pressure altitude plot (2, fig. 164).* The distance corresponding to the difference in height of 426 meters is plotted and the pressure is read as 823 mb. Therefore, the pressure at an altitude of 1,050 meters is predicted as 823 millibars.

## 255. Validity of Predicted Pressure

Pressures predicted in the manner described in paragraph 254 are most valid at the time and place of the surface measurement. The smaller the height difference, the more valid the pressure determined. The same elements which invalidate a ballistic metro message also invalidate a predicted pressure. Those elements are time, distance, terrain, and weather change. When an inversion (increase of temperature with height) exists between the surface and the pressure altitude under consideration, some error will be introduced in the computing of mean virtual temperature with the lapse rate of  $6.5^{\circ} \text{ C.}$  per kilometer. A predicted pressure may be considered valid for a period of 2 hours and up to distances of 50 kilometers. When prominent terrain features, such as mountains or large lakes intervene, the valid distance should be reduced. When rapid weather changes are occurring, both the valid time period and the valid distance should be reduced. Because of the infinite variety of weather patterns and terrain, no specific figures can be given as to how much to reduce the valid time and distance.



## CHAPTER 31

### CAMOUFLAGE PROCEDURES

#### 256. General

During combat operations, the enemy can be expected to have visual or electronic aerial observation techniques. This will require all military equipment to be concealed, using the maximum security measures possible. Failure to do so may result in the complete destruction of the equipment and possibly the personnel. For this reason, it is necessary to camouflage equipment, especially when the equipment cannot be concealed by using natural surroundings, i.e., wooded areas. The rawin set AN/GMD-1( ) and inflation tent M-1957 cannot be placed in wooded areas because of the operational requirements. The use of standard issue netting for camouflaging purposes will solve the problem. The type and size of camouflage nets for different items of metro equipment are explained in the following paragraphs. In addition, the residue from the calcium hydride used to generate the hydrogen gas must also be properly disposed of and concealed,

since the white calcium residue can be seen many miles from the air.

#### 257. Procedure

When a camouflage net is used to conceal equipment, a main point to remember is never to allow an irregular shaped shadow to be cast on the ground from any side of the net. The camouflage net must be draped over the equipment with sufficient room under the net to operate the equipment. When the net is extended, it should be centered over the equipment as much as possible. Improvised poles (tent poles) may be used to support the center of the net. In placing these poles, it should be kept in mind that the lowest possible silhouette is the objective. Each side of the net must be completely spread out, keeping the net taut at all times and extending the net to the ground from all corners. This procedure will provide a low silhouette and make observation from the air very difficult. Ground stakes must be used

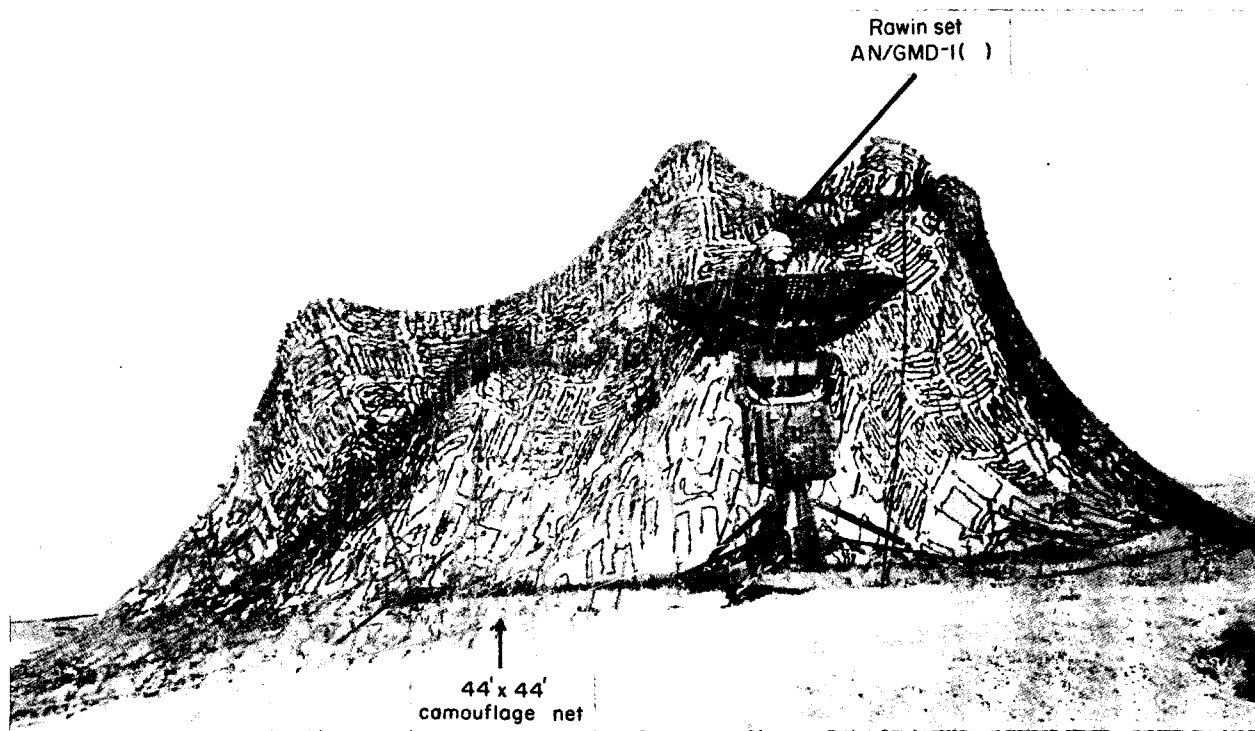


Figure 165. Rawin set camouflaged with rope mesh net.

to secure the edges and corners of the net to the ground.

**258. Rawin Set AN/GMD-1( )**

Rawin set AN/GMD-1( ) must be camouflaged by a rope net only, since a metal mesh net would reflect the signal from the radiosonde during a flight and result in erroneous wind data. To properly camouflage the rawin set, it is recommended that a standard, 44- by 44-foot, camouflage net be used. This rope net will provide complete freedom of movement underneath and will not interfere with the operation of the equipment. The net is made of a rope mesh and is easily erected. An illustration of this rope mesh camouflage net to conceal the rawin set is shown in figure 165.

**259. Inflation Tent M-1957**

Concealment for inflation tent M-1957 involves a different procedure. The portion of the net covering

the opening of the tent must be placed to facilitate removal of inflated balloons. The net is placed so that it can be folded back at the opening of the inflation tent. It is recommended that the standard, 44- by 44-foot, camouflage net be used for inflation tent M-1957. An illustration of the use of this net to conceal the inflation tent is shown in figure 166.

**260. Calcium Waste Sump**

The calcium residue in the hydrogen generator should be poured into a previously dug sump and covered immediately with dirt. However, if a metro section is to operate in one area for a long period of time, a larger sump will be necessary. A sump that is to be used for a long period of time can be concealed by using a camouflage net. It is recommended that a 29- by 29-foot standard issue camouflage net be used to conceal the sump. An illustration of this net is shown in figure 167.

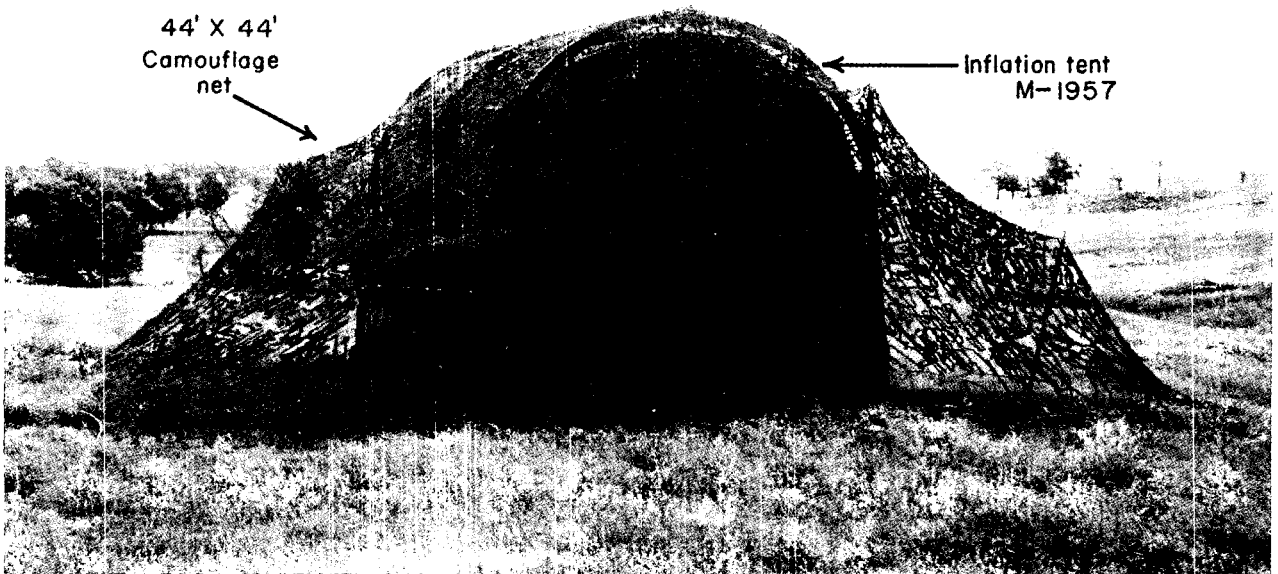
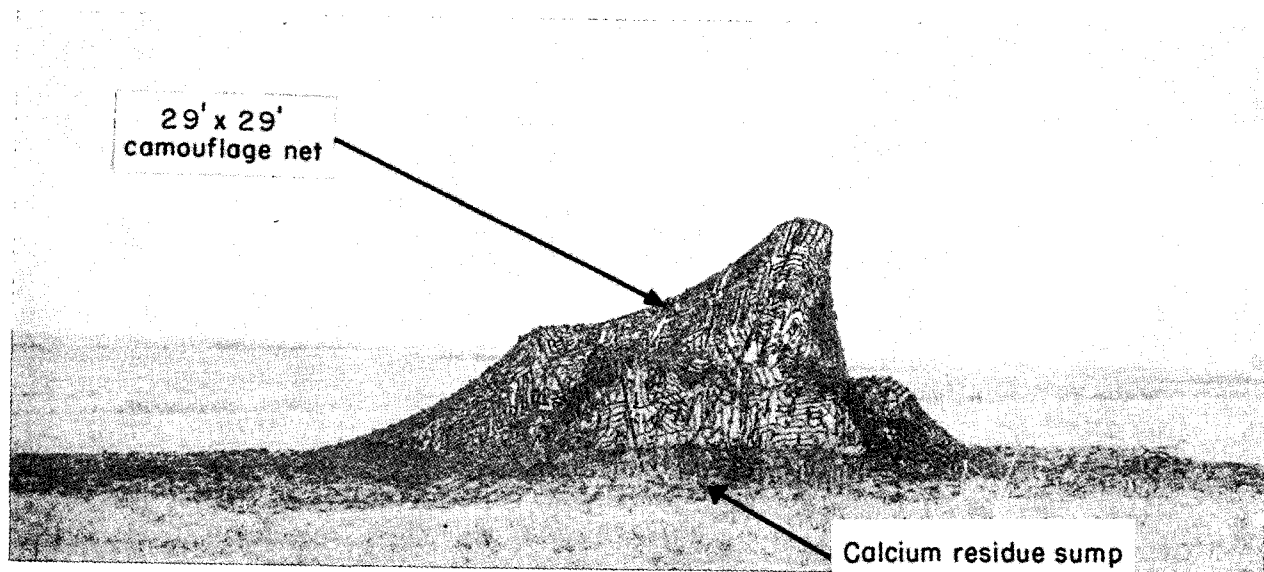


Figure 166. Inflation tent under camouflage net.



*Figure 167. Calcium sump concealed.*





## CHAPTER 32

### DECONTAMINATION OF EQUIPMENT

#### 261. General

a. Equipment which has been contaminated by a chemical, biological, or radiological agent constitutes a danger to personnel. Contamination is defined as the spreading of an injurious agent in any form and by any means upon persons, objects, or terrain. Decontamination is the process of making any contaminated place or object safe for unprotected personnel. This can be done by covering, removing, destroying, or changing into harmless substances the contaminating agent(s). Generally, decontamination is required only when a persistent agent has been used. Extreme care must be exercised during decontamination. This care will include protection of personnel, moving of equipment before and/or after the application of neutralizing agents, or any combination thereof.

b. Although specific procedures are outlined below for the decontamination of exterior surfaces, the only known procedure for interiors and electronic components is that of aeration.

c. DANC (decontamination agent, noncorrosive) is used effectively in many cleaning procedures. However, DANC should not be used on rubber or plastic items.

#### 262. Decontamination of Chemical Agents

a. *Rawin Set AN/GMD-1* ( ). When contamination is visible, apply a thin slurry (mixture of chlorinated lime and water) on exterior surfaces. After applying slurry, wash off with water, scrub with soap and water, and rinse thoroughly.

b. *Control-Recorder*. Decontaminate the exterior of the control-recorder in the same manner as the exterior of the rawin set. In addition, remove and discard the roll of paper tape.

c. *Cables*. Decontaminate the exposed parts of any cable by washing with soap and water only.

d. *Theodolite*. If the theodolite is exposed, clean as soon as possible with alcohol (or gasoline, if no alcohol is available) and apply a thin coat of light machine oil.

e. *Baseline Check Set, Radiosonde Recorder, and Like Equipment*. The baseline check set, radiosonde recorder, and like equipment are decontaminated in the same manner as the rawin set and control-recorder. Discard the chart roll in the radiosonde

recorder and replace it with a new chart roll.

f. *Inflation Tent*. Light contamination may be neutralized by aeration alone. For heavy contamination, apply slurry on surfaces which personnel are likely to touch and rinse thoroughly.

g. *Weapons*. Remove dirt, dust, grease, and oil, then allow surfaces to air before applying slurry. DANC may be used on all metal surfaces except the bore. Hot water, cleaning solvent, or repeated applications of gasoline-soaked swabs are also effective on metal surfaces and may be used in the bore. When gasoline-soaked swabs are used, extreme care must be taken to insure that a hazard does not exist when firing is resumed with the weapon. After decontamination, weapons should be dried and oiled.

h. *Ammunition*. Exposure to air and wind is the only practical method of decontaminating small arms ammunition.

i. *Automotive Equipment and Power Units*. Light contamination may be neutralized by aeration. For heavy contamination, use slurry on surfaces which personnel are likely to touch. For remaining surfaces, wash vehicle or unit with water, scrub with soap and water and rinse thoroughly, or aerate.

#### 263. Decontamination for Biological and Radiological Agents

a. *General*. After a biological or radiological attack, decontamination of equipment may be either rough or detailed, depending on the urgency of the military situation. The procedure adopted will be a command decision.

b. *Rough Decontamination*. Rough decontamination is performed when time is limited. Its purpose is to reduce contamination sufficiently to permit personnel to work with, or close to, equipment for limited periods. Rough decontamination may be achieved by applying water or steam, if available. The use of soap or other detergents with water or steam will aid in decontamination. Care must be taken in the disposal of the water used, since it will have become contaminated.

c. *Detailed Decontamination*. Detailed decontamination, in which thoroughness is emphasized, will be carried out in rear areas and repair bases. This procedure includes surface decontamination, aging and sealing, and disposal.



## CHAPTER 33

## DESTRUCTION OF EQUIPMENT

**264. General**

a. Tactical situations may arise in which it is necessary to abandon equipment in the combat zone. In such a situation, all abandoned equipment must be destroyed to prevent its use and compromise by the enemy.

b. The destruction of equipment subject to capture or abandonment in the combat zone will be undertaken only upon authority delegated by the division or a higher commander.

**265. Principles**

All metro sections should prepare plans for destroying their equipment in order to reduce the time required, if destruction becomes necessary. The principles to apply are as follows:

a. Plans for destruction of equipment must be adequate, uniform, and easily carried out in the field.

b. Destruction must be as complete as the available time, means, and personnel will permit. Since complete destruction requires considerable time, priorities must be established so that the more essential parts are destroyed first.

c. The same essential parts must be destroyed on all like units to prevent the enemy from constructing a complete unit.

d. Spare parts and accessories must be given the same priorities as the parts installed on the equipment.

**266. Methods**

To destroy equipment adequately and uniformly, all personnel of the section must know the plan of destruction and priority of destruction.

a. *Smash.* Smash the controls, tubes, switches, loudspeakers, printing mechanisms, timers, clocks, all instruments on control panels, cylinder heads and blocks, carburetors, magnetos or distributors, storage batteries, fuel pumps, generators and starters, water pumps, telescopes, and testing equipment. Use sledges, axes, handaxes, pickaxes, hammers, crowbars, or any heavy tool that will smash.

b. *Cut.* Cut the cords, wiring, cables, fuel and oil lines, generator windings, belts, ignition wires, radiators, tripods, and all remote cables, lines, and wires. Use axes, handaxes, machetes, or any other tool that will cut.

c. *Burn.* Burn the cords, wiring, manuals, cables, fuel, oil, packing or carrying cases, tenting, wooden tripods, records, and instructions. Burn anything that will burn. Use gasoline, kerosene, oil, flamethrowers, or incendiary grenades. When time is very limited, incendiary grenades are the most effective.

d. *Warning.* Gasoline vaporizes rapidly and may explode when ignited, causing injury or death to personnel nearby. When setting fire to gasoline-soaked material, stand away from the material and throw a lighted torch into it.

e. *Bend.* Bend the panels, cabinets, chassis, tools, housings, fuel tanks, skids, bases, and all other metal parts not otherwise destroyed.

f. *Explode.* To explode the equipment, use firearms, grenades, dynamite, or TNT.

g. *Dispose.* If time permits, dispose of the destroyed parts by burying or scattering; bury in slit trenches, fox holes, or other holes; or throw into streams or lakes.



## CHAPTER 34

## SAFETY PRECAUTIONS

**267. General**

In addition to the normal safety precautions to be observed in handling heavy equipment and practiced by the individual soldier, the meteorological personnel must be extremely cautious in handling the electrical equipment and hydrogen inflation equipment.

**268. Hydrogen**

Hydrogen gas is highly flammable. Therefore, the inert gas "helium" should be used to inflate the balloons when possible. If bottled hydrogen or the hydrogen generator must be used, carefully observe the following safety precautions:

a. Display conspicuous warning signs where hydrogen is generated, used, or stored.

*Example:* DANGER—HYDROGEN—NO SMOKING WITHIN 15 METERS.

b. Never light a match, smoke, or cause a spark near a site where hydrogen is being generated or used. Remove all possible sources of flames and sparks.

c. If possible wear rubber soled shoes during the inflation.

(1) *Do not* wear shoes with exposed nails which might strike against metal, stones, or concrete floors and produce a spark.

(2) *Do not* drop or strike metal tools against anything that might cause a spark.

d. Remove all metallic objects, such as watches and eyeglasses, from personnel involved in the inflation of a balloon.

e. Never mix hydrogen with air. Expel all the air from the balloon before filling it with hydrogen.

f. *Do not* expose the hydrogen cylinder or generator to the sun. Always store hydrogen bottles and calcium hydride in the shade.

g. Static electricity is easily generated on days of low relative humidity. On such days, inflate the balloon slowly and lightly sprinkle the balloon, balloon shroud, and inflation area with water, if the air temperature is above freezing.

h. Remove all constrictions from the balloon neck. Keep all hydrogen passages clear.

**Caution:** Unless all the talc is shaken out of the balloon, talc may enter and clog the inflation nozzle.

i. When using bottled hydrogen gas, inflate the balloon slowly to avoid bursting or overinflation.

**Warning:** If the hissing sound of a gas leaking from the balloon is heard, close the cylinder valve immediately. Twist the neck of the balloon, remove it from the nozzle, and take the balloon to the open air where it may be released.

j. Never deflate a hydrogen-filled balloon. Turn it loose.

k. To prevent the accumulation of hydrogen and to permit its escape, be sure that the inflation tent is ventilated adequately at all times.

l. When heavy woolen or fur clothing is worn during the inflation process, ground all personnel in immediate area to provide a path to the ground for static electricity. Wear a wrist band of metal connected to a flexible wire which is connected to a good ground.

m. Ground the inflation equipment to provide a path to the ground for any static electricity generated in the equipment. Use wire to interconnect all metal parts of the inflation equipment (par. 57).

n. Never remove the hydrogen generator from the water until the generation of hydrogen has stopped. Removing the generator from the water while hydrogen is being generated may cause an explosion. If the balloon is fully inflated before the calcium hydride charges are expanded, dissipate the excess gas outside the inflation tent.

o. Pressure may exist within the calcium hydride charge; therefore, when punching the first knockout hole in the can, the face should be turned away to prevent possible injury.

p. Keep friction between the balloon and balloon shroud to a minimum.

q. For further information on hydrogen safety precautions see—

TM 11-2405 Meteorological Balloons and Inflation and Launching Accessories.

TM 11-2413 Hydrogen Generator ML-303/TM and Hydrogen Generator Set AN/TMQ-3.

**269. Electrical Equipment Safety Precautions**

The first rule of safety is *Be Careful!* Never touch a point in a circuit unless you know that it is not alive. The most dangerous circuits, high-voltage or low-voltage, are those which can deliver high currents. The danger is even greater when dampness is present or when the hands are perspiring.

*a. Rawin Equipment.* The following safety precautions must be observed when operating the rawin equipment.

- (1) Do not make cable connections while power is being supplied to the system. Either open the main circuit breakers or turn *off* the power generator.
- (2) While making electrical adjustments, keep one hand in your pocket so as not to touch "ground" during adjustment.
- (3) Make certain that power is *off* before attempting to replace burned out fuses.
- (4) Make certain that the main assembly is adequately grounded at all times.
- (5) Have the maintenance technician periodically check for shorts between the powerline and equipment chassis.
- (6) Make no adjustments on the main assembly during electrical storms.

(7) Assume that all electrical components possess lethal voltage until proven otherwise.

(8) *Do not* use steel wool to clean electrical equipment or electrical equipment cabinets. Minute particles may enter the case and cause harmful internal shorting or grounding of circuits.

*b. Power Generators.* The following safety precautions must be observed when operating electrical power generators.

- (1) Make sure the circuit breakers are in the OFF position before plugging in power cables.
- (2) Do not attempt an adjustment or changes in wiring while the unit is in operation.
- (3) Exercise extra precaution when the generator is being operated on wet or damp ground.
- (4) Do not service the unit with gasoline while the unit is in operation.
- (5) Since exhaust fumes are poisonous, provide adequate ventilation when power generators are being operated in confined spaces.
- (6) The generator access panel should be closed while the power unit is in operation.

## APPENDIX I

## REFERENCES

**1. Publication Indexes**

Department of the Army Pamphlets of the 310-series should be consulted frequently for latest changes or revisions of references given in this appendix and for new publications relating to material covered in this manual.

**2. Army Regulations**

- AR 115-10/ AFR 105-3 Meteorological support for the U.S. Army.
- AR 115-15 U.S. Army Requirements for Air Weather Service Support.
- AR 320-5 Dictionary of United States Army Terms.
- AR 320-50 Authorized Abbreviations and Brevity Codes.
- AR 700-75 Logistics (General), Use of Meter As a Unit of Linear Measurement in United States Army Weapons.
- AR 700-8120-1 Safe Handling, Storing, Shipping, Use, and Disposal of Compressed Gas Cylinders.
- AR 725-5 Preparation, Processing, and Documentation for Requisitioning, Shipping, and Receiving.
- AR 750-8 Command Maintenance Inspections.
- AR 750-625 Maintenance Inspections and Reports; Signal Equipment.

**3. Department of the Army Pamphlets**

- DA Pam 108-1 Index of Army Motion Pictures, Film Strips, Slides, and Phono Recordings.
- DA Pam 310-series Military Publications Indexes (as applicable).
- DA Pam 750-1 Preventive Maintenance Guide for Commanders.

**4. Field Manuals**

- FM 5-20 Camouflage, Basic Principles and Field Camouflage.
- FM 6-2 Artillery Survey.
- FM 6-16 Tables for Artillery Meteorology.

FM 6-40

FM 6-56

FM 6-61

FM 6-120

FM 6-122

FM 6-125

FM 21-5

FM 21-6

FM 21-26

FM 21-30

FM 21-40

FM 31-25

FM 31-70

FM 31-71

FM 72-20

FM 100-5

Field Artillery Cannon Gunnery.

Field Artillery Missile Battalion (Battery), Little John Rocket.

Field Artillery Missile Battalion, Honest John Rocket, Self-Propelled.

Field Artillery Target Acquisition Battalion and Batteries.

Artillery Sound Ranging and Flash Ranging.

Qualification Tests for Specialists, Field Artillery.

Military Training.

Techniques of Military Instruction.

Map Reading.

Military Symbols.

Small Unit Procedures in Nuclear, Biological, and Chemical Warfare.

Desert Operations.

Basic Cold Weather Manual.

Northern Operations.

Jungle Operations.

Field Service Regulations, Operations.

**5. Technical Manuals**

- TM 3-220 Decontamination.
- TM 5-230 General Drafting.
- TM 5-236-61 (62) The American Ephemeris and Nautical Almanac for the Year 1961 (1962).
- TM 5-6115-204- Operators Manual, Generator Set, 10 kw (John Reiner).
- TM 5-6115-204- Organizational Maintenance Allowance, Generator Set, 10 kw (John Reiner).
- TM 5-6115-232-10 Operators Manual, Generator Set, 10 kw (Hol-Gar).
- TM 5-6115-232-20P Organizational Maintenance Repair Parts and Special Tool Lists, Generator Set, 10 kw (Hol-Gar).
- TM 6-230 Logarithmic and Mathematical Tables.



TM 6-240	Slide Rule, Military, Field Artillery.	TM 11-5820-295-10P	Operator Maintenance Repair Parts and Special Tools Lists: Radio Set AN/GRC-19.
TM 11-427	Barometers ML-102-( ) and ML-316/TM.	TM 11-5820-295-20	Organizational Maintenance: Radio Set AN/GRC-19.
TM 11-661	Electrical Fundamentals (DC).	TM 11-5820-295-20P	Organizational Maintenance Repair Parts and Special Tools List and Maintenance Allocation Chart for Radio Set AN/GRC-19.
TM 11-681	Electrical Fundamentals (AC).		
TM 11-806	Radio Transmitters T-195/GRC-19 and T-195A/GRC-19.		
TM 11-900A	Power Unit PE-75-AF.		
TM 11-2155	Telephone Set TA-312/PT.	TM 11-5820-334-10	Operator's Manual: Radio Receiver R-392/URR.
TM 11-2405	Meteorological Balloons and Inflation and Launching Accessories.	TM 11-5820-334-20	Organizational Maintenance Manual: Radio Receiver R-392/URR.
TM 11-2410	Pilot Balloon Tables (30-Gram).		
TM 11-2411	Pilot Balloon Tables (100-Gram).		
TM 11-2413	Hydrogen Generator ML-303/TM and Hydrogen Generator Set AN/TMQ-3.	TM 11-5820-334-20P	Organizational Maintenance Repair Parts and Special Tools List and Maintenance Allocation Chart: Receiver, Radio R-392/URR.
TM 11-2417	Thermometers ML-4 and ML-5; Psychrometers ML-24 and ML-224; Shelters ML-41, ML-41-A, and ML-41-B.		
TM 11-2421	Barometers ML-330/FM, ML-331/TM, ML-332/TM, ML-333/TM, and Mercurial Barometer ML-330A/FM.	TM 11-6625-213-10P	Operator's Maintenance Repair Parts and Special Tools List: Test Set TS-538/U, TS-538A/U, TS-538B/U, and TS-538C/U.
TM 11-2432A	Radiosondes AN/AMT-4A, AN/AMT-4B, AN/AMT-4C, and Radiosonde Set AN/AMT-4D.	TM 11-6625-213-20P	Organizational Maintenance Repair Parts and Special Tools Lists and Maintenance Allocation Chart: Test Sets TS-538/U, TS-538A/U, TS-538B/U, and TS-538C/U.
TM 11-2436	Radiosonde Recorders AN/TMQ-5, AN/TMQ-5A, AN/TMQ-5B, and AN/TMQ-5C.		
TM 11-2442	Plotting Board ML-122.	TM 11-6660-203-10	Operators Manual: Wind Measuring Sets AN/MMQ-1, AN/MMQ-1A, AN/MMQ-1B, and AN/PMQ-6.
TM 11-2602B	Frequency Standard TS-65C/FMQ-1 and TS-65D/FMQ-1.	TM 11-6660-203-20	Organizational Maintenance Manual: Wind Measuring Sets AN/MMQ-1, AN/MMQ-1A, AN/MMQ-1B, and AN/PMQ-6.
TM 11-3655-200-12P	Operator and Organizational Repair Parts and Special Tools Lists and Maintenance Allocation Chart, Hydrogen Generator Set AN/TMQ-3.		
TM 11-5014	Test Sets TS-538/U, TS-538A/U, TS-538B/U, and TS-538C/U.	TM 11-6660-203-20P	Organizational Maintenance Repair Parts and Special Tools List for Wind Measuring Sets AN/MMQ-1 and AN/MMQ-1A, AN/MMQ-1B, and AN/PMQ-6.
TM 11-5805-201-12P	Operator and Organizational Maintenance Repair Parts and Special Tools List and Maintenance Allocation: Telephone Set TA-312/PT.	TM 11-6660-204-10P	Operator's Maintenance Repair Parts and Special Tools List for Radiosonde Recorders AN/TMQ-5, AN/TMQ-5A.
TM 11-5820-295-10	Operators Manual: Radio Set AN/GRC-19.		

TM 11-6660-204-20P Organizational Maintenance Repair Parts and Special Tools List: AN/TMQ-5, AN/TMQ-5A, and AN/TMQ-5B.

TM 11-6660-206-10 Operators Manual, Rawin Sets AN/GMD-1, 1A, and 1B.

TM 11-6660-206-10P Operator Maintenance Repair Parts and Tools AN/GMD-1, 1A, and 1B.

TM 11-6660-206-20 Organizational Maintenance Manual: Rawin Sets AN/GMD-1, 1A, and 1B.

TM 11-6660-206-20P Organizational Maintenance Repair Parts and Tools AN/GMD-1, 1A, and 1B.

TM 11-6660-218-15 Meteorological Station, Manual AN/TMQ-4.

TM 11-6660-218-15P Operators Organizational, Field, and Depot Maintenance Repair Parts and Special Tools List and Maintenance Allocation Chart for Meteorological Station Manual AN/TMQ-4.

TM 11-6660-219-12 Radiosonde Baseline Check Sets AN/GMM-1, AN/GMM-1A.

TM 11-6660-220-10 Operator's Manual: Radiosonde Set AN/AMT-12.

TM 11-6675-200-10 Operator's Manual: Theodolites ML-47-C Through ML-47-R, ML-247 and ML-247-A, and Double Center Theodolite ML-474/GM.

TM 11-6675-200-20 Theodolites ML-47-C Through ML-47-R, ML-247 and ML-247-A, and Double Center Theodolite ML-474/GM; Organizational Maintenance.

## 6. Blank Forms

DA Form 6-42 Ballistic Winds from Observations of 30- and 100-Gram Balloons.

DA Form 6-43 Radiosonde Data.

DA Form 6-44 Ballistic Density or Temperature.

DA Form 6-46 Rawin Computation.

DA Form 6-47 Radar Flight Data Record.

DA Form 6-48 Weather Data for Sound Ranging.

DA Form 6-49 Pressure-Time Chart.

DA Form 6-50 Ballistic Density from Surface Data.

DA Form 6-57 NATO Metro Message.

DA Form 6-58 Fallout Metro Message.

DA Form 6-59 Computer Metro Message.

DA Form 6-60 Meteorological Data for Artillery-Air Weather Service Exchange.

DD Form 110 Vehicle and Equipment Operational Record.

## 7. Miscellaneous Publications

NATO STANAG 4044 (1958), Adoption of Standard Atmosphere.

NATO STANAG 4061 (1958), Adoption of A Standard Ballistic Metro Message.

FT 155-Q-3, Firing Tables for Cannon, 155-mm Howitzer.

Report—NATO Ninth General Conference on Weights and Measures (1948).

Report—Number 1235, National Advisory Committee for Aeronautics.

Report—U.S. Extension to the ICAO Standard Atmosphere, Geographics Research Directorate and Weather Bureau, U.S. Department of Commerce.

Glossary of Meteorology (1959).

Manual of Radiosonde Observations (WBAN) Circular P, June 1957.

Manual of Winds-Aloft Observation (WBAN) Circular O, Sept 1959.



## APPENDIX II

### INSPECTION CHECKLISTS

#### 1. Purpose

This appendix relates the material presented in the text to inspections and inspection checklists.

#### 2. Checklist for Command Maintenance Inspection

The following inspection checklist for signal corps equipment is used by major commanders and signal corps spot check teams to inspect organizational maintenance and related supply facilities during command maintenance inspections:

##### ORGANIZATIONAL MAINTENANCE FACILITIES, PROCEDURES CHECKLIST

Yes	No	
----	----	1. Are operator maintenance checklists satisfactory?
----	----	2. Is organizational maintenance checklist file satisfactory?
----	----	3. Is adequate time allowed for preventive maintenance inspections?
----	----	4. Are preventive maintenance inspections performed periodically under proper supervision?
----	----	5. Are safety rules and regulations complied with on maintenance operations?
----	----	6. Is prompt action taken to correct shortcomings disclosed by higher echelon of maintenance?
----	----	7. Are repair techniques satisfactory?
----	----	8. Is prompt action taken to evacuate equipment requiring a higher echelon of maintenance?
----	----	9. Are equipment running spares on hand?
----	----	10. Are required repair parts on hand, if authorized?
----	----	11. Are repair parts properly stored and location known?
----	----	12. Are repair parts used discriminately as determined by condition of part replaced?
----	----	13. Are repair parts for unserviceable equipment (requiring organizational maintenance) on requisition?
----	----	14. Does unit comply with provisions of paragraph 3c, AR 750-5?
----	----	15. Are required tools available, if authorized?
----	----	16. Is required test equipment available, if authorized?
----	----	17. Are tools and test equipment properly cleaned and stored when not in use?
----	----	18. Are unserviceable tools turned in for repair or replacement?

Yes	No	
----	----	19. Are DA lubrication orders on hand and used?
----	----	20. Are technical manuals on hand for each type of equipment?
----	----	21. Are technical manuals and supply bulletins 11-100-series used in performing maintenance inspections and services?
----	----	22. Are files of supply bulletins, technical bulletins, signal supply manuals, etc., satisfactory?
----	----	23. Are maintenance personnel familiar with AR 700-38 and AR 700-39 governing submission of Unsatisfactory Equipment Report and Electronics Failure Reports?
----	----	24. Is signal equipment used properly?
----	----	25. Is proficiency of maintenance personnel adequate?

#### INSTRUCTIONS FOR DETERMINING RATING:

Certain questions may not be applicable to all units inspected; therefore, to obtain a correct rating, divide the number of positive answers by the number of applicable questions and multiply the answer by 100 to obtain a percentage figure.

----- RATING                      INSPECTOR -----

#### 3. Checklist for Spot Check Inspection

The following inspection checklist for signal corps equipment is used by signal corps spot check teams at division or higher level to determine minor shortcomings:

##### INSPECTION OF THE ORGANIZATION FACILITIES

Yes	No	
----	----	1. Are operator maintenance checklists on hand and being used?
----	----	2. Is adequate time allowed for preventive maintenance inspections?
----	----	3. Are preventive maintenance inspections performed periodically under proper supervision?
----	----	4. Is prompt action taken to correct shortcomings disclosed by maintenance inspections?
----	----	5. Are equipment running spares on hand?
----	----	6. Are required repair parts on hand, if authorized?
----	----	7. Are repair parts used discriminately as determined by condition of part replaced?



<i>Sat</i>	<i>Unsat</i>	<i>Site</i>
----	----	3. If operating in the field with calcium hydride, is there a nearby source of water? If not, has provision been made for obtaining an adequate supply of water?

<i>Sat</i>	<i>Unsat</i>	<i>Personnel</i>
----	----	4. Is the metro warrant officer trained in maintenance?
----	----	5. Is the section chief trained in maintenance?

<i>Sat</i>	<i>Unsat</i>	<i>Personnel</i>
----	----	1. Are personnel neat and courteous?
----	----	2. Is 50 percent of section personnel school trained?
----	----	3. Do all assigned individuals participate in the section training?

Date.....

Name.....

Comments: .....

.....



## GLOSSARY

### ABBREVIATIONS AND DEFINITIONS

#### Section I. ABBREVIATIONS

The following abbreviations and terms appear throughout this manual. An understanding of them is necessary for a proper understanding of the subject matter contained herein.

AWS—Air Weather Service.

CBR—Chemical, Biological, Radiological.

GMT—Greenwich Mean Time.

ICAO—International Civil Aviation Organization.

MDP—Meteorological Datum Plane.

NATO—North Atlantic Treaty Organization.

RATT—Radio teletypewriter.

SOLOG—Standardization of certain aspects of operations and logistics (among tripartite nations).

SWO—Staff Weather Officer, member of the Air Force, Air Weather Service.

STANAG—Standardization Agreements (among NATO nations).

STRAC—United States Strategic Army Corps.

WBAN—(Weather Bureau, Air Force, Navy) A series of weather observation manuals. The manual covering radiosonde observations is WBAN Circular P.

WMO—World Meteorological Organization.

#### Section II. DEFINITIONS

*Advection*—The process of transport of an atmospheric property solely by the mass motion of the atmosphere, normally in the horizontal direction.

*Air mass*—An extensive body of air within which the conditions of temperature and moisture in a horizontal plane are essentially uniform.

*Albedo*—The ratio of electromagnetic radiation reflected by a body to the amount incident upon it, commonly expressed as a percentage.

*All weather*—The ability to be functional without regard to weather.

*Ambient temperature*—The temperature of the immediate surrounding medium, such as a gas or liquid.

*Anemometer*—The general name for instruments designed to measure the speed (or force) of the wind.

*Aneroid*—Literally, "not wet," containing no liquid; applied to a kind of barometer which contains no liquid, an aneroid barometer.

*Ballistic meteorology*—The study dealing with the phenomena of the atmosphere and its effect upon the motion of a projectile.

*Ballistics*—The science of the motion of projectiles.

*Barometer*—An instrument for measuring atmospheric pressure.

*Baseline check*—The procedure by which an equivalence is established between recorder division values and measured values of temperature and humidity.

*Celsius*—A temperature scale which uses 0 as the ice point and 100 as the boiling point. The same as Centigrade.

*Cirrus*—A principal cloud type composed of detached cirriform elements (mostly ice crystals fairly widely dispersed) in the form of white, delicate filaments, of white (or mostly white) patches, or of narrow bands.

*Climatological information*—That information which deals with weather conditions and variations from normal, for a particular place or area, during a specified period of the year.

*Command post*—The station of a unit's or subunit's headquarters where the commander and the staff perform their activities.

*Condensation*—In meteorology, the physical process by which water vapor is changed to liquid water.

*Condensation nuclei*—A minute particle, either liquid or solid, upon which condensation of water vapor begins in the atmosphere.

*Conduction*—The transfer of energy within a conductor by means of internal molecular activity, and without any net external motion.

*Convection*—Atmospheric motions that are predominantly vertical, resulting in vertical transport and mixing of atmospheric properties; distinguished from advection.

*Coriolis force*—An apparent force which causes moving particles to be deflected to the right in the



- Northern Hemisphere and to the left in the Southern Hemisphere.
- Critical angle*—The limiting angle at which angular data becomes invalid. For rawinsonde data, the critical angle is an angle of 6 degrees.
- Cumuliform*—Like cumulus; generally descriptive of all clouds, the principal characteristic of which is vertical development in the form of rising mounds, domes, or towers. Contrasting to stratiform.
- Cursor*—The runner. On a slide rule, the sliding index. On a humidity-temperature computer, the free turning temperature index.
- Cutoff*—The radiosonde recorder record value at which relative humidity becomes too low to be evaluated.
- Departure method*—The method of predicting ballistic densities by use of a measured surface density and the "Departures from mean surface density" tables of FM 6-16, "Tables for Artillery Meteorology."
- Dewpoint temperature*—The temperature to which air must be cooled in order to cause saturation.
- DI, Discomfort Index*—The temperature-humidity index, specified by the U.S. Weather Bureau, used to report the relative discomfort due to heat.
- Diurnal*—Daily variation of actions which recur every twenty-four hours.
- Doldrums*—A nautical term for the equatorial trough, with special reference to the light and variable nature of the winds.
- D Region*—The lowest ionized layer of the atmosphere which attenuates and reflects low frequency radio waves.
- Effective temperature*—The temperature used in computing corrections for sound ranging, the sonic temperature.
- Ephemeris*—Tabular statement of the assigned places of celestial bodies for regular intervals.
- Equation of state*—An equation relating temperature, pressure, and volume of a system in thermodynamic equilibrium.
- Evaporation*—The physical process by which liquid water is changed to water vapor.
- Exosphere*—The outermost layer of the earth's atmosphere.
- Fallout*—The descent to the ground of dust and other debris raised to great heights in the atmosphere by a violent explosion.
- Free rocket*—Any unguided rocket.
- Fronts*—In general, a transition zone between air masses of different densities.
- Geostrophic wind*—The wind which occurs when the pressure gradient force balances the coriolis force and friction is disregarded.
- Heat of fusion*—The heat released by a fluid when it changes from liquid to solid.
- Horizontal distance*—The arc distance or the distance traveled by a balloon as projected to the earth's curved surface.
- Humidity-temperature computer*—A special circular slide rule used to compute radiosonde temperature and humidity from radiosonde recorder record values.
- Hydrostatic equation*—The basic force equation which states that the change of pressure with respect to height is equal to the negative product of density and the acceleration of gravity.
- Hygristor*—A humidity sensing element or device. A resistor whose resistance varies according to the amount of humidity in the air.
- Hypsometer*—An instrument for measuring height: specifically, an instrument for measuring atmospheric pressure by determining the boiling point of a liquid.
- Inversion*—A layer of atmosphere where the temperature increases rather than decreases with height.
- Isobar*—A line of constant pressure.
- Isobaric*—Of equal or constant pressure.
- Isotherm*—A line of constant temperature.
- Isothermal*—Of equal or constant temperature.
- Isohypnic*—A line of constant density.
- Jet stream*—Relatively strong winds concentrated within a narrow stream in the atmosphere. While this term may be applied to any such stream regardless of direction, it is coming more and more to mean only a quasi-horizontal jet stream of maximum winds in the high troposphere in the midlatitude westerlies.
- Kelvin scale (°K.)*—An absolute temperature scale with an ice point of 273.16° K. and a boiling point of 373.16° K.
- Lapse rate*—The rate at which temperature decreases with altitude.
- Low-level winds*—Winds in the friction layer of the atmosphere.
- Magnetic declination*—The angle between true north and magnetic north.
- Mean sea level pressure*—Station pressure reduced to mean sea level pressure.

- Mean sea level*—The average height of the sea surface, based upon hourly observation of tide height on the open coast or in adjacent waters which have free access to the sea.
- Mesopause*—The top of the mesosphere.
- Mesosphere*—The layer of the atmosphere immediately above the stratopause.
- Metro*—A contraction for “meteorology.”
- Meteorological day*—A 24-hour day divided into three periods: the night period, the afternoon period, and the transition period.
- Meteorological information*—Information concerned with the phenomena of the atmosphere. Data pertaining to the atmosphere, especially wind, temperatures, and air density, which are used in ballistics.
- Meteorology*—The science of the earth’s atmosphere.
- Micrometeorology*—That branch of meteorology that deals with the observation and explanation of the smallest-scale phenomena within the atmosphere.
- Millibar (mb.)*—A unit of pressure, convenient for measuring atmospheric pressure, which is equal to a force of 1000 dynes per square centimeter.
- Modulator*—That part of a radiosonde which contains the sensing elements and baroswitch.
- Monsoon*—Seasonal wind systems which derive their energy from land and water temperature differences.
- Motorboating*—The term used to identify values of relative humidity which are too low to be evaluated from a radiosonde recorder record. Originally, the sound heard on the monitoring speaker of an audio-modulated radiosonde when the audio signal became so low in frequency that it resembled the sound of a motorboat.
- Neoprene*—A synthetic rubber-like plastic material.
- Noctilucent clouds*—Clouds, believed to be composed of either cosmic dust or water droplets, which occur at an altitude of approximately 82 kilometers.
- Occlusion*—An occluded front. A composite of two fronts, formed as a cold front, overtakes a warm front or quasi-stationary front.
- Offset*—The difference in distance and the azimuth from an observing point to the point of release of a sounding or pilot balloon.
- Orographic*—Of, pertaining to, or (frequently in meteorology) caused by mountains.
- Ozone*—A faintly blue, gaseous form of oxygen which exists in the atmosphere.
- Panoramic telescope*—The on-carriage optical sight used to lay an artillery weapon for direction.
- Parameter*—A quantity to which arbitrary values may be assigned such as in a mathematical problem.
- Polar easterlies*—The dominant wind system which exists in polar regions.
- Pilot balloon*—A small balloon whose ascent is followed by a theodolite in order to obtain data for the computation of the speed and direction of winds in the upper air.
- Polarization*—An electro-chemical effect which causes the electrical resistance of a lithium chloride humidity element to vary slightly when a voltage is applied to the element.
- Precipitation*—A form of water, either liquid or solid, that falls from the atmosphere and reaches the ground.
- Pressure gradient force*—The force due to pressure differences within a fluid mass.
- Prevailing westerlies*—The dominant wind system of the atmosphere which occurs in middle latitudes of both hemispheres.
- Prognostic chart*—A chart showing, principally, the expected pressure pattern of a given synoptic chart at a specified future time.
- Projectile*—A body projected by exterior force, and continuing in motion by its own inertia.
- Psychrometer*—An instrument used for determining the water vapor content of the atmosphere.
- Radiation*—The process by which electromagnetic energy is propagated through free space.
- Radioactive fallout*—The eventual descent to the earth’s surface of radioactive matter placed in the atmosphere by atomic or thermonuclear explosion.
- Radiosonde*—A balloon-borne instrument for simultaneous measurement and transmission of meteorological data.
- Radiological fallout*—The fall to the earth of radioactive debris resulting from an atomic or nuclear explosion. Radioactive fallout.
- Rawinsonde*—A method of upper air observation consisting of the evaluation of winds, temperature, pressure, and relative humidity aloft by means of a balloon-borne radiosonde tracked by a radio direction finder.
- Rawin*—A method of winds aloft observation; that is, the determination of wind speed and direction in the atmosphere above the station.

- Relative humidity*—The ratio of the actual vapor pressure of the air to the saturation vapor pressure, usually expressed in percent.
- Significant level*—A level in the atmosphere usually selected as the result of a change in the rate of temperature or humidity with height. The location of the points of evaluation of the radiosonde record.
- Sonic temperature*—The temperature used in computing corrections for sound ranging, the effective temperature.
- Sound ranging*—(Sound locating) The method of locating the source of a sound, such as that of a gun report or a shell burst, by calculations based on the intervals between the reception of the sound at various previously oriented microphone stations.
- Sounding balloon*—A free, unmanned balloon used for sounding the upper air.
- Source region*—An extensive portion of the earth's surface whose temperature and moisture properties are fairly uniform.
- Standard altitude*—The height above surface of the top of a prescribed standard zone.
- Standard ballistic density*—The density of the air as defined by the ICAO standard atmosphere. A density of 100 percent.
- Station model*—A specified pattern for entering, on a synoptic chart, the meteorological symbols which represent the state of the atmosphere at a particular station.
- Station pressure*—Surface pressure at the observing station. The atmospheric pressure computed for the level of the station elevation.
- Stratiform*—Description of clouds of extensive horizontal development, as contrasted to the vertically developed cumuliform types.
- Stratopause*—The top of the stratosphere.
- Stratosphere*—The layer of atmosphere immediately above the tropopause.
- Supercooled*—The reduction of temperature of any liquid below the melting point of that substance's solid phase; that is, cooled beyond its nominal freezing point.
- Surface wind*—The wind speed and direction as measured at the surface with an anemometer or the wind speed and direction detected by a 15 second flight of a 30-gram pilot balloon (10 sec flight of a 100-gram balloon).
- Synoptic weather*—Refers to the use of meteorological data obtained simultaneously over an extensive area for the purpose of presenting a comprehensive picture of the state of the atmosphere.
- Temperature-humidity evaluator*—A special circular slide rule used to convert radiosonde recorder record values to values of temperature and relative humidity.
- Thermistor temperature*—The temperature measured by the temperature element (thermistor) on a radiosonde.
- Terrestrial*—Pertaining to the earth.
- Theodolite*—An instrument which consists of a sighting telescope and graduated scales to read angles of azimuth and elevation.
- Thermosphere*—The layer of atmosphere immediately above the mesopause.
- Trade winds*—The wind system, occupying most of the tropics, which blows from the subtropical highs toward the equatorial trough.
- Trajectory*—The path of a projectile in the earth's atmosphere.
- Tropopause*—The top of the troposphere.
- Troposphere*—The lower layer of the atmosphere from the earth's surface to the tropopause (10 to 20 km) in which the average condition is typified by a decrease of temperature with increasing altitude.
- True north*—The direction from any point on the earth's surface toward the geographic North Pole.
- Topography*—Generally, the disposition of the major natural and man-made physical features on the earth's surface.
- Turbulence*—Irregular motion of the atmosphere, which defies analytical representation, such as when air flows over uneven surfaces of the earth.
- Visual technique*—The determination of upper air conditions from pilot balloon observations and the measurement of surface temperature, pressure, and relative humidity.
- Virtual temperature*—In a system of moist air, the temperature of dry air having the same density and pressure as the moist air. The virtual temperature is always greater than the actual temperature.
- WBGT Index*—A temperature-humidity index, specified by the American Society of Heating and Ventilating Engineers, used to report the relative discomfort due to heat.
- Weather forecast*—A prediction of expected weather conditions at a point, along a route, or within an area, for a given time or specific period of time in the future.

*Weather information*—Information concerning the state of the atmosphere, mainly with respect to its effects upon the military. Data and information concerned with forecasts, summaries, and climatology. Data and information normally associated with the activities of the Air Weather Service.

*Weather radar*—Radar, such as the AN/MPS-34, designed and used for tracking and detecting storm clouds.

*Weighting factors*—The factors used in weighting the effects of metro conditions in each artillery zone.

*Wet-bulb depression*—The difference in degrees between the dry-bulb temperature and the wet-bulb temperature.

*Wind chill*—That part of the total cooling of a body caused by air motion.

*Wind shear*—The local variation of the wind vector or any of its components in a given direction.

*Zone Wind*—The average wind within a zone.



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## BY ORDER OF THE SECRETARIES OF THE ARMY AND THE AIR FORCE:

G. H. DECKER,  
*General, United States Army,*  
*Chief of Staff.*

## Official:

J. C. LAMBERT,  
*Major General, United States Army,*  
*The Adjutant General.*

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 Corps (2)  
 Div (4)  
 AD Bde (5)

FA Gp (1)  
 AD Gp (5)  
 FA Bn (1)  
 Armor Bn (1)  
 AD Bn (1)  
 AD Btry (1)  
 Svc Colleges (2)  
 Br Svc Sch (2) except  
   ARADSCH (10)  
   USAARMS (10)  
   USACMLCSCH (10)  
   USAES (5)  
   USASCS (7)  
   USASESCS (7)  
   USAIS (70)  
   USAAMS (140)  
 USASRD (10)  
 Units org under fol TOE:  
   6-501 (5)  
   6-575 (5)

*NG:* None.

*USAR:* Same as Active Army except allowance is one copy to each unit.

For explanation of abbreviations used, see AR 320-50.



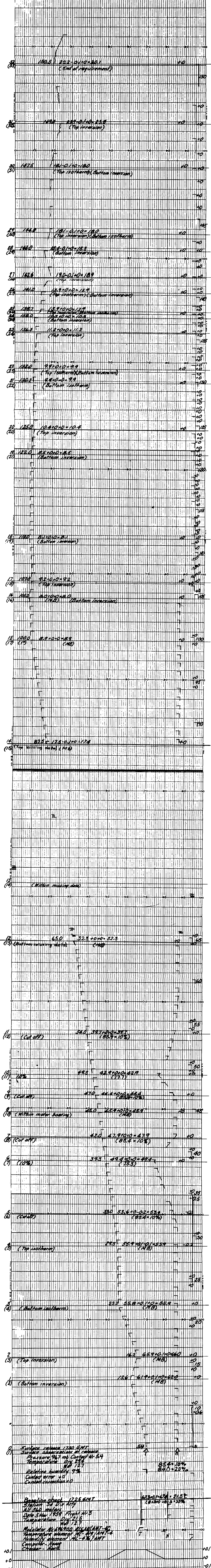


Figure 101. Radiophone recorder record.

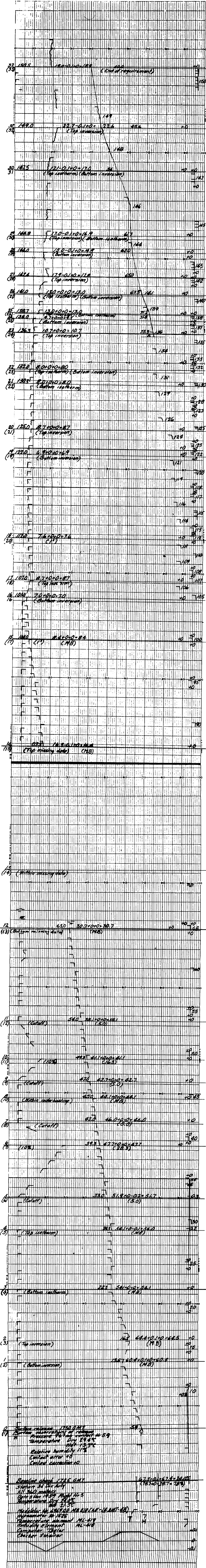
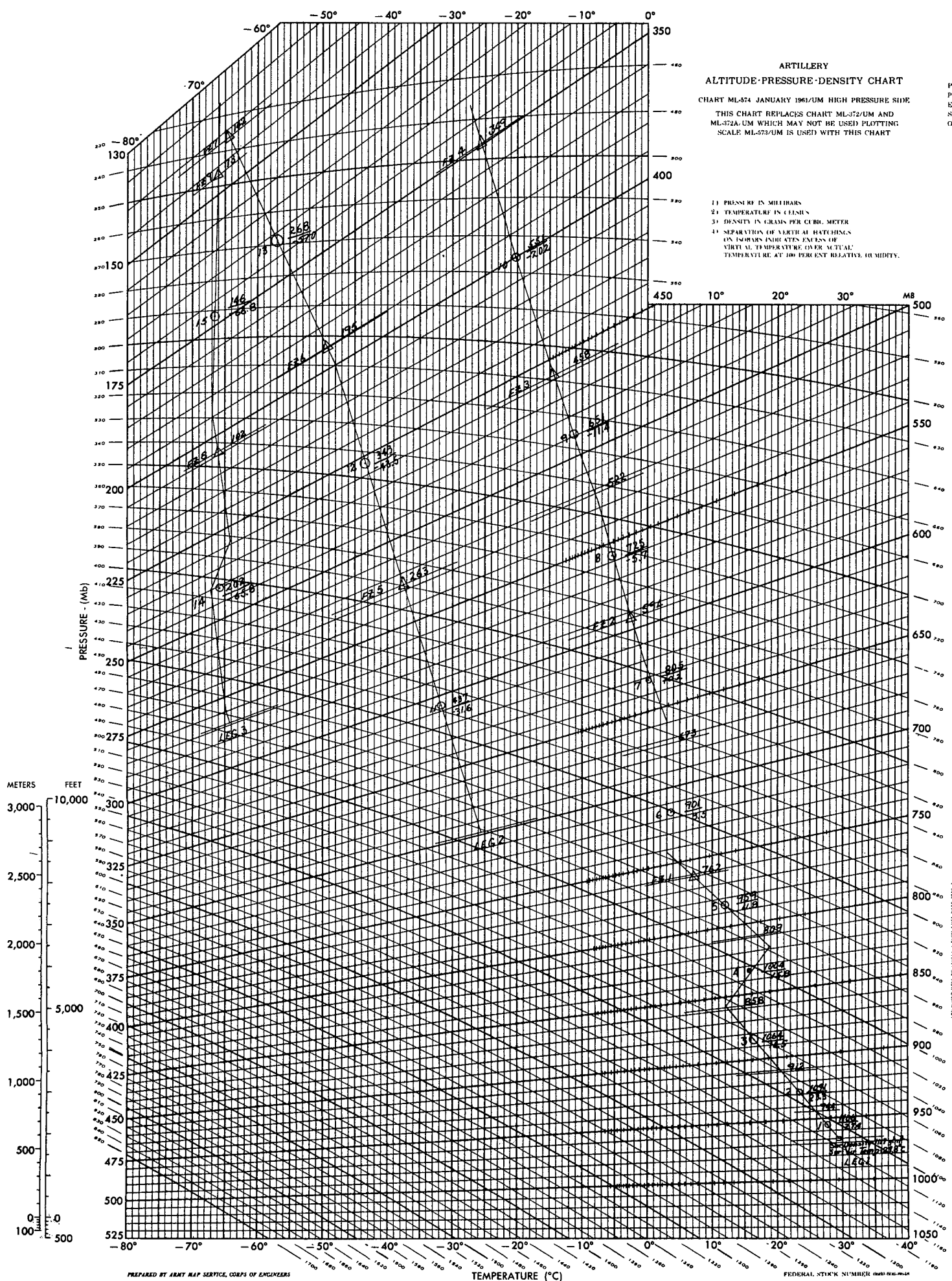


Figure 110. Evaluated radiophone recorder record using humidity element ML-418.

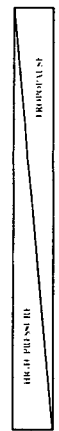


**ARTILLERY  
ALTITUDE-PRESSURE-DENSITY CHART**  
 CHART ML-574 JANUARY 1961/UM HIGH PRESSURE SIDE  
 THIS CHART REPLACES CHART ML-372/UM AND  
 ML-372A/UM WHICH MAY NOT BE USED PLOTTING  
 SCALE ML-373/UM IS USED WITH THIS CHART

- 1) PRESSURE IN MILLIBARS
  - 2) TEMPERATURE IN CELSIUS
  - 3) DENSITY IN GRAMS PER CUBIC METER
  - 4) SEPARATION OF VERT. AIR LAYERS IN METERS
- ON SCALARS FABRICATES EXCESS OF  
 VIRTUAL TEMPERATURE OVER ACTUAL  
 TEMPERATURE AT 100 PERCENT RELATIVE HUMIDITY.

PLOT DATA USING LIGHT  
 PRESSURE OF SOFT PENCIL.  
 ERASE WITH ERASER, ARTGUM,  
 STOCK NO. 7510-223-7044  
 OR EQUAL.

**TROPOPAUSE TEMPLATE**



- TROPOPAUSE CRITERIA**
- 1) TEMPERATURE LOWER THAN 30°C
  - 2) PRESSURE BETWEEN 600 MB AND 30 MB
  - 3) LAPSE RATE OF 1°C OR LESS PER 2000 METERS

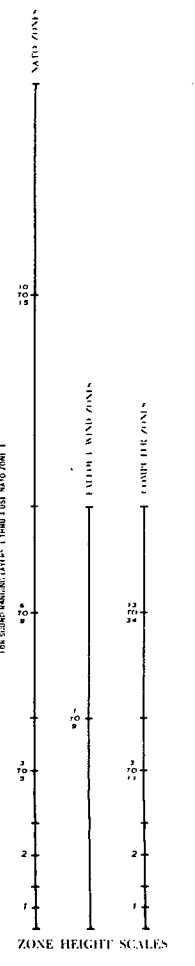


Figure 113. Chart ML-574.